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Multidisciplinary Research on the Ivrea Zone

Report by *A. Zingg**) and *R. Schmid***)

1. INTRODUCTION

The Ivrea Zone consists of a steeply dipping sequence of mafic and pelitic rocks with minor intercalations of ultramafic and carbonate rocks metamorphosed under amphibolite and granulite facies conditions. In the Valle d'Ossola and the Valle Strona pelitic and mafic rocks alternate, whereas SW and NE of this region the mafic rocks are concentrated in a huge mass called «Basischer Hauptzug» (Fig. 1).

According to seismic and gravimetric investigations the Ivrea Zone represents a part of the deepest crust upthrusted from the MOHO region (compare Fig. 2 and "Symposium Zone Ivrea-Verbano" 1968, Schweiz. mineral. petrogr. Mitt., *48,* 1).

Since the first Ivrea-Symposium held in Locarno 1968 important results have been obtained in geophysics, isotope geology and petrology. Most of these new results have been presented at the second Symposium Ivrea-Verbano in Varallo, 1978, organized by our Italian colleagues. (Proceedings printed in Memorie di Scienze Geologiche, *33,* 1978/79).

This summary is based on the abstracts of the second symposium Ivrea-Verbano (1978) and progress reports of Abrecht and Peters (Bern), Hunziker (Bern), Kissling (Zürich), Köppel and Grünenfelder (Zürich), Schwendener (Zürich) and Steck (Lausanne).

2. PETROLOGY

Mineral isograds were mapped by ZINGG (1978) in an area between the Valle d'Ossola and the Valle Sesia. The regular isograd zonation indicative of amphibolite and granulite facies metamorphism in the Ossola region (PEY-

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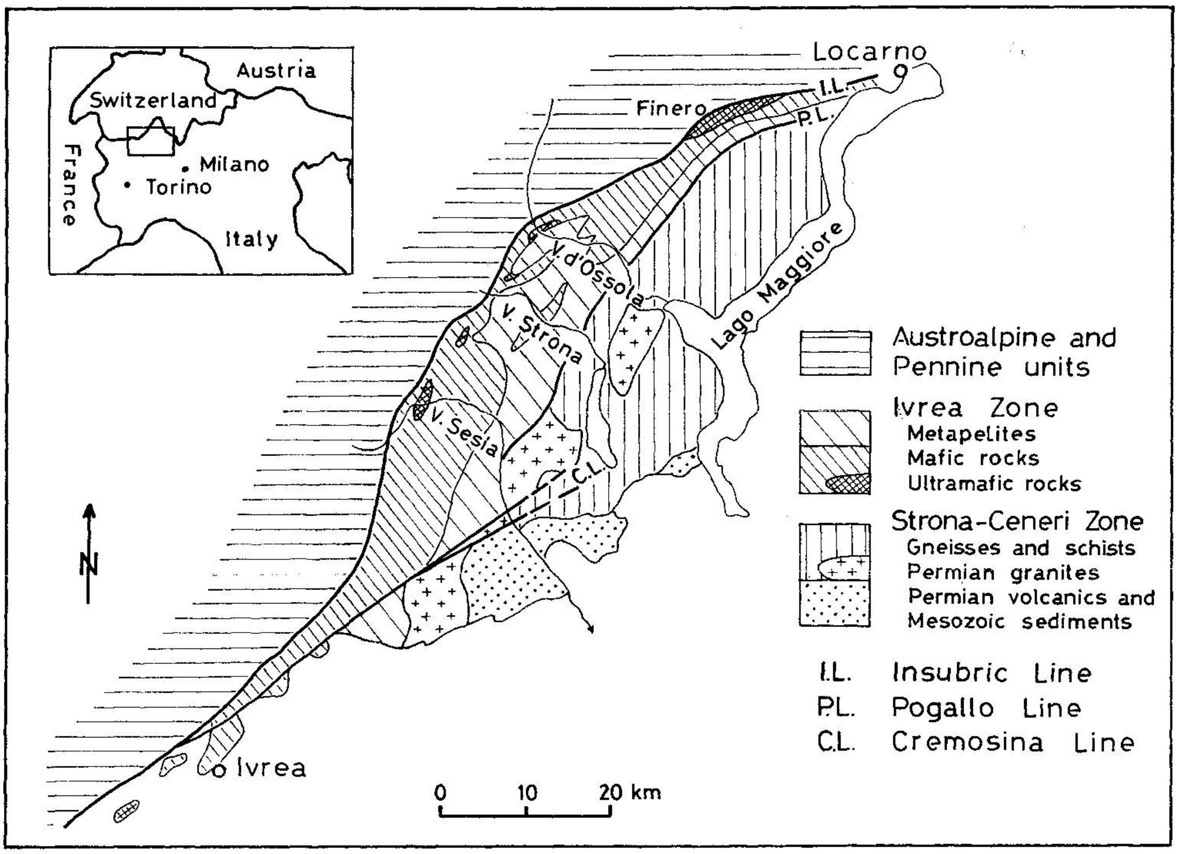

