ORBICULAR DIORITE FROM HARDANGERVIDDA, SOUTH NORWAY

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An erratic boulder of orbicular diorite occurs near Dyranut-Tråastølen, Hardangervidda, in an area underlain by Precambrian rocks. The orbicules are both mono- and multi-shelled, with the darker shells relatively enriched in biotite and magnetite. A radial alignment is defined by plagioclase at places, while biotite is tangentially oriented. Primary textures are masked, however, by strong secondary mineralization. An igneous origin by comb-layering around early-precipitated mineral aggregates (autoliths) is postulated for formation of the orbicules.

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Several authors have recently demonstrated a close connection between comb-layering and formation of orbicules (Van Diver 1968, Barrière 1972, Moore & Lockwood 1973, Bryhni & Dons 1975, Lofgren & Donaldson 1975, and Van Diver & Maggetti 1975). It is sometimes difficult, however, to tell whether comb-layered minerals formed in the magmatic stage or immediately thereafter by replacement (Van Diver 1968, 1975, Bryhni & Dons 1975). Furthermore, orbicular rocks are often strongly affected by subsequent hydrothermal alteration, which obliterates the primary textures. The present contribution describes a new occurrence of orbicular rock in Norway, where there is some evidence for a process of comb-layering around an autolith nucleus, but where secondary mineralization is considerable. The samples are from an erratic boulder about 40 cm in diameter, recently found by B. Stavenes in the Dyranut-Tråastølen area of northern Hardangervidda. The boulder is the fifth occurrence of orbicular rock in Norway and probably derived from the subjacent Precambrian basement. The nearest known occurrence is an orbicular mono-shelled hornblende gabbro with radial hornblende alignment which was described by Rekstad (1907) from Bukkanut in the Precambrian area 90 km to the southwest.

Description

General

Available samples show that the orbicules make up about 70 % of the bulk rock and that they have maximum diameters in the range 6–8 cm (Figs. 1 and 2). The matrix is inhomogeneous with distinguishable fine and coarse domains. Orbicules have light cores and dark grey shells. They have smooth

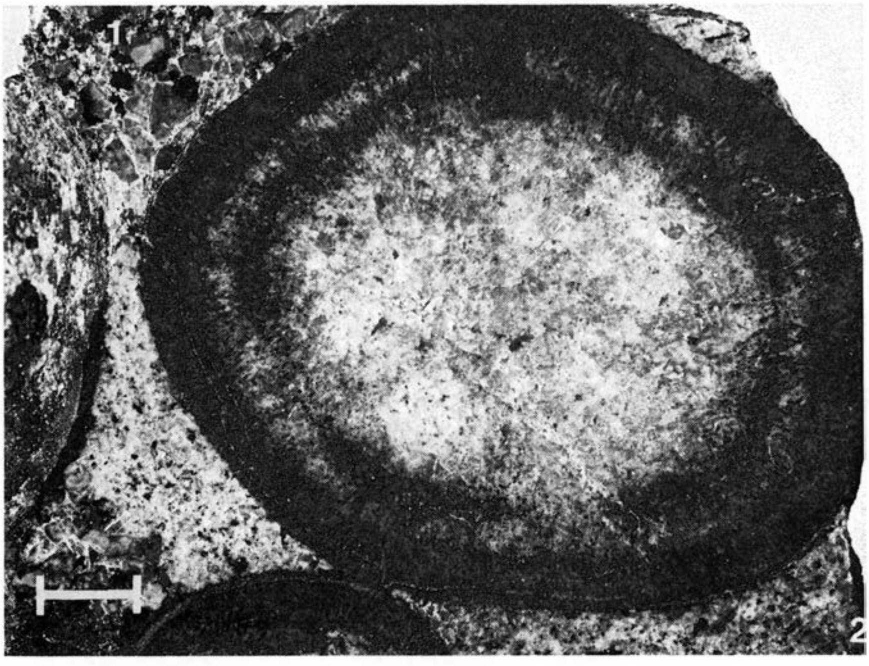

Fig. 1. Multi-shelled orbicule with comb-layered shells and almost pentagonal outline. Matrix is inhomogeneous with coarse (1) and fine (2) domains. Polished section. Length of bar: 1 cm.

surfaces and are easily removable from matrix because of a tangential arrangement of biotite. Most of them are spheres with slightly flattened surfaces in places. One sectioned orbicule has a pentagonal outline which is reflected in the form of the shells (Fig. 1). This particular orbicule is multi-shelled with a medial diffuse and incomplete ring of a light material similar to that of the core. Other orbicules are mono-shelled with a single shell only 0.3–1.0 cm thick.

