INTERNATIONAL CONFERENCE ON
PLANAR AND LINEAR FABRICS
OF DEFORMED ROCKS

ZURICH 1982

EXCURSION F

INSUBRIC LINE

S.M. Schmid
A. Zingg

INTRODUCTION

This guide book is organized into three sections. The first two chapters set the general scene and the third describes the itinerary. We would like to mention that we only recently started work on the Insubric line in a joint project with H.Laubscher (Basel), supported by the Schweizerischer Nationalfonds.

We would like to acknowledge the contributions by N. Mancktelow and B.Wintsch. We had many interesting discussions with J.Hunziker, H.Laubscher, A.G.Milnes and J.G.Ramsay, and with two students working on this project, H.R.Aebli and M.Handy. Dr.R.Liu helped mapping the Arcegno area.

CONTENT

B. Val d'Ossola section

The Val d'Ossola cuts across the root zone of the Pennine and Austro-alpine nappes and across the basement units of the Southern Alps represented by the Ivrea zone and the Strona-Ceneri zone.

The section offers a comparison between alpine deformation in the amphibolite facies rocks of the root zone and the later mylonitization under retrograde conditions within the mylonites of the Insubric line. A stop near the Insubric line (Loro) will illustrate how the different lithologies of Ivrea rocks, Canavese sediments and southern Sesia zone accommodate the displacements at the Insubric line. The last stop (Anzola) will be devoted to prealpine high temperature shear zones within the Ivrea zone

Itinerary:

Leave Domodossola in an eastern direction, cross the Toce river and drive towards Masera. About 1 km after the Toce bridge, take a right turn into the old road towards Trontano.

Stop 1: Centovalli Line between Domodossola and Masera
Coordinates: 668.40/108.10

The Centovalli line branches off the Insubric line near Locarno and, as a diffuse zone of cataclasis, defines the morphology of the E-W running Centovalli and Vigezzo valleys (fig. 24). This line is characterized by near surface deformation. Fault gouges and breccias can be studied in a small, deeply eroded valley.

Go back to Domodossola and drive south into Villadossola across a Pennine unit (Moncucco-Camughera complex) of uncertain tectonic position (see e.g. fig. 2).

Stop 2: Villadossola, contact between the Monte Rosa zone and the Antrona ophiolites
Coordinates: 663.30/102.05

The outcrops are situated in the river bed above the old bridge in the centre of Villadossola. The following lithologies are exposed:

Epidote amphibolites of the Antrona ophiolites, banded white mica - biotite gneisses which might represent the deformed pregranitic basement of the Monte Rosa zone (see fig. 9) and granitic gneisses which represent the Variscan granites of the Monte Rosa zone.

Large feldspar augen within the granitic gneiss exhibit asymmetric tails (fig. 34), macroscopically illustrating one of the criteria used to deduce the sense of shear within the much finergrained insubric mylonites where similar structures can only be found under the microscope. The stretching lineation gently plunges NE and the augen and associated shear bands suggest a dextral shear sense.

Boudins of mafic layers in the banded gneisses suggest a late stretch oblique to the overall trend of the foliation consistent with dextral shearing. Note the asymmetric folds in the boudin necks.

The granitic gneisses exhibit local shear zones associated with quartzo-feldspathic veins. Some dilatant and also dominantly dextral shear zones with en echelon tension gushes post-date the veins and mark the transition into a more brittle mode of deformation.

Cross the Toce river either near Domodossla or south of Villadossola and stop in a large quarry situated south of the Beura village.

Stop 3: Quarry of Beura, Core of the Monte Rosa zone antiform
Coordinates: ± 666.10/102.20

In the Val d'Ossola the Monte Rosa zone forms a large antiform gently plunging NE (see fig.35).

Two rock types are quarried at Beura, a fine grained muscovite biotite gneiss occasionally with turmaline and a granitic augengneiss. The augen consist of single feldspars and, in strongly deformed parts, of feldspar aggregates.

This quarry is located in the core of the antiform and suggests a constrictional state of finite strain which is possibly the result of the superposition of axial planar flattening on an earlier planar anisotropy. Note the large boudinaged turmaline crystals indicating a considerable stretch parallel to the SW-NE-trending fold axis of this antiform.

This constrictional fabric gradually merges into the flattening fabrics observed at the two stops in Villadossola and Creste at the northern and southern limbs of this antiform.

According to Milnes et al. (1980) this large antiform predates the Vanzone antiform found west of the Val d'Ossola, the antiform causing the transition from a region of predominantly flat-lying nappe boundaries in the north into a southern steep zone, i.e. the so-called root zone (fig. 29, from Milnes et al., 1981).

Drive southwards in about 2 km to the next stop on the eastern side of the Ossola valley and walk towards an outcrop underneath an electricity supply pylon.

Stop 4: Creste, Southern margin of the Monte Rosa zone
Coordinates: 665.30/100.90

This outcrop at the southern margin of the Monte Rosa granite gneiss exhibits very strongly flattened xenoliths, mylonitic bands and late shear bands anastomizing around asymmetric feldspar augen. Again, a dextral sense of shear can be inferred. The mylonitic bands have a microstructure undistinguishable from ordinary finegrained gneisses and the outcrop examplifies the difficulty in drawing a boundary between finegrained gneisses and mylonitic rocks formed under high grade metamorphic conditions. These mylonites also differ considerably in microscopic and macroscopic character from the insubric mylonites. Their mineralogy is unchanged in respect to the source rock and biotite remains stable.

The Mesozoic of the Southpennine realm is reduced to lenses of amphibolites, serpentinites and schistes lustrés or, as in the case of this section, they are completely missing. Thus, we directly enter the Austroalpine Sesia zone south of the Central Pennine Monte Rosa zone. The NW and central part of this zone is made up of banded biotite gneisses and granitic gneisses showing small scale isoclinal folds associated with the main schistosity. The SE part of the zone consists of medium to fine grained banded gneisses with large folds (stop 5). The mylonite zone of the Insubric line is situated south of this next stop (5).

Drive south for about 4 km to stop 5 where the main road from Villadossola crosses the Toce river.

Stop 5: Vogogna-Ponte Masone, folded gneisses of the Sesia zone
Coordinates: 665.40/97.10 Masone bridge
665.55/97.10 abandoned quarry

A series of M-shaped chevron folds is best overlooked from the western side of the bridge. This zone of very intense folding very abruptly ends within steeply northwest dipping gneisses north and within NW dipping mylonites south of this locality, where no S-or Z-shaped parasitic folds where found yet. It is still unclear if we are in the core of a large-scale synform or antiform.

- The alpine foliation in unit (3) is discordant to the prealpine fabric at (1) and (2). see fig.
- The development of the Alpine fabric in (3) is reaction controlled (break down of plagioclase and garnet in the pelitic rocks).
- The northplunging stretching lineation is parallel to the axes of isoclinal folds. See structure diagrams of fig.
- A weak crenulation is found especially in mylonites close to the contact between the different units.

Metamorphism

- Prealpine met.: Granulite facies: NW part of (1)
  Amphibolite " (2) and relics in (3)
- Porphyroclastic minerals of (7) and may be also (5) derive from granites presumably of Variscan age.
- Alpine met.: Greenschist facies conditions in (3)-(7) prevailed during mylonitization.

A continuous profile can be traced from the chapel in Loro in a northwestern direction. For a shorter visit two particular outcrops are recommended and described below:

Stop 6A: Fabric boundary at the chapel of Loro

The chapel is situated on an outcrop at the eastern end of the village of Loro. Along the footpath to the chapel impure marbles, an ultramafic lense and mafic rocks of the altered Ivrea zone are exposed. The mafic rocks show narrow shear zones with greenschist minerals. On the other side of the chapel mylonites are exposed. Walking towards the Rio di Loro mafic lenses with preserved prealpine highgrade minerals and structures are found within mylonites derived from pelitic rocks. The impure marbles close to the fabric boundary were regarded as Canavese Mesozoic in older studies, although the mineralogy of these rocks is characteristic for temperatures never reached during alpine metamorphism. These mylonitized marbles contain large boudins of calc-silicate and mafic rocks.

This stop provides a good view across the Val d'Ossola. The NW dipping gneisses and mylonites of the Sesia- and Canavese-zones contrast with the massif rocks of the Ivrea zone. An antiform within the Ivrea rocks is visible near Vogogna.

Both this antiform and another larger antiform mapped by R. Schmid (1967) north of the lower Ossola valley are cut off by the Insubric line further to the east and are presumably representing prealpine structures.

Stop 6B: Lithological boundaries between Ivrea- Canavese- and Sesia zones

The northwestern end of the Ivrea derived mylonites (unit 3) is represented by marbles with actinolite and diopside relics and by pelitic mylonites. They are followed by 1/2m of dark calcschist (Canavese Mesozoic) and by 50 m of granitic mylonites with muscovite clasts (unit 5). This unit is best studied in the river bed. For visiting the Permotriassic sediments (unit 6) follow the path which starts immediately north of the river. After one hundred meters uphill walk you will reach the strongly weathered quartzitic mylonites of the Canavese-Permotriassic. Further NW the Sesia zone starts with grantitic mylonites.

Continue along the road south of the Toce river in an eastward direction towards Anzola and across the large antiform mentioned above, situated within granulite facies Ivrea rocks (Meta-basites, small ultramafic bodies and metapelites).

Turn into the Anzola quarry on a service road 500 m east of the village.

Stop 7: Quarry of Anzola: granulite facies mafic and pelitic rocks of the Ivrea zone with high temperature mylonites and shear zones
Coordinates: 670.86/93.10 stop A
670.60/93.10 stop B

East of the quarry pelitic and mafic rocks alternate. Within the quarry, a large body of mafic rocks is exposed with a weak compositional banding, locally folded (fig. 39). To the west the quarry exposes the contact with pelitic rocks and a lens of marbles. Both, pelitic and mafic rocks have a granoblastic fabric and mineral assemblages of the granulite facies. According to Rb-Sr total rock determination this metamorphism is of Caledonian age.

Mylonites are developed in shear zones at both ends of the quarry. At the eastern end (stop A) the shear zones are nearby vertical and cut the granulite facies foliation at a small angle(fig.39). The shear zone at the western end of the quarry (stop B) is concordant to the old foliation and to the contact between mafic and pelitic rocks.

The matrix of the mylonitized mafic rocks shows a finegrained granoblastic microstructure and contains clinopyroxene, hornblende and plagioclase. These matrix minerals have a chemical composition which indicates higher temperatures compared to the chemistry of the porphyroclasts and the minerals of the unsheared mafics (Brodie 1978, fig.41).

The pelitic mylonites show garnet and deformed feldspar and sillimanite as porphyroclasts, with long tails of very fine grained minerals, presumably feldspar and white mica, embedded in a quartz matrix (fig.40).

Mineral assemblages:

Granoblastic rocks (Caledonian granulite facies metamorphism)

Mafics: Plagioclase, hornblende, ± orthopyroxene
± clinopyroxene, ± garnet

Pelites: Quartz, K. feldspar, palgioclase, sillimanite, garnet and traces
and traces of biotite.

Impure marbles: calcite, clinopyroxen, scapolite, sphene, ± quartz, ± plagioclase.

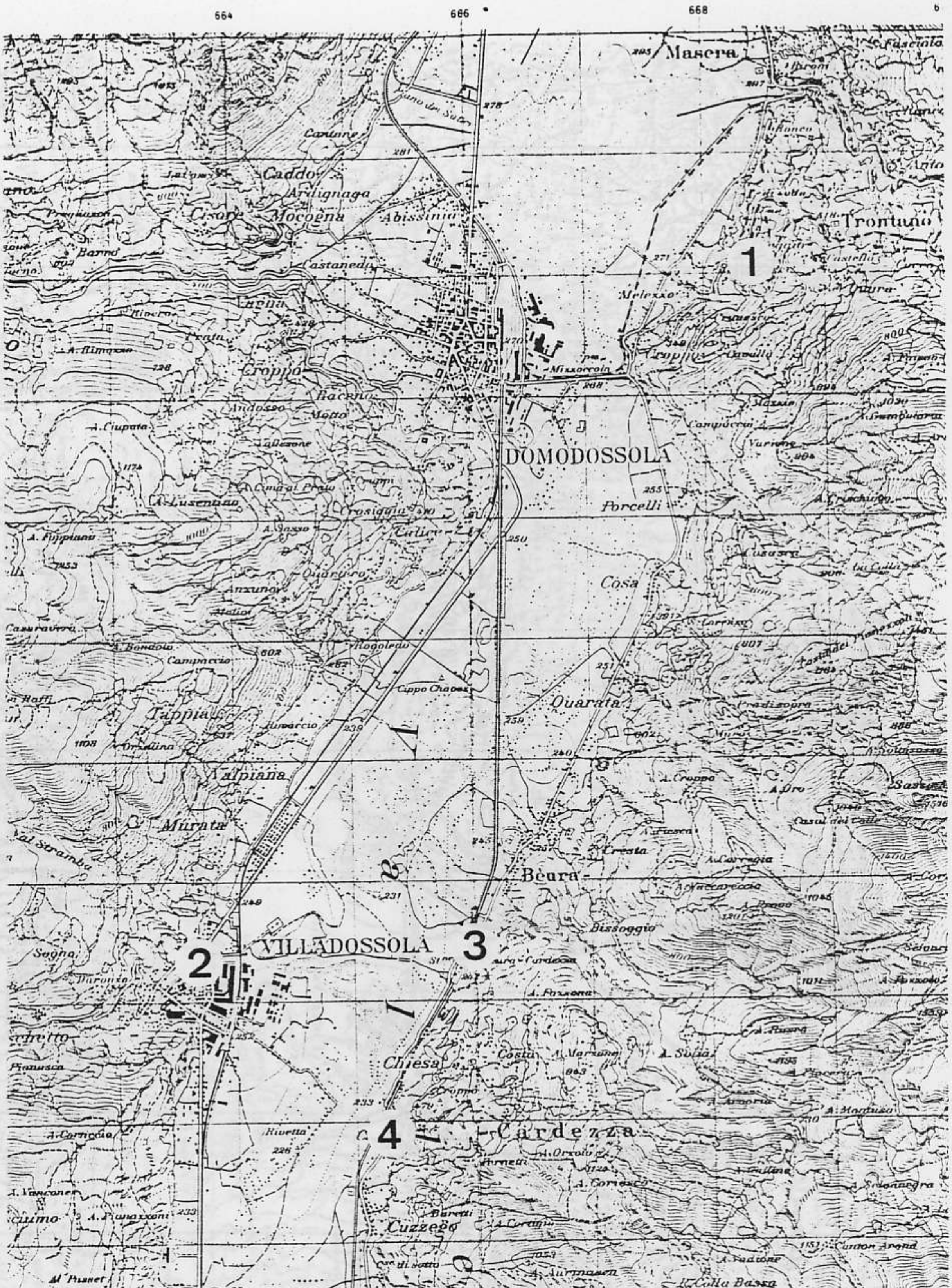


FIG. 32

The stops of the Ossola section on a topographical map 1:50 000

FIG. (33)

The stops of the Ossola section on a topographical map 1:50 000

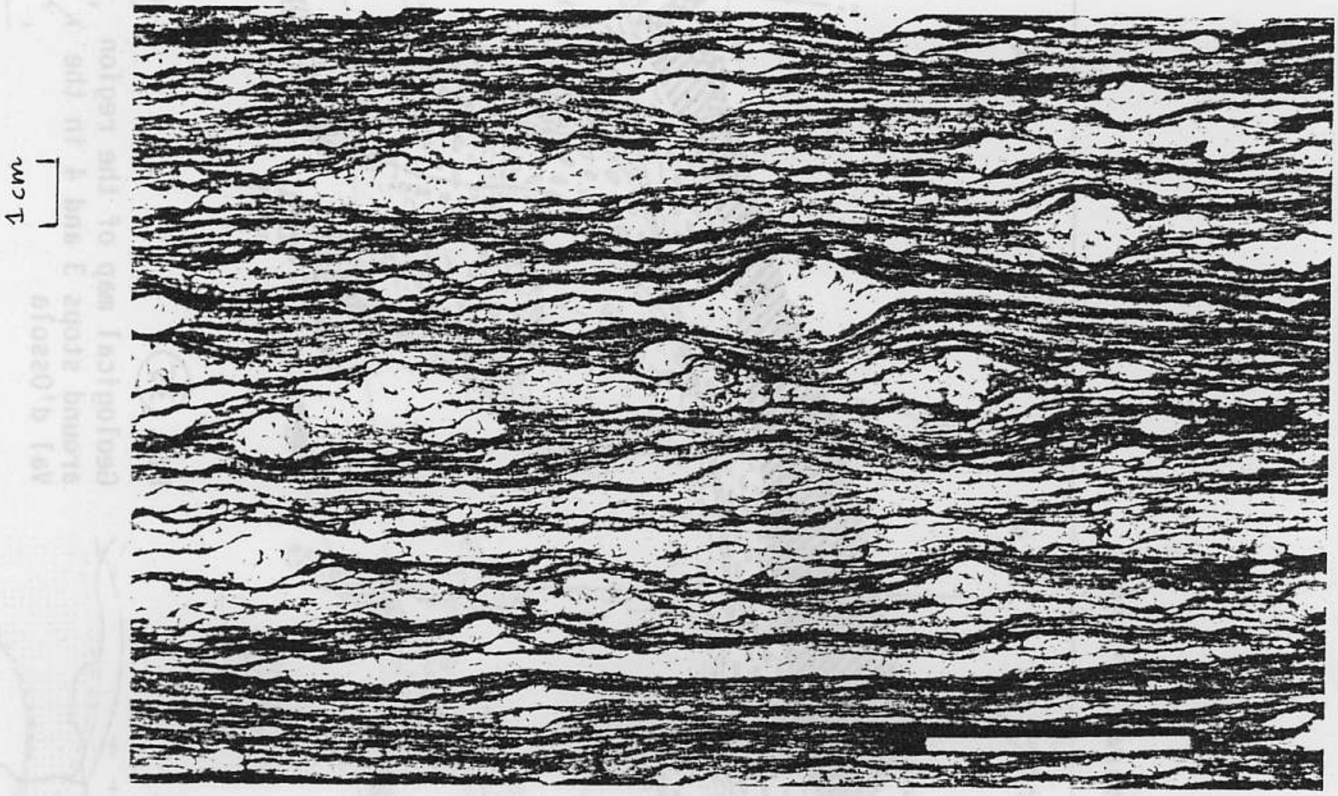


Fig. 34

Asymmetric augen and weakly developed shear bands in Monte Rosa granite gneiss at stop 2, Val d'Ossola section, indicate a dextral shear sense (in reference to this figure and geographical coordinates).

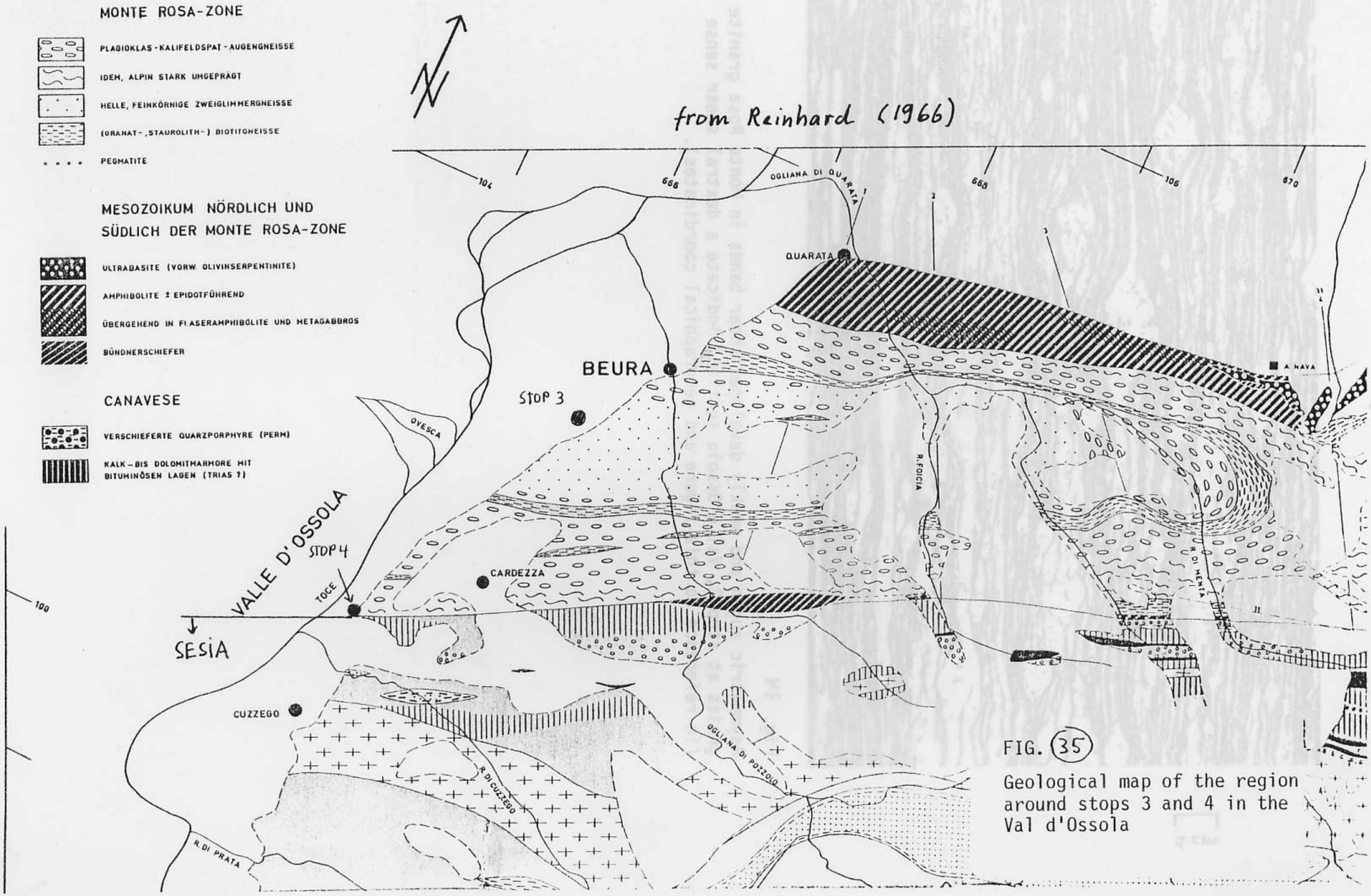


FIG. 35

Geological map of the region around stops 3 and 4 in the Val d'Ossola

Sketchmap of the Loro area (Val d'Ossola)

Unit	Zone	Lithology
1	Ivrea Zone	Pelitic rocks
2	Altered Ivrea Z.	Mafic rocks Impure marbles
3	Mylonitized Ivrea rocks	Pelitic schists and mylonites mafic rocks Impure marbles
4	Canavese Mesozoic	Calcschists and mylonites ± dolomites
5	Mylonitized Sesia Zone ?	Granitic mylonites with muscovite + feldsp.clasts
6	Canavese Permo-triassic	Quarzitic mylonites
7	Mylonitized Sesia Zone	Granitic mylonites with feldspar clasts
8	Sesia zone: micaschists, banded gneisses, granitic gneisses, metadiorites.	

