THE ORIGIN OF DEFORMED CONGLOMERATE AND PSEUDO DEFORMED CONGLOMERATE; WITH PARTICULAR REFERENCE TO THE ROCKS AT GOAT ISLAND, TASMANIA

By

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(With two plates and one text figure.)

ABSTRACT

Rocks produced by the deformation of conglomeratic sediments strongly resemble pseudo-deformed conglomerates in which tectonic disruption of beds, veins and pebbles produce pebble-like bodies.

The Goat Island Conglomerate is a tectonic mélange containing numerous tectonically formed fragments but is dominantly a metaconglomerate.

INTRODUCTION

Foliated rocks containing flat or elongate fragments have been widely recognized as deformed conglomerates (stretched-pebble conglomerates) but it is not generally appreciated that rocks of different origin (pseudo deformed conglomerates) can resemble them very closely.

A deformed conglomerate is a rock of conglomeratic appearance in which the fragments are strongly elongate or flat with a preferred orientation. It is a deformed epiclastic rudite.

A pseudo deformed conglomerate contains flat, elongate or somewhat irregularly shaped fragments which have been formed by tectonic or metamorphic processes. It is generally foliated or lineated and is a cataclastic rudite.

Rocks at Goat Island, near Ulverstone on the central north coast of Tasmania, were considered by Twelvetrees (1903), Dunn (1926), David (1932) and others to be deformed conglomerates. The first suggestion of the pseudo-conglomerate nature of some of the rocks appears to have been made by Professor E. S. Hills on an A.N.Z.A.A.S. excursion in 1949.

The geological environment has been given by Burns (1964) and a detailed discussion of the structure will be presented elsewhere. Both deformed conglomerates and pseudo deformed conglomerates are present. The "Goat Island conglomerate" is a tectonic mélange (Greenly, 1919) derived by the deformation, under low-grade regional metamorphic conditions, of a group of conglomerates, quartzites and phyllites.

A brief review of the nature and origin of metamorphic conglomeratic rocks is presented as a background to the derivation of possible criteria for distinguishing between the various types.

DEFORMED CONGLOMERATES

There are claims in the literature on stretched-pebble conglomerates that various ellipsoidal bodies are sedimentary pebbles which have been distorted, even though, in most cases, no evidence is given to establish that the objects were originally pebbles. It is difficult (Wilson, 1961, p. 517; Hills, 1963, p. 127), and indeed in some cases, impossible, to distinguish between true and pseudo deformed conglomerates and some authors seem to be content to accept a rock as a true deformed conglomerate solely on its appearance. One might, however, question whether an object looking like a "walking stick" with dimensions of 100:3:1 or like a plank (330 x 30 x 8 cms. Kvale, 1948, II, p. 31) or like sheets of cardboard of great size (Van Hise, 1904) are really deformed boulders.

Deformed conglomerates can be classified into a number of groups depending on the internal structure of the fragments which in turn reflects the mechanism of deformation.

I. *Sedimentary.*

Deformation of soft fragments in unconsolidated sediments of low strength takes place by intergranular movement; the deformation is commonly continuous and without fracture. The total amount of strain may be large.

II. *Tectonic.*

(1) Deformation of lithified conglomerate at shallow depths (e.g. of quartzite-conglomerate near faults) may cause small amounts of strain. Deformation is discontinuous, and takes place by shear along conjugate fractures. The sense and amount of movement on the fractures can be recognized by the displacement of the outer surface of the pebbles but the fractures are "healed".

(*a*) In the shallow *Beaverhead type* (Tanner, 1964) the *acute* bisectrix of the shears is parallel to the principle stress axis.

(*b*) Deformation at apparently greater confining pressure, but still at apparently shallow depth in the *Loch Lomond type* (Ramsay, 1964) produces conjugate fractures similar to the previous type except that the *obtuse* bisectrix of the shears is parallel to the maximum stress axis.

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(2) Deformation of conglomerates during regional metamorphism of low to moderate grade may produce moderate amounts of strain by a continuous process involving recrystallization rather than fracture. The mechanism of deformation depends on the physical conditions and ranges from intergranular cataclasis and slip on one or more internal foliations (Goat Island type) to a kind of recrystallization-low (*Fetlar and Bygdin types;* Flinn, 1962; Oftedahl, 1948).

(3) At the high temperatures and pressures of high-grade regional or plutonic metamorphism, conglomerates undergo large amounts of strain by some kind of viscous flow, (*New Hampshire type;* Walton *et al,* 1964).

Lithology.

Pebbles of quartz and quartzite are most common but the occurrence of granite (Elwell, 1955), gneiss (Lawson, 1913), slate (Paige, 1924), limestone (Park and Cannon, 1943) and trachyte (Stockwell and Lord, 1939) as dominant pebbles has been recorded.

