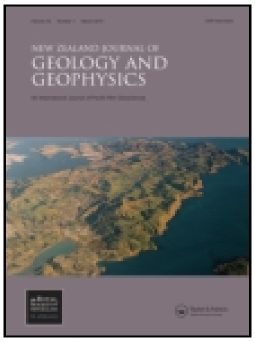

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Petrography of orbicular granitoids in the Separation Point Batholith, northwest Nelson, New Zealand

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Abstract Eleven occurrences of orbicular fabric in the (mostly) coastal exposures of the Separation Point Granite in the Motueka region, northwest Nelson, are described. Alkali-feldspar phenocrysts, biotite clusters, and orbicules may be concentrated locally. The orbicules, from 3 cm to over 20 cm in diameter, occur as a few to many individuals or as densely packed aggregates (orbiculite) in a granitic matrix similar to the main rock.

Orbicules consist of a spheroidal or squarish core either alone or with one to several concentric shells. Cores are essentially plagioclase (often radiating mosaics), whereas shells are either coarse alkali-feldspar (with quartz) or concentrations of magnetite and biotite arranged concentrically or tangentially through the persisting plagioclase, and usually of increasing abundance towards the edges of the orbicules. The orbicules may be elliptically deformed, or even fragmented, indicating a dynamic environment of formation and accumulation in the magma during its consolidation. Aplitic and pegmatitic dikes which crosscut the orbicules are late features.

Keywords Separation Point Granite; northwest Nelson; orbiculite; orbicules; spheroidal fabric

INTRODUCTION

All occurrences of orbicular or spheroidal granite in New Zealand referred to in the literature are from the west Nelson region (Suggate et al. 1978). To date, no occurrence *in situ* has been described in detail, although Kaiteriteri has been mentioned repeatedly and Mt Radiant was named once. The existing descriptions (Marshall 1939, 1946; Reid et al. 1972) refer to boulders only at Karamea and in the Glenroy Valley, respectively, and boulders at Wangapeka have also been mentioned (Fig. 1).

An introduction by M. Heath, Motueka, to most of the outcrops of orbicular granite north and also southwest of Motueka, in the early seventies, initiated more detailed investigations of this fabric type in the Separation Point Granite complex (Kobe 1983, 1987). At all the locations (numbered in Fig. 2), orbicular granite is exposed *in situ*, with the exception of loc. 5, referring to boulders.

Apart from the southwest Motueka occurrences (loc. 5 and 6) which lie inland, outcrops of orbicular granite can best be studied along the narrow strip between low-tide level and the edge of the vegetation on top of the storm-tide cliffs (loc. 1, 2, 7, 3, 4, 9). The outcrop on the ridge at loc. 8, and the blocks of orbicular rock at the foot of the cliff between loc. 3 and 4, suggest there are likely to be more occurrences inland, presently covered by soil and vegetation. However, the cover by lichens and mosses in the bush, and by barnacles in the intertidal zone, hinders severely the recognition of the fabric on exposed rock surfaces. In addition, the weathered rock—particularly inland—precludes practically any meaningful geochemical work. Therefore in this report only a petrographic description is attempted, covering general aspects of fabric variation in the coastal exposures of Separation Point Granite, detailed characteristics of the orbicular fabric in hand specimen, and specific aspects of the outcrops.

Although the variation of orbicular fabric expressions are reviewed, they cannot yet be related to the overall layout of the Separation Point Granite complex for a petrogenetic interpretation.

REGIONAL ASPECTS

The Separation Point Batholith, as exposed along the Tasman Bay coast from Riwaka in the south to west of Separation Point in the north, varies in modal

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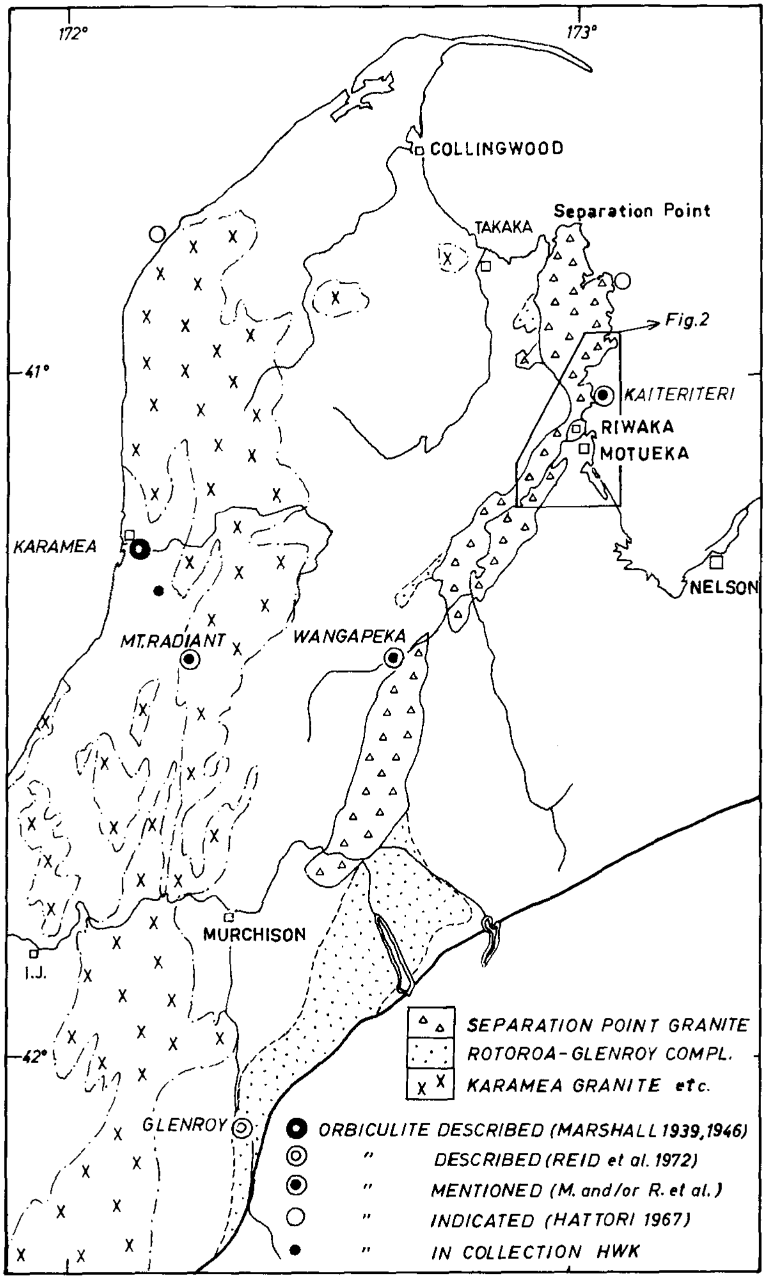