Fig. 1 Sketch map of the Ivrea Zone. Pogallo Line after Boriani and Sacchi (1973).

RONEL PAGLIANI and BORIANI 1967, SCHMID 1967 and BERTOLANI 1968) turned out to be affected in the Valle Sesia by the synmetamorphic intrusion of the "Basischer Hauptzug". The magmatic assemblage of the gabbroic rocks partially re-equilibrated under amphibolite facies conditions in the lower part of the Valle Sesia.

The distribution of the alumosilicate polymorphs and of cordierite indicates not only a strong metamorphic gradient towards the Insubric Line, but also increasing pressures parallel to the strike of the zone towards NE.

SCHMID (1967, 1972 and 1978) observed a progressive loss of granitophile elements in the pelites with increasing metamorphic grade. The difference between the mean chemical composition of common pelites and graywackes and the granulite facies pelites of the Ivrea Zone can be explained by anatexis generating 50–70 weight % of a granitic magma. This melt might have migrated into higher crust levels, e.g. in the adjacent Strona-Ceneri Zone. Using up an important part of H_2O for partial melting, this degranitisation might be responsible for the granulite facies evolution of the pelites.

STECK and TIÈCHE (1976) mapped in detail the Finero ultramafic complex and studied the relation between deformation and crystallisation. Three stages were distinguished: A granulite facies stage with isoclinal folding followed by recrystallisation under amphibolite facies conditions with the generation of

