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Textural banding in igneous rocks: an example from southwestern Oregon

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Abstract

Textural banding, consisting of well-defined alternating thin layers of coarse- and fine-grained rocks, is described for gabbros and metagabbros of the Josephine peridotite–gabbro complex of the Klamath Mountains of southwestern Oregon. The fine-grained layers are interpreted as the recrystallized equivalent of the coarse layers, the original gabbroic rock. The banding was probably formed during a post-intrusive tectonic event under conditions of amphibolite-facies metamorphism. Recrystallization occurred along discrete planar slip surfaces produced in the rock during penetrative deformation which accompanied the metamorphism.

Introduction

A number of examples of banding or layering in igneous rocks which are not related to mineralogical or compositional differences between the layers have been described (Smith, 1948; Battey, 1965; VanDiver, 1967; Moore, 1973). Non-compositional banding is generally ascribed to some sort of textural variation produced by any of a number of possible phenomena ranging from static annealing to mushy flow. Thayer (1963) was the first to deal seriously with banding of this sort, which he called flow layering, in alpine peridotite–gabbro complexes. Although he concentrated mainly on the banding produced in peridotite, he recognized the occurrence of flow layering in associated gabbroic rocks.

I report an occurrence of textural banding in gabbroic rocks of the Josephine alpine peridotite–gabbro complex in the Klamath Mountains of southwestern Oregon, and present evidence which suggests a possible recrystallization origin of the banding. The recrystallization is thought to have been produced along discrete slip surfaces during post-intrusive metamorphism.

Regional geology

The igneous body in which the banding occurs is predominantly hornblende and pyroxene gabbro, but ranges in composition from quartz diorite to anorthosite. It forms a portion of the Josephine Ultramafic Complex in the Klamath Mountains of southwestern Oregon, first mapped and described by Wells *et al.* (1949) (Fig. 1). The peridotite–gabbro is an alpine-type complex (Thayer, 1960) in fault contact with Mesozoic sedimentary and volcanic units. It is a part of an upfaulted wedge of rocks which includes Nevadan age metavolcanics and metasediments, a sequence which forms the essential ingredients of an ophiolite suite. This association of rocks plus the dominant structure of successive arcuate thrust sheets (Irwin, 1964) has prompted a number of hypotheses involving the interactions of the continental mass and ancient ocean floor in a Late Mesozoic subduction zone (Moores, 1970; Dewey, 1976).

More recent work by Dick (1976), however, indicates that these rocks do not necessarily represent a section of ancient ocean crust, and he postulates an origin involving two periods of melting under contrasting conditions in the peridotite. Dick suggests that the peridotite and associated rocks represent the remains of incipient Jurassic arc volcanism on old ocean crust, and that the two episodes of melting may represent mantle events first beneath an ocean rise and later above a young subduction zone.

The rocks have been subjected to amphibolite-facies metamorphism, especially apparent around the periphery of the body. The metamorphism has resulted in the partial replacement of pyroxene by hornblende, and in the albitization of some of the plagioclase.

Description of banding

The banded portion of the gabbro occupies less than five percent of the total area of the exposed

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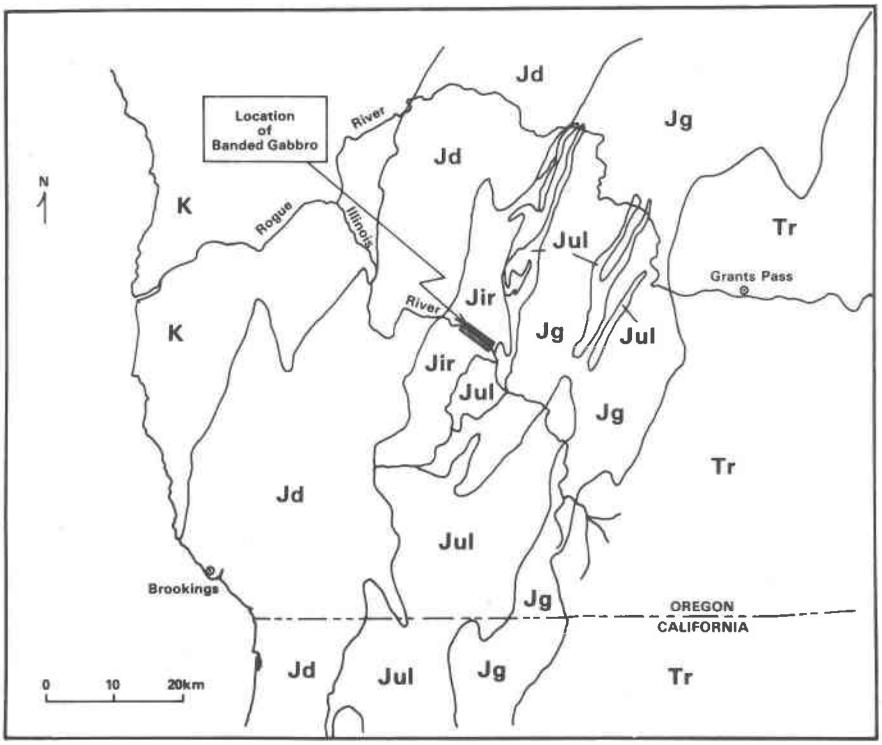

