

Syn-intrusive foliation of the Masino - Bregaglia (Bergell) tonalite and its roof pendants in Val Sissone (Valmalenco, Central Alps, Italy)

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ABSTRACT. — A number of meso- and microstructural data favours the interpretation of the Bergell intrusion through a ballooning mechanism; namely they are: the parallelism of the foliation of the intrusives with the axial surfaces of the folds in country rocks, and the recrystallization - deformation relationships of the Bergell Tonalite mineralogical phases as well as the relationships between formation and folding of the metasomatic veins.

Key words: Tectonics, intrusions, ballooning, mesostructure, microstructure.

Introduction

The intrusive Tertiary Massif of Val Masino-Bregaglia is composed of a wide range of calc-alkaline rock types. On the basis of intersection criteria, MONTRASIO & TROMMSDORFF (1983) established the following chronological sequence among different intrusive rock types: gabbros, tonalites, granodiorites, «minestroniti», medium to fine-grained aplites and pegmatites. The «minestroniti» dykes from Val Sissone were interpreted as the result of explosive magmatic events.

Following the interpretation of THEOBALD

(1866); CORNELIUS (1913); STAUB (1918, 1920a-b, 1921), TROMMSDORFF & EVANS (1972) and TROMMSDORFF & NIEVERGELT (1983), the Val Masino-Bregaglia intrusive body cross-cuts eastwards the pile of the Pennine and Austroalpine nappes in the Rhaetic Alps (Suretta, Malenco-Forno and Margna) (Fig. 1).

GAUTSCHI & MONTRASIO (1978) recognized andesitic to basaltic dykes both in Margna nappe and Valmalenco serpentinites. The dykes are situated within the contact aureole of the Val Masino-Bregaglia intrusives and are thermally metamorphosed; outside the aureole they cross-cut the regional metamorphic fabrics. These observations fit the conclusions of TROMMSDORFF & EVANS (1972) on the relationships between regional and thermal metamorphism and further support a post-nappe intrusion.

Mesostructural observations

A 1:10.000 scale mapping work of the eastern margin of the intrusion shows a severe parallelism of the persistent foliation of the

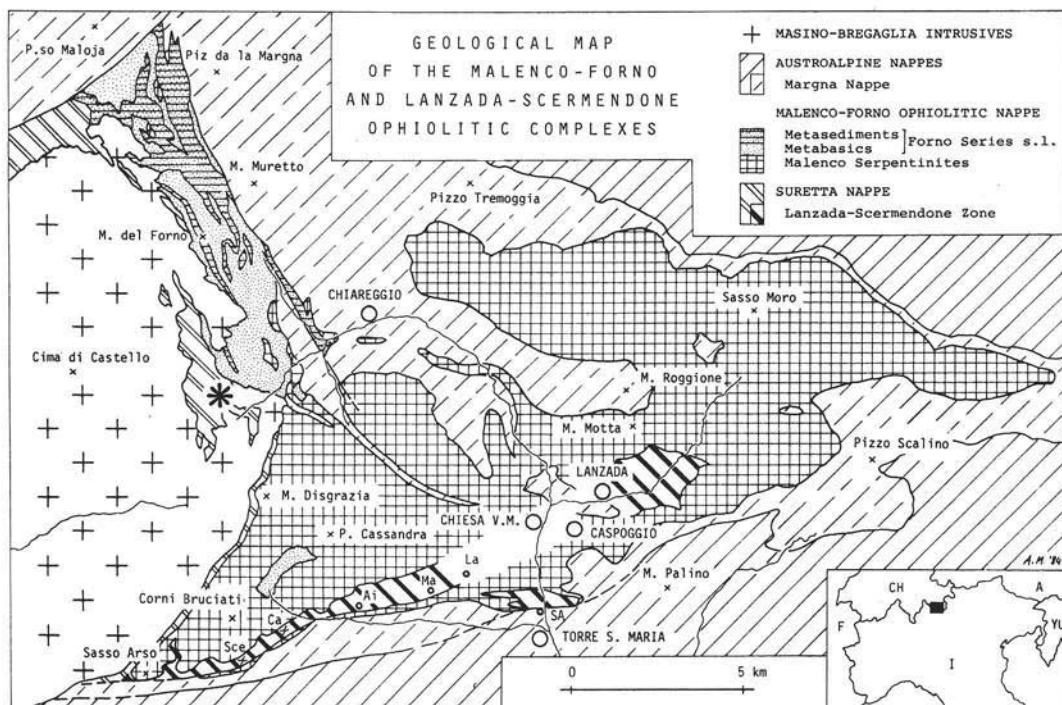


Fig. 1. — Geological sketch-map of Malenco-Forno and Lanzada-Scermendone ophiolitic complexes, showing eastern margin of Masino-Bregaglia intrusives and location of the investigated area (asterisk).

