ORBICULAR ROCK FROM BUFFALO HUMP, IDAHO[1]

G. E. Goodspeed, *University of Washington, Seattle, Washington.*

Abstract

Within the area of the Idaho batholith, remnants of schist presumably of the Belt series, contain zones of orbicular rocks. The orbicules consist mainly of radiating perthitic-like intergrowths of plagioclase. A complete sequence in the schist from groups of feldspar porphyroblasts indicates a metamorphic rather than a magmatic origin. Gradations from a schist with orbicules to a rock composed chiefly of orbicules indicate that this orbicular rock was formed by metasomatic processes.

Buffalo Hump, with an altitude of nearly 9000 feet, forms one of the prominent monadnocks of north central Idaho, and, according to Shenon

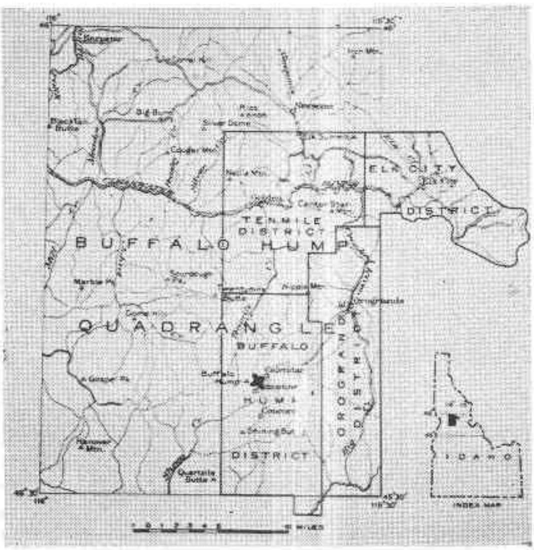


Fig. 1. Index map of Buffalo Hump Quadrangle.

and Reed,[2] rises over a thousand feet above the "so-called" summit of the Idaho peneplain. In their geologic map they show that areas of schist, quartzite, and gneiss, presumably of the Belt series, are nearly equal in extent to the Mesozoic granodioritic rocks of the Idaho batholith. Along a newly constructed mountain road between Calendar and Humptown (Fig. 1), a mile east of Buffalo Hump, several fine outcrops of orbicular

[1] Presented at the annual meeting of the Geological Society of America, Dec. 1940, at Austin, Texas.

[2] Shenon, P. J., and Reed, J. C., Geology and ore deposits of the Elk City, Orogrande, Buffalo Hump and Tenmile districts, Idaho County, Idaho: *Circular* No. 9, *U. S. Geol. Sur.* 1–89 (1934).

rocks are exposed in the road cuts as well as in adjacent glaciated surfaces. These rocks are associated with smaller northerly elongated remnants of schist, and with dike-like masses of pegmatite.

Occurrence of Orbicular Rock

Zones of orbicular rock, approximately 50 feet wide, may be traced parallel to the schistosity for several hundred feet. The orbicules (Fig. 2) in these zones range in size from less than an inch to several inches in diameter. Many of them are fairly regular ovoids with longer axes up to three inches in length. Some of them are more elongated, and a few

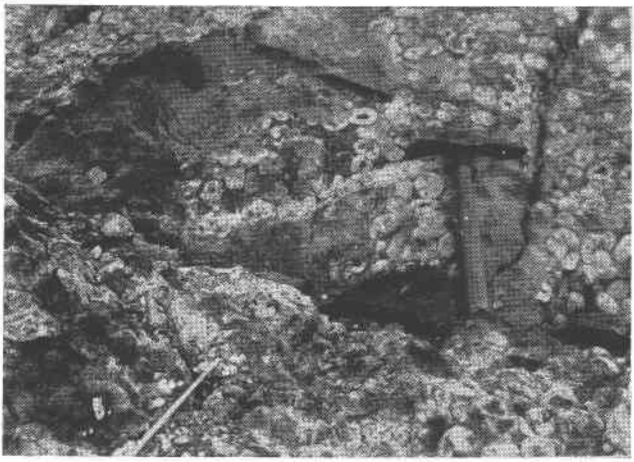


Fig. 2. Orbicular zone and included schist.

are nearly spherical in form. On weathered surfaces the orbicules protrude as egg-shaped masses since they are more resistant to weathering than their enclosing matrix. In road cuts or on fresh glaciated surfaces, white feldspathic orbicules contrast vividly with their darker matrix and exhibit locally irregular or gradational contacts in place of their usual rounded surfaces. Broken orbicules are seen to consist of radiating aggregates of plagioclase with twinning striations readily discernible on some crystals.