Fig. 1. Sketch geologic map of Josephine Complex showing location of exposures of textural banding along Illinois River. (Explanation of symbols: Jir–Illinois River Gabbro; Jul–ultramafic rocks of Josephine Complex; Jg–Galice Formation consisting mostly of metavolcanics and metasediments; Jd–Dothan Formation consisting mostly of volcanic and sedimentary rocks; K–sedimentary rocks mostly Cretaceous and younger; Tr–sedimentary and metasedimentary rocks mostly Triassic and older.)

body. The banding, which is nearly vertical, occurs in the central part of the gabbro, which in turn exhibits a distinct foliation parallel to the banding, with the long directions of pyroxene and hornblende lying in the plane of foliation. As the banding is approached in the field, the foliation in the gabbro becomes progressively more apparent until faint, discontinuous bands appear, delineating the edge of the banded portion. The maximum continuous section of banded gabbro, measured perpendicular to the foliation, is 400 meters. Unfortunately, banding could not be traced along the trend of foliation for more than about 30 meters, due to poor exposures.

Most of the banding occurs in what has been described as gabbro or two-pyroxene gabbro (Jorgenson, 1970), but banding is also found to a limited extent in hornblende gabbro. Banding has not been observed in the anorthosite or troctolite zones of the complex. The two-pyroxene gabbro consists chiefly of plagioclase (ranging from An_{65} to An_{98}), diopsidic augite, and bronzite, with minor amounts of hornblende, quartz, and magnetite. Hornblende gabbro contains plagioclase (An_{50} to An_{75}), hornblende, and magnetite, with a small amount of quartz, and partially replaced pyroxene grains surrounded by hornblende. The banded rocks consist of two juxtaposed textural types, referred to here as the coarse-grained and fine-grained bands (Fig. 2).

The coarse-grained bands have typically igneous textures, being hypidiomorphic with an average grain size of 0.5–1.0 mm (Fig. 3). Normal plagioclase zoning and poikilitic hornblende and pyroxene are common in the coarse bands. Orthopyroxene commonly contains exsolution lamellae of the Bushveld type (Hess, 1960). The preferred mineral orientation of mafic minerals in the coarse-grained bands is apparent both in outcrop and thin section. Plagioclase grains are essentially equidimensional, but petrofabric analysis reveals a definite preferred orientation in both the coarse and fine bands.

The fine-grained bands are allotriomorphic with an average grain size of 0.1–0.2 mm (Fig. 4). Plagioclase zoning is absent, as is exsolution in the orthopyroxene. Hornblende, where present, occurs as discrete grains bearing no particular relation to adjacent or nearby pyroxene grains. Most hornblende grains are elongate in the plane of foliation. Large ragged grains of pyroxene and plagioclase are widely dis-

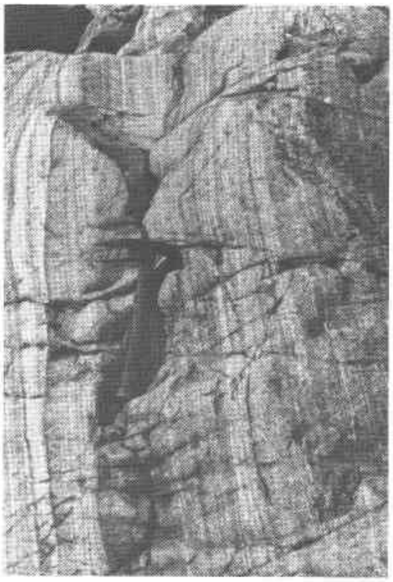

Fig. 2. Outcrop of texturally-banded gabbro. Darker bands are fine-grained, lighter are coarse-grained. Banding is vertical.

persed within the fine-grained bands. Mineral compositions are indistinguishable between the coarse and fine bands.

Mechanism of formation of banding

The banding described here is similar in appearance to what has been called "schlieren," "schlieren banding," or "nebulite" by field geologists. This is a type of discontinuous banding apparently produced in some cases by the smearing out or stretching of xenolithic or other anomalous material as a result of movement within the "mushy" igneous body. Examples of schlieren banding produced by stretching of fine-grained compositionally-distinct material can be found along the borders of the Illinois River gabbro, and field observation leaves little doubt as to their origin. The possibility that the textural banding in the central part of the gabbro was produced in this manner was considered, but field and mineralogical evidence does not support the hypothesis.

