11 Published Papers on the Classfication of the British Brachiopod sub-family productinae

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Notes on the Silurian Brachiopod Genera Delthyris, Uncinulina, *and* Meristina. By HELEN M. MUIR-WOOD, M.Sc., F.G.S.

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SUMMARY.

In this paper the different interpretations of the genus *Delthyris* are discussed, and that given by Schuchert in 1913 is adopted with slight amendment. The species *Delthyris elevata*, *D. crispa*, *D. elegans* (nom. nov. for *D. crispa*, Hisinger, non Linnæus), and *D. tenuilamellata*, sp. n., from the British Silurian, are all described and figured.

The distinguishing characters of the genera *Uncinulus* and *Uncinulina* are pointed out, and *Uncinulina* is retained with *U. fallaciosa* as genotype. *Rhynchonella stricklandi* and *Terebratula lewisi* are transferred to the genus *Uncinulina*. *Meristina tumida* (Dalman) is shown to be a synonym of *Meristina obtusa* (Sowerby).

The British Silurian Spirifers can be separated into two groups:—(1) those with longitudinal folds and a transverse ornament of imbricating lamellæ (=*Delthyris* of Dalman) and (2) those with longitudinal folds bearing fine continuous longitudinal striæ (=*Eospirifer* of Schuchert).

The species referable to both these genera have as a rule been assigned to the genus *Spirifer*, from which, however, they differ in internal characters.

DELTHYRIS, Dalman, 1828.

Genolectotype: *D. elevata*. (See Schuchert *.)

The genus *Delthyris* was first described by Dalman in 1828 † to include the species *D. elevata*, *cyrtæna*, *crispa*, *subsulcata*, *ptychodes*, and *cardiospermiformis*. Of these species *Delthyris cyrtæna* is *Eospirifer plicatellus* (Linnæus) and *D. cardiospermiformis* is *Bilobites biloba* (Linnæus); nor is *D. ptychodes* a Spirifer. The original description, therefore, included a variety of generic forms, and the generic characters other than those of shape and external ornament were not very precisely defined. This at once caused confusion, for Menke in 1830 ‡, although quoting *Delthyris*,

* Bull. U.S. Geol. Surv. lxxxvii. p. 206 (1897).
† Kongl. Svenska Vet.-Akad. Handl. för 1827, p. 93.
‡ 'Synopsis methodica Molluscorum,' ed. ii. p. 96.

Dalman, as including *Spirifer* of Sowerby and *Trigonotreta* of Koenig, yet gives as species of *Delthyris*, *Anomia dorsata* and *Terebratula spatula*, of which *Anomia dorsata* belongs to the genus *Terebratella* and *Terebratula spatula* to *Terebratulina*. Von Buch in 1836* included in *Delthyris* species of *Spirifer* and *Orthis*, which had a triangular foramen.

Among other authors Dall † quoted *Delthyris* as a synonym of *Spirifer*, and it was not until Hall ‡ published his great work on the Brachiopoda in 1894 that the distinctive characters of *Delthyris* were recognized. Of Hall's subdivisions of the genus *Spirifer* the group of Fimbriati Unicispinei is taken to be equivalent to *Delthyris*, s. s. Hall states also that the distinguishing character of this group lies in the ornament of the concentric fimbriæ—namely, short simple spines,—and that it includes the species *Delthyris crispa* and *D. elevata*. The group is said not to extend above the Devonian. On another page of the same work Hall shows how *Reticularia* differs from *Delthyris* in its fimbriæ, which have large spines with lateral branches. *Spirifer sulcatus*, Hisinger, is placed in the Lamellosi Septati, a group which has concentric lamellæ covered with fine radiating striæ, but with no spines, is not punctate, and does not have the primary lamellæ of the spiral arms united as in the Spiriferinas. A probable passage of the Septati into the punctate genus *Spiriferina* is suggested. Both these groups are said to have a median septum in the pedicle-valve. From Hall's description it would appear that there are three groups of impunctate lamellose Spirifers, distinguished only by the character of the ornament of the concentric lamellæ, which in the case of *Delthyris* is said to be composed of short spines.

A more precise and very different interpretation of the genus *Delthyris* was given by Schuchert in 1913 §. In 1897 ‖ he selected the species *Delthyris elevata* as the genotype of *Delthyris*, stating that all specimens examined by him possessed a median septum in the pedicle-valve. *Delthyris sulcata*, Hisinger, was also quoted as a true *Delthyris*, but *D. crispa*, Hisinger, was placed in the genus *Spirifer*.

Schuchert describes *Delthyris* as a subgenus of *Spirifer*,

* "Ueber *Delthyris* oder *Spirifer* und *Orthis*," Abh. K. Akad. Wiss. Berlin, p. 11.

† Bull. U.S. Nat. Mus. viii. p. 25 (1877).

‡ 'Palæontology of New York,' vol. viii. pt. 2, pp. 9 & 16.

§ Zittel-Eastman, 'Text-book of Palæontology,' p. 411.

‖ Bull. U.S. Geol. Surv. lxxxvii. pp. 206 & 386 (1897).

consisting of "small early *Spirifers* that are coarsely plicate, except on fold and sinus. Surface lamellose, the imbricating lamellæ marked with very fine radiating striæ, which do not terminate in spines. Short dental lamellæ present along with a more or less high ventral median septum. Resembles *Spiriferina*, but the shell structure is not finely and regularly punctate. Section Lamellosi-Septati Hall & Clarke." The description of the ornament of the lamellæ given by Schuchert will be seen to be exactly the reverse of that given by Hall. H. S. Williams *, in a discussion on *Delthyris elevata* and allied species, quotes the absence of a median septum in specimens having a groove along the median fold of the brachial valve. He describes two species, *Spirifer trescotti* and *Spirifer cobscooki* from the Silurian of Maine, both similar externally to *Spirifer elevatus* of Dalman, but *Spirifer trescotti* like *S. elevatus* has a median septum developed in the pedicle-valve, while *S. cobscooki* has none.

The development, however, of a median septum in the pedicle-valve does not appear to be constant, even for one species. Investigation of the species *D. crispa*, Linnæus, and *D. elegans*, nom. nov. = *D. crispa*, Hisinger (non Linnæus), showed that the median septum was usually absent, but occurred in an incipient state of development in one or two specimens of *D. elegans*. The contention that there is no median septum in forms which have a median groove along the central fold of the brachial valve does not appear to hold in the case of *Delthyris elevata*, which certainly has a median septum in those individuals whose brachial valves possess a grooved fold. The presence of a median septum in the pedicle-valve does not appear to be of great generic importance in the Silurian species of *Delthyris*, although, according to American authors, it appears to be a more constant feature in Devonian species.

While the lamellæ of *Delthyris elevata*, *crispa*, *elegans*, and *tenuilamellata* are ornamented with granules or longitudinal striæ, those of *Reticularia* and well-preserved specimens of *Spiriferina* have a true spinose ornament. *Spiriferina*, however, usually has smooth lamellæ, which are abundantly punctate. The genus *Tylothyris*, North †, from the Lower Carboniferous limestone, is distinguished by that author from *Delthyris* by its greater size, by its smaller and more numerous costæ, and by the marked development of an

* Proc. U.S. Nat. Mus. Washington, vol. li. p. 75 (1917).
† North, Quart. Journ. Geol. Soc. vol. lxxvi. p. 195 (1920).

apical callosity. Its shell, like that of *Delthyris*, is impunctate, but there is apparently no ornament on the lamellæ. It is possible that some of the species from the Upper Devonian and Lower Carboniferous that have been assigned to the genus *Delthyris* should be more correctly placed in the genus *Tylothyris*. In a group of impunctate lamellose Spirifers which Weller* describes from the Carboniferous beds of Illinois a median septum is present in the pedicle-valve, but the lamellæ in one of the species are said to be fimbriate, while in the remaining species, apparently, the lamellæ are not ornamented. It is doubtful, therefore, whether these species belong to *Delthyris* or whether they should be placed in *Tylothyris*.

A modification of the internal structure of the pedicle-valve is described by Dunbar† in his species *Delthyris cyrtinoides* from the Devonian. The dental plates converge and unite with the median septum, which is continued posteriorly into the cavity formed by union of the dental plates—an example of parallelism with the corresponding structure in *Cyrtina*.

There appears to be no reason for the generic separation of *Delthyris crispa*, Hisinger (non Linnæus), here renamed *D. elegans*, from the species *D. elevata* and *D. sulcata*, though the last two species were described by Schuchert as true *Delthyris*, while he included *D. crispa*, Hisinger, in *Spirifer*.

Additional generic characters in *Delthyris* are afforded by the spirals, which consist of seven coils and have their apices directed towards the cardinal angles.

Delthyris elevata, Dalman‡. (Figs. 7, 8, 8 *a*.)

Genotype of *Delthyris*, see Schuchert (Bull. U.S. Geol. Survey, lxxxvii. (1897), p. 206).

Description.—Width approximately equal to the length, with the widest part of the shell occurring at a point slightly below the hinge. Both valves highly convex. Apical angle 100°. Cardinal angles rounded. Area of pedicle-valve high, its length considerably shorter than that of the hinge. Delthyrium large and open, bordered by linear deltidial plates. Umbo rounded, much incurved. Ornament in the pedicle-valve consists of five rounded costæ on each side of the sinus, while in the brachial valve there

* Illinois Geol. Surv. Mon. i., Text. Mississippian Brachiopoda, p. 300 (1914).

† Trans. Connecticut Acad. xxiii. p. 138 (1920).

‡ Dalman, 1828, Vet.-Akad. Handl. p. 120, pl. iii. fig. 3.

are five costæ on each side of the broad median fold which is frequently longitudinally grooved. The width of the sulci separating the costæ is approximately half that of the costæ. Crossing the costæ there are very numerous concentric growth-lamellæ, along each of which are set numerous slightly elongated granules, the interspaces between the granules being less wide than the width of each granule.

Interior of the pedicle-valve with median septum developed.

Average Dimensions.—Length 18 mm.; width 21 mm.; thickness 16 mm., or 1 : 1·1 : ·8.

Type-specimen.—The specimen figured and described by Dalman from Gothland is hereby selected as the holotype.

Horizons.—Upper Llandovery–Upper Ludlow Beds.

Delthyris crispa (Linnæus). (Figs. 1, 2, 2 *a*.)

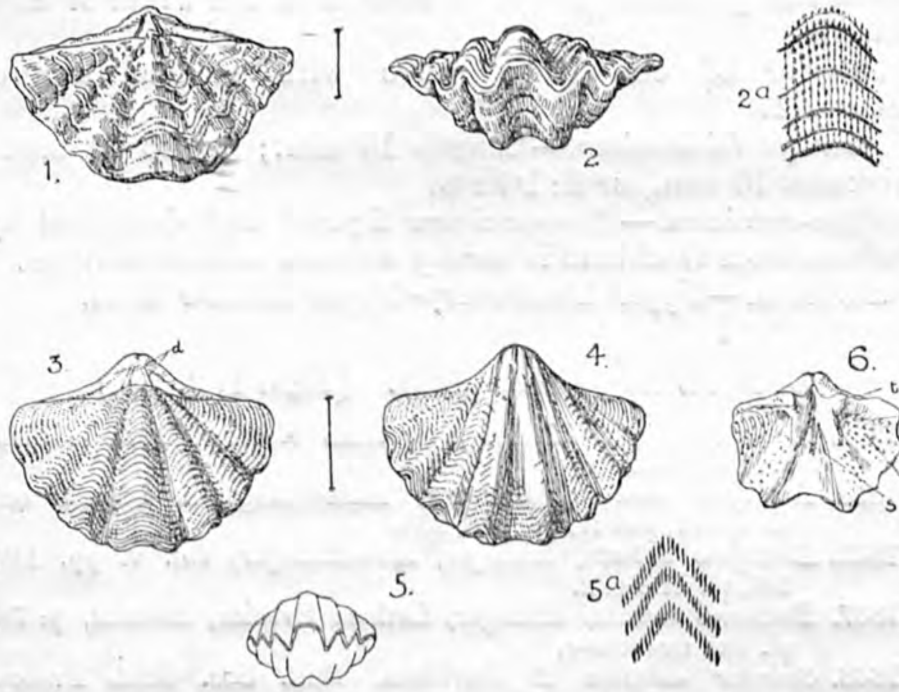
1758. *Anomia crispa*, Linnæus, Systema Naturæ, 10th edition, vol. i. p. 702.
1828. *Delthyris sulcata*, Hisinger, Anteckningar i Physik och Geognosi, vol. iv. pp. 228, 238.
1831. *Delthyris sulcata*, Hisinger, Anteckningar, vol. v. pp. 119, 140, pl. iii. fig. 2.
1837. *Delthyris sulcata*, Hisinger, Lethæa Svecica, Holmiæ, p. 73, pl. xxi. figs. 6 *a–c*.
1848. *Spirifer sulcatus*, T. Davidson, Bull. Soc. Géol. France, 2nd ser. vol. v. pl. iii. fig. 41, p. 325.
1860. *Spirifer sulcatus*, Lindström, Öfv. k. Vet.-Akad. Forhand. xvii. no. 8, p. 359.
1866. *Spirifera sulcata*, T. Davidson, Mon. Brit. Foss. Brach. vol. iii. part i. pl. x. figs. 4, 5, 12, p. 91.
1882. *Spirifera crispa*, T. Davidson, Mon. Brit. Foss. Brach., Suppl. vol. v. pl. iv. figs. 9, 10.

Description.—Laterally elongated, with the hinge-line forming the widest part of the shell. Pedicle-valve more convex than the brachial valve. Apical angle 134°. Cardinal extremities angular. Pedicle-valve with concave area extending along whole length of hinge. Delthyrium open, with linear deltidial plates. Umbo acute, slightly incurved.

In the pedicle-valve there are three rounded longitudinal costæ on each side of the median sinus, while in the brachial valve there are six costæ in addition to the broad median fold. Crossing the costæ there are from 10–15 prominent imbricating lamellæ less than 0·75 mm. apart. The microscopic ornament consists of small granulations arranged in rows along fine longitudinal striæ; the granulations are also seen to form less regular concentric rows. The ornament is interrupted by the transverse lamellæ. Interior of pedicle-valve usually without a median septum.

Average Dimensions.—Length 7 mm.; width 11 mm.; thickness 4·5 mm., or 1 : 1·5 : ·6.

Type-specimen.—The specimen figured in Museum Tessinianum, 1753, tab. v. fig. 7, and referred to by Linnæus in



Figs. 1, 2, 2 *a*. *Delthyris crispa* (Linnæus) from the Wenlock Limestone, Dudley. British Museum Geol. Dept. B. 44,916. 1. Brachial valve showing ornament ($\times 2\frac{1}{2}$). 2. Anterior view showing angular cardinal extremities ($\times 2\frac{1}{2}$). 2 *a*. Ornament under microscope ($\times 10$).

Figs. 3, 4, 5, 5 *a*, 6. *Delthyris elegans*, nom. nov., from Wenlock Limestone, Dudley. British Museum Geol. Dept. B. 44,917. 3. Brachial valve showing ornament, *d*=linear deltidial plates ($\times 2$). 4. Pedicle-valve ($\times 2$). 5. Anterior view showing rounded cardinal extremities (nat. size). 5 *a*. Ornament under microscope ($\times 10$). 6. Interior of pedicle-valve showing low median septum (from Wenlock Limestone, Dudley. British Museum Geol. Dept. B. 44,919); median septum (*s*), hinge-teeth (*t*), dental plates (*h*), and ovarian markings (*o*) ($\times 2$).

'Systema Naturæ' in 1758, is hereby selected as holotype. No horizon or locality is given in the description.

Horizon.—Wenlock Limestone and Shale.

Delthyris crispa was described by Linnæus as *Anomia crispa* in 'Systema Naturæ' in 1758. A brief description is given, and reference is made to Museum Tessinianum, 1753, where Linnæus described and figured this species as *Concha Anomia dilatata.*

The specimen figured is a laterally elongated form, having the greatest width along the hinge-line, with angular cardinal extremities, a broad median fold in the brachial valve and a corresponding sinus in the ventral valve. On either side of the fold and sinus are three rounded costæ. A transverse ornament of imbricating lamellæ is well shown, the lamellæ being separated by an interspace of about 0·75 mm. This figure was reproduced by Davidson in 1866 (fig. 12), but the ornament was not clearly shown.

Hisinger in 1826 * figured without description *Terebratula (Anomia,* L.) *crispa* from the crinoidal limestone of Gothland. This species, unlike Linnæus' species, had rounded cardinal angles, and the greatest width of the shell occurred at a point below the hinge. The transverse lamellæ were not shown at all in the figure. A similar figure was given in 1828 † by Dalman, who described it as *Delthyris crispa* of Hisinger. In the same year Hisinger ‡ figured the same form, but ascribed the species to Dalman, stating in the same publication § three years later that the description given by Linnæus of *Anomia crispa* agreed with one given by himself of *Delthyris sulcata*, but that, since Dalman ‖, under the name of *crispa*, had described a different shell, which lacked the median rib, he was obliged to give the form which he was describing the new name of *sulcata*. He gives a good representation of *Delthyris crispa* of Linnæus in the same work. *Anomia crispa* of Linnæus is again quoted as a synonym of *Delthyris sulcata* by Hisinger in 1837 ¶. In spite of these statements by Hisinger, and that made by Lindström in 1860 **, about the similarity of *Anomia crispa* of Linnæus to *Delthyris sulcata* of Hisinger, the specific names *sulcata* and *crispa* of Hisinger have remained in general use to the present day. According to the rules of zoological nomenclature, therefore, *Delthyris*

* Vet.-Akad. Handl. tab. vii. fig. 4, p. 336 (1826).

† Vet.-Akad. Handl. p. 222, tab. iii. fig. 6 (1828).

‡ 'Anteckningar i Physik och Geognosi,' vol. iv. tab. vii. fig. 4 (1828).

§ Hisinger, *l. c.* vol. v. p. 119 (1831).

‖ As a matter of fact, Hisinger himself had already figured it (Vet.-Akad. Handl. tab. vii. fig. 4, 1826).

¶ 'Lethæa Svecica,' Holmiæ, pl. xxi. figs. 6 *a–c*, p. 73 (1837).

** "Bidrag till kännedomen om Gothlands Brachiopoder," Öfv. K. Vet.-Akad. Forhand. Stockholm, p. 359 (1860).

crispa (Linnæus) must be used for *Delthyris sulcata*, Hisinger; *Delthyris elegans*, nom. nov., may be used for *Delthyris crispa* (Hisinger).

Delthyris elegans, nom. nov. (Figs. 3, 4, 5, 5 *a*, 6.)

1826. *Terebratula crispa*, Hisinger, Vet.-Akad. Handl. tab. vii. fig. 4, p. 336.
1828. *Delthyris crispa*, Dalman, Vet.-Akad. Handl. for 1827, tab. iii. fig. 6, p. 222.
1828. *Delthyris crispa*, Hisinger, 'Anteckningar,' vol. iv. tab. vii. fig. 4, pp. 220, 238.
1836. *Spirifer crispus* (in part.), Von Buch, "Ueber *Delthyris* oder *Spirifer* und *Orthis*," Abh. K. Akad. Wiss. Berlin, p. 40.
1837. *Delthyris crispa*, Hisinger, 'Lethæa Svecica,' p. 73.
1839. *Spirifer crispus*?, J. de C. Sowerby in 'The Silurian System,' pt. ii. pl. xii. fig. 8, p. 624.
1848. *Spirifer crispus*, Davidson, Bull. Soc. Géol. France, 2nd ser. vol. v. pl. iii. fig. 42, p. 325.
1866. *Spirifer crispa*, Davidson, Mon. Brit. Foss. Brach. vol. iii. pt. vii. no. 1, pl. x. figs. 13, 14, 15, p. 97.

Description.—Wider than long, with the widest part of the shell occurring at a point slightly below the hinge. Brachial valve less convex than pedicle-valve. Apical angle 110°. Cardinal angles rounded. Area of pedicle-valve concave, extending only for two-thirds of the length of the hinge. Delthyrium open, bordered by linear deltidial plates. Umbo acute, incurved. Ornament in the pedicle-valve consists of four rounded longitudinal costæ on the lateral slopes on each side of the sinus, while in the brachial valve there are six costæ in addition to the median fold. The sulci separating the costæ are approximately equal in width to the costæ. Crossing these there are about thirty concentric lamellæ forming a regular transverse ornament. Under the microscope the lamellæ are seen to be striated longitudinally with fine somewhat irregular lines not passing from one lamella to the next, the interspaces being approximately equal in width to that occupied by the striæ.

Interior of pedicle-valve with small teeth supported by short dental plates, outside which are numerous rounded pits representing ovarian markings. A low median septum may be developed, but in many of the specimens examined was not present.

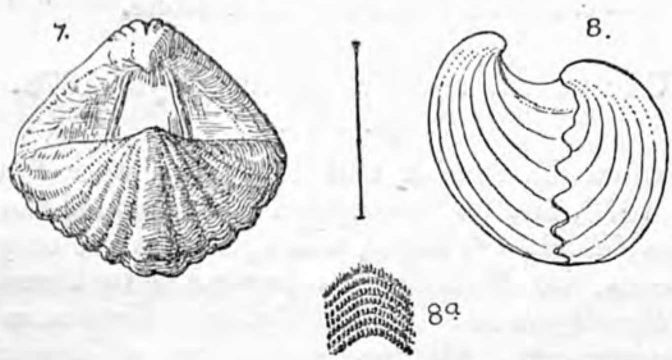
Average Dimensions.—Length 10 mm.; width 13 mm.; thickness 8 mm., or 1 : 1·3 : ·8.

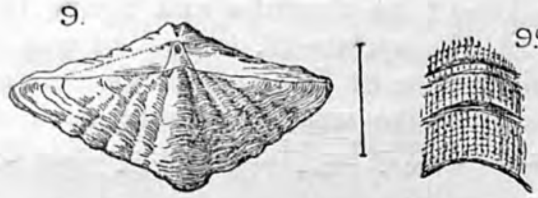
Type-specimen.—The specimen figured by Hisinger from the "Encrinit-kalksten of Djupviken," Gothland, is hereby selected as the holotype.

Horizon.—Upper Llandovery Beds. Wenlock Limestone and Shale and Aymestry Limestone.

Delthyris tenuilamellata, sp. n. (Figs. 9, 9 *a.*)

Description.—Outline transversely rhomboidal, with width of the shell approximately equal to twice the length. Valves equally convex. Apical angle 136°. Cardinal extremities angular. Pedicle-valve with a low area, whose





Figs. 7, 8, 8 *a. Delthyris elevata*, Dalman, from the Wenlock Limestone, Dudley. British Museum Geol. Dept. B. 44,918. 7. Shows ornament of the brachial valve and high area, open delthyrium, and linear deltidial plates of the pedicle-valve (× $1\frac{1}{2}$). 8. Lateral view showing convexity of valves and area of pedicle-valve (× $1\frac{1}{2}$). 8 *a.* Ornament under microscope (× 10).

Figs. 9, 9 *a. Delthyris tenuilamellata*, sp. n., from the Wenlock Shale, Buildwas, Shropshire. British Museum Geol. Dept. B. 44,915. 9. Shows ornament of the brachial valve, area, and conjunct deltidial plates of pedicle-valve (× $1\frac{1}{2}$). 9 *a.* Ornament under microscope (× 10).

length is slightly less than that of the hinge. Deltidial plates conjunct, foramen oval. In the pedicle-valve there are four costæ on each lateral slope, and there are eight costæ in addition to the median fold in the brachial valve. Growth-lamellæ are fairly numerous and very closely placed anteriorly. The ornament tends to become obsolete near the cardinal extremities. The microscopic ornament consists of fine longitudinal striæ, along which are set very small granules. These are also arranged in regular concentric rows, giving the appearance of reticulation. No median septum in the pedicle-valve was developed in any of the specimens examined.

Dimensions.—Length 10·5 mm.; width 21 mm.; thickness 8·5 mm., or 1 : 2 : ·8.

Holotype from Wenlock Shale, Buildwas, Shropshire, preserved in the British Museum (Natural History), Walker Collection (B. 44,915).

Horizon.—Wenlock Shale and Limestone.

UNCINULINA and UNCINULUS, Bayle, 1878.
(Figs. 10, 11.)

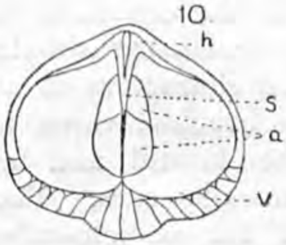
The genera *Uncinulina* and *Uncinulus* were figured by Bayle in 1878, but no description accompanied the plates. *Uncinulina fallaciosa* *, Bayle, was figured as the only species of this genus, but *Uncinulus* is represented by three species, namely, *Hemithyris subwilsoni,* d'Orbigny, *Uncinulus oehlerti,* and *U. imperator* †. All these species are of Devonian age. No internal characters were shown of *Uncinulina,* but those of *Uncinulus subwilsoni* were well depicted. It remained for Oehlert in 1884 ‡ to describe and figure these genera in greater detail, the species *H. subwilsoni* was chosen by him as the genolectotype of *Uncinulus.* Oehlert considered that the genus *Uncinulina* was indistinguishable from *Rhynchonella,* and accordingly he placed the species *U. fallaciosa* in that genus.

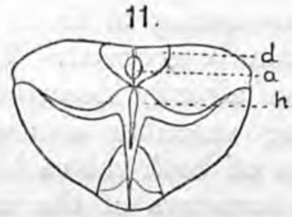
Uncinulina fallaciosa, as figured by Bayle and Oehlert and described by the latter author, has a sub-cuboidal outline with a rather flat pedicle-valve having a shallow median sinus. Each valve is ornamented with 20–24 simple prominent costæ. The umbo is short and incurved till it rests on the brachial valve, and the umbonal slopes are flattened and smooth. In the interior of the ventral valve the diductor muscle-scars are large and flabelliform, and enclose two small oval adductors. The brachial valve is strongly convex with a slightly raised median fold ornamented with six costæ. Internally the hinge-plate is divided into two parts by a narrow oval incision, and there is no cardinal process. The hinge-plate is apparently supported by a median septum, but this is not well represented.

* Explic. de la Carte Géol. de France, vol. iv. pl. xiii. figs. 13–16.
† Explic. de la Carte Géol. de France, vol. iv. pl. xi. figs. 11–16.
‡ Bull. Soc. Géol. France, 3rd ser. vol. xii. pp. 420, 422.

The distinguishing characters of *Uncinulus*, as determined from *U. subwilsoni,* are its spherical contour and external ornament of fine flattened costæ longitudinally grooved near the anterior margin of each valve. In the interior of the pedicle-valve the muscle-scars are surrounded by a narrow ridge ; while in the brachial valve there is a solid undivided hinge-plate, in the centre of which is a broad cardinal process longitudinally notched at the summit. Short crura extend downwards from the hinge-plate, and a median septum separates the two pairs of adductor muscle-scars.

The main points of difference, therefore, between *Uncinulina* and *Uncinulus* are in the contour, costation, and in the tongue of the ventral valve which is truncate in *Uncinulus* and has a straight line of contact with the brachial





Figs. 10, 11. *Uncinulina stricklandi*, J. de C. Sowerby, from the Wenlock Limestone, Much Wenlock, Shropshire. British Museum Geol. Dept. B. 44,920. Nat. size. 10. Diagrammatic drawing of the brachial valve from an internal cast, showing (*s*) median septum, (*h*) hinge-plate, (*a*) adductor muscle-scars, (*v*) vascular markings. 11. Posterior view showing (*a*) adductor, (*d*) diductor muscle-scars of pedicle-valve, (*h*) hinge-plate of brachial valve.

valve, while in *Uncinulina* it is notched owing to the alternation of the costæ of the two valves. Internally the position of the muscle-scars is different in each valve, and in *Uncinulina* the hinge-plate is divided and no true cardinal process is developed.

J. Hall in 1894 * suggested that the name *Uncinulina* should be retained for forms such as *Rhynchonella stricklandi*, in which the hinge-plate is divided anteriorly, but is united towards the apex, and in which the form is sub-cuboidal and less globose than *R. wilsoni*. In the same year, however, he gave *Uncinulina* as a synonym of *Uncinulus* †, while R. S. Bassler in 1915 ‡ quoted *Uncinulina* as a synonym of

* Pal. of New York, vol. viii. pt. 2, p. 199.

† J. Hall and J. M. Clarke, 11th Ann. Rep. State Geologist, p. 828 (1894).

‡ Bull. U.S. Nat. Mus. xcii. vol. ii. p. 1331.

Wilsonia. Cowper Reed, in 1922 *, refers several species from the Devonian of Chitral and the Pamirs to *Uncinulina*, making this a subgenus of *Uncinulus*. He bases his determinations on external rather than on internal characters, and does not mention the hinge-plate in any of his descriptions, but states that the muscle-scars of the brachial valve resemble very closely those of *Uncinulina*, and points out the distinctions between that genus and *Hypothyridina*, S. Buckman = *Hypothyris*, auctt.

It is proposed, therefore, to use the generic name of *Uncinulina* to include such Silurian and Devonian species as agree in external shape and ornament with *Uncinulina fallaciosa* and *U. stricklandi*, i. e., flattened, slightly sinuated forms having the pedicle-valve with umbo incurved, concealing foramen and deltidial plates; the convex brachial valve with slightly raised fold; and the ornament in each valve consisting of from 20 to 30 prominent simple costæ not medianly grooved. The internal characters in addition to those already described in the brachial valve are the radiating vascular sinuses on the lateral and anterior portions of both valves below the muscle-scars. These and other characters of the interior of the pedicle-valve were well shown by Davidson †, but the adductor muscle-scars are not seen for "*Rhynchonella*" *stricklandi*. The position of the muscle-scars and vascular sinuses of the brachial valve are shown in figs. 10 and 11.

A similar internal structure apparently exists in "*Terebratula*" *lewisi*, Davidson ‡, which may also be referred to the genus *Uncinulina*.

MERISTINA, Hall, 1867 §.

Terebratula obtusa, J. Sowerby, Proc. Linn. Soc. vol. xii. pt. 2, pl. xxviii. figs. 3 & 4 (1818) (= *Atrypa tumida*, Dalman, Vet.-Akad. Handl. 1827 (1828), pl. v. figs. 3 *a–d*, p. 134).

Terebratula obtusa is described by J. Sowerby, in 1818, as "a shell curved laterally from the hinge, which must be very short without any space for triangular foramen externally . . . ." He figures the exterior, and in another specimen shows that the spirals had fifteen convolutions, and had their apices laterally directed, and that a median septum was present in the brachial valve. These specimens

* 'Palæontologica Indica,' n. s., vol. vi. no. 2, p. 40.

† Mon. Brit. Foss. Brach. vol. iii. pl. xxi. fig. 6 (1867).

‡ Davidson, Bull. Soc. Géol. France, 2nd ser. vol. v. pl. iii. fig. 30, p. 330 (1848).

§ 20th Rept. N.Y. State Cab. Nat. Hist. p. 157.

were obtained from "Sladacre's Quarry on right-hand side of road from Wych to Calwell Green, Malvern Hill." Judging by Sowerby's description and figures, there is no doubt that his species is identical with *Meristina* (*Atrypa*) *tumida*, figured by Dalman from Gothland, but the dimensions given by Dalman for his species are considerably less than those of the average fully-grown *Meristina obtusa* found in this country, and Dalman was apparently describing a young individual. *Meristina* (*Atrypa*) *tumida*, Dalman, therefore, is a synonym of *Meristina* (*Terebratula*) *obtusa*, Sowerby.

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no 2

Jurassic Brachiopoda from the Jordan Valley.
By HELEN M. MUIR WOOD, M.Sc., F.G.S.

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[Plate XV.]

THE Brachiopoda described in this paper form part of an interesting collection of fossils from the Jordan Valley recently presented to the Natural History Museum. The specimens were obtained from the mouth of Wadi Zerka, the valley of the River Jabbok, a tributary of the Jordan on its east bank, about 20 miles north of the Dead Sea.

The beds from which these specimens were obtained are of Upper Bajocian and Bathonian age.

The Brachiopoda from the Upper Bajocian beds consisted of the following species :—

Cymatorhynchia (?) *quadriplicata* (Hartmann).
Lobothyris ventricosa (Davidson), non Hartmann.
? *Heimia jabbokensis,* sp. n.

In the Bathonian beds the following species occurred :—

Eudesia cardium (Lamarck).
Burmirhynchia tumida, Buckman (=*Rhynchonella concinna,* Davidson, non Sowerby).
Heimia furciliensis (Haas).
Avonothyris jordanensis, sp. n.

There is no evidence of the occurrence of Oxfordian–Kimeridgian beds, although such are to be expected in this neighbourhood.

An account of the former explorations in this area and a description of the molluscan remains contained in the present collection are given by Mr. L. R. Cox in the preceding paper.

Description of Species.

Family Rhynchonellidæ.

Genus Cymatorhynchia, S. S. Buckman, 1914, Genera of some Jurassic Brachiopoda, p. 2.

Defined in Palæontologia Indica, n. s. iii. no. 2, p. 53.

"Hypothyrid (beak short, foramen circular, deltidial plates conjunct); multiplicate, dental plates strong and divergent; ventral muscle-area well marked, large, elongately trigoniform; dorsal septum strong, fairly long; dorsal muscle-scars well marked, forming two elongate-trigonal figures; ovarian areas large, not quite half of valves; vascular system shows numerous approximate shallow channels in the cast" (*S. S. B.*).

Cymatorhynchia (?) *quadriplicata* (Hartmann). (Pl. XV. figs. 8 *a–c*.)

Rhynchonella quadriplicata, Hartmann in Zieten, 1832, Versteinerungen Wurtemburgs, pl. xli. fig. 3.
See also:—Davidson, 1855, Mon. Brit. Foss. Brach. i., Appendix, pl. A, fig. 22.
Deslongchamps, 1855, Bull. Soc. Linn. Normandie, ii. p. 362, pl. v. fig. 5.
Quenstedt, 1858, Der Jura, p. 423, pl. lviii. fig. 6.
Quenstedt, 1868, Petrefactenk. Deutschlands, Brach. pp. 81, 82, t. xxxviii. fig. 42.
Davidson, 1878, Mon. Brit. Foss. Brach. iv. pt. ii. no. 2, p. 201, pl. xxix. figs. 1–3.
Rollier, 1917, Mém. Soc. Pal. Suisse, xlii. p. 148.
Hoppe, 1922, Zeitschr. Deutsch. Palästina-Vereins, xlv. p. 78.

Diagnosis.—Costation coarse and angular, fold and sinus well developed. Brachial valve with four costæ on fold and five on each lateral slope, pedicle-valve with three costæ in sinus and six on each lateral slope. Umbo tapering and incurved. Foramen circular, deltidial plates conjunct. Dental plates long, stout, and slightly divergent. Brachial valve with median septum extending for one-third of length of valve.

Material.—Twenty-four specimens in a fair state of preservation. None showed internal characters. [B. 45377–93, 45398–99.]

Horizon.—Bajocian.

Description.—The number of costæ developed in each valve is a very constant character, unlike the German specimens, where there is enormous variation both in the size and number of the costæ. Hoppe (1922) noted the slight variation in the specimens of this species, collected from the Bajocian beds of Sinai. It was not possible to obtain internal casts by the method of burning, and the generic relationship of the Palestine form is uncertain. The shape and position of the dental plates resemble those of *Cymatorhynchia*. Buckman assigns the German specimens with doubt to his genus *Cymatorhynchia*.

Dimensions of figured specimen.—Maximum height 21 mm.; max. width 23 mm.; max. thickness 18 mm. or 1 : 1·09 : 0·85.

Remarks.—Hartmann (in Zieten) originally described this species from the Upper Inferior Oolite near Gosheim and at Harras, Germany. Quenstedt (1868) figured a typical specimen from the "Braun Jura δ." Davidson (1855) figured a similar form from the Inferior Oolite of Cheltenham. D'Orbigny (1850, 'Prodrome,' i. pp. 314 & 343) quoted *R. quadriplicata* from the Bathonian and Callovian of France, but Deslongchamps (1857), having examined Zieten's original specimen and compared it with French specimens, stated that this species does not occur above the Inferior Oolite. Hoppe (1922) recorded it from the Bajocian of el-Mlēh, Sinai.

Genus BURMIRHYNCHIA, Buckman, 1915,
Rec. Geol. Surv. Ind. xlv. p. 76.

Def. 1917, Palæontologia Indica, n. s. iii. p. 49.

"Hypothyrid (beak massive, springing from a gibbous umbo, apex produced and incurving [foramen subelliptical, deltidial plates narrow, disjunct]); slightly trilobed; multiplicate; dental plates strong, much divergent, ventral muscle-area large, pyriform, dorsal septum strong; dorsal muscle-area quadriform to subcircular pattern—the two anterior scars strongly marked, making a cordate figure, being individually more or less pyriform, bounded by well-marked diverging channels" (*S. S. B.*).

Burmirhynchia tumida, Buckman.
(Pl. XV. figs. 7 *a*, *b*.)

Rhynchonella concinna, Sowerby; Davidson, 1852, Mon. Brit. Foss. Brach. i. pt. iii. no. 2, p. 88, pl. xvii. figs. 6 *a*, *b*.
Terebratula concinna, Sowerby; Quenstedt, 1868, Petrefactenk. Deutschlands, Brach. pl. xxxviii. fig. 36.
Rhynchonella concinna, Sowerby; Szajnocha, 1879, Denk. K. Ak. Wiss. Wien, xli. (2) pl. vi. figs. 10, 11.
Burmirhynchia tumida, Buckman, 1917, Palæontologia Indica, n. s. iii. no. 2, p. 221, pl. xvii. figs. 6 *a*-*c*.

Diagnosis.—Outline trigonal. Brachial valve very globose; pedicle-valve flattened. Umbo massive; apex acute and incurved, hypothyrid. Foramen oval; deltidial plates disjunct. Brachial valve with broad, slightly raised, median fold, ornamented with eight costæ; nine costæ on each lateral slope. Pedicle-valve with median portion slightly depressed, but no true sinus, and twenty-seven costæ at the anterior margin.

Interior shows a short median septum in the brachial valve. Dental plates strong and divergent. Other internal characters unknown.

Material.—One specimen showing external ornament. Dental plates and median septum seen through test. [B. 45301.]

Horizon.—Bathonian.

Dimensions of figured specimen.—Maximum height 23 mm.; max. width 24 mm.; max. thickness 19·5 mm. or 1 : 1·04 : 0·84.

Remarks.—Davidson (1852) described and figured this species from the Great Oolite of Cirencester. Buckman (1917) figured it from the Great Oolite of Fritwell, near Aynhoe, Northants, and stated that its age was post-*subcontractum* and pre-*bathonica*. Quenstedt's specimen was obtained from the Braun Jura δ of Krakau, while Szajnocha figured a similar form from the Balin Oolite of similar age.

Burmirhynchia tumida, Buckman (=*Rhynchonella concinna*, Davidson, in part.), differs from *Rhynchonella* [*Kallirhynchia*] *concinna*, Sowerby, in having a flattened instead of a deeply sinuated pedicle-valve, therefore in having a greater thickness than *K. concinna*. The umbo in *Kallirhynchia concinna* is more erect and less massive than in *Burmirhynchia tumida*. The arrangement of the muscle-scars in the two forms is quite distinct. It is probable that specimens from adjacent areas recorded as "*Rhynchonella concinna*" resemble the Palestine specimen of *B. tumida*.

Fraas (1877, N. Jahrb. Mineral. pp. 22, 29) mentions this species from the Jurassic (Upper Brown Jura) of Mount Hermon, but compares it to Quenstedt's figure (1868), which was quoted by Buckman in his synonymy of *B. tumida*; it also resembles the Palestine species very closely.

The specimen of *Rhynchonella concinna* figured by Douvillé (1916, Mém. Acad. Sci. Paris, liv. pl. i. fig. 21) from the Bathonian of the Moghara Massif is more elongated and appears to have a less-marked fold in the brachial valve, the anterior margin is not abruptly truncated as in *B. tumida*.

Family **Terebratulidæ.**

Genus AVONOTHYRIS, Buckman, 1917.

Palæontologia Indica, iii. no. 2, p. 102.

"Epithyrid (beak rather small, rather short, subcarinate, foramen small, circular, marginate, symphytium rather narrow, fairly well exposed); test finely punctate, with signs of capillation in old age; sulcation of dorsal umbo occasional, but not persistent down valve in biplicates; morphogeny sulcate, to rectimarginate trigonal, to paraplicate, with subsequent elongation; muscle-tracks fairly long, sub-approximate."

Avonothyris jordanensis, sp. n.

Diagnosis. — Outline roughly circular, with the length slightly in excess of the width. Beak-ridges obscure, epithyrid. Beak short and incurved, concealing the fused deltidial plates or symphytium in the adult stage. Foramen circular to oval and labiate. Widest part of shell occurs a short distance above anterior margin. Brachial valve concave near umbo, but becoming very globose. Pedicle-valve convex. Anterior margin irregularly flexuous, but plication of valves never prominent. Shell-surface smooth, with numerous growth-lines. Anterior portion of shell capillate. Interior of brachial valve with strong median septum separating the narrow, slightly diverging posterior adductor scars. Two small oval muscle-scars are distinguishable near their anterior extremities, set close to the median septum. Ovarian markings distinguishable on the posterior lateral portions of this valve. Pedicle-valve with long narrow diductors enclosing oval adductor scars.

Holotype [B. 45302]. Paratypes [B. 45303, 45307].

Material.—Twenty-four specimens with shells preserved in beekite [B. 45306–27]. One specimen [B. 45307], an internal cast, showed muscle-scars of both valves.

Horizon.—Bathonian.

Description.—Growth-stages: brachial valve sulcate in early stages, with slight corresponding carination in the pedicle-valve; sulcation is more persistent and is traceable for 1½ centimetres below the umbo. The valves then flatten and develop a trigonal outline with plane commissure. A broad rounded fold is developed on each side of the median flattened portion, which, again, gradually becomes sulcate, giving rise to a biplicate anterior margin. The amount of plication in the brachial valve is very variable, and in some specimens folding commences at an early stage.

Dimensions of figured specimens (Pl. XV.).—

	Fig. 1. mm.	Fig. 2. mm.
Maximum length	45·5	40·5
„ width	39·5	26·5
„ thickness ..	32	28
or	1:0·86:0·70	1:0·90:0·69

Remarks.—The characters of this species agree very closely with those of the genus *Avonothyris* of Buckman. This genus was proposed for a number of British Bathonian species from Bradford-on-Avon, many of them dwarfs. These species resemble *A. jordanensis* very closely in external form and posterior sulcation of the brachial valve. Young forms of *A. jordanensis* are very similar to *A. trigonata*, Buckman (1917, *loc. cit.* pl. xxi. figs. 10 *a–c*). *A. corpulenta*, Buckman, shows a considerable resemblance to *A. jordanensis*; the anterior margin, however, is more excavated and the umbo less incurved in the British species. The external shell-surface resembles that of *Avonothyris*; the anterior capillation is also characteristic and the growth-stages are similar. In shape and position of the muscle-scars *A. jordanensis* resembles the genus *Holcothyris*, Buckman. This genus was proposed for a number of Indian species, and resembles *Avonothyris* very closely. In *Holcothyris*, however, the whole shell is capillate and the dorsal sulcus is continuous to the anterior margin. The small anterior adductors developed in *A. jordanensis* resemble those of *Holcothyris*. No second pair of adductors is shown in any specimen of *Avonothyris*. This may be due to the bad state of preservation of the British material, for in other characters *A. jordanensis* is in complete accord with the genus *Avonothyris*. A variety of *Terebratula quillyensis*, Bayle, figured by Douvillé (1916, Mém. Acad. Sci. Paris, liv. pl. vii. fig. 5), resembles *A. jordanensis* slightly in outline, but the folding is more prominent and the growth-stages of the two forms are distinct. *A. jordanensis* resembles in shape and contour *Terebratula retrocarinata*, Rothpletz (1886, 'Palæontographica,' xxxiii. pl. ii. figs. 3 *a*, *b*), from the Brown Jura δ–ε. The folding and growth-stages of the two forms are distinct and the adductor scars are broader and longer in *T. retrocarinata*. *A. jordanensis* is distinguished from *Epithyris maxillata* (Sow.) by its shorter less incurved umbo, greater elongation of shell, and difference of internal characters.

Genus Heimia, Haas, 1890.

Abh. d. Schweiz. pal. Ges. xvii. p. 87.

"Hypothyrid (beak short, stout, foramen rounded, symphytium hidden); morphogeny sulcate to plano-perconvex to sulciplicate (? paraplicate); [muscle-tracks narrow, approximate almost parallel]" (*S. S. Buckman*, 1917, p. 103).

Heimia furciliensis (Haas). (Pl. XV. figs. 6 *a–c*.)

Terebratula furciliensis, Haas, 1890, Abh. d. Schweiz. pal. Ges. xvii. p. 95, pl. x. figs. 1-4.
Terebratula stephani, Dav., var. *furciliensis*, Haas; Clerc, 1904, Mém. Soc. Pal. Suisse, xxxi. p. 80, pl. iii. figs. 4 *a–c*.
Heimia furciliensis, Haas; S. S. Buckman, 1917, Palæontologia Indica, n. s. iii. no. 2, p. 103 (list only).
Terebratula furciliensis, Haas; Rollier, 1918, Mém. Soc. Pal. Suisse, xliii. p. 225.

Diagnosis.—Outline elongate-oval, with length of shell in excess of width. Brachial valve depressed; pedicle-valve highly convex. Beak short, incurved, and concealing the fused deltidial plates or symphytium. Beak-ridges not developed. Umbonal slopes meeting at apex in angle of 72°. Shell smooth, with numerous growth-lines. Internal characters unknown.

Horizon.—Bathonian.

Description.—Growth-stages: the brachial valve is sulcate near the umbo, and corresponding carination is developed in the pedicle-valve. Flattening of the brachial valve next occurs, with increasing convexity of the pedicle-valve. Both valves are now circular in outline, with a plane commissure. Biplication of the brachial valve follows directly on this stage, the folds increasing in width and prominence anteriorly, and a median sulcus is formed between the folds. A deep sinus is also developed on the outer side of each fold, thereby adding to its elevation. A median fold is developed in the pedicle-valve corresponding to the median sinus of the brachial valve.

Dimensions of figured specimen.—Maximum length 30 mm.; max. width 24 mm.; max. thickness 17·5 mm. or 1 : 0·8 : 0·58.

Remarks—This species was described by Haas from the Bathonian of Furcil, near Noiraigue, Val de Travers, in the Swiss Juras. Rollier quotes it as being of Bradfordian age. The Palestine specimens agree in shape and dimensions with Haas's figures and with actual specimens of *Terebratula furciliensis*. The incurvature of the umbo so as to conceal the symphytium, absence of beak-ridges, the flattening of the brachial valve, convexity of the pedicle-valve, and anterior biplication are characteristics of this species and of the genus *Heimia*. The folding in the Palestine specimens is slightly less prominent than in the Swiss examples. Haas places his species in the "Globata group," and compares it with *Terebratula ferryi* from the Inferior Oolite, figured by Davidson (1878, Mon. Brit. Foss. Brach. iv. p. 139, pl. xvii. fig. 8). This species is narrower in proportion to its length, and is said by Buckman (1917, p. 116) to belong to the genus *Sphæroidothyris*, while *Terebratula furciliensis*, from its external characters only, is said to belong to the genus *Heimia*. Rollier (1918, p. 225) compared this species with *Terebratula circumdata*, Deslongchamps, from which he considered it to be derived. From this species, however, *Heimia furciliensis* is distinguished by its different growth-stages.

Heimia jabbokensis, sp. n. (Pl. XV. figs. 5 *a–c*.)

Diagnosis.—Outline elongate-oval, with length considerably greater than width. Greatest width of shell occurs at a point midway along the length. Brachial valve flattened; pedicle-valve convex. Beak short, slightly incurved, and in contact with brachial valve, not projecting beyond hinge. Beak-ridges very faint. Umbonal slopes meeting at apex in angle of 108°. Shell smooth. Adductor muscle-scars of brachial valve short, narrow, and subparallel. Cardinal process low, narrow, and posteriorly excavated.

Holotype [B. 45304].

Material.—Thirty-three specimens well preserved and showing external characters. One imperfect specimen showed cardinal process and part of loop [B. 45439] [B. 45304, 45328–60].

Horizon.—Bajocian or Bathonian?

Description.—Growth-stages: the brachial valve is sulcate near the umbo and the pedicle-valve slightly carinate. The brachial valve then flattens and the pedicle-valve becomes convex. Elongation follows on this circular plano-convex stage, and biplication is developed in the brachial valve. The folds are raised up on each side of the median flattened portion and become very prominent anteriorly. A strong median fold is developed anteriorly in the pedicle-valve and a shallow sulcus is formed on each side of the fold.

Dimensions of figured specimen.—Maximum length 35·5 mm.; max. width 27 mm.; max. thickness 21·5 mm. or 1 : 0·7 : 0·6.

Remarks.—This species is distinguished from *Heimia furciliensis* by its larger dimensions, greater width and convexity of the brachial valve, shorter and less incurved beak, and larger apical angle.

Heimia jabbokensis resembles very closely specimens figured by Davidson in 1851 (Mon. Brit. Foss. Brach. i. p. 54, pl. xiii. fig. 7) and 1855 (*loc. cit.*, Appendix, pl. A, fig. 18) as *Terebratula globata* and *Terebratula globata*, var. *fleischeri* (*loc. cit.* iv. p. 137, pl. xvii. fig. 2) from the Upper Inferior Oolite of Cheltenham. The last-named specimen is one of the type-specimens of Oppel's species *Terebratula fleischeri*. Oppel (1856, 'Die Juraformation,' p. 497) remarks on the similarity of this species to *T. globata*, Davidson (1851, pl. xiii. fig. 7). The internal characters of this form is unknown, but *T. fleischeri* is said to have the internal characters of the genus *Cererithyris*, Buckman (1917, p. 109). The umbo of *Cererithyris fleischeri* and of the other specimens probably referable to this species, but renamed by Rollier *T. oppeli* (1918, Mém. Soc. Pal. Suisse, xliii. p. 202), is less incurved, and the symphytium is not hidden. The brachial valve is more convex than in *Heimia jabbokensis*. The Palestine specimens also resemble *Terebratula buckmaniana*, Walker in Davidson, 1878 (*loc. cit.* iv. pl. xix. figs. 15 & 17), also said by Rollier to be a synonym of *T. oppeli*. *Terebratula buckmaniana* is more elongated and has less prominent plication in the brachial valve. Buckman (1917, p. 104) doubtfully refers this and similar species with which *Heimia jabbokensis* would be included to the genus *Heimia*, but states that they may be generically distinct.

Genus LOBOTHYRIS, S. S. Buckman, 1914.

Genera of some Jurassic Brachiopoda, p. 2.
Def. 1917, *loc. cit.* p. 107.

" Epithyrid (beak overhanging dorsal umbo, foramen more or less elliptical, in old forms labiate, symphytium broad); morphogeny subconcavo-convex to biconvex, to elongate, to uniplicate, to sulciplicate—centronella to terebratula stage; muscle-tracks narrow, subapproximate" (*S. S. B.*).

Lobothyris ventricosa (Davidson), non Hartmann. (Pl. XV. figs. 4 *a–c*.)

Terebratula ventricosa, Hartmann (?), Davidson, 1876, Mon. Brit. Foss. Brach. iv. pt. ii. no. 1, p. 127, pl. xv. figs. 10, 11.

Diagnosis.—Outline elongate-oval, with slightly convex biplicate brachial valve and highly convex pedicle-valve.

Pedicle-valve carinate posteriorly. Greatest width occurs about halfway down shell. Beak-ridges obscure, epithyrid. Umbo short, incurved in senile stage. Foramen circular to oval and labiate. Adductor muscle-tracks of brachial valve long, narrow, and subparallel, and resembling those of *Lobothyris*. Median septum extends for one-third of length of brachial valve.

Material.—Fourteen specimens badly preserved in a hard ferruginous sandstone. In one specimen [B. 45374] the muscle-scars and median septum of the brachial valve could be seen through the test. [B. 45361–68, 45370–74.]

Horizon.—Bajocian.

Description.—Growth-stages: the brachial valve is slightly concave near the umbo and the pedicle-valve is carinate, the carination persisting when the sulcation has died out. Both valves then become evenly convex, with circular outline and plane commissure. After considerable elongation a low median fold is developed in the brachial valve. This fold rapidly increases in elevation, and is then medianly depressed by a sulcus, giving rise to strong biplication (sulciplication of Buckman). In the pedicle-valve a median fold corresponds to the sulcus of the brachial valve.

Dimensions of figured specimen.—Maximum length 37 mm.; max. width 30 mm.; max. thickness 22 mm. or 1 : 0·81 : 0·59.

Remarks.—Davidson's specimens were obtained from the Inferior Oolite of Crickley, Cleeve, and Leckhampton Hills, Gloucestershire. The Palestine specimens are associated with *Cymatorhynchia* (?) *quadriplicata* in Bajocian strata.

This species resembles *Terebratula ventricosa*, Davidson, in its external form, dimensions, development, and in having internal characters of the genus *Lobothyris*, Buckman.

In their early stages the Palestine specimens resemble *Lobothyris buckmani*, Davidson, from the Inferior Oolite (1851, Mon. Brit. Foss. Brach. i. p. 44, pl. vii. figs. 15 & 16). This species is oval in outline and dorsally uniplicate, but does not develop prominent biplication as in *Lobothyris ventricosa*. The umbo in *Lobothyris buckmani* is longer and more incurved, and the two valves are less convex. In his description of *Terebratula ventricosa* Davidson queries the identity of his species with that of Hartmann in Zieten (1832, 'Versteinerungen Wurtemburgs,' p. 53, pl. xl. fig. 2). Hartmann's species attains considerably greater dimensions, is elongate-oval in outline, but is dorsally uniplicate and does not appear to develop biplication as in Davidson's species. Deslongchamps (1873, Pal. française, Terr. jurassiques, Brach. p. 260, pls. lxxiii.–lxxvi.) figures specimens similar to that of

Hartmann, but also includes some biplicate forms which appear to be distinct. Deslongchamps mentions the longitudinal striation of the shell—a character also shown in Hartmann's figure and probably representing capillation. This character is remarked upon by Buckman (1917, p. 108), who suggests that Hartmann's species belongs to the section "Capillatæ" of his classification of Jurassic Terebratulas. Capillation does not occur in Davidson's species or in the Palestine specimens. *Lobothyris ventricosa* is distinguished from "*Terebratula*" *perovalis*, Sowerby, by the difference in shape of adductors of the brachial valve, in the more massive umbo truncated by a large foramen. It is possible that *Lobothyris ventricosa* is mentioned in fossil lists from adjacent areas as *Terebratula perovalis*.

Family **Terebratellidæ**.

Genus EUDESIA, King, 1850.

A Monograph of Permian Fossils, p. 81.

Eudesia cardium, Lamarck. (Pl. XV. fig. 9.)

Terebratula cardium, Lamarck, 1819, Histoire Naturelle des Animaux sans Vertèbres, vi. p. 225, no. 47.
Terebratula orbicularis, J. de C. Sowerby, 1829, Mineral Conchology, vi. p. 68, pl. dxxxv. fig. 3.
See also:—Davidson, 1850, Ann. & Mag. Nat. Hist. ser. 2, v. p. 12, pl. xiv. fig. 47.
Davidson, 1851, Mon. Brit. Foss. Brach. i. p. 43, pl. xii. figs. 13–18.
Quenstedt, 1871, Petrefaktenkunde Deutschlands, Brachiopoden, p. 293, t. xlv. figs. 63–69.
Davidson, 1878, *loc. cit.* iv. pt. ii. no. 2, p. 185, pl. xxiv. fig. 22.
Deslongchamps, 1885, Paléontologie française, Terrains Jurassiques, Brachiopodes, vi. p. 388, pl. vi. fig. 4, and pls. cxi.–cxiv. (includes several varieties).
Haas, 1890, Abh. d. Schweiz. pal. Ges. Zurich, xvii. 2, p. 100, pl. x. figs. 8, 9.
Douvillé, 1916, Mém. Acad. Sci. Paris, lv. p. 63, pl. vii. figs. 10–15.

Material.—This species is represented by four well-preserved specimens showing the characteristic shape and ornament [B. 45299, 45400–01].

Description.—The specimens show slight variation in the total number of costæ. One specimen with length 22·5 mm. had twenty-one costæ at the anterior margin. A second specimen with length 23 mm. had twenty-five costæ. This character is also rather variable in European specimens.

Dimensions of figured specimen.—Maximum length 22·5 mm.; max. width 20 mm.; max. thickness 14·5 mm. or 1 : 0·8 : 0·6.

Horizon.—Bathonian.

Remarks.—This species is widely distributed in the Bathonian of Europe. In Great Britain it occurs in the Great Oolite, Bradford Clay, and Forest Marble. Douvillé (1916, p. 63) records *Eudesia cardium* from the Moghara Massif in the Sinai Peninsula. Hoppe (1922, Zeitsch. Deutsch. Palästina-Vereins Leipzig, xlv. p. 101) describes this species from el-Mlēh, Sinai.

No specimens of either *Eudesia plana*, Hoppe, or of *E. cardioides*, Douvillé, were obtained from Palestine, although both species were associated with *E. cardium* in the Bathonian of Sinai.

EXPLANATION OF PLATE XV.

(The figures are all of natural size.)

Fig. 1. *Avonothyris jordanensis*, sp. n. [B. 45303.] Paratype.

Fig. 2. *Avonothyris jordanensis*, sp. n. [B. 45302.] Holotype. *a*, dorsal view, showing shell preserved in beekite; *b*, lateral view; *c*, anterior view, with brachial valve uppermost.

Fig. 3. *Avonothyris jordanensis*, sp. n. [B. 45307.] Paratype. *a*, internal cast, showing posterior and anterior adductor scars of brachial valve and median septum; *b*, internal cast, showing diductor and adductor muscle-scars of the pedicle-valve.

Fig. 4. *Lobothyris ventricosa* (Davidson). [B. 45374.] Immature specimen. *a*, dorsal view, showing muscle-scars and median septum; *b*, lateral view; *c*, anterior view, showing uniplication of brachial valve and initiation of median sinus.

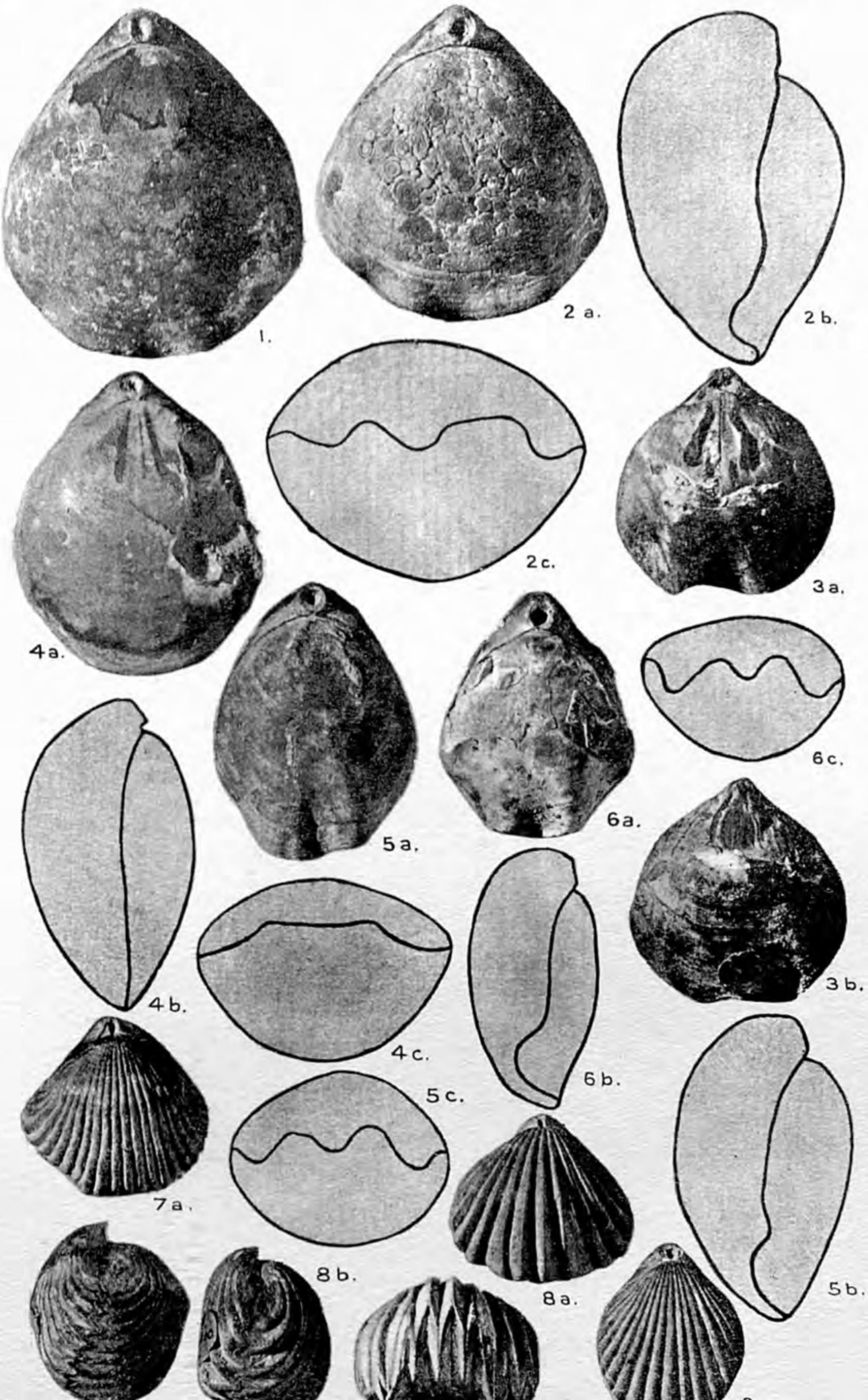
Fig. 5. *Heimia jabbokensis*, sp. n. [B. 45304.] Holotype. *a*, dorsal view, showing biplication; *b*, lateral view; *c*, anterior view, with brachial valve uppermost.

Fig. 6. *Heimia furciliensis* (Haas). [B. 45376.] *a*, dorsal view; *b*, lateral view; *c*, anterior view, with flattened brachial valve uppermost.

Fig. 7. *Burmirhynchia tumida*, Buckman. [B. 45301.] *a*, dorsal view; *b*, lateral view, showing gibbous umbo with incurved apex and convex pedicle-valve.

Fig. 8. *Cymatorhynchia* (?) *quadriplicata* (Hartmann). [B. 45300.] *a*, dorsal view; *b*, lateral view; *c*, anterior view.

Fig. 9. *Eudesia cardium* (Lamarck). [B. 45299.]



H. G. Herring photo.

JURASSIC BRACHIOPODA FROM PALESTINE.

From the ANNALS AND MAGAZINE OF NATURAL HISTORY,
Ser. 9, Vol. xix. p. 286, *February* 1927.

Two new Species of Lower Carboniferous Brachiopoda from Northumberland. By HELEN M. MUIR-WOOD, M.Sc., F.G.S.

(Published by permission of the Trustees of the British Museum.)

THE material to be described was collected by Mr. A. Templeman of H.M. Geological Survey, and kindly lent to me for description by Mr. J. Pringle, to whom I am also indebted for a list of the associated fossils given below. All the specimens were obtained from shales overlying the Upper Fell Top Limestone, and exposed in a small stream joining Hartley Burn, near Burnfoot, four miles S.S.W. of Haltwhistle. The beds have yielded the following fossils :—

Crinoid ossicles.
Serpulites sp.
Chonetes laguessiana, de Kon.
Productus carbonarius, de Kon.
—— ——, sp. n.*.

* Description by the author to be published shortly in Mem. Geol. Survey on "Carboniferous *Producti*."

Productus pugilis, Phill.
Grammatodon regularis, Hind.
Nuculana sp.
Schizodus antiquus, Hind.
Conularia quadrisulcata, J. Sow.

The presence of such species as *Productus pugilis*, Phill., and *P. carbonarius*, de Kon., indicates a high horizon in the Carboniferous Limestone Series, since *P. carbonarius* ranges from the top of the D_2 subzone up to the Millstone Grit.

Mr. F. M. Trotter (1926, p. 82*), who has surveyed this area, has taken as the base of the Millstone Grit the first bed of thick sandstone overlying these fossiliferous shales, about 110 ft. above the Upper Fell Top Limestone. This limestone represents the D_3 subzone of Prof. Garwood's classification (1910, p. 681) or the subzone DY of Dr. S. Smith (1910, pp. 596, 598).

The new species *Pustula thomasi* has not, so far as is known, been collected from any other locality in Northumberland or from Cumberland. Mr. Pringle informs me that shells comparable to *Punctospirifer northi* have been collected during the progress of the Geological Survey, the results of which are included in the Brampton Sheet of the 1-inch map. The species is first found in shales about the horizon of the Corbridge Limestone, and ranges upwards to the base of the Millstone Grit as defined by Mr. Trotter; but the early forms are usually smaller than the later ones, and, as a rule, show no trace of that thickening and irregular development of the ornament which is characteristic of the later forms. The "*Spiriferina* sp.," which Dr. S. Smith (1910, p. 627) records without description from the Thornbrough Limestone of Stanton may possibly be a *Punctospirifer*.

Description of Species.

Productidæ, Gray.

Pustula, I. Thomas, 1914, Mem. Geol. Surv. Gt. Britain, Palæontology, i. 4, p. 259.

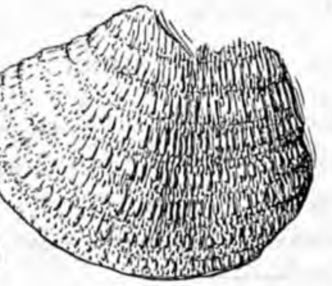
Pustula thomasi †, sp. n. (Text-figs. 1 & 2.)

Diagnosis.—*Pustula* in which the concentric bands are somewhat obscurely defined on the venter, having prominent

* See List of References at end of paper.
† Named after the late Dr. I. Thomas.

and rounded ribs on the flanks, and having no smooth interspaces between the concentric bands.

Description.—The pedicle-valve, 34 mm. long and 40 mm. wide, has an approximately circular outline, is depressed, and has a shallow rounded median sinus ; there is no geniculation between the visceral disc and the venter, and no trail is developed ; the umbo and hinge are not preserved in the type-specimen. The ornament consists of spine-bases inserted on concentrically-arranged band-shaped areas ; each band is about 5 mm. wide on the venter and narrows on the flanks and on the anterior part of the shell, where it is nearly half as wide as on the venter. The spine-bases are of two sizes, major and minor ; the major are arranged in a single row on each band and occupy more than three-quarters of



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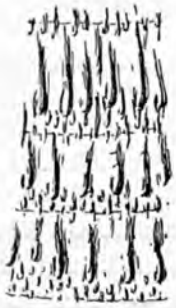


2

Pustula thomasi, sp. n. Holotype in Museum of Practical Geology [37582].

Fig. 1.—Pedicle-valve incomplete near umbo. Slightly reduced.
Fig. 2.—Details of ornament. × 2.

its width, being inserted on its posterior edge or on the anterior edge of the neighbouring band, and extending across the boundary ; the minor spine-bases lie in two or three rows on the anterior part of the concentric bands, often overlapping the boundary and extending on to the posterior part of the neighbouring band. The major spines diminish in length on the anterior portion of the shell, and the minor spines become much crowded, while on the flanks the major spines disappear.

Type-specimen.—Holotype, no. 37582, Museum of Practical Geology, London.

Remarks.—*Pustula thomasi* appears to resemble closely *Productus juresanensis*, Tschernyschew (1902, p. 620, and 1914, p. 62, pl. viii. fig. 6, pl. ix. fig. 1), from the Upper Carboniferous, *Schwagerina* Kalk, of the Ural Mountains ;

but the bands in the Russian species are more clearly defined.

Pustula subelegans, I. Thomas (1914, p. 298, pl. xvii. figs. 9–12), differs from *P. thomasi* in being smaller and having a more convex shell and narrower concentric bands.

Pustula defensa, I. Thomas (1914, p. 310, pl. xvii. figs. 20–23), from the Six-Yard Limestone of Northumberland (horizon D_2–D_3)—that is, from a lower horizon than *P. thomasi*,—resembles that species in its adpressed spine-bases, but differs from it in its elongate-oval outline, greater convexity, and in its concentric bands, which are separated by smooth grooves and are only 2 mm. wide on the venter.

Suessidæ, Waagen.

Punctospirifer, F. J. North, 1920, Quart. Journ. Geol. Soc. vol. lxxvi. p. 212.

Punctospirifer northi *, sp. n.

Diagnosis.—*Punctospirifer* about 25 mm. in length, with a small apical callosity; having a broader sinus and fold than *P. scabricosta*, North, costæ coarser and of variable width, fewer (7–8) costæ on the lateral slopes, and less prominent and less regular lamellar ornament.

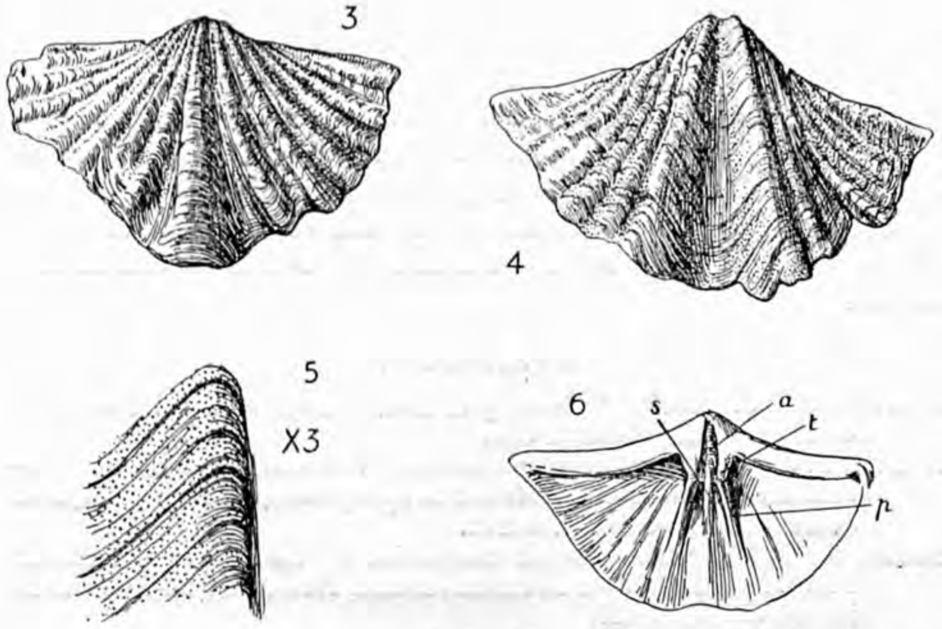
Description.—The much-thickened shell is spiriferoid, alate, about twice as wide as long, and widest at the hinge-line; the cardinal extremities are subangular. The shell-substance is fibrous and strongly punctate.

Pedicle-valve (holotype) 27 mm. long, 46 mm. wide; (specimen B. 47307) 21 mm. long, 42 mm. wide, 8·5 mm. thick; slightly convex, with a broad rounded median sinus at the anterior margin, about four times the width of the bounding costæ. The umbo is acute and slightly incurved. The low cardinal area extends along the whole hinge-line and is sharply differentiated from the lateral slopes. The area is longitudinally striated, flattened along the hinge, but concave near the umbo. The apical angle is 110°; the delthyrial angle 63°. The delthyrium is slightly higher than wide. The deltidial plates are not visible in the specimens examined. There are seven or eight rounded and slightly curved costæ on each lateral slope; their width is inconstant, but increases anteriorly to about 2·5 mm.; the intervening sulci are rounded and of approximately the same width as the costæ; there are six

* Named after Dr. F. J. North.

costæ at the umbo, and the remainder are developed at varying distances from it. The costæ are crossed by concentric growth-lines which frequently form a strong lamellar ornament.

An internal cast of the pedicle-valve shows a narrow median septum and slightly divergent delthyrial supporting plates. The septum passes backwards into a narrow, rounded, apical callosity.



Punctospirifer northi, sp. n.

Fig. 3.—Brachial valve showing broad median fold and curved costæ on the lateral slopes. Paratype. Museum of Practical Geology [37979]. Natural size.

Fig. 4.—Pedicle-valve showing broad median sinus. Holotype. M. P. G. [37978]. Natural size.

Fig. 5.—Details of ornament showing punctæ and irregularly developed concentric lamellæ. M. P. G. [37978]. × 3.

Fig. 6.—Interior of pedicle-valve drawn from rubber impression in British Museum (Nat. Hist.) [B. 47349], and taken from an internal cast in Museum of Practical Geology [37980]. Median septum (*s.*), hinge-teeth (*t.*), apical callosity (*a.*), delthyrial supporting plates (*p.*). Paratype. Natural size.

Brachial valve (specimen no. 37979) 24·5 mm. long, 42 mm. wide, 11·5 mm. thick; slightly convex, with a rounded prominent median fold, which at the anterior margin is about three times the width of the bounding costæ. There are six or seven rounded costæ on each lateral slope; at the umbo there are five costæ as well as the median fold. The costæ are crossed by concentric growth-lines, forming an irregular lamellar ornament. The interior of the brachial valve is unknown.

Type-specimen.—Holotype, no. 37978, Museum of Practical Geology, London. Paratypes, British Museum, B. 47306–07, two pedicle-valves. Museum of Practical Geology, 37979, 37980, Tm. 50, seven pedicle and two brachial valves.

Remarks.—The irregular external ornament of *P. northi*, the thickening of the shell, and the small apical callosity in the pedicle-valve are phylogerontic characters. Besides the congeneric *P. scabricosta*, North, which occurs at a lower horizon (S_2–D_1), *P. northi* resembles *Tylothyris laminosa* (M'Coy), but can be at once distinguished by its punctate shell. It may be distinguished from all species of *Spiriferina* by the differentiation of its hinge-line from the lateral slopes, by the great width of the hinge, by the subangular cardinal extremities, and by the more numerous costæ on the lateral slopes.

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MEMOIRS OF THE GEOLOGICAL SURVEY OF GREAT BRITAIN.

PALÆONTOLOGY.

VOL. III. PART 1.

PAGES 1–217; PLATES I–XII.

THE BRITISH CARBONIFEROUS PRODUCTI

II.—*PRODUCTUS* (*sensu stricto*); *SEMIRETICULATUS* and *LONGISPINUS* GROUPS.

BY

HELEN MARGUERITE MUIR-WOOD, M.Sc.

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CONTENTS.

THE BRITISH CARBONIFEROUS PRODUCTI.

II.—*PRODUCTUS* (*sensu stricto*); *SEMIRETICULATUS* and *LONGISPINUS* GROUPS.

I. Introduction.

This contribution has been made possible by the aid of a part-time grant from the Department of Scientific and Industrial Research. It is an attempt to continue the very valuable work of the late Dr. Ivor Thomas on the Carboniferous *Producti*, and, as far as possible, the general plan and arrangement of that work has been followed. Efforts have been chiefly directed towards describing and figuring the more commonly occurring forms of the *semireticulatus* and *longispinus* groups, and in defining some of the more important varieties. To figure or even to describe all the forms of these groups is beyond the scope of one monograph. The species have been precisely limited in order to render them of greater value to the stratigrapher as zonal indices.

The term mutation has been employed in Waagen's sense for variation in time, and the term variety used for space variants. The two terms, however, are used only when there is no doubt as to the relationship. In all doubtful cases a new name has been employed, but it is probable that further information from zonally collected material will enable some of the forms of the *longispinus* group, and possibly some of the *semireticulatus* group, to be linked together as mutations or variants. Synonymic references are given only when the material described by other authors has been actually examined, or when the descriptions are illustrated by accurate figures which leave no doubt as to the nature of the form intended. Specimens referred to in the locality lists have been examined by the author, and their register-numbers are quoted when possible. Specimens formerly in the Geological Society's collection are now preserved in the Museum of Practical Geology.

References to literature are given by the date of the paper, the date being cited in round brackets after the author's name. The literature quoted in the list of works with which this memoir concludes is given in alphabetical order under authors, and the works of each author are arranged in chronological order; two works appearing in the same year are quoted as A and B. It has not been found possible to take into account all the references to *Productus semireticulatus* and *Productus longispinus,* owing to the immense amount of literature dealing with the Carboniferous system; but it is hoped that the descriptions and figures given in this work will be sufficient for the ready determination of any specimens not mentioned.

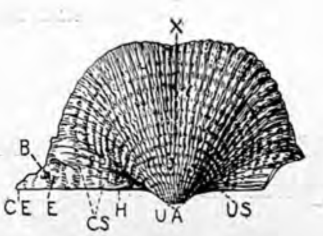
The figures reproduced as text-illustrations throughout these pages were drawn by Miss G. M. Woodward, who also prepared the following drawings reproduced in the plates: pl. ii, figs. 11, 12a, 12b, 13a, 13b; pl. vi, figs. 1, 4a to 4c, 5; pl. viii, fig. 5a; pl. ix, fig. 4; pl. xi, figs. 3, 8a, 8b, 14a; and pl. xii, fig. 6. The remainder of the figures in the plates are from photographs of the specimens. All except five of these were taken by Mr. J. Rhodes, Jun.; those shown in pl. iv, figs. 1a, 1b, 1c, 3, and pl. viii, fig. 4, are by Mr. H. G. Herring.

I am greatly indebted to Sir Arthur Smith Woodward, F.R.S., to Dr. F. A. Bather, F.R.S., and to Mr. T. H. Withers, for assistance and advice while carrying out this research at the Natural History Museum; to Dr. F. L. Kitchin, Dr. G. W. Lee, Mr. J. Pringle and Mr. C. P. Chatwin of the Geological Survey for help and encouragement, and to Professor E. J. Garwood, F.R.S., and Miss Goodyear for assistance in the field and for the loan of material. My thanks are due to the following for the loan or gift of material: Professor G. Delépine, Mr. J. Dunn, Dr. G. H. Girty, Mr. R. G. S. Hudson, Mr. J. Wilfrid Jackson, Mr. P. Macnair, Professor S. H. Reynolds, the late Mr. Philip Roscoe, Dr. T. Franklin Sibly, and Dr. Stanley Smith; also the Directors of the Bristol Museum, the National Museum of Ireland, Dublin, the Geological Survey of Ireland, the Kelvingrove Museum, Glasgow, the Royal Scottish Museum, Edinburgh, the Geological Survey of Great Britain, the University Museum, Oxford, the Sedgwick Museum, Cambridge, Trinity College Museum, Dublin, and York Museum. For permission to examine specimens in their charge I have to thank Dr. H. Bolton, Dr. J. A. Douglas, Professor J. W. Gregory, Dr. J. Ritchie and Professor W. J. Sollas; for the gift of plaster casts of type specimens, Professor M. Boule, of Paris, and the authorities of the National Museum of Ireland, Dublin.

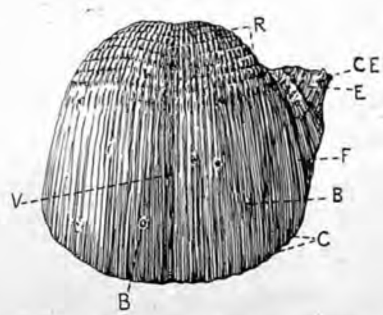
II. Terminology.

The terms used in this work are in agreement as far as possible with those defined by Hall and Clarke (1892A and B; 1894A and B), and Schuchert (1897), but some are new or little known terms which are defined here in order to institute a standard terminology for the *Producti.*

The term *pedicle valve* has been used for the larger convex valve and *brachial valve* for the smaller one, which may be flattened, concave or geniculated. The incurved apical portion of the pedicle valve is termed the *umbo*, and the regions adjacent to it the *umbonal slopes.* The angle formed by the umbonal slopes at the umbo is called the *umbonal angle.* That part of the shell from the umbo to a transverse line drawn through the middle of the shell is termed *posterior*, and the lower portion of the shell *anterior.* The posterior part of the shell which bounds the visceral cavity is referred to as the *visceral disk.* If this is separated from the anterior part of the shell by a *geniculation* or knee-bend, this anterior part of the shell is termed the *trail.* The front of the shell bounded on each side by the *lateral slopes* or *main flanks* is called the *venter.* The rounded depression down the venter is the *sinus*, and a corresponding *fold* may be developed in the brachial valve.



TEXT-FIG. 1.—Posterior view of pedicle valve of *Productus*, showing the sinus (X), cardinal slopes (CS), cardinal extremities (CE), ears (E), hinge-margin (H), umbonal angle (UA), umbonal slopes (US), and spine-base (B). British Museum, B.45943.



TEXT-FIG. 2.—Ventral view of specimen shown in text-fig. 1, tipped forward to show part of visceral disk. Venter (V), flank (F), costae (C), ribs (R); other letters as in fig. 1.

The posterior line of junction of the two valves is termed the *hinge* or *cardinal margin*, and the region bordering on it the *cardinal slopes.* The lateral extremities of the hinge are termed the *cardinal extremities*, and the regions adjacent to them, usually triangular and flattened, the *ears.* The ears may be sharply demarcated from the visceral disk by a deep, angular depression or sulcus. The flattened rim round the anterior end of the visceral disk of the brachial valve, seen when the visceral disk of the pedicle valve has split off, is called the *diaphragm.* The incision encircling the pedicle valve of some species at the anterior end of the visceral disk is the *cincture.* The longitudinal ribs are termed *costae,* and these are separated by *interspaces* or *sulci.* The transverse folds are referred to as *ribs,* or, if flattened and bearing numerous small spines, as *bands.* An appearance of reticulation is caused by the intersection of ribs and costae, and by the development of nodular swellings at the points of intersection. The growth-lines are seen as transverse striae.

On the inner surface of the pedicle valve, the elongated dendritic scars are those of the *adductor* or closing muscles, and these are enclosed by broad longitudinally striated scars of the *diductor* or opening muscles. On the inner surface of the brachial valve the trilobate apophysis projecting above the hinge is the *cardinal process* which serves for the attachment of the diductor muscles. The longitudinal ridge given off anteriorly is the *median septum,* and the lateral ridges extending along the hinge and frequently curving round the lateral margins are the *marginal ridges.* The dendritic muscle-scars situated on each side of the median septum are the *adductors,* and the hook-shaped ridges given off at their antero-lateral extensions are the *brachial ridges.*

The youthful growth-stages are referred to as *neanic,* the mature as *ephebic,* and the senile as *gerontic.*

III. Morphology and Growth-stages of the *Producti,* with special reference to the *semireticulatus* and *longispinus* groups.

External Shape-characters.—The shells of *Producti* show remarkable and almost infinite variation in size, contour, and form, which cannot be paralleled in any other group of closely related genera. The size ranges from a breadth and length of 5 mm. in such species as *Productus nystianus* de Kon. and *Etheridgina complectens* (R. Eth. Jun.), in which the two valves are thin and fragile, to a breadth of 300 mm. and a length of 200 mm. in *P. giganteus* (Martin), the largest known brachiopod, in which the valves are enormously thickened.

In the adult shell the contour varies from plano-convex in some species of *Pustula,* to concavo-convex in *P. semireticulatus* (Martin), to geniculate in *Sinuatella sinuata* (de Kon.), and spirally curved, as in *P. sulcatus* J. Sow. and *P. latissimus* J. Sow. The pedicle valve in every case is more or less convex.

The outline of the shell also shows the greatest possible variation, and may be circular, as in *P. rotundus* Garwood, oval in *P. muricatus* Phill., quadrate in *P.*

semireticulatus (Martin), laterally elongated in *P. costatus* J. de C. Sow., lenticular in *P. latissimus* J. Sow., or longitudinally elongated as in some gerontic, and all phylogerontic forms of the *semireticulatus* group. Elongation of the shell with an extravagant development of the trail occurs in such forms as *P. productus* (Martin), in which the anterior part of the shell is outspread like a wide skirt, the two flanks extending dorsally, resulting finally in the curious umbrella-like form figured by Davidson from Wetton, Staffordshire, in which the two flanks are nearly in contact. In *Proboscidella proboscidea* (de Vern.) the flanks of the pedicle valve extend dorsally to meet the brachial valve, unite along a median line immediately below this valve, and are produced anteriorly as a long parallel-sided tube. Two tubes are found in some specimens in which the flanks do not unite. The brachial valve in this genus acts as an operculum closing the tube formed by the pedicle valve. The incipient formation of a tube is seen in *P. ermineus* de Kon., in which the flanks do not spread so far dorsally.

The front of the shell forming the trail of the pedicle valve is frequently more developed than adjacent portions, and may extend in a V-shaped prolongation, as in *P. setosus*, or it may be arched into a median longitudinal fold, as in *P. tissingtonensis* Sibly and *P. concinnus* J. Sow. A tongue-like projection is the incipient stage in the development of a *Proboscidella*-like tube in such species as *P. pseudoaculeatus* and *P. stuckenbergi* Krotow. In *P. simiensis* Tschernyschew the flanks curve round and are almost in contact to form a complete tube, while in *Productus genuinus* Kutorga, which is ornamented posteriorly like *P. sulcatus* J. Sow., a perfect tube is developed anteriorly and is marked with fine costae like that of *Proboscidella*.

There is a tendency for a ledge or fringe to be developed round the anterior margin in the gerontic stage in *P. projectus* sp. nov. and in such species as *P. wortheni* Hall, *P. sulcomarginatus* Prout and *P. marginicinctus* Prout, the rim projecting horizontally and being separated from adjacent parts of the shell-surface of the pedicle valve by a deep sulcus. The costae in *P. projectus* are continuous on to this ledge, which may be reflected anteriorly at its outer margin, parallel to the direction of the trail posterior to the ledge. In *P. duponti*, figured by Barrois, this rim is smooth, but normal costation is developed on the shell below it, while in *P. wortheni* Hall the band is spinose. The development of a similar ledge in *Proboscidella kutorgae* Tschernyschew (1902, pl. xxxi, figs. 2, 3) is preliminary to the formation of a tube. The development of a ledge round the anterior margin is not limited to any one group of species and may be due to increased activity of the mantle. A repetition of the ledge has been observed in some species.

A remarkable development of fringes is seen in some specimens of *P. tessellatus* de Kon., and in the example figured by Davidson (1880, pl. xxxvi, figs. 4, 5) the anterior and lateral margins of the pedicle valve are recurved dorsally and in contact with the anterior and lateral margins of the brachial valve. A similar outgrowth from the edge of the brachial valve is inrolled and the two fringes developed from the lateral margins are nearly in contact along a median longitudinal line. These fringes are ornamented by costae, finer than those on the normally developed part of the two valves.

I. Thomas (1914, p. 237) stated that these fringes are superficial and have no intimate connexion with the underlying shell, and that with the exception of a narrow extension along the frontal margin, they are due to an encrusting organism. This organism, he stated, would probably have enveloped the shell after the death of the *Productus*, since after its formation it would have been impossible for the valves of the shell to open. The ornament is mimetic of that of the underlying shell but the costae are finer.

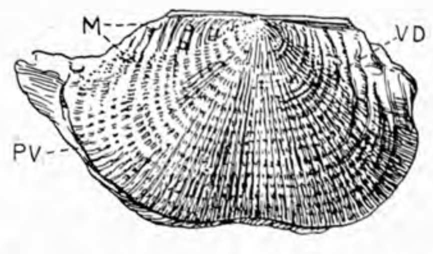
A cincture or narrow incision extending right round the pedicle valve has been observed in *P. projectus* sp. nov., where it separates the ledge from the venter, and in *P. triquetrus* sp. nov., and *P. minutus* sp. nov., where it occurs at the anterior end of the visceral disk. This cincture is followed by an arching of the front of the trail. A similar cincture is seen in some species of *Marginifera* from the Upper Carboniferous, where it evidently corresponds to the internal, thickened ridges; it is well seen in *Marginifera clarkei* Tschern. (1902, pl. lviii, figs. 1-3). In *Proboscidella kutorgae* Tschern. a cincture marks the development of a ledge with similar ornament to that on the remainder of the shell, and below this ledge the front of the trail becomes incurved to form a slight tube. A cincture is also developed in *Diaphragmus fasciculatus* (McChesney), and is said by Dr. Girty (1915B, p. 52) to represent a thickened ring on the inside of the shell, probably corresponding to the diaphragm of the other valve. The internal characters of all the British species in which a cincture is developed are unknown, so that it is uncertain whether a diaphragm is developed in any of these forms.

The ears vary considerably in size in the different species and may be separated from the visceral disk by a more or less deep sulcus. In some species such as *P. rotundus* Garwood they are minute, while in *P. minutus* sp. nov. they are flat and project laterally like small triangular platforms. In *P. sulcatus* J. Sow. they are large and slightly convex, while in *P. carbonarius* de Kon. they taper laterally, forming a long spine-like extension.

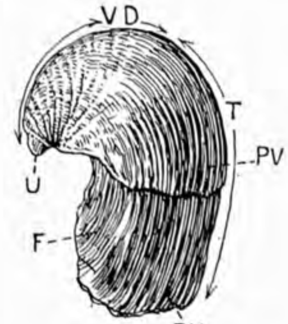
In specimens of the *semireticulatus* and *longispinus* groups the valves are normally plano- to concavo-convex in the neanic stage, and the visceral cavity is enlarged by the increasing convexity of the pedicle valve. A geniculation may be developed at the anterior end of the visceral disk in one or both valves in the ephebic stage, and a more or less extended trail developed, with steepening of the flanks. The brachial valve tends to grow less quickly than the pedicle valve, and in the gerontic stage a deposit consisting of successive shelly laminae may be deposited round the anterior and lateral ends of the visceral disk of the brachial valve, in order to keep pace with the great extension of the trail in the pedicle valve. These laminae, which are imbricated, lack the normal ornament of costae. This character is seen in *P. pugilis* Phill., *P. scoticus* J. Sow., *P. setosus* Phill., and *P. praecursor* sp. nov., and also in other species. In *P. setosus* the successive shelly layers round the anterior and lateral margins may attain a thickness of 5-10 mm., and they are curved outwards, appearing in the dorsal aspect like the piled-up leaves of a book. There is a tendency for longitudinal folds to be developed on the anterior parts of the trail of the pedicle valve in the gerontic stage, the fold arising below a spine-base, beneath which the costae tend to bifurcate, as in *P. pugilis* Phill. Broad, longitudinal folds are also developed in the gerontic stage in the typical form of *P. giganteus* (Martin).

With growth the two valves are rotated about the hinge, sometimes through an angle of 90°. The umbo becomes increasingly incurved over the hinge with age, and the visceral disk tends to become more highly arched.

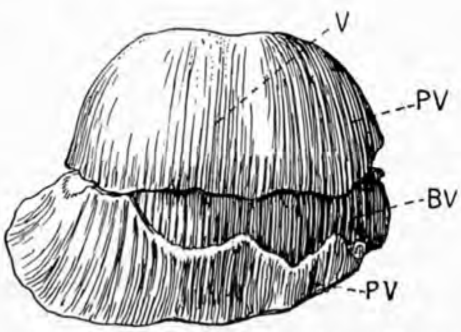
A gaping of the valves occurs commonly in some species of the *semireticulatus* group, such as *P. sulcatus* J. Sow. and *P. multispiniferus* sp. nov. Waagen (1884, p. 690) mentions this character in his species *P. indicus* and quotes Quenstedt in 'Petrefactenkunde Deutschlands,' where he remarks on this character in *P. semireticulatus*, and states that the valves had turned so far on the hinge that the shell became widely open before being embedded in the rock. This was considered to be impossible by Quenstedt unless the two valves had been united by a ligament. Waagen gives a similar explanation. No trace of a ligament has been observed, and in every species of *P. sulcatus* so far examined the gaping of the valves has been due to crushing in the umbonal region, the two valves not being in true symmetrical position about a median line, and it is this crushing which has forced the anterior ends of the two valves apart.



TEXT-FIG. 3.—Visceral disk of brachial valve of *Productus*. The pedicle valve, together with the internal layer of the brachial valve, has split off, as frequently occurs in species of the *semireticulatus* group, leaving the next layer of the brachial valve exposed. Visceral disk (VD), trail of pedicle valve (PV), impression of spine-bases (M). British Museum, B.45508.



TEXT-FIG. 4.—Lateral view of specimen shown in text-fig. 3, with pedicle valve attached (PV), showing extension of the visceral disk of the pedicle valve (VD), extension of trail (T), trail of brachial valve in close contact with that of the pedicle valve (BV), flank (F), and umbo (U).



TEXT-FIG. 5.—Ventral view of specimen illustrated in the two previous figures, showing pedicle valve (PV), and transverse fracture by means of which the pedicle valve is separated from the brachial valve. Trail of brachial valve (BV), venter (V).

A cardinal area is rarely developed, although a small area has been observed in some specimens of *P. productus* from Settle. This appears to be composed of two parts, an inner smooth layer representing the posterior part of the marginal ridges, and an outer longitudinally striated part, separated by a narrow longitudinal ridge. Davidson (1861B, pl. xliii, fig. 5) figured an example of '*P. semireticulatus*' from ?Derbyshire showing a small cardinal area and delthyrium, but as this specimen is apparently lost, it is not possible to ascertain the species.

A small area with a triangular delthyrium for the passage of the pedicle is developed in *Sinuatella sinuata* (de Kon.) from the Lower Carboniferous, and is also seen in the Devonian *Productellae* and in the Permian species *Productus latirostratus* Howse. A pedicle opening has not, however, been observed in other British species of *Productus.*

S. S. Buckman (1919, p. 452), in a discussion on the terminology for beak and foraminal development in Brachiopoda, stated that 'In *Productus* the pedicle certainly was functionless, the foramen being more or less sealed up, the animal having no need to use the pedicle, as it could anchor itself by its long spines.' He proposed the term *clistothyrid* for this condition.

Dwarfing, and conversely gigantism, is commonly observed in the *semireticulatus* and *longispinus* groups of *Productus* and in species of *Pustula,* and causes great confusion in specific determinations. These giant or dwarf forms resemble the typical form in shape and ornament, but differ from it in their considerably larger or smaller dimensions. They have been observed in *P. derbiensis* sp. nov., *P. triquetrus* sp. nov., *P. vaughani* sp. nov. (giants); and in *P. hindi* sp. nov., *P. sulcatus* J. Sow. and *Pustula plicatilis* (J. de C. Sow.) (dwarfs).

Professor Garwood has suggested to me that this difference in size may be accounted for by difference in sex. Recent Brachiopoda do not appear to provide any evidence in support of this theory; in these the sexes are probably separate, with no difference in the size of the shells of the two forms. Morse (1902, p. 321) remarked on the occurrence of two series of forms of *Lingula lepidula,* one broad and the other narrow, which were thought by that author to be due to sexual differences. Further examination of material, however, proved that the two varieties blended, and were apparently the extremes of variation.

Other dwarfed forms, caused by the injury of the shell during life, have the senile type of ornament characterized by irregular flexuous costae and numerous spine-bases.

Mr. J. Smith (1911, p. 140, pl. xvi) described and figured diseased specimens of *Productus* which appeared to him to have suffered from a hereditary complaint of the internal organs, resulting in a pinching of the valves in certain regions. It is not possible to ascertain from the rather poor illustrations the nature of the injury to the shell, which is said to be quite distinct from that produced mechanically.

Ornament.—In the *semireticulatus* and *longispinus* groups of *Productus* the ornament consists of costae, ribs and spines. The costae in the *semireticulatus* group radiate evenly from the umbo in the neanic stage, but in the ephebic and gerontic stages tend to increase in number by means of repeated bifurcations. They are usually developed irregularly on various parts of the shell, though always abundant on the flanks and on the anterior part of the trail. Repeated bifurcation of the costae is seen on the trail of *P. productus* (Martin), and they become flexuous and uneven in width. Bifurcation of the costae occurs frequently in *P. concinnus* J Sow., mainly on the flanks; in *P. furcatus* sp. nov., on the entire trail; in *P. pugilis* Phill. and in other species, below the spine-bases of the trail. Intercalated costae are less often developed except on the trail and on the flanks, unlike the *corrugatus* and *hemisphericus* groups, where intercalated costae are extremely numerous. Costae are not developed on the ears, tend to become obsolete on the flanks, as in *P. multispiniferus* sp. nov., and gradually cease to be developed round the front of the shell, as in *P. scoticus* J. Sow.

In *P. multispiniferus* sp. nov., the costae on the flanks are replaced by a large group of very fine spines, while in *P. flexistrius* M'Coy the costae are curved semi-circularly on the flanks and enclose a smooth space, which was probably similarly ornamented by spines. In *P. pugilis* Phill. numerous longitudinal folds are developed in the gerontic stage, the costae bifurcating below the large, scattered spine-bases, and these costae are raised up to form prominent folds which may continue to the anterior margin. A similar character, but developed to a less extent, is seen in *P. scoticus* J. Sow., and in *P. hindi*, var. *wettonensis* var. nov. In *P. pugilis,* mut. *senilis* mut. nov. the costation below the visceral disk tends to become finer and more irregular anteriorly, until it becomes obsolete near the anterior margin, the shell-surface being formed of lamellae, and the longitudinal folds, which are so prominent in *P. pugilis,* flatten out on the posterior part of the trail.

Thickening of the shell occurs in the senile stage and shelly deposits may mask the ornament, as in phylogerontic forms of *P. muricatus* Phill., in which the costation is only seen where the shell has become slightly decorticated. The whole shell may become very massive, or thickening may occur locally near the anterior margin.

In the *longispinus* group the costae become uneven in width in the gerontic stage, but bifurcation of the costae rarely occurs, except below the spine-bases. Longitudinal folds are developed below the spine-bases on the flanks and on the front of the pedicle valve in the gerontic stage.

The costae are said to be *fine* when there are 18-25 in a breadth of 10 mm. about 10 mm. below the umbo, as in *P. vaughani* sp. nov. and *P. longispinus* J. Sow.; *medium* when there are 13-17 costae, as in *P. hindi* sp. nov.; *moderately coarse* when there are 10-12 costae, as in *P. pinguis* sp. nov.; and *coarse* when there are 6-9 costae at a similar point, as in *P. costatus* J. de C. Sow. Slight variation may occur in the number of costae of any one species on account of the difference in the number of bifurcating costae.

The costae, which appear externally as ridges and correspond to furrows on the inner surface of the shell, may have been developed in a similar manner to those in the young shell of the recent species *Terebratulina septentrionalis* (Couthouy) described by Morse (1871, p. 33), and also by Hancock in the adult shell. In this recent species it was observed that the radiating 'ribs' (costae) corresponded in position with the setae given off from the anterior and lateral margins of the mantle and extending a short distance beyond the shell margin. The costae are formed on the inner surface of the shell as longitudinal sulci, the setae inducing and directing the furrow. Later (1902, p. 325, pl. xliv, figs. 13, 14) Morse figured and described these setae and also showed three setae springing from a single follicle in the mantle; these last seem to suggest a possible cause of the bifurcation of the costae. Morse suggests that the spinous character in *Productus* may be explained in a similar way to the formation of costae in *Terebratulina*.

It seems probable, therefore, that the costae in some fossil Brachiopoda may be similarly explained, and this view is supported by H. S. Williams (1895), who states that the radial striae are due to setose prolongations of the edge of the mantle, their appearance in the structure of the shell being probably the result of aggregation round individual bristles.

In *P. medusa* de Kon. spines are given off from the anterior margin of the shell, and correspond in position to the sulci separating the costae.

In the genus *Avonia* the costae on the trail have arisen through the development of longitudinal plications of the shell below the spine-bases on the visceral disk. These plications tend to increase in prominence, and the spines become more numerous until true costation is apparently developed from the overlapping of successive plications. The formation of similar plications below the spine-bases is seen in *Pustula aculeata* (Martin).

In *Buxtonia*, in which numerous spines are developed, the costae are hollow for a distance of about 5 mm. above the spine-bases, and in decorticated specimens are seen to be in direct continuity with the spines.

The ribbing is a very variable character and may be in the form of prominent folds extending from the cardinal slopes round the front of the shell, as in *P. semireticulatus* (Martin) and *P. multispiniferus* sp. nov., or it may be developed on the cardinal slopes only, as in *P. vaughani* sp. nov. Development of nodular swellings at the point of intersection of ribs and costae varies with the relative width and prominence of the ribs and costae. Bifurcation of the ribs on the sides of the visceral disk and the intercalation of ribs in the same region may occur, as in *P. projectus* sp. nov. The ribs are usually more numerous in the brachial valve.

The cause of formation of the ribs which form such a marked feature of the ornament of the *semireticulatus* group was suggested by Dr. Grabau (quoted by I. Thomas, 1914, p. 223) as being due to periodical weakening of the mantle. The mantle during growth tends to lose its normal shell-depositing function, and is unable to retain its outward extension with the usual rigidity; it would droop and then regain its strength, which would result in the formation of ribs on the corresponding parts of the shell. The ultimate failure of the mantle to revive would be a contributory cause of the geniculation and formation of a trail laterally and anteriorly.

In the brachial valve the weakening of the mantle is more noticeable than in the pedicle valve, resulting in the more prominent and very numerous ribs, and the less rapid growth of this valve as compared with the pedicle valve. The weakening of the mantle in the pedicle valve occurs first on the cardinal slopes, shown by the more marked development of ribs in this part of the shell.

Spine-bases are a very important character for the *semireticulatus* and *longispinus* groups of *Producti,* and those which are developed in the early stages are of importance in distinguishing the species. The spine-bases may be arranged in two rows along the cardinal slopes, as in *P. productus* (Martin); in groups on the ears, as in *P. redesdalensis* sp. nov.; in a group on the flattened flanks, as in *P. multispiniferus* sp. nov. and *P. semireticulatus* (Martin); in a row across the flanks, as in *P. antiquatus* J. Sow.; in a row up the flanks parallel to the costae, and in a row along the hinge, as in *P. muricatus* Phill.; in a row set on a prominent ridge up the flanks, as in *P. sulcatus* J. Sow., *P. hindi* sp. nov. and *P. costatus* J. de C. Sow.; or arranged on the visceral disk roughly in quincunx, as in *P. carbonarius* de Koninck.

Spines developed in the gerontic stage are of little specific importance and occur irregularly scattered over the shell, as in *P. pugilis* Phill.; or in bands round the anterior margin, as in *P. howratensis* sp. nov. and *P. redesdalensis* sp. nov. In phylogerontic forms spine-bases tend to disappear on the trail, or to diminish in size.

Spines of any great length are rarely preserved, except in specimens of *P. hindi* sp. nov. from the Lower Limestones of Beith, Ayrshire, where spines 10 cms. in length have been observed. These spines have a silvery lustre and are about 1·5—2·5 mm. in diameter, but the width is very variable even in one spine. They are frequently intertwined and curved round and over adjacent objects as though they were flexible in life. Some of the spines show an incision down the centre for some distance. Spine-bases may be developed on the brachial valve but are not often seen, owing to decortication.

The character of 'spines within spines' was described by J. Young (1891), who referred to their occurrence in *P. semireticulatus* (Martin), *P. longispinus* J. Sow. and *P. scabriculus* (Mart.). Some of the forms described as *P. semireticulatus* from the Lower Limestones of Ayrshire belong to *P. hindi* sp. nov. Microscope-sections showing these 'spines within spines' were figured by I. Thomas in 1914 (pl. xx, fig. 6, p. 231), who also gave a detailed description of this structure. The spines of these specimens are plainly seen with very low magnification, and similar ones have been observed in specimens of *P. pugilis* Phill. from North Wales.

In the *longispinus* group there are six spines more or less symmetrically developed and referred to as the 'major spines.' These are placed, one on each cardinal slope, near the cardinal extremities, one on each flank, and two on the venter, usually separated by the sinus. These major spines are found in every member of the *longispinus* group. In addition to these, a few smaller spines are scattered irregularly over the shell, but there is no increase in spinosity in the gerontic stage, as in the *semireticulatus* group.

Growth-lines are always numerous on the anterior part of the shell, where they are usually crowded, indicating a slow rate of growth. They tend to become lamellose in the gerontic stage. Rarely, deep incisions occur round the shell, probably indicating arrested growth. Growth-lines are always more crowded in the vicinity of spine-bases, which were evidently regions of slow growth, and the costae were also regions of slower development than the sulci.

Growth of the shells of brachiopods was found by Carpenter (1853, p. 24) to take place by means of additions to the margin, and 'lines of growth' on the external surface of the shell do not always correspond with actual marginal additions, which may occur at some distance from it and show no external break. The well marked transverse incisions characteristic of the ornament of *P. margaritaceus* Phill. may be expansions of the outer shell-layer only, similar to those seen in species of *Athyris* in which extensive lamellae, sometimes bearing fringes of hollow spines, are developed as an outgrowth from the epidermis.

Thickening of the shell in *P. giganteus* (Martin) took place by deposition of internal layers along the inner surface of previously formed layers.

Deceptive appearances sometimes arise through the tendency in shells of the *semireticulatus* and *longispinus* groups to split across the anterior end of the visceral disk (text-figs. 3-5). The visceral disk of the pedicle valve and the inner layer of that of the brachial valve split off, leaving the trails of the two valves in contact with the lower layer of the visceral disk of the brachial valve. The ornament of the latter part of the shell is the reverse of that of the exterior of the brachial valve and frequently leads to confusion in identification, as it is assumed to belong to the pedicle valve. The positions of the spine-bases of the visceral disk of the pedicle valve are represented on this lower layer of the brachial valve as rounded protuberances, whereas on the exterior of the brachial valve they are seen as rounded pits. The cardinal process is frequently seen in contact with the lower layer of the brachial valve when the pedicle valve and inner layers have split off.

In *Pustula* the ornament consists of numerous small spine-bases, more or less regularly arranged on broad flat bands, while in *Overtonia* there is normally a single row of spine-bases, set on the summit of rather angular bands. The ornament of *Buxtonia* resembles that of the *semireticulatus* group, but the spines are more numerous and extend tangentially to the shell-surface, forming an enveloping coat, and bands bearing numerous spines are developed anteriorly. Both ribs and costae are developed in *Sinuatella*, but the costae are not prominent on the visceral disk immediately below the umbo. Costae are lacking on the posterior part of the pedicle valve of *Avonia*, and this portion is ornamented by spine-bases, but costae bearing spines are developed anteriorly. Shells which are ribbed posteriorly and costate anteriorly are seen in the species *P. nystianus* de Kon. and *P. wrighti* Dav. In *P. corrugatus* M'Coy, *P. hemisphericus* J. Sow. and related species the shell is ornamented by fine costae which increase in number by means of numerous intercalations, and a few broad folds or wrinkles may be developed on the cardinal slopes and flanks. *Proboscidella* has a similar ornament of fine costae, while in *Etheridgina* there are numerous undulating ribs bearing small spines.

Homoeomorphy in external characters.—Similarity of ornament or form due to homoeomorphy occurs in members of the *semireticulatus* group and in genera allied to *Productus*, for example in *P. muricatus* Phill. and *Avonia sp. nov.* from the Upper Limestones of Scotland. The costation in each case is moderately coarse and spinose, but in *P. muricatus* the costae are continuous to the umbo, while in the *Avonia* the posterior part of the shell is ornamented by spine-bases only. *P. derbiensis* sp. nov. and *P. productus* (Mart.) show a certain resemblance to each other in the posterior part of the shell in shape and ornament. *P. tissingtonensis* Sibly has coarse, rather angular costae resembling those of *P. sulcatus* J. Sow. and *P. costatus* J. de C. Sow., of which it has been considered a young form by some authors. *P. projectus* sp. nov. and *Buxtonia sp. nov.* from Derbyshire have a rather similar shape in the pedicle valve, and each has a ledge developed round the anterior margin of the pedicle valve. *P. semireticulatus* (Mart.) resembles a large species of *Buxtonia* from the Carboniferous Limestone of Yorkshire and is only distinguished from it by internal characters and by the tangentially arranged spine-bases of the *Buxtonia*. A similarly ornamented tubular trail is developed in both *Productus genuinus* Kutorga and *Proboscidella proboscidea* (de Vern.), while a tubular inrolling of the front of the trail is seen in *P. concinnus* J. Sow. and in *P. kilbridensis* sp. nov.

Internal characters.—No dental sockets or hinge-teeth have been observed in any specimen of the *semireticulatus* or *longispinus* groups, but they may occur in specimens of *Sinuatella sinuata* (de Kon.), although none have been observed in British examples. Articulation of the shell was effected by means of powerful muscles, and also by the incurvature of the umbo of the pedicle valve over the cardinal process of the brachial valve. The crenulations on the marginal ridges in the brachial valve of some species of the *longispinus* group may have fitted into notches in the interior of the pedicle valve Faint traces of a corresponding row of incisions in the pedicle valve of *P. setosus* Phill. were observed in one specimen (text-fig. 32A). The spines developed along the hinge of the pedicle valve in the semireticulate species penetrate into the interior of the shell, where they appear as circular orifices, sometimes surrounded by raised rims. These orifices correspond in position with circular bosses developed on the interior of the brachial valve, and these may possibly have assisted in the articulation of the two valves.

The scars of the adductor muscles are usually dendritic and somewhat triangular in outline in the brachial valve, with the longest side parallel to the median septum. They may be distinctly divided into posterior and anterior adductors. The position and shape of the scars varies with the age of the individual, and the scars tend to become elevated anteriorly and laterally in the gerontic stage. These muscles extended across to the pedicle valve, and the elongated scar of attachment is seen between those of the broad, longitudinally striated diductor muscles. The diductors were attached to the anterior part of the cardinal process in the brachial valve, and by their contraction forced the brachial valve away from the pedicle valve at the anterior margin. It is probable that this anterior gape was extremely small in the *Producti* owing to the close contact of the trails of the two valves in most species.

The cardinal process in the *semireticulatus* and *longispinus* groups projects above the margin of the brachial valve, and is divided by a median furrow into two parts which are smooth and rounded; these are continued dorsally as two curved laminae separated from the median process by deep sulci. The dorsal view of the process shows it to be trilobate and transversely striated. Slight variation in the shape and size of the cardinal process has been observed in the different species. In *P. giganteus* the cardinal process is flattened anteriorly and is divided posteriorly into four lobes, which are smooth in the interior of the valve but are produced dorsally as four prominent transversely striated ridges, separated by deep grooves, the ridges tapering and terminating in a point about 5 mm. below the hinge-margin.

In some specimens of *P. productus* (Martin) from Oswestry (M.P.G., 38320)*, an oval notch was observed externally at the base of the trilobate cardinal process. The passage to the interior of the shell was blocked by shelly matter. A similar notch was depicted by Kozlowski (1914, p. 14, fig. 8) at the anterior extremity of the cardinal process in *P. cora* d'Orbigny from the Upper Carboniferous of Bolivia. A shallow rounded depression at the anterior end of the cardinal process is also shown by the same author in the interior of the same species, and in *P. villiersi* d'Orbigny (op. cit., p. 44, fig. 12). These notches, which occur both in the interior and exterior of the shell, appear to indicate an outlet for some definite purpose, and they may have served as the visceral foramen. In the Recent Inarticulate brachiopod-genera, the anus opens within the mantle-cavity, as in *Lingula* and *Discinisca*, or the alimentary canal may terminate posteriorly as in *Crania*, while in the more specialized Articulate forms it ends blindly, the waste products being

*See p. 42, footnote.

extruded from the mouth. It has been suggested, however, that in the primitive Articulate genera there may have been an anal opening, and Beecher (1892, p. 147) stated that the opening occurring between the cardinal processes of *Strophomena, Stropheodonta* and allied genera, and the furrow on the chilidium of *Leptaena rhomboidalis,* may have served this purpose, and is in no way connected with the pedicle opening.

In *Buxtonia* the elongated notch caused by the splitting of the posterior part of the septum possibly had the same function as these notches in the cardinal process. A similar structure was observed by Prout (1857, p. 43), who stated that in grinding the beak region of his *P. marginicinctus* he found four or five petaloid expansions [=cardinal process] and a notch below for the passage of the ligament. Bouchard-Chantereaux (1842) also quoted the occurrence of a large circular cavity at the base of the central tooth [cardinal process] which, he suggests, was for the insertion of part of the muscular fibres forming the peduncle in *Productus.* A circular foramen immediately below the cardinal process is also figured by King (1850, pl. x, fig. 9) in '*Cleiothyris*' *pectinifera* (J. de C. Sow.).

The marginal ridges are variably developed along the hinge and round the lateral margins of the brachial valve in both the *semireticulatus* and *longispinus* groups, and are usually smooth in the *semireticulatus* group, and transversely crenulated in the *longispinus* group. A row of small pustules may also be developed on these ridges at the base of the ears in the brachial valve in such species as *P. lobatus* J. Sow. and *P. setosus* Phill., and these correspond in position to the narrow incisions seen on the low transverse ridge in the pedicle valve. The marginal ridges may have served to strengthen the shell along the hinge, which lacked the cardinal area, dental plates, etc., found in other genera.

The median septum in *P. productus, P. concinnus* and allied species is flattened immediately below the cardinal process and longitudinally furrowed, but the furrow disappears between the adductor scars and the septum becomes narrowed and more prominent. In *P. pugilis* Phill. and *P. scoticus* J. Sow. the septum is rounded and less flattened below the cardinal process. When this septum is worn, the lower layers show a median longitudinal furrow, as though it were composed of two parts. The septum may extend to the anterior end of the adductor scars or beyond them. In the *longispinus* group the septum is posteriorly flattened and divided by a longitudinal furrow as in *P. productus,* but the anterior part is knife-like and the extremity is enlarged.

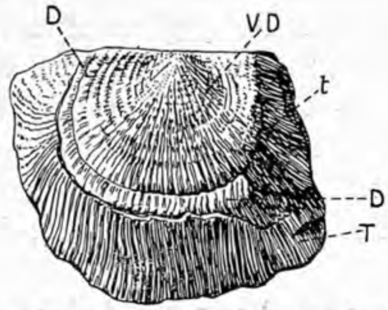
The brachial ridges or impressions vary in size and position in different species, and in successive growth-stages of the brachial valve. They are given off at the anterior lateral margin of the adductor muscle-scars in the *semireticulatus* and *longispinus* groups, and curve downwards, and then inwards and upwards towards the median septum, nearly enclosing a smooth portion of the shell. These ridges mark the point of attachment of the fleshy spiral or brachial arms which lacked any calcareous support, and were apparently attached by their lower or first whorl. The remainder of the spire projected ventrally, and large rounded cavities, sometimes bearing traces of spiral markings, are observed in the pedicle valve immediately below the diductor muscle-scars in *P. giganteus* (Martin), and in internal casts of *P. humerosus* J. Sow.

The brachial impressions in the *semireticulatus* and *longispinus* groups are cut by numerous fine, transverse incisions in the posterior 4 mm. or 5 mm. of the ridge near the adductor scars; the apex of the impressions, which is usually enlarged, is also distinctly separated from the remainder. In Recent Brachiopoda the spiral arms bear tentacles or filaments which are covered by rows of fine thread-like setae, and the incisions seen in the brachial impressions of *Productus* may have served for the passage of setae. This view is supported by the fact that fine branching hair-like structures are seen traversing the smooth part of the shell nearly enclosed by the impressions, and extending through these incisions in *P. vaughani* sp. nov. (pl. ii, fig. 13a). The hair-like structures are forked and the branches give off lesser branches which always fork at the same angle, resembling the setae given off from the mantle in the recent species *Discinisca lamellosa* Broderip (Morse, 1902, pl. xliv, figs. 6, 9). Neumayr (1883, pl. i, fig. 2b) figured narrow, transverse ridges in the interior of the brachial impressions, which he considered to be due to cirri.

The smooth portion of the shell, nearly enclosed by the brachial ridges, frequently shows an oval impression which is probably that of the muscle holding the spiral arms. The whole of the brachial impressions becomes greatly thickened in the gerontic stage.

There is, apparently, no trace of either vascular or ovarian markings in the interior of the brachial valve, comparable with those which are seen in other genera belonging to the Strophomenacea.