intrusive types with the axial surfaces of the folded roof pendants and country rocks; this is in agreement with the evidences reported in DRESCHER & STORZ (1926), DRESCHER-KADEN (1940, 1969), GIERÉ (1984) and DIETHELM (1985). The structure of a single roof pendant, composed of dolomitic marbles with contact metamorphic assemblages, suggesting $T = 500^{\circ}\text{--}650^{\circ}\text{C}$ and $P = 3\text{ kb}$ (BUCHER - NURMINEN, 1977), has been compared in detail with that of the emboding intrusives. The mesoscale structures within the roof pendant are dominated by a fold system (F_2 , Fig. 2) with an axial plane foliation parallel to the first foliation formed within the flanking intrusives (also labelled S_2). These folds overprint an earlier group of isoclinal meter-scale folds (F_1) occurring exclusively in the pendant. The intrusives, here of quartzdioritic composition («Bergell tonalite» or «Serizzo»), are foliated and the included felsic dykes are folded and

boundinaged conformably both in the quartzdiorite and in the pendant (Fig. 3). The foliation is positioned at a low angle in the pendant margins and cross-cuts mesoscopic relics of magmatic layering. Folds of a later post-intrusive deformation are also distinguished (F_3) and their axial surfaces cut at a high angle across the roof pendants and quartzdiorite boundaries.

Progressive deformation of the country rock is deduced by the opening of fractures in the dolomitic rocks in the $X'Z'$ or $Y'Z'$ planes; the fractures and their mineralogical infilling are folded coherently with the $X'Y'$ plane relative to the S_2 foliation (Fig. 4). This deformational scheme is coherent with that of TRÖMMSDORFF & NIEVERGELT (1983) and PERETTI (1985); a solid state deformation of both stockwalls and country rocks is proposed here, suggesting that successive magmatic pulses induced deformation on the previously consolidated igneous material, like in

