

STRUCTURAL GEOLOGY OF THE CENTRAL SESIA LANZO ZONE¹

CEES W. PASSCHIER², JANOS L. URAI³, JOEP VAN LOON³
& PAUL F. WILLIAMS⁴

ABSTRACT

Passchier, C. W., J. L. Urai, J. van Loon & P. F. Williams 1981 Structural Geology of the Central Sesia Lanzo Zone – Geol. Mijnbouw 60: 497-507.

A synthesis of the metamorphic and structural history of the Central Sesia-Lanzo Zone (Western Alps) is proposed, based upon detailed mapping. Four lithologic units are distinguished. The metamorphic history can be divided into a pre-Alpine amphibolite facies event, an early Alpine HP-LT event and a late Alpine greenschist facies event. Five generations of folds are distinguished. F_0 is probably of pre-Alpine age. F_1 produced isoclinal folds, part of the regional foliation and major shear zones along which the lithologic units are brought into their present relative positions. F_2 , F_3 and F_4 are subsequent phases of folding, each producing a locally developed foliation. Some F_2 folds occur on a km scale and can be seen on the map. F_4 might be related to a young, postulated major fold that trends NE-SW through the entire Sesia-Lanzo Zone.

A detailed map and three-dimensional interpretation of the major structure in the central Sesia-Lanzo Zone are presented, including a new interpretation of the IIDK body at Mt. Nery.

INTRODUCTION

The Sesia-Lanzo Zone (SLZ) is an elongate body (25 x 90 km) trending NE-SW and is the most internal unit of the Western Alps. It is bounded, to the east, by the Canavese Line, a steep major crustal dislocation that separates the Sesia-Lanzo Zone from the Canavese basin and the pre-Alpine Ivrea zone (AHRENDT 1972). In the west it overlies the 'Schistes Lustrés' and metaophiolites of the Piemonte zone (DAL PIAZ, 1965; DAL PIAZ ET AL., 1972, 1978). It consists of polymetamorphic rocks of the Austroalpine continental crust and is interpreted as the root zone of the Dent Blanche nappe (DAL PIAZ ET AL., 1972, 1973, 1978; COMPAGNONI ET AL., 1977; HUNZIKER, 1974). The Sesia-Lanzo zone is generally divided into four major rock complexes on the basis of differences in lithology and metamorphic evolution. They are the Lanzo ultrabasic complex and the Sesia Eclogitic Mica Schist (EMS),

Gneiss Minuti (GM) and Second Dioritic Kinzigitic (II DK) complexes (Fig. 1, COMPAGNONI ET AL., 1977; DAL PIAZ ET AL., 1972, 1973). The SLZ is generally considered to comprise two tectonic units: an upper element comprising the II DK and a lower element comprising the EMS and the GM (COMPAGNONI ET AL., 1977). WILLIAMS (1977) however, suggested that the EMS and GM are separated by a thrust in the Aosta valley and a jump in metamorphism has since been demonstrated across this fault (WILLIAMS & COMPAGNONI, in prep.). Thus the lower element has now been further divided into a lower (GM) and middle element (EMS) (WILLIAMS & COMPAGNONI, in prep.).

It can be seen from the map (Fig. 1) that these three elements of the SLZ meet at a point close to Mt. Nery. This junction has been interpreted as a tight synform in the thrust contact between the upper element (II DK) and the lower element, as previously defined (i.e. EMS and GM), with a lithological contact between the EMS and GM that just happens to coincide with the hinge of the fold (DAL PIAZ ET AL., 1971, GOSSO ET AL., 1979). Since this lithological contact is steeply inclined to the thrust contact between the two elements, the result is the observed three way junction. WILLIAMS & COMPAGNONI (in prep.) have suggested that the junction is due to pinching out of the II DK where the thrusts separating it from the EMS and GM converge (Fig. 2). The purpose of the

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² Geological Institute, University of Amsterdam, Nieuwe Prinsengracht 130, Amsterdam, The Netherlands.

³ Instituut voor Aardwetenschappen, University of Utrecht, P.O. Box 80021, Utrecht, The Netherlands.

⁴ Dept. of Geology, University of New Brunswick, Fredericton, N. B., Canada, E3B 5A3.