A smooth or faintly costate border from 3-4 mm. in width is seen round the anterior and lateral margins in the interior of the brachial valve of the species *P. productus* (Martin), *P. concinnus* J. Sow., *P. redesdalensis* sp. nov., *P. garwoodi* sp. nov., and *P. carbonarius* de Kon. This border is seen to be a thin plate, separated from the broken-off edges of the trail of the pedicle valve by an incision, and developed from the brachial valve at the point of its geniculation at right angles to form the trail. It extends in the plane of the visceral disk of the brachial valve, frequently showing a continuation of the ornament of that part of the shell, and it bridges over the space between the trails of the two valves. This plate appears to have been continuous with the inner layer of the visceral disk of the brachial valve. Shells of *P. productus*, *P. concinnus*, etc., tend to fracture along a layer just below this internal layer, which splits off with the visceral disk of the pedicle valve, and the plate is seen to lie at a slightly lower level than the adjacent layer of the visceral disk. A smooth rim is seen round the edge of the part of the brachial valve that has split off. In some cases there is a repetition of this rim at a slightly lower level than the first formed one, and there is a great increase in the width of the diaphragm in specimens from the Upper Carboniferous.



TEXT-FIG. 6.—*Productus productus* (Martin), from knoll reefs, Elbolton, Yorkshire. British Museum, B.49872. Specimen from which the visceral disk of the pedicle valve and inner layers of the brachial valve have split off, leaving a lower layer of the visceral disk of the brachial valve in contact with the trails of both valves. The diaphragm (D) is seen as a flattened rim with slightly different ornament round the anterior margin of the visceral disk (VD). Trail of pedicle valve (T), trail of brachial valve (t), the latter exposed by fracture of shell, which has removed part of the diaphragm.

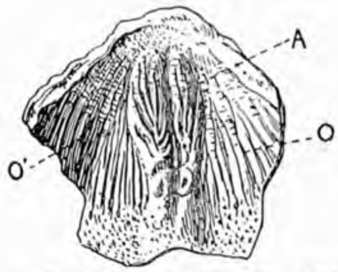
This rim seems to be identical with the structure, described by Dr. Girty (1910, pp. 217, 218) as the diaphragm, in his new genus *Diaphragmus*, from the Upper Mississippian of the United States of America. The diagnostic character of this genus is internal and consists of the presence of a partition 'passing completely across the interior of the shell. This structure appears to be an out-growth of the dorsal valve from the geniculation where the flattened visceral disk abruptly joins the lateral areas. It lies in the same plane as the visceral area and appears, as it were, as an extension of it. This structure frequently forms the plane of dehiscence when specimens are broken out of the rock, the visceral disk of the ventral valve and diaphragm remaining on one piece while the lateral and anterior extensions of both valves which are almost in contact, together with the mold of the diaphragm of the visceral disk of the brachial valve remain on the other. The diaphragm and visceral disk of the brachial valve which are essentially on the same plane are readily distinguished, being separated by a slight ridge or groove and marked by different sculpture, the regular strong costae of the external shell being replaced on the diaphragm by fine radiating striae.' No illustration accompanies this description, but further details and figures are given in later papers by the same author (1915B, p. 47), and an examination of specimens of *Diaphragmus* leaves no doubt as to the identity of this structure with that found in British species (pl. ii).

Dr. Girty described, in a letter to the author, the complex form of diaphragm. In this form the diaphragm is similarly given off at the point of geniculation of the brachial valve, and extends in the plane of the visceral disk, but on meeting the trail of the pedicle valve it is deflected anteriorly along the inner surface of that valve, thus repeating the trail of the brachial valve. This repetition of the trail may occur two or three times in one specimen, and clearly proves that the diaphragm was developed in connection with, and at the same time as, this portion of the brachial valve.

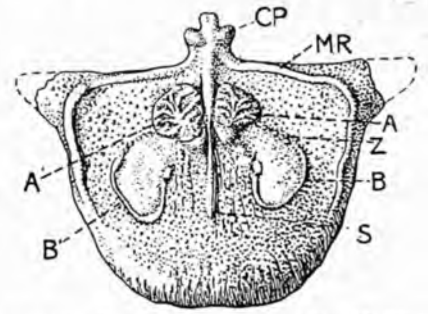
The diaphragm must have acted as a rigid plate and have effectively closed the two valves, with the possible exception of a very small outlet between the plate and the trail of the pedicle valve. It is probable that specimens with long extended trails such as *P. productus* could not open their shell anteriorly to any great extent, and they may even have been permanently open with the diaphragm acting as a closing structure. It is difficult, however, to explain the passage of water in and out of the shell unless the diaphragm were cellular and porous.

I. Thomas (1914, pp. 223, 238) describes the diaphragm as a flattened surface round the anterior margin of the brachial valve corresponding to the thick layers of the trail which have separated from the visceral part. The broken-off edges of the trail, however, can be readily seen beyond the diaphragm, which is distinguished as a horizontal plate. In another part of the same work Thomas remarks on the similarity of this external border with that found in the genus *Diaphragmus*.

Dr. Girty distinguishes the Marginiferal type of structure from that of *Diaphragmus* by the heavy callosity developed in *Marginifera*, formed by layers of shell superimposed one on top of the other like leaves of a book. These layers are said to face outwards, and the back inwards, to form a projecting ledge.



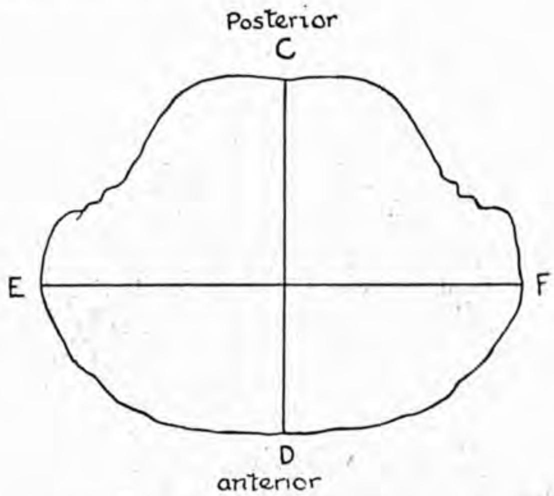
TEXT-FIG. 7.—*Productus pugilis* Phillips, from Farhouse Shales, Settle, Yorkshire. British Museum, B.45580. Part of interior of the pedicle valve, showing the elongated dendritic adductor muscle-scars (A), enclosed by the flabellate diductor scars (O).



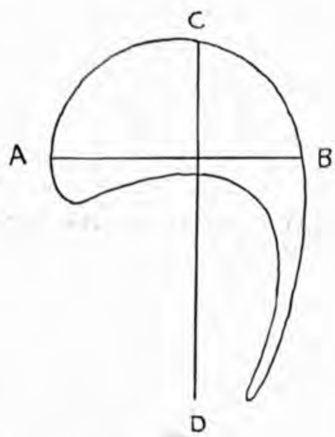
TEXT-FIG. 8.—*Productus pugilis* Phillips, from the Thornbrough Limestone, Styford, Northumberland. British Museum, B.41914. Slightly restored. Interior of brachial valve, showing the trilobate cardinal process (CP), marginal ridges (MR), median septum (S), separating the dendritic adductor-scars (A and A¹). The brachial impressions (B and B¹) are discontinuous near the adductor scars at Z, and also at their extremities.

Waagen (1884, p. 614) defined the genus *Marginifera* as having ' shell externally very much like *Productus*. Internally a thickened shelly margin extends parallel to, and at a certain distance from, the edge of both valves, thus causing a partition to be formed within the shell.' He states also that these prominent concentric ridges are sometimes finely striated and crenulated, and sometimes smooth. This character is said to be not yet well developed in the Mountain Limestone, although indications of such ridges occur in some specimens of *P. longispinus*. Waagen also states that the genus has taken its origin from *P. longispinus* J. Sow., as all forms of *Marginifera* appear to be more or less related to Sowerby's species. The geologically oldest species of *Marginifera* is said by Waagen to be *M. splendens* (Norw. and Pratt.), from the Coal Measures of Illinois.

The origin and development of these Marginiferal ridges have been the subject of great diversity of opinion among subsequent authors. Nikitin (1890, p. 159) was of the opinion that they are only the result of the thickening of calcareous secretions along the line of contact of the two valves, and that they also occur in *P. longispinus*. He considered them to be old age characters and not of generic importance. The essential point of difference between the Marginiferal ridge and that found in the *longispinus* group is in the very slight development of a ridge in the pedicle valve of the latter, which has only been observed in one specimen of *P. setosus* Phill., and in the absence of the external crenulations seen in the dorsal aspect of species of *Marginifera*. The piled-up shelly layers in the brachial valves of such species as *P. setosus* Phill. and *P. lobatus* J. Sow. may be ancestral to the true Marginiferal ridges, which do not appear to be typically developed in the Lower Carboniferous.



TEXT-FIG. 9.—Outline drawing of shell of *Productus*, showing maximum width along line EF, and maximum height along line CD.



TEXT-FIG. 10.—Outline drawing of shell of *Productus*, showing maximum height along line CD, and maximum thickness along line AB.

Habit and Growth.—A pedicle for the attachment of the shell by the pedicle valve was only functional in the early growth-stages of *Productus*. Its absence during later growth-stages would allow freedom for enlargement of the shell in any direction, and may account in part for the remarkable diversity of form in the *Producti*. The influence of the length, flexibility, and position of the pedicle on the form of the shell can be seen in recent Brachiopoda. Shells having a long pedicle emerging freely between the valves, or having a functional pedicle in all growth-stages, have biconvex valves and are elongated, tapering posteriorly to the short hinge-line, as in *Lingula* and *Magellania*. Shells with a short pedicle attaching them closely to the object of support tend to develop a long hinge through the addition of successive increments of growth along the lateral as well as the anterior margin. A flattened and orbicular lower valve is developed in genera such as *Discinisca,* which have a short pedicle extending at right angles to the plane of the pedicle valve.

Hall and Clark (1892B, p. 157) suggest that there is a definite relation between the angle at which the pedicle is protruded and the size of the two valves. They also state that in concavo-convex shells the pedicle was always atrophied early in the history of the individual, the concavity of the brachial valve being a necessary result of the obstruction of its marginal growth by the more rapid growth of the pedicle valve.

It seems possible that the shells of such species as *P. productus* (Martin), which have a flat visceral disk in the brachial valve and are geniculated at a right angle to form the trail, may have been attached during the early growth-stages when the shell was normally plano-convex in contour, and then later have fallen from the object of support. Geniculation of the shell might occur as a result of this, and the elongated trail then produced would extend downwards into the muddy sea-bottom. Douvillé, however, suggested (1909, p. 157) that the *Leptaena*-like form [geniculate] of the Productidae is characteristic of a muddy habitat, and that a similar form of the shell is found in the lamellibranch-genus *Liogryphaea* and in some Pectens.

The shell of *Productus* was apparently anchored by means of the long spines which projected from the cardinal slopes and flanks in the pedicle valve of most species, but are seldom preserved in situ. These mooring spines were of considerable length and thickness in some species, and spines five or six inches in length have been observed in specimens of ***P. hindi*** sp. nov., from the Lower Limestones of Scotland. Dr. Trechmann figured and described (1921, p. 542, pl. xii) interesting specimens of *P. horridus* from the Permian, Lower Magnesian Limestone, of East Thickley Quarry, Durham. In one specimen thick, slightly curved spines about three inches in length, which were probably double this length in the live shell, extend laterally from the ears and cardinal slopes. A second smaller specimen in which the hinge is exposed shows spines stretching out from both valves, and apparently balancing the shell.

In shells of *Etheridgina* the spines along the hinge of the pedicle valve curve towards the umbo and were apparently flexible in life, as they are frequently found clasped round slender crinoid stems. Similarly curved spines have been observed in *P. projectus* sp. nov. and *P. nystianus* de Kon., but it is not known if they ever served as a similar means of attachment.

Large numbers of shells of the ***Producti*** are frequently found closely associated, as in an oyster-bed. Specimens of *P. striatus* (Fischer) are often crowded together in such numbers as to interfere with the normal growth and development of the individual, resulting in a narrowing of the hinge until this is only a few millimetres wide, the flanks expanding rapidly forward from the umbo. In normally developed specimens the hinge is broad and approximately equal to the width of the shell. A similar crowding together of four specimens of *P. scoticus* J. Sow. was observed in a small block of limestone from Corrie, Arran (Hunterian Mus., Glasgow, L.211). The four individuals have the normal shape and ornament, but are seen with their shells arranged one on top of the other, all with the pedicle valve in the same relative position.

The general opinion with regard to the orientation of the valves of ***Productus*** during life has been that the smaller or dorsal valve was uppermost. Hall & Clarke (1892B, p. 157) stated that ' shells in becoming freed from the surface to which they were attached, would fall upon the sea-bottom, the heavier or pedicle valve down.' D'Orbigny also thought that the animal lay in the mud with the smaller valve uppermost as in most oysters, and that the spines retained it in a fixed position. This theory was also supported by Davidson (1880, p. 305), who stated that ' Some of the species in all probability lay on soft muddy bottoms on their larger or ventral valves; and this was evidently the case in *Prod. llangollensis*, *P. giganteus*, and other species which possessed very thick and massive ventral valves, and very thin dorsal ones: and the hollow spines in some forms may have helped them to steady themselves on the soft bottom on which they lived, the immensely long and spread out spines of *P. semireticulatus* leading to that conclusion.'

In specimens of the *semireticulatus* group which are apparently preserved in the position held during life and supported by spines projecting from the shell, the pedicle (ventral) valve is usually uppermost, although the angle of the shell seems to vary with growth. The visceral disk of the brachial valve is horizontal in a large number of cases, and the trails of both valves extended down into the muddy sea-bottom. This view that the pedicle valve was uppermost is supported by the fact that the mantle of the pedicle valve was frequently injured, which resulted in irregular sulci and a gerontic type of ornament on the corresponding part of the shell. The brachial valve seldom bears these marks of injury, and appears to have been more protected, bearing fewer spines than the pedicle valve; and it is also in such close contact with the matrix that in many species of the *semi-reticulatus* group it has never been possible to observe it.

Specimens of *Etheridgina* which are attached by the clasping spines have the dorsal valve uppermost, and a similar orientation of the valves was described by Douvillé (1909, p. 157) in young specimens of *Derbyia* which he compares with *Productus*.

The orientation and attachment of the valves of *Productus* was also discussed by de Koninck (1847A, p. 112), who objected to the theory of the support or attachment of the shell by the spines, in that they were too long and delicate and would be readily fractured. The growth of the shell with the pedicle valve uppermost suggests a definite mode of attachment, which, he states, must have been by muscular fibres emitted from the anterior end of the shell, and the formation of a tube in *P. genuinus* and *P. proboscideus* would be for this purpose.

A most interesting theory as to the relation of the external form of the shell with the passage in and out of food-bearing currents, has been put forward by Dr. Orton (1914, p. 295), who has made a detailed examination of the ciliary mechanism in the recent *Crania*. In this genus there are two main respiratory and food-bearing streams entering the shell by the anterior lateral margins, and one outgoing current expelled from the middle of the anterior margin. The brachial arms are situated symmetrically on the right and left sides of the mantle cavity, which in many fossil genera is definitely subdivided by a median septum. The tentacles, or filaments, attached to the brachial arms or lophophore, bear rows of cilia, and other cilia are developed on the mantle and lophophore itself. These cilia keep up a constant lashing and maintain a current in the right and left halves of the mantle cavity, and this passes between the filaments of the first turn of the spiral arms and outwards through the second and succeeding turns. The lashing of the cilia sends food particles along the food or buccal groove to the mouth, which is situated between the two spiral arms, the digestive organs being posteriorly directed. The cilia are so arranged that an outgoing current is produced and passes out at the front of the shell. A similar condition obtains in *Lingula* (Morse, 1902), where three distinct tubes strengthened by mucus are formed by the setae which are given off from the mantle and extend for a short distance outside the two valves. Dr. Orton suggests that a similar condition prevails in all Brachiopoda, and that in the trilobation of the shell of recent and fossil genera the apertures correspond to the inlets for ingoing and outgoing currents. 'In all Brachiopods there would thus appear to be little doubt of the physiological independence of the right and left halves of the mantle cavity. Hence variations in the direction of formation of antero-posterior median septa, as shown in *Stringocephalus*, *Conchidium*, and many other genera, of trilobation of the shell, as shown in many Rhynchonellidae, and bilobation of the shell, as shown in *Orthis biloba*, *Terebratula diphya*, and other forms, do not interfere with the functions of the two portions of the lophophore, and it is conceivable that these variations may be advantageous to certain forms under certain conditions.

'The disposition of the lophophore in the Spiriferidae indicates that the main ingoing current entered the mantle cavity in the front middle portion and was expelled in the two outgoing currents at the postero-lateral angles of the shell, a condition exactly the reverse of that obtaining in *Crania*, where the ingoing current is two-fold and the outgoing current single. Thus the production of the shell —frequently occurring in this group—into postero-lateral angles, somewhat like those occurring in modern Pectens, may have served as a sort of siphon for carrying away the exhalent streams.'

In a comparison of the Brachiopoda with the Lamellibranchiata, Dr. Orton (op. cit., p. 308) states that the nearest approach to siphonate forms among the Brachiopoda is represented by those forms in which the postero-lateral angles of the shell are much drawn out, as in *Productus giganteus* and *Spirifer verneuili*, or in forms of the Rhynchonellidae in which the front middle part of the shell is differentiated in such a way as to resemble a siphon.

The formation of tubes and an arched front of the trail in many species of *Productus*, and the trilobation of the shell by the development of a deep median sinus may, therefore, possibly be due to inhalent and exhalent currents. It is an interesting fact that the trilobation of the pedicle valve and a tube-like trail were developed in many distinct and unrelated species such as *P. tissingtonensis*, *P. concinnus*, *Sinuatella sinuata*, *P. genuinus*, *Proboscidella proboscidea*, and in forms related to *Productus giganteus*. A laterally elongated form in species such as *P. latissimus* may, as Dr. Orton suggests, be similarly correlated with physiological processes.

Currents of water may also have passed into the shell by the hollow spines, and especially by those situated on the cardinal slopes and flanks, which in the *semireticulatus* group are frequently of large size. The openings of these spines are seen in the interior of the pedicle valve, sometimes surrounded by a circular depression in the semireticulate forms or by a raised collar in the *longispinus* group (text-fig. 32A). The function of the 'spines within spines,' already described on p. 15, may have been that of obstructions to the passage of foreign bodies into the shell. De Koninck (1847A, p. 105) was of the opinion that the spines contained prolongations of the mantle, and were surmounted by a cilium which kept the extremity open, and whose movement maintained a current round the shell favourable to the growth and development of the animal. Other theories as to the functions of the spines were quoted by I. Thomas (1914, p. 229).

The shell of *Productus* consists of three layers: the inner prismatic layer in which the prisms are nearly parallel to the surface of the shell; the intermediate laminar layer; and the outer layer or epidermis. The prismatic and laminar layers are pierced by punctae which, however, do not penetrate to the exterior, their terminations being covered by the imperforate epidermis. On removal of the epidermis, the punctae are seen as circular orifices usually surrounded by a raised collar, and distributed equally over the costae and sulci. They appear to be simple and not branched as in many other genera, and they pierce the shell at right angles to its surface. A larger and a smaller series of punctae were observed in shells of *Buxtonia*, and Davidson also figured (1880, pl. xxxvi, fig. 21) two sets of different size in *P. giganteus* (Martin). A similar series of large and small perforations was noticed by Leidhold (1925) in *Orthis fascicularis* d'Orb., but was not found by him in other species of Devonian Orthids. The function of these pores has been variously explained. The fact that they never penetrate to the exterior of the shell precludes the possibility of their having been used in respiration. It is possible that the spines which pierced the epidermis in *Productus* may have acted in conjunction with the punctae in the transportation of water in and out of the shell.

In recent genera the punctae contain extensions of the mantle or caecal tubes, the function of which has been variously explained. Carpenter (1853, p. 30) considered that they were vascular processes, but not connected with the nutrition of the shell, because they are absent in some genera. Prof. Sollas (1886) interpreted them as sense organs and affected by light, since the periostracum or outer layer is transparent, while Morse (1871, 1902) suggested that they were organs of general sensibility. King (1869) stated that the epidermis is cellular and that water may pass through to the caecal tubes, each of which apparently bears a fringe of cilia designed to produce currents of water over the extremities of the caeca.

Percival (1916) examined the punctae of many genera and found that they varied considerably both in size and density on different parts of the same shell, and that therefore they can be of no use in distinguishing different species.

IV. Evolution and Range.

It is not proposed to attempt a detailed account of the phylogeny of the *Producti* until further study has been made of the groups of species still undescribed.

The *Producti* were derived from an unknown Ordovician or Silurian Strophomenid ancestor. They are linked to the Devonian *Productellae* by a similarity in internal characters, but, with a few exceptions, lack the articulating processes and cardinal area and delthyrium characteristic of the Devonian forms.

The earliest British species ascribable to the *Producti* are represented by small specimens bearing numerous spine-bases on the visceral disk and costae on the trail, as in *Avonia*, to which genus they probably belong. These are found in the Pilton Beds of North Devon (?=Upper Devonian or basal Carboniferous), and another form, *Avonia bassus* (Vaughan), occurs in the K_2 beds of the Bristol district. In all these, costae are developed, apparently by the gradual elongation of the plications developed below the spine-bases on the visceral disk. Small forms having ornament characteristic of *Buxtonia* and *Pustula* are also present in the Pilton Beds, and in the Zaphrentis zone of the Avon section. Finely costate shells of the *semireticulatus* group also make their appearance in the *Zaphrentis* zone. The *Producti* evolved rapidly during *Zaphrentis* times, and favourable conditions leading to the knoll reef type of deposit in some areas during *Syringothyris* times resulted in large massive-shelled forms of the *semireticulatus* group. Early types of the *longispinus* group also made their appearance at this time. During *Seminula* times conditions were unfavourable to the development of the *semireticulatus* group, which was practically limited to a few areas where knoll reef conditions persisted. A few small spinous forms are found in the normal and usually crinoidal deposits, in which shells having the *corrugatus* type of ornament were abundant.

A multitude of forms suddenly appeared in *Dibunophyllum* times, including the first *Sinuatella*, *Etheridgina*, *Proboscidella* and *Overtonia*. The instability of the group at this time is shown in the development of over-specialized species such as *Productus productus* and *Proboscidella proboscidea*, which had a very limited range and distribution. The fact of their sudden disappearance and also of the extinction of the *Producti* in Permian times was probably due in part to the over-secretion of carbonate of lime disadvantageous to the growth of the animal, and shown in the development of abnormally long trails in some species, the formation of the diaphragm, the numerous spines, or the massive shelly marginal deposits and ridges, together with the enormous thickening of the shell of such species as *P. giganteus*. Dr. Lang (1919, p. 105) describes the extinction of the Cheilostome Polyzoa as due to an increasing deposit of calcium carbonate until the skeleton becomes so massive that the apertures are only tubular holes in a thick block of calcareous matter. He also states that in no case does this potentiality for the secretion of carbonate of lime become exhausted. 'Again and again a lineage has broken through an inhibition and acquired the calcium carbonate habit which has led to a brilliant, but comparatively brief career of skeleton-building, and has doomed the organism finally to evolve but the architecture of its tomb.'

A gradual waning in development then ensued, followed by the complete extinction of the group at the end of Permian times. The last British species of the *semireticulatus* group occurs in the marine bands of the Coal Measures of Coalbrookdale. Species of this group occurring in the marine Upper Carboniferous of Europe are, as a rule, bizarre in shape, with massive shells, and they frequently develop long tubes by inrolling the lateral parts of the trail.

Forms of the *semireticulatus* group from the lower zones of the Carboniferous Limestone are usually distinct from those of the upper zones, both in ornament and in internal characters. A diaphragm has not been observed in Tournaisian species, and the marginal ridges are less extended than in later forms. The shell is, as a rule, thin in the lower forms, the spines small and few in number and the reticulation of the shell not marked.

The range of many species is now proved to be longer than is generally recognized. Many forms considered characteristic of the D_2 subzone also occur in the C zone of the Waulsortian and in equivalent beds of Ireland. Such species as *P. semireticulatus* (Mart.), *P. multispiniferus* sp. nov., *P. minutus* sp. nov., and *P. derbiensis* sp. nov. have been found in the Z zone and C_2 subzones of the above-mentioned areas and also in the D_2 subzone (Brachiopod beds) of Derbyshire and Staffordshire. Species such as *P. pinguis* sp. nov., *P. muricatus* Phill., and *P. pugilis* Phill., which occur in the normal coral-brachiopod phase of D_2 deposits, have not been observed in the lower zones.

It seems certain that the *Producti* were evolved along parallel lines in widely separated areas. The external characters of distinct forms may be almost identical, and species such as *P. longispinus* and *P. semireticulatus*, characteristic of the British Lower Carboniferous, have been described from nearly every foreign locality in which Carboniferous rocks are found. In practically every case these specimens are similar to, but not identical with, the British species, being frequently homoeomorphs belonging to other genera of *Producti*. It is interesting to note that forms resembling those of the *longispinus* group (characterized by six major spines), which have a world-wide distribution, appear to have been independently evolved in different areas.

In the *semireticulatus* group the ornament appears to be developed in the order of costate to smooth, which, according to the observations of other palaeontologists, indicates a catagenetic series. There is no trace of any spinose stage in the earliest known members of this group. In *Avonia* the ornament is also developed in the catagenetic order of spinose to costate, but in *Buxtonia* the costae evolved in the early stages give place to bands of spines in later stages and apparently indicate an anagenetic series.

V. *Productus* (*sensu stricto*) and the *P. semireticulatus* group.

The generic name *Productus* was introduced by J. Sowerby (1812-15, p. 153) in 1814, and the genus was defined as 'An equilateral unequal-valved bivalve with a reflexed, more or less cylindrical, margin; hinge transverse, linear; beak imperforate; one valve convex, the other flat or concave externally.' He adds: 'Martin has pointed out several divisions of the Genus Anomia; one of them which he defines to be "imperforate, with one valve gibbous, the other flat or concave, hinge on a straight line," includes these shells and I expect several others, as he considers the reflected margin to be accidental. His Conch. Anomites productus is a good type of the Genus, therefore, as the name Anomites must be laid aside, I have adopted his specific name as the Generic one, the character it expresses being also peculiar.' Following the example of Conybeare and Phillips, J. de C. Sowerby altered the name to *Producta*, and this was adopted by many authors such as J. Phillips and F. M'Coy.

The name *Producta*, or later again *Productus*, was used indiscriminately for all productoid shells and comprised species of *Leptaena*, *Strophomena*, etc., as

Sowerby's description did not include any account of the internal characters of the genus. An attempt was made to subdivide the species of *Productus* in 1836 by Phillips, who suggested two main groups :—A. with radiating striae predominant; B. with spines arranged on transverse undulations. A different classification was proposed by L. von Buch in 1842. He divided the *Producti* into 'dorsati' and 'lobati,' the former 'Mit gewölbtem Rücken' and the latter 'Mit flachem oder eingesenktem Rücken'; and the species of the *semireticulatus* group consequently were placed in the 'dorsati' or 'lobati' according to whether a sinus was developed. Quenstedt in 1852 adopted von Buch's classification, and included *P. antiquatus* in the 'lobati,' but did not mention any semireticulate form in the 'dorsati.'

The first attempt to subdivide the *Producti* into groups of species was made by de Verneuil (in Murchison, Verneuil and Keyserling, 1845, p. 253). His first group, 'à surface ornée de stries longitudinales,' is composed of the divisions 'Striati,' 'Semireticulati,' and 'Spinosi.' His second group consists of the 'Pustulosi,' 'Punctati,' 'Horridi,' and 'Caperati.' The 'Semireticulati' are said to be 'reticulées dans leur première moitié par le croisement de plis transverses,' and the division comprises the species *P. undatus, semireticulatus, lobatus, sublaevis, leplayi, costatus, carbonarius, plicatilis,* etc., and includes several species which are no longer placed in the *semireticulatus* group.

In 1847 de Koninck emended the classification of de Verneuil and divided the *Producti* into two main groups :—1, ornamented with longitudinal ribs; 2, without longitudinal ribs. The first group was composed of the divisions 'Striati,' 'Undati,' 'Proboscidei,' 'Semireticulati' and 'Spinosi.' The 'Semireticulati' were said to include species whose ribs are rarely very spinose and are crossed on the visceral disk only by concentric folds which make them tuberculose; most of the species are sinuated and geniculated. He included *P. sublaevis* and *P. plicatilis* with the 'Semireticulati,' and placed *P. flexistria* in the 'Striati' with *P. giganteus.*

Abich in 1878 divided the *Producti* into three groups or Formenkreise :—i, with *P. costatus* and *P. semireticulatus*; ii, with *P. intermedius* and *P. horridus* (as in original); iii, with *P. aculeatus* and *P. spinulosus.* Other groups were proposed in 1884 by Waagen, who divided the *Producti* into 'Lineati,' 'Semireticulati,' 'Spinosi,' 'Fimbriati,' 'Horridi,' and 'Irregulares.' In the 'Semireticulati' he described groups of species such as the group of *P. semireticulatus*, including the species *P. spiralis* Waagen, etc., the group of *P. costatus* and the group of *P. portlockianus*, while he included the group of *P. muricatus* in his 'Spinosi.'

In 1899 Diener adopted a rather similar classification, with the addition of the groups 'Undati' and 'Caperati'; and Schellwien in 1900 also adopted the system of division into species-groups, using *P. semireticulatus* and *P. griffithianus* as two distinct group-names. A further subdivision of the *semireticulatus* group was suggested by Tschernyschew in 1902. The two subdivisions are:—(1) *P. semireticulatus*, with a flat dorsal valve and a high visceral area, and (2) *P. boliviensis*, with a concave dorsal valve and a relatively low visceral area. He gave *P. longispinus* and *P. costatus* as separate groups. Girty in 1908 adopted Waagen's subdivisions and then divided these again into groups of species characterized by their external ornament; while Gröber in 1909 followed Tschernyschew in his division of the *semireticulatus* group.

An entirely different classification was suggested by Frédérics in 1915. He divided the *Producti* into two groups:—A. *Producti* typici, B. *Producti* proboscidei. The '*Producti* typici' are said to comprise 'les coquilles à accroissement illimité le long de la cavité viscérale.' This latter group is further subdivided into: α, those species which have a 'cavité viscérale profonde, valve dorsale plate ou faiblement concave,' e.g. *P. punctatus*, *P. cora*, etc.; and β, those with the 'cavité viscérale étroite, la valve dorsale suit la courbure de la valve ventrale,' e.g. *P. koninckianus* and *P. striatus*. In the '*Producti* proboscidei,' 'les coquilles ont l'accroissement limité le long de la cavité viscérale; la valve dorsale chez les individus adultes est plus ou moins fortement geniculée. Chez plusieurs formes on observe une tendance à former le prolongement cylindrique,' e.g. *P. semireticulatus*, *P. genuinus*, *P. tenuistriatus*, and *P. cancriniformis*.

The distinguishing characters of these sections appear to be in the form of the brachial valve. This is flat or concave and geniculated in *Producti* typici α, the trails of the two valves being developed simultaneously, or at different times; it is concave in the *Producti* typici β, where no trails are developed and the front margin in the ventral valve is arched. In the *Producti* proboscidei the shells are said to develop as in the 'typici,' but the dorsal valve becomes geniculated and then grows parallel to the ventral valve.

This form of classification ignores differences in internal characters and also in external ornament, and some species which belong to the 'typici' in early mutations would tend to pass into the 'proboscidei' in their later mutations.

A more general description of the history of *Productus* was given by I. Thomas in 1914, in pt. 4 of the first volume of these Memoirs.

VI. Classification.

The Carboniferous *Producti* lend themselves to division into at least eight distinct genera by means of their external ornament and internal characters, although the latter are still unknown in some species. The classification given below follows to some extent that proposed by I. Thomas in 1914, but the genera, with the exception of *Overtonia* and *Pustula*, are now redefined.

1. Productus J. Sowerby, 1814 (1812—15, p. 153), *emend.* H. M. Muir-Wood.

(Genotype : *Anomites productus* W. Martin. Petrificata Derbiensia, p. 9, pl. xxii, figs. 1—3. Wigan, 1809.)

Costate in neanic and ephebic stages, with definitely arranged groups of spines on ears and flanks, becoming increasingly spinose in gerontic stage, with gradual loss of ornament on flanks and anterior part of trail. Ribs may be developed on visceral disk. Umbo incurved over hinge. Flanks steep and often subparallel. Visceral disk of pedicle valve frequently separated from trail by a more or less abrupt geniculation. Brachial valve flattened, concave, or geniculated. Teeth, dental sockets, and delthyrium absent. Cardinal area rarely developed. Cardinal process prominent and externally trifid. Marginal ridges in brachial valve extend along hinge and continue round the postero-lateral margins of shell. Median septum never bifid, but may be flattened, with a median longitudinal depression. Adductor muscle-scars dendritic in both valves.

This genus includes the *semireticulatus* and *longispinus* groups. Since the diaphragm, the distinguishing character of the genus *Diaphragmus,* occurs also in *Productus productus* (Mart.), genotype of *Productus, Diaphragmus* becomes a synonym of *Productus.* It is not proposed to separate from the genus *Productus* specimens of the *semireticulatus* group in which a diaphragm has not been observed.

Other groups of species still included in *Productus,* but possibly divisible into distinct genera or subgenera on account of difference of ornament and slight differences in internal characters, are : the *giganteus* and *latissimus* groups, the *hemisphericus, corrugatus* and *undatus* groups, and the *margaritaceus* group.

2. Avonia I. Thomas, 1914 (p. 259), *emend.* H. M. Muir-Wood.
Plate XII, figs. 6—10.

(Genotype : *Productus youngianus* T. Davidson. A Monograph of the Carboniferous Brachiopoda of Scotland, p. 45, pl. ii, fig. 26; pl. v, fig. 7. London, 1860.)

Spinose in the neanic stage, developing costae bearing spine-bases in the ephebic stage. Phylogerontic individuals may be smooth. Pedicle valve rarely geniculated, more often evenly convex. Brachial valve concave. Marginal ridges short, diverging from hinge-line. Cardinal process small. Median septum narrow. Adductor muscle-scars not dendritic.

This genus includes also *Productus bassus* Vaughan, *Productus aculeatus*, var. *davidsoni* Jarosz (1917, p. 88, pl. x, figs 12, 12a) and *Avonia sp. nov.* (pl. ii, fig. 8).

3. Buxtonia I. Thomas, 1914 (p. 259), *emend.* H. M. Muir-Wood.
Plate XII, figs. 19—21.

(Genotype : *Anomites scabriculus* W. Martin. Petrificata Derbiensia, p. 8, pl. xxxvi, fig. 5. Wigan, 1809.)

Costate and spinose in neanic and ephebic stages, developing concentric bands on which are numerous small spine-bases in the gerontic stage. In phylogerontic individuals bands are developed in the ephebic stage. Spine-bases developed in pedicle and brachial valves. Pedicle valve evenly convex, rarely geniculated. Brachial valve flattened or concave. Marginal ridges short. Median septum usually bifurcating about 5 mm. below the cardinal process, the two branches uniting with the two lobes of the cardinal process.

This also includes *Productus scabriculo-costatus* Vaughan and *Buxtonia sp.* (pl. xii, figs. 20, 21). Species occur from Z zone up to the Coal Measures.

4. Pustula I. Thomas, 1914 (p. 259).

(Genotype : *Producta pustulosa* J. Phillips. Illustrations of the Geology of Yorkshire, part ii, p. 216, pl. vii, fig. 15. London, 1836.)

The genus *Echinoconchus* was proposed by Prof. Weller in October, 1914 (p. 138) for *Productus punctatus* (Mart.) and allied species. The distinguishing character of this genus is its ornament of concentric bands with small spine-bases. This ornament is also characteristic of *Pustula pustulosa* (Phill.), the genotype of

Pustula; and since the account of Thomas's genus was published in June of the same year, the name *Echinoconchus* is a synonym.

5. Overtonia I. Thomas, 1914 (p. 259).

(Genotype: *Producta fimbriata* J. de C. Sowerby. The Mineral Conchology of Great Britain, vol. v, p. 85, pl. cccclix, fig. 1. London, 1824.)

6. Sinuatella gen. nov.

Plate XII, figs. 11—15.

(Genotype: *Leptaena sinuata* L. de Koninck. Description des Animaux Fossiles qui se trouvent dans le Terrain Carbonifère de Belgique, p. 654, pl. lxi, figs. 2*a*, *b*, *c*, *d*, *e*. Liége, 1851.)

Ribbed in neanic stage and developing costae which are superimposed on ribs at a later stage, but not extending within 2 or 3 mm. of umbo. Trail ornamented by costae only. Spine-bases definitely arranged in rows on ears. Visceral disk of pedicle valve flat and separated from trail by a sharp geniculation. Brachial valve geniculated. Cardinal area developed in pedicle valve, with small triangular delthyrium closed by deltidium. Teeth and sockets usually not developed. Diductor muscle-scars of pedicle valve situated immediately below umbo and enclosing elongated adductors. Adductor muscle-scars of brachial valve dendritic. Cardinal process small. Median septum slightly enlarged at its anterior extremity.

7. Proboscidella D. P. Œhlert, 1887 (p. 1277, fig. 1038).

Plate XII, figs. 16a, b, 17.

(Genotype: *Productus proboscideus* P. E. P. de Verneuil. Sur quelques espèces intéressantes de Brachiopodes des terrains anciens, *Bull. Soc. Géol. France*, vol. xi, 1840, p. 259, pl. iii, figs. 3a—d. Paris.)

Valves very unequal, the brachial valve small, concave and operculiform; the pedicle valve large, convex on the visceral disk, which is separated from the flanks and trail by a deep furrow. A furrow corresponding in position to that of the pedicle valve is seen on the brachial valve. Flanks spreading, uniting along a median line below the brachial valve and then produced anteriorly in the form of a long cylindrical tube. When the two flanks do not meet, two tubes may be developed. Surface ornamented with concentric ribs which become more numerous on the trail, where they take the form of annulations. Costae fine, increasing by numerous intercalations and developed over the entire shell. Interior unknown.

8. Etheridgina D. P. Œhlert, 1887 (p. 1278).

(Genotype: *Productus complectens* R. Etheridge, jun. On an adherent form of *Productus* and a small *Spiriferina* from the Lower Carboniferous Limestone Group of the East of Scotland, *Quart Journ. Geol. Soc.*, vol. xxxii, 1876, p. 454, pl. xxiv, figs. 1-14; pl. xxv, figs. 15-24 [described and figured as *Productus sp.*]. Further remarks on adherent Carboniferous Productidae, *Quart. Journ. Geol. Soc.*, vol. xxxiv, 1878, p. 498.)

Shell of small size, nearly as broad as long, adherent to foreign bodies by the spines along hinge of pedicle valve and by attachment of pedicle valve. Cardinal margin straight, nearly equalling greatest width of shell. Surface ornamented with concentric undulating ribs bearing a few scattered spines. Cardinal process and median septum bifid. Cardinal area not developed.

This volume deals only with the *semireticulatus* and *longispinus* groups of *Productus* (*sensu stricto*), which comprise the following species:—

A. Species of the Group of *Productus semireticulatus*.

B. Species of the Group of *Productus longispinus.*

VII. Descriptions of Species.

A. Species of the Group of *Productus semireticulatus.*

Productus productus (Martin).

Plate I, figs. 1a—d, 2—6. Text-figs. 6, 11.

1809. *Anomites productus* W. Martin. Petrificata Derbiensia, p. 9, pl. xxii, figs. 1—3.

1821. *Productus martini* J. Sowerby (in part). Mineral Conchology of Great Britain, vol. iv, p. 15, pl. cccxvii, fig. 2.

1836. *Productus martini* J. Phillips (in part). Illustrations of the Geology of Yorkshire, part ii, p. 213, pl. vii, fig. 1.

?1847. *Productus semireticulatus*, var. *concinnus* L. de Koninck. Monographie du genre *Productus*, *Mém. Soc. Roy. Sci.*, Liége, vol. iv, p. 189, pl. viii, figs. 1g, h.

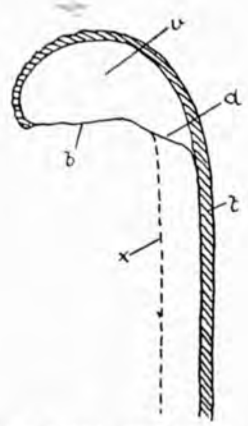
?1847. *Productus semireticulatus*, var. *martini* L. de Koninck (in part). *Ibid.*, p. 188, pl. ix, fig. 1g.

1861. *Productus semireticulatus* T. Davidson (in part). Mon. Brit. Foss. Brach., vol. ii, pt. v, No. 4, p. 149.

1861. *Productus semireticulatus*, var. *martini* T. Davidson. *Ibid.*, pl. xliii, figs. 7, 7a, 8, ?6.

1863. *Productus martini* T. Davidson. *Ibid.*, No. 5, pl. lv, fig. 11.

Diagnosis.—Shell elongated, about 54 mm. high, 48 mm. wide and 28 mm. thick, or 1 : ·9 : ·5; greatest width at the anterior margin. Pedicle valve with long, laterally spreading trail; flanks steep and flattened posteriorly; umbonal angle 108°; ears small. Brachial valve with flattened visceral disk at right angles to trail. Diaphragm developed, and frequently exposed. Costae about 14 in 10 mm. at distance of 20 mm. below umbo, uneven in width, flexuous and frequently bifurcating on trail. Ribs rarely continuous across front of visceral disk. Spine-bases rare, except on visceral disk, and in two rows on cardinal slopes at angle of 10° and at angle of 25° to hinge-margin.



TEXT-FIG. 11.—*Productus productus* (Martin), Carb. Limestone, subzone D_2, Narrowdale, Staffordshire. British Museum, B.45519. Diagrammatic longitudinal section, natural size, showing thickness of pedicle valve (t), visceral cavity (v), visceral disk of brachial valve (b), trail of brachial valve (x), and diaphragm (d).

Description.—Pedicle valve. The longitudinal contour of this valve shows a slightly convex portion for about 10 mm. below the umbo, then a flattening of the visceral disk for about 15 mm. which terminates in the rounded geniculation, joining the visceral disk to the long, straight or slightly curved trail. In the gerontic stage the trail may develop broad, longitudinal folds. The flanks are steep and flattened posteriorly but become very widespread in the later growth-stages. An extreme example of this is seen in the specimen figured by Davidson (1863) from Wetton, B.M., B.5809, in which the trail and flanks expand in an umbrella-like form. A shallow sinus may be developed on the visceral disk and be flattened out on the trail, or the venter may be only slightly flattened. The umbo is small and rounded, the apex projecting very slightly beyond the hinge, while the umbonal slopes expand rapidly. The hinge is extended into small, flattened, trigonal earlets which are separated from the flanks by a right-angled geniculation.

The costae are narrow and rounded on the visceral disk, but they increase in width and become slightly flattened on the posterior part of the trail. Increase in the number of costae on the visceral disk occurs by means of intercalations, as well as by bifurcation of previously existing costae, the angle between the two resulting costae being small. These two costae attain normal width in a space of 2—3 mm. from the point of division. Bifurcations are very frequent, one costa tending to split into two or three very narrow costae on the anterior part of the trail and on the flanks. In these parts of the shell the costae become sinuous and very uneven in width. Bifurcation also occurs below the scattered spine-bases on the trail, and an intercalated costa is often developed at the side of the bifurcation. The sulci are narrow and always of less width than the costae.

The ribs vary in number from 12 to 16, and form low folds on the cardinal slopes, but are rarely developed across the visceral disk. They frequently undulate, but rarely bifurcate. The point of intersection of ribs and costae is marked by a slight enlargement of the costae.

Spine-bases are fairly numerous and are scattered irregularly over the visceral disk; usually accompanied by coalescence of two costae posterior to the spine-base, and bifurcation anterior to it. On the trail, spine-bases are rare and when developed are of large size, averaging about 2 mm. in diameter. In addition to the two rows of spines on the flanks already mentioned, a few spine-bases may be seen on the flanks below the cardinal extremities.

Growth-lines are very marked, especially on the anterior portion of the trail, and on the ears.

Brachial valve. The exterior of this valve is not seen, as the lower or outer layer invariably remains in contact with the matrix enclosing the specimen. The reverse or inner side of this layer shows a flattened visceral disk with a slight median concavity near the anterior end corresponding to the flattening of the pedicle valve. The visceral disk is separated at an angle of 90° from the trail by a geniculation. The trail follows the contour of the pedicle valve but is not in contact with it.

The shell tends to split along the visceral disk of the pedicle valve, and internal layers of the brachial valve split off with the pedicle valve. The lower or outer layers of the visceral disk of the brachial valve remain in contact with the trails of both valves. A flattened rim is visible round the anterior and lateral margins of the visceral disk of the lower part of the brachial valve. This rim, or diaphragm, is less than 0·5 mm. in thickness and is from 2·5 to 5 mm. in width vertically below the umbo, but decreases laterally. It differs in ornament from the remainder of the brachial valve and may be smooth, longitudinally striated, or pustulose.

The ornament of the brachial valve is similar to that of the pedicle valve, but the ribs are more numerous and the appearance of reticulation on the visceral disk is more marked. The costae on the trail are flexuous and uneven in width.

Internal characters. The interior of the pedicle valve is unknown.

The interior of the brachial valve is rarely seen except in specimens[1] from Oswestry, Shropshire, M.P.G., 38320—38323, and ?near Settle, Yorkshire, B.M., B.13834, B.5804. These specimens show a prominent cardinal process which is bilobed on its interior face with smooth, rounded lobes, but is trifid on its exterior face, the three divisions bearing deep transverse striations. These features are shown in the specimens from ?Settle, Yorkshire, figured in pl. i, figs. 2, 3. On each side of the cardinal process is a flattened region bounded internally by the marginal ridges, which appear to diverge from the hinge about 1 mm. from the cardinal process and extend towards the lateral margin of the valve. Below the cardinal process the median septum is broad, flattened and medianly depressed, but it narrows and becomes more prominent anteriorly. Complete interiors of the brachial valve are unknown, but the septum is probably continuous to the anterior end of the visceral disk.

The adductor muscle-scars are small, dendritic and ovoid in outline, and the anterior end is set on a slight ridge. The brachial impressions extend outwards horizontally from the anterior lateral margin of the adductors, then they are bent anteriorly and are finally recurved upwards, enclosing a space about 3 mm. wide. The inner end of the brachial impressions is slightly enlarged, and is distinctly separated from the main part of the impression. A narrow ridge extends from the end of the impression and curves round to join the anterior end of the median suptum. The space enclosed by the impressions is smooth, unlike the other parts of the interior of the brachial valve, which are markedly pustulose. The smooth portion possibly served as the point of muscle attachment for the spiral arms.

[1] The register-numbers of the specimens are distinguished as explained in the footnote on the following page.

Dimensions.—

	(1)	(2)	(3)	(4)	
Maximum height	35	45	54	60	mm.
„ width	34	48	48·5	54	„
„ thickness ...	20	27·5	28	28	„
Length of hinge	25	27	34·5	—	„
„ „ visceral disk ...	19·5	21	27	31·5	„
Width „ „ „ ...	25·5	28	33	24	„
Number of costae in breadth of 10 mm. at distances vertically below umbo:					
at 15 mm.	14	16	14	12	
„ 30 „	16	16	13	13	

(1) B.M.,[1] 43377, Sowerby Coll., from Derbyshire.

(2) B.M., B.40952, White Watson Coll., from Derbyshire.

(3) B.M., B.42164, Sibly Coll., from Calver, Derbyshire.

(4) Geol. Surv., London, I.T.692, from Park Hill, Derbyshire.

Type.—Martin gave three figures of *Anomites productus* from Derbyshire in 'Petrificata Derbiensia.' Pl. xxii, fig. 1 of Martin shows an entire specimen, while figs. 2 and 3 of the same plate represent a slightly smaller specimen which is split across the visceral disk. Both specimens are probably lost. The original of pl. xxii, figs. 2 and 3, is chosen as lectotype.

Distribution.[1] —Range, D_2 subzone.

England.

Derbyshire: Calver Park Quarry, Calver (D_3 ?) (B.M., B.42164, Sibly Coll.); Park Hill (B.M., B.43842, B.43843, W. Hind Coll.; M.P.G., 32453—32458, 48263; Geol. Surv., London, I.T.669, 692—694, 786); Thorpe Cloud (B.M., B.43826); Siggate, Castleton (Mr. J. W. Jackson); Beresford Hall, Beresford Dale (B.M., B.46909—10); Chrome Hill (B.M., B.46903—08).

[1] The following abbreviations have been used in this and in successive pages:—M.P.G. = Museum of Practical Geology; B.M. = British Museum (Natural History); R. Scot. Mus., Edinburgh = Royal Scottish Museum, Edinburgh; Geol. Surv. = Geological Survey Collection.

Specimens from a similar locality in different collections are quoted thus:—Kildare (B.M., B.41815; M.P.G., 35542), signifying that a specimen from Kildare is preserved both in the British Museum and in the Museum of Practical Geology.

Isle of Man: Poolvash (B.M., B.42026, B.43827; Prof. S. H. Reynolds); Castletown (B.M., B.10533).

Lancashire: Clitheroe (B.M., B.43849).

Shropshire: Oswestry (M.P.G., 38320—38323).

Staffordshire: Wetton (B.M., B.5809, Davidson Coll., figd. 1863A, pl. lv, fig. 11); Narrowdale (B.M., B.43840, B.43841, 45519).

Yorkshire: (B.M., B.8938, Gilbertson Coll., figd. J. Phillips, 1836, pl. vii, fig. 1); Elbolton (B.M., B.49872; Prof. E. J. Garwood); Elbolton Limestone, stream near Micklefoot's Lathe, Burnsall (Mr. R. G. S. Hudson); Scaleber Bridge, Settle (M.P.G., d.2407, 32459); ½ mile S. of Escow House, Grassington (M.P.G., o.3694).

Wales.

Flintshire: Halkin Hill (B.M., B.10522); Holywell (B.M., B.23540).

Remarks.—Productus productus is distinguished from *P. concinnus* J. Sow. by its greater size, longer and more spreading trail, and the absence of a tube-like enfoldment of the front of the trail. The costae of *P. productus* are more sinuous and irregular than those of *P. concinnus*, and there are two rows of spines on the cardinal slopes of *P. productus* in place of the group of spines on the ears in *P. concinnus*. It is distinguished from *P. multispiniferus* sp. nov. by its smaller visceral disk and more spreading trail, and by the absence of the large patch of small spine-bases on the flanks.

This species is very variable both in size and ornament. The costae may be flattened and separated by narrow sulci, or rounded and prominent, with wide interspaces. The amount of bifurcation and intercalation of costae also varies, and with it the size of the costae of the trail. The trail may be fan-shaped or steep and slightly outspread on the flanks.

Martin's drawings show a rather massive form with long spreading trail, and rather spinose visceral disk. If fig. 1 of his plate represents the same specimen as figs. 2, 3, the length of the visceral disk has been considerably exaggerated, and does not agree with that of fig. 3. The diaphragm is well shown but is not mentioned in his description.

Martin distinguished two varieties of his *Anomites productus*: '(a) valvâ convexâ tuberculis raris aspersâ, (b) valvâ convexâ tuberculis destitutâ.' The variety (a) may represent the more spinose form which occurs at the same horizon as the typical shells, and is probably to be identified with the variety *P. productus*, var.

hispidus var. nov. described on p. 47. The variety (b) was probably based on decorticated specimens since not one specimen, among the large number recently examined, was found to be devoid of spine-bases. Actual spines are seldom seen in situ, and this may have misled Martin in drawing up his description. It is not possible to give any interpretation of (b).

Sowerby's specimen of *P. martini* (1821, pl. cccxvii, fig. 2) is a smaller individual than Martin's shell and the trail is incomplete. Sowerby mentions the two rows of spines on the ears, and in his description of *P. concinnus* he notes the presence of the flat space round the edge of the valve (=diaphragm) as occurring also in *P. martini*. Of the two remaining figures of *P. martini* given by Sowerby, fig. 3 represents a badly preserved specimen, possibly belonging to a variety of *P. pinguis* sp. nov., while fig. 4 is a poor specimen of *P. carbonarius* de Kon. The latter, preserved in brown sandstone, is described in the supplementary index to Sowerby's volume, by J. Farey, p. 160, as *P. martini β*. The two limestone specimens, figs. 2, 3, are called *Productus martini α*.

Phillips (1836, pl. vii, fig. 1; pl. viii, fig. 19) figured two specimens as *P. martini*, one of which, pl. viii, fig. 19, is quite distinct from *P. productus* and may be an imperfect example of *P. antiquatus* J. Sow. or *P. pinguis* sp. nov.

Productus martini was described by M'Coy (1844, p. 111) as a distinct species, and he noted the presence of a smooth area (diaphragm) round the margin of the ventral (=brachial) valve. This he described more fully later (1851—55, p. 467), stating that this narrow flattened border has been taken to represent the thickness of stone between the two valves. 'An attentive examination will shew, however, that this is not the case, a portion of the shell smoother than the rest being bent at right angles to the preceding, and to the following parts of the valve, covering over that peculiar margin represented in Martin's plate. This character seems to be only developed in the adult, or when the visceral disk of the entering valve [brachial] is seven or eight lines long, when the width of the border is rather more than a line.'

De Koninck (1842—44, p. 160) confused *P. productus* with elongated forms of *P. semireticulatus*, which he described as *P. martini*, using this term in preference to *P. antiquatus* or *P. semireticulatus*. None of the figures of *P. martini* given by de Koninck can be ascribed to this species, and the specimen shown in pl. vii, fig. 2, is an example of *P. multispiniferus* sp. nov. In his later work (1847B, p. 83) de Koninck employed the name *semireticulatus* instead of *martini*, but still kept *P. martini* as a distinct variety.

Davidson (1861B) added to the confusion started by de Koninck, by describing *P. martini* as well as several other forms as identical with *P. semireticulatus*, stating that he could not draw any line of distinction between them. The specimen figured by Davidson from Park Hill (1861B, pl. xliii, fig. 7), preserved in the Museum of Practical Geology, is mistakenly represented as having a deep sinus. The feature indicated is due to injury to the shell during the life of the animal, resulting in irregular, sinuous costae and closer approximation of growth-lines due to retardation in development.

G. B. Sowerby figured a typical specimen as *P. martini* (1822—34, fig. 1); but the specimen described by Deshayes (1832, p. 848) appears to be too deeply lobate for the typical form.

De Verneuil (1845, pl. xviii, p. 9) figured a small form from Russia quite distinct from *P. productus*, having a row of spines on each flank. He quoted *P. martini* and *P. concinnus* as varieties of *P. semireticulatus* and distinguished *P. concinnus* from *P. martini* by the gradual disappearance of the sinus, and the absence of ribs. Fischer de Waldheim also recorded *P. martini* from Mjatschowa, Russia, but gave no figure of the form indicated in his description in 1837 (p. 42).

Abich figured specimens (1878, pl. v, figs. 1a, b; pl. ix, figs 4, 4a) as *Productus martini* from Armenia, but these do not appear to belong to the *semireticulatus* group, while von Arthaber (1900, p. 266) included *P. martini* as well as *P. carbonarius* de Koninck, *P. nystianus* de Koninck, and other species in the genus *Marginifera*.

Von Buch did not figure his *P. martini* (1842, p. 30) but quoted as reference Phillips's figure which, however, does not represent this species; and Winchell in 1863 (p. 4) recorded *P. martini* from the Burlington Limestone of Iowa, but gave no figure.

M. Demanet (1921—23, pl. vi, fig. 30) figured the posterior portion of a specimen labelled *P. semireticulatus*, var. *martini*, from the Waulsortian of Four à Chaux, Maredsous, Belgium, subzone C_2. The specimen is too incomplete for precise determination, but *P. productus* has not so far been found elsewhere below the D_2 subzone. Dr. Wilmore (1916, p. 428) distinguished the knolls of C_2—S age in Yorkshire, in which *P. semireticulatus* occurs, from those of D_2 age which contain *P. martini*.

The *P. semireticulatus*, var. *martini* recorded by Kirkby (1888, p. 750) from the Coal Measures of Fife is probably a specimen of *P. carbonarius* de Koninck.

Vaughan's specimens described as *P.* cf. *martini* (1905A, p. 288), and later as *P. burlingtonensis*, are in part redescribed in the present work as *P. vaughani* sp. nov. (p. 65).

Dr. Sibly (1908, p. 76) described *P. martini* from the D_2 and D_3 subzones of the Midlands, but the typical form is said to attain its maximum in the 'Brachiopod Beds' of D_2 age. He distinguished *P. martini* from *P. concinnus* J. Sow. by the non-sulcate convex valve, inconspicuous 'semireticulation,' and the 'square-shaped' intersection of the valves of the former. *P. concinnus* is said to be smaller, with sulcate, convex valve and less extended skirt. The 'semireticulation' is strong on the wings and possibly extends over the front of the valve, and the intersection of the two valves is transverse.

Productus productus, var. hispidus var. nov.

Plate III, figs. 13a, b.

Diagnosis.—Shell elongated, about 47 mm. high, 38 mm. wide, and 24 mm. thick, or 1 : ·8 : ·5; maximum width near anterior margin. Pedicle valve with broad visceral disk geniculated to form a slightly spreading trail. Ears rather large, triangular in outline and separated from visceral disk by deep sulcus. Shell not tending to split along visceral disk, and diaphragm rarely exposed. Costae about 14 in 10 mm. at distance of 20 mm. below umbo, coarse and rather prominent, bearing numerous large spine-bases near which costae thicken. Three rows of small spine-bases on ears and continuing down flanks.

Dimensions.—

	(1)	(2)	
Maximum height	45	47	mm.
,, width	37	38	,,
,, thickness	23	24	,,
Length of hinge	32	26	,,
,, ,, visceral disk	21	17	,,
Width ,, ,, ,, ...	20	21	,,
Number of costae in breadth of 10 mm. at distances vertically below umbo:			
at 15 mm.	13	14	
,, 25 mm.	14	14	

Both specimens, from Humphrey Head, Lancashire, subzone D_2, are in Prof. E. J. Garwood's collection. Specimen (1) is incomplete, and its original height has been estimated.

Type.—Holotype, from Humphrey Head, Lancashire, subzone D_2, is preserved in Prof. E. J. Garwood's collection. Paratypes: a number of specimens mentioned below in the paragraphs on 'Distribution.'

Distribution.—Range, D_2 to D_3 subzones.

England.

Derbyshire: N.E. slope of Chrome Hill, Hindlow (Geol. Surv., London, I.T.826); S.W. slope of Park Hill (Geol. Surv., London, I.T.769); Cawdor Quarry, Matlock Bridge, *Cyathaxonia* Beds, subzone D_3 (Geol. Surv., London, J.M.361); New Low Quarry, Castleton (Mr. J. W. Jackson); Mich Low, near Bradwell (Mr. J. W. Jackson).

Isle of Man: Poolvash (B.M., B.43845).

Lancashire: Humphrey Head, near Grange, subzone D_2 (Prof. E. J. Garwood.)

Staffordshire: Narrowdale Hill, subzone D_2 (B.M., B.45850—52, Roscoe Coll.); Hope Dale (Mr. J. W. Jackson); near Alstonfield (Mr. J. W. Jackson).

Yorkshire: Elbolton, subzone D_2 (B.M., B.2473); Brockthorn, Settle (B.M., B.20550).

Wales.

Anglesey: Quarry in field, 550 yards E. of California Inn, and 1½ miles S. of Llanallgo Church (Geol. Surv., London, Af.2052).

Flintshire: Upper Grey Limestone, Mold (B.M., B.23881).

Pembrokeshire: East side of Bullslaughter Bay (Geol. Surv., London, I.T.610, 619).

Remarks.—Productus productus, var. *hispidus* is distinguished from *P. productus* (Martin) by its slightly broader visceral disk and less spreading trail in the pedicle valve. The costae in *P. productus*, var. *hispidus* are coarser and slightly more prominent than in the parent species, and spine-bases are differently arranged in the two forms.

This variety is readily confused with another species with a long trail which also occurs in the D_2—D_3 subzone of Derbyshire. That form is extremely spinose, especially on the visceral disk, and the ornament resembles that of *Buxtonia*. Its relationship to *P. productus* is uncertain, but it is probably a homoeomorph belonging to the genus *Buxtonia*.

It is possible that the specimen figured by de Koninck (1847B, pl. ix, fig. 1g) and doubtfully identified as *P. productus* may belong to *P. productus*, var. *hispidus*, as it has the rows of spine-bases on the flanks characteristic of this variety.

PRODUCTUS CONCINNUS J. Sowerby.

Plate I, figs. 7, 8a, b, 9, 10a, b. Text-fig. 12.

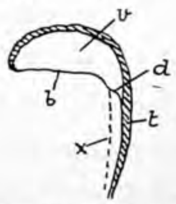
1821. *Productus concinnus* J. Sowerby. Mineral Conchology of Great Britain, vol. iv, p. 16, pl. cccxviii, fig. 1.

1860. *Productus semireticulatus*, var. B, or *martini* T. Davidson (in part). The Carboniferous System in Scotland characterized by its Brachiopoda, *The Geologist*, vol. iii, p. 109.

1860. *Productus semireticulatus*, var. *concinnus* T. Davidson. *Ibid*., p. 268 [in explanation of pl. iii, under heading ' Plate iv '], pl. iii, fig. 12.

1861. *Productus semireticulatus*, var. *concinnus* T. Davidson. Mon. Brit. Foss. Brach, vol. ii, pt. v, No. 4, pl. xliii, figs. 9, 10.

1906. *Productus concinnus*, mut. D_2 T. F. Sibly. On the Carboniferous Limestone (Avonian) of the Mendip Area (Somerset), *Quart. Journ. Geol. Soc.*, vol. lxii, p. 372, pl. xxxii, figs. 3a, 3b.



TEXT-FIG. 12.—*Productus concinnus* J. Sowerby. Lectotype from the Carb. Limestone of Derbyshire, or Richmond, Yorkshire. British Museum, B.47991. Diagrammatic longitudinal section, natural size, showing thickness of pedicle valve-wall (t), visceral cavity (v), visceral disk of brachial valve (b), trail of brachial valve (x), and diaphragm (d).

Diagnosis.—Shell about 40 mm. high, 30 mm. wide and 16 mm. thick, or 1 : ·7 : ·4; elongated; hinge slightly less than widest part of shell. Pedicle valve with median fold on front of trail, forming tube-like development anteriorly; trail never spreading; flanks steep; umbonal angle 105°; ears large and flattened. Brachial valve with flat visceral disk sharply geniculated to form trail; diaphragm developed and frequently exposed. Costae about 17 in 10 mm. at distance of 20 mm. from umbo, flattened on trail and slightly sinuous. Ribs feebly developed on cardinal slopes and on front of visceral disk. Spine-bases scattered on visceral disk, in groups on ears and on flanks below cardinal extremities.

Description.—Pedicle valve. The visceral disk is short and slightly convex, and is separated from the rather short, moderately curved trail by a rounded geniculation. The flanks are flattened and slope gently outwards anteriorly but are never spreading, and the venter is flattened or slightly sinuated, the sinus dying out on the posterior part of the trail. The umbo is small, the apex pointed and projecting slightly beyond the hinge. The ears are separated from the flanks by a deep sulcus.

The costae are fine on the visceral disk, but they increase in width and become flattened on the trail. Bifurcation of the costae occurs frequently on all parts of the shell and not necessarily in the region of a spine-base. Intercalated costae occur on the visceral disk and flanks. In the gerontic stage the costae tend to become uneven in width and slightly sinuous, and to develop irregular swellings and excrescences. In decorticated parts of the shell the costae may decrease to half their normal width. The sulci are about half the width of the costae.

The ribs are usually about 10 in number and are feebly developed. On the cardinal slopes they form angular wrinkles which increase very slightly in size on the lateral slopes of the visceral disk. Enlargement of the costae at the point of intersection with the ribs is never marked.

Spines appear to have extended tangentially to the shell on the visceral disk, where a few scattered spine-bases are usually seen. A few larger, elongated spine-bases are developed on the trail, their diameter exceeding the width of the costae supporting them. In addition to the group of spine-bases on the ears a row is sometimes developed on the cardinal slopes and extends at an angle of 10° to the hinge-margin. A group of spine-bases may occur on the flanks immediately below the cardinal angles. The average diameter of a spine-base is less than 1·25 mm. and the greatest length of spine observed is 1·3 cm.

Growth-lines are very numerous on the trail.

Brachial valve. The visceral disk is flattened, but has a slight median fold corresponding to the sinus in the pedicle valve, and it is separated from the trail by a geniculation at an angle of 90°. The actual exterior of this valve is unknown, as it invariably remains in contact with the matrix. The shell tends to split along the visceral disk of the pedicle valve, and the inner layers of the visceral disk of the brachial valve split off with the visceral disk of the pedicle valve. When this latter portion is removed the diaphragm is seen as a smooth rim round the visceral disk of the brachial valve. This rim is from two to three millimetres in width and is usually seen to lie at a slightly lower level than the visceral disk.

The ornament is similar to that of the pedicle valve.

Internal characters. The interior of the pedicle valve is unknown.

In the brachial valve there is a small bifid cardinal process extending downwards as a broad and flat median septum which narrows between the adductor muscle-scars and extends to the anterior end of the visceral disk. About 1 mm. from the cardinal process the marginal ridges diverge from the hinge and slope down to the lateral margin, along which they continue for a distance of 2 or 3 mm.; they always remain extremely narrow and delicate.

The adductor muscle-scars are small and dendritic. Their posterior ends are inserted about 1·5 to 2 mm. below the hinge-margin and they are in contact with the median septum along their inner margin. The brachial impressions are given off at the anterior end of the adductors and this posterior portion of the impression is discontinuous, being cut by narrow transverse incisions. The apex does not seem to be separated from the remainder of the impression, although it is slightly enlarged. The anterior part of the impression is set on the edge of the visceral disk, just above the diaphragm, as shown in pl. i, fig. 9.

Dimensions.—

	(1)	(2)	(3)	(4)	
Maximum height	24	25	26·5	42	mm.
,, width	27	29·5	25	33	,,
,, thickness ...	16	18·5	16	16·5	,,
Length of hinge	—	17	2	22	,,
,, ,, visceral disk ...	15	14·5	14·5	15	,,
Width ,, ,, ,, ...	19·5	21·5	18·5	22	,,
Number of costae in breadth of 10 mm. at distances vertically below umbo :					
at 10 mm. ...	17	17	19	19	
,, 15 ,, ...	13	15	17	16	
,, 20 ,, ...	14	17	16	17	

(1) Geol. Surv., London, Pr.2340, from east side of Ragwen Point, Carmarthenshire.

(2) B.M., B.42163, Sibly Coll., from N. of Bakewell, Derbyshire, subzone D_3.

(3) B.M., B.47992, Sowerby Coll., from Derbyshire, or Richmond, Yorkshire.

(4) Kelvingrove Mus., Glasgow, 01·53 afn, Young Coll., from the Hurlet Limestone, Sculliongour, Campsie, Stirlingshire.

Type.—Sowerby figured three specimens from Richmond, Yorkshire, or from Derbyshire. One specimen, the right-hand figure of pl. cccxviii, fig. 1, is in two parts and shows the diaphragm. This specimen [B.47991] is chosen as lectotype. The other two specimens are embedded in a fragment of black limestone. The specimens are preserved in the British Museum, Sowerby Coll. [B.47991, B.47992].

Distribution.—Range, D_2 subzone to Millstone Grit.

England.

Derbyshire: Quarry, S. of Rowdale House, N. of Bakewell, subzone D_3 (B.M., B.42162, B.42163, Sibly Coll.); Shaws Quarry, S. of station, Matlock Bath (Geol. Surv., London, C.B.W. 931, 932, 934, 943, 944).

Northumberland: Six-Yard Limestone, Little Mill, subzone D_2—D_3 (B.M., B.41965—41968, S. Smith Coll.); upper beds of Eight-Yard Limestone, old quarry, Dunstan Hill (Geol. Surv., London, J.R.1148, 1149).

Somerset: Long Ashton, horizon ϵ (B.M., B.1528); Wick, horizon ϵ (Bristol Univ.); Emborough, subzone D_2—D_3 (Bristol Univ.); Honeypen Hill, Clifton, Bristol, horizon ϵ (Bristol Mus., C.1234); Avon Section, subzone D_3 (Bristol Mus.).

Yorkshire: Millstone Grit, top of Great Standards Fell (B.M., B.43731, B.43732, W. Hind Coll.); Hardraw Shale, Mill Gill, Askrigg, Wensleydale (Mr. R. G. S. Hudson); ? Richmond (B.M., B.47991—92).

Wales.

Anglesey: Escarpment above cliff, Pen-y-Coed, Anglesey (Geol. Surv., London, Af.622); quarry, 1,370 yards W.N.W. of Llanddyfnan Church (Geol. Surv., London, Af.2164).

Carmarthenshire: Beds below lowest sandstone of Millstone Grit, east side of Ragwen Point, S.W. of Pendine Post Office (Geol. Surv., London, Pr.2340, 2344-2346); Ragwen, near Pendine (Bristol Univ.).

Carnarvonshire: Great Orme's Head (B.M., B.43822).

Glamorganshire: Port Eynon, subzone D_2 (Bristol Univ.).

Pembrokeshire: East side of Bullslaughter Bay, Pembroke, subzone D_3 (Geol. Surv., London, I.T.603).

Scotland.

Ayrshire: Lower Limestones, blaes between Broadstone and Dockra Limestones, Auchenmade (Geol. Surv., Edinburgh, V.2502A, 2506A, 2507A); Cleugh Burn, Ayrwater, at Brocklar Limeworks (Geol. Surv., Edinburgh, M.2811); Laigh Hole House, Ayrwater (Geol. Surv., Edinburgh, M.2810); S. of Hillhouse, E. of Howcommon (Geol. Surv., Edinburgh, T.3123E); stream, north side of Cessnock Castle, below old bridge (Geol. Surv., Edinburgh, T.3255E); Lower Limestones, Auchenskeoch, Dalry (R. Scot. Mus., Edinburgh, 23); Lower Limestones, coal-shale, Beith (R. Scot. Mus., Edinburgh, 22); Hurlet Limestone, Dockra, Beith (Kelvingrove Mus., Glasgow, 96·65 ilf); shale above Main Clay Ironstone, Netherton, Dunlop (R. Scot. Mus., Edinburgh, 24).

Buteshire: Hurlet Limestone, 200 yards N. of Laggan shore, Arran (Geol. Surv., Edinburgh, T.780).

Edinburghshire: Mount Lothian, E. of Penicuik (M.P.G., 38324—38327); Bore, S.E. side of Breichwater, ¼ mile N. of Handaxwood (Geol. Surv., Edinburgh, T.4266E); Hillhead Quarry, N. of Cockmuir Bridge (Geol. Surv., Edinburgh, B.1478C, 1480C, 1485C, 1519C).

Lanarkshire: Duntocher, Hamilton, Carluke (M.P.G., 34459); Johnstone Shell-bed, section above McDonald Mine, S.W. of Sitehill, Coalburn (Geol. Surv., Edinburgh, M.4647G); nodules on underside of Main or Hurlet Limestone, Birkwood Burn, 1½ miles N.W. of Lesmahagow (Geol. Surv., Edinburgh, T.4665E); Lower Limestones, Basket Shell-bed, Cot Castle Farm, left bank of Avon Water, 2 miles N.E. of Strathaven (Geol. Surv., Edinburgh, T.2772D, 2776D, 2777D, 2779D, 2780D); Hagshaw Burn (Geol. Surv., Edinburgh, T.606D, 607D); Lower Limestones, Boghead, Hamilton (Hunterian Mus., Glasgow, L.209).

Peeblesshire: Whitfield Limestone Quarry, S. side of road, near Macbiehill Railway Station (Geol. Surv., Edinburgh, T.3665A).

Stirlingshire: Lower Limestones, Upper Bannock Burn, above Third Reservoir, Grangemouth Supply (Geol. Surv., Edinburgh, T.1849F); Lower Limestones, Craigenglen, Campsie (Geol. Surv., Edinburgh, T.2904B); Lower Limestones, Corrieburn, Campsie (R. Scot. Mus., Edinburgh, 21); Lower Limestones, Hurlet Limestone, Sculliongour, Campsie (Kelvingrove Mus., figd. Davidson, 1861B, pl. xliii, fig. 10; 01·53 aft; also 01·53 afm and afn).

Ireland.

Co. Mayo: Shales above Main Limestone, North Star Colliery, Ballycastle (Bristol Univ.).

Remarks.—Productus concinnus is distinguished from *P. productus* (Martin) by its less globose visceral disk, and by its shorter and less spreading trail, the front of which tends to develop a prominent median fold. The ears are larger in *P. concinnus* than in *P. productus* and bear groups of spine-bases, and the costae in the former are less irregular and flexuous than in the latter species. *P. concinnus* is distinguished from *P. carbonarius* by its larger visceral disk, more extended trail and spreading flanks, coarser and more prominent costae and fewer and larger spine-bases on the visceral disk and trail.

As already mentioned, one specimen figured by Sowerby, which is in two parts, shows the diaphragm preserved round the visceral disk of the brachial valve. Sowerby referred to this when he said: 'The flat space around the edge of the lower valve occurs also in *P. Martini*, as Mr. Martin's excellent figure shews, but it does not appear to be constant.' This apparent lack of constancy is only due to the way in which the visceral disk of the pedicle valve splits off, the diaphragm sometimes being preserved in the upper and sometimes in the lower portion of the shell. Sowerby mentioned *P. concinnus* as occurring with *P. lobatus* at Little Park Tower, Northumberland.

Davidson (1861B, p. 151) considered *P. concinnus* to be a variety of *P. semireticulatus* and to be a small form of *P. martini*. He figured (1860B, pl. iv, figs. 10, 10a) a form as *P. semireticulatus*, var. *martini*, which has a longer and more spreading trail than is found in typical specimens of *P. concinnus*. This form occurs rarely in the Lower Limestones of Scotland, associated with *P. concinnus*.

Phillips's figure of *Producta concinna* (1836, pl. vii, fig. 9) shows only a posterior part of a pedicle valve in which no ribs or spines are visible, and it can only be doubtfully referred to this species.

M'Coy included *P. concinnus* as a synonym of *P. martini* (1851—55, p. 467), which he distinguished from *P. semireticulatus*.

In 1842—1844 (p. 160) de Koninck regarded *P. concinnus* as a synonym of *P. martini*, but later (1847B, p. 87) he described it as a small variety of *P. semireticulatus*. The specimens figured by de Koninck in 1847B (pl. viii, figs. 1g, 1h) as

P. concinnus from Visé appear to have a squarer visceral disk and slightly coarser costae than are common in this species, and they have been doubtfully assigned to *P. productus*.

The specimen figured by Dr. Lee as *P. concinnus* (1909, pl. ii, fig. 33) from Novaja Semlja, and now preserved in the Royal Scottish Museum, is not typical, and no diaphragm seems to be developed in it.

Dr. Bolton figured *P. concinnus*, mut. towards *muricatus* in 1907 (pl. xxx, figs. 5a, b) from the basement-beds of the Bristol coalfield. The specimen, a brachial valve, is more coarsely costate than *P. concinnus*, but a diaphragm is developed and this distinguishes it from *P. muricatus*. A similar form is said by Dr. Bolton to occur in the Millstone Grit of Pateley Bridge, Yorkshire. Specimens from this horizon and locality have, however, been referred to the species *P. carbonarius* de Koninck in this work (p. 58).

The species referred to by Vaughan as *P.* aff. *concinnus* and by Dr. Sibly (1906) as *P. concinno-martini* from the *Syringothyris* zone of the Mendips is probably related to *P. garwoodi* sp. nov. The specimens are much crushed and very spinose, but the development of a diaphragm in the brachial valve distinguishes them from specimens of *P.* cf. *martini* Vaughan (=*P. vaughani* sp. nov.). Dr. Sibly (1905B, pp. 556, 557) records this form as *P. semireticulatus* mut. (cf. *P. concinnus*) from the C zone to the top of S_1 subzone of Weston-super-Mare. *Productus* cf. *concinnus* of Vaughan (Matley and Vaughan, 1906, p. 296) from the C_2 beds of Rush, Ireland, may be identified in part with *P. derbiensis* sp. nov. Vaughan (op. cit., 1906, opp. p. 307) endeavoured to trace the evolution of *P. concinnus* from *P.* cf. *martini* of the Z zone through *P.* aff. *concinnus* of the C_2—S_1 subzones, and regarded *P. longispinus* as derived partly from *P. concinnus*.

M. Demanet (1921—23, pl. vi, fig. 31) figured a portion of the visceral disk of a semireticulate specimen as *P. semireticulatus*, var. *concinnus*, from the Waulsortian of Belgium. This specimen is not identical with *P. concinnus*.

Dr. T. F. Sibly (1906, p. 372, pl. xxxii, figs. 3a, 3b) figures *P. concinnus* from Emborough, Somerset, subzone D_2, and quotes it as occurring abundantly at this horizon in the Mendip area. Vaughan mentioned this species (Matley and Vaughan, 1906, p. 299) as occurring in the Curkeen Limestone, Rush, subzone D_2, in the Lower *Posidonomya* Beds of Loughshinny (Matley and Vaughan, 1908, p. 451), and in the D_2 subzone of Gower (Dixon and Vaughan, 1911, p. 549).

Dr. Stanley Smith (1910, p. 616) records it under the name *P. martini* from the Six-Yard Limestone, subzone D_2—D_3, Northumberland. Wheelton Hind (1907, p. 144) recorded this species from the Isle of Man in the section from Cass ny Hawin to Ronaldsway, ?D_2—D_3 subzone.

PRODUCTUS CARBONARIUS de Koninck.

Plate II, figs. 3—7. Text-fig. 13.

?1821. *Productus martini* J. Sowerby (in part). Mineral Conchology of Great Britain, vol. iv, p. 15, pl. cccxviii, fig. 4.

1842. *Productus carbonarius* L. de Koninck. Description des Animaux Fossiles qui se trouvent dans le Terrain Carbonifère de Belgique, p. 181, pl. xii bis, figs. 1a—c.

1847. *Productus carbonarius* L. de Koninck. Recherches sur les Animaux Fossiles. Pt. i. Monographie des Genres *Productus* et *Chonetes*, p. 90, pl. x, figs. 4a—e.

1860. *Productus carbonarius* T. Davidson. The Carboniferous System in Scotland characterized by its Brachiopoda, *The Geologist*, vol. iii, p. 111 [in explanation of pl. iii, under heading ' Plate iv '], pl. iii, figs. 14, 14a, 14b.

1861. *Productus carbonarius* T. Davidson. Mon. Brit. Foss. Brach., vol. ii, pt. v, No. 4, p. 160, pl. xxxiv, figs. 6, 6a, 6b.

1880. *Productus carbonarius* T. Davidson (in part). Mon. Brit. Foss. Brach., Suppl., vol. iv, pt. iii, p. 309, pl. xxxvi, figs. 7, 7a.

TEXT-FIG. 13.—*Productus carbonarius* de Koninck. Pendleside Series, Congleton Edge, Cheshire. British Museum, B.43722. Diagrammatic longitudinal section, natural size.

Diagnosis.—Shell about 21 mm. high, 24 mm. wide and 14 mm. thick, or 1 : 1·1 : ·6; oval in outline, width slightly greater than length and hinge forming widest part of shell. Pedicle valve with short convex visceral disk geniculated at its anterior extremity and forming short curved trail; venter flattened; umbonal angle 110°; ears tapering laterally to form spine-like projection. Brachial valve with flat or slightly concave visceral disk, geniculated abruptly to form slightly curved trail. Diaphragm developed. Costae about 19 in 10 mm. at distance of 15mm. from umbo, irregular, sinuous on trail and bifurcating below spine-bases. Ribs flattening out on front of shell. Spine-bases numerous, of small size, scattered irregularly over pedicle valve, and in two or three transverse rows on ears, with one row extending down flanks.

Description.—Pedicle valve. The shell is frequently broken along the end of the visceral disk and the trail is seldom preserved. The ears tend to become fractured, the spine-like projection being very rarely seen. The venter is broad and flat but not sinuated. The umbo tapers to a fine point and is much incurved over the hinge.

The costae are fine and thread-like on the visceral disk, but increase in width anteriorly, becoming flatter. They are never prominent. Near the anterior margin the numerous bifurcations cause a great decrease in width of the costae. The two costae formed by a bifurcation are separated by an extremely narrow sulcus.

A low, longitudinal fold may be developed below the spine-bases on the trail near the anterior margin. When the shell is decorticated the shell-surface appears to be lacking in spines, the bases of which are only recognizable as rounded pits above which the costae are worn down and hollow for a space of 2 to 3 mm. The greatest length of spine observed is 8 mm., with a diameter of 0·75 mm.

Growth-lines are very numerous on the trail and are undulating owing to a retardation in the growth of the shell in the region of the spine-bases.

Brachial valve. The shell tends to split along the visceral disk of the pedicle valve, leaving the visceral disk of the brachial valve and the diaphragm exposed. The diaphragm is from 3 mm. to 4 mm. in maximum width vertically below the umbo, and usually lacks ornament.

The ornament is similar to that of the pedicle valve.

Internal characters. The interior of the pedicle valve is unknown.

In the brachial valve the cardinal process is small and bilobed on its internal surface, and is produced anteriorly to form a median septum which is slightly shorter than the length of the visceral disk.

The adductor muscle-scars are small and are set close to the septum.

The marginal ridges follow the hinge for a space of about 2 mm. from the cardinal process, then diverge slightly from it and finally curve downwards near the cardinal extremities.

The above remarks are based on imperfect interiors of this valve from Congleton Edge. The brachial impressions were not preserved in any specimen.

Dimensions.—

	(1)	(2)	(3)	(4)	
Maximum height	19	20·5	21	26	mm.
,, width	25	23	24	19	,,
,, thickness ...	15·5	14·5	13	14·5	,,
Length of visceral disk ...	13·5	11	10·5	11	,,
Width ,, ,, ,, ...	—	18	—	—	,,
Length of hinge	18	16	—	14·5	,,
Number of costae in breadth of 10 mm. at distances vertically below umbo :					
at 10 mm.	24	25	—	19	
,, 15 ,, ...	19	21	18	18	

(1) B.M., B.43720, from the Pendleside Series, Congleton Edge, Cheshire.

(2) M.P.G., 38319, from Garngad Rd., Glasgow.

(3) R. Scot. Mus., Edinburgh, 1911.62.964, same locality as (2).

(4) Kelvingrove Mus., Glasgow, from the Lower Limestones, Crookhill, Beith, Ayrshire.

Type.—De Koninck gave a poor figure of this species in 1842, from an unknown locality. A second specimen showing the characteristic ornament of the species was figured in 1847 from the vicinity of Chokier, Belgium, and has been chosen as lectotype. Both specimens are apparently lost.

Distribution.—Range, D_2 subzone to Millstone Grit.

England.

Cheshire: Pendleshire Series, Congleton Edge (B.M., B.43720, 43786—98, W. Hind Coll.).

Northumberland: Shale with ironstone nodules, Gofton Burn (Geol. Surv., London, A1616); Berwick-on-Tweed (M.P.G., 34470).

Shropshire: Oswestry Race Course (B.M., B.43750—58, W. Hind Coll.)

Yorkshire: Millstone Grit, Pateley Bridge (Bristol Univ.).

Wales.

Brecknockshire : Millstone Grit Shales, Pitwellt Stream, in burn below Brecon and Merthyr Railway (Geol. Surv., London, J.P.530, 541, 542).

Scotland.

Ayrshire : Shale below Upper Linn Limestone, Glencart, Dalry (Kelvingrove Mus., Glasgow, 08·153 jn); Upper Limestones, Upper Linn Limestone, Bowertrapping, Dalry (R. Scot. Mus., Edinburgh; Kelvingrove Mus., Glasgow); shale in ironstone measures, Crookhill, Beith (Kelvingrove Mus., Glasgow, 08·153 js); Lower Limestones, No. 2 Limestone, Kersland Glen, Beith (Kelvingrove Mus., Glasgow); Lower Limestones, Hillhead of Broadstone, Beith (R. Scot. Mus., Edinburgh, Neilson Coll.).

Fifeshire : First limestone above St. Monan's Limestone, shore on E. side of St. Monan's Burn (Geol. Surv., Edinburgh, T.274F, 275F, 277F, 278F, 279F, 285F).

Haddingtonshire : Shale above Vaults Limestone, shore opposite Vaults, 1 mile E. of Dunbar (Geol. Surv., Edinburgh, B.2033E).

Lanarkshire : Upper Limestones, Garngad Road, near Glasgow (B.M., B.13827, 45677; M.P.G., 38319; R. Scot. Mus., Edinburgh, 1911.62.964); thick limestone with *P. giganteus*, Craig Burn, 2½ miles N.N.E. of Douglas (Geol. Surv., Edinburgh, T.744D); shale above Hosie Limestone, old quarry on Hillhead Farm, 1 mile N.E. of Carluke (Geol. Surv., Edinburgh, B.4530A); pit on Bashaw Farm, 2 miles N.E. of Carluke (Geol. Surv., Edinburgh, B.4523A, 4525A); white nodular limestone, Birkwood Burn, Lesmahagow (Geol. Surv., Edinburgh, T.361F).

Peeblesshire : Shelly band in arenaceous series, N.Esk River, 30 yards up right bank from Carlops (Geol. Surv., Edinburgh, M.4977E).

Ireland.

Co. Wexford : Black bryozoal limestone, Hook Point (M.P.G., Geol. Soc. Coll. 38385, 38386).

Remarks.—Productus carbonarius is distinguished from *P. concinnus* J. Sow. by its short, slightly curved trail, finer costae, and the very numerous spine-bases scattered over the entire shell. It is distinguished from *P. muricatus* Phill. by its finer and more irregular costae, and by irregularly distributed spine-bases. Spine-bases occur as a group on the ears in *P. carbonarius* and in a row along the cardinal margin in *P. muricatus*.

De Koninck's original figure of this species in 1842 is poor and only shows spine-bases on the visceral disk, but from his description it is certain that a similar form is intended to that figured in 1847B, in which the ornament and numerous scattered spine-bases are well shown.

De Verneuil (1845, pl. xvi, fig. 2) figured a specimen as *P. carbonarius* from the valley of the Prikcha, Valdaï, Russia. This locality was also quoted for the species by de Koninck. The specimens are, however, not identical with *P. carbonarius*, and have a smaller shell, coarser and more prominent costae, and fewer spines than in the Belgian species.

The specimen figured by Sowerby as *P. martini* from the River Barn, Yorkshire, may be *P. carbonarius*, and is preserved as a cast in brown sandstone showing the group of spines on the ears and numerous spines on the trail, and a rather wide diaphragm characteristic of this species. It is possible also that Sowerby's specimen of *P. spinosus* may be the posterior part of a *P. carbonarius*.

Davidson figured and described specimens of *P. carbonarius* from the Upper Limestones of Garngad Road, Glasgow, but also included (1880, pl. xxxvi, fig. 8) a brachial valve of an *Avonia* (species not yet described) which is often confused with specimens of *P. muricatus* Phill. This brachial valve has been refigured on pl. ii, fig. 8, of this work and shows clearly the spinose visceral disk and coarse prominent costae characteristic of this species of *Avonia*. The original specimen of *P. carbonarius*, which was figured by Davidson (1860A, pl. iii, fig. 14) was identified by de Koninck as belonging to his species.

M'Coy (1851—55, p. 472) included *P. carbonarius* in his synonymy of *P. setosus*, but the description applies to *P. carbonarius* rather than to *P. setosus*.

P. carbonarius was recorded by M. J. Cornet (1906, p. 36) from the Houiller supérieur, H_2, of Ghlin, N. of Mons Basin; and by Norwood and Pratten (1855, p. 11) from the Mountain Limestone of Illinois.

Mr. Bisat (1914, p. 24) recorded this species from the Cayton Gill Beds, Millstone Grit of Yorkshire, between Masham and Great Whernside.

A small and spinose *Productus*, generally much crushed and having a wide diaphragm, occurs in the Coal Measures of Coalbrookdale, and may be a mutation of *P. carbonarius*.

PRODUCTUS REDESDALENSIS[1] sp. nov.

Plate II, figs. 9a—c ,10, 11. Text-fig. 14.

1915. *Productus semireticulatus* R. Dunlop. Notes on the Discovery of Fossil Chitons in Fife; with photographs and drawings of all the Fossils found in the section, *Trans. Geol. Soc. Glasgow*, vol. xv, p. 167, pl. xx, fig. 8.

TEXT-FIG. 14.—*Productus redesdalensis* sp. nov. Holotype, Redesdale Ironstone Shale, Redesdale, Northumberland. British Museum, B.43830. Diagrammatic longitudinal section showing position of diaphragm, natural size.

Diagnosis.—Shell about 25 mm. high, 22 mm. wide and 16 mm. thick, or 1 :·8 :·6; elongate oblong in outline, maximum width along hinge. Pedicle valve with slightly convex visceral disk, geniculated to form short, curved trail; flanks steep and rounded; venter flat; umbonal angle 112°. Ears small, tapering towards cardinal extremities. Brachial valve with flattened visceral disk, geniculated abruptly to form short curved trail. Diaphragm developed. Costae about 17 in 10 mm. at distance of 15 mm. from umbo, rather fine, regular, thickening near spine-bases. Ribs faintly traceable across front of visceral disk. Spine-bases small, scattered over trail, rare on visceral disk and occurring as narrow band round anterior margin, and in group on ears.

Description.—*Pedicle valve.* The shell rarely splits along the visceral disk but commonly fractures across the trail, the full length of which is rarely seen. The cardinal extremities are also seldom preserved. The umbo is small and incurved and projects slightly beyond the hinge.

The costae are fine and even on the visceral disk, but increase in width slightly and become more prominent on the trail. Intercalated costae as well as bifurcations of previously existing costae occur on the visceral disk, and occasional bifurcations occur below the spine-bases on the trail. The sulci are never as wide as the costae except in decorticated parts of the shell, where the costae decrease to half their normal width and the sulci increase in width by a corresponding amount.

[1] Name derived from Redesdale, Northumberland, where the species is abundant.

About twelve ribs are developed as low narrow folds on the cardinal slopes, but only the posterior seven or eight cross the visceral disk, and there is little enlargement of the costae at the point of intersection with the ribs.

Spine-bases are scattered over the trail and occur as a band round the anterior margin. The spines spring from the summit of the costae and average 1 mm. in diameter on the trail, where they project at right angles to the shell surface. On the posterior part of the shell the spines are few in number and less than 0·5 mm. in diameter, and they extend along the surface. About fifteen spine-bases form a group on the ears, and another group may also occur on the flanks, with a row of spine-bases extending up on to the ears and terminating about 2 mm. from the umbo.

Brachial valve. The diaphragm is rarely seen and is, as a rule, ornamented with costae as on the visceral disk.

The ornament of this valve is similar to that of the pedicle valve.

Internal characters. The interior of the pedicle valve is unknown.

In the brachial valve the cardinal process is small and bifid and is produced anteriorly to form a flat median septum which decreases in width and becomes thread-like between the two adductor muscle-scars. The septum is about half the length of the visceral disk.

Marginal ridges extend along the hinge and are recurved round the inner edge of the ears, and continue down the lateral margins of the shell for about 5 mm.

The adductor muscle-scars are small and dendritic, and the brachial impressions are given off at their anterior extension. The portion of the impression adjacent to the adductors is intersected by transverse incisions.

Dimensions.—

	(1)	(2)	(3)
Maximum height	16	23	26·5 mm.
„ width	21	22·5	22·5 „
„ thickness	—	16	15·5 „
Number of costae in breadth of 10 mm. at distances vertically below umbo:			
at 10 mm.	18	23	—
„ 15 „	17	17	19
„ 20 „	—	14	—

(1) Geol. Surv., Edinburgh, T.3259E, from the Lower Limestones, N. of Cessnock Castle, Ayrshire.

(2) Holotype.

(3) Geol. Surv., Edinburgh, B.3418A, from four miles south-east of East Kilbride.

Type.—Holotype, from the Redesdale Ironstone Shale, Redesdale, Northumberland, subzone D_1 ?, is preserved in the British Museum, B.43830, Wheelton Hind Coll. Paratypes: a number of specimens mentioned below in paragraphs on 'Distribution.'

Distribution.—Range, D_1 subzone to top of D_2 subzone.

England.

Northumberland: Redesdale Ironstone Shale, Redesdale (B.M., B.23070, 41924—41954, B.43830, S. Smith and W. Hind Coll.; Prof. E. J. Garwood; Mr. J. Dunn).

Wales.

Anglesey: Escarpment, 1,150 yards S.E. of Bod Gynda (Geol. Surv., London, Af.2149); escarpment, 930 yards N.W. of Plas Llanddyfnan (Geol. Surv., London, Af.2089); quarry, 550 yards E. of California Inn, S. of Llanallgo Church (Geol. Surv., London, Af.2051).

Scotland.

Ayrshire: Lower Limestones, stream on N. side of Cessnock Castle, on lower side of old bridge (Geol. Surv., Edinburgh, T.3254E, 3257E—3260E).

Dumfriesshire: Streamlet, above Archerbeck Cottage, 4 miles N. of Canonbie (Geol. Surv., Edinburgh, M.4567B); Upper Calcareous Sandstone, Archerbeck Burn below bridge near Nether Millsteads, Canonbie (Geol. Surv., Edinburgh, M.270C).

Edinburghshire: Boring, S.E. side of Breichwater, $\frac{1}{4}$ mile N. of Handaxwood (Geol. Surv., Edinburgh, T.4277E).

Lanarkshire: Nodules on under side of Main Limestone, Birkwood Burn, $1\frac{1}{2}$ miles N.W. of Lesmahagow (Geol. Surv., Edinburgh, T.4664E, 4668E, 4670E); Basket Shell Bed, Cot Castle Farm, right bank of Avon Water, N.E. of Strathaven (Geol. Surv., Edinburgh, T.2863D, 2865D, 2699D); Forestfield bore, $\frac{3}{8}$ mile E. of railway station (Geol. Surv., Edinburgh, T.2024E); Hurlet or Main Limestone, Thorn old limestone quarry, 2 miles N.E. of Carluke (Geol. Surv., Edinburgh, T.722F, 726F, 730F, 735F); shale heaps in old quarries, on farm of Burnlead, Craigend Hill, and Boghead, 4 miles S.E. of East Kilbride (Geol. Surv., Edinburgh, B.3418A, B.4056A).

Linlithgowshire : Lower Limestones, old quarry, Cauldhame, 1½ miles S.E. of Linlithgow (Geol. Surv., Edinburgh, B.2820B, 2828B); ashy bed below Bathgate Limestone, West Quarry, Kirkton (Geol. Surv., Edinburgh, B.3717B).

Remarks.—Productus redesdalensis is distinguished from *P. carbonarius* de Koninck by its coarser, more even and more prominent costae, and its fewer spines on the visceral disk. The spines on the trail of *P. redesdalensis* extend at right angles to the shell-surface, not tangentially to it as in *P. carbonarius*. The flanks of the former are steeper and more flattened than in the latter species. It is distinguished from *P. concinnus* J. Sow. by its smaller dimensions, shorter trail, finer costae and greater development of spines.

Specimens of *P. redesdalensis* obtained from Redesdale are usually found with the brachial and pedicle valves separated along the hinge. In some cases the brachial valve has been rotated through an angle of 90°, due to the pressure of the matrix infilling the visceral cavity, and this causes the valves to gape anteriorly. This is well shown by the holotype, in which the two valves are nearly in contact at the hinge.

This species occurs very abundantly in the Lower Limestones of Scotland, especially in the Hurlet Limestone, and is probably the form recorded by Dr. Lee (in Carruthers, 1915, p. 165) as *Productus sp. nov.* from the Basket Shell Bed, at Cot Castle, Lanarkshire.

The specimen figured by Mr. R. Dunlop is a visceral disk of the pedicle valve obtained near Dunfermline, Fifeshire.

Sowerby's species *P. flemingi* may possibly be identified as *P. redesdalensis*. This species, figured in 'Mineral Conchology,' 1814, pl. lxviii, fig. 2, is vaguely described, and the specimen is an imperfect visceral disk of the pedicle valve in which the ornament is not well shown; but there seems to be a group of spine-bases on one ear and a few scattered spines on the remainder of the shell, as in *P. redesdalensis*. The type is lost and most authors have assumed that *P. flemingi* is synonymous with *P. longispinus* J. Sow. or *P. lobatus* J. Sow. The definitely arranged spines on the ear of *P. flemingi* would, however, distinguish it from any species of the *longispinus* group. *P. flemingi* is said to come from Linlithgowshire, where *P. redesdalensis* also occurs.

PRODUCTUS VAUGHANI[1] sp. nov.

Plate II, figs. 12a—c, 13a—c. Text-fig. 15.

1905. *Productus* cf. *martini* A. Vaughan (in part). The Palaeontological Sequence in the Carboniferous Limestone of the Bristol Area, *Quart. Journ. Geol. Soc.*, vol. lxi, p. 288, pl. xxv, figs. 2, 2a.

1905. *Productus* cf. *martini* A. Vaughan (in part). Notes on the Brachiopods and Corals, collected by Dr. Brendon Gubbin from the Carboniferous Limestone of S. W. Gower, *Proc. Bristol Nat. Soc.*, ser. 4, vol. i, pt. 1 (1904), p. 54. (List only).

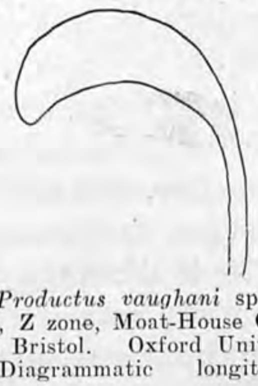
1906. *Productus* cf. *burlingtonensis* A. Vaughan (in part). The Carboniferous Limestone Series (Avonian) of the Avon Gorge, *Proc. Bristol Nat. Soc.*, ser. 4, vol. i, pt. 2 (1905), p. 128. (List only).

1911. *Productus burlingtonensis*, mut. β S. H. Reynolds and A. Vaughan (in part). Faunal and Lithological Sequence in the Carboniferous Limestone Series (Avonian) of Burrington Combe (Somerset), *Quart. Journ. Geol. Soc.*, vol. lxvii, p. 364. (List only).

1911. *Productus burlingtonensis* G. Delépine. Recherches sur le Calcaire Carbonifère de la Belgique, *Mém. et Trav. publiées par des Professeurs des Facultés Cath. de Lille*, fasc. viii, p. 392, pl. xiii, figs. 3, 3 bis.

1915. *Productus burlingtonensis* A. Vaughan (in part). Correlation of Dinantian and Avonian, *Quart. Journ. Geol. Soc.*, vol. lxxi, p. 7.

1917. *Productus* cf. *martini*, form *a* J. Jarosz (in part). Fauna des Kohlenkalks in der Umgebung von Krakau. Brachiopoden II, *Bull. Intern. Acad. Sci. Cracovie*, B, p. 71, pl. x, figs. 20, 20a.



TEXT-FIG. 15.—*Productus vaughani* sp. nov. Lower Carboniferous, Z zone, Moat-House Quarry, west of Failand, near Bristol. Oxford University Museum Collection. Diagrammatic longitudinal section, natural size.

[1] Named in honour of the late Dr. A. Vaughan.

Diagnosis.—Shell about 30 mm. high, 24 mm. wide and 18 mm. thick, or 1 : ·8 : ·6; elongate oblong in outline, with hinge slightly less wide than widest part of shell. Pedicle valve with highly convex visceral disk and trail; flanks steep and flat; venter convex; umbonal angle 108°; ears minute. Brachial valve flattened on visceral disk and geniculated to form trail. No diaphragm developed. Costae about 19 in 10 mm. at distance of 15 mm. from umbo, fine and thread-like posteriorly, increasing slightly in width on trail and becoming sinuous and uneven. Ribs developed near hinge. Spine-bases numerous, scattered irregularly over shell and in two rows on cardinal slopes, along hinge and at angle of 30° to hinge.

Description.—*Pedicle valve.* In early growth-stages the pedicle valve is convex, with the width slightly greater than the length. This valve becomes increasingly convex and the length becomes approximately equal to the width, when the shell is recurved anteriorly with the development of steep subparallel flanks and a short curved trail. The umbo is much incurved and the apex is acutely pointed and projects slightly beyond the hinge. The venter is usually highly convex, but in the giganteid specimen (pl. ii, fig. 13c) it is slightly flattened.

The costae are fine and thread-like on the visceral disk but increase slightly in width on the trail, where they are frequently sinuous and even in width. Bifurcation of the costae and the intercalation of costae occur frequently over the entire shell, also two costae may coalesce to form one thickened costa. The sulci are always narrow and less than the width of the costae. The shell is frequently decorticated and the cast is nearly smooth. There is a tendency for the costae on the flanks and anterior part of the shell to disappear gradually. This character is shown in the large specimen figured on pl. ii, fig. 13b.

About ten ribs are developed on the cardinal slopes, but are not traceable across the front of the visceral disk.

Spine-bases, averaging 1 mm. in diameter, are rather numerous, and are scattered over the flanks and trail with no definite arrangement; the spines apparently projected at right angles to the surface. In addition to these a row of spine-bases may be observed on the cardinal slopes close to, and parallel with, the hinge, and a second row is set at an angle of 30° to the hinge. Slight longitudinal folds may be developed below the spine-bases on the flanks.

Brachial valve. The visceral disk is flat and is geniculated at its anterior extension to form the trail, which is in contact with that of the pedicle valve. The shell tends to split along the visceral disk of the pedicle valve, leaving the visceral disk of the brachial valve exposed, but the actual exterior of the brachial valve is rarely seen.

The ornament is similar to that of the pedicle valve.

Internal characters. The interior of the pedicle valve is unknown.

An interior of the brachial valve from the β horizon, Avon Section, Bristol (pl. ii, fig. 13a), preserved in the Bristol University Collection, shows a long posteriorly flattened median septum extending to the anterior end of the visceral disk. The septum narrows between the adductor muscle-scars, and becomes thin and plate-like anteriorly to them. The cardinal process is badly preserved in this specimen, but other specimens show it to be prominent and bifid. The marginal ridges are given off at the base of the cardinal process and curve down and away from the hinge, and reach the lateral margin of the brachial valve about 3 mm. below the cardinal extremities. Here they are deflected anteriorly at an angle of about 120° and continue for 2 or 3 mm. along the lateral margin. The ridges are rounded and are from 1—2 mm. in width.

The adductor muscle-scars are small and triangular in outline, the longest side of the triangle being parallel to the median septum. The anterior and lateral margins of the scars are set on a rounded ridge. The brachial impressions are given off from the lateral apex of the adductor scars and curve downwards at an angle of 60° to the vertical, and then inwards, and finally recurve upwards nearly parallel to their posterior limb. The whole of the impressions are cut by minute transverse incisions, and traces of fine branching thread-like structures are seen in the smooth part of the shell enclosed by the brachial impressions. One of these thread-like structures proceeds from the incision immediately below the extremity of the left impression and extends almost horizontally, giving off two branches after a space of 2 mm. These two branches, one extending anteriorly, the other posteriorly, are given off at the same point and diverge from the main stem at an angle of 45°. The anterior branch also forks at an angle of 45°, and both these threads can be traced through adjacent incisions in the brachial impression. Traces of other thread-like structures can be seen passing through other incisions, but do not project for more than 1 mm. outside the brachial impressions. These threads may represent setae given off by the spiral arms.

Dimensions.—

	(1)	(2)	(3)	(4)
Maximum height	27	30·5	34	35·5 mm.
,, width	24	23	24·5	30 ,,
,, thickness ...	18	18	21	22 ,,
Length of visceral disk ...	16·5	16·5	22	21 ,,
Width ,, ,, ,, ...	20	19	24·5	25·5 ,,
Length of hinge	—	—	22·5	27·5 ,,
Number of costae in breadth of 10 mm. at distances vertically below umbo :				
at 10 mm.	—	23	26	—
,, 15 ,, ...	19	18	23	20
,, 20 ,, ...	17	—	21	—

(1) Dr. L. B. Smyth's coll., Dublin, from the Z zone, Malahide.

(2) Bristol University, from Z_1 subzone, Burrington.

(3) Oxford University Mus., from Z zone, Moat House, Failand, near Bristol.

(4) Bristol University, from β horizon, Avon Section.

Type.—Holotype from the Z_1 subzone, Avon Section, Bristol, is preserved in Bristol University Museum. Paratypes : a number of specimens mentioned below in paragraphs on ' Distribution.'

Distribution.—Range, K_2 subzone to ?C_1 subzone.

England.

Somersetshire : S. of Penpole Point, subzone K_2 (Bristol Univ.); Durdham Down, Bristol (B.M., 97481); No. 1 quarry, Avon section, Bristol, horizon β (B.M., B. 45509; Bristol Univ.); Avon section, subzone Z_1 (Bristol Univ.); St. Monica's Home, Westbury, subzones K_1, K_2, Z_1 (Bristol Univ.); Abbot's Leigh, near Bristol, subzone Z_1 (Bristol Univ.); Elborough Hill, W. Mendips, subzone Z_2 (Bristol Univ.); Biddle Combe, Wells, subzone Z_1 (Bristol Univ.); Christon Plantation, W. Mendips, subzone Z_1 (Bristol Univ.); Moat House, Failand, near Bristol, Z zone (Oxford Univ. Mus., 647).

Wales.

Carmarthenshire : Exposure of reddened limestone, W.S.W. of Tremoillet, Pendine (Geol. Surv., London, Pr.3325); Ragwen, near Pendine (Bristol Univ.).

Glamorganshire : Rhossili, subzone Z_1 (R. Scot. Mus., Edinburgh, Gubbin Coll.).

Pembrokeshire : Old Quarry, opposite Cornmill Pond, Merrion, base of Z_2 subzone (Geol. Surv., London, Pl. 996).

Ireland.

Co. Dublin : Malahide, Z zone (Dr. L. B. Smyth).

Remarks.—Productus vaughani is distinguished from *P. productus* (Martin) by its more arched visceral disk, steeper flanks, finer costation, and by the absence of a diaphragm in the brachial valve. It is distinguished from *P. teres* sp. nov. by its broader, more globose visceral disk, less curved trail and finer costation.

This species, first described as *P.* cf. *martini*, with a suggestion of the probable identity with *P. flemingi*, var. *burlingtonensis* Hall from the Burlington Limestone, U.S.A., was later said by Vaughan to be synonymous with *P. burlingtonensis.* Hall described *P. flemingi*, var. *burlingtonensis* in 1858 (p. 598, pl. xii, fig. 3), the reference being to *P. flemingi* de Koninck, *non* Sowerby. Examples of this species, described later as *P. burlingtonensis* by Keyes (1894, p. 41), from the Burlington Limestone, Burlington, Iowa, differ from *P. vaughani* in their larger dimensions, longer and more arched visceral disk and longer, more deeply sinuated trail. The umbo in the American species is more incurved, the costae are coarser and the ribs more prominent than in *P. vaughani.*

In 1915 Vaughan suggested the possible identity of his '*P. burlingtonensis*' with the *P. flemingi* of de Koninck. The latter form is, however, distinct both from *P. flemingi* of Sowerby and from Vaughan's species, and is described and figured as a new species, *P. derbiensis*, in this work.

In his original description Vaughan (1905A, p. 288) distinguished *P.* cf. *martini* from the true *P. martini* [=*P. productus*] and from *P. semireticulatus*, and described, as a variety, specimens resembling *P. longispinus* with symmetrically placed spines. This may refer to some doubtfully localized specimens of *P. tissingtonensis* Sibly which were labelled by Vaughan *P.* cf. *martini*, in the Bristol University collection. Several forms, including a species of *Buxtonia*, were included by Vaughan under the term of *P.* cf. *martini.*

Prof. Delépine (1911, pl. xiii, figs. 3, 3 bis) figures a specimen of '*P. burlingtonensis*' from Tournai, which appears to be indistinguishable from the specimens of *P. vaughani* of the South-west Province. He records (1914, p. 187) *P. burlingtonensis* Hall=*P. flemingi* de Kon. from the Tournaisian near Ath, and states that there is a passage from this species to larger forms from higher zones figured in his earlier paper as *P.* cf. *semireticulatus.*

Demanet (1921—23, pl. vi, figs. 25—27) figures several specimens as *P. flemingi,* var. *burlingtonensis* Hall from the Waulsortian of Sosoye, Belgium. These are said to be identical with Vaughan's *P.* cf. *martini,* but they are larger and nearer to *P. semireticulatus.*

One of the specimens figured by Jarosz (1917) as *Productus martini,* form *a,* appears to be similar to *P. vaughani* and was obtained from Raclawka-Tal, Poland, with *Spirifer tornacensis.*

Hind and Stobbs (1905, p. 531) recorded a new species, *P. anthrax* Vaughan, from the Coal Measures of N. Staffordshire. This species was described by Vaughan as being homoeomorphous with *P.* aff. *burlingtonensis*=*P.* cf. *martini.* The ornament of *P. anthrax* is quite different from that of *P. vaughani* [=*P.* cf. *martini*] and is near to that of *P. arcuarius* de Koninck.

Vaughan (1905A) records *P.* cf. *martini* from the subzones K_2, β horizon, Z_1 and Z_2 of the Bristol district and from the Z zone of the Rush Slates, Co. Dublin (Matley and Vaughan, 1906, p. 295). Reynolds and Vaughan (1911, p. 364) record *P. burlingtonensis* from β horizon and Z_1 subzone of Burrington Combe, and Dixon and Vaughan (1911, p. 544) record it from the Z_1 subzone of Gower. Vaughan in 1915 (p. 11) also mentions its occurrence in Belgium in the Assise d'Hastière=Z_1 subzone, and from the C_1 subzone, and Dixey and Sibly (1918, p. 135) record it from the K_2 and Z_1 subzones of the Carboniferous Limestone bordering the S. Wales Coalfield. Dr. L. B. Smyth (1920, pp. 11—15) mentioned the occurrence of this species from the Z zone to the C_1 subzone of Malahide, Co. Dublin, while Dr. J. A. Douglas collected it in the Z zone of Co. Clare, Ireland (1909, p. 549).

PRODUCTUS GARWOODI[1] sp. nov.

Plate II, figs. 14a—c.

Diagnosis.—Shell about 23 mm. in height and width, and 16 mm. thick, or 1 : 1 : ·7; approximately circular in outline; hinge slightly less than the widest part of shell. Pedicle valve with short, globose visceral disk, geniculated to form short curved trail; flanks steep and subparallel; venter convex; umbonal angle 105°;

[1] Named in honour of Prof. E. J. Garwood, F.R.S.

ears small and slightly flattened. Brachial valve with flat visceral disk, geniculated to form trail. Diaphragm developed. Costae about 22 in 10 mm. at distance of 10 mm. from umbo, fine and thread-like, even and regular posteriorly, frequently bifurcating. Ribs few, traceable round front of visceral disk. Spines in curved rows on flanks, on ears, and scattered over shell.

Description.—Pedicle valve. The shell rarely splits across the visceral disk of the pedicle valve, as occurs in other species in which a diaphragm is developed. The visceral disk is highly arched and the rounded umbo is much incurved and projects beyond the hinge. A shallow depression extends down the flanks below the cardinal extremities.

The costae, which are fine and regular on the visceral disk, thicken slightly near the anterior margin of the shell below the spine-bases. Intercalated costae are numerous on the visceral disk, while bifurcations occur on the venter and trail.

About 16 ribs are developed as narrow folds on the cardinal slopes and round the front of the visceral disk, but the point of intersection of ribs and costae is never marked.

Spine-bases are found on the flanks in curved rows situated on thickened costae which enclose a smooth flat space below the ears. Three rows of spine-bases extend up from the flanks to the ears, and smaller spine-bases are scattered over the remainder of the shell.

Brachial valve. The exterior of this valve is never seen, as it invariably remains in contact with the matrix, and the flat visceral disk is exposed when the shell has split across the visceral disk of the pedicle valve. A diaphragm is developed and is from 2 mm. to 3 mm. wide at the widest point.

The ornament seen on the reverse of the exterior is similar to that of the pedicle valve.

Internal characters. The interior of the pedicle valve is unknown.

The interior of the brachial valve, which is rarely seen, shows a small, finely trifid cardinal process and a narrow median septum extending for two-thirds of the length of the visceral disk. Narrow marginal ridges extend for 3 mm. along the hinge, then curve downwards to meet the lateral margin about 3 mm. below the cardinal angles. The adductor muscle-scars are triangular in outline, with the anterior margin excavated; the brachial impressions are given off from the lateral rounded lobe.

Dimensions.—

	(1)	(2)	
Maximum height	22	23	mm.
„ width	20	23	„
„ thickness	13	16	„
Length of hinge	12	13	„
Number of costae in breadth of 1 cm. at distances vertically below umbo :			
at base of visceral disk	28	22	
„ 17 mm.	18	18	

(1) Prof. E. J. Garwood's collection, from Lyvennet Beck, Westmorland.

(2) Holotype.

Type.—Holotype, from the Bryozoa bed, S_2—D_1 subzones, Roman Fell, Westmorland, is preserved in Prof. E. J. Garwood's collection. Paratypes : a number of specimens in the same collection.

Distribution.—Range, C_1 subzone to S_2—D_1 subzones.

England.

Westmorland : Limestone above Fawcett Mill, Shap district, subzone C_1; Arnside shore, subzone C_2; Bryozoa Bed, Lyvennet Beck, Shap district, subzone S_2—D_1; same bed and zone from Orton Knott; Roman Fell; and Sweetholme, near Thrimby, Shap district. All the specimens are in Prof. E. J. Garwood's collection.

Remarks.—*Productus garwoodi* is distinguished from *P. redesdalensis* sp. nov. (p. 61) by its more convex visceral disk and rounded venter, and by its finer costation and fewer and smaller spine-bases. Its more prominent costae and better defined ribs, together with the development of a diaphragm, distinguish it from *P. vaughani* sp. nov. (p. 65). From *P. rotundus* Garwood it differs by its longer trail, geniculation of the brachial valve, and numerous spine-bases, and by the development of the diaphragm.

Badly crushed specimens with long spines attached, having a narrow, elongated pedicle valve, occur in the S_1 subzone of the Avon Section, Bristol, and may belong to this species. Vaughan records these specimens (1905B, pl. xxix) as *P. semireticulatus*, mut. S_1. Other specimens from the *Syringothyris* zone of the Mendips, said by Dr. Sibly to be allied possibly to the S_1 form, are recorded by him as *P. concinno-martini* (1906, p. 371), and a similar form is probably referred to by Vaughan (Matley and Vaughan, 1906, opp. p. 307) as *P.* aff. *concinnus* from C_2—S_1 subzone. The ornament of these forms is rather similar to that of *P. garwoodi* sp. nov., and a diaphragm is developed in the brachial valve as in that species. The proportions of the S_1 form agree with those of *P. garwoodi*.

Productus garwoodi appears to be closely related to *P. redesdalensis* sp. nov., of which it may be an ancestral form, *P. garwoodi* occurring from the C_1 to S_2—D_1 subzones and *P. redesdalensis* ranging from D_1—D_2 subzones.

Productus griffithianus de Koninck.

Plate III, figs. 1, 2a, b, 3. Text-fig. 16.

1847. *Productus griffithianus* L. de Koninck. Recherches sur les Animaux Fossiles. Pt. i, Monographie des Genres *Productus* et *Chonetes*, p. 74a, pl. xviii, figs. 7a—c.

Text-fig. 16.—*Productus griffithianus* de Koninck. Carb. Limestone, Little Island, Cork. British Museum, B.44007. Diagrammatic longitudinal section, natural size.

Diagnosis.—Shell about 13 mm. high, 17 mm. wide, and 8 mm. thick, or 1 : 1·3 : ·6; laterally elongated, with the hinge forming widest part of shell. Pedicle valve with slightly convex visceral disk separated from short trail by sharp geniculation; shallow sinus on visceral disk increasing in depth on trail; umbonal angle 105°; ears small and flat. Brachial valve geniculated. Costae about 20 in 10 mm. at distance of 5 mm. from umbo, fine and not prominent on visceral disk, but thickening slightly on trail. Ribs numerous, prominent, regular on visceral disk, continuous round front of shell, and causing prominent nodular swellings at point of intersection with costae. Spines few, extending in one row from umbo across cardinal slopes and down flanks.