Pebbles in deformed conglomerates appear to be invariably surrounded by a matrix which may be siliceous, arkosic, greywacke or pelitic. The proportion of matrix ranges up to 40% (Billings, 1937), 50% (Gunning, 1941), even 80% (Brace, 1955). The matrix is schistose or mylonitic and has apparently undergone considerable movement.

The final shape of a pebble depends on its initial shape, size, physical properties, the total strain of the enclosing rock and the proportion of strain in the matrix. It is generally assumed that the original pebbles were near-spherical but the original shape has a profound influence on the shape after deformation. Variation in shape between closely spaced pebbles of the same composition is probably due to differences in original shape rather than to inhomogeneity of strain.

The amount of deformation of a pebble is related to its size because the larger pebbles in some conglomerates are less-deformed than the smaller (Gruner, 1941; Osberg, 1952; Elwell, 1955).

Mehnert (1938, p. 252) showed that quartzite pebbles were elongated to 10 times their least diameter whereas micaceous greywacke pebbles in the same rock were elongated 45 times. Work of Gunning (1941), Kvale (1948, II, p. 28) and Flinn (1956) showed that a given conglomerate, coarse acid-igneous pebbles are least deformed, quartzites are next, then greywackes, with pelitic pebbles undergoing greatest deformation.

The longest and mean axes of the pebbles are generally parallel to the foliation in the matrix (although this is not always the case) and the long axes are parallel giving a pronounced lineation.

Deformed conglomerates belong to a number of tectonic environments:

(1) The Beaverhead and Loch Lomond types with their fractured pebbles are related to steep faults.

(2) Some normal deformed conglomerates, (e.g. Bygdin type) occur in regions of alpine tectonics. It has been said that the elongation is related to movements parallel to large thrusts, and that deformation is greatest near the thrust (Goldschmidt, 1916; Oftedahl, 1948; Flinn, 1956, 1961; Kvale, 1946; 1948; Strand, 1945) but this is in doubt.

(3) Some normal deformed conglomerates are enclosed in strongly folded meta-sediments (commonly isoclinal with several episodes of folding) where the pebbles are generally elongate parallel to fold axes and other lineations (Stockwell and Lord, 1939; Cloos, 1946; Brace, 1955; Hobbs, 1962). However some examples have elongation "down-dip" or normal to the fold axes (Billings, 1954, p. 357-8; Paige, 1924; Osberg, 1952).

(4) Little is known of the tectonic environment of the deformed conglomerates associated with gneisses and granulites.

The mechanism by which near-spherical pebbles are changed to ellipsoids is not known but four kinds have been discussed:

1. The simplest case is that of a sphere which is converted to an ellipsoid by pure shear. The symmetry of the strain and of the rock is orthorhombic. This fits the example of Lawson (1913) and Osberg (1952) where the long and mean axes of the pebbles lie in a foliation and the pebble-axes are perpendicular to the fold-axes. It has not been regarded as compatible with the common case where the pebble axes are parallel to the fold axes. "Flattening" by slip along conjugate shears is dominant in the Loch Lomond and Beaverhead types and is important at Goat Island.

2. A sphere may be converted to an ellipsoid by simple shear along a single set of shear surfaces. The long axis of the ellipsoid is at an angle to the shear surfaces and the symmetry of the movement and of the rock is monoclinic. Oftedahl (1948) and others have regarded the foliation in the matrix as representing the surfaces of slip, but they are faced with the anomaly that the long and mean axes of the pebbles are parallel to the schistosity and not oblique. Oftedahl suggested that the simple shear was followed by rotation of the pebble into the schistosity but the pebbles are significantly different from the shape predicted by such a mechanism and no evidence was found of a slip surface in the pebbles. Brace (1955) suggested that the pebbles in the Vermont conglomerate could not have rotated because of the lack of disturbance of fine sedimentary lamination. Shear along a single set of surfaces has operated at Goat Island where some fragments are oblique to that matrix foliation which passes through them.

3. A sphere may be converted to a cylindrical shape by rolling, e.g. a ball of putty rolled between the hands takes on a cigar-shape (Hills, 1940; Elwell, 1955). Such an hypothesis allows correlation of pebble axes with the fold axes and with the fabric of the rocks, but pebbles such as Kvale's 100:3:1 "walking sticks" would require a great deal of rolling. The hypothesis is inadequate to account for the very flat pebbles which are common in deformed conglomerates.

4. Various complex combinations of "rolling and flattening" (Flinn, 1962) may be closer to the truth and many authors have considered a rather vague process of rock flow and viscous drag. This concept was recognized as long ago as 1862 when Scrope discussed the elongation of vesicular cavities in

lavas; Harker (1885) applied it to the deformation of fossils &c., in metamorphic rocks and Flinn (1956, p. 503 showed experimentally its application to the deformation of conglomerates. This hypothesis requires that the main flow in the rocks is parallel to fold axes and this is not accepted by many workers.