Fig. 1 Locations of orbicular (spheroidal) granites in the west Nelson region.

composition from alkali-syenite and alkali-granite to granite and granodiorite (field terminology according to the nomenclature of Streckeisen 1967), with finer grained, darker varieties, reaching mela-granitic composition, including some dikes. The chemistry of the principal types of this granitic complex is summarised in Tulloch (1983).

Fabric variations of these granitic rocks include aplitic (fine-grained) and pegmatitic (coarse-grained) dikes, layered series, and schlieren. Equigranular (fine to medium grained) and porphyritic main rock may contain locally minor, irregular, orbicular portions. The dikes (not reviewed in this report) have sharp boundaries against all other rock types,

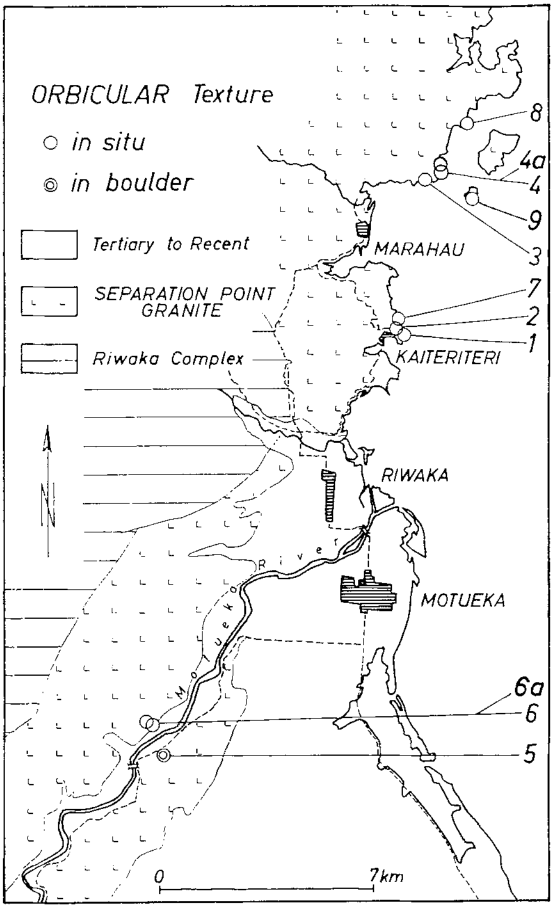


Fig. 2 Localities of orbicular fabric (*in situ* and in boulders) in the Separation Point Granite, Motueka region: (1) Kaka Pah Hill, (2) Breaker Bay, (3) Coquille Bay, (4) Guilbert Point – North, (4a) Apple Tree Bay – South, (5) Alexander Bluff, (6, 6a) Motueka–southwest, (7) Honeymoon Bay, (8) Yellow Point, (9) Fisherman Island.

and the fact that they cut occasionally across orbicules demonstrates their generally late intrusion. The outcrop sketches (Fig. 3) show the field relations of orbicular portions to the other varieties at most occurrences reviewed below.

A distinctive feature of the main rock is the variability of alkali-feldspar phenocrysts in size, quantity, and arrangement in space, resulting in irregular distribution of fabric expressions, very rarely with well-defined contacts between them. Alkali-feldspar phenocrysts, usually sharply idiomorphic and simply twinned, are from 1 cm to over 10 cm in length. Their quantity varies from 0 to near 100%. In the low range, a near-equigranular fabric is expressed (fine to medium grained granite), whereas, in the high range, a coarse-grained orthoclasite ("syenite" according to the modal classification of Streckeisen 1967) is realised.

The spatial distribution of phenocrysts may be random, or along streaks, clustered in irregular schlieren-like accumulations, occasionally in subparallel fluidal or gneissose arrangement. Along the coast, the alkali-feldspar phenocrysts weather out of the rock to accumulate as gravel and coarse sand on the shore. Where the main rock is equigranular, the sand derived locally may be strongly enriched in micas and/or magnetite. Another noticeable feature is the clustering of biotite with magnetite (often in radiating array) instead of its usual dissemination through all granite main rock varieties. These black clusters range from millimetres to several centimetres in diameter and are distributed very irregularly, although often a greater abundance is observed among and near orbicular fabric.

In most of the coastline exposed for 40 km north of Riwaka the granitic rock is porphyritic, varying locally to equigranular types, while orbicular fabric was observed only at the locations indicated on Fig. 2. No particular trend in modal composition over this distance was recognised.

ORBICULE DESCRIPTION (hand-specimen scale)

Orbicular granite is characterised by distinct ellipsoidal to globular bodies (orbicules, orbs), from a few centimetres to a few tens of centimetres in diameter, with concentrically arranged concentrations of their components (see Fig. 4 for some examples). Within such layers or bands, the dark minerals may show radiating and/or tangential orientation. For descriptive purposes, cores, shells, and matrix to orbicules may be distinguished, although the first two terms should not be applied too rigidly (see Fig. 5).