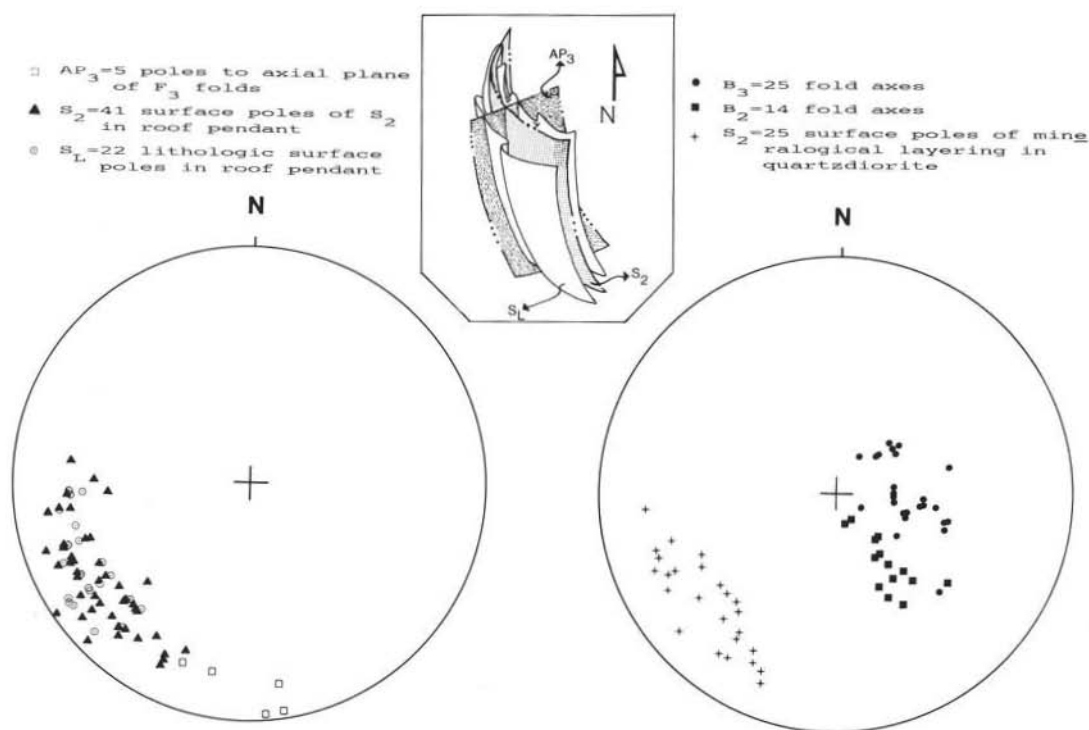


Fig. 2. — Lower hemisphere Schmidt plots of some fabric elements of a single roof-pendant and its flanking quartzdiorite wall. Positions of S_2 in intrusives and country rock are coincident, and shape of F_2 folds is tight.

«balloon»-tectonics (RAMSAY, 1975, 1981; HOLDER, 1981; CASTRO, 1987).

Microstructural observations

Qualitative microstructural observations of the quartzdiorite mineralogical foliation are added to clarify its conditions of deformation. The quartzdiorite is dominated by a planar biotite layering. Its granular fabric shows overgrowths of biotite grains with {001} parallel to the layering, at the expenses of magmatic biotite lying in mechanically unfavourable positions (Fig. 5). Plagioclase, often cataclastically deformed, is replaced by multigranular aggregates of recrystallized or mechanically twinned plagioclase II. The deformation and recrystallization patterns of the plagioclase suggest an environment of relatively high temperature and strain rate (VERNON, 1976). Interstitial quartz give rise to subgrain structure or recrystallized

aggregates when localized within intense deformation microzones, also involving deformation of biotite and plagioclase. K-feldspar is the only mineral that exclusively suffers cataclasis.

Conclusions

The meso- and microstructures of the country rocks and solidified quartzdiorite marginal walls of the stock indicate that compressional pulses took place during the intrusion of new magma. At the margin of the stock, mineralogical magmatic sites are microstructurally reworked and mostly plastically deformed. New grains of biotite, quartz and plagioclase grow, replacing pre-existing grains of the same mineralogical phases, forming a differentiated mineralogical foliation under solid state conditions, with the possible presence of fluid films.