Description.—Pedicle valve. In early growth-stages the pedicle valve is convex, but at a distance of about 4 mm. from the umbo a broad rounded sinus is developed which divides the shell into two rounded shoulders. The umbo is acute and not incurved over the hinge, and the ears are not sharply demarcated from the visceral disk by a sulcus.

The costae are rather fine on the visceral disk and are subordinate to the ribs, which are numerous and very regular; the costae thicken slightly on the trail and become more prominent. Bifurcation of the costae and intercalated costae are rarely observed.

About eighteen ribs are developed on the cardinal slopes, and can be traced across the visceral disk as prominent folds separated by interspaces about half the width of the costae. The ribs are so prominent that the costae are traceable only by the nodular swellings developed at the point of intersection with the ribs.

The spine-bases are few in number. A row of five spine-bases extends across the cardinal slopes and is continuous on the flanks, where the spines usually spring from a prominent costa. A few spine-bases of small size are scattered over the remainder of the shell.

Brachial valve. The visceral disk is flattened, and a slight geniculation is developed at its anterior extension.

The ornament is similar to that of the pedicle valve, but the ribs are more prominent, and the costae are only faintly traceable on the visceral disk.

Internal characters. Internal casts of this species from Visé, Belgium, show in the pedicle valve a semicircular muscle-area situated immediately below the umbo; the diductor muscle-scars enclose the adductors except at their anterior margin.

In the brachial valve the cardinal process is small and the median septum extends for about two-thirds of the length of the visceral disk.

The adductor muscle-scars are very small and distinctly bilobed. The brachial impressions are given off at the outer extension of the adductor-scars and are enlarged at the extremity.

The marginal ridges extend along the cardinal margin and terminate a short distance below the cardinal extremities.

Dimensions.—

	(1)	(2)	(3)	
Maximum height	11·5	11·5	13	mm.
„ width	14	19·5	18·5	„
„ thickness ...	5	9	10	„
Length of hinge	—	—	18·5	„
„ „ visceral disk ...	8·5	9·5	10	„
Width „ „ „ ...	12·5	18	16·5	„
Number of costae in breadth of 10 mm. at distances vertically below umbo :				
at 5 mm.	21	19	18	
„ 10 „	16	15	15	

(1) B.M., 64979, de Koninck Coll., from Visé, Belgium.

(2) B.M., B.44007, from Carb. Limest., Little Island, Cork.

(3) Prof. E. J. Garwood's coll., from Botany Beds, Botany, Hunderthwaite Moor, Yorkshire.

Type.—Holotype, de Koninck's specimen from the Carboniferous Limestone, Visé, Belgium, figured in 1847. This specimen is probably lost.

Distribution.—Range, D_2 to Millstone Grit.

England.

Derbyshire : Park Hill, subzone D_2 (Geol. Surv., London, I.T.806).

Shropshire : Cefn-y-Fedw Sandstone, Cyrn-y-Bwch (B.M., B.24059, Morton Coll.).

Yorkshire : Botany Beds, Botany Farm, Hunderthwaite Moor, subzone D_3 (Prof. E. J. Garwood); Malham, knoll reefs, subzone D_2 (Prof. E. J. Garwood); Scaleber, Settle, subzone D_2 (Bristol Univ.).

Wales.

Denbighshire : Cefn-y-Fedw Sandstone, Cefn-y-Fedw (B.M., B.24066, Morton Coll.).

Pembrokeshire : East side of Bullslaughter Bay, subzone D_3 (Geol. Surv., London, I.T.640).

Ireland.

Co. Cork : Little Island (B.M., B.44006—07, J. Wright Coll.).

Remarks.—Productus griffithianus is distinguished from *Sinuatella sinuata* de Koninck by the absence of a cardinal area and delthyrium, and by its less deep sinus. Its flat, quadrate visceral disk, short trail and very prominent ribs, are characters distinguishing it from other species of the *semireticulatus* group.

De Koninck refers M'Coy's figure (1844, pl. xviii, fig. 11) of *Leptaena?* to his species *P. griffithianus.* M'Coy figured, but did not describe, this specimen from Ireland, and from the figure it does not appear to be costate, although numerous ribs are developed on the visceral disk as in *P. wrighti* Dav., to which species it is probably related.

The specimen figured by de Koninck (1842—44, pl. xii, figs 7a, b) as *P. plicatilis* does not belong to this species, but seems to resemble *P. griffithianus* rather than *P. pseudoplicatilis* sp. nov. (p. 189). It appears to have true costation developed over the entire shell, and to have the visceral disk geniculated at right angles to the short trail. The nodular swellings at the point of intersection of the ribs and costae are well shown.

Davidson (1880, pl. xxxvi, figs. 6, 6a, 6b) figured a specimen as *P. griffithianus*, from the Lower Limestones of Brockley, Lesmahagow, Lanarkshire, which is not identical with de Koninck's species, and in this work it is referred to the species *P. praecursor* sp. nov. (p. 191).

Waagen compared his species *P. gratiosus* (1884, p. 693) with *P. griffithianus*, and stated that it has similar reticulation near the beak but is smaller and flatter than *P. griffithianus.*

Productus rotundus Garwood.

Plate III, figs. 4a, b. Text-fig. 17.

1912. *Productus rotundus* E. J. Garwood. The Lower Carboniferous Succession in the North-West of England, *Quart. Journ. Geol. Soc.*, vol. lxviii, p. 569, pl. li, figs. 3a, b.

1916. *Productus rotundus* E. J. Garwood. The Faunal Succession in the Lower Carboniferous Rocks of Westmorland and North Lancashire, *Proc. Geol. Assoc.*, vol. xxvii, pt. 1, pl. xii, fig. 11 (fig. 12 on plate).

TEXT-FIG. 17.—*Productus rotundus* E. J. Garwood. Carb. Limestone, above Fawcett Mill, Shap, Westmorland. Prof. E. J. Garwood's coll. Diagrammatic longitudinal section, natural size.

Diagnosis.—Shell about 16 mm. high, 18 mm. wide, and 14 mm. thick, or 1 : 1·1 : ·8; circular in outline, with greatest width near anterior margin. Pedicle valve convex, not geniculated; flanks rather steep and convex; venter highly arched; umbonal angle 90°; ears small. Brachial valve with slightly concave visceral disk, geniculated abruptly to form curved trail. Diaphragm not developed. Costae rather fine, about 17 in 10 mm. at distance of 10 mm. from umbo, uneven and frequently bifurcating. Ribs faintly traceable round front of shell. Spines numerous, scattered over shell, and in two rows on flanks curving up on to ears.

Description.—Pedicle valve. In some specimens the shell is produced to form a short trail, but the shell is never sharply geniculated. The umbo is incurved and projects slightly beyond the hinge; the ears are minute but are not sharply demarcated from the visceral disk by a sulcus.

The costae are fine and even posteriorly, but irregular and uneven in width on the trail, where they become thickened. Bifurcation of the costae occurs frequently, and usually below the spine-bases. The sulci are deep and of less width than the costae.

The ribs are about twelve in number and are faintly traceable across the visceral disk, where slight enlargement occurs at the point of intersection with the costae.

Spine-bases of small size arise from the summit of the costae and are scattered over the whole shell. Two or three rows of spine-bases are seen on the ears, and two rows extend down the flanks.

Growth-lines are very numerous and are crowded together on the anterior part of the shell, causing slight transverse ridges on the costae.

Brachial valve. The visceral disk is slightly concave below the umbo, flattening anteriorly and then becoming sharply geniculated to form the short curved trail, which is nearly in contact with that of the pedicle valve. The pedicle valve frequently splits off, together with the internal layers of the brachial valve, leaving the visceral disk and trail of the lower layers of the brachial valve exposed. The actual exterior of this valve is rarely seen.

The ornament is similar to that of the pedicle valve.

Internal characters. Unknown.

Dimensions.—

	(1)	(2)	
Maximum height	15·5	16	mm.
,, width	17	18	,,
,, thickness	14·5	14·5	,,
Length of hinge	14·5	15·5	,,
Number of costae in breadth of 10 mm. at distances vertically below umbo :			
at 5 mm.	24	23	
,, 10 ,, ...	18	17	

(1) Holotype.

(2) Prof. E. J. Garwood's coll., from base of *Seminula gregaria* subzone, C_1, above Fawcett Mill, S.E. of Shap, Westmorland.

Type.—Holotype, the specimen figured by Prof. Garwood in 1912 from the *Productus globosus* band, at base of *Seminula gregaria* subzone, Fawcett Mill, Shap district, Westmorland, is preserved in Prof. Garwood's collection, University College, London.

Distribution.—Range, C_1 subzone.

England.

Westmorland : *Productus globosus* band at base of *Seminula gregaria* subzone, Friar's Bottom, Ravenstonedale; same horizon, Fawcett Mill, Shap district, Westmorland. All the specimens are in Prof. E. J. Garwood's collection.

Remarks.—*Productus rotundus* is distinguished from *P. derbiensis* sp. nov. (p. 170) by its slightly coarser costae, and by the difference in the arrangement of the spines.

This species has not so far been found outside Westmorland.

Demanet (1921—23, p. 154, pl. vii, fig. 38) describes and figures a specimen as *P. rotundus* from the Waulsortian of Four à Chaux, Maredsous, Belgium. The description indicates a form similar to *P. rotundus*, but the specimen figured has coarser and more prominent costae.

PRODUCTUS MURICATUS J. Phillips.

Plate III, figs. 5, 6, 7a—c. Text-fig. 18.

1836. *Producta muricata* J. Phillips. Illustrations of the Geology of Yorkshire, pt. ii, p. 214, pl. viii, fig. 3.

1860. *Productus costatus*, var. *muricatus* T. Davidson. The Carboniferous System in Scotland characterized by its Brachiopoda, *The Geologist*, vol. iii [in explanation of pl. iii, under heading 'Plate iv'], pl. iii, fig. 25; *Productus costatus* (in part), p. 179.

1860. *Productus*? Undetermined species. T. Davidson, *ibid.*, pl. ii, figs. 25, 25a, b, c.

1861. *Productus muricatus* T. Davidson. Mon. Brit. Foss. Brach., vol. ii, part v, No. 4, p. 153, pl. xxxii, figs. 10, 11, 12, 13, 13a, 13b, 14, 14a.

TEXT-FIG. 18.—*Productus muricatus* J. Phillips. Lower Limestones, Corrieburn, Campsie, Stirlingshire. British Museum, B.13815. Diagrammatic longitudinal section, natural size.

Diagnosis.—Shell about 24 mm. high, 22 mm. wide, and 14 mm. thick, or 1 : ·9 : ·6; elongate-oval in outline, with the greatest width occurring near the anterior margin. Pedicle valve convex, not geniculated; venter flat; umbonal angle 100°; ears small. Brachial valve highly concave. Body cavity small. Costae about 10 in 10 mm. at distance of 15 mm. from umbo, rather prominent and regular, rarely bifurcating. Ribs faintly developed on front of visceral disk. Spine-bases spring from summit of costae on trail, and spines extend at right angles to shell surface; also in curved row on flanks and ears and in row close to, and parallel with hinge.

Description.—Pedicle valve. In early growth-stages the shell is laterally elongated, with the greatest width occurring along the hinge, but it becomes circular in outline in the ephebic stage and elongate-oval in the gerontic stage. Phylogerontic individuals, such as the specimens from the Upper Limestones of Scotland, have a well developed trail, and the length is greatly in excess of the width.

The umbo is large and rounded and projects for a short distance beyond the hinge. The flanks are slightly convex and slope gently outwards towards the anterior margin. The ears are separated from the visceral disk by a narrow sulcus, along which the shell tends to fracture.

The costae are fine on the visceral disk, but they increase in width anteriorly and become moderately coarse and rounded. Some costae are more prominent than others, while those on the front of the venter fail to thicken and do not converge. Bifurcation of the costae may occur on the venter, but the two costae so formed usually reunite after a short distance, with the exception of those on the flanks or near the anterior margin of the shell. Increase in the number of costae on the visceral disk occurs by means of intercalations as well as by bifurcations. The sulci vary considerably in width and are wider in the holotype than in any other specimen so far observed. In most specimens the sulci are considerably narrower than the costae, but in decorticated specimens the sulci are wider than the costae, and at a further stage of weathering the cast appears smooth, with rounded pits marking the position of the spine-bases.

About ten ribs are developed on the cardinal slopes as narrow wrinkles, and slight nodular swellings are developed at the point of their intersection with the costae.

Spine-bases are very numerous and small in diameter, the largest, which are situated on the flanks, do not exceed 1mm. in diameter. The six or seven spine-bases in a row on each side of the umbo, set at a distance of 0·5 mm. from the hinge-margin, decrease in diameter from the ears towards the umbo. The second curved row extends from each anterior lateral margin to the hinge, about 4 mm. from the umbo. The diameter of the spine-bases on the trail does not exceed the width of the costae supporting them.

Brachial valve. This valve is deeply concave, with a slight flattening along the hinge, and follows closely the contour of the pedicle valve, leaving only a small body-cavity, as shown in text-fig. 18.

The ornament is similar to that of the pedicle valve, but the costae are finer and less pronounced. Traces of spine-bases have been observed and appear to be fewer in number than in the pedicle valve.

Internal characters. The interior of the pedicle valve is unknown.

An internal cast of the brachial valve in the Kelvingrove Museum [01·53 agf] shows very small dendritic adductor muscle-scars set close to the median septum and about 2 mm. below the cardinal margin. The brachial impressions are only faintly seen.

Dimensions.—

	(1)	(2)	(3)	(4)	(5)	
Maximum height	20·5	21	22	24	24	mm.
„ width	23	22	23	22	21·5	„
„ thickness ...	15	11	15	13	16	„
Length of hinge	19·5	20	—	—	20·5	„
Number of costae in breadth of 10 mm. at distance of 15 mm. below umbo	11	8	11	10	9	
Total number of costae at anterior margin ...	26	18	27	—	—	

(1) B.M., B.45676, from the Lower Limestones, Corrieburn, Stirlingshire.

(2) Holotype.

(3) B.M., 47281, from Bakewell, Derbyshire.

(4) R. Scot. Mus., Edinburgh, Neilson Coll., 26, from the Lower Limestones, Hillhead of Broadstone, Beith, Ayrshire.

(5) Nat. Mus. of Ireland, Dublin, from Old Leighton, Co. Carlow, Ireland. M'Coy's type-specimen of *P. costellatus*.

Type.—Holotype, the specimen figured by Phillips in 1836 from the Mountain Limestone, Harelow, Northumberland, is preserved in the York Museum.

Distribution.—Range, D_2 subzone to Millstone Grit.

England.

Derbyshire : Bakewell, Derbyshire (B.M., 47281); old quarry, E. of Hilts Quarry, Crich, *Cyathaxonia* zone, D_3 (Geol. Surv., London, J.M.39, 41).

Isle of Man : Poolvash (B.M., B.42022).

Northumberland : Six-Yard Limestone, Little Mill Quarry, D_2—D_3 subzone (Geol. Surv., London, J.R. 4754; B.M., B.41889—41892); Lowick (Sedgwick Mus., Cambridge); Thornbrough Limestone, subzone D_3 (Bristol Univ.).

Yorkshire: Botany Beds, Botany Farm, Hunderthwaite Moor, subzone D_3 (Prof E. J. Garwood); Main Limestone, Wold Fell, head of Dentdale (Prof. E. J. Garwood).

Wales.

Denbighshire: Arenaceous Limestone, Craig Fechan, Minera (B.M., B.24037); Bog Mine, Llanarmon (B.M., B.23875).

Flintshire: Pentre Halkin, Holywell (B.M., B.23993, Morton Coll.).

Scotland.

Ayrshire: Cessnock (B.M., B.13809, Davidson Coll., figd. 1860A, pl. iii, fig. 25); Girdle Quarry, Dalry (B.M., B.43763—64); Bowertrapping, Dalry (R. Scot. Mus., Edinburgh, 27; Kelvingrove Mus., Glasgow, 01·53 agf); Hillhead of Broadstone, Beith (R. Scot. Mus., Edinburgh, 26); Lower Limestones, Main Post Subseries, Overton, Beith (Kelvingrove Mus., Glasgow, Craig Coll.); shale above Highfield Limestone, Girtle, Ardrossan (Geol. Surv., Edinburgh).

Buteshire: Maoldon, Arran (R. Scot. Mus., Edinburgh, 42).

Edinburghshire: Boring, S.E. of Breichwater, ¼ mile N.W. of Handaxwood (Geol. Surv., Edinburgh, T.4165E, 4166E, 4168E); Forestfield Bore, 7 miles W.S.W. of Bathgate (Geol. Surv., Edinburgh, T.2109E, 2112E).

Fifeshire: Walton Quarry, near Lochgelly (Geol. Surv., Edinburgh, B.4930D); shale above ? No. 1 Limestone, Lododdie Quarry, N.E. of Cupar (Geol. Surv., Edinburgh, B.4973D); white limestone, little cliff at high-water mark, near Coal Farm, between St. Monance and Pittenweem (Geol. Surv., Edinburgh, T.165F).

Haddingtonshire: Aberlady Bay, Aberlady Point (Geol. Surv., Edinburgh, B.2047C); shale below Skateraw Limestone, Skateraw shore (Geol. Surv., Edinburgh, T.1102F, 1103F); lowest post of Middle Skateraw Limestone, shore at point E. of sea-quarry at Catcraig (Geol. Surv., Edinburgh, M.3982E); Skateraw Limestone, shore E. of Skateraw Harbour (Geol. Surv., Edinburgh, M.3885E).

Lanarkshire: *Lithostrotion* band, bank of Poniel Water, 385 yards W. of Brackenside, near Coalburn (Geol. Surv., Edinburgh, M.4839F); Upper Limestones, Garngad, near Glasgow (Kelvingrove Mus., Glasgow, 01·53 afa); Lower Limestones, Boghead, near Hamilton (Kelvingrove Mus., Glasgow, 01·53 afo; Hunterian Mus., Glasgow, L.222).

Renfrewshire: Lower Limestones, ¼ mile W.N.W. of Corkerhill, about 3 miles S.W. of Glasgow (Geol. Surv., Edinburgh, T.2960B, 2408B, 2409B, 2410B, 2412B);

railway-cutting, Auchenbeck (Geol. Surv., Edinburgh, T.2294B); Upper Limestones, Inkerman, near Paisley (Kelvingrove Mus., Glasgow, Young Coll.).

Stirlingshire: Corrieburn and Campsie (B.M., B.45672—45676, Davidson Coll., figd. 1861B, pl. xxxii, fig. 14); Lower Limestones, Campsie, Corrieburn (Kelvingrove Mus., Glasgow, 01·53 afe and aez); Lower Limestones, Craigenglen, near Lennoxtown (R. Scot. Mus., Edinburgh, 9); Lower Limestones, upper Bannock Burn, S.W. of Todholes (Geol. Surv., Edinburgh, T.1886F).

Ireland.

Co. Carlow: Old Leighton (Nat. Mus. Ireland, Dublin, figd. M'Coy as *P. costellatus*, 1844, pl. xx, fig. 15).

Co. Tyrone: Benburb (Geol. Surv., Dublin).

Remarks.—*Productus muricatus* is distinguished from *P. sulcatus* J. Sow. and *P. costatus* J. de C. Sow. by its smaller dimensions and oval outline, by the absence of the angular ridge on the flanks of the pedicle valve, and by a difference in the ornament. It is distinguished from *P. insculptus* sp. nov. (p. 89) by its small size, more even costae and greater spinosity.

Productus muricatus Norwood and Pratten (1855, p. 14, pl. i, figs 8 a—e) differs from *P. muricatus* Phill. both in shape and ornament. The internal characters of Norwood and Pratten's species resemble those of the *longispinus* group, and it has been referred to the genus *Marginifera* by some authors (Girty, 1903, p. 374).

M'Coy's *Productus costellatus* appears to be a specimen of *P. muricatus* Phill. with more prominent costae and a slightly longer trail than normally found in the latter. The spine-bases in '*P. costellatus*' are scattered over the pedicle valve and are also arranged in a row on the flanks, as in *P. muricatus* Phill. M'Coy's specimen of *P. costellatus* is preserved in the National Museum, Dublin, and a plaster cast of this specimen is in the British Museum, B.41872. M'Coy (1844, p. 108) describes the interiors of both valves of his species and states that 'the supports (AA) [adductor muscles of brachial valve] form but two lobes on each side of the septum, instead of the numerous complex turns of the corresponding parts in the more typical species; the cardinal tooth of the ventral valve (B) [brachial] is large, and distinctly notched; . . . the central septum is particularly large.' This description is interesting, as interiors of the valves of *P. muricatus* are very rare.

There is some doubt as to the locality from which the type-specimen of *P. muricatus* was obtained. Phillips (1836, p. 242) quotes it as occurring at Harelaw, and on another page of the same work he states that this locality is in Northumberland and the horizon Yoredale Rocks, while the specimen bears the label Harelow, Northumberland. It may therefore have been obtained either from Harlaw, Northumberland, from the Six-Yard Limestone, D_2—D_3 subzone, or from Harlow Hill, Northumberland, where the Fell Top Limestone is exposed. Specimens of *P. muricatus* have been obtained from the Six-Yard Limestone of Northumberland and also from the Fell Top Limestone of Harlow Hill, Northumberland.

The type-specimen, preserved in black shale, is considerably distorted by crushing. The figures of this species given by Davidson (1861B) and Phillips (1836) are considerably restored.

Specimens occur in the Upper Limestones of Scotland which are homoeomorphous with *P. muricatus*, but they have an ornament of spine-bases on the visceral disk and only develop costae on the trail, while in *P. muricatus* the costae are continuous to the umbo. The Upper Limestone species has the type of ornament spinose to costate, characteristic of *Avonia*, and the specimen figured by Davidson (1880), pl. xxxvi, fig. 8, as *P. carbonarius* belongs to this form.

In examples of *P. muricatus* from the D_3 subzone and from the Upper Limestones of Scotland the shell tends to become much thickened; the additional layers mask the normal ornament and cause the shell to appear nearly smooth on the trail. Numerous growth-lines cause deep transverse striations in this form, and a rather deep sinus is developed in the pedicle valve, and a slight geniculation in the brachial valve. These features are all characteristic of phylogerontic individuals. Variation in the number of costae has been observed in specimens of *P. muricatus* from the D_2 subzone, 'Brachiopod Beds' of the Midlands; this is due to more frequent bifurcation of the costae. The shell of these specimens is usually decorticated, and spine-bases are represented by pits on the ears and flanks. These specimens have, on an average, 14 costae in 10 mm. as compared with 10 costae in 10 mm. in the typical form, at a distance of 15 mm. below the umbo.

De Koninck (1842—44, pl. ix, fig. 2; pl. xiii bis, fig. 5) described and figured specimens of *P. tessellatus* under the name of *P. muricatus*. This was corrected in his later work (1847B, p. 110), where *P. muricatus* is included rather doubtfully as a synonym of *P. costatus*, while the specimens figured from Botscharova, Russia, though not identical with *P. muricatus*, are nearer to that species than to *P. costatus*. The specimens of *P. clarkei* figured in 1878 (pl. x, fig. 2) from New

South Wales were said by de Koninck to be allied to *P. muricatus*; they should, however, be assigned to the genus *Pustula*, and they have the ornament characteristic of that genus.

Benson, Dun and Browne in 1920 (pl. xxiii, figs. 1—3) figured a specimen from New South Wales as *P. muricatus*; this differs from Phillips's species in having finer costation and fewer spines in the pedicle valve, and it apparently lacks costae in the brachial valve.

Trautschold figured a small elongated form from Mjatschkowa (1876, pl. xxxii, fig. 6) which differs from *P. muricatus* Phill. in ornament, while Waagen (1884, p. 693) compared *P. muricatus* to his species *P. gratiosus*, and considered that both species belonged to the group 'spinosi,' and not to the 'semireticulati' group of *Productus*.

Jarosz's (1917, pl. viii, figs. 4, 4a) specimen of *P. muricatus* from Poland is a coarsely costate form with spreading flanks, and is unlike the type. Demanet (1921—23, pl. vii, figs. 34, 35) figured a specimen from the Waulsortian of Four à Chaux, Maredsous, Belgium, which is larger than *P. muricatus* and has a longer trail; it is probably allied to *P. flexistrius* M'Coy, having curved costae on the flanks similar to those of M'Coy's species.

Dr. L. B. Smyth (1924, p. 104) recorded, without figuring, *P. muricato-costatus* from the Ballycastle district, Ireland. Its relation to *P. muricatus* is not known.

Productus furcatus sp. nov.

Plate III, figs. 8a, b.

Diagnosis.—Shell about 33 mm. long, 22 mm. wide, and 13 mm. thick, or 1 : ·6 : ·4; elongated, greatest width occurring near the anterior margin. Pedicle valve with short highly convex visceral disk, geniculated to form long spreading trail; umbonal angle 105°; ears small, slightly flattened; shallow sinus on visceral disk. Costae uneven, about 19 in 10 mm. at distance of 15 mm. below umbo, sinuous on trail, semicircularly curved on flanks, and frequently bifurcating. Ribs developed on cardinal slopes. Spine-bases in three curved rows on flanks and extending on to ears.

Description.—*Pedicle valve.* The trail and flanks spread outwards near the anterior margin, and the front of the trail tends to project abruptly forwards, although no true rim is developed. The sinus, if developed on the visceral disk, flattens out on the posterior part of the trail. The umbo is broad and rounded and is incurved over the hinge. Specimens frequently occur with a flattened or distorted shell and the visceral disk may appear to be considerably laterally elongated

The costae are very irregular in width, and one costa may be enlarged at the expense of two or three adjacent ones. They are sinuous on the trail, frequently bifurcate on all parts of the shell, and are semicircularly curved on the flanks. They become more prominent on the trail, with wider sulci. Intercalated costae are rare.

About fifteen ribs are developed on the cardinal slopes, but are only faintly traceable across the front of the visceral disk. Enlargement of the costae at the point of intersection with the ribs is slightly marked on the sides of the visceral disk.

Spine-bases are rarely seen except on the flanks, where there are three curved rows near the cardinal extremities, and these extend to the ears. One row of spine-bases, at least, is continuous to the anterior lateral margin of the shell.

Brachial valve. This valve has not been observed, as it invariably remains in contact with the matrix, and the shell does not split across the visceral disk of the pedicle valve. It is not known if a diaphragm is developed.

Internal characters. Unknown.

Dimensions.—

	(1)	(2)	(3)	
Maximum height	21	22·5	33	mm.
„ width	21	26	20	„
„ thickness	13	12	15	„
Length of hinge	16	19	18	„
Number of costae in breadth of 10 mm. at distances vertically below umbo :				
at 10 mm.	18	19	24	
„ 15 „	21	16	19	

(1) B.M., 68449, from Little Island, Cork.

(2) Holotype.

(3) B.M., B.40241, from Little Island, Cork.

Type.—Holotype, from Carb. Limestone, Derbyshire, is preserved in the British Museum, Morton Coll. [B.45517]. Paratypes : eight specimens mentioned below in paragraphs on ' Distribution.'

Distribution.—Range, ?C_2 subzone and D_2 to D_3 subzones.

England.

Derbyshire : (B.M., B.45517, Morton Coll.); Hall Dale, Dovedale, Derbyshire (Mr. J. W. Jackson).

Yorkshire : *P. hemisphericus* bed, Hardraw Limestone, Fawcetts Quarry, near Hawes (Mr. R. G. Hudson); thirty feet above Main Limestone, Redmire (Mr. R. G. Hudson).

Ireland.

Co. Kerry : Kerry (Oxford Univ. Mus.).

Co. Kildare : Kildare (M.P.G., Geol. Soc. Coll., 31817).

Co. Cork : Little Island, Cork (B.M., B.40241, 68449).

Remarks.—*Productus furcatus* is distinguished from *P. productus* (Martin) and *P. concinnus* J. Sow. by its smaller proportions, shorter and flatter visceral disk, finer costae and different arrangement of the spine-bases. It differs from species of the *P. longispinus* group by its more spreading trail and different spine-arrangement, and by the frequently bifurcating and flexuous costae.

This species is characteristic of the D_2 subzone of Derbyshire and Yorkshire, and probably also occurs in the Waulsortian of Ireland.

PRODUCTUS TERES sp. nov.[1]

Plate III, figs. 9a, b.

Diagnosis.—Shell about 26 mm. high, 22 mm. wide, and 15 mm. thick, or 1 : ·8 : ·6; elongated, with greatest width occurring at anterior margin. Pedicle valve with globose visceral disk geniculated to form short, highly curved trail; flanks steep and concave; venter flattened; umbonal angle 95°; ears minute. Brachial valve with flat visceral disk, geniculated. Diaphragm not developed. Costae of moderate width, about 17 costae in 10 mm. at distance of 10 mm. from umbo, irregular and frequently bifurcating. Ribs numerous on cardinal slopes. Spine-bases of large size, numerous on trail. One row of spine-bases on curved costae of flanks and extending on to ears.

[1] Latin, *teres*=smooth, polished. So named from its usually smooth polished surface, due to decortication.

Description.—Pedicle valve. In early growth-stages the pedicle valve is convex for a distance of about 5 mm. from the incurved umbo, then it flattens and becomes increasingly convex, with the development of a geniculation and the formation of a strongly curved trail. The flanks are steep and not spreading.

The costae are separated by narrow, shallow sulci, and on decorticated parts of the shell the cast is seen to be nearly smooth. The costae are very irregular in width and become greatly thickened near the anterior margin, where numerous bifurcations occur on the trail below the spine-bases. Two costae may unite above the spine-bases, or one costa may become thickened. Intercalated costae are numerous on the visceral disk.

About ten ribs are developed on the cardinal slopes, but are only faintly traceable across the visceral disk.

Spine-bases are numerous on the trail and flanks and there is a tendency for slight longitudinal folds to be developed below them. One or two rows may be developed on the anterior part of the trail and extend on to the flanks.

Brachial valve. The visceral disk is flat, but a geniculation is developed and the trail is practically in contact with that of the pedicle valve. The shell tends to split along the visceral disk of the pedicle valve, exposing the visceral disk of the brachial valve; no diaphragm has been observed. The actual exterior of the brachial valve is rarely seen.

The ornament is similar to that of the pedicle valve.

Internal characters. The interior of the pedicle valve is unknown.

The interior of the brachial valve is rarely seen. One specimen examined, showed a strong bilobed cardinal process projecting above the hinge, and lacking the deep median furrow commonly seen in other species. Other characters unknown.

Dimensions.—

	(1)	(2)	
Maximum height	25	26	mm.
„ width	22	22·5	„
„ thickness	14	16	„
Length of hinge	16	—	„
Number of costae in breadth of 10 mm. at anterior end of visceral disk	17	17	

(1) Prof. E. J. Garwood's coll., from subzone C_1, Friar's Bottom, Ravenstonedale, Westmorland.

(2) Holotype.

Type.—Holotype, from quarry opposite Park House, Ravenstonedale, Westmorland, subzone C_1, is preserved in Prof. E. J. Garwood's collection. Paratypes: six specimens in the same collection.

Distribution.—Range, C_1—C_2 subzone.

England.

Westmorland: Friar's Bottom, Ravenstonedale, subzone C_1; Fawcett Mill, Shap district, subzone C_1; quarry opposite Park House, Ravenstonedale, subzone C_1; Tarn Sike, S.E. of Ravenstonedale, subzone C_2; Brunt Hill, S.E. of Ravenstonedale, subzone C_1; Dobby Hole Sike, Roman Fell, subzone C_1. All the specimens are in Prof. E. J. Garwood's collection.

Remarks.—*Productus teres* is distinguished from *P. rotundus* Garwood by its more extended trail, greater incurvature of the umbo, and slightly coarser, less prominent costae. It is distinguished from *P. garwoodi* sp. nov. (p. 70) by its slightly coarser costae, larger spine-bases on the trail, the absence of a diaphragm, and the less curved trail.

This species occurs commonly in the Lower Carboniferous of the North of England, usually in the C_1 subzone.

PRODUCTUS INSCULPTUS sp. nov.

Plate III, figs. 10a, b, 11a—c, 12.

1860. *Productus semireticulatus*, var. *sulcatus* T. Davidson. The Carboniferous System in Scotland characterized by its Brachiopoda, *The Geologist*, vol. iii, p. 109 [in explanation of plate iii, under heading 'Plate iv'], pl. iii, figs. 6, 6a.

Diagnosis.—Shell about 32 mm. high, 30 mm. wide, and 20 mm. thick, or 1 : ·9 : ·6; elongate-oblong in outline, with hinge forming widest part of shell. Pedicle valve with short laterally elongated visceral disk, geniculated to form slightly curved trail; flanks steep, bearing low ridge; sinus on visceral disk increasing in depth on trail, and continuous to anterior margin; umbonal angle 100°; ears large and laterally reflexed, tapering to spine-like projection. Brachial valve with flat visceral disk, geniculated at angle of 90° to form trail. Costae rather fine, about 15 in 10 mm. at distance of 15 mm. from umbo; even, rarely bifurcating. Ribs faintly traceable across front of visceral disk. Spines in row on flanks, and set on summit of costae on trail.

Description.—Pedicle valve. In the early growth-stages the pedicle valve is slightly convex and the brachial valve flat. The width of the visceral disk increases with age until it is about twice the length. The ears become gradually marked off from the visceral disk by a sulcus which increases in depth and finally flattens out against the flanks, about 20 mm. from the umbo. The visceral disk of both valves becomes sharply recurved downwards with the development of the trail, the contour of the trail of the brachial valve following that of the pedicle valve. In most specimens the height seems to be considerably greater than the width of the shell, owing to the non-preservation of the large ears. The narrow rounded ridge on the flanks, which is caused by the greater development of one costa, disappears about 5 mm. from the hinge, and is separated from the front of the shell by a shallow depression.

The costae are fine on the visceral disk, but increase in width on the trail and become slightly flattened. Costae are not usually developed on the ears or on the rounded depression in front of them. Bifurcation of the costae may occur on the trail.

About twenty ribs are developed on the visceral disk, and slight, rounded swellings arise at the point of intersection of ribs and costae.

Four or five spine-bases, averaging about 1·5 mm. in diameter, occur as a curved row, set in front of, or on, the ridge on the flanks. Large spine-bases are developed on the costae of the trail.

Brachial valve. The exterior of this valve is never seen, as it always remains in contact with the matrix, and the pedicle valve tends to split off, leaving the visceral disk and trail of the brachial valve exposed. The internal layer of the brachial valve, bearing the muscle-scars and brachial impressions, tends to split off with the pedicle valve.

The costae are fine and not prominent, and frequently bifurcate, while the ribs are more marked than in the pedicle valve, and continue round the front of the visceral disk.

Internal characters. The interior of the pedicle valve is unknown.

An imperfectly preserved interior of the brachial valve in the Geological Survey Collection, Edinburgh [M.3856F], shows a small bifid cardinal process which is continued anteriorly in a median septum about 10 mm. in length. The marginal ridges diverge from the hinge at a point about 4 mm. from the cardinal process, and curve downwards, meeting the lateral margin of the valve about 3 mm. below the cardinal extremities.

Dimensions.—

	(1)	(2)	(3)
Maximum height	26·5	27	32 mm.
„ width	30	30	30 „
„ thickness	18	19	20 „
Length of hinge	—	—	29 „
„ „ visceral disk	14 mm.		
Width „ „ „	22 „		
Number of costae in breadth of 10 mm. at distances vertically below umbo :			
at 15 mm.	15	16	15
„ 20 „	14	11	13
Total number of costae at anterior margin	—	—	34

(1) Holotype.

(2) R. Scot. Mus., Edinburgh, Neilson Coll., from Dockra, Beith, Ayrshire.

(3) M.P.G., 26682, from subzone D_2, Narrowdale, Staffordshire.

Type.—Holotype, from the Carb. Limestone, near Carluke, Lanarkshire, is preserved in the British Museum, Davidson Coll. [B.13868]. Paratypes : a number of specimens mentioned below in paragraphs on 'Distribution.'

Distribution.—Range, D_2 subzone.

England.

Derbyshire : Cracknowl Quarry, Hassop (Bristol Univ.); Mich Low, near Bradwell (Mr. J. W. Jackson); Upper beds, High Tor, Matlock Bath (Mr. J. W. Jackson).

Isle of Man : Poolvash (Bristol Univ.).

Staffordshire : Narrowdale (M.P.G., 26682).

Yorkshire : Ingleborough (Bristol Univ.); blue limestone above *P. giganteus* bed, Mill Gill, Askrigg (Mr. R. G. Hudson).

Scotland.

Ayrshire : Bowertrapping, Dalry (R. Scot. Mus., Edinburgh); Lower Limestones, Blackbyre Limestone, Dockra, Beith (Kelvingrove, Mus., Glasgow, 01·53 afy; R. Scot. Mus., Edinburgh, Neilson Coll.); No. 2 Limestone, Kersland Glen, Beith (Kelvingrove Mus., Glasgow); Lower Limestones, Broadstone, and Trearne, Beith (Kelvingrove Mus., Glasgow).

Buteshire : Red Shales, 2 miles S. of Corrie, Arran (Geol. Surv., Edinburgh, T.218).

Edinburghshire : Bathgate, Edinburgh (B.M., B.1116); Lower Limestones, Whitfield Quarry, Edinburgh (Geol. Surv., Edinburgh, T.3686A); Crichton Limestone Quarry, near Pathhead, Edinburgh (Geol. Surv., Edinburgh, B.970); Currilee Quarry, Lyne Water (Geol. Surv., Edinburgh, B.881).

Haddingtonshire : Shelly band in No. 1 Limestone, Blanceburn new quarry, 1 mile S.E. of East Salton (Geol. Surv., Edinburgh, B.2188C, 2189C).

Lanarkshire : Carluke (B.M., B.13868, Davidson Coll.); white shelly limestone, in bank of Poniel Water, near Brackenside, Coalburn (Geol. Surv., Edinburgh, M.4486F, 4489F); Basket Shell Bed, Cot Castle Farm, left bank of Avon Water, near Strathaven (Geol. Surv., Edinburgh, T.2867D).

Linlithgowshire : Bathgate Limestone, Linlithgow (Geol Surv., Edinburgh, B.3645B).

Remarks.—Productus insculptus is distinguished from *P. sulcatus* J. Sow. by its smaller proportions, less prominent ridge on the flanks, finer costation, and greater development of spines on the trail. It is distinguished from *P. muricatus* Phill. by the marked geniculation of the brachial valve, large flat ears, and fewer spines.

This species is one of the most characteristic brachiopods of the Blackbyre Limestone, which is equivalent to the white shelly limestone of the Lower Limestone Group of Scotland. It occurs more rarely in the D_2 subzone of Derbyshire and Yorkshire.

The ornament and spine-arrangement of *P. insculptus* are very similar to those of *P. gratiosus* Waagen (1884, pl. lxxii, figs. 3—7), from the Productus Limestone of the Salt Range, India.

It also resembles *P. portlockianus* Norwood and Pratten (1855, pl. i, figs 9a—c) and *P. morrowensis* Mather (1915, pl. x, figs. 1—4a), from Arkansas.

PRODUCTUS SEMIRETICULATUS (Martin).
Plate IV, figs. 1a—c, 2a—c. Text-fig. 19.

1809. *Anomites semireticulatus* W. Martin (in part). Petrificata Derbiensia, p. 7, pl. xxxii, figs. 1, 2; pl. xxxiii, fig. 4.

1836. *Producta antiquata* J. Phillips. Illustrations of the Geology of Yorkshire, pt. ii, p. 213, pl. vii, fig. 3.

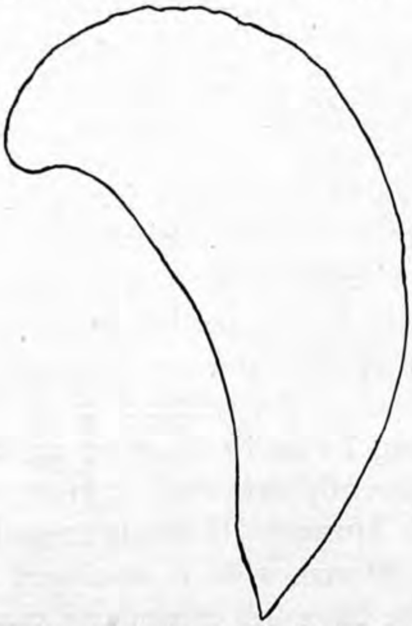
1860. *Productus semireticulatus* T. Davidson (in part). The Carboniferous System in Scotland characterized by its Brachiopoda, *The Geologist*, vol. iii, p. 109 [in explanation of plate iii, under heading 'Plate iv'], pl. iii, fig. 1.

1861. *Productus semireticulatus* T. Davidson (in part). Mon. Brit. Foss. Brach., vol. ii, pt. v, No. 4, p. 149, pl. xliii, figs. 1, 1b.

1911. *Productus semireticulatus* G. Delépine. Recherches sur le Calcaire Carbonifère de la Belgique, *Mém. et Trav. publiées par des Professeurs des Facultés Cath. de Lille*, fasc. viii, p. 392, pl. xiii, fig. 7.

1915. *Productus doulaghensis* A. Vaughan. Correlation of Dinantian and Avonian, *Quart. Journ. Geol. Soc.*, vol. lxxi, p. 47, pl. vii, fig. 7.

1921—23. *Productus semireticulatus*, var. *antiquatus* F. Demanet. Le Waulsortien de Sosoye, *Mém. Inst. Géol. Louvain*, vol. ii, p. 142, pl. vi, figs. 28, 29.



TEXT-FIG. 19.—*Productus semireticulatus* (Martin), from Carb. Limestone, Bolland, Yorkshire. British Museum, B.413. Diagrammatic longitudinal section, natural size.

Diagnosis.—Shell large, about 72 mm. high, 77 mm. wide, and 42 mm. thick, or 1 : 1·07 : ·6; quadrate in outline, with greatest width occurring near anterior margin. Pedicle valve evenly convex, with no geniculation; flanks steep; venter broad and flattened, or with broad, shallow sinus posteriorly; umbonal angle 90°. Brachial valve slightly concave. Costae moderately coarse, about 10 in 10 mm. at distance of 20 mm. from umbo, rounded and uneven in width. Ribs numerous, developed over entire shell, and continuous from hinge round front of visceral disk. Spine-bases numerous, scattered irregularly on anterior part of shell and on flanks.

Description.—Pedicle valve. The contour of this valve shows an even curvature from the umbo to the anterior part of the visceral disk, and slightly less marked curvature on the trail. In early growth-stages the pedicle valve is slightly convex, and the width is considerably in excess of the length. With age, the convexity increases and the flanks become arched till the adult stage is reached, when the flanks fall more steeply outwards. The umbo is rounded and much incurved, and projects for a short distance beyond the hinge.

The costae are usually prominent, except in decorticated parts of the shell, where the cast appears nearly smooth. The shell tends to flake off in patches and the apparently uneven development of the ornament is very characteristic. On the visceral disk, increase in the number of costae takes place by means of bifurcations as well as by intercalations, but on the trail bifurcations alone occur. The costae tend to become obsolete on the flanks and cardinal slopes. The sulci are equal in width to, or wider than, the costae.

The ribs are numerous and form narrow irregular folds near the hinge, and flatten slightly on the front of the shell. Bifurcation of the ribs frequently occurs on the lateral slopes of the visceral disk. On the posterior part of the shell the ribs are set in close proximity to one another, but anteriorly they are wider apart. At the point of intersection of ribs and costae elongated nodular swellings are developed, but are less marked on the venter than on the cardinal slopes.

Spine-bases not exceeding 1 mm. in diameter are developed on the summit of the costae. The spines apparently extended at right angles to the shell, and in one specimen in the British Museum [B.45681] from Bolland, Yorkshire, a band of minute spine-bases about 20 mm. wide is developed round the anterior margin. About twenty or thirty spine-bases are irregularly placed on the flanks near the cardinal extremities, and below these low longitudinal folds may be developed. Spines are sometimes seen springing from the ribs on the cardinal slopes and on the front of the visceral disk. The costae bearing the spines tend to become more prominent about 2 mm. or 3 mm. posteriorly to the spine-base, and to bifurcate anteriorly to it.

Brachial valve. The posterior portion of this valve is only slightly concave and the anterior portion is more concave, but a geniculation is never developed. The ears are flat, and a rounded transverse fold, extending at an angle of 45° to the hinge-margin, separates them from the remainder of the visceral disk. A slight longitudinal median fold corresponds to a shallow sinus (if developed) in the pedicle valve.

The ornament is similar to, but less prominent than that of the pedicle valve. The ribs are fewer in number and the costae narrower than in the pedicle valve. A few spine-bases are developed, generally near the anterior margin.

Internal characters. The interior of the pedicle valve is unknown.

A specimen in the British Museum [B.5805] from Castlecary, Dumbartonshire, shows a long, narrow, median septum extending nearly to the anterior margin of the brachial valve. The marginal ridges are rounded and prominent and extend along the hinge margin, broadening towards the cardinal extremities, where they are bent sharply downwards, and continuing for about 10 mm. along the postero-lateral margin. A faint indication of one brachial impression shows that it commences at the anterior end of the large triangular adductor muscle-scar and extends nearly to the anterior margin of the valve. The extremity of the brachial impression is enlarged and distinctly separated from the remainder of the impression.

Dimensions.—

	(1)	(2)	(3)	
Maximum height	62·5	71	72·5	mm.
,, width	63	73	77	,,
,, thickness	41	41	42·5	,,
Length of hinge	—	63	70·5	,,
,, ,, visceral disk	32	37	36	,,
Width ,, ,, ,, ...	37	44	46	,,
Number of costae in breadth of 10 mm. at distances vertically below umbo :				
at 15 mm.	11	11	10	
,, 20 ,, ...	9	11	10	
,, 40 ,, ...	8	9	9	

(1) B.M., B.3685, from Derbyshire.

(2) B.M., B.413, from Bolland, Yorkshire.

(3) B.M., B.13980, from Kildare, Ireland.

Type.—Martin figured three specimens as *P. semireticulatus*, from Derbyshire. The specimen figured on pl. xxxii, figs. 1, 2, is chosen as lectotype. The specimen figured on pl. xxxiii, fig. 4, is an imperfectly preserved brachial valve of *P. semireticulatus*, while that figured in pl. xxxii, fig. 3, is a smaller shell, and is probably allied to *P. antiquatus* J. Sow. All the specimens are lost.

Distribution.—Range, Z—D zones.

England.

Derbyshire: (B.M., B.3685, B.23536); Siggate, Castleton (Mr. J. W. Jackson).

Lancashire: Pimlico Quarry, Clitheroe (Mr. J. W. Jackson).

Northumberland: Stanton Limestone, Stanton, subzone Dy (B.M., B.41882); Brunton (B.M., B.20484).

Staffordshire: Narrowdale, subzone D_2 (B.M., B.48500, Roscoe Coll.).

Yorkshire: (B.M., B.13852); Bolland (B.M., B.413, figd. J. Phillips, 1836, pl. vii, fig. 3); Botany Beds, Hunderthwaite Moor, subzone D_3 (B.M., B.42015, S. Smith Coll.).

Wales.

Flintshire: Holywell, subzone D_2 (B.M., B.23540).

Scotland.

Dumbartonshire: Upper Limestones, Castlecary (B.M., B.5805, Davidson Coll.; R. Scot. Mus., Edinburgh; Kelvingrove Mus., Glasgow, 01·53afv, afw).

Linlithgowshire: Bathgate (B.M., B.8461).

Ireland.

Co. Clare: Tulla, subzone C_2 (Dr. J. A. Douglas).

Co. Dublin: Black Limestone, near Dublin (M.P.G., Geol. Soc. Coll., 31826); St. Doolagh's, subzone C_1 (Oxford Univ. Mus.; Dr. L. B. Smyth).

Co. Kildare: Kildare (B.M., B.13980, Davidson Coll.; M.P.G., Geol. Soc. Coll., 31806, 31809, 31811; ?Sedgwick Mus., Cambridge, 95).

Unlocalized: (M.P.G., 34460, 34461; B.M., 11470, 11467).

Remarks.—*Productus semireticulatus* is distinguished from *P. pinguis* sp. nov. by its shorter and more triangular visceral disk, less rounded venter, and less convex flanks. The costae are less prominent, and the ribs less well defined in *P. semireticulatus* than in *P. pinguis*, also the spine-bases on the flanks are of smaller size and not arranged in three rows as in specimens of *P. pinguis*. It is distinguished from *P. antiquatus* J. Sow. by its larger dimensions, broader venter, and different ornament; and from *P. multispiniferus* sp. nov. (p. 121) by its more quadrate outline, more sloping flanks, and the absence of a large patch of spine-bases on the flanks.

Martin's figures of *Anomites semireticulatus* are poor, and he included more than one species in his description. He mentioned (p. 7) two varieties, '(a) V. nate valvulae convexae aequatâ; (b) V. nate valvulae convexae gibbo trilobato notatâ.' As he gave no figure of either of these varieties it is impossible to interpret his variety (a), but the variety (b) is probably referable to the form described in this volume (p. 104) as *P. pinguis* sp. nov. This last species is often decorticated near the umbo of the pedicle valve, revealing what might be termed the 'trilobate gibbosity' of Martin. This feature is shown in the specimen of *P. pinguis* figured on pl. vi, fig. 1, of this work. The type-description of *P. semireticulatus* is rather vague, and the shell is said to have one valve concave and the other convex, generally marked on the back by a slight concave wave, and to be imperforate. A slight sinus is usually developed in the pedicle valve of *P. semireticulatus*, but the shell is always perforate. The striae are said by Martin to be rude, strong and uneven, and to be dichotomous and forked near the anterior margin, while the beak is described as small and pointed, and barely curving over the hinge. Martin mentions one variety of this shell which has the sides extended as in *Anomites* [*Productus*] *giganteus*. The dichotomy of the costae near the margin is characteristic of *P. pinguis*, = var. b. of Martin, while the beak-characters are those of *P. semireticulatus*. Some specimens of *P. pinguis* resemble *P. giganteus* in having the sides extended, such as those figured in this work on pl. v, figs. 1, 3, in which the shell is laterally elongated. Martin's drawings, pl. xxxii, figs. 1, 2, show only the posterior part of the shell, with the characteristic nodular swellings on the costae at the point of intersection with the ribs, while a brachial valve of *P. semireticulatus* is shown in pl. xxxii, fig. 4.

J. Sowerby in his description of *P. antiquatus* (1821—22, pp. 15 and 18) queried the possibility of the identity of this species with '*Anomites semistriatus*,' later corrected to *A. semireticulatus*, of Martin, but stated that his specimens were not sufficiently reticulated, and were probably only varieties of Martin's species.

Later authors did not attempt to distinguish between the two species *P. antiquatus* and *P. semireticulatus*, and Phillips figured a typical specimen of *P. semireticulatus* as *Producta antiquata* in 1836 (pl. vii, fig. 3); while de Koninck included both species in his synonymy of *P. martini* (1842—44, p. 161), but later (1847B, p. 83) described both species under the name *P. semireticulatus*. One specimen figured in the latter work, from Visé, Belgium, pl. ix, fig. 1e, may be a *P. semireticulatus*. M'Coy (1844, p. 106) also considered *P. antiquatus* and *P. semireticulatus* to be identical.

Davidson (1861B, p. 149) included a large number of species in his synonymy of *P. semireticulatus*, and figured several distinct forms. The specimen figured in his pl. xliii, figs. 1, 1b, from Kildare, Ireland, and that figured in another work (1860A, pl. iv, fig. 1), from Castlecary, Dumbartonshire, are typical *P. semireticulatus*. The interior of a brachial valve figured in 1859, pl. iii, fig. 5, as *P. semireticulatus*, from Redesdale, Northumberland, belongs to a species of *Buxtonia* in which the cardinal process and median septum have been restored, as Davidson stated, from another specimen probably belonging to the *semireticulatus* group. The specimens recorded by Davidson in 1862 (p. 31) from the Salt Range, India, as *P. semireticulatus* were later redescribed by Waagen (1884, p. 680) as *P. spiralis* and *P. aratus* spp. nov., while neither of his specimens from Kashmere figured as *P. semireticulatus* in 1866 (pl. i, fig. 6; pl. ii, fig. 12) resembles this species. Davidson also figured shells which he assigned to this species from Nova Scotia in 1863B (pl. ix, figs 20, 21); but one specimen is nearer to *P. pugilis* Phill., and the other does not resemble Martin's species.

P. semireticulatus was recorded by Armstrong and Young (1871, p. 40) from Broadstone, Beith, Ayrshire, but these specimens should be referred to *P. hindi* sp. nov. (p. 108). The specimens referred to *P. semireticulatus* from the Coal Measures of N. Staffordshire by Hind and Stobbs in 1905 (p. 531) are probably a mutation of *P. carbonarius* de Koninck.

Parsons (1918, p. 91) recorded *P. semireticulatus* from subzones D_2—D_3 of Derbyshire and Leicestershire, but did not figure any specimen. Vaughan recorded a number of forms as *P.* aff. *semireticulatus* from different zones. Vaughan's specimen from the Z zone may be identical with that figured in this work as *P. bristolensis* sp. nov. (p. 140), but he gave no description of the form intended. The species recorded, but not described by Vaughan (1906A, p. 113) as *P. semireticulatus*, mut. S_1, probably includes more than one form, for large specimens of

P. multispiniferus sp. nov. occur in this subzone, and small specimens belonging to the *semireticulatus* group and near to *P. garwoodi* sp. nov. (p. 70) occur in the S_1 subzone of the Avon Section in Vaughan's '*longispinus* bed,' so named on account of the long spines attached to the much crushed valves.

In 1905A (p. 289) Vaughan stated that the typical *P. semireticulatus* was evolved from *P.* cf. *martini* during Z_2 time and attained its maximum at γ and in C. He quoted (1915, p. 47, pl. vii, fig. 7) Davidson's specimen (1861, pl. xliii, fig. 1) from Kildare, which is a typical *P. semireticulatus*, as being identical with examples of his species *P. doulaghensis*. The latter species is therefore a synonym of *P. semireticulatus*. Prof. Sibly (1905A, pp. 25, 30) also recorded *P. semireticulatus*, mut., in subzone C_2 of Burrington Combe.

Prof. Delépine (1911, p. 392, pl. xiii, fig. 7) figured as *P. semireticulatus* the specimen depicted by Vaughan as *P. doulaghensis* in 1915, from Pont à Rieux, Tournai, subzone C_1. The specimen has a more arched venter than is commonly found in British material. The *P.* cf. *semireticulatus* of the same author (pl. xiii, figs. 6, 6 bis) was referred by him to *P. concinnus* J. Sow. or to P. *burlingtonensis* Hall, but the dimensions of the visceral disk are greater than normally occur in either of these species.

M. Demanet's (1921—23, pl. vi., figs. 32a—c) *P. semireticulatus*, var. *minimus*, from the Waulsortian of Sosoye, is a small specimen probably belonging to the *longispinus* group.

Julien (1896) figured a number of specimens from Central France, none of which can be identified as *P. semireticulatus*.

P. semireticulatus was the name given to specimens figured by Roemer (1863, pl. xvi, fig. 2) from Upper Silesia, by Sommer (1909, pl. xxvii, fig. 4; pl. xxix, fig. 2) from the Culm of Königsberg, and by Nebe (1911, pl. xiii, fig. 2) from the Culm of Hagen; but none of these forms can be assigned to *P. semireticulatus*.

Schellwien (1892, pl. ii, figs. 1—3; pl. iii, figs. 4, 5) figured *P. semireticulatus* from the Fusulina Limestone of the Carnic Alps, but one specimen resembles *P. antiquatus* J. Sow. A similar form was figured by him in 1900 (pl. vii, figs. 8, 9), and a second specimen approaches *P. pugilis* Phill. He also recorded *P. semireticulatus* from Wadi-el-Arabah in the Arabian Desert (1894, p. 70).

Tornquist figured as *P. semireticulatus* a specimen having ornament resembling that of *P. pugilis* Phill., from the Lower Carboniferous of the Southern Vosges, in 1895 (pl. xiv, fig. 10).

Many authors have figured specimens ascribed to *P. semireticulatus* from Russia, among whom may be mentioned de Verneuil, Grünewaldt, Trautschold, and Fischer de Waldheim. De Verneuil's specimens from the Ural Mts. (1845, pl. xviii, figs. 10a, b) do not belong to the *semireticulatus* group, while Grünewaldt (1860, pl. iii, figs. 1, 2) figured two specimens, one nearer to *P. pinguis* sp. nov. (p. 104), and the other resembling *P. hindi* sp. nov. (p. 108), from the same area. Trautschold (1876, pl. xxxii, figs 3a—g) figured specimens resembling *P. pinguis* and *P. hindi* from the Mountain Limestone of Mjatschowa. Fischer de Waldheim in 1809 (pl. iii, fig. 5) figured a specimen from Russia as *Terebratula reticularis*, described subsequently in 1830 as *Productus*, and in 1837 as *Leptaena*; but this is a brachial valve ornamented like *P. sulcatus* J. Sow.

Frech's specimen of *P. semireticulatus*, mut., figured in 1900 (pl. xv, figs. 3a, b) from the Demawend district, Persia, is a small, imperfectly preserved specimen, resembling a typical *P. semireticulatus*. Loczy (1897, pl. i, figs. 29—31) figured specimens having ornament like that of *P. multispiniferus* sp. nov.

Romanovskiĭ (1880, pl. xix, figs. 2a, b) figured a broad massive form as *P. semireticulatus* from Turkestan, but it has an ornament nearer to that of *P. pinguis*. Beyrich (1864, pl. ii, figs. 1, 2) figured specimens from Timor which cannot be identified as *P. semireticulatus*.

Diener in 1897 and 1899 figured specimens from Tibet as *P. semireticulatus*, some of which were subsequently (1915, p. 69) renamed *P. narastanensis*. In 1910 (pl. xiv, figs. 1, 2) he figured specimens from Moravia which are near to *P. antiquatus* in ornament; a year later (1911, p. 30) they were referred by him to *P. transversalis* Tschernyschew and to the group of *P. boliviensis*.

Hayasaka (1924, pl. v, figs. 1, 2) figured as *P. semireticulatus* an elongated massive form unlike any British species, from the Permo-Carboniferous of Japan.

Whitfield's specimen of *P. semireticulatus arctica* (1908, pl. ii, figs. 8—10) resembles *P. horridus* J. de C. Sow. in shape, but it has faint costae and ribs, while Salter's figures of *P. semireticulatus*, var. *frigidus* from the Arctic regions (1855, pl. xxxvi, figs. 13, 14) represent two distinct forms, one resembling *P. latissimus* J. Sow. and the other *P. hindi* sp. nov. (p. 108). Toula's specimen (1875A, pl. vi, figs. 1a, b) of *P. semireticulatus* from the Permo-Carboniferous of Spitzbergen is not typical of this species.

The specimen described and figured as *P. semireticulatus* by de Koninck (1878, pl. ix, fig. 2) from New South Wales is said to approach *P. pugilis* of Phillips, while Dun (1902, pl. xxiii, figs. 4—9) figured specimens, from the same country, which resemble *P. antiquatus* J. Sow. and a species of *Buxtonia*.

Derby (1874) figured several specimens from Brazil as *P. semireticulatus*, but none resembles British species; Kozlowski's (1914, pl. iii, figs. 1—7) specimens of *P. semireticulatus*, var. *inca*, from Bolivia, resemble *P. antiquatus* but are more coarsely costate and spinose.

A large number of forms have been described by American authors as *P. semireticulatus*, but many of these shells have since been redescribed as new species. Figures of *P. semireticulatus* have been given by Marcou (1858), Meek (1864 and 1872), Hall and Whitfield (1877), Winchell (1865), Weller (1900), Keyes (1894), Hall (1858), Morningstar (1922), and Thomas (1923). None of the specimens figured are identical with *P. semireticulatus*.

Gröber (1909, pl. iii, figs. 9a—c) figured two specimens as *P. semireticulatus*; one of these is from Wetton, Staffordshire, and the other from the Upper Carboniferous or Permian of Nebraska. The English specimen should probably be referred to *P. antiquatus* J. Sow., but the American specimen is a thick-shelled spinose form unlike any British species.

Dr. Girty (1903, p. 358) mentions *P. semireticulatus*, var. *hermosanus* as a variety of typical *P. semireticulatus* from the Upper Coal Measures of Kansas. The variety figured is, however, near to *P. antiquatus*.

PRODUCTUS PROJECTUS sp. nov.[1]

Plate IV, fig. 3.

1847. *Productus semireticulatus* L. de Koninck (in part). Recherches sur les Animaux Fossiles. Pt. i. Monographie des Genres *Productus* et *Chonetes*, p. 83, pl. ix, fig. 1f.

Diagnosis.—Shell about 22 mm. high, 20 mm. wide, and 12 mm. thick, or 1 : ·9 : ·5; trigonal in outline, with hinge slightly less than widest part of shell. Pedicle valve globose; flanks steep and convex; venter rounded; umbonal angle 85°; ears small and rather flat. Horizontal rim developed round anterior margin.

[1] Latin, *projectus*=jutting out. So named from the characteristic projecting ledge.

Brachial valve geniculated. Costae about 13 in 10 mm. at distance of 15 mm. below umbo. Ribs prominent on cardinal slopes. Spine-bases in row on flanks and two or three rows on cardinal slopes.

Description.—Pedicle valve. The visceral disk, which is triangular in outline, is not sharply separated from the trail by a geniculation. The umbo is acutely pointed and much incurved. The convex rim round the anterior margin of the shell is separated from the adjacent part of the shell by a geniculation at an angle of 90°, and the outer edge of the rim is abruptly reflected downwards. The width of the rim varies from 1·5 mm. on the flanks to 3 mm. on the front of the venter. A repetition of the rim at a lower level may be seen in some specimens, and apparently indicates a variation in the rate of growth of the shell.

The costae are moderately coarse and rounded and are never prominent, and they radiate evenly from the umbo. Bifurcation of the costae occurs at the anterior end of the visceral disk and on the flanks, but rarely on other parts of the shell. Intercalated costae are rare. On the rim the costae are of the same width as the sulci separating them, but on other parts of the shell the costae are considerably wider than the sulci.

The ribs form broad prominent folds on the cardinal slopes, but flatten on the lateral slopes of the visceral disk, where they bifurcate. Two narrow ribs may be traced round the front of the visceral disk, and slight enlargement of the costae is caused at the point of intersection with the ribs.

Spine-bases are never numerous, and are not seen except on the flanks and cardinal slopes. The row of spine-bases on the flanks can be traced back on to the ears and thence obliquely across the cardinal slopes to the umbo. Two or three rows of spine-bases may also be developed on the cardinal slopes, set at a small angle to the hinge. The posterior row was observed in a specimen in the Geological Survey Coll., London, I.T.820, inserted along the hinge-margin, the spines curving towards the umbo.

Brachial valve. The visceral disk is slightly concave below the umbo and then flattens, with the exception of a low median fold; it is geniculated sharply to form the curved trail, which is in contact with that of the pedicle valve.

The ornament is similar to that of the pedicle valve.

Internal characters. Unknown.

Dimensions.—

	(1)	(2)	(3)	
Maximum height	21 (estimated)	22	25·5	mm.
,, width	18	20	32	,,
,, thickness	12·5	11·5	18·5	,,
Number of costae in breadth of 10 mm. at distances vertically below umbo :				
at 10 mm.	15	17	18	
,, 15 ,, ...	12	14	13	
,, 20 ,, ...	—	13	13	

(1) Holotype. Specimen incomplete and height estimated.

(2) B.M., B.44010, from Little Island, Cork.

(3) Same coll. and locality [B.40103].

Type.—Holotype, from the Carboniferous Limestone, Little Island, Cork, is preserved in the British Museum, Davidson Coll. [B.13892]. Paratypes : four specimens mentioned below in paragraphs on ' Distribution.'

Distribution.—Range, ?C_2 and D_2 subzones.

England.

Derbyshire : N.E. slope of Chrome Hill (Geol. Surv., London, I.T.840).

Ireland.

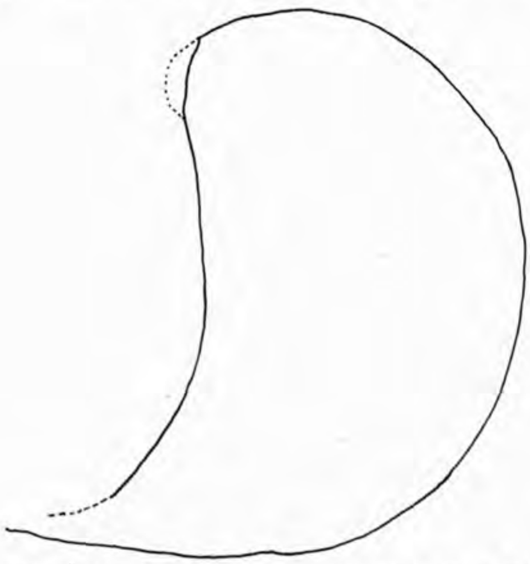
Co. Cork : Little Island (B.M., B.13892, B.44010, B.40103; Hunterian Mus., Glasgow, L.215).

Remarks.—*Productus projectus* is distinguished from other species of the *semireticulatus* group in having a ledge developed round the anterior margin of its shell. It is distinguished from a species of *Buxtonia*, also from Little Island, Cork, figured by Davidson in 1880 (pl. xxxvi, fig. 12), in having fewer spine-bases. Spines are developed on the entire shell of *Buxtonia* and extend along the shell-surface. In this species figured by Davidson a broad, flat rim is developed, and specimens from Derbyshire, possibly belonging to the same species, have the ledge ornamented with small spines and not with costae as in *P. projectus*.

Specimens of *P. projectus* from Little Island, Cork, are usually distorted, a character common to most species derived from this locality. The Derbyshire specimens are normally developed.

PRODUCTUS PINGUIS sp. nov.

Plate V, figs. 1, 2a—d, 3; Plate VI, fig. 1. Text-fig. 20.



TEXT-FIG. 20.—*Productus pinguis* sp. nov. British Museum, B.45996. Diagrammatic longitudinal section, natural size.

Diagnosis.—Shell large, about 79 mm. long, 82 mm. wide, and 54 mm. thick, or 1 : 1·03 : ·6; approximately circular in outline, greatest width occurring slightly below hinge. Pedicle valve with globose visceral disk, geniculated and forming short curved trail; flanks convex; venter broad and flat, or slightly sinuated; umbonal angle 115°. Brachial valve geniculated. Costae moderately coarse and prominent, about 10 in 10 mm. at distance of 20 mm. from umbo, frequently bifurcating. Ribs prominent on cardinal slopes, not traceable across front of visceral disk. Spine-bases of large diameter, scattered over trail, and in three curved rows on flanks and two rows on cardinal slopes.

Description.—Pedicle valve. In early growth-stages the pedicle valve is slightly convex and its width is considerably in excess of its length. The visceral disk becomes increasingly globose until the shell is recurved downwards and a short trail is developed, when the width is approximately equal to the height. The umbo is small and pointed, and only projects slightly beyond the hinge in the adult condition. The ears are rarely preserved, but in the holotype they are seen to be flattened along the hinge and to taper and become reflexed laterally. A fracture frequently occurs along the shallow sinus separating them from the visceral disk. The flanks, which are convex posteriorly, become steeper and slightly flattened in later growth-stages, when they rise to meet the massive venter. The venter may be slightly sinuated, the sinus commencing about half-way down the visceral disk and disappearing on the trail.

The costae are fairly coarse and prominent and are separated by narrow sulci which are always narrower than the costae They radiate regularly on the visceral disk, but thicken and become flattened, and vary greatly in width on the trail. Increase in the number of costae occurs by means of occasional bifurcations on the visceral disk, but splitting of the costae occurs frequently on the trail. When the shell is decorticated the costae tend to decrease to half their normal width, and the sulci to increase by a corresponding amount. At a further stage of decortication the cast is practically smooth.

About 25 broad, prominent ribs are developed on the cardinal slopes, but only those within a space of 15 mm. from the umbo cross the front of the visceral disk, and the remainder are faintly traceable by means of slight nodular swellings on the costae. The ribs undulate and bifurcate on the lateral slopes of the visceral disk, and an intercalated rib may be developed between the two ribs arising from the bifurcation.

A few large spine-bases occur on the trail, the diameter of each spine being greater than the width of the costae from which it springs, and there is a tendency for the costae to thicken or coalesce above a spine-base and to bifurcate anteriorly to it. The average diameter of these spine-bases is from 1·5 to 2 mm. Three curved rows occur on each flank, but do not spring from the summit of the costae. These rows of spine-bases, which are slightly smaller in diameter than those on the trail, terminate near the cardinal extremities, while two rows are seen on the cardinal slopes diverging from the hinge at a small angle.

Brachial valve. The visceral disk is flat for a space of 20 mm. below the umbo, and then becomes slightly concave. A geniculation is developed at its anterior extension and the trail is almost in contact with that of the pedicle valve.

The ornament is similar to that of the pedicle valve, but is reversed, the sulci being wider than the costae. Increase in the number of costae occurs mainly by means of intercalations. The ribs are narrower and less prominent than in the pedicle valve, and are faintly traceable across the visceral disk.

Internal characters. An internal cast of the pedicle valve from Derbyshire preserved in the Sedgwick Museum, Cambridge, 98 (pl. vi, fig. 1), shows large flabellate diductor muscle-scars which are longitudinally striated and marked with transverse striae. These diverge from a prominent boss about 5 mm. long, which is posteriorly curved and anteriorly truncate, and is developed immediately below the umbo and probably served as a point of muscle attachment. The adductor muscle-scars are dendritic, oval in outline, and are situated between the anterior part of the diductors.

An internal cast of the brachial valve from Bolland, Yorkshire [B.M., B.45505, Gilbertson Coll.] (pl. v, fig. 3), shows the marginal ridges extending along the hinge for a distance of 30 mm. from the umbo, then recurving anteriorly and continuing along the lateral margin of the shell for about 15 mm. The median septum is stout, but tapers anteriorly and extends for about two-thirds of the length of the visceral disk. The adductor muscle-scars are large and dendritic, triangular in outline, with the longest side practically in contact with the median septum. The brachial impressions have not been observed.

Dimensions.—

	(1)	(2)	(3)	
Maximum height	66	76	79	mm.
,, width	77	85·5	82	,,
,, thickness	48	51·5	54	,,
Length of visceral disk	36	43	48·5	,,
Width ,, ,, ,, ...	63	61	70	,,
Length of hinge (estimated) ...	74	73	71	,,
Number of costae in breadth of 10 mm. at distances vertically below umbo :				
at 15 mm.	9	10	11	
,, 20 ,, ...	11	9	9	
,, 30 ,, ...	11	9	10	

(1) B.M., B.23540, from Holywell, Flintshire.

(2) B.M., B.3685, from Derbyshire.

(3) Sedgwick Mus., Cambridge, 98, from Derbyshire.

Type.—Holotype from Clapham, Yorkshire, is preserved in the Royal Scottish Museum, Edinburgh, Natural History Collection. Paratypes: a number of specimens mentioned below in paragraphs on 'Distribution.'

Distribution.—Range, D_2 subzone.

England.

Derbyshire: (B.M., B.3685; Sedgwick Mus., Cambridge, 98); quarry on S. side of Middle Hill, near Castleton (Mr. J. W. Jackson); basal beds of cherty series, S. of Mich Low Fault, Smalldale, near Bradwell (Mr. J. W. Jackson); N.E. flank of Snels Low, near Castleton (Mr. J. W. Jackson); Back of Ecton (B.M., B.48446).

Isle of Man: Balladoole, near Castletown (B.M., B.23099).

Staffordshire: Narrowdale (B.M., B.43921, W. Hind Coll.; M.P.G., 34450).

Yorkshire: Bolland (B.M., B.413, B.45505, Gilbertson Coll.); near Bolton Bridge (B.M., B.2636); S. of Escow House, Grassington (M.P.G., 34454); Clapham (R. Scot. Mus., Edinburgh); Parson's Pulpit, Malham (Prof. E. J. Garwood); S. of Back Scar, Settle (Prof. E. J. Garwood); Settle, knoll reefs, subzone D_2 (B.M., B.48442); outcrop, just below 1,200 ft. contour, Cam Beck, near Ribblehead (Prof. E. J. Garwood); Gayle Shale, and from *P. giganteus* bed, Mill Gill, Askrigg, Wensleydale (Mr. R. G. S. Hudson, 566, 620, 573, 142, 143); Gayle Shale, Widdale Beck, Appersett (Mr. R. G. S. Hudson, 220); top of Gayle Limestone, quarry N. of Countersett, Semerdale (Mr. R. G. S. Hudson, 654, 656, 661, 667, 766).

Wales.

Carnarvonshire: Bishop's Quarry, S.10°W. of summit of Great Orme's Head, subzone D_2.

Flintshire: Upper Black Limestone, Halkin Mountain (B.M., B.23998, Morton Coll.); Holywell, subzone D_2 (B.M., B.23540).

Remarks.—*Productus pinguis* is distinguished from *P. semireticulatus* by its more convex flanks, rounded outline, broader venter and incurved umbo, and also by the geniculation of the brachial valve. The costae in *P. pinguis* are coarser and more prominent than in *P. semireticulatus*. It is distinguished from *P. antiquatus* J. Sow. by its larger dimensions, greater globosity and different ornament.

J. Sowerby's '*Productus martini*' figured in 'Mineral Conchology,' vol. iv, pl. cccxvii, fig. 3 only, may be a small form related to *P. pinguis*. The ornament is rather similar, but the brachial valve is more concave than in typical specimens.

Specimens resembling *P. pinguis* in external form, but having less prominent costae and narrower ribs, have been observed from the D_2 subzone of Westmorland and N. Yorkshire.

The specimen figured by the late Prof. Hughes (1908, pl. xxxix, fig. 3) as *P. costatus* from the *P. giganteus* bed, Hull Pot, Horton, Yorkshire, may be a small specimen of *P. pinguis*, which is common at this horizon. The shell of the figured specimen was evidently injured during life, and a deep sinus developed down the front of the pedicle valve has resulted from this injury. The venter of this specimen is too broad and massive for *P. sulcatus* J. Sow., which also occurs at this horizon.

P. pinguis is referred to by Mr. Hudson (1925, p. 182) as occurring in the Gayle Limestone of Wensleydale, Yorkshire.

PRODUCTUS HINDI[1] sp. nov.

Plate VI, figs. 3, 4a—c, 5, 6. Text-figs. 1—5, 21.

1880. *Productus semireticulatus* T. Davidson (in part). Mon. Brit. Foss. Brach., Suppl., vol. iv, pt. iii, p. 307, pl. xxxv, figs. 1, 2.

TEXT-FIG. 21.—*Productus hindi* sp. nov., from knoll reefs, Malham, Yorkshire. British Museum, B.45508. Diagrammatic longitudinal section, natural size.

Diagnosis.—Shell about 45 mm. high, 54 mm. wide, and 28 mm. thick, or 1 : 1·2 : ·6; quadrate in outline, with hinge forming widest part. Pedicle valve with convex visceral disk, geniculated to form slightly curved trail; flanks subparallel, bearing prominent ridge; venter with shallow sinus; umbonal angle 110°; ears large, reflexed. Brachial valve flattened on visceral disk and geniculated. Diaphragm not developed. Costae fine, about 14 in 10 mm. at distance of 20 mm. from umbo, even and regular in width. Ribs flattening on front of visceral disk.

[1] Named in honour of the late Dr. Wheelton Hind.

Spine-bases of large size in two rows on cardinal slopes at angle of 5° and 20° to hinge, and in row on flanks. Spines of exceptional length.

Description.—Pedicle valve. The transverse section of the visceral disk is nearly rectangular, and in early growth-stages the width is considerably greater than the length; but with the development of a geniculation at the anterior end of the visceral disk the shell becomes gradually elongated. The umbo is acutely pointed, much incurved, and frequently embedded in matrix. The ears are separated from the visceral disk and flanks by a deep sulcus, which commences about 3 mm. below the cardinal margin and increases in width towards the lateral margin. The shell frequently fractures along this sulcus, and the ears are rarely preserved entire.

The flanks are steep posteriorly, but in later growth-stages spread outwards, and a prominent ridge extends from the anterior lateral margin up the flanks, and dies out about 10 mm. vertically below the hinge-margin. Five or six large spine-bases are set on the summit of this ridge.

The venter is broad and sinuated; the sinus is developed near the umbo and continues to the anterior margin, remaining shallow and rounded.

The costae are rather fine on the visceral disk, but increase slightly in width on the trail and are even and regular and never prominent. Increase in the number of costae occurs by means of bifurcations, the two costae arising from the bifurcation attaining normal width in the space of 3 or 4 mm. Two costae may coalesce above a spine-base, and bifurcate below it. In the gerontic stage the costae become irregular and less prominent, and growth-lines are numerous. The shell tends to decorticate readily, and is rarely preserved entire over the whole pedicle valve; on decorticated parts the costae appear to be about half the normal width and the sulci correspondingly wider, or the cast may be nearly smooth. The sulci are normally less than half the width of the costae.

About twenty ribs are developed on the cardinal slopes as irregular wrinkles which flatten out on the visceral disk, only the posterior ten or eleven being traceable round the front of the shell. Intercalated ribs occur on the lateral slopes of the visceral disk. Slight enlargement of the costae occurs at the point of intersection with the ribs.

A few spines are developed on the visceral disk and spring from the summit of the costae. Two rows of spine-bases are seen on the cardinal slopes, and one row at an angle of 20° to the hinge joins another set on the ridge up the flanks.

The spines on the flanks are of considerable length but are rarely preserved in situ. The specimen figured in plate vi, fig. 5, shows one incomplete spine in position. Detached spines, 80 mm. in length, are often found associated with shells of *P. hindi* in the Lower Limestones of Scotland.

Brachial valve. The visceral disk is flat, with a slight median fold corresponding to the sinus of the pedicle valve. A geniculation separates the visceral disk from the curved trail, which is in close contact with that of the pedicle valve. The exterior of the brachial valve is rarely seen, as the outer layers remain in contact with the matrix, while the inner layers are exposed through the splitting of the pedicle valve.

The ornament is similar to that of the pedicle valve, but the ribs are more marked and cross the visceral disk, causing slight enlargement of the costae at the point of intersection.

Internal characters. An internal cast of the pedicle valve from the Lower Limestones, Bowertrapping, Dalry, Ayrshire, preserved in the British Museum [B.13863], Davidson Coll., and figured on pl. vi, fig. 6, shows broad, longitudinally striated diductor muscle-scars enclosing narrow lens-shaped adductors.

The only interior of the brachial valve known is preserved in Prof. Garwood's collection, and was obtained from Feizor, near Settle, Yorkshire. This specimen shows part of one of the adductor muscle-scars, and a portion of one of the brachial impressions with the extremity enlarged and distinctly separated from the main portion.

Dimensions.—

	(1)	(2)	(3)	(4)	
Maximum height	38·5	40	40	45·5	mm.
„ width	53·5	46	52·5	54	„
„ thickness ...	28	27	28	28·5	„
Length of visceral disk ...	24	22	22·5	26	„
Width „ „ „ ...	34·5	37	38	37	„
Number of costae in breadth of 10 mm. at distances vertically below umbo :					
at 15 mm.	15	14	14	15	
„ 20 „	13	15	—	14	
„ 25 „	14	15	12	14	

(1) Geol. Surv., Edinburgh, M.4484F, from the Lower Limestones, Coalburn, Lanarkshire.

(2) B.M., B.5738, from the Lower Limestones, Brockley, Lesmahagow, Lanarkshire.

(3) B.M., B.45508, from Malham, Yorkshire.

(4) Holotype.

Type.—Holotype, from the Carb. Limestone, Dovedale, Derbyshire, is preserved in the British Museum, J. W. Jackson Coll. [B.47860]. Paratypes: a number of specimens referred to below in section on 'Distribution.'

Distribution.—Range, D_2 subzone to Millstone Grit.

England.

Cheshire: Congleton Edge, Pendleside series (B.M., B.43815, W. Hind Coll.).

Derbyshire: (B.M., 74331); Edensor (B.M., B.23040); Matlock Bridge (Geol. Surv., London, C.B.W.1002); Millersdale (Hunterian Mus., Glasgow); Cracknowl Quarry, Hassop, subzone D_3 (Bristol Univ.); Castleton (Oxford Univ. Mus.); Park Hill (B.M., B.48449).

Isle of Man: On shore, Castletown (B.M., B.10535).

Somerset: Emborough, subzone D_2 (Bristol Univ.).

Staffordshire: Narrowdale, subzone D_2 (M.P.G., 34447; B.M., B.48466).

Yorkshire: Malham, knoll reefs, subzone D_2 (B.M., B.45508); Wedber Brow, Malham, subzone D_2 (Prof. E. J. Garwood); roadside, E. of Settle, knoll reefs, subzone D_2 (Prof. E. J. Garwood); hill 925, 1½ miles E. of Brunton House, near Settle (Prof. E. J. Garwood); Upper *Lonsdalia* chert bed, S. of Back Scar, Settle (Prof. E. J. Garwood); old shafts, W. of Pikedaw, Settle (Prof. E. J. Garwood); 800 hill, S.E. of Rane's Lane, Feizor, near Settle (Prof. E. J. Garwood); Burtersett, Hawes (B.M., B.48469).

Wales.

Anglesey: Quarry, ⅛ mile W. by S. of Plas Newydd, Cromlech (Geol. Surv., London, Af.3380); quarry, N. of Tyn-y-Gongl Post Office, N.N.E. of California Inn (Geol. Surv., London, Af.2020).

Carnarvonshire: Great Orme's Head, subzone D_2 (B.M., B.43717).

Flintshire: Axton, subzone D_2 (B.M., B.23711, Morton Coll.).

Scotland.

Ayrshire: Blackbyre Limestone, Broadstone, Beith (Kelvingrove Mus., Glasgow, 01·53 agc and agi); Lower Limestones, Dockra, Beith (Kelvingrove Mus., Glasgow, 01·53 afx); Lower Limestones, Roughwood, Beith (Kelvingrove Mus., Glasgow, 01·53 afs); (spines) Trearne, Beith (Hunterian Mus., Glasgow, L.340).

Fifeshire: No. 1 Limestone, Inverteil Quarry, N. of Linktown, Kirkcaldy (Geol. Surv., Edinburgh, B.3186D); shale, Roscobie Quarry, 4 miles N. of Dunfermline (Geol. Surv., Edinburgh, M.822c, 824c).

Lanarkshire : See (1) and (2) of the above table of measurements.

Ireland.

Co. Cork : Little Island (B.M., B.44008).

Remarks.—Productus hindi is distinguished from *P. antiquatus* J. Sow. by its more rectangular visceral disk and more incurved umbo, by the development of a ridge up the flanks, and by its finer costae and less prominent ribs. It is distinguished from *P. sulcatus* J. Sow. by its greater width and thickness, by its finer costation, and by the less marked ribbing on the visceral disk.

This species has probably been included with *P. antiquatus* J. Sow. or with *P. semireticulatus* (Martin) by previous writers. The only figures that can be ascribed with certainty to this species are those of specimens from the Lower Carboniferous Limestone, West Broadstone, Beith, Ayrshire, given by Davidson in 1880 (pl. xxxv, figs. 1, 2). These specimens are much crushed, but they plainly exhibit the enormous development of spines on the flanks and cardinal slopes. Fig. 2 of Davidson's plate shows a specimen with the visceral disk of the pedicle valve removed, and with the markedly ribbed visceral disk of the brachial valve exposed.

Some of the microscopic sections of spines showing the structure ' spines within spines,' described by J. Young in 1893 (pp. 86—90) as belonging to *P. semireticulatus* (Martin), must be ascribed to this species. These sections are preserved in the Kelvingrove Museum, Glasgow. In examples from the Lower Limestones of Trearne, Beith, there are from six to twelve lesser spines of fair size within the transverse section of one spine, and plainly visible without a lens.

Productus hindi is characteristic of the D_2 subzone of England and Wales, but it also occurs abundantly in the Blackbyre Limestone, Lower Limestone Group of Scotland.

Specimens which are much crushed and imperfectly preserved as casts, in the Millstone Grit of Harrogate and Great Whernside, may belong to this species. In external ornament and general shape they appear to agree with *P. hindi.*

PRODUCTUS HINDI, var. WETTONENSIS[1] var nov.

Plate VI, figs. 2a—c.

Diagnosis.—Shell massive, about 53 mm. high, 59 mm. wide, and 35 mm. thick, or 1 : 1·1 : ·6. Pedicle valve with broad flat visceral disk and curved trail; ears large and slightly flattened. Costae about 10 in 10 mm. at distance of 20 mm. from the umbo, irregular in development. Ribs numerous, continuous across visceral disk.

Description.—Pedicle valve. The shell is quadrate in outline, with the hinge forming the widest part. The flanks are steep and subparallel and bear a ridge on which are set large spine-bases. A shallow sinus is developed down the front of the shell.

The costae frequently bifurcate below the spine-bases, which are numerous on the trail, and a low longitudinal fold may be developed below these spine-bases. Spine-bases also occur in two rows on the cardinal slopes, as in the parent species. About 25 ribs are developed and are traceable across the visceral disk, causing slight enlargement of the costae at the point of intersection.

Brachial valve. The contour of this valve resembles that of the parent species. The exterior is rarely seen, as it remains in contact with the matrix, but the pedicle valve tends to split away, leaving the lower layers of the brachial valve exposed.

The ornament is similar to that of the pedicle valve.

Internal characters. Unknown.

Dimensions.—

	(1)	(2)	
Maximum height	46·5	53	mm.
„ width	57·5	59	„
„ thickness	30·5	35	„
Length of hinge	64	56·5	„
„ „ visceral disk	25·5	30·5	„
Width „ „ „	42	47	„
Number of costae in breadth of 10 mm. at distances vertically below umbo :			
at 10 mm.	13	12	
„ 25 „	11	10	

[1] Name derived from Wetton, Staffordshire, whence the type-specimen was obtained.

(1) B.M., 24760, from Breedon Hill, Leicestershire.

(2) Holotype.

Type.—Holotype, from the Carb. Limestone, Wetton, Staffordshire, subzone D_2, is preserved in the British Museum, Wheelton Hind Coll. [B.43814]. Paratypes: a number of specimens referred to below in the section on 'Distribution.'

Distribution.—Range, D_2 subzone.

England.

Derbyshire: Pike Acre Fence (B.M., B.2462); Siggate, Castleton (Mr. J. W. Jackson).

Leicestershire: Breedon Hill (B.M., 24760).

Staffordshire: Wetton (B.M., B.43814, W. Hind Coll.); Narrowdale (B.M., B.48464); Beresford Dale (B.M., B.48450); Ecton (B.M., B.48448).

Yorkshire: Top bed of Gayle Limestone, N. of Countersett, Semerdale (Mr. R. G. S. Hudson, 642, 659); Skelterton Limestone, ?= Pendleside Limestone, Skelterton (Mr. R. G. S. Hudson); quarry between Carden and Skelterton, Threapland Gill (Mr. R. G. S. Hudson).

Wales.

Flintshire: Upper Grey Limestone, Axton (B.M., B.23711).

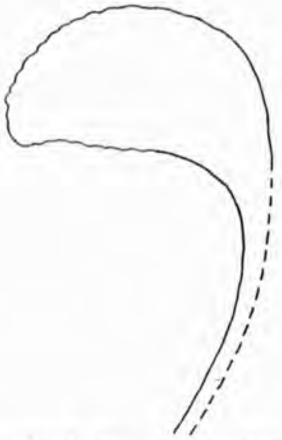
Remarks.—Productus hindi, var. *wettonensis* is distinguished from *P. hindi* by its greater size, broader and flatter visceral disk, and more curved trail. The ears in *P. hindi*, var. *wettonensis* are larger and slightly less convex than those of the parent species.

This variety is apparently restricted to the D_2 subzone and is less common than *P. hindi* sp. nov.

PRODUCTUS ANTIQUATUS J. Sowerby.

Plates VI, fig. 7; VII, figs. 1—4a—c. Text-fig. 22.

1821. *Productus antiquatus* J. Sowerby. Mineral Conchology of Great Britain, vol. iv, p. 15, pl. cccxvii, figs. 6 and ?5.



TEXT-FIG. 22.—*Productus antiquatus* J. Sowerby. Carb. Limestone, Malham, Yorkshire. British Museum, B.45511. Diagrammatic longitudinal section, natural size.

Diagnosis.—Shell about 40 mm. long, 54 mm. wide, and 32 mm. thick, or 1 : 1·3 : ·8; quadrate in outline, hinge forming widest part of shell. Pedicle valve with convex visceral disk, geniculated to form curved trail; flanks subparallel, flat; venter sinuated; umbonal angle 125°; ears large, triangular in outline. Brachial valve geniculated. Costae prominent, irregular, about 9 in 10 mm. at distance of 20 mm. from umbo. Ribs broad, causing nodular enlargement of costae at point of intersection. Spines in two rows on cardinal slopes, one row extending across flanks.

Description.—Pedicle valve. In the earliest growth-stages this valve is convex, with the width equal to the length. At a distance of about 15 mm. below the umbo a sinus is developed which increases in width at the anterior end of the visceral disk and divides the shell into two rounded shoulders. The sinus gradually flattens out on the trail. The width of the valve increases until it is almost twice the length, a geniculation is then developed and the shell becomes increasingly quadrate in outline. The umbo is rounded and much incurved, projecting slightly beyond the hinge. The ears are separated from the visceral disk by a deep angular sulcus which commences at the hinge-margin, increases in depth and terminates at the posterior lateral margin of the shell. The shell is frequently fractured along this sulcus, and the ears are usually not preserved. A sharp geniculation separates the posterior extension of the flanks from the ears.

The costae are moderately coarse and prominent, and tend to thicken above spine-bases and to bifurcate anteriorly to them, while the two costae on either side of the spine-base decrease in width at the point of emergence of the spine, and thicken again below it. Bifurcation of the costae occurs on the visceral disk and on the trail not necessarily below a spine-base, and intercalated costae occur on the visceral disk and flanks. The sulci are about half the width of the costae, except on decorticated parts of the shell, where they increase in width with a corresponding decrease in width of the costae.

About 25 ribs are developed on the cardinal slopes, but the anterior 7 or 8 are not continuous across the sinus. Bifurcation may occur on the lateral slopes of the visceral disk and rarely an intercalated rib is developed. The nodular swellings at the point of intersection of the ribs and costae are marked.

Spine-bases are developed in a row on the cardinal slopes at an angle of about 5° to the hinge, and in a second row at an angle of 30°. This latter row extends across the flanks, but is not continuous to the anterior margin of the shell. Spine-bases of smaller size are also scattered over the venter and trail.

Growth-lines are a prominent feature on the anterior part of the trail and on the ears.

Brachial valve. The visceral disk is flat and a geniculation occurs at its anterior extension, with the formation of a curved trail which follows the contour of that of the pedicle valve. The exterior of this valve is rarely seen, being usually in contact with the matrix. The reverse of this, however, is seen by the splitting off of the pedicle valve and internal layers of the brachial valve.

The ornament is similar to that of the pedicle valve, but the ribs are more prominent.

Internal characters. Unknown.

Dimensions.—

	(1)	(2)	(3)	(4)	
Maximum height	37	37·5	40	42	mm.
„ width	50	54	54	41·5	„
„ thickness ...	33	31·5	32	29	„
Length of hinge	50	—	54	—	„
„ „ visceral disk ...	30	31·5	30	25	„
Width „ „ „ ...	42	42	42·5	38	„
Number of costae in breadth of 10 mm. at distances vertically below umbo :					
at 10 mm.	15	15	16	16	
„ 15 „	9	10	13	13	
„ 25 „	8	9	9	10	

(1) B.M., B.45503, from Narrowdale, Staffordshire.
(2) Lectotype.
(3) B.M., B.45504, from Narrowdale.
(4) Prof. E. J. Garwood's coll., from knoll reefs, Cracoe, Yorkshire.

Type.—J. Sowerby in the 'Mineral Conchology' figured three specimens from Derbyshire and from Cloghran, Co. Dublin. One of these (pl. cccxvii, fig. 1) is the posterior portion of *Productus sulcatus* J. Sow. The original specimen of pl. cccxvii, fig. 6, is not preserved in the Sowerby Coll., British Museum, and the original of fig. 5 from Co. Dublin is apparently lost. The specimen labelled by Sowerby '*Prod*^ts. *antiquatus* t.317.f.6.' in the Sowerby Coll. [43378], but not identical with that figured in the plate, is chosen as lectotype.

Distribution.—Range, D_2 subzone.

England.

Derbyshire: (B.M., B.2466, B.23536); N.E. slope of Chrome Hill (Geol. Surv., London, I.T.875); Peakshill, opposite Giant's Hole, near Castleton, subzone D_2 (Mr. J. W. Jackson); Treak Cliff, Castleton (Mr J. W. Jackson); Cave Dale, Castleton (Mr. J. W. Jackson).

Staffordshire: Narrowdale Hill, subzone D_2 (B.M., B.45503, 45504); Bonsall's Paddock, Narrowdale (B.M., B.45693); near limekiln, E. of Narrowdale Hill (Mr. J. W. Jackson).

Yorkshire: Malham, knoll reefs, subzone D_2 (B.M., B.45512; Prof. E. J. Garwood); High Hills, Settle (Prof. E. J. Garwood); Stockdale Gorge, S. of Craven Fault, Scaleber (Prof. E. J. Garwood); Cracoe, knoll reefs, subzone D_2 (Prof. E. J. Garwood); top of Gayle Limestone, quarry N. of Countersett, Semerdale (Mr. R. G. Hudson, 669, 676, 768).

Wales.

Denbighshire: Upper Grey Limestone, Llangollen (B.M., B.23766).

Ireland.

Co. Kildare: Kildare (M.P.G., Geol. Soc. Coll., 31822).

Remarks.—*Productus antiquatus* is distinguished from *P. semireticulatus* (Martin) by its smaller dimensions and shorter, more convex visceral disk; and by the different arrangement of the spines on the visceral disk. From *P. hindi* sp. nov. (p. 108) it is distinguished by its coarser costation and absence of a prominent ridge up the flanks.

Sowerby described *P. antiquatus* as being possibly identical with *P. semireticulatus* (Martin). His description is indefinite and his figures are extremely poor, so that later authors, such as M'Coy (1844, p. 106; 1851—55, p. 471), assumed that the two species were synonymous and used either specific name, usually including most species of the *semireticulatus* group.

De Koninck in 1842—44 (p. 160) quoted *P. antiquatus* as being synonymous with *P. martini*, which name he used instead of *P. semireticulatus*; but no specimen figured by him can be identified as *P. antiquatus*.

J. Phillips in 1836 (pl. vii, fig. 3) figured a typical specimen of *P. semireticulatus* as *Producta antiquata*, while the specimen figured by G. B. Sowerby (1822-34, fig. 3) as *P. antiquata* should probably be referred to the species *P. pinguis* sp. nov. (p. 104). In his later work (1842, p. 237, fig. 206) G. B. Sowerby figured a specimen which is said to be *Producta antiquata*, in the explanation of the figures, but is, in reality, the pedicle valve of a *Leptaena*; it is referred to *Producta* [*Leptaena*] *depressa* in the text.

Von Buch in 1848 (p. 28, pl. ii, figs. 7—9, 12) figured several specimens as *Productus antiquatus*. That figured on pl. ii, fig. 7 resembles *P. semireticulatus* (Martin) in shape and ornament, but there is a row of spines set along the hinge-margin, as found in *Chonetes*, but never in *P. semireticulatus*. The specimen from Ratingen, Germany (pl. ii, fig. 12) resembles *P. pinguis* sp. nov. (p. 104) in outline and arrangement of the spine-bases.

Kutorga in 1842 (p. 21, pl. v, figs. 4a—e) figured two distinct species from Russia as *P. antiquatus*. One species (figs. 4a, b) resembles *P. insculptus* sp. nov. (p. 89), while the other (figs. 4c—e) is larger, more coarsely costate, and approaches *P. antiquatus*. A specimen similar to the last is figured by Eichwald (1840, pl. iv, fig. 11) as *P. antiquatus* Bronn, *non* Sowerby, from the Mountain Limestone of Waldai, Russia. It is said to be distinguished from Sowerby's species by a deeper sinus, coarser costae, and 'pearl-shaped bodies'—the swellings developed at the point of intersection of the ribs and the costae, which are, however, also found in *P. antiquatus*.

The specimen of *Leptaena antiquata* from Russia figured by Fischer de Waldheim in 1837 (pl. xxvi, fig. 4) is an elongated form with a spreading trail comparable with that of *P. productus* (Martin).

De Castelnau (1843, p. 39) recorded, but did not figure, a specimen of *P. antiquatus* from Lake Huron.

Dr. L. M. Parsons (1918) recorded *P. antiquatus* from the D_2—D_3 subzone of Ticknall, Derbyshire, and from Breedon-on-the-Hill, Leicestershire.

Productus kilbridensis sp. nov.

Plate VII, figs 5a—c.

Diagnosis.—Shell about 48 mm. high, 37 mm. wide, and 27 mm. thick, or 1 : ·7 : ·5; elongate-oblong in outline, hinge forming widest part. Pedicle valve with highly convex visceral disk, geniculated to form long straight trail; flanks subparallel, slightly convex; venter depressed; umbonal angle 108°; ears small, flat. Brachial valve geniculated, visceral disk slightly concave. Costae fine and irregular, about 17 in 10 mm. at distance of 20 mm. from umbo. Ribs few on cardinal slopes. Spine-bases numerous, minute, in two rows on cardinal slopes.

Description.—The visceral disk is highly arched, and the umbo much incurved, the apex projecting for some distance beyond the hinge. The venter is broad and massive and slopes down to the steep flanks, while the front of the trail projects slightly forward near the anterior margin; the lateral part of the trail is incurved to form a tube-like structure. The ears are separated from the visceral disk by a shallow depression.

The costae are fine and never prominent, irregular in development and sinuous on the trail and flanks. Increase in the number of costae occurs by means of bifurcations and intercalations on the visceral disk and trail. Costae may unite or bifurcate on any part of the shell, but bifurcations occur commonly below spine-bases, and an intercalated costa may be developed on each side of the bifurcation. In decorticated parts of the shell the cast appears nearly smooth.

About ten ribs are developed on the cardinal slopes as undulating folds, but are not continuous across the front of the visceral disk. Only slight enlargement of the costae is caused at the point of intersection of the ribs and costae.

Spine-bases are numerous on the trail, and on the ears and cardinal slopes, where two rows are occasionally preserved, but in most specimens this portion of the shell is decorticated and the ornament obscure. The spines on all parts of the shell are fine and thread-like.

Brachial valve. The visceral disk is slightly concave and is geniculated at its anterior extremity to form a straight trail, which is almost in contact with that of the pedicle valve. The exterior of this valve is rarely seen.

The ornament is similar to that of the pedicle valve, but the ribs are more prominent.

Internal characters. Unknown.

Dimensions.—

		(1)	(2)	(3)	
Maximum height ...	... ...	39	43·5	48·5	mm.
„ width ...	... ...	35·5	38	34	„
„ thickness	... ...	25·5	29·5	27	„
Length of hinge (estimated)	...	37	40	—	„
„ „ visceral disk ...	...	23	26	25	„
Width „ „ „ ...	...	31	31·5	30	„
Number of costae in breadth of 10 mm. at distances vertically below umbo :					
at 15 mm. ...	... ...	18	17	15	
„ 20 „ ...	... ...	20	16	15	
„ 25 „ ...	... ...	17	15	15	

(1) R. Scot. Mus., Edinburgh, 4, from the Lower Limestones, Overton, Beith, Ayrshire.

(2) Same Museum, 6, from the Lower Limestones, Dockra, Beith.

(3) Holotype.

Type.—Holotype, from the Lower Ironstone Series, Kilbride, Ayrshire, is preserved in the Royal Scottish Museum, Edinburgh, Neilson Collection [1911.62.112]. Paratypes : a number of specimens referred to below in section on 'Distribution.'

Distribution.—Range, D_2 subzone.

Scotland.

Ayrshire : Lower Limestones, Bluestone Bed, Overton, Beith (R. Scot. Mus., Edinburgh, Neilson Coll., 4); upper part of Lower Limestones, Dockra, Beith (R. Scot. Mus., Edinburgh, Neilson Coll., 6); Lower Ironstone Series, Kilbride, Ayrshire (R. Scot. Mus., Edinburgh, Neilson Coll., 1911.62.112).

Lanarkshire : Garnkirk (R. Scot. Mus., Edinburgh, Neilson Coll., 18).

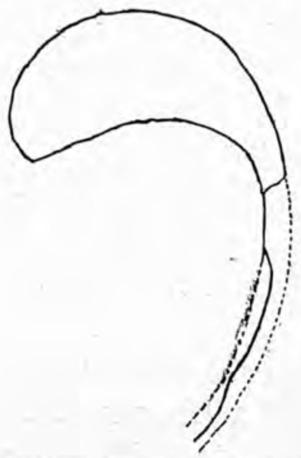
Remarks.—Productus kilbridensis is distinguished from *P. scoticus* J. Sow. by the greater length of its trail; steeper flanks; absence of sinus; more concave brachial valve and finer costae. From *Productus productus* (Martin) *P. kilbridensis* is distinguished by its more massive visceral disk in the pedicle valve and by its finer costae and spines.

P. kilbridensis has so far only been found in the Scottish Carboniferous rocks.

PRODUCTUS MULTISPINIFERUS sp. nov.

Plates VII, figs 6a—c; VIII, figs. 1a—c, 2. Text-fig. 23.

1861. *Productus semireticulatus* T. Davidson (in part). Mon. Brit. Foss. Brach., vol. ii, part v, No. 4, pl. xliii, fig. 4.



TEXT-FIG. 23.—*Productus multispiniferus* sp. nov. Locality unknown. British Museum, 47281. Diagrammatic longitudinal section, natural size.

Diagnosis.—Shell about 48 mm. high, 51 mm. wide, and 35 mm. thick, or 1 : 1·06 : ·7; quadrate in outline, hinge slightly less than widest part of shell. Pedicle valve with globose visceral disk, geniculated, with slightly curved trail; flanks subparallel, flat; venter broad and flat; umbonal angle 135°; ears small. Brachial valve geniculated. Costae uneven and prominent, about 15 in 10 mm. at a distance of 15 mm. below umbo. Ribs numerous, crossing visceral disk. Spine-bases small, numerous, in groups of about 100 on flanks.

Description.—Pedicle valve. In early growth-stages the width of the pedicle valve is considerably greater than the length, and the hinge considerably less than the widest part. In later stages the hinge is produced into small triangular ears which taper to the blunt cardinal extremities, and are separated from the flanks by a geniculation at an angle of 90°. With the development of a geniculation the length of the shell increases, but is usually slightly less than the width. The umbo is rounded and much incurved, projecting slightly beyond the hinge, and the umbonal slopes diverge at a wide angle. A shallow sinus may develop at the anterior end of the visceral disk and flatten out half-way down the trail, but the venter is usually broad and rather flat.

The costae are narrow on the visceral disk but, increasing in width, become prominent and rounded on the trail, with considerable irregularity in width. In some specimens in which a long trail is preserved, the costae become flexuous near the anterior margin. Increase in the number of costae on the visceral disk occurs by means of bifurcations of the originally formed costae, as well as by intercalation of new costae, but only rare bifurcations occur on the trail. The sulci are approximately equal in width to the costae except on decorticated parts of the shell, where the sulci become wider and there is a corresponding loss in width of the costae.

About thirty prominent rounded ribs cross the visceral disk, and decrease in width, becoming angular and undulating on the cardinal slopes. Bifurcation of the ribs may occur on the lateral slopes of the visceral disk, or one or two ribs may disappear. At the point of intersection of ribs and costae, elongated, nodular swellings are developed.

Spine-bases are scattered over the visceral disk, springing from the summit of the costae, which are enlarged for a distance of 2—3 mm. above them. Below the visceral disk the spines were probably equally numerous, but the decortication of the shell has usually removed all traces of them. It is possible that spine-bases about 0·75 mm. in diameter may have covered the entire trail, and have been continuous with the large patch of about 100 spine-bases usually preserved on each flank. The curved costae tend to disappear on the anterior part of the flanks and below the cardinal extremities, and they are then only traceable by means of the spine-bases. The spines projected at right angles to the shell-surface, but they have not been observed *in situ*.

Brachial valve. The visceral disk is concave, with a slight flattening along the hinge and ears, and is geniculated at its anterior extension to form the trail, which is in close contact with that of the pedicle valve.

The ornament is similar to that of the pedicle valve, but the ribs are more numerous. Spine-bases are developed, but are less abundant than in the pedicle valve.

Internal characters. The interior of the pedicle valve has not been observed.

The only interior of the brachial valve observed (Sedgwick Mus., Cambridge, 930) shows a short median septum, and marginal ridges extending along the hinge-margin.

Dimensions.—

	(1)	(2)	(3)	
Maximum height	44	46	55·5	mm.
„ width	49	46	58·6	„
„ thickness	35·5	33·5	37·5	„
Length of hinge-line	43	43·5	46	„
„ „ visceral disk	31·5	30·5	34	„
Width „ „ „	35	37	40	„
Number of costae in breadth of 10 mm. at distances vertically below umbo :				
at 15 mm.	14	15	15	
„ 30 „	10	10	19	

(1) B.M., B.13980, from Kildare, Ireland.

(2) Holotype.

(3) B.M., B.414, from Bolland, Yorkshire.

Type.—Holotype, from Hall Dale, Dovedale, Derbyshire, is preserved in the British Museum, J. Wilfrid Jackson Coll. [B.47981]. Paratypes : a number of specimens referred to in the paragraphs on ' Distribution.'

Distribution.—Range, Z zone to D_2 subzone.

England.

Derbyshire : Hall Dale, Dovedale (B.M., B.47981); Ilam Top's Low Quarry, Dovedale (Mr. J. W. Jackson); Thorpe Cloud, subzone D_2 (Mr. J. W. Jackson); Peak's Hill, opposite Giant's Hole, near Castleton (Mr. J. W. Jackson).

Lancashire : Withgill, Clitheroe (M.P.G., 34451); Bellman Quarry, Clitheroe S zone (Geol. Surv., London, Rh.862).

Somerset : Bristol district, Z zone (Bristol Univ.); Avon Section, S_1 subzone (Bristol Univ.).

Westmorland : Kirkby Lonsdale (Sedgwick Mus., Cambridge, 122).

Yorkshire : Yorkshire (B.M., B.13852, B.23541, 27056); Bolland (B.M., B.414, Gilbertson Coll.); quarry by roadside, S. of Coniston House, ' Fogga Rock ' (Geol. Surv., London, Rh.1629); gorge above Scaleber, lower Stockdale Beck, S. of Craven Faults, E. of Settle (Prof. E. J. Garwood); Malham, knoll reefs, D_2 subzone (Prof. E. J. Garwood); Cracoe, D_2 subzone (Prof. E. J. Garwood).

Ireland.

Co. Cork : Cork (Hunterian Mus., Glasgow, L.217).

Co. Donegal : Bundoran (Mr. W. B. Wright).

Co. Kildare : Clane (Sedgwick Mus., Cambridge, 124, 930); Kildare (B.M., B.13980; M.P.G., Geol. Soc. Coll., 31822).

Remarks.—Productus multispiniferus is distinguished from *P. semireticulatus* (Martin) by its narrower visceral disk, greater curvature of the pedicle valve, prominent ribs on the visceral disk, and by the development of numerous small spine-bases on the flanks. This arrangement of the spines also distinguishes it from *P. sulcatus* J. Sow. and *P. antiquatus* J. Sow.

The specimen figured by Davidson in 1861B (pl. xliii, fig. 4) as *P. semireticulatus* is here referred to *P. multispiniferus*. It is apparently decorticated and shows fewer spine-bases on the flanks and fewer costae than normally occur in this species. The original of this figure is not preserved in the Davidson Collection.

De Koninck (1847B, p. 86) probably includes *P. multispiniferus*, as well as *P. semireticulatus*, in his description of *P. semireticulatus*, var. *antiquatus*. He describes the brachial valve as being geniculated and in close contact with the pedicle valve, and describes the group of spines on the flanks as occupying a space ' entièrement plane, quadrangulaire, un peu déprimé et dans une direction perpendiculaire à celle des oreillettes.' These two statements apply to this species rather than to *P. semireticulatus*. The specimen figured in 1847B (pl. ix, fig. 1b) is apparently an example of *P. multispiniferus* from ? Visé. Quenstedt in 1852 (pl. xxxix, fig. 31) also figured a specimen from Visé as *P. antiquatus*. This appears to be *P. multispiniferus*, although the trail is spreading, and no group of spine-bases can be seen on the flanks. An incomplete specimen in the Sowerby Collection also has a very spreading trail, which is an uncommon character in this species.

The specimens of *Productus semireticulatus*, var. *martini* from the lowest bed of Carboniferous Limestone in Poland, figured by Jarosz in 1917 (pl. viii, figs. 1, 1a, 2, 3), resemble *P. multispiniferus* in shape and ornament, and a patch of spines is developed on the flanks of this species. It is said to occur abundantly in the *Productus sublaevis* horizon which, if corresponding to that of Belgium, is of C_2 age.

Specimens of *P. multispiniferus* from the Z zone of the Bristol district have the typical ornament, but are smaller than those from Derbyshire; examples from the S_1 subzone are more massive, and have a broad visceral disk, and more prominent costae on the flanks as in Davidson's specimen from Kildare. The latter specimen, however, was probably obtained from the beds corresponding to the Waulsortian of Belgium, and therefore from the C zone.

PRODUCTUS SCOTICUS J. Sowerby.

Plate VIII, figs. 3a, b, 4, 5a—c, 6. Text-fig. 24.

1814. *Productus scoticus* J. Sowerby. Mineral Conchology of Great Britain, vol. i, p. 158, pl. lxix, fig. 3.

1860. *Productus semireticulatus*, var. *scoticus* T. Davidson. The Carboniferous System in Scotland characterized by its Brachiopoda, *The Geologist*, vol. iii, p. 109 [in explanation of pl. iii, under heading ' Plate iv '], pl. iii, figs 5, 5a, 5b.

1861. *Productus semireticulatus* T. Davidson (in part). Mon. Brit. Foss. Brach., vol. ii, pt. v, No. 4, p. 150, pl. xliii, figs. 2a, 2b.

TEXT-FIG. 24.—*Productus scoticus* J. Sowerby. Upper Limestones, Robroystone Series, Garnkirk, Scotland. Kelvingrove Museum, Glasgow, Young Coll., 01·53 agg. Diagrammatic longitudinal section, natural size.

Diagnosis.—Shell about 34 mm. high, 39 mm. wide, and 19 mm. thick, or 1 : 1·1 : ·5; quadrate in outline, hinge forming widest part of shell. Pedicle valve with short, laterally elongated visceral disk, geniculated, with slightly convex trail; flanks convex; venter broad, sinuated; umbonal angle 110°; ears small, flat. Brachial valve with concave visceral disk, geniculated. Costae fine, irregular, about 16 in 10 mm. at distance of 15 mm. below umbo. Ribs not continuous across front of visceral disk. Spine-bases numerous on trail and in two rows on cardinal slopes.

Description.—Pedicle valve. The posterior portion of this valve is evenly convex for about 10 mm. from the umbo. A broad rounded sinus is then developed, and increases in depth about half way down the visceral disk, flattening out on the trail. The umbo is rounded, and tapers to an acute extremity which is slightly incurved and does not project beyond the hinge. The ears are small and taper towards the cardinal extremities, but are usually not seen, as the shell tends to fracture along the shallow sinus separating the ears from the visceral disk.

The costae, which are sinuous on the trail, are of moderate width, irregular, and never prominent. Increase in their number occurs by means of bifurcations as well as by intercalations on the visceral disk, but on the trail intercalated costae are more numerous, and frequently arise on either side of the costa supporting a spine-base, and rapidly attain normal width. Two costae may coalesce above a spine-base or a single costa may thicken. The sulci are always narrower than the costae.

About twenty ribs occur as undulating folds on the cardinal slopes, but are not continuous round the front of the visceral disk. An occasional intercalated rib may occur on the lateral slopes of the visceral disk. Slight enlargement of the costae occurs at the point of intersection with the ribs.

Spine-bases, rarely exceeding 1 mm. in diameter, are numerous on the anterior part of the trail, and low longitudinal folds may be developed below them. Numerous small spines are also seen on the visceral disk, where they extend along the shell-surface, whereas on the trail the spines extend at right angles to the shell-surface. Two rows of spine-bases are developed on the cardinal slopes; the posterior row of 6—8 spines is set close to the hinge, and diverges from it at an angle of 2° or 3°, and a second row extends along the depression separating the ears from the visceral disk. The anterior 20 mm. or 30 mm. of the pedicle valve is frequently decorticated, and the cast appears nearly smooth, with rounded pits marking the position of the spine-bases.

Brachial valve. The visceral disk is slightly concave and is separated from the flattened portion along the ears by a rounded fold. A geniculation is developed at the anterior extension of the visceral disk, and the two valves are in contact about half way down the trail. The brachial valve tends to fracture along the geniculation, while the pedicle valve splits across slightly below this level. The trail of the brachial valve is rarely preserved.

The costae are narrow and irregular and are separated by sulci of greater width, but costation is not developed on the trail, where shelly laminae take the place of the normal costation of the pedicle valve.

The ribs are numerous, narrow, and angular, and cross the visceral disk.

Internal characters. One example of the pedicle valve in the Geological Survey Coll., Edinburgh, M.1604A, shows large longitudinally striated, flabellate diductor muscle-scars which enclose, and are in contact with, the narrow elongated adductors.

A perfectly preserved interior of the brachial valve from the Redesdale Ironstone, Redesdale, Northumberland, B.M., B.43810, pl. viii, fig. 4, shows a prominent, trifid cardinal process, the central lobe being divided by a deep longitudinal sulcus. The external face of the process is bifid. The cardinal process is continued anteriorly as a strong median septum which extends for two-thirds of the length of the visceral disk. The septum is much thickened at the point of emergence of the two marginal ridges, which extend along the hinge for a space of about 5 mm. and then diverge from it, curving downwards and reaching the lateral margin of the valve about 17 mm. below the cardinal extremities.

The adductor muscle-scars are dendritic, trigonal in outline, with the longest side lying along the median septum. The posterior part of the muscle-scars is seen about 3 mm. below the hinge-margin. The inner portion, next the septum, lies in a slight depression, while the outer and anterior margins of each adductor are elevated, and a short rounded ridge extends from the anterior margin towards the septum.

The brachial impressions are given off near the anterior margin of the adductors, and extend laterally and parallel to the hinge for about 10 mm., then curve vertically downwards to a point about 1 mm. below the level of the median septum, and are finally recurved upwards, nearly enclosing a space about 5 mm. wide. The rounded extremity is separated from the remainder of the impression by a transverse incision. The oval, smooth areas enclosed by the impression probably served as points of muscle-attachment of the brachia.

Another specimen in the Neilson Collection, Royal Scottish Museum, Edinburgh [15], from the Upper Limestones of Orchard, Lanarkshire, shows the interior of the brachial valve with characters similar to those described above, but having a rounded ridge round the shell about 3 mm. below the anterior extension of the brachial impressions, and dividing the posteriorly costate portion of the valve from the anterior smooth portion.

Dimensions.—

	(1)	(2)	(3)	(4)	
Maximum height	30	30	32	34·5	mm.
,, width	39	38	39	36·5	,,
,, thickness ...	19	18·5	19	24·5	,,
Length of hinge (incomplete)	—	38	35·5	33	,,
Number of costae in breadth of 10 mm. at distances vertically below umbo :					
at 10 mm.	19	19	19	19	
,, 15 ,, ...	15	16	16	16	
,, 25 ,, ...	13	17	14	—	

(1) Holotype.

(2) R. Scot. Mus., Edinburgh, 2, from the Upper Limestones, Arden, Thornliebank, Renfrewshire.

(3) B.M., B.43728, from Redesdale, Northumberland.

