**Zeitschrift:** Schweizerische mineralogische und petrographische Mitteilungen = Bulletin suisse de minéralogie et pétrographie

**Band:** 56 (1976)

**Heft:** 3

**Artikel:** Fabrics and metamorphism from the Monte Rosa root zone into the Ivrea zone near Finero, southern margin of the Alps

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**DOI:** https://doi.org/10.5169/seals-43707

*Schweiz. mineral. petrogr. Mitt. 56, 627–633, 1976*

# Fabrics and Metamorphism from the Monte Rosa Root Zone into the Ivrea Zone near Finero, Southern Margin of the Alps

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**Abstract**

This study contains a summary of the results about the sequence of deformational acts and conditions of metamorphism during and between these acts at the S margin of the Alps near Finero, including the position and deformation of subvolcanic rocks within this zone.

We distinguish the following zones from N to S:

*Zone 1:* Root of the Monte Rosa nappe. K-feldspar augengneiss dominates.

*Zone 2:* Width: 3 km. Rock-types: Kinzigites (Hb-granulite-facies gneisses similar to those of zone 3), amphibolites and garnet-amphibolites, serpentinite-hornfels, marbles, augengneiss similar to that of zone 1, dykes of subvolcanic trachyandesites and biotite-(mu)-plagioclase-gneiss. All these rocks are strongly flattened and stretched. This is characteristic for this zone.

*Zone 3:* Follows S, separated by the Insubric Line. It contains the Finero-complex with hornblende- and phlogopite peridotites and garnet-2 pyroxene metagabbros, embedded in kinzigites.

Zone 2 contains Sesia- and Canavese-Zone, zone 3 is the Ivrea-Zone.

## DEVELOPMENT OF ZONE 3

*The first deformation* of the (ultra-) basic complex created isoclinal cm–m folds folding a compositional layering which – on scarce evidence of grading, current bedding and spinel-enriched layers may well be a magmatic bedding. Fold axes are ± horizontal, limbs are strongly extended and often boudinaged. Ortho-, clino-pyroxenes and hornblendes are oriented with (100) parallel to a penetrative axial plane cleavage correlated to these folds. Olivin displays a very weak preferred orientation of (010) within this axial plane or – in limbs –