Foliation: 40-59° 60-80° > 80°

31 stretching lineation

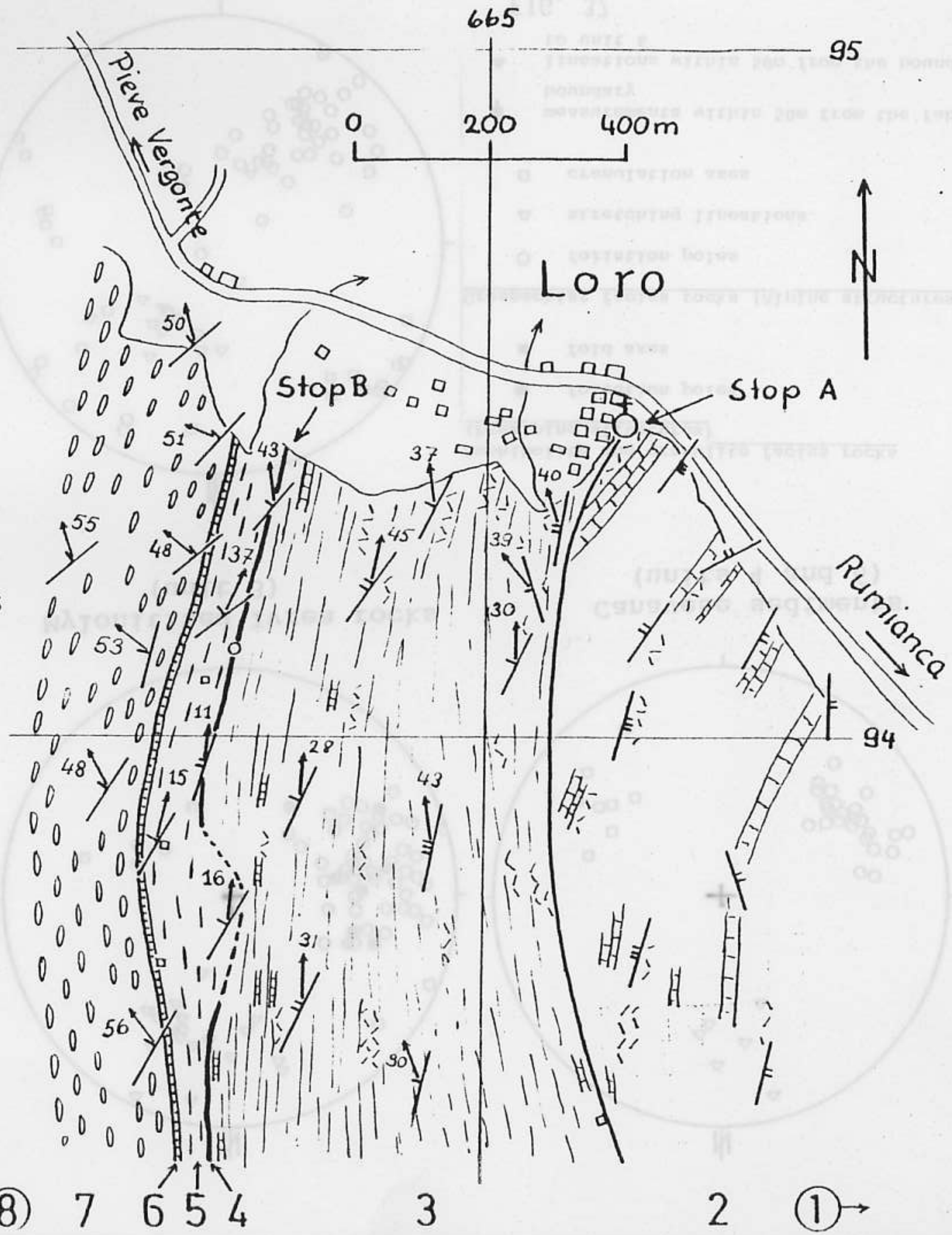


FIG. 36

Map of the area around stop 6, Val d'Ossola

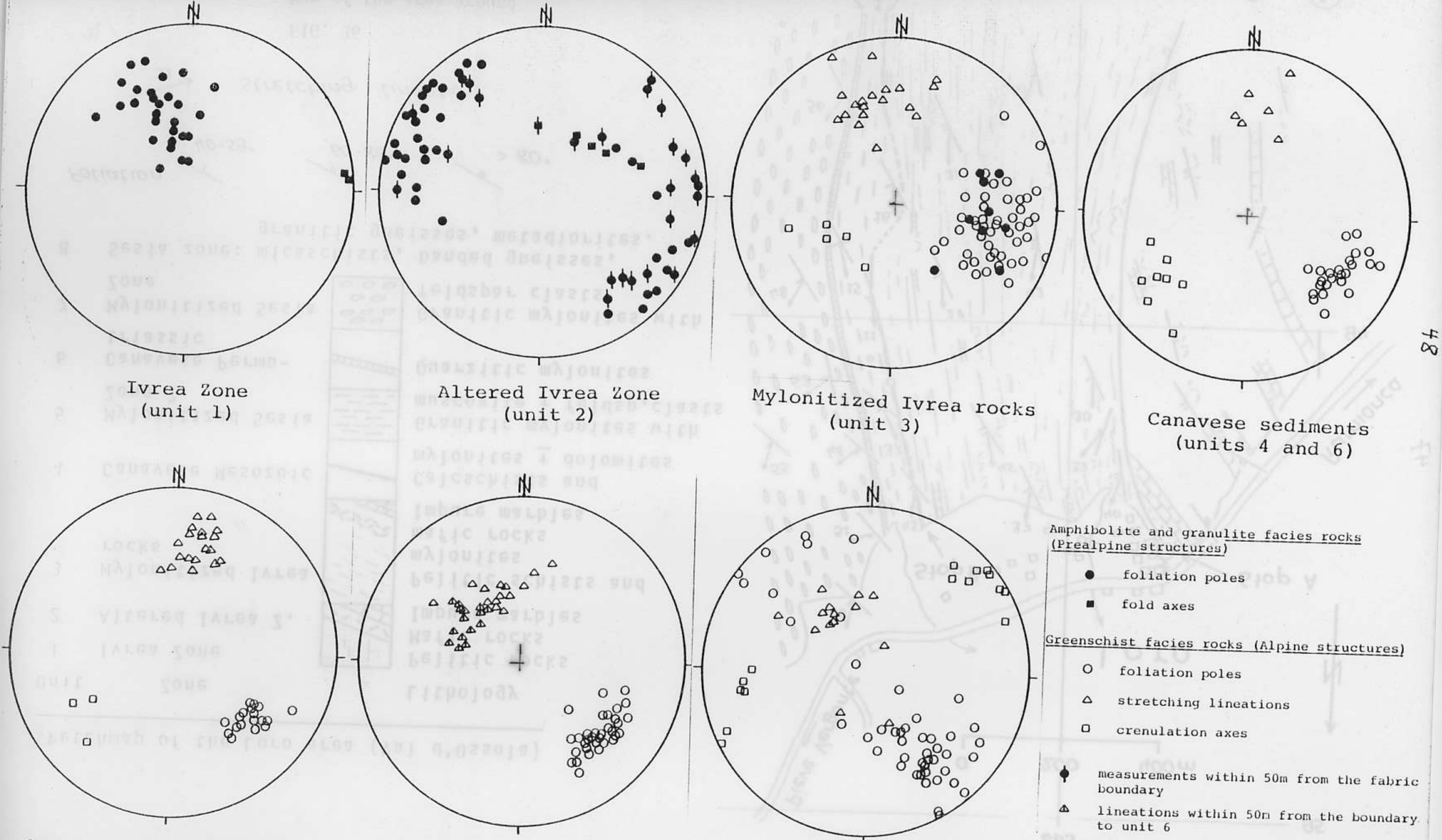


FIG. 37

Structural data of the area around stop 6, Val d'Ossola

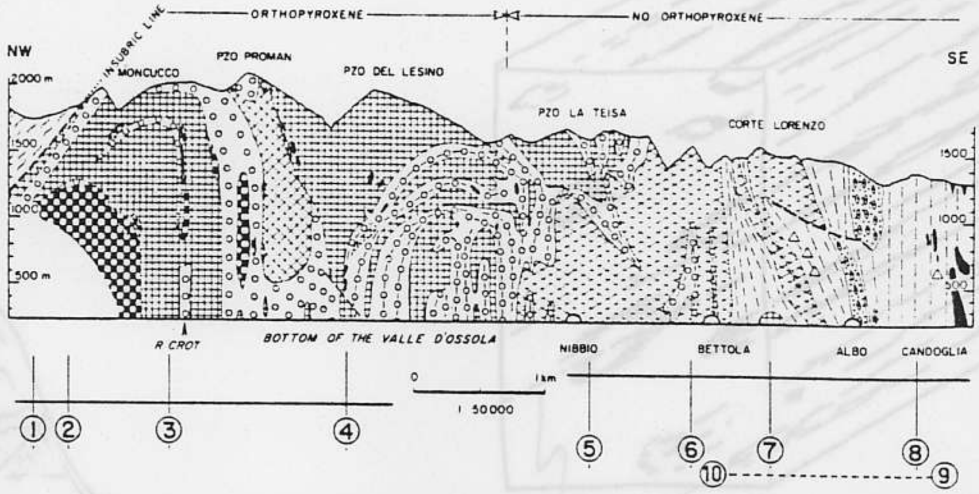


Fig. 1. Profile through the Ivrea–Verbano Zone on eastern side of the Valle d'Ossola, simplified after SCHMID (1967, table X), with positions of the observation points corresponding to this profile (no. 1—4, 9—10 on the western side, no. 5—8 on the eastern side of the Valle d'Ossola). Legend in Fig. 2.

from Schmid (1968)

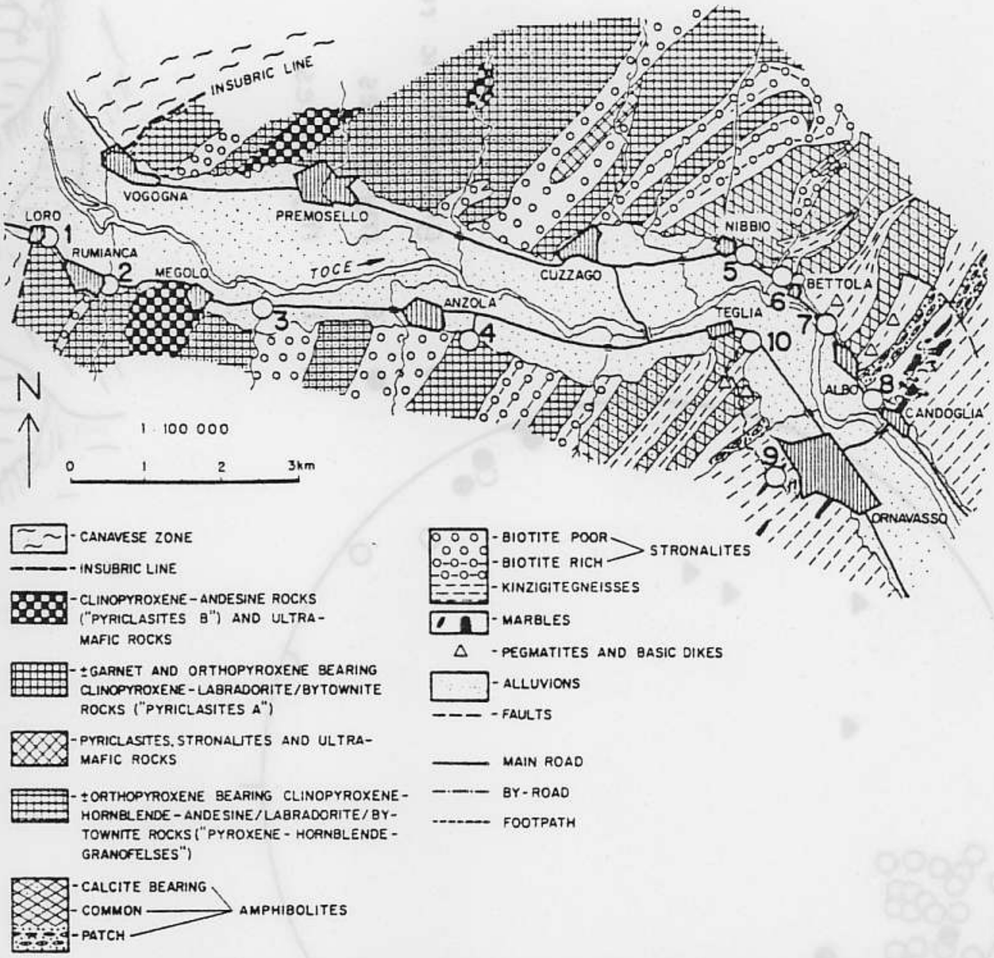
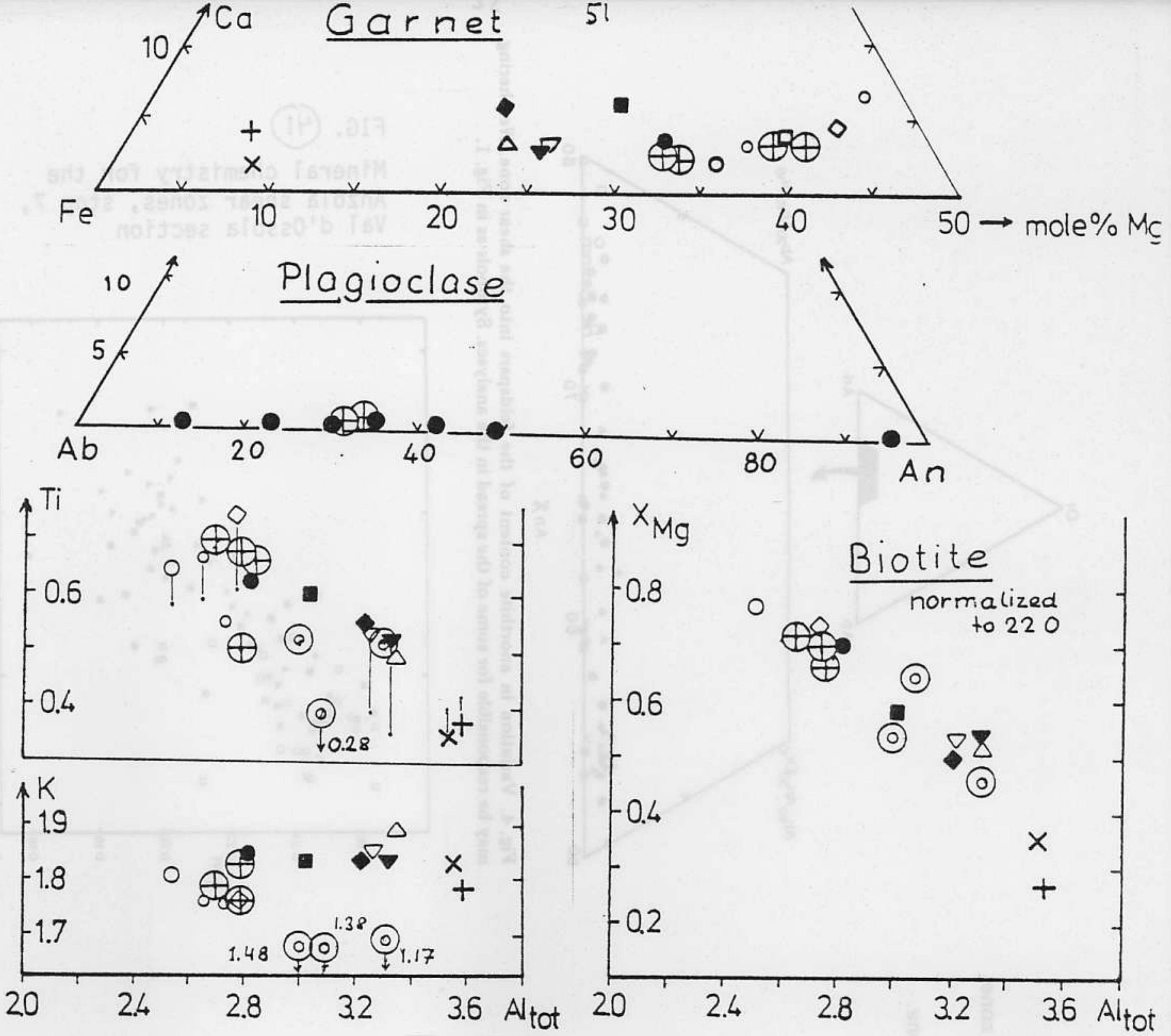


Fig. 2. Petrographical map of the lower part of the Valle d'Ossola, after SCHILLING (1957), BORIANI (1966) and SCHMID (1967), with observation points 1—10 of the excursion.

FIG. 38

Map and cross section of the Ivrea zone in the Val d'Ossola near stop 6



Composition of garnet, biotite and plagioclase

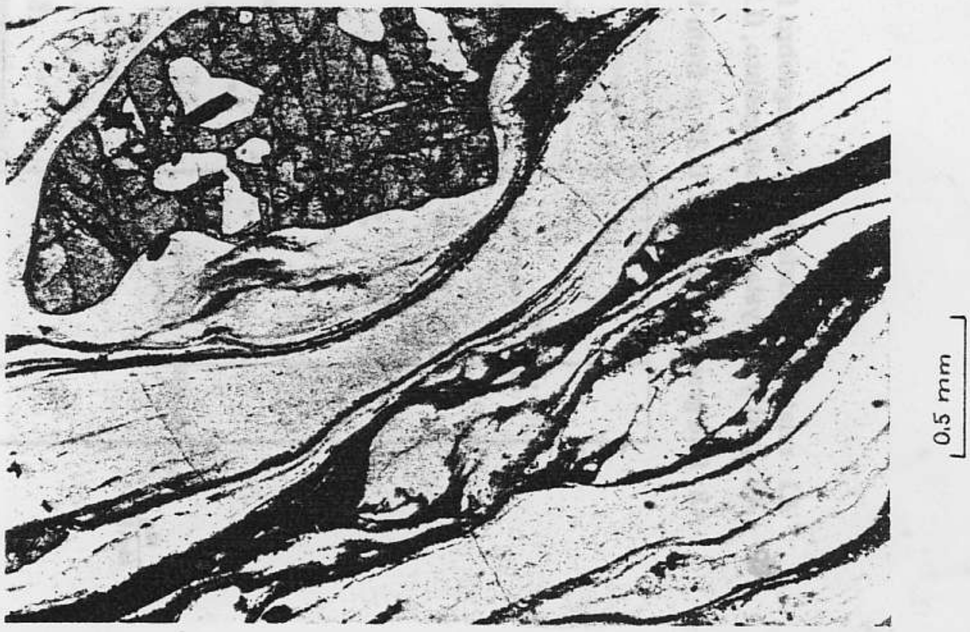
⊕ : Porpyroclasts from the Anzola mylonites (unpublished data)

Other symbols: Minerals from a prograde sequence of granoblastic metapelites (data from Hunziker and Zingg, 1980)

◎ : New formed biotite from the mylonites.

FIG. 40

Mylonitized metapelite with garnet and feldspar porphyroclasts.



A1: relatively undeformed metagabbro from the edge of the shear zone;
A6: partly recrystallized metagabbro, 0.2 m into the shear zone;

A8: fine grained mylonite, 0.35 m from the margins of the shear zone.

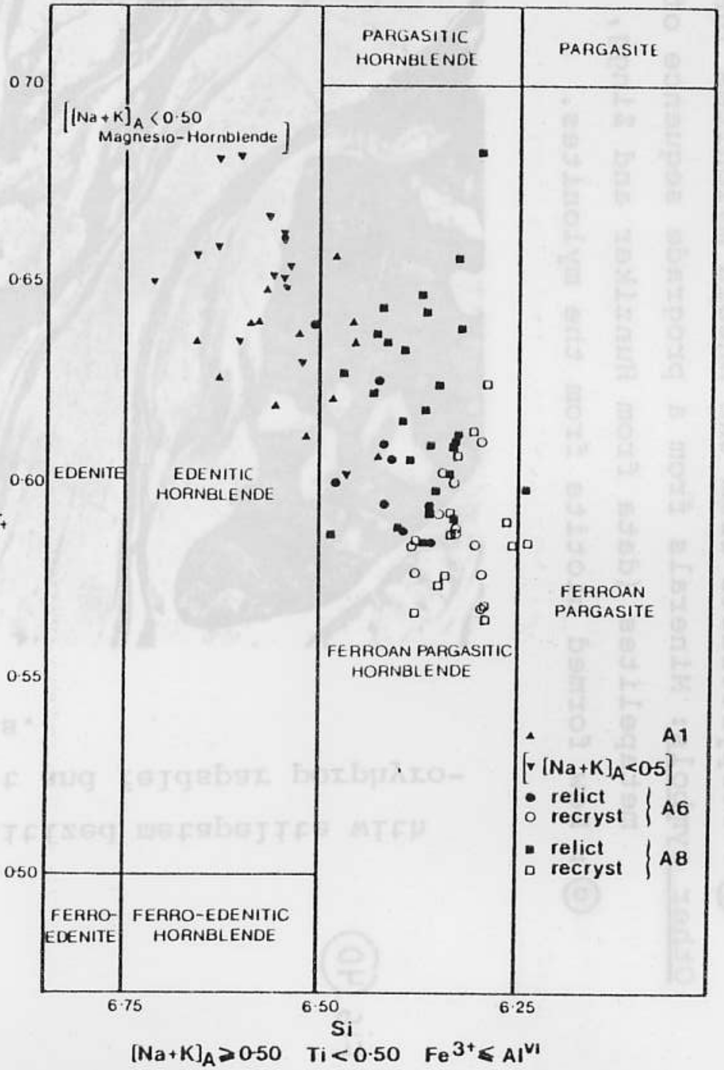


Fig. 1. Variation of $Mg/Mg + Fe^{2+}$ with Si content of the amphiboles showing the change from a magnesio-hornblende to a ferroan pargasitic hornblende into the shear zone. Nomenclature after Leake (1978).

from Brodie (1981)

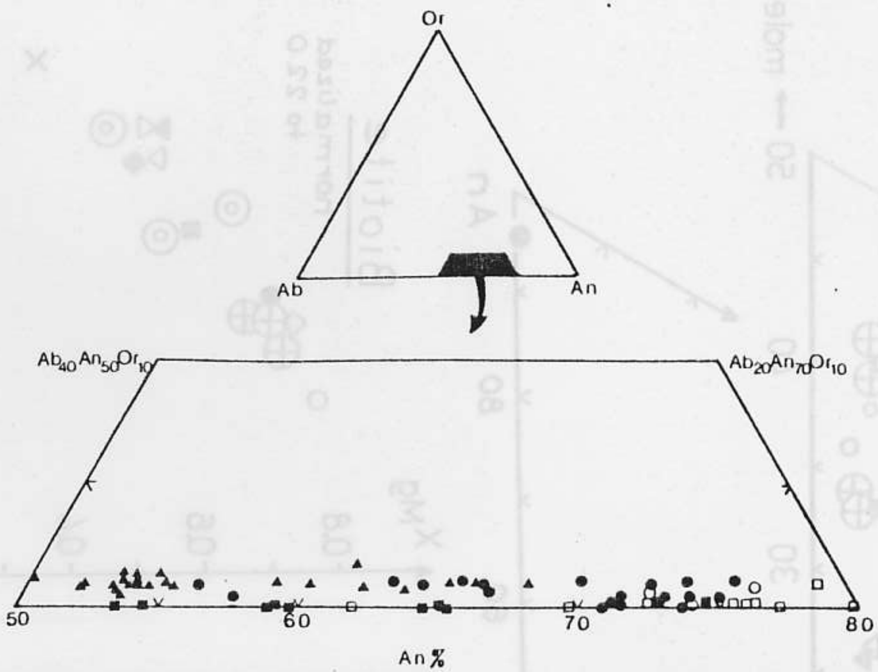


Fig. 4. Variation in anorthite content of the feldspars into the shear zone. Weathering may be responsible for some of the spread in the analyses. Symbols as in Fig. 1.