The country rocks and solidified marginal

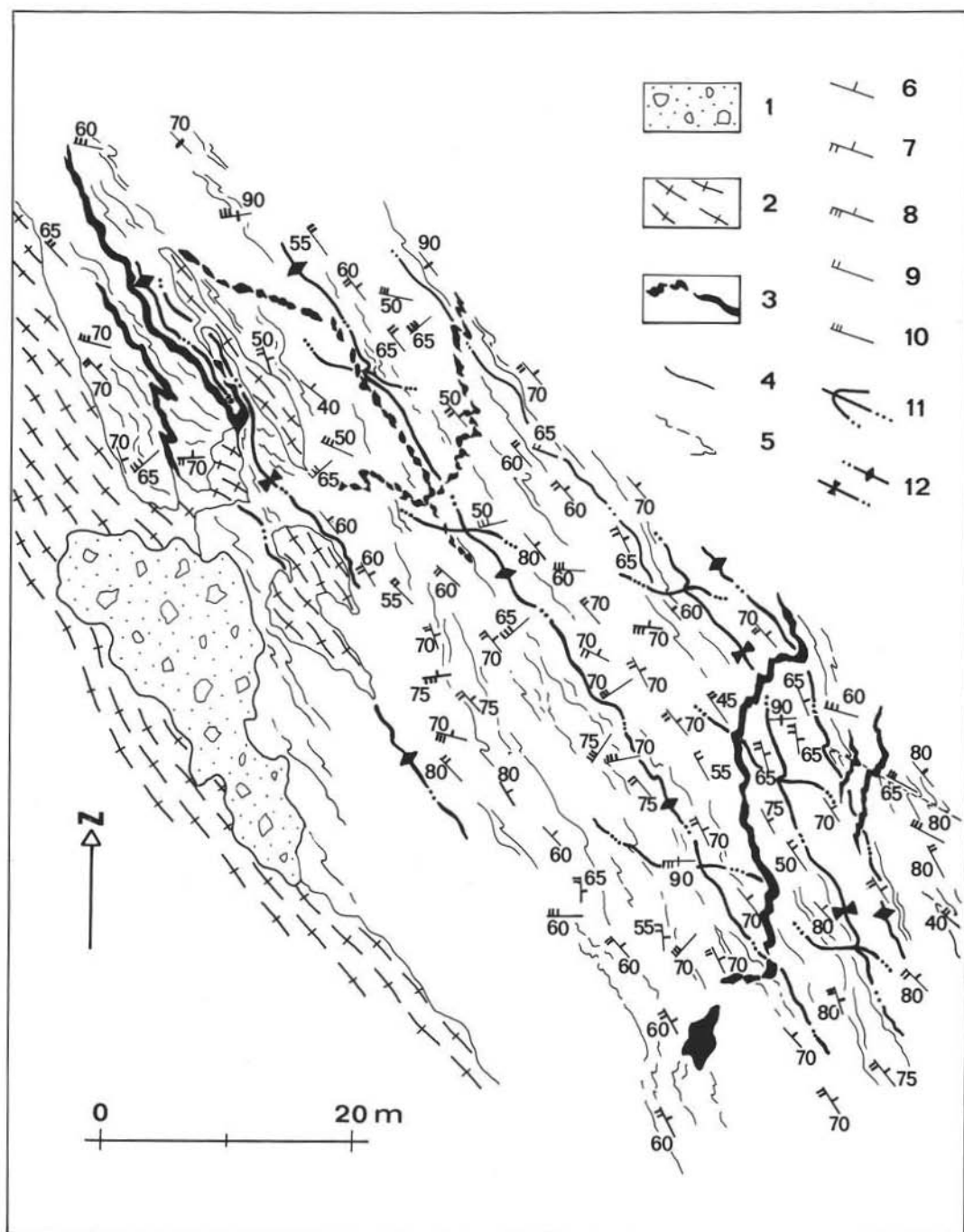


Fig. 3. — Form surface map of a test area (for location see Fig. 1). Legend: 1 = gravels; 2 = «Serizzo»; 3 = marbles (d = aplitic dykes); 4 = geological boundaries; 5 = sense of asymmetry of minor folds, looking down plunge; 6 = attitude of lithological layering with dip; 7 = axial plane foliation of F_1 folds; 8 = estimated attitude of the axial surface of F_1 folds; 9 = fold axis of F_2 folds; 10 = fold axis of F_3 folds; 11 = axial surface trajectories; 12 = antiform, synform.

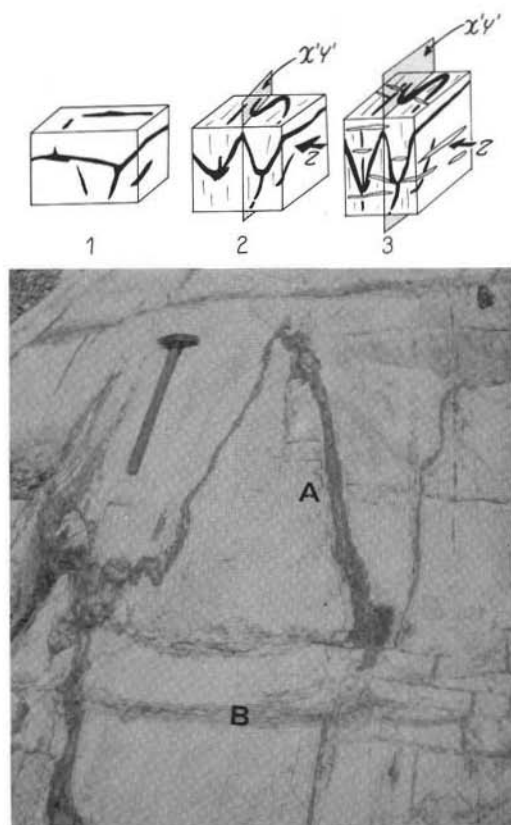


Fig. 4. — Syn-intrusive deformation of a dolomitic layer of country rock with progressive shortening of earlier formed extension metasomatic veins (fibrous tremolite and calcite, tremolite and calcite). Deformation mechanism evolves through stage 1: formation of a first generation of metasomatic veins (a); stage 2: early stage of F_2 deformation; stage 3: final stage of F_2 deformation and development of a new generation of metasomatic veins (b) (modified from ETHERIDGE et al., 1984, and BELL et al., 1986). The $X'Y'$ plane corresponds to the S_2 foliation in the pendant and in the quartzdiorite.

shells of the «Serizzo» were deformed coherently with their included magmatic dykes and metasomatic veins at each progressive pulse of new magma input (Fig. 6).

