The lithostratigraphy of the Shales-with-Beef Member of the Charmouth Mudstone Formation, Lower Jurassic

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Gallois, R.W. 2008. The lithostratigraphy of the Shales-with-Beef Member of the Charmouth Mudstone Formation, Lower Jurassic. *Geoscience in South-West England,* **12**, 32-40.

The Shales-with-Beef Member of the Charmouth Mudstone Formation (Lower Jurassic) crops out in almost continuous cliff and foreshore sections over a distance of *c.* 5 km between Pinhay Bay, east Devon and Charmouth, west Dorset. A fault-bounded outlier, 3.5 km west of Pinhay Bay, exposes the lower part of the member. At its type section on the foreshore and in cliffs below Black Ven, Charmouth, the member consists of *c.* 30 m of thinly interbedded organic-rich mudstones and calcareous mudstones with numerous thin beds of fibrous calcite ('beef') and several beds of tabular and nodular limestone. Many of the individual beds of mudstone are richly fossiliferous and this has previously been used, in combination with the lithological variations, to divide the succession into over 100 numbered and lettered beds. However, as noted in the original study, many of the thinner beds are laterally impersistent and few can be recognised with confidence away from the type section. In addition, the type section is separated from the main Shales-with-Beef Member outcrop in the Lyme Regis area by a penecontemporaneously active fault belt that had an effect on sedimentation. Other fault belts at Lyme Regis and westwards from there divide the outcrop into areas with successions that differ in detail from the type section and from one another. As a result, few of the numbered beds can be traced from one of these areas into the adjacent area. A simplified system of bed numbering is described here based on sections that crop out on the west and east sides of Lyme Regis, supplemented by the successions proved in cored site-investigation boreholes drilled at Lyme Regis. The proposed lithostratigraphy provides a framework that takes account of the lateral variations in the member over its full outcrop distance, and enables material collected from any part of the exposure to be placed in its correct stratigraphical context.

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Keywords: Charmouth Mudstone Formation, lithostratigraphy, Lower Jurassic, Devon, Dorset.

Introduction

The wholly exposed, richly fossiliferous Lower Jurassic succession exposed in the cliffs between the Axe Valley in east Devon and Seatown in west Dorset has attracted geologists and fossil collectors for over 200 years. The contributions to the early development of the earth sciences made by fossil collectors such as Mary Anning and the Philpot sisters, and by local geologists Henry de la Beche, William Buckland and William Conybeare, have been well documented. They were instrumental in changing the study of the physical and biological history of the Earth from one based on a literal reading of the Bible to one based on observation and hypothesis. Buckland's (1829) discovery of the "the faeces of the Ichthyosaurus" in the Lias at Lyme Regis was a turning point that was to lead on to the theory of evolution and a reassessment of the age of the Earth.

De la Beche (1826), using the nomenclature of William Smith's (1815) geological map of England and Wales, described the Jurassic succession exposed in the coastal sections around Lyme Regis as Blue Lias overlain by *c.* 36 m of fossiliferous 'slaty marls' with thin beds of indurated marl, nodular concretions and selenite crystals. He subsequently (Buckland and De la Beche, 1836) referred to the thin seams of fibrous calcite that are common in the lower part of the succession as 'beef', a term adopted from quarrymen working the Purbeck Beds in west Dorset (Challinor, 1961).

The first detailed description of the beds that overlie the Blue Lias was that of Woodward (1893) under the name Black Ven Beds: this was repeated and expanded on in Woodward and Ussher (1911). It included most of the named marker beds of later descriptions, in particular Table Ledge at the base of the succession and the Birchi Tabular Bed in the middle part. Woodward (1893), working on the exposures adjacent to Lyme Regis, divided the succession between these two marker beds into nine units in which five limestones (0.1 to 0.3 m thick) were separated by mudstones (3 to 7.5 m thick). Lang (1914) introduced the name Shales-with-'beef' for this part of the succession which he described as "paper-shales, marls, indurated bands, and limestone nodule-beds, with numerous, more or less impersistent, interbedded seams of fibrous calcite". In the formalised nomenclature of the Lias Group (Cox *et al.*, 1999) the Shales-with-Beef is now the basal member of the Charmouth Mudstone Formation (formerly the Lower Lias Clay). The base of the formation is defined as the top of the youngest limestone in a mudstone succession that contains numerous limestone beds. At Lyme Regis, the junction is taken (following Hallam, 1960) at an erosion surface at the top of a limestone bed (Grey Ledge) that marks a sudden upward change from a succession of mudstones with numerous limestone beds (*c.* 40% by volume) to mudstones with few (<5% by volume) limestones.

Lang *et al.* (1923) used the cliff and foreshore reefs [SY 357 930 to 362 930] immediately west of Charmouth to produce detailed bed-by-bed descriptions of the lithologies and ammonite assemblages of the Shales-with-Beef. With the exception of specimens collected from a few cemented beds, the ammonites are crushed and difficult to extract from the cliffs, and the reefs in the intertidal area are the most accessible