Cores

Very few orbs contain a core of an individual phenocryst (e.g., alkali-feldspar, plagioclase), and orbicular growth around xenoliths (which are generally rare) is virtually absent. Idiomorphic alkali-feldspar phenocrysts may be coated by a thin, discontinuous layer of biotite (loc. 1) but these are not considered to be "orbicules". Very few orbicules appear to have alkali-feldspar cores (perhaps at loc.

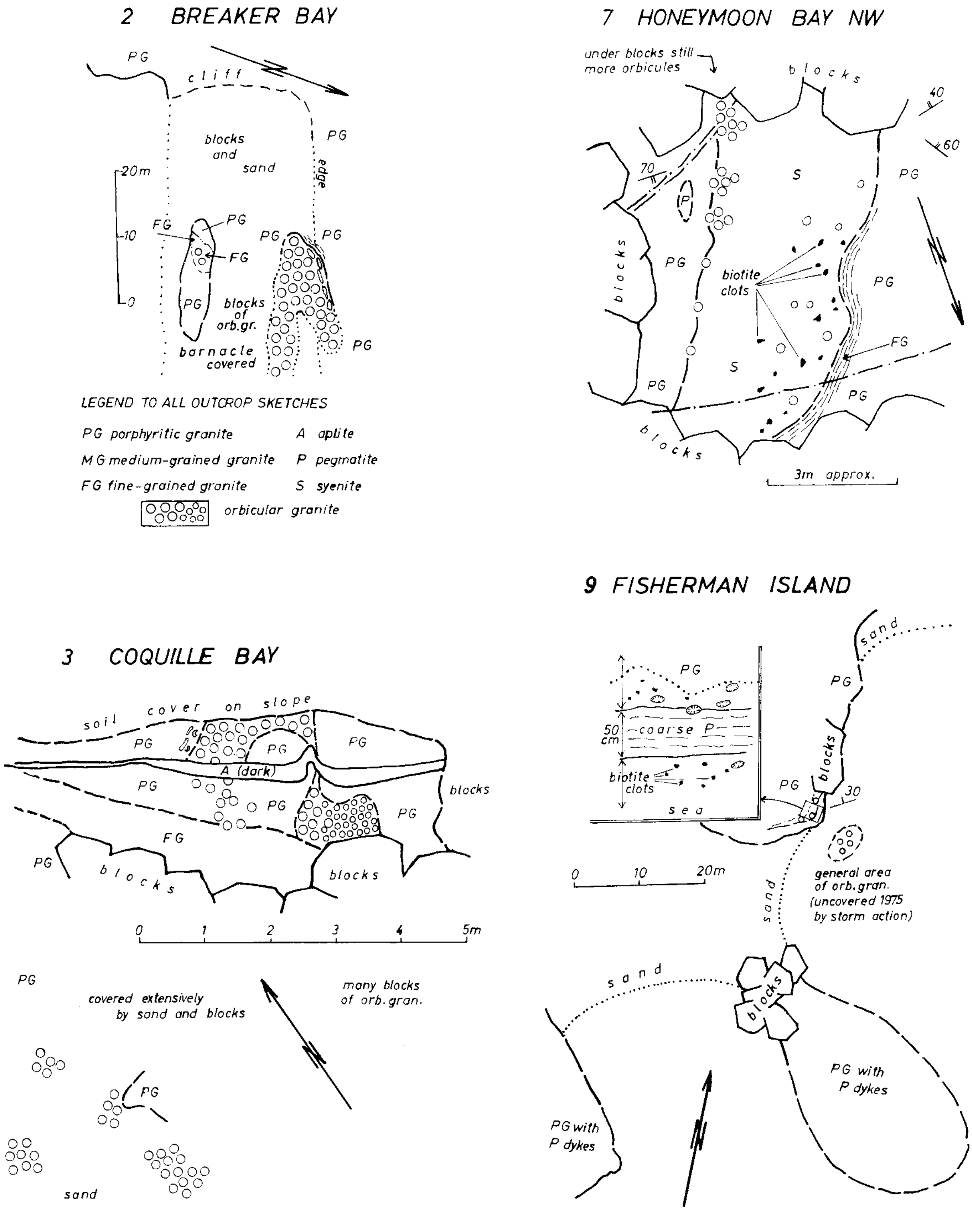


Fig. 3 (*above and opposite*) Outcrop sketch maps (all maps are oriented with the seashore below and the hillside towards the top). For localities mentioned in the text refer to Fig. 2.