Another distinctive feature of some orbicules is the presence of dark cores (Fig. 3) which commonly constitute less than 10 per cent of the orbicules, but which may attain three or four times that figure. A few of these cores consist of tabular fragments of schist which determine the shape of the orbicule. Some of the cores appear to have been recrystal-

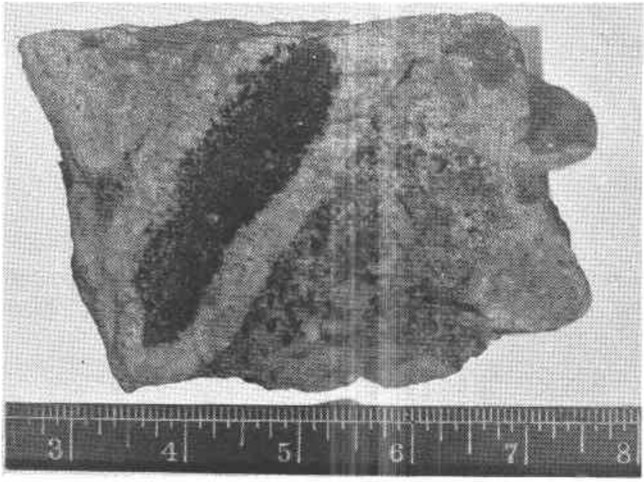


FIG. 3. Orbicule with core of recrystallized schist.

lized showing a concentration of mafic minerals with or without a suggestion of schistosity. Although a few have fairly even contacts with the surrounding aggregates of feldspar, most of them show uneven or grada-

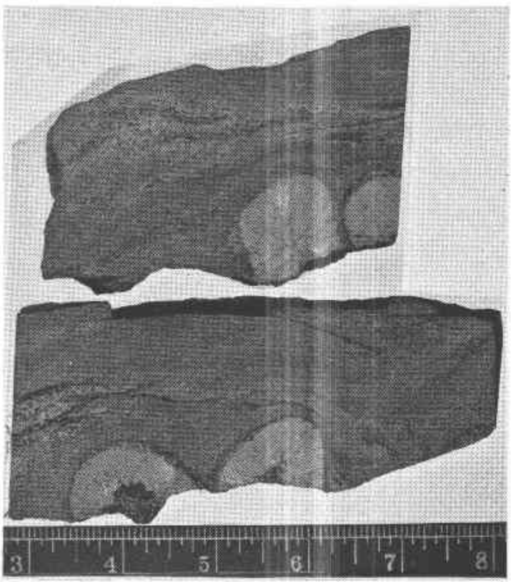


FIG. 4. Polished section of orbicules in schist adjacent to areas of feldspathization.

tional boundaries. A few of the orbicules contain nuclei of biotite which locally is arranged in radial flakes while others exhibit ill defined thin concentric ring-like inclusions of mafics, usually near the periphery.

Although most of the orbicules are closely clustered some are scattered in adjacent fine-grained quartz biotite schist. Some of these feldspar orbicules in forming have apparently pushed aside the schist in a manner similar to a garnet porphyroblast. In polished sections (Fig. 4), a later or secondary schistosity may be seen parallel to the rounded surfaces of these ovoids. The schist immediately adjacent to portions of some of these orbicules shows an increase in mafic minerals as discontinuous concentric zones which locally grade into the feldspar aggregates of the orbicules as well as into the schist. Many of the orbicules surrounded by schist also contain cores of schist or recrystallized schist.

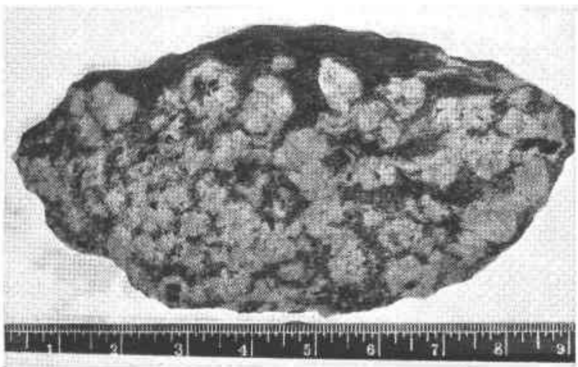


FIG. 5. Feldspar porphyroblasts and incipient orbicules in schist.