(4) R. Scot. Mus., Edinburgh, 14, from Kilbride, Ayrshire.

Type.—Holotype, the specimen from Scotland figured by J. Sowerby in 'Mineral Conchology of Great Britain,' is preserved in the Royal Scottish Museum, Edinburgh, Fleming Collection [1870.14.237]. In the 'Supplementary Index' to vol. i of 'Mineral Conchology,' in which a list of localities of the species described by Sowerby is given by J. Farey, ***Productus scoticus*** is stated to come from Linlithgowshire.

Distribution.—Range, D zone.

England.

Northumberland: Redesdale Ironstone Shale, Redesdale, ? subzone D_1 (B.M., B.41956, S. Smith Coll., and B.43802—13, W. Hind Coll.; Mr. J. Dunn); Berwick-on-Tweed (Sedgwick Mus., Cambridge, 73B).

Scotland.

Ayrshire: Bowertrapping, Dalry (B.M., B.13863, Davidson Coll.); Lower Limestones, Bowertrapping, Dalry (R. Scot. Mus., Edinburgh, 7); Lower Ironstone Series, Kilbride, Ayrshire (R. Scot. Mus., Edinburgh, Neilson Coll., 14; Kelvingrove Mus., Glasgow, 01·53 age); quarry near Shield, S. of Cumnock (Geol. Surv., Edinburgh, M.2737); Upper Linn Beds, Linn Spout, Dalry (Kelvingrove Mus., Glasgow, 08·153 ja).

Buteshire: Corrie, Arran (Hunterian Mus., Glasgow, L.211).

Dumbartonshire: Old quarries at Ravenswood, $1\frac{1}{2}$ miles S.W. of Cumbernauld (Geol. Surv., Edinburgh, M.3630A).

Lanarkshire: Carluke (B.M., B.13893, Davidson Coll.); Upper Limestones, Orchard Limestone, S.W. bank of Avon Water, near Birkenshaw (Geol. Surv., Edinburgh, T.1210E, 1211E); old pit, side of stream, $3\frac{1}{2}$ miles N.W. of Coatbridge (Geol. Surv., Edinburgh, M.1603A, 1604A); old pit, side of stream near Glenpark Cottage, 4 miles N.N.W. of Coatbridge (Geol. Surv., Edinburgh, M.1593A); Poniel Water, near Brockley (Geol. Surv., Edinburgh, M.492, 494); Upper Limestones, Orchard, near Glasgow (R. Scot. Mus., Edinburgh, 15); Gare, Carluke (Hunterian Mus., Glasgow, L.207); Upper Limestones, Robroystone Series, Garnkirk (Kelvingrove Mus., Glasgow, 01·53 agg).

Renfrewshire: Upper Limestones, Arden Limestone, old quarry, $\frac{3}{4}$ mile S.W. of Darnley (Geol. Surv., Edinburgh, M.3337, 3338); old quarry, S. of Stanley Reservoir (Geol. Surv., Edinburgh, M.3149); Upper Limestones, Arden, Thornliebank (R. Scot. Mus., Edinburgh, 2; Hunterian Mus., Glasgow, L.213); Upper Limestones, Thornliebank (Kelvingrove Mus., Glasgow, 96·65 iky).

Remarks.—Productus scoticus is distinguished from *P. pugilis* Phill. by its smaller proportions; more deeply sinuated venter; narrower and less prominent costae; shorter trail and less incurved umbo. The spines on the ears and trail of *P. scoticus* are smaller than in *P. pugilis,* and there is only a slight development of the longitudinal folds below the spine-bases on the trail. The absence of a ridge on the flanks, and the smaller dimensions of *P. scoticus,* distinguish it from *P. hindi* sp. nov.

J. Sowerby's drawing of *P. scoticus* in 'Mineral Conchology,' vol. i, shows the distinguishing characters of this species fairly well. Confusion about the identity of this species was caused by J. de C. Sowerby in 1827, 'Mineral Conchology,' vol. vi (pl. mlxi, figs. 1—3), who figured as *Producta hemispherica* some large specimens which, he stated, were formerly referred to *P. scotica,* but did not agree with those figured by J. Sowerby (1814, pl. lxix, fig. 3) and lacked spine-bases. Later authors—such as M'Coy (1844, p. 114; 1855, p. 464), de Koninck (1847B, p. 39), and de Verneuil (1845, p. 253) assumed that *P. scoticus* was either identical with *P. giganteus* or *P. hemisphericus,* and included it in their description of these species and allied forms of the *P. giganteus* group. Keyserling in 1846 (p. 198) also included *P. scoticus* in his synonymy of *P. hemisphericus,* but on p. 211 of the same work he questioned the identity of *P. scoticus* with *P. quincuncialis* Phill.

In 1842 (p. 24) von Buch recorded *P. scoticus* from Altwasser, in Silesia, without figuring or describing any specimen, and only quoted *P. margaritaceus* Phill. as a variety with stronger costae.

Davidson referred *P. scoticus* to the *semireticulatus* group of *Producti* and quoted it in 1860A (p. 109) as a variety of *P. semireticulatus* (Martin). His specimens figured in 1861B (pl. xliii, figs. 2a, b) from Nellfield, Lanarkshire, as *P. semireticulatus* should be identified as *P. scoticus.*

Dr. S. Smith's specimens from the Redesdale Ironstone Shale and Four Laws Limestone, recorded in 1910 as *P. antiquatus* J. Sow., are typical examples of *P. scoticus.*

PRODUCTUS HOWRATENSIS[1] sp. nov.

Plate VIII, figs. 7a, b.

Diagnosis.—Shell about 36 mm. high, 38 mm. wide, and 17 mm. thick, or 1 : 1·05 : ·4; quadrate in outline, hinge forming widest part. Pedicle valve convex, not geniculated; flanks rounded; venter slightly sinuated; umbonal angle 98°; ears small. Brachial valve flat posteriorly, concave anteriorly. Costae prominent, about 13 in 10 mm. at 15 mm. from umbo. Ribs faintly traceable across front of visceral disk. Spine-bases quincuncially arranged on anterior part of shell, and in two rows on cardinal slopes.

[1] Name derived from Howrat, Ayrshire, the locality from which the type-specimen was obtained.

Description.—Pedicle valve. In early growth-stages the shell is globose and then flattens with the development of a shallow, rounded median sinus. At the anterior end of the visceral disk the shell becomes increasingly convex and is produced to form a short curved trail. The ears, which are slightly flattened along the hinge, are separated from the visceral disk by a deep sulcus, along which the shell tends to fracture, and consequently the ears are rarely preserved. The umbo is acute, slightly incurved, and projects a short distance beyond the hinge.

The costae are rounded and prominent and are separated by narrow sulci. Bifurcation of the costae occurs rather frequently, especially below the spine-bases, and intercalated costae, attaining normal width in a space of 3 to 4 mm., are developed on all parts of the shell. In the gerontic stage the costae become very irregular in width and less prominent, with repeated bifurcations or even trifurcations. Growth-lines are very numerous on the anterior part of the shell and form marked transverse striations on the costae.

About twenty ribs are traceable across the front of the visceral disk, causing a slight enlargement of the costae at the point of intersection. On the cardinal slopes the ribs are seen as irregular, undulating wrinkles, and intercalated ribs may be developed.

Spine-bases, which are scattered over the shell, spring from the summit of the costae; the spines apparently projected at right angles to the shell-surface. Two rows of spines occur on the cardinal slopes, one row being set close to the hinge-margin. A marked increase in spinosity occurs at the anterior end of the visceral disk, and a band of spine-bases about 10 mm. in width, with the spines arranged more or less regularly in quincunx, is developed near the anterior margin. Slight longitudinal folding of the shell may be seen below the spine-bases near the anterior margin.

Brachial valve. The visceral disk is flat, but with a low median fold corresponding to the shallow sinus of the pedicle valve; the anterior part of the shell is slightly concave, but no geniculation is developed.

The ornament is similar to that of the pedicle valve, except that the sulci are wider than the costae. Traces of spines have been observed.

Internal characters. Unknown.

Dimensions.—

	(1)	(2)	
Maximum height	30	36	mm.
" width	39·5	38	"
" thickness	17	17·5	"
Number of costae in breadth of 10 mm. at distances vertically below umbo :			
at 10 mm.	14	14	
" 15 "	12	13	
" 20 "	11	10	

(1) Geol. Surv., Edinburgh, B.4039A, from 4 miles S.E. of East Kilbride, Lanarkshire.

(2) Holotype.

Type.—Holotype, from the Lower Limestones, Howrat, three miles N.W. of Dalry, Ayrshire, is preserved in the Royal Scottish Museum, Edinburgh, Neilson Collection [5]. Paratypes : four specimens referred to below in section on 'Distribution.'

Distribution.—Range, D_2 subzone

Scotland.

Ayrshire : Lower Limestones, Howrat, 3 miles N.W. of Dalry (R. Scot. Mus., Edinburgh, 5).

Lanarkshire : Shale between No. 1 and No. 2 Limestones of Calderwood Section, shale-heaps in old quarries on farms of Burnlead, Craigend Hill and Boghead, 4 miles S.E. of East Kilbride (Geol. Surv., Edinburgh, B.4039A); Lower Limestones, Boghead, near Hamilton (Kelvingrove Mus., Glasgow, Young Coll.).

Remarks.—Productus howratensis differs from *P. scoticus* J. Sow. in having a flatter pedicle valve, coarser costae, and a large development of spine-bases on the anterior part of the pedicle valve. *P. howratensis* is distinguished from *P. pugilis* Phill. by its more numerous and smaller spine-bases, which are also differently arranged on the cardinal slopes, its numerous intercalated costae, and the slight development of longitudinal folds below the spine-bases in the pedicle valve.

P. howratensis is at present known only from the Scottish Carboniferous rocks.

PRODUCTUS PUGILIS J. Phillips.

Plate IX, figs. 1a, b, 2—5. Text-figs. 7, 8, 25.

1836. *Producta pugilis* J. Phillips. Illustrations of the Geology of Yorkshire, part ii, p. 215, pl. viii, fig. 6.

1860. *Productus semireticulatus* T. Davidson (in part). The Carboniferous System in Scotland characterized by its Brachiopoda, *The Geologist*, vol. iii, p. 108 [in explanation of pl. iii, under heading 'Pl. iv'], pl. iii, figs. 2, 2a.

1861. *Productus semireticulatus* T. Davidson (in part). Mon. Brit. Foss. Brach., vol. ii, part v, No. 4, p. 150, pl. xliii, fig. 2.

1924. *Productus pugilis* E. J. Garwood and E. Goodyear. The Lower Carboniferous Succession in the Settle District, *Quart. Journ. Geol. Soc.*, vol. lxxx, p. 205, pl. xviii, fig. 1.

TEXT-FIG. 25.—*Productus pugilis* J. Phillips, from Yorkshire. British Museum, B.415. Diagrammatic longitudinal section, natural size.

Diagnosis.—Shell about 60 mm. high, 47 mm. wide, and 34 mm. thick, or 1 : ·8 : ·6; quadrate to elongate in outline, greatest width along hinge. Pedicle valve with globose visceral disk, geniculated to form long, slightly curved trail; flanks steep, subparallel; venter broad, depressed, or sinuated; umbonal angle 100°; ears large, tapering to cardinal extremities. Brachial valve concave. Costae 14 in 10 mm. at distance of 15 mm. from umbo, becoming irregular and sinuous on trail. Ribs traceable across front of visceral disk. Spines of large diameter on trail, below which prominent longitudinal folds are developed, causing fluting of trail. Spines in two rows on ears.

Description.—Pedicle valve. In early growth-stages the shell is slightly convex, with the width approximately equal to the length, and the hinge considerably less than the widest part of the shell. The width increases till it is about one and a half times the length. A geniculation is then developed and the shell becomes considerably elongated. The venter is broad and may be slightly sinuated, the sinus arising about 20 mm. from the umbo and extending to the anterior end of the trail. The flanks are steep and flat and curve up to the ears, which are large and reflexed, but are rarely preserved. The umbo is rounded and much incurved, the apex projecting slightly beyond the hinge.

The costae are fine, rounded on the visceral disk and only increase very slightly in width on the trail. On the flanks the costae are narrower than those on the venter, owing to increase in the number of bifurcations and intercalated costae, while on the trail they are irregular and sinuous, and develop gerontic swellings. About 2 mm. below the spine-bases on the trail two or three costae may arise out of a single costa and be raised into a prominent longitudinal fold. The costae on the fold may bifurcate again and the fold increases in width anteriorly and becomes less prominent, unless a second spine arises from it, when elevation of the fold again occurs. In specimens which have a long trail the shell appears to be deeply fluted. When the shell is decorticated the cast is nearly smooth.

From twelve to fourteen undulating ribs occur on the ears and cardinal slopes, and widen and decrease in elevation on the front of the visceral disk. Slight elongated swellings occur on the costae at the point of intersection with the ribs. Bifurcation of the ribs, or intercalated ribs, may arise on the lateral slopes of the visceral disk.

Small spine-bases are scattered irregularly over the visceral disk, and bifurcation of the costae usually occurs below each spine-base. On the trail the spines are less numerous and vary from 2·5 mm. to 3 mm. in diameter. Two rows of spine-bases spring from the ears; the posterior row of 6 to 8 spines is set close to the hinge margin, and diverges from it at an angle of about 5°, the diameter of the spines varying from ·25 mm. near the umbo to 2 mm. near the cardinal extremities. The anterior row of 3 or 4 spines of large diameter is developed near the cardinal extremities. A third row of spine-bases is occasionally seen in the depression separating the ears from the visceral disk.

Brachial valve. The visceral disk is slightly concave, with a flat portion along the cardinal slopes and ears. The concavity of the shell increases anteriorly, but no geniculation is developed, the longitudinal contour showing an even curvature from the umbo to the anterior margin. The two valves are in contact slightly below the visceral disk.

The costae are narrower and the sulci wider than those of the pedicle valve. The ribs are traceable across the visceral disk, where the enlargement of the costae at the point of intersection with the ribs is rather marked. No spines have been observed in this valve. Below the visceral disk the normal ornament is replaced by successive imbricating shelly laminae which break off irregularly. These laminae were developed in order to keep pace with the great anterior extension of the trail of the pedicle valve, and are a gerontic character. Traces of fine irregular costae may be seen on the posterior laminae.

Internal characters. The interior of the pedicle valve is rarely seen, but crushed specimens preserved in the British Museum, B.20450, B.45580—81 (pl. ix, fig. 3, and text-fig. 7), from Far House Shales, Cam Beck, Yorkshire, show large, longitudinally striated diductors, and narrow dendritic adductors which are much elongated.

A well preserved specimen of the brachial valve from subzone Dy, Styford or Stanton, Northumberland, B.M., B.41914 (pl. ix, fig. 5, and text-fig. 8) shows a prominent bifid cardinal process, which is continued anteriorly as a strong median septum for about two-thirds of the length of the visceral disk. The anterior half of the median septum is narrow and rather prominent.

The marginal ridges diverge from the hinge-line and curve downwards until the lateral margin of the shell is reached, where they are sharply bent anteriorly and continue along the margin for about half the length of the visceral disk. The anterior portion of the ridge is slightly undulating, but the width of the ridge is constant, and is about 1·5 mm.

The adductor muscle-scars are elongated and the anterior end is set on a rounded ridge, about 2 mm. long, which curves inwards towards the median septum. The posterior end is almost in contact with the marginal ridges.

The brachial impressions are given off at the anterior lateral extremity of the adductor-scars, and curve outwards for about 5 mm. at an angle of 20° to the hinge;

they are then sharply recurved downwards for about 6 mm., and finally curved inwards and upwards in a nearly vertical direction. The extremity is separated from the remainder of the impression by a transverse incision, and the posterior portion next to the adductor-scars also appears to be discontinuous.

The cardinal process is occasionally seen in crushed specimens from the Far House Shales, Settle district, Yorkshire. The specimen figured on pl. ix, fig. 3, shows the prominently trifid exterior of the cardinal process, each of the three lobes being transversely striated.

A specimen from Cumnock, Ayrshire, preserved in the Hunterian Museum, Glasgow, L.208, also shows the interior of the brachial valve with similar characters to those already described.

Dimensions.—

	(1)	(2)	(3)	
Maximum height	35	56·5	63·5	mm.
„ width	47·5	44	50	„
„ thickness	21	36·5	32·5	„
Length of hinge (estimated) ...	52	44	—	„
„ „ visceral disk	—	31	29	„
Width „ „ „	—	37	38	„
Number of costae in breadth of 10 mm. at distances vertically below umbo :				
at 15 mm.	14	14	13	
„ 20 „	15	12	12	
„ 30 „	—	12	14	

(1) Prof. E. J. Garwood's coll., from Sellet Mill, Westmorland.

(2) B.M., B.23838, from Upper Grey Limestone, Minera, Flintshire.

(3) Same locality and coll. as (1).

Type.—Holotype, the specimen from Kir[k]by Lonsdale, figured by Phillips in 'Illustrations of the Geology of Yorkshire,' is apparently lost.

Distribution.—Range, D_2 subzone and Yoredalian.

England.

Derbyshire: Park Hill, Longnor, subzone D_2 (M.P.G., 38329—38330); Ticknall, Ashby-de-la-Zouch (M.P.G., 34452); pit, 100 yards S.E. of Greenhill's Farm, Matlock Bridge (M.P.G., 38346); Hay Dale, Monsal Dale, subzone D_2 (Bristol Univ.); Castleton, subzone D_2 (Oxford Univ., Mus., U.P.425).

Lancashire: Gleaston, Furness, subzone D_2 (Prof. E. J. Garwood).

Northumberland: Thornbrough Limestone, Stanton or Styford, subzone Dy (B.M., B.41913—15, S. Smith Coll.).

Somerset: Mendip Hills (B.M., 74394).

Westmorland: Sellet Mill, near Kirkby Lonsdale, subzone D_2 (Prof. E. J. Garwood).

Yorkshire: Grey limestone, bed of stream above pot-hole, Dowgill, 2 miles N.E. of Horton-in-Ribblesdale (Geol. Surv., London, Rh.2353, 2354); Browgill, 4 miles N. of Horton-in-Ribblesdale (Geol. Surv., London, Rh.2400, 2401); Far House Shales, Cam Beck (B.M., B.20450, B.45580—81); Goyden Pot, Niddersdale (Mr. R. G. S. Hudson); old quarry, W. of Fawcetts Quarry, near Hawes (Mr. R. G. S. Hudson, 36); *P. giganteus* bed, Mill Gill, Askrigg, *Orionastraea phillipsi* zone (Mr. R. G. S. Hudson, 179); Back Scar, E. of Settle (B.M., B.45686, H.M. Muir-Wood Coll.).

Wales.

Anglesey: Cliff, N.E. end of Puffin Island (Geol. Surv., London, Af.2803, 2805); escarpment, 1,100 yards E.S.E. of Bod Gynda (Geol. Surv., London, Af.2113); cliff, 25 yards E. of Fedw Fawr (Geol. Surv., London, Af.2646); cliff, 50—75 yards S.W. of Penmon lifeboat-station (Geol. Surv., London, Af.2775).

Carnarvonshire: Great Orme's Head (B.M., B.43730).

Denbighshire: Llangollen (B.M., B.23765); Chirk (B.M., B.23819, Morton Coll.).

Flintshire: Upper Grey Limestone, Minera (B.M., 23543, B.23837—8, 23840); Upper Black Limestone, Pentre Halkin, Holywell (B.M., B.23996, 23540); Pen-y-lall, Holywell (M.P.G., 38318).

Scotland.

Ayrshire: Top of grey limestone, S. of Hillhouse, and E. of Howcommon (Geol. Surv., Edinburgh, T.3199E); Coral shale, Broadstone, Beith (R. Scot. Mus., Edinburgh, 1911.62.117); Cumnock (Hunterian Mus., Glasgow, L.208).

Buteshire : Lower Limestones, Hurlet Limestone, Bute (Geol. Surv., Edinburgh, T.876); Lower Limestones, Corrie, Arran (Hunterian Mus., Glasgow).

Edinburghshire : Left bank of R. Esk, below Valleyfield Paper Mill, Penicuik (Geol. Surv., Edinburgh, B.3245c).

Haddingtonshire : Aberlady, East Lothian (B.M., B.8474); No. 5 Limestone, tile-works at Morrison's Haven, Prestongrange, W. of Prestonpans (Geol. Surv., Edinburgh, B.2805c).

Lanarkshire : (B.M., B.13894, Davidson Coll.); Lower Limestones, Duntocher, Hamilton, Carluke (M.P.G., 34457); Lower Limestones, Birkwood Burn, 1½ miles N.W. of Lesmahagow (Geol. Surv., Edinburgh, T.4638E, 4639E, 354F, 345F); Basket Shell Bed, Lower Limestones, Cot Castle Farm, right bank of Avon Water, 2½ miles N.E. of Strathaven (Geol. Surv., Edinburgh, T.2698D); railway-cutting, Badley, 3½ miles N.N.W. of Coatbridge (Geol. Surv., Edinburgh, M.1560A, 1561A); Rutherglen (Hunterian Mus., Glasgow, Ure Coll.); Blackbyre Limestone, Brockley, Lesmahagow (Kelvingrove Mus., Glasgow).

Renfrewshire : Old quarry in field, S.W. of Brownside (Geol. Surv., Edinburgh, M.3319); Hollybush Limestone, Hawkhead Reservoir, 2 miles S.E. of Paisley (Geol. Surv., Edinburgh).

Stirlingshire : Lower Limestones, white nodular limestone, S.W. of Todholes, Upper Bannock Burn (Geol. Surv., Edinburgh, T.1890F); Main or Hurlet Limestone, Glenwhapple Burn, S. of Craigenglen, 1½ miles S. of Lennoxtown (Geol. Surv., Edinburgh, M.2908A); Lower Limestones, Craigenglen, Campsie (Kelvingrove Mus., Glasgow; R. Scot. Mus., Edinburgh, 9).

Ireland.

Co. Londonderry : Londonderry (M.P.G., Geol. Soc. Coll. 31827).

Remarks.—Productus pugilis is distinguished from *P. antiquatus* J. Sow. and *P. sulcatus* J. Sow. by its more irregular costae and by the development of large spines on the venter, below which the shell is longitudinally folded. The absence of any ridge on the flanks also distinguishes it from *P. sulcatus*.

J. Phillips described *P. pugilis* in 1836 (p. 215) as having 'Auricles acute, spinous; radiating striae equal, a few strong spines toward the margin.' This description, together with the imperfect drawing of a much distorted specimen, caused some difficulty in the interpretation of the species. Phillips's specimen, now apparently lost, was obtained from the Yoredales, or top of the Lower Scar

Limestone of Kirkby Lonsdale, Westmorland. There seems little doubt that it was collected from, or near, the quarry in the D_2 subzone at Sellet Mill near Kirkby Lonsdale, where the species occurs abundantly and the specimens show similar crushing and distortion to that depicted in Phillips's drawing. A specimen from this locality is figured on plate ix, fig. 2, of this work.

Various interpretations of this species were given by later authors. M'Coy in 1844 (p. 113) described it as a distinct species, but later (1855) placed it in the synonymy of *P. flemingi*, while de Koninck in 1842—44 (p. 175) refers to *P. pugilis* in his description of *P. giganteus*, although he did not mention its occurrence in Belgium. Von Buch (1842, p. 21) also considered *P. pugilis* to be allied to *P. giganteus*, although he regarded it as synonymous with *Productus comoides* [*Daviesiella*].

Davidson described this species as a synonym of *Productus semireticulatus* (Martin). A specimen in the Davidson Collection, from the Carboniferous Limestone of Lanarkshire [B.13894], bears a label stating that 'this specimen though smaller agrees well with Phillips's *Productus pugilis*, which is a synonym of *semireticulatus*.' This shell is similar to that figured by Davidson in 1861B (pl. xliii, fig. 2) which, however, was said to have been obtained from Stirlingshire.

Dr. Stanley Smith (1910, p. 609) recorded a small form of *P.* aff. *pugilis* from the Woodend Limestone of Northumberland. This form seems to be an early mutation found in the D_1 subzone.

Prof. Garwood and Miss Goodyear (1924) figured a typical specimen of *P. pugilis* showing the fluting of the trail. This specimen, which was obtained from the D_2 subzone, east of Settle, Yorkshire, has been refigured on pl. ix, fig. 4 of this memoir.

Specimens of *P. pugilis* from the Yoredalian Series of Yorkshire have, as a rule, a squarer visceral disk and finer costation than is normal for this species.

PRODUCTUS PUGILIS, mut. SENILIS mut. nov.

Plate IX, figs. 6a—d.

Diagnosis.—Resembling *P. pugilis*, but with a slightly deeper sinus in pedicle valve; normal costation and spine-bases on trail, replaced by smooth or finely striated imbricating lamellae. Fluting of trail not developed. Ornament of brachial valve feebly developed.

Description.—In the pedicle valve the flanks are steep and flat, while the median portion of the trail is produced beyond the lateral parts and forms a V-shaped projection.

The costae on the visceral disk are of moderate width and frequently bifurcate, especially below the spine-bases on the posterior part of the trail, where prominent folds are developed. The folds flatten out about 20 mm. below the anterior end of the visceral disk, when the costae bifurcate and trifurcate repeatedly until fine sinuous striae replace the normal costae. These striae are usually absent on the anterior part of the trail, and the shell-surface is composed of imbricating shelly lamellae which tend to break off irregularly.

The ribs are narrow, irregular and slightly prominent, and spine-bases are developed on the posterior part of the shell, as in *P. pugilis.*

In the brachial valve the ornament resembles that of the parent species, but is more uneven on the visceral disk, and the costae bear irregular swellings.

Type.—Holotype, from the Upper Limestones, Thornliebank, Renfrewshire, is preserved in the R. Scot. Mus., Edinburgh, Neilson Coll., **1911.62.954.**

Distribution.—*P. pugilis,* mut. *senilis* is characteristic of the Upper Limestones of Scotland and of the upper part of the D zone of England and Wales.

PRODUCTUS BRISTOLENSIS[1] sp. nov.

Plate IX, figs. 7a, b.

Diagnosis.—Shell about **42** mm. high, **40** mm. wide, and **27** mm. thick, or 1 : ·9 : ·6; approximately circular in outline, maximum width near anterior margin. Pedicle valve slightly geniculated, visceral disk short; flanks rounded, venter flattened; umbonal angle 100°; ears minute. Brachial valve concave. Costae about **12** in **10** mm. at distance of **20** mm. from umbo. Ribs numerous, with narrow interspaces crossing front of visceral disk. Spine-bases numerous on trail, with slight longitudinal folding of shell anterior to them, rare on visceral disk.

[1] Named from its occurrence in the Bristol district.

Description.—Pedicle valve. In early growth-stages the shell is globose, with the width approximately equal to the length. At a distance of about 15 mm. from the umbo the shell becomes flatter and the width of the shell increases until it is about twice the length. With the development of the rounded geniculation joining the visceral disk to the trail the shell elongates rapidly, and becomes rather convex. The flanks are convex and curve up on to the broad flattened venter. The hinge is short and is produced into minute earlets; the umbo is rounded and incurved, projecting a short distance beyond the hinge.

The costae radiate evenly from the umbo on the visceral disk, and intercalations are rather numerous, and on the posterior part of the trail the costae become more prominent and slightly wider. On the anterior part of the shell they become sinuous and irregular, with numerous bifurcations which occur commonly below the numerous spine-bases. Low folds may be developed below the spine-bases near the anterior margin, but these flatten out in a distance of 4 or 5 mm. The shell tends to become decorticated very readily and the cast appears smooth.

About thirty ribs are developed as narrow regular folds on the cardinal slopes. They increase very slightly in width on the front of the shell and are readily traced across the visceral disk by means of the nodular enlargements at the point of their intersection with the costae. Intercalated ribs may occur on the lateral slopes of the visceral disk where they are undulating.

Spine-bases are irregularly scattered over the anterior part of the trail, where they are about 1 mm. in diameter, but are rare on the visceral disk, where they arise from the nodular enlargements of the costae. A row of spine-bases of small size occurs along the hinge and diverges from it at an angle of 2—3°. A second row may be seen on the cardinal slopes at an angle of 30° to the hinge, and it may continue down the flanks, where the ornament, owing to decortication, is usually obscure.

Brachial valve. The visceral disk is slightly concave, with the exception of a nearly flat triangular portion along the cardinal slopes and ears. The shell becomes increasingly concave on the trail.

The costae are narrower and the sulci correspondingly wider than in the pedicle valve, and the ribs are better defined.

Internal characters. Unknown.

Dimensions.—

	(1)	
Maximum height	42	mm.
,, width	40	,,
,, thickness	27	,,
Length of hinge	30	,,
,, ,, visceral disk	27	,,
Width ,, ,, ,, ...	36	,,
Number of costae in breadth of 10 mm. at distances vertically below umbo :		
at 10 mm.	16	
,, 15 ,, ...	12	
,, 20 ,, ...	12	

(1) Holotype.

Type.—Holotype, from the Z_2 subzone, Avon Gorge, Clifton, Bristol, preserved in the Bristol Museum, C.4104.

Distribution.—Z_2 subzone and ?γ horizon of the Bristol District.

Remarks.—*Productus bristolensis* is distinguished from *P. pugilis* Phill. by its shorter visceral disk and trail, narrow hinge and rounded flanks. In *P. bristolensis* the ribs are more numerous, the spine-bases less numerous and differently arranged, and the longitudinal folds shorter and less prominent than in *P. pugilis.*

This species was possibly referred to by Vaughan in 1905B (pp. 192, 247) as a mutation of *P.* cf. *martini* towards *P. semireticulatus,* which is said to occur in the Z_2 subzone. In pl. xxix of the same work Vaughan speaks of this form as originating in the Z_1 subzone, attaining its maximum development in Z_2 subzone, and continuing through the C zone. He considered it to be related to forms occurring in the S_1 subzone. One of these is a considerably smaller shell, and has been doubtfully referred to the species *P. garwoodi* sp. nov. (p. 70). A larger shell, also occurring in the S_1 subzone, and rarely in the C zone, has been referred to *P. multispiniferus* sp. nov. (see p. 121), and cannot be said to be related to *P. bristolensis.*

PRODUCTUS COSTATUS J. de C. Sowerby.

Plate X, figs. 1a—c, 2, 3.

1827. *Producta costata* J. de C. Sowerby. Mineral Conchology of Great Britain, vol. vi, p. 115, pl. mlx, fig. 1.

1847. *Productus costatus* L. de Koninck. Recherches sur les Animaux Fossiles. Pt. i. Mon. des Genres *Productus* et *Chonetes*, p. 92, pl. x, figs. 3a, b.

1860. *Productus costatus* T. Davidson (in part). The Carboniferous System in Scotland characterized by its Brachiopoda, *The Geologist*, vol. iii, p. 44, pl. ii, fig. 22.

1861. *Productus costatus* T. Davidson (in part). Mon. Brit. Foss. Brach., vol. ii, pt. v, No. 4, p. 152, pl. xxxii, figs. 2, 8.

1880. *Productus costatus* T. Davidson. Mon. Brit. Foss. Brach., Suppl., vol. iv, pt. iii, pl. xxxvi, figs. 9, 18, 19.

Diagnosis.—Shell about 33 mm. high, 50 mm. wide, and 22 mm. thick, or 1 : 1·5 : ·6; laterally elongated, maximum width along hinge. Pedicle valve with slightly convex visceral disk, geniculated to form highly convex trail; flanks convex, bearing prominent ridge; venter deeply sinuated; umbonal angle 108°; ears large. Brachial valve geniculated, with flat visceral disk. Costae about 7 in 10 mm. at distance of 20 mm. below umbo, coarse and prominent, converging in median sinus. Ribs extending round front of visceral disk. Spine-bases of large diameter in row on ridge up flanks and in second row on cardinal slopes at angle of 15° to hinge.

Description.—Pedicle valve. The shell is slightly convex for about 10 mm. from the umbo, and the width is slightly greater than the length at this stage. A broad rounded sinus is then developed and increases in depth at the anterior end of the visceral disk, and is continuous to the anterior margin. The width of the shell becomes approximately equal to the length, when a geniculation is developed, and a short trail is formed which is posteriorly nearly flat, but anteriorly is highly convex. At the anterior end of the visceral disk there is a low rounded ridge on the flanks, which increases in height towards the anterior margin. Behind this ridge, and separating it from the large, laterally reflexed ears, is a shallow sulcus, which disappears about 10 mm. from the umbo. The cardinal extremities are rounded and the hinge-line slopes down towards them on each side of the umbo. The umbo is rounded and slightly incurved, and projects for about 1 mm. beyond the hinge.

The costae radiate evenly from the umbo on the visceral disk and increase in number by means of rare intercalations. Below this region the costae thicken considerably, and become irregular in width and prominently rounded. Two or three costae occupying the centre of the sinus fail to thicken and converge, usually dying out at varying distances below the umbo, and these are replaced by two adjacent costae which may unite near the anterior margin. Bifurcation and trifurcation of the costae may occur on the anterior part of the trail. Decortication of the shell causes slight flattening of the costae, and at an advanced stage of weathering one original costa may be replaced by two or three narrow costae. The sulci separating the costae are deep and rounded, and are usually narrower than the costae. Growth-lines are numerous and are seen as deep striae crossing the costae.

About twenty ribs are developed on the visceral disk and form narrow, slightly prominent folds on the cardinal slopes, and they bifurcate rarely on the lateral slopes of the visceral disk. The ribs increase in width on the front of the shell, where nodular swellings mark the point of their intersection with the costae.

A row of five or six large spine-bases, varying in diameter from 1 to 2 mm., springs from the ridge on the flanks, and a second row extends along the cardinal slopes at an angle of about 15° to the hinge. A few scattered spine-bases of smaller size occur on the visceral disk, arising from the point of intersection of ribs and costae, but they are rarely seen on the trail.

Brachial valve. The visceral disk is flat, with a median ridge corresponding to the sinus of the pedicle valve, and a geniculation is developed at its anterior extension, joining it to the highly concave trail. The trail is only in contact with that of the pedicle valve at the anterior and lateral margins of the shell.

The costae are narrower and more angular, and the sulci are of greater width than in the pedicle valve; the nodular enlargement of the costae at the point of intersection with the ribs is less marked.

Internal characters. The interior of the pedicle valve is unknown.

In the interior of the brachial valve (pl. x, fig. 3) the cardinal process is small and bifid, while its external face is trifid and transversely striated. The median septum is flat below the cardinal process, but narrows between the adductor-scars and forms a thin, prominent ridge anteriorly.

The marginal ridges diverge from the hinge about 2 mm. from the cardinal process and curve rather abruptly downwards, but do not extend as far as the posterior lateral margin of the shell.

The trigonal adductor muscle-scars are dendritic and their anterior and lateral margins are raised above the level of the remainder of the scar on a rounded ridge. Each ridge flattens out against the median septum about 2 mm. below the anterior end of the adductor-scars. The brachial impressions are given off at the anterior lateral margin of the adductors and extend outwards for about 10 mm.; they are then bent abruptly downwards, and finally inwards and upwards. The posterior portion of the impression is discontinuous, and the inner extremity is enlarged and separated from the remainder of the impression by a wide incision. Beyond the extremity of the brachial impressions a few small detached pustules are seen in a row, curving inwards towards the adductors and then extending anteriorly to the end of the median septum.

Dimensions.—

	(1)	(2)	
Maximum height	30	33	mm.
,, width	50	39·5	,,
,, thickness	20	22	,,
Length of hinge	49	—	,,
,, ,, visceral disk	18	18	,,
Width ,, ,, ,, ...	30	29	,,
Number of costae in breadth of 10 mm. at distances vertically below umbo :			
at 20 mm.	7	7	

(1) B.M., B.5761, from the Upper Limestones, Orchard, Glasgow.

(2) Holotype.

Type.—Holotype, the specimen from Glasgow figured by J. de C. Sowerby in the 'Mineral Conchology of Great Britain,' is preserved in the British Museum [B.44118], Sowerby Coll.

Distribution.—Range, D_2 subzone to Millstone Grit.

England.

A form resembling *P. costatus,* but having a shallower sinus and less prominent costae, occurs in the Thornbrough Limestone of Northumberland. No specimen, however, from England has been found to be identical with the type, although shells referred to this species have been recorded from many localities.

Scotland.

Ayrshire: Diamond-bore, 10 feet from top of top limestone, $\frac{1}{8}$ mile N.N.W. of South Gailes, near Troon (Geol. Surv., Edinburgh).

Renfrewshire: Upper Limestones, Orchard, near Glasgow (B.M., B.5759, B.5761, B.13812, Davidson Coll.; R. Scot. Mus., Edinburgh, 1911.62.955); Orchard, Pollokshaws (Hunterian Mus., Glasgow, L.221; Kelvingrove Mus., Glasgow, 01·53 afg and afe, figd. Davidson, 1880, pl. xxxvi, figs. 18, 19); Barrhead (B.M., B.5760, Davidson Coll.); Waukmill Glen, 1 mile S.E. of Barrhead (Kelvingrove Mus., Glasgow, 01·53 afi); Upper Limestones, Thornliebank (B.M., B.157; R. Scot. Mus., Edinburgh, 1911.62.955; Kelvingrove Mus., Glasgow); Arden, Thornliebank (Hunterian Mus., Glasgow, L.219, 220).

Stirlingshire: Campsie (B.M., B.5760, Davidson Coll.).

Remarks.—Productus costatus is distinguished from *P. sulcatus* J. Sow. by the sharper geniculation between the visceral disk and trail of the pedicle valve, flatter visceral disk, shorter trail, and deeper, more angular sinus; also by the greater convergence of costae on the front of the pedicle valve.

Sowerby's specimen is imperfect and lacks the large ears characteristic of this species. It is also slightly decorticated and the costae appear more rounded and less prominent than in well preserved specimens.

Davidson failed to distinguish this species from *P. sulcatus* and greatly exaggerated the resemblance in his drawings.

Other authors such as Phillips (1836, p. 213) and von Buch (1842, p. 33) also failed to distinguish between the two species *P. costatus* and *P. sulcatus*, and regarded them as synonymous.

The specimens of *P. costatus* figured by de Koninck in 1847B, pl. x, figs. 3c, d, from Sloboda, Russia, appear from the figures to be similar in ornament, but the sinus is less wide and the pedicle valve appears to be less convex. Sowerby's drawings in 'Mineral Conchology' are reproduced on pl. x, figs. 3a, b.

Tolmatchoff in 1924 (p. 230) referred some of de Koninck's figures of *P. costatus* (1842—44, pl. viii bis, fig. 3) to a new species *P. robustus*, which is described in Russian and not figured, and its relation to *P. costatus* is uncertain.

De Verneuil in 1845 (pl. xv, figs. 13a, b) also figured a specimen from Russia as *P. costatus.* It resembles the type in costation and in the development of a deep sinus, but the outline of the shell is less laterally extended, the ears are smaller and the visceral disk narrower.

The specimen figured as *Productus costatus* by Fischer de Waldheim in 1830 (pl. xxvi, fig. 2), and referred to in 1837 as *Leptaena costata*, resembles a *Spirifer* and is quite distinct from Sowerby's species.

The specimen identified by Davidson in 1862 (pl. i, figs. 20, 21) from India as *P. costatus* was described by Waagen in 1884 (p. 687) as a new species, *P. indicus*. It differs from *P. costatus* in its greater size, squarer outline, and coarser costation.

Etheridge in 1878 (p. 631) recorded this species as occurring very commonly in the Arctic Regions, but did not give any figure.

The specimen of *P. costatus* figured by Toula in 1875B (pl. ii, figs. 9a—c) from Barents Island is a small form with a deep, angular sinus, and two rows of spine-bases along the cardinal slopes parallel to the hinge, and is unlike any British species.

Neumayr figured a specimen from Tournai, Belgium, as *P.* cf. *costatus* in 1883 (pl. i, figs. 2a, b). This specimen resembles *P. muricatus* in size and shows the internal cast of the brachial valve with muscle-scars and brachial impressions. An enlarged view of one brachial impression shows horizontal markings of transverse cirri across the closed part of the impression. These would correspond to incisions seen in the brachial impressions of many specimens.

American authors figure as *P. costatus* specimens which are quite readily distinguished from Sowerby's species. Thus, the *P. costatus*, var., of Hall (1858, pl. xxviii, figs. 3a, b, 4a—c) differs from the typical form in the absence of a deep sinus and of the ridge up the flanks, and has less prominent costae. The specimens figured by Meek in 1872 (pl. vi, figs. 6a, b) and by Keyes in 1894 (pl. xxxvi, figs. 1a—c) from N. America resemble *P. muricatus* Phill. in costation and in the development of a large number of spine-bases springing from the summit of the costae.

Beede's specimen of *P. costatus* from the Coal Measures and Permian of N. America and figured in 1900 (pl. x, figs. 1a, b; pl. ix, fig. 8) is nearer to *P. sulcatus* J. Sow., and has very similar ornament on the visceral disk.

Productus sulcatus J. Sowerby.

Plate X, figs. 4, 5a, b, 6, 7a—c. Text-fig. 26.

1821. *Productus antiquatus* J. Sowerby (in part). Mineral Conchology of Great Britain, vol. iv, p. 15, pl. cccxvii, fig. 1.

1822. *Productus sulcatus* J. Sowerby. *Ibid.*, vol. iv, p. 17, pl. cccxix, fig. 2.

1836. *Producta costata* (*et sulcata*) J. Phillips. Illustrations of the Geology of Yorkshire, part ii, p. 213, pl. vii, fig. 2.

1861. *Productus costatus* T. Davidson (in part). Mon. Brit. Foss. Brach., vol. ii, part v, No. 4, p. 152, pl. xxxii, figs. 3, 4, 6, 6a, 7.

1911. *Productus sulcatus* A. Vaughan, in E. E. L. Dixon and A. Vaughan. The Carboniferous Succession in Gower (Glamorganshire), with Notes on its Fauna and Conditions of Deposition, *Quart. Journ. Geol. Soc.*, vol. lxvii, p. 559, pl. xli, figs. 1a, 1b.

TEXT-FIG. 26.—*Productus sulcatus* J. Sowerby, from Hull Pot Beck, Horton, Yorkshire. British Museum, B.45689. Diagrammatic longitudinal section, natural size.

Diagnosis.—Shell about 40 mm. high, 47 mm. wide, and 27 mm. thick, or 1 : 1·1 : ·6; quadrate in outline, hinge forming widest part. Pedicle valve short, highly arched, geniculated, with long curved trail; flanks subparallel, with angular ridge; venter flat or sinuated; umbonal angle 110°; ears large. Brachial valve geniculated, visceral disk slightly concave. Costae about 8 in 10 mm. at distance of 20 mm. from umbo, coarse and rounded. Ribs continuous round front of visceral disk. Spine-bases in row on ridge on flanks; and a second row on cardinal slopes at angle of 3° to hinge.

Description.—Pedicle valve. The shell is slightly convex for a space of about 5 mm. from the umbo. A broad and shallow sinus is then developed and increases slightly in depth below the visceral disk, but becomes shallow and extremely narrow on the anterior part of the trail. In early growth-stages the width of the shell is in excess of the length, but the length increases so as to equal the width until, with the development of the large convex ears in the ephebic stage, the width again exceeds the length of the valve. Elongation of the shell and the development of a trail occurs in the gerontic stage. The flanks are steep and bear a prominent angular ridge which arises about 20 mm. from the umbo, becoming wider and more rounded anteriorly. The wearing-down of this ridge causes an apparent flattening of the flanks. A deep sulcus, along which the shell tends to fracture, separates the ridge from the ears. The umbo is large, rounded and much incurved, and projects for a considerable distance beyond the hinge.

The costae are narrow and prominent on the visceral disk, but become coarse and rounded on the trail. Bifurcation of the costae rarely occurs, except on the flanks and on the anterior part of the trail, but intercalations are rather numerous on the visceral disk. The two costae occupying the centre of the median sinus remain unthickened and usually converge and disappear about half way down the trail. The costae bordering the sinus also converge. The sulci separating the costae are about half the width of the costae, except on decorticated parts of the shell, where there is a decrease in the width of the costae with a corresponding increase in width of the sulci.

About twenty ribs are developed as narrow angular folds on the cardinal slopes, and these increase in width and become more rounded on the front of the shell, where prominent nodular swellings mark the point of intersection of ribs and costae. Bifurcation of the ribs may occur on the lateral slopes of the visceral disk, and intercalated ribs may arise in the same region.

A row of spine-bases increasing in diameter from ·5 mm. to 2·5 mm. extends from the hinge down the flanks. The posterior two or three spine-bases arise from the cardinal slopes near the umbo, and five or six spine-bases spring from the rounded ridge, while the anterior spines of this series arise from the hollow in front of the ridge. A second row is seen on the cardinal slopes near the hinge and diverging from it at an angle of about 3°. Spine-bases are rarely developed on the trail, where they spring from the summit of the costae, and they may also occur on the visceral disk, arising from the nodular enlargements of the costae.

Brachial valve. The visceral disk is slightly concave, and is separated by a low ridge from the triangular, nearly flat portion along the cardinal slopes and ears. The shell is geniculated at an angle of 120° at the anterior end of the visceral disk, and the trail is in contact with that of the pedicle valve.

The ornament is similar to that of the pedicle valve, but the sulci are considerably wider than the costae, and the ribs are prominent and well defined. A row of circular pits on the brachial valve corresponds with the row of spines on the cardinal slopes of the pedicle valve.

Internal characters. Unknown.

Dimensions.—

	(1)	(2)	(3)	(4)	
Maximum height	38	38	41	44	mm.
,, width	45	45·5	49	47	,,
,, thickness ...	28·5	25	27	27·5	,,
Length of hinge	45	48	49	47	,,
,, ,, visceral disk ...	18	18	21	20·5	,,
Width ,, ,, ,, ...	29	28	28	28	,,
Number of costae in breadth of 10 mm. at distances vertically below umbo :					
at 20 mm.	8	9	8	9	
,, 25 ,, ...	—	6	—	—	
Total number of costae at anterior margin ...	24	25	28	26	

(1) Holotype.

(2) B.M., B.13808, from Richmond, Yorkshire.

(3) B.M., B.43727, from Narrowdale, Staffordshire.

(4) B.M., 47271, from Preston, Lancashire.

Type.—Holotype, the specimen from Derbyshire figured by J. Sowerby in 'Mineral Conchology of Great Britain,' is preserved in the British Museum [43382], Sowerby Coll.

Distribution.—Range, D_2 subzone and Yoredalian.

England.

Derbyshire : (B.M., 43382, Sowerby Coll.); pit in white limestone just above first Toadstone, 100 yards N.W. of Ash Plantation, Wensley and Snitterton, (Geol. Surv., London, C.B.W.1137); Shining Cliff, immediately above Cliff House, Matlock Dale (Geol. Surv., London, C.B.W.973); N.E. slope of Chrome Hill, near Hindlow, subzone D_2 (Geol. Surv., London, I.T.832); quarry, N. of Great Longstone, subzone D_3 (Bristol Univ.); Castleton (Prof. Hawkins, 704); Hope Dale (Mr. J. W. Jackson); Mich Low, near Bradwell (Mr. J. W. Jackson).

Lancashire : Preston (B.M., 47271); Ulverston (R. Scot. Mus., Edinburgh); Gleaston, Furness (Prof. E. J. Garwood).

Staffordshire : Narrowdale, subzone D_2 (B.M., B.43726—43727; M.P.G., 26683—26686); N.W. of Narrowdale Hill (Mr. J. W. Jackson).

Westmorland : Sellet Mill, subzone D_2 (Prof. E. J. Garwood).

Yorkshire : Richmond (B.M., B.13808, Davidson Coll.; M.P.G., 34363, 34364, 34366, 34367; Kelvingrove Mus., Glasgow); Hill Stebden and Keale Hill, Cracoe, subzone D_2 (B.M., B.43746, B.43747, W. Hind Coll.); Great Scar Limestone, Burtensett, Hawes (M.P.G., 38328); grey limestone, Dowgill, 2 miles N.E. of Horton-in-Ribblesdale (Geol. Surv., London, Rh.2344, 2346); Browgill, 4 miles N. of Horton-in-Ribblesdale (Geol. Surv., London, Rh.2399); *P. giganteus* bed, above Hull Pot, near Horton, and from same bed below waterfall, Cow Gill, Bordley, E. of Malham (Prof. E. J. Garwood); Hunt Pot, near Horton (Prof. E. J. Garwood); *Lonsdalia* bed, Gauber, High Pasture, N. end of Ingleborough, and same bed from Cam Scar, above Kettlewell, Wharfedale (Prof. E. J. Garwood); Hardraw Scar Limestone, cliff on left bank of Cow Gill, and same bed from 800 hill, near Brunton House, S.E. of Ranes Lane, Feizor, N.W. of Settle (Prof. E. J. Garwood); limestone below Hardraw Scar Limestone, Fairweather Spring, N. end of Ingleborough (Prof. E. J. Garwood); Bryozoa-bed, Overclose, at Cowside Fault, and same bed at Langcliffe Scar, Settle (Prof. E. J. Garwood); *Girvanella*-bed, S. end of Grizedales Scar, Settle (Prof. E. J. Garwood); Malham, knoll reefs, subzone D_2 (Prof. E. J. Garwood); Lower Stockdale Beck, gorge above Scaleber, E. of Settle (Prof. E. J. Garwood); blue limestone above *P. giganteus* bed, Mill Gill, Askrigg, Wensleydale (Mr. R. G. S. Hudson, 169); beds above *P. giganteus* bed, old level, R. Barn (Mr. R. G. S. Hudson, 516); Gayle Shale, Grange Gill, near Askrigg, subzone D_2 (Mr. R. G. S. Hudson); top of Gayle Limestone, quarry above Countersett, Semerdale (Mr. R. G. S. Hudson, 652); and same bed, Hunger Hill Sike, Wensleydale (Mr. R. G. S. Hudson, 401).

Wales.

Carmarthenshire : Ragwen Point, Pendine, subzone D_2—D_3 (Bristol Univ.).

Carnarvonshire : Bishop's Quarry, S.W. of summit of Great Orme's Head, subzone D_2 (Dr. L. B. Smyth; Bristol Univ.).

Denbighshire : Upper Grey Limestone, Bog Mine, Llanarmon (B.M., B.23868, Morton Coll.).

Flintshire : Axton (B.M., B.23701, Morton Coll.).

Glamorganshire: Castle, Mumbles, subzone D_2 (M.P.G., 34368—34373; Hunterian Mus., Glasgow, L.336); Oystermouth Quarry, Gower, subzone D_2—D_3 (Bristol Univ.).

Ireland.

Co. Tyrone: Dungannon (M.P.G., 7767).

Remarks.—Productus sulcatus is distinguished from *P. costatus* J. de C. Sow. by its more convex visceral disk, longer trail, less sharp geniculation of the pedicle valve, and narrower, less prominent costae and shallower sinus. It differs from *P. antiquatus* J. Sow. in its shorter visceral disk, coarser costae, and in the development of the prominent ridge on the flanks.

The specimen figured by Sowerby is much decorticated, and does not show the typical ribbing and nodular enlargements of the costae on the visceral disk. The ridges on the flanks are also considerably worn, and spine-bases are not apparent, as stated by Sowerby in his definition of this species. One specimen figured by J. Sowerby as *P. antiquatus* in 'Mineral Conchology,' vol. iv, pl. cccxvii, fig. 1, is the posterior part of *P. sulcatus*, showing the characteristic ornament and the beginning of the angular ridge on the flanks.

The specimens figured by Davidson (1861B, pl. xxxii, figs. 3, 4) as *P. costatus* from Richmond, Yorkshire, are indistinguishable from the Derbyshire type, but the specimen figured in 1860 (pl. iii, figs. 6, 6a) as *P. semireticulatus*, var *sulcatus*, from Carluke, is smaller, more finely costate, and has fewer and narrower ribs. This form is now described as *P. insculptus* sp. nov. (see page 89).

In 1836 Phillips figured a typical specimen of *P. sulcatus*, as *P. costata et sulcata*, while M'Coy described *P. sulcatus* as a distinct species in 1844 (p. 116) but assumed it to be a variety of *P. flemingi* J. Sow. (1851—55, p. 461). De Koninck (1847B, p. 87) on the other hand distinguished *P. sulcatus* from *P. costatus* J. Sow., but considered it to be a variety of *P. semireticulatus* (Martin); and Deshayes (1832, p. 848) described *P. sulcatus* as *Productus* silloné, but the relationship of this form to Sowerby's species is uncertain.

Quenstedt in 1868 (pl. lviii, fig. 38) figured a specimen from Visé, which resembles the typical *P. sulcatus*, but Fischer de Waldheim's specimen figured in 1830 (pl. xxii, fig. 2) as *Leptaena sulcata*, and later in 1837 as *Terebratula sulcata*, does not seem to be a *Productus*.

The American authors Marcou (1858, pl. v, fig. 5) and de Castelnau (1843, pl. xiii, fig. 7) figured specimens of *P. sulcatus,* that figured by Marcou resembling the typical form in ornament. De Castelnau's specimen appears to be a *Leptaena.*

The specimen figured by Hughes in 1908 (pl. xxxix, fig. 3) from the lower '*giganteus*' zone, Hull Pot, Horton, as *P. costatus* does not belong either to that species or to *P. sulcatus,* but is a broader, more massive shell which should probably be identified as *P. pinguis* sp. nov.

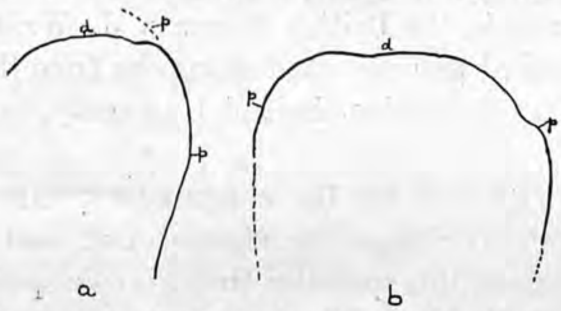
A supposed variety of this species, *P. sulcatus,* var. *borealis,* was figured by Haughton (1858, pl. vii, figs. 1—4, 7) and Whitfield (1908, pl. i) from the Arctic Regions, but these specimens are distinguished from *P. sulcatus* by the greater width of the shell and the coarser costae and deeper sinus, and appear to resemble *P. pinguis* sp. nov.

Specimens from the Redesdale Ironstone Shale and from the Lower Limestones of Scotland are frequently referred to as *P. sulcatus.* They are, however, distinct from this species and from *P. insculptus* sp. nov. (p. 89), although certain characters are common to both forms. The prominent ridge on the flanks is never developed, the sinus is very narrow, and the costae are coarse, with rather numerous spine-bases. These shells may belong to an early mutation of *P. costatus* J. de C. Sowerby.

PRODUCTUS FLEXISTRIUS M'Coy.

Text-fig. 27.

1844. *Producta flexistria* F. M'Coy. A Synopsis of the Characters of the Carboniferous Limestone Fossils of Ireland, p. 109, pl. xx, fig. 16.



TEXT-FIG. 27.—*Productus flexistrius* M'Coy. Holotype, from Millicent, Clane, Co. Kildare, Ireland. National Museum of Ireland, Dublin. Profiles, natural size: a, side view, showing visceral area of brachial valve and trail of pedicle valve; b, the same, front view. On the figures, d = brachial valve, p = pedicle valve.

Type.—Holotype, the unique specimen figured by M'Coy in 1844 from the Lower Carboniferous, Millicent, Clane, Co. Kildare, is preserved in the National Museum of Ireland, Dublin. A plaster cast of this specimen is preserved in the British Museum [B.41871].

Remarks.—Owing to the lack of available Irish Carboniferous material, and also to the poor state of preservation of M'Coy's specimen, it is not possible to give a diagnosis or a detailed description of this species.

In M'Coy's specimen the posterior portion of the pedicle valve has split off, leaving the visceral disk of the brachial valve in contact with the trail of the pedicle valve. The ribs on the visceral disk of the brachial valve are well defined and the costae on the trail of the pedicle valve are moderately coarse and rather irregular. The distinguishing character of this species appears to be in the development of rather prominent, semicircularly curved folds on the flanks, posterior to which, immediately below the cardinal angles, the costae appear to be lacking, or less prominent. The arrangement of the spines is unknown. The dimensions of M'Coy's specimen are: height, 27·5 mm.; width, 34·5 mm.; thickness, 22·5 mm.; and there are fourteen costae in the breadth of 10 mm. on the venter.

M'Coy considered *P. flexistrius* to be most closely allied to *P. sulcatus* J. Sow.

In 1862 (p. 231) Sir Richard Griffith, in his Appendix to M'Coy's 'Carboniferous Limestone Fossils of Ireland,' quoted *P. flexistrius* from the Lower Carboniferous of St. Doolagh's, Dublin, and from Millicent, Clane, Kildare, and Little Island, Cork. All these localities are probably in either the Z or C zone.

Examples of this species are preserved in the Hunterian Museum, Glasgow, from Ireland [L.1160] and in the British Museum, J. Wright Coll., from Cork, Ireland [B.40240]. Crushed and distorted specimens from the Calp, Belleek, Sligo, preserved in the Vaughan Collection, Bristol University, may also be referred to *P. flexistrius*.

De Koninck in 1847B (pl. xvii, figs 1a—c) figured a specimen from Visé, Belgium, as *P. flexistrius*, but it lacks ribs on the visceral disk and M'Coy in 1851—55 remarked on the differences of this specimen from his own species.

Davidson (1861B, p. 149) assumed *P. flexistrius* to be identical with *P. semireticulatus* (Martin), while Hall in 1858 (p. 676) compared it with his species *P. tenuicostatus*, stating, however, that the latter is more finely costate and has spines developed on the anterior part of the shell.

In 1915B (p. 56) Girty suggested that the species *Diaphragmus fasciculatus* (McChesney) is synonymous with *Productus flexistrius* M'Coy, 'from which it differs in being much less inflated over the ears and toward the beak, and in the striae uniting into fascicles toward the front.' It is uncertain if a diaphragm is developed in *P. flexistrius*, while this structure is characteristic of *D. fasciculatus*.

PRODUCTUS SPINOSUS J. Sowerby.

1814. *Productus spinosus* J. Sowerby. Mineral Conchology of Great Britain, vol. i, p. 157, pl. lxix, fig. 2.

1861. *Productus longispinus,* var. *P. spinosus* T. Davidson. Mon. Brit. Foss. Brach., vol. ii, p. 155, pl. xxxv, figs. 17a, b.

Type.—Holotype, the specimen from Linlithgowshire figured by Sowerby in 'Mineral Conchology of Great Britain,' is not preserved in the Fleming Collection, Royal Scottish Museum, Edinburgh, and is apparently lost.

Remarks.—As no specimen so far examined has been found to agree with Sowerby's drawing of *P. spinosus,* no diagnosis or description can be given of this species.

Sowerby described *P. spinosus* as being similar to *Conch. Anomites productus,* of which it may be a variety, 'the spines, however, being more prominent and the hinge shorter.' From the figure, *P. spinosus* seems to be most closely related to *P. carbonarius* de Kon., but only the posterior portion is preserved; the costae appear to be coarser, and the spines larger and more prominent than in *P. carbonarius.*

Eight specimens preserved in the Fleming Collection, Royal Scottish Museum, Edinburgh, and labelled *P. spinosus* var., include a number of spinose forms, now identified as *P. pugilis* Phill., *P. muricatus* Phill., *P. setosus* Phill., and *P. longispinus* J. Sow.

References to *P. spinosus* were made by M'Coy, who described it as a distinct species (1844, p. 115), and by Davidson in 1861B (pl. xxxv, figs. 17a, b), who examined the type-specimen and figured it as a variety of *P. longispinus.* The specimen from Russia figured by Kutorga (1842, pl. v, fig. 2) is a very spinose form and resembles *P. spinulosus* J. Sow.

Dr. Lee (1909, p. 169, pl. ii, fig. 32) figured and described a specimen from Nowaja Semlya as *P. longispinus*, ? var., and stated that it resembled *P. spinosus*. This specimen is much decorticated, and it appears to be smaller and to have coarser costae than *P. spinosus*.

B. Species of the Group of *Productus longispinus*.

This group includes numerous forms, usually of small size, which are linked together by the possession of a similar spine-arrangement. Six spines of slightly larger diameter than the rest, and referred to as the major spines, are symmetrically placed on the pedicle valve in mature specimens. Two spine-bases are seen on the front of the shell below the visceral disk, and set one on each side of the sinus, if developed. One spine-base is set on each flank below the visceral disk, but not on the same level as those on the front. The remaining two spine-bases are seen, one on each ear near the cardinal extremities. Other spines of smaller size may be also symmetrically placed on similar parts of the pedicle valve nearer the umbo. Enormous variation may be shown in size, shape, and ornament, but the spine-arrangement seems to be constant.

The external lamellose thickening round the anterior and lateral margins of the brachial valve, and the internal marginal ridges, are developed to a greater or lesser extent in all the members of the *longispinus* group.

The relationship of the members of the group is very uncertain. Many shells which are distinguished by separate specific names may prove to be only varieties of a single species, while other forms which have been classed together may prove to have had a different ancestry.

PRODUCTUS LONGISPINUS J. Sowerby.

Plate XI, figs. 1, 2a, b, 3, 4. Text-fig. 28.

1814. *Productus longispinus* J. Sowerby. Mineral Conchology of Great Britain, vol. i, p. 154, pl. lxviii, fig. 1.

1860. *Productus longispinus* T. Davidson (in part). The Carboniferous System in Scotland characterized by its Brachiopoda, *The Geologist*, vol. iii, p. 110, pl. ii, fig. 12.

1861. *Productus longispinus* T. Davidson (in part). Mon. Brit. Foss. Brach., vol. ii, part v, No. 4, p. 154, pl. xxxv, fig. 5.

TEXT-FIG. 28.—*Productus longispinus* J. Sowerby. Carluke, Lanarkshire. British Museum, B.45688. Diagrammatic longitudinal section, natural size.

Diagnosis.—Shell about 13 mm. high, 13 mm. wide, and 8 mm. thick, or 1 : 1 : ·6; quadrate in outline, maximum width along hinge. Pedicle valve geniculated, with convex visceral disk and curved trail; flanks steep and slightly convex; venter flat; umbonal angle 102°; ears well demarcated from visceral disk. Brachial valve geniculated, visceral disk nearly flat. Costae about 26 in 10 mm. at distance of 10 mm. from umbo, fine and not prominent. Ribs few, crossing visceral disk. Spine-bases rare except major spines.

Description.—Pedicle valve. The visceral disk is slightly flattened for 3 mm. or 4 mm. immediately below the umbo, then becomes arched and geniculated at its anterior extension, with the formation of a short convex trail. The flanks, which are steep and subparallel, slope up to the flattened or slightly sinuated venter; the sinus, which is developed in rare instances, is always shallow and disappears about half way down the trail. The ears are triangular in outline, with the lateral margin abruptly truncated, and are cylindrically curved along an axis parallel to the hinge. A broad sulcus extending from the postero-lateral margin of the shell at an angle of 45° to the hinge separates the ears from the visceral disk and flanks. This sulcus decreases in width and dies out about 1 mm. from the hinge-margin.

The costae are fine and thread-like on the visceral disk, and increase slightly in width on the trail, but are never prominent and may disappear on the flanks and anterior part of the trail. Some irregularity in the width of the costae may occur on the trail, and in specimens having a median sinus the costae tend to become closely crowded on the front of the shell, but do not converge. The costae increase by means of bifurcations which take place principally anterior to the spine-bases, while thickening of one costa, or coalescence of two costae, may occur posteriorly to a spine-base. The sulci are always narrower than the costae.

About ten ribs are developed as low, narrow folds which cross the front of the visceral disk, but do not cause any enlargement of the costae at the point of intersection. Ribs are omitted in Sowerby's figure of the type, although they are quite distinguishable in the specimen.

Spine-bases are rarely developed, except those belonging to the six major spines. A narrow longitudinal fold is frequently developed below the two major spine-bases on the flanks. Spines not exceeding 10 mm. in length are sometimes preserved.

Brachial valve. The visceral disk is nearly flat posteriorly, then becomes increasingly concave, and is finally geniculated at its base, when the two valves are practically in contact. The ears are separated from the visceral disk by a transverse ridge, corresponding in position to the sulcus in the pedicle valve.

The ornament is similar to that of the pedicle valve.

Internal characters. The interior of the pedicle valve is unknown.

In the interior of the brachial valve the cardinal process is bifid and rather prominent, and is continued anteriorly as a short, narrow median septum, which decreases in width and is not enlarged at its extremity.

The marginal ridges diverge slightly from the hinge-margin and slope across to the postero-lateral margin of the shell, where they are sharply bent downwards, and continue along the margin for about half the length of the valve.

The adductor muscle-scars are triangular in outline and are distinctly divided into two lobes. The brachial impressions are given off from the antero-lateral lobe of the adductors and extend horizontally for 2 mm. or 3 mm. and then curve downwards and inwards towards the median septum. The extremity of each impression is enlarged and distinctly separated from the remainder.

Dimensions.—

	(1)	(2)	(3)	(4)	
Maximum height	10	12	13·5	15·5	mm.
,, width	13	13	12·5	15·5	,,
,, thickness ...	7	7·5	9	9·5	,,
Length of hinge	13	—	—	—	,,
Number of costae in breadth of 10 mm. at distances vertically below umbo :					
at 5 mm.	26	26	—	—	
,, 10 ,, ...	26	25	26	27	

(1) Holotype.

(2) R. Scot. Mus., Edinburgh, Neilson Coll., 32, from the Lower Limestones, Cunningham-Baidland, Ayrshire.

(3) Same coll., 35, from the Lower Limestones, Beith, Ayrshire.

(4) B.M., B.1476, from the Lower Limestones, Corrieburn, Stirlingshire.

Type.—Holotype, the specimen from Linlithgowshire, Scotland, figured by Sowerby in 'Mineral Conchology of Great Britain,' is preserved in the Royal Scottish Museum, Edinburgh, Fleming Collection [1870.14.226].

Distribution.—Range, D_2 and D_3 subzones, and Yoredalian.

England.

Derbyshire: Lower Middleton Quarry, subzone D_3 (M.P.G., 34405—34407).

Northumberland: Scremerston (B.M., B.43723—25); lower part of Eight-Yard Limestone, old quarry, between Dunstan Square and Dunstan Steads, subzone D_2—D_3 (Geol. Surv., London, J.R.910).

Yorkshire: Botany Beds, Botany, Hunderthwaite Moor, subzone D_3 (Prof. E. J. Garwood); Main Limestone, Whernside, subzone D_3 (Prof. E. J. Garwood).

Wales.

Denbighshire: Cefn-y-Fedw Sandstone, Tyfyn-uchaf, Ruabon (B.M., B.24057).

Flintshire: Upper Black Limestone, Pentre Halkin, Holywell (B.M., B.23993); arenaceous limestone, Mold (B.M., B.24022).

Scotland.

Ayrshire: Lower Limestones, Cunningham-Baidland, Dalry (B.M., B.5746, B.45515, Davidson Coll.; R. Scot. Mus., Edinburgh, Neilson Coll, 32; Kelvingrove Mus., Glasgow, 01·53 aig); Auchenmade, near Dalry (R. Scot. Mus., Edinburgh, 48, Neilson Coll.); Lower Limestones, Beith (B.M., B.23572; R. Scot. Mus., Edinburgh, 35, 43, 57); Lower Limestones, Broadstone, Beith (R. Scot. Mus., Edinburgh, 39); Lower Limestones, Trearne, Beith (R. Scot. Mus., Edinburgh, 49); Blackbyre Limestone, Lower Limestones, Dockra, Beith (Kelvingrove Mus., Glasgow, 01·53 aii); railway-cutting, Waterland, near Lugton Inn (Geol. Surv., Edinburgh, B.438A); 50 yards down stream from weir, ½ mile N.E. of Kilmaurs (Geol. Surv., Edinburgh, T.3029E).

Edinburghshire: Lower Limestones, Crichton Quarry, near Pathhead (Geol. Surv., Edinburgh, B.940); Lower Limestones, shale in No. 2 Limestone, Mount

Lothian Quarry, near Penicuik (Geol. Surv., Edinburgh, B.1466c); shale above No. 1 Limestone, Hillhead Quarry, N. of Cockmuir Bridge (Geol. Surv., Edinburgh, B.1474c); No. 1 Limestone, No. 1 Quarry, right bank of Tyne, Currilee (Geol. Surv., Edinburgh, B.4519B).

Fifeshire: Shale above ?No. 1 Limestone, Bogie Quarry, 2 miles N.W. of Kirkcaldy (Geol. Surv., Edinburgh, B.3208D).

Lanarkshire: Brockley, Lesmahagow (Kelvingrove Mus., Glasgow, 96·65 ikc; Hunterian Mus., Glasgow, L.227); Lower Limestones, white shelly limestone, bank of Poniel Water, 290 yards up from Brackenside, Coalburn (Geol. Surv., Edinburgh, M.4506F); Lower Limestone, white shelly limestone, cliff above Poniel Water, below Bankend Lime quarry (Geol. Surv., Edinburgh, M.4616G).

Linlithgowshire: Lower Limestones, shale below Bathgate Limestone, Petershill Quarry, 1 mile N.E. of Bathgate (Geol. Surv., Edinburgh, B.3591B).

Renfrewshire: N.W. corner of Balgray Reservoir, near Auchenbeck railway-bridge cutting (Geol. Surv., Edinburgh, T.2298B).

Stirlingshire: Lower Limestones, Corrieburn, Kilsyth (B.M., B.1476; Hunterian Mus., Glasgow, L.229); Blackbyre Limestone, Corrieburn, Campsie (Kelvingrove Mus., Glasgow, 01·53 aie).

Remarks.—Productus longispinus is distinguished from *P. setosus* Phill. and *P. tissingtonensis* Sibly by its steeper, more flattened flanks, absence of any median ridge or V-shaped extension of the trail of the pedicle valve, and by its very fine costae and ill defined ribs. The interior of the brachial valve of *P. longispinus* differs from that of *P. setosus* Phill. in the less prominent and shorter marginal ridges, which are never transversely plicated, and in having a narrower median septum. *P. longispinus* differs from *P. derbiensis* sp. nov. (p. 170) in its smaller dimensions, smaller ears, finer costation and less numerous ribs. The symmetrical arrangement of the spines distinguishes *P. longispinus* from *P. rotundus* Garwood and *P. muricatus* Phill.

Sowerby's specimen from Linlithgowshire is preserved as a natural cast in a soft, brownish matrix, and the mode of preservation is similar to that of specimens from the Lower Limestones, Cunningham-Baidland, Dalry, Ayrshire, where examples are found with very well preserved spines. Specimens from the latter locality were described by Armstrong and Young in 1871, who stated that *P. longispinus* occurred in crevices in the quarry-face, entirely weathered out of the matrix, and bearing spines which projected from the ventral valve for more than an inch.

The type-specimen, which is said by Sowerby to come from Linlithgowshire, may have been obtained from the Lower Limestones, Petershill Quarry, Bathgate, Linlithgowshire.

P. longispinus is characteristic of the Lower Limestones, but a shell resembling *P. longispinus* in ornament, and having a narrower and more triangular visceral disk and larger and more flattened ears, is found in the Upper Limestones, especially in the Arden Limestone.

Specimens of *P. longispinus* preserved in limestones are frequently larger and more massive and have slightly coarser costation than the type, which was obtained from an arenaceous deposit.

Davidson considered *P. setosus* Phill., *P. lobatus* Sow., *P. flemingi* Sow. and other species as varieties of *P. longispinus,* but the only figure given by Davidson that can be ascribed to *P. longispinus* (*sensu stricto*) is an enlarged drawing of Sowerby's specimen showing two long spines on the flanks. These spines are not seen in the specimen. The specimen figured by Davidson in 1865 (pl. xx, fig. 7) from the Upper Devonian Grits, top of Orchard Quarry, Pilton, Devonshire, as *P. longispinus,* is probably similar to specimens preserved in the British Museum, B.42596—98, Hamling Collection. These are moderately coarsely costate, but the costae are undeveloped near the umbo, as in the genus *Avonia.* The different spine-arrangement also readily distinguishes these Devonian specimens from any species of the *longispinus* group.

M'Coy (1851—55, p. 461) included *P. longispinus* and several other species as varieties of *P. flemingi* J. Sow., stating of *P. longispinus* that 'this variety passes to the *P. Flemingi* by getting the striae a little coarser, which again passes into the next . . .' [*P. lobatus*]. De Koninck (1842—44, p. 187) also described a number of species as *P. longispinus,* but no specimen figured can be referred to Sowerby's species.

P. longispinus has been recorded and figured by numerous authors from almost every country in which Carboniferous rocks have been found, but none of these specimens appears to be similar to the type.

Specimens of *P. longispinus* are said to come from the Lower Series of Coal Measures of Kent by Dr. Bolton (1915, p. 190); from Harelaw Hill quarry, Dumfriesshire, by Peach and Horne (1903, p. 849); and *P.* cf. *longispinus* from Ballycastle district, Ireland, by Dr. L. B. Smyth (1924, p. 111). No figure is given of any of these specimens, but the Ballycastle specimen is said to resemble that figured by Davidson in 1861B (pl. xxxv, fig. 7), which resembles *P. lobatus*.

Among specimens figured as *P. longispinus* from Germany may be mentioned that given by Roemer in 1863 (pl. xvi, figs. 1a, b) from Silesia, and resembling *P. carbonarius* de Kon.; and that given by Nebe (1911, pl. xiii, fig. 9) from the Culm of Hagen, which resembles *P. setosus* Phill.

Carpentier (1913, pl. v, fig. 4) figured a shell from Northern France which is larger and more strongly ribbed than the type; while the specimen from the Carnic Alps figured by Schellwien (1900, pl. vii, figs. 4—7) resembles *P. longispinus* in shape and outline, but is larger and has coarser costae and a less concave brachial valve.

Specimens from Russia were figured by Davidson (1859, pl. iii, fig. 6) and by Nikitin (1890, pl. i, figs. 7—14). Davidson's specimen resembles *P. muricatus* Phill., while those depicted by Nikitin include a variety of forms belonging to the *longispinus* group, but more allied to *P. setosus* Phill. than to *P. longispinus*. One specimen from the Moscovian of Mjatschkowa showed a crenulated marginiferal ridge on the exterior of the brachial valve, a character not seen in British species. Trautschold (1876, pl. xxxii, figs. 4a—e) also figured specimens from Mjatschkowa which resemble *P. setosus* Phill. in shape and ornament.

Among specimens from Asia figured as *P. longispinus* may be mentioned that of Gröber in 1908 (pl. xxv, figs. 3—5; pl. xxx, figs. 2, 3) from Tian Schan; those of Diener from the Himalayas (1899, pl. i, fig. 11); and those of Loczy from E. Asia (1897, pl. ii, figs. 9—12). Gröber's specimen shows a remarkable resemblance to *P. concinnus* Sow., while Loczy's and Diener's specimens, although belonging to the *longispinus* group, cannot be identified as *P. longispinus*. The forms from Eastern Asia resemble *P. praecursor* sp. nov. (p. 191), while the Indian specimens are nearer to *P. setosus*. In a later paper (1915, pl. xi, figs. 13a, b) Diener figured specimens showing a remarkable similarity to *P. derbiensis* sp. nov. (p. 170). A brachial valve of a large specimen from Queensland figured by Etheridge (1872, pl. xviii, fig. 9) also shows a marked resemblance to *P. derbiensis*.

P. longispinus was recorded by Wiman (1914, p. 67) from Brögger's Peninsula, Arctic Regions, and by Grönwall (1917, p. 579) from Andrups Land, Greenland. The latter author compared his specimens with those figured by Schellwien and Nikitin (mentioned above), none of which resembles *P. longispinus*. Decorticated specimens were also figured by Dr. Lee (1909, pl. ii, figs. 31, 32) from Nowaja Semlya, but are not identifiable.

American authors—Meek (1877), Meek and Worthen (1873), and White (1877), figured specimens as *P. longispinus* from N. America, none of which are identical with the type; they show a greater resemblance to *P. setosus* Phill. or *P. tissingtonensis* Sibly. Salter's specimen from Bolivia (1861, pl. iv, fig. 2) has an ornament similar to that of *P. lobatus* Sow., but the costae are slightly coarser and the spines more numerous than in Sowerby's species.

PRODUCTUS TRIQUETRUS sp. nov.[1]

Plates XI, figs. 7a—c; XII, figs. 18a—c.

Diagnosis.—Shell about 25 mm. high, 23 mm. wide, and 16 mm. thick, subquadrate to trigonal in outline, hinge forming widest part of shell. Pedicle valve with slightly convex visceral disk, geniculated to form curved trail which bears median fold anteriorly; flanks steep; venter sinuated; umbonal angle 112°; ears large, trigonal. Incision developed round front of shell immediately below visceral disk. Brachial valve geniculated, visceral disk slightly concave. Costae about 12 in 10 mm. at distance of 15 mm. from umbo, coarse and rather prominent. Ribs numerous, faintly traceable across front of visceral disk. Spine-bases rarely seen, except of the six major spines.

Description.—Pedicle valve. The visceral disk is flattened posteriorly, but it becomes moderately convex anteriorly, and is separated from the slightly curved trail by a rounded geniculation. The transverse section of the visceral disk is rectangular. The ears are large, triangular and flat, with acutely pointed cardinal extremities, and are separated from the visceral disk by a deep incision, which starts near the hinge and curves round the front of the pedicle valve. The ears appear to project at right angles from about the middle of the steep flanks, from which they are separated by a geniculation at an angle of 90°. The umbo is much incurved and projects slightly beyond the hinge. The venter is broad and a shallow sinus commences about half way down the visceral disk and flattens out on the trail. In the gerontic stage the median portion of the trail is arched to form a

[1] Latin *triquetrus*=triangular. Referring to outline of shell.

broad longitudinal fold, which extends slightly beyond the level of the remainder of the trail and is V-shaped at its anterior extension.

The costae are rather coarse and prominent and become flattened on the trail. Bifurcation occurs rather frequently, and the costae may become irregular and slightly flexuous, or two costae may unite to form one thickened costa. The sulci are slightly less wide than the costae.

About 16 ribs are faintly traceable round the front of the visceral disk, and the point of intersection of ribs and costae is marked by the development of nodular swellings.

Spine-bases are rare in addition to those of the six major spines.

Brachial valve. The visceral disk is slightly concave and is geniculated at its anterior extension to form the trail, which is in close contact with that of the pedicle valve.

The ornament is similar to that of the pedicle valve.

Internal characters. Unknown.

Dimensions.—

	(1)	(2)	(3)	
Maximum height	22·5	24	34	mm.
,, width	23·5	22·5	36	,,
,, thickness	16·5	15	19	,,
Length of hinge	23·5	22·5	36	,,
,, ,, visceral disk	13	12	18	,,
Width ,, ,, ,, ...	18	17	22·5	,,
Number of costae in breadth of 10 mm. at distances vertically below umbo :				
at 10 mm.	10	13	—	
,, 15 ,, ...	12	13	12	
,, 20 ,, ...	—	—	13	

(1) B.M., B.23707, from Axton, Flintshire.

(2) B.M., B.23544, from Derbyshire.

(3) Geol. Surv., London, 38395, from subzone D_2, near Underhill Farm, S.W. of Hitter Hill, Glutton, Derbyshire.

Types.—Holotype, from Carboniferous Limestone, S.W. slope of Park Hill, Derbyshire, subzone D_2, is preserved in the Museum of Practical Geology, London [38345]. Paratypes: a number of specimens referred to below in section 'Distribution.'

Distribution.—Range, D_2 subzone.

England.

Derbyshire: (B.M., B.23544); Chrome Hill (B.M., B.45858; M.P.G., 38344); S.W. slope of Park Hill (Geol. Surv., London, I.T.784); N.E. slope of Park Hill (Geol. Surv., London, I.T.836); Dovedale (Mr. J. W. Jackson); roadside, near Underhill Farm, S.W. of Hitter Hill (Geol. Surv., London, 38395, I.T.909).

Isle of Man: Poolvash Limestone, Poolvash (B.M., B.42029).

Staffordshire: Wetton (B.M., B.5806); Narrowdale (B.M., B.45853—66; M.P.G., 34388).

Yorkshire: Settle (Sedgwick Mus., Cambridge, 130); Hardraw Scar Limestone, Ingleborough (Prof. E. J. Garwood).

Wales.

Carnarvonshire: Escarpment, W.S.W. of Great Orme's Head (Prof. S. H. Reynolds).

Flintshire: Upper Grey Limestone, Axton (B.M., B.23707, Morton Coll.).

Remarks.—*Productus triquetrus* is distinguished from *P. derbiensis* sp. nov. (p. 170) by its flatter visceral disk, less curved trail, large flat ears, and arched front of trail in the gerontic stage; and by its coarser and more flattened costae. The absence of any shelly deposit round the anterior margin of the brachial valve distinguishes it from *P. setosus* Phill. and *P. tissingtonensis* Sibly.

P. triquetrus is remarkable for the curious incision developed round the front of the pedicle valve just below the visceral disk. This causes slight discontinuity of the costae but does not affect the contour of the trail. A similar incision is seen in *P. minitus* sp. nov. (p. 195), and in *P. expansus* de Kon. (1842—44, pl. vii, figs. 4a, b). Dr. Girty (1915, p. 56) also figures and describes a similar 'cincture' in *Diaphragmus* = *Productus fasciculatus* McChesney. This, he states, is due to a thickened ring on the inside of the shell, probably corresponding to the diaphragm of the other valve. No interior of *P. triquetrus* has been observed, but it is possible that a diaphragm is developed, and this may account for the incision.

The specimens are normally of small size, but a 'giganteid' specimen is depicted in pl. xii, figs. 18a—c, in which the shell is twice the normal size; the ornament, however, is similar to that of typical examples.

PRODUCTUS TISSINGTONENSIS Sibly.

Plate XI, figs. 5, 8a, b, 9. Text-fig. 29.

1908. *Productus setosus* Phill., var. *tissingtonensis* T. F. Sibly. The Faunal Succession in the Carboniferous Limestone (Upper Avonian) of the Midland Area (North Derbyshire and North Staffordshire), *Quart. Journ. Geol. Soc.*, vol. lxiv, p. 77, pl. i, figs. 6a, b.

1911. *Productus* (*Marginifera*) *longispinus*, var. A. Vaughan in Dixon, E. E. L., and Vaughan, A., The Carboniferous Succession in Gower (Glamorganshire), with Notes on its Fauna and Conditions of Deposition, *Quart. Journ. Geol. Soc.*, vol. lxvii, p. 560, pl. xli, figs. 2a, b.

TEXT-FIG. 29.—*Productus tissingtonensis* Sibly. Lower Carboniferous, Halkin Mountain, Flintshire. British Museum, B.11601. Diagrammatic longitudinal section, natural size.

Diagnosis.—Shell about 14 mm. high, 16 mm. wide, and 9 mm. thick, quadrate in outline, hinge forming widest part of shell. Pedicle valve with short visceral disk, geniculated, forming short curved trail; flanks convex, venter depressed; umbonal angle 110°; ears large, tapering to cardinal extremities. Brachial valve slightly concave. Costae about 10 in 10 mm. at distance of 10 mm. below umbo, coarse and rounded; two median costae unite on trail to form prominent longitudinal fold, two costae bordering flanks thickened. Ribs numerous, faintly traceable across front of shell. Few spine-bases on visceral disk in addition to those of major spines.

Description.—*Pedicle valve.* The posterior 4 mm. of the valve are rather flat, but the shell becomes increasingly convex with the development of a rounded geniculation joining the visceral disk to the curved trail. The flanks slope gently and spread laterally at the anterior margin, and are separated from the large convex ears by a narrow sulcus which extends from the hinge at an angle of 45°, dying out at the posterior lateral margin. The venter is broad and flat, and the umbo rounded and incurved, the apex projecting for a short distance beyond the hinge.

The costae are moderately coarse and rounded on the visceral disk, and thicken on the trail, where they are very irregular in width. Increase in the number of costae occurs by means of bifurcations, which take place frequently on the visceral disk and are also seen on the flanks. In the gerontic stage the two median costae unite about half way down the trail, and form a prominent fold which increases in width and elevation towards the anterior margin. This fold is crossed by numerous growth-lines, but is not costate. The two costae bordering the flanks, one on each side of the median fold, are often thickened from about 10 mm. above the anterior margin, but never form prominent folds. These costae may bifurcate on the anterior part of the shell. The sulci are always narrower than the costae.

About 14 ribs are faintly traceable across the front of the visceral disk and are as wide as the costae. At the point of intersection of ribs and costae rather prominent rounded swellings are developed, giving the visceral disk a reticulated appearance.

A few small spine-bases may occur on the visceral disk in addition to those of the six major spines.

Brachial valve. The exterior is slightly concave, with a nearly flat zone along the ears. No geniculation is developed.

The ornament is similar to, but less prominent than, that of the pedicle valve, but ribs are developed over the whole valve.

The anterior and lateral margins are thickened by the deposition of successive thin shelly laminae parallel to the margin, in order to keep pace with the anterior growth of the trail of the pedicle valve. This deposit rarely exceeds 2 mm. in thickness.

Internal characters. Internal casts of the pedicle valve occur in the D_2—D_3 subzone of Port Eynon Bay, Gower, and show large diductor muscle-scars extending nearly to the anterior end of the visceral disk and enclosing narrow, elongated adductor muscle-scars. No trace of any marginal ridges was observed in this valve.

In the interior of the brachial valve (pl. xi, fig. 5) there is a small bifid cardinal process, from each side of which arises a low rounded ridge, diverging from the hinge-margin at an angle of about 15°, and dying out about 3 mm. from the cardinal process. A raised rim, about 1 mm. in width, starts just above the cardinal extremities and curves round each lateral margin, decreasing in width before it disappears on the anterior margin. The lateral margin of this ridge is vertical and crenulated, the crenulations being most marked on the posterior part of the ridge. They are not visible on the exterior of the valve.

The adductor muscle-scars are small and bilobed; they are separated by a very narrow median septum, which extends from the cardinal process for about half the length of the valve. The termination of the septum is enlarged and very prominent.

The brachial impressions are given off at the anterior end of the adductors between the two lobes. No transverse incisions cut the impressions, nor does the apex appear to be separated from the main portion. The specimens are, however, much thickened in this portion of the shell, probably masking this character.

Dimensions.—

	(1)	(2)	(3)	(4)	
Maximum height	13·5	13·5	14	16	mm.
„ width	16·5	16	16·5	18·5	„
„ thickness ...	8	8·5	10	9	„
Length of hinge	16·5	16	—	18·5	„
Number of costae in breadth of 10 mm. at distances vertically below umbo:					
at 5 mm.	11	11	12	11	
„ 10 „	10	10	10	10	

(1) B.M., B.11601, from the Upper Black Limestone, Pentre Halkin, Holywell, Flintshire.

(2) B.M., 30120, from black shale, Ulverston, Lancashire.

(3) B.M., B.42161, Sibly Coll., from subzone D_3, Tissington, near Ashbourne, Derbyshire.

(4) Lectotype.

Type.—Prof. Sibly figured two specimens from the D_3 subzone, Tissington, near Ashbourne, Derbyshire, in 1908. The specimen figured by him in pl. lxiv, fig. 6a, is chosen as lectotype, B.42160. Both specimens are preserved in the British Museum, B.42160, 42161.

Distribution.—Range, D_2 subzone to D_3 subzone.

England.

Derbyshire: Tissington, near Ashbourne, subzone D_3 (B.M., B.42160, B.42161, Sibly Coll., figd. 1908); Intake Quarry, 1,050 yards S.W. of Middleton Cross, subzone D_2 (Geol. Surv., London, J.M.304).

Lancashire: Black shale, Ulverston, subzone D_3 (B.M., 30120).

Shropshire: Oswestry (M.P.G., 38336—38341).

Yorkshire: Far House Shales, Settle (B.M., B.20463, B.45518); base of Hardraw Scar Limestone, above Far House Barn, Cam Beck, and same horizon from Mill Gill, subzone D_2 (Prof. E. J. Garwood); Hardraw Scar Limestone, Gauber High Pasture, N. end of Ingleborough, subzone D_2 (Prof. E. J. Garwood); Hardraw Shale, Mill Gill, Askrigg, Wensleydale, subzone D_2 (Mr. R. G. S. Hudson, 107); limestone below Hardraw Limestone, Fairweather Spring, N. end of Ingleborough, subzone D_2 (Prof. E. J. Garwood); Bryozoa Bed, E. of Waterfall, Moor Close Gill, subzone D_2 (Prof. E. J. Garwood).

Wales.

Carnarvonshire: Great Orme's Head (B.M., B.24078, B.43741—44, B.45542; M.P.G., 34411—16).

Denbighshire: Upper Grey Limestone, Bog Mine, Llanarmon (B.M., B.23875); Chirk, subzone D_2 (B.M., B.23817, Morton Coll.).

Flintshire: Upper Black Limestone, Pentre Halkin, Holywell (B.M., B.11601, B.23993); Mold (M.P.G., 38331—38335).

Glamorganshire: Oystermouth Quarry, Gower, subzone D_2—D_3 (Bristol Univ., figd. Dixon and Vaughan, 1911, pl. xli, fig. 2b; B.M., B.42245, figd. *ibid.*, pl. xli, fig. 2a); Port Eynon Bay, Gower (B.M., B.48913—25).

Ireland.

Co. Antrim: Main Limestone, North Star Colliery, Ballycastle (Bristol Univ.).

Remarks.—Productus tissingtonensis differs from *P. setosus* Phill. by its smaller dimensions; larger ears; more marked ribs; and coarser costae, which thicken to form a median longitudinal fold in the pedicle valve. The coarser costation and absence of a sinus in *P. tissingtonensis* distinguish it from *P. lobatus* Sow.

Prof. Sibly described this species from the D_3 subzone of Derbyshire, and stated that he considered it to be a variety of *P. setosus* Phill., and that the external ornament indicated convergence of *P. setosus* with forms of *P. costatus* which are characteristic of D_3.

Vaughan described a similar shell from the Oystermouth Quarry, Gower, subzone D_2—D_3. He was of the opinion that this form should be regarded as a variant of *P. longispinus,* and not of Phillips's *P. setosus.*

This species is characteristic of the D_2—D_3 subzones of England and Wales, and can be distinguished from *P. setosus* in the neanic as well as in the gerontic stage; and it cannot be regarded as a variety of *P. setosus* or *P. longispinus.*

The specimen figured as *P. lobatus* by Tschernyschew (1902, pl. lvii, figs 10, 11) from the *Omphalotrochus* horizon of the Russian Carboniferous, is very similar to *P. tissingtonensis* in shape and ornament.

PRODUCTUS DERBIENSIS sp. nov.

Plate XI, figs. 10, 11, 19a—c. Text fig. 30.

1842. *Productus longispinus* L. de Koninck (in part). Description des Animaux Fossiles qui se trouvent dans le Terrain Carbonifère de Belgique, p. 187, pl. xii bis, figs. 2a—d; pl. xiii, figs 11a, b.

1847. *Productus longispinus* L. de Koninck (in part). Monographie du genre *Productus, Mem. Soc. Roy. Sci.,* Liége, vol. iv, pl. x, figs. 2e, f.

1847. *Productus flemingi* L. de Koninck (in part). *Ibid.,* p. 196.

TEXT-FIG. 30.—*Productus derbiensis* sp. nov. Holotype from Carb. Limestone, Thorpe Cloud, Derbyshire. British Museum, B.43730. Diagrammatic longitudinal section, natural size.

Diagnosis.—Shell variable in size, oval in outline, length slightly greater than width, hinge forming widest part of shell. Pedicle valve with globose visceral disk, geniculated, with short curved trail; flanks steep and convex; venter highly arched; umbonal angle 115°; ears small. Brachial valve geniculated, visceral disk concave. Costae about 17 in 10 mm. at distance of 10 mm. from umbo, fine and rounded. Ribs numerous, not traceable across front of visceral disk. Spine-bases rarely seen with the exception of major spines.

Description.—Pedicle valve. The posterior portion of the shell is highly convex, but slight flattening occurs about 5 mm. from the umbo; and after a space of about 4 mm. the shell becomes very globose, flattening again on the anterior part of the trail. The transverse section of the visceral disk is quadrate in outline. The umbo is small, pointed, and much incurved, the apex projecting slightly beyond the hinge. The venter is highly arched and rounded, or in rare cases flattened, but a sinus is never developed. It slopes down to the flanks, which expand very slightly anteriorly but are never spreading. A shallow depression which forms an angular sulcus on the flanks separates the small triangular flattened ears from the visceral disk.

The costae are fine and rounded on the visceral disk, where numerous bifurcations occur. They increase in width and become more prominent and irregular on the trail, but bifurcations are rare in this region. The sulci are considerably narrower than the costae.

There are about 16 ribs on the cardinal slopes, forming low rounded folds, but only the posterior 8 or 10 are traceable across the front of the visceral disk. The ribs are frequently undulating on the lateral slopes of the visceral disk; rarely a rib is intercalated towards the front. The point of intersection of ribs and costae is marked by slight elongated swellings.

Spines are few and do not exceed 1 mm. in diameter. In addition to the six major spines a few scattered spines occur on the venter. A longitudinal fold is developed below the two major spines on the flanks, and may continue to the anterior-lateral margin of the shell.

Brachial valve. The visceral disk is slightly concave and is geniculated rather abruptly at its anterior extension to form a convex trail, which is in close contact with that of the pedicle valve. The exterior of this valve is seldom seen, since it remains in contact with the matrix, while the pedicle valve and inner layers of the brachial valve split off together, leaving the lower layers of the brachial valve exposed.

The ornament is similar to that of the pedicle valve, but the ribs are more numerous and all cross the visceral disk.

Internal characters. Unknown.

Dimensions.—

	(1)	(2)	(3)	
Maximum height	18	22·5	28	mm.
„ width	18·5	23	25·5	„
„ thickness	13·5	18	20·5	„
Length of visceral disk	13	12	18	„
Width „ „ „	17	17	24	„
Number of costae in breadth of 10 mm. at distances vertically below umbo :				
at 10 mm.	18	15	17	
„ 15 „	15	15	14	

(1) Holotype.

(2) B.M., B.4704, from Wetton, Staffordshire.

(3) B.M., B.23856, from Coed-yr-Esgob, Prestatyn, Flintshire. Giganteid form.

Type.—Holotype, from Thorpe Cloud, Derbyshire, subzone D_2, is preserved in the British Museum [B.43730]. Paratypes: a number of specimens referred to below in section on 'Distribution.'

Distribution.—Range, Z zone to D_2 subzone.

England.

Derbyshire: Thorpe Cloud, subzone D_2 (B.M., B.43730; Mr. J. W. Jackson); Earl Sterndale, subzone D_2 (B.M., B.23576); Dovedale, subzone D_2 (Mr. J. W. Jackson).

Lancashire: Withgill Quarry, 2¼ miles W.S.W. of Clitheroe (Geol. Surv., London, Rh.1212).

Somerset: Whatley, Frome (M.P.G., Geol. Soc. Coll., 31773); Bristol district, ?Z zone (Bristol Univ.).

Staffordshire: Narrowdale, subzone D_2 (B.M., B.43729, W. Hind Coll.); Wetton, subzone D_2 (B.M., B.4704, B.45516).

Yorkshire: Upper Scar Limestone, Settle (Bristol Univ.).

Wales.

Flintshire: Upper Grey Limestone, Coed-yr-Esgob, Prestatyn, subzone D_2 (B.M., B.23856).

Ireland.

Co. Dublin : Rush Conglomerate, subzone C_2 (Dr. L. B. Smyth).

Co. Kildare : Kildare (M.P.G., Geol. Soc. Coll., 31821).

Remarks.—Productus derbiensis is distinguished from *P. longispinus* J. Sow. by the greater globosity of the shell, greater width of the visceral disk, and more prominent costae. Large specimens of *P. derbiensis* are distinguished from *P. productus* (Martin) by their less extended trail, more regular costae, and different arrangement of the spines.

Some of the specimens figured by de Koninck as *P. longispinus* or *P. flemingi* from Tournai, Belgium, can be referred to *P. derbiensis.* Vaughan in 1915 regarded de Koninck's *P. flemingi* as identical with *P. burlingtonensis,* from the Z zone of Belgium, but specimens said by Vaughan to belong to the latter species have been redescribed in part in this monograph as *P. vaughani* sp. nov. (p. 65).

Hayasaka in 1922 (pl. ix, figs. 1, 2; pl. x, figs. 1, 2) figured as *P. flemingi* from the Permian of Japan a much decorticated specimen resembling *P. derbiensis* in shape, but its ornament is obscure.

Large examples of this species, about twice the size of the normal form, occur rarely in the D_2 subzone.

Productus lobatus J. Sowerby.

Plate XI, figs. 6, 12, 13.

1821. *Productus lobatus* J. Sowerby (in part). Mineral Conchology of Great Britain, vol. iv, p. 16, pl. cccxviii, figs. 2, 4, 6.

1861. *Productus longispinus* T. Davidson (in part). Mon. Brit. Foss. Brach., vol. ii, p. 154, pl. xxxv, figs. 11, 13.

Diagnosis.—Shell about 18 mm. high, 20 mm. wide, and 12 mm. thick, or 1 : 1·1 : ·6; quadrate in outline, hinge forming widest part of shell. Pedicle valve with flat visceral disk, geniculated abruptly to form curved trail; flanks steep and flat; venter with deep, angular sinus; umbonal angle 105°; ears large. Brachial valve geniculated, visceral disk nearly flat. Costae about 14 in 10 mm. at distance of 10 mm. from umbo. Ribs rather prominent, not traceable across sinus. Spines rare, except six major spines.

Description.—Pedicle valve. In the neanic stage the shell is slightly convex, then flattens for a distance of 4 or 5 mm. It becomes increasingly convex in the ephebic stage, with the development of a rounded geniculation, joining the visceral disk to the curved trail. The ears are large, triangular and convex, with subangular cardinal extremities, and are separated from the visceral disk by a rather deep sulcus. A deep angular sinus is developed about 5 mm. from the umbo and increases in width at the anterior end of the visceral disk, then gradually decreases in width and depth on the trail. The venter is divided by the sinus into two prominent rounded shoulders, which arch down to the rather steep, laterally sloping flanks. The umbo, which is small and acute, is very slightly incurved.

The costae are rather coarse and prominent and thicken on the trail, except those costae within the sinus which converge; and two or three disappear, while the costae adjacent to these may unite. Bifurcation occurs very frequently below the visceral disk, usually anterior to the spine-bases, while a few intercalated costae may occur just below the visceral disk. The sulci are slightly narrower than the costae. When the shell is decorticated the costae become about half their original width.

About 12 ribs are developed as narrow folds on the cardinal slopes, and expand in width on the front of the shell, causing rather marked nodular swellings at the point of intersection with the costae. The anterior two or three ribs are not continuous across the sinus.

There are few spine-bases present in addition to those of the six symmetrically placed major spines, and these are of smaller diameter.

Growth-lines are well marked on the anterior part of the trail, and cause the shell to flake off very irregularly.

Brachial valve. The visceral disk is nearly flat, with a rounded median fold corresponding to the sinus of the pedicle valve. The shell is geniculated at the anterior extension of the visceral disk, and the trail follows the contour of that of the pedicle valve. The ears are slightly concave, and are separated from the visceral disk by a narrow angular ridge.

The ornament is similar to that of the pedicle valve.

Internal characters. The interior of the pedicle valve is unknown.

Interiors of the brachial valve occur rather commonly in the Carboniferous Limestone of Northumberland and in the Lower Limestones of Scotland. The specimen figured in pl. xi, fig. 6, shows a bilobed cardinal process projecting slightly above the hinge, and continued anteriorly as a median septum. The septum, which is deeply furrowed posteriorly, extends for about three-quarters of the length of the valve, terminating in a narrow elevated knob.

The marginal ridges diverge from the hinge and curve half way round the lateral margin, but are never prominent. The anterior part of the ridges is crenulated.

Brachial impressions are given off at the anterior end of the adductor-scars, and extend outwards for 2 mm. or 3 mm., then curve downwards for about 3 mm. and finally bend sharply upwards. The extremity is separated from the remainder of the impression by a very narrow, transverse incision. The posterior portion of the brachial impressions may also be intersected. A low ridge extends from each side of the anterior end of the septum to the extremity of the impressions.

Dimensions.—

	(1)	(2)	(3)	(4)	(5)	
Maximum height	15·5	16	16·5	18·5	22·5	mm.
,, width	20·5	20·5	18	20·5	18	,,
,, thickness ...	11	14	12·5	13·5	12	,,
Length of hinge	20·5	—	18	—	—	,,
Number of costae in breadth of 10 mm. at distances vertically below umbo :						
at 10 mm.	13	16	16	14	13	
,, 15 ,, ...	—	14	11	12	14	

(1) Kelvingrove Mus., Glasgow, 01·53 aib, from Upper Limestones, Capelrig, East Kilbride.

(2) B.M., B.15505, from Kirke Harle Burn, near Wallington, Northumberland.

(3) Geol. Surv., Edinburgh, M.4488G, from Lower Limestones, Poniel Water, Coalburn, Lanarkshire.

(4) B.M., B.41187, from Kirke Harle Burn, near Wallington, Northumberland.

(5) Lectotype.

Type.—J. Sowerby figured five specimens as *P. lobatus* in 'Mineral Conchology of Great Britain.' Of these, two are here redescribed (on pp. 178, 180) as varieties of *P. lobatus*. The specimen from Little Park Tower, Northumberland, figured by Sowerby in pl. cccxviii, fig. 4, and preserved in the British Museum, B.47993, Sowerby Coll., is chosen as lectotype.

Distribution.—Range, D_2—D_3 subzone, and Yoredalian.

England.

Cumberland: Penton Linns, Liddle Water, $\frac{1}{4}$ mile below bridge at Penton Station (Geol. Surv., Edinburgh, M.4513B).

Northumberland: Kirk Harle Burn, near Wallington (B.M., B.15505, B.41187); Holy Island (B.M., B.24393); Low Dean Limestone, Scremerston, subzone D_2—D_3 (B.M., B.41969—73, S. Smith Coll.); upper beds of Eight-Yard Limestone, old quarry, between Dunstan and Caister, subzone D_2—D_3 (Geol. Surv., London, J.R.1142); between lower and upper beds of Eight-Yard Limestone, same locality (Geol. Surv., London, J.R.947); Little Park Tower (B.M., B.47993—94, Sowerby Coll.).

Yorkshire: Five-Yards Limestone, Skell Gill, N. of Pateley Bridge (Mr. R. G. S. Hudson).

Wales.

Anglesey: Cliffs, N.E. end of Puffin Island (Geol. Surv., London, Af.2804); cliffs, 25 yards E. of Fedw Fawr (Geol. Surv., London, Af.2649).

Flintshire: Upper Grey Limestone, Minera (B.M., B.23836, Morton Coll.); Upper Grey Limestone, Halkin Hill (B.M., B.10509, B.10516).

Scotland.

Edinburghshire: Bed No. 15, shelly shale above $1\frac{1}{2}$ft. limestone, Skolie Burn, near Addiewell (Geol. Surv., Edinburgh, T.630F, T.636F); Bed No. 17, same section (Geol. Surv., Edinburgh, T.658F).

Haddingtonshire: Longcraig Limestone, Aberlady Bay (Geol. Surv., Edinburgh, T.1082F).

Lanarkshire: Shale between No. 1 and No. 2 Limestone of Calderwood Section, shale-heaps in quarry on farms of Auchentibber, and Broomhouse New Field, 3 miles from East Kilbride (Geol. Surv., Edinburgh, B.3696A); Lower Limestones, bank of Poniel Water, S.E. of Bankend, Coalburn (Geol. Surv., Edinburgh, M.4488G); Wildshaw old limestone quarry, head of Birkshaw Burn, 3 miles S.E. of Douglas (Geol. Surv., Edinburgh, T.724D); Upper Limestones, Capelrig, East Kilbride (Kelvingrove Mus., Glasgow, Young Coll., figd. T. Davidson, 1880, pl. xxxvi, fig. 1b); Rutherglen (Hunterian Mus., Glasgow, Ure Coll.).

Remarks.—Productus lobatus is distinguished from *P. setosus* Phill. by its deeper sinus, narrower visceral disk and more sharply demarcated ears. The costae are slightly coarser and more prominent and the ribs better defined in *P. lobatus* than in *P. setosus* or *P. longispinus* J. Sow.

Sowerby (1821, pl. cccxviii, figs. 2—6) figured five specimens as *P. lobatus*, two of which are here redescribed (pp. 178, 180) as varieties of this species. In the Supplementary Index to 'Mineral Conchology,' vol. iv, J. Farey referred to Sowerby's specimen preserved in brown sandstone from Cumberland as *Productus lobatus* β, and the four specimens from Northumberland and Arran as *Productus lobatus* α. The specimen occurring in the form of a cast from Cumberland, and two of the specimens from Northumberland are, however, to be regarded as typical *P. lobatus*, while the specimen from Arran is described on p. 180 as *P. lobatus*, var. *flexus* var. nov., and one specimen from Northumberland (fig. 3 of Sowerby's plate) is described on p. 178 as *P. lobatus*, var. *laqueatus* var. nov.

Davidson regarded *P. lobatus* as a variety of *P. longispinus* and figured a specimen (1861B, pl. xxxv, fig. 14) which resembles *P. longispinus* in its ornament but has an exceptionally deep sinus. The specimens figured from the arenaceous limestone of Rutcheugh, Northumberland (1861B, pl. xxxv, fig. 13) and from East Kilbride, Lanarkshire (pl. xxxv, fig. 11) appear to be *P. lobatus*.

Ure in 1793 (p. 314, pl. xv, fig. 4) included several species under the term *Anomiae Echinatae* and figured a specimen which is readily recognized as *P. lobatus*. The typical outline and deep sinus are well shown, and the six major spines are preserved. An interior of the brachial valve, rather poorly preserved, is shown in fig. 3 of the same plate.

M'Coy in 1844 (p. 111) described *P. lobatus* as a distinct species, but later (1851—55, p. 461), as in the case of many species of *Productus*, included it in the general term *P. flemingi;* and a similar course was taken by de Koninck (1847A, p. 196), who also included *P. lobatus* in the synonymy of *P. flemingi*.

Keyserling described but did not figure specimens of *P. lobatus* from the Mountain Limestone of Russia in 1846 (p. 206), and mentioned three varieties, one of which appears to resemble the typical form, but is of smaller size. Kutorga (1842, pl. v, fig. 3) figured a specimen as *P. lobatus*, from the Mountain Limestone of Orenburg, which is larger than the type and has coarser costae.

De Verneuil figured (1845, pl. xvi, fig. 3; pl. xviii, fig. 8) two forms as *P. lobatus* from Russia, one of which is very spinose and not markedly lobate, while the second specimen resembles *P. longispinus* J. Sow. in outline, but the ornament is obscure.

The *Productus lobatus*, var. *paucicostatus* of Trautschold (1867, pl. v, fig. 2), from the Fenestellenkalk of Russia, is more coarsely costate than *P. lobatus*, while the *P. lobatus* figured by Tschernyschew (1902, pl. lvii, figs. 10, 11) is a small specimen with costation like that of *P. tissingtonensis* Sibly, but without the median fold.

Grünewaldt figured a specimen as *P. flemingi*, var. *lobatus* from the Ural Mts. in 1860 (pl. iii, figs. 4a, b), but the costae are finer than in the type and no spines are visible. Schellwien's specimen of *P. longispinus*, var. *lobata*, from the Carnic Alps, figured in 1900 (pl. vii, figs. 1—3), is also not identical with *P. lobatus*.

Figures of *P. lobatus* have also been given by Deshayes (1831, pl. ix, figs. 6, 7) and by von Buch (1842, pl. ii, fig. 17), but neither of the specimens figured is typical of the species.

PRODUCTUS LOBATUS, var. LAQUEATUS[1] var. nov.

Plate XI, figs. 16a, b, 18.

1821. *Productus lobatus* J. Sowerby (in part). Mineral Conchology of Great Britain, vol. iv, p. 16, pl. cccxviii, fig. 3.

Diagnosis.—Resembles *P. lobatus*, but visceral disk convex, venter flat or slightly sinuated. Costae finer, about 19 in 10 mm. at distance of 10 mm. below umbo, bifurcating more frequently, and slightly converging on front of trail. Ribs less prominent than in parent species. Spine-bases rather numerous on trail, and on visceral disk; slight longitudinal folds developed below spine-bases of trail.

Dimensions.—

	(1)	(2)	(3)	
Maximum height	19	21	22	mm.
„ width	17	16·5	21·5	„
„ thickness	12	11	13	„
Number of costae in breadth of 10 mm. at distances vertically below umbo:				
at 10 mm.	21	18	18	
„ 15 „	15	17	18	

[1] Latin, *laqueatus*=folded or fluted. So named from longitudinal folding of pedicle valve.

(1) Holotype.
(2) B.M., B.47995, Sowerby Coll., from Little Park Tower, Northumberland.
(3) R. Scot. Mus., Edinburgh, from the Upper Limestones, Orchard, near Glasgow.

Type.—Holotype, from Upper Limestones, Cock of Arran, is preserved in the Royal Scottish Museum, Edinburgh, Neilson Collection [38]. Paratypes: a number of specimens mentioned below in section on 'Distribution.'

Distribution.—Range, D_2 subzone to D_3 subzone.

England.

Northumberland: Well Houses Farm, Little Park Tower (B.M., B.47995, Sowerby Coll.).

Scotland.

Ayrshire: 50 yards downstream from weir, ½ mile N.E. of Kilmaurs (Geol. Surv., Edinburgh, T.3030E—3032E).

Buteshire: Red Limestone, Cock of Arran (Geol. Surv., Edinburgh, T.997); Upper Limestones, Cock of Arran (R. Scot. Mus., Edinburgh, 38).

Lanarkshire: Carluke, Hamilton (M.P.G., 34422); Croftfoot Bore, E. side of Ruthlin Burn, N.W. of Glenboig (Geol. Surv., Edinburgh, T.4302c).

Renfrewshire: Upper Limestones, Orchard, Pollokshaws (R. Scot. Mus., Edinburgh, Neilson Coll.).

Remarks.—*Productus lobatus*, var. *laqueatus* is distinguished from *P. lobatus* by its more rounded visceral disk and shallower sinus. The costae are finer, less prominent and bifurcate more frequently than in *P. lobatus*.

Specimens of *P. lobatus*, var. *laqueatus* are frequently preserved in shale, and the front of the shell may be crushed, producing a deep angular longitudinal furrow on the front of the trail and simulating a deep sinus, as in Sowerby's specimen. The latter specimen is said to have been obtained from Well Houses Farm, Little Park Tower, Northumberland, from which locality two specimens now regarded as typical *P. lobatus* were also obtained. Sowerby's specimen from Northumberland is preserved in a reddish limestone, while the two specimens of *P. lobatus* from the same locality are preserved in black shale. There is no doubt therefore that the former was obtained from a different horizon from that yielding the specimens of *P. lobatus*, if indeed it came from the same locality.

This species is characteristic of the Upper Limestones of Scotland.

PRODUCTUS LOBATUS, var. FLEXUS var. nov.

Plate XII, figs. 4, 5.

1821. *Productus lobatus* J. Sowerby (in part). Mineral Conchology of Great Britain, vol. iv, p. 16, pl. cccxviii, fig. 5.

1860. *Productus longispinus* T. Davidson (in part). The Carboniferous System in Scotland characterized by its Brachiopoda, *The Geologist*, vol. iii, p. 110, pl. ii, fig. 17.

1861. *Productus longispinus* T. Davidson (in part). Mon. Brit. Foss. Brach., vol. ii, pt. v, No. 4, p. 154, pl. xxxv, figs. 10, 10a.

Diagnosis.—Resembles *P. lobatus* but visceral disk much flattened, abruptly geniculated to form short curved trail; flanks steep and flat; venter broad, slightly sinuated; ears small, not sharply demarcated from visceral disk. Brachial valve concave. Costae about 17 in 10 mm. at distance of 10 mm. from umbo, rarely bifurcating, and slightly converging in sinus, thickening on trail. Ribs not prominent, faintly visible on front of visceral disk. Spine-bases rare except six major spines.

Description.—The short, rather flat visceral disk is separated from the trail by an angular geniculation. A shallow sinus is developed about 8 mm. below the umbo and is continuous to the anterior margin. The small, rather flat ears, with a perpendicular lateral margin, are separated from the visceral disk by a shallow sulcus.

The costae are angular and rather prominent, and rarely bifurcate except on the flanks. Slight convergence of the costae within the sinus may occur, and the median costa may disappear. About 18 ribs are developed on the cardinal slopes and are faintly traceable across the front of the visceral disk, causing slight enlargement of the costae at the point of intersection. A few small spine-bases may be seen on the visceral disk in addition to the six major spine-bases.

The interior of the brachial valve (pl. xii, fig. 5) shows a small bifid cardinal process, projecting slightly above the hinge and continued anteriorly as a short flattened septum which is medianly depressed. About 2 mm. below the cardinal process the septum narrows and becomes thread-like, and terminates in a rounded and prominent knob. The adductor muscle-scars are small and trigonal in shape, and are inserted close to the median septum, and immediately posterior to them are two triangular cavities. The narrow marginal ridges are given off on each side of the cardinal process, and slope away from the hinge at an angle of 45°, becoming more prominent on the lateral margin of the shell, and terminating about 5 mm. below the cardinal extremities. Slight transverse crenulations are developed on the marginal ridges.

The brachial impressions are given off at the antero-lateral margin of the adductors and are cut by transverse incisions.

Dimensions.—

	(1)	(2)	
Maximum height	12	14	mm.
,, width	15	15	,,
,, thickness	9	10·5	,,
Number of costae in breadth of 10 mm. at distances vertically below umbo :			
at 5 mm.	—	21	
,, 10 ,, ...	17	14	

(1) Holotype.

(2) B.M., B.47996, Sowerby Coll., from Arran.

Type.—Holotype, from Main Limestone, Campsie, Stirlingshire, is preserved in the Kelvingrove Museum, Glasgow, Young Collection [01·53 aid]. Paratypes : a number of specimens mentioned below in section on 'Distribution.'

Distribution.—Range, D_2 subzone.

Scotland.

Ayrshire : Paduff Burn, Kilbirnie, 760 yards up stream from Largs Road (Geol. Surv., Edinburgh, M.2057F).

Buteshire : Isle of Arran (B.M., B.47996, Sowerby Coll.).

Edinburghshire : Shale above No. 2 Limestone, quarry on right bank of Skolieburn, 2½ miles W. of West Calder (Geol. Surv., Edinburgh, B.4045B); Bed No. 7 of section, Skolieburn, near Addiewell (Geol. Surv., Edinburgh, T.612F).

Haddingtonshire : Longcraig Limestone, Aberlady Bay (Geol. Surv., Edinburgh, T.1077F).

Lanarkshire : Lower Limestones, small stream entering Hagshaw Burn, ½ mile S.W. of Sitehill, Coalburn (Geol. Surv., Edinburgh, M.4643G, 4644G); Lower

Limestones, bank of Poniel Water, 440 yards S.E. of Bankend, Coalburn (Geol. Surv., Edinburgh, M.4487G, 4489G—4491G); shale above No. 2 Limestone, Calderwood Section, left bank of Calder Water, opposite old mines at Calderside (Geol. Surv., Edinburgh, B.3957A); Colston Bore, Ashfield Farm, Lambhill, Glasgow (Geol. Surv., Edinburgh, T.463F, 465F).

Stirlingshire : Lower Limestones, Main Limestone, Campsie (Kelvingrove Mus., Glasgow, 01·53 aid).

Remarks.—P. lobatus, var. *flexus* is distinguished from *P. lobatus* J. Sow. by its much flattened visceral disk in the pedicle valve, and the abrupt geniculation between it and the slightly curved trail, and by the shallower sinus and smaller ears.

This variety is characteristic of the lower part of the Lower Limestone Group of Scotland, where it is associated with typical *P. lobatus*.

Davidson figured the interior of the brachial valve in 1860 and refigured the same specimen in 1861B. This specimen is also represented in pl. xii, fig. 5, of this work.