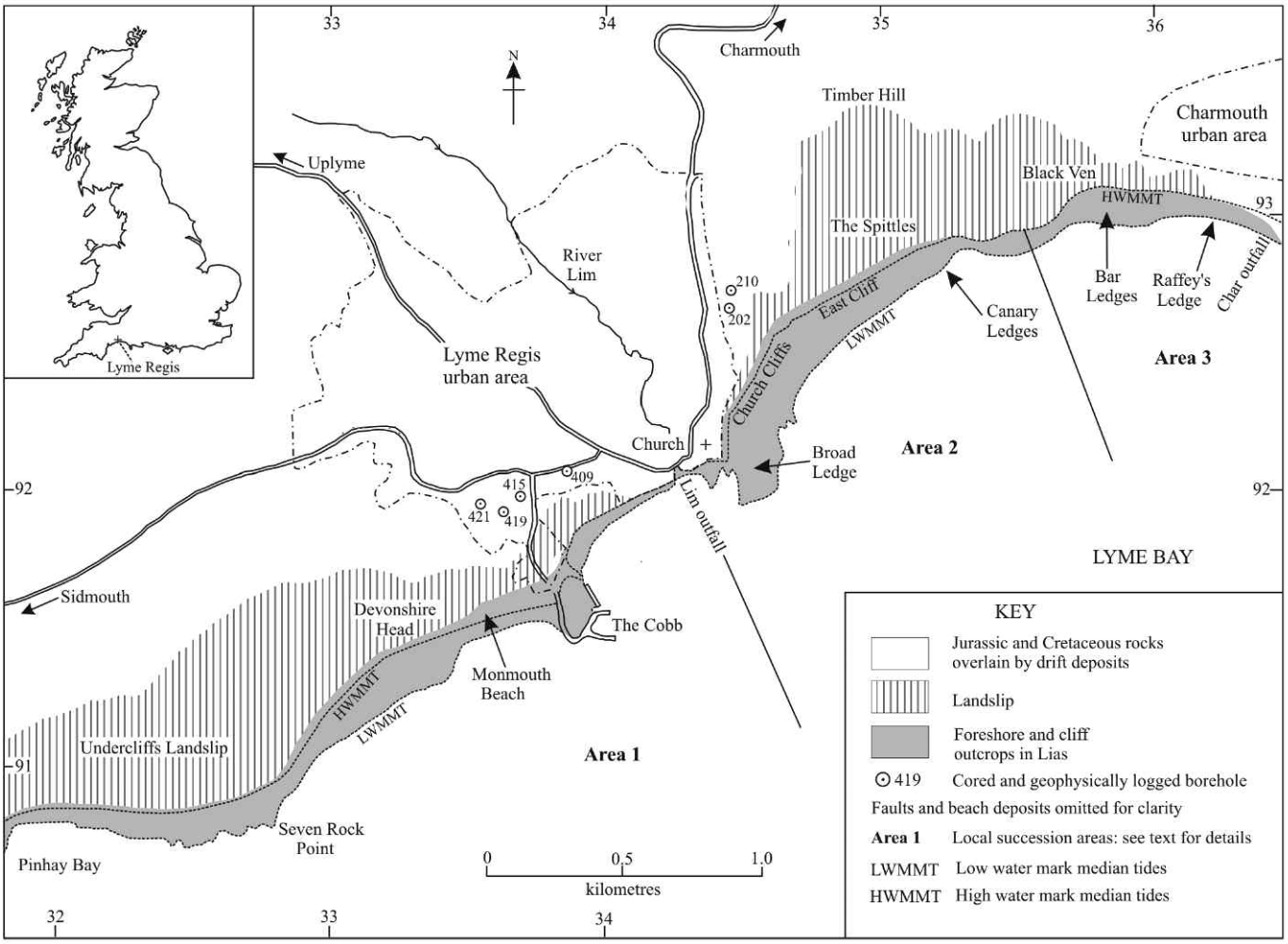

Figure 1. *Sketch map of the coastal outcrop of the Lias Group in the Lyme Regis-Charmouth area.*

sections for palaeontological collecting. Lang *et al.* (1923) divided the Shales-with-Beef succession at Charmouth into 23 beds (numbers 53 to 75) commencing with Table Ledge and following on from Lang's (1924) numbering of the Blue Lias. The 23 beds were further divided into over 100 subsidiary beds, many less than 50 mm thick (Figure 2). Some of these are laterally discontinuous beds of beef, others are characterised by one or more crushed layers of a particular ammonite. Lang himself noted (in Lang *et al.*, 1923) that "it is not to be supposed that the minute subdivisions will be found farther along the cliff, or even that the prominent beds at the Charmouth end of the section will necessarily persist as far as Lyme". This has proved to be the case, but it does not detract from the value of Lang's account which remains a fine example of detailed lithological description and faunal collecting.

Geological structure

The post-Variscan evolution of southern Britain and the adjacent offshore areas was predominantly influenced by three tectonic events. Thermal relaxation and stretching of the thickened continental crust beneath the Variscan fold belts, thermal uplift and stretching related to the opening of the Atlantic Ocean, and the Cimmerian and Alpine compressional phases. The early Jurassic in southern England was a tectonically quiet period as evidenced by the deposition of lithologically similar, relatively shallow-water, marine-shelf muds over very large areas. There are, however, minor variations in the successions at any one stratigraphical level that are indicative of differences in subsidence rates over short (<100 m) distances. In the Shales-with-Beef Member in the Lyme Regis-Charmouth area, the principal changes occur across two well-defined structures, the Lim Valley and Black Ven fault zones (Figure 3). In the early Jurassic these may have been single faults which subsequently acted as foci for folding and further faulting in the early Cretaceous and Miocene.

In 1995, West Dorset District Council (WDDC) initiated long-term engineering, geological and geomorphological studies of the onshore and nearshore areas at, and adjacent to, Lyme Regis in advance of landslip remediation and coastal defence works. They included aerial photography of the cliff and intertidal areas; bathymetric, seismic-reflection and sidescan-sonar surveys of the subtidal area fronting and adjacent to the town; trial pits and continuously cored boreholes; and ground and LiDaR surveys of the landslipped areas west and east of the town (Gallois and Davis, 2001). The stratigraphy of the Shales-with-Beef Member was of particular engineering interest because the member was known to contain more than one weak mudstone bed that had given rise to major slope failures.

The combined results of these surveys showed that the tectonic structure of the area was more complex than previously known, that there were lateral variations in the Shales-with-Beef Member that had not been recorded, and that the more significant of these variations were related to two principal fault belts. These fault belts divide the outcrop into three parts: between Pinhay Bay and the River Lim, between the River Lim and the western edge of Black Ven, and between Black Ven and Charmouth (Figure 1). Parts of the Shales-with-Beef Member are exposed from time to time west of Pinhay Bay at the foot of the Undercliffs Landslip, but the succession there is incompletely known and is not discussed here.

In the area between Pinhay Bay and the River Lim, the full thickness of the Shales-with-Beef Member is exposed in the cliffs between Seven Rock Point [SY 329 909] and Monmouth Beach [SY 332 915], and can be measured in the cliffs below