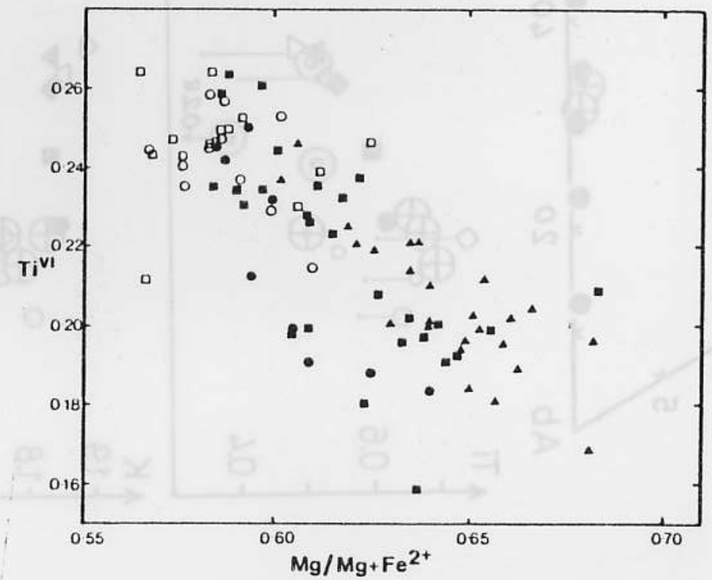


Fig. 3. Variation of $Mg/Mg + Fe^{2+}$ with Ti^{vi} content of the amphiboles. Symbols as in Fig. 1.

FIG. 41

Mineral chemistry for the Anzola shear zones, stop 7, Val d'Ossola section

C. The Val Loana section

This section offers the opportunity of a pleasant one day hike, through a large variety of mylonitic rocks. It displays good exposures of the mesozoic rocks (Lanavese s.l.) and insubric mylonites in the uppermost Val Loana, situated between Finero and the Ossola section.

1) General description (compare the profile, fig.42)

The meta-diorites and -gabbros of unit 1 (fig.42) are part of the Ivrea zone. Alpine shearing along discrete shear planes, preserving the prealpine penetrative fabric becomes more intense in a northward direction (2), where high grade marbles (3) are found, Unit 4 contains metadiorites (dykes?) interlayered with biotite schists of unit 5, which we will refer to as the Scaredi formation. Thus, units 4 and 5 indicate the existence of a northern metasedimentary envelope of the Ivrea metadiorites and -gabbros (compare the profile in Loro, Val d'Ossola section).

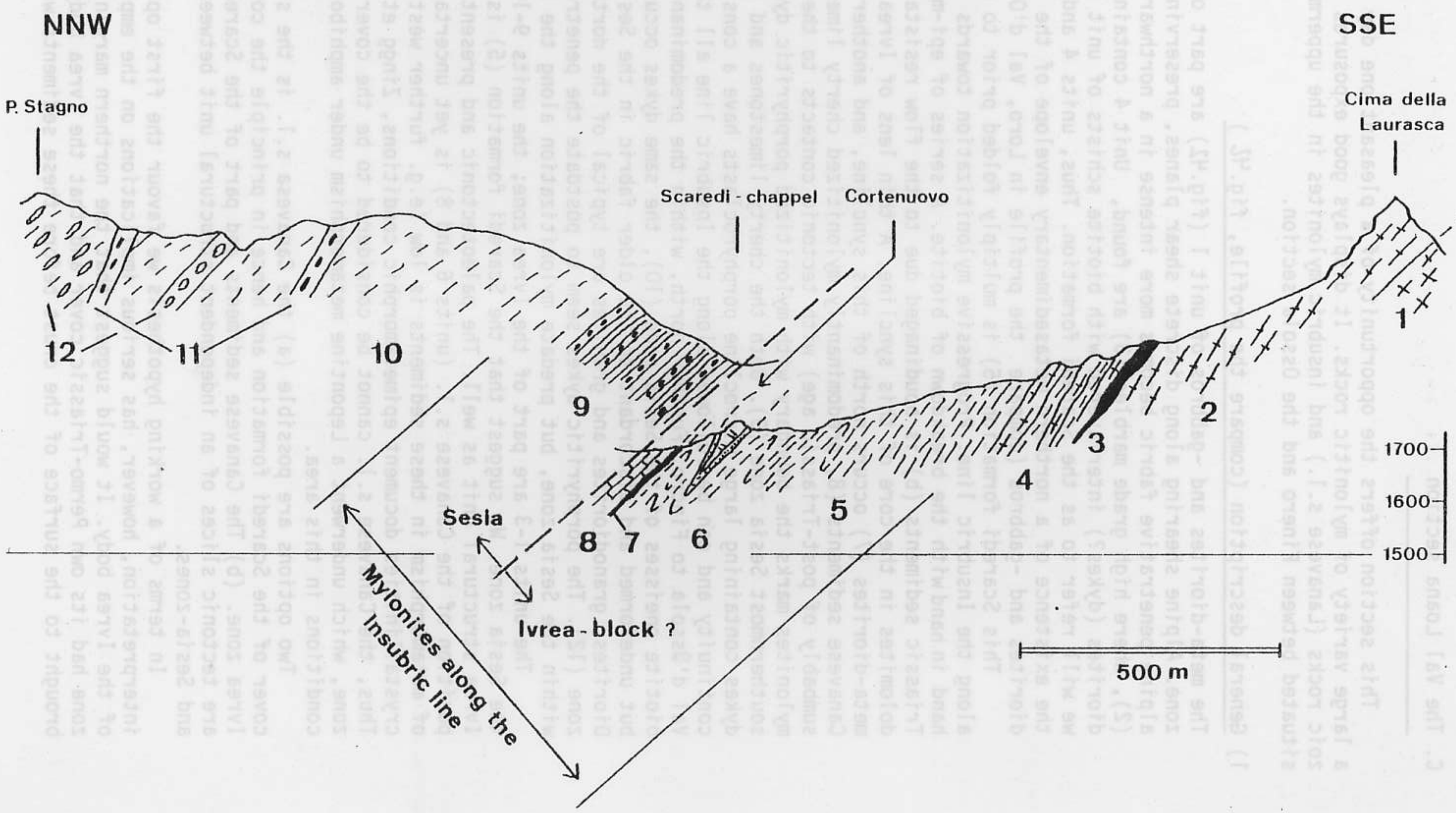
This Scaredi formation (5) is multiply folded prior to mylonitization along the Insubric line. Progressive mylonitization towards the north goes hand in hand with the breakdown of biotite. A series of epi-metamorphic Permo-Triassic sediments (b) is boudinaged due to the flow resistant Triassic dolomites in the core of this syncline. A thin lens of Ivrea marbles and meta-diorites (7) occurs north of this syncline, and another train of Canavese sediments (8, predominantly mylonitized cherty limestones, presumbably of post-Triassic age) with tectonic contacts to the Scaredi mylonites marks the boundary with mylonitized porphyritic dykes of the southernmost Sesia zone (9). Both the cherty limestones and the porphyritic dykes containing large microcline porphyroclasts have a considerable lateral continuity and can be followed along the Insubric line all the way from the Val d'Ossola to Fincro. Further north, within the predominantly finegrained biotite gneisses of the Sesia zone (10), the same dykes occur again (11), but undeformed and discordant to the older fabric in the Sesia gneisses. Diorites, granodiorites and granites are typical of the northern Sesia zone (12). The porphyritic dykes seem to postdate the penetrative fabric within the Sesia zone, but predate mylonitization along the Insubric line.

The units 1-3 are part of the Ivrea zone; the units 9-12 belong to the Sesia zone. We suggest that the Scaredi formation (5) is part of the Ivrea structural unit as well. The paleotectonic and present structural position of the Canavese s.l. (units 6 and 8) is yet uncertain. The degree of metamorphism in these sediments is low (e.g. further west the illite crystallinities document epimetamorphic conditions, Zingg et al. 1976). Thus, the Canavese s.l. cannot be considered to be the cover of the Sesia zone, which underwent a Lepontine metamorphism under amphibolite facies conditions in this area.

Two options are possible (a) the Canavesa s.l. is the stratigraphic cover of the Scaredi formation and hence in principle the cover of the Ivrea zone. (b) The Canavese sediments and part of the Scaredi-mylonites are tectonic slices of an independent structural unit between the Ivrea- and Sesia-zones.

In terms of a working hypothesis we favour the first option. This interpretation, however, has serious implications on the emplacement history of the Ivrea body. It would suggest that the northern margin of the Ivrea zone had its own Permo-Triassic cover and that the Ivrea body was essentially brought to the surface of the crust before these sediments were deposited.

FIG. 42 Profile through the upper Val Loana, for the numbers, see text.



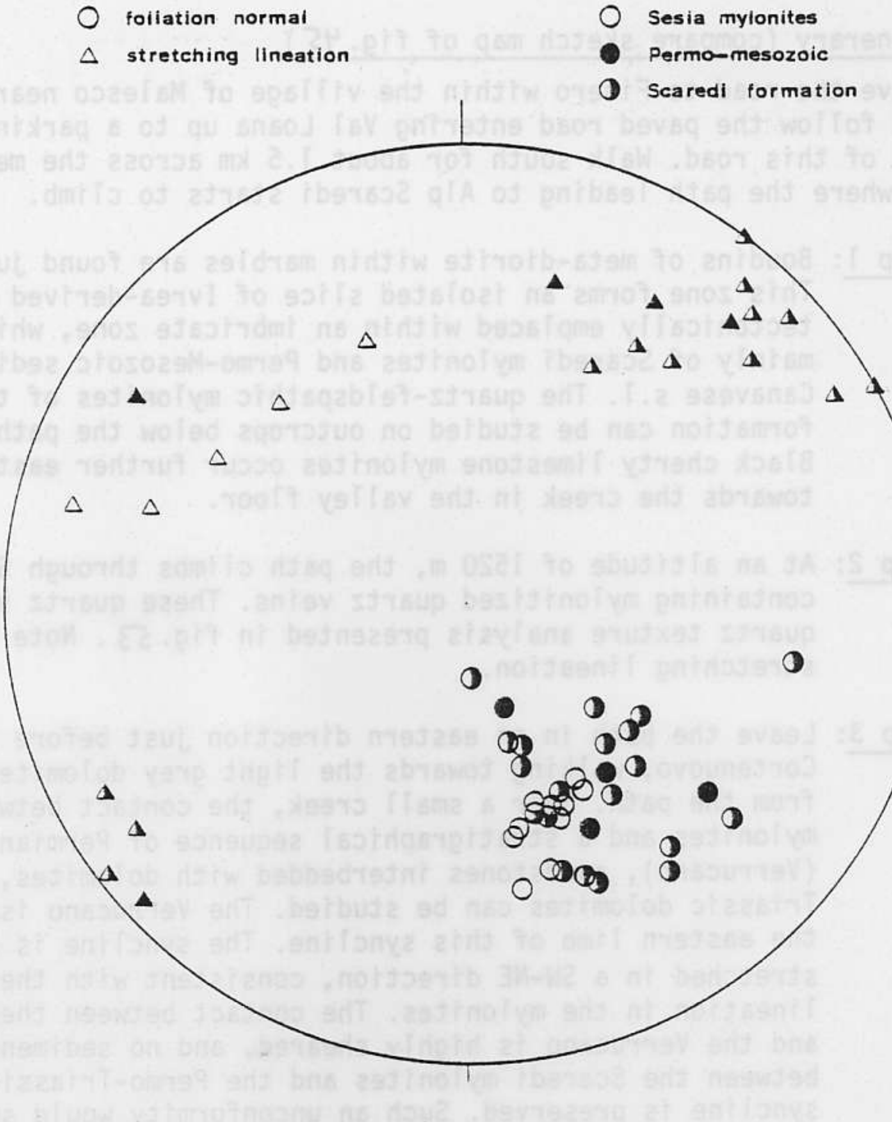


Fig. 43 : Strucural data, lower hemishere, equal area.

Figure 43 summarizes some structural data collected within the mylonites. On average, the mylonitic foliation dips 40° to the NW. The lineations scatter considerably within the foliation plane. It is interesting to note, however, that the lineations within the Scaredi mylonites are predominantly subhorizontal, whereas the lineations within the Sesia-derived mylonites are oriented down-dip. Various micro-structural data (figs. 47, 49, 51), supported by the interpretation of quartz fabrics (fig. 53), were used to deduce the shear sense for oriented specimens. The Scaredi mylonites consistently indicate a dextral shear sense, whereas the Sesia mylonites suggest southward thrusting of the Sesia zone into the Ivrea unit and the Canavese s.l.

This suggests that the mylonites of the Scaredi formation may not have been formed at the same time the Sesia mylonites formed. Thrusting of the Sesia zone pre- or postdates the strike slip movements.

Thrusting of the Sesia zone onto the Ivrea zone is consistent with the juxtaposition of the amphibolite facies rocks of the Sesia zone (Lepontine metamorphism) with the relatively "cool" Ivrea zone (prealpine metamorphism) and the epi-metamorphic sediments of the Canavese s.l.. Dextral strike slip along the Insubric line is consistent with large scale kinematic models (Laubscher 1970).

2) Itinerary (compare sketch map of fig. 45)

Leave the road to Finero within the village of Malesco near the church, and follow the paved road entering Val Loana up to a parking lot at the end of this road. Walk south for about 1.5 km across the meadows to stop 1, where the path leading to Alp Scaredi starts to climb.

stop 1: Boudins of meta-diorite within marbles are found just by the path. This zone forms an isolated slice of Ivrea-derived material tectonically emplaced within an imbricate zone, which consists mainly of Scaredi mylonites and Permo-Mesozoic sediments of the Canavese s.l. The quartz-feldspathic mylonites of the Scaredi formation can be studied on outcrops below the path at stop 1. Black cherty limestone mylonites occur further east of this stop, towards the creek in the valley floor.

stop 2: At an altitude of 1520 m, the path climbs through Scaredi mylonites containing mylonitized quartz veins. These quartz veins yielded the quartz texture analysis presented in fig. 53. Note the subhorizontal stretching lineation.

stop 3: Leave the path in an eastern direction just before reaching Alp Cortenuovo, walking towards the light grey dolomite cliffs visible from the path. Near a small creek, the contact between the Scaredi mylonites and a stratigraphical sequence of Permian clastics (Verrucano), sandstones interbedded with dolomites, and cryptalgal Triassic dolomites can be studied. The Verrucano is found again on the eastern limb of this syncline. The syncline is boudinaged and stretched in a SW-NE direction, consistent with the stretching lineation in the mylonites. The contact between the Scaredi mylonites and the Verrucano is highly sheared, and no sedimentary unconformity between the Scaredi mylonites and the Permo-Triassic cover of the syncline is preserved. Such an unconformity would support the hypothesis that these sediments were originally deposited on the Scaredi formation.

stop 4: Here, the Scaredi formation is somewhat less mylonitic, and relict biotite is found. Note the pegmatitic dykes, which have remained relatively undeformed. Along the path to the chapel (stop 5), progressive mylonitization can be studied. Eventually the pegmatitic veins acquire a mylonitic foliation as well.

Alp Scaredi offers a splendid view of the continuation of the Insubric line in a westward direction. The line runs through the Val Grande and over A. la Colma into the Val d'Ossola. The Mt. Rosa is visible in a far distance (see fig. 44).

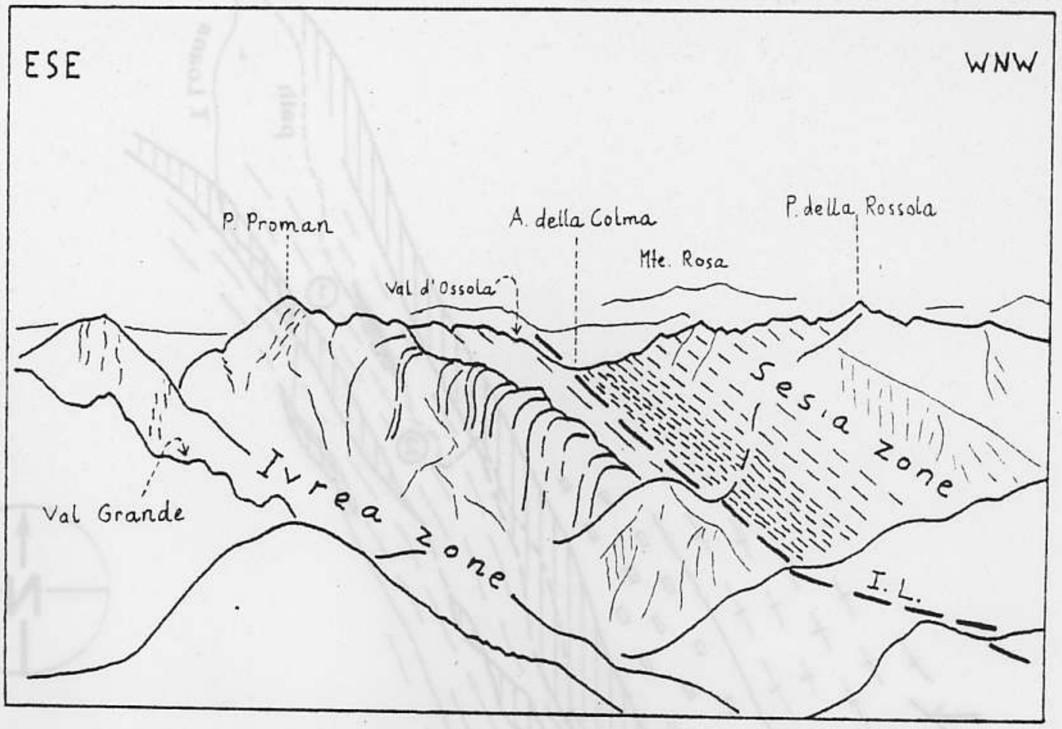


Fig. 44 : View from Alp Scaredi in the direction towards Val d'Ossola. The Insubric line (I.L.) cuts a large antiform within the northern Ivrea zone (R.Schmid 1967) discordantly.

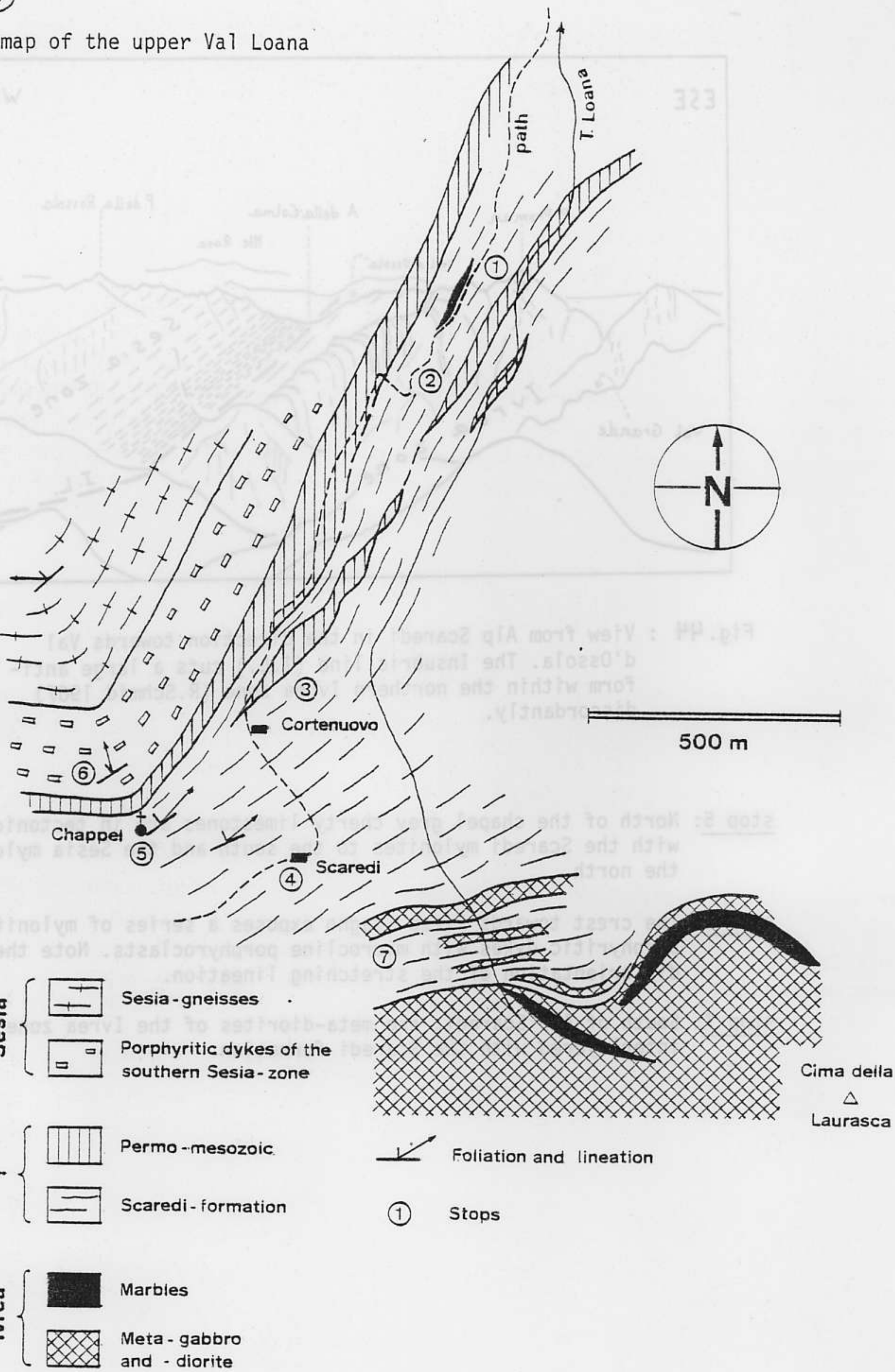
stop 5: North of the chapel grey cherty limestones are in tectonic contact with the Scaredi mylonites to the south and the Sesia mylonites to the north.

stop 6: The crest towards Pizzo Stagno exposes a series of mylonitized porphyritic dykes with microcline porphyroclasts. Note the down dip orientation of the stretching lineation.

stop 7: South of Alp Scaredi, the meta-diorites of the Ivrea zone are found interlayered with the Scaredi formation.