PSEUDO DEFORMED CONGLOMERATES

These rocks contain flat, elongate or somewhat irregularly shaped fragments in a foliated matrix and resemble deformed conglomerates very closely. They may result from the following processes:—

(1) Mechanical disruption (cataclasis) of various elements which were originally planar (beds, veins, dykes), cylindrical (mullions, quartz rods) or ellipsoidal (pebbles, boudins).

(2) Growth of ellipsoidal bodies, e.g. elongate, pebble-like blebs of quartz or pegmatite in schist (Quirke and Collins, 1930; Wilson, 1953; Reynolds, 1961).

(3) Accumulation of elongate clastic fragments under normal sedimentary conditions. Lineated quartzites commonly weather into cigar-shaped ellipsoidal fragments which might pack together to give a conglomerate with elongate fragments. With slight deformation a cleavage might be produced and the pebbles rotate to become parallel to the cleavage (Pettijohn, 1943; Glenn, Donner and West, 1957).

Pseudo-conglomerates produced by the first (tectonic) process above, have been found in regions where there are alternations of thin layers of differing competency. They are commonly associated with isoclinal folds in rocks which have been folded several times. The long- and mean-axes of the pseudo-pebbles are parallel to the foliation of the rock, and the long axes impart a lineation which is parallel to adjacent fold axes and other lineations. Such rocks are not uncommon and have been described by Paige (1924); Wegmann (1934); Engel (1949); Bailey and Tilley (1952); Sutton and Watson (1952); Wilson (1953, 1961); King and Rast (1956); Ramsay (1956); Back (1961); Baird (1962); Hills (1963); and Christensen (1963).

Pseudo-pebbles are a type of boudin. Pseudo deformed conglomerates have been called "boudinées" (Wegmann, 1934) and the deformation processes are related to boudinage. Two main genetic types of boudins may be recognized; the first is produced by non-rotational strain and could be called the *symmetrical type* (Ramberg, 1955) and the second is produced by rotational strain and could be called the *asymmetrical type* (Hills, 1940; Wilson, 1953; Rast, 1956; Baird, 1962; and Christensen, 1963).

The most common, simple, symmetrical boudins are sausage-like with one long axis, or barrel-shaped (Rast, 1956) or approximately equidimensional (chocolate-block). They are formed by the flow of less-competent past more-competent layers so that the more viscous or brittle layers are necked or ruptured to give lenticular, oval or blocky cross sections. Ramberg (1955) produced this kind of boudinage experimentally by flattening.

Many quartzite layers, quartz veins, quartzite fold-mullions and pebbles at Picnic Point and Goat Island have been fragmented by this process. They are characterized by orthorhombic symmetry of form, pointed ends, incompletely disrupted boudins, lines of closely spaced fragments of similar size, shape and composition, and by a foliation wrapping around the boudin. Some examples contain internal shears which are symmetrically developed as two sets at 40° to each other with the long axis of the boudin as the acute bisectrix.

Asymmetrical boudins formed by the intersection of compositional layering and a foliation are related to the cleavage mullions of Wilson (1953). Shearing takes place along the bounding surface of the mullions. Rotation of the cleavage mullions on the limbs of folds produce "lozenge-shaped" cleavage boudins (Rast, 1956). Baird (1962) showed that this process produced pseudo deformed conglomerates in the cores of folds where curved and intersecting near-axial fracture-cleavage sliced quartzite layers into pebble-like rods. All gradations from undissected folds to tectonic breccias with relict isolated fold hinges were found. Matley described similar rocks as long ago as 1899 and noted that the harder layers were drawn out into lenses, rolled into strings or broken into fragments.

Christensen (1963) showed the importance of bedding-cleavage intersections in producing lenticular layering which simulated flattened and stretched pebbles. The limbs of folds were disrupted by slip on closely spaced cleavage and the fragments were rotated to form lenticular fragments lying with their long and mean axes parallel to the cleavage, and their long axes parallel to the bedding-cleavage intersection. Cores of isoclinal folds were detached and rolled into cylinders.

These processes have all operated at Goat Island and Picnic Point. Quartzite layers and quartz veins have been sliced through by an oblique, penetrative foliation leaving lines of *en echelon* lenses resembling pebbles. Large fragments (some of which were probably boulders but some certainly detached fragments of beds) and fold mullions (with folded cores visible) have been sliced through by intersecting foliation surfaces. The smaller fragments are still in contact in many places but others are slightly or greatly displaced. These commonly have concave surfaces. Nested fragments and "tadpoles" are also commonly formed in this way and many thin wisps and flakes have been sliced off larger bodies.