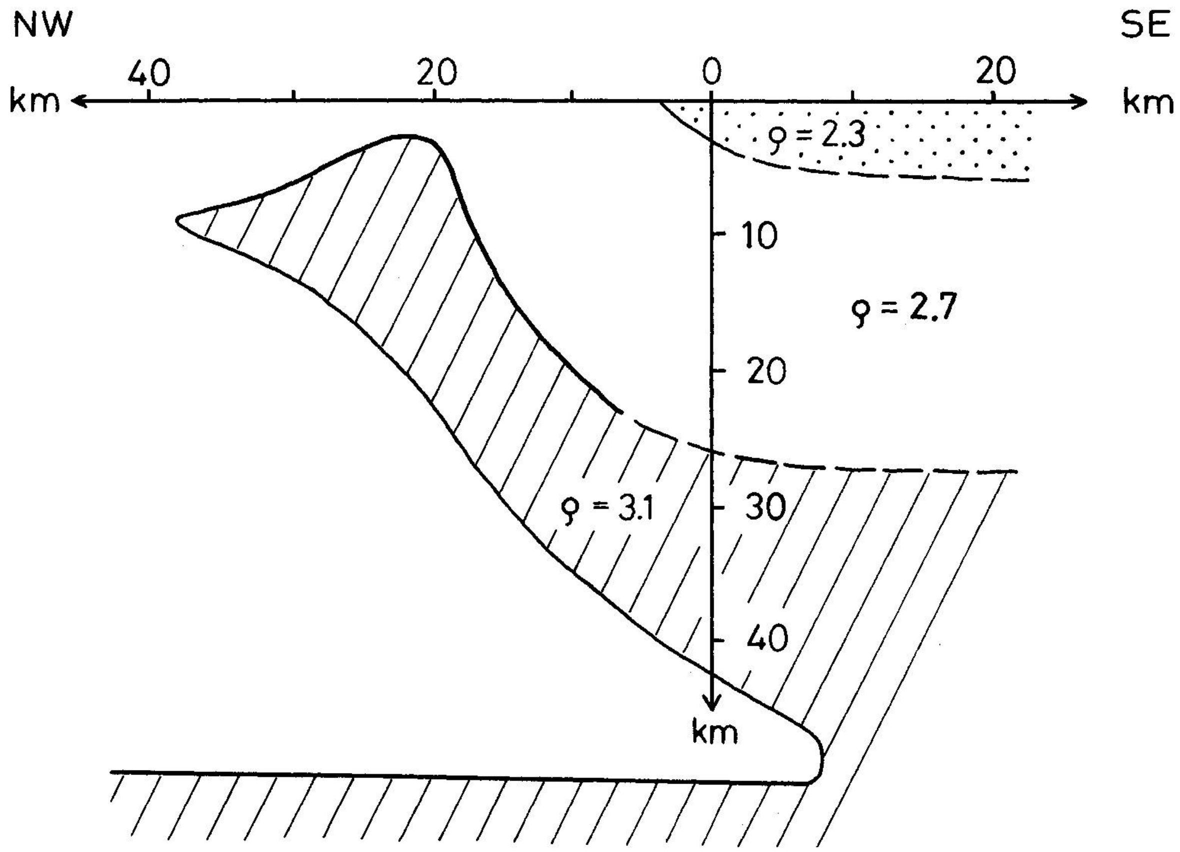

Fig. 2 Model of the crust in the Ivrea Zone region according to the German Research Groupe for Explosion Seismology (BERCKHEMER, 1968).

blastomylonites and of the Finero antiform, and finally a faulting, shearing and folding stage under greenschist facies conditions, related to deformations along the Insubric Line.

Microprobe work on pelite samples (SCHMID and WOOD 1976, ZINGG 1978) shows that the minerals are quite homogeneous even where textures in thin sections suggest different episodes of mineral growth. Appreciable Fe-Mg zonation was observed only in garnet-biotite and garnet-cordierite pairs within some 10μ of their common grain boundary, indicating retrograde cation exchange during cooling.

Using different phase equilibria in pelitic rocks temperatures increasing from 580 to 820 °C towards the Insubric Line were obtained. In the Insubric Line region the calculated temperatures are significantly lower although mineral assemblages and mineral composition indicate further increase of metamorphic grade. This is probably due to disequilibrium between garnet and biotite because of later hydrothermal influence documented by secondary aqueous fluid inclusions (DE NEGRI and TOURET 1978) and by partial sericitisation of the feldspars.

For an important part of the Ivrea pelites good geobarometers are lacking. Therefore, the estimated pressures ranging from 5 to 11 kb must be considered with caution.

A retrograde cation exchange is also indicated by investigations on the ultramafics of the Ivrea Zone by ENGI (1978), who recalibrated the olivine-spinel geothermometer of EVANS and FROST (1975) in a temperature range of 900 to 1200 K. Application of this thermometer gave temperatures between 900 and 980 K. These low temperatures for granulite facies conditions might reflect re-equilibration during cooling.

ABRECHT, PETERS and SOMMERAUER (1978) studied the manganese rocks of Alpe Ravinello situated in the granulite facies part of the Valle Strona. The chemical composition of coexisting rhodonite and bustamite was compared with the experimentally determined miscibility gap in the system $CaSiO_3$ - $MnSiO_3$, and equilibrium temperatures between 600 and 650 °C were obtained. These temperatures are too low compared with the degree of metamorphism shown by the mineral assemblages of the surrounding rocks. They probably reflect a blocking temperature for the rhodonite-bustamite equilibrium.

3. ISOTOPE GEOLOGY

KÖPPEL (1974) found discordant ages in Precambrian zircon populations from metapelites of the Ivrea Zone indicating the end of the high temperature metamorphism at 280–300 m.y. These zircons have a low trace element content and consist today to 99% of a crystalline phase. Therefore, the temperatures required for a significant Pb loss are thought to be at least 600–700 °C (KÖPPEL and SOMMERAUER 1974, SOMMERAUER 1976). The zircon ages from the Ivrea Zone do not point to a Caledonian event. A Caledonian Pb loss is, however, not excluded, but the Hercynian event must have been the dominant one according to ALLÈGRE et al. (1974).

In the lower part of the Valle Strona migmatites of the Strona-Ceneri Zone contain zircon populations of Precambrian origin which were affected by a Caledonian migmatisation and suffered additional Pb loss 340 m.y. ago or later. Monazites of this locality gave concordant ages of 290 m.y.

Concordant ages 270±5 m.y. were obtained from the monazites of the Ivrea Zone (KÖPPEL 1974). According to investigations in the Lepontine area by KÖPPEL and GRÜNENFELDER (1975) the U-Pb monazite ages give the time of crystallization or of cooling down to temperatures between 600–650 °C.