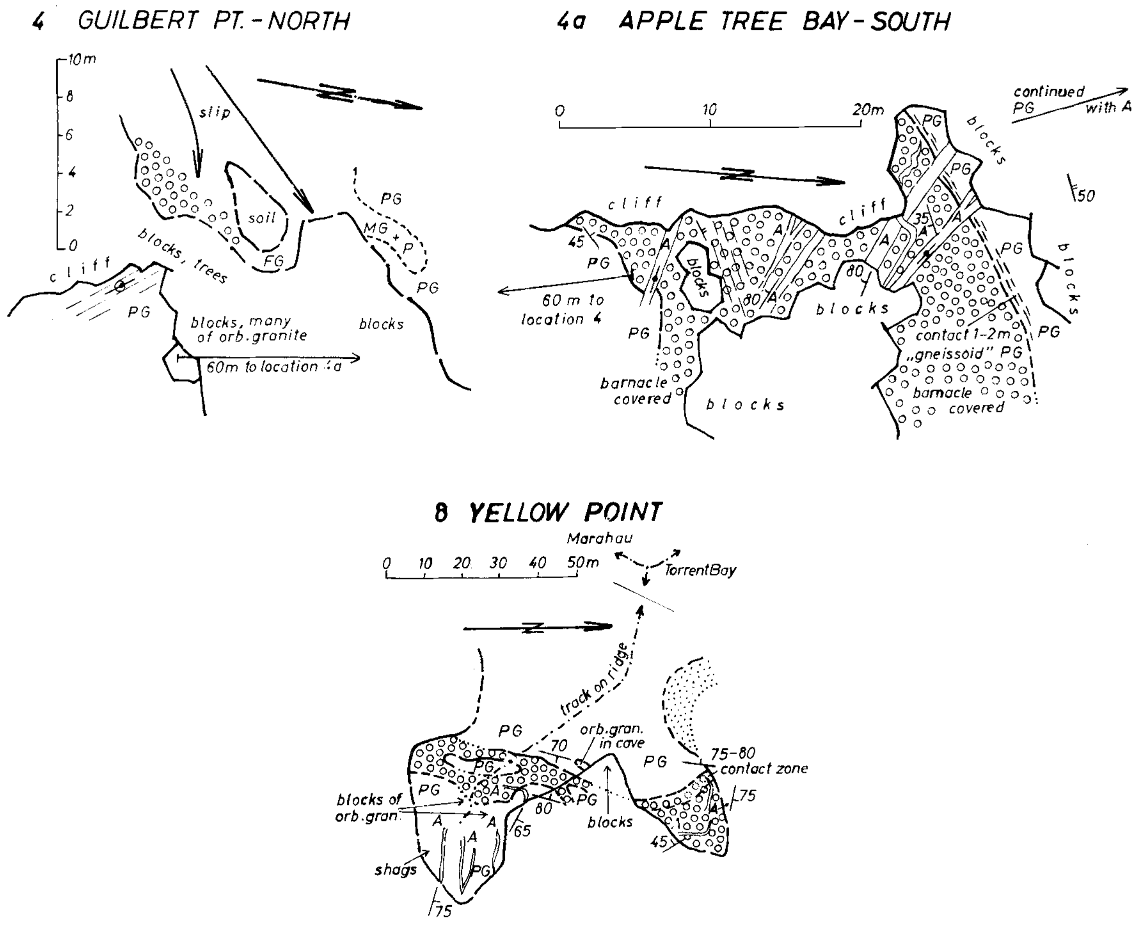


Fig. 3 (*continued*)

1 and 7). Also, the abovementioned clusters of coarse biotite (not xenoliths) cannot in themselves be called "orbicules", but may form the cores of such plagioclase-rich configurations (especially at loc. 3, 4, 4a, 8) (see Fig. 7C, 8B). Most orbicules have a plagioclase-rich core, either as a granular aggregate of squarish, zoned and twinned crystals, and/or radiating individuals with typical feathery outlines. What appears at first sight to be a large individual phenocryst is more or less distinctly subdivided into a mosaic of individuals with slight deviation in the direction of cleavages and twins, though subparallel to the orientation of the large "composite" individual.

Small quartz grains are intercalated along plagioclase grain boundaries, and in larger diameter cores quartz grains may be more numerous in concentric zones accompanied by magnetite and biotite, generally more abundant in the outer portions of the orbicule. Finely disseminated micas, darkening the cores, are more obvious where orbicules have an alkali-feldspar rim (loc. 4). Some orbicules (marked C in Table 1) consist solely of these plagioclase-rich, trondhjemitic core aggregates (loc. 6 and 8) (see Fig. 4A and 7C), which form spherical to slightly ellipsoidal bodies, up to 6 cm long, which are usually tightly aggregated in little granitic matrix.

Shells

Similar cores may be wrapped in an envelope of radiating alkali feldspar (usually following an intermediate enrichment of magnetite and/or biotite) (loc. 4) and are seen to develop into single-shelled orbicules of considerable dimensions (15–20 cm long). The thick alkali-feldspar shell of the orbs at