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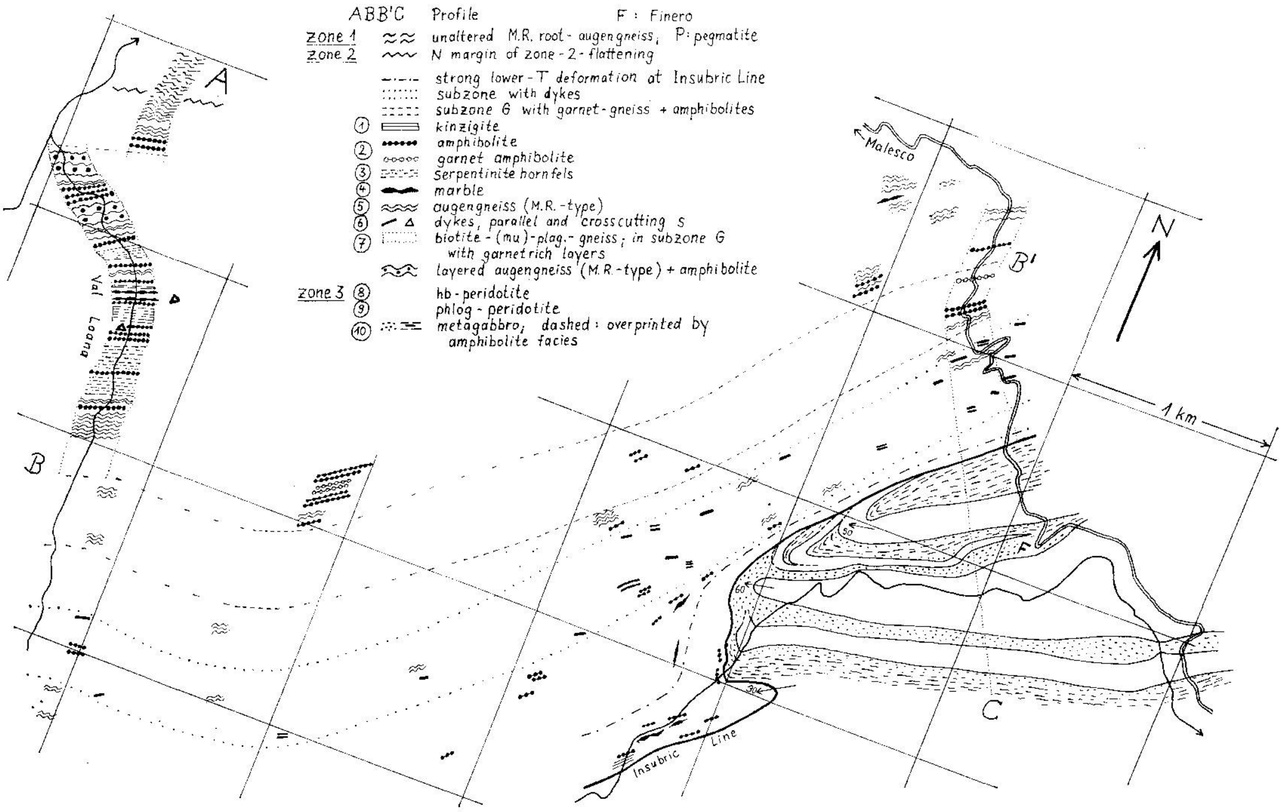
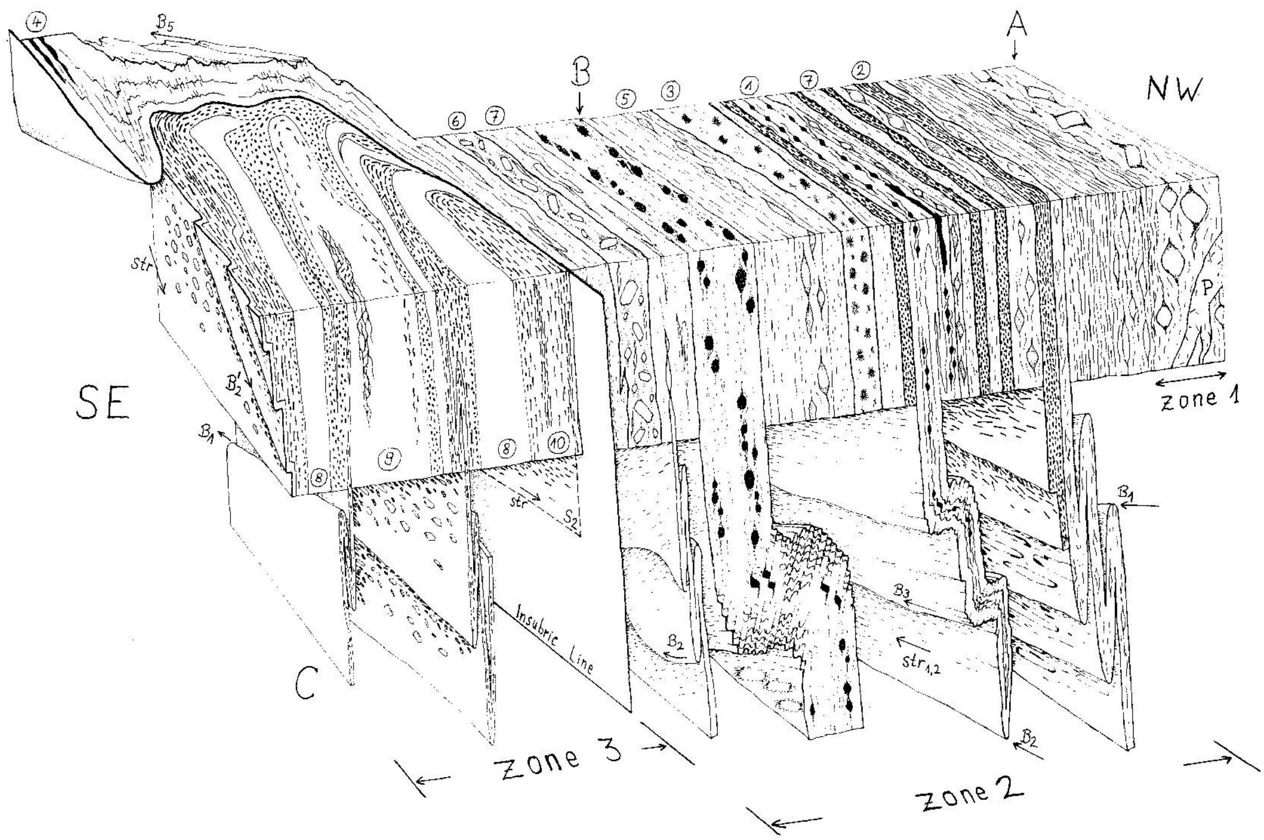
the compositional layering, a and c being randomly oriented in this plane. This may be largely a magmatic-sedimentary orientation. We regard phlogopite as having acquired its always good preferred orientation during this stage and not during the following amphibolite facies act. For this orientation with (001) parallel to compositional layering is found everywhere, even where there is no trace of the amphibolite facies deformation in or at the sides of the peridotite. This first deformation occurred under hb-granulite-facies conditions followed by static annealing under the same conditions. The latter caused polygonal grainshapes of all minerals, randomly oriented symplectites between sapphirine, orthopyroxene (and plagioclase), spherical outlines of included grains against garnet and equilibration of interfacial angles.