Sowerby's specimen figured in 'Mineral Conchology,' 1821, as *P. lobatus*, was obtained from Arran.

Productus setosus Phillips.

Plate XI, figs. 14a—d, 15a—c. Text-figs. 31, 32, 32A, 32B, 33.

1836. *Producta setosa* J. Phillips. Illustrations of the Geology of Yorkshire, part ii, p. 214, pl. viii, fig. 17 and ?9.

1860. *Productus longispinus* T. Davidson (in part). The Carboniferous System in Scotland characterized by its Brachiopoda, *The Geologist*, vol. iii, p. 110, pl. ii, figs. 10, 11, 11a, 11b, 15, 15a, 16, 16a.

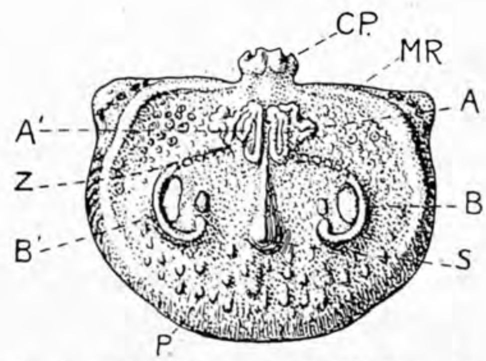
1861. *Productus longispinus*, var. *P. setosa* T. Davidson. Mon. Brit. Foss Brach., vol. ii, part v, No. 4, p. 156, pl. xxxv, fig. 16 and ?15.

1861. *Productus longispinus* T. Davidson (in part). *Ibid.*, p. 154, pl. xxxv, figs. 6, 8, 8a, 8b, 9, 9a, 9b.

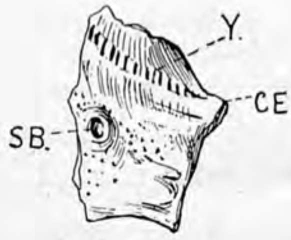
1915. *Productus longispinus* R. Dunlop. Notes on the Discovery of Fossil Chitons in Fife; with photographs and drawings of all the Fossils found in the Section, *Trans. Geol. Soc. Glasgow*, vol. xv, p. 167, pl. xx, fig. 6.

Text-fig. 31.—*Productus setosus* Phillips, from Carb. Limestone, Gorbeck, Settle, Yorkshire. British Museum, B.20496. Diagrammatic longitudinal section, natural size.

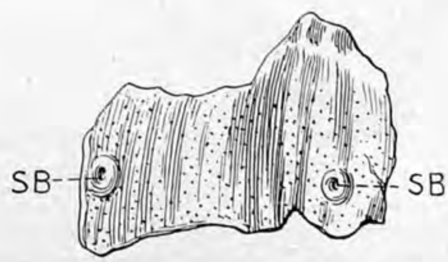
Text-fig. 32.—*Productus setosus* Phillips, from the Lower Limestones, Carluke, Lanarkshire. British Museum, B.48940, Davidson Coll. Interior of pedicle valve showing diductor muscle-scars (O), enclosing elongated adductor muscle-scars (A), x 3.



Text-fig. 33.—*Productus setosus* Phillips, from the Lower Limestones, Carluke, Lanarkshire. British Museum, B.48941, Davidson Coll. Interior of brachial valve showing cardinal process (CP), marginal ridges (MR), adductor muscle-scars (A & A'), brachial impressions (B & B'), cut by incisions at Z, median septum (S), pustules (P), x 3; slightly restored.



Text-fig. 32a.—*Productus setosus* Phill., from the Lower Limestones of Capelrig, East Kilbride, Lanarkshire. British Museum, B.48942. Fragment of interior of pedicle valve showing spine-base (SB), and row of incisions (Y) extending from cardinal extremity (CE), x 4.



Text-fig. 32b.—*Productus setosus* Phill. Same horizon and locality as text-fig. 32a. British Museum, B.48943. Fragment of interior of pedicle valve showing two major spine-bases, x 4.

Diagnosis.—Shell about 20 mm. high, 18 mm. wide, and 12 mm. thick, or 1 : ·9 : ·6; quadrate in outline, maximum width along the hinge. Pedicle valve with slightly convex visceral disk, geniculated and forming curved trail; flanks subparallel and almost flat; venter broad, with slight median depression; umbonal angle 115°; ears small. Brachial valve concave. Costae about 15 in 10 mm. at distance of 10 mm. from umbo, fine and numerous. Ribs well defined, traceable across front of visceral disk. Spine-bases few.

Description.—*Pedicle valve.* The shell is slightly convex for a distance of 3 mm. or 4 mm. below the umbo, and the width is about twice the length at this stage. A very shallow rounded depression is then developed and disappears just below the anterior end of the visceral disk. The length of the shell increases until it is about three-quarters of the width, when a rounded geniculation is developed, and the shell elongates with the development of a slightly curved trail. In the gerontic stage the median portion of the trail is produced anteriorly as a V-shaped extension, but it is not elevated above the level of the remainder of the shell. The umbo is acutely pointed and only slightly incurved, and the ears are small and not sharply demarcated from the visceral disk.

The costae on the visceral disk are fine and rounded, and increase in number by means of intercalations as well as by bifurcation of previously existing costae. On the trail and flanks the costae thicken and become more prominent and irregular in width. Bifurcations are very numerous, especially on the anterior part of the trail. The sulci are narrower than the costae, except on decorticated parts of the shell. Growth-lines are very marked and may appear as deep incisions, causing slight discontinuity of the costae on the trail, especially on the V-shaped extension.

About 16 ribs are developed on the visceral disk, but only the posterior 10 or 11 are traceable across the front of the shell. They form narrow, angular folds on the cardinal slopes and increase very slightly in width on the lateral slopes of the visceral disk. Slight elongated enlargements of the costae mark the points of intersection with the ribs.

A few small spine-bases are seen on the visceral disk, but with the exception of the major spines are not developed on other parts of the shell.

Brachial valve. The shell is highly concave for about 3 mm. from the umbo, and then flattens for a further 5 or 6 mm., becoming increasingly concave below this region.

The costae are less prominent than in the pedicle valve, while ribs are developed over the entire shell and are narrower and more numerous than in the pedicle valve. Spine-bases have not been observed.

The brachial valve is not produced into a long trail, as in the pedicle valve, but successive laminae are deposited round the anterior and lateral margins, their edges superimposed on one another like the leaves of a book. After a layer 1—2 mm. thick has been formed, the deposit is on the median portion of the valve only, in order to correspond with the V-shaped extension of the trail of the pedicle valve.

Internal characters. A complete interior of the pedicle valve has not been observed. Fragments from the Lower Limestone Series of Carluke, Lanarkshire (B.M., B.13835), show large flabellate diductor muscle-scars enclosing two small adductors about 4 mm. in length (text-fig. 32).

In the interior of the brachial valve, shown in text-fig. 33, the cardinal process is small, internally bifid, and is continued anteriorly as a median septum which terminates in an elongated knob-like protuberance. The posterior part of the septum is flattened and about 1 mm. in width, but it narrows between the adductor muscle-scars.

The marginal ridges arise about 3 mm. from the cardinal process and extend along the hinge, increasing in elevation at the cardinal extremities, and recurving round the lateral margin of the shell. They flatten about 2 or 3 mm. below the cardinal extremities and then continue as a broad flat rim round the anterior margin of the shell. This rim is composed of successive shelly layers, the edges of which are seen externally along the anterior margin of the brachial valve. Transverse crenulations are developed on the ridge lying along the lateral margin of the shell, while posterior to this a row of very small pustules is developed on the summit of the ridge.

Small trigonal adductor muscle-scars are inserted about 2 mm. below the hinge, and are bilobed, the two lobes in some specimens being distinctly separated, the posterior lobe lying about 1 mm. from the cardinal margin, and the anterior set close to the median septum.

The brachial impressions are given off at the antero-lateral margin of the adductors, and extend outwards at an angle of 40° to the septum, and finally recurve upwards, nearly enclosing a space 2 mm. wide. The apex of the impression is enlarged, and separated from the remainder by a deep transverse incision.

Dimensions.—

	(1)	(2)	(3)	(4)	(5)
Maximum height	16·5	17·5	20	21	21·5 mm.
,, width	17	18	17·5	20	20 ,,
,, thickness ...	11·5	12	12	12·5	14·5 ,,
Number of costae in breadth of 10 mm. at distances vertically below umbo:					
at 10 mm.	15	16	14	19	15
,, 15 ,, ...	15	15	15	17	12

(1) R. Scot. Mus., Edinburgh, 46, from the Lower Limestones, Skateraw Harbour, Dunbar, Haddingtonshire.

(2) B.M., B.23034, from Houghton, Northumberland.

(3) M.P.G., 32447, from East Barns, Dunbar.

(4) B.M., B.20496, from Gorbeck, Langcliffe Moor, Settle, Yorkshire.

(5) B.M., B.23856, from the Upper Grey Limestone, Minera, Denbighshire.

Type.—J. Phillips figured two specimens from Rokeby, Yorkshire, and Northumberland in 'Illustrations of the Geology of Yorkshire.' The original of fig. 9 is only doubtfully referred to *P. setosus;* the original of fig. 17 is chosen as lectotype. Both specimens are apparently lost.

Distribution.—Range, D_2 subzone to D_3 subzone.

England.

Cumberland: Penton Linns (B.M., B.43854—55; Geol. Surv., Edinburgh, M.4661B).

Northumberland: Houghton (B.M., B.23034, B.2432); shore, Howick (B.M., B.23056); Acre Limestone, Ancroft, subzone D_2—D_3 (B.M., B.41881, S. Smith Coll.); Six-Yard Limestone, old quarry, $\frac{3}{8}$ mile W. of Dunstan Hill (Geol. Surv., London, J.R.1199).

Yorkshire: Gorbeck, Langcliffe Moor, Settle, subzone D_2 (B.M., B.20496); Coldstones Quarry, Greenhow Hill, W. of Pateley Bridge, subzone D_2 (Prof. E. J. Garwood).

Wales.

Denbighshire: Upper Grey Limestone, Minera, subzone D_2 (B.M., B.23856, B.45679).

Flintshire: Holywell, subzone D_2 (B.M., B.23540); Halkin Mountain, subzone D_2 (B.M., B.10508).

Scotland.

Ayrshire: Beith (B.M., B.23572); shale above 4in. coal, ironstone measures, Crookhill, Beith (Kelvingrove Mus., Glasgow); limestone-bed in shales overlying upper part of Lower Limestone Group, Dusk Water, Dustyridge, Beith (Kelvingrove Mus., Glasgow).

Fifeshire: Dunfermline (B.M., B.8470); Camden's Quarry, Dunfermline (M.P.G., 32444, 32445); Linn Quarry, near Dunfermline (Geol. Surv., Edinburgh, B.2574c); shale above limestone, Roscobie Quarry, 4 miles N. of Dunfermline (Geol. Surv., Edinburgh, B.772c); Lower Limestones, Lathalmond, Dunfermline (R. Scot. Mus., Edinburgh, 130.XX); ashy bed below Bathgate Limestone, West Quarry, Kirkton (Geol. Surv., Edinburgh, B.3709c); Thornton (R. Scot. Mus., Edinburgh, 47).

Haddingtonshire: Railway, East Barns, Dunbar (M.P.G., 32425—32452); Lower Limestones, East Barns Quarry, near Dunbar (Geol. Surv., Edinburgh, B.2440D, 2412D, 2432D; R. Scot. Mus., Edinburgh, 131.XX); Lower Limestones, coast, East Barns, Dunbar (Kelvingrove Mus., Glasgow, 01·53 aif); No. 1 or No. 2 Limestone, quarry W. of limekiln, Harelaw Limeworks, near Longniddry Station (Geol. Surv., Edinburgh, B.1936c); shale above No. 2 Limestone, Little Kinchie Quarry, 3 miles W. of East Salton (Geol. Surv., Edinburgh, B.2315c); shale above No. 2 Limestone, Kidlaw Quarry, 3½ miles S. E. of East Salton (Geol. Surv., Edinburgh, B.2299c); Lower Limestones, Skateraw Harbour, Dunbar (R. Scot. Mus., Edinburgh, 46).

Lanarkshire: Carluke (B.M., B.13839, Davidson Coll.); Carluke, Hamilton (M.P.G., 34420, 34421); Lower Limestones, Thornmuir (Hunterian Mus., Glasgow, L.225).

Remarks.—Productus setosus is distinguished from *P. longispinus* J. Sow. by its more quadrate outline, coarser, more prominent costae, and more numerous and better defined ribs. Its longer visceral disk, finer costation and the absence of a longitudinal fold on the anterior part of the trail distinguish it from *P. tissingtonensis* Sibly.

J. Phillips in 1836 (p. 214, pl. viii, figs. 9, 17) figured two specimens as *P. setosus*, but fig. 9 represents a broader, flatter shell with larger ears than is shown in fig. 17; it may, however, be only crushed. The V-shaped extension of the trail is well shown in Phillips's specimen (fig. 17) and the outline and ornament agree very well with those of the specimens figured in the present work. He quoted this species as occurring in Northumberland, and at Rokeby, Yorkshire, in the Yoredale rocks.

Davidson copied Phillips's figures and stated (1861B, p. 156) that *P. setosus* could only be considered as a variety of *P. longispinus* J. Sow. Two other specimens figured by him (1861B, pl. xxxv, figs. 6, 8) as *P. longispinus*, from the Lower Limestones of Craigie, Kilmarnock, and of Lanarkshire, belong to *P. setosus*. A shallow sinus is seen in each of these specimens, but in drawings of the same specimens in 1860A (pl. ii, figs. 10, 11) this sinus is less emphasized, and the ribs are altogether lacking. In the figure showing the restoration of the spines in '*P. longispinus*' (=*P. setosus*) Davidson (1861B, pl. xxxv, fig. 6) has probably greatly exaggerated their number.

M'Coy (1844, p. 115; 1851—55, p. 472) described *P. setosus* as a distinct species, but included *P. carbonarius* de Kon. in the synonymy, and his description apparently also covers a number of other species.

De Koninck included *P. setosus* as a synonym of *P. longispinus* in 1842—44 (p. 187), but later (1847A, p. 197) he quoted it as a synonym of *P. flemingi* and suggested that it is probably the same as *P. spinosus* J. Sow.

Toula's specimen of *P. longispinus*, var. *setosus* figured in 1875 (pl. viii, figs. 8a, b), from the west coast of Spitzbergen, is nearer to *P. tissingtonensis* Sibly in costation and dimensions, but has a well marked sinus not seen in that species.

Dunlop (1915, pl. xx, fig. 6) figured a typical specimen of *P. setosus* from above the Hurlet Limestone, S.E. of Dunfermline, under the name *P. longispinus*.

P. longispinus, var. *setosus* was recorded by Dr. Stanley Smith in 1910 (p. 616) from the Acre Limestone, D_2—D_3 subzone of Northumberland, and by Vaughan in 1910 (p. 108) from the D_2 subzone; while *P.* aff. *setosus* was mentioned by Dr. Sibly (1908, pp. 47, 77) from the D_2 and D_3 subzones of Derbyshire.

PRODUCTUS PSEUDOPLICATILIS[1] sp. nov.
Plate XI, figs. 17a—c. Text-fig. 34.

TEXT-FIG. 34.—*Productus pseudoplicatilis* sp. nov. Holotype from Carb. Limestone, Settle, Yorkshire. British Museum, B.20540. Diagrammatic longitudinal section, natural size.

Diagnosis.—Shell about 20 mm. long, 24 mm. wide, and 13 mm. thick, or 1 : 1·2 : ·6; oval in outline, maximum width above anterior margin. Pedicle valve convex, not geniculated; visceral disk short; flanks rounded; venter broad and flat; umbonal angle 115°; ears small. Brachial valve deeply concave. Costae about 20 in 10 mm. at distance of 10 mm. from umbo, fine and even. Ribs forming prominent folds extending from hinge round front of visceral disk. Spine-bases rare, major spines usually developed.

Description.—Pedicle valve. The shell is slightly convex in the neanic stage and then becomes depressed, the width of the shell being about twice the length at this stage. It becomes increasingly convex at the anterior end of the visceral disk and the convexity continues on the trail. The ears are small and nearly flat, and are not sharply demarcated from the flanks and visceral disk, and the umbo is slightly incurved.

The costae are fine and even and bifurcate on the visceral disk, where they are only faintly traceable. The sulci separating the costae are extremely narrow.

About 16 ribs are developed as even prominent folds which extend from the hinge round the front of the visceral disk, maintaining a constant width. Elongated swellings are developed at the point of intersection of ribs and costae, the ribs being considerably more prominent than the costae.

Two major spine-bases are developed on the flanks, below which narrow longitudinal folds extend to the anterior margin, and two spine-bases are seen on the venter. Other spine-bases are rarely developed.

Brachial valve. This valve is concave, with a flattened portion along the cardinal slopes and ears, but no geniculation is developed.

[1] So named on account of its strong resemblance to *Pustula plicatilis*.

The costae are slightly less prominent than in the pedicle valve, and ribs are developed over the entire shell and are narrower and closer than in the pedicle valve.

Internal characters. Unknown.

Dimensions.—

	(1)	(2)	
Maximum height	20	24·5	mm.
,, width	24	33·5	,,
,, thickness	13	20·5	,,
Number of costae in breadth of 10 mm. at distances vertically below umbo :			
at 10 mm.	20	17	
,, 15 ,, ...	17	18	

(1) Holotype.

(2) B.M., B.45692, from Narrowdale, Staffordshire, subzone D_2.

Type.—Holotype, from the Carboniferous Limestone, Settle, Yorkshire, is preserved in the British Museum [B.20540]. Paratypes: a number of specimens mentioned below in section on 'Distribution.'

Distribution.—Range, D_2 subzone.

Derbyshire: Thorpe Cloud (B.M., B.43745); N. of Raven's Tor, Dovedale (Mr. J. W. Jackson).

Staffordshire: Narrowdale (B.M., B.45692).

Westmorland: Kendal (Oxford Univ. Mus.).

Yorkshire: Settle (B.M., B.20540).

Remarks.—*Productus pseudoplicatilis* is distinguished from *Pustula plicatilis* (J. Sow.) in having true costation developed on both valves. In *P. plicatilis* faint thread-like striations are seen on decorticated parts of the shell, and have been regarded by some authors as true costation.

I. Thomas (1914, p. 33) referred to a form closely resembling *Pustula plicatilis*, but having true costation as in the genus *Productus*. As stated by this author, there is some doubt as to whether the figure of *Producta plicatilis* given by Phillips in 1836 (pl. viii, fig. 4), and those by de Koninck (1842—44, pl. xii, figs. 7, 7a), really represent *Pustula plicatilis*. Both specimens appear to have rather coarse costation and well marked ribs, but Phillips's specimen has a deep sinus which is not characteristic of *Productus pseudoplicatilis*.

Jarosz (1917, pl. viii, figs. 7, 7a, b) figures a specimen from the Carboniferous of Poland as *P. longispinus*, which resembles *P. pseudoplicatilis* very markedly in shape and ornament. This specimen occurs in the C_2—S subzone with *Productus sublaevis*, whereas in this country *P. pseudoplicatilis* has not been found below the D_3 subzone.

PRODUCTUS PRAECURSOR[1] sp. nov.

Plate XII, figs. 1, 2. Text-fig. 35.

1860. *Productus longispinus* T. Davidson (in part). The Carboniferous System in Scotland characterized by its Brachiopoda, *The Geologist*, vol. iii, p. 110, pl. ii, figs. 18, 18a.

1861. *Productus longispinus* T. Davidson (in part). Mon. Brit. Foss. Brach., vol. ii, pt. v, No. 4, p. 154, pl. xxxv, figs. 18, 19, 19a.

1880. *Productus griffithianus* T. Davidson. Mon. Brit. Foss. Brach., Suppl., vol. iv, pt. iii, p. 308, pl. xxxvi, figs. 6a, 6b.

TEXT-FIG. 35.—*Productus praecursor* sp. nov., from Lower Limestones, Beith, Ayrshire. Royal Scottish Museum, Edinburgh, Neilson Coll., 57. Diagrammatic longitudinal section, natural size.

Diagnosis.—Shell about 10 mm. high, 11 mm. wide, and 7 mm. thick, or 1 : 1·1 : ·7; approximately circular in outline, hinge forming widest part of shell. Pedicle valve geniculated, visceral disk slightly concave, trail curved, flanks convex; venter rounded; umbonal angle 117°. Brachial valve slightly concave, costae about 16 in 10 mm. at distance of 10 mm. from umbo, fine and rather regular. Ribs few, crossing visceral disk. Spines rare, except six major spines.

Description.—*Pedicle valve.* The shell is globose immediately below the umbo, but becomes depressed on the anterior part of the visceral disk, which is joined to the curved trail by a rounded geniculation In the gerontic stage the median portion of the trail is produced and slightly elevated, forming a V-shaped extension.

[1] Latin, *praecursor*=forerunner, possibly of *P. setosus*.

The flanks are steep and slightly spreading anteriorly, and slope up to the rounded or slightly flattened venter. The ears are small, triangular in outline and reflexed, and are separated from the visceral disk and flanks by a deep sulcus, along which the shell frequently fractures. The umbo is small, pointed, and slightly incurved.

The costae are fine on the visceral disk and increase slightly in width on the trail, but remain even and regular, rarely bifurcating except below the spine-bases.

Six or seven narrow ribs cross the visceral disk, causing slight enlargement of the costae at the point of intersection.

The six major spine-bases are usually seen, and in addition to these one or two small spines may be developed on the visceral disk.

Brachial valve. A geniculation is not developed in this valve, which is rather concave immediately below the umbo and then becomes nearly flat. In the gerontic stage normal growth of the valve ceases, and successive shelly laminae are deposited round the anterior and lateral margins to keep pace with the increase in length of the pedicle valve. This deposit may be about 1·5 mm. thick.

The ornament is similar to that of the pedicle valve, but the ribs are more numerous and are developed over the entire valve.

Internal characters. Unknown.

Dimensions.—

	(1)	(2)	(3)	
Maximum height	10	10·5	12	mm.
,, width	11·5	10	12·5	,,
,, thickness	7·5	7	7	,,
Length of hinge	11·5	10	12·5	,,
Number of costae in breadth of 10 mm. at distances vertically below umbo :				
at 5 mm.	18	24	18	
,, 10 ,, ...	14	18	16	

(1) R. Scot. Mus., Edinburgh, 56, from the Lower Limestones, Beith, Ayrshire.

(2) Same museum and locality.

(3) Same museum, 39, from Broadstone, Beith.

Type.—Holotype, from Blackbyre Limestone, Roughwood, Beith, Ayrshire, is preserved in the Royal Scottish Museum, Edinburgh, Neilson Collection [34]. Paratypes: a number of specimens referred to in the section on 'Distribution.'

Distribution.—Range, D_2 subzone.

Scotland.

Ayrshire: Lower Limestones, Roughwood, Beith (R. Scot. Mus., Edinburgh, 132.XX, and 34); Broadstone, Beith (R. Scot. Mus., Edinburgh, 39); Beith (R. Scot. Mus., Edinburgh, 56, 57).

Edinburghshire: No. 1 Limestone, right bank of Tyne in No. 1 quarry, Currilee (Geol. Surv., Edinburgh, B.4519B).

Lanarkshire: Lower Limestones, Brockley, Lesmahagow (B.M., B.13807, Davidson Coll.); Lower Limestones, about 60 yards up from sheep-fold, Hagshaw Burn (Geol. Surv., Edinburgh, T.595D); Basket Shell Bed, Cot Castle Farm, right bank of Avon Water, 2½ miles N.E. of Strathaven (Geol. Surv., Edinburgh, T.2701D); Lower Limestones, Main or Hurlet Limestone, in small ditch entering Poniel Water, 1,650 yards S. of Bankend, Coalburn (Geol. Surv., Edinburgh, M.4600G, 4601G); Lower Limestones, grey shelly limestone, in stream entering Poniel Water, 333 yards W. of Brackenside, Brockley, Coalburn (Geol. Surv., Edinburgh, M.3876F, 3881F); blue limestone, same locality (Geol. Surv. Edinburgh, M.4021F, 4066F); Blackbyre Limestone, Brockley, near Lesmahagow (Kelvingrove Mus., Glasgow, 01·53 aih and ait).

Stirlingshire: White nodular limestone, Upper Bannock Burn, S.W. of Todholes (Geol. Surv., Edinburgh, T.1887F, 1888F); small burn, Kilsyth (R. Scot. Mus., Edinburgh, 138.XX, specimens 3, 4); Lower Limestones, Corrieburn, Campsie (Kelvingrove Mus., Glasgow, 01·53 aie, Young Coll.).

Remarks.—*Productus praecursor* is distinguished from *P. longispinus* J. Sow. by its coarser, more prominent costae and better defined ribs; and by the absence of a sinus on the venter. The small dimensions of *P. praecursor* distinguish it from *P. longispinus* as well as from *P. setosus* Phill.

P. praecursor appears to be limited in distribution to the Lower Limestones of Scotland, and it is characteristic of the Blackbyre Limestone or Coral Reef Limestone, where it occurs with *P. longispinus*. The Blackbyre Limestone overlies the

Hollybush Limestone and is followed by the Hurlet or Main Limestone in the West of Scotland sequence, and it has been correlated with the White Coral and Middle Longcraig Limestones of the East of Scotland.

The affinities of *P. praecursor* appear to be with *P. setosus* Phill. rather than with *P. longispinus* J. Sow., but the typical form of *P. setosus* does not appear until a slightly higher horizon, and the species under discussion may be an early mutation of *P. setosus*. The true relations of these species cannot be determined until further collections of Carboniferous material have been made from the successive Scottish limestones.

The specimen figured by Davidson in 1880 (pl. xxxvi, figs. 6, 6a, 6b) as *P. griffithianus* de Kon., from Brockley, Lesmahagow, Lanarkshire, is an example of *P. praecursor* in which the visceral disk only is preserved. It differs from *P. griffithianus* in shape and ornament, and Davidson has exaggerated the resemblance in his enlarged drawings. Davidson's drawing of *P. longispinus* in 1861B (pl. xxxv, fig. 18) is an enlargement of *P. praecursor* and appears to be identical with that of the specimen figured in 1860A (pl. ii, fig. 18a).

Waagen in 1884 (p. 660) referred the specimen figured by Davidson in 1861 (pl. xxxv, fig. 18) to the genus *Chonetella* in his description of *Chonetella nasuta*, stating that Davidson had drawn a distinct cardinal area in the ventral valve. The genus *Chonetella* is characterized by the narrow area in the pedicle valve with a deltidial fissure, and by the development of a row of spines along the hinge-margin, as in *Chonetes*. Not one of these characters is found in *Productus praecursor*, and the only point of resemblance appears to lie in the V-shaped prolongation of the trail, which occurs both in *P. praecursor* and in *Chonetella nasuta* Waagen.

In 1890 (p. 26) Nikitin referred to Davidson's figures of *P. longispinus* in 1861B (pl. xxxv, figs. 18, 19), now ascribed to *P. praecursor*, as a new species, *Productus* aff. *longispinus*. He quoted it as occurring in the Moscovian of Pesski and Koroptscheewo, Russia, but gave no description or illustration beyond a reference to Davidson's figures in Russian. 'Here I place the form apparently identical with the illustration of Davidson. . . A more exact determination and description will be given in the discussion of the fauna of the Samara Basin where this form abounds in the lower horizons.' No further reference to this species, however, has been found.

PRODUCTUS MINUTUS sp. nov.

Plate XII, figs. 3a—c.

Diagnosis.—Shell about 11 mm. high, 13 mm. wide, and 9 mm. thick, or 1 : 1·1 : ·8; highly globose, maximum width along hinge. Pedicle valve geniculated, visceral disk globose, trail slightly convex; flanks steep; venter rounded; umbonal angle 115°; ears triangular and flat, sharply demarcated by incision or cincture extending from hinge round front of shell, costae fine and rounded, variable in number. Ribs few on cardinal slopes. Spine-bases rare.

Description.—Pedicle valve. The shell is evenly convex on the visceral disk and flattens on the short trail. The ears are separated from the flanks by a geniculation at an angle of 90°, and they project at right angles to the globose visceral disk. A cincture separates the visceral disk from the trail, and appears as a deep sulcus on the lateral slopes of the visceral disk, but it becomes shallow on the front of the shell and does not cause any discontinuity in the ornament. The umbo is rounded and incurved.

The costae are fine and bifurcate frequently on the visceral disk and trail. Intercalations also occur on the trail. Costae are not developed on the ears.

From six to eight ribs are developed on the cardinal slopes, but are only traceable across the front of the shell in rare instances.

The six major spine-bases are usually preserved, but other spines are rarely developed.

Brachial valve and internal characters. Unknown.

Dimensions.—

	(1)	(2)	(3)	
Maximum height	10	11	12	mm.
,, width	11·5	13·5	13	,,
,, thickness	9	9	9·5	,,
Length of hinge	11·5	13·5	13·5	,,
Number of costae in breadth of 5 mm. at distances vertically below umbo :				
at 5 mm.	15	13	10	
,, 10 ,, ...	18	11	9	

(1) B.M., B.40704, from subzone D_2, Wetton, Staffordshire.

(2) Same museum, 65209, from Black Rock, Cork.

(3) Holotype.

Types.—Holotype, from Little Island, Cork, is preserved in the British Museum, J. Wright Coll. [B.40200]. Paratypes: nine specimens mentioned below in paragraphs on ' Distribution.'

Distribution.—Range, ?C_2 subzone and D_2 subzone.

England.

Derbyshire: Peakshill Farm by Mam Tor, subzone D_2 (B.M., B.41247, W. Hind Coll.).

Staffordshire: Wetton, subzone D_2 (B.M., B.40704; M.P.G., 34400, 34402, 34404).

Ireland.

Co. Cork: Little Island, Cork (B.M., B.40200, J. Wright Coll.); Black Rock, Cork (B.M., 65209); Cork (Hunterian Mus., Glasgow, L.231).

Co. Dublin: S. of Skerries (M.P.G., Geol. Soc. Coll., 31820); Holmpatrick Limestone, Loughshinny (Dr. L. B. Smyth).

Co. Kildare: Kildare (M.P.G., Geol. Soc. Coll., 31820).

Co. Louth: Near Drogheda (B.M., 65194).

Remarks.—*Productus minutus* is distinguished from *P. triquetrus* sp. nov. (p. 163) by its smaller dimensions, finer costation, and ill-defined ribs. Its large flat ears, which appear to project at right angles to the flanks, are a character distinguishing it from *P. longispinus* J. Sow.

P. minutus is common in the Carboniferous Limestone of the Cork district, where the beds probably belong to the Z or C zone and are the equivalent of the Waulsortian reefs of Belgium. It occurs again in the Brachiopod Beds of D_2 age in the Midlands, but has not been found, so far, in the intervening S beds. A similar distribution in reefs of Z or C and D_2 age has been already mentioned for the species *P. semireticulatus* (Martin) and *P. multispiniferus* sp. nov.

Vaughan's (1908, p. 439) specimens of *P. concinno-longispinus* from the Holmpatrick Limestone, Loughshinny, may be identical with *P. minutus*, and Gröber's (1911, p. 33) specimens of *P. concinno-martini* from the C_2 subzone of Soignies, Belgium, may also belong to *P. minutus*.

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The names of genera, species and varieties described or figured in this work are printed in roman type; all others are in italics. In the case of described forms, the essential page-references are placed first, separated from the others by a semi-colon.

A list of the species and varieties described is given on pages 38 and 39.

EXPLANATION OF PLATE I.

All figures in Plates I—XII are of natural size.

The abbreviations B.M. and M.P.G. indicate the British Museum (Nat. Hist.) and the Museum of Practical Geology, London, respectively.

Productus productus (Martin). Page 39.

Carb. Limest., subzone D_2, Park Hill, Derbyshire.

FIG.

1a. Ventral view of whole specimen, showing line of fracture. M.P.G., 32453.

1b. Same, lateral view.

1c. Same, visceral disk of pedicle valve.

1d. Same, visceral disk of brachial valve, showing diaphragm, the visceral disk of the pedicle valve having been removed.

Carb. Limest., ? near Settle, Yorkshire.

2. Interior of brachial valve. B.M., B.13834.

? Same locality.

3. Exterior of brachial valve, showing trifid cardinal process. B.M., B.5804.

Carb. Limest., subzone D_2, Narrowdale, Staffordshire.

4. Visceral disk of pedicle valve. B.M., B.45519.

Carb. Limest., subzone D_2, Park Hill, Derbyshire.

5. Visceral disk of brachial valve, showing diaphragm, and trail of pedicle valve. M.P.G., 48263.

Carb. Limest., Scaleber Bridge, Settle, Yorkshire.

6. Ventral view, showing spreading trail with flexuous costae. M.P.G., 32459.

Productus concinnus J. Sowerby. Page 49.

Shale above Main Clay Ironstone, Lower Limestones, pit, Netherton, Dunlop, Ayrshire.

7. Visceral disk of brachial valve surrounded by diaphragm. R. Scot. Mus., Edinburgh, Neilson Coll., 24.

Lower Limestones, Main Limestone, Campsie, Stirlingshire.

8a. Ventral view, showing tube-like form of front of trail. Kelvingrove Mus., Glasgow, 01.53 afn.

8b. Same, posterior view, showing visceral disk of pedicle valve.

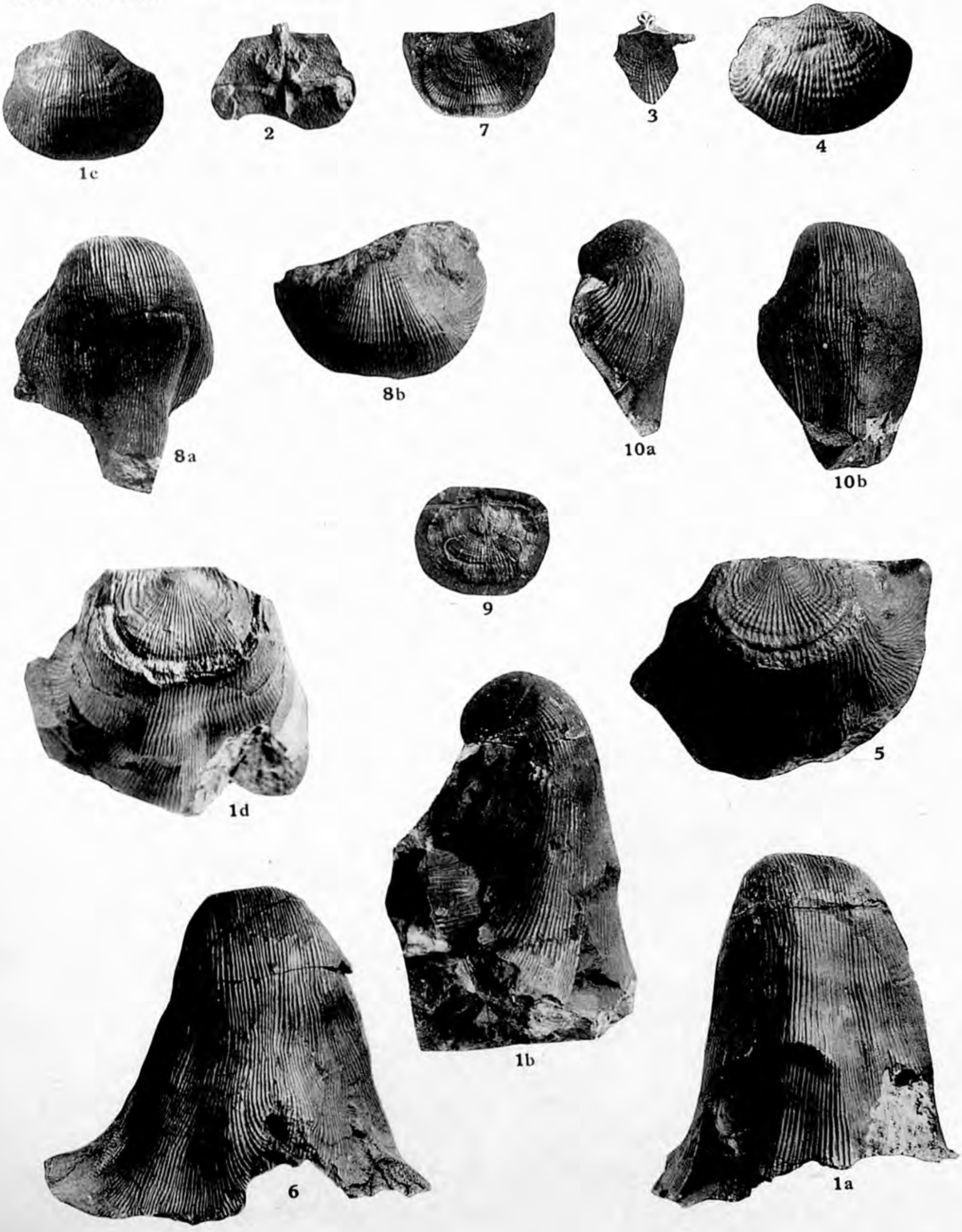
Upper Limestones, Muirhouse Diamond Bore, 2½ miles N.N.E. of Omoa Station, Lanarkshire.

9. Interior of brachial valve. Geol. Surv., Edinburgh, M.1254F.

Six-Yard Limestone, subzone D_2—D_3, Little Mill, Northumberland.

10a. Lateral view of pedicle valve. B.M., B.41967, S. Smith Coll.

10b. Same, ventral view, showing slight arching up of front of trail.



PRODUCTUS.

EXPLANATION OF PLATE II.

Diaphagmus 'elegans' (Norwood & Pratten). Page 21.
Lower Carb., Newtonville Limestone, ? = Maxville Limestone, Kent's Run, near Newtonville, Ohio, U.S.A.

FIG.

1. Visceral disk of brachial valve, surrounded by diaphragm with different ornament. Presd. by Dr. G. H. Girty to B.M., B.43444.
2. Inner layers of visceral disk of brachial valve which have split off from specimen in fig. 1.

Productus carbonarius de Koninck. Page 56.
Pendleside Series, Congleton Edge, Cheshire.

3. Visceral disk of pedicle valve, showing numerous fine spine-bases. B.M., B.43720, W. Hind Coll.
4. Same, trail with bifurcating costae.

Upper Limestones, Garngad Road, Glasgow.

5. Ventral view, showing numerous spine-bases. R. Scot. Mus., Edinburgh, 1911. 62. 964. (Figd. Davidson, 1880, pl. xxxvi, figs. 7a, b).

Pendleside Series, Congleton Edge, Cheshire.

6. Visceral disk of brachial valve and diaphragm. B.M., B.43721, W. Hind Coll.

Upper Limestones, Garngad Road, Glasgow.

7. Visceral disk of pedicle valve. B.M., B.45677, Davidson Coll.

Avonia sp. nov. Pages 36, 60.
Upper Limestones, Garngad Road, Glasgow.

8. Interior of brachial valve, showing adductor muscle-scars and median septum. R. Scot. Mus., Edinburgh, 1911. 62. 964. (Figd. Davidson, 1880, pl. xxxvi, fig. 8, as *P. carbonarius*).

Productus redesdalensis sp. nov. Page 61.
Redesdale Ironstone Shale, subzone D_1 ?, Redesdale, Northumberland.

9a. Holotype. Lateral view of pedicle valve. B.M., B.43830, W. Hind Coll.
9b. Same, ventral view, showing anterior development of spines.
9c. Same, visceral disk with spines almost lacking.

Same locality.

10. Visceral disk of pedicle valve and part of trail. B.M., B.41951, S. Smith Coll.

Same locality.

11. Pedicle valve, showing group of spine-bases on ear, and one spine in position. B.M., B.23070.

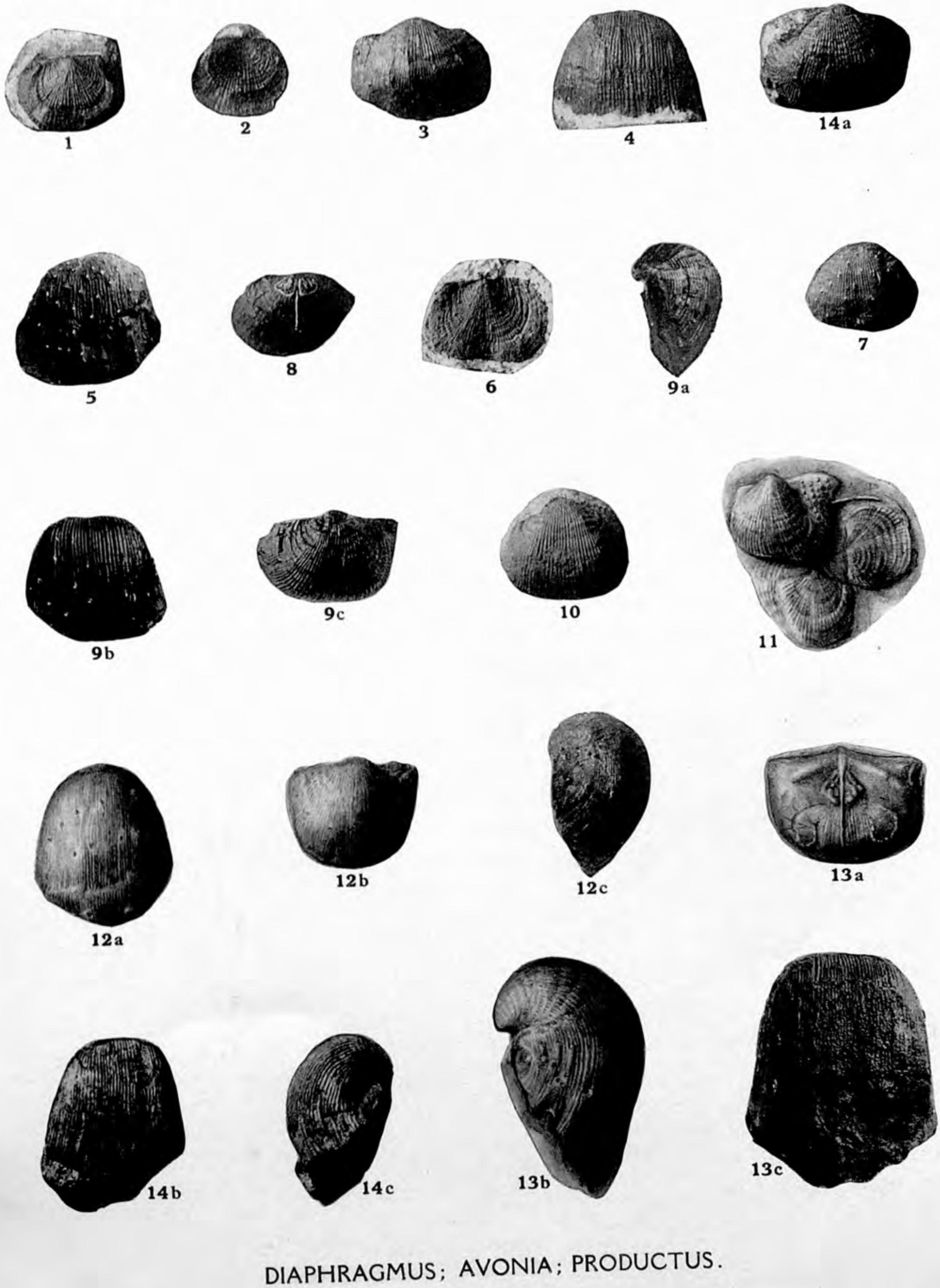
Productus vaughani sp. nov. Page 65.
Carb. Limest., subzone Z_1, Avon Section, Bristol.

12a. Holotype, ventral view. Bristol Univ.
12b. Same, posterior view.
12c. Same, lateral view.

MEMOIRS OF THE GEOLOGICAL SURVEY OF GREAT BRITAIN.

Palaeontology. Vol. III, 1928.

Plate II.



DIAPHRAGMUS; AVONIA; PRODUCTUS.

PLATE II—*continued.*

Productus vaughani sp. nov. Page 65.

Carb. Limest., horizon β, Avon Section.

FIG.

13a. Interior of brachial valve, showing brachial impressions and markings within the impressions, possibly representing setae given off by the spiral arms. Bristol Univ.

Carb. Limest., Zone Z, Moat House Quarry, west of Failand, near Bristol.

13b. Lateral view, showing folds below spine-bases on flanks of pedicle valve. Oxford Univ. Mus., 647 (Figd. Vaughan, 1905, pl. xxv, figs. 2, 2a).

13c. Same, ventral view, specimen much decorticated.

Productus garwoodi sp. nov. Page 70.

Carb. Limest., subzone S_2—D_1, Bryozoa Bed, Roman Fell, Westmorland.

14a. Holotype, posterior view of pedicle valve. Prof. E. J. Garwood's collection.

14b. Same, ventral view.

14c. Same, lateral view.

EXPLANATION OF PLATE III.

Productus griffithianus L. de Koninck. Page 73.
Carb. Limest., Botany Beds, subzone D_3, Botany, Yorkshire.

FIG.

1. Visceral disk of brachial valve, showing well-defined ribs. Prof. E. J. Garwood's collection.

Same locality.

2a. Visceral disk of pedicle valve. Prof. E. J. Garwood's collection.

Same locality.

2b. Trail of pedicle valve. Prof. E. J. Garwood's collection.

Carb. Limest., Little Island, Cork.

3. Visceral disk of pedicle valve. B.M., B.44007, J. Wright Coll.

Productus rotundus Garwood. Page 76.
Carb. Limest., base of *Seminula gregaria* subzone, C_1, above Fawcett Mill,
S.E. of Shap, Westmorland.

4a. Brachial valve. Prof. E. J. Garwood's collection.
4b. Same, pedicle valve.

Productus muricatus Phillips. Page 79.
Lower Carboniferous, ' Harelow,' Northumberland.

5. Holotype. Ventral view, showing prominent costae and numerous spine-bases. York Museum.

Lower Carb. Limest. Series, about 41 fathoms above Top Hosie Limestone,
Pollock Pit, ¼-mile W.N.W. of Corkerhill, about 3 miles S.W. of Glasgow.

6. Ventral view. Geol. Surv., Edinburgh, T.2410B.

Lower Limestones, Corrieburn, Campsie, Stirlingshire.

7a. Ventral view. B.M., B.45676, Davidson Coll. (Figd. 1861, pl. xxxii, fig. 14).
7b. Same, lateral view.
7c. Same, posterior view, showing row of spines along hinge.

Productus furcatus sp. nov. Page 85.
Carb. Limest., Derbyshire.

8a. Holotype. Posterior view of pedicle valve. B.M., B.45517, Morton Coll.
8b. Same, trail of pedicle valve, showing bifurcating costae.

Productus teres sp. nov. Page 87.
Carb. Limest., subzone C_1, quarry opposite Park House, Ravenstonedale,
Westmorland.

9a. Holotype. Lateral view of pedicle valve. Prof. E. J. Garwood's collection.
9b. Same, ventral view.

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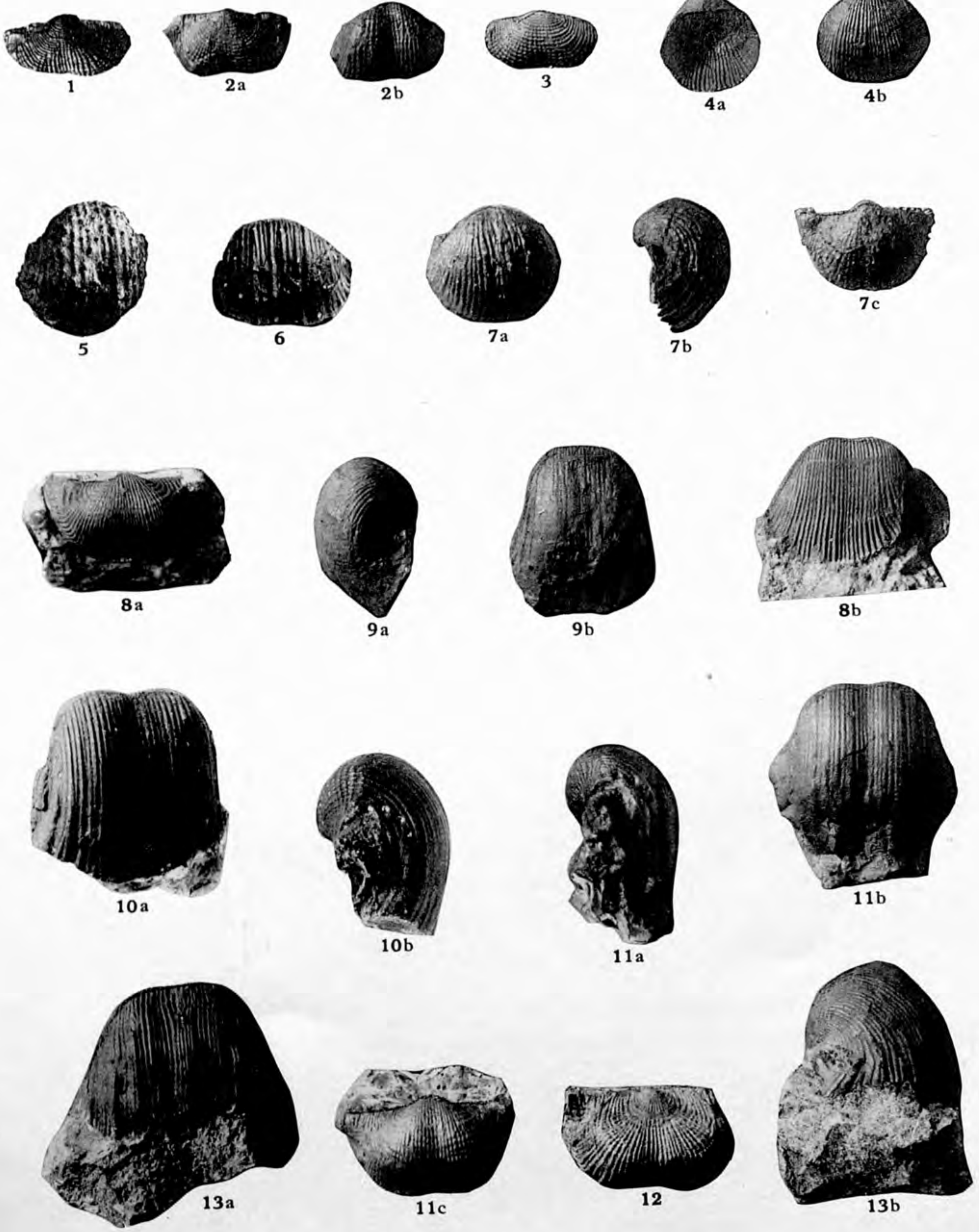
Plate III.



PRODUCTUS.

PLATE III—*continued.*

Productus insculptus sp. nov. Page 89.

Carb. Limest., subzone D_2, Narrowdale, Staffordshire.

FIG.

10a. Ventral view. M.P.G., 26682.

10b. Same, lateral view, showing row of spines on flank.

Lower Limestones, near Carluke, Lanarkshire.

11a. Holotype. Lateral view of pedicle valve. B.M., B.13868, Davidson Coll.

11b. Same, ventral view.

11c. Same, posterior view.

Lower Limestones, Trearne, Beith, Ayrshire.

12. Visceral disk of brachial valve, separated from trail by a geniculation. R. Scot. Mus., Edinburgh, 1911. 62. 113.

Productus productus, var. *hispidus* var. nov. Page 47.

Carb. Limest., subzone D_2, Humphrey Head, Lancashire.

13a. Holotype. Ventral view, showing numerous spine-bases. Prof. Garwood's collection.

13b. Same, lateral view, showing three rows of spine-bases on the cardinal slopes.

EXPLANATION OF PLATE IV.

Productus semireticulatus (Martin). Page 93.
Carb. Limest., Kildare, Ireland.

FIG.

1a. Ventral view. B.M., B.13980, Davidson Coll.

1b. Same, lateral view, showing spine-bases on flanks.

1c. Same, posterior view.

Carb. Limest., Derbyshire.

2a. Visceral disk and posterior part of trail of pedicle valve. B.M., B.3685.

2b. Same, lateral view.

2c. Same, visceral disk of pedicle valve.

Productus projectus sp. nov. Page 101.
Carb. Limest., Little Island, Cork, Ireland.

3. Ventral view, showing horizontal rim round the anterior margin. B.M., B.13892, Davidson Coll.

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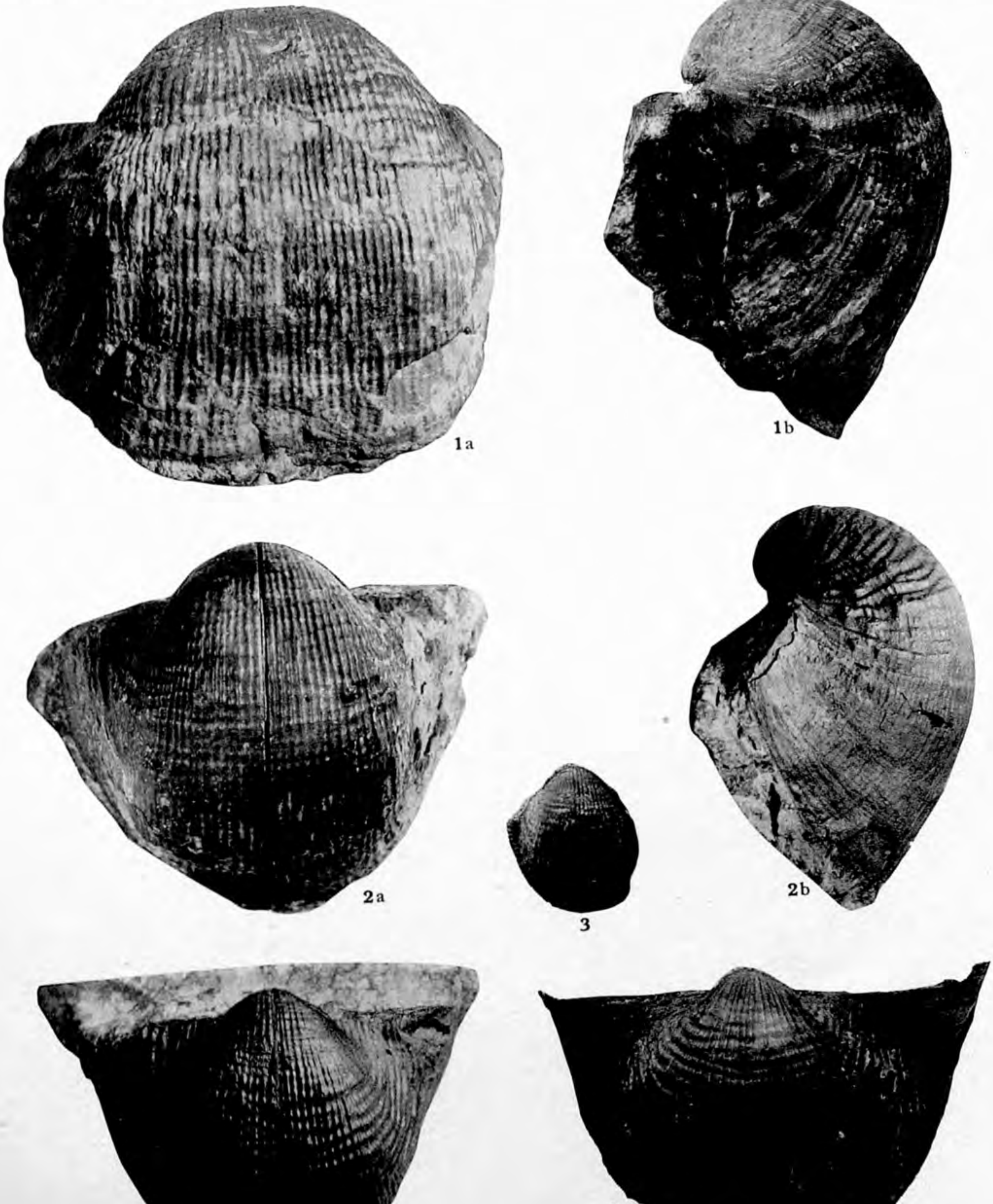
Plate IV.



PRODUCTUS.

EXPLANATION OF PLATE V.

Productus pinguis sp. nov. Page 104.

Carb. Limest., subzone D_2, half mile S. of Escow House, Grassington, Yorkshire.

FIG.

1. Ventral view. M.P.G., 34454.

Carb. Limest., Clapham, Yorkshire.

2a. Holotype. Lateral view of pedicle valve, showing three rows of large spine-bases on flanks. R. Scot. Mus., Edinburgh.

2b. Same, visceral disk.

2c. Same, trail of pedicle valve.

2d. Same, anterior part of visceral disk and trail.

Carb. Limest., Bolland, Yorkshire.

3. Brachial valve, much decorticated and showing adductor muscle-scars, median septum, and marginal ridges. B.M., B.45505, Gilbertson Coll.

MEMOIRS OF THE GEOLOGICAL SURVEY OF GREAT BRITAIN.

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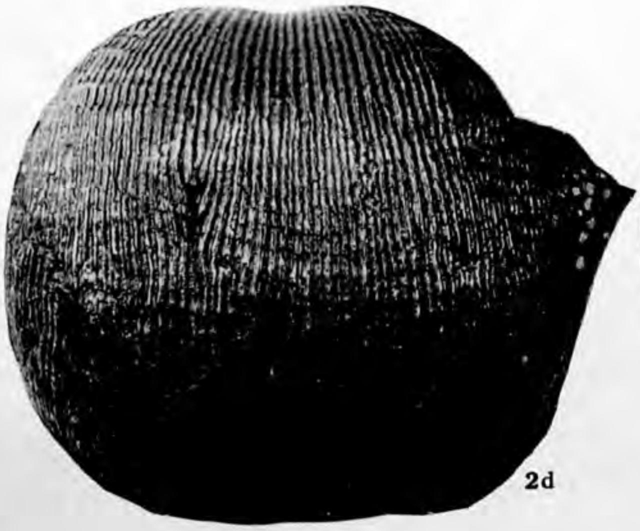
Plate V.

1

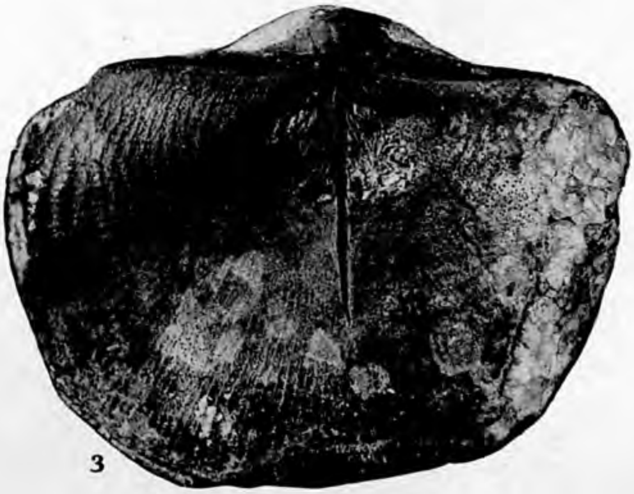
2a

2b

2c



2d



3

PRODUCTUS.

EXPLANATION OF PLATE VI.

Productus pinguis sp. nov. Page 104.

Carb. Limest., Derbyshire.

FIG.

1. Internal cast of pedicle valve, showing small dendritic adductor muscle-scars, and large striated diductor scars. Sedgwick Mus., Cambridge, 98.

Productus hindi, var. *wettonensis* var. nov. Page 113.

Carb. Limest., subzone D_2, Wetton, Staffordshire.

2a. Holotype. Visceral disk of pedicle valve, showing row of spine-bases on cardinal slopes. B.M., B.43814, W. Hind Coll.

2b. Same, lateral view, showing large spine-bases on flanks.

2c. Same, ventral view.

Productus hindi sp. nov. Page 108.

Carb. Limest., Derbyshire.

3. Visceral disk of brachial valve. B.M., 74331, Etheridge Coll.

Carb. Limest., quarry N. of Pike House, near Dovedale, Derbyshire.

4a. Holotype. Visceral disk of pedicle valve, showing spine-bases on cardinal slopes. B.M., B.47860, J. W. Jackson Coll.

4b. Same, lateral view.

4c. Same, ventral view.

Lower Limestones, in bank of Poniel Water, Brackenside, Coalburn, Lanarkshire.

5. Lateral view of pedicle valve, showing one spine in position. Geol. Surv., Edinburgh, M.4484F.

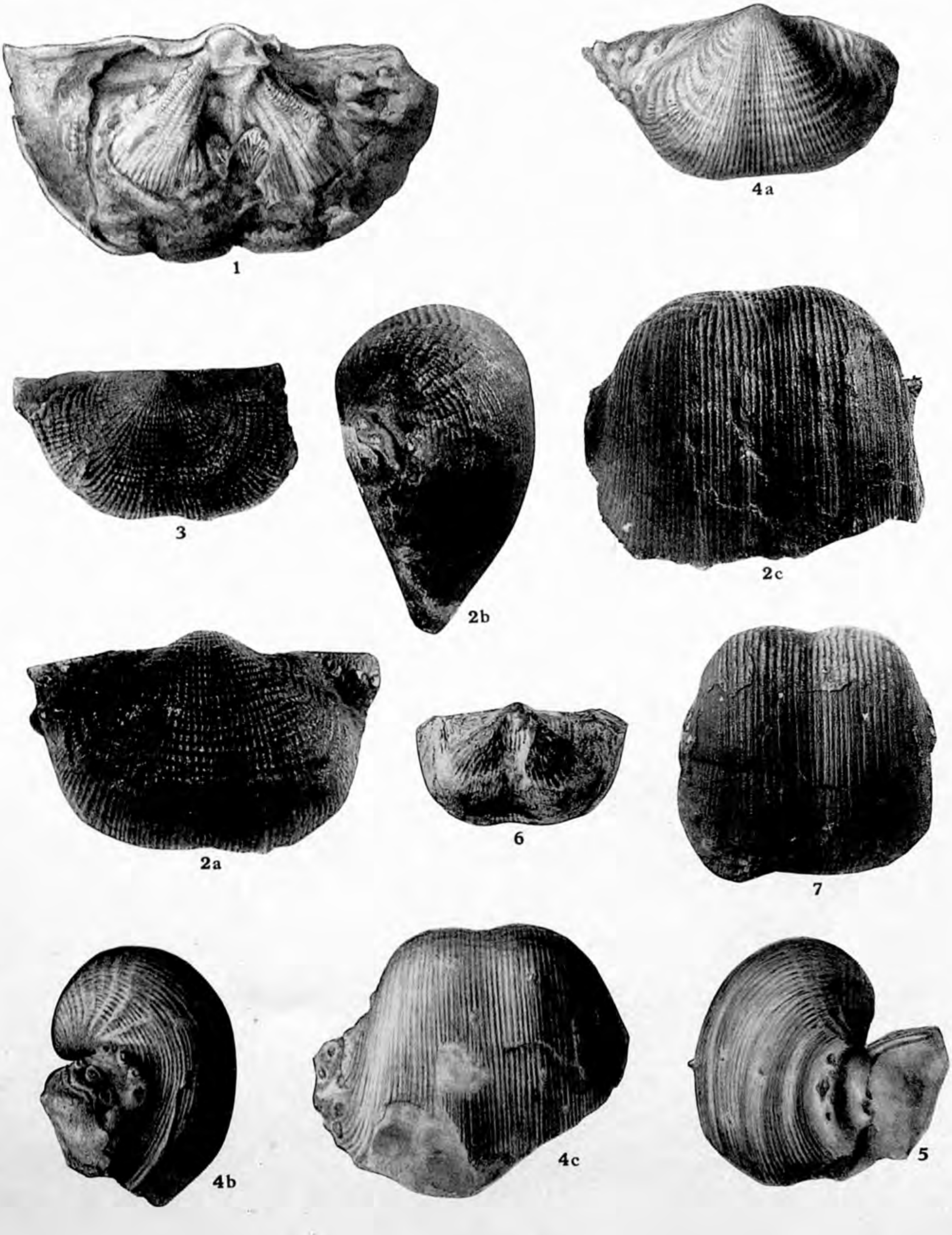
Lower Limestones, Bowertrapping, Dalry, Ayrshire.

6. Internal cast of pedicle valve, showing adductor and diductor muscle-scars. B.M., B.13863, Davidson Coll.

Productus antiquatus J. Sowerby. Page 114.

Carb. Limest., subzone D_2, Cracoe, knoll reefs, Yorkshire.

7. Ventral view of decorticated specimen. Prof. E. J. Garwood's collection.



PRODUCTUS.

EXPLANATION OF PLATE VII.

Productus antiquatus J. Sowerby. Page 114.

Carb. Limest., subzone D_2, Cracoe, knoll reefs, Yorkshire.

FIG.

1. Lateral view of specimen figured in pl. vi, fig. 7, showing spine-bases on flanks. Prof. E. J. Garwood's collection.

Carb. Limest., subzone D_2, Malham, knoll reefs, Yorkshire.

2. Visceral disk of brachial valve. B.M., B.45512.

Carb. Limest., subzone D_2, Narrowdale Hill, Staffordshire.

3. Lateral view of pedicle valve, showing ear and posterior part of flank preserved. B.M., B.45504.
4a. Visceral disk of pedicle valve. B.M., B.45503.
4b. Same, lateral view.
4c. Same, ventral view.

Productus kilbridensis sp. nov. Page 119.

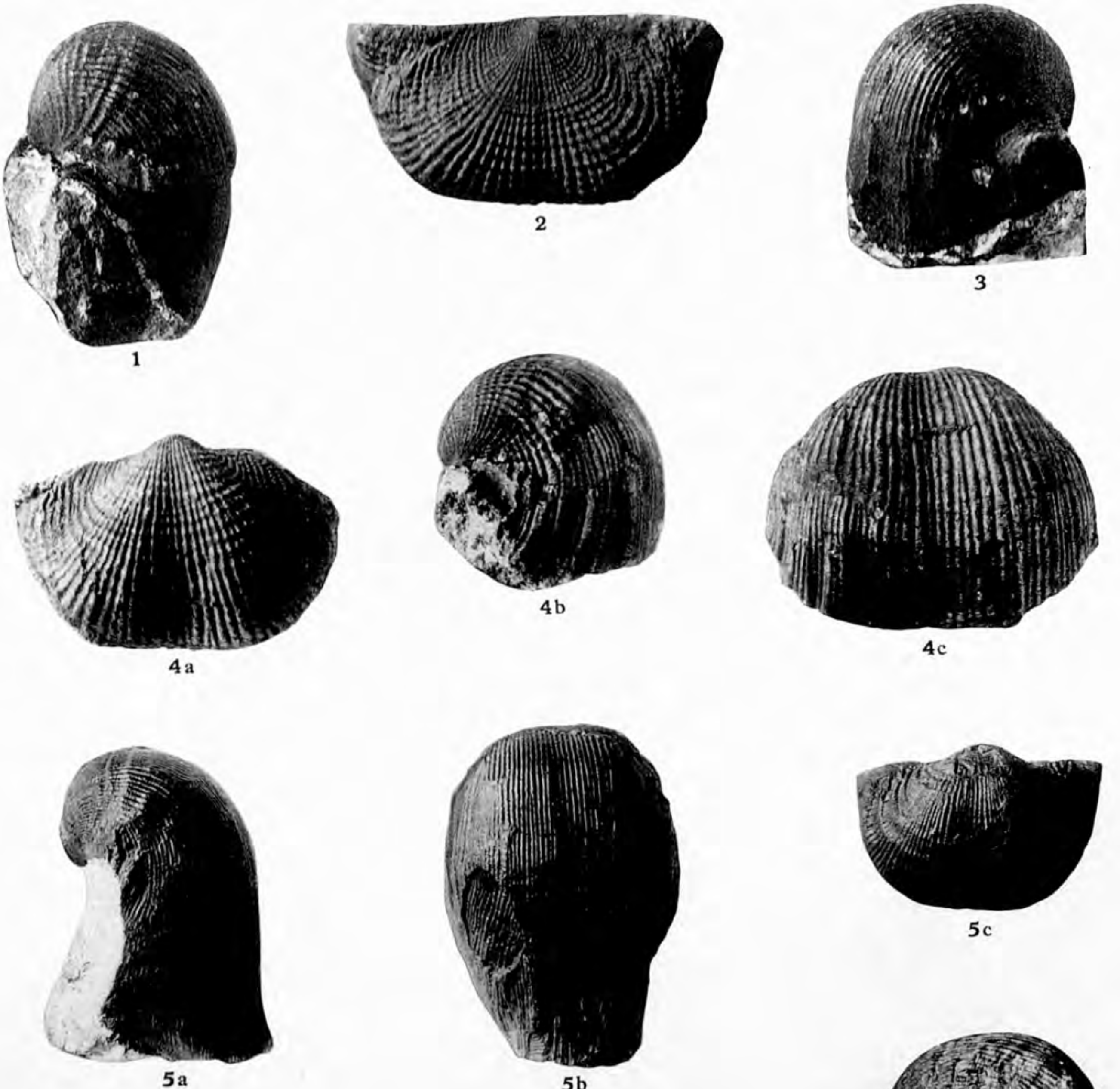
Lower Ironstone Group, Kilbride, Ayrshire.

5a. Holotype. Lateral view. R. Scot. Mus., Edinburgh, 1911. 62. 112, Neilson Coll.
5b. Same, ventral view, showing slight tube-like formation of front of trail.
5c. Same, visceral disk of pedicle valve.

Productus multispiniferus sp. nov. Page 121.

Carb. Limest., Hall Dale, Dovedale, Derbyshire.

6a. Holotype. Ventral view, showing prominent costae. B.M., B.47981, J. W. Jackson Coll.
6b. Same, visceral disk of pedicle valve.
6c. Same, lateral view, showing group of spine-bases on flank.



PRODUCTUS.

EXPLANATION OF PLATE VIII.

Productus multispiniferus sp. nov. Page 121.
Carb. Limest., Yorkshire.

FIG.

1a. Ventral view. B.M., 27056.

1b. Same, lateral view, showing rows of small spine-bases.

1c. Same, visceral disk.

Carb. Limest., Withgill, Clitheroe, Lancashire.

2. Visceral disk of brachial valve. M.P.G., 34451.

Productus scoticus J. Sowerby. Page 125.
Lower Carboniferous, Redesdale Ironstone, ? subzone D_1, Redesdale, Northumberland.

3a. Ventral view. B.M., B.43728, W. Hind Coll.

3b. Same, dorsal view.

4. Interior of brachial valve. B.M., B.43810, W. Hind Coll.

Lower Ironstone Group, Kilbride, Ayrshire.

5a. Ventral valve, showing longitudinal folds near anterior margin. R.Scot. Mus., Edinburgh, 14, Neilson Coll.

5b. Same, lateral view.

5c. Same, visceral disk of pedicle valve.

Upper Limestones, Garnkirk, Lanarkshire.

6. Interior of brachial valve. Kelvingrove Mus., Glasgow, 01.53 agg.

Productus howratensis sp. nov. Page 130.
Lower Limestones, Howrat, 3 miles N.W. of Dalry, Ayrshire.

7a. Holotype. Ventral view. R. Scot. Mus., Edinburgh, 5, Neilson Coll.

7b. Same, lateral view, showing band of spines near anterior margin.

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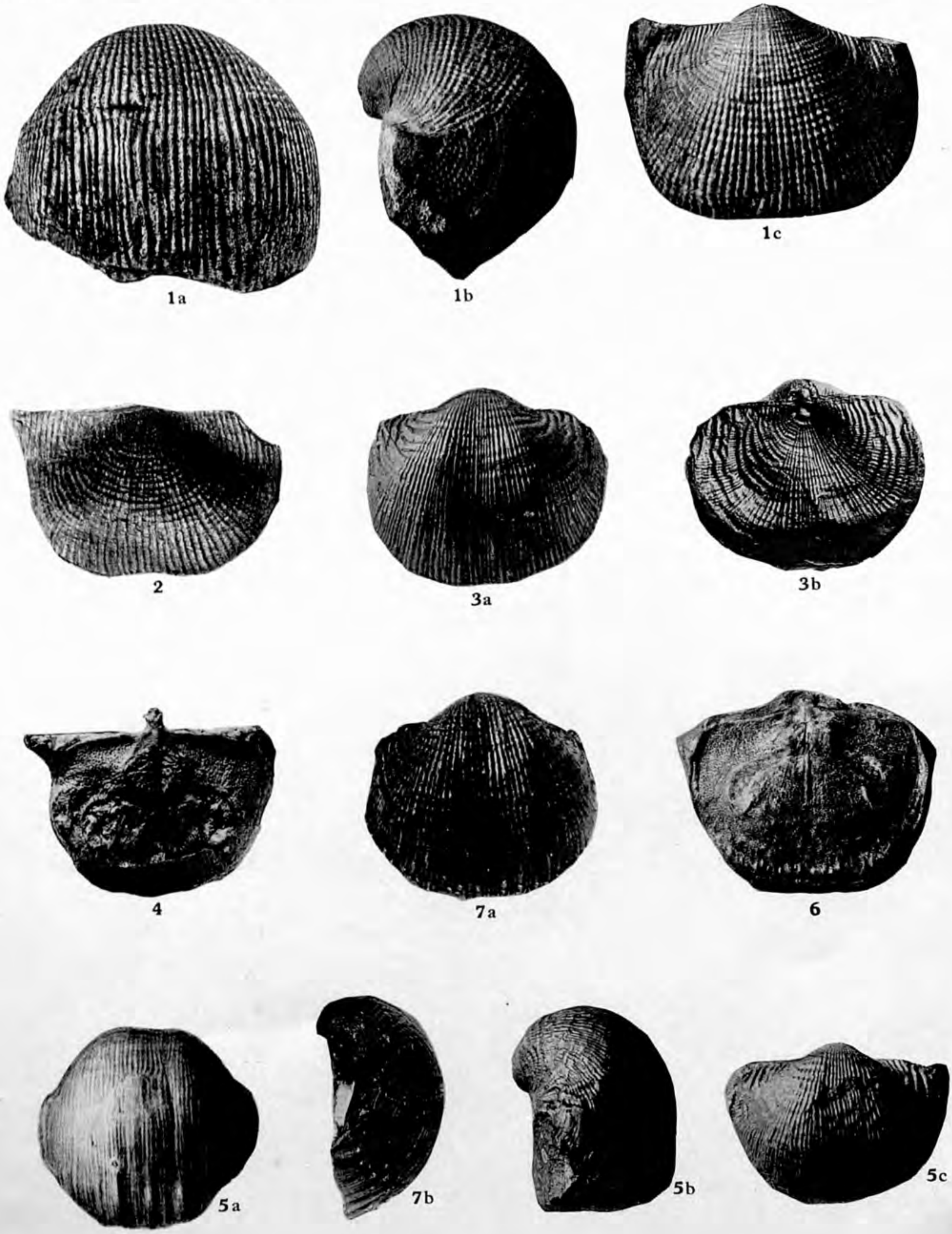
Plate VIII.



PRODUCTUS.

EXPLANATION OF PLATE IX.

Productus pugilis J. Phillips. Page 133.

Carb. Limest., Ticknall, Ashby-de-la-Zouch, Derbyshire.

FIG.

1a. Ventral view of decorticated specimen. M.P.G., 34452.

1b. Same, lateral view.

Carb. Limest., subzone D_2, Sellet Mill, S. of Kirkby Lonsdale, Westmorland.

2. Crushed specimen resembling Phillips's type. Prof. E. J. Garwood's collection.

Lower Carboniferous, Far House Shales, Cam Beck, Yorkshire.

3. Crushed specimen, showing trifid exterior of cardinal process against adductor muscle-scars of pedicle valve. Portion of the diductor scars is visible. B.M., B.20450.

Lower Carboniferous, Back Scar, E. of Settle, Yorkshire.

4. Pedicle valve, showing prominent longitudinal folds developed below spine-bases. B.M., B.45686, H. M. Muir-Wood Coll.

Carb. Limestone, subzone Dv, Styford or Stanton, Northumberland.

5. Interior of brachial valve. B.M., B.41914, S. Smith Coll.

Productus pugilis, mut. *senilis* mut. nov. Page 139.

Upper Limestones, Thornliebank, Renfrewshire.

6a. Holotype. Ventral view, showing irregular costation on anterior part of trail. R. Scot. Mus., Edinburgh, 1911. 62. 954.

6b. Same, lateral view.

6c. Same, brachial valve, showing disappearance of costae below the visceral disk and development of scale-like laminae on anterior part of shell.

6d. Same, visceral disk of pedicle valve.

Productus bristolensis sp. nov. Page 140.

Carb. Limest., subzone Z_2, Avon Gorge, Clifton, Bristol.

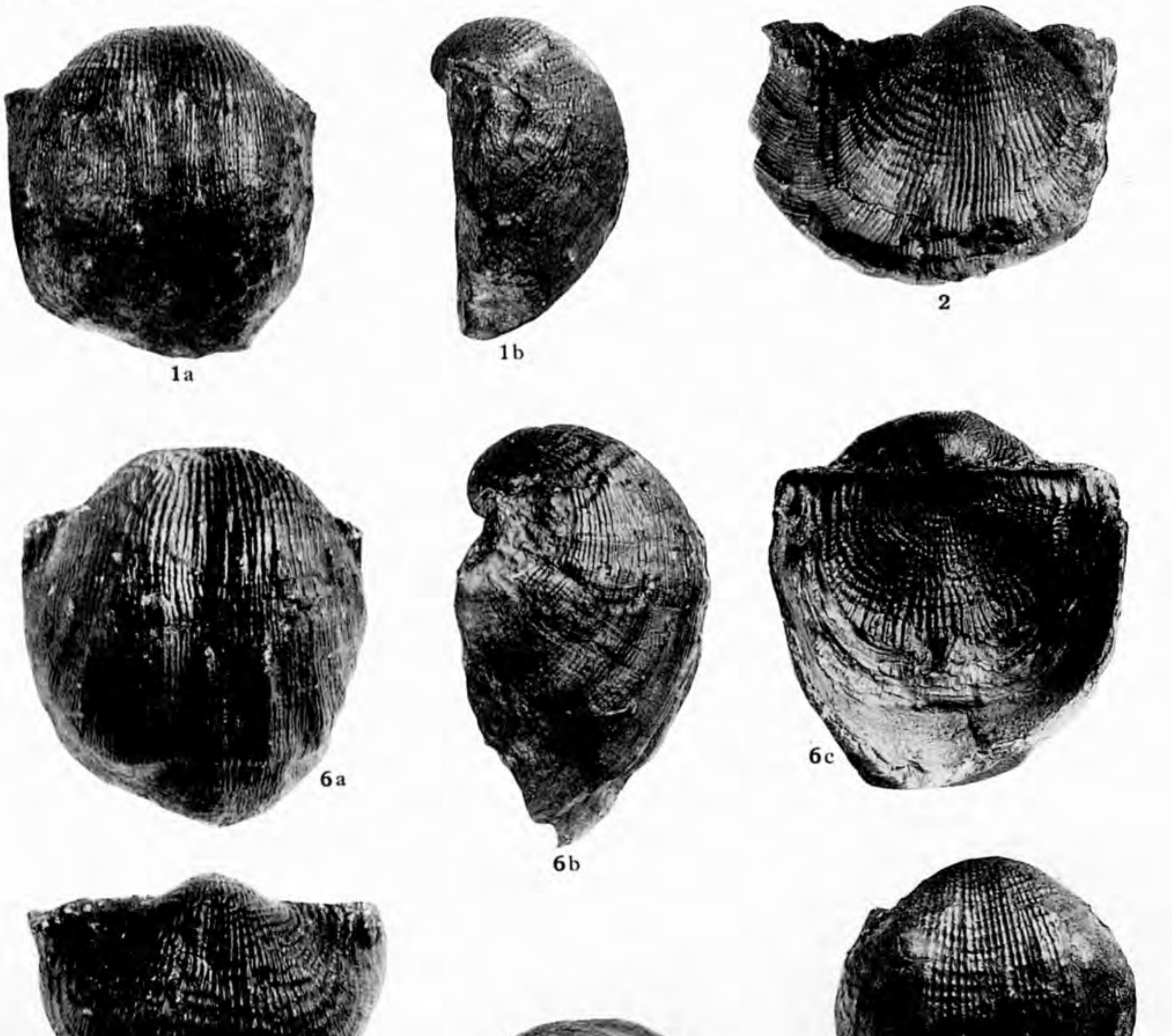
7a. Holotype. Ventral view. Bristol Mus., C.4104.

7b. Same, lateral view.

MEMOIRS OF THE GEOLOGICAL SURVEY OF GREAT BRITAIN.

Palaeontology. Vol. III, 1928.

Plate IX.



PRODUCTUS.

EXPLANATION OF PLATE X.

Productus costatus J. de C. Sowerby. Page 143.

Upper Limestones, Orchard, near Glasgow.

FIG.

1a. Ventral view. B.M., B.5761, Davidson Coll. (Figd. 1861, pl. xxxii, fig. 2).

1b. Same, lateral view.

1c. Same, posterior view, showing row of spines along hinge and up flanks.

2. Ventral view. Kelvingrove Mus., Glasgow, 01.53 afe.

Upper Limestones, Thornliebank, Renfrewshire.

3. Interior of brachial valve. R. Scot. Mus., Edinburgh, 1911. 62. 955.

Productus sulcatus J. Sowerby. Page 147.

Carb. Limest., subzone D_2, Oystermouth Castle, Mumbles, Glamorganshire.

4. Visceral disk of brachial valve. M.P.G., 34372.

5a. Ventral view, showing ear. M.P.G., 34370.

5b. Same, posterior view, showing row of spine-bases along hinge.

Carb. Limest., subzone D_2, Narrowdale, Staffordshire.

6. Ventral view. B.M., B.43727, W. Hind Coll.

Carb. Limest., Preston, Lancashire.

7a. Lateral view, showing row of spine-bases, set on ridge up flanks. B.M., 47271.

7b. Same, posterior view.

7c. Same, ventral view.

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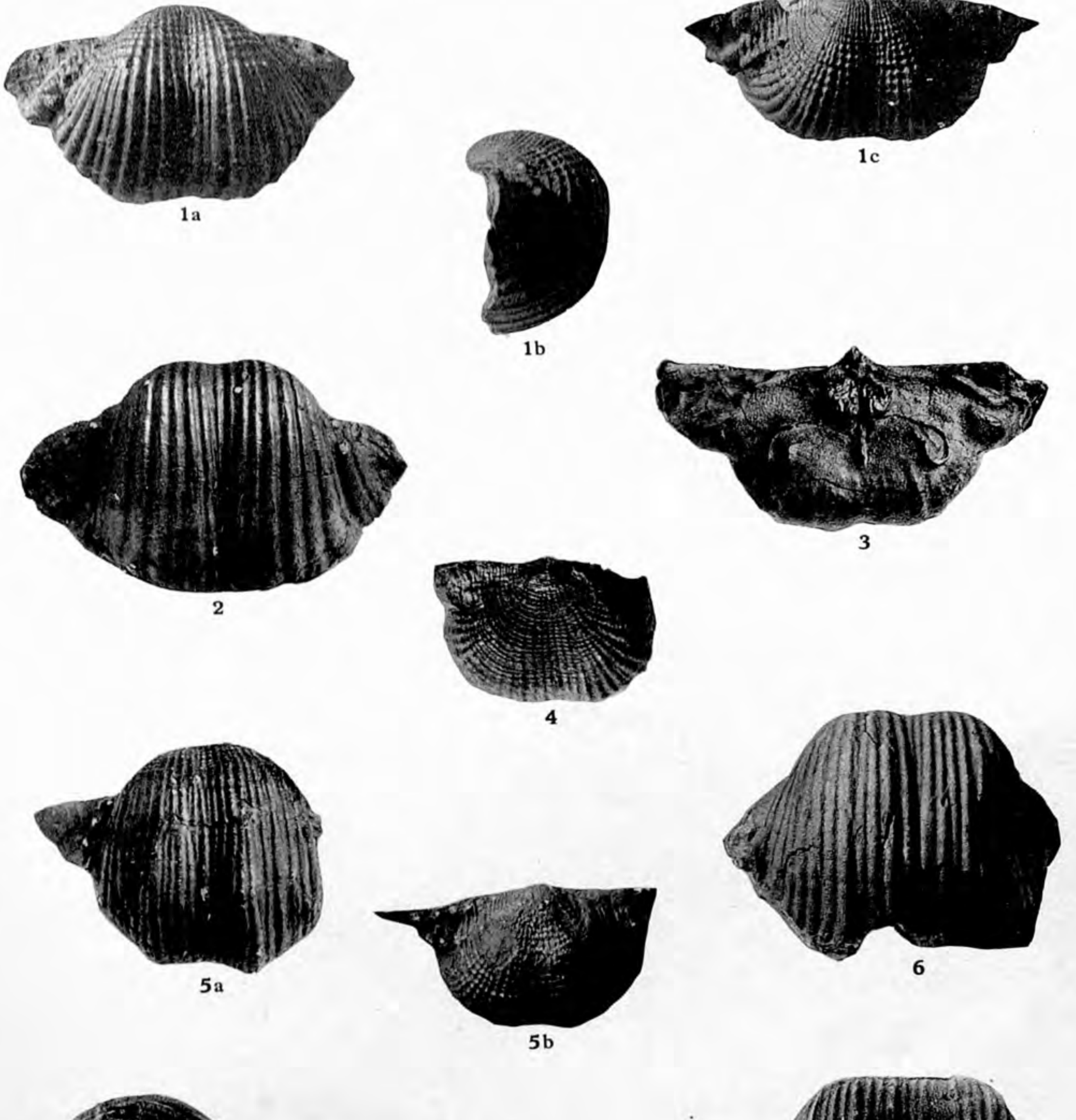
Plate X.



PRODUCTUS.

EXPLANATION OF PLATE XI.

Productus longispinus J. Sowerby. Page 156.

Lower Limestones, bank of Poniel Water, Brackenside, Coalburn, Lanarkshire.

FIG.

1. Visceral disk of brachial valve. One spine preserved near cardinal angle. Geol. Surv., Edinburgh, M.4506F.

Carb. Limest., Scremerston, Northumberland.

2a. Visceral disk of pedicle valve. B.M., B.43723, W. Hind Coll.

2b. Same, ventral view, showing two symmetrically placed spines on front of trail.

Lower Limestones, Cunningham-Baidland, Dalry, Ayrshire.

3. Pedicle valve, showing six major spine-bases on venter, flanks and ears. B.M., B.45515, Davidson Coll.

Lower Limestones, Auchenmade, 3½ miles S.E. of Dalry, Ayrshire.

4. Internal cast of brachial valve. R. Scot. Mus., Edinburgh, 48, Neilson Coll.

Productus tissingtonensis Sibly. Page 166.

Lower Carboniferous, Far House Shales, Settle, Yorkshire.

5. Interior of brachial valve. B.M., B.45518.

Productus lobatus J. Sowerby. Page 173.

Lower Carboniferous, Northumberland.

6. Interior of brachial valve. B.M., B.45687.

Productus triquetrus sp. nov. Page 163.

Carb. Limest., subzone D_2, N.E. slope of Chrome Hill, Derbyshire.

7a. Visceral disk of pedicle valve. M.P.G., 38344.

7b. Same, ventral view, showing two major spines.

7c. Same, lateral view.

Productus tissingtonensis Sibly. Page 166.

Carb. Limest., subzone D_3, Tissington, Derbyshire.

8a. Lectotype. Visceral disk of pedicle valve. B.M., B.42160, Sibly Coll.

8b. Same, ventral view, showing median fold.

Carb. Limest., subzone D_2—D_3, Bishop's Quarry, Great Orme's Head, N. Wales.

9. Ventral view. B.M., B.45542, L. B. Smyth Coll.

Productus derbiensis sp. nov. Page 170.

Carb. Limest., subzone D_2, Thorpe Cloud, Derbyshire.

10. Holotype. Pedicle valve. B.M., B.43730, W. Hind Coll.

Carb. Limest., subzone D_2, Narrowdale, Staffordshire.

11. Visceral disk of brachial valve. B.M., B.43729, W. Hind Coll.

MEMOIRS OF THE GEOLOGICAL SURVEY OF GREAT BRITAIN.

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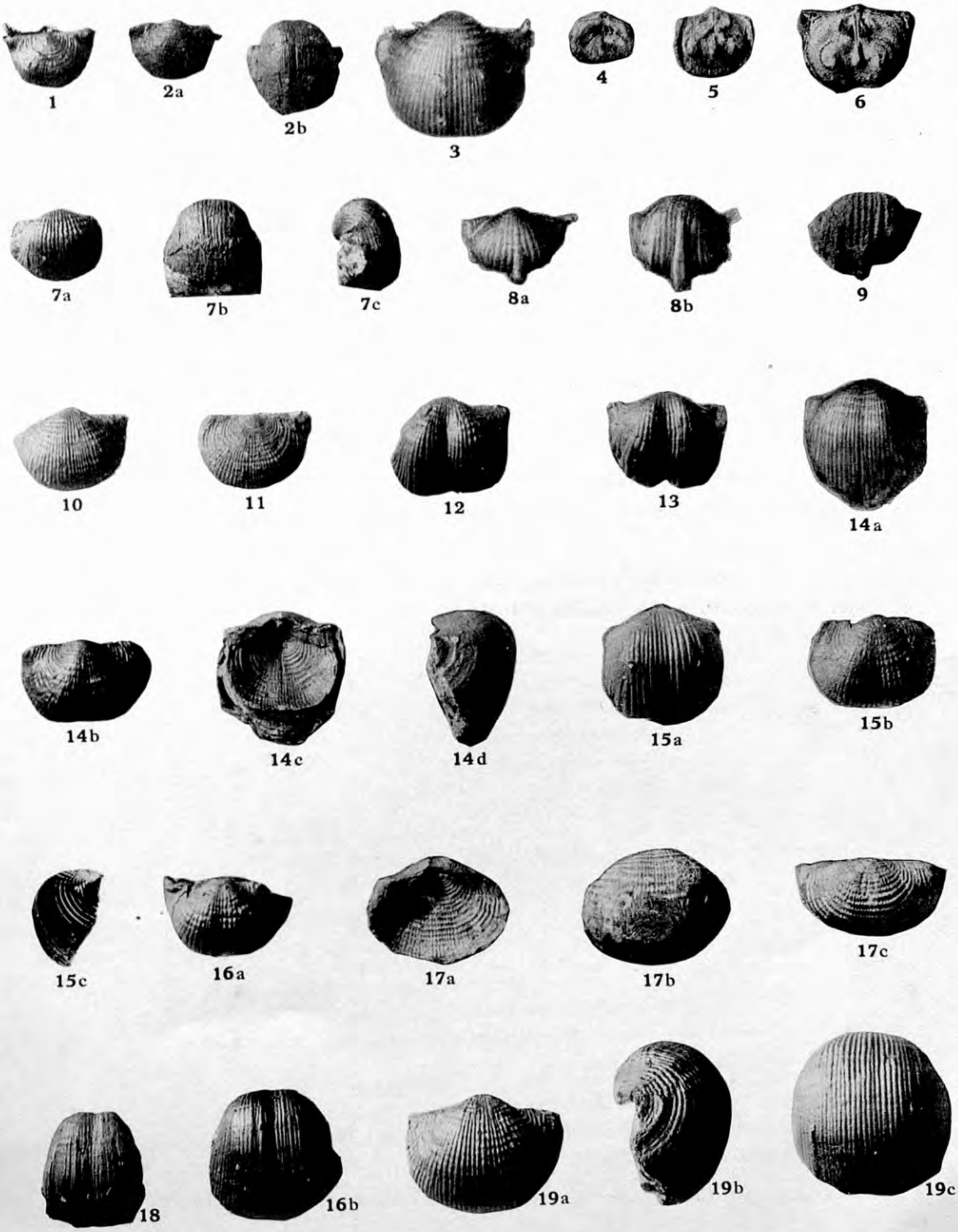
Plate XI.



PRODUCTUS.

PLATE XI—*continued.*

Productus lobatus J. Sowerby. Page 173.
Lower Carboniferous, shale in Kirke Harle Burn, near Wallington, Northumberland.

FIG.
12. Ventral view, showing deep sinus. B.M., B.15505.

Lower Limestones, bank of Poniel Water, S.E. of Bankend, Coalburn, Lanarkshire.

13. Ventral view. Geol. Surv., Edinburgh, M.4488G.

Productus setosus J. Phillips. Page 182.
Lower Carboniferous, Gorbeck, Settle, Yorkshire.

14a. Ventral view, showing V-shaped extension of front of trail. B.M., B.20496.
14b. Same, visceral disk.
14c. Same, brachial valve, showing successive laminae deposited round margin of brachial valve to correspond with normal growth of trail of pedicle valve.
14d. Same, lateral view, showing one major spine on flank.

Carb. Limest., Upper Grey Limestone, Minera, Denbighshire.

15a. Ventral view, showing two major spines. B.M., B.45679, Morton Coll.
15b. Same, posterior view.
15c. Same, lateral view.

Productus lobatus, var. *laqueatus* var. nov. Page 178.
Upper Limestones, Orchard, near Glasgow.

16a. Visceral disk of pedicle valve. R. Scot. Mus., Edinburgh, 36, Neilson Coll.
16b. Same, ventral view.

Productus pseudoplicatilis sp. nov. Page 189.
Carb. Limest., Settle, Yorkshire.

17a. Holotype. Brachial valve. B.M., B.20540.
17b. Same, pedicle valve, much decorticated anteriorly.
17c. Same, visceral disk of pedicle valve.

Productus lobatus, var. *laqueatus* var. nov. Page 178.
Upper Limestones, Cock of Arran, Scotland.

18. Holotype. Ventral view. R. Scot. Mus., Edinburgh, 38, Neilson Coll.

Productus derbiensis sp. nov. Page 170.
Carb. Limest., subzone D_2, Wetton, Staffordshire.

19a. Giganteid Form. Visceral disk of pedicle valve. B.M., B.45516, Davidson Coll.
19b. Same, lateral view.
19c. Same, ventral view.

EXPLANATION OF PLATE XII.

Productus praecursor sp. nov. Page 191.

Lower Limestones, Beith, Ayrshire.

FIG.

1. Brachial valve, showing slight thickening of shell round margin. R. Scot. Mus., Edinburgh, 57, Neilson Coll.

Lower Limestones, Roughwood, Beith, Ayrshire.

2. Holotype. Pedicle valve, showing slight folding of front of trail. R. Scot. Mus., Edinburgh, 34, Neilson Coll.

Productus minutus sp. nov. Page 195.

Carb. Limest, Little Island, Cork.

3a. Holotype. Lateral view, showing cincture extending from hinge round front of shell. B.M., B.40200, J. Wright Coll.

3b. Same, ventral view.

3c. Same, visceral disk, showing flattened, triangular ears.

Productus lobatus, var. *flexus* var. nov. Page 180.

Lower Limestones, Main Limestone, Campsie, Stirlingshire.

4. Holotype. Ventral view. Kelvingrove Mus., Glasgow, 01.53 aid, Young Coll. (Figd. Davidson, 1861, pl. xxxv, fig. 10).

5. Interior of brachial valve, showing small triangular adductors, and enlargement of anterior end of median septum. Same coll., 01.53 aid.

Avonia youngiana (Davidson). Page 36.

Lower Limestones, Corrieburn, Campsie, Stirlingshire.

6. Young specimen, showing spinose ornament of the posterior portion of shell. B.M., B.45685, Davidson Coll.

7. Interior of brachial valve, showing small, non-dendritic adductor scars, median septum and brachial ridges. B.M., B.45681, Davidson Coll.

Lower Limestones, Lilyburn, Campsie, Stirlingshire.

8. Interior of brachial valve. Kelvingrove Mus., Glasgow, 01.53 agy.

Lower Limestones, Corrieburn, Campsie, Stirlingshire.

9. Ventral view, showing numerous spine-bases springing from summit of costae. B.M., B.45680, Davidson Coll.

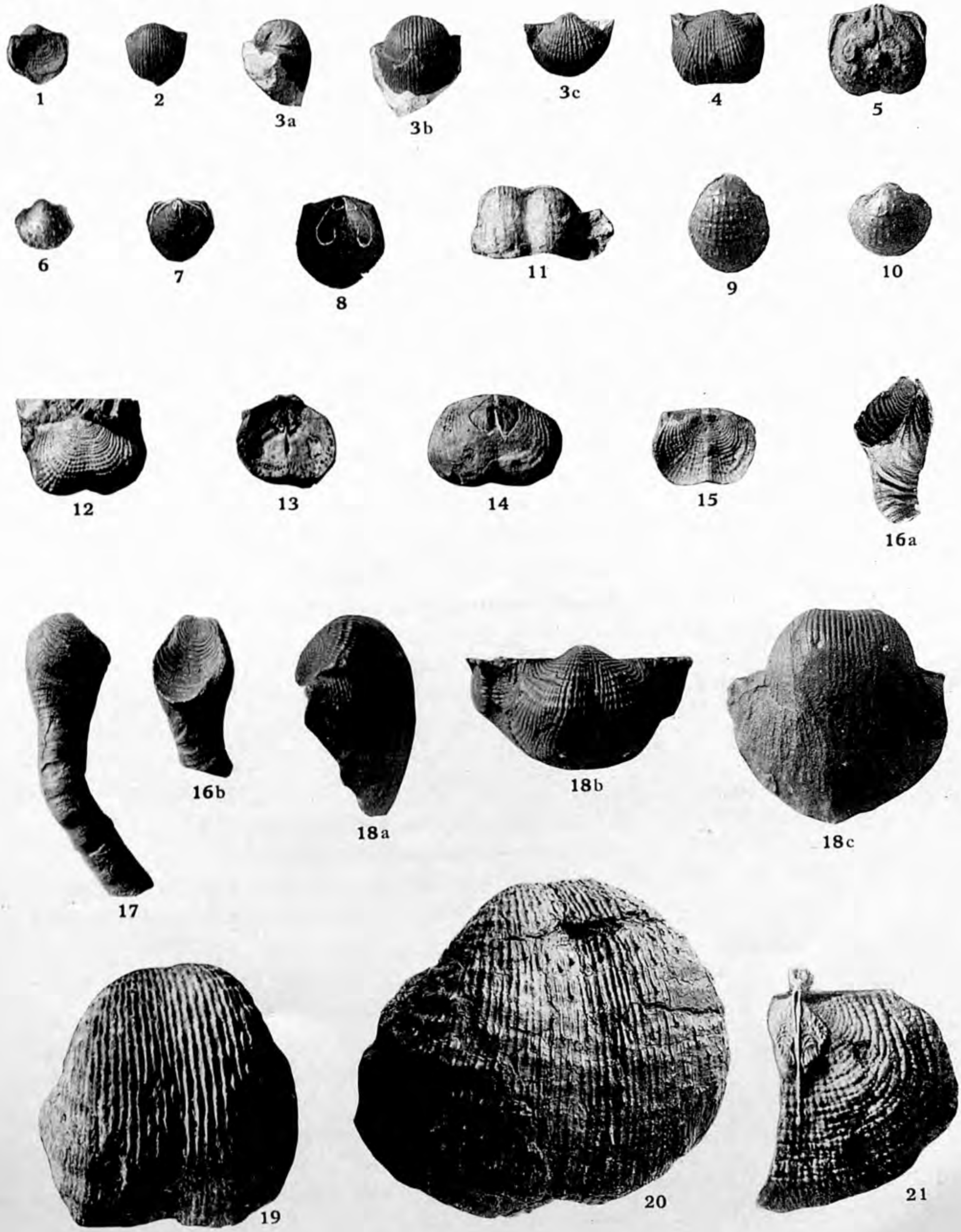
10. Same, visceral disk, showing ornament of spine-bases.

Sinuatella sinuata (de Koninck). Page 37.

Carb. Limest., Settle, Yorkshire.

11. Ventral view, showing deep sinus. Sedgwick Mus., Cambridge, 148, Burrow Coll.

12. Same, visceral disk.



PRODUCTUS; AVONIA;

SINUATELLA; PROBOSCIDELLA; BUXTONIA.

PLATE XII—*continued.*

Sinuatella sinuata (de Koninck). Page 37.

Upper Limestones, Bowertrapping, Dalry, Ayrshire.

FIG.

13. Cast of interior of brachial valve. Kelvingrove Mus., Glasgow, 01.53 ahj, Young Coll.

Carb. Limest., Visé, Belgium.

14. Cast of interior of pedicle valve, showing diductor scars enclosing oval adductors. B.M., B.45684, de Koninck Coll.

Carb. Limest., Settle, Yorkshire.

15. Exterior of brachial valve and cardinal area, with small triangular delthyrium. Sedgwick Mus., Cambridge, 148.

Proboscidella proboscidea (de Verneuil). Page 37.

Carb. Limest., Visé, Belgium.

16a. Lateral view of shell. B.M., B.45682, de Koninck Coll.

16b. Same, brachial valve, which serves as cap to tube-like pedicle valve. The vertical line of junction of the flanks of the pedicle valve can be seen immediately below the brachial valve.

17. Ventral view, showing long tube with fine costae and ribs. B.M., B.45683, de Koninck Coll.

Productus triquetrus sp. nov. Page 163.

Carb. Limest., roadside near Underhill Farm, S.W. of Hitter Hill, Gluttondale, Derbyshire.

18a. Giganteid form. Lateral view, showing posteriorly flattened visceral disk, and one major spine on flank. M.P.G., 38395.

18b. Same, visceral disk, with two major spines on venter.

18c. Same, ventral view, showing triangular outline of shell.

Buxtonia scabricula (Martin). Page 36.

Carb. Limest., Cork, Ireland.

19. Ventral view, showing costae bearing numerous spine-bases posteriorly, and bands bearing small spine-bases near anterior margin. B.M., B.45678, J. Wright Coll.

Buxtonia sp. Page 36.

Redesdale Ironstone Shale, Redesdale, Northumberland.

20. Ventral view, showing bands of spines near anterior margin. M.P.G., 34439.

21. Interior of brachial valve, showing bifid cardinal process, below which two narrow lamellae converge and unite to form a solid median septum. B.M., B.45579, W. Hind Coll.

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No 5

BRACHIOPODS FROM THE BELEMNITE MARLS.

By HELEN MARGUERITE MUIR-WOOD, M.Sc., F.G.S.

Brachiopoda occur scattered throughout the Belemnite Marls, but are abundant only at two horizons, namely in Beds 111–112, where several species of *Cincta* form a well-marked band; and in Beds 118–119, where crushed specimens of *Tropiorhynchia thalia* (A. d'Orbigny) are predominant. A remarkably large number of species are represented in the small amount of material to be described, all of which was collected by Dr. Lang and is now preserved in the British Museum (Natural History) Collection.

The material is poorly preserved, much flattened, and distorted, rendering specific determinations a matter of extreme difficulty. The specimens, however, are found to agree very well with better-preserved material from the Lias of Northern France, and from the Lias γ of Germany. Comparison has also been made with specimens from the Lias of Radstock (Somerset) and Yorkshire.

Family DISCINIDÆ.

Genus DISCINISCA Dall, 1871.

DISCINISCA (?) HOLDENI (Tate).

Discina holdeni R. Tate, 1867, p. 314.
Discina holdeni Tate; T. Davidson, 1876, p. 85 & pl. x, figs. 7, 8, 12, 12*a*, pl. xi, fig. 32..

Small examples measuring about 3 mm. in diameter occur in the Middle pale band, Bed 113 (specimen B 45898) and in the Upper darker marls, Beds 118 *c*, 119 (specimens B 49490, 45872). The upper, or conical, valve alone is preserved, and is of a pale-brown colour with a highly polished surface and numerous growth-lines. One specimen is attached to *Tropiorhynchia thalia* (A. d'Orbigny). From the form of the pedicle-opening seen in other specimens this species appears to belong to the genus *Discinisca* rather than to *Orbiculoidea*.

This species was recorded by Tate from the *angulatus* zone of County Antrim and the *ibex* zone of Cheltenham, but is said by Davidson to range throughout the Lower Lias.

Family RHYNCHONELLIDÆ.

Genus GIBBIRHYNCHIA S. S. Buckman, 1914.

GIBBIRHYNCHIA CURVICEPS (Quenstedt). (Fig. 2, p. 247.)

Terebratula curviceps Quenstedt, 1858, p. 138 & pl. xvii, figs. 13-15.
Terebratula curviceps Quenstedt, 1871, p. 57 & pl. xxxvii, figs. 118-120.
Rhynchonella curviceps (Quenstedt); Haas & Petri, 1882, p. 188 & pl. iii, fig. 33.
Rhynchonella curviceps Quenstedt; Rau, 1905, p. 18 & pl. ii, figs. 14-17.
Gibbirhynchia curviceps (Quenstedt); S. S. Buckman, 1917, p. 44.

One imperfect specimen from the Belemnite Stone, Bed 121 (B 49491), has half of the brachial valve and a small part of the pedicle-valve preserved. It is extremely gibbous, being 18·6 mm. long, 18 mm. wide, and 15 mm. thick. It has a prominent median fold and strongly curved lateral slopes in the brachial valve. A well-developed dorsal septum is visible through the test. Since the umbo of the pedicle-valve is missing, the beak-characters are unknown.

The costæ are prominent and sub-angular anteriorly. Six occur on the median fold, and eight to ten on each lateral slope. Two costæ unite to form one thickened costa in the depression separating the median fold from the lateral slope.

This specimen agrees very well in form and ornament with Quenstedt's figures of this species, but it has more numerous costæ on the lateral slopes.

Previous records.—Quenstedt (1858) figures this species from the Lias, lower γ, Spiriferenbank of Riederich. Rau figures specimens from the same bed at various localities in Swabia, and records it from the *jamesoni* zone of Oldershausen (Northern Germany). Haas & Petri also figure this species from the *Davœi*kalk, Bévoie, near Metz.

Genus Tropiorhynchia S. S. Buckman, 1914.

Tropiorhynchia thalia (A. d'Orbigny). (Figs. 3 *a* & 3 *b*, 4 *a* & 4 *b*, below.)

Rhynchonella thalia A. d'Orbigny, 1850, No. 225, p. 239; No. 268, p. 258.
Terebratula thalia A. d'Orbigny; Quenstedt, 1871, p. 53 & pl. xxxvii, fig. 94.
Rhynchonella thalia A. d'Orbigny; Thévenin, 1908, p. 50.
Tropiorhynchia thalia (A. d'Orbigny); S. S. Buckman, 1917, p. 34 & pl. xviii, fig. 10.

Figs. 1–5 *c* *(Brachiopods).*

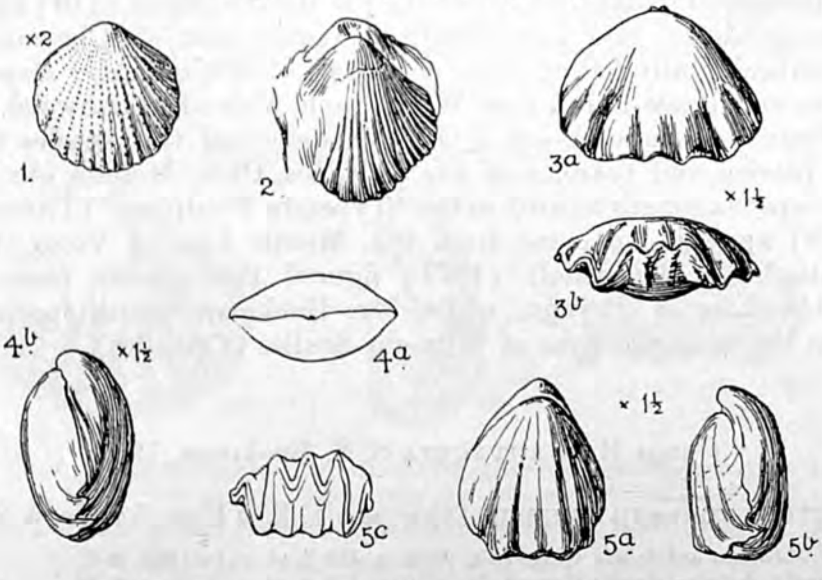


Fig. 1. *Acanthothiris* sp. Lower dark marls, Bed 110, north of Peace Farm, Whitchurch (Dorset). B.M. B 45821. × 2. (See p. 250.)

2. *Gibbirhynchia curviceps* (Quenstedt). Belemnite Stone, Bed 121, Stonebarrow (Dorset). B.M. B 49491. Natural size. (See p. 246.)

Figs. 3 *a* & 3 *b*. *Tropiorhynchia thalia* (A. d'Orbigny). Upper darker marls, Bed 118 *a* or 118 *b*, foreshore south-east of Golden Cap. 3 *a* = dorsal view. 3 *b* = anterior view. B.M. B 49494. × 1½. (See above.)

4 *a* & 4 *b*. Another specimen. Same horizon, Bluntshay, north-east of Whitchurch. 4 *a* = lateral view, × 1½. 4 *b* = posterior view showing umbo truncated by foramen, natural size. B.M. B 45844.

5 *a*–5 *c*. *Rudirhynchia calcicosta* (Quenstedt)? Lower pale band, Bed 111 *a*, between Westhay and Ridge, east of Charmouth. 5 *a* = dorsal view. 5 *b* = lateral view, × 1½. 5 *c* = anterior view, natural size. B.M. B 49473. (See p. 248.)

This species is represented by numerous crushed specimens from the Upper darker Marls (Bed 118), Belemnite Shales (Bed 119), and Pyritic Marls (Bed 120). The specimens vary considerably in size, but in all the pedicle- and brachial valves are gibbous, posteriorly smooth, but plicated on the anterior third of the shell. Three broad rounded plications are developed on the low, dorsal median fold, and two in the corresponding sinus of the pedicle-valve, while three occur on each lateral slope. The beak of the pedicle-valve is incurved, and in contact with the brachial valve, thus concealing the deltidium; the apex is truncated by a circular foramen. The internal characters are unknown, but the truncated mesothyrid umbo is characteristic of the genus *Tropiorhynchia*.

These specimens agree very well in both size and ornament with examples of *Tropiorhynchia thalia* from Calvados (Lower Normandy), whence they were originally described by A. d'Orbigny.

Dimensions.—Specimen B 45844. Length=12·5 mm; width =17 mm.; thickness=8·5 mm.

Locality and horizon.—Middle dark band (114), Westhay Cliffs, east of Charmouth; Upper pale Marls (117), foreshore south-east of Golden Cap, and Upper darker Marls (118) of the same locality; Bed 118, Westhay Water, east of Charmouth; Breakneck Gully; Bluntshay, north-east of Whitchurch; Gasson's Lane, and Peace Farm, near Whitchurch, Vale of Marshwood.

Previous record.—A. d'Orbigny described this species from the Liasien and Toarcien of the Calvados, Cher, Moselle, etc., but the type-specimens figured in the 'Types du Prodrôme' (Thévenin, 1908) are said to come from the Middle Lias of Vieux Pont (Calvados). Quenstedt (1871) figured this species from the Middle Lias of Bayeux, while Mr. Buckman figures specimens from the *jamesoni* zone of Tilly-sur-Seulles (Calvados).

Genus Rudirhynchia S. S. Buckman, 1914.

Rudirhynchia calcicosta (Quenstedt)?. (Figs. 5 *a*–5 *c*, p. 247.)

Terebratula calcicosta Quenstedt, 1852, p. 451 & pl. xxxvi, figs. 6–9.
Terebratula calcicosta Quenstedt, 1858, p. 138 & pl. xvii, figs. 16, 17.
Terebratula calcicosta Quenstedt, 1871, p. 51 & pl. xxxvii, figs. 82–91.
Rhynchonella calcicosta (Quenstedt): Haas & Petri, 1882, p. 181 & pl. i, fig. 11.
Rhynchonella calcicosta Quenstedt: Rau, 1905, p. 388 & pl. i, figs. 110–19.
Rhynchonella calcicosta Quenstedt; Davidson, 1878, pl. xxviii, figs. 24, 25, & 31–32.
Rudirhynchia calcicosta (Quenstedt?); S. S. Buckman, 1917, p. 45.

One imperfect crushed specimen (B 49473) from the Lower pale band (111 *a*) of Westhay or Ridge, east of Charmouth, is doubtfully referred to Quenstedt's species. The costæ are almost continuous from the umbo to the anterior margin, but there is a smooth portion immediately below the beak of each valve. Three costæ occur on the median dorsal fold, two in the corresponding sinus of the pedicle-valve, and two to three on each lateral slope. The beak is erect, but other umbonal characters are obscure. The growth-lines form a prominent transverse ornament, and are frequently imbricating.

The general shape and ornament of this specimen agree very well with those of Quenstedt's species.

Previous record.—Quenstedt figured this species from the

Lias β, γ of Germany, and Rau's specimens are from the Lower Lias γ, Spiriferenbank of Swabia. Haas & Petri record it from the Middle Lias γ of Alsace-Lorraine, while Davidson's specimens are from a higher horizon, namely, the *margaritatus* zone of Yorkshire.

RUDIRHYNCHIA (?) FALLAX Deslongchamps. (Figs. 6 *a*–6 *c*, below.)

Rhynchonella fallax E. Deslongchamps, 1863, p. 267 & pl. iii, figs. 1–4.

One example of this species (B 49470) was obtained from the Lower pale band (111) in the bed of the Gwyle, north-west of Charmouth. It resembles Deslongchamps's figures in the trigonal outline of the shell, in the suberect, massive beak, in the broad dorsal median fold, and in the well-demarcated sinus. The dorsal valve is strongly depressed in the umbonal region. The dental plates are strong, and slightly divergent; the other internal

Figs. 6 *a*–6 *c* *(Brachiopods)*.

Figs. 6 *a*–6 *c*. *Rudirhynchia (?) fallax* (Deslongchamps). Lower pale band, Bed 111, Gwyle, north-east of Charmouth. 6 *a* = dorsal view. 6 *b* = lateral view. 6 *c* = anterior view. B.M. B 49470, × 1½. (See above.)

characters are unknown. Five broad, angular costæ are developed on the median fold, four in the sinus of the pedicle-valve, and from two to four on each lateral slope. Growth-lines form a prominent transverse ornament.

Dimensions.—Length = 15 mm.; width = 17·5 mm.; thickness = 8 mm. Deslongchamps quotes the following similar dimensions for his specimen:—Length = 15 mm.; width = 17 mm.; thickness = 8 mm.

Previous record.—Deslongchamps recorded his species from the Middle Lias of May and Bretteville-sur-Laize (Calvados); and Davidson (1878, p. 225) quoted the occurrence of this species on the authority of Moore from the Middle Lias of Whatley (Somerset). The specimens figured by Davidson (1884, pl. xx, figs. 4, 4 *a*, 4 *b*) from the Middle Lias of Huish Quarry, Radstock, have less angular costæ, which are only developed on the anterior half of the valves. These forms have been referred by Rollier to his species *Rhynchonella fallaciosa*.

Genus PIARORHYNCHIA S. S. Buckman, 1914.

PIARORHYNCHIA FRONTO (Quenstedt)?

Terebratula triplicata fronto Quenstedt, 1871, p. 71 & pl. xxxvii, figs. 177–83.
Rhynchonella triplicata (Quenstedt); Haas & Petri, 1882, pl. i, figs. 29 *a*–29 *c*, 31 *a*–31 *c*.
Rhynchonella variabilis var. *fronto* Quenstedt; Rau, 1905, pl. i, figs. 92–97.
Piarorhynchia triplicata fronto (Quenstedt); S. S. Buckman, 1917, p. 34.
Rhynchonella fronto Rollier, 1917, p. 91.

This species is represented by one imperfect brachial valve (B 49485) from the Middle dark band (114) of the cliff-foot, Westhay to Ridge, east of Charmouth. The specimen is crushed, but the median fold is still prominent, and bears three angular costæ, while three curved costæ are developed on the lateral slopes. The ornament agrees exactly with that of figures of *Terebratula triplicata fronto* Quenstedt.

Previous record.—Quenstedt figures this species from the Lias γ of Germany, while Rau's specimens are from the middle of Lias γ of Swabia, where, he states, it is characteristic of the *taylori*, *ibex*, and *jamesoni* zones. Haas & Petri figure this species from the *Davœi*kalk, Lias γ near Metz.

Genus ACANTHOTHIRIS A. d'Orbigny, 1849.

