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Stress-induced natural transformation of ortho- to clinohypersthene in metagabbros of the Ivrea Zone, Northern Italy

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Stress-induced Natural Transformation of Ortho- to Clinohypersthene in Metagabbros of the Ivrea Zone, Northern Italy

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With 3 Figures

Summary

Orthopyroxenes of a high temperature protomylonite of the Ivrea Zone, Northern Italy show twin like polysynthetic lamellae parallel to {210} of the hypersthene host. The transformation is caused by plastic deformation under high metamorphic conditions which has resulted in dynamic recrystallization of pyroxene and plagioclase. The lamellae consist of clinohypersthene. The twin plane and the lamellar clino-ortho-inversion of hypersthene due to natural deformation have not been described hitherto.

Zusammenfassung

Stressinduzierte natürliche Transformation von ortho- zu Klinohypersthen in Metagabbros der Ivrea-Zone, Norditalien

Orthopyroxene aus hoch temperierten Protomyloniten der Ivrea-Zone, Nord Italien zeigen polysynthetische Lamellen parallel {210} des Wirtes. Ihr Erscheinungsbild entspricht Deformationszwillingen. Die Lamellen sind invertiert zu Klinohypersthen. Die Ortho-Klino-Transformation ist auf eine Hochtemperaturdeformation zurückzuführen, wie dies anhand der dynamischen Rekristallisation der Pyroxene und Plagioklase bewiesen werden kann. Weder die speziellen Verwachsungsflächen noch die Ortho-Klino-Inversion durch natürliche Deformation wurden bisher beschrieben.

Introduction

Orthopyroxene is commonly regarded as a rigid mineral with a brittle deformation behavior in crustal environments. Plastic deformation is mostly restricted to the

formation of subgrains, kinkbands and recrystallized grains under lower crustal and mantle conditions. Simple and lamellar growth twins with twin planes parallel to (011), (023) and (043) are of rare occurrence (*Deer* et al., 1978, *Tröger*, 1982), lamellar twinning possibly due to mechanical shearing parallel to {210} has not been described so far.

Analytical Techniques

The chemistry of the main phases were analyzed, using a CAMEBAX electron microprobe. A Phillips PSEM 500 electron microscope (SEM) was used for additional grain boundary analyses of the recrystallized orthopyroxenes.

Geological Setting

The Ivrea Zone represents a cross section through the pre-Alpine middle to lower crust and upper mantle of the Southern Alps (*Zingg*, 1978, 1980 and *Schmid* et al., 1987, Fig. 1). During the Variscan large volumes of ultramafic and mafic intrusions (Main basic formation) were emplaced into a series of deformed, high-grade metasedimentary rocks and the peak of regional and contact metamorphism occurred.