GOAT ISLAND CONGLOMERATE

Abundant exposures of the rock known as "Goat Island Conglomerate" on the beach and wave-cut platform between Goat Island and Picnic Point (Burns, 1964) are composed of detached, rootless quartzite bodies of various shapes and sizes in a sparse, foliated quartz-mica (phyllite) or quartzose matrix. The quartzite bodies include many pebble-like or boulder-like objects which range from a centimetre or so to a metre in length, with the dimensions 30 x 15 x 7 cms. being common. Most fragments are composed of medium to fine-grained quartzite, mainly white but some pink or grey, some foliated and some massive. Grey flaky fragments of phyllite are common in some places.

The rock is monolithologic and a comprehensive search has failed to locate a range of rock types among the fragments; this would have established the existence of primary conglomerate. True conglomerate is known from the Ulverstone Metamorphics at Spalford, 10 miles to the south (Burns, 1964), and conglomerate on the beach midway between Goat Island and Picnic Point is only very slightly deformed (Plate I). Much of the Goat Island rock was probably originally conglomerate.

The shapes of the fragments are not generally geometrically simple and it is difficult to classify them but the following twelve types are most common at Goat Island:—

1. Sub-spherical simple ellipsoids.
2. Simple triaxial ellipsoids—prolate (cigar-shaped).
3. Simple triaxial ellipsoids—oblate (plate-shaped).
4. Platy flakes or wisps.
5. Asymmetrical twisted ellipsoids.
6. Concave-convex ellipsoids.
7. Tadpole-shapes (asymmetrical ellipsoids with one rounded bulbous end and a sharp " tail ").
8. Sub-quadrate ellipsoids.
9. Single-boudinaged ellipsoids (with one neck).
10. Multiple-boudinaged ellipsoids (with several necks).
11. Nested groups.
12. Irregular shapes which cannot be named.

This classification is somewhat arbitrary but some outcrops mid-way between Goat Island and Picnic Point are composed mainly of types 1 and 2; strongly deformed conglomerates at Goat Island contain abundant examples of types 2 to 8; pseudo deformed conglomerates from Picnic Point are rich in types 9 to 12.

At the Goat Island outcrop, the long axes of the parallel ellipsoidal fragments constitute a strong lineation which is parallel to fold axes in adjacent or enclosed phyllite and quartzite and to lineation (ribbing, mineral elongation) in quartzite. The mean and long axes of flat " pebbles " lie in the dominant foliation (S_2) which is subparallel to the axial surfaces of F_2 folds. Considerable departure from parallelism occurs and many pebbles are slightly oblique to the foliation. These are cut by " internal shears " which pass out into S_2 of the matrix and which range from one set of parallel planar surfaces to complex systems of curved surfaces intersecting the exterior of the fragments to give curved, crossing lineations. The internal shears make large angles with the short axes of the fragments. Movements which can be seen to have taken place parallel to the shears are always compatible with the apparent deformation of the fragments; displacements are usually very small but range up to almost a centimetre. The internal shear surfaces exposed on broken " pebbles " are commonly covered with a film of mica flakes and some show a fine lineation parallel to the visible displacement. Under the microscope the internal shears appear as zones of cataclasis and elongation of small recrystallized quartz grains or as intersecting lines of parallel mica flakes.

Petrofabric Analysis

Detailed petrofabric analysis of a variety of rocks from Goat Island to Picnic Point (presented elsewhere) shows that the quartz fabrics of quartzites, boudins, deformed pebbles and pseudo-pebbles are generally similar.

The main fabric-elements consist of a girdle of quartz {0001} normal to the long axis of pebbles and boudins and to the lineation of interbedded quartzites. A small-circle concentration with an axis perpendicular to the major foliation is most notable in the boudins where its axis is parallel to the shortest axis of the boudin. The girdle normal to the lineation is strongest in the quartzites.

Examination of petrofabric diagrams for quartz in deformed pebbles from other conglomerates by Strand (1945), Brace (1955), Flinn (1956) and Koark (1961) and in boudins by Delitsin (1964) suggests some features in common. Most important is the persistence of the plane of symmetry normal to the long axis of the pebble. The common lack of quartz optic axes near the long axis of the pebble may be expressed as a single strong girdle (Strand, 1945), as two girdles, symmetrically disposed about the long axis (Brace, 1955) or as a cleft girdle whose axis is the long axis of the pebble. The fabrics at Goat Island show all three tendencies. A general lack of optic axes near the mean pebble-axis causing a symmetrical break in the main girdle pattern is also seen in the diagrams of Strand. The tendency for optic axes to be concentrated near the short axis (with perhaps a broken small-circle near this axis) is also shown by Flinn.