FIG. 45

Sketch map of the upper Val Loana



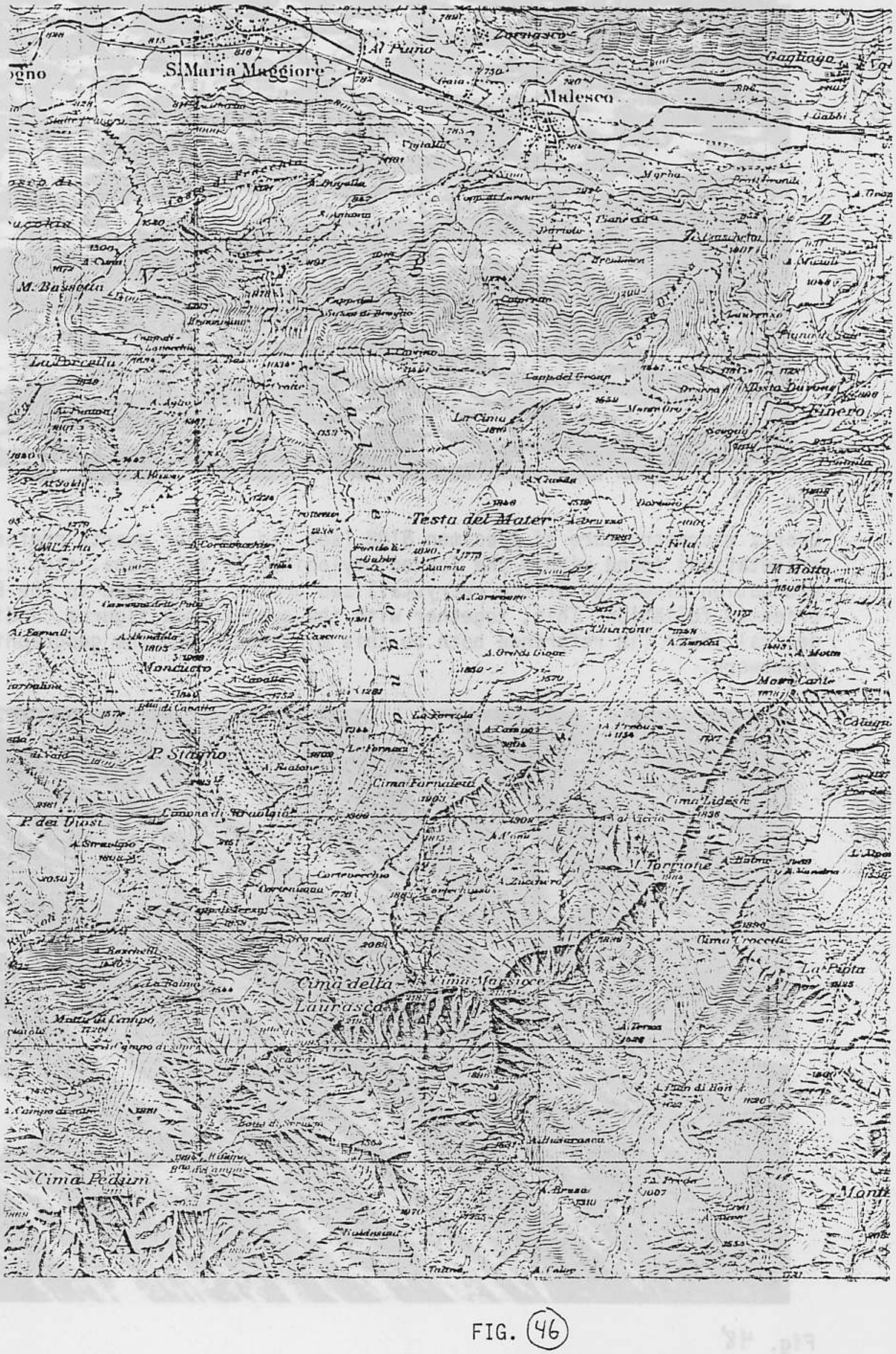


FIG. 46

Topographic map of the Val Loana, 1:50 000

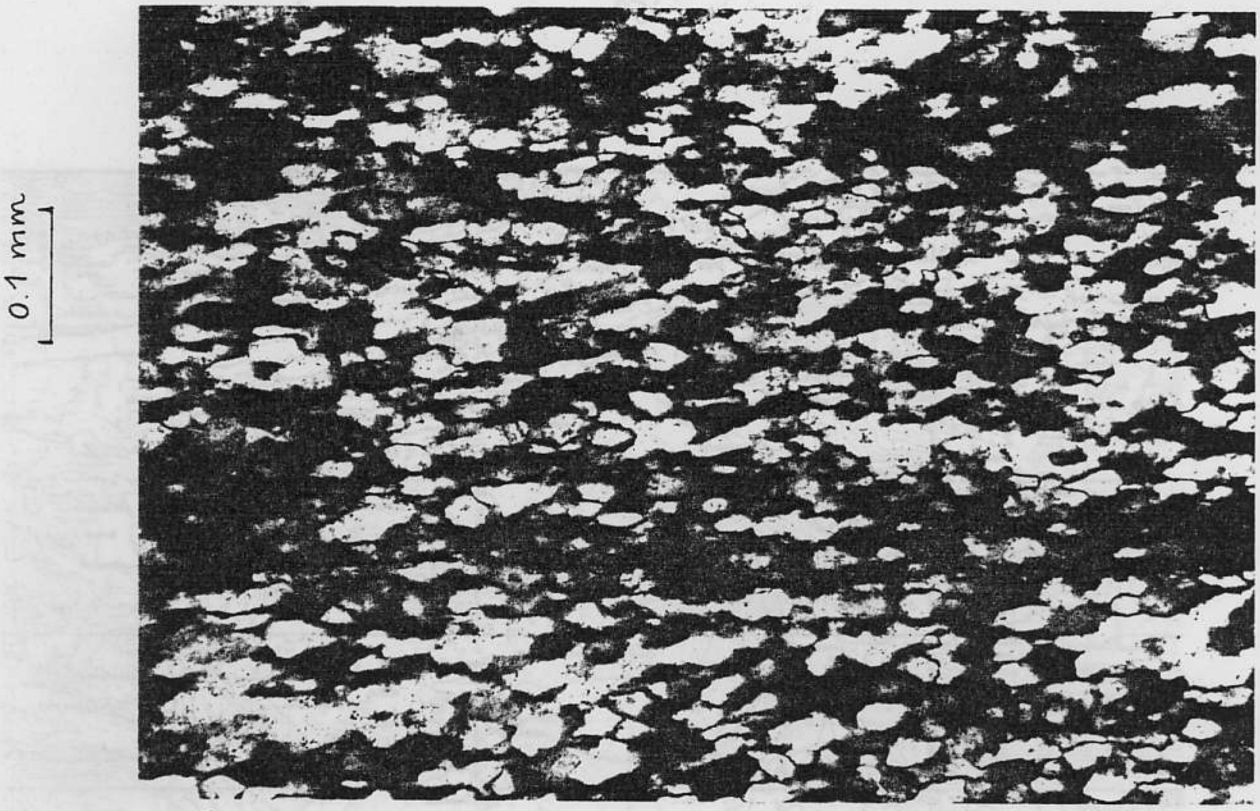


Fig. 47

Quartz microstructure of specimen 8198 (see fig. 53 for quartz preferred orientation) found within the Scaredi mylonites in Val Loana, stop 2. The elongation direction of the recrystallized grains is oblique to the EW-oriented foliation. This, together with the quartz pole figures, indicates dextral shear (in reference both to this micrograph and the geographical framework.

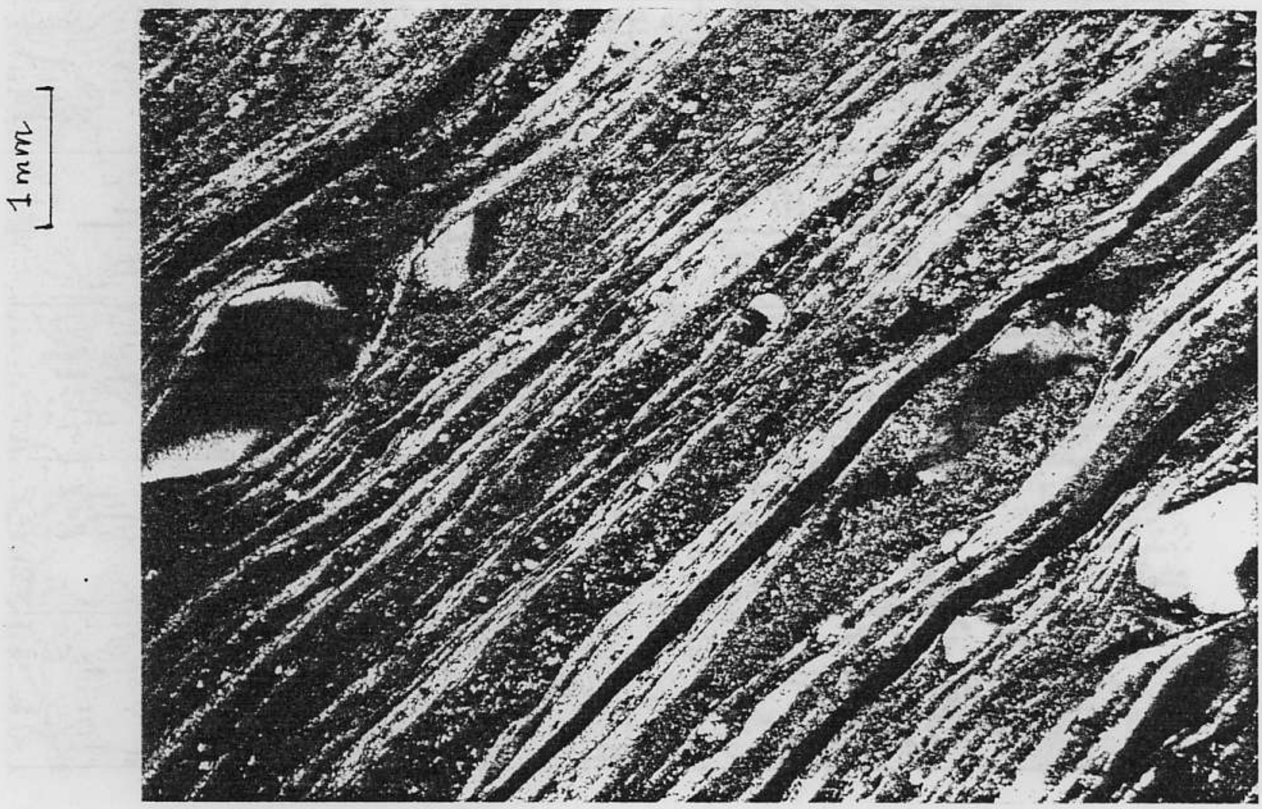


Fig. 48

Mylonitized Permian clastics from Val Loana, near stop 3. Note the quartz clasts floating in a sericitic matrix.

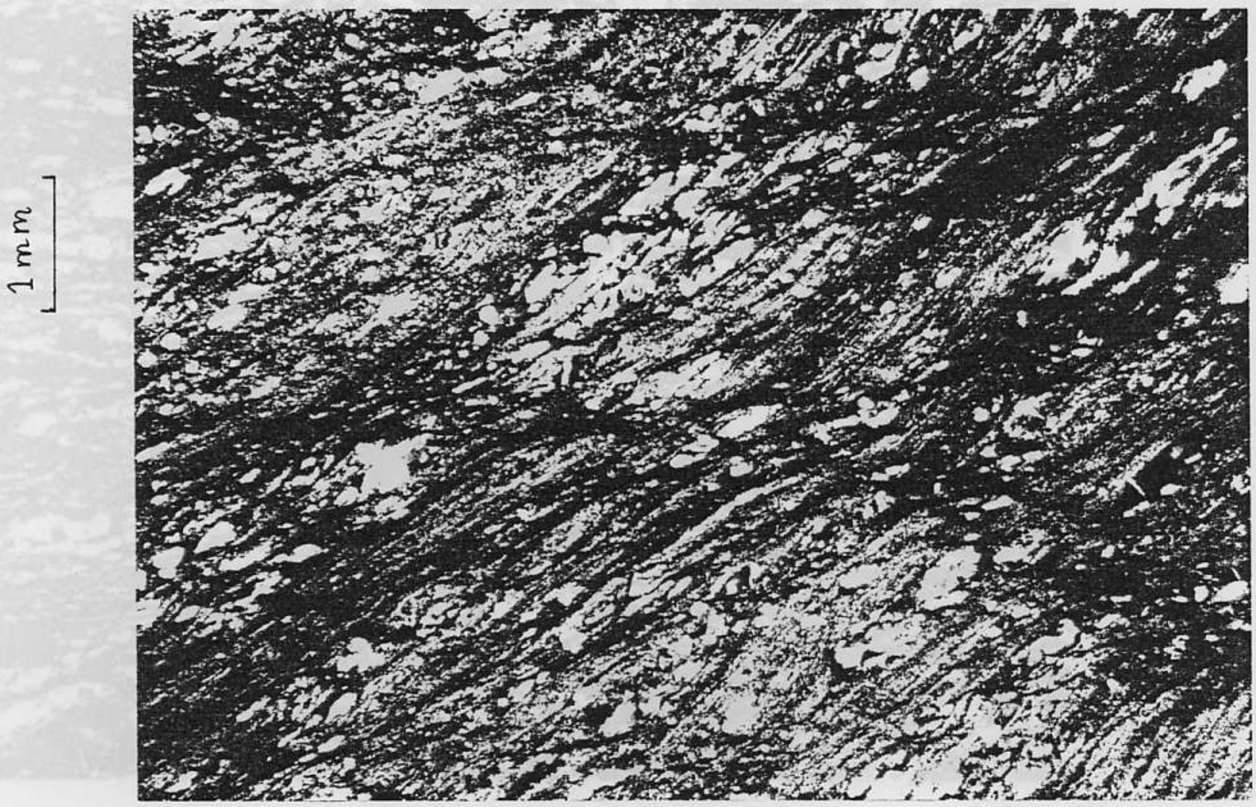


Fig. 49

Mylonite of the Scaredi formation collected between stop 3 and 4, Val Loana section. Note the dextral shear bands indicationg an overall dextral shear sense (in reference to this micrograph and the geographical framework).

Fig. 50

Unmylonitized relict of the Scaredi formation near Alp Scaredi, stop 4, Val Loana (biotite-muscovite schist).

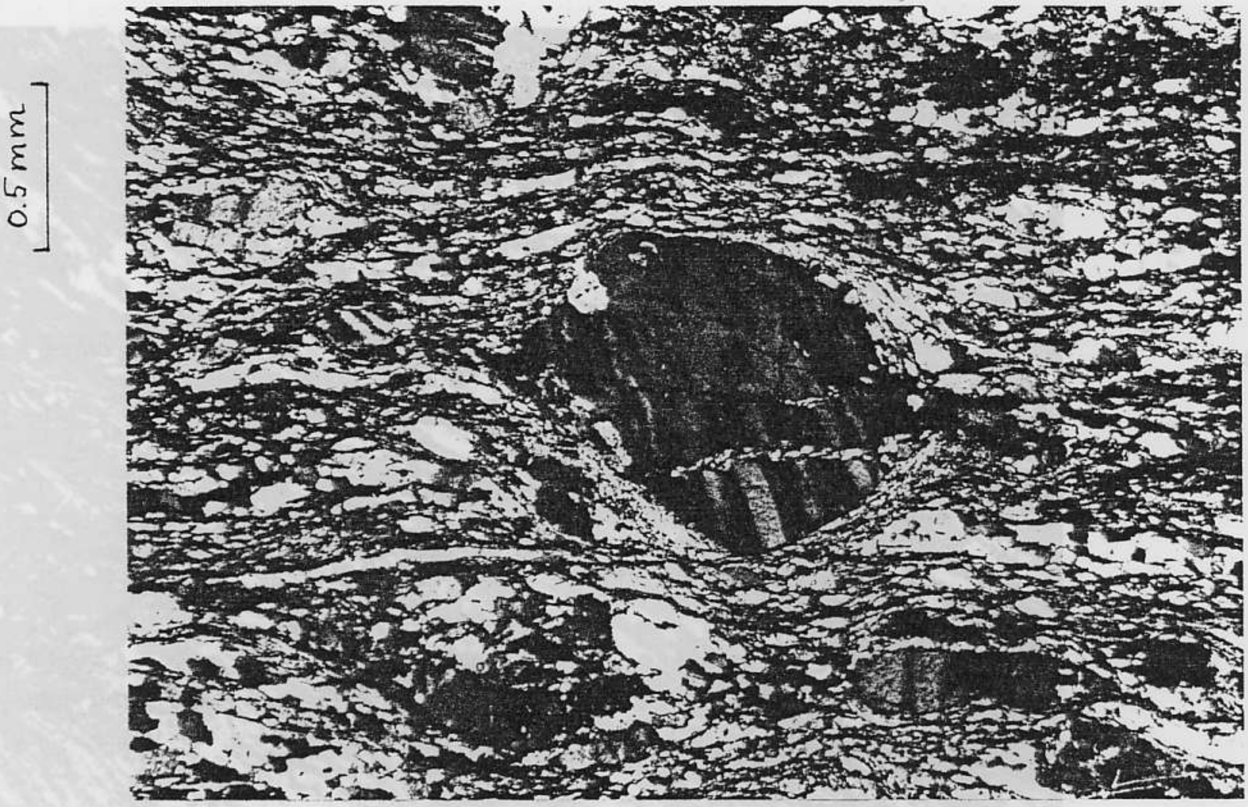


Fig. 51

Microcline porphyroclast with asymmetric tails, suggesting a sinistral sense of shear (thrusting of the Sesia zone onto the Ivrea zone in the geographical framework) from the granitic mylonites at stop 6, Val Loana.

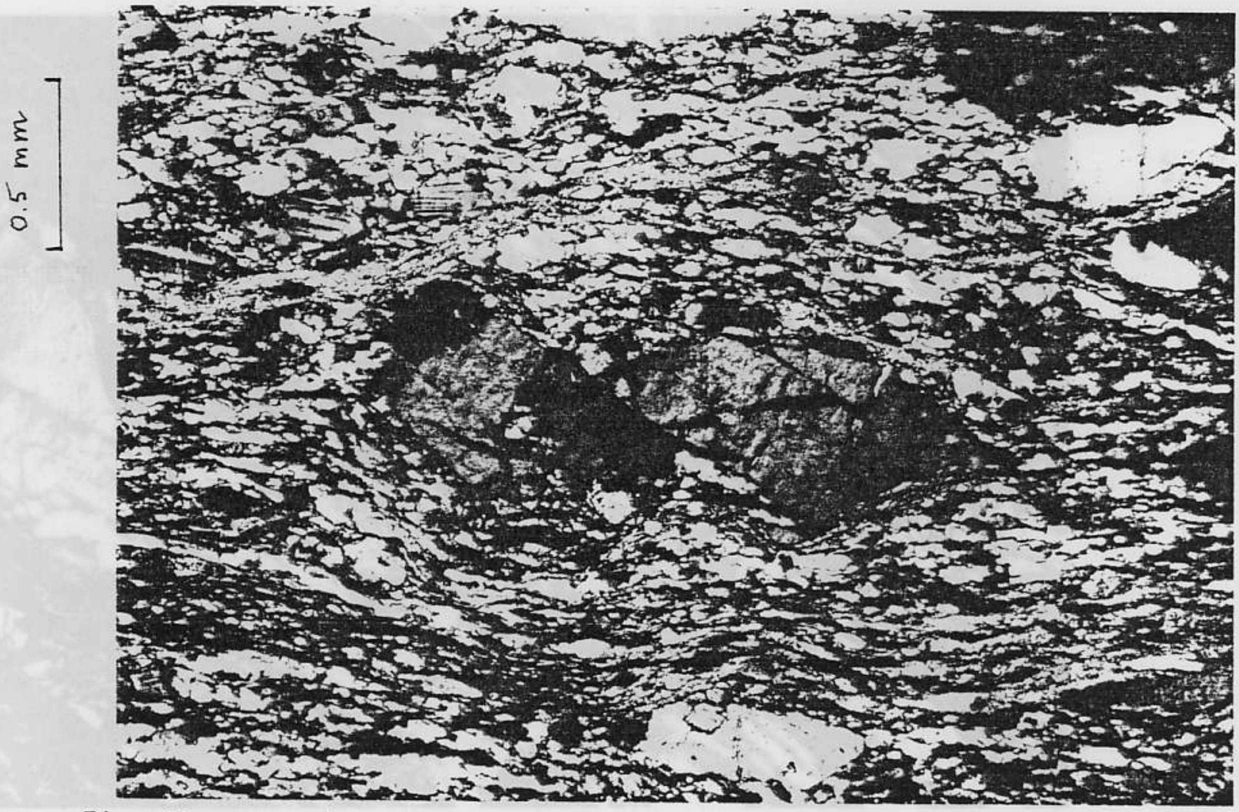


Fig. 52

Fractured microcline porphyroclast within the granitic mylonites, derived from porphyritic dykes of the southern Sesia zone, stop 6, Val Loana. Note the dextral fracture plane within the clast, opposite in shear sense to the overall sense of shear within this mylonite.