ACANTHOTHIRIS (?) sp. (Fig. 1, p. 247.)

One small dorsal valve from the Lower dark Marls (110), north of Peace Farm near Whitchurch, is doubtfully referred to the genus *Acanthothiris*. The specimen (B 45821), which is 7·5 mm. long and 7·5 mm. wide, is slightly convex and rectimarginate. The internal and beak-characters are unknown. The ornament consists of eighteen rounded, non-dichotomous costæ, each bearing a single row of very fine spine-bases, and resembling those of the genus *Acanthothiris*, which has, however, so far not been recorded from beds below the Aalenian. Further material is required before an adequate diagnosis can be given of this species.

Family TEREBRATULIDÆ.

Genus LOBOTHYRIS S. S. Buckman, 1914.

LOBOTHYRIS OVULUM (Quenstedt). (Figs. 8 *a* & 8 *b*, p. 251.)

Terebratula numismalis ovalis Quenstedt, 1858, p. 143 & pl. xviii, figs. 1, 2.
Terebratula numismalis ovulum Quenstedt, 1871, p. 325 & pl. xlvi, figs. 33–38, 40, 41.
Terebratula ovulum Rollier, 1918, p. 198.
? *Terebratula grammontensis* Peterhans, 1926, p. 372 & pl. i, figs. 1–7.

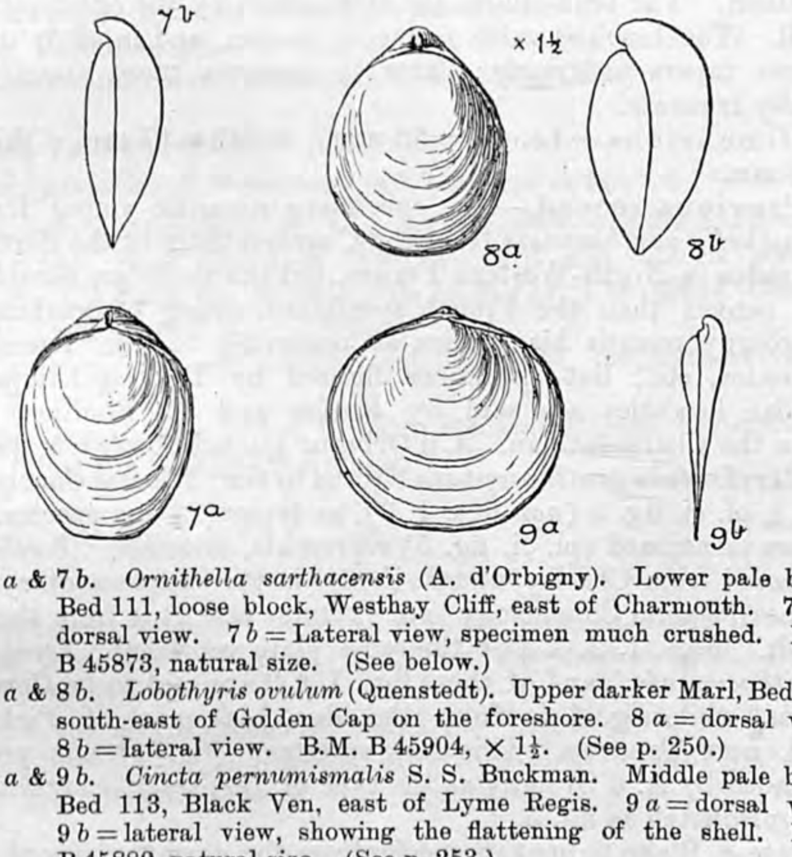
Examples of this species were obtained from the Upper darker Marls (118) from the foreshore, south-west of Golden Cap, east of Charmouth.

The specimens (B 45904, B 49487) are about 14 mm. in length, 13 mm. in width, and 8 mm. in thickness. They have a slightly-convex brachial valve, which is sulcate posteriorly, and incipiently uniplicate at the anterior margin. The more convex pedicle-valve has a small incurved beak, with obscure beak-ridges, and is truncated by a circular foramen.

The contour and the general form of these specimens agree with those from the German Lias γ, in which the muscle-scars are characteristic of the genus *Lobothyris*. *Terebratula grammontensis* Peterhans, from the Sinemurian of Valais (Switzerland), resembles this species in outline and dimensions.

Previous record.—Quenstedt figures this species from the Lias γ of Metzingen, and similar, though slightly more globose, forms were figured by Rau from the *jamesoni* zone of Balingen (Würtemberg).

Figs. 7 *a*–9 *b* (*Brachiopods*).



Figs. 7 *a* & 7 *b*. *Ornithella sarthacensis* (A. d'Orbigny). Lower pale band, Bed 111, loose block, Westhay Cliff, east of Charmouth. 7 *a* = dorsal view. 7 *b* = Lateral view, specimen much crushed. B.M. B 45873, natural size. (See below.)

8 *a* & 8 *b*. *Lobothyris ovulum* (Quenstedt). Upper darker Marl, Bed 118, south-east of Golden Cap on the foreshore. 8 *a* = dorsal view. 8 *b* = lateral view. B.M. B 45904, × 1½. (See p. 250.)

9 *a* & 9 *b*. *Cincta pernumismalis* S. S. Buckman. Middle pale band. Bed 113, Black Ven, east of Lyme Regis. 9 *a* = dorsal view, 9 *b* = lateral view, showing the flattening of the shell. B.M. B 45880, natural size. (See p. 253.)

Family TEREBRATELLIDÆ.

Genus Ornithella Deslongchamps, 1884.

Ornithella sarthacensis (A. d'Orbigny). (Figs. 7 *a* & 7 *b*, above.)

Terebratula sarthacensis A. d'Orbigny, 1850, p. 258, No. 270.
Terebratula (Waldheimia) sarthacensis (A. d'Orbigny); Deslongchamps, 1863 (1862–85), p. 130 & pl. xxxi.

Waldheimia sarthacensis A. d'Orbigny; Tate & Blake, 1876, p. 418 & pl. xv, fig. 11.
Waldheimia (Zeilleria) sarthacensis A. d'Orbigny; Haas & Petri, 1882, p. 279 & pl. xiv, figs. 5–8, 15, 16.
Zeilleria sarthacensis A. d'Orbigny; Rollier, 1919, p. 291.
Zeilleria sarthacensis Deslongchamps: La Bouillerie, 1919–20, p. 107 & pl. vi, figs. 12–16.

This species is represented by several specimens from the Lower pale band (111) of Westhay Cliff and Ridge, east of Charmouth; from Black Ven; from the Gwyle, north-west of Charmouth; and from the foreshore, south-east of Golden Cap (figs. 7 *a* & 7 *b*, p. 251).

The shell is elongate-oval in outline, tapering gradually to the anterior margin, which is slightly truncate and has a plane commissure. The convex pedicle-valve is slightly carinate posteriorly; it has a suberect beak, discrete deltidial plates, and an oval foramen. The beak-ridges are emphasized by the crushing of the shell. The brachial valve is evenly convex, and in early growth-stages tapers anteriorly; later it becomes more rounded, and finally truncate.

Dimensions.—Length=23 mm.; width=17 mm.; thickness =8 mm.

Previous record.—The specimens resemble young forms of *Ornithella sarthacensis* from the Charmouthian of the Sarthe and Calvados in North-Western France, but the shells are considerably less convex than the French specimens, owing to crushing. A. d'Orbigny records his species as occurring in the Toarcian of Calvados, etc., but specimens figured by Deslongchamps from similar localities are said by Rollier and La Bouillerie to be from the Charmouthian. A. d'Orbigny quoted Sowerby's specimen of *Terebratula ornithocephala* figured in the 'Mineral Conchology' vol. i, pl. ci, fig. 5 (*non* figs. 1, 2), as typical of his species. The figure mentioned (pl. ci, fig. 5) represents, however, '*Terebratula obovata*' from Chatley, and J. Farey (in the Supplementary Index to the 'Mineral Conchology' vol. i) states that it is from the Cornbrash. Figs. 1, 2, & 4 of the same plate represent '*Terebratula ornithocephala*', and of these figs. 1 & 2 are said to be Cornbrash forms, while fig. 4 is from the blue Lias marl of Pickeridge Hill, near Taunton. This last specimen (fig. 4) was probably intended by A. d'Orbigny as the type of *Terebratula sarthacensis*, but misquoted as fig. 5.

Tate & Blake figure this species from the *armatus* beds of Robin Hood's Bay (pl. xv, fig. 11), but also quote it as occurring in the *jamesoni* and *spinatus* zones of the Yorkshire Lias. The illustrated specimen resembles that figured by Davidson as *Waldheimia perforata* Piette (1878, pl. xxiv, fig. 1) from the same locality, but said to be from the *jamesoni* zone; and both are similar to the Charmouth forms. Davidson's specimen of *Waldheimia perforata* Piette, from the *angulatus* zone of Charmouth (1878, pl. xxiv, fig. 2), like that figured by Tate & Blake from the same zone of Yorkshire (pl. xv, fig. 10), resembles Piette's figure of *Terebratula perforata*.

Haas & Petri record this species from the Lias γ and δ of Germany, and especially from the *Davœi*schichten near Metz.

Genus Cincta Quenstedt, 1868.

Cincta pernumismalis S. S. Buckman. (Figs. 9 *a* & 9 *b*, p. 251.)

Cincta pernumismalis S. S. Buckman, 1907, p. 49 & pl. v, figs. 19, 20.

This species is abundant in the Lower pale band (111), and Lower dark band (112), and Middle pale band (113) of Westhay and Stonebarrow Cliffs; banks of the Gwyle, north-west of Charmouth; and Black Ven.

The specimens are crushed, and completely flattened anteriorly, as shown in a lateral view of this species (fig. 9 *b*), but the outline of the shell and the early growth-stages correspond with well-preserved specimens of *Cincta pernumismalis*.

Mr. Buckman records this species from the *jamesoni* zone of Radstock and from Toddington (Gloucestershire).

Cincta paupercula S. S. Buckman.

Cincta paupercula S. S. Buckman, 1907, p. 54 & pl. vi, figs. 7, 8.

Numerous examples of this species were obtained from the Lower pale band (111) of Westhay Cliff and east of Westhay Water; and from the Middle pale band (113) of Black Ven, and Ridge Cliff, east of Charmouth.

The specimens are crushed and deformed, but both valves are slightly convex.

The species is recorded by Mr. Buckman from Radstock and from Tilly-sur-Seulles (Normandy).

Cincta opulenta S. S. Buckman.

Cincta opulenta S. S. Buckman, 1907, pp. 55 & pl. vi, figs. 15, 16.

Imperfect examples of this species were obtained from the Lower pale band (111 *c*, 111 *d*) of Westhay and Ridge Cliffs, east of Charmouth.

This species has been recorded (S. S. Buckman, 1907, p. 56) from Churchdown and Aston Magna (Gloucestershire), probably from the *jamesoni* zone.

Cincta nummosa S. S. Buckman.

Cincta nummosa S. S. Buckman, 1907, p. 48 & pl. v, figs. 17, 18.

This species was obtained from the Lower pale band (111 *b*) of Westhay Cliff and Ridge Cliff; and from the Middle pale band (113 *a*) of Stonebarrow Cliff, east of Charmouth.

The specimens are flattened, and their preservation is similar to that of *Cincta pernumismalis*.

This species was recorded by Mr. Buckman from Radstock and from Gloucestershire, probably from the *jamesoni* zone; also from Calvados (Normandy) and from near Balingen (Würtemberg).

CINCTA NUMMATA S. S. Buckman.

Cincta nummata S. S. Buckman, 1907, p. 49 & pl. v, figs. 1–4.

One large specimen was obtained from the Upper darker Marls (118 *a*), from the foreshore south-west of Golden Cap, and agrees in shape with Mr. Buckman's figures of this species.

It has previously been recorded from the *jamesoni* zone of Radstock and from Normandy.

CINCTA NUMMUS S. S. Buckman.

Cincta nummus S. S. Buckman, 1907, p. 47 & pl. v, fig. 21.

Immature examples of this species were obtained from the Lower pale band (111 *d*) of Ridge Cliff and Stonebarrow Cliff, east of Charmouth.

The specimens are crushed and decorticated, as in the abovementioned species.

Cincta nummus has been recorded by Mr. Buckman from Radstock (Somerset) and from Normandy.

CINCTA SESTERTIUS S. S. Buckman.

Cincta sestertius S. S. Buckman, 1907, p. 56 & pl. v, figs. 11, 12.

A crushed specimen from the Middle Marls (111 or 112) from Stoke Mill, north of Whitchurch Canonicorum, and one specimen from the Upper darker Marls (118 *b*), south-east of Golden Cap, are doubtfully referred to this species. The latter specimen has the shell of one valve preserved in an uncrushed condition.

The only previous record of this species is from the *armatus* zone of Radstock.

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A NEW BRACHIOPOD *Discinisca ferroviæ* FROM THE WOOLWICH BEDS.

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I. Introduction.

THE specimens of *Discinisca* described in this paper were collected by Messrs. A. G. Davis and A. Wrigley from the Woolwich Beds, exposed in the new boring for the City and South London Tube at Tooting Broadway, at Waddon, Surrey, and at High Street, Beckenham, Kent. Many specimens, some in a fragmentary condition, were obtained from the Oyster rock and the *Cyrena* marls, in the upper part of the Woolwich Beds, and from the "Mudstone" (=Bed 1) of Mr. Davis's paper. In addition to these, two poorly preserved specimens were obtained from the sands with *Ostrea* near the base of the Blackheath Beds, at the Rock Pit, Sundridge, near Elmstead Station, Kent. One specimen of this limpet-like shell was previously obtained from the conglomerate bed of the last locality, and was described and figured as *Patella* by Prestwich in 1854. This specimen is now preserved in the Prestwich collection in the British Museum, G. 2227, and is indistinguishable from, but less well preserved than, the material recently collected by Messrs. Wrigley and Davis.

Sixteen specimens, including the holotype and fifteen paratypes, have been presented to the British Museum by the collectors.

These Brachiopod specimens are chiefly interesting for their limpet-like mode of attachment, usually to the shells of *Ostrea bellovacina*, and for their association in an estuarine and shallow-water deposit with such estuarine species as *Cyrena cuneiformis* Fer., *Melanatria inquinata* (Defr.), and *Tympanotomus funatus* (Mant.), and the possibly marine species *Barbatria striatularis* (Desh.), *Calyptræa* sp., and *Tritonidea lata* J. Sow.

Although the form of the pedicle opening in the lower valve, a diagnostic character of *Discinisca*, is unknown in these Eocene shells, they have been referred to that genus on account of their similarity to recent *Disciniscas* in shape, size and ornament.

My thanks are due to Mr. Wrigley for making the drawings that illustrate this paper.

II. Description of Species.

DISCINIDÆ.

Discinisca Dall 1871. Bul. Mus. Comp. Zool. III, No. 1, p. 37.

Discinisca ferroviæ sp. nov.

Text-fig. 42 (3–5).

1854. *Patella* ? J. Prestwich. On the Structure of the Strata between the London Clay and the Chalk in the London and Hampshire Tertiary Systems. *Quart. Journ. Geol. Soc.* X, p. 155, pl. ii., fig. 24.

1927. *Patella sp.* A. G. Davis. On the Blackheath Beds at Beckenham, Kent. *Proc. Croydon Nat. Hist. Sci. Soc.* X, p. 47.

Diagnosis. *Discinisca*, about 10 mm. long, 10 mm. wide and 2 mm. high, circular in outline, upper valve depressed-conical with sub-central apex. Shell thin, chitinous ; light or dark brown in colour. Ornament of fine raised striæ, radiating from umbo, increasing by means of numerous intercalations and rare bifurcations. Growth lines numerous.

Holotype. British Museum, Specimen No. B. 49867, from the Woolwich Beds, City and South London Railway Cutting, Tooting Broadway.

Paratypes. Specimens No. B. 49869, 49600–07, 49610, from the Woolwich Beds, City and South London Railway Cutting, Tooting ; specimen No. B. 49868, from the same beds at High Street, Beckenham, Kent ; specimens No. B. 49608–09, from the Blackheath Beds at Rock Pit, Sundridge, Kent. All in the British Museum (Nat. Hist.) collections.

Locality and Horizon.—In addition to the localities mentioned above, specimens not examined by the author have been obtained from the Oyster rock, Woolwich Beds, at the new post office, Village Way, Beckenham ; same horizon, in the excavation for the new Telephone Exchange, High Street, Beckenham ; and from the excavation for the new gas-holder, Waddon, Surrey.

Description.—The upper conical valve in the holotype B.49867 is 8 mm. long, 8 mm. wide, and 1.5 mm. high, and in specimen B. 49606 10 mm. long, 10 mm. wide and 2 mm. high. It varies slightly in outline from sub-circular to sub-trapezoidal, narrowing posteriorly, and there is a corresponding change in the position of the apex from sub-central to sub-posterior. The striæ radiate from the apex of the cone, and are slightly flexuous, increasing somewhat in width near the margin of the shell. In the holotype the striæ are very numerous owing to the large number of intercalations, and are so fine as to be scarcely visible to the naked eye ; while on a fragment of shell from the Blackheath Beds, Sundridge, they are slightly coarser and enlarged at the point of intersection with the growth lines. The radial markings are frequently absent on the smooth and highly polished apex.

The shell varies in colour from light to dark brown, and frequently shows the original concentric colour banding. This is exceptionally well preserved in the specimen B. 49868, in which the umbonal portion is light brown for a distance of about 2.5 mm. from the umbo, followed by a paler band about 1 mm. in width, and succeeded by a black band about 2 mm. wide and divided into two parts by a narrow cream-coloured band.

Three interiors of the upper valve are poorly preserved and show faint traces of muscle markings. One of these is shown in text-figure 42 (3).

The lower or pedicle valve is unknown.

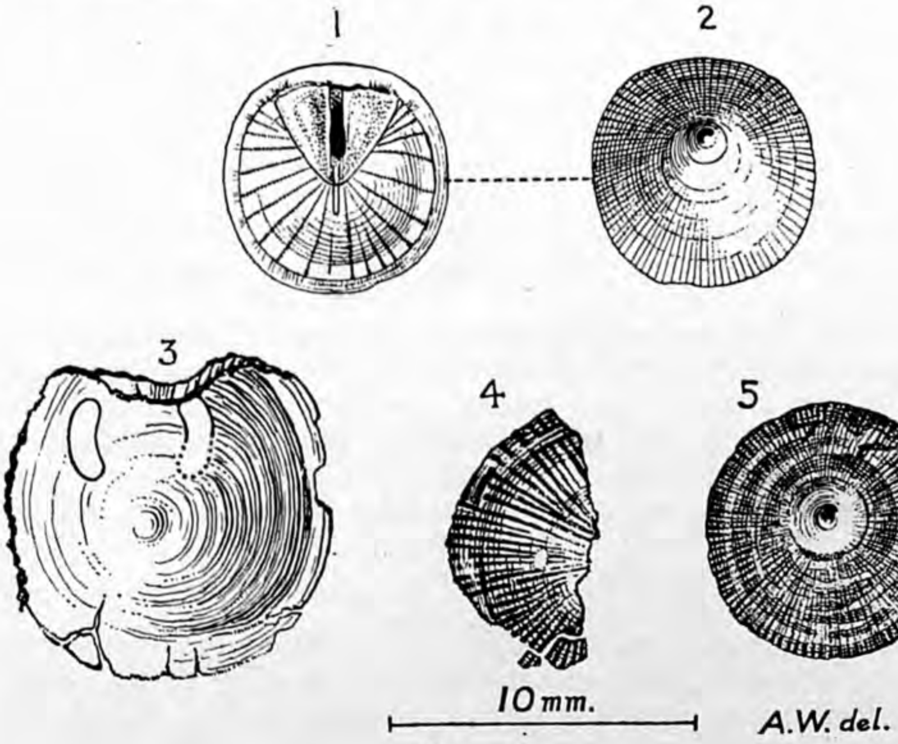

FIG. 42.

1, 2. *Discinisca stella* Gould. Recent, from Japan or China. British Museum, B. 49870.

1. Lower valve showing the v-shaped pedicle-area covered by a delicate membrane, and pierced by an oval slit for the passage of the pedicle. × 3.

2. Upper valve of same specimen showing radial striae. × 3.

3, 4, 5. *Discinisca ferroviæ* sp. nov.

3. Interior of upper conical valve showing two muscle scars. Eocene, Woolwich Beds exposed in boring for City and South London Tube, Tooting Broadway. British Museum, B. 49869. × 3.

4. Fragment of conical valve showing colour-banding. Same horizon, High St. Beckenham, Kent. B. 49868. × 3.

5. Conical valve of holotype also showing concentric colour bands. Same horizon and locality as fig. 3. B. 49867. × 3.

III. Comparison with other Fossil Species.

The only species of *Discinisca* previously recorded from the British Tertiary is *D. fallens* (S. V. Wood, 1874, pl. xi., fig. 6) = *Orbicula lamellosa* (Davidson, 1852, pl. i., figs. 9a, b) from the Pliocene, Coralline Crag of Sutton, Suffolk. The upper valve of this species is about 4 mm. in diameter, has a sub-central apex, and is ornamented by concentric lamellæ without radial striæ. The lower valve, which is always poorly preserved, has the foraminal opening characteristic of *Discinisca*.

Several species of *Discinisca* occur in the Miocene or Pliocene of North and South America, and of these *D. lugubris* (Conrad) and *D. multilineata* (Conrad 1845, pl. xliii, figs. 2, 3) from the Miocene of Virginia and Maryland, and *D. oregonensis* Dall (1909) from the Miocene of Coos Bay, Oregon, are ornamented by radial striæ. These species are readily distinguished from *D. ferroviæ* by their greater size, and by the greater elevation of their pedicle valves. *D. lugubris* and *D. multilineata* attain a diameter of 20 mm., and *D. oregonensis* 35 mm., as compared with 10 mm. in *D. ferroviæ*. In *D. lugubris* and *D. multilineata* the lower valve is thin and fragile, and therefore is rarely preserved, but the upper valves, also chitinous, are thicker and more massive.

Among Tertiary radially striated species of *Discinisca* may be mentioned *D. multiradiata* Dollfus and Dautzenberg and *D. scutellum* Dreger. The former species was figured by J. de Morgan in 1915 (p. 272) from the Middle Miocene of North-West France and the Faluns of Touraine. Only the upper valve of this species is known, and it resembles *D. ferroviæ* in having a radially striated shell, but the striæ are coarser in the Belgian species and increase only by means of intercalations, and do not bifurcate as in the English form.

A fragment of an upper valve of *D. scutellum* ornamented by radial striæ bearing fine pustules was described by Dreger (1889, pl. v., figs. 16 a–c) from the Tertiary of Immendorf in the Vienna Basin, and is readily distinguished from *D. ferroviæ* by the coarser nature of its ornament.

"*Discina*" *suessi* Bosquet (1862, figs. 1–5) = *O. nysti* Davidson) from the Middle Oligocene of Elsloo, Limbourg, but enclosed in the Miocene, Bolderien, has rather massive black lustrous valves bearing concentric markings and traces of radial furrows. The flat lower valve has a narrow pedicle-groove like that of the genus *Orbiculoidea*, but the internal characters and much thickened shell margin show a greater resemblance to *Crania* or *Discina*, and the exact relationship of this form is uncertain.

Although both Hall and Clarke and Schuchert suggest that the genus *Discinisca* ranges from Mesozoic to Recent times, only one species, *D. kawhiana* has actually been recorded from the Mesozoic rocks. This form, described by Boehm, occurs in the passage beds between the Jurassic and Cretaceous of Kawhia in the northern island of New Zealand. The upper valve is ornamented only by fine concentric lines, while the lower valve is marked by radial striæ and radiating furrows as in the recent species *D. indica* Dall. A rather similar ornament of the pedicle valve is seen in specimens of "*Discina*" *holdeni* Tate from the Lower Lias of Warwickshire. "*Discina*" *reflexa* Sow., from the Upper Lias and Inferior Oolite, resembles the recent species *D. lævis* in the shape of the pedicle area, and also resembles *D. holdeni* in having a curious flattened rim to the lower valve. It is possible that these two species, which should be referred to the genus *Disciniscа*, were attached by means of cementation of the lower valve, as well as by a functional pedicle.

Another radially striated form, "*Discina*" *humphriesiana* J. de C. Sow., which shows a remarkable resemblance to Tertiary and Recent species of *Discinisca*, is commonly attached to shells of *Ostrea deltoidea* from the Kimmeridge Clay of Shotover, Oxfordshire. It resembles *D. ferroviæ* in the suborbicular outline of the shell, and in the dichotomy of the striæ, but it is usually of larger size. The lower valve described by Deslongchamps from Northern France (1862, pl. vi., figs. 12b, 14, p. 283) is characteristic of *Discinisca*. A small variety of *D. humphriesiana* occurs in the Portlandian and was figured by Blake (1880, pl. x., fig. 9).

Among other species probably referable to the genus *Discinisca* should be mentioned *D. babeana* d'Orb. (=*Orbicula townshendi* Forbes-Davidson) from the Rhætic of Gloucestershire.

One species, *Discinisca forrienensis*, has been recorded from the Devonian, Coblenzian of Belgium by Maillieux (1910, p. 348), who, unfortunately, gave no figure to illustrate his description. He compared his species with the Recent *Discinisca lamellosa*, and also with Kayser's species *Discina* cf. *forbesi* and *D. anomala*, which are also from the Devonian. It is impossible to tell from the illustrations whether the two latter species should be referred to *Discinisca*.

Discinisca, therefore, may possibly have persisted almost unchanged from Devonian to Recent times, and this long range may be compared with that of the genera *Lingula* and *Crania*, both of which have existed since Ordovician times.

FOSSIL SPECIES OF DISCINISCA.

(a) Conical valve radially striated.

T e r t i a r y.

D. multiradiata Dollfus and Dautz.	Miocene, France and Belgium.
D. scutellum Dreger	Tertiary, Austria.

D. lugubris (Conrad)	Miocene, U.S.A.
D. multilineata (Conrad)	,,
D. oregonensis Dall.	,,
Mesozoic.	
D. humphriesiana (J. de C. Sow.)	Kimmeridge Clay England, etc.
D. humphriesiana var.	Portlandian, Dorset.
(b) Conical valve lamellose or smooth.	
Tertiary.	
D. fallens (S. V. Wood)	Pliocene, England.
D. singewaldi Schuchert	Tertiary, Bolivia.
Mesozoic.	
D. kawhiana	Jurassic—Cretaceous, New Zealand.
D. holdeni (Tate)	Lias, England, etc.
D. reflexa (Sow.)	Inf. Oolite or Lias, England.
D. babeana (d'Orb.)	Rhætic.
Palæozoic?	
? *D. forrienensis* Maillieux.	Devonian.
? *D. anomala* (Kayser).	

IV. Comparison with Recent Forms.

Discinisca ferroviæ shows a close resemblance to the recent species *D. stella* (Gould), *D. cumingi* (Broderip) and *D. antillarum* (d'Orb.), all of which have chitinous or chitino-calcareous shells and are ornamented with radial striæ and fine growth lines. *Discinisca cumingi* and *D. antillarum* are elongated-oval in outline, while *D. stella* is approximately circular. All are thin-shelled forms of light brown or yellow colour, and all have a sub-central apex. No concentric colour bands are developed in the Recent species, but there are radial stripes of dark colour on the shells of *D. strigata* (Broderip).

In *D. cumingi* the radial striæ are very fine and slightly enlarged at the point of intersection with the concentric growth lines. *D. antillarum* has sparsely developed radial striæ and a smooth, posteriorly situated apex, while *D. stella* has coarse ornament and a sub-central apex.

In Recent species the lower valve is flat, moulded to the surface of support, and extremely fragile and thin. The pedicle area is depressed, and is v- or heart-shaped, and in the adult form seldom reaches the posterior margin ; it is covered by a delicate membrane, pierced by an oval slit for the passage of the large, fleshy pedicle. Outside this area the shell is differently ornamented in the several species, and may have radial markings or arcuate striæ.

The extreme fragility of the lower valve in the Recent species is probably the explanation of the absence of this valve in both *D. ferroviæ* and other fossil forms.

Its chitinous and more fragile shell distinguishes *Discinisca ferroviæ* from the Recent *Discina striata* Schumacher, which also has a conical upper valve with fine, radial ornament.

V. Distribution and Habitat of Recent Species.

The Recent species of *Discinisca* may be divided into three groups :—

(a.) Large thin-shelled forms with concentric, lamellar ornament ; such as *D. lamellosa* (Broderip) and *D. laevis* (G. de B. Sowerby), both of which are found adhering in large numbers to other individuals of the species, at a depth of 5–9 fathoms off the coasts of Chile and Peru and western shore of North America, or attached to living shells of *Mytilus*.

(b.) Large massive-shelled forms with faint, radial sculpture and concentric lamellæ ; such as *D. strigata* (Broderip) and *D. cumingi* (Broderip), which are also found on the western coast of America and on the coast of Panama. *D. cumingi* is found attached to shells or stones in sandy mud at low-water, or at a depth of 6–8 fathoms off the coasts of Mexico and Peru and Panama ; while *D. strigata* is found at a depth of 18 fathoms off the coast of Guatemala.

(c.) Small forms with regular, radiating sculpture ; such as *D. stella* (Gould), *D. antillarum* (d'Orbigny) and *D. indica* Dall, which occur off the east coasts of Asia and associated islands, and on the tropical shores of the Atlantic. *D. stella* is found at a depth of 17–25 fathoms off the coasts of Japan and China, while *D. indica*, according to Dall (1920, p. 278), is a deeper water form and occurs at a depth of 37–180 fathoms.

Thus all Recent *Disciniscas* are tropical, marine and shallow-water forms occurring as a rule at a depth of 0–20 fathoms and attached to other shells. The occurrence, therefore, of the fossil species *D. ferroviæ* attached to shells of *Ostrea* in a shallow-water, marine, or even estuarine deposit would not be unexpected. There appears to be no evidence that the fossil species of *Discinisca* were other than marine forms, although the allied genus *Orbiculoidea* is found in deposits where conditions were unfavourable to all other Brachiopods.

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The Classification of the British Carboniferous Brachiopod Subfamily Productinæ. By HELEN M. MUIR-WOOD, M.Sc., F.G.S.

(Published by permission of the Trustees of the British Museum.)

DURING the last fifteen years much has been written on the subject of *Productus*, and more detailed investigation of the many species belonging to this genus has led to its subdivision into at least twenty genera or subgenera by Thomas, Chao, Fredericks, Muir-Wood, and others. There are, however, at least three well-defined groups of species still included in the genus *Productus* (sensu stricto). Recent researches have shown that this genus should be even more precisely limited to a small group of species having a peculiar internal structure.

The genus *Productus* was described by James Sowerby (1814, 'Mineral Conchology,' i. p. 153) as "an equilateral unequal-valved bivalve with a reflexed, more or less cylindrical, margin; hinge transverse, linear; beak imperforate; one valve convex, the other flat or concave externally." He also adds:—" His [Martin's] Conch. *Anomites productus* is a good type of the Genus, therefore, as the name *Anomites* must be laid aside, I have adopted his specific name as the Generic one, the character it expresses being also peculiar." Sowerby (*op. cit.* p. 158) renamed *Anomites productus* of Martin *Productus martini,* and describes it in 1821 (Min. Conch. iv. p. 15). Since the species *Anomites productus* (=*Productus martini*) was considered by Sowerby to be typical of his genus, it is in strict accordance with the Rules of Zoological Nomenclature to regard it as the genotype of *Productus*.

Confusion arose as Sowerby figured more than one species as *Productus martini*, and only one of these specimens is identical with *Anomites productus*, Martin. Following de Koninck's and Davidson's lead the species *Productus martini* was regarded as either identical with or a variety of *Productus semireticulatus* (Martin), itself an ill-defined species. In consequence of this, Dall (1877, Bull. U.S. Nat. Mus. viii. p. 58) quoted *Productus martini* Sowerby = *Anomites semireticulatus* (Martin) + *A. productus*, Martin, as the genotype of *Productus*; while Hall (1893, 'Palæontology New York,' viii. p. 325) quoted *P. martini*, Sowerby = *Anomites productus*, Martin = *A. semireticulatus*, Martin = *Productus semireticulatus* as the genotype. Later (1894, Eleventh Annual Report State Geol. p. 297) Hall and Clarke reduced this quotation of the genotype simply to *Productus semireticulatus*.

Productus semireticulatus was, therefore, regarded as the type of the genus *Productus* until I. Thomas (1914, Mem. Geol. Surv. Gt. Brit. Palæont. i. pt. 4, p. 258) quoted *P. productus* as the genotype. This was adopted by Chao in 1927 (Pal. Sinica, B. v. fasc. 2, p. 26) and by me in 1928 (Mem. Geol. Surv. Gt. Brit. Palæontology, iii. pt. 1, p. 35), when the species *P. productus* and *P. semireticulatus* were finally disentangled.

Investigation of the species *P. productus* (= *P. martini*, pars) has shown that it differs in internal structure from *P. semireticulatus* in having an extra shelly plate or diaphragm, which is developed round the anterior end of the visceral disk of the brachial valve and extends between the trails of the two valves, usually at right angles to them.

A similar shelly plate was found by Dr. Girty in the North American species, *P. elegans*, Norwood & Pratten, and this species became the type of his genus *Diaphragmus*. Since the two genera *Productus* and *Diaphragmus* are characterised by a similar internal structure, *Diaphragmus* must be regarded as a synonym of *Productus*.

Productus thus becomes limited to a small group of species, including *P. productus* (Martin), *P. concinnus*, J. Sow., *P. carbonarius*, de Koninck, *P. redesdalensis*, Muir-Wood, *P. garwoodi*, Muir-Wood, etc. A new name is required for *Productus semireticulatus* and allied species, and also for such forms as *P. longispinus* and *P. lobatus*, all of which are at present grouped under the generic name *Productus*. The name *Dictyoclostus*, gen. nov., is therefore proposed for the *semireticulatus* group with *P. semireticulatus* as genotype, and *Eomarginifera*, gen. nov., is proposed for the *longispinus* group with *P. longispinus* as genotype.

Subfamily *Productinæ*, Waagen.

Productus, J. Sowerby, 1814 (' Mineral Conchology,' vol. i. p. 153), *emend.* H. M. Muir-Wood.

Genotype. *Anomites productus*, W. Martin (= *P. martini*, J. Sowerby, pars).
Syn. *Diaphragmus*, Girty (1910, Ann. N.Y. Acad. Sci. xx. pt. 2, no. 3, pp. 217, 218).

Diagnosis.—Shell elongate, both valves geniculate; hinge narrow; pedicle valve with long spreading trail. Flanks steep and posteriorly flattened. Shell costate in all growth-stages, costæ numerous, flexuous. Ribs few, seldom prominent. Spines set in rows on ears and cardinal slopes and scattered on trail. Teeth, dental sockets, and delthyrium absent. Marginal ridges narrow, short. A thin shelly plate or diaphragm developed round anterior margin of visceral disk of brachial valve, extending across space between trails of the two valves.

Species.—*Productus carbonarius*, de Kon., *P. concinnus*, J. Sow., ? *P. furcatus*, Muir-Wood *, *P. garwoodi*, Muir-Wood *, *P. elegans*, Norwood & Pratten, *P. productus* (W. Martin), *P. productus*, var. *hispidus*, Muir-Wood, *P. redesdalensis*, Muir-Wood.

Range.—*Syringothyris* zone to Upper Carboniferous.

Remarks.—This genus has not been found below the C. zone and the geologically earliest described species is *P. garwoodi*, which occurs in the C_1–S_2–D_1 sub-zones of Westmorland. This species, which was apparently developed from *P. rotundus*, Garwood, was probably the ancestor of *P. redesdalensis*, which occurs in the D_1–D_2 sub-zones of N. England and of Scotland. *P. redesdalensis* probably gave rise to *P. carbonarius*, which ranges from D_2 sub-zone up to the Upper Carboniferous. The interior of *P. furcatus* is at present unknown, and this species is doubtfully referred to the genus *Productus*. *P. concinnus* and *P. productus* were probably derived from a form resembling *P. furcatus*.

The distinguishing character of *Productus* is the diaphragm which extends across the narrow space between the trails of the two valves and closes the entrance to the visceral cavity. The diaphragm must therefore have been either porous or movable, in order to admit the passage of water into the shell.

* Ref. Muir-Wood, Mem. Geol. Surv. Gt. Brit. Palæont. i. pt. 4 (1928).

DICTYOCLOSTUS, gen. nov.

Genotype. *Anomites semireticulatus*, W. Martin (in part.), Petrificata Derbiensia, p. 7, pl. xxxii. figs. 1, 2, pl. xxxiii. fig. 4 (Wigan, 1809).
Syn. *Productus*, J. Sowerby (in part.).

Diagnosis.—Shell elongate or quadrate in outline. Hinge moderately wide; pedicle valve evenly convex or produced into a short curved trail, brachial valve concave or geniculate. Costate in all growth-stages, costæ often prominent, bearing numerous spine-bases. Spines also in rows on ears and cardinal slopes. Ribs on visceral disk numerous and forming net-like ornament by enlargement at point of intersection with costæ. Diaphragm absent. Marginal ridges prominent, extending along hinge. Hinge-teeth, sockets, and cardinal area not developed.

Species.—*Productus antiquatus*, J. Sow., *P. bristolensis*, Muir-Wood, *P. costatus*, J. de C. Sow., ? *P. flexistrius*, M'Coy, *P. griffithianus*, de Kon., *P. hindi*, Muir-Wood, and var. *wettonensis*, Muir-Wood, *P. howratensis*, Muir-Wood, *P. insculptus*, Muir-Wood, *P. kilbridensis*, Muir-Wood, *P. multispiniferus*, Muir-Wood, *P. muricatus*, Phill., *P. pinguis*, Muir-Wood, *P. projectus*, Muir-Wood, *P. pugilis*, Phill., and mut. *senilis*, Muir-Wood, *P. rotundus*, Garwood, *P. scoticus*, J. Sow., *P. semireticulatus* (Mart.), *P. sulcatus*, J. Sow., *P. teres*, Muir-Wood, *P. vaughani*, Muir-Wood.

Range.—*Zaphrentis*-zone to Permian.

Remarks.—This genus ranges throughout the British Lower Carboniferous and also occurs abundantly in the marine Upper Carboniferous of Europe and North America, as well as in the Permian.

Dictyoclostus is distinguished from *Productus* by the absence of a diaphragm, by its wider hinge, less spreading trail, more prominent and less flexuous costæ.

EOMARGINIFERA, gen. nov.

Genotype. *Productus longispinus*, J. Sowerby, Mineral Conchology, vol. i. 1814, p. 154, pl. lxviii. fig. 1.
Syn. *Productus*, J. Sowerby (in part.).

Diagnosis.—Shell small, quadrate or elongate in outline. Pedicle valve evenly convex or slightly geniculate, with cincture often separating visceral disk from trail, brachial valve concave or geniculate. Costate in all growth-stages, costæ usually fine. Ribs slightly enlarged at point of intersection with costæ. Spines few, not increasing in number in senile stage, six spines symmetrically developed. Exterior of brachial valve with lamellose thickening round anterior and lateral margins. Interior of brachial valve with thickened shelly ridge, bearing slight crenulations, extending from cardinal process round lateral margins.

Species.—*Productus derbiensis*, Muir-Wood, *P. lobatus*, J. Sow., and var. *flexus*, var. *laqueatus*, Muir-Wood, *P. longispinus*, J. Sow., *P. minutus*, Muir-Wood, *P. præcursor*, Muir-Wood, *P. pseudoplicatilis*, Muir-Wood, *P. setosus*, Phill., *P. tissingtonensis*, Sibly, *P. triquetrus*, Muir-Wood.

Range. — Lower Carboniferous, ? C zone to Upper Carboniferous.

Remarks.—This genus is distinguished from *Productus* by the absence of a diaphragm. The symmetrical arrangement of six spines—one on each cardinal extremity, two on the front of the shell below the visceral disk, and one on the posterior part of each flank—distinguishes it from both *Prodactus* and *Dictyoclostus*. *Eomarginifera* is distinguished from *Marginifera* by the less-marked marginal ridges in the brachial valve and the absence of these ridges in the pedicle valve, also by the lack of crenulations on the exterior of the marginal ridges of *Eomarginifera*. The ornament and arrangement of the spines of *Eomarginifera* are also distinct from those of *Marginifera*. The latter genus is confined to the Upper Carboniferous and Permian.

Classification of the *Productinæ*.

A considerable amount of overlapping is shown in the researches of Chao, Fredericks, Sarytcheva, and Whitehouse on the subject of the classification of the Productinæ and the following pairs of genera are synonymous. It is unfortunate that Fredericks' genera are described in Russian, with only a short *résumé* in English, and that many of his genera are vaguely described:—

Sowerbina, Fredericks, 1928 (Bull. Com. Géol. Leningrad, xlvi. 7, p. 789): genotype, *P. timanicus*, Stuckenberg = *Horridonia*, Chao, 1927 (Pal. Sinica, B. v. fasc. 2, pt. 1, p. 24): genotype, *P. horridus*, J. de C. Sow. (includes also *P. timanicus*).

Ruthenia, Fredericks, 1928 (*loc. cit.* p. 789): genotype, *P. irginæ*, Stuckenberg (includes also *P. humboldti*, d'Orb., and *P. purdoni*, Dav., etc.) = *Waagenoconcha*, Chao, 1927 (*loc. cit.* p. 85): genotype, *P. humboldti*, d'Orb. (includes also *P. irginæ* and *P. purdoni*).

Cora, Fredericks, 1928 (*loc. cit.* p. 790): genotype, *P. cora*, d'Orbigny [also *Euproductus*, Whitehouse, 1928, nom. nud. (Rept. Aust. Ass. Adv. Sci. xviii. p. 281)]: genotype, *P. cora*, d'Orb. = *Linoproductus*, Chao, 1927 (*loc. cit.* p. 128) : genotype, *P. cora*, d'Orb.

Cancrinella, Fredericks, 1928 (*loc. cit.* p. 791) : genotype, *P. cancrini*, De Vern., ? = *Linoproductus*, Chao, 1927.

Gigantella, Sarytcheva, 1928 (Mem. Geol. Sci. Res. Inst. Moscow, Geology, p. 13) : genotype, *P. giganteus* (Martin) (includes also *P. edelburgensis*, Phill., and *P. latissimus*, J. Sow.) = *Kansuella*, Chao, 1928, pars (Pal. Sinica, B. v. fasc. 3, pt. 2, p. 67) : genotype, *K. kansuensis*, Chao (includes also *P. giganteus* and *P. edelburgensis*).

Key to the Classification of the British Productinæ.

A. Shell costate in all growth-stages.

1. Shell ornamented by ribs and costæ on the visceral disk and anteriorly by costæ only. Costæ bifurcating, intercalations rare.
   - (*a*) With diaphragm .... *Productus*, J. Sowerby, 1814, emend. Muir-Wood, 1929 (see p. 102).
   - (*b*) Without diaphragm .... *Dictyoclostus*, Muir-Wood, 1929 (see p. 103).
   - (*c*) Marginal ridge in interior of brachial valve. Shell small, with six spines symmetrically arranged on pedicle valve .... *Eomarginifera*, Muir-Wood, 1929 (see p. 103).
2. Shell costate and ribbed on visceral disk, costate on trail, both valves geniculate. Cardinal area in pedicle valve with delthyrium closed by deltidium ...... *Sinuatella*, Muir-Wood, [1928.
   Genotype: *P. sinuatus*, de Kon.
3. Shell convex (not geniculate), ornamented by costæ and well-marked concentric growth-lines .... *Thomasia*, Fredericks, [1928.
   Genotype: *P. margaritaceus*, Phill.
4. Shell ornamented by fine costæ and numerous intercalations, usually with broad wrinkles on lateral slopes.
   - (*a*) Shell regular, quadrate, pedicle valve highly convex or geniculate .... *Linoproductus*, Chao, [1927.
     Genotype: *P. cora*, d'Orbigny; also *P. corrugatus*, M'Coy, *P. hemisphericus*, J. Sow., *P. koninckianus*, de Vern., *P. undatus*, Defrance.
   - (*b*) Shell irregular or elongate-triangular, tapering to umbo, pedicle valve slightly convex .... *Striatifera*, Chao, 1927.
     Genotype: *P. striatus* (Fischer de Waldheim).
   - (*c*) Pedicle valve cylindrical, brachial valve operculiform .... *Proboscidella*, Oehlert, [1887.
     Genotype: *P. proboscideus* de Vern.; also *P. ermineus*, de Kon.

5. Shell large, massive, hinge long. Costæ fine, irregular. Ribs developed posteriorly.
   (*a*) Cardinal area rarely developed on pedicle valve. .... *Gigantella*, Sarytcheva, [1928.
   Genotype: *P. giganteus* (Martin); also *P. latissimus*, J. Sow., *P. maximus*, M'Coy, *P. edelburgensis*, Phill.
   (*b*) Cardinal area developed in both valves, delthyrium closed by deltidium in pedicle valve .... *Kansuella*, Chao, 1928, emend. H. Muir-Wood, 1929.
   Genotype: *K. kansuensis*, Chao. Probably includes certain undescribed British species.

B. Shell spinose in all growth-stages.

6. Shell ornamented by numerous scattered spine-bases which are anteriorly elongated. Ribs faintly developed on cardinal slopes .... *Krotovia*, Fredericks, [1928.
   Genotype: *P. spinulosus* (Martin); also *P. aculeatus* (Martin).
7. Shell ornamented by elongated spine-bases and concentric ribs.................. *Pustula*, I. Thomas, [1914.
   Genotype: *Productus pustulosus*, Phill.; also *Pustula distorta*, Thomas, *P. interrupta*, Thomas, *P. magnituberculata*, Thomas, *P. nodosa*, Thomas, *Pr. ovalis*, Phill., *P. pilosa*, Thomas, *Pr. pyxidiformis*, de Kon., *Pr. rugatus*, Phill., *P. subpustulosa*, Thomas, *P. tenuipustulosa*, Thomas.
8. Shell ornamented by broad concentric bands bearing rows of spine-bases .... *Echinoconchus*, Weller, [1914.
   Genotype: *Productus punctatus* (Martin); also *P. elegans*, M'Coy, *Pustula subelegans*, Thomas, *P. venusta*, Thomas, *P. defensa*, Thomas, *P. exquisita*, Thomas, *P. eximia*, Thomas.
9. Shell ornamented by concentric bands bearing one row of spine-bases. Brachial impressions spoon-shaped .... *Overtonia*, Thomas, [1914.
   Genotype: *P. fimbriatus*, J. de C. Sow.

C. Shell spinose and costate.

10. Shell ornamented by spines posteriorly and costæ anteriorly .... *Avonia*, Thomas, emend. [Muir-Wood, 1928.
    Genotype: *P. youngianus*, Dav.; also *P. bassus*, Vaughan, *P. davidsoni*, Jaross, *P. keyserlingianus*, de Kon.

D. Shell costate, ribbed, and spinose.

11. Shell ornamented posteriorly by ribs and by costæ bearing elongated spine-bases, and anteriorly by flattened bands bearing

rows of spine-bases. Median septum posteriorly bifurcating .... *Buxtonia*, Thomas, 1914, emend. Muir-Wood, 1928.
Genotype: *P. scabriculus* (Martin), also *P. scabriculo-costatus*, Vaughan.

E. SHELL RIBBED.

12. Shell ornamented by prominent concentric ribs. Anterior margin surrounded by ribbed rim projecting at right angles to shell .... *Thomasella*, Fredericks, [1928.
Genotype: *P. wrighti*, Dav.
13. Shell ornamented by concentric ribs, and attached by cementation or by spines along hinge of pedicle valve .... *Etheridgina*, Oehlert, [1887.
Genotype: *P. complectens*, Etheridge.
14. Shell ornamented by ribs and large scattered spines .... *Plicatifera*, Chao, 1927.
Genotype: *P. plicatilis*, J. de C. Sow.; also *P mesolobus*, Phill., ? *P. carringtonianus*, Dav.

F. SHELL SMOOTH.

15. Shell ornamented by large spines and growth-lines, and rarely by faint traces of costation .... *Horridonia*, Chao, 1927.
Genotype: *P. horridus*, J. de C. Sow.

The precise range of many of these genera is uncertain. *Horridonia* is apparently limited to the Permian. *Thomasia* and *Thomasella* occur in the Upper *Dibunophyllum*-zone, but may range upwards. *Kansuella* is possibly confined to the Lower Carboniferous, and occurs in the *Dibunophyllum*-zone. *Gigantella* and *Striatifera* are not known below the *Seminula*-zone, and are especially characteristic of the Upper *Dibunophyllum*-zone, but they extend up into the Upper Carboniferous or even into the Permian. *Productus*, *Linoproductus*, *Plicatifera*, and *Eomarginifera* were probably evolved in Upper *Zaphrentis* or Lower *Syringothyris* times, but became more abundant in D_2. *Linoproductus* and *Productus* extend up to the Upper Carboniferous. *Buxtonia*, *Pustula*, *Echinoconchus*, *Avonia*, and *Dictyoclostus* appear in the *Cleistopora*-zone or early *Zaphrentis* times, and range throughout the Carboniferous.

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(For more complete lists, see MUIR-WOOD and THOMAS.)

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THE BRACHIOPODA.

PLATES V TO VI.

By

HELEN MARGUERITE MUIR-WOOD, M.Sc., F.G.S.

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CONTENTS.

FOSSIL FAUNA OF THE SAMANA RANGE AND SOME NEIGHBOURING AREAS.

PART III

THE BRACHIOPODA.

BY

HELEN MARGUERITE MUIR-WOOD, M.Sc., F.G.S.

(With Plates V and VI.)

1. INTRODUCTION.

THE Brachiopoda, collected by Col. L. M. Davies from the Samana range, include a number of species, many of which are represented by a single specimen. Most of the specimens are preserved as internal casts in an irony quartzose grit which coats as well as infills them. These casts are associated with undoubted Lower Gault ammonites, such as *Douvilleiceras mammillatum*, which establish the age of the fauna. In addition to these a few imperfect specimens were collected from a compact gray limestone, the lowest fossiliferous bed found on the Samana range. These specimens are referred in this paper to the species *Rhynchonelloidea arcuata* (Quenstedt) and the beds are therefore assumed to be of Upper Bathonian or Lower Callovian age.

This Jurassic species is of considerable importance, as it is the only fossil collected from these lower beds, and *R. arcuata* has not been previously recorded from India.

The Gault specimens are also interesting since brachiopods are practically unknown in the Lower Gault. They are apparently, entirely new forms belonging to new subgenera of *Rhynchonella* and *Terebratula*, which owing to the lack of material and the poor state of preservation of most of the specimens, cannot be described.

One Gault specimen is referred to the species *Kingena spinulosa* Morris and is indistinguishable from forms occurring in the Gault of Folkestone.

All the specimens are preserved in the collections of the Geological Survey of India at Calcutta.

2. DESCRIPTION OF SPECIES.

JURASSIC.

RHYNCHONELLIDÆ, Gray.

RHYNCHONELLOIDEA ARCUATA (Quenstedt). (Pl. V, figs. 1—4.)

Terebratula varians F. A. Quenstedt, 1852, Handbuch der Petrefaktenkurde, p. 454, pl. xxxvi, fig. 19.

Terebratula varians arcuata F. A. Quenstedt, 1871, Petrefactenкunde Deutschlands, Abt. 1, Bd. II, Brachiopoden, p. 89, pl. xxxviii, figs. 71—80.

Rhynchonella varians G. Müller, 1900, in Bornhardt, W. Zur Oberflächengestaltung und Geologie Deutsch-Ostafrikas, Bd. VII, p. 527, pl. xvii, fig. 9.

Rhynchonella arcuata L. Rollier, 1917, *Mém. soc. pal. Suisse*, XLII, 2, p. 152.

Rhynchonelloidea varians arcuata S. S. Buckman, 1917, *Pal. Ind.*, N. S. III, No. 2, p. 38. (Name only.)

Rhynchonelloidea, S. S. Buckman, 1914, Genera of some Jurassic Brachiopoda: London, p. 1.

This species is represented by two almost complete, young individuals and six imperfect specimens embedded in a hard, dark grey limestone. The pedicle valve, only preserved in the two entire specimens, has a broad median sinus, sharply demarcated from the lateral slopes. The umbo is broken in both specimens, but the outline of it, seen in another example, shows it to have been slightly incurved but well separated from the brachial valve. The dental lamellæ are strong and slightly divergent. The ornament consists of rather angular costæ continuous from the umbo to the anterior margin. Four or five costæ occupy the sinus and there are seven on each lateral slope.

The brachial valve is sub-cynocephalous in contour with a rather prominent median fold ornamented by four or five subangular costæ. Seven or eight strongly curved costæ are seen on each lateral slope. A strong median septum is developed in this valve. The position and shape of the muscle-scars is unknown, and the limited amount of material did not allow of investigation by burning off the shell. Traces of a fine transverse ornament crossing the costæ are seen in some of the specimens.

Dimensions.—Specimen no. 14,429 figured on pl. II, fig. 1, length, 13·5 mm.; width, 14 mm.; thickness, 12·5 mm. Specimen figured on pl. II, fig. 3, length, 11 mm.; width, 11·5 mm.; thickness, 7 mm. Specimen from the Brown Jura of Eichberg, Baden, figured for comparison, British Museum, B. 49819, length, 13·5 mm.; width, 13·5 mm.; thickness, 12 mm.

Material.—Eight specimens preserved in the collections of the Geological Survey of India, Calcutta.

Remarks.—The Samana specimens agree very well in size, form and ornament, with examples of *Rhynchonella varians arcuata* (Quenstedt) from the Brown Jura, *Varians*-schichten of Germany. These beds, which occur at the base of the Callovian of Germany, contain a number of forms which Quenstedt considered to be varieties of the species *Rhynchonella varians* (Schlotheim). The latter species, however, comes from a higher horizon. In Quenstedt's species *R. varians arcuata*, later (1917) called *R. arcuata* by Rollier, the rather prominent median fold is ornamented by four or five costæ, and the curved lateral slopes bear seven or eight costæ, as in the Indian specimens. The transverse ornament which is so prominent in the German shells is faintly seen on the specimens from Samana.

Rhynchonelloidea arcuata is distinguished from *R. spathica* (Lamarck) from the Oxfordian and *R. thurmanni* Voltz from the Corallian by its smaller size, more angular fold in the brachial valve, and also by its less globose brachial valve. In the Oxfordian and Corallian forms the umbo is more incurved over the brachial valve, than in the Bathonian species. The smaller incurvature of the umbo as well as the less sharply differentiated median fold distinguishes *R. arcuata* from the form figured by Davidson as *R. varians* (=*R. alemanica* Rollier, 1917, p. 151) from the Callovian of Yorkshire.

Rhynchonella varians var. *oolithica* Haas (1882, p. 229, pl. VI, figs. 14a—c) from the Upper Dogger of Alsace is a smaller form than *R. arcuata* with three costæ on the median fold and seven on each lateral slope.

Kitchin (1900, p. 61, pl. XIII, figs. 1—5) describes *Rhynchonella brevicostata* from the Callovian of Cutch as belonging to the group of *Rhynchonella varians*, but this species is readily distinguished from the Samana specimens by the absence of costæ on the posterior part of the shell as well as by its smaller dimensions and the greater convexity of the brachial valve.

Specimens from the Bathonian of Dar-es-salem, East Africa, were figured as *Rhynchonella varians* but described as being similar to *R. varians arcuata* by Müller (1900, p. 527, pl. XVII, fig. 9). These specimens are slightly smaller than the Indian shells but are apparently similar in form and ornament. Dacqué (1910, p. 51) later correlated the beds containing these specimens with similar beds containing Callovian ammonites in Tanganyika territory.

The age of the beds, in which the Samana specimens of *Rhynchonelloidea arcuata* occur, is probably uppermost Bathonian or possibly early Callovian, but the small amount of material and the complete absence of other fossil groups render any exact zonal determination impossible.

CRETACEOUS. GAULT.

RHYNCHONELLA SAMANENSIS sp. nov. (Pl. V, figs. 13—17).

Diagnosis.—'*Rhynchonella*' about 25 mm. long, 30 mm. wide, and 18 mm. thick, shell transversely oval or circular in outline; brachial valve globose; pedicle valve flattened; median fold and sinus ill-defined; anterior commissure evenly curved; beak gibbose, suberect. Ornament of eighteen prominent, widely spaced, subangular costæ with irregular, nodose swellings. Dental plates short, stout, and subparallel.

Type-specimens.—Holotype, specimen no. 14,434. Paratypes, nos. 14,432, 14,435—14,441, 14,433. All preserved in the Geological Survey collections, Calcutta.

Description.—The material consists of ten internal casts, imperfectly preserved. In the holotype the shell is laterally elongated in outline with a gibbose brachial valve and depressed pedicle valve. The median fold in the brachial valve, bearing six angular costæ, is very slightly raised above the level of the lateral slopes, and the median sinus of the pedicle valve is broad and shallow, and is ornamented by six costæ. Six curved costæ are developed on each lateral slope. The anterior commissure is evenly curved. The beak is suberect but delthyrial plates and beak-ridges are not preserved. The dental plates are short, subparallel, and massive, and support the strong teeth. These fit into the transversely crenulated sockets which are supported by strong socket plates.

In the brachial valve the median septum is short and strong posteriorly, but tapers anteriorly, and separates the two adductor muscle-scars. The adductor scars are trigonal in outline with their inner margin in contact with the median septum, while their anterior margin is almost horizontal. The outer margin is obscure. Ovarian markings, represented on the cast by pittings, are seen on the posterior part of the pedicle and brachial valves.

The muscle-scars of the pedicle valve are well preserved in specimen no. 14,435. The diductor scars are crescent-shaped and enclose the oval adductors, while vascular markings radiate from the anterior margin of the diductors and the oval area bearing the ovarian markings.

The remaining specimens represent different growth-stages and are usually circular in outline.

Dimensions.—Holotype, length, 25 mm.; width, 30 mm.; thickness, 18 mm. Specimen no. 14,435—length, 26·5 mm.; width, 22·5 mm.; thickness, 16·5 mm.

Remarks.—*Rhynchonella samanensis* differs from *Stolmorhynchia sulcata* (Parkinson, 1819, p. 59) from the Albian of Europe in the greater convexity of its brachial valve, less prominent median fold, and fewer and more angular costæ. The muscle-scars in the two species are also quite distinct. In the brachial valve of *Rhynchonella samanensis* the adductors are wedge-shaped and their anterior margin is practically horizontal, while in *R. sulcata* the adductors are longitudinally elongated and pear-shaped. *Rhynchonella polygona* d'Orbigny from the Albian of France is also readily distinguished from *R. samanensis* by its more pentagonal outline, steeper cardinal slopes, and more numerous costæ. The shape and position of the muscle-scars in *R. polygona* is at present unknown. The costæ in *R. emerici* d'Orbigny from the Albian of France and Switzerland resemble those of *R. samanensis* but the shell of *R. emerici* is smaller and the costæ are less numerous. Pictet and Roux (1852, pl. I, figs. 6a—c) and Pictet (1872, pl. CXCVIII, figs. 11, 12) represent this species as having very prominent incisions, crossing the costæ at regular intervals, and suggestive of the transverse folds of *R. samanensis*, and the costæ appear slightly enlarged at the point of intersection.

Owing to the incomplete preservation of the muscle-scars in the brachial valve, as well as the absence of beak characters, it is not possible to assign this species to any sub-genus of *Rhynchonella*. The adductor scars of *R. samanensis* resemble those of species of *Cyclothyris* which occur throughout the Cretaceous.

The costation of *R. samanensis* however, is coarser than in any species of *Cyclothyris*, and no median septum is developed in that genus. It resembles species of *Rhactorhynchia* S. S. Buckman (1917, p. 50) in having a stout median septum, and strong dental plates, coarse prominent costæ, and an ill-defined fold and sinus. This genus has not been recorded from beds above the Kimeridgian. Slight nodular swellings on the costæ are seen in the species *Rhactorhynchia faecunda* and *R. turgidula* S. S. Buckman from the Bradford Clay (1917, pl. XIV, figs. 8d, 10d), and are apparently similar to those seen in *R. samanensis*. The muscle-scars of the pedicle valve of *R. samanensis* are narrower and more elongated than in any species of *Rhactorhynchia*, but the shape of the muscle-scars of the brachial valve is very similar to that of the Jurassic species.

RHYNCHONELLA RETICULATA sp. nov. (Pl. V, figs. 12a—c.)

Diagnosis.—'*Rhynchonella*' differing from *R. samanensis* in having a less inflated brachial valve, more flattened pedicle valve, more numerous, and less prominent costæ in each valve.

Type-specimen.—Holotype, specimen no. 14,442, preserved in the Geological Survey collections, Calcutta.

Description.—This species is represented by one imperfect specimen in which the shell is partially preserved. The outline of the shell is approximately circular and the anterior commissure is slightly curved. The brachial valve lacks a median fold, and is regularly convex in both longitudinal and transverse contour, while the pedicle valve is convex posteriorly, but becomes depressed medianly, on the anterior part of the shell. The beak is not preserved, and the internal characters are unknown.

The ornament consists of twenty-five rounded costæ which radiate from the umbo of each valve, and are separated by interspaces which are equal to the width of the costæ. The nodular swellings on the costæ are of small size and are arranged concentrically, 10 nodules are developed on one costa in a space of 12 mm. The outer shell-layers are not preserved, and it is not possible to ascertain if this enlargement of the costæ is caused by marked incisions cutting across the costæ, due possibly to a periodic cessation of growth.

Dimensions.—Length, 21 mm.; width, 24 mm.; thickness, 13 mm.

Remarks.—The rather marked nodular enlargement of the costæ gives the shell a somewhat spinose appearance, resembling that of species of *Acanthothiris*. Careful examination, however, of the shell of *Rhynchonella reticulata* shows that the nodules are not hollow, nor were they ever produced into spines. Lack of material unfortunately, hindered any attempt to ascertain the internal characters of this species.

TEREBRATULIDÆ Gray.

TEREBRATULA SAMANENSIS sp. nov. (Pl. VI, figs. 5—8).

Diagnosis.—'*Terebratula*', with large, massive shell, elongate-oval in outline; pedicle valve more convex than brachial valve, slightly biplicate anteriorly, folding paraplicate. Umbo massive, vertically truncated by large labiate foramen, mesothyrid, beak-ridges obscure.

Type-specimen.—Holotype, specimen no. 14,446. Paratypes, nos. 14,447, 14,448, 14,445, 14,444, 14,449, 14,450, 14,451, 14,452.

Description.—This species is represented by eight imperfect specimens all in the form of internal casts with small portions of the outer shell preserved in two specimens.

In the holotype which is a gerontic individual, the outline of the shell is more complete than in the other specimens, and the greatest width of the shell occurs about half-way down the length. The brachial valve is evenly convex and rectimarginate in the early growth-stages, becoming biplicately folded only at the anterior margin by the formation of a low rounded ridge on either side of a shallow median sinus (paraplication of S. S. Buckman, 1917). In the pedicle valve a shallow sinus is formed on either side of a low median fold. The two valves slope down abruptly to the anterior margin. The lateral commissure curves gently backwards from the brachial to the pedicle valve, and is sharply recurved dorsally near the anterior margin. The umbo is massive and is truncated by a circular foramen which in a young specimen 14,448, is horizontal, but with the incurvature of the umbo, it becomes vertical in position and labiate. The umbo is always well separated from the brachial valve. No deltidial plates are preserved in any specimen.

The adductor muscle-scars of the brachial valve are well preserved in specimen 14,445 and are elongated, narrow and subparallel, and expand into spoon-shaped protuberences at their anterior end. In the pedicle valve the muscle-area is situated about 1 cm. from the umbo, but the details of the scars are obscure. The vascular markings in both valves are seen as prominent, longitudinal ridges on the cast.

The shell is finely punctate and the surface usually smooth, but traces of fine, longitudinal striations are seen in specimen 14,450 on the shell of the pedicle valve, but this is not constantly developed as in many terebratulid shells.

Dimensions.—Holotype, length, 48 mm.; width, 42·5 mm.; thickness, 26·5 mm. Paratype, specimen no. 14,445, length incomplete; width, 40 mm.; thickness, 26 mm.

Remarks.—*Terebratula samanensis* is distinguished from *T. biplicata* Sow. non Brocchi (=*T. dutempleana* d'Orbigny, 1847) from the British Gault and Cambridge Greensand, by its more massive shell, and absence of marked folds which extend three-quarters of the way up the shell in *T. dutempleana*. The adductor muscle-scars in the brachial valves of the two species are also distinct as shown in pl. III, figs. 1a, 2. Brocchi's species *T. biplicata* (1814), to which most biplicate Cretaceous specimens are referred, is said to be from San Quirico, Tuscany. Saemann and Triger (1862) examined the specimens and came to the conclusion that they were incorrectly labelled, and that they were probably from a French locality. There seems to be no doubt that *T. biplicata* Brocchi is not a Cretaceous species, but a Jurassic shell, probably from the Middle Lias, and that it is a *Zeilleria* closely allied to *Zeilleria indentata* (Sow).

Terebratula dutempleana d'Orbigny is recorded, not only from the Albian of Europe, France, Switzerland, and the Ardennes, etc., but Stoliczka (1872, p. 20, pl. V, figs. 1—3) figured *T. biplicata* var. *dutempleana* from the Cretaceous Trichinopoly group (=Turonian and Lr. Senonian) of S. India. The latter specimens are distinct from the European forms, and are also distinguished from the Samana specimens by their slightly larger size, more massive shells, more prominent biplication of the shell, and less curved lateral commissure. *T. samanensis* shows a closer resemblance in external form to specimens of *T. biplicata* var. *gigantea* and var. *ingens* Lamplugh and Walker from the Shenley Hill Cretaceous, usually taken to be of upper Albian or Cenomanian age, but the English forms have a flatter brachial valve, and are slightly larger and more elongated.

Specimens of *T. obesa* Sow., from the Ootatoor group (=Cenomanian of Southern India) figured by Stoliczka (1872, pl. V, figs. 4, 5) are slightly narrower than specimens of *T. samanensis* although the somewhat massive, slightly biplicate shell is apparently similar in the two species. The folding in *T. obesa* starts with uniplication of the dorsal valve and subsequent biplication, the reverse of that in *T. samanensis* where a median sulcus is first developed in the dorsal valve.

The adductor muscle-scars in the brachial valve of *T. samanensis* resemble very closely those figured by Stoliczka (1872, pl. VI, fig. 11*a*) in *T. subrotunda* Sow. from the Arrialoor group (=Senonian of S. India). This species is a smaller form but the folding of the shell is paraplicate, as in *T. samanensis*, to which it may be generically related.

Specimens from the Albian of Hazara, N. India, which have been compared with *T. samanensis* are readily distinguished from this species by their very prominent biplication, the folds extending backwards for about three-quarters of the length of the shell. The shell of the Hazara specimens is shorter and slightly more globose than that of the Samana species, and the adductor scars in the brachial valve are similar to those of *T. dutempleana*, to which species they should probably be referred. Specimens of *T. dutempleana* from Hazara, and from the Cambridge Greensand (Albian), have been figured for comparison with *T. samanensis*.

TEREBRATULA SAMANENSIS var. (Pl. VI, figs. 9*a*—*b*).

Two imperfect examples, 14,453 and 14,454, which are distinguished from specimens of *T. samanensis* by their more elongate-oval outline, smaller foramen, and slightly less convex valves, are probably a variety of that species. The anterior margin, though imperfectly preserved, is apparently slightly more truncate than in the typical form and slight biplication is developed at an earlier stage. Faint indications of adductor muscle-scars are seen in the brachial valve of specimen 14,453, and these are apparently similar to those of *T. samanensis*.

Dimensions.—Length, 39 mm.; width, 31 mm.; thickness, 19 mm.

The outline of the shell of this variety resembles that of the English species *T. depressa* var. *shenleyensis* Lamplugh and Walker (1903) from the Shenley Hill Beds (?=Albian or Cenomanian). The brachial valve of the English form, however, is uniplicate before becoming biplicate, whereas in the Indian form the brachial valve is first sulcate and then biplicate.

TEREBRATULA sp. (Pl. V, figs. 8*a*—*c*, 9).

Two internal casts, 14,456 and 14,455, approximately circular in outline with a slightly truncated anterior margin, are too imperfectly preserved for specific determination. The valves are biconvex with no fold or sinus and meet anteriorly in a plane commissure. The umbonal region is imperfectly preserved but the beak was apparently erect and truncated by a small foramen.

In the brachial valve the adductor muscle-scars are elongated, narrow, and strap-shaped, while in the pedicle valve the muscle-area is narrow and oval in outline. No dental plates are developed in the pedicle valve and no median septum in the brachial valve.

The shell is very finely punctate but there is no trace of either longitudinal or transverse ornament.

Dimensions.—Length, 16·5 mm.; width, 15·5 mm.; thickness, 8·5 mm.

Remarks.—This species resembles the Jurassic *Cinctas* in outline of the shell but the muscle-scars are characteristic of the Terebratulids. The absence of a median septum in the brachial valve distinguishes it from the Terebratellids, including the genera *Ornithella* and *Zeilleria.*

It resembles the specimen of *Terebratula lentoidea* Leymerie (1842, p. 12, pl. XV, figs. 10*a*—*c*) from the ? Albian of France in its general shape, but the Indian shell is not dorsally uniplicate as in that species.

Terebratula lens Nilsson (1827, p. 35, pl. IV, figs. 6*a*—*c*), from the Danian of Sweden, also has a very similar outline and contour, but is slightly larger and has a more carinate pedicle valve than the species under discussion.

TEREBRATULA DAVIESI sp. nov. (Pl. V, figs. 5*a*—*d*).

Diagnosis.—Shell small, circular in outline, valves biconvex, prominently biplicate anteriorly, paraplicate; dental lamellæ delicate. Shell surface capillate.

Type-specimen.—Holotype, specimen no. 14,457, preserved in the Geological Survey collections, Calcutta.

Description.—One imperfect specimen, lacking the umbonal region, is the sole example of this species. The pedicle valve is convex, with a median fold developed just above the anterior margin. On each side of this fold is a shallow sinus and a second fold is developed beyond each sinus. The lateral commissure is deflected towards the pedicle valve, and then is recurved backwards and forwards, forming two rounded lobes projecting dorsally. The anterior commissure is in the form of an inverted W, seen with the brachial valve uppermost, the two lobes extending upwards for a considerable distance into the brachial valve. The latter valve is slightly more convex than the pedicle valve and is sulcate immediately below the umbo. The greatest width of the shell occurs about half-way along the length. The umbonal characters of the shell are unknown, but a fracture across the umbo exposes delicate, dental lamellæ which support small teeth (Pl. V, fig. 5*b*). In the brachial valve there is no median septum, and the sockets are transversely crenulated. Other internal characters of both valves are unknown.

The shell is very finely punctate, and is ornamented by fine longitudinal striæ, which are seen on the outer surface of the shell, as well as on the internal cast. The striæ are even and radiate regularly from the umbo, and are crossed by a few fine lines of growth.

Dimensions.—Holotype, length, 12·5 mm.; width, 12·5 mm.; thickness, 9 mm.

Remarks.—Lack of information about the internal characters and position of the muscle-scars, as well as the loss of the umbonal region, make it impossible to assign this species to any genus. It probably belongs to a new genus of the Terebratulidæ, characterized by prominent paraplication of the shell, capillation of the test, and by the development of slender dental lamellæ. It appears at first sight to be similar to specimens of *Trichothyris compressa* (Kitchen) from the Jurassic beds of Kutch, India. In this species the shell is radially striated but the folding is parasulcate, *i.e.*, the dorsal valve is uniplicate and a sinus is developed on either side of the median fold. The anterior commissure of *Trichothyris compressa* is in the form of a W the reverse of that in *T. daviesi*, and the shell is larger and more elongated. A median septum is developed in the dorsal valve, and no dental plates occur in the pedicle valve, of this Jurassic species.

The plication of the shell of *T. daviesi* is similar to that of shells belonging to the Jurassic genus *Holcothyris*, described by S. S. Buckman from the Namyau beds of India. A similar type of folding is found in many Cretaceous species.

Krenkel (1910, p. 302) figured and described a biplicate, radially striated species *Terebratula matapuana* from the Lower Chalk of German East Africa. The shell is paraplicate but the specimens are larger and more elongated than those of *T. daviesi*.

Schloenbach's specimen of *Terebratula phaseolina* Valenciennes, figured in 1868 (p. 150, pl. V, fig. 1) from the Cenomanian of Bohemia, also resembles *T. daviesi* in the paraplication of the shell, but the folds are less prominent than in the Indian species. It is said to have an ornament of fine radial striæ but these are less well defined than in *T. daviesi*.

The common radially striated species of the European Albian, *T. capillata* d'Archiac (1847), differs from *T. daviesi*, not only in its considerably larger size but also in the uniplication of its brachial valve.

TEREBRATELLIDÆ King (emend. Beecher).

KINGENA Davidson 1852.

KINGENA SPINULOSA Morris. (Pl. V, figs. 6a—d).

Kingena spinulosa J. Morris, 1847, *Ann. Mag. Nat. Hist.* XX, p. 253, pl. xviii, figs. 6, 6*a*—*c*.

One specimen, from which the shell is entirely lost, has been compared with specimens of *Kingena* from the English Gault. The shell is circular in outline, with the pedicle valve slightly more convex than the brachial valve, and the anterior and lateral commissures give no indication of folding. Both the anterior and lateral margins are much thickened. The umbo is incurved and truncated by a small circular foramen, and the angular beak ridges are separated from the hinge by a rather narrow, concave false area. The dental plates are short and slightly divergent, and the median septum in the brachial valve extends for about half the length of this valve. The shell is very finely punctate, and traces of a fine, radial ornament are visible near the anterior margin, but the granulations characteristic of the genus *Kingena* are not preserved. In the pedicle valve the muscle-scars correspond in position with those of *Kingena*, but all traces of muscle-scars in the brachial valve are lost.

Dimensions.—Length, 14 mm.; width, 15 mm.; thickness, 10 mm.

This specimen resembles very closely examples of *Kingena spinulosa* Morris from the English Gault. This species is very variable in shape, Morris' type-specimen being considerably more elongated than the Samana example, but among specimens in the British Museum collections from the Gault of Folkestone, are some [B. 49599] which are indistinguishable from it in shape and contour. *K. spinulosa* is distinguishable from *K. lima* by the radial arrangement of the small, rounded spinules which cover the shell surface, and by the development of fine, radial striæ in the former species. In typical specimens of *K. lima*, the shell lacks radial striæ and the surface is covered by smaller, rounded tubercles, which are not definitely arranged or produced into spines.

Kingena newtonii Lamplugh and Walker (p. 258, pl. XVIII, figs. 5a—6c), is also ornamented by fine, radial striæ, in addition to the rounded granules, but the shell is larger than that of the Samana specimen, and has a pentagonal outline.

Stoliczka (1872, pl. VII) figures several species of *Kingena* from the Cretaceous rocks of South India, none of which resemble this species in external shape. His specimen of *K. lima* (pl. VII, figs. 13, a, b, c) is larger, and more elongated, than the specimen of *Kingena spinulosa* from Samana.

KINGENA TUMIDA sp. nov. (Pl. V, figs. 7a—c).

Diagnosis.—*Kingena*, with both valves highly globose, shell elongate-oval in outline, width and thickness of shell approximately equal; anterior commissure slightly sulcate; umbo incurved, false area very narrow, hinge line curved. Shell without radial striæ.

Type-specimen.—Holotype, specimen no. 14,459, preserved in the collections of the Geological Survey of India, Calcutta.

Description.—This species is represented by one internal cast in which the pedicle valve is considerably more globose than the brachial valve, and no fold or sinus are developed. The greatest width occurs about half way down the shell. The lateral commissure is straight and the lateral slopes flattened. The umbo is truncated by a circular foramen. The dental plates are long and narrow, and enclose the muscle-scars, which correspond in position to those of *Kingena.* In the brachial valve the socket-ridges are short and curved, and the median septum, which extends for about half the length of the valve, separates the elongated, narrow adductor scars which are set close to the septum.

The shell is finely punctate, but no trace of radial or granular ornament is visible.

Dimensions.—Length, 14·5 mm.; width, 12 mm.; thickness, 11·5 mm.

Remarks.—Although the external shell surface is missing, the internal characters and shape and position of the muscle-scars are sufficient evidence for referring this species to the genus *Kingena*, and the globosity of the shell distinguishes it from all other species belonging to that genus.

ZEILLERIA sp. (Pl. V, figs. 10*a*—*b*, 11*a*—*c*).

Two imperfect internal casts, 14,460 and 14,461, having the umbonal region poorly preserved, are doubtfully assigned to the genus *Zeilleria.* The shell is elongate-oval in outline with a highly convex brachial and pedicle valve. In the smaller specimen the valves have no fold or sinus, and meet anteriorly at an acute angle with a plane commissure, while the lateral commissure is deflected slightly into the pedicle valve. The foramen was apparently small and the beak-ridges are obscure.

In the larger specimen, the shell is considerably more inflated, growth having resulted in thickening at the anterior and lateral margins without any increase in length or width, and consequent flattening of the flanks and truncation of the anterior margin. The presence of a median septum in the brachial valve is indicated by a shallow longitudinal incision, showing that this shell had a long loop, and that it belongs to the family Dallininæ.

Dimensions.—Specimen, 14,460, length, 21 mm.; width, 16 mm.; thickness, 13 mm.; specimen, 14,461, length, 23 mm.; width, 16 mm.; thickness, 17 mm.

This species resembles *Terebratula becksii* Römer (1840, p. 44, pl. VII, fig. 14) from the Pläner (Cenomanian) of Germany in general shape and relative convexity of the valves, but the brachial valve narrows more towards the umbo than in the Indian species. *Terebratula nicaisei* Coquand (1862, p. 235, pl. XVI, figs. 19—21) from the Albian near Aumale, Algeria, has a similar shape, but the valves are considerably less convex, and a shallow sinus is developed near the anterior margin. The complete loss of the shell and all umbonal characters renders any comparison with other species a matter of extreme difficulty.

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EXPLANATION OF PLATE V.

All figures are of natural size except when otherwise stated.

Figs. 1—4. RHYNCHONELLOIDEA ARCUATA (Quenstedt), p. 26.

Fig. 1. Dorsal view of specimen from the Bathonian, Samana range. G. S. I. No. 14,429.

Fig. 2. Dorsal view of specimen, same horizon and locality. G. S. I. No. 14,430.

Figs. 3*a*—*d*. Lateral, anterior, ventral and dorsal views of young specimen. Same horizon and locality. G. S. I. No. 14,431.

Fig. 3*d* × 1½.

Figs. 4*a*—*d*. Anterior, ventral and dorsal views of specimen B. 49819, British Museum (Nat. Hist.). Fig. 4*c* figured in similar position to fig. 1. Fig. 4*d* × 1½. Bathonian, Brown Jura, ε *varians*-schichten, Eichberg, Wutach, Baden, Germany.

Fig. 5. TEREBRATULA DAVIESI sp. nov., p. 32.

Fig. 5*a*. Dorsal view of holotype, specimen × 1½. Gault, Samana range. G. S. I. No. 14,457.

Fig. 5*b*. Enlarged view of umbonal region of same specimen showing slender dental lamellæ, teeth, and crenulated sockets, ×3.

Figs. 5*c*—*d*. Lateral and anterior views of same specimen.

Fig. 6. KINGENA SPINULOSA Morris, p. 34.

Figs. 6*a*—*d*. Lateral, anterior, umbonal and dorsal views of specimen. Gault, Samana range. G. S. I. No. 14,458.

Fig. 7. KINGENA TUMIDA sp. nov., p. 34.

Figs. 7*a*—*c*. Umbonal, anterior and lateral views of holotype. Gault, Samana range. G. S. I. No. 14,459.

Figs. 8—9. TEREBRATULA sp., p. 32.

Figs. 8*a*, *b*, *c*. Ventral, dorsal, and lateral views of specimen showing muscle-scars of both valves. Gault, Samana range. G. S. I. No. 14,455.

Fig. 9. Dorsal view of specimen, showing adductor muscle-scars. Same horizon and locality. G. S. I. No. 14,456.

Figs. 10—11. ZEILLERIA sp., p. 35.

Figs. 10*a*, *b*. Lateral and dorsal views of specimen. Gault, Samana range. G. S. I. No. 14,460.

Figs. 11*a*, *b*, *c*. Dorsal, lateral and anterior views of specimen. Same horizon and locality. G. S. I. No. 14,461.

Fig. 12. RHYNCHONELLA RETICULATA sp. nov., p. 29.

Figs. 12*a*—*c*. Lateral, anterior and dorsal views of holotype. Gault, Samana range. G. S. I. No. 14,442.

Figs. 13—17. RHYNCHONELLA SAMANENSIS sp. nov., p. 27.

Fig. 13. Dorsal view of specimen. G. S. I. No. 14,432.

Fig. 14. Anterior view of specimen. G. S. I. No. 14,433.

Fig. 15. Umbonal view of specimen. G. S. I. No. 14,432.

Figs. 16*a*, *b*. Dorsal and lateral views of holotype. Indication of adductor muscle-scars shown in dorsal view. G. S. I. No. 14,434.

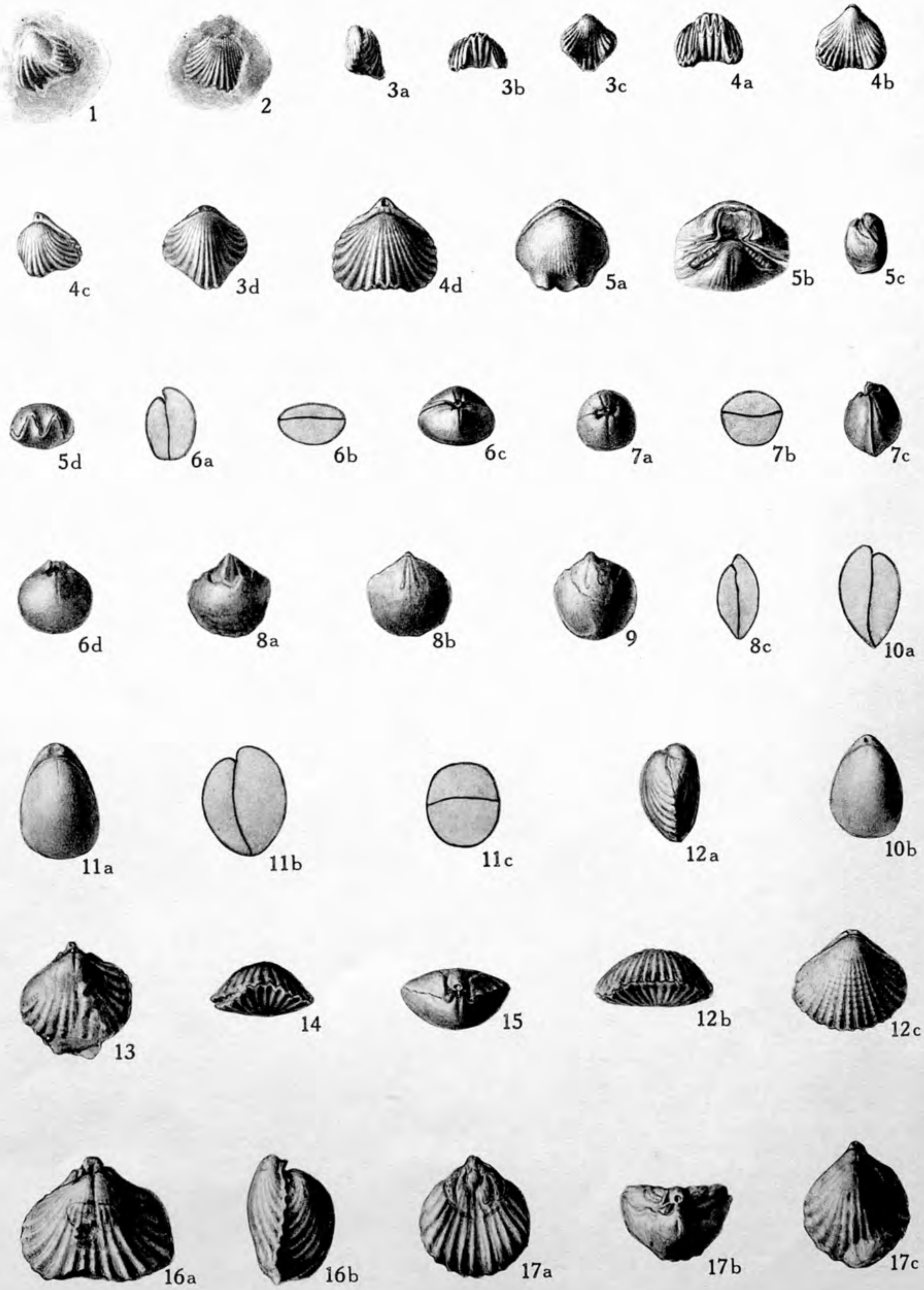
Figs. 17*a*, *b*, *c*. Ventral, umbonal, and dorsal views of specimen. Ventral view, showing adductor and diductor muscle-scars and ovarian markings. G. S. I. No. 14,435.

All specimens from the Gault, Samana range.

FOSSIL FAUNA OF THE SAMANA RANGE.

Geol. Surv. of India

Plate V.



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EXPLANATION OF PLATE VI.

Figs. 1—4. TEREBRATULA DUTEMPLEANA d'Orbigny. p. 31.

Figs. 1*a*, *b*, *c*. Dorsal, anterior and lateral views of specimen B. 49817, British Museum (Nat. Hist.). Dorsal view showing adductor muscle-scars, exposed by removal of outer shell. Cambridge Greensand, Cambridge.

Fig. 2. Ventral view of specimen B. 49818, British Museum (Nat. Hist.), showing muscle-scars and biplicate anterior margin. Same horizon and locality.

Figs. 3*a*, *b*. Dorsal and anterior views of specimen. Gault, Jabri, Haro river, Hazara, N. India. G. S. I. No. 14,462.

Fig. 4. Dorsal view of specimen, showing adductor muscle-scars, and prominent biplication of shell. Albian, Summit of Janomar hill, Hazara. G. S. I. No. 14,463.

Figs. 5—8. TEREBRATULA SAMANENSIS sp. nov., p. 29.

Fig. 5. Dorsal view of specimen. G. S. I. No. 14,443.

Fig. 6. Dorsal view of specimen showing adductor muscle-scars. G. S. I. No. 14,444

Fig. 7. Dorsal view of specimen also showing adductor muscle-scars and labiate foramen. G. S. I. No. 14,445.

Figs. 8*a*, *b*, *c*, *d*. Dorsal, lateral, anterior, and ventral views of holotype, G. S. I. No. 14,446.

All specimens from the Gault, Samana range.

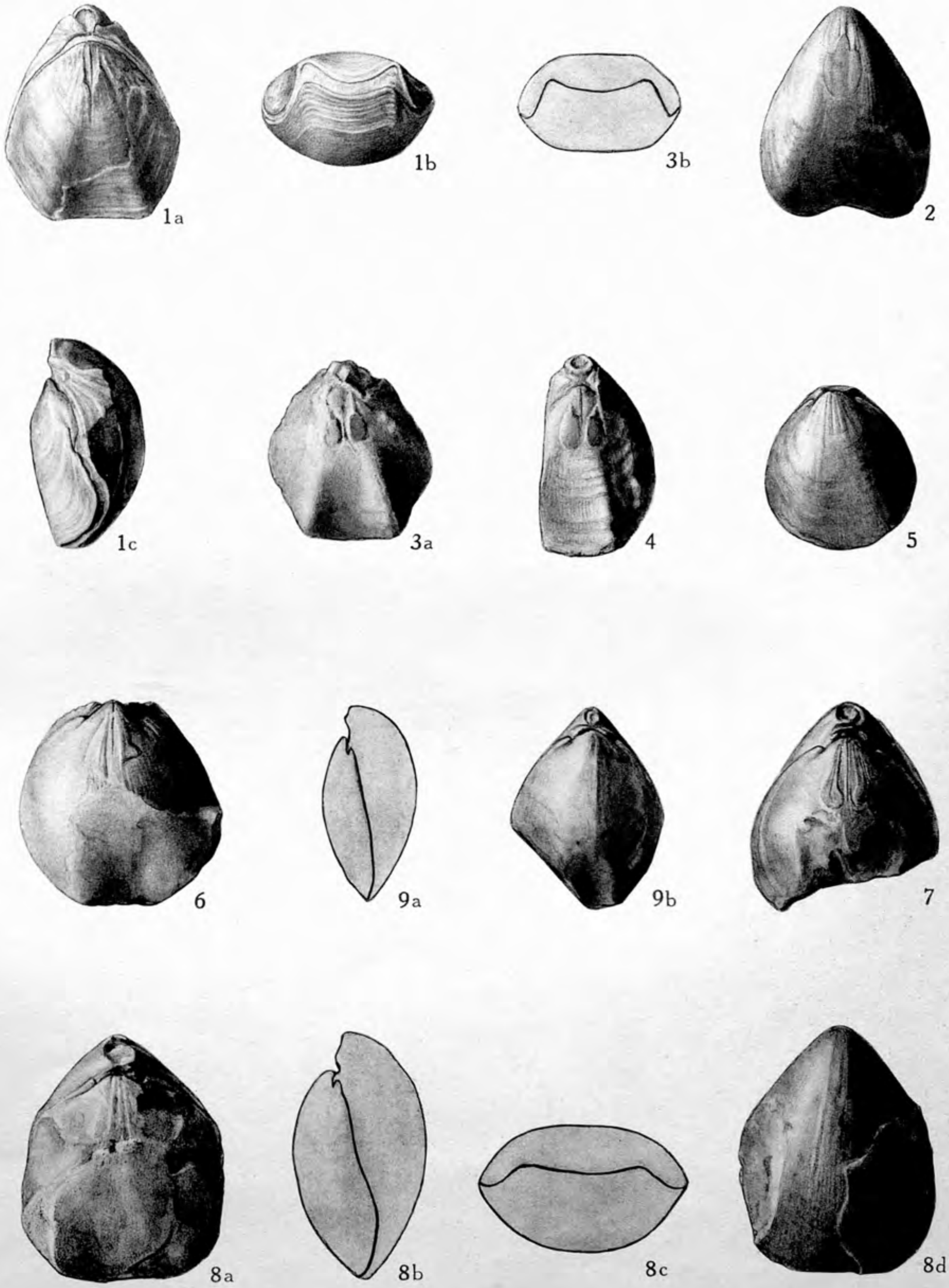
Fig. 9. TEREBRATULA SAMANENSIS var., p. 31.

Figs. 9*a*, *b*. Lateral and dorsal views of specimen. Gault, Samana range. G. S. I. No. 14,453.

FOSSIL FAUNA OF THE SAMANA RANGE.

Geol. Surv. of India

Plate VI.



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Vol. lxxxvii, part 1, 1931.]

APPENDIX—BRACHIOPODA OF THE TUEDIAN BEDS OF NORTHERN CUMBERLAND

VII. Appendix—Brachiopoda of the Tuedian Beds of Northern Cumberland

BY HELEN MARGUERITE MUIR-WOOD, M.SC., F.G.S.

Brachiopoda are numerous in the marine beds of the Tuedian rocks of Northern Cumberland and Roxburghshire, and are associated together in sufficient numbers at some horizons to form definite bands, which are important as constituting zones. Most species are confined to one band and rarely occur above or below it, with the exception of *Dictyoclostus* [*Productus*] *teres*, which is found in the Lower *Dictyoclostus teres* Band, Lynebank Beds, of Z_2–C_1 age, and recurs in the Upper *Dictyoclostus teres* Band, Cambeck Beds, of C_2 age.

The interiors of several brachial valves of different species of *Productus* are excellently preserved, also the interior of the pedicle valve of *Syringothyris* showing the syrinx or split pedicle-tube, a structure which is rarely seen exposed in this genus.

The occurrence of *Derbyia ambigua sp. nov.* in the C_2 Sub-zone of Westmorland, the Isle of Man, and the Rush-Skerries district, Co. Dublin, and the occurrence of *Dictyoclostus teres* and *Chonetes cumbriensis sp. nov.* in the C_2 Sub-zone of Hook Head, Co. Wexford, prove that these areas and Northern Cumberland were connected in *Syringothyris* times.

Several new forms have been collected and three new species are described in the following notes.

The holotypes and figured specimens have been presented to the British Museum (Natural History), and the remainder of the material is in Professor Garwood's collection at University College, London.

Description of Species

Family STROPHOMENIDÆ King

Subfamily ORTHOTETINÆ Waagen

Genus Derbyia Waagen 1884, emend. Girty 1908, p. 151.

Derbyia ambigua [1] sp. nov. (Pl. X, figs 4–6, text-fig. 3.)

Streptorhynchus crenistria T. Davidson, 1860, p. 124, pl. xxvi, figs. 1, 1*a*, 1*b*, & 1c.
Schellwienella cf. *crenistria* E. J. Garwood, 1912, p. 468. (Name only.)

Diagnosis.—*Derbyia*, about 50 mm. long, 82 mm. wide, 5 mm. thick or 100 : 164 : 10, resembling *D. gigantea* I.

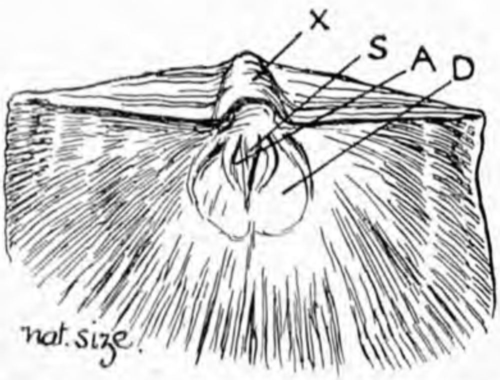
[1] So named on account of the frequent difference of ornament in the two valves.

Thomas, but differing from it in having (1) a flatter and more laterally elongated shell, (2) more numerous costæ and fine striæ developed between the costæ, (3) a shorter and less prominent median septum in the pedicle valve.

Description.—The shell is semicircular in outline, wider than long, with the hinge forming the widest part of the shell. The shell is moderately thin and is punctate.

Pedicle Valve.—(Holotype) 54 mm. long, 82 mm. wide, 4 mm. thick; convex round the umbo, but becoming depressed and slightly concave anteriorly. The cardinal area is from 8–9 mm. in height at the widest part and slopes down rapidly to the cardinal extremities. The delthyrium is closed by a convex deltidium (text-fig. 3). No secondary area has been observed.

FIG. 3.



Derbyia ambigua sp. nov. Paratype. Interior of pedicle valve showing cardinal area and muscle-scars, slightly restored from second specimen. X = deltidium, S = median septum, A = adductor muscle-scar, D = diductor muscle-scar. Cambeck Beds, Upper *Dictyoclostus teres* Band, Cam Beck, Cumberland. [B. 56425]. Natural size.

The shell is ornamented by fine longitudinal costæ (from 12–14 costæ in 10 mm. near the anterior margin) (Pl. X, fig. 4). The costæ increase by means of numerous intercalations which attain normal width in a distance of about 10 mm., and bifurcation of the costæ may occur near the umbo. In addition to this, two or more longitudinal striæ may be developed between the costæ, but these are rarely seen in the pedicle valve. The growth-lines make a rather prominent transverse ornament appearing as narrow rugæ between the costæ.

In the interior of the pedicle valve, the shell is concave immediately below the umbo. The median septum is broad and flattened posteriorly and arises from a point about 2 mm. below the deltidium. The elevation of the septum is variable, in some specimens it is low and not prominent. It does not exceed 10 mm. in length. The outline of the muscle-scars is obscure. The hinge-teeth are small and not supported by dental lamellæ.

Brachial Valve.—Flat posteriorly, but becomes slightly convex anteriorly. No cardinal area is developed in this valve. The ornament consists of fine radiating costæ increasing by means of numerous intercalations, and in addition to this from 2 to 5 very fine longitudinal striæ are usually developed between the costæ (Pl. X, fig. 6). The number and development of these striations varies with different specimens. The interior of the brachial valve is unknown.

Type-specimen.—Holotype from the Upper *Dictyoclostus teres* Band, Cambeck Beds, C_2 Sub-zone, White Beck, Bewcastle, is preserved in the British Museum (Natural History) collections [B. 56411].

Horizon and Locality.—C_2 Sub-zone, Cambeck Beds. Paratypes are preserved in Prof. Garwood's collection from the Bewcastle district, top of Crewe Burn, Gillalees Beck, Spadeadam, Rough Sike near Roadhead, Show Burn, above High Grains, upper ford Birky Cleugh, and from Harden Burn, Roxburghshire. Three paratypes are preserved in the British Museum (Natural History) collections [B. 56410, 56415, 56416].

Previous Record.—This species has been recorded from the *Chonetes carinata*, C_2 Sub-zone, Arnside, from Kirkby Lonsdale, and from Derbyhaven, Isle of Man (Garwood, 1912, p. 468). The Arnside specimens frequently attain a width of 15 cm. by a length of 7·5 cm. It also occurs in the Tuedian of Catcleugh Burn and Lewis Burn, Northumberland (Garwood, 1910, p. 676). Dr. L. B. Smyth (1915, p. 542) records this species as *Schellwienella* cf. *crenistria* from the Holmpatrick Limestone, C–S Zone, of the Rush-Skerries section, Co. Dublin. A large specimen showing both valves was figured by Davidson from Kendal, where the beds are of similar age to those of Arnside.

Remarks.—Waagen's species *Derbyia grandis* (Waagen, 1884, p. 597) from the Permo-Carboniferous of the Salt Range, India, although resembling *D. ambigua* in its large dimensions, differs from it in being considerably more convex and less transversely elongated in outline. The ornament of the two forms is also quite distinct, that of the Indian species exhibiting gerontic characters, shown by the sinuosity and irregularity in development of the costæ.

Examination of a number of specimens of *Derbyia hindi* I. Thomas from the Pendleside Series of Congleton Edge, Cheshire, has proved that the ornament in that species is also variable, and differs slightly in the two valves. In the pedicle valve, the costæ are more widely spaced and intercalations are fewer than in the brachial valve. In the brachial valve, one intercalation may be replaced by two or three finer costæ as in the brachial valve of *D. ambigua.*

Family CHONETIDÆ Hall & Clarke

Genus Chonetes Fischer de Waldheim, 1837, emend. Pæckelmann, 1930, p. 233.

Chonetes cumbriensis sp. nov. (Pl. X, figs. 2*a*, 2*b* & 3, text-figs. 4 & 5.)

Diagnosis.—*Chonetes* about 6 mm. long, 9 mm. wide, and 1·5 mm. thick or 100 : 150 : 25, resembling *C. laguessiana* de Koninck, but differing from it in having (1) smaller and less transverse shell, (2) more convex pedicle valve medianly depressed or sulcated, (3) ears not sharply demarcated by sulcus, (4) finer costæ (30–35 in 5 mm.).

Description.—The shell is semicircular in outline with the width exceeding the length, and the hinge forming the widest part of the shell. The cardinal area is narrow in both valves. The shell is thin and fragile.

Pedicle Valve.—(Holotype) 5 mm. long, 8 mm. wide, 1·5 mm. thick; (paratype) 6 mm. long, 9 mm. wide, 1·75 mm. thick; slightly convex with shallow median sulcus or depression. The umbo is minute and slightly incurved. The cardinal extremities are acute, and in well-preserved specimens are produced laterally in a short spine-like projection. The ears are small and not clearly demarcated from the remainder of the shell.

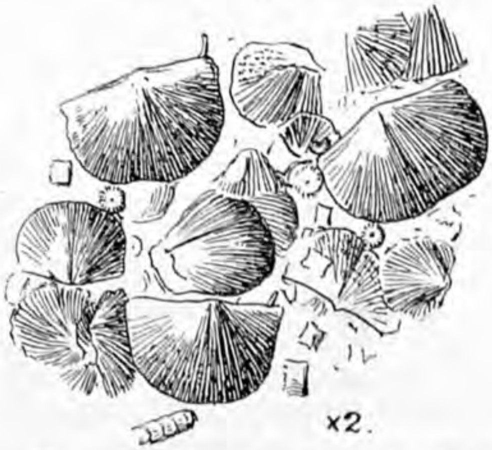
The shell is ornamented by about 100 fine costæ radiating out evenly from the umbo (Pl. X, figs. 2 & 3). Bifurcation of the costæ occurs frequently, usually each costa splits between the umbo and the anterior margin. Intercalated costæ are rare. No costæ are developed on the ears and cardinal slopes. Spines are developed along the hinge-margin, four spines projecting from the hinge on either side of the umbo at an angle of about 30°. Spine-apertures are seen on the summit of the costæ over the entire valve. Fine detached spines not exceeding 3 mm. in length are found associated with the specimens.

The internal characters of this valve are unknown.

Brachial Valve.—Concave with a low median fold corresponding to the sulcus of the pedicle valve. The ornament is similar to that of the pedicle valve. In the interior of the brachial valve (Pl. X, fig. 2*a*, & text-fig. 5) the crural plates, which are from 1·5 mm. to 2·0 mm. in length, diverge from the minute bifid cardinal process at an angle of 15° to the hinge. A narrow median septum about 3 mm. in length arises about 2 mm. below the cardinal process. This septum was only preserved in a few specimens. Immediately below the cardinal process, two low ridges diverge at an angle of about 5° and continue half-way down the shell. The anterior part of the brachial impressions, about 2 mm. in length, appear as narrow ridges between the crural plates and inner forked ridges. The remainder of the brachial impressions and the adductor muscle-scars are not seen in any specimen.

Type-specimen.—Holotype from the *Chonetes cumbriensis* Band, Cambeck Beds, Butter Burn, Bewcastle district, Cumberland, is preserved in the British Museum (Natural History) collections [B. 56426].

FIGS. 4 & 5.—*Chonetes cumbriensis sp. nov.*



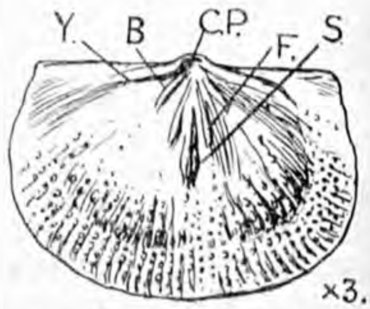


Fig. 4. *Chonetes cumbriensis sp. nov.* Holotype. Group of specimens associated with crinoid stems. Cambeck Beds. *Chonetes cumbriensis* Band, Butter Burn, Bewcastle district, Cumberland. [B. 56418]. × 2.

Fig. 5. *Chonetes cumbriensis sp. nov.* Paratype. Interior of brachial valve. Y = crural plates; B = posterior end of brachial impressions; F = forked ridges; S = median septum; C.P. = cardinal process. Same horizon as fig. 2, Spadeadam, Cumberland. [B. 56412]. × 3.

Locality and Horizon.—C_2 Sub-zone, Cambeck Beds. Paratypes from the head of Butter Burn and from Jock's Hill, Bewcastle, and from Spadeadam Bed, Green's Burn, Northern Cumberland, are preserved in Prof. Garwood's collection. Two paratypes are preserved in the British Museum (Natural History) collections [B. 56412, 56418].

Remarks.—This species is smaller, has a more convex pedicle valve, and is more finely costate and less spinose than *Chonetes hardrensis* (Phillips) from the D_2 Sub-zone of Hardraw, Yorkshire. There has been considerable doubt as to the correct interpretation of *Chonetes hardrensis*, which was described by J. Phillips from Berry Pomeroy (Devonian) Devon, Westleigh (Culm) Devon, and Hardraw (Lower Carboniferous)

Yorkshire (Phillips, 1841, pp. 147, 229). Recently, Dr. Pæckelmann (1930, p. 234) proposed to follow M'Coy's lead (1855, p. 454) in fixing *Chonetes hardrensis* as the Carboniferous species (Phillips, pl. 58, fig. 104 b–d) and referring the Devonian form (Phillips, pl. 58, fig. 104a) to *Chonetes sarcinulata* (Schlotheim).

Vaughan (1905, p. 293) described a number of small species of *Chonetes* from the Tournaisian of the Bristol district under the name *Chonetes* cf. *hardrensis* and figured *C.* cf. *laguessiana* (loc. cit. pl. xxvi, fig. 1) from K and Z_1, and *C.* cf. *crassistria* (= *C. failandensis* Smith, 1925, p. 86) from β. *C. crassistria* is readily distinguished from *C. cumbriensis* by its considerably coarser costation. *C.* cf. *laguessiana* is distinguished from *C. cumbriensis* by its larger size and greater width, as well as by its flatter pedicle and brachial valves and finer costæ.

A form which was described by Vaughan as *Chonetes* cf. *hardrensis* from the C Zone appears to be nearer to *C. cumbriensis*, but no specimen was available for comparison.

C. cumbriensis is distinguished from *C. zelteri* Pæckelmann (1930, p. 253) from the Tournaisian of Germany by the difference in internal characters of the brachial valve. It is distinguished from *C. perlata* (M'Coy) in having a less transversely elongated shell than in the Irish species, and in having a median sulcus in the pedicle valve.

Specimens indistinguishable from *C. cumbriensis* occur in the C_2 Sub-zone of Hook Head, Wexford. The interior of the brachial valve shows similar characters to that of *C. cumbriensis*. *Chonetes elegans* Smyth (1922, p. 21) non de Koninck, from the D_2 Sub-zone of Ballycastle, Antrim, has similar internal characters in the brachial valve, but the inner forked ridges are in contact with the septum in this species.

Family PRODUCTIDÆ Gray

Subfamily PRODUCTINÆ Waagen

Genus Linoproductus Y. T. Chao, 1927, pp. 25 & 128.

Linoproductus bioni [1] sp. nov. (Pl. IX, figs. 4*a* & 4*b*, text-figs. 6 & 7.)

Diagnosis.—*Linoproductus*, about 23 mm. in length, 22 mm. in width, and 18 mm. in thickness, having a more globose pedicle valve and longer trail than *L. globosus* (Garwood), broader venter, steeper flanks, finer costæ (20–25 in 5 mm.) and fewer intercalated costæ.

Description.—The shell is almost globular, with the

[1] Named after the late H. S. Bion, who was associated with Prof. Garwood in the early stages of the investigation of this area.

length approximately equal to the width, and the hinge-line considerably less than the maximum width of the shell.

Pedicle Valve.—(Holotype) 23·5 mm. long, 23 mm. wide, 18 mm. thick; (paratype) 25 mm. long, 23 mm. wide, 20·5 mm. thick; much inflated and geniculated at the anterior end of the visceral disk and forming a slightly curved trail. The visceral disk is convex, tapers rapidly to the umbo, and is scarcely demarcated from the small ears. The flanks are nearly vertical, and arch up to the rounded venter. The beak is much incurved. The apical angle is 114°.

The shell is ornamented by numerous fine, rather even costæ separated by sulci about half their width (Pl. IX, fig. 4 & text-figs. 6 & 7). There are about 40 costæ in 10 mm. near

FIGS. 6 & 7.—*Linoproductus bioni sp. nov.* Holotype.

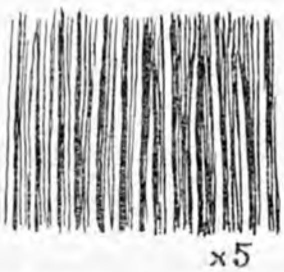


Fig. 6.—Lateral view of pedicle valve. × 2.
Fig. 7.—Enlargement of ornament. × 5.
Cambeck Beds, Upper *Dictyoclostus teres* Band, Gillalees Beck, Bewcastle district. [B. 56417].

the anterior margin. Intercalations are numerous on the flanks and at the anterior end of the visceral disk, but rapidly attain normal width. The costæ become slightly sinuous on the trail. There are about 5 angular folds on the flanks, but these flatten out before reaching the front of the shell. Growth-lines are not apparent. Spine-bases of small size are scattered over the venter, and spring from the summit of the costæ, and a group of spine-bases is developed on each ear. Two costæ tend to unite immediately posteriorly to the point of insertion of each spine-base.

Brachial Valve.—Slightly concave posteriorly, and geniculated at the anterior end of the visceral disk. The ornament is similar to that of the pedicle valve, but the concentric ribs extend across the front of the visceral disk. The internal characters are unknown.

Type-specimen.—Holotype from the Upper *Dictyoclostus teres* Band, C_2 Sub-zone, Gillalees Beck, Bewcastle, is preserved in the British Museum (Natural History) collections [B. 56417].

Horizon and Locality.—C_2 Sub-zone, Cambeck Beds. Paratypes are preserved in Prof. Garwood's collection from the Bewcastle district, from Bull Cleugh, Melefarm Beck, cliff-section south of Wintershields, King Water, mouth of Trout Beck, and Brackenrow Sike.

Remarks.—*Linoproductus bioni* is at present only known from the Northern Cumberland district, where it is extremely rare. It is probably derived from *Linoproductus globosus* (Garwood) of the C_1 Sub-zone.

Genus Dictyoclostus Muir-Wood 1930, p. 103.

Dictyoclostus teres (Muir-Wood) (Pl. IX, figs. *5a*, *5b* & 6).

Productus teres H. M. Muir-Wood, 1928, p. 87.

This species occurs abundantly in the Lynebank Beds, Lower *Dictyoclostus teres* Band, and in the Cambeck Beds, Upper *Dictyoclostus teres* Band of Northern Cumberland. The specimens are considerably better preserved and less decorticated than those previously described from Westmorland, and the following notes supplement the original description.

The pedicle valve is convex, with steep flanks and a much incurved umbo. The hinge forms the widest part of the shell. The convex ears, which are produced laterally into spine-like projections, bear a group of about 25 spines, and are frequently found detached from the shell with the spine-bases perfectly preserved. Spine-bases are also very numerous on the flanks and trail. Long, detached spines, having a metallic lustre, are commonly found in both Lower and Upper *Dictyoclostus teres* Bands. The spines are curved, and rarely exceed 2·5 mm. in length and 0·5 mm. in width. The costæ are rather fine—from 15 to 16 in 10 mm. at the anterior end of the visceral disk. Nine or ten ribs are developed on the cardinal slopes, and are faintly traceable across the visceral disk.

In the interior of the brachial valve (Pl. IX, fig. 6) the cardinal process is slightly bi-lobed internally, and deeply excavated into three lobes externally. The lateral ridges diverge slightly from the hinge-margin, and are sharply recurved anteriorly near the cardinal extremities. A broad septum arises immediately below the cardinal process and narrows considerably between the adductor muscle-scars. The adductors are trigonal in outline, dendritic, and distinctly divided into posterior and anterior scars. The anterior adductor is set on a slight ridge and is less dendritic than the posterior adductor. The brachial impressions are given off half-way down the length of the adductors.

Horizon and Locality.—C_1 and C_2 Sub-zones. Bewcastle district, White Lyne, Kirk Beck, Ashy Cleugh below Stockstead, Bull Cleugh Ford, Birky Cleugh, above High Grains, White Beck above algal reef, beck west of Gillalees Beck, Melefarm Beck, Eliot's Burn, and limestone in Fell Sandstone, south of Hazel Gill Crag.

Previous Record.—This species was previously recorded from the C_1 and C_2 Sub-zones of Westmorland. It occurs also in the C_2 Sub-zone of Hook Head, Co. Wexford.

Remarks.—*Dictyoclostus teres* differs from species of the *Productus productus* group or *Productus s.s.* in having no diaphragm or shelly plate developed in the interior of the brachial valve round the edge of the visceral disk, and it is, therefore, allied to the *semireticulatus* group of *Productus*, lately re-named *Dictyoclostus*. *D. teres* is associated in both Lower and Upper *Productus* Bands with specimens of *Crania quadrata* (M'Coy), which are attached to the shell of the *Productus*, often taking on its longitudinal ornament.

Genus Pustula I. Thomas, 1914, p. 259.

Pustula interrupta I. Thomas (Pl. IX, figs. 2 & 3.)

Well-preserved specimens showing the external ornament as well as interiors of the brachial valve occur in the lowest beds of the Tuedian of Northern Cumberland of Z_2 age. They are associated with specimens of *Athyris concentrica* (Von Buch) and *Crania quadrata* (M'Coy).

In the pedicle valve, the spines are usually well preserved and extend along the surface of the shell. Fine detached spines not exceeding 10 mm. in length are very numerous.

The interior of the brachial valve (Pl. IX, fig. 3), previously unknown, has a small bifid cardinal process from which narrow ridges are given off laterally, extending for 7 mm. along the hinge and then curving anteriorly for about 1 mm. A narrow median septum, about 17 mm. long, extends from the cardinal process anteriorly.

Previous Record.—This species has been recorded from the Z_2 Sub-zone of the Mendip Hills, C_2 Sub-zone of Arnside, Westmorland, of Co. Clare, Ireland, and of Clitheroe, Lancashire.

Family SPIRIFERIDÆ

Subfamily SYRINGOTHYRINÆ Schuchert & Le Vene

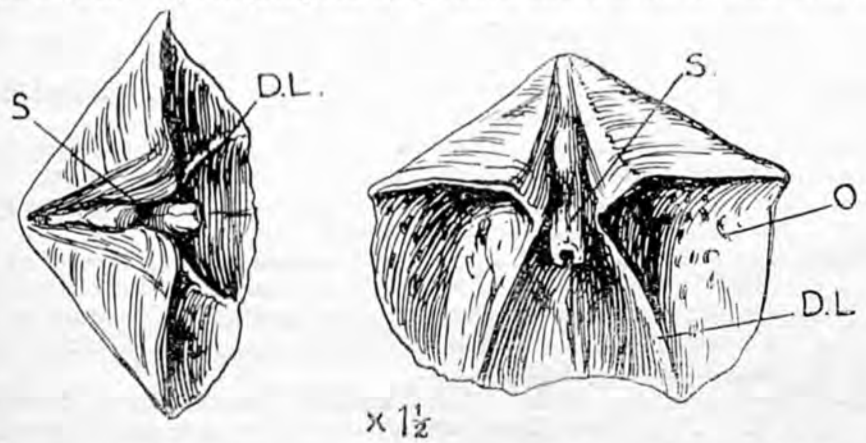
Genus SYRINGOTHYRIS Winchell, 1863, p. 6.

SYRINGOTHYRIS CUSPIDATA mut. EXOLETA var. North
(Pl. IX, figs. 7 & 8, text-figs. 8 & 9.)

Syringothyris cuspidata E. J. Garwood, 1912, pp. 516 & 518.
Syringothyris cuspidata T. Davidson, 1857, pl. viii, fig. 20.
Syringothyris cuspidata mut. *exoleta* var. North, 1920, p. 185.

Numerous interiors of the pedicle valve showing the pedicle tube or syrinx and the delthyrial supporting-plates, also one specimen with the two valves in contact, are found in the equivalent of the Cambeck Beds, C_2 Sub-zone, of Harden

FIGS. 8 & 9.—*Syringothyris cuspidata* mut. *exoleta* var. North.



Two views of same specimen. S = syrinx; D.L. = delthyrial supporting-plates; O = ovarian markings. Cambeck Beds, Harden Burn, Roxburghshire. [B. 56422]. × 1½.

Burn, Roxburghshire. Exteriors of the shell are also found associated with specimens of *Derbyia ambigua sp. nov.* in the Cambeck Beds of Northern Cumberland.

The syrinx (Pl. IX, figs. 7 & 8, & text-figs. 8 & 9) arises from the transverse plate joining the delthyrial supporting-plates and projects as a tube, split on its lower surface, into the cavity between the delthyrial supporting-plates for a distance of 3–4 mm. The upper surface of the syrinx and transverse plate bears an elevated ridge. The syrinx is frequently asymmetrical and varies in diameter in different specimens.

Previous Record.—*Syringothyris cuspidata* mut. *exoleta* has been recorded from Z_2 Sub-zone of the Bristol district, γ of Eastern Glamorgan, and C_1 of Mendip Hills and Ireland.

Prof. Garwood records this form as *S. cuspidata* from the Brownber Pebble-Beds of C_2 age, and also from Kendal. Davidson figures this species from a gritty sandstone at Kendal.