*The second deformation:* created pronounced planar and axial parallel textures. Unmixed clinopyroxenes recrystallize as non-unmixed clinopyroxenes, now the only stable pyroxene. Orthoproxenes do not recrystallize but continue unmixing; unmixed clinopyroxene is redistributed, orthopyroxene not stable any more. Garnets are replaced by symplectites of plagioclase (An 50–70) + brown hornblende or diopsidic pyroxene. Plagioclase recrystallizes (An 30–50) or develops a subgrain-structure. In peridotites olivine recrystallizes ($Fo_{95}$ to $Fo_{95}$), parent grains acquire a pronounced preferred orientation with a parallel to the new str and random orientation of b and c around a. Amphiboles in the peridotites often remain the course crystals of granulite facies conditions. They are, however, now oriented with c parallel to the new str and with (100) parallel to the new plane of flattening. In metagabbros brown hornblende unmixes and recrystallizes, again as brown hornblende. Often remainders of parent grains and recrystallized ones are replaced by diopside. Coarse symplectites of either spinel or sapphirine and pyroxene (+ plagioclase) recrystallize.

This deformation and recrystallization are restricted to narrow zones. They comprise the outer metagabbros and thin layers of the inner ones (away from the neighbouring peridotites), thin layers in the N- and S-hornblende-peridotites. The plane of flattening of this deformation is parallel to compositional layering, the according str is bent round the Finero anticline (4th act). Therefore it strikes 60° in the N-part (dip $\pm 0°$) and 70° in the S-part of the anticline (dip there 40° NE). The only folds found with this deformation occur in the main basic complex S of the Finero ultrabasic complex. Their axes are parallel to str, the axial plane strikes 70°, dips 75° NW. This is interpreted as a B′ normal B refolding under amphibolite facies conditions.

Interference of this deformation with recrystallization and neocrystallization is indicated by garnet coronas extended as pressure shadows, by strong deformation of plagioclase- and hornblende-recrystallization aggregates. A static annealing under same conditions survives the deformation, indicated by not extended coronas and polygonal grainshapes acquired by recrystallized plagioclase and olivines.


ABB'C Profile
F : Finero
zone 1 unaltered M.R. root - augengneiss; P: pegmatite
zone 2 N margin of zone - 2 - flattening
strong lower - T deformation at Insubric Line
subzone with dykes
subzone G with garnet - gneiss + amphibolites
① kinzigite
amphibolite
② garnet amphibolite
③ serpentinite hornfels
④ marble
⑤ augengneiss (M.R. - type)
⑥ dykes, parallel and crosscutting s
⑦ biotite - (mu) - plag. - gneiss; in subzone G with garnetrich layers
layered augengneiss (M.R. - type) + amphibolite
zone 3 ⑧ hb - peridotite
⑨ phlog - peridotite
⑩ metagabbro; dashed : overprinted by amphibolite facies
A
B
B'
C
Val Loana
Malesco
N
1 km
Insubric Line