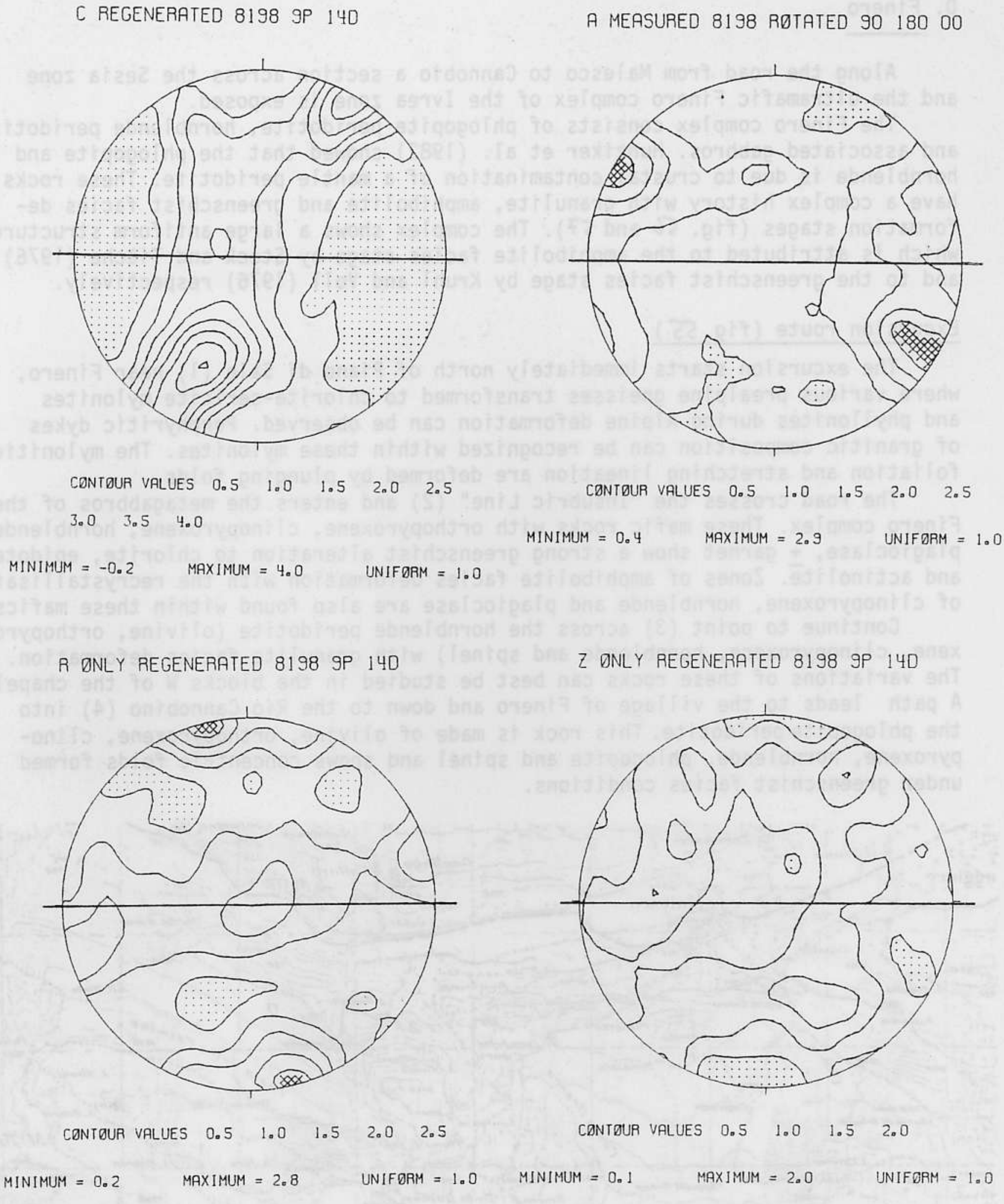


FIG. 53

Quartz X-ray pole figure data for quartz in quartz-mylonite-layer of the Scaredi formation, stop 2, Val Loana. Foliation horizontal, lineation EW.

C-axis crossed girdle with tendency towards an oblique single girdle. Strong a-axis maximum. Dextral shear is inferred. Glide on the basal planes and the negative rhombs in the ⟨a⟩-direction is suggested. For microstructure see fig. 47.

D. Finero

Along the road from Malesco to Cannobio a section across the Sesia zone and the ultramafic Finero complex of the Ivrea zone is exposed.

The Finero complex consists of phlogopite peridotite, hornblende peridotite and associated gabbros. Hunziker et al. (1982) showed that the phlogopite and hornblende is due to crustal contamination of a mantle peridotite. These rocks have a complex history with granulite, amphibolite and greenschist facies deformation stages (fig. 56 and 57). The complex shows a large antiform structure which is attributed to the amphibolite facies stage by Steck and Tièche (1976) and to the greenschist facies stage by Kruhl and Voll (1976) respectively.

Excursion route (fig. 55)

The excursion starts immediately north of Piano di Sale (1) near Finero, where various prealpine gneisses transformed to chlorite-sericite mylonites and phyllonites during Alpine deformation can be observed. Porphyritic dykes of granitic composition can be recognized within these mylonites. The mylonitic foliation and stretching lineation are deformed by plunging folds.

The road crosses the "Insubric Line" (2) and enters the metagabbros of the Finero complex. These mafic rocks with orthopyroxene, clinopyroxene, hornblende, plagioclase, ± garnet show a strong greenschist alteration to chlorite, epidote and actinolite. Zones of amphibolite facies deformation with the recrystallisation of clinopyroxene, hornblende and plagioclase are also found within these mafics.

Continue to point (3) across the hornblende peridotite (olivine, orthopyroxene, clinopyroxene, hornblende and spinel) with granulite facies deformation. The variations of these rocks can best be studied in the blocks W of the chapel. A path leads to the village of Finero and down to the Rio Cannobino (4) into the phlogopite peridotite. This rock is made of olivine, orthopyroxene, clinopyroxene, hornblende, phlogopite and spinel and shows concentric folds formed under greenschist facies conditions.

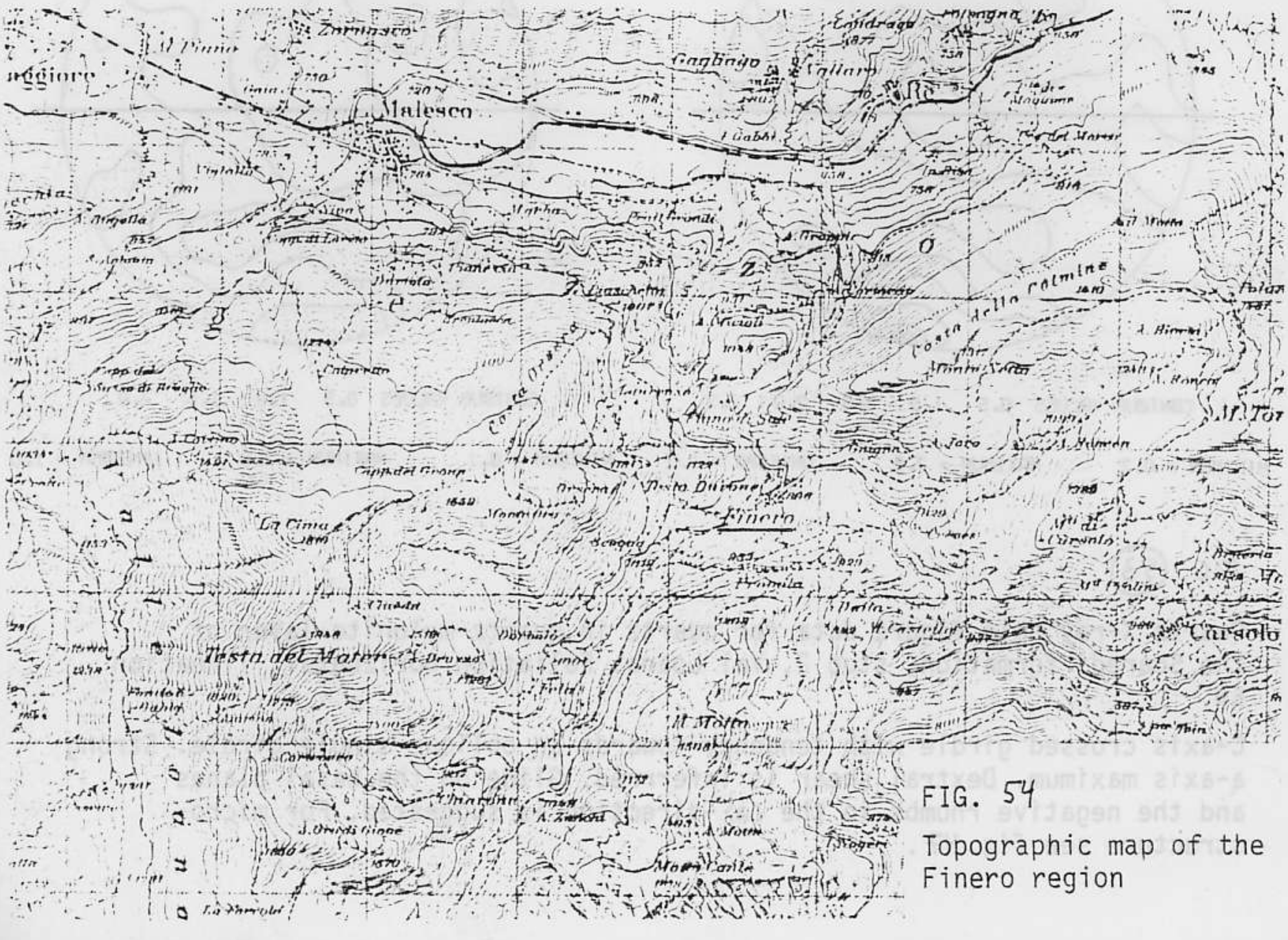


FIG. 54
Topographic map of the Finero region

Kruhl 1978, Finero-Peridotitkomplex und Gneiszone W'Finero

Geologie und Gefüge

from Kruhl, 1979

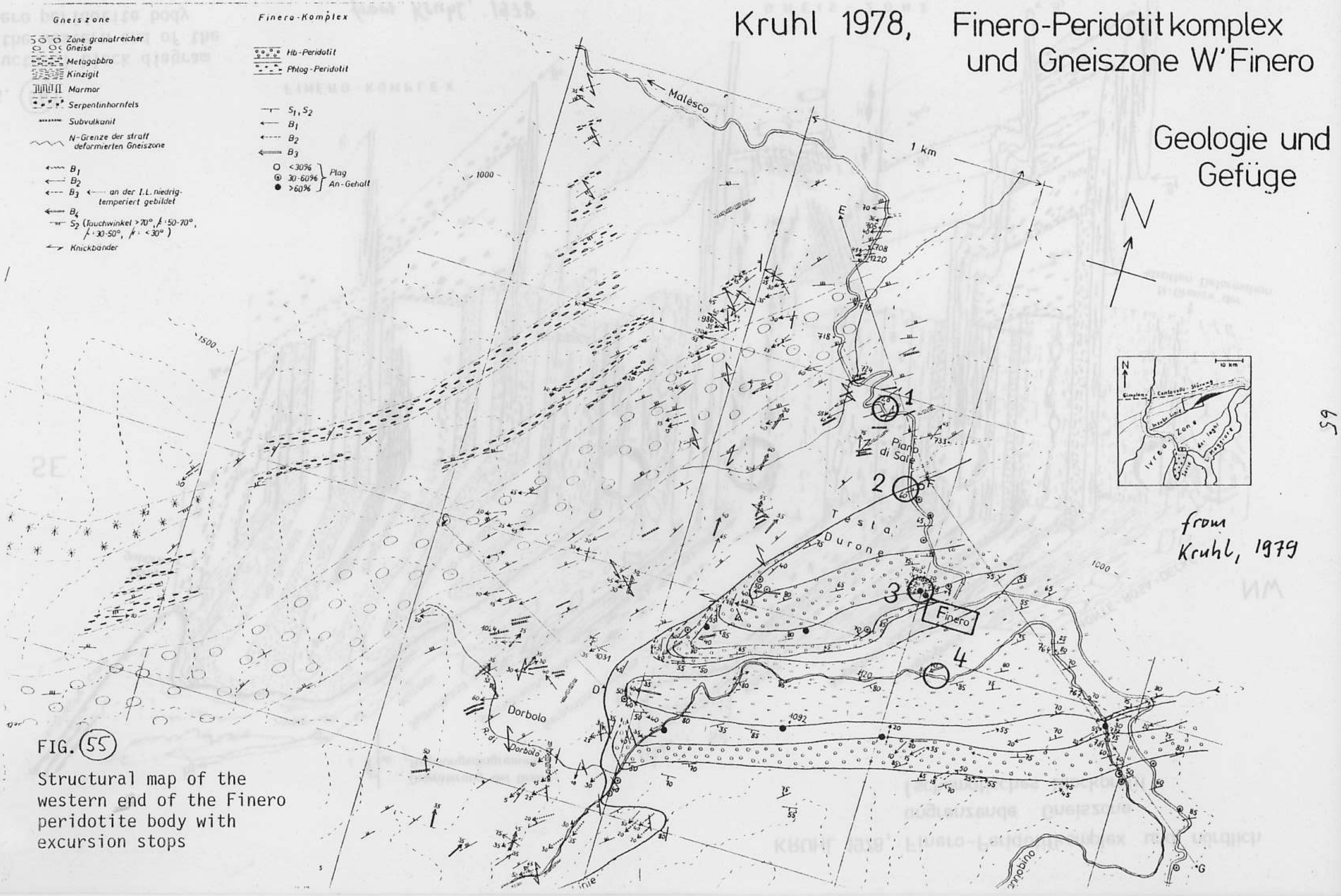


FIG. (55)

Structural map of the western end of the Finero peridotite body with excursion stops

KRUHL 1978, Finero-Peridotitkomplex und nördlich angrenzende Gneiszone (schematisches Blockprofil)

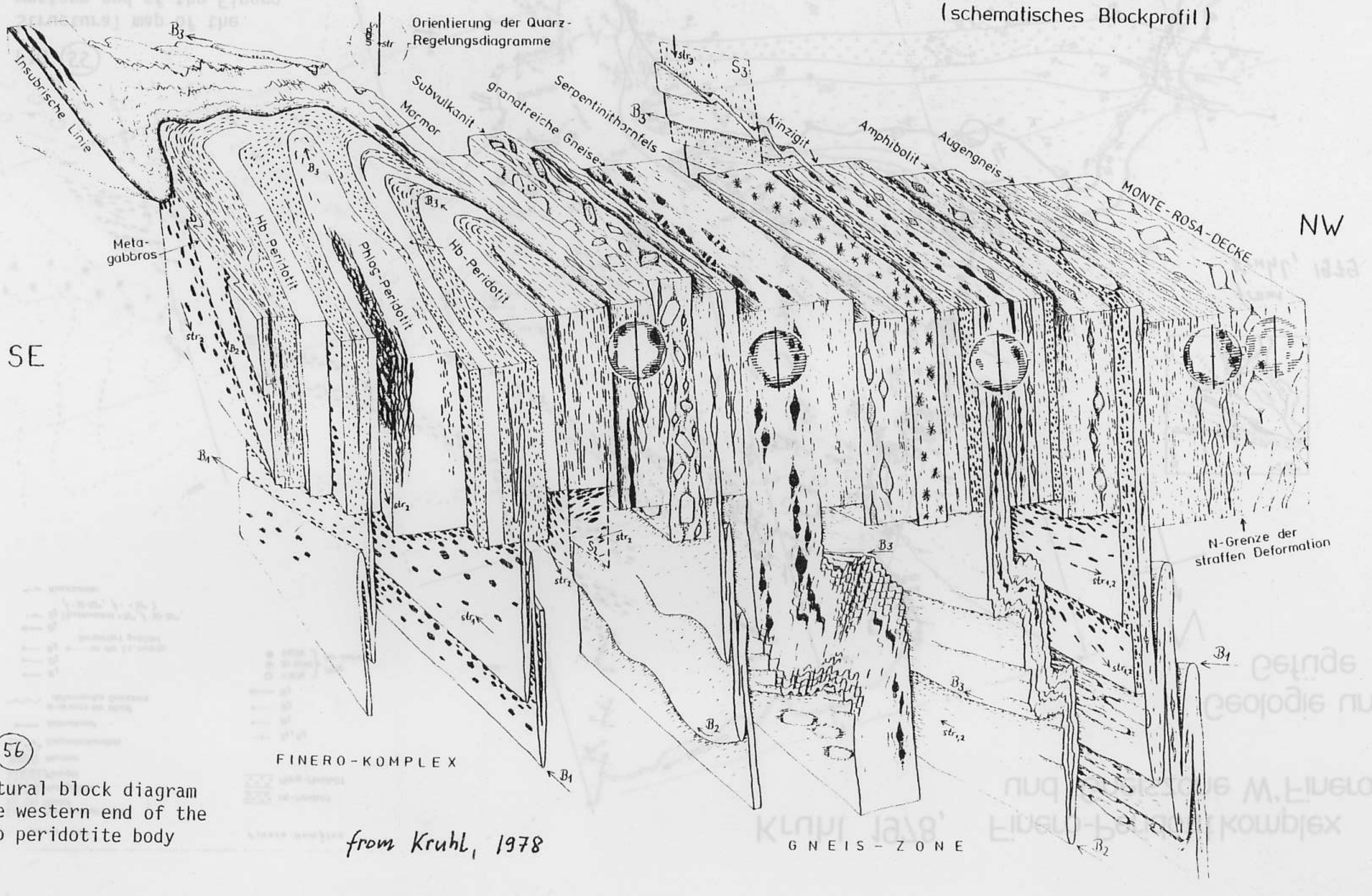


FIG. 56
Structural block diagram of the western end of the Finero peridotite body

from Kruhl, 1978

Fig. 2

from Steck and Tièche, 1976

FIG. 57

Structural history of the Finero peridotite body

E. The Arcegno section (with contribution by B. Wintsch)

The region of Arcegno, west of Locarno, offers a cross-section through the northern Ivrea zone, the Insubric mylonites, the Sesia zone and the Monte Rosa granite gneisses over a very short distance. All these structural units are telescoped into a steeply north-dipping root zone by post-nappe N-S compression. They asymptotically approach the Insubric line in an eastward direction. The Insubric line steepens and at the same time bends into an E-W orientation and runs through the Magadino plain east of Locarno. The area marks the eastern end of the Ivrea zone to the south of the Insubric line, as well as the eastern end of both the Sesia and Monte Rosa units north of the line. The segments of the Insubric line east of Locarno, referred to as the Tonale line, is characterized by a late brittle fault plane, which is well expressed morphologically. This late, brittle deformation along the Tonale line is accommodated by movements along the Centovalli line, located immediately north of the Arcegno region and joining the Insubric line somewhere under the cover of the Magadino plain east of Locarno.

1) General description (compare profile, fig.58)

The northern margin of the Ivrea meta-diorites and meta-gabbros is extremely sharp; this is in contrast to the Val d'Ossola and Val Loana sections. Banded meta-diorites and -gabbros (1), contain thin bands of high-grade metapelites (2) and preserved their pre-alpine fabric almost perfectly up to their northern contact with the predominantly quartzo-feldspathic Insubric mylonites. The only evidence for alpine deformation is found in conjugate fault planes covered by a film of epidote and chlorite, often in the form of slickensides. Pseudotachylites (3) are found along the northern margin of units preserving the pre-alpine fabric. We refer to this northern margin as the "fabric boundary". The pseudotachylites only occur within meta-diorites and -gabbros, but not within the quartzo-feldspathic mylonites north of the fabric boundary.

In some, but not all localities, mylonitized amphibole-rich Ivrea rocks are found north of the fabric boundary. These mylonites acquire an alpine penetrative fabric, and under the microscope it becomes obvious that the breakdown of the prealpine mineral composition (notably hornblende changing to actinolite) is a necessary prerequisite for the formation of these mylonites.

Two distinct types of quartzo-feldspathic mylonites can be mapped further north: extremely finegrained sericitic mylonites and ultramylonites (4), followed by "granitic" mylonites (5). The granitic mylonites are rich in microcline and white mica porphyroclasts, and resemble many of the mylonites found within the southern Sesia zone in the Val d'Ossola and Val Loana profiles. They contain small lenses of cherty limestone mylonites. The source rock of the fine-grained sericitic mylonites is probably found in the high grade meta-pelites of the Ivrea zone. Both mylonite types are locally strongly crenulated.

The bulk of the Canavese sediments (7) is found north of a lithologically heterogeneous suite of mylonites (6), containing amphibolite mylonites and quartzo-feldspathic material. This Canavese s.l. is predominantly cherty limestone; no Permian clastics or Triassic dolomites were found.

The finegrained biotite gneisses of the Sesia zone (9) are strongly mylonitic and chloritized at their southern margin, and grade into phyllonites (8).

Porphyritic dykes with microcline porphyroclasts (10), granitic (11) and dioritic (12) bodies, are found further north within the Sesia biotite gneisses. A zone (13) of staurolite-garnet schists, associated with amphibolites and ultramafic relicts, is likely to represent the southern envelope of the Monte Rosa granite gneisses (14).

Profile through the Arcegno region, for the numbers, see text

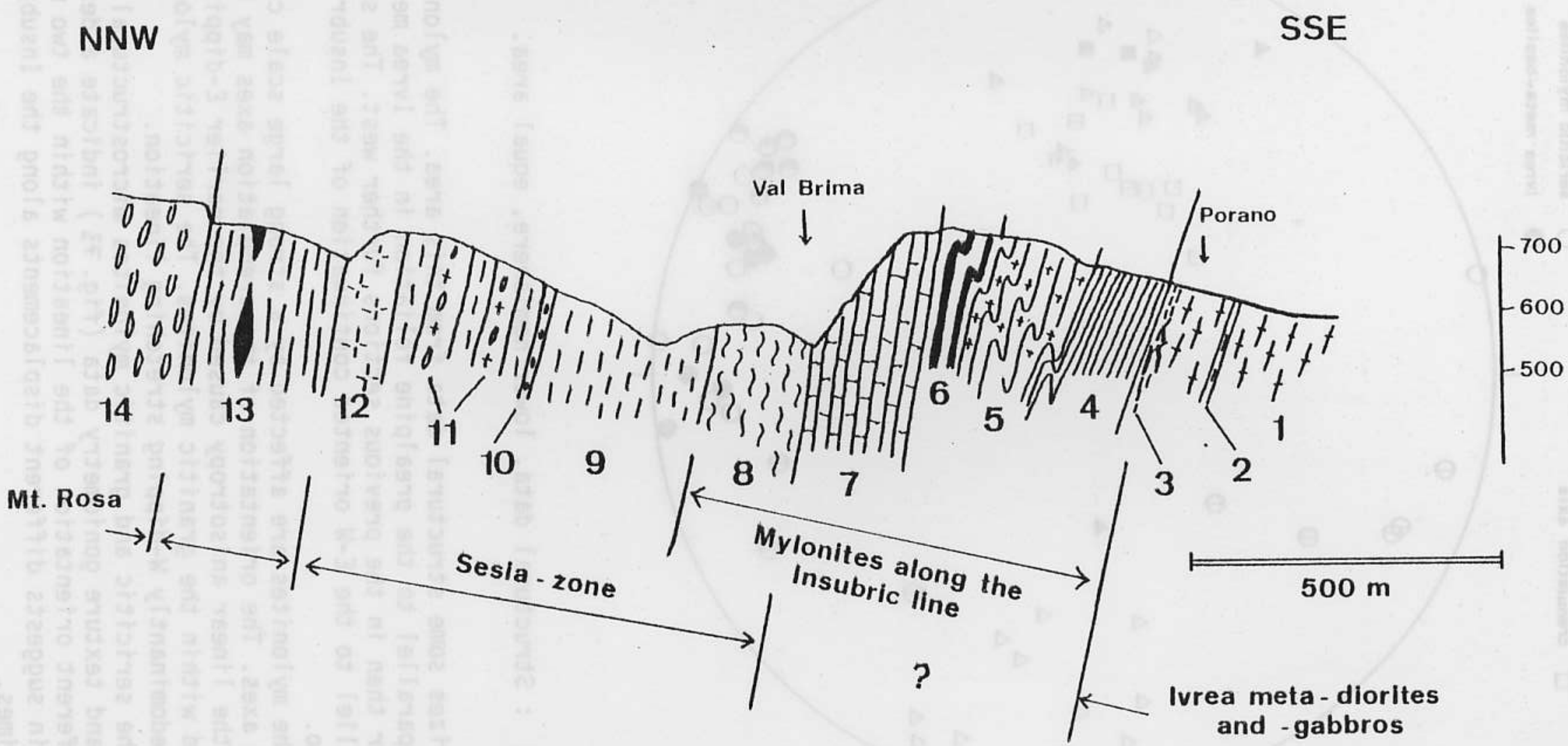


FIG (58)

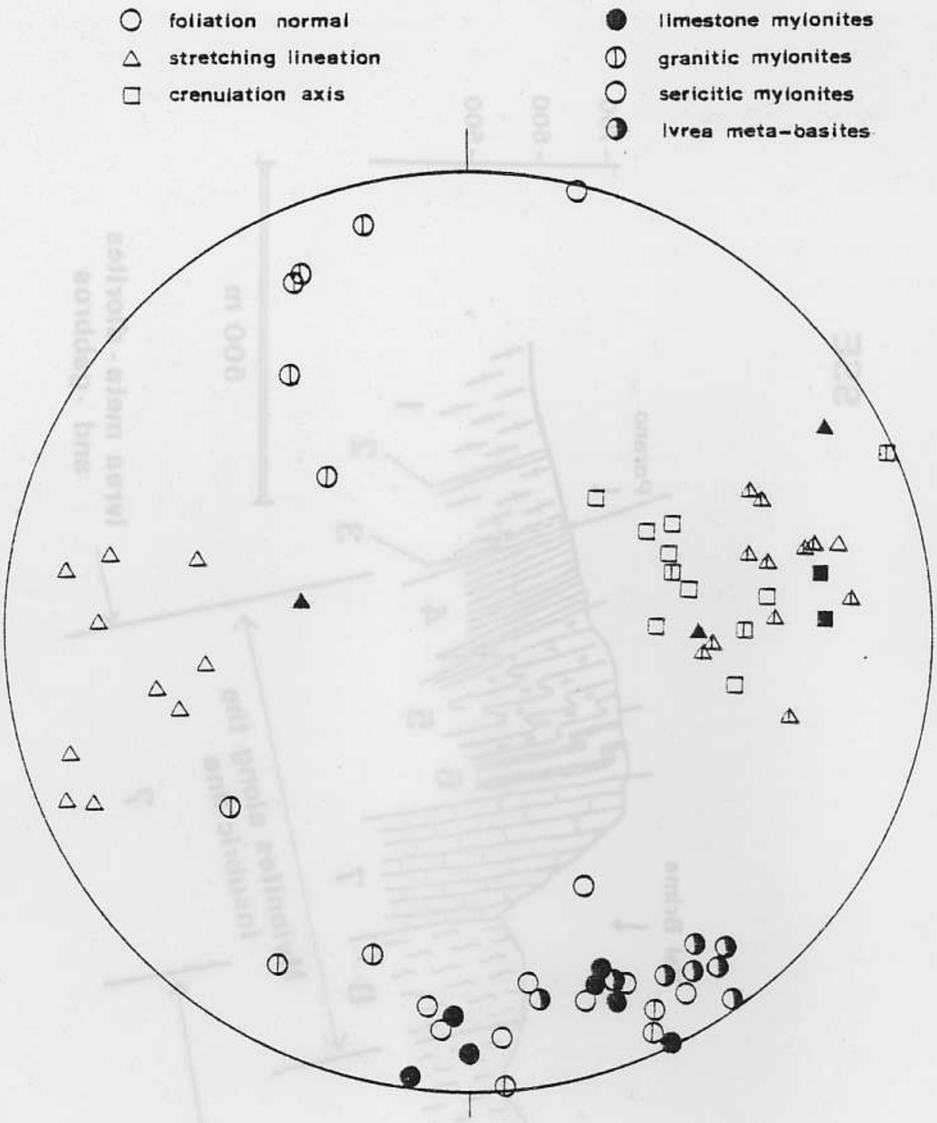


Fig. 59 : Structural data, lower hemishere, equal area.

