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Radiolaria as Critical Indicators of Deformation

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The distortion of various spherical and cylindrical bodies, organic and inorganic, has been used from time to time as a measure of the stresses to which the containing beds have been subjected. The most notable of these studies is that of Ernst Cloos (1947) who, after citing in historical review the earlier efforts, based his own approach to the subject on a study of the deformation of oolites. It would appear from Cloos' comprehensive introduction and from other literature on the subject that little if any use has hitherto been made of spherical radiolaria for this purpose, although Hudson, McGugan and Morton (1954, p. 135) have recently referred to the radiolaria of some of the cherts of Trucial Oman as being "uniformly compressed parallel to the bedding."

Radiolarian-bearing rocks have been recorded in south-eastern Queensland by Richards and Bryan (1923, 1924, pp. 57, 82, 1925) and by Denmead (1928, pp. 92-95). In all of these local examples the radiolarian skeletons are spherical in shape and are preserved as translucent chalcedonic casts in cherts, jaspers, quartzites or other very siliceous rocks of Devonian or earlier age.

The only reference to deformed radiolaria in Queensland is a short one by Richards and Bryan (1924) where Figure 3 of Plate XI is described as "Banded radiolarian chert found as a pebble" in which "as a result of considerable pressure the rounded radiolaria have been compressed into lenticular shapes."

The radiolaria which form the basis of this paper occur at Upper Brookfield, a western, outer-suburb of Brisbane. Here they occur as numerous translucent chalcedonic casts set in an opaque red jasper of the Neranleigh-Fernvale Group of possibly Silurian age (Bryan and Jones 1951, p. 2). The containing rock is remarkably uniform in character and measures approximately 150 feet in present thickness, striking W.N.W. and dipping at 70° to the S.S.W. The rock cleaves readily parallel to the bedding which thus becomes a conspicuous feature. A well-developed joint set takes a N.E.-S.W. direction while another less pronounced is approximately parallel to the strike.

The most notable feature of the radiolaria in these jaspers, and the one which forms the basis of this paper is their abnormal shape. But, fortunately for our purpose, the individuals on at least one horizon appear to be regular in all respects. These consequently provide a useful standard for comparative purposes. The skeletons are very numerous (over 100,000 to the cubic inch) and must be virtually perfect spheres, for slices in all directions are circular in outline (pl. 1, fig. 1). These undistorted radiolaria are all pierced by numerous evenly distributed circular openings which give them a reticulate appearance. This combined with their spherical shape places them in the sub-order Spumellina of the order Porulosida which ranges from Cambrian to Recent (Campbell 1954). Cross-sections of a few individuals each exhibit a single stout spine with an axial canal. It would seem from this evidence that spines were extraordinarily fragile or few in number and possibly limited to one for each individual.

In view of the striking similarity displayed by all these radiolaria and the suggestion put forward by Haecker (quoted in Glaessner 1944, p. 8) that only the adults possessed skeletons, the possibility was examined of all the circular sections having been derived from adults and these of nearly the same dimensions. A histogram was prepared based on a group of one hundred individuals in which frequency of occurrence was plotted against diameters. This showed clearly that the radiolaria, of which these sections represented random slices, could not all have been of the same size. Indeed the histogram showed that the size distribution is that to be expected in a normal population. The great majority of the circular sections were found to be between 0.06 and 0.12 mm. across. The maximum of 0.15 mm. reached by about 5 per cent. of the radiolaria probably represented great-circle sections of large individuals. A few very rare individuals, none of which was present in the group from which the histogram was made, are larger than all the others, have larger pores and, since these are less effective filters, are filled with an opaque red material similar to the groundmass.

Apart from these rare exceptions, each spherical skeleton is completely filled with radially arranged fibres of chalcedony which give a characteristic black-cross extinction pattern (pl. III, fig. 1b).

By contrast with the above, the radiolaria which provide the subject of this paper are all triaxial ellipsoids (pl. I, fig. 2). The axial proportions, while similar for the individuals of any one horizon may differ markedly in adjoining horizons. On every horizon examined the individual ellipsoids are in strictly parallel alignment.