In the Valle d'Ossola the monazite ages increase across the Pogallo Line towards the Strona-Ceneri Zone from 270–280 m.y. to 320–330 m.y. indicating differential uplift along this line (KÖPPEL and GRÜNENFELDER 1978). The Pogallo Line is a fault zone with mylonites and small intrusions of dioritic rocks 300±5 m.y. ago.

Rb-Sr whole rock determinations by HUNZIKER (unpublished results) on 10 pelite samples of 30 kg weight from the amphibolite and granulite facies define an isochron of 475±20 m.y. This age is thought to give the upper time limit for the metamorphism of the Ivrea Zone.

From the Sr87/Sr86 initial of .708 and the present Sr87/Sr86 and Rb87/Sr86 ratio determined on 70 pelite samples by XRF an upper age limit for the sedimentation of the pelites of 500–700 m.y. can be calculated, assuming a closed system.

Small scale Sr isotope exchange in the range of cm to dm was studied in a banded mylonite from the granulite facies domain (compare GRAESER and HUNZIKER 1968). New Rb-Sr determinations on the single bands define an isochron of 320±20 m.y., whereas the whole sample plots on the Caledonian isochron. Further data are in preparation to decide whether Hercynian small scale Sr homogenization is a general feature in the Ivrea Zone or if it is restricted to rocks with intensive postmetamorphic deformation.

An isochron giving the same age of 320±20 m.y. has been obtained from the phlogopite peridotite of Finero.

Additional Rb-Sr and K-Ar determinations on biotite and phlogopite have confirmed that the whole Ivrea Zone has been lifted as a block and cooled down to 300±50°C about 180±20 m.y. ago (HUNZIKER 1974). A regional trend of the ages between 160 and 200 m.y. cannot be observed and the two phlogopite generations identified in the peridotite of Finero (KRUHL and VOLL 1976, STECK and TIÈCHE 1976) gave the same age within the analytical error.

4. GEOPHYSICS

The gravity field along a profile in the Valle d'Ossola was measured in detail by KISSLING, KLINGELÉ and KAHLE (1978) and compared with the density distribution of surface rocks sampled along the same profile. From the observed anomaly and the current seismic information a new 3-dimensional model has been constructed. This model allows to calculate the edge effect of the Ivrea body along the Swiss geotraverse.

Detailed measurements of the total intensity of the magnetic field on both sides of the Valle d'Ossola and in the Valle Strona show a regional anomaly of about 300 γ and some local anomalies in the range of 0.2–2 km with intensities up to some 1000 γ (SCHWENDENER 1978). Both type of anomalies are related to the mafic rocks. The correlation between local anomalies and the corresponding rock units was checked by model calculations using magnetic data determined in the laboratory on these rocks.

The measured regional anomaly can be modeled by a slab dipping approximately 40° SE to a depth of 20 km (Curie temperature) with a susceptibility of 10^{-3} G/Oe. The surface outcrop of this slab is 5–6 km in length. It starts at a distance of 3–4 km from the Insubric Line and extends up to the SE boundary of the "Basischer Hauptzug".

Similar investigations have been performed by WAGNER, CHESSEX, DUMORTIER, ESPINOSA, GALLAY, NERI and WEBEL (1978) over 12 profiles across the Ivrea Zone between Locarno and Cuneo. The measured magnetic anomaly coincides more or less with the mafic rocks of the Ivrea Zone. This anomaly can be split into two parts: 1) a major symmetrical base-level anomaly with values between -300 and $+300\ \gamma$ associated with a "magnetic Ivrea body" and 2) several sharp peaks with values up to $1200\ \gamma$, which could be produced by dike-like structures possibly associated with the "Basischer Hauptzug".

Rock magnetic investigations on samples from the area of the anomaly point to the mafic rocks as source of the magnetic anomaly. Their susceptibilities are of the order of 10^{-3}G/Oe. The Koenigsberger ratio indicates that the anomalies are essentially induced ones.

Two-dimensional computer models based on induced magnetisation have been used to simulate the Ivrea body. The result using magnetic susceptibilities from the amphibolites is a wedge-shaped body with the subvertical surface dipping to the NW. The top of the body lies at depths varying from 1 to 8 km.

HELLER and SCHMID (1974) measured natural remanent magnetisation in mafic and ultramafic rocks of the Ivrea Zone. Their data suggest, that the remanent magnetisation was imprinted to the already steeply dipping series of the Ivrea Zone during late Palaeozoic or Triassic time.

The open arc shape of the Ivrea Zone is younger than the magnetization. In addition the whole Ivrea Zone rotated anticlockwise by the same amount as the surrounding units in upper Tertiary time.