In the schist near some of the orbicules there are ill defined feldspar-rich bands roughly parallel to the schistosity and scattered feldspar crystals throughout the schistose matrix. Although some of these crystals are rudely rectangular in outline, many of them are irregular and have gradational contacts with the schist, thus indicating a porphyroblastic origin. Some contain mafic inclusions from the schist in a helixitic-like arrangement. Radial groups of some of these feldspar porphyroblasts (glomeroblastic aggregates) have the appearance of miniature incipient orbicules (Fig. 5). These display transitions from aggregates of porphyroblasts to small but fully formed orbicules, some of which appear to have developed around a core of schist in a concentric shell-like manner, while other groups seem to have coalesced as a unit developing radially from a central point rather than surrounding a fragment of schist.

Where the orbicules are closely clustered they form rounded polygons apparently due to mutual interference, and some actually merge with one another (Fig. 6). Here the matrix loses most of its schistosity, becomes slightly coarser grained in texture and shows a marked increase in crystalloblastic feldspar. Even in some highly orbicular portions, however, relics of thin tabular masses of schist grade into this coarser grained

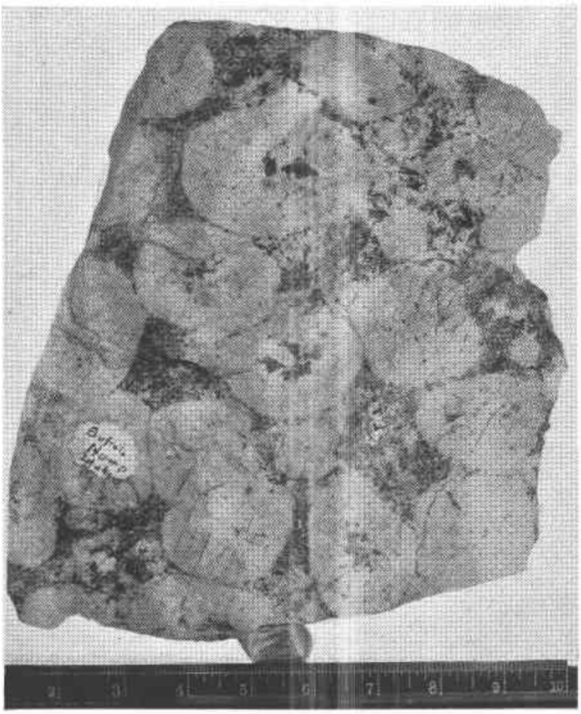


FIG. 6. Closely spaced and merging orbicules.

matrix which otherwise has the appearance of a fine grained granitic rock.

Locally both the matrix and orbicules are transected by small pegmatite dikes and veinlets (Fig. 7). Larger dikes of coarse quartz-feldspar pegmatite are also present in the orbicular zones. The gradational borders of these dikes with the orbicular rock and their content of relics of orbicules indicates that the later pegmatization has obliterated an earlier orbicular structure (Fig. 8). The pegmatized orbicular rock shows numerous slickensided surfaces along which elongated flakes of muscovite or biotite are common. Discontinuous slickensided surfaces are also

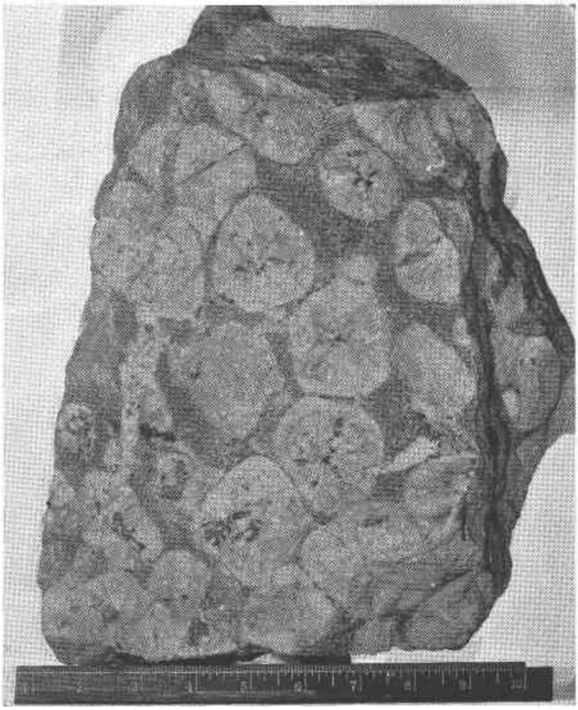


FIG. 7. Pegmatitic veinlets transecting orbicules.