A band, not much more than one inch in thickness, was selected for more detailed examination and numerous thin sections prepared. These showed that the ellipsoidal skeletons did not represent the original shape of the radiolaria, for the resemblance of these to the truly spherical skeletons in every thing but external shape is very striking and in shape itself, as the field evidence shows, there is an almost perfect gradation from strongly ellipsoidal assemblages in some bands, to nearly spherical assemblages in others.

It is true that one group of radiolaria, the Larcoidea of Glaessner (1944, p. 9) form triaxial ellipsoid skeletons, but that group is not found earlier than the Tetirary and figured specimens of it are quite unlike those under consideration (Piveteau, 1952, p. 309).

We conclude therefore that the ellipsoidal skeletons have been produced by the deformation of normally spherical individuals such as those already referred to. This conclusion is reinforced by the observation that while the spherical radiolaria show no disturbance of the radially arranged chalcedonic fibres with which they are filled, the ellipsoidal skeletons invariably show infillings of finely cataclastic aggregates patently produced by micro-brecciation of the brittle chalcedony (pl. III, *cf.* fig. 2a with fig. 2b).

In order to study the degree of deformation of the radiolaria, microslides were prepared in various directions through the parent rock, but all on the same horizon and within a few centimeters of each other.

A study of these slides showed that the direction of maximum elongation of each ellipsoid makes an angle of 20° with the direction of dip but lies in the bedding plane and is parallel to the more important joint set. The minimum diameter is at right angles to the bedding planes or nearly so.

This arrangement produces a lineation of the type assigned by Cloos (1946, p. 16) to the third of his ten categories, namely, "Lineation due to secondary flowage."

In an attempt to arrive at a quantitative estimate of the amount of distortion that had been suffered it was assumed that the largest individuals in any particular micro-section could be compared directly with the largest in closely adjacent sections, in whatever direction such sections were cut.

Measurements on this basis indicated that the ellipsoidal diameters of these large individuals were in the approximate ratio of 10 : 7 : 3. A simple calculation gives the diameter of a sphere of equal volume as almost exactly 6 and indicates that the maximum diameter of the ellipsoid represents an extension of the "a" axis by two-thirds and the minimum a reduction of the "c" axis by one half. The intermediate "b" axis has increased by one-sixth.

It is of interest and significance to note that this calculated diameter of the undistorted sphere (in the scale adopted here six which is equivalent to 0.2 mm.) is considerably larger than that of any of the undistorted spheres which we are using as a standard of reference and which reach only .15 mm. in diameter. From this we may conclude that the ellipsoidal radiolaria have experienced a notable increase in volume during and as a result of their deformation. Such an increase of volume could have been anticipated, especially in view of the brittle nature of the material. (See Nevin, 1949, pp. 32-33).

This increase in volume indicates that the force which brought about the distortion was not a simple compression. In particular the special case of vertical compression due to the weight of overlying sediments, even if it be admitted as theoretically possible, is ruled out not only by increase in volume but by the occurrence of quite undeformed radiolaria in a closely adjacent bed and by the variation in amount of deformation from bed to bed.

On the other hand, the increase in the length of the intermediate "b" axis indicates that the deforming force was not tensional (Fairbairn, 1949, pp. 199 and 202). But as Cloos (1946, p. 42) has shown "lineation accompanied by elongation of fossils, pebbles, ooids, and other shapes can well be recognised as secondary flowage," such as may occur in the forward motion of rock masses in folding and thrusting.

In an earlier publication (Bryan and Jones, 1954) we have shown that a large area including that under discussion has been subjected to the powerful Hamilton Thrust and been pushed forward some seven miles in a south-westerly direction. Such a thrust would be capable of producing the effects observed in the distorted radiolaria, namely, the differential effects in neighbouring bands, the direction of lineation, the pronounced elongation of the "a" axes, the comparable shortening of the "c" axes, the minor extension of the "b" axes, the cataclasis of the chalcedonic infillings and the increase in volume of the deformed individuals.

One important feature that is not in harmony with such a simple thrust from the N.E. is the present attitude of the containing beds which dip very steeply to the S.S.W., that is in a direction away from the thrust and diverging some 20° from it. But this apparent discrepancy is in agreement with other evidence that the Hamilton Thrust proper was not the final episode in the complex orogenic movement of which it was a part.