While taking their foliation, by forces acting from the inner side of the pluton, the marginal shells of the stock were able to cause deformation effects in its roof pendants and therefore to act as stress guides onto the country rock.

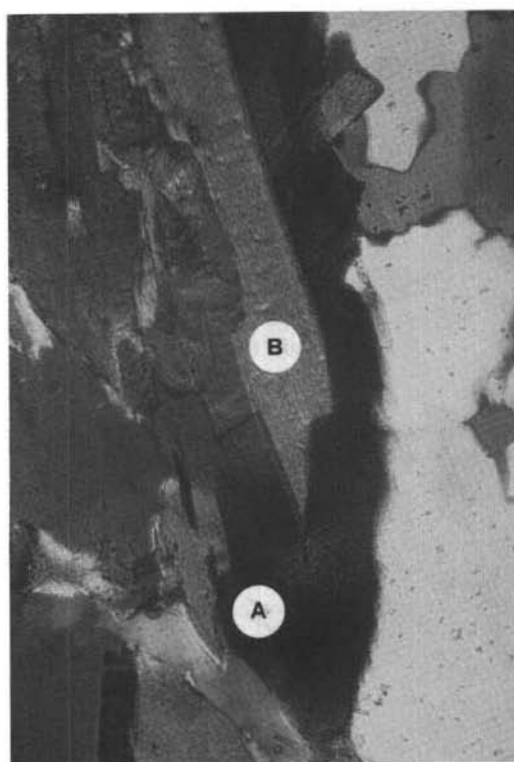


Fig. 5. — A biotite grain (a) lying in a mechanically unfavourable position (darker grain), with respect to the S_2 foliation surface, feeds the growth of a new biotite grain (b) aligned in S_2 .

These petrographical and mesostructural features combined with the observations of DRESCHER & STORZ (1926) and DRESCHER-KADEN (1969) closely reproduce the situation depicted by SUAREZ et al. (1987) in the Santa Rosa and Castore plutons (Chile) and interpreted as a ballooning mechanism intrusion; therefore we favour the same mechanism for the Bergell Massif.

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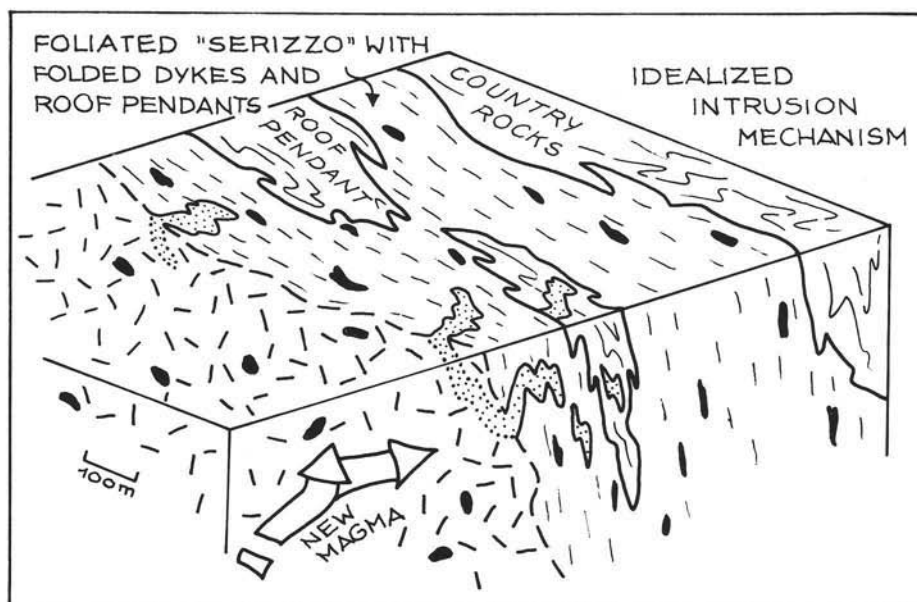


Fig. 6. — Idealized intrusion mechanism of a single magma pulse of Bergell quartzdiorite. Shortening of a marginal shell of «Serizzo tonalite», nearly completely solidified, is shown by coherent folding and boundinage of the metasomatic veins and dykes and of the lithologic layering of roof pendants, alignment of dark inclusions and formation of a mineralogical foliation. Country rock wall is consistently deformed.

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