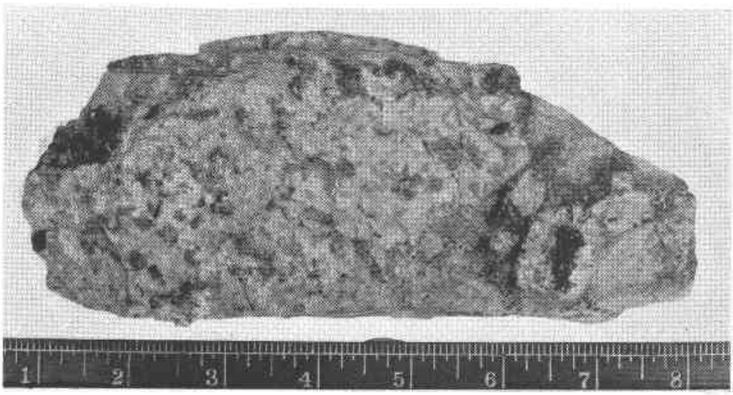


FIG. 8. Gradation of pegmatite into orbicular rock.

present in the orbicular rock. Some of these planes of fracture are bordered with a veneer of pegmatitic material, some transect orbicules, while others appear to have been healed by the development of the orbicules. These slickensided surfaces are commonly irregular and approach somewhat the coarse foliation of contorted metamorphic rocks.

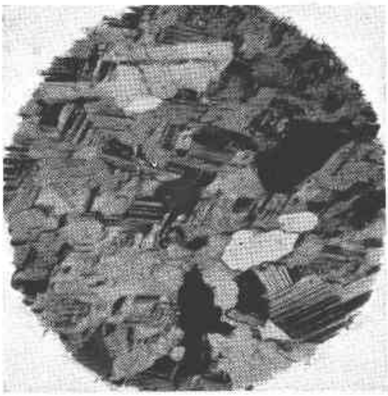
Petrography

The matrix between orbicules shows many variations in texture and mineralogy, ranging from a fine grained quartz biotite schist to a feldspar-rich or mafic-rich granular rock. The schist is a fine grained grayish rock with megascopic biotite, quartz, and feldspar. Polished sections cut at right angles to the schistosity disclose discontinuous quartz and feldspar veinlets parallel to the schistosity. Feldspathization appears along these veinlets and locally extends into the schist 2 mm. to 10 mm. on each side of the veinlet to form gradational contacts speckled with hornblende.

Under the microscope the schist is seen to consist of a fine aggregate of quartz, plagioclase, flakes of brown biotite in alignment with subordinate amounts of sphene, and garnet. Some of the smaller grains of quartz, about 0.1 mm. in diameter, are well rounded, and their shape indicates a detrital origin. The larger quartz grains average about twice this size and form a part of an interlocking mosaic texture. The plagioclase which is about the same size as the larger quartz grains, is calcic oligoclase, (An_{28}), in composition, and shows irregular boundaries indicative of crystalloblastic origin. Flakes of brown biotite interlocking with quartz and feldspar are about 0.6 mm. in length and 0.3 mm. in width. A few of them contain minute inclusions showing pleochroic haloes. Sphene and garnet occur commonly in small (0.1 mm.) rounded anhedra, although there are a few subhedral grains of these minerals.

In thin sections the quartz-feldspar veinlets traversing the schist adjacent to the orbicules show many features characteristic of replacement veinlets; uneven borders, irregular widths, bridge-like septa of schist, sieve structures caused by included minerals and crystalloblastic extension of the vein minerals. These veinlets also contain hornblende, both as relatively large anhedra (1.5 mm. in diameter), and as subhedral crystals. This mineral appears to have in part replaced biotite. The size of biotite is increased and the amount of sphene in these veinlets is also noticeable in greater quantities than in the schist. Adjacent to these quartz feldspar veinlets and to the associated areas of feldspathization, small (1 or 2 mm.) rounded aggregates of feldspar suggest incipient orbicules.