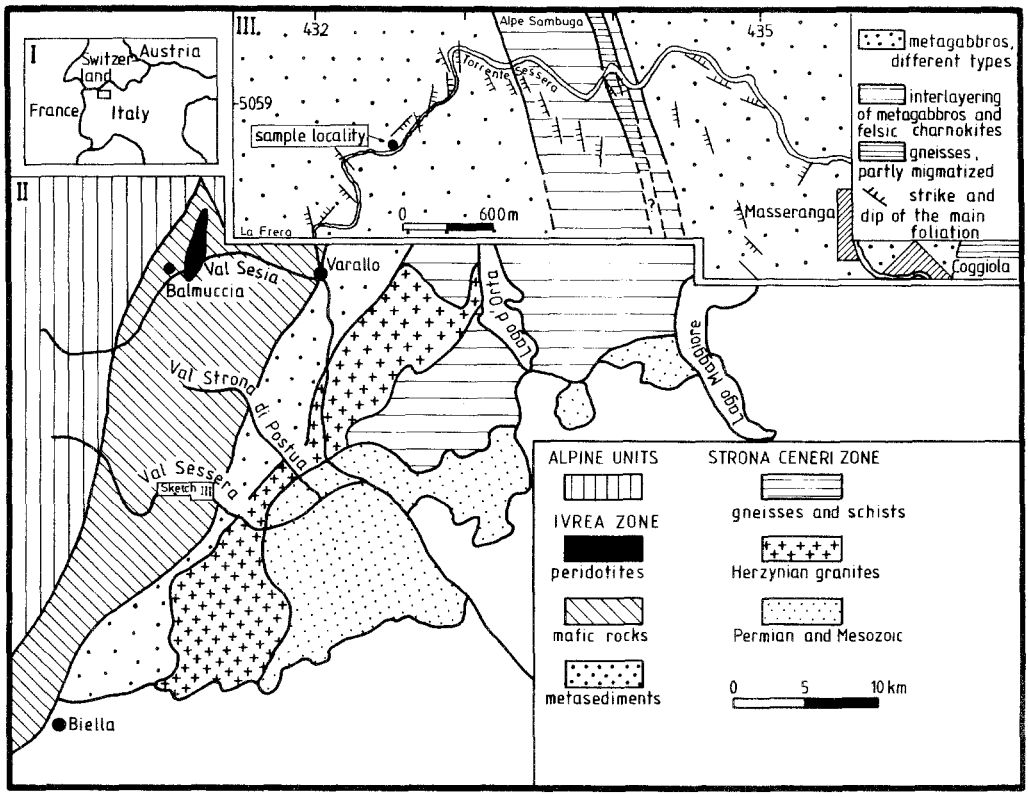

Fig. 1. Geological and geographical sketch maps. *I* Geographical position of map II. *II* Geological sketch map based on *Zingg* 1980 with the geographical position of sketch III. *III* Geological and tectonic map of the Val Sessera between La Frera and Masseranga with sample location. Map based on *Altenberger* (in prep.)

After these thermal events the rocks suffered multiphase regional deformation and metamorphism in extensional and compressional environments (*Capedri* and *Rivalenti* 1973, *Brodie* and *Rutter* 1987, *Altenberger* 1991). The Val Sessera region NE of Biella/Northern Italy (Fig. 1) comprises a sequence of metagabbros with variable chemistry and modal composition. The sequence is stratigraphically overlain by and in places interfingered with metasedimentary rocks. At their contacts migmatization resulted in formation of leucocratic charnokites by anatexis. Although the basic rocks are reequilibrated under granulite facies conditions, compositional banding on the centimeter to decimeter scale is preserved and represents magmatic banding in the protolith. The main structural feature of the basic rocks is a pervasive schistosity parallel to the magmatic layering. In some places, this foliation shows a protomylonitic character with recrystallization of orthopyroxene, clinopyroxene and plagioclase. Cross-cutting relationships indicate that these mylonites are older than the high-temperature shear zones of the Ivrea Zone as described by *Brodie* and *Rutter*, 1987 and *Altenberger*, 1991.

Sample Description, Deformation Features and Conditions of Deformation

The metagabbros of the sample location SE of the farm La Frera (Fig. 1) show a well defined steeply dipping schistosity. The rock has a gabbronoritic composition with 40 vol.% hypersthene and ferroaugite and of about 54 vol.%. bytownitic plagioclase (Table 1). The minor amount of chlorite and hornblende are retrograde phases, the opaques are mainly magnetite and ilmenite. Orthopyroxene grains occasionally show very thin clinopyroxene exsolution lamellae parallel to (100). The foliation is defined by the elongated grain shapes of plagioclase and the pyroxene porphyroclasts. The matrix produced by syntectonic recrystallization comprises not more than 20 vol.%. Using the nomenclature suggested by *Wise* et al. (1984) the sample has a protomylonitic texture. The surviving megacrysts have mean diameters of about 3 mm. The analyses of three sections perpendicular to each other reveals axes ratios of the porphyroclasts of 1 : 2 : 3 for plagioclase and 1 : 3 : 5 for the pyroxenes. The recrystallized grains have a maximum size of 20 microns. In some cases new and old grains form the typical core and rim structures. The ratio of surviving megacrysts to the matrix produced by syntectonic recrystallization is 17%, whereas 33% of plagioclase are recrystallized grains and only 5% of the pyroxenes are newly formed grains (Fig. 2). In addition plagioclase and orthopyroxene are strained by defomation twins and kinkbands. The kinkband planes in orthopy-

Table 1. *Chemical characterisation of the main minerals, based on microprobe analyses*

	Plagioclase			Orthopyroxene		Clinopyroxene
	porpyrocl.	recryst. gr.		porphyrocl.	recryst. gr.	porphyroclast
(mol %)			(mol %)			
Ab	19.94	15.82	Wo	0.70	0.42	49.35
An	79.49	84.05	En	68.50	69.69	38.87
Or	0.56	0.13	Fs	30.80	29.88	11.78