5. CONCLUSIONS

Present knowledge does not yet allow a full reconstruction of the history of the Ivrea Zone. In particular the interpretation of the age data, the emplacement history of the "Basischer Hauptzug" and the timing of the tilting and upthrusting of the Ivrea Zone from the MOHO region are still subject to discussion. Nevertheless, a relative chronology of the most significant events is attempted and further results of importance for the interpretation of the Ivrea Zone are summarized.

1. The sedimentation age of the pelitic sequence of the Ivrea Zone is Cambrian or late Precambrian. (Rb-Sr investigations).
2. The mafic and ultramafic rocks intruded the pelite sequence at a deep crustal level and re-equilibrated under the new P-T conditions (CAPEDRI et al. 1976, SHERVAIS 1978). Parts of the "Basischer Hauptzug" are similar to a layered intrusion (RIVALENTI et al. 1975). Pb, Sr and S isotope ratios support a mantle origin for at least part of the mafic and ultramafic rocks of the "Ba-

sischer Hauptzug" (GRAESER and HUNZIKER 1968, GRAESER 1970, HEILMANN and LENSCH 1977).

3. Metamorphism grading from amphibolite to granulite facies and isoclinal folding developed. Thin sections and microprobe studies of the pelites indicate only one phase of progressive metamorphism followed by few discontinuous retrograde reactions, retrograde cation exchange, mylonitization and partial recrystallisation under dry conditions. A later recrystallisation under amphibolite facies conditions, e.g. at Finero, seems to be a local feature, probably restricted to areas where significant amounts of fluid could reenter the rocks.
   According to the U-Pb mineral ages the most important metamorphic event is Hercynian. The Rb-Sr whole rock data from the same samples, however, point to a Caledonian age for the metamorphism.
4. After the intrusion of the "Basischer Hauptzug" and the regional metamorphism the Ivrea Zone was tilted from a horizontal to its present subvertical position. This tilting occurred in the adjacent Strona-Ceneri Zone prior to Permian time.
5. The now steeply dipping Ivrea Zone was then lifted as a block. This is documented by the monazites and biotites which give the same ages of 270 and 180 m.y., respectively, over the whole Ivrea Zone.
6. A model of the present structure of the crust is shown in Fig. 2. Below the Po plain the MOHO is located at a depth of more than 20 km from where it rises close to the surface of the earth in the Ivrea Zone region. A large inversion zone of the seismic velocities is observed indicating rocks of lower densities under the sheet of deep crust and upper mantle rocks represented by the Ivrea body.

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References

Abbreviations: SMPM = Schweiz. mineral. petrogr. Mitt.
AS = Abstracts of the 2nd Symposium Ivrea-Verbano, Varallo, 1978

ABRECHT, J., TJ. PETERS and J. SOMMERAUER (1978): Manganiferous mineral assemblages of Ravinella die Sotto, Valle Strona. AS.

ALLÈGRE, C. J., F. ALBARÈDE, M. GRÜNENFELDER and V. KÖPPEL (1974): 238U/206Pb-235U/207Pb-232Th/208Pb Zircon Geochronology in Alpine and Non-Alpine Environment. Contr. Mineral. Petrol. *43*, 163–194.

BERCKHEMER, H. (1968): Topographie des «Ivrea-Körpers», abgeleitet aus seismischen und gravimetrischen Daten. SMPM *48*, 235-246.

BERTOLANI, M. (1968): La petrografia della Valle Strona (Alpi Occidentali Italiane). SMPM *48*, 695-732.

BORIANI, A., and R. SACCHI (1973): Geology of the junction between the Ivrea-Verbano and Strona-Ceneri zones. Mem. Ist. Geol. Mineral. Univ. Padova, *28*, 35 p.

CAPEDRI, S., C. B. GOMES, G. RIVALENTI and E. RUBERTI (1976): Pyroxenes and Olivines as Indicators of the Petrological Evolution of the Ivrea-Verbano Basic Formation (Italian Western Alps). Tscherm. mineral. petrogr. Mitt. *23*, 175-190.

DE NEGRI, G. and J. TOURET (1978): Fluid inclusions in paragneisses from Valle Strona. AS.

ENGI, M. (1978): Mg-Fe exchange equilibria among Al-Cr spinel, olivine, orthopyroxene, and cordierite. Dissertation ETH Zürich, 95 p.

EVANS, B. W. and B. R. FROST (1975): Chrome-spinel in progressive metamorphism - a preliminary analysis. Geochim. cosmochim. Acta, *39*, 959-972.