A slight radial arrangement of minerals or crystal boundaries is mesoscopically evident in some orbicules. Plagioclase ($\sim An_{35}$), quartz and biotite are essential minerals and the rock can be classified as an orbicular diorite. The dark grey rims are relatively enriched in biotite and magnetite while the cores are relatively enriched in plagioclase and quartz (Table I). Primary compositions and textures are very blurred by saussuritization, sericitization and partial recrystallization of the plagioclase.

Matrix

There are distinct coarse- and fine-grained domains in the matrix between the orbicules (Figs. 1 and 2). Plagioclase occurs both as idiomorphic or hypidiomorphic grains showing strong secondary alteration, but clear, recrystallized rims; and as recrystallized, irregularly shaped grains which engulf the other minerals. Individual grain boundaries are hard to see in the fine-

Table 1. Estimated composition of orbicular diorite (volume %). — means "not observed", × means "occurs in minor amounts". * Excluding very fine grains in the altered plagioclase.

	Potash feldspar	Plagioclase	Quartz	Amphibole	Biotite	White mica*	Epidote minerals*	Sphene	Carbonate	Scapolite	Apatite	Magnetite	Pyrite
Matrix (coarse)	×	80	10	—	5	2	3	×	—	—	—	×	—
Matrix (coarse)	×	75	15	—	5	2	2	×	—	1	×	×	—
Matrix (fine)	—	90	5	×	5	×	×	×	—	—	×	×	—
Rim of orbicules	—	60	5	—	20	×	×	—	—	—	—	15	×
Rim of orbicules	—	70	5	—	20	×	×	×	—	×	—	5	—
Core of orbicules	—	80	15	—	×	2	2	1	×	—	—	×	×
Core of orbicules		80	15	—	—	2	3	×	—	—	—	×	—

grained domains because of secondary alteration, but rather idiomorphic outlines are preserved within an orthite megacryst which transects the domain contact. Sphene also occurs as rather well-formed crystals in the matrix.

Core

The cores are essentially pale yellow-green coarse- or medium-grained aggregates of saussuritized/sericitized plagioclase with minor quartz and small

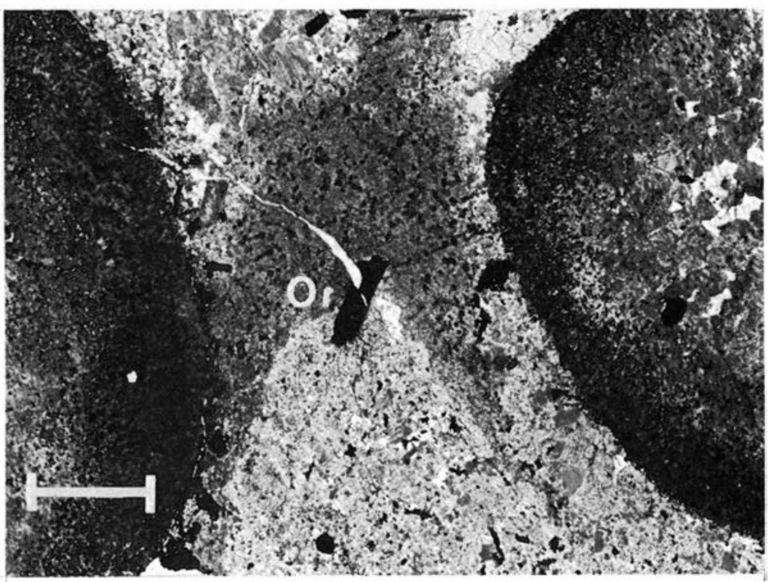

Fig. 2. Inhomogeneous matrix between two mono-shelled orbicules. The contact between two domains in the matrix is transected by an orthite megacryst (Or). Thin section. Length of bar: 1 cm.

idiomorphic crystals of sphene. A few large crystals of biotite and quartz can locally be seen in the centre (Fig. 3). Twin lamellae are only barely visible in plagioclase under a decussate blanket of secondary epidote-minerals and sericite, which occur everywhere except at the rims of the grains. Primary texture is masked by this alteration but it appears that plagioclase grains in the centre of the core are equant, 2–5 mm in diameter, and commonly display idiomorphic outlines towards quartz. Homogeneous mesoscopic luster from one of the cleavage surfaces in plagioclase indicates that a megacryst, or perhaps a cluster of grains with similar orientation, extends radially into the shell from a central clot of large biotite and quartz grains in the core. Radiating plagioclase can also be seen in the outer part of the core of the multishelled orbicule (Figs. 1 and 4), where it cuts across the shells.