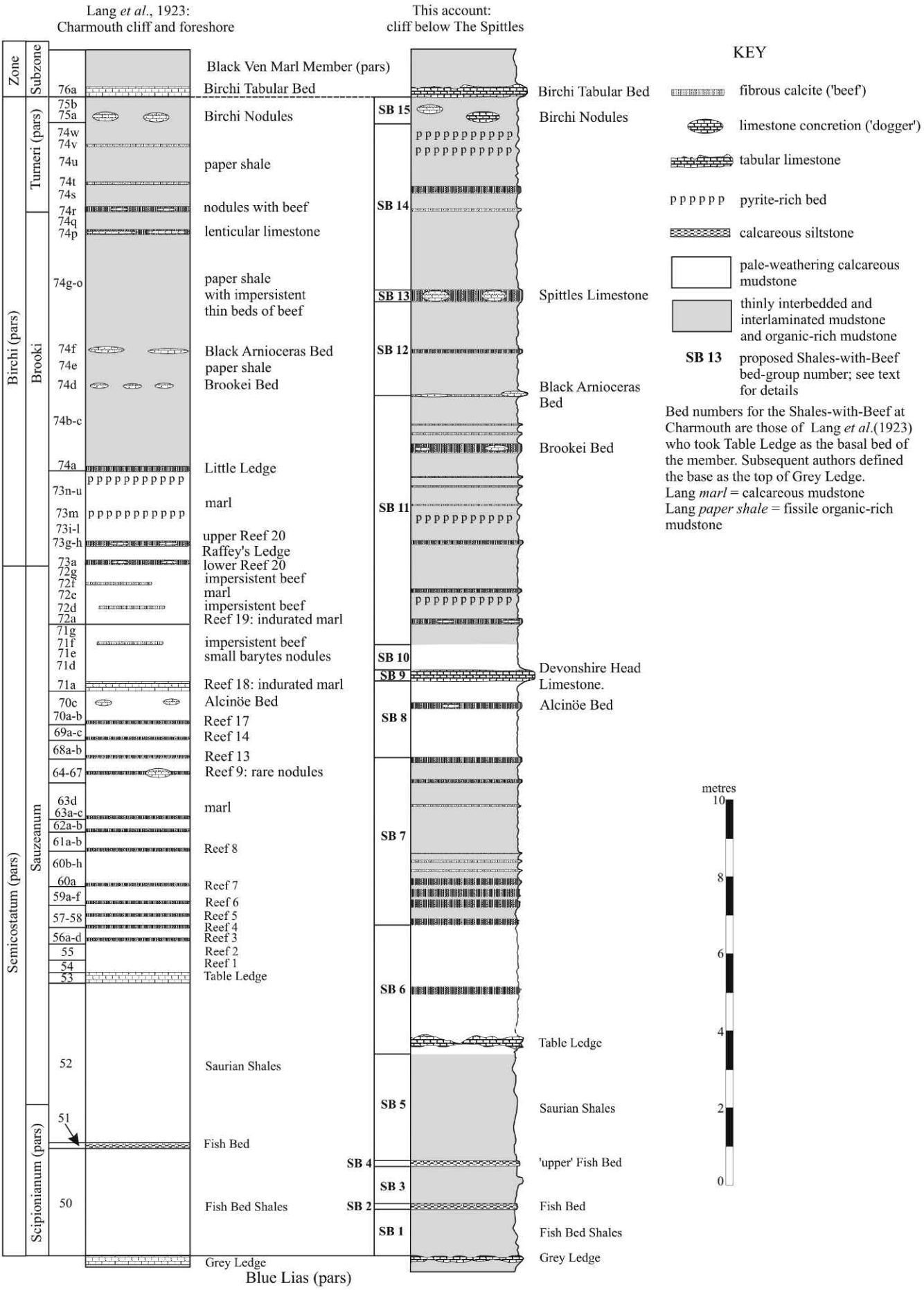

Figure 2. *Generalised vertical section for the Shales-with-Beef Member of the area immediately east of Lyme Regis based on cored boreholes and a cliff section [SY 3468 9268] below The Spittles.*

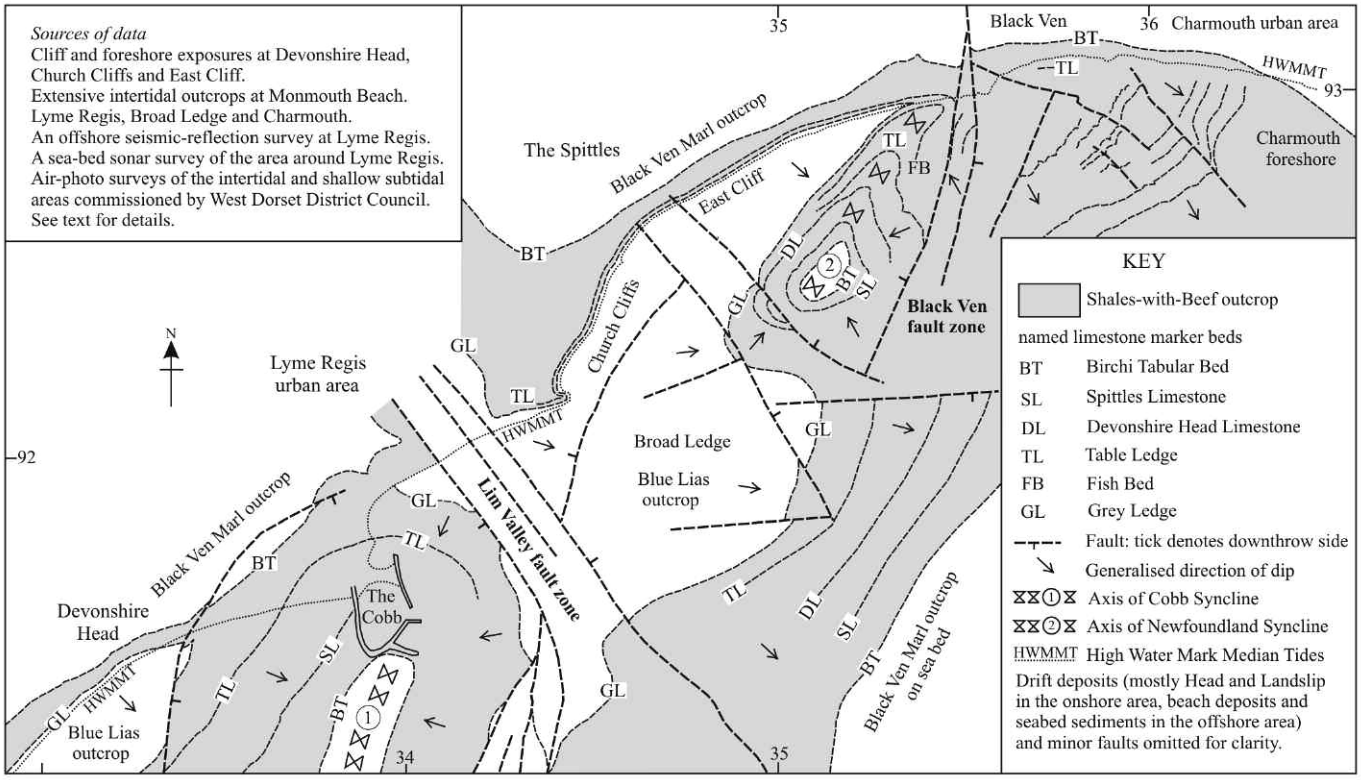

Figure 3. *Geological sketch map of the Shales-with-Beef outcrop in the onshore and nearshore area between Lyme Regis and Charmouth.*

Devonshire Head. The more strongly cemented beds up to and including the level of Table Ledge crop out in the intertidal areas at Monmouth Beach [SY 337 914] and on Lyme Regis foreshore. Contrary to Palmer's (1984) statement that Woodward (1893) and subsequent authors had incorrectly interpreted the Lias outcrops at Lyme Regis, and his assertion that the "Birchi Beds do not descend to beach level anywhere between Pinhay Bay and Charmouth", the Birchi Nodules and Birchi Tabular Bed crop out in the Cobb Syncline in the intertidal area adjacent to the outer wall of The Cobb.