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Explanation of Plates

PLATE I

Fig. 1—Spherical (undeformed) radiolaria in red jasper. Ord. light X 34. Univ. of Qld. Slide No. 4729.

Fig. 2—Ellipsoidal (deformed) radiolaria in red jasper. Elongation is in direction of bedding. Ord. light X 34. Univ. of Qld. Slide No. 4723.

The two specimens were collected from within a few feet of one another.

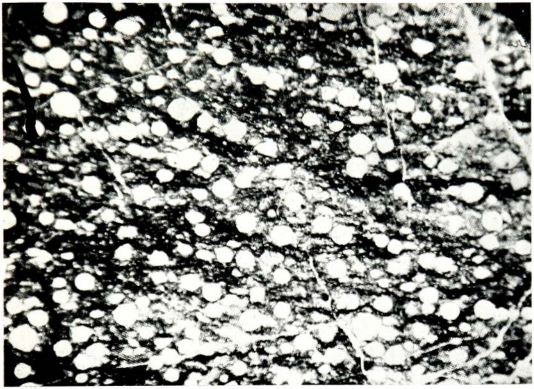
PLATE II

Three Photomicrographs taken from slides cut in three planes at right angles and assembled in the form of a block diagram to show the relative amounts of deformation in the three principal directions. Ord. light X 34. Univ. of Qld. Slides Nos. 4724-6.

PLATE III

Fig. 1—Undeformed radiolaria—
(*a*) Ord. light X 170. Univ. of Qld. Slide No. 4729.
(*b*) Crossed nicols X 170. Univ. of Qld. Slide No. 4729.

Fig. 2—Deformed radiolaria—
(*a*) Ord. light X 170. Univ. of Qld. Slide No. 4725.
(*b*) Crossed nicols X 170. Univ. of Qld. Slide No. 4725.



1

2

PLATE I

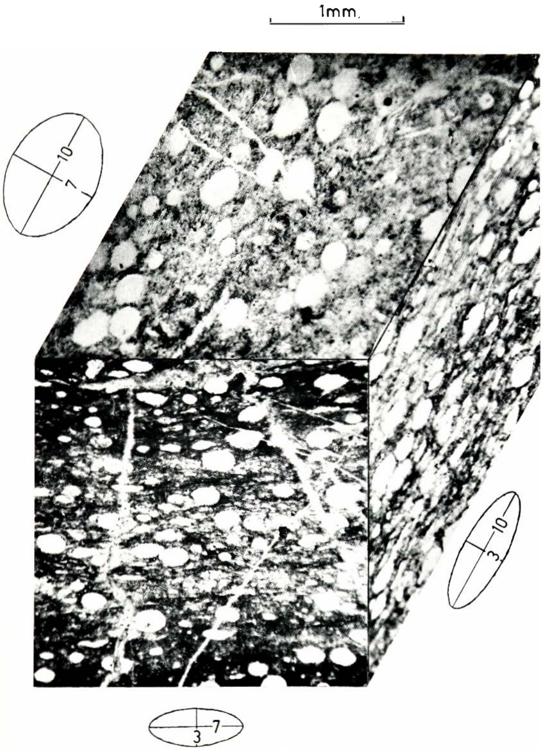
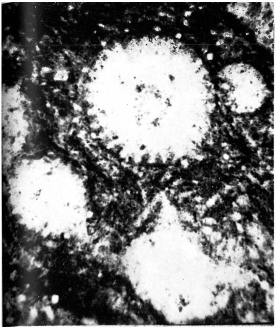


PLATE II



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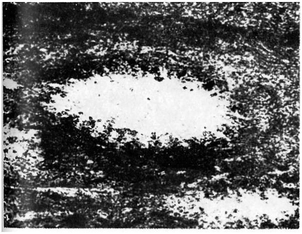
1b.



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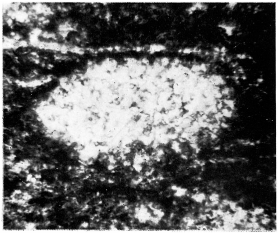

2b.

PLATE III