SE
NW
A
B
C
Insubric Line
zone 1
zone 2
zone 3
P
str
$str_{1,2}$
$B_1$
$B_2$
$B_2'$
$B_3$
$B_5$
$S_2$

*The third deformation:* causes formation of ultra-blastomylonites in metagabbros and peridotites. In metagabbros amphiboles and plagioclase recrystallize with fine grains and altered composition. In peridotites orthopyroxenes do not recrystallize, olivine and phlogopite display extreme recrystallization. A shear-zone of this kind 80 m NW of Ponte Creves in the river bed produces sharp s planes striking 70°, dipping 75° N carrying a stretching fibre dipping 65° NE. The s planes of mylonitization are refolded round this str. It may well be that these shear zones develop from amphibolite facies conditions over considerable times into lower temperatures.

*The fourth deformation:* created the LENSCH-anticline (1968). There are, however, two anticlines. They bend planes and axes from earlier stages. The anticlinal axes plunge 60° at the W ends. There the compositional layering within the rock units and their boundaries may be traced completely round the fold hinges. Eastwards the axes must flatten out but they have not been found there. We think it impossible that the LENSCH-anticline(s) are of amphibolite facies age especially as the amphibolite facies deformation does not penetrate essential parts of the LENSCH-anticline and as its plane of flattening is bent round this anticline. Even the shear zones of act 3 are bent round it. There is no penetrative fabric correlate to this fold but flexure gliding slickensides on bent layers normal to B. They are formed together with serpentinization indicating a green schist facies condition.

The Insubric Line cuts these folds being younger than all acts mentioned so far.

## DEVELOPMENT OF ZONE 2

Zone 2 contains rocks which had acquired high grade metamorphism before alpine deformation. This zone contains augengneisses as they form the main rock type in the Monte Rosa root zone. There they are derived from a prealpine basement but have suffered alpine high grade metamorphism. In zone 2 they occur essentially in the N-part, but occasionally S to the Insubric Line. They even occur between kinzigite gneisses which are typical for zone 3. A middle part of zone 2 is richer in overprinted kinzigites and amphibolites. Marbles occur in the middle and especially in the S-part. They are intimately associated with kinzigites and amphibolites. This association of rocks differs from that of all neighbouring series: from the series dei laghi, from the Ivrea-Zone association, from that of the Monte Rosa root zone. We do not know much about the origin of this association of zone 2 and its structures before the deformations which shall be described now:

*The first to third deformation act:* cannot be separated as acts superimposed upon each other and separated by large time gaps. They start at a sharp boundary still affecting the S-part of the Monte Rosa root zone and continue

S to the Insubric Line throughout zone 2. 1,2 or 3 acts of folding and refolding occurred as a continuous rotational deformation, advanced to more stages of folding in softer rocks. Looking E the short limbs of all the resulting monoclinic folds are rotated clockwise, 1st, 2nd and 3rd cleavages intersect the pregiven layering from NW to SE downward. Axes of 1st and 3rd folds are parallel to $str_1$, $str_2$ which usually have the same attitude, on $s_{1,2}$ plunging 25–30° SW. $Str_1$ and $str_2$ may, however, change attitude from 50° SW to 30° NE-plunge within lamellae only cm–dm apart. Axes of 2nd folds curve within $s_2$ from a plunge 70° SW to 70° NE with transitions via the horizontal. $str_2$ however remains constant. $str_{1,2}$ are expressed by long axes of feldspar- and mica-recrystallization aggregates and by drifting apart of fragmented garnets. On s-planes of 3rd folds a very fine mica fibre may be seen subnormal to $B_3$; this may be a $str_3$. $s_{1,2}$ dip 60–90° to the NW, $s_3$ somewhat steeper. 1st and 2nd folds are isoclinal with amplitudes from the cm–m range, 3rd folds more open with amplitudes in the cm–100 m range.