The full thickness of the member is exposed east of Lyme Regis in the area between East Cliff [SY 346 925] and the western edge of Black Ven [SY 357 931]. The lower beds and the junction with the Blue Lias are patchily exposed in Church Cliffs, and the succession between the Blue Lias and the Devonshire Head Limestone is exposed in East Cliff, but is difficult to access. Eastwards from there, Table Ledge and the remainder of the member are well exposed in accessible sections below The Spittles, and the Fish Bed and Table Ledge are exposed in the intertidal area in, and adjacent to, the fault zone. The highest bed exposed in the Newfoundland reef, the Birchi Tabular Bed, is occasionally exposed at unusually low tides. The structure named here as the Newfoundland Syncline, is well displayed on aerial photographs taken when the sea is calm and clear (Figure 4).

In the area between Black Ven and Charmouth, east of the Black Ven fault zone, a low easterly dip brings the member down to beach level between Bar Ledges [SY 358 930] and the outfall of the River Char [SY 364 930] where there are extensive outcrops in the intertidal area, albeit broken by faults and covered by variable amounts of beach deposits. The middle and upper parts of the Shales-with Beef Member are exposed in the adjacent cliff. Taken together the cliff and foreshore exposures are the type section of Lang *et al.* (1923). Because of the difficulty of bed-by-bed collecting in the Shales-with-Beef Member, the ammonite biostratigraphy is still poorly known outside the Charmouth foreshore section. Ammonites indicative of the zones and subzones, and some of the biohorizons within them, have been recorded in fallen blocks and landslipped material west of the Charmouth section (Page, 2002).

Lateral variations in the succession

At outcrop in the Lyme Regis-Charmouth coastal area the Shales-with-Beef Member comprises 28 to 30 m of thinly bedded medium and dark grey mudstones, pale weathering, blocky calcareous mudstones and thinly bedded and laminated brownish grey organic-rich ('bituminous') mudstones with relatively common bedding-parallel, thin (mostly <100 mm thick) beds of fibrous calcite ('beef'), a few beds of nodular and tabular limestone, and laterally impersistent beds with separation concretions (Figure 5a). The lower part of the member is more calcareous overall and contains a greater number of laterally persistent marker beds. The upper part consists largely of thinly interbedded mudstones and fissile weathering organic-rich mudstones (Figure 5b) with few lithologically distinctive beds (Figure 2).

The base of the member rests on a prominent bioturbated erosion surface that caps the highest limestone (Grey Ledge) of the Blue Lias throughout the full length of the outcrop. Within the member the most laterally persistent prominent marker beds are the Fish Bed (a laminated calcareous siltstone), Table Ledge (lenses of very pale, muddy limestone with nests of rhynchonellid brachiopods), the Devonshire Head and the Spittles limestones (tabular, lenticular and nodular limestones) and the Birchi Nodules (septarian concretions). The Shales-with-Beef is capped by the Birchi Tabular Bed, which is also present throughout the outcrop. Taken together these beds form a stratigraphical framework that can be traced throughout the onshore and nearshore areas between Lyme Regis and Charmouth. Grey Ledge, the Devonshire Head and the Spittles limestones and the Birchi Tabular Bed give rise to strong reflections in offshore seismic-reflection surveys and they crop out as prominent reefs on the sea bed (Gallois and Davis, 2001, figures 4 and 5). The limestones give rise to prominent lows in the total-gamma-ray logs in boreholes. In the middle and upper parts of the member, the fossiliferous Alcinöe Bed, with numerous crushed *Paranioceras alcinoë*, and the Black Arnioceras Bed, a storm-deposit crowded with jumbled up *Arnioceras* at all stages of development from eggs to maturity (Figures 5c and 5d), are laterally impersistent micrites that