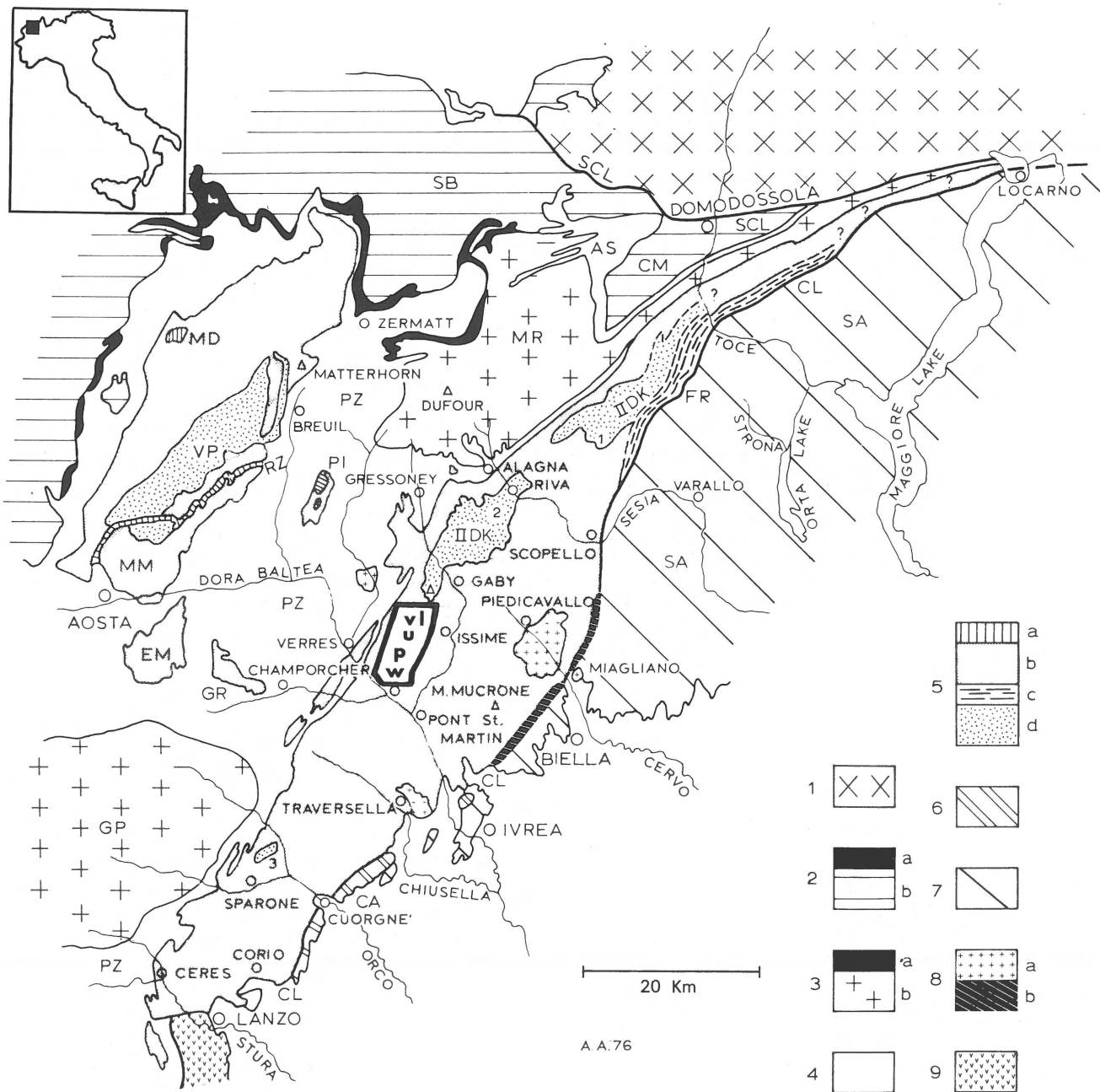


Fig. 1

Tectonic sketch map of the internal Northwestern Alps after Compagnoni et al. (1977). The areas mapped by van Loon, Urai, Passchier, and Williams are outlined and labeled in the centre of the figure. 1- Lower Pennine Nappes. 2- Bernhard Nappe (SB) and Camughera - Moncucco Unit (CM); a: sedimentary cover; b: basement. 3- Monte Rosa (MR) - Gran Paradiso (GP) Nappe; a: sedimentary cover; b: basement. 4- Piemonte Zone (PZ) and Antrona Syncline (AS). 5- Dent Blanche Nappe and Sesia - Lanzo Zone; a: sedimentary cover, Roisan Zone (RZ) and Mont Dolin (MD); b: Lower element, Mont Mary Klippe (MM), Monte Emilius Klippe (EM), Glacier-Rafraay Klippe (GR), Pilonnet Klippe (PI); c: Fobello-Rimella Schists (FR); d: Upper element, Valpelline Series (VP), II Zona Diorito-Kinzigitica (II DK) (1: II Zona Dioritica-Kinzigitica s.s.; 2: Val Vogna-Valle di Gressoney Klippe; 3: Varaso Klippe). 6- Canavese Zone (CA). 7- Southern Alps (SA). 8- Biella and Traversella stocks (a), trachyandesite volcanics (b). 9- Lanzo Lherzolite.