In general, the Goat Island fragments have fabrics which are most similar to Flinn's Fetlar specimens. The degree of preferred orientation is not nearly as high as Brace's Vermont specimens in which no diagram contains a maximum weaker than 5%, with abundant 8% maxima and one of 16%. Maxima of 3, 4 and 5% are found in diagrams from Bygdin, Fetlar and Goat Island.

Neither Brace (*ibid*, p. 135) nor the authors have been able to find a correlation between the amount of deformation indicated by the form of the pebble and the degree of preferred orientation of the quartz optic axes. There is however a suggestion in the work of Flinn (figure 7 and p. 502) that the preferred orientation of quartz is stronger in more-strongly deformed pebbles.

DISTINGUISHING CHARACTERISTICS OF DEFORMED CONGLOMERATES AND PSEUDO DEFORMED CONGLOMERATES

Pseudo deformed conglomerates so closely resemble true deformed conglomerates as to be indistinguishable in certain instances. An observer who begins at the Picnic Point end of the exposure passes west across the strike from tightly folded quartzites and phyllites into the same rocks with detached and boudinaged beds, fold-mullions and quartz-veins, thence into pseudo deformed conglomerates in which the abundant lenticular quartzite fragments in a phyllite matrix have been produced by boudinage of interbedded thin quartzite and phyllite. Further west he passes into rocks which were probably originally conglomerates but which now contain abundant examples of boudinaged beds and veins and he might well conclude that no conglomerates are present at all. On the other hand if he began about mid-way between Goat Island and Picnic Point he would find slightly deformed rocks containing almost-spherical quartzite pebbles with smooth surfaces in a semi-pelite matrix. He could pass from these into rocks of similar appearance in which the fragments are long or flat and conclude that the rocks are generally true deformed conglomerates.

A deformed conglomerate can only be recognized *with certainty* if it contains, in some sufficiently undeformed part, bodies which cannot be anything else but pebbles. Nearly-spherical bodies with smooth surfaces have apparently the only shape common in pebbles which is not produced by tectonic processes *in situ*, although in high grade metamorphics, tectonic inclusions take on a well rounded form.

A gradation from a comparatively undeformed condition may allow a deformed conglomerate to be recognized, or some feature may be locally diagnostic of pebbles (Hills, 1963, p. 124). A range of composition of pebbles is generally taken as strong evidence against a pseudo-conglomeratic origin.

A detailed study of the fabric of deformed pebbles and pebble-like tectonic inclusions at Goat Island has not revealed reliable criteria for distinguishing between them by petrofabric analysis.

The features which suggest a pseudo deformed conglomerate are—

(1) Fragments with shapes different from those known to be produced by deformation of clastic particles;
(2) A limited range of compositions e.g. quartzite fragments in phyllite matrix, granite fragments in mica schist, amphibolite fragments in greenschist;
(3) Arrested stages in the boudinaging of beds, veins, mullions &c.;
(4) Lines of closely spaced fragments of identical composition;
(5) Extreme irregularity and variety of shape and size of fragments;
(6) Fragments with extreme dimensions;
(7) Concave surfaces on fragments;
(8) Restrictions of the conglomeratic rock to certain tectonic positions;
(9) Lack of true conglomerate in undeformed equivalents.

Empirically, it seems that pseudo-stretched conglomerates are found only in rocks which have been isoclinally folded, especially those folded twice.

The application of these criteria to the rocks from Goat Island and Picnic Point indicate fairly conclusively that true deformed conglomerate is abundantly present but that a significant proportion of the "pebbles" are not simple deformed pebbles.

Boudinage is common in the interbedded quartzites and phyllites at Picnic Point (Plate I). The boudins are up to 10 metres long with pronounced thinning-down or pulling-apart at the necks with extension fractures filled by secretion quartz. Many layers are boudinaged sheets but some are boudinaged fold cores (Plate I, No. 5).

Some simple and sub-spherical ellipsoids appear to have been originally somewhat spherical bodies, i.e. pebbles and boulders (Plate I, Nos. 2, 3). The single- and multiple-boudinaged fragments are regarded as arrested stages in the formation of ellipsoids or tadpole shapes and have been formed from ellipsoids (pebbles), cylinders (fold mullions) and sheets (beds) by a simple boudinage process. The nested varieties, at least in some instances, were originally larger bodies (ellipsoids, cylinders, or sheets) which have been sliced into an aggregate of smaller bodies by curved and intersecting shear surfaces. These shear surfaces pass through the fragments ("internal shears"), and are expressed in the fabric. They are essentially parallel to, and continuous with, the foliation in the matrix of the rock. Most of the "flakes" or "wisps" are thin slices which have been removed from other fragments. Other ellipsoids appear to have been larger bodies which have been disrupted by the somewhat irregular injection of matrix and may be related to the boudins in the cores of folds described by Baird (1962).