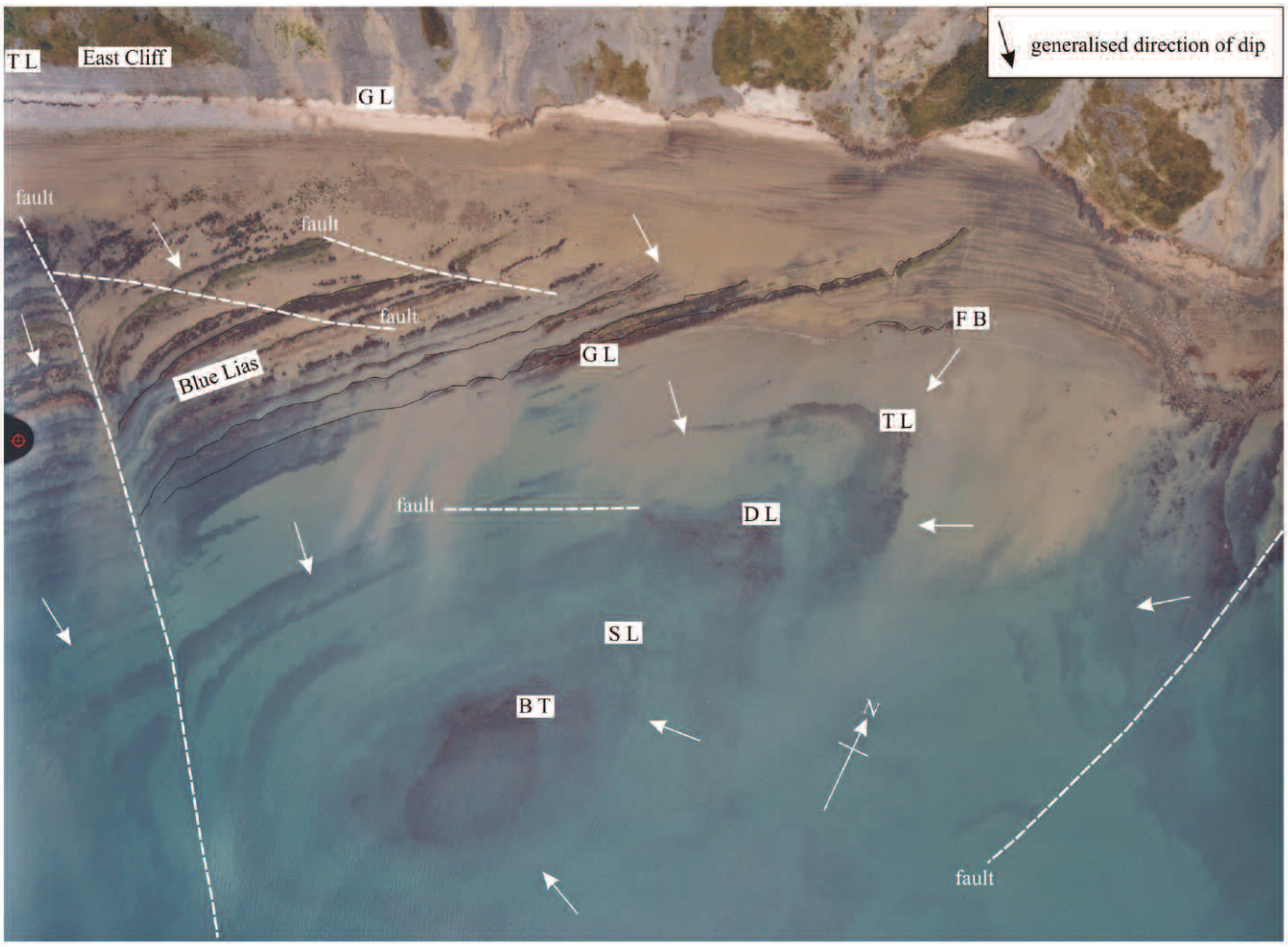

Figure 4. *Aerial view of the Newfoundland submerged reef and the syncline on the north side of the Black Ven fault zone. See Figure 3 for abbreviations of the principal marker beds in the Shales-with-Beef Member. Part of West Dorset District Council Frame J2334, 17th September, 2001.*

provide supplementary marker beds between Lyme Regis and Charmouth but are weakly developed west of Lyme Regis.

Lang (in Lang *et al.*, 1923) recorded the thickness of the beds between Table Ledge and the Birchi Tabular Bed in the cliff and foreshore at Charmouth as 22 m. This has proved to be remarkably accurate given the difficulty of making thickness measurements in sub-vertical cliffs and gently dipping foreshore outcrops. Hesselbo and Jenkyns (1995) measured the same beds in the same section to be 33 m thick. Initial attempts to measure the thicknesses of the Charmouth Mudstone members in the principal exposures between Lyme Regis and Black Ven proved to be so different (up to 20% at some stratigraphical levels) from those proved in cored boreholes that the outcrops were re-measured using an electronic theodolite. The outcrop thicknesses quoted here were made in collaboration with Mr Geoff Davis and Mr Henry Middleton of WDDC.

Measurements made in the best exposed and most easily accessible sections in the Shales-with-Beef Member, those in the cliffs below The Spittles, proved a broadly similar succession of lithologies and thicknesses to that described by Lang *et al.* (1923) at Charmouth. However, two of the most prominent laterally persistent beds below The Spittles, the Devonshire Head and Spittles limestones, are absent at Charmouth. When traced across the Black Ven fault zone the Devonshire Head Limestone might be the correlative of Lang's "indurated marl" (Bed 71a).

The thicknesses of the successions measured below The Spittles and at Charmouth during the present survey were roughly similar. In contrast, those recorded to the west of Lyme Regis in the Devonshire Head area were up to 3 m less, with much of the difference concentrated in the beds between Table Ledge and the Devonshire Head Limestone. Two patterns of site-investigation boreholes drilled on the west and east sides of the River Lim confirmed that this difference was not a measuring artefact and was related to the Lim Valley fault zone (Figure 6). In the boreholes east of the river (WDDC 80 and 200 series) the distance between the top of Grey Ledge and the Devonshire Head Limestone was 14.4 ± 0.1 m. In those west of the river (WDDC 90 series) it was 12.1 ± 0.1 m. The change occurs within an east-west distance of less than 50 m across the fault belt (Figure 6).

Comparison of the lateral variations in the lower part of the Shales-with-Beef Member in and adjacent to Lyme Regis shows that the variations in thickness are related to sedimentary breaks in the succession that are marked by sudden changes in lithology (Figure 6). The most prominent of these appears to occur at the top of the Devonshire Head Limestone (Figure 7) which is locally capped by concentrations of phosphatic nodules. There is little lateral variation in thickness in the beds between the Devonshire Head Limestone and the Birchi Tabular Bed in the Lyme Regis-Charmouth area.

Revised bed-numbering system

The simplified classification proposed here is based on the recognition of marker beds that are present throughout most of the coastal outcrop. Some of these can be correlated with the Charmouth foreshore 'type section' and enable the detailed ammonite-based biostratigraphy recorded by Lang *et al.* (1923) to be related to the Shales-with-Beef successions exposed in the main outcrop. In the following summary beds SB 1 to SB 15