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EXPLANATION OF PLATES VII–XVI

PLATE VII

Main Algal Series. Harden Burn, Roxburghshire, as seen in 1925, showing honeycomb 'reef' 7 inches thick, overlying compact algal limestone largely composed of *Bevocastria* and *Ortonella*. This exposure has since been quarried away. (See p. 129.)

PLATE VIII

View of algal limestone, Quarry at The Glebe, Whittondean, Rothbury. At least 15 feet in this section is composed of algal structures, notably *Ortonella furcata*. This limestone is the highest but one occurring in the Tuedian Cementstone Group of the Rothbury district. A similar development occurs in Whitefield Beck near Hepple. Scale shown by penny. (From a photograph in the Geological Survey Collection, by permission of the Controller of H.M. Stationery Office.) (See p. 136.)

PLATE IX

(All figures are of natural size unless otherwise stated.)

Figs. 1*a* & 1*b*. *Athyris concentrica* (Von Buch). 1*a*, Dorsal view showing concentric ornament. 1*b*, Ventral view of same specimen, slightly reduced. *Pustula interrupta* Beds, Lynebank Beds, Z_2 Sub-zone, Ellery Sike, Bewcastle. British Museum (Natural History) [B. 56419]. (See p. 105.)

Fig. 2. *Pustula interrupta* I. Thomas. Ventral view. *P. interrupta* Beds, Lynebank Beds, Z_2 Sub-zone, Ellery Sike, Bewcastle. British Museum (Natural History) [B. 56421]. (See p. 152.)

3. *Pustula interrupta* I. Thomas. Interior of brachial valve showing cardinal process, lateral ridges, and median septum well preserved. Lynebank Beds, Z_2 Sub-zone, Cat Scar, White Lyne, Bewcastle. British Museum (Natural History) [B. 56424].

Figs. 4*a* & 4*b*. *Linoproductus bioni* Muir-Wood *sp. nov.* Holotype. × $1\frac{1}{3}$. 4*a*, Lateral view. 4*b*, Ventral view. Upper *Dictyoclostus* [*Productus*] *teres* Band, Cambeck Beds, C_2 Sub-zone, Gillalees Beck, Bewcastle. British Museum (Natural History) [B. 56417]. (See p. 149.)

5*a* & 5*b*. *Dictyoclostus* [*Productus*] *teres* (Muir-Wood). 5*a*, Umbonal view showing spine-bases on ears and cardinal slopes. 5*b*, Latero-ventral view showing ornament on venter and flanks. × $1\frac{1}{2}$. Upper *Dictyoclostus teres* Band, Cambeck Beds, Birky Cleugh, Bewcastle. British Museum (Natural History) [B. 56413]. (See p. 151.)

Fig. 6. *Dictyoclostus* [*Productus*] *teres* (Muir-Wood). Interior of brachial valve. Upper *Dictyoclostus teres* Band, Cambeck Beds, C_2 Sub-zone, Birky Cleugh, Bewcastle. British Museum (Natural History) [B. 56414].

Figs. 7 & 8. *Syringothyris cuspidata* mut. *exoleta* var. North. Interior of pedicle valve showing syrinx and delthyrial supporting-plates. Equivalent of Cambeck Beds, C_2 Sub-zone, Harden Burn, Roxburghshire. British Museum (Natural History) [B. 56422]. (See p. 153.)

Fig. 9. Algal growth round *Modiola lata* Portlock. Main Algal Series, near mouth of Harden Burn, under road-bridge, Roxburghshire. (See p. 130.)

10. *Orthoceras breyni* Portlock. Cast of body-chamber and eleven gas chambers. Main Reef, Bull Cleugh, Bewcastle. (See p. 110.)

11. *Orthoceras breyni* Portlock. Transverse section showing excentric siphuncle. Cambeck Beds, C_2 Sub-zone, Birky Cleugh, Bewcastle.

Plate X

(All figures are of natural size unless otherwise stated.)

Fig. 1. *Dentalium priscum* Muenster and small gastropod. Upper *Dictyoclostus teres* Band, Cambeck Beds, C_2 Sub-zone, Ashy Cleugh, Bewcastle.

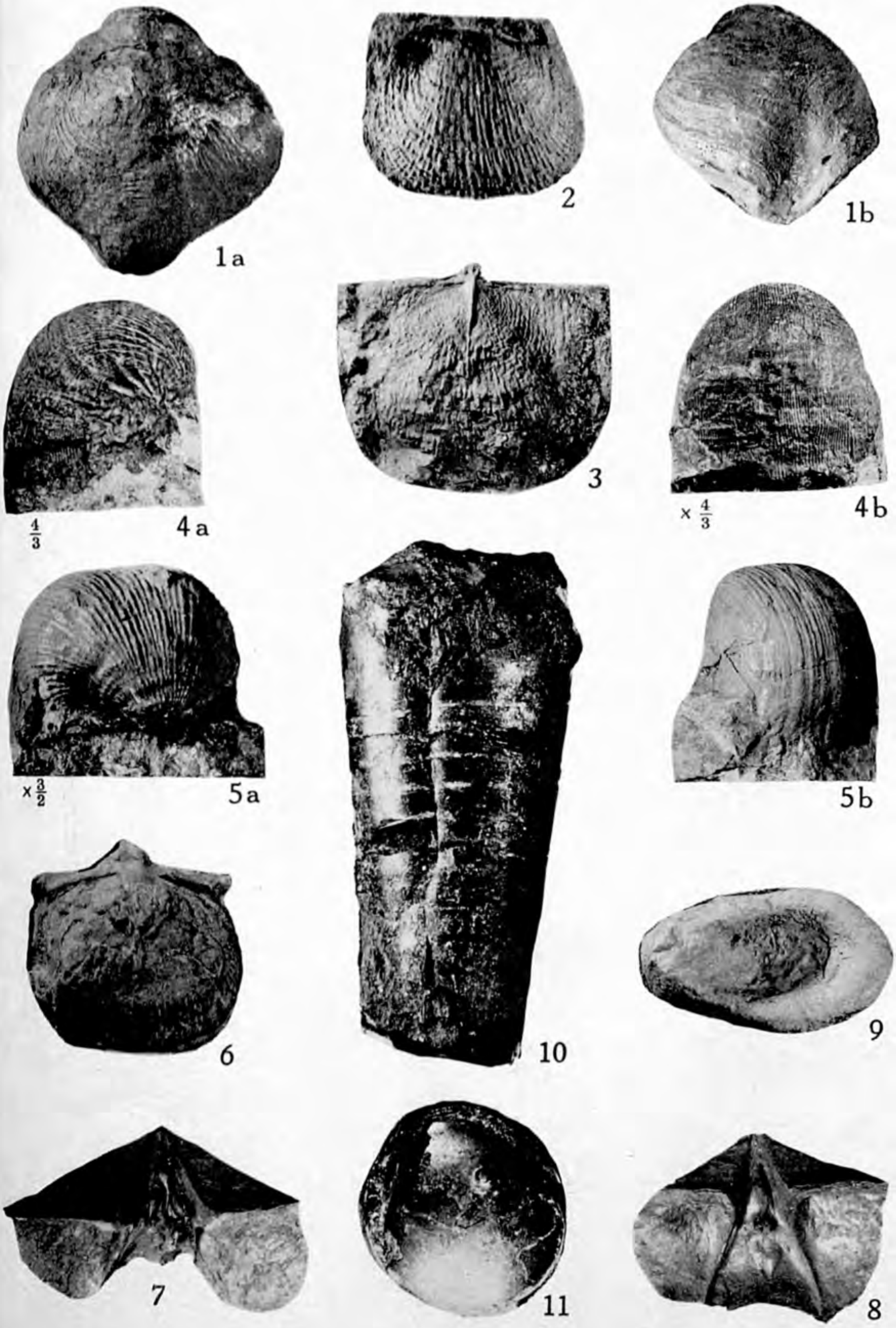
Figs. 2*a* & 2*b*. *Chonetes cumbriensis* Muir-Wood *sp. nov.* Paratypes. 2*a*, Group of specimens showing ornament and the interior of the brachial valve. 2*b*, Enlargement of interior of brachial valve seen on left of fig. 2*a*, and showing ridges on each side of median septum. × 3 approx. Spadeadam Beds (Cambeck Beds), C_2 Sub-zone, Green's Burn, Northern Cumberland. British Museum (Natural History) [B. 56412]. (See p. 147.)

Fig. 3. *Chonetes cumbriensis* Muir-Wood *sp. nov.* Holotype, × $2\frac{1}{2}$. Enlargement showing ornament of pedicle valve, and spine-bases along the hinge. Cambeck Beds, Butter Burn, Bewcastle. British Museum (Natural History) [B. 56418].

4. *Derbyia ambigua* Muir-Wood *sp. nov.* Holotype. Pedicle valve somewhat weathered and showing cast of median septum near the umbo. Upper *Dictyoclostus teres* Band, Cambeck Beds, C_2 Sub-zone, White Beck, Bewcastle. British Museum (Natural History) [B. 56411]. (See p. 144.)

5. *Derbyia ambigua* Muir-Wood *sp. nov.* Paratype. × 2 approx. Interior of pedicle valve showing median septum. Cambeck Beds, Upper Ford, Birky Cleugh, Bewcastle. British Museum (Natural History) [B. 56416].

6. *Derbyia ambigua* Muir-Wood *sp. nov.* Portion of brachial valve to show fine longitudinal striations between the costæ. *Chonetes carinata* Sub-zone, C_2, Arnside, Westmorland. British Museum (Natural History) [B. 56415].



E. J. G., photo.

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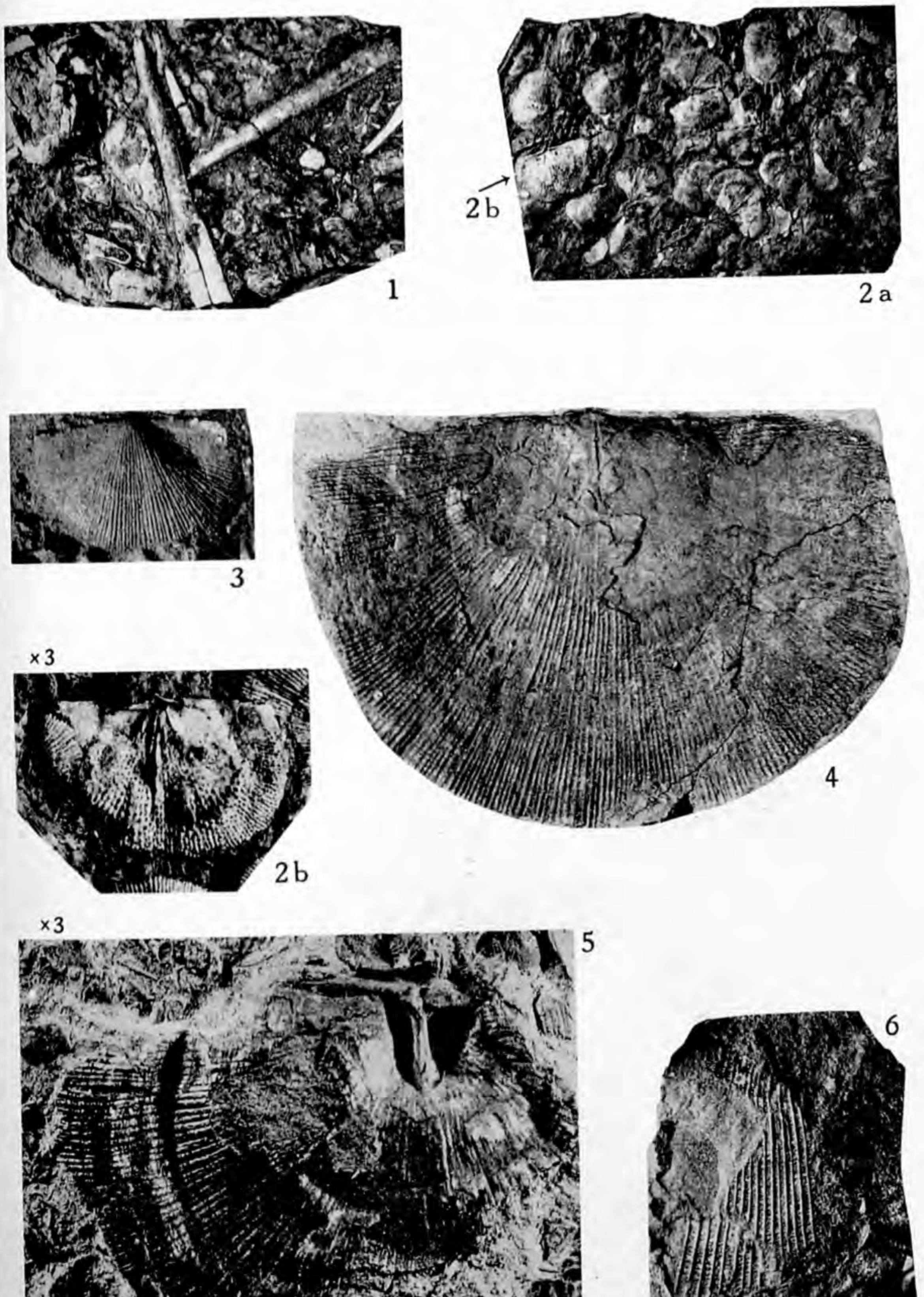
ORTHOCERAS and BRACHIOPODA.



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DENTALIUM and BRACHIOPODA.

THE BRACHIOPOD SPECIES TEREBRATULA BISINUATA, VALENCIENNES IN LAMARCK, AND TEREBRATULA BARTONENSIS AND TEREBRATULA HANTONENSIS spp. n.

By HELEN M. MUIR-WOOD, M.Sc., F.G.S.

[*Received 26th February, 1933*].

THE species *Terebratula bisinuata* was briefly described by Valenciennes in Lamarck in 1819 [**1**][1] as 'T. testâ subrotundâ, subdepressâ, antiquatâ, fragili, laevi, supernè biplicatâ nate productâ non incurvâ. Habite—Fossile de Grignon . . .' No figure was given by Valenciennes, but Davidson [**2**] in 1850, after examining Lamarck's collection, gave a much restored figure of this species, and remarked that it occurred in the Tertiary beds of the Paris Basin.

In the 'Catalogue Illustré de la Collection Lamarck, Pt. i, Fossiles,' published by the Natural History Museum of Geneva in 1918, seven specimens of *Terebratula bisinuata* are excellently depicted by photographs on pl. viii, figs. 43-47. A note in this publication, copied from the MS. catalogue of Lamarck's collection, states that five of the seven specimens are typical, and the remaining two are varieties. It is suggested by the compilers of the 'Catalogue Coll. Lamarck,' that the broad flattened specimen shown in pl. viii, figs. 43a, b, represents the variety, and the remaining figures 44-47 the typical form. Careful examination of the specimens represented in figs. 44-47 appears to show, however, that there are two distinct forms, and it is proposed to select the specimen figured on pl. viii, fig. 46, a, b, of the 'Catalogue Coll. Lamarck' as lectotype of *Terebratula bisinuata*. This specimen agrees in external characters with that figured by Deshayes in 'Coquilles Fossiles Environs Paris,' I, 1824-37, p. 389, pl. lxv, figs. 1, 2, and it conforms with Lamarck's description in having an erect beak and depressed valves. The figure given by Davidson, already referred to, also appears to have been taken from this specimen. The detached brachial valves shown in pl. viii, figs. 44a, b, and 47a, b, of the 'Catalogue Coll. Lamarck' probably belong to *Terebratula bisinuata* sensu stricto, while the more globose specimen with incurved umbo shown in pl. viii, figs. 45, a, b, may be a distinct species or an extreme variety.

Turning from the Middle Eocene, Calcaire Grossier, of the Paris Basin to the British Upper Eocene of the Hampshire Basin, we find that the specimen which was figured by Davidson [**3**] in 1852 from the Barton Beds as "*T. bisinuata*" is quite distinct from the lectotype of *T. bisinuata*. Examination of specimens of *T. bisinuata* from the Calcaire Grossier of Grignon

[1] For list of References see p. 173.

and other localities near Paris shows that the species is thin-shelled, moderately biconvex and markedly sulciplicate, elongate-oval in outline, and tapering rapidly to the umbo which is moderately produced, suberect, and obliquely pierced by an oval slightly labiate foramen. The symphytium is about 2 mm. in depth antero-posteriorly and is partly concealed by the labrum of the foramen. A short pedicle-collar is developed. In the interior of the brachial valve the cardinal process is a small trigonal flattened disk. The inner hinge-plates are broad and almost horizontal. The crural bases separating the inner hinge-plates from the slightly curved outer hinge-plates do not form a prominent ridge. The adductor muscle-scars are slender and flask-shaped. The lectotype of *T. bisinuata* measures 25 mm. in length, and 36 mm. in width, while the thickness is uncertain owing to crushing of the shell.

The difference in beak characters, shell outline, and folding in the two forms is marked enough to warrant the recognition of the rare Barton form as a new species, here described and named *Terebratula bartonensis* sp. nov.

TEREBRATULA BARTONENSIS sp. nov.

Fig. 18; 2, 2a, 2b.

Terebratula bisinuata? T. Davidson, 1852, Mon. Brit. Foss. Brach., I, p. 19, pl. i, fig. 17.

Non *Terebratula bisinuata* Valenciennes in Lamarck.

Diagnosis. Shell about 45 mm. long and 40 mm. wide, pedicle valve 14 mm. thick; subcircular in outline, tapering slightly to umbo and towards anterior margin, uniplicate with tendency to sulciplication. Umbo short, massive, erect, truncated obliquely by circular marginate foramen. Symphytium narrow, exposed. Beak-ridges obscure. Teeth elongate, small. Pedicle-collar developed. Adductor muscle-scars narrow, 10 mm. in length, in contact laterally with crescentic diductors. Shell moderately thick, with marked concentric growth-lines. Brachial valve fragile, not observed entire.

Holotype. The pedicle-valve figured by Davidson in 1852 (loc. cit.) and preserved in the Brit. Mus. (Nat. Hist.) Morris Coll. B.81096, from the Barton Sands, Barton, Hants.

Paratype. A pedicle-valve in the British Museum (Nat. Hist.) Walker Coll. from the same locality and horizon. B.24836.

Remarks. Davidson (op. cit., p. 19) describes a specimen complete with both valves from Barton as being 'circular, rather longer than wide, very thin, not much convex, and presenting *scarcely* any trace of the bisinuation—characteristic of the Lamarckian type.'

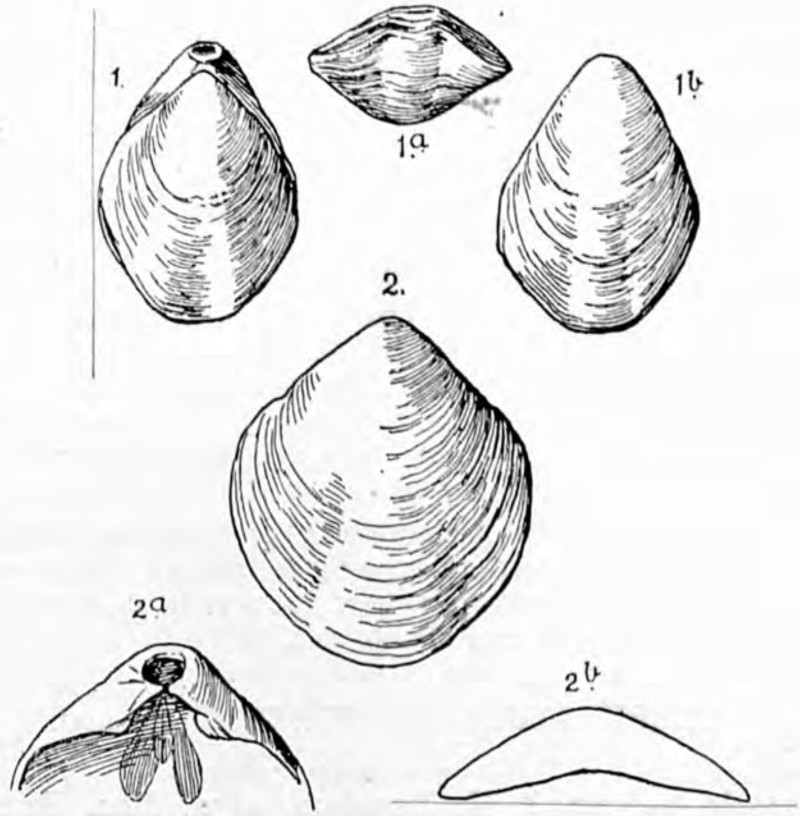

FIG. 18.—*Terebratula bisinuata* Val. in Lamarck and *T. bartonensis* sp. nov.

T. bartonensis is readily distinguished from the Lower Eocene, London Clay specimens found at Catisfield, near Fareham, Hants., which were identified by J. F. Walker in 1888 [**4**] and referred to by T. F. Osborne White in 1913 [**5**] as *T. bisinuata*. This species is described below as *Terebratula hantonensis* sp. nov.

TEREBRATULA HANTONENSIS sp. nov.

Fig 19; 3, 4, 4a, 5.

Terebratula bisinuata J. F. Walker, 1888, Rep. Yorks. Phil. Soc., p. 3.

Non *Terebratula bisinuata* Valenciennes in Lamarck.

Diagnosis. Shell about 45 mm. long, 33 mm. wide, and 19 mm. thick; biconvex, sulciplicate, elongate-oval in outline, tapering gently to anterior margin which is rounded or subtruncate. Umbo short, massive, erect, truncated and pierced by circular marginate foramen. Symphytium narrow. Beak-ridges obscure. Teeth elongate, small. Pedicle-collar developed. Inner hinge-plates narrow, dorsally deflected. Cardinal process a flattened disk. Crural processes slender incurved, almost in contact.

Holotype. A specimen in the British Museum (Nat. Hist.) J. F. Walker Coll. from the Lower Eocene, London Clay of Catisfield Railway-cutting, Fareham, Hants, Brit. Mus. B.81611.

Paratypes. About sixty specimens in the British Museum (Nat. Hist.) Walker Coll. from the same locality and horizon.

Description. The brachial valve is convex in the neanic stage, but the umbonal portion of the pedicle valve is slightly carinate. In early growth-stages the shell is biconvex circular in outline, but the anterior margin soon becomes acuminate. At maturity the anterior margin is truncated and the shell

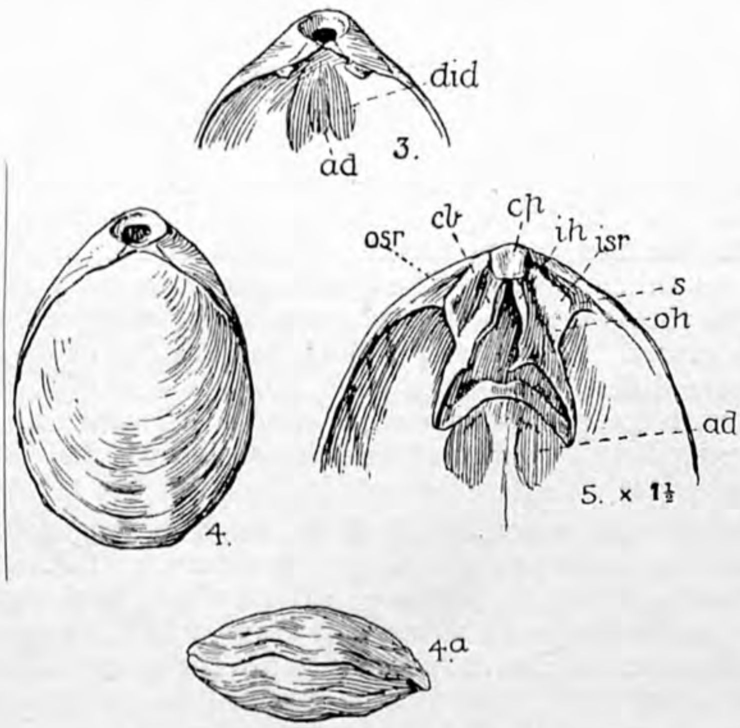

Fig. 19.—*Terebratula hantonensis* sp. nov.

develops a low median dorsal fold which is soon depressed by a median sinus causing biplication (sulciplication) of the anterior commissure in the gerontic stage. The shell elongates until the length is considerably in excess of the width. The foramen is circular and surrounded by a concave rim which increases in width with age. A narrow pedicle-collar is developed in the interior of the umbonal portion of the pedicle-valve and is attached to the shell-wall posteriorly, but becomes free anteriorly. The diductor muscle-scars of the pedicle-valve are crescentic in outline and enclose the narrow adductors.

In the interior of the brachial valve the loop extends for 11 mm., and the transverse band and crural processes project ventrally for a distance of 9 mm. above the shell floor. The crura are delicate, tapering to an acute apex and incurve so as to be practically in contact with one another. The inner hinge-plates are from 0.5 to 1 mm. in width and are deflected dorsally. They are separated from the concave outer hinge-plates by the crural bases which project as narrow vertical ridges about 0.5 mm. in height. The outer hinge-plates curve upwards from the shell floor to join the low inner socket-ridges. The sockets are narrow and are over-lapped to a small extent by the inner socket-ridges. The outer socket-ridges are low, rounded and impersistent. The cardinal process consisting of a subrectangular flattened disk with slightly raised rim projects from the umbo at an angle of 45°. The adductor muscle-scars are subtrigonal in outline with the longest side abutting on a low median longitudinal ridge. No true septum is developed.

Remarks. *Terebratula hantonensis* is distinguished from *T. bartonensis* sp. n. by its narrower shell which is elongate-oval in outline, by the biplication of the anterior commissure, by its smaller foramen, by the broader rim surrounding the foramen, and by its thinner shell. The beak characters are sufficiently similar in the two species to warrant their being assigned to the same genus. The interior of the brachial valve of *Terebratula hantonensis* differs from that of *T. grandis* auct. [*T. maxima* Charlesworth in part], from the British Pliocene, in having very narrow, dorsally deflected inner hinge-plates. In *T. maxima* these plates are considerably broader, and project horizontally.

T. hantonensis resembles *T. bisinuata* in having a biplicate shell, but less accentuated folding. It differs from *T. bisinuata* in its beak characters, narrower symphytium, and marginate foramen, in the shape of the brachial valve, which does not taper posteriorly as in the French species ; and in the internal characters of the brachial valve, namely, the shape of the cardinal process, the inner hinge-plates, and the crural bases.

The three forms occurring respectively in the Lower, Middle, and Upper Eocene, and formerly included under *T. bisinuata*, can therefore be shown to belong to three distinct species ; moreover, *T. hantonensis* and *T. bartonensis* probably belonging to one genus, and *T. bisinuata* to another. Both these genera appear to be represented in the Pliocene, but until the internal structure of the Italian Pliocene species, *T. terebratula* Linné, the genotype of *Terebratula*, has been investigated, it is uncertain which should be described as *Terebratula* sensu stricto. The beak characters of the specimen figured by S. S. Buckman as *T. terebratula* in 1907 [**6**] resemble those of *T. bisinuata* Val. in Lamarck.

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2. DAVIDSON, T., 1850. *Ann. Mag. Nat. Hist.* V., p. 440, pl. xiii., fig. 32.
3. ———, 1852, *Mon. Brit. Foss. Brach.*, I., p. 19, pl. i, fig 17.
4. WALKER, J. F., 1888. *Rep. Yorks. Phil. Soc.*, p. 3.
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6. BUCKMAN, S. S., 1907. *Ann. Mag. Nat. Hist.* (7) XIX., p. 528, pl. xii., figs. a-c.

EXPLANATION OF TEXT FIGURES 18 and 19.

Figs. 1, a, b. *Terebratula bisinuata* Val. in Lam. Middle Eocene, Calcaire Grossier, Grignon, Paris Basin. *Brit. Mus.*, B. 6086. × $\frac{3}{4}$.

Fig. 1. Dorsal view showing labiate foramen.

Fig. 1a. Anterior view showing the marked biplication of the anterior commissure.

Fig. 1b. Ventral view.

Figs. 2, a, b. *Terebratula bartonensis* sp. nov. Holotype. Upper Eocene, Barton Sands, Barton, Hampshire Basin. *Brit. Mus.*, B. 81096. × $\frac{3}{4}$.

Fig. 2. Ventral view showing uniplication of shell.

Fig. 2a. Posterior portion of interior of pedicle valve showing large marginate foramen, hinge teeth, and adductor muscle-scars enclosed by large diductor muscle-scars.

Fig. 2b. Section through pedicle valve, the lower curve being that of the anterior commissure.

Figs. 3, 4, 4a, 5. *Terebratula hantonensis* sp. nov. Lower Eocene, London Clay, Catisfield railway-cutting, Fareham, Hants.

Fig. 3. Posterior portion of interior of pedicle valve showing muscle-scars and marginate foramen. ad = adductor muscle-scars ; did = diductor muscle-scars. Paratype, *Brit. Mus.* B. 81614. × $\frac{3}{4}$.

Fig. 4. Dorsal view of holotype. *Brit. Mus.* B. 81611. × $\frac{3}{4}$.

Fig. 4a. Anterior view of holotype showing biplication of commissure.

Fig. 5. Posterior portion of interior of brachial valve showing brachial loop. cb = crural base ; cp = cardinal process ; ad = adductor muscle-scars ; ih = inner hinge-plate ; oh = outer hinge-plate ; isr = inner socket-ridge ; osr = outer socket-ridge ; s = socket. Paratype, *Brit. Mus.* B. 81612. × $1\frac{1}{2}$.

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PHILOSOPHICAL TRANSACTIONS

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SERIES B, VOL. 223. Pp. 511–567.

[PLATES 62–63.]

ON THE INTERNAL STRUCTURE OF SOME MESOZOIC BRACHIOPODA.

BY

HELEN M. MUIR-WOOD, M.Sc., F.G.S.
(FROM THE DEPARTMENT OF GEOLOGY, BRITISH MUSEUM (NATURAL HISTORY.)

B 503.

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XII. *On the Internal Structure of some Mesozoic Brachiopoda.*

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(*Communicated by* W. D. LANG, *F.R.S.*)

(Received September 12, 1933—Read January 25, 1934.)

[PLATES 62–63.]

I. INTRODUCTION.

Discussion of Modern Methods of Investigating the Internal Structure of Fossil Brachiopod Shells.

The present paper shows how a method of research hitherto but tentatively used by a few workers on the internal characters of Brachiopod shells has been elaborated and applied to certain Mesozoic genera of different families, and has resulted in establishing the relationships of the forms examined more satisfactorily than by methods hitherto employed. It embodies some results of two years' research on the identification and classification of such numerous species of the Brachiopod families Rhynchonellidæ, Terebratulidæ, and Terebratellidæ, as are found in Jurassic and Cretaceous rocks. At the present time less than half of the Mesozoic Brachiopods are specifically determinable, and little or nothing is known of their internal structure, their mutual relationship, or their evolution. This is probably because internal casts are rare, and in Jurassic and Cretaceous species the two valves are not as a rule found detached from one another.

Comparatively little advance has been made in the study of Jurassic and Cretaceous forms since DAVIDSON's monumental work (1851–1884), until the appearance of S. S. BUCKMAN's (1901–1915) numerous papers on British Jurassic species. The last culminated in 1917 in the memoir on the Jurassic Brachiopoda of the Namyau Beds, Northern Shan States, Burma, in which a new classification of the Jurassic Rhynchonellids and Terebratulids was proposed. BUCKMAN defined many new genera which he based on the external shape and folding of the shell, beak characters, shape of the muscle-scars, and, in the Rhynchonellids, on the character of the dental lamellæ. No consideration was taken of the form of the loop or crura in the brachial valve, or the cardinalia, consisting of hinge-plates, cardinal process, etc.

BUCKMAN's classification may be criticized for being based mainly on a single internal structure. It is therefore not to be compared with that of Palæozoic genera as defined by HALL and CLARKE (1892–94), BEECHER (1893, *a-c*), WELLER (1910, 1911, 1914), and other American authors ; or with that of Tertiary and Recent genera, as proposed by THOMSON (1915, *a-d*, 1916, 1925–27), JACKSON (1912, 1916, 1918) and others. In these the whole internal structure of the shell has been considered, and the importance of the shape and development of the brachial loop, hinge-plate, cardinal process, etc., has been well demonstrated. In BUCKMAN's classification specimens having similar external shape and folding of the shell and somewhat similar muscle-scars have been grouped together as related forms, although it can often be proved that these superficially similar forms are only homœomorphs, and have totally different internal hinge-characters. Too little is at present known about the internal structure of Mesozoic Brachiopods for any definite statement to be made as to the extent and importance of homœomorphy, either in internal or external form, but similar trends in parallel lineages have probably resulted in a large number of externally similar forms. Forms externally homœomorphic were described by BUCKMAN (1901, 1906, *a*, *b*, 1907, *a*) from the Jurassic, but no attempt was made to distinguish them by internal characters.

A practical objection to BUCKMAN's classification is the difficulty of preparing good internal casts of Terebratulid and Rhynchonellid genera, and even when prepared, of determining the exact outline of the muscle-scars, and so distinguishing the various genera.

Following on BUCKMAN's work came SAHNI's researches (1925, *a*, *b*, 1929) on the Chalk Terebratulids. He criticized BUCKMAN's classification for being based on the muscle-scars alone, and himself investigated the muscle-scars of various Chalk species. As a result of this work SAHNI stated that the muscle-scars were similar in shape in externally different forms, and therefore of no use in classification. He diagnosed twelve new genera on the external shell-characters and on the form of the brachial loop and cardinal process. Unfortunately, SAHNI examined insufficient material to give any description of the development of the loop, which certainly does undergo resorption and redeposition in successive growth-stages.

Much work remains to be done on the Cretaceous species before SAHNI's classification can be safely adopted.

SAHNI (1928) extended his investigation to certain of BUCKMAN's Jurassic Terebratulid genera, namely, *Lobothyris*, *Plectoidothyris*, *Plectothyris*, etc., and dissected out the loops of several genera. From a similarity of the dorsal adductor muscle-scars of *Lobothyris* and *Plectoidothyris*, and of the shape of the brachial loop in these two genera, SAHNI erroneously assumed *Lobothyris* to be identical with *Plectoidothyris*, having failed to take into consideration the external shape and folding of the two genera, or any other internal characters of the shell, except the loop and muscle-scars. He also showed that the loop in such genera as *Plectoidothyris* and *Plectothyris* was of different form and greater length than that of the Chalk specimens examined by him.

The examination of the interior of Brachiopod shells by preparing a small number of polished serial sections of a single specimen has been practised by BELANSKI (1928, *a* and *b*), WELLER (1910, 1911, 1914), KOZLOWSKI (1929), GEORGE (1927, 1930, 1932, 1933), DUNBAR (1932), SCHUCHERT and COOPER (1932), and others, on Palæozoic species, and by ROTHPLETZ (1886), KITCHIN (1900), and WIŚNIEWSKA (1932) on Mesozoic species. With the exception of KOZLOWSKI and WIŚNIEWSKA, no author has attempted to make reconstructions of the internal structure of the specimens sectioned.

No previous description has been given of the articulation of the two valves of Mesozoic forms, and no attempt has been made to figure the detailed structure of the hinge-plate. Most of the serial sections in the works above referred to are depicted as small diagrams showing the position of dental lamellæ, septa, and spondylia, but these are not as a rule accurately drawn from the actual specimens. No idea of the relationship of the various plates can be obtained from the sections, and the actual articulation of the two valves is frequently not shown.

Two of the Jurassic genera, namely, *Lobothyris* and *Plectoidothyris*, originally diagnosed by BUCKMAN, and even described as synonymous by SAHNI, have now proved to be totally unrelated. Equally interesting results were obtained in the investigation of the five other genera, namely, *Ornithella*, *Obovothyris*, *Kallirhynchia*, *Terebrirostra*, and *Digonella* gen. nov. Both the external and internal characters of the seven genera have been investigated in detail, and the genera have been re-defined on the external and internal characters collectively. A full description of the method employed is given in Part II.

II. IMPROVED METHOD OF INVESTIGATION.

Its application to Jurassic and Cretaceous Genera.

One or two specimens, preferably topotypes, which are identical in external characters with the type of the species which is either the genoholotype or genolectotype, are carefully selected, measured, and either photographed or drawn, or, with rare specimens, an external cast of the shell is prepared in plaster. The specimens are heated to redness in a Bunsen flame, better results being obtained with this than with a methylated spirit lamp or with an oxy-acetylene flame, and the specimens are then allowed to cool without being plunged into water. When cold the specimens are painted with a solution of amyl acetate and collodion, and this process is repeated after twelve hours, or when the hardening solution is dry. Three or four coats of this solution are applied until the shell is again hardened. If this process is omitted the shells tend to split and much of the internal detail may be lost. Longitudinal and horizontal axes are marked on the shell, and the specimens are embedded in a rectangular block of plaster, and transverse sections are then prepared by grinding the specimens either on a large carborundum wheel worked by a dental engine; or by hand, when they are rubbed down on ground glass with carborundum powder, or on a flat slab of carborundum. The shells are ground down from the umbones, and care must be taken to keep the longitudinal axis of the specimen vertical and the transverse section exactly horizontal. The grinding is continued until the whole of the internal structure of the shell is exposed. A more elaborate apparatus, such as that used by SOLLAS (1903) or SIMPSON (1933), may be used if serial sections are required. KOZLOWSKI (1932) described a method of preparing serial sections by embedding the specimen to be sectioned in a cylinder of cement formed within a steel ring. The cement cylinder is rubbed down to the level of the top and bottom margins of the ring to ensure that both the upper and lower surface of the cement cylinder are horizontal. The cylinder of cement is then removed from the steel ring and sectioned. A rectangular block of plaster, however, is easier to orientate than a cylinder when making drawings or photographs, and is readily prepared in a wooden or metal mould made in two sections.

Drawings of the transverse sections are made whenever there is the slightest change in the internal structure, and usually from 5—10 drawings are required to every millimetre of shell removed by grinding. The exact thickness of shell removed by each successive grinding is measured with a vernier gauge.

Owing to the heating of the shell, the test and internal plates, cardinalia, etc., are calcined and appear white in contrast to the dark matrix. The details of the internal structure can, therefore, be readily drawn or photographed without the labour of polishing the surface of the section. In sections of specimens which had not previously been calcined, it was found that much of the structure was quite indeterminable, especially in those which had a limestone matrix. In silicified specimens the skeleton is not affected by heating, but the matrix infilling the shell is frequently darkened.

The transverse sections have been drawn with the pedicle valve above and the brachial valve below. This orientation of the valves was adopted because Brachiopod shells are normally viewed from the dorsal side, with the brachial valve nearest to the observer.

The drawings are made by means of an apparatus which was constructed on the principle of that form of epidiascope invented by Mr. TAMS, of the Entomological

Department, British Museum (Natural History). An enlarged image of the sections is thrown on the paper, and is readily traced. As the sections are all drawn with the same magnification, it is possible to reconstruct the specimen either by modelling in plasticine or wax, or by preparing diagrams on squared paper.

In Rhynchonellids with much incurved umbones, the transverse sections must be ground at right angles to the hinge-plate, etc., and true horizontal sections can only be used as "identification" sections and not for reconstruction of the shell, since the umbonal incurvature will result in the reversal of the sequence of the sections.

Transverse sections show the shape and size of hinge-teeth and sockets; the shape of the umbonal cavity of the brachial valve; and of the dorsal side of the hinge-plate, etc., which cannot be obtained from the examination of separated valves of the shell. It is impossible to investigate the relationship of teeth and sockets even in perfectly-preserved detached valves, as the teeth tend to split across when the two valves are separated, and a portion of each tooth is frequently left in contact with the sockets of the brachial valve.

A certain amount of information about the length and shape of the brachial loop can also be obtained from these transverse sections. In Terebratulids and Ornithellids, however, it is often difficult to distinguish the thread-like descending branches of the loop from the matrix in the anterior transverse sections of the shell.

In order to gain some further idea of the form of the brachial loop two other specimens are selected, corresponding in external characters with the shell already sectioned. These are also heated in the Bunsen flame, and when cool hardened with amyl acetate and collodion. Longitudinal sections approximately parallel to the plane of symmetry of the shell are then prepared by grinding the half of one specimen. A few drawings are made to show the articulation of the two valves, and the relationship of loop, crura, etc., to the hinge-plate. The loop may either be reconstructed from successive longitudinal sections, or, as soon as any portion of the loop is exposed in grinding, the remainder may be completely dissected out with the aid of a needle. The latter process is found to be more profitable, since the loop is permanently retained.

The dorsal and ventral views of the loop are obtained from another specimen, which is ground longitudinally at right angles to the plane of symmetry of the shell, and the loop dissected out from the hard matrix by chisels worked by a dental engine. The loop appears as a white thread against the darker matrix, and is readily seen during dissection. In some of the specimens the loop is encrusted with calcite crystals,* which, however, can be removed by careful grinding and the perfect loop exposed. Excellent preparations were made in this way of the loop of *Digonella digona*, with its accompanying spines (fig. 12, section 20). The heating of the shell tends to loosen the calcite crystals, and the shell frequently tends to split open, exposing the loop with the crystals removed.

* The methods employed by the Rev. NORMAN GLASS (1888) and described by DAVIDSON (1881), could also be used for such specimens.

Internal casts showing the muscle-scars of the two valves are obtained by heating a fourth specimen of the same species ; or, if material is scarce, the test of a specimen can be split off and the muscle-scars exposed before the longitudinal sections are ground to show the dorsal and ventral views of the loop, as already described.

If material for investigation is not readily obtained, transverse serial sections can be cut from a single specimen, and the sections subsequently heated to bring out the structure. A permanent record of the internal structure of the specimen is thus obtained, but the relationship of the various internal plates cannot be satisfactorily shown, as it is impossible to prepare sufficiently thin sections.

In all the seven species examined, abundant duplicate material was available for investigation. By examining several examples of each species and carefully correlating the internal structure seen in the longitudinal and transverse sections and internal casts, it was ensured that a single species was described, and not two or more homœomorphous forms.

It is believed that careful examination of the interior of Brachiopod shells by the method employed by the author would not only be the means of building up a practical classification, but would also help to establish relationships, to work out lineages, and should give much needed information about the evolution of the whole group.

III. Results of Investigation.

Morphology and new Terminology for internal structures of Mesozoic Telotremata.

In describing the various structures seen in the transverse and longitudinal sections, and in the internal casts of the Mesozoic Telotremata which have been studied, it is necessary to establish a definite terminology. Reference is made to figs. 2—14, and also to the enlarged diagram, fig. 1, for explanation of the terms employed.

The following abbreviations have been used in the figures throughout the paper :—

ad = adductor muscle-scar,
al = ascending branch of loop,
b = attachment of dental lamellæ,
br = beak-ridge,
c = denticular cavity between tooth and denticulum,
ca = cardinal area,
cb = crural base,
cp = cardinal process,
cr = crura,
crp = crural process,
d = dental lamella,
dd = ventral end of dental lamella,
did = diductor muscle-scar,
dl = descending branch of loop,

dp = deltidial-plate,
f = false area,
for = foramen,
g = cavity of pedicle valve,
h = hinge-plate,
ih = inner hinge-plate,
isr = inner socket-ridge,
j = insertion of septum,
k = spine,
l = loop,
m = denticulum,
oh = outer hinge-plate,
osr = outer socket-ridge,
p = outer periphery of shell,
pb = ,, ,, ,, of brachial valve,
pv = ,, ,, ,, of pedicle valve,
q = accessory socket in outer socket-ridge,
s = median septum of brachial valve,
sp = septalium,
spl = septalial plate,
sw = shell wall,
t = hinge-tooth,
tr = transverse band of loop,
u = umbo,
uc = umbonal cavity of brachial valve,
x = socket,
xf = socket-floor,
y = ridge on septum of brachial valve,
z = pedicle-collar,
zs = septum supporting pedicle-collar.

In the enlarged transverse section of the shell of *Digonella digona* (SOWERBY) fig. 1, the *pedicle* or *ventral* valve is shown above, and the *brachial* or *dorsal* valve below. The outer surface of the pedicle valve is labelled (*pv*), and of the brachial valve (*pb*). In the pedicle valve the slender *dental lamellæ* (*d*) are in contact with the *teeth* (*t*), but have split away from the inner surface of the pedicle valve to which, however, a part of each dental lamella (*dd*) is still attached. In the more posterior sections the *cavity of the pedicle valve* (*g*) is divided into three chambers by the dental lamellæ.

The *hinge-teeth* (*t*) are inserted into the crenulated *sockets* (*x*), which are bounded and supported by the *inner socket-ridges* (*isr*) and *outer socket-ridges* (*osr*). Articulation of the shell is also effected by the tooth-like terminations of the *false area* (*f*), which are described in this paper as the *denticula* (*m*). Each *denticulum* fits into a depression or cavity in the outer socket-ridge, which has been described in this paper as the *accessory socket* (*q*). A small projection from the outer socket-ridge is inserted between the hinge-tooth and denticulum into a cavity which may be termed the *denticular cavity* (*c*).

The united *hinge-plates* (*h*) are demarcated from the inner socket-ridges by a shallow depression, and from one another by a median sulcus, or *septalium*. The floor of the septalium is formed by two plates, referred to in this paper as *septalial plates*, which fuse together to form a septum supporting the hinge-plates. The true *median septum* (*s*) is short and the apex is inserted within the septalial plates. The median septum and fused septalial plates are clearly distinguishable in specimens which have been burnt. Beneath each hinge-plate is the *umbonal cavity* (*uc*), bounded by the hinge-plate, septalial plate, shell-wall, and *socket-floor* (*xf*).

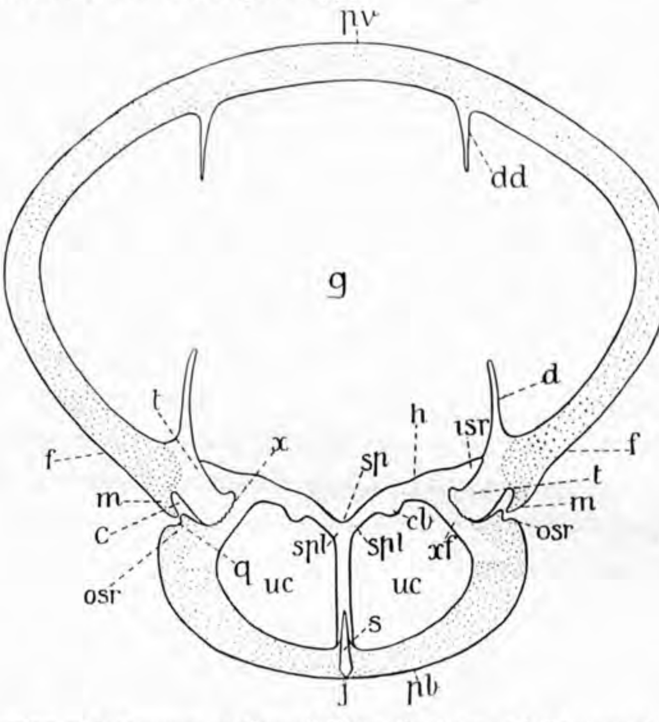

FIG. 1.—Enlarged drawing of transverse section of *Digonella digona* (J. SOWERBY) showing hinge-teeth in contact with sockets. × approximately 8. The punctate parts of the shell are dotted.
The key to the lettering will be found on p. 516.

The *crural-bases* (*cb*) are seen as rounded swellings on the dorsal side of the hinge-plate, which in more anterior sections of *Digonella digona* (fig. 11, sections 29–38) project dorsally into the umbonal cavity, and finally unite with the loop.

The shell-wall and callus thickening in specimens of *Digonella digona* are found to be punctate, but punctæ are usually absent from the teeth, hinge-plates, and median septum. Scattered punctæ are seen on the ventral portion of the dental lamellæ. The punctate portions of the shell are dotted in fig. 1, and impunctate parts are left white.

Internal Structure of the Pedicle Valve.

Dental lamellæ.—In internal casts of Rhynchonellids and Ornithellids these two plates diverge from the umbo of the pedicle valve at an angle varying slightly in different genera, but more or less constant for one species. They appear on the cast as two slits extending for a distance of 2–10 mm. In transverse sections the dental lamellæ are seen to extend across the cavity of the pedicle-valve dividing it into three chambers posteriorly, but they gradually recede from the shell-wall and remain in contact with the hinge-teeth anteriorly. The height of the dental lamellæ dorso-ventrally varies not only in specimens of one species, but the two lamellæ may vary in development in a single specimen, as shown in *Kallirhynchia yaxleyensis*, fig. 2, sections 11, 12. The dental lamellæ may be more strongly developed in the adult than in young specimens, or conversely they may become obsolete, or embedded in a thick callus deposit in the gerontic stage, as in *Ornithella bathonica*, fig. 7, and *Obovothyris magnobovata*, fig. 9. In the seven species examined dental lamellæ were developed in *Kallirhynchia yaxleyensis*, *Ornithella bathonica*, *Obovothyris magnobovata*, *Digonella digona*, and *Terebrirostra lyra*. In *Terebrirostra*, figs. 13, 14, the dental lamellæ extend the whole length of the much elongated umbo. Posteriorly, fig. 13, sections 1–4, the lamellæ extend across the cavity of the valve from the inner margin of the fused deltidial plates, but anteriorly they recurve sharply towards the thickened lateral margins of the pedicle valve, to which they are attached (fig. 13, sections 5–10, fig. 14, sections 1–5).

In the longitudinal sections ground either parallel, or at a small angle, to the plane of symmetry of the shell, the postero-anterior extension of the dental lamellæ is well shown. In *Ornithella*, fig. 8, sections 3–6, the dental lamella is seen to unite with the false area, and the actual line of fusion of the two structures is faintly seen. In *Obovothyris*, fig. 10, section 1, and *Digonella*, fig. 12, section 2, however, the dental lamella does not appear to fuse with the false area, and the two plates, although adjacent, are clearly demarcated.

Hinge-teeth.—These are rarely distinguishable in artificially prepared internal casts, but are well shown in longitudinal and transverse sections. The angle of insertion of the teeth within the sockets is usually remarkably constant for any species, although the teeth may vary in size in adult individuals of one species, according to the amount of callus thickening.

The long, slender tongue-like teeth of *Lobothyris* form a marked contrast to the massive teeth of *Plectoidothyris* with their hammer-shaped termination. The depth of insertion of the teeth posteriorly within the sockets is well shown in *Kallirhynchia*, fig. 2, sections 10, 11, and *Plectoidothyris*, fig. 4, sections 7–11, in which the posteriorly inserted portion of the tooth appears to be detached from the remainder.

Denticula.—Articulation is effected not only by the teeth and sockets, but in addition by the false areas. These usually terminate in a small tooth which is described in this paper as a denticulum. The denticula vary in size in different genera. In *Lobothyris*, fig. 5, sections 12, 13, they are long, slender, and finger-like, and fit completely into a cavity, or accessory socket, in the outer socket-ridges of the brachial valve. In *Kallirhynchia*, fig. 2, section 12, *Digonella*, fig. 11, section 23, and *Plectoidothyris*, fig. 4, section 12, the denticula are short and massive, and the rounded apex rests in a shallow depression in the outer socket-ridge. In *Terebrirostra* there is no false area and consequently no denticula are developed. The part of the outer socket-ridge forming the inner margin of the accessory socket may also interlock with the cavity between the hinge-tooth and denticulum as seen in *Lobothyris*, fig. 5, section 12. In the latter genus articulation of the two valves is therefore effected by three different structures: (1) hinge-tooth and socket; (2) denticulum and accessory socket; and (3) outer socket-ridge and denticular cavity.

Denticula are distinct from the small processes on the posterior surface of the hinge-socket in the Palæozoic Orthoidea which are described as "denticles" by SCHUCHERT and COOPER (1932). The denticles like the denticula assist in the articulation of the two valves.

Pedicle-collar.—The term pedicle-collar was proposed by JACKSON in 1916 (p. 24) for a plate on the inner side of the apex of the pedicle-valve. This structure is probably secreted by the mantle of the pedicle valve. The pedicle-collar is described as being "a kind of continuation of the deltidial plates, is free in front, and separated from the shell by a narrow cavity." This structure was observed by JACKSON in twenty-four recent Terebratulid species, but it was not found in forms having an advanced type of long loop, such as *Magellania, Terebratella, Dallina*, and *Macandrevia*. In some of these long-looped forms, however, there is a thickening in the umbo round the foramen resembling a pedicle-collar, but this is always fused to the shell, and never free anteriorly. This thickening round the foramen was described later by JACKSON (1918, p. 196) as a *pseudo-pedicle-collar*, and is the same as the *sessile pedicle-collar* of THOMSON (1927, p. 74).

A true pedicle-collar is said (JACKSON, 1916, p. 25) to occur in the fossil species *Terebratula grandis, Cyclothyris latissima*, and *Megathyris decollata* (= *detruncata*). In the last species the pedicle-collar is supported by a median septum.

The pedicle-collar was described by FISCHER and OEHLERT (1891) as "doublure sous-apicale et sous-cardinale," and before JACKSON's description of the pedicle-collar appeared in 1916, THOMSON (1915 *b*, p. 390) had observed and figured a similar structure in *Hemithyris psittacea*. In a later publication THOMSON (1927, p. 75) discussed the development of a pedicle-collar in Tertiary and Recent species and stated that "In general, species with a marginate or labiate foramen possess a well-developed pedicle-collar within the beak, forming a complete tube extending forward some little distance. . . ."

WIŚNIEWSKA (1932, p. 7) in a monograph on the Upper Jurassic Rhynchonellids of Poland stated that a pedicle-collar was developed in every species examined by her.

In the seven genera examined by me a pedicle-collar was observed in *Digonella*, *Obovothyris*, *Lobothyris*, *Plectoidothyris*, and *Kallirhynchia*, but it varies considerably in form in the different genera. In *Digonella*, fig. 11, sections 1–7, the pedicle-collar forms a complete ring, well separated from the inner wall of the pedicle valve anteriorly, and it is supported posteriorly by a short septum. This septum can be seen in internal casts of *Digonella digona*, and its postero-anterior extension is shown in the longitudinal section, fig. 12, sections 15, 16. In *Obovothyris*, fig. 9, sections 1–4, the pedicle-collar is masked by posterior deposits of callus, but the septum supporting the pedicle-collar is prominently developed. Although the transverse sections of *Ornithella* were carefully examined a pedicle-collar was only observed in one specimen, so that if normally developed in this genus it must be embedded in the thick callus deposits filling the apex of the shell. No trace of a pedicle-collar was seen in young shells of *Ornithella*, or in young or adult shells of *Terebrirostra*. In *Lobothyris* the pedicle-collar is supported by a rudimentary septum, while in *Plectoidothyris* the pedicle-collar is developed as a thickened disk on the inner side of the deltidial plates. In longitudinal sections of *Kallirhynchia*, fig. 3, sections 13–15, the pedicle-collar is seen as a thickening on the ventral side of the umbo of the pedicle valve. At a short distance from the apex of the shell the pedicle collar becomes detached from the inner wall of the pedicle valve and projects into the cavity of the pedicle-valve like a short spine.

Further research is needed before anything definite can be said about the importance for generic diagnoses of the development or non-development of the pedicle-collar, and of its supporting septum.

Deltidial Plates.—In six of the seven genera examined the deltidial plates are conjunct, and no line of junction of the two plates is distinguishable in the transverse sections. In some genera belonging to the Zeilleriinæ the two deltidial plates may become conjunct, and further growth result, either in the overlapping of the two plates, or, in their being spirally coiled on the inner dorsal surface of the pedicle valve. In *Kallirhynchia*, fig. 2, sections 5–7, the deltidial plates are disjunct.

In the longitudinal sections the deltidial plate may appear as a narrow curved plate in contact with the outer edge of the false area, or as a small semicircular plate anterior to the pedicle opening or foramen.

In *Terebrirostra* the conjunct deltidial plates or symphytium extend the whole length of the elongated umbo.

Cardinal Area or Interarea.—In the seven genera specially investigated a true cardinal area is only developed in the genus *Terebrirostra*. In longitudinal sections of *T. incurvirostrum*, fig. 14, sections 5–8, the cardinal area is seen to be fused with the dorsal end of one of the curved dental lamellæ. The outer surface lacks the prominent costation of the remainder of the shell, but is marked by numerous growth-lines which cross the two inter-areas at an angle of about 45°.

Muscle-scars.—To the pedicle valve of the Telotremata are attached three sets of muscles—the adductors for closing the shell, the diductors for opening the shell, and the pedicle muscles which serve to retract the pedicle, and also attach the pedicle to the posterior part of the valve. The three sets of muscles leave scars which mark the region of their attachment to the shell, and these scars appear as more or less prominent ridges on the internal cast of the shell. The adductors have a double attachment to the pedicle valve and the scars of their attachment are usually enclosed by those of the diductor muscles. The pedicle muscles consist as a rule of two pairs of muscles known as the dorsal and ventral adjustors, and a single muscle which leaves a scar posterior to those of the adductors and diductors. The dorsal adjustors are usually attached to the hinge-plate of the brachial valve, and the two ventral adjustors leave a scar on the outer side of each of the diductor muscle-scars of the pedicle valve. In most of the genera examined the outline of the whole muscle-area was distinguishable, but the outlines of the individual muscle-scars were obscure. Better results, however, were obtained with the Ornithellids and Rhynchonellids than with the Terebratulids.

Buckman (1917) gave no description of the muscle-scars of the pedicle valve in any of his Terebratulid genera owing to the difficulty of preparing internal casts of this valve.

In *Lobothyris* the muscle-area is elongated and narrow, and extends from the umbo as a prominent ridge, about 12 mm. long, and 3 mm. wide at the anterior end. In *Plectoidothyris* the muscle-area is obscure and does not form a prominent ridge. The posterior end of the diductor and adductor scars are situated about 8 mm. anterior to the umbo, and the scars form an oval area about 11 mm. in width and 10 mm. in length.

After removing a thick deposit of callus, the muscle-scars were satisfactorily exposed in *Ornithella*, fig. 23, Plate 62. The diductor scars are elongated and narrow, and enclose two small oval adductor scars. The anterior adjustors are seen as small oval scars outside the posterior end of the diductors. In *Obovothyris*, *Digonella*, and *Terebrirostra*, the shell flakes off very readily when the specimens are heated, but the muscle-scars are usually obscure. An attempt has been made to figure the ventral muscle-scars of *Obovothyris* and *Digonella*, figs. 18*b*, 27, Plate 62, but the outline of the adductor and diductor scars is difficult to distinguish. The muscle-scars in these two genera are posteriorly situated. In *Kallirhynchia yaxleyensis* the muscle-area lies below the anterior end of the dental lamellæ and extends for about half the length of the pedicle valve. The two adductor scars are in contact along their inner margins, and together form an elongated oval area which is in contact on its lateral and anterior margins with the broad crescentic diductors. The adjustors leave a narrow linear scar on the outer margin of the diductors, fig. 16, Plate 62.

Vascular markings.—These are referred to in a paragraph describing this structure in the brachial valve (p. 530).

Internal Structure of the Brachial Valve.

Hinge-sockets and Socket-ridges.—The depth and width of the hinge-socket and the amount of overlap of the socket by the inner and outer socket-ridges are characters which vary considerably in the seven genera investigated. In the Terebratulid genera *Lobothyris* and *Plectoidothyris* the sockets do not appear to be crenulated. In *Lobothyris* the sockets are narrow and deeply excavated for the reception of the elongated linguiform teeth, and the elaborate processes for the articulation of the two valves (described on p. 520) probably render unnecessary any crenulation of teeth and sockets. In *Plectoidothyris* the sockets are broad and shallow, and the socket floor tends to split away from the outer socket-ridge while the anterior portion of each tooth is still in contact with the socket and inner socket-ridge, fig. 4, sections 13–15.

The crenulæ of the teeth and sockets in the genera *Ornithella, Obovothyris*, and *Digonella*, fig. 1, are so minute that they are only perceptible with a high-powered lens. In these three genera the outer socket-ridge does not play an important part in the articulation of the two valves, but the inner socket-ridge overlaps the socket and interlocks with a sulcus on the ventral side of a lip-like projection of each tooth. In *Kallirhynchia*, on the contrary, the crenulæ are clearly seen with a magnification of five diameters, and they interlock with corresponding crenulæ on the teeth.

The sockets in *Terebrirostra* are shallow and coarsely crenulated, and are only slightly overlapped by the outer socket-ridges which fit into a depression in the dorsal margin of the teeth. The inner socket-ridges, however, project for a short distance across the socket and interlock with a sulcus on the ventral surface of each tooth.

Additional information about the sockets, and inner and outer socket-ridges, can be obtained from the longitudinal sections ground approximately parallel to the plane of symmetry of the shell. In the sections farthest from the median line the outer socket-ridge is first seen as a slight thickening of the umbonal portion of the shell of the brachial valve. This thickening is increased to form a rounded lobe with a shallow depression on its anterior ventral margin. The depression deepens and forms the hinge-socket which is bounded posteriorly and anteriorly by a rounded lobe. The anterior lobe is the inner socket-ridge and the posterior the outer socket-ridge. In longitudinal sections near a median line through the shell the inner socket-ridge is seen to be deflected posteriorly and so to enclose the tooth within the socket. In longitudinal sections of some genera, such as *Obovothyris*, fig. 10, section 8, the inner socket-ridge is seen to persist as a posteriorly directed lip, when teeth and sockets can no longer be observed.

Cardinal Process.—This structure, which serves for the attachment of the diductor muscles in the brachial valve, is developed in the genera *Lobothyris, Plectoidothyris*, and *Terebrirostra*. In *Lobothyris* the cardinal process is developed as a small laterally elongated boss which is sessile on the inner wall of the brachial valve. It is never prominent and is only about 0·6 mm. long postero-anteriorly. The ventral surface is concave posteriorly, but slightly trilobate anteriorly. In *Plectoidothyris* the cardinal process is considerably larger and more prominent than in *Lobothyris*, and projects ventrally beyond the hinge-plates into the cavity of the pedicle valve. It is separated from the shell wall by a deep umbonal cavity. Posteriorly the ventral surface is medianly depressed and the depression is bounded on each side by a projecting lobe.

Anteriorly, however, the outer lobes broaden and the median depression becomes correspondingly narrower and finally a low median ridge is developed and the cardinal process becomes slightly trilobed. In *Terebrirostra* the cardinal process is even more prominently developed than in *Plectoidothyris* and curves upwards away from the hinge, and projects ventrally into the cavity of the pedicle valve, appearing in transverse sections as a trilobed hollow boss with a short stalk which is entirely detached from the brachial valve. In *T. lyra* the trilobation and posterior denticulation of the cardinal process are well developed, fig. 3, sections 4–9, but in the geologically older species, *T. incurvirostrum* the cardinal process is simpler, the denticulation is not apparent, and the trilobation is less marked. No cardinal process is developed in the Ornithellid genera, *Ornithella, Obovothyris, Digonella,* or in the Rhynchonellid genus, *Kallirhynchia.*

Hinge-plates.—These plates serve for the attachment of the dorsal adjustor-muscles of the pedicle, and also for the diductor muscles in genera in which no cardinal process is developed. In the seven genera specially investigated the hinge-plate is not divided by the crural base into an inner and outer hinge-plate. Inner and outer hinge-plates are developed in the Tertiary Terebratulid shells in which the crural bases are given off ventrally and intersect the hinge-plate. The hinge-plates are among the most important structures in the brachial valve, as they are more constant in development and exhibit less variation in subsequent growth-stages than other internal characters. The difference between the hinge-plates of the various genera is best studied in the transverse sections. In *Kallirhynchia* the hinge-plates are thin, dorsally concave plates extending more or less horizontally and separated from one another by a narrow cavity. They are well demarcated from the inner socket-ridges by a shallow sulcus. In the more anterior transverse sections of *K. yaxleyensis*, fig. 2, sections 18, 19, the crural bases are seen as small angular projections from the dorsal surface of the hinge-plates. In *Lobothyris* and *Plectoidothyris* the hinge-plates are ventrally concave, and the inner extremities of each plate which are sharply deflected ventrally are extended anteriorly to form the crural bases. In *Lobothyris* the hinge-plates are not sharply demarcated from the inner socket-ridges, and posteriorly are sessile on the inner wall of the valve. Anteriorly, however, a narrow elongated umbonal cavity is developed beneath each hinge-plate, fig. 5, sections 12–20. A deep umbonal cavity separates the hinge-plates from the floor of the brachial valve in *Plectoidothyris*, and the inner socket-ridges and hinge-plates are well differentiated. The hinge-plates become free and detached from the cardinal process about 6 mm. below the apex of the valve.

A somewhat unusual type of hinge-plate is seen in *Terebrirostra*, in that each plate extends dorso-ventrally, fig. 13, section 11, and projects for a considerable distance into the cavity of the pedicle valve. The hinge-plates are separated by a narrow, deep septalium and are differentiated from the inner socket-ridges by a sulcus. In this genus the hinge-plates are united and supported by a median septum.

The hinge-plates of *Ornithella, Obovothyris,* and *Digonella* resemble one another in extending medio-laterally, but a careful examination of these plates in the three genera reveals various minor differences. No cardinal process is developed and the hinge-plates are united throughout, and supported by a median septum. In *Ornithella* the hinge-plates are approximate posteriorly and are separated by a deep V-shaped septalium. They tend to flatten and increase in width medio-laterally away from the umbones. The septalium becomes shallower, until it is scarcely distinguishable, and it is finally replaced by a rounded median ridge. The hinge-plates are separated from the inner socket-ridges by a shallow depression. In adult specimens of *O. bathonica* and other species of *Ornithella* the posterior part of the shell is much infilled by callus, and these deposits tend to mask the outline of the hinge-plates, fig. 7, sections 8–16. In transverse sections of burnt specimens, however, the outline of hinge-plates, teeth, and sockets, etc., can be readily distinguished from the secondary thickening. The septum supporting the hinge-plates and umbonal cavity is scarcely distinguishable in the adult shell owing to the callus infilling. The crural bases are seen as rounded swellings on the ventral side of the hinge-plates.

In *Obovothyris* the septalium is shallow even near the umbo of the brachial valve, and anteriorly is scarcely distinguishable. The ventral side of the hinge-plates is convex posteriorly, but tends to flatten out horizontally away from the umbo. The inner socket-ridges are not clearly differentiated from the hinge-plates. In adult shells of this genus the umbonal cavity is only infilled with callus for a distance of about 0·5 mm. from the umbo, and the septum supporting the hinge-plates is clearly defined. The crural bases are given off from the dorsal side of the hinge-plates.

The hinge-plate of *Digonella* shows a certain resemblance to that of *Obovothyris* in the early growth-stages, but in the adult is sufficiently distinct to warrant the description of the two species *D. digona* and *D. digonoides* as belonging, either to a distinct genus, or to a subgenus of *Obovothyris*. Posteriorly the hinge-plates are narrow and approximate, and are separated by a deep septalium, as in *Ornithella*. Anteriorly they increase in width medio-laterally and flatten, but the septalium is always distinguishable. The inner socket-ridges are deflected ventrally at a slight angle to the hinge-plates, and the crural bases are first seen as swellings on both the dorsal and ventral sides of the hinge-plate, fig. 11, section 16. The swellings on the ventral surface become less apparent, while the dorsal swellings increase in size anteriorly and form angular points which project into the umbonal cavity.

Crura and Brachial Loop.—The crural bases seen in transverse sections through the shell have already been described in the section entitled "Hinge-plates." Additional information about the relationship of these structures to the hinge-plate and inner socket-ridges can be obtained from the longitudinal sections parallel to the plane of symmetry of the shell.

In *Kallirhynchia* the crural bases which are given off from the dorsal side of the hinge-plate project ventrally and unite with the crura. The crura consist of two flattened, curved, posteriorly concave laminæ which project from the hinge-plate into the cavity of the pedicle valve. Each primary lamina unites at the ventral end with a second curved lamina, which is suspended from it and projects dorsally like a spur. A ventral extension of this second lamina beyond the point of attachment with the primary lamina terminates in a hook-shaped process, the apex of which is directed posteriorly, fig. 3, section 15. In immature specimens the crura appear to be longer than in senile individuals, and to extend almost across the entire cavity of the pedicle valve. The primary and second lamellæ are not clearly differentiated. The spur-like extension of the second lamella is anterior to, but almost in contact with, the primary lamella. The ventral extension of the second lamella is thread-like and curves round so that the apices of the two crura are practically in contact. The hook-shaped process, which terminates the crura in the gerontic form, is considerably less developed in immature specimens. This type of crura, which has not been previously described, may be known as calcarifer. Little is known at present of the interior of Jurassic Rhynchonellids, so no comparison can be made with other genera until further work on similar lines has been undertaken. From the differences of the shape of the hinge-plates of such genera as *Rhactorhynchia*, *Burmirhynchia*, and *Kutchirhynchia* when compared with those of *Kallirhynchia* it is reasonable to suppose that the crura of these genera will also differ in outline.

Owing to the poor state of preservation of the interior of the shell of *Terebrirostra lyra* it was only possible to make out details of the loop in one of the specimens examined. The crural bases are given off ventrally, and are a direct anterior continuation of the hinge-plates. The slender crural processes in *Terebrirostra incurvirostrum* are about 3·5 mm. in length in the adult, and curve anteriorly away from the crural bases. The loop in adult specimens of *T. incurvirostrum* extends as a narrow ribbon scarcely visible to the naked eye, parallel to, and about 4 mm. from, the outer surface of the brachial valve. The two descending branches of the loop are about 4 mm. apart. About 4 mm. from the anterior margin the loop recurves, and the ascending branch of the loop is directed posteriorly, almost in the same dorso-ventral plane as the descending branch, and at a distance of about 2 mm. from it. From the dorsal or ventral view only one branch of the loop is distinguishable anteriorly. About 11 mm. from the anterior margin the ascending branch of the loop is directed inwards, and bends round towards the pedicle valve and finally unites with the curved transverse band about 15 mm. from the anterior margin. A few small spines were seen projecting from the loop of one specimen. In the adult specimen illustrated in fig. 14, section 10, the brachial valve is 23·5 mm. long and the loop is entirely free from the septum. In an immature specimen [B. 84534] with a brachial valve 19·5 mm. long the loop is attached by slender connecting bands to a ridge on the septum about 0·5 mm. from the anterior end of the septum. In this specimen the connecting bands are 1·4 mm. long and project horizontally from the septum, and are then deflected at right angles and join the descending lamellæ. In the longitudinal section of a still younger specimen [B. 84535] having a brachial valve 14 mm. long the connecting bands are about 1·5 mm. long and extend almost horizontally from loop to septum. The deflection of the band in the slightly older specimen probably indicates that the connecting band is about to be detached from the descending lamellæ by resorption. This resorption of the connecting bands was seen in a transverse section of a brachial valve 20 mm. long, in which one connecting band is still attached to the septum but has split away from the descending lamella, while the other band has become detached from the septum but is still united with the loop.

The loop of *Ornithella* is given off from the ventral side of the hinge-plate. The descending branches curve forward following the contour of the lateral margin of the shell, and are about 10 mm. apart. The ribbon is narrow and flattened dorso-ventrally, and is broadest in lateral view. Small spines spring from one edge of the ribbon, but are rarely preserved. The anterior part of the descending branches is directed towards the ventral valve and the loop recurves upwards about 4 mm. from the anterior margin. The ascending branches are short and curve at first dorsally, then recurve ventrally and unite with the broad horizontal transverse band about 15 mm. from the anterior margin. The ascending branches and the transverse band form a pentagonal figure. The crural processes are small and project forward into the cavity of the pedicle valve, converging slightly towards the median septum. No spines were observed on the ascending branches of the loop of *Ornithella*, or of any the genera specially investigated.

In *Obovothyris* the loop is rather similar in shape to that of *Ornithella*, but the spines on the descending branches are longer and usually well preserved. In both *Obovothyris* and *Digonella* spines are developed on the outer margin of the descending branches and are even seen on that portion which unites with the crural bases (fig. 9, section 26, and fig. 11, sections 37, 38). In *Obovothyris* the crural processes are short and converge towards one another. The slightly curved descending branches of the loop are about 10 mm. apart, and usually extend to within 3 or 4 mm. of the anterior margin, but in some specimens they are almost in contact with the margin. The anterior portion of the ascending branches is practically in the same dorso-ventral plane as the descending branches, but they are deflected ventrally and unite with the transverse band about 10 mm. from the anterior margin. The transverse band is horizontal in adult specimens, and ascending branches and transverse band form a broad pentagonal figure.

In *Digonella* the descending branches diverge at a low angle from the hinge-plate, but do not converge anteriorly. Spines are usually preserved on the descending branches and in one specimen, fig. 12, section 20, they are fine and hairlike, about 1·5 mm. in length, and eight spines occupy a vertical distance of 5 mm. The descending branch of the loop in this specimen is flattened dorso-ventrally, and the spines project dorsally, curving round from under the loop anteriorly where the ribbon twists. The loop in *Digonella digona* extends almost to the anterior margin of the shell. The ascending branches either may be abruptly recurved upwards in the same dorso-ventral plane as the descending branches, or they may project laterally beyond the descending branches. They unite with the slightly curving transverse band about 8 mm. from the anterior margin. The transverse band is bounded at each end by a small flange which projects posteriorly. The ascending branches and transverse band form a rounded arch, which is never pentagonal in outline. The crural processes are large and project well forward into the cavity of the valve.

In *Obovothyris* and *Digonella* the loop is given off from the dorsal side of the hinge-plate, and in neither of these genera, or in *Ornithella*, is the loop attached to the median septum in the adult.

In a specimen of *Digonella digona* having a brachial valve 10 mm. long the loop resembled that of the adult shell, and was not attached to the septum. Examination of a smaller specimen with a brachial valve 5·5 mm. long showed that the loop resembled that of the adult, but the descending lamella was much thickened for about 2 mm. below the dorsal umbo. A narrow connecting band was seen attached to the descending lamella about 2·5 mm. below the umbo, but it did not extend across to the median septum. In still younger forms the loop was no doubt attached to the septum by narrow connecting bands. A similar terebratellid stage has not yet been observed in young specimens of *Ornithella* and *Obovothyris*.

In *Lobothyris* and *Plectoidothyris* the crural bases are given off ventrally, and project almost at right angles to the more or less horizontal hinge-plates. In both these genera the descending branch of the loop is a broad ribbon, flattened dorso-ventrally, and in dorsal or ventral view the edge of the ribbon appears as a thin thread. In *Lobothyris punctata* the loop is usually about 8·5 mm. long, while in *Plectoidothyris polyplecta* it is about 18·5 mm. long. The descending branches in both these genera are abruptly deflected upward to form the ascending branches. In *Plectoidothyris* the ascending lamellæ slope gently towards the ventral valve and unite with the transverse band about 5 mm. from the anterior end of the loop. The transverse band is rather narrow and slightly curved, and is demarcated from the ascending lamellæ by a bend in the loop. The crural processes are given off about 7 mm. below the umbo.

In *Lobothyris* the ascending lamellæ unite with the curved transverse band about 2·5 mm. above the anterior end of the loop.

In the longitudinal section of *L. punctata*, fig. 6, section 12, the broad ribbon of the descending lamellæ obscures the ascending lamellæ and transverse band. The crural processes project ventrally in the same plane as the descending lamellæ, of which they appear to be triangular extensions.

Median septum, Septalium, and Septalial Plates.—The V-shaped cavity between the united hinge-plates of many Rhynchonellid and Zeilleriid species was described by LEIDHOLD (1920, p. 354) as the septalium. Before the publication of this work, however, WELLER (1910, p. 502) had described this cavity in Palæozoic Rhynchonellid species as the crural cavity. As the term crural cavity is thought to be misleading, since the cavity is not connected with the crura, LEIDHOLD's term, septalium, has been adopted. The floor of the septalium is formed by two plates, the septalial plates, which converge and fuse together to form a septum. This septum supports the hinge-plates, and appears to be distinct from the true median septum in many species. In the transverse section of *Digonella*, fig. 1, it was found that the dorsal end of the so-called median septum tended to split along the centre, as though composed of two separate plates, and also to become detached from a short septum, the dorsal end of which is inserted in the wall of the brachial valve. This short septum is the true median septum. The actual splitting away of the septalial plates from the median septum is shown in *Digonella digona*, fig. 11, sections 30–34, in *Terebrirostra lyra*, fig. 13, section 21, and in *Kallirhynchia yaxleyensis*, fig. 2, sections 7, 8.

It has been found that the calcining of the shell tends to separate the true median septum fairly readily from the septalial plates. The division of the septum into the true median septum and septalial plates can be seen equally well in transparent transverse sections of the brachial valve, as was shown by WIŚNIEWSKA in 1932 (p. 6, fig. 1, A–C) in the Rhynchonellid species, *Rhynchonella loxia* (FISHER DE W.), *Septaliphoria pinguis* (ROEMER), and *S. astieriana* (D'ORBIGNY). In the transparent sections of these species the true median septum appears as a short rudimentary structure, at the base of, and enclosed by, a second septum which unites with the hinge-plates.

In transverse sections of Rhynchonellid species which have a much incurved umbo in the brachial valve the septalium appears to be reversed, and the two septalial plates, which are only fused together and in contact with the median septum in the posterior part of the shell, project freely as two diverging plates into the umbonal cavity, fig. 2, sections 8–10.

The true median septum in *Kallirhynchia* only extends across the umbonal cavity for a distance of about 0·5 mm. from the umbo of the valve, anterior to this it is of such a low elevation as to be almost indistinguishable in the transverse sections of *K. yaxleyensis*.

No septalium is developed in Terebratulid species in which a cardinal process is developed, since the hinge-plates are not united. A rudimental septum is observed in the anterior transverse sections of *Lobothyris punctata*, but this septum is probably formed as a thickening along the inner margin of the adductor muscle-scars. FREDERICKS (1918, 1927, p. 2) suggests the term "euseptoidum," for a similar development in the pedicle valve of *Spirifer*, *Schizophoria*, etc. In *Terebrirostra*, however, in which the hinge-plates remain united at the base of the cardinal process, a deep septalium is seen. The septum in *Terebrirostra* bears a low rounded ridge, in fig. 14, section 10, *y*, springing from the dorsal edge near the umbo and extending across the septum to its anterior margin. The slender connecting bands joining loop and septum in immature forms unite with this ridge about 1·5 mm. above the anterior termination of the septum. A septalium, varying in depth in different species, is developed in many genera of the Zeilleriinæ as the hinge-plates are united.

Vascular sinuses.—These are extensions of the cœlome, or visceral cavity, into the dorsal and ventral mantle-lobes which line the shell, and they contain the circulatory fluid or blood. The shell secreted by the mantle is usually thinner along the vascular sinuses so that their position can often be traced as furrows on the interior of fossil shells, or as ridges on internal casts. The vascular sinuses consist usually of two or more main trunks which branch more or less frequently towards the shell margin. The disposition of the sinuses varies in different genera, and may differ also in the two valves of a single species. The arrangement of the sinuses appears to be sufficiently constant for this character to be considered in the description of Brachiopod genera and families. A special study has been made of the vascular sinuses in the genus *Zeilleria*, in connection with a piece of research on the Jurassic Zeilleriids. The disposition of the four main trunks and the number of bifurcations of the trunks was found to be similar in different species, but the angle of divergence of the inner trunks from the end of the septum, and of the divergence of the two secondary sinuses formed by bifurcation of the two outer main trunks, varied in shells of different width and convexity. In the pedicle valve there are also four main trunks, the outer two of which bifurcate once.

In most of the artificially prepared casts of Terebratulids no trace of vascular sinuses can be seen, owing, no doubt, to the difficulty of separating the shell from the internal cast, since on naturally formed internal casts the vascular markings are usually preserved. Better results are obtained with artificially prepared casts of the Zeilleriids, but in Rhynchonellids the position of the sinuses is often masked by the longitudinal costation.

In the internal casts of the brachial valve of *Kallirhynchia yaxleyensis* traces of branching canals can be seen on some of the costæ anterior to the muscle-scars, but in no specimen of *Kallirhynchia*, so far examined, are the vascular sinuses perfectly preserved. In most Rhynchonellid genera there are two main trunks given off from the anterior end of the median septum, and curving outwards and backwards round the outer margin of the adductor muscle-scars. Numerous secondary sinuses which frequently bifurcate are given off anteriorly and laterally from the main trunks.

No traces of vascular sinuses are seen on the artificially prepared internal casts of *Lobothyris* and *Plectoidothyris*. In a specimen of *Lobothyris punctata* from the French Middle Lias which has the two valves separated, the vascular sinuses are seen as two main trunks in the brachial and pedicle valves. In the brachial valve the two main trunks are given off from between the anterior ends of the adductor muscle-scars. They diverge slightly and each sinus bifurcates a short distance below its point of origin, and each of these secondary sinuses also bifurcates anteriorly, but the four resultant sinuses remain in close proximity to one another near the anterior margin. In the pedicle valve the two main trunks are given off along the lateral margin of the diductor muscle-scars and each splits into two at the anterior end of the scar. Each lesser sinus bifurcates anteriorly as in the brachial valve.

In *Terebrirostra* the vascular markings are usually obscure. In the brachial valve one sinus follows the outer margin of each of the posterior adductor muscle-scars. Two other sinuses appear to extend vertically across the adductor muscle-scars, and to converge towards the median septum, and then to extend, parallel to, and at a short distance from, it. In the pedicle valve also, there appear to be four main trunks, two extending from the anterior end of the dental lamellæ, and one extending along each outer margin of the muscle area. All four trunks bifurcate frequently.

In adult shells of *Ornithella* it is seldom possible to prepare internal casts to show all the vascular markings, owing to the difficulty of removing the thick deposits of callus. Four main trunks can be distinguished in each valve. In the brachial valve the two outer trunks follows the outer margin of the adductor muscle-scars and diverge outwards from their anterior lateral margin, and then bifurcate. The two inner main trunks are given off from the anterior end of the median septum, and diverge slightly towards the anterior margin. In the pedicle valve the two outer main trunks are given off just above the anterior end of the dental lamellæ, and the two inner main trunks from the umbo ; the latter extend along the inner margin of the diductor muscle-scars. The outer main trunks bifurcate shortly below their point of origin, the branch curving outwards and extending parallel to the lateral margin of the shell.

In the brachial valve of *Digonella digona* the two outer main trunks are given off from the posterior end of the adductor muscle-scars, and extend along the outer margin of the anterior adductor scar, as in *Ornithella*. The two inner trunks extend across the adductor muscle-scars, and extend vertically downwards towards the anterior margin. No bifurcations were observed. In the pedicle valve the two outer main trunks extend along the outer margin of the dental lamellæ, and the two inner main trunks extend from the anterior end of the diductor scars, but no bifurcations were observed.

In *Obovothyris* the vascular markings are usually obscure but there are apparently four main trunks in each valve. In the brachial valve two inner main trunks are given off from the anterior end of the median septum. The two outer main trunks extend, as in *Digonella*, but converge inwards at the anterior end of the muscle area and bifurcate, the bifurcations curving inwards towards the inner main trunks. In the pedicle valve the four main trunks are similarly placed to those of *Digonella*, but no bifurcations were observed.

Muscle-scars.—In the brachial valve each of the two adductor muscles is split into two parts, and consequently leaves two scars of attachment, which are known as the posterior and anterior adductor muscle-scars. The relative position and shape of these two scars varies in different genera. The diductor muscles are attached to the cardinal process, or to the hinge-plates in genera in which no cardinal process is developed. The dorsal adjustors of the pedicle are also attached to the hinge-plate.

In Rhynchonellids and Zeilleriids the posterior and anterior adductor-scars are usually well demarcated, but in Terebratulids the two parts of the scar are not as a rule distinguishable in internal casts. In *Kallirhynchia* the subtrigonal anterior adductor scars are almost in contact with the median septum along their inner margin and with the posterior adductors along part of their outer margin. The posterior adductors project posteriorly beyond the anterior scars, but are less extended anteriorly. They are linear in outline, increasing slightly in width anteriorly.

The adductor muscle-area in *Lobothyris punctata* is narrow and spatulate in outline, tapering rapidly posteriorly, and usually about 2 mm. in width anteriorly. The muscle-scars rarely exceed 8 mm. in length, and usually diverge from the umbo at an angle of about 40°. In *Plectoidothyris polyplecta* the adductor muscle-scars are strap-shaped and do not narrow rapidly towards the umbo. They are usually about 14 mm. in length and 2·5 mm. in width, and diverge from the umbo at an angle of about 20°. In *Terebrirostra* the adductor muscle-area is trigonal in outline and tapers posteriorly to an acute extremity. The longer side is almost in contact with the median septum. The posterior and anterior lateral margins are sub-rounded. The division between the posterior and anterior scars is obscure, but the anterior adductors appear to be narrow and linear in outline. In *Ornithella*, *Digonella*, and *Obovothyris* the adductor muscle-scars are somewhat similar in outline. In *Digonella* and *Obovothyris* the outer margin of the scars is marked by a vascular sinus which extends nearly vertically. In *Digonella* the outer or posterior adductor scars are elongate-oval in outline and project posteriorly for a short distance beyond the anterior scars, with which they are in close contact along their inner margin. The anterior adductors are subtrigonal in outline and increase slightly in width anteriorly, while their inner margin remains in contact with the median septum. In *Obovothyris* the anterior adductors are broader than in *Digonella*, and the posterior and anterior adductors are about the same length. In both these genera the longitudinal axis of both adductor-scars are approximately vertical. In *Ornithella* the anterior adductors are elliptical in outline, and the posterior adductors are crescentic. The longitudinal axis of both the scars is inclined at an angle of about 20° to the median septum.

Punctation of shell.—No study has been made of the shell structure, although it was observed that in the transverse sections of *Digonella*, *Obovothyris*, and *Ornithella* the number of punctæ varied in different parts of the section, and that no punctæ were developed on the teeth, hinge-plates, and septum, although sparingly developed on the dental lamellæ. This character has been investigated by CARPENTER (1845, 1848), PERCIVAL (1916), LEIDHOLD (1922, 1925), THOMSON (1927), KING (1869), and other authors who have shown that the number and size of the punctæ do vary in different species. This character might be of use in distinguishing species, provided a similar area of shell surface were studied for each species, since the density of the punctæ is known to vary in different parts of the same shell.

Calcareous spicules.—The development of minute calcareous spicules in the mantle and brachia of some Recent Brachiopods has been studied by HANCOCK (1859), VAN BEMMELEN (1883), DESLONGCHAMPS (1860, 1865), THOMSON (1927), JACKSON (1912), BLOCHMANN (1906, 1908), and others. THOMSON (1927) states that spicules are developed in the Recent Protremata, and among the Telotremata in the Terebratulidæ and some

Terebratellidæ. The presence or absence of these spicules and their arrangement is of considerable help in establishing the relationship of recent species and genera. The spicules are formed of crystals of calcite which vary in shape and size in different species, and are often branched or fused together to form a network. They apparently formed an additional internal skeleton for reinforcing the soft parts, and are especially found along the walls of the vascular sinuses.

These spicules may be preserved in the interior of fossil Brachiopod shells as gray powdery matter, and they have already been studied in the Thecidiidæ. DESLONGCHAMPS (1865, p. 21) records their occurrence in a Liassic species *Kingena* [*Pseudokingena*] *deslongchampsi*, in which the spicules were evidently very numerous in the mantle.

Traces of small spicules were observed by the author when dissecting out the loops of the Terebratulid species under the microscope, but their significance was not realized at that time. A careful examination may reveal the presence of these spicules in fossil as well as in recent species.

External Morphology.

No new terms have been used in the description of the external shell characters in Part IV, and the terms employed have been defined by BUCKMAN (1917, 1919) and THOMSON (1915a, 1927).

As BUCKMAN has made a thorough study of the external morphology of Jurassic species it is not proposed to duplicate his work in giving detailed descriptions of the exterior of the shell in the seven species specially examined.

Homœomorphy.

Forms which are superficially similar but which differ structurally were described by BUCKMAN (1901) as homœomorphs. These were said to be either isochronous, which occur in deposits of approximately the same age, or heterochronous, which occur in beds of different ages.

The question of homœomorphy has been touched on in the "Introduction" and further reference is made to the subject in the "Systematic Descriptions" (p. 541).

As examples of isochronous homœomorphs may be mentioned the Middle Liassic species, *Lobothyris punctata* which is similar in external form to two undescribed species, belonging to different genera. These three forms are only distinguishable externally by the different folding of the shell and by slight differences in beak characters, but are readily distinguished by their internal structure. Other examples of isochronous homœomorphs are provided by *Ornithella bathonica* and "*Ornithella*" *cadomensis* from the Fullers Earth Rock; and *Obovothyris* sp., and *Microthyridina lagenalis* from the Upper Cornbrash.

Excellent examples of heterochronous homœomorphs are provided by "*Terebrirostra*" [*Terebratulina*] *neocomiensis* and species of *Terebrirostra* from the Albian and Cenomanian.

Lobothyris punctata and *Plectoidothyris polyplecta* are distinct from one another in external characters, but have rather similar dorsal adductor-scars and brachial loops and are to a certain extent internal homœomorphs. Further investigation of internal characters, however, has shown these two species to be totally unrelated.

Such a list can be added to indefinitely and will serve to show the importance of a careful examination of internal as well as external characters.

IV. Systematic Descriptions.

Emended diagnoses of the genera Kallirhynchia, Lobothyris, Plectoidothyris, Ornithella, Obovothyris, *and* Terebrirostra, *and description of a new genus* Digonella.

As a result of my researches on the genotypes of *Kallirhynchia, Lobothyris, Plectoidothyris, Terebrirostra, Digonella, Obovothyris,* and *Ornithella,* much additional information about the internal structure of the two valves has been obtained, and described in Part III. Several internal structures, which have not previously been investigated, have been found to be of diagnostic importance, and are therefore included in the generic diagnoses. In consequence of this, it is necessary to redefine Buckman's genera, *Kallirhynchia, Lobothyris, Plectoidothyris, Obovothyris,* on the internal and external characters of the genotype collectively, and to assign to these genera only those species which are similar in structure to the genotype, and are obviously related forms.

The internal structure of the Cretaceous genus *Terebrirostra* is more fully described and one new genus, *Digonella* from the Bathonian is defined.

As no specimens of the genotype of *Ornithella* were available, examination has been made of the common Fullers Earth Rock species, *O. bathonica,* which is closely related to the type both in external form and in internal structure.

No attempt is made to assign these genera to sub-families on account of the confusion prevailing in existing classifications.

Family Rhynchonellidæ, Gray.

Genus *Kallirhynchia*, Buckman.*

Emended H. M. Muir-Wood.

Figs. 15–17, Plate 62 ; fig. 32, Plate 63 ; and figs. 2, 3.

Kallirhynchia, Buckman (1914), p. 1.
Kallirhynchia, Buckman (1915), p. 76.
Kallirhynchia, Buckman (1917), p. 31.

Emended diagnosis.—Shell posteriorly norelliform, anteriorly everted, pedicle valve with well-defined sinus, linguiform extension of pedicle valve with approximately

* Unless otherwise stated the reference is to S. S. Buckman.

rectangular termination, brachial valve with flattened median fold. Hypothyrid, beak suberect, foramen elliptical to circular, deltidial plates disjunct to just conjunct. Shell

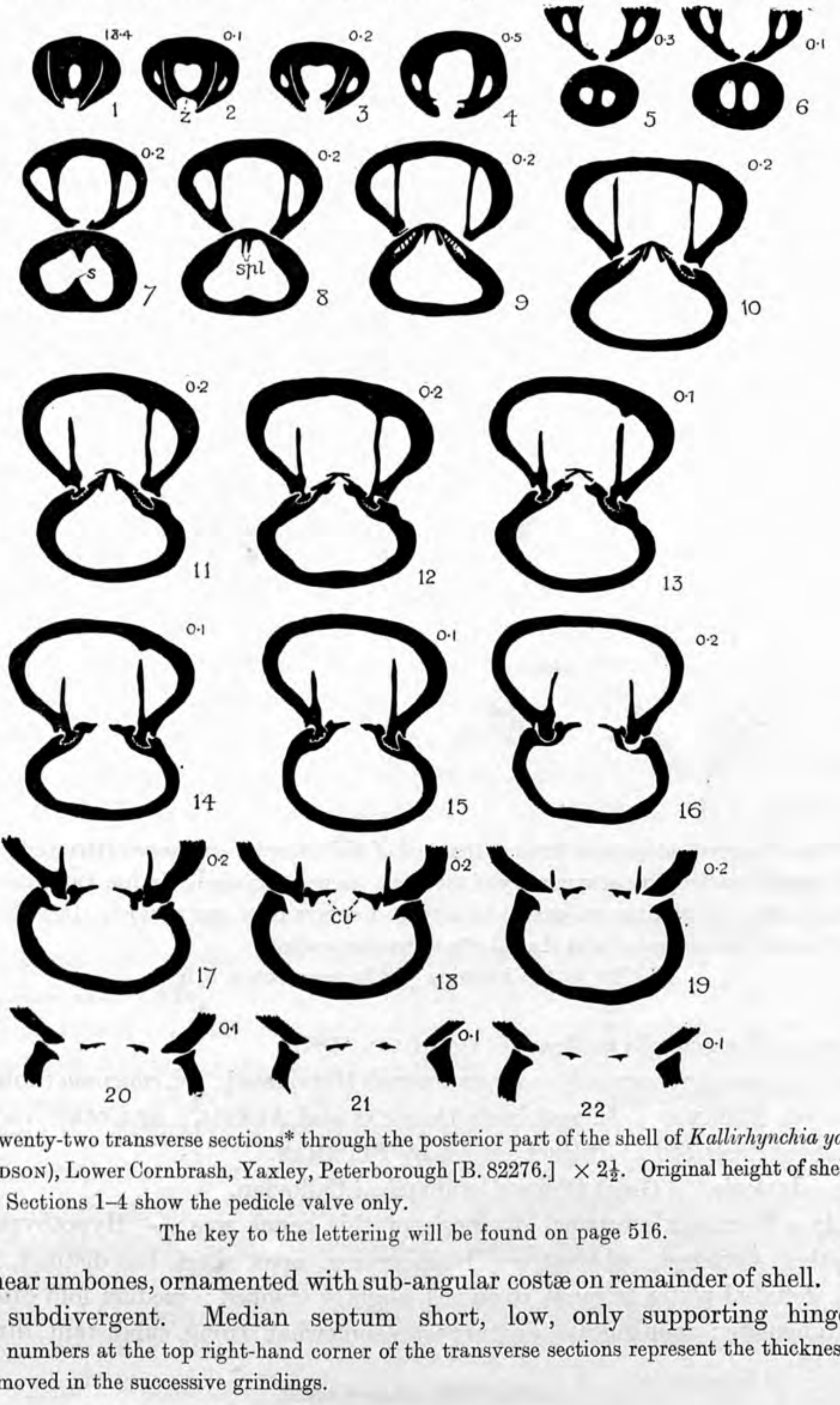

FIG. 2.—Twenty-two transverse sections* through the posterior part of the shell of *Kallirhynchia yaxleyensis* (DAVIDSON), Lower Cornbrash, Yaxley, Peterborough [B. 82276.] $\times 2\frac{1}{2}$. Original height of shell = 18·8 mm. Sections 1–4 show the pedicle valve only.

The key to the lettering will be found on page 516.

smooth near umbones, ornamented with sub-angular costæ on remainder of shell. Dental lamellæ subdivergent. Median septum short, low, only supporting hinge-plates

* The numbers at the top right-hand corner of the transverse sections represent the thickness of shell in mm. removed in the successive grindings.

posteriorly. Hinge-plates curved, sharply differentiated from inner socket-ridges. Crural bases given off dorsally. Teeth terminally flabellate. Crura long, curved, in adult slender laminæ, terminating ventrally in a hook-shaped process (Calcarifer). Pedicle collar developed. Posterior adductor-scars of brachial valve narrow, linear, anterior adductor-scars subtrigonal extending anteriorly beyond posterior adductors.

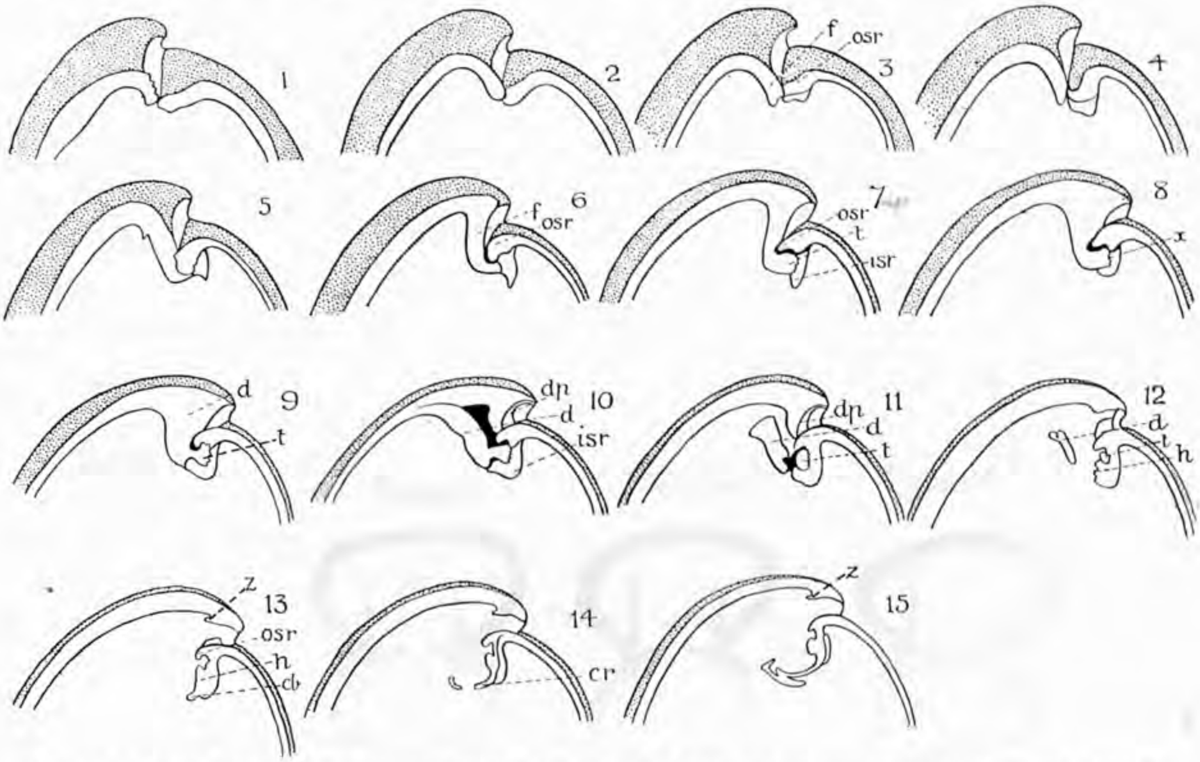

FIG. 3.—Fifteen longitudinal sections through the shell of *Kallirhynchia yaxleyensis* (DAVIDSON) approximately parallel to the plane of symmetry of the shell. Lower Cornbrash, Yaxley, Peterborough. [B. 81639.] × 2½. The sections are ground at varying distances from one another. In section 15 the complete crus was excavated with the aid of a dissecting needle.*

The key to the lettering will be found on p. 516.

Genotype.—*Rhynchonella yaxleyensis* DAVIDSON, 1878.

Species (at present recognized).—*K. yaxleyensis* (Davidson) ; *K. concinna* (SOWERBY) ; *K. crassicosta* BUCKMAN ; *K. multicosta* DOUGLAS and ARKELL ; and other variants of *K. yaxleyensis* described as distinct species by BUCKMAN.

Range.—Jurassic. ? Great Oolite, Cornbrash, ? Callovian.

Remarks.—BUCKMAN'S original diagnosis of this genus was :—" Hypothyrid (beak stout, rather flattened, suberect, rarely incurving, apex short, but distinct, foramen elliptical, deltidial plates trigonal, disjunct), slightly trilobed ; median fold often more or less strangulate ; multiplicate, dental plates somewhat strong, subdistant, divergent ;

* Outer shell-surface stippled.

ventral muscle-area fairly large, pyriform ; dorsal septum not strong ; dorsal muscle-scars elongate, anterior scars well in front of posterior scars and suboblong."

The distinguishing characters of the genus are not very clear from BUCKMAN'S diagnosis, and he included several species which, even from external characters, are obviously unrelated to the type. He expressed a doubt, however, whether the Vesulian and Great Oolite species were really related to the Cornbrash forms, but included them on account of the similarity of the muscle markings. He cited *Rhynchonella yaxleyensis* DAVIDSON as the genotype, but on another page (1917, Plate 15, fig. 23) he figured a specimen in his own collection from the Cornbrash of Yetminster, Dorset, as the "genotype." DAVIDSON'S unique specimen, and therefore the holotype, figured in 1878, his Plate 27, fig. 23, was obtained from the Cornbrash of Yaxley, Peterborough, and this specimen is preserved in the British Museum (Nat. Hist.) Coll. [B. 82289]. In accord with the rules of Zoological nomenclature I have taken DAVIDSON'S species *Rhynchonella concinna* var. *yaxleyensis* as the genotype of *Kallirhynchia* and have investigated the structure of topotypes in the Davidson collection from the Cornbrash of Yaxley. BUCKMAN'S specimen figured by him as the "genotype" is a variety of *K. yaxleyensis*.

BUCKMAN included certain forms described by many authors as the *Rhynchonella concinna*-group in his list of species of *Kallirhynchia*. The name *Rhychonella concinna* has been applied to species ranging from the Inferior Oolite to the Cornbrash, and there is still some doubt about the exact horizon of SOWERBY'S type-specimen. The holotype of *R. concinna*, Brit. Mus. (Nat. Hist.) [B. 71570], is said (SOWERBY, 1815, Feb., p. 192) to have come from the Great Oolite at Aynhoe [Northants]. The two specimens on the tablet which were not figured are undoubtedly Great Oolite forms belonging to BUCKMAN'S genus *Burmirhynchia*. The type, however, appears to be a typical *Kallirhynchia* and closely related to *K. yaxleyensis*. In the Davidson Collection, one specimen labelled *Rhynchonella yaxleyensis* from the Cornbrash of Yaxley is indistinguishable from the type of *R. concinna* SOWERBY, and other specimens though smaller in size have similar ornament and folding.

BUCKMAN (1917, Plate 15, fig. 24) figured a poor plaster cast of *R. concinna*, and stated that it was from the Lower Cornbrash between Ardley and Aynhoe, Northants. DOUGLAS and ARKELL (1932, p. 153) (ARKELL, 1933), on the other hand, state that *K. concinna* is a Great Oolite species, and that specimens indistinguishable from the type could be obtained in a Great Oolite quarry a quarter of a mile E. of Aynhoe. They also state that WALFORD (1917, p. 10) found typical specimens of *R. concinna* in Aynhoe Allotments Quarry in 1883, and that he considered it to be from a bed a little above the Stonesfield Slate. If genuinely a Great Oolite species, *K. concinna* must have persisted practically unchanged until the Lower Cornbrash times. Owing to lack of material no investigation was made of the internal structure of *K. concinna*.

ROTHPLETZ (1886) stated that the crura of *Rhynchonella concinna* are radulifer in shape, but from illustrations of radulifer crura given by ROTHPLETZ and by WIŚNIEWSKA there do not appear to be any spur-like lamellæ projecting dorsally from the primary lamellæ, as in *Kallirhynchia*.

Family TEREBRATULIDÆ, GRAY.

Genus *Plectoidothyris*, BUCKMAN.

Emended H. M. MUIR-WOOD.

Figs. 30, 31, Plate 62 ; fig. 35, Plate 63, and fig. 4.

Plectoidothyris, BUCKMAN (1914), p. 2.
Plectoidothyris, BUCKMAN (1915), p. 78.
Plectoidothyris, BUCKMAN (1917), p. 122.
Plectoidothyris, BUCKMAN : SAHNI (1928), p. 134.

Emended diagnosis.—Shell sulco-convex in neanic stage becoming biconvex, elongate-oval in outline, anterior commissure plane to uniplicate, to multiplicate. Umbo short, erect, slightly incurved in gerontic stage, obliquely truncate, foramen subapical, circular, marginate, epithyrid, beak-ridges obscure. Symphytium short. Pedicle-collar developed. Cardinal process prominent, bilobed, separated from shell floor by deep umbonal cavity. Hinge-plates narrow, concave, demarcated from inner socket-ridges and ventrally deflected crural bases. Loop extending for approximately two-thirds of length of brachial valve, descending branches broad, flat dorso-ventrally directed plates. Teeth mallet-shaped, deeply inserted. Outer socket-ridges interlocking between teeth and massive denticula. Dorsal adductor scars elongated, narrow, strap-shaped.

Genotype.—*Terebratula polyplecta* BUCKMAN, Oolite Marl, *bradfordensis* zone.

Species.—*P. polyplecta* (S. S. BUCKMAN), *P. plicata* (J. BUCKMAN).

Range.—Inferior Oolite.

Remarks.—S. S. BUCKMAN's original diagnosis of this genus was " Permesothyrid (young), epithyrid (adult), (beak short, obliquely truncate, incurved only in old age, foramen somewhat large, almost apical, attrite, symphytium broad, very short) ; morphogeny concavo-convex to elongately biconvex, to fimbriate (multiplicate) ; muscle-tracks long, sub-approximate, subdivergent."

BUCKMAN points out the similarity of growth-stages, before multiplication, of *Plectoidothyris* with those of *Lobothyris*, and this led to confusion of the two genera by Sahni as already stated on p. 513.

Plectoidothyris polyplecta is distinguished from *Plectothyris fimbria* (SOWERBY), the genotype of BUCKMAN's genus *Plectothyris*, by its more erect umbo and subapical foramen, more elongate shell ; less divergent and narrower dorsal adductor muscle-scars, and by the differences in internal characters, shape of hinge-plate, teeth and sockets, etc.

BUCKMAN (1917, p. 122) cites *P. polyplecta* as the genotype of *Plectoidothyris*, and on Plate 20, fig. 14*a*, of the same work figures a specimen from the Oolite Marl, Notgrove Station, Glos. as the " genotype." The holotype of this species was described by BUCKMAN (1901, p. 242) from the same horizon and locality.

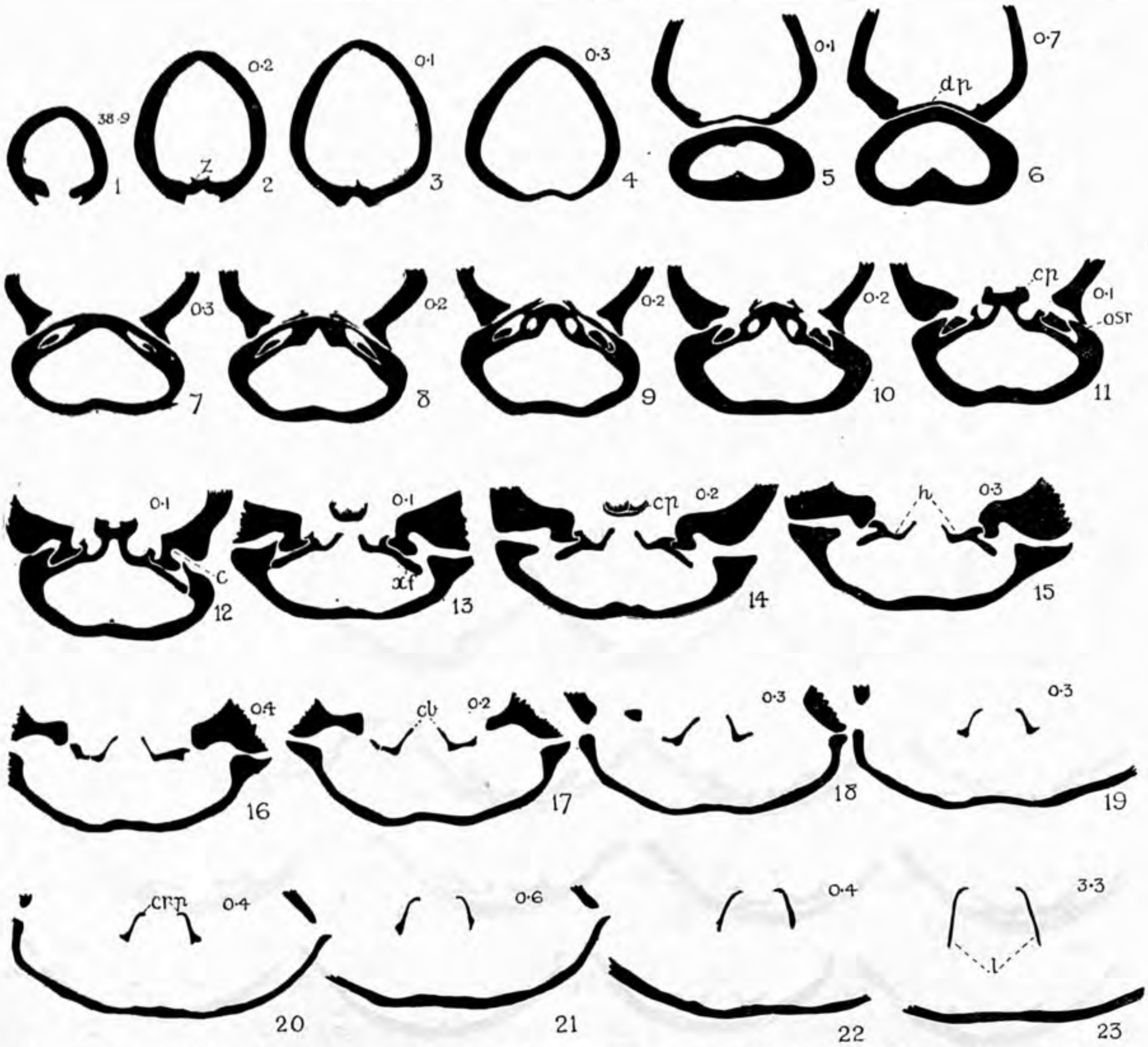

FIG. 4.—Twenty-three transverse sections through the posterior part of the shell of *Plectoidothyris polyplecta* (BUCKMAN). Inferior Oolite, Oolite Marl, Notgrove, Glos. [B. 67617.] × 2½. Original height of shell = 42·1 mm. Sections 1–4 show the pedicle valve only.

The key to the lettering will be found on page 516.

Genus *Lobothyris*, BUCKMAN.

Emended H. M. MUIR-WOOD.

Figs. 28, 29, Plate 62 ; fig. 37, Plate 63, and figs. 5, 6.

Lobothyris, BUCKMAN (1914), p. 2.
Lobothyris, BUCKMAN (1915), p. 78.
Lobothyris, BUCKMAN (1917), p. 107.
Plectoidothyris, BUCKMAN : SAHNI (1928, in part), p. 120.

Emended diagnosis.—Shell plano-convex in neanic stage, becoming biconvex, elongate-oval in outline, anterior commissure plane to uniplicate to ? sulciplicate. Umbo rounded, suberect to incurved ; foramen circular to oval labiate ; epithyrid, beak-ridges angular. Cardinal process small, trilobed, not separated from shell floor by umbonal cavity. Hinge-plates concave, fused with inner socket-ridges. Crural bases sharply recurved ventrally from hinge-plates. Descending branches of loop forming broad plates extending dorso-ventrally. Loop approximately one-third of length of brachial valve. Pedicle collar supported by short septum. Symphytium narrow anterio-posteriorly. Teeth linguiform, deeply inserted, denticula interlocking with outer socket-ridges.

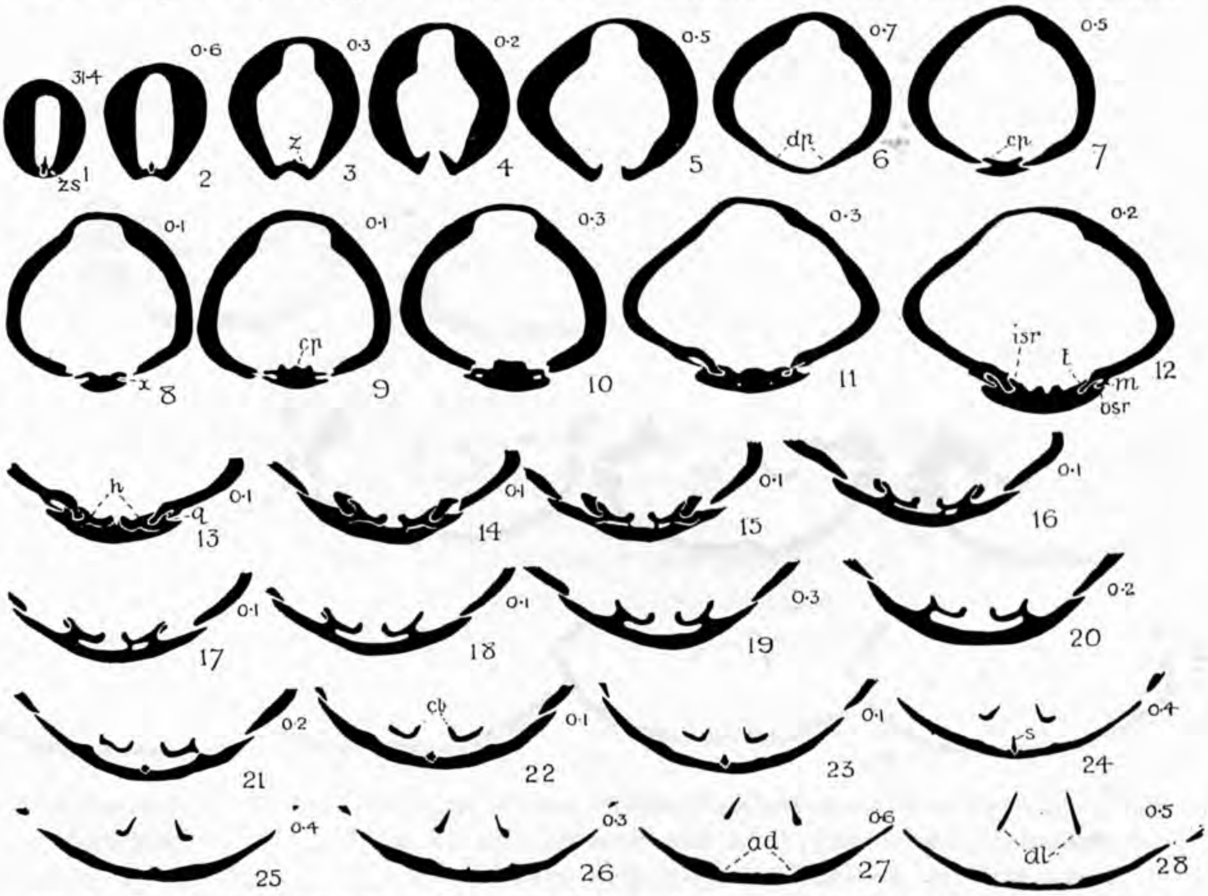

FIG. 5.—Twenty-eight transverse sections through the posterior part of the shell of *Lobothyris punctata* (SOWERBY). Middle Lias, Tilton, Leicestershire. [B. 65240.] $\times 2\frac{1}{2}$. Original height of shell = 31·8 mm. Sections 1–6 show the pedicle valve only.

The key to the lettering will be found on page 516.

Adductor muscle-scars of brachial valve short, narrow, spatulate, diverging at angle of about 40°.

Genotype.—Terebratula punctata J. SOWERBY, 1813.

Species (at present recognized).—*L. punctata* (SOWERBY), *L. subpunctata* (DAVIDSON in part), *L. edwardsi* (DAVIDSON).

Range.—Lias— ?

Remarks.—S. S. BUCKMAN's original diagnosis of this genus was " Epithyrid (beak overhanging dorsal umbo, foramen more or less elliptical, in old forms labiate, symphytium broad); morphogeny, subconcavo-convex to biconvex, to elongate, to uniplicate, to sulciplicate—centronella to terebratula stage; muscle-tracks, narrow, sub-approximate."