Under the microscope the orbicules present a striking array of radiating intergrowths. A few are simple sheaf-like aggregates of andesine (An_{34}), elongated parallel to the fast vibration direction. Even where the albite twinning is prominent there may be included plagioclase crystals of various orientations and irregular patches of unstriated feldspar (Fig. 9). In some orbicules earlier andesine (An_{36-37}) seems to have been replaced by later oligoclase-andesine (An_{28-30}). Here the oligoclase surrounds, transects and invades the earlier andesine with embayments typical of re-



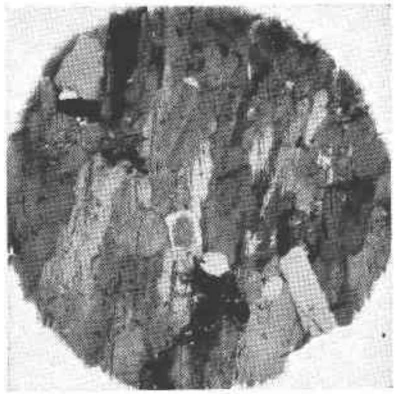


FIG. 9. Photomicrograph from a thin section of an orbicule cut tangentially to the radiating feldspar aggregate.
FIG. 10. Photomicrograph of an orbicule showing a mottled appearance.

placement. Many orbicules show radiating perthitic-like intergrowths which in certain sections produce a crisscross diamond shaped pattern under crossed nicols. The feldspar in other orbicules has a decided mottled appearance (Fig. 10) as though originally it had consisted of many individuals. In some of the feldspars the outline of earlier more calcic included plagioclase is distinct and these crystals may be roughly zoned, the central portion being more calcic. Similar zoning is also present in a few of the larger later feldspars. The plagioclase in some of the orbicules exhibits both albite and pericline twinning, showing the characteristic grid effect. Although resembling microcline these plagioclases have indices of refraction greater than Canada balsam, and they are probably close to andesine (An_{34}) in composition. The twinning lamella of some of the feldspars show a slight amount of curvature usually in areas close to the periphery of an orbicule (Fig. 11). In polished sections some orbicules may be seen to contain minute vugs showing crystal faces of the constituent minerals.

In addition to the inclusion of earlier plagioclase the feldspars of the orbicules contain scattered grains of zoisite, epidote, quartz, hornblende, garnet, sphene, occasional small crystals of pyrite which may be altered to limonite, and a few flakes of muscovite and chlorite. Zoisite occurs in the feldspar aggregate of the orbicules both interstitially and as included grains. The larger aggregates of quartz are later than the feldspar which

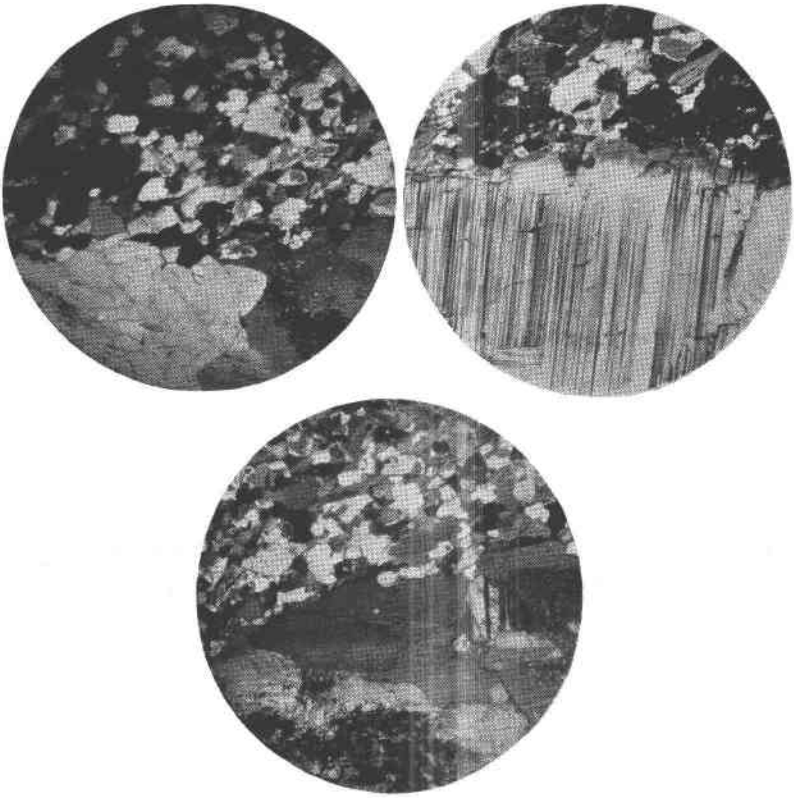


Fig. 11. Photomicrographs showing contact of orbicules and schist.

shows embayments indicative of replacement. A little micropegmatite is present in a few of the orbicules. Most of the feldspars in the orbicules have a turbidity which is due to included kaolinitic material, minute vacuole inclusions, and a very finely divided aggregate which appears to consist of zoisite and sericite. Although this finer included material is as a rule irregular in distribution, it is locally concentrated in certain portions of feldspar aggregates outlining perhaps an earlier feldspar or successive (010) twinning planes.