SCL = Sempione - Centovalli Line; Cl = Canavese Line; Triangle west of Gaby is Mt. Nery.

work reported here was to map a section between the established thrust (WILLIAMS & COMPAGNONI, in prep.) in the Aosta valley and the Mt. Nery junction in order to establish the relationship between the two and to synthesize the metamor-

phic and deformational history of the three elements.

We mapped an area of approximately 40 km² at 1:10,000 scale. The project was carried out under the auspices of the Leiden State University.

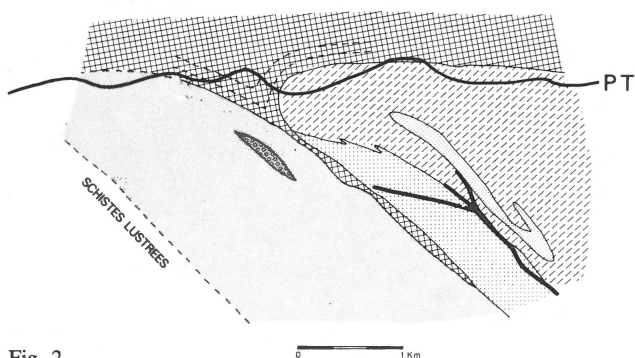


Fig. 2
Diagrammatic section (looking NE) through the Central Sesia Lanzo Zone showing the relative positions of the various units after F_1 thrusting. The legend of Fig. 3 explains the patterns. PT = present topography.

LITHOLOGICAL UNITS

Four lithological units are distinguished in the central SLZ and they are described briefly below. More detailed descriptions of the lithologies can be found in COMPAGNONI ET AL. (1977), PASSCHIER (unpubl. M.Sc. thesis, Leiden, 1978), URAI (unpubl. M.Sc. thesis, Leiden, 1980) VAN LOON (in prep.) and WILLIAMS & COMPAGNONI (in prep.). The units are separated by sharp boundaries and trend approximately NE-SW (Fig. 3). They are described in sequence from SE to NW.

Unit A

This unit comprises alternating micaschist, metabasite, marble, orthogneiss and quartzite with superbly developed high pressure – low temperature (HP-LT) assemblages. Relics of the assemblage jadeite + quartz have been found in this unit in the south of the area mapped. Unit A is part of the 'Eclogitic Micaschist Unit' of earlier publications (COMPAGNONI & MAFFEO, 1973; COMPAGNONI, 1977) and coincides with units I and II of WILLIAMS & COMPAGNONI (in prep.).

Unit B

This unit comprises orthogneiss with minor intercalation of micaschist and metabasite, and contains omphacite and glaucophane or relics of these minerals. This unit belongs to the 'Gneiss Minuti' of earlier publications and coincides with unit III of WILLIAMS & COMPAGNONI (in prep.).

Unit C

This unit comprises fine grained paraschists and gneisses, which have been mylonitised, amphibolite and marble. Lithologically the unit is identical to the II DK of earlier publications (DAL PIAZ ET AL., 1971; GOSSO, 1977; GOSSO ET AL., 1979; ISLER & ZINGG, 1974) and our mapping shows that it is in fact continuous with the main allochthonous mass of II DK that outcrops at Mt. Nery.

Unit D

This unit is identical to unit B except that it contains no omphacite, glaucophane, or relics of these minerals. Like unit B it belongs to the 'Gneiss Minuti' of earlier workers (e.g. COMPAGNONI ET AL., 1977).

METAMORPHISM

The metamorphic history of the Sesia is generally divided into three main events (see Fig. 4) (e.g. COMPAGNONI ET AL., 1977). Amphibolite facies metamorphic assemblages (event I) are overprinted by high pressure/low temperature assemblages (event II) and both are overprinted by greenschist facies assemblages (event III). Fig. 4 shows the complete metamorphic history as undergone by unit A. Part or all of event II assemblages are lacking in units C and D.