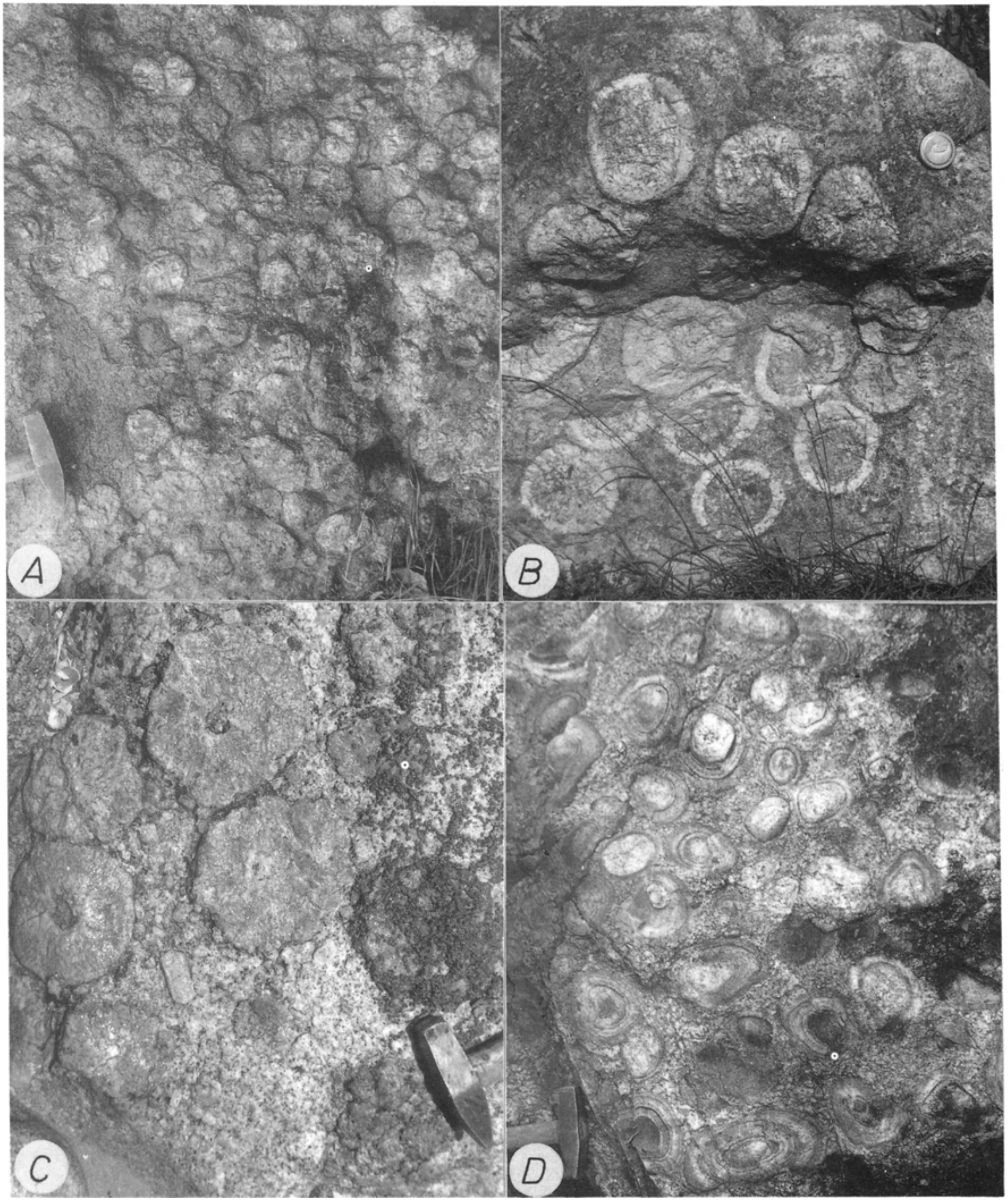


Fig. 4 Principal varieties of orbicules in their outcrop: **A** core orbicules (loc. 6); **B** single-shelled orbicules (loc. 5); **C** single-shelled orbicules (loc. 2); **D** multishelled orbicules (loc. 3). Scales: lens cover 4 cm diameter; hammer head 13 cm long.

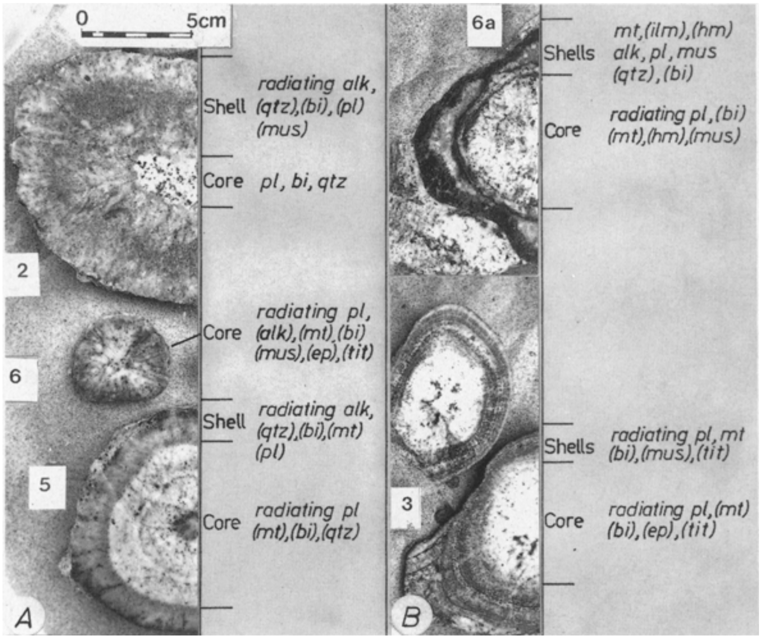


Fig. 5 Fabric and mineral constitution of orbicules: A core- and single-shelled orbicules; B multishelled orbs. Symbols: alk alkali feldspar, bi biotite, ep epidote, hm hematite, ilm ilmenite, mt magnetite, mus muscovite, pl plagioclase, tit titanite (minor constituents in brackets).

loc. 4 may consist of either long radiating or irregular coarse knobbly individuals. However, the ratio of core radius to shell thickness varies considerably from about 5 (loc. 5) to 0.1 (loc. 2), with the shells ranging in width from centimetres (loc. 4 and 5) to decimetres (loc. 2) (see Fig. 4B,C, respectively).

Multishelled orbicules are more common and conspicuous, although nowhere as spectacular as those with sharply defined shells from Karamea (Marshall 1946). The radiating plagioclase, in continuation from the core often through to the rim, contains irregularly spaced concentrations of magnetite/biotite in fine (–mm) to thick (+mm) layers and clusters, concentric to the outline of the orbs. Quartz and (in the outer shells also) some alkali-feldspar and muscovite are minor components (loc. 3, 6a, and 7) (see Fig. 4D, 6, and 8D). The dark components may display radial as well as tangential tendencies of orientation. If the latter prevail in the outermost layers, the coherence between orbicule and matrix is severely lowered, resulting in the weathering-out of the whole orbs from the rock (loc. 3) (see Fig. 7D).

Matrix

The matrix to the orbicules is extremely varied and usually much more inhomogeneous compared with the main granite elsewhere. All fabric varieties of the latter may be present (i.e., fine to medium grained, equigranular, porphyritic, and pegmatitic). In addition a matrix of "hash" of broken, comminuted orbs is abundant at loc. 3 (see Fig. 8C). The volume ratio of orbs to matrix varies widely, from the presence of a few individual orbicules dispersed in the main rock (= matrix) (loc. 1 and 7) to a tight packing of orbs with very little interorbicular matrix (loc. 6, 4a, and 8).

OUTCROP CHARACTERISTICS AND CONTACT RELATIONSHIPS

Contacts in the main "orbicular granite" rock (see Table 1) can only be defined where orbicules are abundant or densely packed. Otherwise the relation is "diffuse". In addition the term "discordant" is used only where a sharp contact cuts across orbicules. However, the very restricted extent of some outcrops (e.g., at loc. 3, 4, 6a) does not allow one to differentiate whether the crosscutting phase involves a larger volume of granite or a dike.