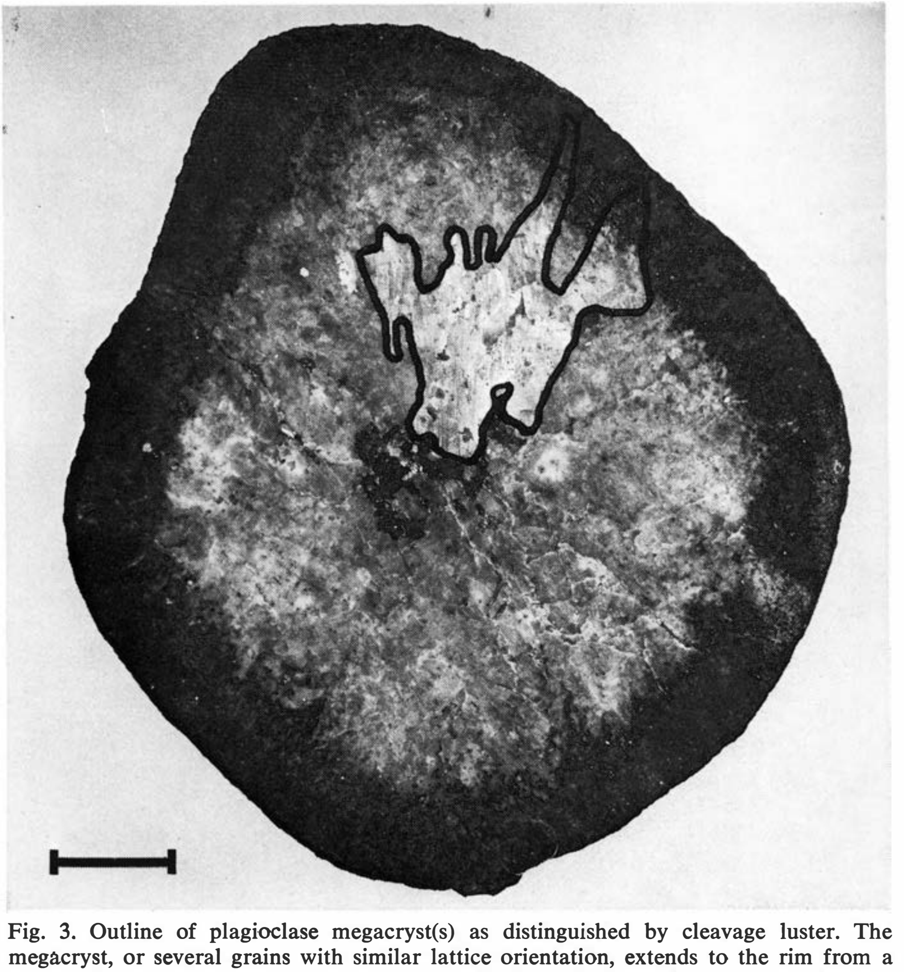

Fig. 3. Outline of plagioclase megacryst(s) as distinguished by cleavage luster. The megacryst, or several grains with similar lattice orientation, extends to the rim from a clot of biotite and quartz in the core. Polished section. Length of bar: 1 cm.