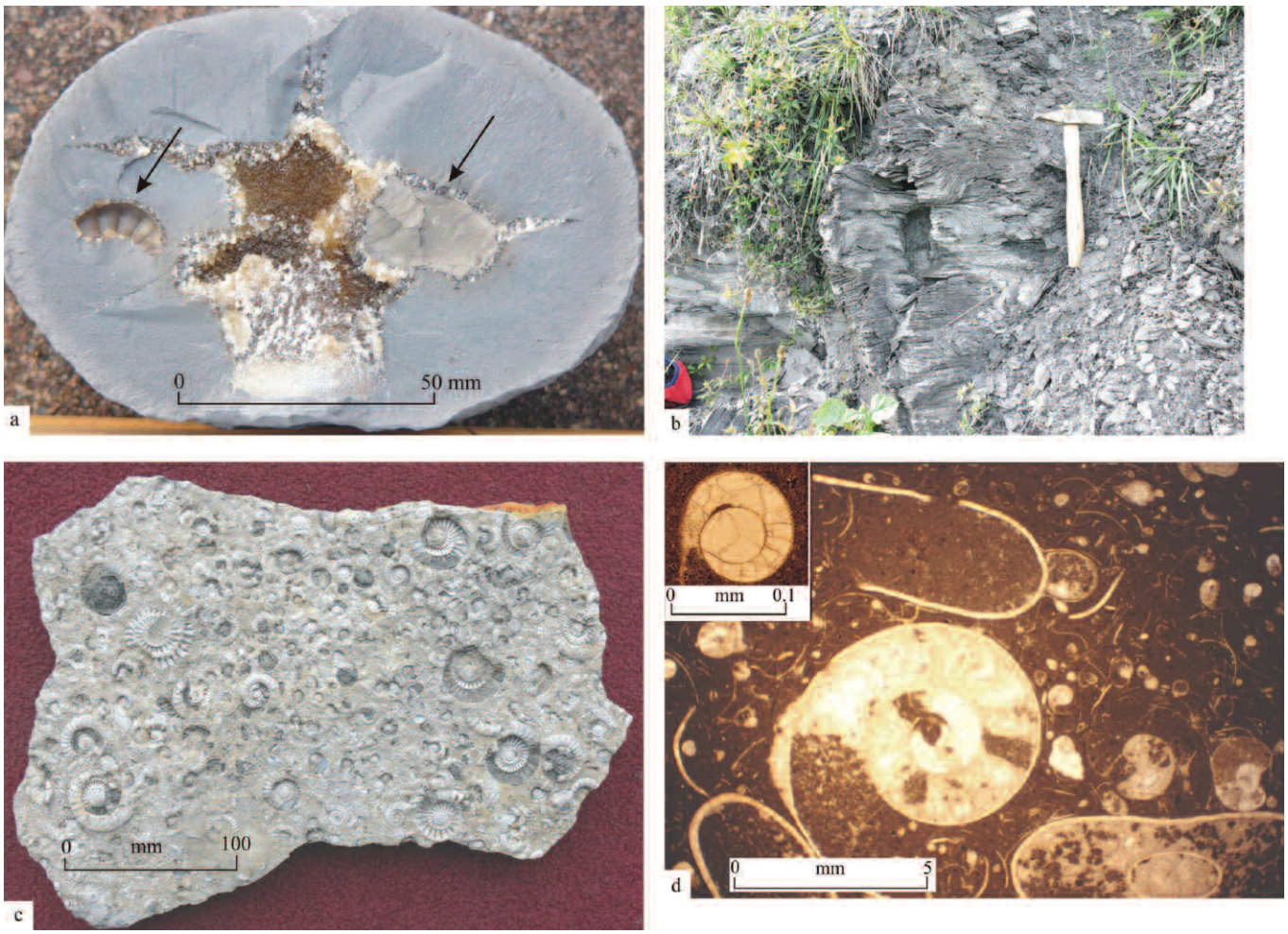

Figure 5. *Examples of Shales-with-Beef lithologies. (a) Septarian concretion, Bed SB 8, excavation in Lister Gardens, Lyme Regis. This and similar nodules were watertight but water filled when freshly excavated. They appear to have nucleated around a bed of partially phosphatised ammonites at about the level of the Alcinoë Bed. (b) Bituminous mudstones with fissile 'curly' weathering, basal Bed SB 11, Devonshire Head. This type of weathering is typical of the more organic-rich parts of the member. On sunny days these beds smell strongly of hydrocarbons. (c) Lenticular slab of shelly Black Arnioceras Bed limestone, cliff below The Spittles. Loose blocks of this bed are common on the outcrop east of the River Lim, but are rare westwards from there. (d) Thin section of the Black Arnioceras Bed viewed in transmitted light. The bed is crowded with ammonites at all stages of maturity from eggs (<0.1 mm diameter) and post-embryonic forms (insert) to mature specimens >40 mm in diameter. They lie at all angles to the bedding and probably represent a shallow-water life assemblage that was swept into deeper water during a storm.*

(Figure 2) comprise a combination of laterally persistent marker beds and groups of intervening beds. Over the short distance of the coastal outcrop the bed groups approximate to chronostratigraphical units.

Black Ven Marl Member (pars): almost continuous tabular, dense muddy limestone (Birchi Tabular Bed) (0.15 to 0.30 m).

Bed SB 15: thinly interbedded dark grey mudstones and laminated brownish grey organic-rich mudstones with several thin (<10 mm thick) beds of beef; one, locally two, lines of septarian nodules 1 to 2 m apart in the lower part of the bed; mostly ellipsoids up to 0.3 m diameter and 0.2 m thick, some enclosing *Microderoceras birchi* (Birchi Nodules) (0.30 to 1.10 m).

Bed SB 14: thinly interbedded grey mudstones and organic-rich mudstones as above with 3-4 thin (<10 mm thick) beds of beef and several pyritised beds up to 10 mm thick (3.30 to 4.30 m).

Bed SB 13: tabular densely cemented muddy limestone (Spittles Limestone) passing locally in the eastern part of the outcrop into muddy limestone septaria coated with beef, or into a thick multiple layer of beef (0.20 to 0.35 m).

Bed SB 12: thinly interbedded mudstones and organic-rich mudstones as above with several thin (<10 mm thick) beds of beef; base taken at base of discontinuous lenses of limestone up to 0.12 m thick and 0.6 m long, mostly crowded with *Arnioceras*, but locally barren (Black Arnioceras Bed); pyritic basal bed gives rise to ferruginous seepages; limestone lenses widely spaced (>20 m) west of Lyme Regis (2.30 to 2.50 m).

Bed SB 11: laminated organic-rich mudstones with thin interbeds of dark grey mudstone; prominent beef seam in top part of bed east of Lyme Regis with widely spaced, small (up to 0.1 m across) septarian nodules with *Arietities brookei* (Brookei Bed); fissile organic-rich bed (0.4 m thick) at base rests with sharp lithological contrast and possible erosion on bed below (5.00 to 6.50 m).

Bed SB 10: calcareous mudstone, weathering to pale and very pale grey; widely spaced (2 to 3 m) small very pale-weathering concretions; highest 80 mm locally very pale grey with cream-coloured phosphatic nodules indicative of condensed deposition (0.50 to 0.70 m).