The following features describing external (contact) and internal relationships around and within orbicular or orbicule-bearing granite can be distinguished (cf. outcrop maps Fig. 3 and Table 1):

(1) contacts to the main rock are usually sharp (especially against dikes) (loc. 6a, 2, 7, 3, 9, 4, 4a, 8) (Fig. 6, 7, 8A, B) although often not straight;

Table 1 Synopsis of features observed at the 11 locations of orbicular granite described in this report (reference roughly from south to north—see Fig. 2).

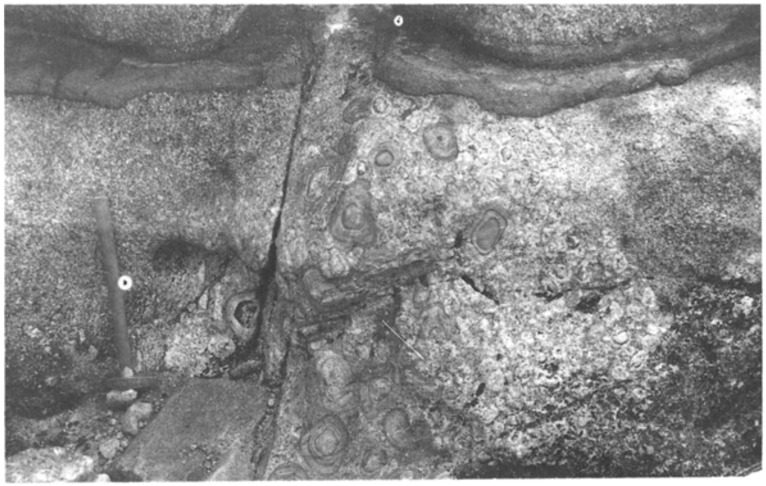
Locality no.	Locality	Nature of occurrence: O = outcrop B = blocks	Photos, Fig.	Map, Fig.	Orbicule type: C = core S = single shell M = multishelled	Orbicule diameter, range in cm	Orbicule abundance f = few, m = many d = densely packed	Composition () minor components (legend see below) Core	Shells	Matrix (legend see below)	Contacts s = sharp disc = discordant d = diffuse	Main rock (legend see below)
5	Alexander Bluff	B	4B, 5A	–	S	15–20	m	pl (qz)	af, qz	MG	–	–
6	Motueka-South	O	4A, 5A	–	C	5–7	d	pl (qz, af, mu, bi, mt, ti)	(bi)	MG	–	–
6a	Motueka-South	O	5B	–	S, M	8–12	m	pl (bi, mt, hm, mu)	af, pl, mu, mt, (qz, bi, il, hm)	FG	s-disc	FG–MG
1	Kaiteriteri Kaka Pah Hill	O	–	–	S	5–8	f	pl	bi, mt	FG, PG P	-, d	PG
2	Breaker Bay	O	4C, 5A	3	S	10–20	m	pl, bi (ep, qz, ti)	af, qz, (bi, ti, pl)	PG, MG	s	PG
7	Honeymoon Bay	O	8A	3	S, M	5–8	f	pl (qz, bi, ep, mt, ti)	mt, pl, bi, (qz, mu)	S	s	PG
3	Coquille Bay	O, B	4D, 5B, 6, 7D, 8C, D	3	M (C, S)	5–12	f, m, d	pl (qz, af, ti, ep, mt)	mt (ti, il, pl) (af, pl, qz)	MG, hash	s-disc, d	PG, A
4	Guilbert Pt-North	O, B	–	3	S, M	5–10	m, d	pl (qz)	mt, bi, pl, af, (qz)	FG, PG	s, d	PG, A
4a	Apple Tree Bay South	O	–	3	C, S	3–5	m, d	pl, bi (mt, ti, mu, ep)	af, qz (mt, il)	FG, PG	s	PG, A
8	Yellow Point	O	7A, C, 8B	3	C, S	3–7	d	pl, bi (mt, ti, mu)	al, qz (mt, il)	FG	s, d	PG, A
9	Fisherman Island	O	7B	3	S	3–6	f*	pl (qz)	bi, mt	PG	d	PG, P

*Outcrop exposed 1975: m

Composition: af alkali-feldspar; bi biotite; ep epidote; hm hematite; il ilmenite; mt magnetite; mu muscovite; pl plagioclase; qz quartz; ti titanite.

Rock types: FG fine-grained granite; MG medium-grained granite; PG porphyritic granite; S syenite (orthoclasite); P pegmatite; A aplite.

Fig. 6 Outcrop at loc. 3: equigranular to porphyritic granite (left) in contact with orbiculite (centre) giving way to core- and single-shelled orbicular fabric and "hash" of broken multishelled orbs (right). A later, flat mela-granitic dike cuts across this assemblage (top). Scale: hammer handle 40 cm long.



(2) mica enrichment in the main rock along the contact can often be observed (loc. 2, 7, 3, 4a) (Fig. 7D);

(3) a gneissose fabric may be developed usually only a few tens of centimetres on either side of a contact, but this effect may extend locally more than 10 m into the orbicular granite (loc. 8, northern contact zone) (Fig. 8B);

(4) orbicules may appear plastically deformed against each other (loc. 3) (Fig. 8D);

(5) diffuse interpenetration of the fine-grained, pegmatitic, and porphyritic granite containing biotite-rimmed alkali-feldspar phenocrysts, biotite clusters, and a few single-shelled orbicules (loc. 1) and an accumulation of coarse alkali-feldspar phenocrysts (orthoclasite or "syenite") with biotite clusters and odd single-shelled orbicules (the latter also aggregated along the eastern contact to porphyritic granite) occurs at loc. 7 (Fig. 8A);

(6) a mixture of core-, single-, and multishelled orbicules, broken orbicules, peeled-off shell fragments ("hash"), and biotite clusters form part of the rock at loc. 3 (Fig. 8C).