A large number of species ranging from the Lower Lias to the Kimeridgian were isted by BUCKMAN as belonging to *Lobothyris*, but he suggested that these species might

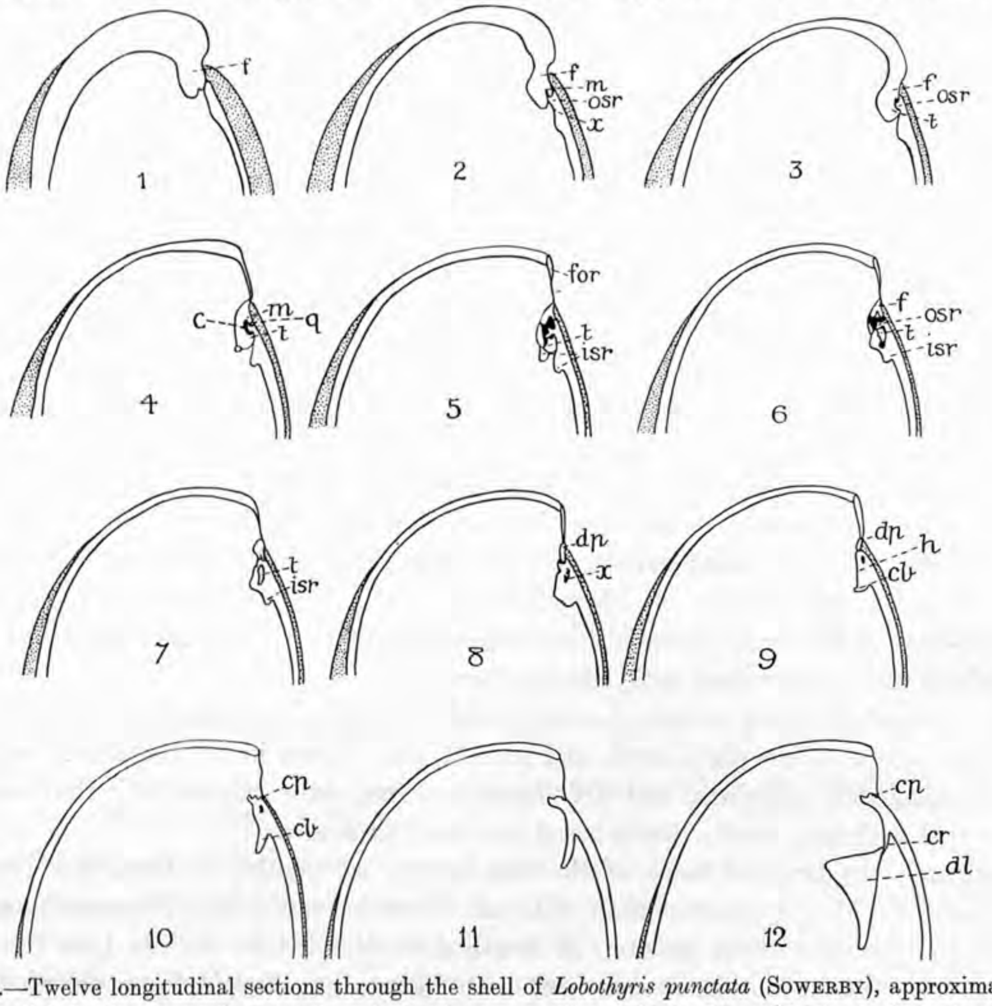

FIG. 6.—Twelve longitudinal sections through the shell of *Lobothyris punctata* (SOWERBY), approximately parallel to the plane of symmetry of the shell. × 2½. Middle Lias, Halstead, Leicestershire. [B. 81638.] In section 12 the complete loop was dissected out with the aid of a dissecting needle. The key to the lettering will be found on page 516.

be successive offshoots from a plano-convex or circular biconvex stock, and that they might not belong to one genetic series. Many of these species can be distinguished from *L. punctata* by marked differences in external characters, and in the shape of the dorsal adductor scars, and will, no doubt, prove to have a totally different internal structure. Investigation of the Liassic species *Lobothyris punctata* (SOWERBY) and *L. subpunctata* (DAVIDSON) has shown that they are homœomorphous with forms having a different internal structure. Some of these homœomorphs differ from *Lobothyris punctata* in having sulcation of the posterior portion of the brachial valve; a more incurved beak and broader adductor muscle-scars, and differences in the hinge-plates as well as a longer loop in the adult shell. Other homœomorphs of *L. punctata* having anterior sulcation of the brachial valve may belong to BUCKMAN's genus *Euidothyris*, or to a genus apparently homœomorphous with *Sphæroidothyris*, but with the anterior commissure sulcate.

DUBAR (1925, 1931) figures specimens with a silicified brachial loop belonging to the group of *Terebratula punctata* and *T. davidsoni* from the Lias of the French Pyrenees. Careful examination of DUBAR's plates shows that the species of the *punctata* and *davidsoni* group belong to two or possibly three distinct series differing slightly in external and internal characters. The narrow elongated form figured as *T. davidsoni* HAIME has a sulcate brachial valve, a much incurved carinate umbo in the pedicle valve, and a longer loop than in *Lobothyris*, and belongs to another genus, although included by BUCKMAN in *Lobothyris*. *Terebratula radstockiensis* DAVIDSON, identified as belonging to the genus *Lobothyris* by BUCKMAN, has a sulcate brachial valve and a different internal structure from *L. punctata*, and may belong to the same undescribed genus as *T. davidsoni*.

SAHNI (1928, p. 135) copied one of DUBAR's figures (1925, Plate 6, fig. 18) showing the loop of *Terebratula punctata*, var. *lata*, and pointed out the similarity in form to that of *Plectoidothyris polyplecta* (BUCKMAN). He also figured somewhat inaccurately the adductor muscle-scars of *Plectoidothyris* and *Lobothyris*, and from the close resemblance of the brachial loops and muscle-scars of the two genera he stated that *Lobothyris* was synonymous with *Plectoidothyris*.

The marked difference in beak characters and the differences in the internal structure, cardinal process, hinge-plate, teeth and sockets, etc., shown in the transverse sections of *Plectoidothyris polyplecta*, and *Lobothyris punctata*, show conclusively that we are concerned with two totally distinct and unrelated genera.

Although the brachial loops of the two genera are similar in form, the loop of *Lobothyris* is always shorter than that of *Plectoidothyris*. In adult specimens of *Lobothyris punctata* about 30 mm. in length from the British Middle Lias the loop averages 9 mm. in length, as compared with 18 mm. in *Plectoidothyris polyplecta*, in adult shells about 38 mm. long. SOWERBY figures (1813, Plate 15, fig. 2) a young specimen of *Terebratula punctata* having a brachial valve 21 mm. in length in which the loop is only 8·5 mm. in length. Another specimen from the same locality and collection, but not figured by SOWERBY, has a brachial valve 23 mm. in length and a loop 9 mm. in length. In a homœomorph of *Lobothyris punctata* from the British Middle Lias the loop averages 14 mm. in length in an adult shell 30 mm. long. The crura in this form are considerably longer than in *L. punctata*.

The lectotype of *Terebratula punctata* SOWERBY (1813, Plate 15, fig. 4) was obtained from the [Middle] Lias of Hornton [Oxfordshire], and is not identical with the specimen figured as " genotype " of *Lobothyris* by BUCKMAN (1917, Plate 20, fig. 7, *a*) from the Middle Lias of Le Pont Rouge, Vendée, France. Investigation of an externally similar specimen from the same French locality shows that BUCKMAN's form is congeneric, and that it is probably a more massive and elongated variety of SOWERBY's species.

As BUCKMAN cites *T. punctata* SOWERBY as the genotype of the genus *Lobothyris*, this species has been accepted as such by me, and investigation has been made of the internal structure of specimens externally similar to the lectotype of SOWERBY's species.

DESLONGCHAMPS (1884, p. 249) in his classification of *Terebratula* divided the genus into a number of species groups, and *T. punctata* is the type of " group C." The species belonging to this group are described as " allongées, renflées, à crochet épais et court." DESLONGCHAMPS (1884, Plate 10, figs. 1, 2) also figured the loop of a French specimen of *T. punctata* which does not agree in form with that of the English species. In the lateral view of the loop of the English species the transverse band is concealed by the broad ribbon of the descending lamellæ, while in the French form the descending lamellæ are narrow and the transverse band is well exposed.

ALKINS (1923) measured 300 specimens of " *Terebratula punctata* " from the Middle Lias of Stathern, Leicestershire, and worked out the ratios of width/length and depth/length. After plotting his results in the form of graphs, he stated that the species as represented by these shells was perfectly homogeneous.

Family TEREBRATELLIDÆ, KING.

Genus *Ornithella*, DESLONGCHAMPS.

Emended H. M. MUIR-WOOD.

Figs. 22–24, Plate 62 ; fig. 38, Plate 63, and figs. 7, 8.

Ornithella, DESLONGCHAMPS (in part), 1884. pp. 273, 292, 293.
Ornithella, auctt. in part.

Emended diagnosis.—Shell plano-convex in neanic stage, becoming biconvex ; elongate-oval to pentagonal in outline ; truncated or strangulate anteriorly. Anterior commissure plane. Maximum width about half-way down length of shell. Umbo rounded, suberect to incurved, frequently in contact with the brachial valve in the gerontic stage ; permesothyrid. Dental lamellæ embedded in callus in adult. Median septum less than half length of brachial valve, short, stout, supporting hinge-plate. Septalium shallow. Crural bases given off ventrally. Inner socket-ridges separated from hinge-plates by shallow depression. Loop with short spines, long, not attached to septum in adult. Muscle-area of brachial valve lens-shaped with longitudinal axis inclined at an angle of about 20° to median septum. Posterior adductors crescentic, anterior adductors lenticular. Pedicle-collar rarely observed.

Genotype.—*Terebratula ornithocephala* J. SOWERBY, 1815.

Species.—*O. ornithocephala* (J. SOWERBY), *O. bathonica* ROLLIER, *O. brutonensis*

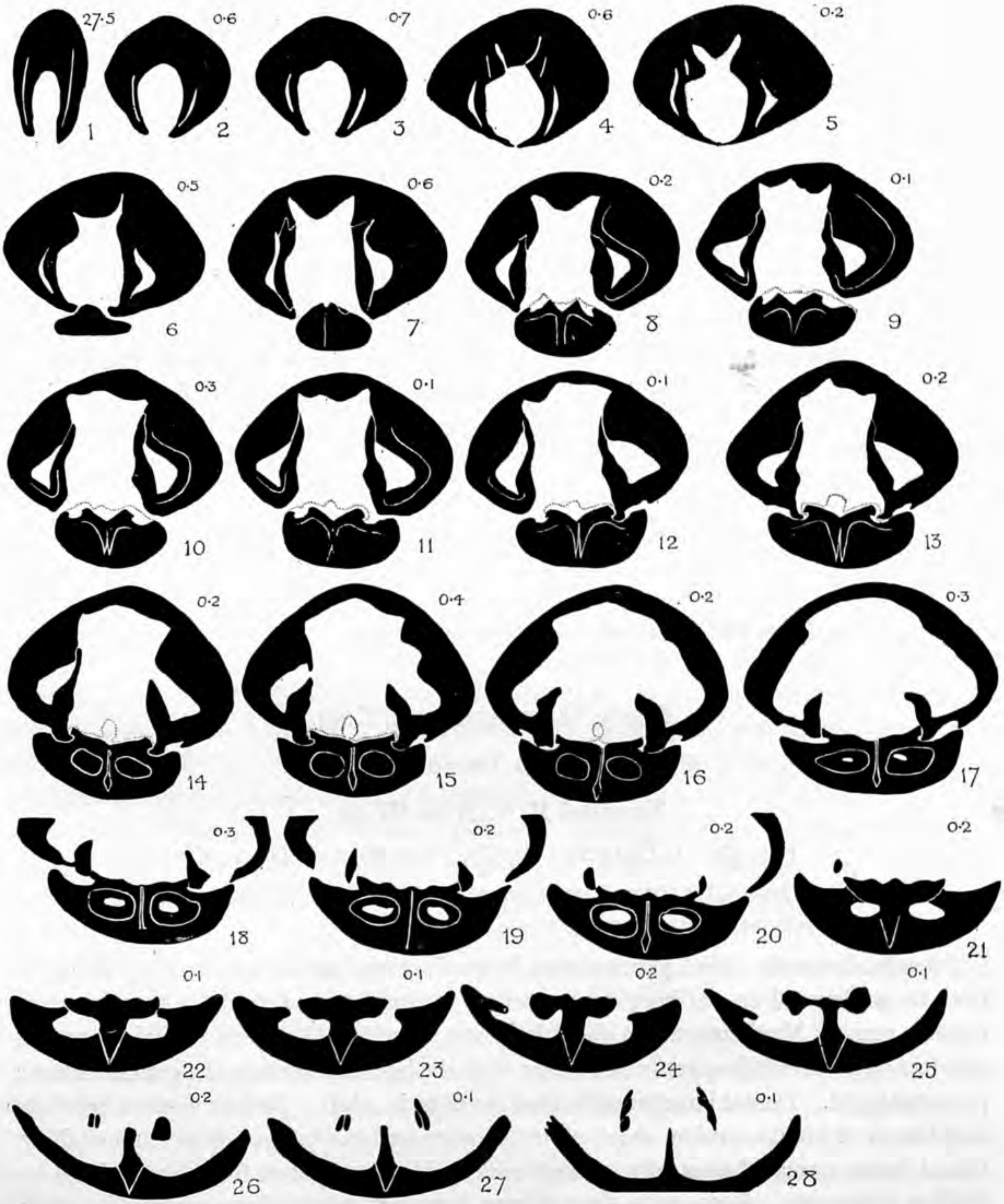

FIG. 7.—Twenty-eight transverse sections through the posterior part of the shell of *Ornithella bathonica* ROLLIER. Fullers Earth Rock, Box Tunnel, Wilts. [B. 82278.] $\times 2\frac{1}{2}$. Original height of shell = 29·8 mm. Sections 1–5 show the pedicle valve only. Deposits of callus on the hinge-plates are indicated by means of a dotted line. The thick callus deposits in the umbonal region of the pedicle valve cause the apparent obsolescence of the dental lamellæ.

The key to the lettering will be found on page 516.

ROLLIER, *O. triquetra* (J. DE C. SOWERBY) [= *O. subtriquetra* D'ORB. *sp.*], *O. bathiensis* ROLLIER ; **O. haydonensis* and *O. pupa* MUIR-WOOD MS.

Range.—Bathonian—Fullers Earth—Cornbrash, and ? Upper Jurassic.

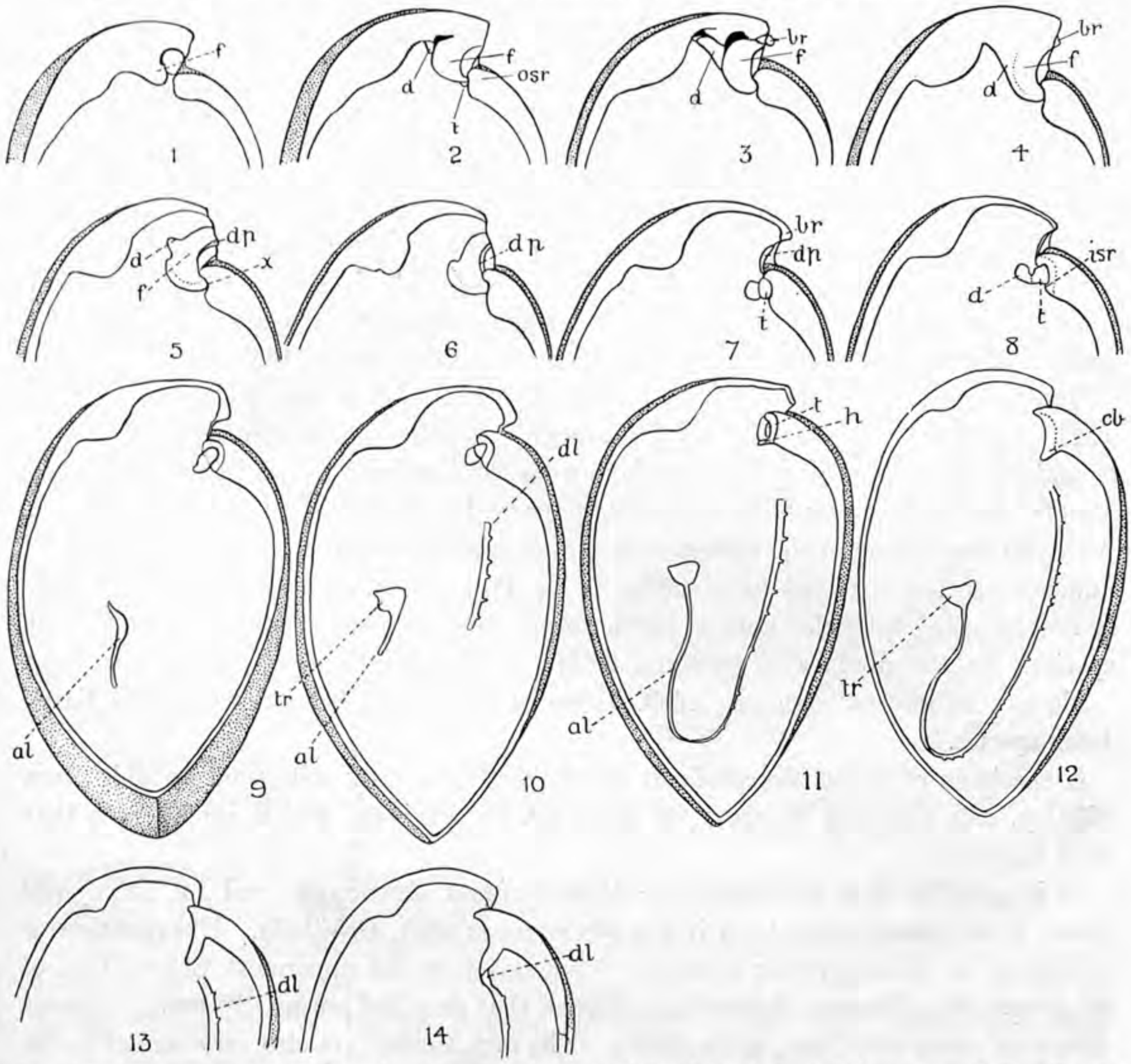

FIG. 8.—Fourteen longitudinal sections through the shell of *Ornithella bathonica* ROLLIER. Fullers Earth Rock, Box Tunnel, Wilts. [B. 82277.] × 2½. Sections 1–6 were ground at an angle of about 25° to the plane of symmetry of the shell. Sections 7–14 were ground so as to expose one-half of the complete loop and its relationship to the crus.

The key to the lettering will be found on page 516.

Remarks.—DESLONGCHAMPS (1884, pp. 273, 292, 293) described *Ornithella* as a section of *Zeilleria*, BAYLE, with *Terebratula ornithocephala* SOWERBY, as the type. He included the species *T. indentata* SOWERBY, *T. umbonella* (LAMARCK), *T. bucculenta* SOWERBY,

* Descriptions of these species will appear shortly in another paper by the author.

and *T. celtica* MORRIS, in his description of the genus. All these species, however, have a different muscle-arrangement and a different hinge-plate from that of *O. ornithocephala* and are not congeneric.

The genotype of *Ornithella*, *Terebratula ornithocephala* was described by SOWERBY in 1815 (Plate 101, figs. 1, 2, 4). He figured three specimens of which the specimen depicted in Plate 101, fig. 1, from Chatley, Somerset, probably from the Lower Cornbrash, has been selected as lectotype. The specimen represented by fig. 2 of the same plate from an unknown locality has been renamed *Ornithella fullonensis* by RICHARDSON (1907, p. 430). SOWERBY's third specimen (Plate 101, fig. 4) from the Lower Lias of Pickeridge, Somerset, is the type of *Terebratula sarthacensis* D'ORBIGNY.

The question of the genotype of *Ornithella* was discussed by BUCKMAN in 1907*b* (p. 379), while the identity of the species *Ornithella ornithocephala* was discussed by the same author in 1904 (p. 396), and by DOUGLAS and ARKELL in 1928 (p. 165).

DOUGLAS and ARKELL (1928, p. 165) were unable to find any trace of Upper Cornbrash at Chatley in their recent mapping of Cornbrash outcrops, and no specimens of *O. ornithocephala* were collected by these authors from the Lower or Upper Cornbrash of any locality, nor are any Cornbrash specimens preserved in the British Museum collections. A careful comparison of the type-specimen of *O. ornithocephala* has been made with the numerous species of *Ornithella* occurring in the Fullers Earth Rock. *O. ornithocephala* is not identical with the Fullers Earth forms, and must be regarded as a distinct species. In the absence of material from the Cornbrash, investigation has been made of the internal structure of *O. bathonica* ROLLIER, the common Fullers Earth Rock species.

A specimen of *O. ornithocephala* in the duplicate Sowerby collection, possibly from Chatley, was dissected to show the loop, fig. 38, Plate 63, which agreed with that of *O. bathonica*.

It is probable that *Microthyris* [= *Microthyridina*, SCHUCHERT and LE VENE] will prove to be closely related to, if not synonymous with, *Ornithella*. Examination of specimens of *Microthyridina lagenalis* (SCHLOTH.) from the uppermost Brown Jura of Beggingen, Schaffhausen, Switzerland, showed that they had essentially similar internal structure, hinge-plate, etc., as *Ornithella*. The muscle-scars are also very similar in the two genera. The specimens investigated agreed in size and external shape with that figured by VON BUCH in 1834 (Plate 3, fig. 43) from Aarau, Switzerland, the type locality for *Terebratula lagenalis*.

In the British Upper Cornbrash there appear to be *lagenalis*-like forms with at least three distinct types of internal structure, one belonging to *Obovothyris*, another probably to *Microthyridina*, and the third to an undescribed genus. The matter is further complicated by the selection of DESLONGCHAMPS' figure of *Terebratula lagenalis* in Paléontologie franç., Plate 107, fig. 1, from an unknown locality, as geno-holotype of *Microthyridina* by SCHUCHERT and LE VENE (1929, p. 84).

ROLLIER (1919, p. 321) refers to *Ornithella* as being a synonym of *Microthyris*, a subgenus of *Zeilleria*, and restricts the application of the name *Ornithella* to the " *emarginata* " group of species. As *Z. emarginata* is not mentioned by DESLONGCHAMPS in his original description of *Ornithella* ROLLIER's interpretation of the genus is incorrect.

Genus *Obovothyris*, BUCKMAN.

Emended H. M. MUIR-WOOD.

Figs. 25–27, Plate 62 ; fig. 33, Plate 63 ; and figs. 9, 10.

Obovothyris, BUCKMAN (1927), p. 32.
Ornithella, DOUGLAS and ARKELL (in part) (1928), p. 160.
Ornithella, auctt. (in part).

Emended diagnosis.—Shell sulco-carinate in neanic stage, becoming biconvex ; subpentagonal in outline ; antero-lateral margins with subangular carinæ ; anterior margin truncate or excavate, anterior commissure plane or slightly waved dorsally. Maximum width occurring at about two-thirds of the length of shell. Umbo carinate, suberect to incurved. Permesothyrid. Median septum about two-thirds of length of brachial valve, thin and plate-like supporting hinge-plate. Septalium shallow. Inner socket-ridges and hinge-plates fused. Crural bases and loop given off dorsally. Loop spinose, long, not attached to septum in adult. Muscle-area of brachial valve lens-shaped, anterior scar almost in contact with septum. Pedicle-collar supported by stout septum.

Genotype.—*Obovothyris magnobovata* BUCKMAN, 1927.

Species (at present recognized).—*O. obovata* (SOWERBY), *O. grandobovata* and *O. magnobovata* BUCKMAN, also a new species from the Upper Cornbrash and homœomorphous with *Microthyridina lagenalis* (SCHLOTH.).

Range.—Lower Cornbrash—Upper Cornbrash.

Distinctions.—*Obovothyris* is distinguished from *Ornithella* by differences in the shape of the hinge-plate ; by the more spinose loop which is given off from the dorsal side of the hinge-plate ; by the development of a pedicle-collar supported by a septum ; by its longer median septum ; and by the development of subangular carinæ at the antero-lateral margins of the shell.

Remarks.—In the original diagnosis of this genus, BUCKMAN did not clearly define the characters by which it could be distinguished from *Ornithella*, and subsequent authors* have, therefore, not adopted his genus, but have preferred to retain the name *Ornithella* for the " *obovata* " group. No internal characters were described by BUCKMAN with the exception of the muscle-scars which are indistinguishable in his figure of the type, and the long septum of the brachial valve. Investigation of internal characters, however, indicates that *Obovothyris* should be regarded as a distinct genus,

* DOUGLAS and ARKELL (1928), p. 160.

although related to *Ornithella* and *Digonella*, as shown by a similarity in the shape of the muscle-scars, in the form of the loop which in each type is spinose, and in the shape of the hinge-plate. The differences in internal characters have already been discussed

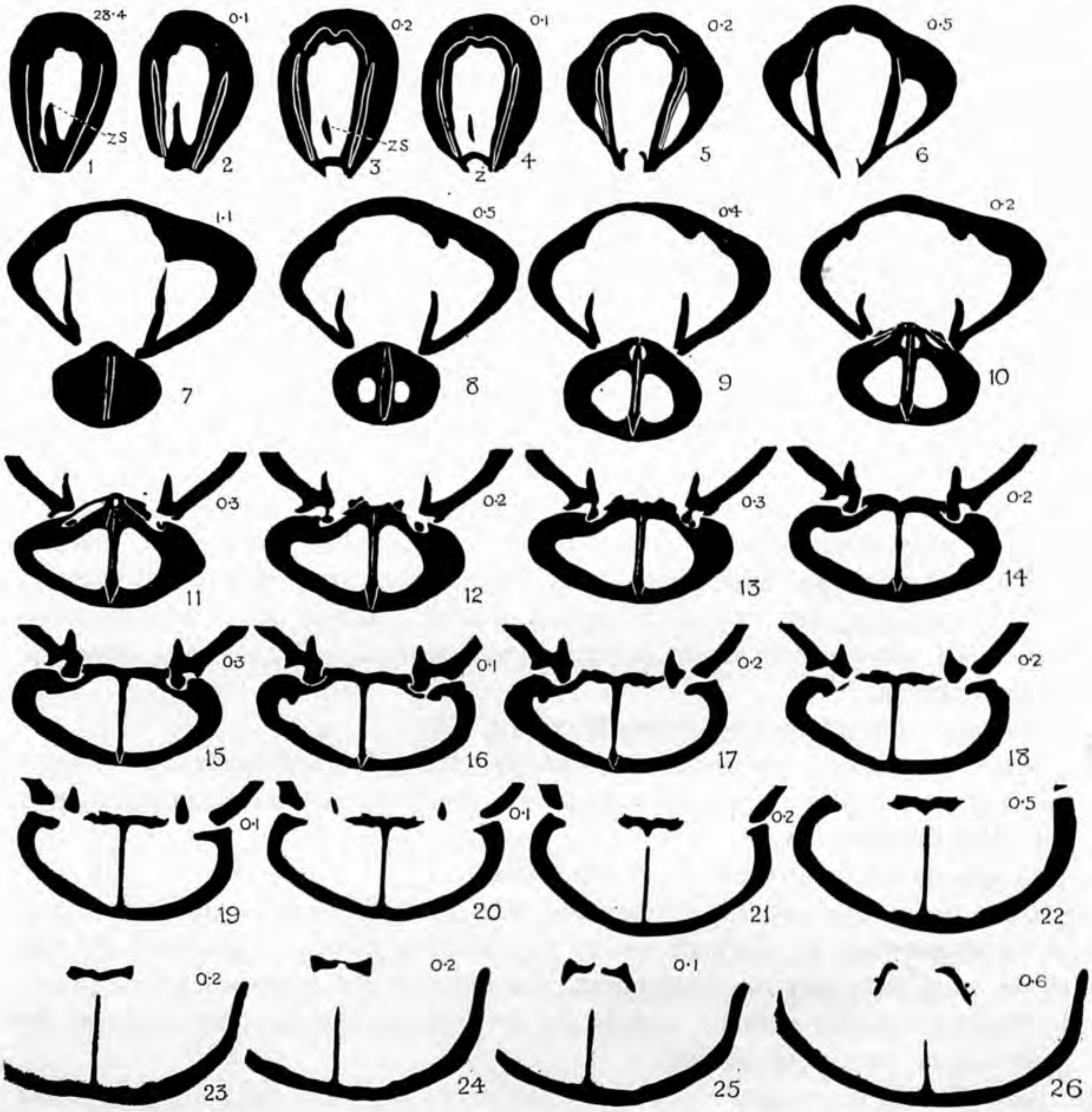

FIG. 9.—Twenty-six transverse sections of the posterior part of the shell of *Obovothyris magnobovata* S. S. BUCKMAN. Cornbrash, Blackthorn Hill, Bicester. [B. 68325.] × 2½. Original height of shell = 29·6 mm. Sections 1–6 show the pedicle valve only.

The key to the lettering will be found on page 516.

in the section on "Morphology and Nomenclature." The genera *Ornithella*, *Digonella*, and *Obovothyris* should probably be grouped together in one subfamily.

The sulcate umbo of the brachial valve and corresponding carination of the pedicle valve of *Digonella* and *Obovothyris* indicate derivation from a sulcate ancestor, and in this connection it is interesting to mention that the internal structure and hinge-plate of "*Aulacothyris*" *meriani* (OPPEL) from the Inferior Oolite, Lower Trigonia Grit are remarkably similar to those of *Ornithella* and *Obovothyris*. Although possessing a sulcate

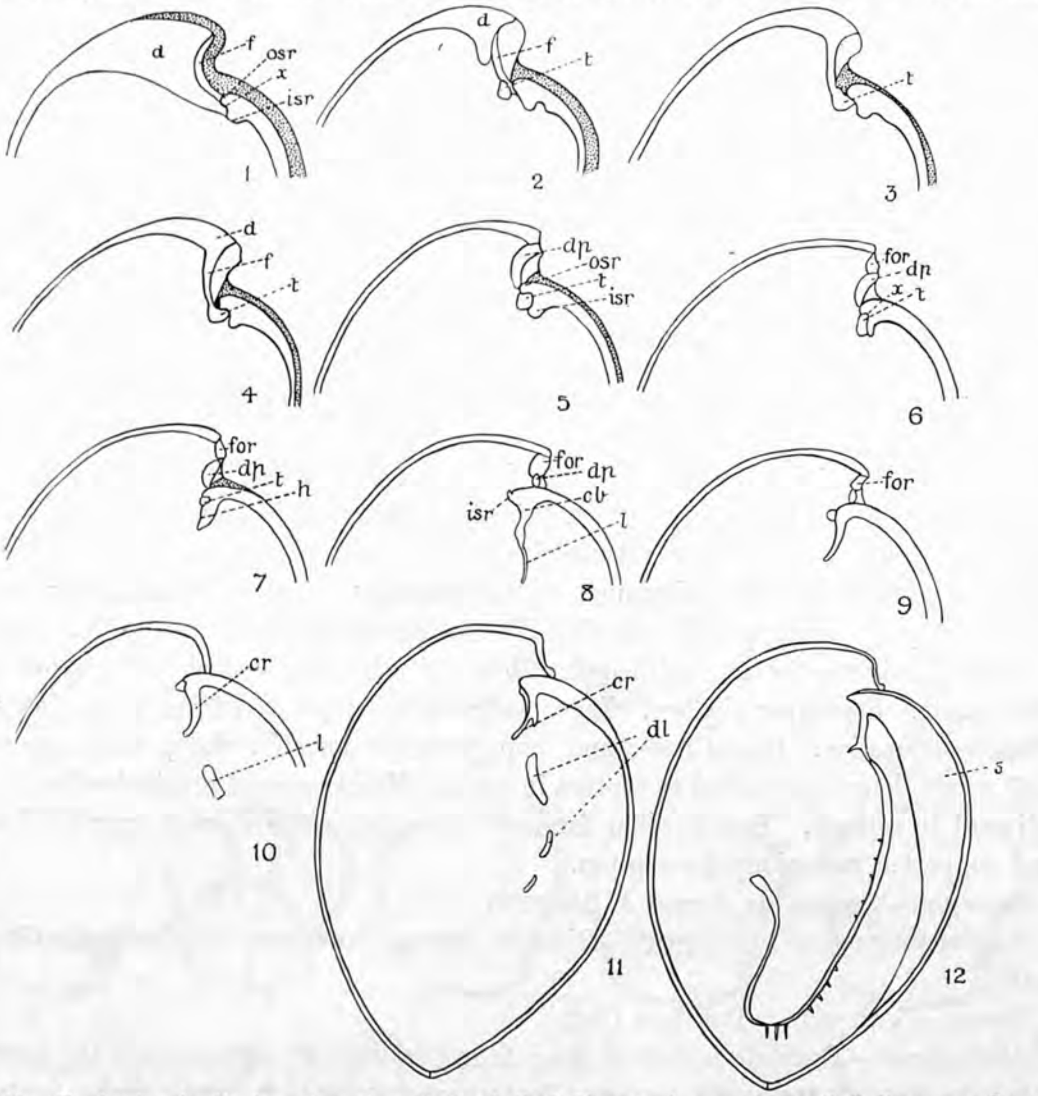

FIG. 10.—Twelve longitudinal sections through the shell of *Obovothyris magnobovata* S. S. BUCKMAN, Lower Cornbrash, Blackthorn Hill, Bicester. [B. 57807.] × 2½. Sections 1–11 were ground at an angle of about 25° to the plane of symmetry of the shell. Section 12 shows the spinose loop and median septum dissected out in a second specimen from the same horizon of Rushden, Northants. [B. 81636.] The key to the lettering will be found on page 516.

brachial valve and a carinate pedicle valve, this species is totally unrelated to *Aulacothyris resupinata* (SOWERBY), the genotype of *Aulacothyris*, from the Middle Lias. More research is needed before any attempt can be made to work out the lineages of the species at present grouped together in the subfamily Zeilleriinæ.

It is possible that some of the more globose forms at present included in the "*obovata*" group may be found to have a similar internal structure to that of "*Ornithella*" *umbonella* (LAMARCK). This species belongs to a new genus which is being described by the author in another paper.

DESLONGCHAMPS (1884, p. 274) subdivided the genus *Zeilleria* into a number of species groups of which *Terebratula obovata* and *Terebratula digona* are examples of group "*h*" which, however, was not given a special name.

The holotype of *O. magnobovata* was described by BUCKMAN (1927, Plate 1, figs. 9, *a*, *b*) from the Lower Cornbrash of Blackthorn Hill, Bicester, Oxon. This specimen is preserved in the Buckman collection, British Museum (Nat. Hist.) [B. 58321].

Genus *Digonella* gen. n.

Figs. 18, 19, Plate 62; fig. 34, Plate 63; and figs. 1, 11, 12.

Syn. *Ornithella* auctt. (in part).

Diagnosis.—Shell sulco-carinate in neanic stage, becoming biconvex, elongate-oval to trigonal in outline; antero-lateral margins with angular carinæ, anterior commissure plane or dorsally waved. Maximum width occurring at, or near, anterior margin. Umbo flattened, suberect. Mesothyrid. Dental lamellæ slender, sub-parallel. Median septum slightly greater than half length of brachial valve, thin and plate-like supporting hinge-plate. Septalium shallow. Inner socket-ridges separated from hinge-plates by shallow depression. Crural bases and loop given off dorsally. Loop with numerous long spines, long, unattached to septum in adult. Muscle-area of brachial valve linear, adjacent to septum. Pedicle-collar forming a complete ring detached from shell wall and supported posteriorly by septum.

Genotype.—*Terebratula digona* J. SOWERBY, 1815.

Species (at present recognised).—*Digonella digona* (SOWERBY), *D. digonoides* (BUCKMAN).

Range.—Bathonian. Bradford Clay.

Distinctions.—*Digonella* is distinguished from *Ornithella* by differences in the internal structure shown in transverse sections; by its more spinose loop, longer median septum; and by its trigonal shell outline, and prominent lateral carinæ. From *Obovothyris* it is distinguished by differences in the shape of the hinge-plate; shorter median septum; more persistent and slender dental lamellæ; and by its trigonal shell outline, and more erect, flattened umbo.

Remarks.—SOWERBY (1815, p. 217) figures four specimens as *Terebratula digona* of which figs. 1–3 of Plate 96 are from the Bradford Clay of Bradford (Wilts.) or Pickwick (Wilts.). Of these the specimen represented as fig. 1 is selected as lectotype. This specimen is preserved in the British Museum (Nat. Hist.) collection [B. 71586]. The specimen represented by figs. 4, 5 of the same plate from Felmersham (Bedfordshire), probably from the Great Oolite, should be referred to *Digonella digonoides* (BUCKMAN).

DAVIDSON (1878, Plate 22, fig. 22) figured the interior of the brachial valve of "*Waldheimia*" *digona* showing the spines on the loop exceptionally well preserved. Much restored drawings of the spines in this species were also given by DESLONGCHAMPS (1884).

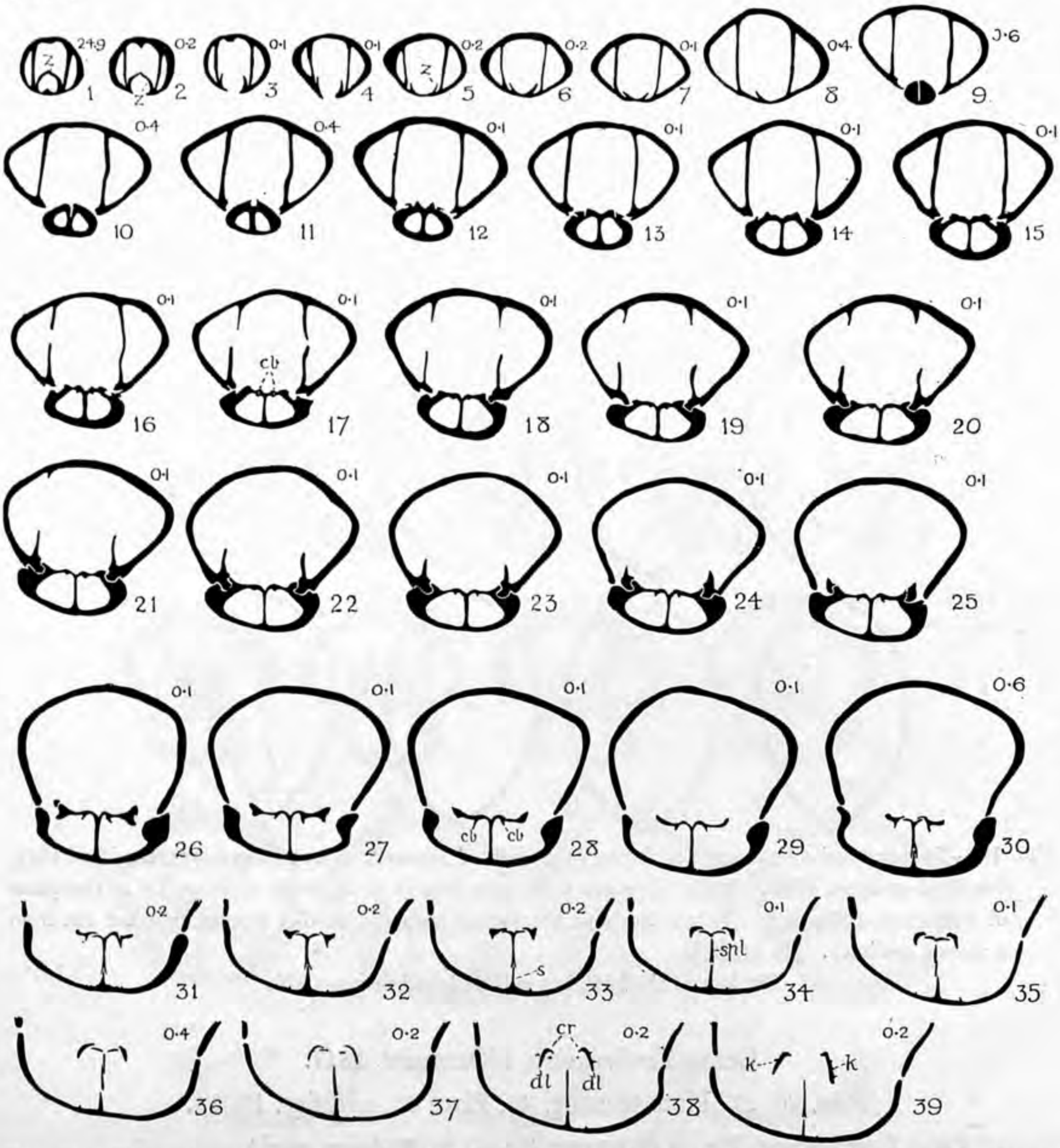

FIG. 11.—Thirty-nine transverse sections through the posterior part of the shell of *Digonella digona* (SOWERBY). Bradford Clay, Bradford-on-Avon, Wilts. [B. 82279.] $\times 2\frac{1}{2}$. Original height of shell = 25·9 mm. Sections 1–8 show the pedicle valve only.

The key to the lettering will be found on page 516.

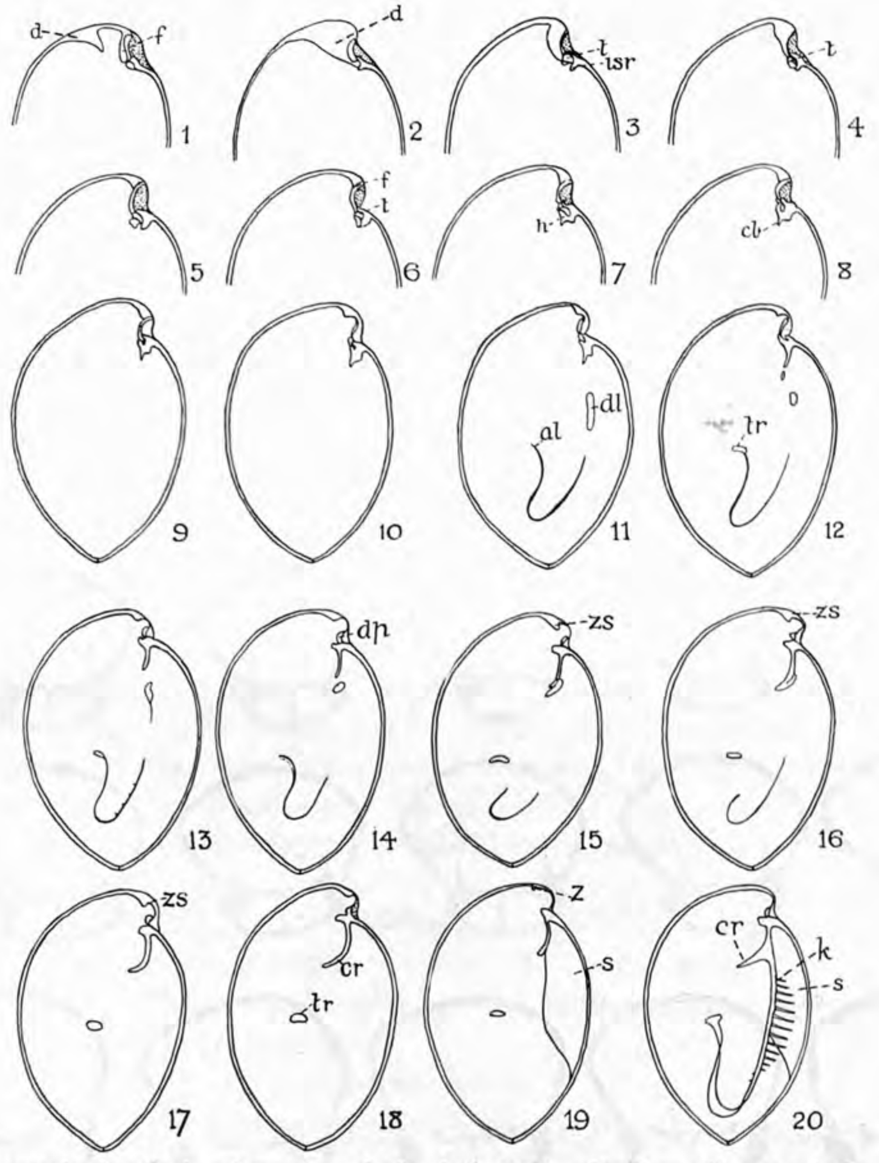

FIG. 12.—Twenty longitudinal sections through the shell of *Digonella digona* (SOWERBY), Bradford Clay, Bradford-on-Avon, Wilts. × 2½. Sections 1–19 were ground at an angle of about 15° to the plane of symmetry of the shell. Section 20 shows the spinose loop and median septum dissected out from a second specimen. [B. 84289.]

The key to the lettering will be found on page 516.

Genus *Terebrirostra*, D'ORBIGNY, 1847.

Figs. 20, 21, Plate 62; fig. 36, Plate 63, and figs. 13, 14.

Lyra, Cumberland MS. in SOWERBY (1816), p. 88 (*nom. nud.*).
Trigonosemus, KOENIG (in part) (1825), p. 3.
Terebrirostra, D'ORBIGNY (1847), p. 269.
Terebrirostra, D'ORBIGNY (1850a), p. 126.

Terebrirostra, D'ORBIGNY (1850b), p. 345.
Terebrirostra, D'ORBIGNY (1850c), [1849-52], p. 85.
Terebrirostra, D'ORBIGNY (1851), p. 222.
Terebrirostra, D'ORBIGNY : DAVIDSON (1852), p. 31.
Terebrirostra, D'ORBIGNY : DAVIDSON (1853), p. 67.
Terebrirostra, D'ORBIGNY : DALL (1877), p. 72.
Lyra, Cumberland : DALL (1877), p. 45.
Lyra, Cumberland : DESLONGCHAMPS (1884), p. 266.
Lyra, Cumberland : HALL and CLARKE (1894), p. 890.
Lyra, Cumberland : SCHUCHERT and LEVENE (1929), p. 78.

Diagnosis.—Shell biconvex, folding subintertext to incipiently ligate; brachial valve elongate-oval to subtrigonal in outline, pedicle valve resembling brachial valve

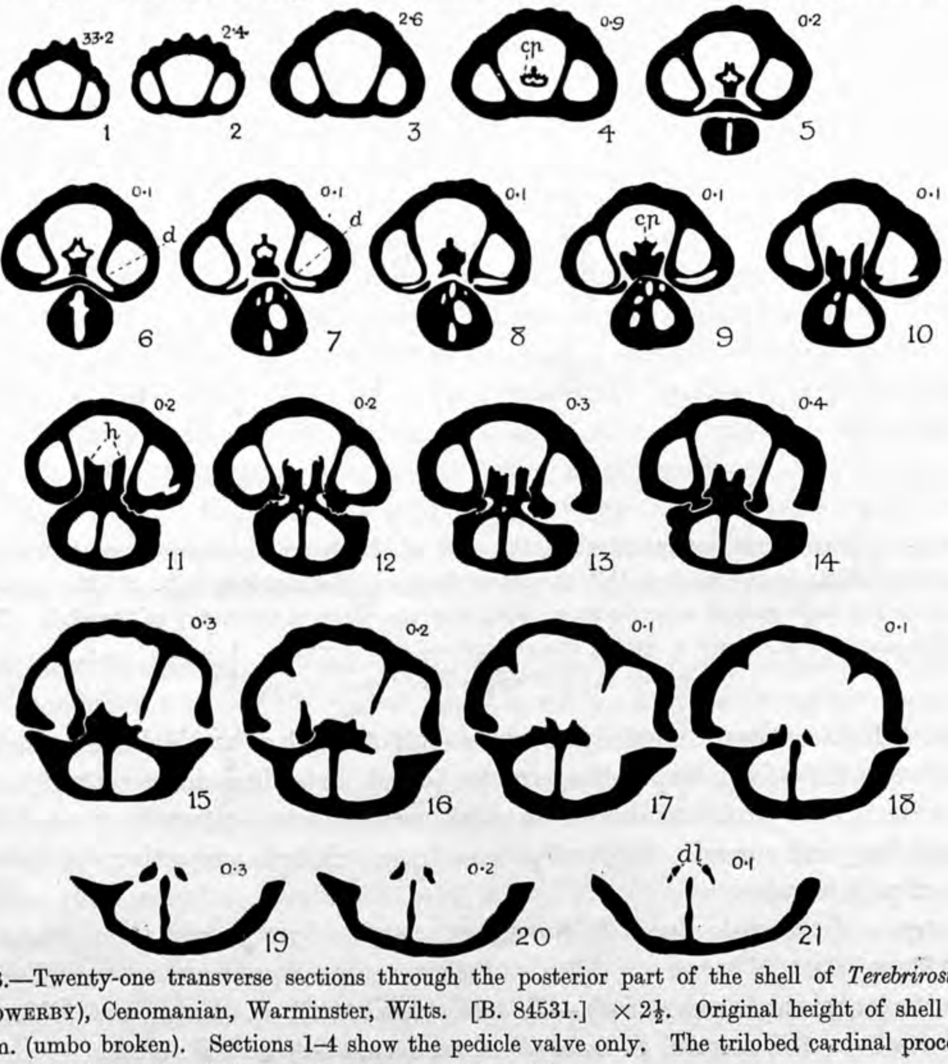

FIG. 13.—Twenty-one transverse sections through the posterior part of the shell of *Terebrirostra lyra* (SOWERBY), Cenomanian, Warminster, Wilts. [B. 84531.] $\times 2\frac{1}{2}$. Original height of shell = 35·2 mm. (umbo broken). Sections 1–4 show the pedicle valve only. The trilobed cardinal process projects into the cavity of the pedicle valve in sections 4–9.

The key to the lettering will be found on page 516, but with long curving, suberect umbo ; anterior margin rounded, becoming truncate or excavate ; anterior commissure slightly sulcate or plane ; lateral commissure deflected towards pedicle valve anteriorly. Beak-ridges angular. Deltidial plates fused. Dental lamellæ extending whole length of umbo, anteriorly curved and uniting with lateral

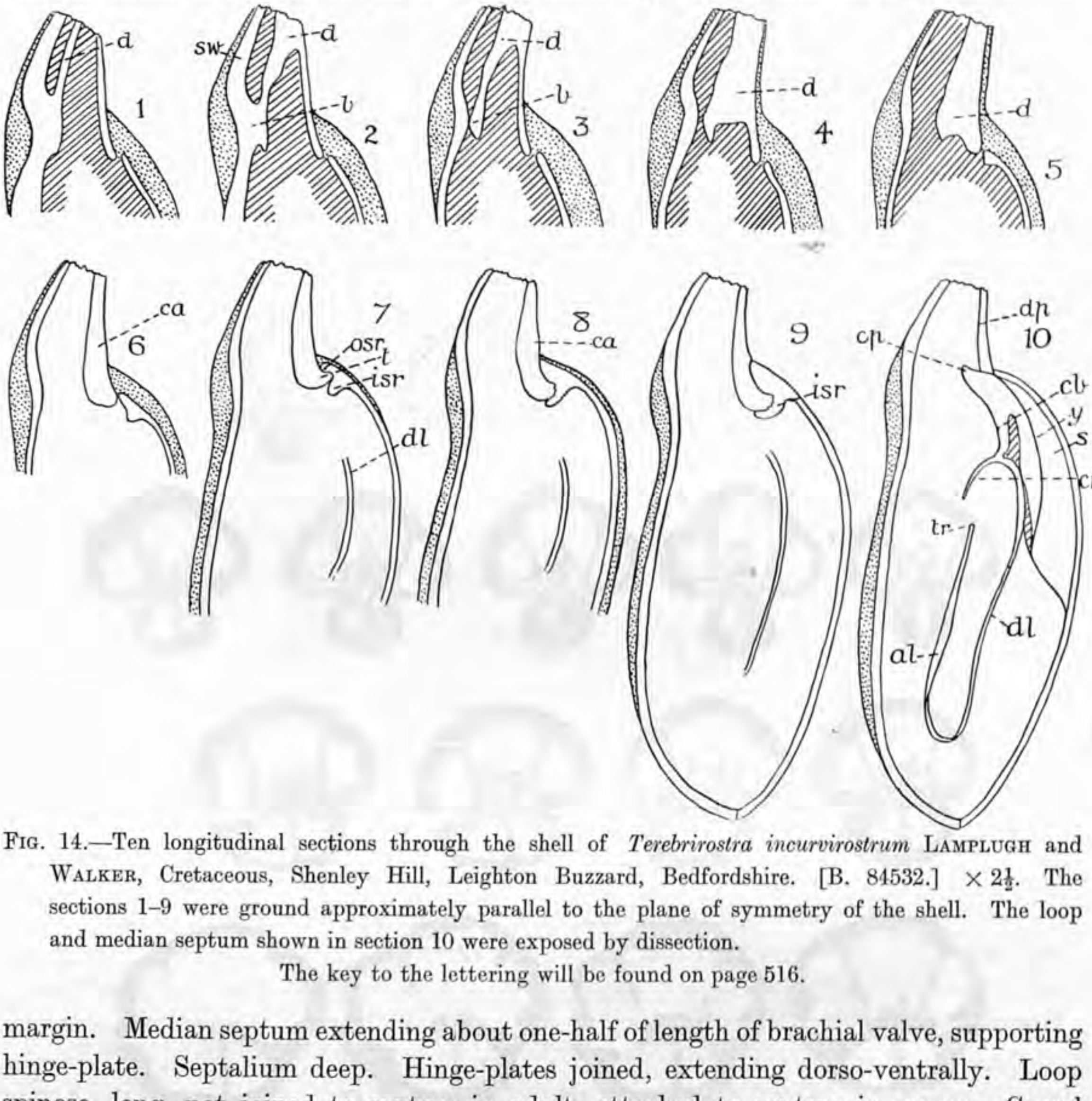

FIG. 14.—Ten longitudinal sections through the shell of *Terebrirostra incurvirostrum* LAMPLUGH and WALKER, Cretaceous, Shenley Hill, Leighton Buzzard, Bedfordshire. [B. 84532.] $\times 2\frac{1}{2}$. The sections 1–9 were ground approximately parallel to the plane of symmetry of the shell. The loop and median septum shown in section 10 were exposed by dissection.

The key to the lettering will be found on page 516.

margin. Median septum extending about one-half of length of brachial valve, supporting hinge-plate. Septalium deep. Hinge-plates joined, extending dorso-ventrally. Loop spinose, long, not joined to septum in adult, attached to septum in young. Crural processes long and curved. Cardinal process large, trilobed, projecting ventrally into cavity of pedicle valve.

Genotype.—Terebratula lyra J. SOWERBY, 1816 = *Lyra meadii* Cumberland MS. : J. SOWERBY.

Species (at present recognized).—*T. lyra* (SOWERBY), *T. bargesiana* D'ORBIGNY, *T. arduennensis* D'ORBIGNY, *T. incurvirostrum* LAMPLUGH and WALKER.

Range.—Cretaceous.

Remarks.—*Terebrirostra* is distinguished from Recent Terebratellas in having the brachial loop unattached to the median septum in the adult; and in having a larger cardinal process and different hinge-plate. The numerous fossil species at present described as *Terebratella*, vary considerably in their hinge-characters, but most of these forms have a Terebratellid or doubly attached loop in the adult. *Terebrirostra* is distinguished from *Trigonosemus* by the simpler form of the loop; by the differences in the hinge-characters, and by its angular beak-ridges.

The name *Lyra*, employed by so many authors, has never been definitely described or figured in any publication. The only mention of it was in the description of *Terebratula lyra* by JAMES SOWERBY in 1816 (p. 88), as follows:—" Mr. Cumberland, indeed, considered it a new Genus and named it *Lyra Meadi*, in compliment to our worthy friend, whom I esteem so much, but the term *Lyra* is so apt I could not resist applying it to the specific name."

The first published description of the genus was by D'ORBIGNY in 1847, who called it *Terebrirostra*, which name must be adopted, with genotype *Terebratula lyra* SOWERBY.

D'ORBIGNY did not describe or figure the loop of this genus in any of his publications. DESLONGCHAMPS (1884, p. 267), however, dissected out the loop of *Terebrirostra bargesiana* D'ORBIGNY, from the Albian of the Ardennes, and described it as being similar to that of *Waldheimia* and not terebratellid in the adult. In his description of this genus under the name of *Lyra*, DESLONGCHAMPS mentioned that the megerliform and terebratelliform stages persist in the early growth-stages of the shell. The terebratelliform stage of loop development was observed in immature specimens of *T. incurvirostrum*.

In most of the British specimens of *Terebrirostra* the umbo of the pedicle valve is imperfectly preserved, and the pedicle opening cannot be studied. This structure was seen, however, in a young specimen of *T. lyra* from the French Cenomanian in the British Museum (Nat. Hist.) collections [B. 82453], which has a complete umbo showing the oval terminal foramen surrounded by a slightly raised rim. In this specimen the umbo was somewhat curiously curved ventrally, and away from the brachial valve.

The folding of the shell in *Terebrirostra* is peculiar. In young forms of *T. lyra* the anterior commissure is slightly sulcate, but the sulcation of the brachial valve is not met by a corresponding fold in the pedicle valve. Such a condition is described as non-intertext by BUCKMAN (1917, p. 80). In the adult shell the anterior portion of the brachial valve becomes medianly depressed, and a shallow median sulcus is developed in the pedicle valve. The anterior commissure is now plane, and the folding of the shell approaches the ligate stage (BUCKMAN, 1917, p. 79), but the lateral carinæ do not extend up the shell.

Terebrirostra neocomiensis D'ORBIGNY (1850a, p. 127), has a shorter umbo than *T. lyra*, and has no dental lamellæ in the pedicle valve. The shell is dorsally uniplicate, and the ornament consists of fine thread-like costæ unlike that of *T. lyra*. From the external characters and folding of the shell as well as from the absence of dental lamellæ, this species appears to be allied to *Terebratulina* and is certainly not to be identified as a *Terebrirostra.*

Owing to lack of specimens of *T. lyra* from the Cenomanian, and also to the poor state of preservation of the interior of the shell of this species, it was necessary to dissect out the loop of adult specimens of *T. incurvirostrum* LAMPLUGH and WALKER (1903), from the Cretaceous, ? Albian of Shenley Hill, Leighton Buzzard. Attempts to dissect out the loop of *T. lyra* from the Cenomanian of Warminster were usually unsuccessful owing to the partial silicification of the interior of the shell. The cardinal process and hinge-plate of *T. incurvirostrum* are less advanced than those of *T. lyra,* and probably indicate an earlier age than the Cenomanian for the Shenley Hill deposits.

The remarkable elongation of the beak in the pedicle valve of *Terebrirostra* is paralleled to some extent in other genera of the Terebratulacea, and appears to be a trend in development, which is seen in species of Terebratulids in the Upper Jurassic, in ? *Terebratulina* in the Neocomian, in *Terebratella* in the Aptian, and in ? *Trigonosemus* in the Upper Chalk. This elongation of the umbo was probably favourable at first to the growth of the animal, but was finally carried to such an exaggerated pitch as to cause the extinction of the genus.

JAKOVLEV (1908, p. 31) discussed the length of the cardinal area in the genera *Terebratella, Trigonosemus,* and *Terebrirostra,* as well as that of Permo-Carboniferous genera of the Donez-Basin, and suggested that the high area was due to rapid accumulation of sediment.

V. CLASSIFICATION.

Until more research on the lines already described has been carried out on the Mesozoic Telotremata it is not proposed to put forward any new classification of the genera into families and subfamilies. When the external morphology, as well as the internal structure of these Mesozoic species, has been thoroughly studied it should be possible to outline trends, to build up lineages and so to construct some rational system of classification. Division of the genera into families and subfamilies will probably be based on internal characters, such as the form of the loop, and its developmental stages, and the form of the cardinalia. The genera will be defined by internal as well as external characters, and the species mainly by external shape, folding, and ornament.

In the genera specially investigated, the most important diagnostic internal characters were found to be those of the brachial valve. The form of the hinge-plates and cardinal process (cardinalia), size of the umbonal cavity, development of the septalium, size and shape of the hinge-sockets and angle of insertion of teeth, and additional articulation of denticula and socket-ridges, form of the loop, and position of crural bases are all characters which have been found to vary more or less in different genera, but which are fairly constant for one genus. The hinge-plate is found to vary less in form in successive growth-stages than the cardinal process and loop. The frequent asymmetry of the loop owing to injury during the life of the animal, or other causes, renders any classification relying on this character alone unsatisfactory. The median septum, or septum and fused septalial plates, is found to be variable in dorso-ventral height, but to be fairly constant in antero-posterior length in related species.

In the pedicle valve the dental lamellæ vary considerably in development not only in successive growth-stages of one specimen, but also the two lamellæ of one specimen may be unevenly developed. In the gerontic stage the lamellæ may either become embedded in thick deposits of callus, and therefore appear to be obsolete, as in *Ornithella*, or they may become more strongly developed than in the young specimens, or they may disappear entirely. For these reasons the dental lamellæ are not of much diagnostic importance.

The significance of the development of the pedicle-collar and its supporting septum is not at present known. This structure, without supporting septum, appears to be developed in many of the Jurassic Rhynchonellids and Terebratulids, and in *Obovothyris* and *Digonella* is accompanied by a supporting septum. It is interesting that this structure is found in many Recent Terebratulids and Rhynchonellids, but is not developed in most of the Recent Dallininæ and Magellaniinæ, although usually present in the less advanced long-looped genera.

In the external morphology, the folding of the shell and the ornament in successive growth-stages and the beak characters are found to be important diagnostic characters.

Each character evolves separately and at a different rate, so that it is necessary to take this into consideration in the diagnosis of genera. The present piece of research has emphasized the importance of not relying on a single character, but of diagnosing genera on the internal and external characters collectively.

The metamorphoses of the loop in successive growth-stages by resorption and redeposition have been worked out in Recent and Tertiary species by FRIELE (1877), DESLONGCHAMPS (1884), BEECHER (1893a-c), THOMSON (1927), FISCHER and OEHLERT (1892), and others. Although it is not likely that the Terebratulid loop undergoes a series of remarkable developmental changes similar to those of the Terebratellid loop, there is no doubt that its form must vary with the growth of the shell, and any classification based on the form of the loop must take this factor into consideration.

The primitive centronellid loop, consisting of two short descending lamellæ united in a triangular median plate in the Devonian Terebratulid genus, *Centronella*, forms the early growth-stage of the loop of the more advanced Palæozoic Terebratulid genus, *Dielasma* (WATSON, 1909), and probably occurs in young specimens of all Mesozoic Terebratulids. In the Recent Terebratulid genus, *Gryphus*, no mention of the centronellid stage is made by DESLONGCHAMPS (1884, p. 194), who describes the growth of the loop as a continuous development. In *Liothyrina* [*Gryphus*] *vitrea*, he found that it originated as short crural processes given off from the hinge-plate. The crural processes gradually elongated, and formed not only crura, which converged towards the median line, but also the two branches of the loop, which grew anteriorly, recurved upwards, and finally became united. This is confirmed by THOMSON (1927), who states that the

Centronella stage is lost by tachygenesis. The centronellid loop is present also as an early stage of growth of the spiralia of some Spiriferidæ and is described by BEECHER and SCHUCHERT (1893) in the primitive Palæozoic genus *Zygospira*. In Recent species of *Terebratulina* the development of the loop is similar, as shown by MORSE (1871, a and b), but the crura unite in the adult stage to form a complete ring.

It is not known at present if the centronellid stage occurs in the immature stages of loop development of the Ornithellids. There is no evidence that the ornithellid loop was attached to the septum in the young stage, although traces of connecting bands were seen in *Digonella digona*, or that it ever passed through the complicated series of metamorphoses that are known to occur in the Dallininæ and Magellaniinæ. It is possible that the ornithellid loop may be derived from the Palæozoic long-looped genera, such as *Cryptacanthia* or *Harttina*, in which the loop is not joined to the septum. Further research on the long-looped genera is being undertaken by the author, and it is hoped to throw light on some of these doubtful points.

At least five distinct series of long-looped forms with dorsal septa are represented in the Mesozoic rocks :—(1) with ornithelliform loops ; (2) with ismeniform loops ; (3) with magadiform loops ; (4) with terebratelliform loops ; (5) with terebrirostriform loops. Group (5) differs from group (4) in having the loop attached to the septum in the early growth-stages only and also in having different cardinalia. Forms with ismeniform loops have been described from the Jurassic by MOORE (1860, 1863) in *Terebratella* [*Hamptonina*] *buckmani*, and by ZITTEL (1870) in *Megerlea* [*Trigonellina*] *pectunculus* and other species. The adult loops of these forms resemble the early growth-stages of the loop of the Recent Dallininæ. *Magas*, in section 3, has a loop somewhat resembling that of young stages of Recent Magellaniinæ. The relationship of fossil Terebratellas to the Recent genus is not clear. MEYER (1868, p. 269), who examined the loop of *Terebratella menardi* from the Cenomanian, stated that it was attached to the septum even in young forms, and he did not describe any change in the form of the immature loop.

Many schemes for the classification of the Terebratulids, Terebratellids, and Rhynchonellids into families and subfamilies have been outlined by successive workers on the Brachiopods, usually without any regard for the work of previous authors. Some of these classifications, such as that of VON BUCH (1834), QUENSTEDT (1871), ROTHPLETZ (1886), and BUCKMAN (1917), are based entirely on the shape and folding of the shell and on the shell ornament. BUCKMAN's four divisions are :—I. Læves, II. Capillatæ, III. Rugosæ, IV. Ornatæ. It has already been shown by SAHNI that " Læves " include genera with entirely different lengths of loop which probably indicate different phylogenetic development. The " Capillatæ " include the genera *Terebratulina*, *Disculina*, *Trichothyris*, and *Holcothyris*, all four of which are capillate but are totally unrelated in their internal characters. It is doubtful also if the " Rugosæ " and " Ornatæ " should be separated from one another or from the " Capillatæ." BUCKMAN criticizes the classification of ROTHPLETZ and DOUVILLÉ as being artificial, but his own system possesses all the defects of those earlier workers.

Among classifications relying mainly on internal characters may be mentioned that of KING (1850), DAVIDSON (1853), DOUVILLÉ (1880), DALL (1870–1871), and BEECHER (1893*a*).

SCHUCHERT modified BEECHER's classification in 1913 and again in 1929. In the latter publication the sub-family Zeilleriinæ is introduced to include *Zeilleria, Ornithella,* etc. The name Zeilleriinæ is attributed by SCHUCHERT and LE VENE to ROLLIER (1919). The latter author, however, proposed the family Zeillérides to replace the Waldheimiidæ of DOUVILLÉ and included in it all Jurassic long-looped genera. The name Zeilleriinæ should therefore be correctly attributed to SCHUCHERT and LE VENE. Among genera with ornithelliform loops are included forms with ismeniform and terebratelliform loops which are obviously unrelated, and should be removed from the Zeilleriinæ to the Dallininæ or Magellaniinæ. *Obovothyris* and *Cincta,* which have ornithelliform loops, are placed by SCHUCHERT and LE VENE in the Dallininæ, where they obviously cannot belong. A considerable amount of rearrangement of the genera will have to be made in SCHUCHERT and LE VENE's classification before it can be adopted.

The Mesozoic, Tertiary, and Recent Terebratulids are left undivided in the subfamily Terebratulinæ by these authors with the exception of *Pseudoglossothyris, Tegulithyris,* and *Avonothyris* which are placed in the Nucleatinæ, presumably on account of the sulcation of the brachial valve. Examination of the species at present grouped together in *Pseudoglossothyris* shows, however, that we are dealing with a number of unrelated homœomorphous forms which will, no doubt, prove to be sulcate relations of various plano-convex or biconvex genera of the Terebratulinæ.

An improved classification based on BEECHER's work was proposed by THOMSON (1927) for the Tertiary and Recent forms. It introduces a number of new characters not previously used in any classification, and it should form a useful basis for the classification of Mesozoic genera.

A brief outline of the history of the classification of the Rhynchonellidæ was given by WIŚNIEWSKA (1932), and need not therefore be repeated here. Reference, however, should be made to the tentative classification by ROTHPLETZ (1886, p. 86) by means of the form of the crura in Mesozoic species which are described as (*a*) radulifer ; (*b*) falcifer ; (*c*) septifer. A fourth type (*d*) is described by WIŚNIEWSKA as arcuifer, and a fifth type (*e*) by the author in *Kallirhynchia* as calcarifer. LEIDHOLD (1920) also describes what appears to be another distinct type in his genus *Thurmanella* from the Upper Jurassic.

VI. SUMMARY.

(1) In this paper attention has been drawn to the importance of the question of homœomorphy in Brachiopoda due to parallel development. In consequence of this a careful examination of internal as well as of external characters is essential for the determination of genera and species.

(2) Seven common Mesozoic species, six of which are the genotypes of previously described genera, have been selected for detailed examination, and their little known internal structure has been studied. This investigation has been by means of longitudinal and transverse sections, internal casts, and dissected specimens.

(3) It is found that by heating the specimens before sectioning or dissecting, the internal plates and brachial loop appear white against a dark matrix, and can be accurately drawn or photographed.

(4) Reconstructions have been made from the transverse and longitudinal sections of the interior of the brachial valve of *Kallirhynchia yaxleyensis*, *Lobothyris punctata*, *Plectoidothyris polyplecta*, *Ornithella ornithocephala*, *Obovothyris magnobovata*, and *Digonella digona* from the Jurassic, and of *Terebrirostra, incurvirostrum* from the Cretaceous.

(5) Much new information regarding the internal morphology of these genera has thus been obtained, and the previously unknown structures "accessory socket," "denticulum," "denticular cavity," and "septalial plate," are defined.

(6) The cardinalia and articulatory processes of the two valves in these genera have been described in detail, and illustrated by means of enlarged diagrams.

(7) The complete loop seen in dorso-ventral view and in contour has been dissected out in each of the seven species, and the minute spines springing from one edge of the loop of *Ornithella*, *Digonella*, *Obovothyris*, and *Terebrirostra*, have been investigated.

(8) The median septum in *Ornithella*, *Obovothyris*, and *Digonella* has been found to be composed of, (*a*) a short septum, (the true septum) springing from the floor of the brachial valve; (*b*) two plates (septalial plates) fused together dorsally to form a septum, but diverging from one another ventrally and uniting with the hinge-plates. The apex of the true septum is inserted within the dorsal end of the fused septalial plates.

(9) Growth-stages in the development of the brachial loop, due to resorption and redeposition, have been observed in specimens of *Terebrirostra incurvirostrum*, and also in the "calcarifer" crura of *Kallirhynchia yaxleyensis*.

(10) Five unrelated groups of long-looped Brachiopods are now known from the Mesozoic, some of which are ancestral forms of Recent species.

(11) The emended diagnoses of the above-mentioned six genera and the diagnosis of *Digonella* gen. n., are based on the internal and external characters collectively. The diagnostic importance of the internal characters of the brachial valve has been emphasized.

(12) A brief résumé has been given of modern methods employed in the investigation of Brachiopod shells, and of the defects of former classifications based only on external characters or on single internal characters.

Work on the lines described in this paper should make it possible to outline trends, to build up lineages, and to construct a natural system of classification.

IX.—Index of Genera, Species, and Families.

INDEX OF INTERNAL CHARACTERS.

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IX.—EXPLANATION OF PLATES.

(All specimens of natural size unless otherwise stated.)

PLATE 62.

FIG. 15, *a*.—*Kallirhynchia yaxleyensis* (DAVIDSON). Holotype. Dorsal view. Lower Cornbrash. Yaxley, Peterborough. [B. 82289.]

FIG. 15, *b*.—Ditto, lateral view of the same specimen.

FIG. 15, *c*.—Ditto, anterior view of same specimen.

FIG. 16.—Ditto, internal cast of pedicle valve showing adductor, diductor, and pedicle muscle-scars and dental lamellæ. Same horizon and locality. [B. 82299.]

FIG. 17.—Ditto, internal cast of brachial valve showing adductor muscle-scars. Same horizon and locality [B. 82298.]

FIG. 18, *a*.—*Digonella digona* (J. SOWERBY). Internal cast of brachial valve showing adductor muscle-scars and slit representing median septum. Bradford Clay, Bradford-on-Avon, Wilts. [B. 84527.]

FIG. 18, *b*.—Ditto, internal cast of pedicle valve of same specimen showing posteriorly situated muscle-scars.

FIG. 19, *a*.—Ditto, dorsal view of lectotype. Same horizon, and ? same locality. [B. 71586.]

FIG. 19, *b*.—Ditto, lateral view of same specimen.

FIG. 20.—*Terebrirostra incurvirostrum* LAMPLUGH & WALKER. Internal cast of brachial valve showing muscle-scars. Cretaceous, ? Albian, Shenley Hill, Leighton Buzzard, Bedfordshire. [B. 82256.] × 2.

FIG. 21, *a*.—*Terebrirostra lyra* (J. SOWERBY). Anterior view of topotype. Cenomanian, Horningsham, Warminster, Wilts. [B. 84525.]

FIG. 21, *b*.—Ditto, lateral view of same specimen.

FIG. 21, *c*.—Ditto, dorsal view of same specimen showing length of pedicle umbo.

FIG. 22, *a*.—*Ornithella ornithocephala* (J. SOWERBY). Lectotype. Dorsal view. Lower Cornbrash, Chatley, Somerset. [B. 49540.]

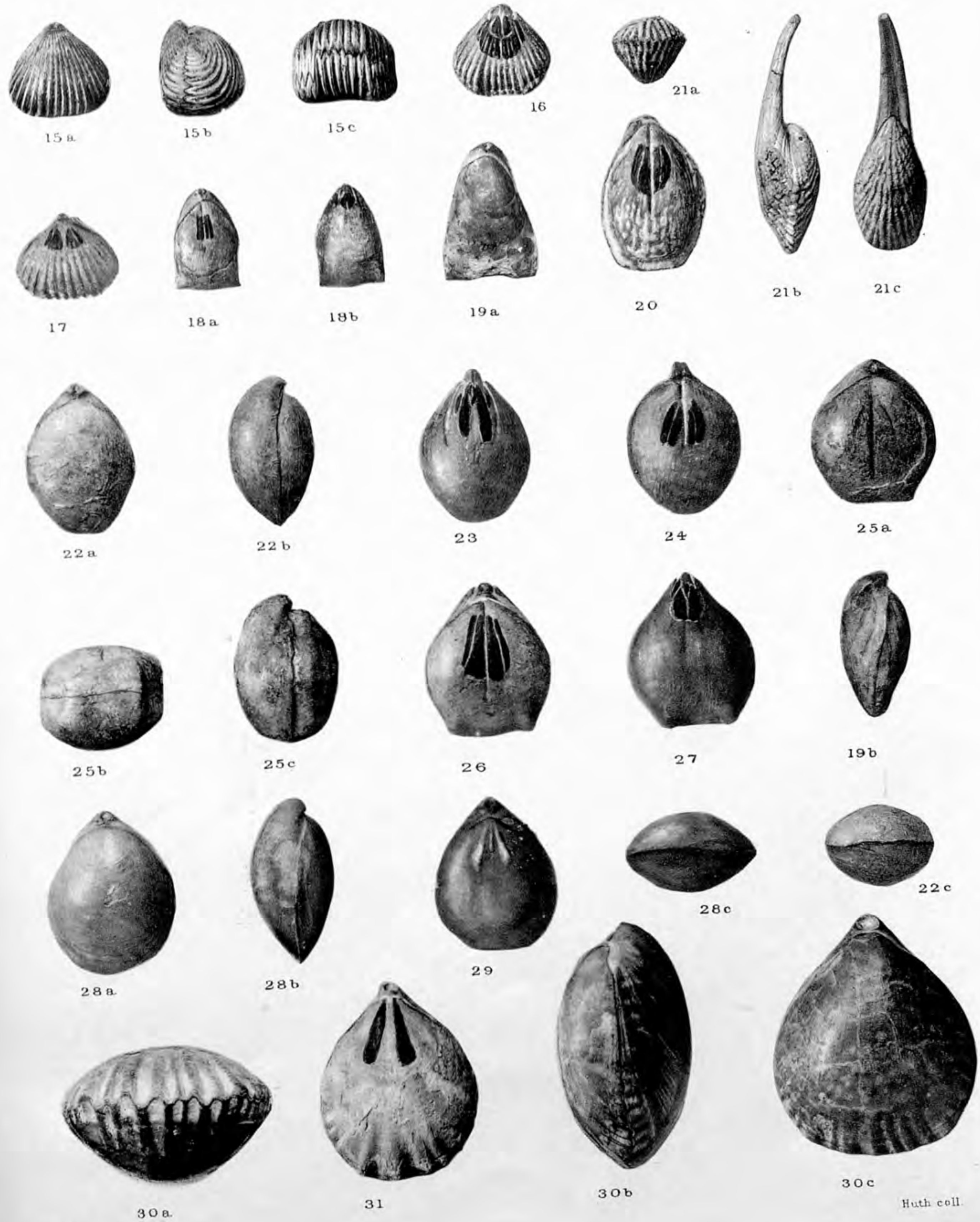
FIG. 22, *b*.—Ditto, lateral view of same specimen.

FIG. 22, *c*.—Ditto, anterior view of same specimen.

FIG. 23.—*Ornithella bathonica* ROLLIER. Internal cast of pedicle valve showing adductor, diductor, and pedicle muscle-scars. Fullers Earth Rock, Box Tunnel, Wilts. [B. 84526.]

Muir-Wood

Phil. Trans. B, vol. 223, Pl. 62.



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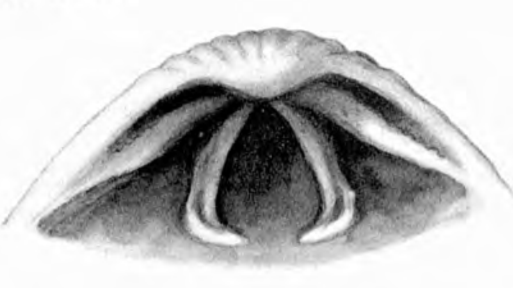

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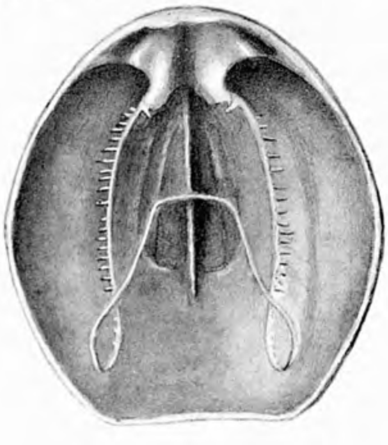

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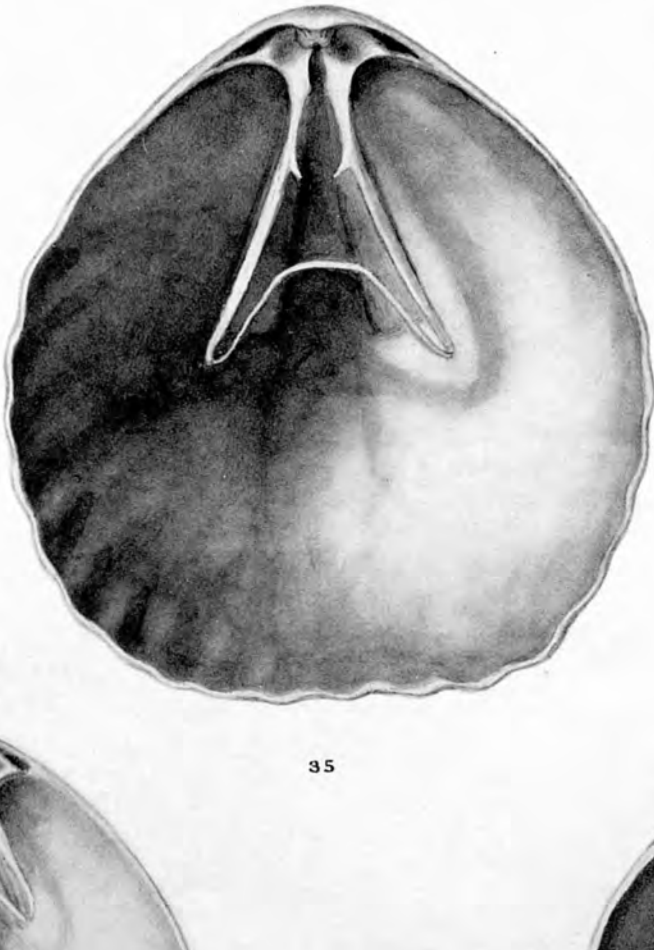

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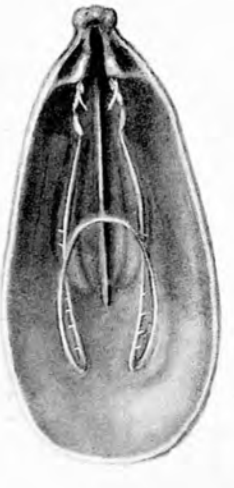

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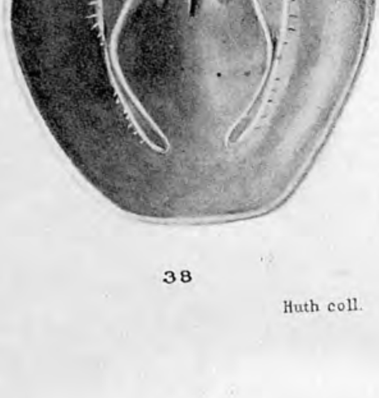

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Huth coll.

FIG. 24.—*Ornithella bathonica* ROLLIER. Internal cast of brachial valve showing adductor muscle-scars and slit representing median septum. Same horizon and locality. [B. 84529.]

FIG. 25, *a*.—*Obovothyris magnobovata* S. S. BUCKMAN. Holotype. Naturally formed internal cast of brachial valve showing trace of muscle-scars. Lower Cornbrash, Blackthorn Hill, Bicester. [B. 58321.]

FIG. 25, *b*.—Ditto, anterior view of same specimen.

FIG, 25, *c*.—Ditto, lateral view of same specimen.

FIG. 26.—Ditto, internal cast of brachial valve. Lower Cornbrash, Rushden, Northants. [B. 84530.]

FIG. 27.—Ditto, internal cast of pedicle valve. Lower Cornbrash, Rushden, Northants. [B. 84523.]

FIG. 28, *a*.—*Lobothyris punctata* (J. SOWERBY). Lectotype. Dorsal view. Middle Lias, Hornton, Oxon. [B. 61522.]

FIG. 28, *b*.—Ditto, lateral view of same specimen.

FIG. 28, *c*.—Ditto, anterior view of same specimen.

FIG. 29.—Ditto, internal cast of brachial valve showing adductor muscle-scars. Middle Lias, Tilton, Leicestershire. [B. 84524.]

FIG. 30, *a*.—*Plectoidothyris polyplecta* (S. S. BUCKMAN). Topotype. Anterior view. Inferior Oolite, Oolite Marl. Railway cutting, Notgrove Stn., Glos. [B. 47184.]

FIG. 30, *b*.—Ditto, lateral view of same specimen.

FIG. 30, *c*.—Ditto, dorsal view of same specimen.

FIG. 31.—Ditto, internal cast of brachial valve showing adductor muscle-scars. Same horizon and locality. [B. 84528.]

PLATE 63.

FIG. 32.—*Kallirhynchia yaxleyensis* (DAVIDSON). Reconstruction of posterior portion of interior of brachial valve from dissected specimens showing the upper surface of curved calcarifer crura, and hinge sockets. $\times$ 5.

FIG. 33.—*Obovothyris magnobovata* S. S. BUCKMAN. Reconstruction of interior of brachial valve from dissected specimens and transverse sections showing the fused hinge-plates and septalium, hinge-sockets, inner and outer socket-ridges, median septum and complete loop with spines on the descending branches. $\times 2\frac{1}{2}$.

FIG. 34.—*Digonella digona* (J. SOWERBY). Reconstruction of interior of brachial valve from dissected specimens and transverse sections showing the fused hinge-plates, shallow septalium, hinge-sockets, socket-ridges, and complete loop with long spines on the descending branches. $\times 2\frac{1}{2}$.

FIG. 35.—*Plectoidothyris polyplecta* (S. S. BUCKMAN). Reconstruction of interior of brachial valve from dissected specimens and transverse sections showing the incurved umbo, cardinal process, divided hinge-plates and long loop. $\times 2\frac{1}{2}$.

FIG. 36.—*Terebrirostra incurvirostrum* LAMPLUGH & WALKER. Reconstruction of interior of brachial valve from dissected specimens showing the prominent cardinal process and divided hinge-plates, hinge-sockets, median septum, and complete loop with spines on the descending branches. $\times 2\frac{1}{2}$.

FIG. 37.—*Lobothyris punctata* (J. SOWERBY). Reconstruction of interior of brachial valve from dissected specimens and transverse sections showing the small cardinal process, divided hinge-plates, and short loop. $\times 2\frac{1}{2}$.

FIG. 38.—*Ornithella ornithocephala* (J. SOWERBY). Reconstruction of interior of brachial valve from a dissected specimen showing slightly incurved umbo, fused hinge-plates, deep septalium, hinge sockets, hinge-plates, median septum and complete loop with short spines on descending branches. $\times 2\frac{1}{2}$.

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Notes on the Silurian Brachiopod Genera Delthyris, Uncinulina, *and* Meristina. By Helen M. Muir-Wood, M.Sc., F.G.S.

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Summary.

In this paper the different interpretations of the genus *Delthyris* are discussed, and that given by Schuchert in 1913 is adopted with slight amendment. The species *Delthyris elevata*, *D. crispa*, *D. elegans* (nom. nov. for *D. crispa*, Hisinger, non Linnæus), and *D. tenuilamellata*, sp. n., from the British Silurian, are all described and figured.

The distinguishing characters of the genera *Uncinulus* and *Uncinulina* are pointed out, and *Uncinulina* is retained with *U. fallaciosa* as genotype. *Rhynchonella stricklandi* and *Terebratula lewisi* are transferred to the genus *Uncinulina*. *Meristina tumida* (Dalman) is shown to be a synonym of *Meristina obtusa* (Sowerby).

The British Silurian Spirifers can be separated into two groups:—(1) those with longitudinal folds and a transverse ornament of imbricating lamellæ (=*Delthyris* of Dalman) and (2) those with longitudinal folds bearing fine continuous longitudinal striæ (=*Eospirifer* of Schuchert).

The species referable to both these genera have as a rule been assigned to the genus *Spirifer*, from which, however, they differ in internal characters.

Delthyris, Dalman, 1828.

Genolectotype: *D. elevata*. (See Schuchert *.)

The genus *Delthyris* was first described by Dalman in 1828 † to include the species *D. elevata*, *cyrtæna*, *crispa*, *subsulcata*, *ptychodes*, and *cardiospermiformis*. Of these species *Delthyris cyrtæna* is *Eospirifer plicatellus* (Linnæus) and *D. cardiospermiformis* is *Bilobites biloba* (Linnæus); nor is *D. ptychodes* a Spirifer. The original description, therefore, included a variety of generic forms, and the generic characters other than those of shape and external ornament were not very precisely defined. This at once caused confusion, for Menke in 1830 ‡, although quoting *Delthyris*,

* Bull. U.S. Geol. Surv. lxxxvii. p. 206 (1897).
† Kongl. Svenska Vet.-Akad. Handl. for 1827, p. 93.
‡ 'Synopsis methodica Molluscorum,' ed. ii. p. 96.

Dalman, as including *Spirifer* of Sowerby and *Trigonotreta* of Koenig, yet gives as species of *Delthyris*, *Anomia dorsata* and *Terebratula spatula*, of which *Anomia dorsata* belongs to the genus *Terebratella* and *Terebratula spatula* to *Terebratulina*. Von Buch in 1836* included in *Delthyris* species of *Spirifer* and *Orthis*, which had a triangular foramen.

Among other authors Dall † quoted *Delthyris* as a synonym of *Spirifer*, and it was not until Hall ‡ published his great work on the Brachiopoda in 1894 that the distinctive characters of *Delthyris* were recognized. Of Hall's subdivisions of the genus *Spirifer* the group of Fimbriati Unicispinei is taken to be equivalent to *Delthyris*, s. s. Hall states also that the distinguishing character of this group lies in the ornament of the concentric fimbriæ—namely, short simple spines,—and that it includes the species *Delthyris crispa* and *D. elevata*. The group is said not to extend above the Devonian. On another page of the same work Hall shows how *Reticularia* differs from *Delthyris* in its fimbriæ, which have large spines with lateral branches. *Spirifer sulcatus*, Hisinger, is placed in the Lamellosi Septati, a group which has concentric lamellæ covered with fine radiating striæ, but with no spines, is not punctate, and does not have the primary lamellæ of the spiral arms united as in the Spiriferinas. A probable passage of the Septati into the punctate genus *Spiriferina* is suggested. Both these groups are said to have a median septum in the pedicle-valve. From Hall's description it would appear that there are three groups of impunctate lamellose Spirifers, distinguished only by the character of the ornament of the concentric lamellæ, which in the case of *Delthyris* is said to be composed of short spines.

A more precise and very different interpretation of the genus *Delthyris* was given by Schuchert in 1913 §. In 1897 ‖ he selected the species *Delthyris elevata* as the genotype of *Delthyris*, stating that all specimens examined by him possessed a median septum in the pedicle-valve. *Delthyris sulcata*, Hisinger, was also quoted as a true *Delthyris*, but *D. crispa*, Hisinger, was placed in the genus *Spirifer*.

Schuchert describes *Delthyris* as a subgenus of *Spirifer*,

* "Ueber *Delthyris* oder *Spirifer* und *Orthis*," Abh. K. Akad. Wiss. Berlin, p. 11.

† Bull. U.S. Nat. Mus. viii. p. 25 (1877).

‡ 'Palæontology of New York,' vol. viii. pt. 2, pp. 9 & 16.

§ Zittel-Eastman, 'Text-book of Palæontology,' p. 411.

‖ Bull. U.S. Geol. Surv. lxxxvii. pp. 206 & 386 (1897).

consisting of "small early *Spirifers* that are coarsely plicate, except on fold and sinus. Surface lamellose, the imbricating lamellæ marked with very fine radiating striæ, which do not terminate in spines. Short dental lamellæ present along with a more or less high ventral median septum. Resembles *Spiriferina*, but the shell structure is not finely and regularly punctate. Section Lamellosi-Septati Hall & Clarke." The description of the ornament of the lamellæ given by Schuchert will be seen to be exactly the reverse of that given by Hall. H. S. Williams *, in a discussion on *Delthyris elevata* and allied species, quotes the absence of a median septum in specimens having a groove along the median fold of the brachial valve. He describes two species, *Spirifer trescotti* and *Spirifer cobscooki* from the Silurian of Maine, both similar externally to *Spirifer elevatus* of Dalman, but *Spirifer trescotti* like *S. elevatus* has a median septum developed in the pedicle-valve, while *S. cobscooki* has none.

The development, however, of a median septum in the pedicle-valve does not appear to be constant, even for one species. Investigation of the species *D. crispa*, Linnæus, and *D. elegans*, nom. nov. = *D. crispa*, Hisinger (non Linnæus), showed that the median septum was usually absent, but occurred in an incipient state of development in one or two specimens of *D. elegans*. The contention that there is no median septum in forms which have a median groove along the central fold of the brachial valve does not appear to hold in the case of *Delthyris elevata*, which certainly has a median septum in those individuals whose brachial valves possess a grooved fold. The presence of a median septum in the pedicle-valve does not appear to be of great generic importance in the Silurian species of *Delthyris*, although, according to American authors, it appears to be a more constant feature in Devonian species.

While the lamellæ of *Delthyris elevata*, *crispa*, *elegans*, and *tenuilamellata* are ornamented with granules or longitudinal striæ, those of *Reticularia* and well-preserved specimens of *Spiriferina* have a true spinose ornament. *Spiriferina*, however, usually has smooth lamellæ, which are abundantly punctate. The genus *Tylothyris*, North †, from the Lower Carboniferous limestone, is distinguished by that author from *Delthyris* by its greater size, by its smaller and more numerous costæ, and by the marked development of an

* Proc. U.S. Nat. Mus. Washington, vol. li. p. 75 (1917).

† North, Quart. Journ. Geol. Soc. vol. lxxvi. p. 195 (1920).

apical callosity. Its shell, like that of *Delthyris*, is impunctate, but there is apparently no ornament on the lamellæ. It is possible that some of the species from the Upper Devonian and Lower Carboniferous that have been assigned to the genus *Delthyris* should be more correctly placed in the genus *Tylothyris*. In a group of impunctate lamellose Spirifers which Weller * describes from the Carboniferous beds of Illinois a median septum is present in the pedicle-valve, but the lamellæ in one of the species are said to be fimbriate, while in the remaining species, apparently, the lamellæ are not ornamented. It is doubtful, therefore, whether these species belong to *Delthyris* or whether they should be placed in *Tylothyris*.

A modification of the internal structure of the pedicle-valve is described by Dunbar † in his species *Delthyris cyrtinoides* from the Devonian. The dental plates converge and unite with the median septum, which is continued posteriorly into the cavity formed by union of the dental plates—an example of parallelism with the corresponding structure in *Cyrtina*.

There appears to be no reason for the generic separation of *Delthyris crispa*, Hisinger (non Linnæus), here renamed *D. elegans*, from the species *D. elevata* and *D. sulcata*, though the last two species were described by Schuchert as true *Delthyris*, while he included *D. crispa*, Hisinger, in *Spirifer*.

Additional generic characters in *Delthyris* are afforded by the spirals, which consist of seven coils and have their apices directed towards the cardinal angles.

Delthyris elevata, Dalman ‡. (Figs. 7, 8, 8 *a*.)

Genotype of *Delthyris*, see Schuchert (Bull. U.S. Geol. Survey, lxxxvii. (1897), p. 206).

Description.—Width approximately equal to the length, with the widest part of the shell occurring at a point slightly below the hinge. Both valves highly convex. Apical angle 100°. Cardinal angles rounded. Area of pedicle-valve high, its length considerably shorter than that of the hinge. Delthyrium large and open, bordered by linear deltidial plates. Umbo rounded, much incurved. Ornament in the pedicle-valve consists of five rounded costæ on each side of the sinus, while in the brachial valve there

* Illinois Geol. Surv. Mon. i., Text. Mississippian Brachiopoda, p. 300 (1914).

† Trans. Connecticut Acad. xxiii. p. 138 (1920).

‡ Dalman, 1828, Vet.-Akad. Handl. p. 120, pl. iii. fig. 3.

are five costæ on each side of the broad median fold which is frequently longitudinally grooved. The width of the sulci separating the costæ is approximately half that of the costæ. Crossing the costæ there are very numerous concentric growth-lamellæ, along each of which are set numerous slightly elongated granules, the interspaces between the granules being less wide than the width of each granule.

Interior of the pedicle-valve with median septum developed.

Average Dimensions.—Length 18 mm.; width 21 mm.; thickness 16 mm., or 1 : 1·1 : ·8.

Type-specimen.—The specimen figured and described by Dalman from Gothland is hereby selected as the holotype.

Horizons.—Upper Llandovery–Upper Ludlow Beds.

Delthyris crispa (Linnæus). (Figs. 1, 2, 2 *a*.)

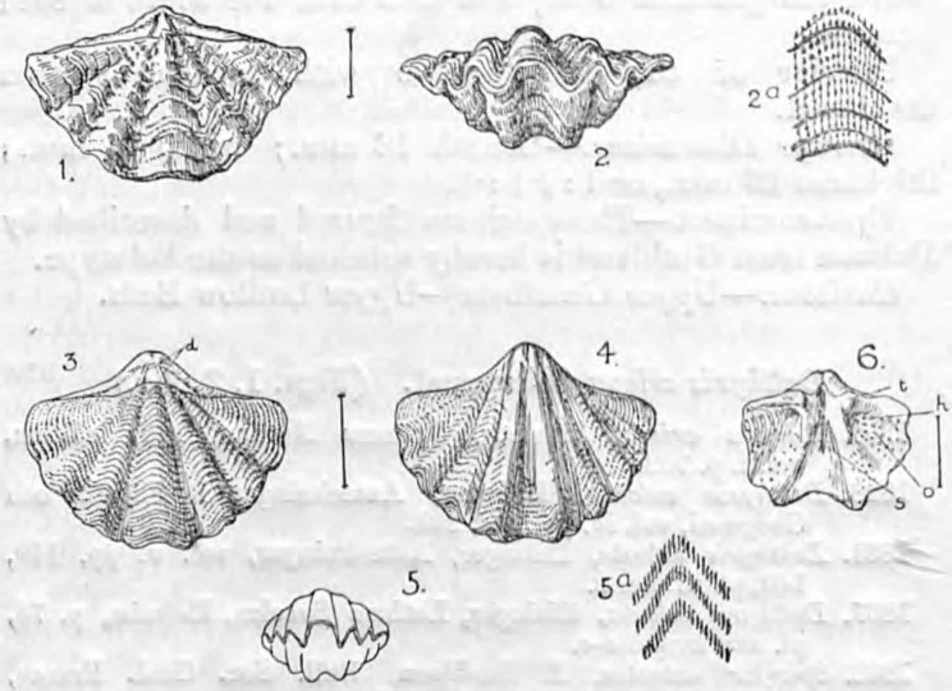
1758. *Anomia crispa*, Linnæus, Systema Naturæ, 10th edition, vol. i. p. 702.
1828. *Delthyris sulcata*, Hisinger, Anteckningar i Physik och Geognosi, vol. iv. pp. 228, 238.
1831. *Delthyris sulcata*, Hisinger, Anteckningar, vol. v. pp. 119, 140, pl. iii. fig. 2.
1837. *Delthyris sulcata*, Hisinger, Lethæa Svecica, Holmiæ, p. 73, pl. xxi. figs. 6 *a–c*.
1848. *Spirifer sulcatus*, T. Davidson, Bull. Soc. Géol. France, 2nd ser. vol. v. pl. iii. fig. 41, p. 325.
1860. *Spirifer sulcatus*, Lindström, Öfv. k. Vet.-Akad. Forhand. xvii. no. 8, p. 359.
1866. *Spirifera sulcata*, T. Davidson, Mon. Brit. Foss. Brach. vol. iii. part i. pl. x. figs. 4, 5, 12, p. 91.
1882. *Spirifera crispa*, T. Davidson, Mon. Brit. Foss. Brach., Suppl. vol. v. pl. iv. figs. 9, 10.

Description.—Laterally elongated, with the hinge-line forming the widest part of the shell. Pedicle-valve more convex than the brachial valve. Apical angle 134°. Cardinal extremities angular. Pedicle-valve with concave area extending along whole length of hinge. Delthyrium open, with linear deltidial plates. Umbo acute, slightly incurved.

In the pedicle-valve there are three rounded longitudinal costæ on each side of the median sinus, while in the brachial valve there are six costæ in addition to the broad median fold. Crossing the costæ there are from 10–15 prominent imbricating lamellæ less than 0·75 mm. apart. The microscopic ornament consists of small granulations arranged in rows along fine longitudinal striæ; the granulations are also seen to form less regular concentric rows. The ornament is interrupted by the transverse lamellæ. Interior of pedicle-valve usually without a median septum.

Average Dimensions.—Length 7 mm.; width 11 mm.; thickness 4·5 mm., or 1 : 1·5 : ·6.

Type-specimen.—The specimen figured in Museum Tessinianum, 1753, tab. v. fig. 7, and referred to by Linnæus in



Figs. 1, 2, 2 *a*. *Delthyris crispa* (Linnæus) from the Wenlock Limestone, Dudley. British Museum Geol. Dept. B. 44,916. 1. Brachial valve showing ornament (× 2½). 2. Anterior view showing angular cardinal extremities (× 2½). 2 *a*. Ornament under microscope (× 10).

Figs. 3, 4, 5, 5 *a*, 6. *Delthyris elegans*, nom. nov., from Wenlock Limestone, Dudley. British Museum Geol. Dept. B. 44,917. 3. Brachial valve showing ornament, *d*=linear deltidial plates (× 2). 4. Pedicle-valve (× 2). 5. Anterior view showing rounded cardinal extremities (nat. size). 5 *a*. Ornament under microscope (× 10). 6. Interior of pedicle-valve showing low median septum (from Wenlock Limestone, Dudley. British Museum Geol. Dept. B. 44,919); median septum (*s*), hinge-teeth (*t*), dental plates (*h*), and ovarian markings (*o*) (× 2).

'Systema Naturæ' in 1758, is hereby selected as holotype. No horizon or locality is given in the description.

Horizon.—Wenlock Limestone and Shale.

Delthyris crispa was described by Linnæus as *Anomia crispa* in 'Systema Naturæ' in 1758. A brief description is given, and reference is made to Museum Tessinianum, 1753, where Linnæus described and figured this species as *Concha Anomia dilatata.*

The specimen figured is a laterally elongated form, having the greatest width along the hinge-line, with angular cardinal extremities, a broad median fold in the brachial valve and a corresponding sinus in the ventral valve. On either side of the fold and sinus are three rounded costæ. A transverse ornament of imbricating lamellæ is well shown, the lamellæ being separated by an interspace of about 0·75 mm. This figure was reproduced by Davidson in 1866 (fig. 12), but the ornament was not clearly shown.

Hisinger in 1826 * figured without description *Terebratula* (*Anomia,* L.) *crispa* from the crinoidal limestone of Gothland. This species, unlike Linnæus' species, had rounded cardinal angles, and the greatest width of the shell occurred at a point below the hinge. The transverse lamellæ were not shown at all in the figure. A similar figure was given in 1828 † by Dalman, who described it as *Delthyris crispa* of Hisinger. In the same year Hisinger ‡ figured the same form, but ascribed the species to Dalman, stating in the same publication § three years later that the description given by Linnæus of *Anomia crispa* agreed with one given by himself of *Delthyris sulcata*, but that, since Dalman ‖, under the name of *crispa*, had described a different shell, which lacked the median rib, he was obliged to give the form which he was describing the new name of *sulcata*. He gives a good representation of *Delthyris crispa* of Linnæus in the same work. *Anomia crispa* of Linnæus is again quoted as a synonym of *Delthyris sulcata* by Hisinger in 1837 ¶. In spite of these statements by Hisinger, and that made by Lindström in 1860 **, about the similarity of *Anomia crispa* of Linnæus to *Delthyris sulcata* of Hisinger, the specific names *sulcata* and *crispa* of Hisinger have remained in general use to the present day. According to the rules of zoological nomenclature, therefore, *Delthyris*

* Vet.-Akad. Handl. tab. vii. fig. 4, p. 336 (1826).

† Vet.-Akad. Handl. p. 222, tab. iii. fig. 6 (1828).

‡ 'Anteckningar i Physik och Geognosi,' vol. iv. tab. vii. fig. 4 (1828).

§ Hisinger, *l. c.* vol. v. p. 119 (1831).

‖ As a matter of fact, Hisinger himself had already figured it (Vet.-Akad. Handl. tab. vii. fig. 4, 1826).

¶ 'Lethæa Svecica,' Holmiæ, pl. xxi. figs. 6 *a–c*, p. 73 (1837).

** "Bidrag till kännedomen om Gothlands Brachiopoder," Öfv. K. Vet.-Akad. Forhand. Stockholm, p. 359 (1860).

crispa (Linnæus) must be used for *Delthyris sulcata*, Hisinger; *Delthyris elegans*, nom. nov., may be used for *Delthyris crispa* (Hisinger).

Delthyris elegans, nom. nov. (Figs. 3, 4, 5, 5 *a*, 6.)

1826. *Terebratula crispa*, Hisinger, Vet.-Akad. Handl. tab. vii. fig. 4, p. 336.
1828. *Delthyris crispa*, Dalman, Vet.-Akad. Handl. for 1827, tab. iii. fig. 6, p. 222.
1828. *Delthyris crispa*, Hisinger, 'Anteckningar,' vol. iv. tab. vii. fig. 4, pp. 220, 238.
1836. *Spirifer crispus* (in part.), Von Buch, "Ueber *Delthyris* oder *Spirifer* und *Orthis*," Abh. K. Akad. Wiss. Berlin, p. 40.
1837. *Delthyris crispa*, Hisinger, 'Lethæa Svecica,' p. 73.
1839. *Spirifer crispus*?, J. de C. Sowerby in 'The Silurian System,' pt. ii. pl. xii. fig. 8, p. 624.
1848. *Spirifer crispus*, Davidson, Bull. Soc. Géol. France, 2nd ser. vol. v. pl. iii. fig. 42, p. 325.
1866. *Spirifer crispa*, Davidson, Mon. Brit. Foss. Brach. vol. iii. pt. vii. no. 1, pl. x. figs. 13, 14, 15, p. 97.

Description.—Wider than long, with the widest part of the shell occurring at a point slightly below the hinge. Brachial valve less convex than pedicle-valve. Apical angle 110°. Cardinal angles rounded. Area of pedicle-valve concave, extending only for two-thirds of the length of the hinge. Delthyrium open, bordered by linear deltidial plates. Umbo acute, incurved. Ornament in the pedicle-valve consists of four rounded longitudinal costæ on the lateral slopes on each side of the sinus, while in the brachial valve there are six costæ in addition to the median fold. The sulci separating the costæ are approximately equal in width to the costæ. Crossing these there are about thirty concentric lamellæ forming a regular transverse ornament. Under the microscope the lamellæ are seen to be striated longitudinally with fine somewhat irregular lines not passing from one lamella to the next, the interspaces being approximately equal in width to that occupied by the striæ.

Interior of pedicle-valve with small teeth supported by short dental plates, outside which are numerous rounded pits representing ovarian markings. A low median septum may be developed, but in many of the specimens examined was not present.

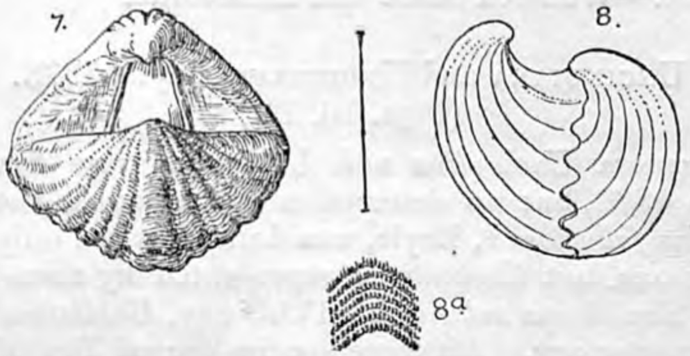
Average Dimensions.—Length 10 mm.; width 13 mm.; thickness 8 mm., or 1 : 1·3 : ·8.

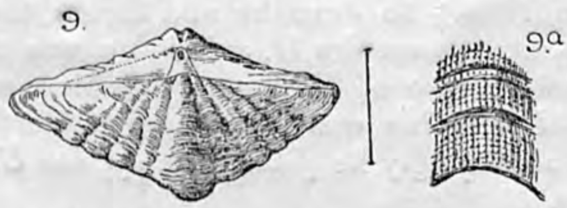
Type-specimen.—The specimen figured by Hisinger from the "Encrinit-kalksten of Djupviken," Gothland, is hereby selected as the holotype.

Horizon.—Upper Llandovery Beds. Wenlock Limestone and Shale and Aymestry Limestone.

Delthyris tenuilamellata, sp. n. (Figs. 9, 9 *a*.)

Description.—Outline transversely rhomboidal, with width of the shell approximately equal to twice the length. Valves equally convex. Apical angle 136°. Cardinal extremities angular. Pedicle-valve with a low area, whose





Figs. 7, 8, 8 *a*. *Delthyris elevata*, Dalman, from the Wenlock Limestone, Dudley. British Museum Geol. Dept. B. 44,918. 7. Shows ornament of the brachial valve and high area, open delthyrium, and linear deltidial plates of the pedicle-valve ($\times 1\frac{1}{2}$). 8. Lateral view showing convexity of valves and area of pedicle-valve ($\times 1\frac{1}{2}$). 8 *a*. Ornament under microscope ($\times 10$).

Figs. 9, 9 *a*. *Delthyris tenuilamellata*, sp. n., from the Wenlock Shale, Buildwas, Shropshire. British Museum Geol. Dept. B. 44,915. 9. Shows ornament of the brachial valve, area, and conjunct deltidial plates of pedicle-valve ($\times 1\frac{1}{2}$). 9 *a*. Ornament under microscope ($\times 10$).

length is slightly less than that of the hinge. Deltidial plates conjunct, foramen oval. In the pedicle-valve there are four costæ on each lateral slope, and there are eight costæ in addition to the median fold in the brachial valve. Growth-lamellæ are fairly numerous and very closely placed anteriorly. The ornament tends to become obsolete near the cardinal extremities. The microscopic ornament consists of fine longitudinal striæ, along which are set very small granules. These are also arranged in regular concentric rows, giving the appearance of reticulation. No median septum in the pedicle-valve was developed in any of the specimens examined.

Dimensions.—Length 10·5 mm.; width 21 mm.; thickness 8·5 mm., or 1 : 2 : ·8.

Holotype from Wenlock Shale, Buildwas, Shropshire, preserved in the British Museum (Natural History), Walker Collection (B. 44,915).

Horizon.—Wenlock Shale and Limestone.

UNCINULINA and UNCINULUS, Bayle, 1878.
(Figs. 10, 11.)

The genera *Uncinulina* and *Uncinulus* were figured by Bayle in 1878, but no description accompanied the plates. *Uncinulina fallaciosa* *, Bayle, was figured as the only species of this genus, but *Uncinulus* is represented by three species, namely, *Hemithyris subwilsoni*, d'Orbigny, *Uncinulus oehlerti*, and *U. imperator* †. All these species are of Devonian age. No internal characters were shown of *Uncinulina*, but those of *Uncinulus subwilsoni* were well depicted. It remained for Oehlert in 1884 ‡ to describe and figure these genera in greater detail, the species *H. subwilsoni* was chosen by him as the genolectotype of *Uncinulus*. Oehlert considered that the genus *Uncinulina* was indistinguishable from *Rhynchonella*, and accordingly he placed the species *U. fallaciosa* in that genus.

Uncinulina fallaciosa, as figured by Bayle and Oehlert and described by the latter author, has a sub-cuboidal outline with a rather flat pedicle-valve having a shallow median sinus. Each valve is ornamented with 20–24 simple prominent costæ. The umbo is short and incurved till it rests on the brachial valve, and the umbonal slopes are flattened and smooth. In the interior of the ventral valve the diductor muscle-scars are large and flabelliform, and enclose two small oval adductors. The brachial valve is strongly convex with a slightly raised median fold ornamented with six costæ. Internally the hinge-plate is divided into two parts by a narrow oval incision, and there is no cardinal process. The hinge-plate is apparently supported by a median septum, but this is not well represented.

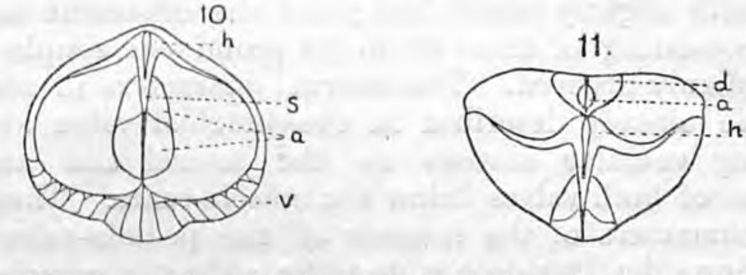
* Explic. de la Carte Géol. de France, vol. iv. pl. xiii. figs. 13–16.

† Explic. de la Carte Géol. de France, vol. iv. pl. xi. figs. 11–16.

‡ Bull. Soc. Géol. France, 3rd ser. vol. xii. pp. 420, 422.

The distinguishing characters of *Uncinulus*, as determined from *U. subwilsoni*, are its spherical contour and external ornament of fine flattened costæ longitudinally grooved near the anterior margin of each valve. In the interior of the pedicle-valve the muscle-scars are surrounded by a narrow ridge ; while in the brachial valve there is a solid undivided hinge-plate, in the centre of which is a broad cardinal process longitudinally notched at the summit. Short crura extend downwards from the hinge-plate, and a median septum separates the two pairs of adductor muscle-scars.

The main points of difference, therefore, between *Uncinulina* and *Uncinulus* are in the contour, costation, and in the tongue of the ventral valve which is truncate in *Uncinulus* and has a straight line of contact with the brachial



Figs. 10, 11. *Uncinulina stricklandi*, J. de C. Sowerby, from the Wenlock Limestone, Much Wenlock, Shropshire. British Museum Geol. Dept. B. 44,920. Nat. size. 10. Diagrammatic drawing of the brachial valve from an internal cast, showing (*s*) median septum, (*h*) hinge-plate, (*a*) adductor muscle-scars, (*v*) vascular markings. 11. Posterior view showing (*a*) adductor, (*d*) diductor muscle-scars of pedicle-valve, (*h*) hinge-plate of brachial valve.

valve, while in *Uncinulina* it is notched owing to the alternation of the costæ of the two valves. Internally the position of the muscle-scars is different in each valve, and in *Uncinulina* the hinge-plate is divided and no true cardinal process is developed.

J. Hall in 1894 * suggested that the name *Uncinulina* should be retained for forms such as *Rhynchonella stricklandi*, in which the hinge-plate is divided anteriorly, but is united towards the apex, and in which the form is sub-cuboidal and less globose than *R. wilsoni*. In the same year, however, he gave *Uncinulina* as a synonym of *Uncinulus* †, while R. S. Bassler in 1915 ‡ quoted *Uncinulina* as a synonym of

* Pal. of New York, vol. viii. pt. 2, p. 199.

† J. Hall and J. M. Clarke, 11th Ann. Rep. State Geologist, p. 828 (1894).

‡ Bull. U.S. Nat. Mus. xcii. vol. ii. p. 1331.

Wilsonia. Cowper Reed, in 1922 *, refers several species from the Devonian of Chitral and the Pamirs to *Uncinulina*, making this a subgenus of *Uncinulus*. He bases his determinations on external rather than on internal characters, and does not mention the hinge-plate in any of his descriptions, but states that the muscle-scars of the brachial valve resemble very closely those of *Uncinulina*, and points out the distinctions between that genus and *Hypothyridina*, S. Buckman = *Hypothyris*, auctt.

It is proposed, therefore, to use the generic name of *Uncinulina* to include such Silurian and Devonian species as agree in external shape and ornament with *Uncinulina fallaciosa* and *U. stricklandi*, i. e., flattened, slightly sinuated forms having the pedicle-valve with umbo incurved, concealing foramen and deltidial plates; the convex brachial valve with slightly raised fold; and the ornament in each valve consisting of from 20 to 30 prominent simple costæ not medianly grooved. The internal characters in addition to those already described in the brachial valve are the radiating vascular sinuses on the lateral and anterior portions of both valves below the muscle-scars. These and other characters of the interior of the pedicle-valve were well shown by Davidson †, but the adductor muscle-scars are not seen for "*Rhynchonella*" *stricklandi*. The position of the muscle-scars and vascular sinuses of the brachial valve are shown in figs. 10 and 11.

A similar internal structure apparently exists in "*Terebratula*" *lewisi*, Davidson ‡, which may also be referred to the genus *Uncinulina*.

Meristina, Hall, 1867 §.

Terebratula obtusa, J. Sowerby, Proc. Linn. Soc. vol. xii. pt. 2, pl. xxviii. figs. 3 & 4 (1818) (= *Atrypa tumida*, Dalman, Vet.-Akad. Handl. 1827 (1828), pl. v. figs. 3 *a–d*, p. 134).

Terebratula obtusa is described by J. Sowerby, in 1818, as "a shell curved laterally from the hinge, which must be very short without any space for triangular foramen externally . . . ." He figures the exterior, and in another specimen shows that the spirals had fifteen convolutions, and had their apices laterally directed, and that a median septum was present in the brachial valve. These specimens

* 'Palæontologica Indica,' n. s., vol. vi. no. 2, p. 40.
† Mon. Brit. Foss. Brach. vol. iii. pl. xxi. fig. 6 (1867).
‡ Davidson, Bull. Soc. Géol. France, 2nd ser. vol. v. pl. iii. fig. 30, p. 330 (1848).
§ 20th Rept. N.Y. State Cab. Nat. Hist. p. 157.

were obtained from "Sladacre's Quarry on right-hand side of road from Wych to Calwell Green, Malvern Hill." Judging by Sowerby's description and figures, there is no doubt that his species is identical with *Meristina* (*Atrypa*) *tumida*, figured by Dalman from Gothland, but the dimensions given by Dalman for his species are considerably less than those of the average fully-grown *Meristina obtusa* found in this country, and Dalman was apparently describing a young individual. *Meristina* (*Atrypa*) *tumida*, Dalman, therefore, is a synonym of *Meristina* (*Terebratula*) *obtusa*, Sowerby.