Pseudo conglomerates at Picnic Point are recognizable where the disruption of the boudinaged quartzite layers has been arrested and the lenses are still just connected by thin necks. "Stretched" conglomerate is recognized by the presence, particularly in the central part of the area, of abundant, smooth, sub-spherical quartzite bodies which have the appearance of undeformed pebbles, impinge on each other with convex surfaces, have no linear arrangement in the matrix, or whose origin cannot be explained in terms of boudinage.

Once a rock has been moderately deformed however, it may not be possible to decide whether an individual fragment was once a pebble which has been simply elongated, or whether it was a pebble which has been singly or multiply boudinaged or is a boudinaged mullion.

This limits the use of pebbles as strain indicators. Deformed pebbles have been regarded as strain ellipsoids (Turner and Weiss, 1963, p. 389) and conclusions have been derived as to the kind, symmetry, or amount of strain of the region from a study of pebble shape. Quantitative evaluation of strain is unlikely to be valid in many regions because—

(1) Many deformed conglomerates are in structurally complex areas which have undergone several deformations;
(2) Practically all have an abundant matrix in which large amounts of unmeasureable strain has taken place;
(3) Some very oddly shaped fragments are probably pseudo-pebbles;
(4) Pebbles may undergo profound volume changes due to recrystallization, disruption such as pull-apart during boudinage or slicing off of corners.

CONCLUSION

Although many of the fragments in the Goat Island conglomerate were once pebbles there is evidence that the deformation was a cataclasis or disruption rather than a homogeneous deformation of closed bodies which retained their identity during deformation. There is also evidence that some of the fragments are not pebbles but are boudinaged and dismembered beds so that some rocks are, in fact, only pseudo deformed conglomerate, i.e., the *boudinée* of Wegmann (1934). Thus the metaconglomerate is an assemblage containing fragments of diverse origins; some are pebbles, some are boudinaged and dismembered pebbles, and some are boudinaged and dismembered beds.