Fig. 59 summarizes some structural data from this area. The mylonitic foliation, subparallel to the prealpine foliation in the Ivrea meta-basites, is much steeper than in the previous sections further west. The strike starts to become parallel to the E-W oriented continuation of the Insubric line east of Locarno.

Locally the mylonites are affected by a strong large scale crenulation, with E-dipping axes. The orientation of the crenulation axes may be predetermined by the linear anisotropy caused by the earlier E-dipping stretching lineation found within the granitic mylonites. The sericitic mylonites, however have a predominantly W-dipping stretching lineation.

In both the sericitic and granitic mylonites microstructural criteria (fig. 71) and texture goniometry data (fig. 73) indicate a dextral shear sense. The different orientation of the lineation within the two mylonite formations again suggests different displacements along the Insubric line at different times.

As in Val Loana, mylonitization is associated with a retrograde metamorphic overprint of both the Ivrea- and Sesia rocks.

2) Itinerary (compare sketch map, fig. 60)

Take the road from Malesco across the Swiss border into the Centovalli where plenty of evidence for late cataclastic movements on the Centovalli line can be found all along the road. Turn off the main road in Intragna and follow the road south of the River Melezza into Losone, where you turn off to Arcegno. All the stops can easily be visited by foot.

stop 1: A small road climbing into the mountains above Ronco leaves the main road between Arcegno and Ronco at coordinates 700 600 / III 950. This road winds through banded meta-diorites and -gabbros of the Ivrea zone. Slickensides on conjugate alpine faults are best exposed near a left turn at an altitude of 500 m.

stop 2: Behind a new villa at the next left turn of the road (550 m), sillimanite-garnet paragneisses of the Ivrea zone can be found in fairly dense forest. These paragneisses demonstrate that in this region as well, the northern boundary of the Ivrea zone is not identical with the northern margin of the Ivrea meta-diorites and -gabbros.

stop 3/4: At stop 3 the unmylonitized Ivrea meta-basites are in direct contact with the very finegrained sericitic mylonites. The road section between stop 3 and 4 exposes the sericitic mylonites which are isoclinally folded parallel to the stretching lineation, and subsequently crenulated. Above the left turn in the road at stop 4, the granitic mylonites can be studied.

stop 5: (Description by B. Wintsch, see fig. 62)

This is an excellent place to examine the relationship between amphibolites of the Ivrea zone and the Insubric mylonites. Unmylonitized amphibolite is exposed along an unpaved service road SW of the parking area. Here a porphyroblastic texture defined by chemically zoned hornblende crystals set in a plagioclase-rich matrix is dominant. This rock is cut by dykes of pseudotachylite and by brittle faults filled with clinozoisite.

The overlying mylonites are primarily hornblende-rich, and are often associated with less deformed tectonic lenses of porphyroblastic amphibolite. These mylonites are interlayered with blastomylonites. The plagioclase porphyroblasts are complexly zoned, suggesting several growth cycles. Both mylonitic rock types contain veins of quartz and plagioclase, which are sometimes mylonitized along their edges (see quartz texture, fig. 73).

To the N, these mylonites, grade rapidly into the muscovite-rich mylonites.

The lower contact with the amphibolites is a brittle fault, which marks the southern limit of the alpine fabric. This fault cuts both the mylonitic foliation and the prealpine fabric of the Ivrea amphibolites and must be later than the development of the mylonite.

stop 6: Here the road section offers a good opportunity to study the various lithologies and prealpine structures within the Ivrea meta-basites.

stop 7: Isolated pseudotachylite veins occur within sheared but unfoliated cataclasites of the Ivrea-basites. Some of the veins are a few centimeters wide, and exhibit chilled margins with hornblende phenocrysts in the center, which grew during devitrification (fig. 69). The northernmost 10 meters of this outcrop largely consist of pseudotachylite material. Large amphibolite "xenoliths", preserving their prealpine foliation, are surrounded by glassy material with the foliation rotated from one "xenolith" to the next.

The contact to the mylonites would follow immediately to the north of this outcrop but unfortunately does not outcrop.

stop 8: Granitic mylonites with isolated limestone mylonite lenses occur north of a small path leaving the road near stop 7 to the NE. The stretching lineation plunges east, parallel to younger crenulation fold axes. Quartzitic veins from an uncrenulated area exhibit the quartz textures shown in fig. 74, indicating a dextral shear sense.

stop 9: Retrograde chlorite-muscovite phyllonites can be studied along the road to Losone.

stop 10: The small road north of the village crosses finegrained biotite gneisses of the Sesia zone, interlayered with amphibolites. Further north along the road the contact with finegrained granite gneisses is exposed.

stop 11: High grade staurolite-garnet schists and amphibolites contain isolated boudins of ultramafics (the latter only as loose boulders at this locality).

stop 12: Monte Rosa granite gneisses with a steeply inclined stretching lineation can be examined on glacially polished surfaces perpendicular to the lineation. Several generations of quartzo-feldspathic veins are folded, sheared and boudinaged. Late discrete shear zones offset the veins and indicate a late E-W directed extension.

Sketch map of the Arcegno-region near Locarno, partly after Walter, 1950

(for legend, see next page)

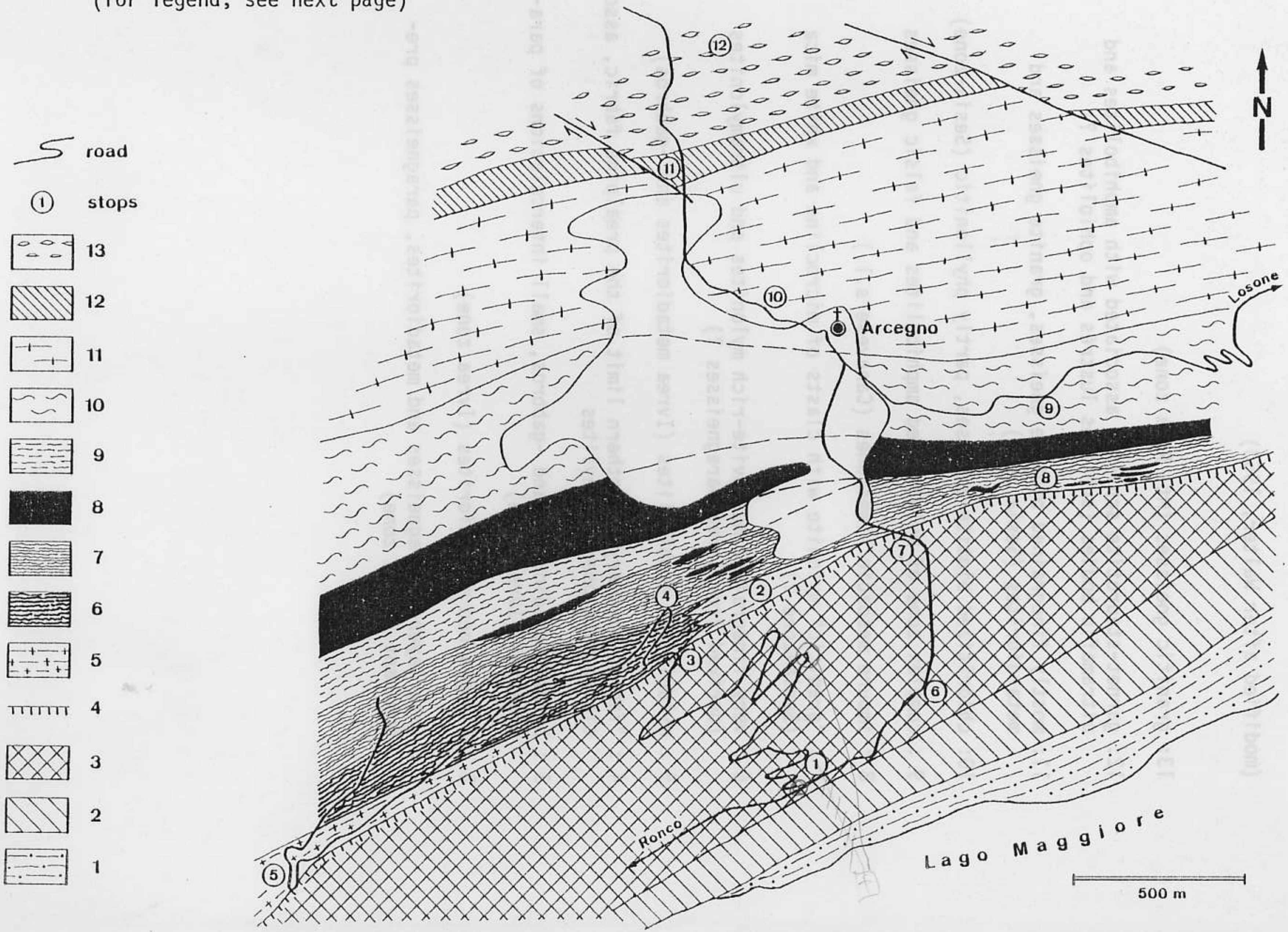


FIG. 60

LEGEND TO THE SKETCH MAP OF THE ARCEGNO-REGION NEAR LOCARNO

(modified after Walter, 1950)

13: granitic gneisses (Mt. Rosa zone)

12: garnet-staurotite schists, associated with amphibolites and ultramafic bodies (schistes lustrés and ophiolites ?)

11: mostly finegrained biotite gneisses, granite gneisses and meta-diorites (Sesia zone)

10: chloritized biotite gneisses, partly phyllonitic (Sesia-zone)

9 : complex zone of mylonitized amphibolites and felsic gneisses

8 : impure mesozoic limestones (Canavese s.l.)

7 : "granitic" mylonite with clasts of microcline and white mica (Sesia-zone ?)

6 : very finegrained muscovite-rich mylonites and ultramylonites (derived from Ivrea paragneisses ?)

5 : mylonitized amphibolites (Ivrea metadiorites and -gabbros)

4 : "fabric boundary": northern limit of the prealpine fabric, associated with pseudotachylites

3 : banded metadiorites and -gabbros, small intercalations of paragneisses (Ivrea zone)

2 : finegrained meta-diorites (Ivrea zone)

1 : Interlayered paragneisses and metadiorites, paragneisses predominant (Ivrea zone)

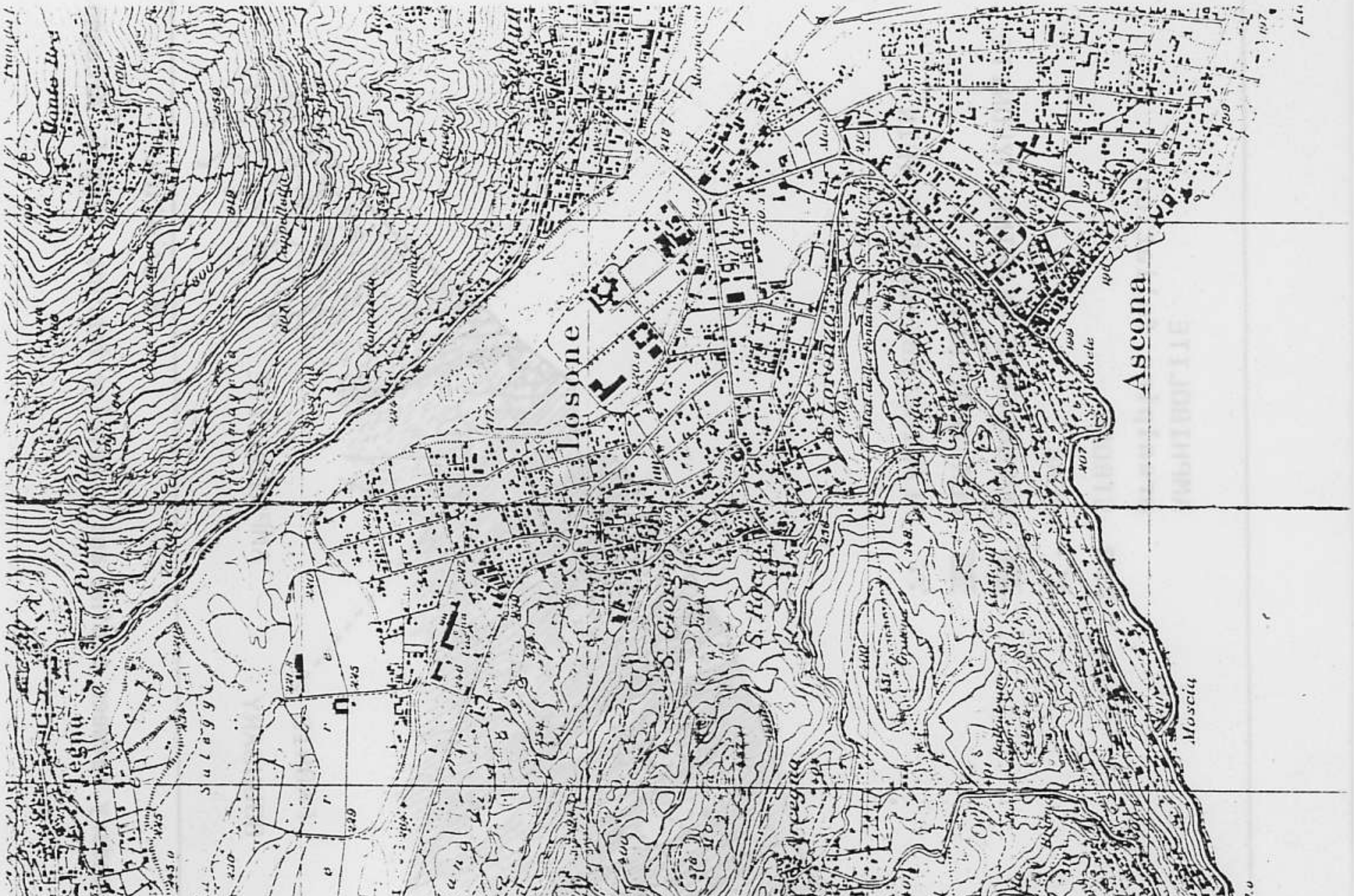


FIG. 61

Topographic map of the
Arcegno region, 1:25 000

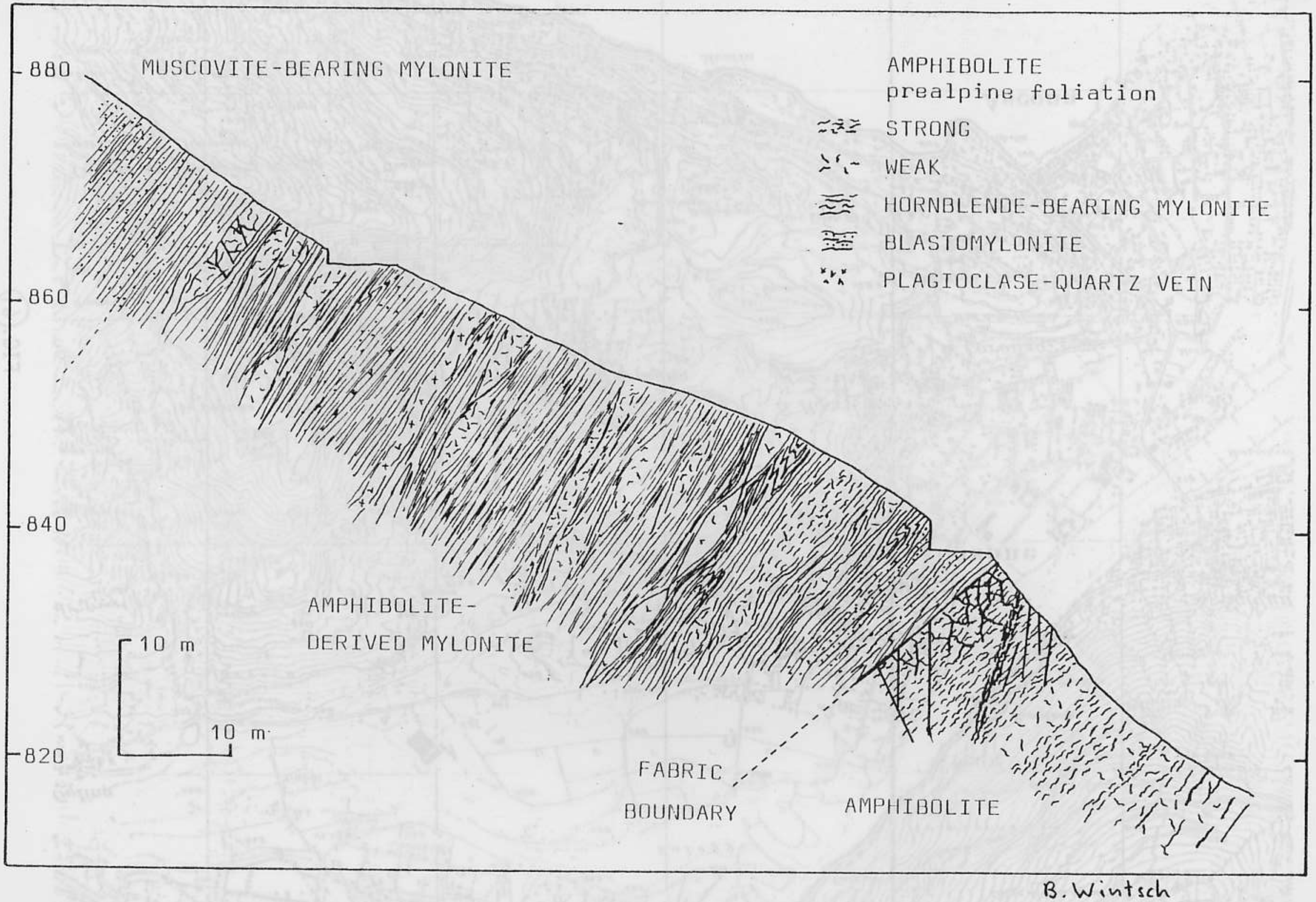


Fig. 62 : Partly schematic section across the boundary between alpine and prealpine fabrics, stop 5, Arcegno.

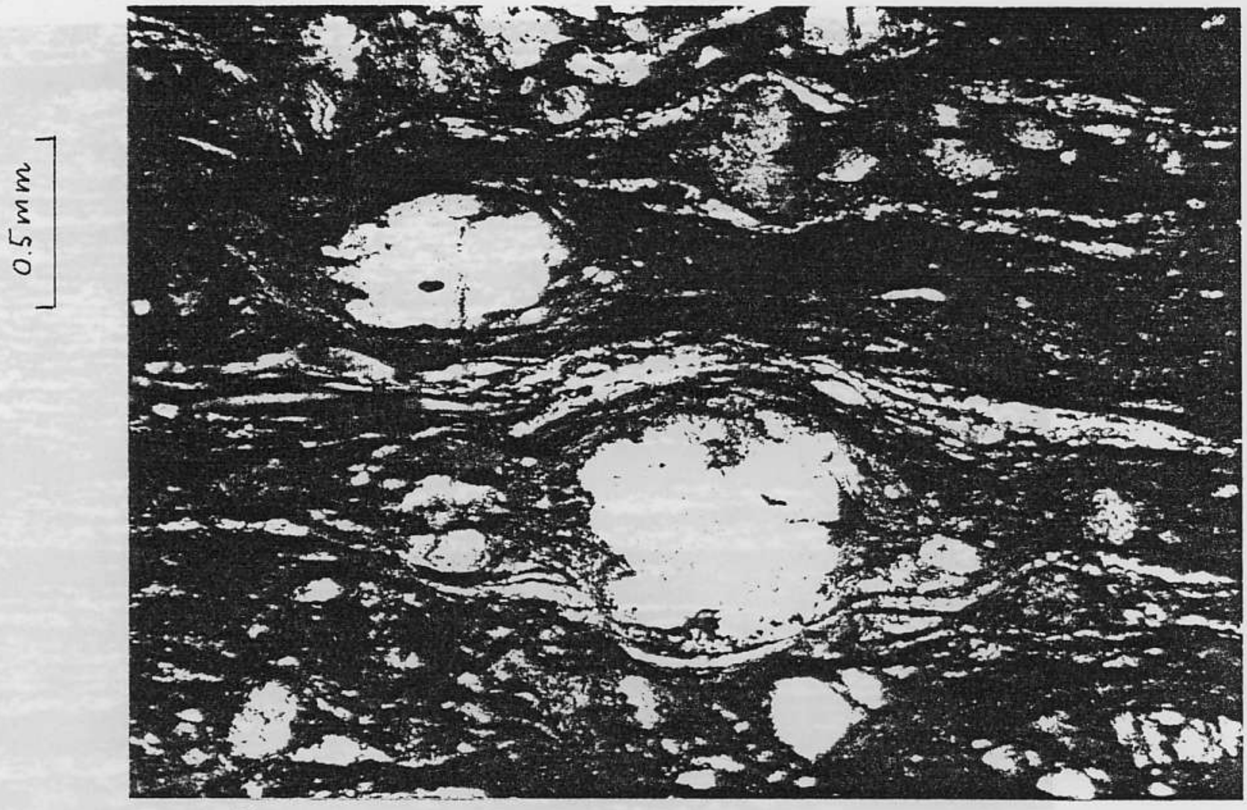


Fig. 63

Felsic blastomylonite found at stop 5, Arcegno-region. This mylonite is found interlayered with amphibolite derived mylonites. B.Wintsch found evidence for syntectonic growth of the larger, complexly zoned plagioclase augen. Note the strong plastic deformation within the quartz layers curving around the feldspar crystals.