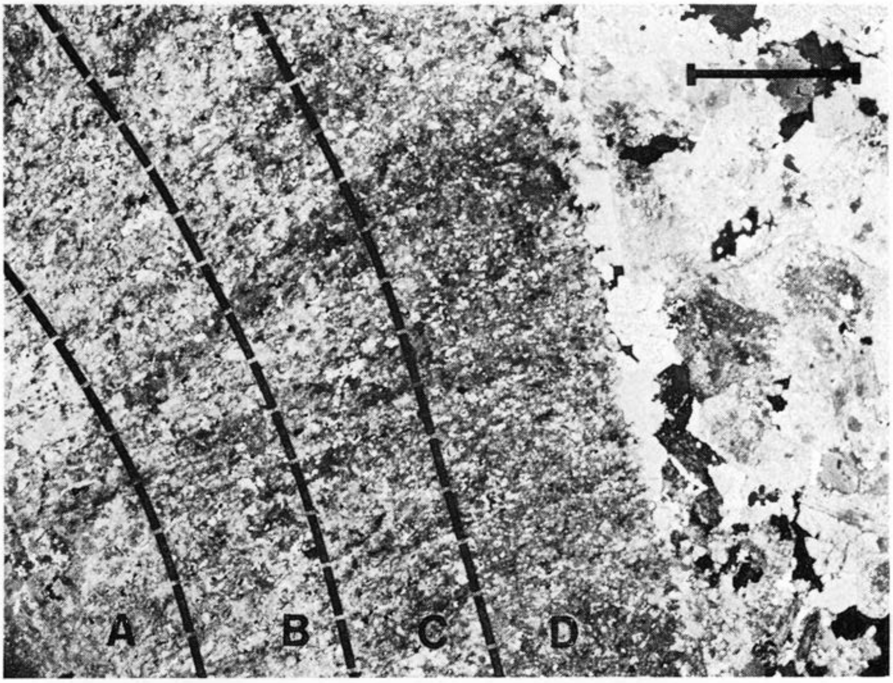

Fig. 4. Radiating pattern (in strongly altered plagioclase) through the shell boundaries of the multi-shelled orbicule shown as Fig. 1. A: core; B, C, D: outer shells. Thin section, crossed polars. Length of bar: 0.5 cm.

Rim

The core/shell boundary is marked by a gradual increase in the content of biotite and magnetite, which occur as grains 0.1–0.2 mm in diameter in a matrix of strongly altered plagioclase. Biotite is present as equant grains with serrated outline, but cleavage traces are often parallel and tangential to the orbicule outline. Adjacent inclusions of biotite in plagioclase have sometimes identical interference colours as if they were parts of the same grain.

Comb-layering is hard to see in most of the shells because the original plagioclase boundaries are blurred by secondary mineralization, but the structure shows up fairly well in the multi-shelled orbicule (Figs. 1 and 4). The radiating, and probably also branching, plagioclase laths are here up to 15 mm long, and parallel to {010} as shown by albite twins. The various shells are here defined by dissimilar amounts of dark inclusions within plagioclase at various distances from the core.

Discussion

Rather idiomorphic outlines of plagioclase grains in the central part of some orbicules and in the matrix indicate that the rock is igneous in origin. By analogy with the studies of Barrière (1972) and Moore & Lockwood

(1973) this would indicate that the boulder of orbicular diorite has been derived from the *marginal* zone of an intrusion.

The formation of orbicules must be related to the observed evidence that:

Matrix is inhomogeneous with texturally distinguishable domains.

Core and matrix are sometimes similar in composition and texture.

Plagioclase grains in some orbicules extend radially from the core through the shells. All this could be related to formation of the orbicules by comb-layering around early-precipitated autolithic nuclei.

The fine grains of biotite with similar, tangential orientation within larger, radiating plagioclase can be related to three alternative modes of formation:

They are relicts of larger grains which were partially replaced during the growth of plagioclase.

They are physically continuous as parts of a very irregular, large inclusion in plagioclase.

They owe their similar orientation to nucleation on parallel surfaces in the radiating plagioclase crystals.

We have no evidence of the metasomatism that would be involved in the first alternative, and the second alternative would require an unlikely interprenetration of two large crystals of biotite and plagioclase. The third alternative is more satisfactory. Plagioclase grew radially while biotite precipitated intermittently on the exposed ends of the advancing crystals. Parts of cores and the light shells formed at stages dominated by plagioclase growth, while darker shells formed when also biotite and magnetite were precipitated. The adjacent biotite grains nucleated on plagioclase surfaces with almost identical lattice orientation; and, therefore, obtained a preferred parallel alignment.

The original magma probably became relatively enriched in iron, potassium and volatiles during the crystallization process. This might explain the relative concentration of biotite and magnetite towards the margin, and the final strong hydrothermal alteration. Porphyroblasts of orthite, which cut across domain boundaries in the matrix and preserve textures elsewhere obliterated by hydrolysis, belong to an early stage of the post-orbicule hydrothermal phase.

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