Some orbicules in schist are surrounded by a secondary schistosity apparently induced by the crystallization of the feldspar, others display locally irregular contacts due both to the inclusion of minerals of the schist in the orbicule and to the extension of the feldspar into the schist. Such crystalloblastic contacts which are most apparent in thin section are accentuated where the matrix is coarser grained and more highly feldspathized. Some sections show an outer zone of clear untwinned more sodic feldspar interlocking with the minerals of the schist, while the more calcic plagioclase toward the central portion of the orbicules, is polysynthetically twinned (Fig. 11). Slight bending of the twinning lamellae may be due to crystallization pressure. The projection of relatively slim extensions of the matrix into the orbicule indicates the absence of mass movement demanded by magmatic flow.

As seen in thin section, the common characteristic of the coarser granular matrix is the crystalloblastic habit of the constituent minerals. Typical sieve structures are common. Hornblende contains numerous rounded grains of quartz similar to the grains in the original schist and forms an irregular interlocking mosaic with quartz and feldspar. Some of the biotite occurs in small flamboyant aggregates and irregular flakes which surround other minerals. Paragenesis may be complex; some of the hornblende appears to be derived in part from an earlier biotite, while some of the biotite is later than the hornblende. In some thin sections of the matrix there is an increase in the amount of hornblende, biotite, sphene, and garnet. Zircon is also noticeable and a few crystals of pyrite are present. Plagioclase is distinctly of a crystalloblastic habit with irregular interlocking boundaries and abundant included grains of quartz and hornblende. Larger plagioclase crystals are typical porphyroblasts. Some later quartz and a little myrmekite, chlorite, and kaolinitic material are present.

Where many orbicules have become fully developed and are closely spaced, the matrix may almost disappear as the orbicules merge with one another. In such orbicules it is common to find a concentric ring of mafics which probably represents an early boundary of the orbicule now enclosed by continued or recurrent feldspathization, which extended the orbicule beyond its earlier limit.

Conclusions

Johannsen gives a complete summary of many types of orbicular rocks, and according to genesis has grouped orbicular granites as: (1) produced by the assimilation of foreign inclusions, (2) produced by portions of more basic or more acid segregations previously separated from the same magma, (3) group of so-called pudding granites, and (4) rocks whose structures are primary or due to endomorphic contact action.[3] In a recent paper Eskola points out that the interpretation of orbicular rocks as examples of magmatic differentiation has had very far reaching consequences for petrogenic ideas in general.[4] He concludes that esboitic (plagioclase-rich) orbicular rock has been formed by concretionary crystallization due to a metasomatic replacement of pre-existing minerals.

A summary of the significant features of the orbicular rock from Buffalo Hump, Idaho, is as follows: (1) some orbicules occur in schist of probable sedimentary origin; (2) these orbicules in themselves are not schistose; (3) a secondary schistosity in the schist around these orbicules is noticeable; (4) many orbicules have cores of schist or recrystallized schist; (5) replacement intergrowths and relics are common in the orbicules; (6) orbicules characteristically exhibit crystalloblastic contacts with granular matrix and other orbicules; (7) minerals common to metamorphic rocks are associated with the orbicular rocks; (8) minute vug-like cavities are noticeable in some orbicules; (9) orbicules occur adjacent to locii of feldspathization; (10) various stages of development from groups of feldspar porphyroblasts to fully formed orbicules are present.

This evidence, and especially the last two points just listed, indicates to the writer that the orbicules were formed in the schist as a result of metasomatic action of quartz feldspar-rich solutions penetrating local zones of fracture. The concretionary growth of the orbicules would have absorbed the mafic constituents of the schist and would have concentrated these constituents either in the cores of the ovoidal masses or at their peripheries. The secondary schistosity presumably was induced by the growth of the radiating aggregate. The orbicular rock at this locality is, therefore, an example of metamorphic rather than magmatic differentiation.[5]

[3] Johannsen, A., Descriptive Petrography of the Igneous Rocks: *Univ. Chicago Press* (1932).

[4] Eskola, Pentti, On the esboitic crystallization of orbicular rocks: *Jour. Geology*, **46**, (No. 3), 448–486, April–May (1938).

[5] Eskola Pentti, On the principles of metamorphic differentiation; Extrait des *Comptes Rendus de la Societe geologique de Finlande*, N: 05, (**1932**).