$B_{1-3}$ and $s_{1-3}$ cause the same characteristic, orthorhombic preferred orientation for quartz-c-axis. c of hornblendes is oriented parallel $str_{1,2}$ and (100) parallel $s_{1,2}$. $B_{1-3}$ occur during conditions of low amphibolite Barrow facies. Staurolite, kyanite and garnet grow late during these deformations, prealpine garnets continue growing. There are indications of rising temperature during this metamorphism: outer higher-An-zone in recrystallized oligoclase grains, Fe-richer cores within clinozoisite, epidote included in new garnets where it disappeared outside. In Val Loana serpentinite hornfelses of this zone contain oriented talc with spherulites of olivine. We think that the reaction serpentine = forsterite + talc + $H_2O$ had reached the righthand side at a pressure of 5–7 kbar, i.e. a T of circa 580° C. A T around this value seems also reasonable as the staurolite isograd and that of oligoclase is surpassed, but clinozoisite still stable in parts of the rocks. Where micas and clinozoisites or hornblendes ar bent round $B_2$ or $B_3$ they are largely reoriented but partly still follow the refolded s-planes. Micas form polygonal arcs round these folds. Staurolite is still affected by 4th folds of opposite vergency found only locally in Val Loana. There it includes a finegrained matrix which was strongly coarsened outside. This deformation and metamorphism is superimposed upon augengneisses of the Monte Rosa root. The transition from this root to typical zone 2 – deformation occurs within 20 m. Course K-feldspars of the root gneisses recrystallize, course quartzes too and acquire a strong preferred orientation. It seems likely that the zone 2 – deformation and its T-rise was superimposed upon a M.R.-root which was already partly cooled after its high root-metamorphism.

N of the Insubric Line there is a small zone – c. 30 m in the E and 1000 m in the W – where older rocks are more strongly flattened and metamorphosed under slightly lower T. This results in a sharp and finegrained cleavage and second folds of the same geometry as in zone 2. However, very coarse amphiboles and plagioclases are bent, broken but do not recrystallize as is common in zone 2 further N. We are not certain yet whether this means that metamorphism within zone 2 decreases slightly southward or wether the sharp deformation at the Insubric Line is superimposed upon a different unit – with the zone 2 – deformation missing – at somewhat lower T. Quartz and biotite recrystallize to very fine grains, calcite of marbles shows strong mechanical deformation without correlated recrystallization. This indicates a T slightly below 500° C. Kinzigites still occur within this zone. This deformation probably affects the metagabbros in zone 3 very close to the Insubric Line. Here plagioclase and amphibole still recrystallize with altered composition.

*A last act of deformation:* folds the Insubric Line and its neighbourhood – i.e. the narrow zone N of it. A big fold (axis: strike 60°, plunge 30° SW) bends the rocks of this narrow zone towards the S where they cover the west end of the LENSCH-anticline with flat s-planes. There is a penetrative cleavage and fine plication correlated and parallel to the steep axial plane of this late fold. Quartz still recrystallizes with very fine, well oriented grains, calcite and plagioclase do not recrystallize any more. We estimate T at close to 350° C. This fold is indexed as $B_5$.

Zone 2 contains subvolcanic dykes, especially in a narrow zone close to the S margin. They contain phenocrysts of intimately zoned plagioclase, of biotite and ± K-feldspar and quartz, within a fine-grained matrix. The width is now – after deformation – 1 dm to 10 m. They usually follow an older layering but occasionally crosscut it. They have suffered all the deformations mentioned above and usually are strongly flattened and stretched, occasionally even refolded. Their intrusion precedes deformation and metamorphism as mentioned within zone 2 and indicates cooling which allowes dyke formation and a fine-grained matrix to develop. Quartz and biotite are recrystallized as in other rocks of zone 2, feldspars are usually not recrystallized but may be changed marginally by diffusion to higher An-contents. Allanite phenocrysts are changed towards epidote and continue growing as epidote. As usually in zone 2 a static annealing has slightly survived the deformation.

## CONCLUSIONS

The deformation mentioned of zone 2 is alpine, late Lepontine. For: it is superimposed upon the M.R. root zone. Further indications for this point are given by identity of deformation and mineralization within an identical zone E of Bellinzona (VOGLER and VOLL, 1976). Zone two was cooled to allow formation of subvolcanic dykes. The metamorphism of zone 2 occurred during T-rise at least between 500 and 580° C. All deformations within zone 3 are prealpine. The position of granulite facies rocks of basic, ultrabasic or gneissose composition close to the S margin of the alps has no genetic connection with this margin. The S margin of the alps cuts the Finero ultrabasic complex which had its recent position long before. The Insubric Line is – at least in essential parts of its history – a structure of alpine age, closely correlated to deformation in zone 2.

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