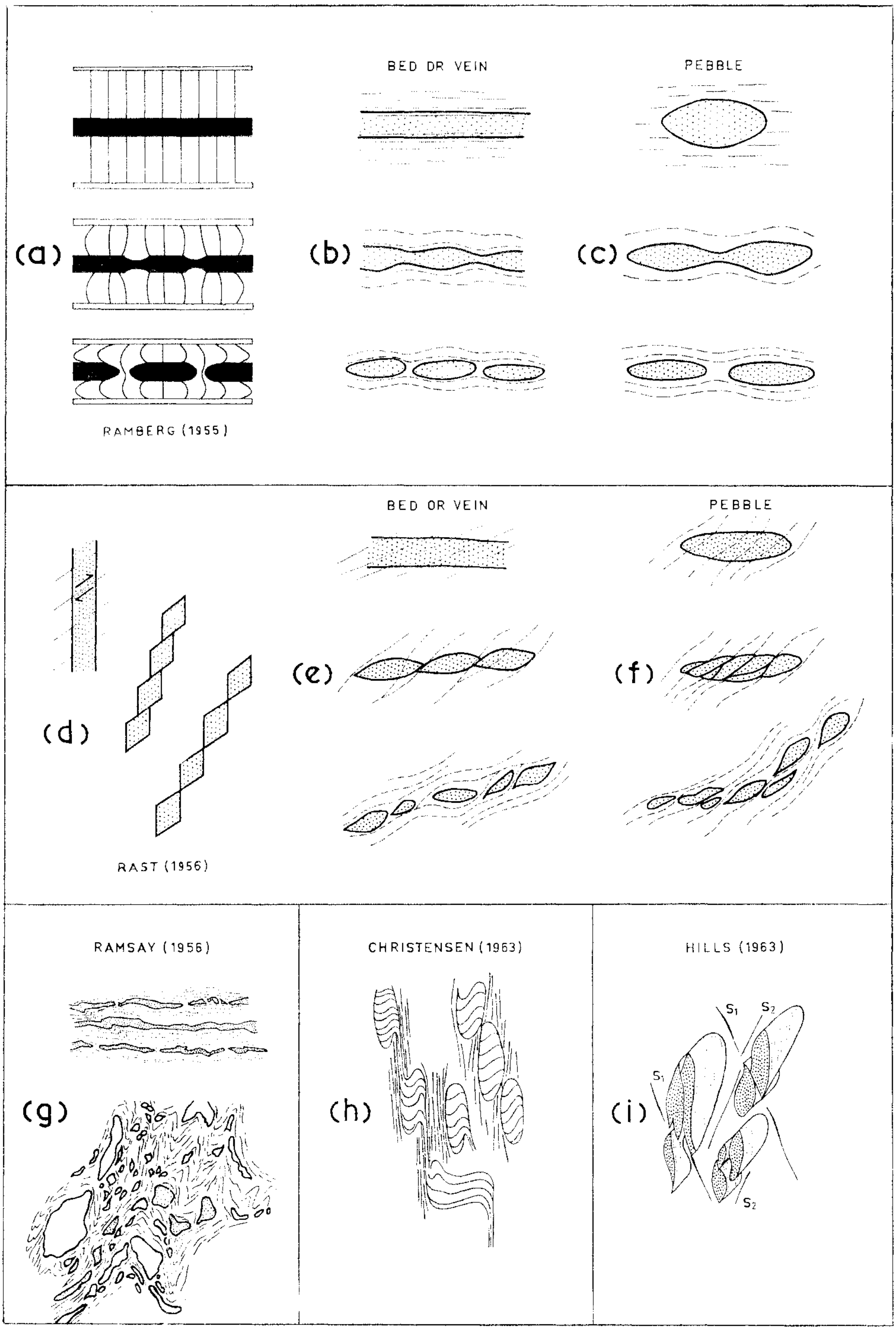

FIG. 1.—Boudinage mechanisms. (a) Experimental boudinage by pure shear after Ramberg (1955), (b) boudinage of a bed, (c) boudinage of a pebble, (d) boudinage produced by simple shear after Rast (1956), (e) boudinage of a bed or vein, (f) boudinage of a pebble, (g) Pseudo deformed conglomerate (Ramsay, 1956), (h) Disruption of layers in a fold-core to produce pseudo-pebbles (Chistensen, 1962), (i) Disruption of layers by movements on two shears, S_1 and S to produce pseudo-pebbles (Hills, 1963).

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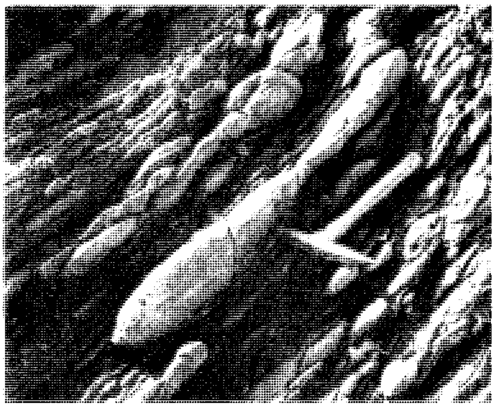

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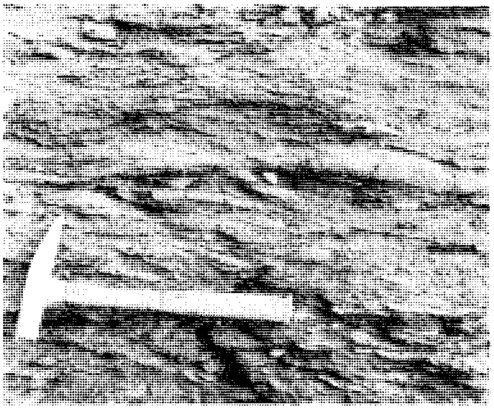

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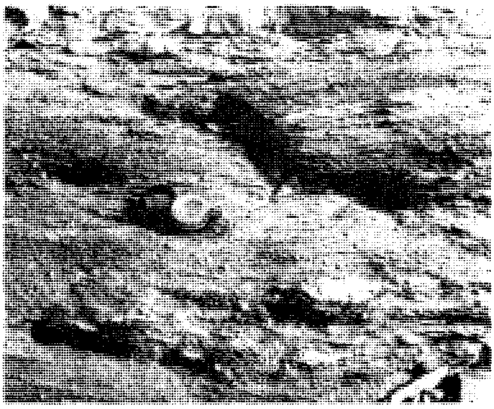

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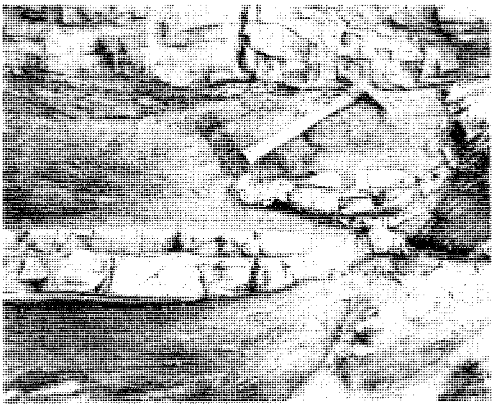