The most intricate relationships and most complete multishelled orbicules are found at loc. 3 and 4. It is likely that the two occurrences, outcropping on either side of Guilbert Point, actually connect inland, but rock is rarely exposed and of difficult access on the ridge. However, several blocks on the foreshore suggest continuity of outcrop in the cliffs above. The outcrop at loc. 4 was severely modified and obscured by a recent slip, reducing the possibilities for investigations of orbicular rock exposed *in situ*, although many blocks can still be studied (Fig. 3).

An orbicular granite outcrop on Fisherman Island (loc. 9) (Fig. 3) was exposed only shortly after the clearing action of tropical cyclone Alison, 1975 (M. Heath, pers. comm.), and it contains biotite-rich single-shelled orbicules similar to some at loc. 1, 3, 6a and of course those still exposed on shore at loc. 9 (Fig. 7B). The two outcrops at loc. 6 (along the road, see Fig. 4A) and 6a (20–30 m distant in the bush) have no connection to the country rock at large, although a short, sharp contact to a medium-grained granite was observed at the latter locality.

The origin of two blocks of orbicular granite found at loc. 5 (see Fig. 4B) could not be located, and therefore their contact relations remain unknown.

CONCLUSIONS

This petrography of the occurrences of orbicular granite in the southeastern part of the Separation Point Batholith highlights the complexity of features to consider in a future genetic interpretation of orbicular fabric.

In most outcrops orbicules vary widely, in shape, size, composition, number, and distribution of shells (with due consideration of the fact that only some of the exposed surfaces represent sections through their centres). The diversity of interior characteristics of orbicules suggests that they grew under quite variable conditions, probably in various places within the magma chamber. Their association with biotite clusters and uncoated alkali-feldspar phenocrysts

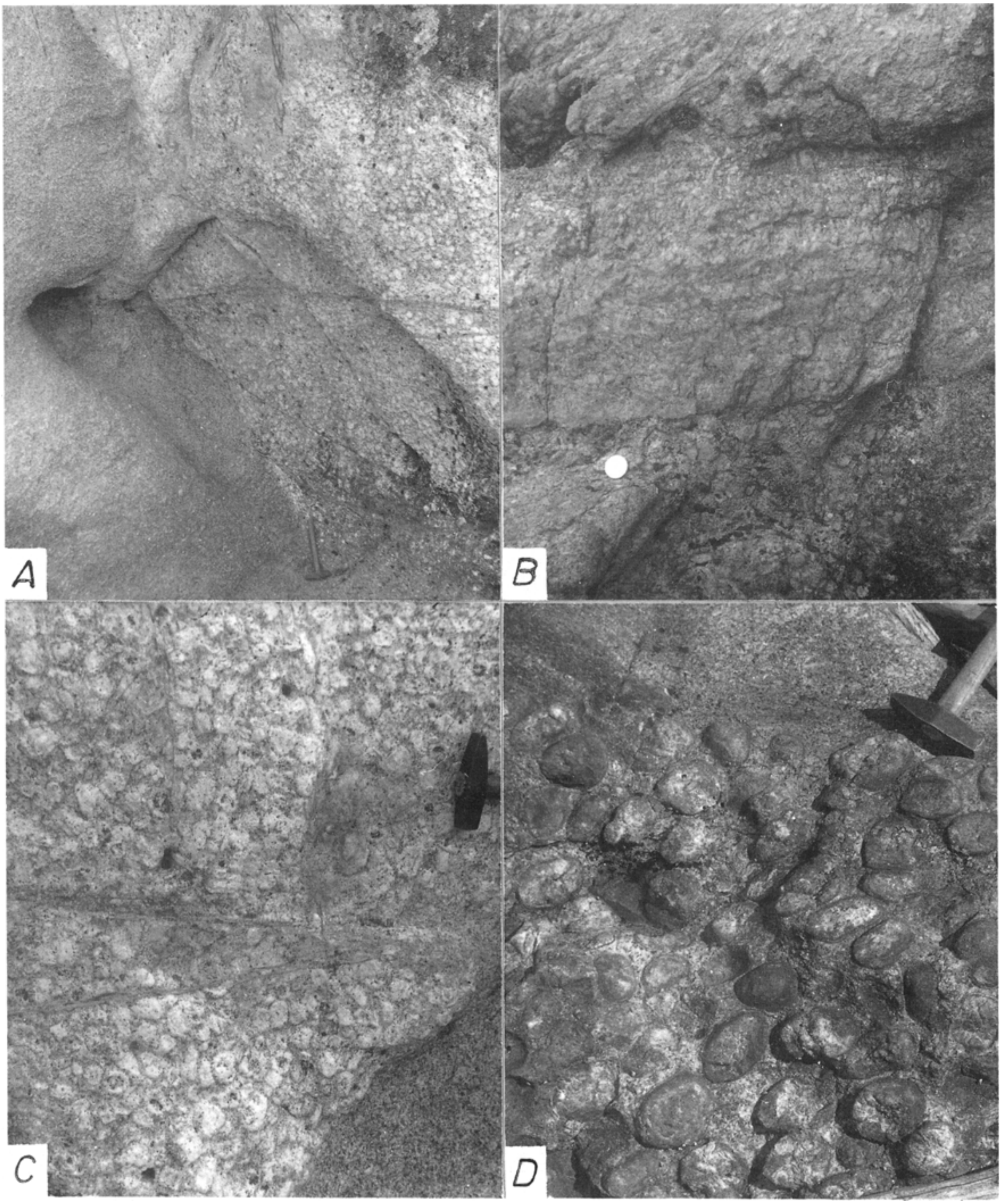


Fig. 7 Contact relationships: **A** porphyritic granite against orbiculite (core- and single-shelled orbs and biotite clusters) (loc. 8); **B** odd orbs in porphyritic granite cut by flat pegmatite (loc. 9); **C** detail of orbicular granite (loc. 8); **D** fine-grained (dike?) (top) with biotite enrichment along contact with orbiculite (loc. 3).