I propose that the textural banding was produced by a process of syntectonic recrystallization during penetrative deformation which accompanied regional metamorphism in the area. The evidence suggesting a recrystallization origin is summarized below:

1. The presence of large ragged crystals in a matrix of smaller mineral grains in the fine-grained bands appears to indicate incomplete recrystallization. These grains commonly show signs of strain and have "necklaces" of smaller grains around them.

2. Grain edges in thin sections of the fine-grained bands are equilibrated, commonly forming angles of 120° at triple junctions. This apparently indicates equilibrium recrystallization (Vernon, 1968).

3. The lack of plagioclase zoning and pyroxene exsolution features in the fine-grained bands results from the homogenization of mineral phases during recrystallization.

4. Numerous fractures in the coarse bands parallel to the banding are especially common along the borders between the bands, suggesting a brittle response to the penetrative deformation.

A recrystallization process can readily account for the features described here. The fine-grained bands represent discrete planes of recrystallization within the gabbro body, and the coarse-grained bands represent original gabbroic textures. The timing of recrystallization relative to intrusion and metamorphism, however, is not known with certainty. Similar layering in other areas has been ascribed to cataclasis followed by static annealing (VanDiver, 1967), recrystallization under metamorphic conditions (Battey, 1965), flow in a mush form at the time of emplacement (Smith, 1948), or as a result of syntectonic recrystallization along discrete thrust fault planes (Moore, 1973).

Discussion

The fact that plagioclase grains in both types of bands are not elongate, yet have a strong preferred optical orientation, is considered evidence against an origin of foliation as a result of "mush flow" in a largely fluid body (Moore, 1973). Although cataclas-

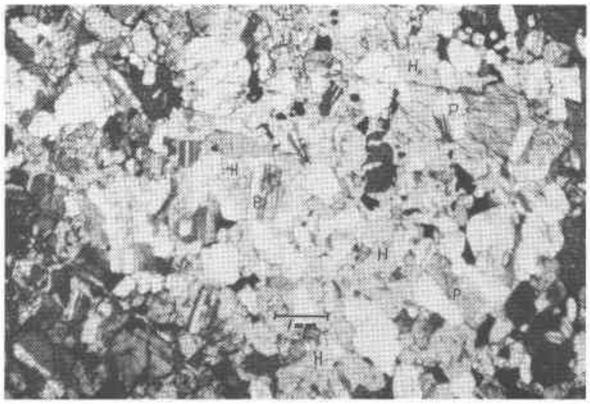

Fig. 3. Photomicrograph of coarse-grained portion of banded gabbro. Hornblende oikocryst (H) encloses plagioclase euhedra (P). Figs. 3 and 4 are photos of adjacent bands.

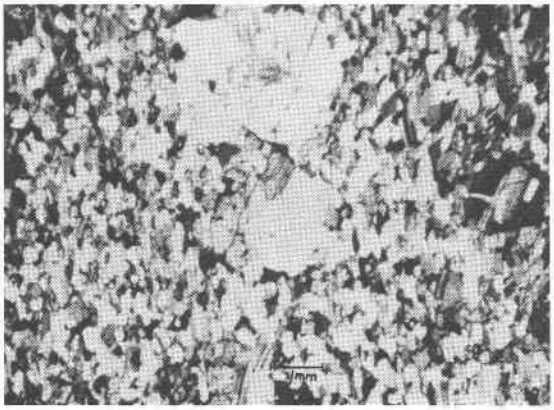

Fig. 4. Photomicrograph of fine-grained portion of banded gabbro. Note relict plagioclase and preferred orientation of mineral grains.

tic deformation can produce distinct layering in originally homogeneous rocks, the textures produced would be quite different from those described here (Prinz and Poldervaart, 1964). A later period of static recrystallization could produce the appropriate textures, but would not produce the strong preferred orientations observed and would probably tend to destroy any pre-existing mineral orientation (Raleigh, 1963).

The identical mineral chemistries of the coarse and fine bands, the abundance of hornblende and the tendency toward albitization of plagioclase, the evidence indicating recrystallization, and the strong preferred orientations of minerals in both bands suggest that the banding and foliation were formed during a post-intrusive event under conditions of amphibolite-facies metamorphism. Recrystallization occurred along discrete planar slip surfaces produced locally in the rocks as a result of penetrative deformation accompanying the metamorphism.

The textural banding is somewhat analogous to flow layering in alpine-type peridotites described by Thayer (1960; 1963). Flow layering in the Josephine Peridotite, however, is compositionally defined, and its orientation is different from that of the banded gabbros (Dick, 1976). Dick has also described banding in gneisses and schists associated with the Illinois River gabbro which is defined mostly by compositional differences.

Banding throughout the Illinois River gabbro and associated rocks apparently represents a complex history of intrusion and deformation, and the textural banding described here is related to only a single event in the history of the pluton. The timing of this event is unclear, but field and petrographic evidence suggests a fairly close association with later intrusive events, since later gabbroic and anorthositic rocks in the central part of the pluton are neither banded nor metamorphosed.

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