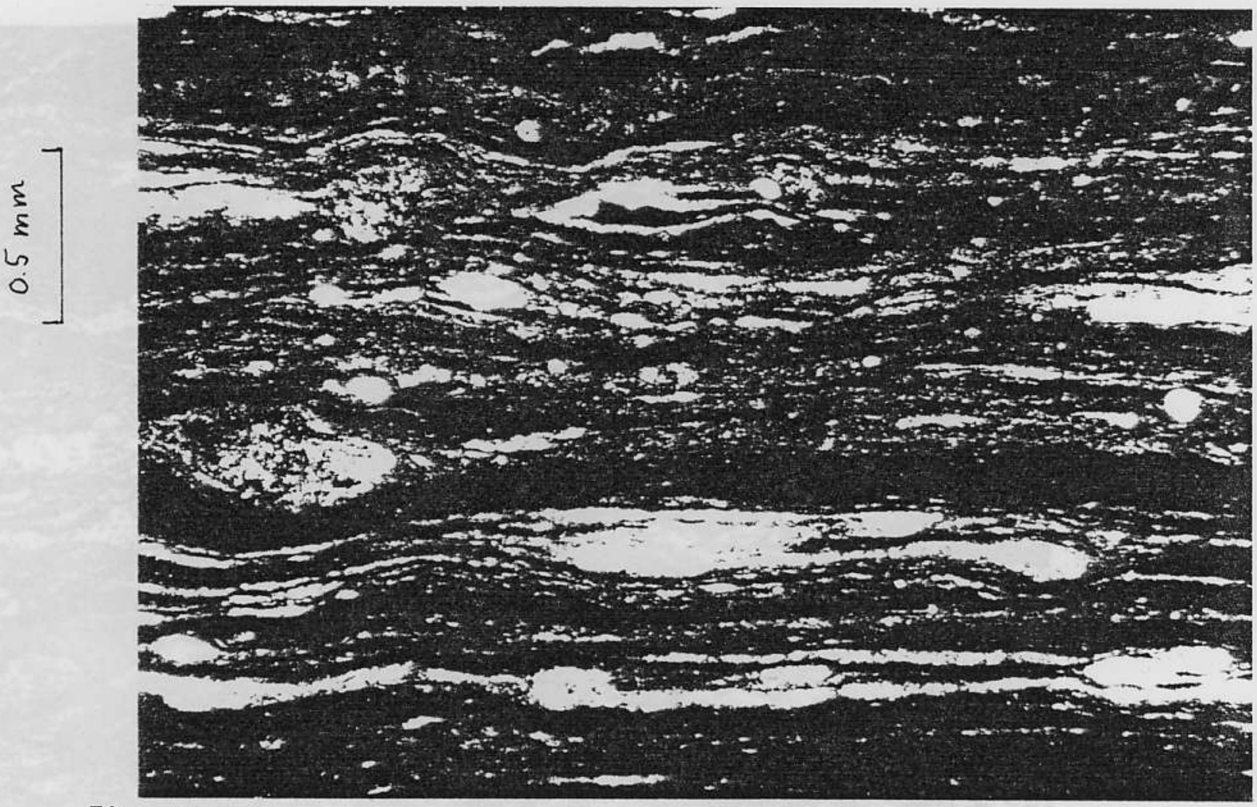


Fig. 64

Microstructure of the extremely finegrained sericitic mylonites between stop 3 and 4, Arcegno region. Thin layers of isoclinally folded quartz are dynamically recrystallized to a grain size of around 10 µm (not visible in micrograph). The finegrained, mica-rich matrix has not been analysed yet, but chloritized garnets and plagioclase are found as porphyroclasts. These mylonites were probably derived from Ivrea-metapelites.

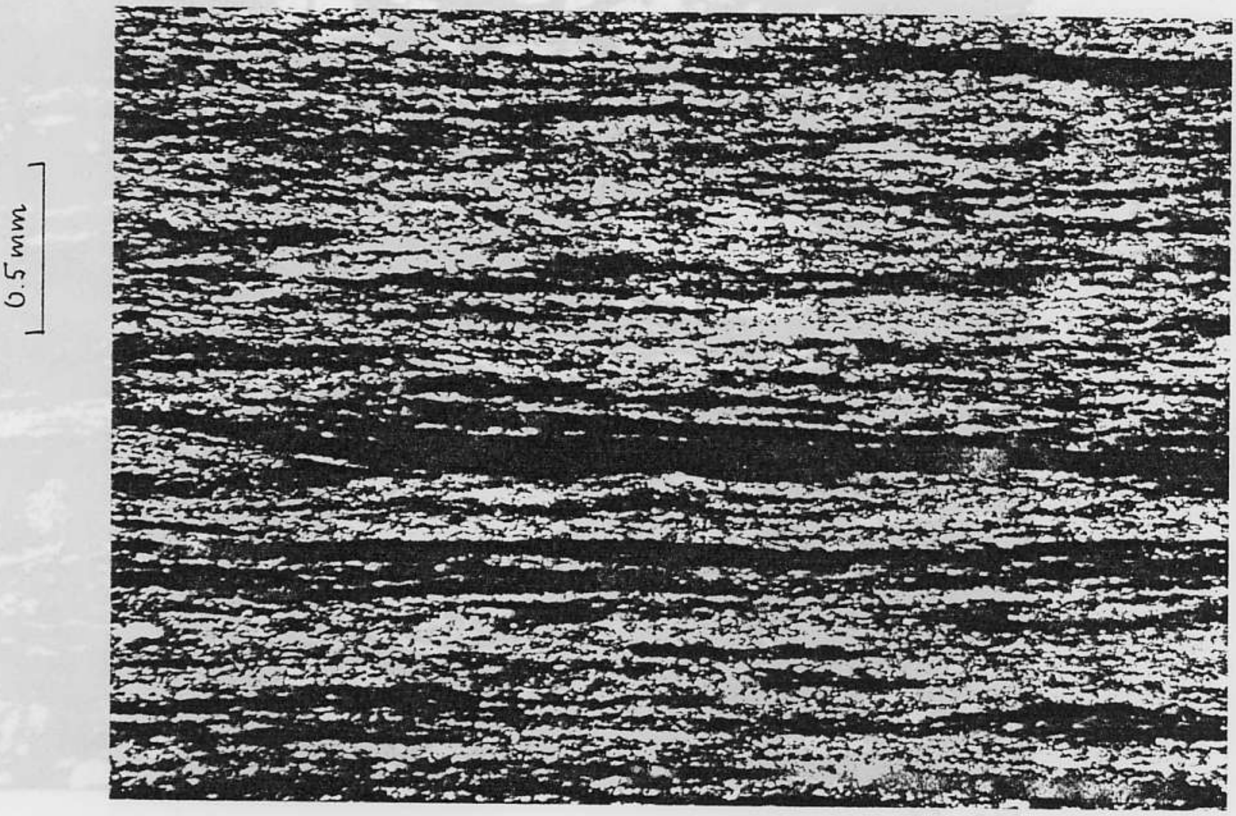


Fig. 65

Quartz microstructure from a quartzo-feldspathic vein within amphibolite mylonites, stop 5, Arcegno region (for quartz preferred orientation, see fig. 73). Partial recrystallization (grain size around 10 μm) around extremely elongated quartz crystals.

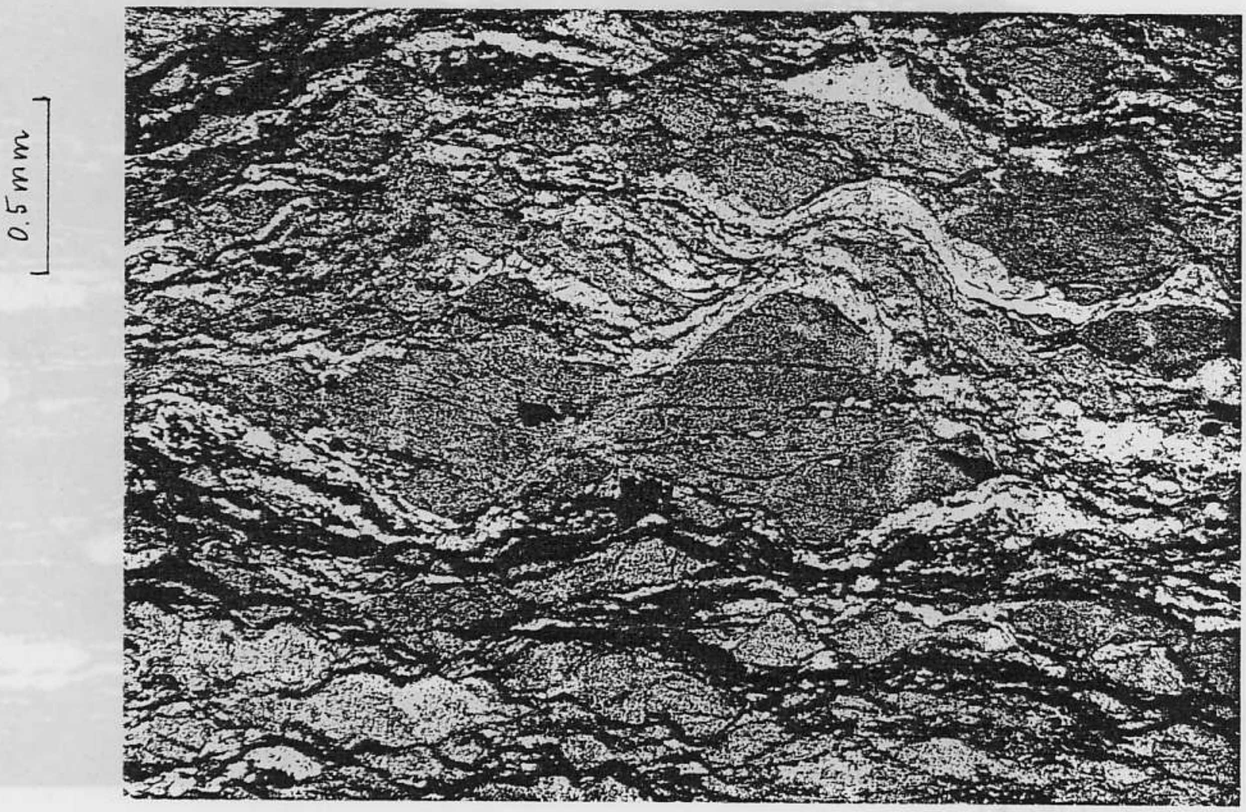


Fig. 66

Mylonitized amphibolite with fibrous growth of actinolite along intracrystalline shears, cracks and near the tails of hornblende crystals. From stop 5, Arcegno region.

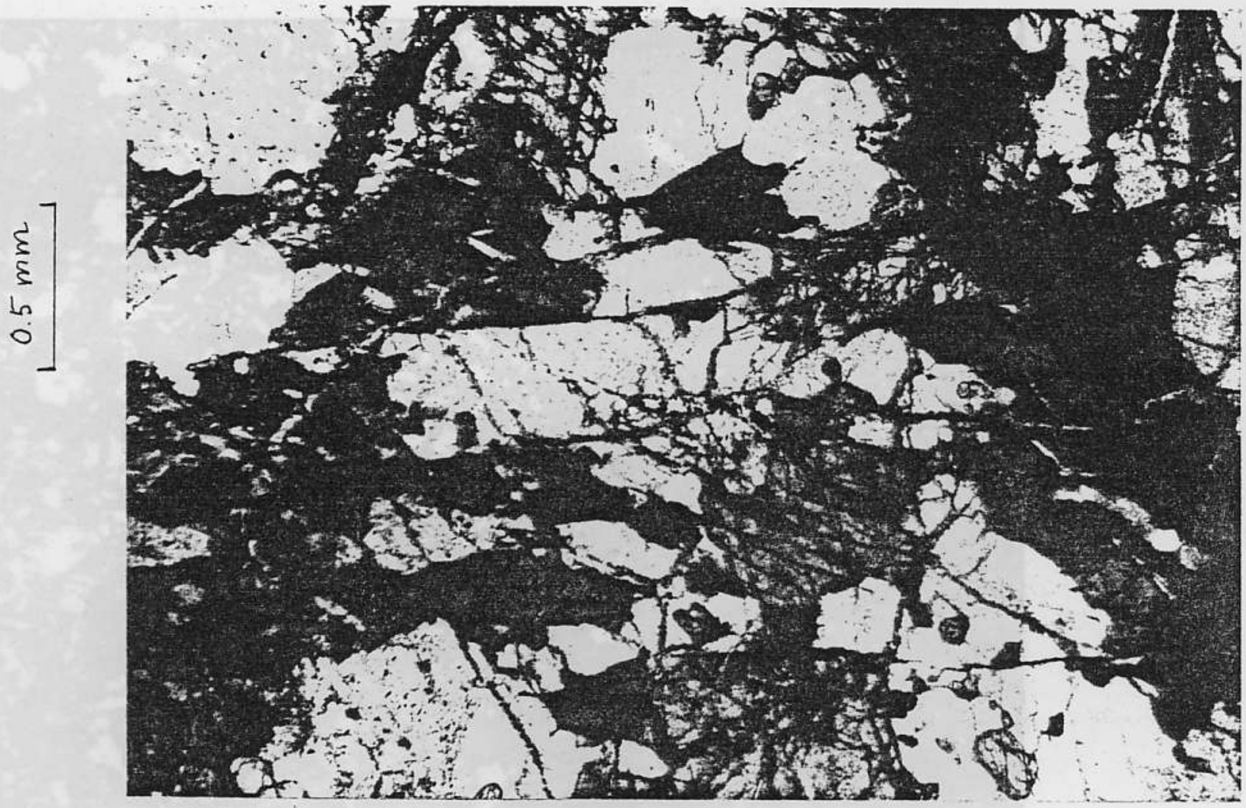


Fig. 67

Diorite cataclasite, frequently associated with pseudotachylites near the fabric boundary, south of stop 2, Arcegno region.

Fig. 68

Contact between pseudotachylite and country rock (left) and contact between the chilled margin and the central portion of a pseudotachylite dyke, containing hornblende phenocrysts in the devitrified central portion of the dyke. The larger white crystals represent mineral fragments, mechanically incorporated from the wall rock.

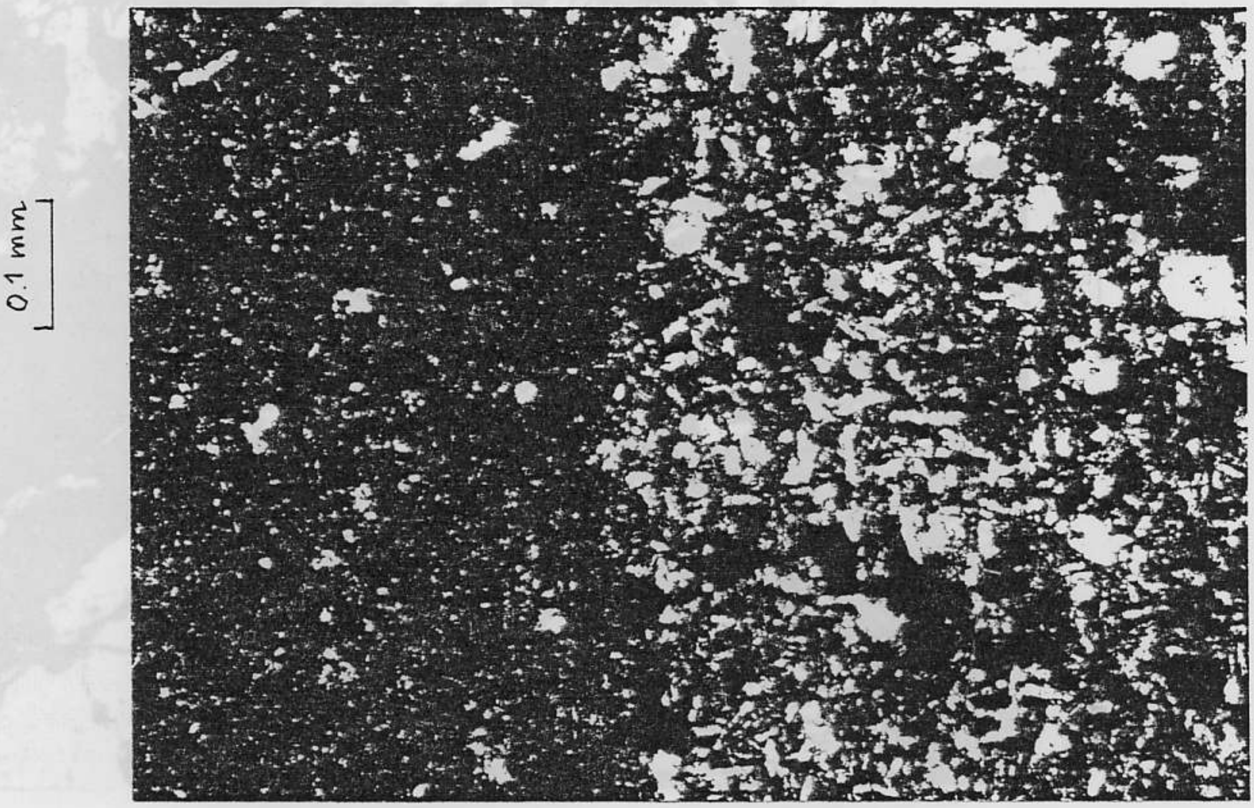


Fig. 69
Detail from the boundary between the chilled margin (left) and the center of the pseudotachylite vein (right). Note the hornblende phenocrysts, intermixed with mineral fragments.

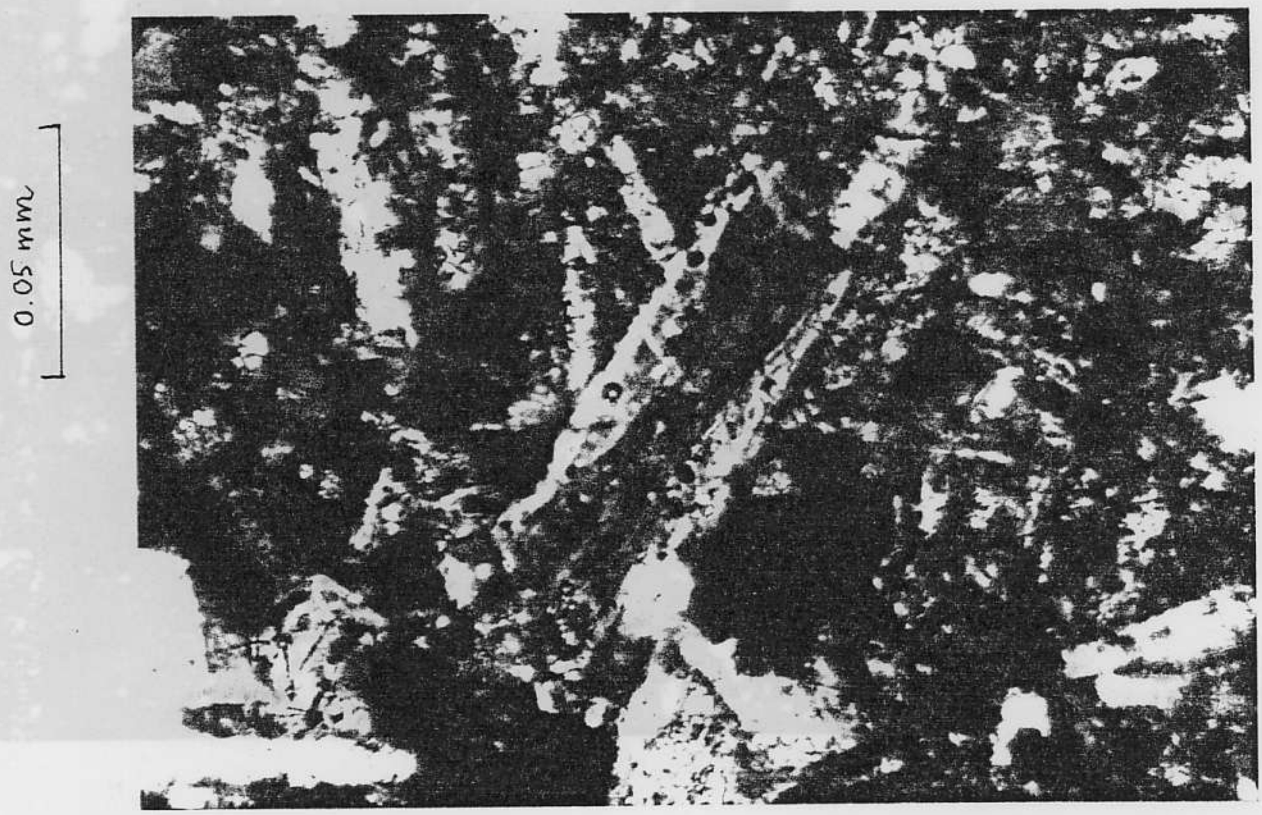


Fig. 70
Detail of a zoned hornblende phenocryst (compare fig. 69).