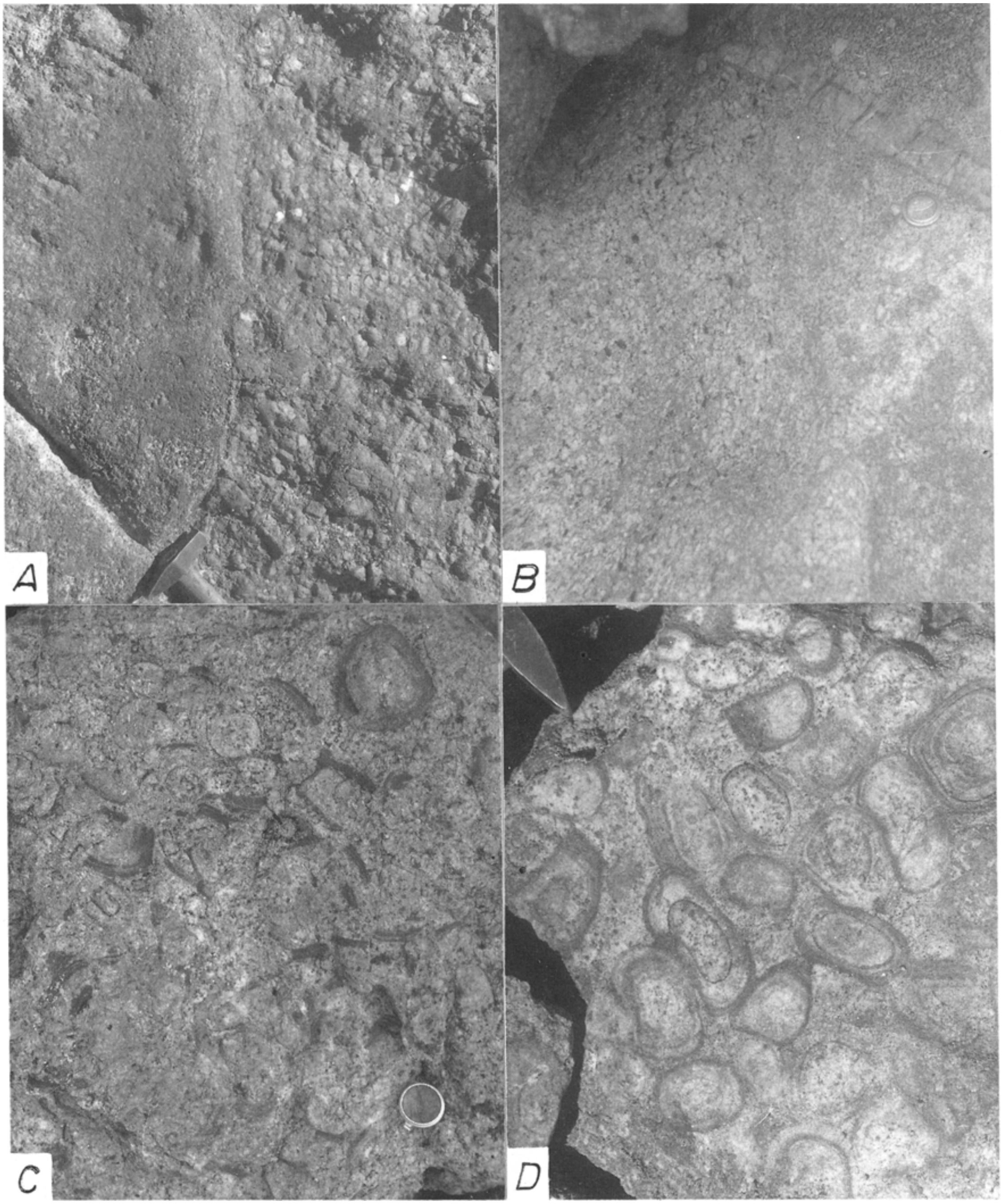


Fig. 8 Contact relationships: **A** slightly porphyritic granite (left) against orthoclasite ("syenite") (right) with odd orbicules along contact (loc. 7); **B** gneissose zone along contact between porphyritic granite (right) and orbicular granite with biotite clusters (left), crossed by thin oblique aplite (top) (loc. 8). Particular internal characteristics: **C** fragmented orbicules "hash" (loc. 3); **D** deformed multishelled orbicules (loc. 3).

(both common, though less concentrated components of the main rock) indicates that the orbicules also were early crystallisations in the magma. Elliptical deformation of orbicules in general, and their plastic molding against each other, points to a moderately mobile environment, while the breaking-up of orbicules and the aggregation of this "hash" suggests transport in the magma of variable viscosity and accumulation of all these early consolidated particulates by a sweeping action into certain embayments of the magma chamber.

Yet the process of orbiculation appears to be singular, as only one or two fragments of orbicule shells were seen to be coated by a feldspar shell, and nowhere was fusion of two orbs by envelopment in a common outer shell observed. This implies that the smaller orbs with core only are to be considered as fully developed orbicules under the local environmental conditions, while single-shelled and multi-shelled orbs grew independently under different circumstances, and are not seen as further developments of the former. Development of a gneissose orientation on both sides of a contact may indicate movement between main rock and orbicular portion, both being in an advanced high viscosity stage of consolidation. However, the sharp and occasionally discordant truncation of orbicular granite by dikes refers to a much later event, when the granite was fully consolidated.

While the above considerations are attempts to elucidate the possible ways of formation of orbicular fabric based on field observations, it is clear that further investigations (structural, mineralogical, geochemical) at microscopic scale and by analytical methods are needed. Because most of the described occurrences of orbicular granite display their relationship to the adjacent main rock, a more detailed study of them, together with an integration of the fairly voluminous international literature, could contribute substantially to the common knowledge of their petrogenesis.

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