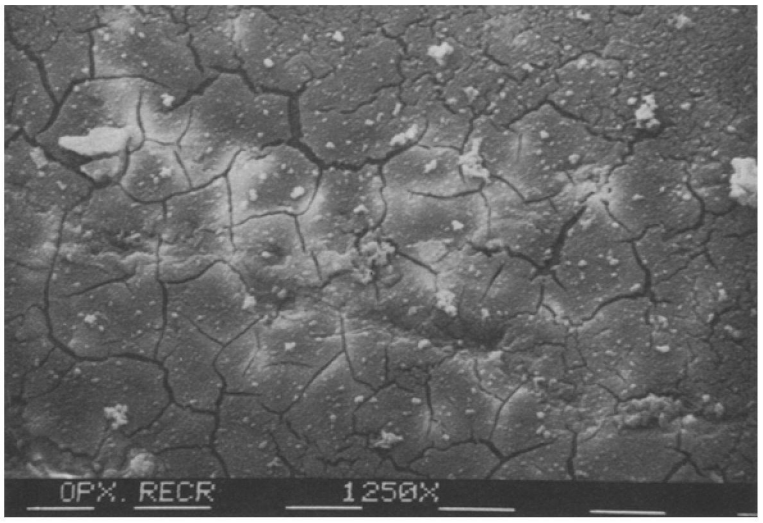

Fig. 2. Dynamically recrystallized grains of orthopyroxene. SEM photograph. Grain boundaries are strongly etched by hydrofluoric acid treatment. Scale bars 10 microns

roxene are parallel to subparallel to (001) indicating dislocation glide on (100). Dynamic recrystallization of the main phases is diagnostic for high temperature deformation. The formation of newly crystallized orthopyroxene, clinopyroxene and plagioclase by deformation indicates granulite facies conditions during shearing.

The sample is also influenced by a younger brittle to ductile shear zone which cuts off the protomylonite. In the younger zone the mafic minerals are fractured and plagioclase is again deformed plastically.

Lamellar Deformation Twins in Orthopyroxene

Occasionally, the hypersthene grains of the sample examined contain polysynthetic lamellae with tapered ends as are commonly described for deformation twins (Fig. 3). They consist of sets of three to nine lamellae with a thickness of 13 to 64 microns (μm). They are developed parallel to {210} of the host orthopyroxene and possess the same chemical composition as the enclosing hypersthene. Universal stage measurements of some broader lamellae reveal a smaller 2V for the lamellae ($2V = 30° \pm 3°$) than for the host ($2V = 60° \pm 3°$) and a positive optical character instead of a negative one for the enclosing phase. The optical data led to the conclusion that the deformation twins are clinohypersthene lamellae in an orthohypersthene host. The transformation is induced by the strong deformation under high PT-conditions. The experimental work on the ortho-clino inversion in enstatites shows that regimes are favoured, in which the activation energy required for slip is not reached (*Raleigh* et al., 1971). In contrast the present study of the hyperstene-clinohyperstene transformation indicates that the activation energy is high enough for recrystallization and dislocation glide and dislocation creep. Similar results are reported by *Trommsdorff* and *Wenk* (1968). They describe the inversion of bronzite to clinoentstatite in kinkbands of highly deformed and partially metamorphosed gabbros from Central Australia.

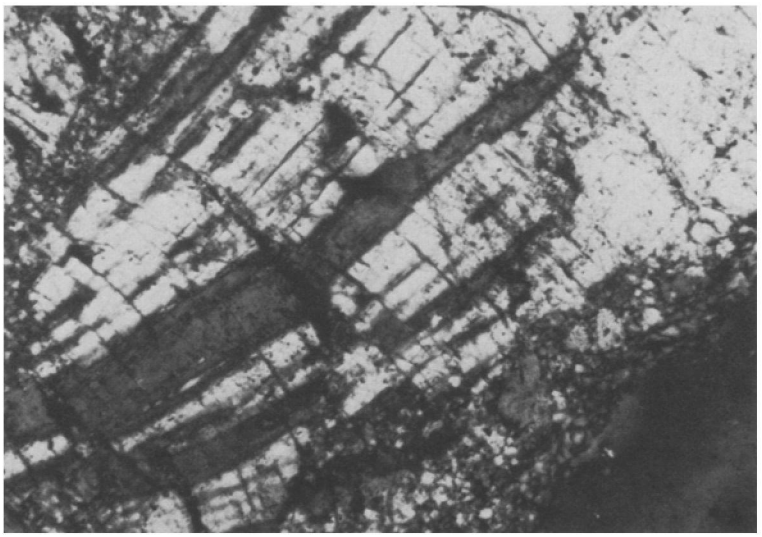

Fig. 3. Polysynthetic deformation twins in hypersthene. The very small grains (on the bottom right) are dynamically recrystallized. The fine lines indicate the {210} cleavage. Crossed nicols. Width of photomicrograph is 0.11 mm

Acknowledgements

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