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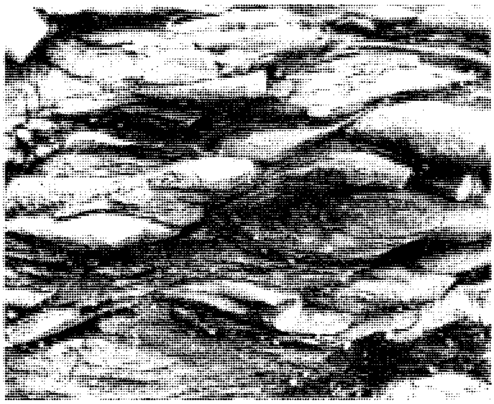

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PLATE I.—

No. 1.—Thick quartzite, Picnic Point. The foliation in enclosing phyllite is S_1 parallel to S_2. The boudin node is milky quartz.

No. 2.—Necked pebble, Picnic Point. A quartzite layer just above the fragment has been sliced into pebble-like fragments.

No. 3.—Boudinaged quartzite layer, strongly necked.

No. 4.—Isolated quartz lenses in phyllite due to disruption of a quartz vein.

No. 5.—Boudinaged isoclinal folds in quartzite, Picnic Point.

No. 6.—Pebbles disrupted at a shear surface crossing the foliation at a low angle.

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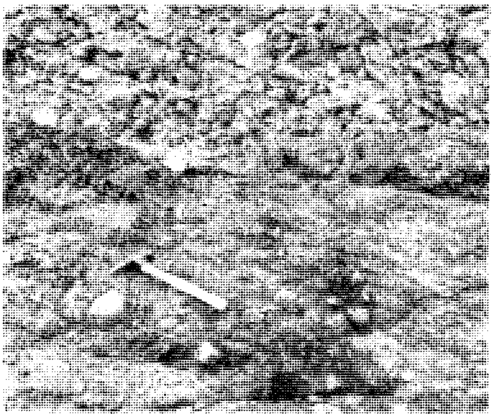

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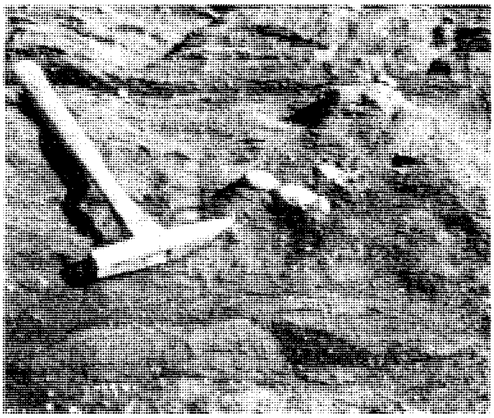

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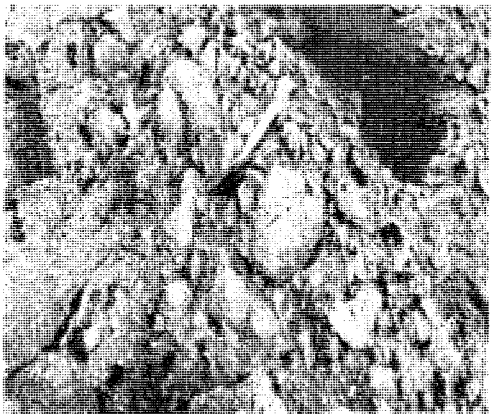

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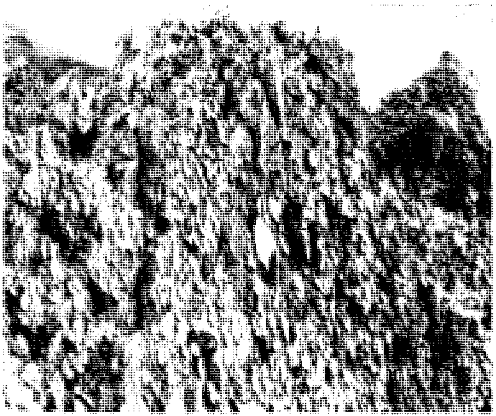

6

PLATE II.—

No. 1.—Almost undeformed conglomerate, "central outcrop", (mid-way between Goat Island and Picnic Point), with subspherical boulders in a phyllite matrix.

No. 2.—Isolated, subspherical quartzite pebbles in phyllite matrix, central outcrop.

No. 3.—Mildly deformed conglomerate, central outcrop.

No. 4.—Folded pebbly layer in phyllite, eastern end of marine platform, Goat Island. The principal foliation in the phyllite, S_2 is axial-surface to the near-isoclinal folds.

No. 5.—Thick layers of quartz-rich phyllite overlying metaconglomerate, North-east Goat Island.

No. 6.—Metaconglomerate at Goat Island viewed along the lineation, with a layer of phyllite strongly transposed along the foliation.

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