GRAESER, S. (1970): Isotope Composition of Lead in Basic and Ultrabasic rocks of the Alps. Eclogae geol. Helv. *63*, 105-109.

GRAESER, S. und J. C. HUNZIKER (1968): Rb-Sr- und Pb-Isotopen-Bestimmungen an Gesteinen und Mineralien der Ivrea-Zone. SMPM *48*, 189-204.

HEILMANN, H. und G. LENSCH (1977): Sulfur Isotope Investigation of Sulfides and Rocks from the Main Basic Series of the Ivrea Zone. SMPM *57*, 349-360.

HELLER, F. und R. SCHMID (1974): Paläomagnetische Untersuchungen in der Zone Ivrea-Verbano (Prov. Novara, Norditalien): Vorläufige Ergebnisse. SMPM *54*, 229-242.

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*, 54 p.

KISSLING, E., E. KLINGELÉ and H.-G. KAHLE (1978): New gravitiy data in the northern Zone of Ivrea-Verbano and geophysical implications. AS.

KÖPPEL, V. (1974): Isotopic U-Pb Ages of Monazites and Zircons from the Crust Mantle Transition and Adjacent Units of the Ivrea and Ceneri Zones (Southern Alps, Italy). Contr. Mineral. Petrol. *43*, 55-70.

KÖPPEL, V. and M. GRÜNENFELDER (1975): Concordant U-Pb ages of monazite and xenotime from the Central Alps and the timing of the high temperature Alpine metamorphism, a preliminary report. SMPM *55*, 129-132.

- (1978): Monazite and Zircon U-Pb Ages from the Ivrea and Ceneri Zones. AS.

KÖPPEL, V. and J. SOMMERAUER (1974): Trace Elements and the Behaviour of the U-Pb System in Inherited and Newly Formed Zircons. Contr. Mineral. Petrol. *43*, 71-82.

KRUHL, J. H. and G. VOLL (1976): Fabrics and Metamorphism from the Monte Rosa Root Zone into the Ivrea Zone near Finero, Southern Margin of the Alps. SMPM *56*, 627-633.

PEYRONEL PAGLIANI, G. e A. BORIANI (1967): Metamorfismo crescente nelle metamorfiti del "Massiccio dei Laghi" nella zona bassa Val d'Ossola-Verbania. Rend. Soc. mineral. ital. *23*, 351-397.

RIVALENTI, G., G. GARUTI and A. ROSSI (1975): The origin of the Ivrea-Verbano basic formation (Italian Western Alps). Whole rock geochemistry. Boll. Soc. geol. ital. *94*, 1149-1186.

SCHWENDENER, H. (1978): Magnetische und seismische Messungen an Gesteinen der Zone Ivrea-Verbano und Strona-Ceneri. Diplomarbeit ETH Zürich.

SCHMID, R. (1967): Zur Petrographie und Struktur der Zone Ivrea-Verbano zwischen Valle d'Ossola und Val Grande (Prov. Novara, Italien). SMPM *47*. 935-1117.

- (1972): Substitution von Biotit durch Granat und «Degranitisierung» in granulitischen Paragneissen der Ivreazone (N-Italien). Habil.schrift ETH Zürich, 49 p.
- (1978): Are the metapelites of the Ivrea-Verbano Zone restites? AS.

SCHMID, R. and B. J. WOOD (1976): Phase Relationships in Granulitic Metapelites from the Ivrea-Verbano Zone (Northern Italy). Contrib. Mineral. Petrol. *54*, 255-279.

SHERVAIS, J. (1978): Mafic layers in the alpine-type lherzolite massif at Balmuccia, N.W. Italy. AS.
SOMMERAUER, J. (1976): Die chemisch-physikalische Stabilität natürlicher Zirkone und ihr U-(Th)-Pb System. Dissertation ETH Zürich, 151 p.
STECK, A. et J.-C. TIÈCHE (1976): Carte géologique de l'antiforme péridotitique de Finero avec des observations sur les phases de déformation et de recristallisation. SMPM *56*, 501-512.
WAGNER, J.-J., R. CHESSEX, ST. DUMORTIER, A. ESPINOSA, CL. GALLAY, PH. NERI and S. WEBEL (1978): The total field magnetic anomalies of the Ivrea Zone: Tentative model. AS.
ZINGG, A. (1978): Regionale Metamorphose in der Ivrea-Zone. Dissertation ETH Zürich, 220 p.

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