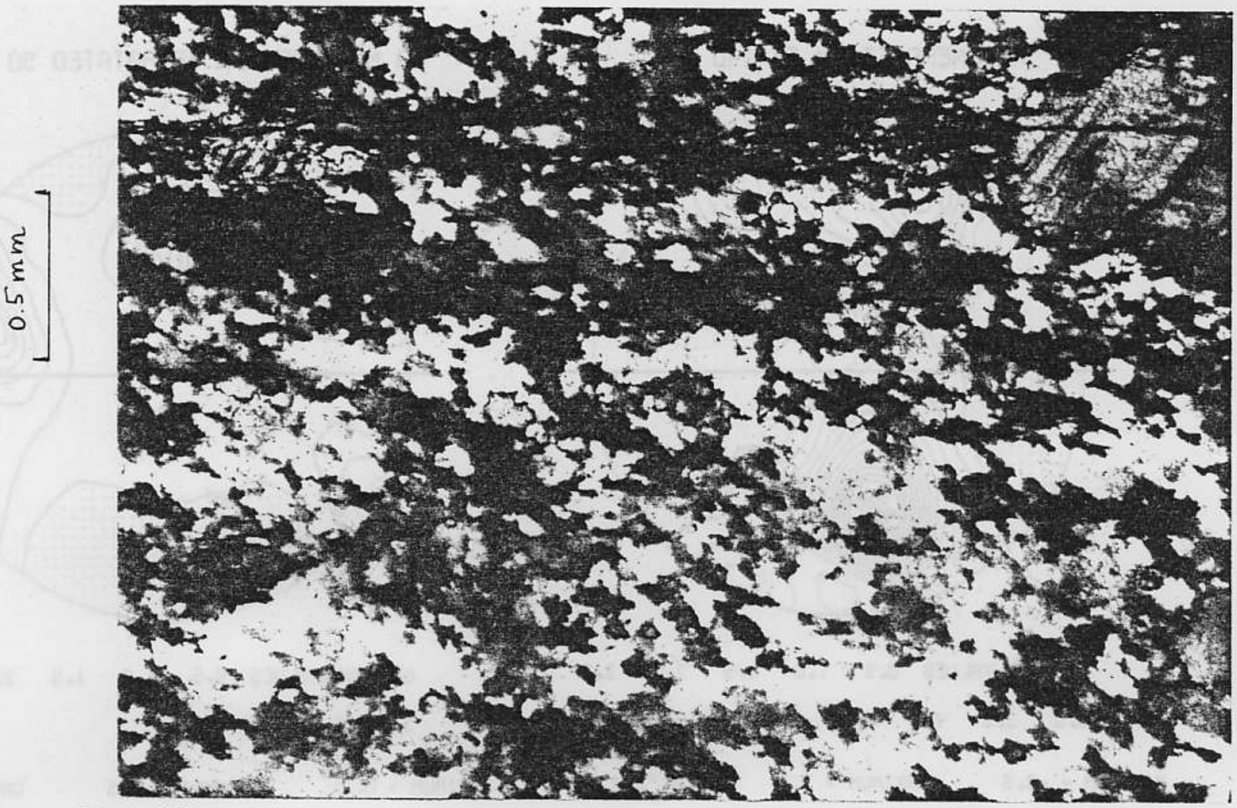


Fig. 71

Quartz microstructure of specimen 8227 (compare quartz preferred orientation in fig. 74), collected in a mylonitic quartz vein within the granitic mylonites near stop 8, Arcegno region. Note the obliquity of the long axes of quartz grains and subgrains in respect to the EW-oriented foliation, indicating a sinistral shear sense in respect to the orientation of the micrograph (dextral in geographical orientation), consistent with the quartz preferred orientation data.

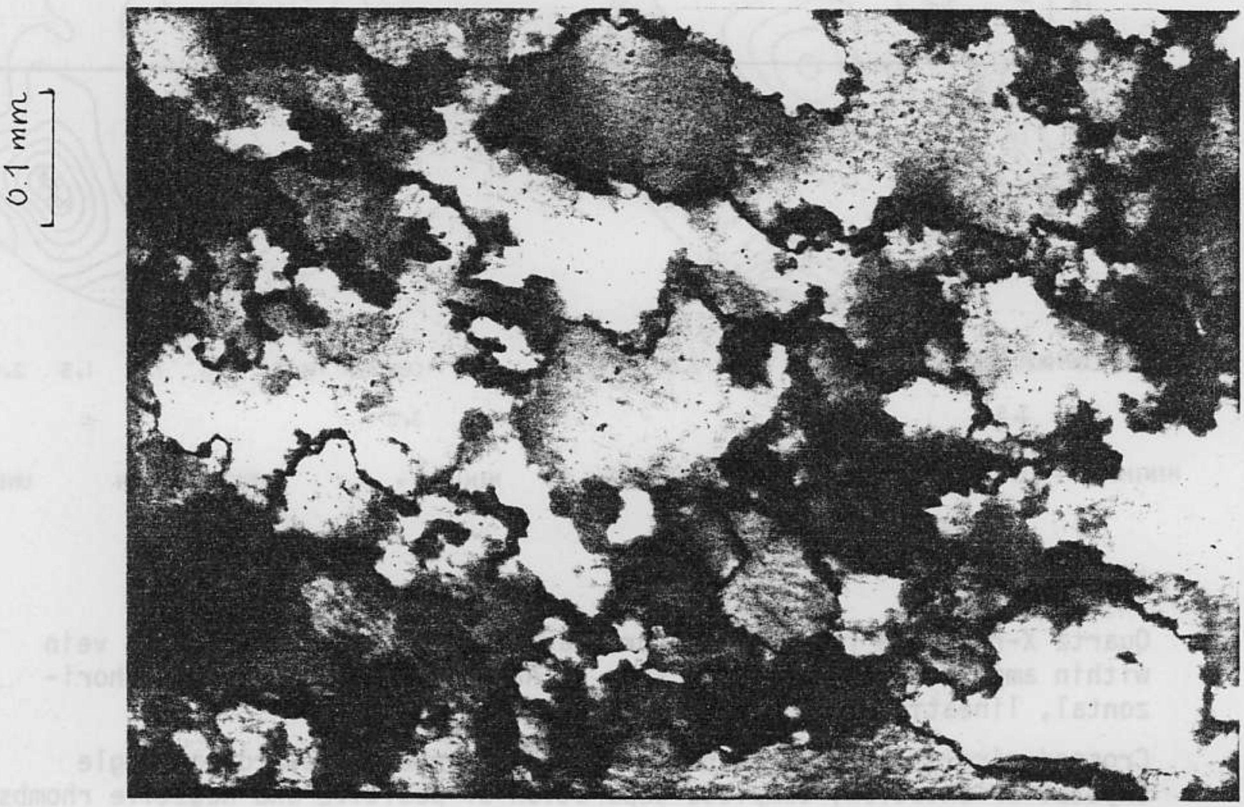


Fig. 72

Detail of fig. 71, showing sutured grain boundaries. The very finegrained subgrains and recrystallized grains in the grain boundary region suggest a high stress environment during mylonitization.

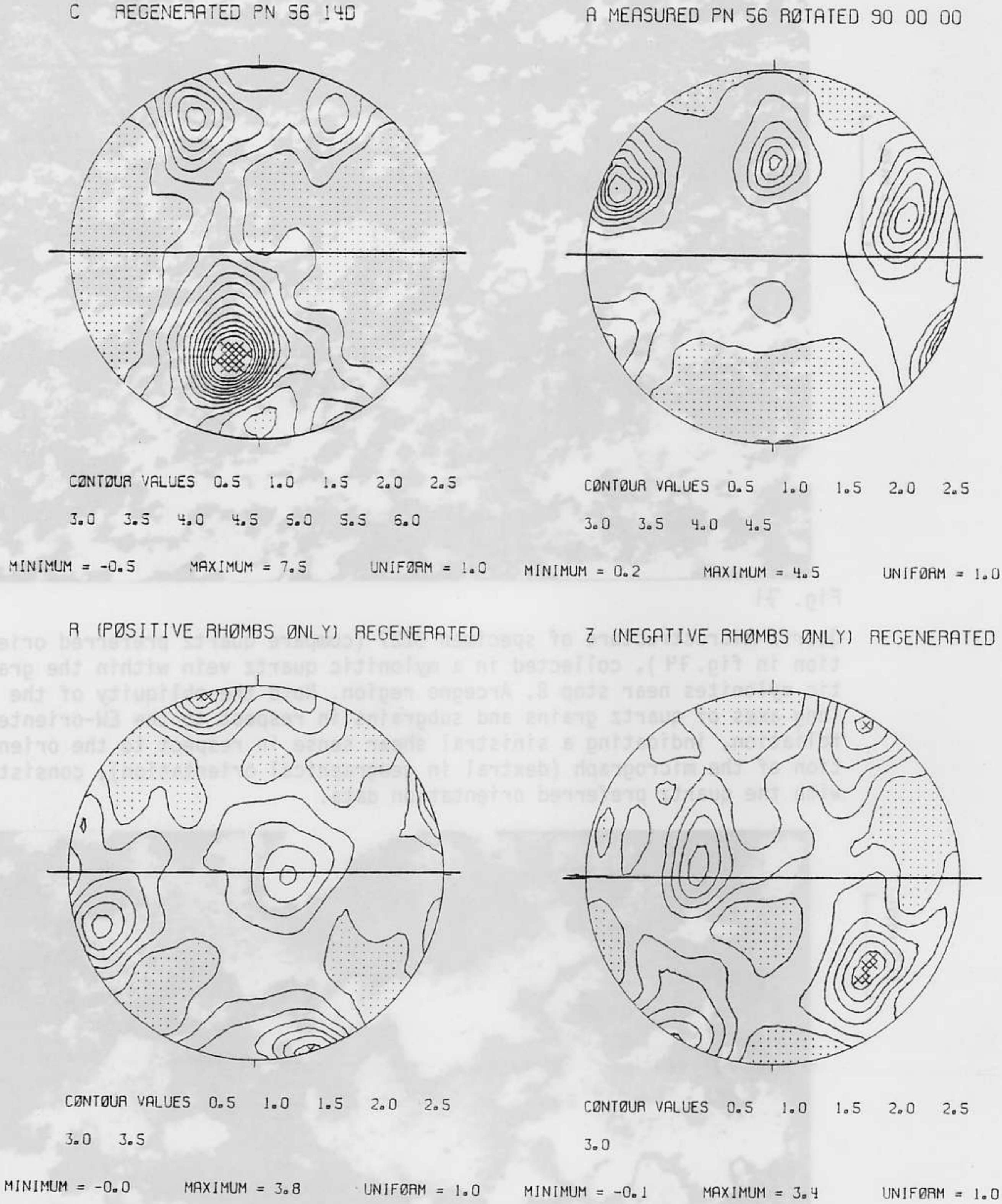


FIG. 73

Quartz X-ray pole figure data for quartz from quartz mylonite in vein within amphibolite mylonites, stop 5, Argegno region. Foliation horizontal, lineation EW.

Crossed girdle c-axis pattern with strong tendency towards a single crystal orientation, complete separation of positive and negative rhombs. The strong asymmetry in the a-axis pole figure suggests dextral shear. Glide on the negative rhombs and basal planes in an <a>-direction is suggested. For microstructure, see fig. 65 .

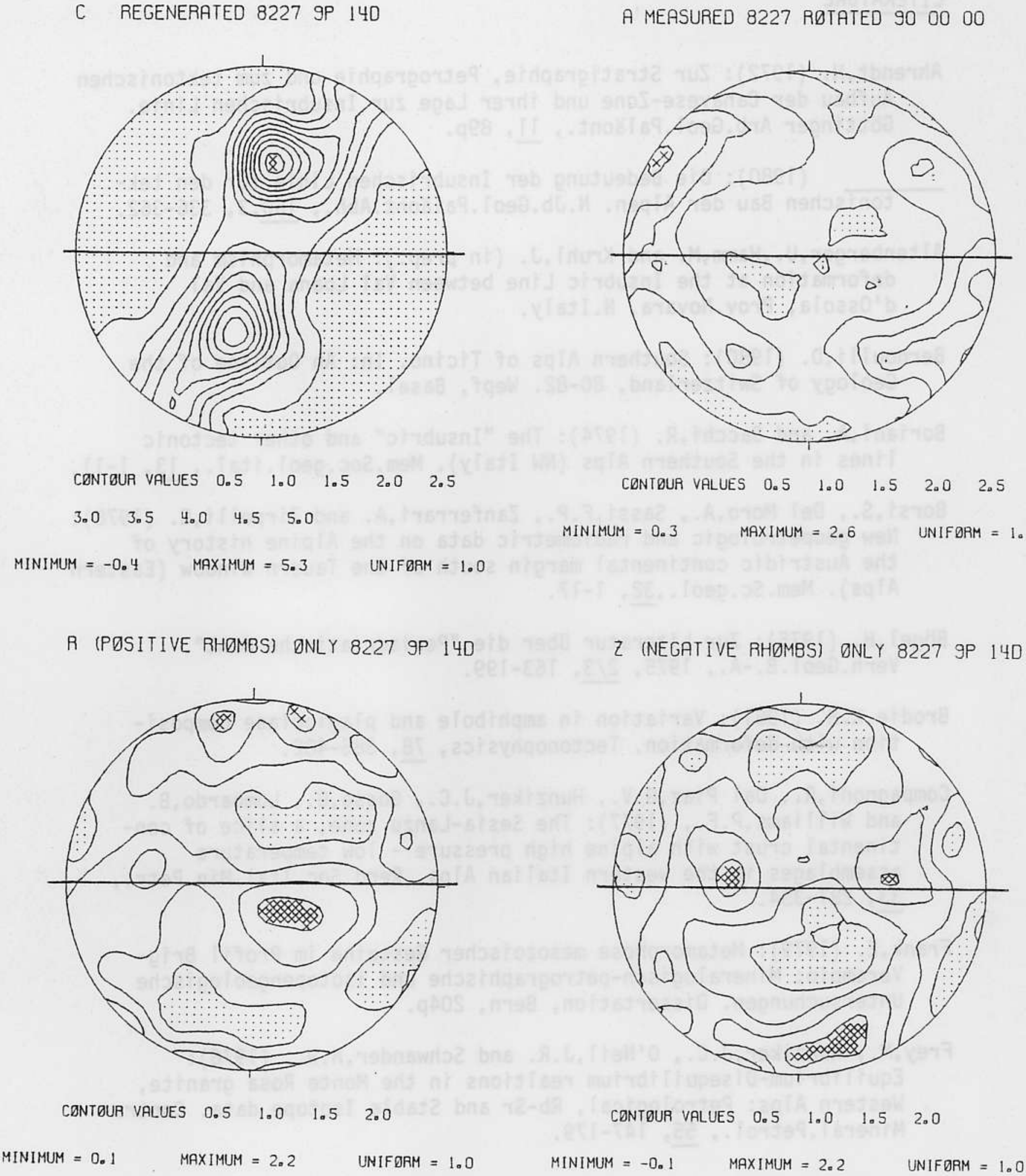


FIG. 74

Quartz X-ray pole figure data for quartz-mylonite within the granitic mylonites, near stop 8, Arcegno-region. Foliation horizontal, lineation EW.

Single oblique c-axis girdle. Oblique a-axis maximum. Dextral shear is inferred. Glide on the positive rhombs and the basal planes in an <a>-direction is suggested. For microstructure see fig. 71 .

Measurement by Dr.Liu.

LITERATURE

Ahrendt,H. (1972): Zur Stratigraphie, Petrographie und zum tektonischen Aufbau der Canavese-Zone und ihrer Lage zur Insubrischen Linie. Göttinger Arb.Geol.Paläont., 11, 89p.

_______ (1980): Die Bedeutung der Insubrischen Linie für den tektonischen Bau der Alpen. N.Jb.Geol.Paläont.Abh., 160,3, 336-362.

Altenberger,U.,Hamm,M. and Kruhl,J. (in prep.): Metamorphism and deformation at the Insubric Line between Val Loana and Val d'Ossola, Prov.Novara, N.Italy.

Bernoulli,D. (1980): Southern Alps of Ticino. In: An Outline of the Geology of Switzerland, 80-82. Wepf, Basel.

Boriani,A. and Sacchi,R. (1974): The "Insubric" and other tectonic lines in the Southern Alps (NW Italy). Mem.Soc.geol.ital., 13, 1-11.

Borsi,S., Del Moro,A., Sassi,F.P., Zanferrari,A. and Zirpolli,G. (1978): New geopetrologic and radiometric data on the Alpine history of the Austridic continental margin south of the Tauern window (Eastern Alps). Mem.Sc.geol.,32, 1-17.

Bögel,H. (1975): Zur Literatur über die "Periadriatische Naht". Verh.Geol.B.-A., 1975, 2/3, 163-199.

Brodie,K.H. (1981): Variation in amphibole and plagioclase composition with deformation. Tectonophysics, 78, 385-402.

Compagnoni,R., Dal Piaz,G.V., Hunziker,J.C., Gosso,G., Lombardo,B. and Williams,P.F., (1977): The Sesia-Lanzo zone, a slice of continental crust with alpine high pressure - low temperature assemblages in the western Italian Alps, Rend.Soc.Ital.Min.Petr., 33, 281-334.

Frank,E. (1979): Metamorphose mesozoischer Gesteine im Profil Brig-Verampio: Mineralogisch-petrographische und isotopengeologische Untersuchungen. Dissertation, Bern, 204p.

Frey,M., Hunziker,J.C., O'Neil,J.R. and Schwander,H.W., (1976): Equilibrium-Disequilibrium realtions in the Monte Rosa granite, Western Alps: Petrological, Rb-Sr and Stable Isotope data. Contr. Mineral.Petrol., 55, 147-179.

Fumasoli,M. (1974): Geologie des Gebietes nördlich und südlich der Jorio-Tonale-Linie im Westen von Gravedona. Diss. Zürich, Mitt. aus dem geol.Inst.ETH u. Univ.Zürich, NF 194, 230p.

Gansser,A. (1968): The Insubric Line, a major geotectonic problem. Schweiz. Mineral.Petrogr.Mitt., 48, 123-144.

German research group for explosion seismology (1968): Topographie des "Ivrea-Körpers", abgeleitet aus seismischen und gravimetrischen Daten. Schweiz.Mineral.Petrogr.Mitt., 48, 235-246.

Hunziker,J.C., (1974): Rb-Sr and K-Ar age determination and the alpine tectonic history of the Western Alps. Mem.Ist.Geol.Mineral. Univ. Padova, 31, 1-54.

Hunziker,J.C. and Bearth,P. (1969): Rb-Sr-Altersbestimmungen aus den Walliser Alpen, Biotitalterswerte und ihre Bedeutung für die Abkühlungsgeschichte der alpinen Metamorphose. Eclogae geol.Helv., 62, 205-222.

Hunziker,J.C. and Zingg,A. (1980): Lower Paleozoic amphibolite to granulite facies metamorphism in the Ivrea zone (Southern Alps, N.Italy). Schweiz.Min.Petr.Mitt., 60, 181-213.

Jäger,E. (1979): Introduction in geochronology. In: Lectures in Isotope Geology. Springer Verlag, Heidelberg.

Koenenmann,F. (1980): Die strukturelle Entwicklung der Sesia- und Ivrea-zone and der Insubrischen Linie im Valle d'Ossola (Italien-Westalpen). Diplomarbeit Göttingen.

Kruhl,J. (1979): Deformation und Metamorphose des südwestlichen Finero-komplexes (Ivreazone, Norditalien) und der nördlich angrenzenden Gneiszone. Dissertation Bonn, 142p.

Kruhl,J. and Voll,G. (1976): Fabrics and metamorphism from the Monte Rosa root zone into the Ivrea zone near Finero, Southern margin of the Alps. Schweiz.Mineral.Petrogr.Mitt., 56, 627-633.

Laubscher,H.P. (1970): Bewegung und Wärme in der alpinen Orogenese. Schweiz. Mineral.Petrogr.Mitt., 50, 565-596.

Laubscher,H.P and Bernoulli,D. (1980): Cross-section from the Rhine Graben to the Po plain. In: Geology of Switzerland, a guide-book, 183-209. Wepf,Basel.

MacDowell,F.W.(1970): Potassium-argon ages from the Ceneri zone, Southern Alps. Contr.Mineral.Petrol., 28, 165-182.

Milnes,A.G., Greller,M. and Müller,R. (1981): Sequence and style of postnappe structures, Simplon-Pennine Alps. J.Structural Geol., 3, 441-420.

Müller,S. (1980): Crustal structure. In: An outline of the Geology of Switzerland, p.93-97. Wepf,Basel.

Reinhardt,B. (1966): Geologie und Petrographie der Monte-Rosa-Zone, der Sesia-Zone und des Canavese im Gebiet zwischen Valle d'Ossola und Valle Loana (Prov.di Novara, Italien). Schweiz.Mineral. Petrogr.Mitt., 46.

Schmid,R.(1967): Zur Petrographie und Struktur der Zona Ivrea-Verbano zwischen Valle d'Ossola und Val Grande (Prov.Novara, Italien). Schweiz.Mineral.Petrogr.Mitt., 47, 935-1117.

_______ (1968): Excursion guide for the Valle d'Ossola section of the Ivrea-Verbano Zone (Prov. Novara, Northern Italy). Schweiz. Mineral. Petrogr. Mitt., 48, 305-314.

Steck,A., Ramsay,J.G., Milnes,A.G. and Burri,M. (1979): Compte rendu de l'excurion de la société géologique suisse de minéralogie et pétrographie en Valais et Italie nord du 2 au 5 octobre 1978. Eclogae geol.Helv., 72, 287-311.

Steck,A. and Tieche,J.C. (1976): Carte géologique de l'antiforme péridotique de Finero avec des observations sur les phases de déformation et de récristallisation. Bull.Suisse Mineral.Pétrogr., 56, 501-512.

Trommsdorff,V. (1980): Alpine metamorphism and Alpine intrusions. In: An outline of the Geology of Switzerland, 82-87. Wepf, Basel.

Trümpy,R. (1980): An outline of the Geology of Switzerland, 104p., Wepf, Basel.

Vecchia,O. (1968): La zone Cuneo-Ivrea-Locarno, élément fondamental des Alpes -- Géophysique et géologie. Schweiz.Mineral.Petrogr. Mitt., 48, 215-226.

Wagner,G.A., Reimer,G.M. and Jäger,E. (1977): Cooling ages derived by apatite fission track, mica Rb-Sr and K-Ar dating: The uplift and cooling history of the Central Alps. Mem.Ist.Geol.Mineral. Padova, 30, 1-27.

Walter,P. (1950): Das Ostende des basischen Gesteinszuges Ivrea-Verbano und die angrenzenden Teile der tessiner Wurzelzone. Schweiz.Mineral.Petrogr.Mitt., 30, 1-116.

Zingg,A. (1980): Regional metamorphism in the Ivrea zone (Southern Alps, N.Italy): Field and microscopic investigations. Schweiz.Mineral. Petrogr.Mitt., 56, 153-179.

Zingg,A., Hunziker,J.C., Frey,M. and Ahrendt,H. (1976): Age and degree of metamorphism of the Canavese zone and of the sedimentary cover of the Sesia zone. Schweiz.Mineral.Petrogr.Mitt., 56, 361-375.

Excursion Guides:

-- Geologischer Führer der Schweiz, Heft 5, published by the Schweiz. Geologische Gesellschaft. Wepf, Basel, 1967.

-- Geologischer Führer zu den Exkursionen des Symposiums "Zona Ivrea-Verbano", Schweiz.Mineral.Petrogr.Mitt., 48, 1968.

-- Excursions, 2nd Symposium Ivrea-Verbano, Mem.Sci.geol., 33, 1978/79.

-- Geology of Switzerland, a guide book. Wepf, Basel, 1980.