Bed SB 9: tabular densely cemented muddy limestone capped

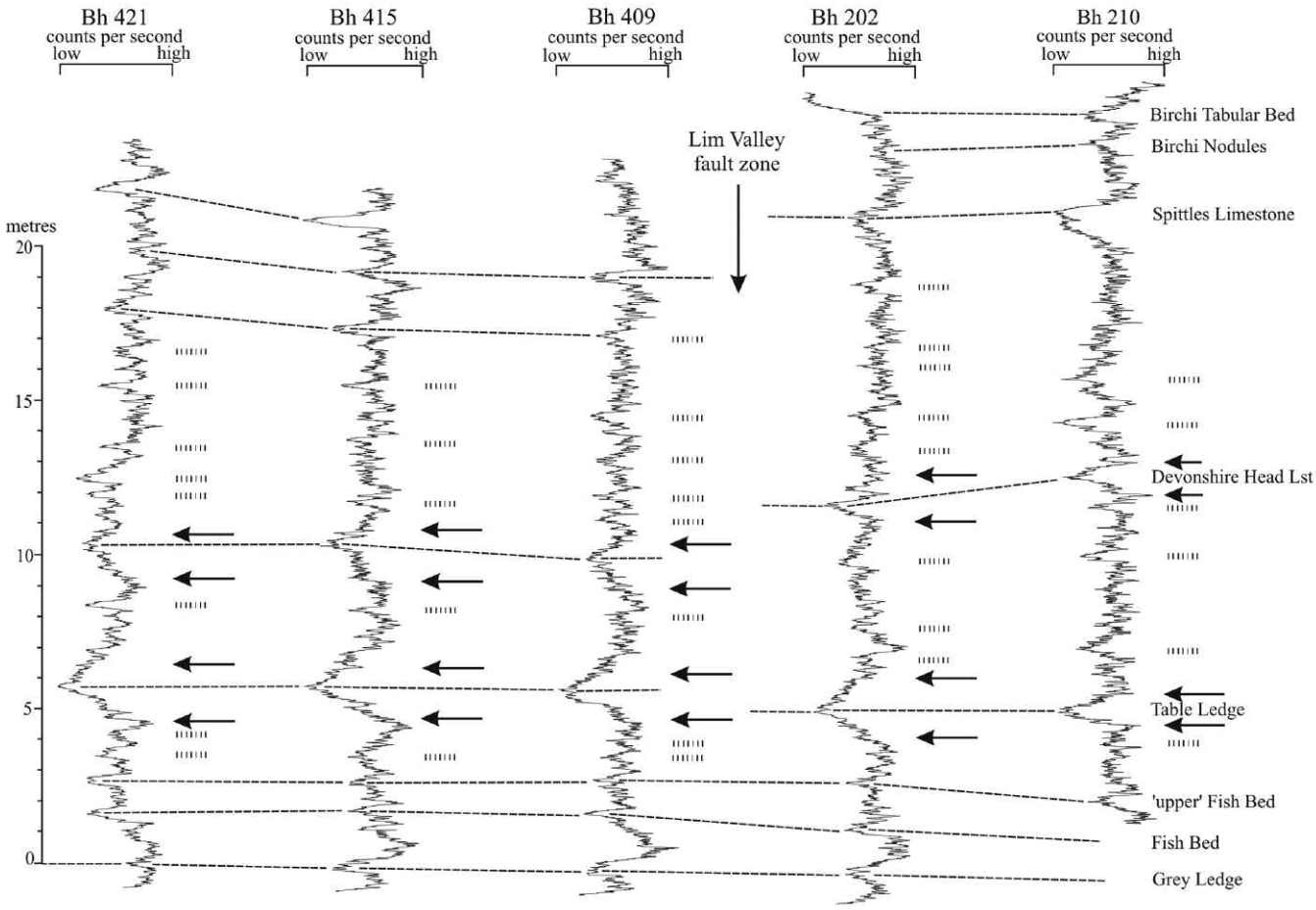

Figure 6. *Correlations based on total-gamma-ray logs between the Shales-with-Beef successions proved in boreholes in Lyme Regis.*

by 20 to 30 mm thick layer of beef (Devonshire Head Limestone) (0.25 to 0.30 m).

Bed SB 8: calcareous mudstone weathering pale and very pale grey; prominent very pale grey calcareous mudstone in middle part of bed locally contains widely spaced, ovoid calcareous concretions with *Pararnioceras alcinoë* (Alcinoë Bed) and septarian nodules (0.90 to 2.00 m).

Bed SB 7: thinly bedded medium and dark grey mudstones with thin interbeds of organic-rich mudstone and numerous thin (<10 mm thick) beds of beef; distinct colour contrast at base (2.10 to 4.40 m).

Bed SB 6: calcareous mudstones weathering to pale and very pale grey, with an almost continuous, patchily cemented muddy limestone in the lower part (Table Ledge, 0.15 to 0.4 m thick) with nests of iridescent rhynchonellid brachiopods (1.80 to 3.20 m).

Bed SB 5: thinly bedded medium and dark grey mudstones with thin interbeds of organic-rich mudstones (Saurian Shales) (2.50 to 3.80 m).

Bed SB 4: tabular, calcareously cemented, bioturbated siltstone ('upper' Fish Bed) (0.10 to 0.15 m).

Bed SB 3: thinly bedded medium and dark grey mudstones with thin interbeds of organic-rich mudstones (Fish Bed Shales) (1.00 to 1.30 m).

Bed SB 2: tabular, calcareously cemented, strikingly laminated siltstone (Fish Bed) (0.15 to 0.20 m).

Bed SB 1: thinly interbedded medium and dark grey mudstones and interlaminated organic-rich mudstones (Fish Bed Shales); basal bed, a pyritic laminated organic-rich mudstone crowded with crushed *Arnioceras*, rests with sharp lithological contrast on an erosion surface with *Diplocraterion* and other burrows; basal bed locally calcareously cemented to the top of Grey Ledge west of Lyme Regis (1.20 to 1.60 m).

Blue Lias Formation (pars): almost continuous tabular, dense muddy limestone (Grey Ledge) crowded with large *Paracoroniceras* in upper part; passing into discontinuous lenses and doggers east of Lyme Regis (up to 0.30 m).

Summary and conclusions

The Shales-with-Beef Member of the early Jurassic Charmouth Mudstone Formation crops out almost continuously in cliffs and foreshores over a distance of 5 km between Pinhay Bay, east Devon and Charmouth, west Dorset (Figure 1). The member comprises 28-30 m of fossiliferous marine mudstones with a few thin limestone beds. A combination of field surveys and cored site-investigation boreholes has shown that the succession is laterally variable in detail, and that the outcrop can be divided into three areas in which the stratigraphy is relatively constant. Each area is separated from its neighbour by a fault zone that is presumed to have given rise to small variations in the rates of subsidence and resultant depositional thickness.

The type section of the Shales-with-Beef Member (Lang *et al.*, 1923) at Charmouth is separated from the main outcrop of the member by the Black Ven fault belt with the result that most of the 100+ numbered and lettered beds of their description

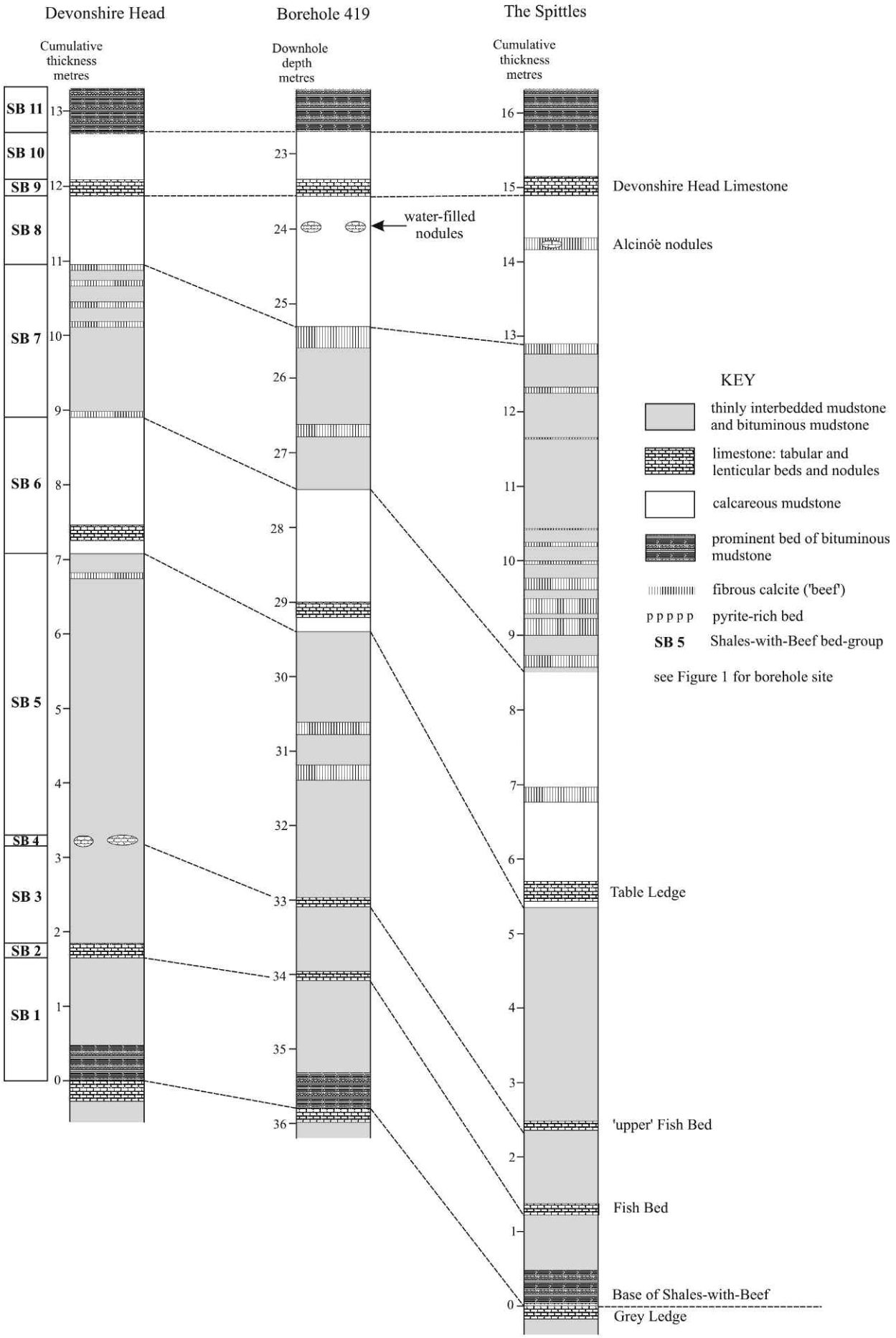

Figure 7. *Correlation of the successions in the lower part of the Shales-with-Beef between Devonshire Head, central Lyme Regis and The Spittles.*

cannot be recognised in the main outcrop. Nevertheless, the numbering system has been used in published accounts to identify the stratigraphical positions of fossil and mineral specimens even where the specimens were collected from sections where few of the numbered beds of the type section can be recognised. The simplified bed-numbering system proposed here is applicable to all the coastal outcrops between Pinhay Bay and Charmouth, and should enable material collected from any part of the outcrop to be more accurately related to the succession at the type section.

Acknowledgements

Much of the data referred to in this account were collected in collaboration with West Dorset District Council (WDDC) as part of preliminary studies for sea-defence and landslip-remediation works at Lyme Regis. Geoff Davis and Henry Middleton of WDDC are thanked for their help at all stages of the study. Figure 4 and the geophysical logs in Figure 6 are published by permission of WDDC.

References

BUCKLAND, W. 1829. On the discovery of a new species of pterodactyle; and also of the faeces of the Ichthyosaurus; and of a black substance resembling sepia, or indian ink, in the Lias at Lyme Regis. *Proceedings of the Geological Society of London*, **1**, 96-98.

BUCKLAND, W. and DE LA BECHE, H.T. 1836. On the geology of the neighbourhood of Weymouth and the adjacent parts of the coast of Dorset *Transactions of the Geological Society of London*, Series 2, **4**, 1-46.

CHALLINOR, J. 1961. *A dictionary of geology*. University of Wales Press, Cardiff.

COX, B.M., SUMBLER, M.G. and IVIMEY-COOK, H.C. 1999. A formational framework for the Lower Jurassic of England and Wales (onshore area). *British Geological Survey Research Report*, No. RR/99/01.

DE LA BECHE, H.T. 1826. On the Lias of the coast in the vicinity of Lyme Regis, Dorset. *Transactions of the Geological Society of London*, **2**, 21-30.

GALLOIS, R.W. and DAVIS, G.M. 2001. Saving Lyme Regis from the sea: the results of recent geological site investigations. *Geoscience in south-west England*, **10**, 183-189.

HALLAM, A. 1960. A sedimentary and faunal study of the Blue Lias of Dorset and Glamorgan. *Philosophical Transactions of the Royal Society of London*, Series B, **243**, 1-44.

HESSELBO, S.P. and JENKYNS, H.C. 1995. A comparison of the Hettangian to Bajocian successions of Dorset and Yorkshire. In: TAYLOR, P.D. (Ed.), *Field Geology of the British Jurassic*. Geological Society, London, 105-150.

LANG, W.D. 1914. The geology of the Charmouth cliffs, beach and foreshore. *Proceedings of the Geologists' Association*, **25**, 293-360.

LANG, W.D. 1924. The Blue Lias of the Devon and Dorset coasts. *Proceedings of the Geologists' Association*, **35**, 169-185.

LANG, W.D., SPATH, L.F. and RICHARDSON, W.A. 1923. Shales-with-'beef,' a sequence in the Lower Lias of the Dorset Coast. *Quarterly Journal of the Geological Society*, **79**, 47-66.

PAGE, K.N. 2002. A review of the ammonite zonation and standard zonation of the Hettangian and Lower Sinemurian succession (Lower Jurassic) of the east Devon coast (south-west England). *Geoscience in south-west England*, **10**, 293-303.

PALMER, C.P. 1984. A note on the Birchi Beds, Lower Jurassic, at Lyme Regis, Dorset. *Geological Magazine*, **121**, 645-647.

SMITH, W. 1815. *Geological map of England and Wales and part of Scotland*. J. Cary, London.

WOODWARD, H.B. 1893. *The Jurassic Rocks of Britain, Vol. 3. The Lias of England and Wales (Yorkshire excepted)*. Memoirs of the Geological Survey of Great Britain. HMSO, London.

WOODWARD, H.B. and USSHER, W.A.E. 1911. *Geology of the Country near Sidmouth and Lyme Regis*. Memoirs of the Geological Survey of Great Britain. 2nd edition. HMSO, London.