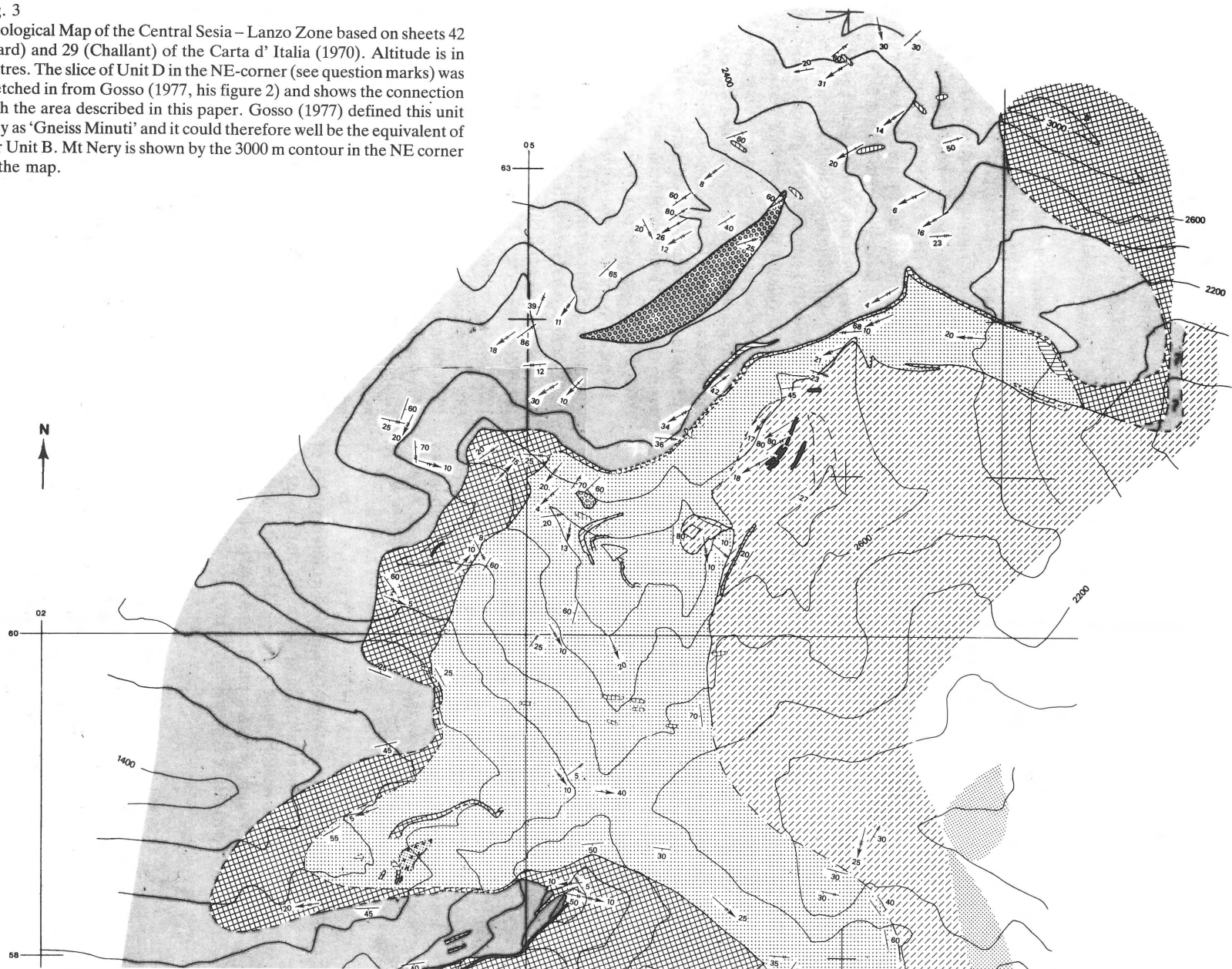
The best preserved relics from the event I metamorphism occur as large amphibolite lenses that were too poor in sodium to be converted to eclogites during event II. They are eclogitised at their contact with pegmatite veins and surrounding schists. Microstructural relics include some garnets and large flakes of graphite. Evidence of this metamorphic event is found in units A and C. The orthogneisses of units B and D are interpreted as granitoids that were emplaced in the crust during the event I metamorphism. The latter is believed to be Hercynian in age (HUNZIKER, 1974; COMPAGNONI ET AL., 1977).

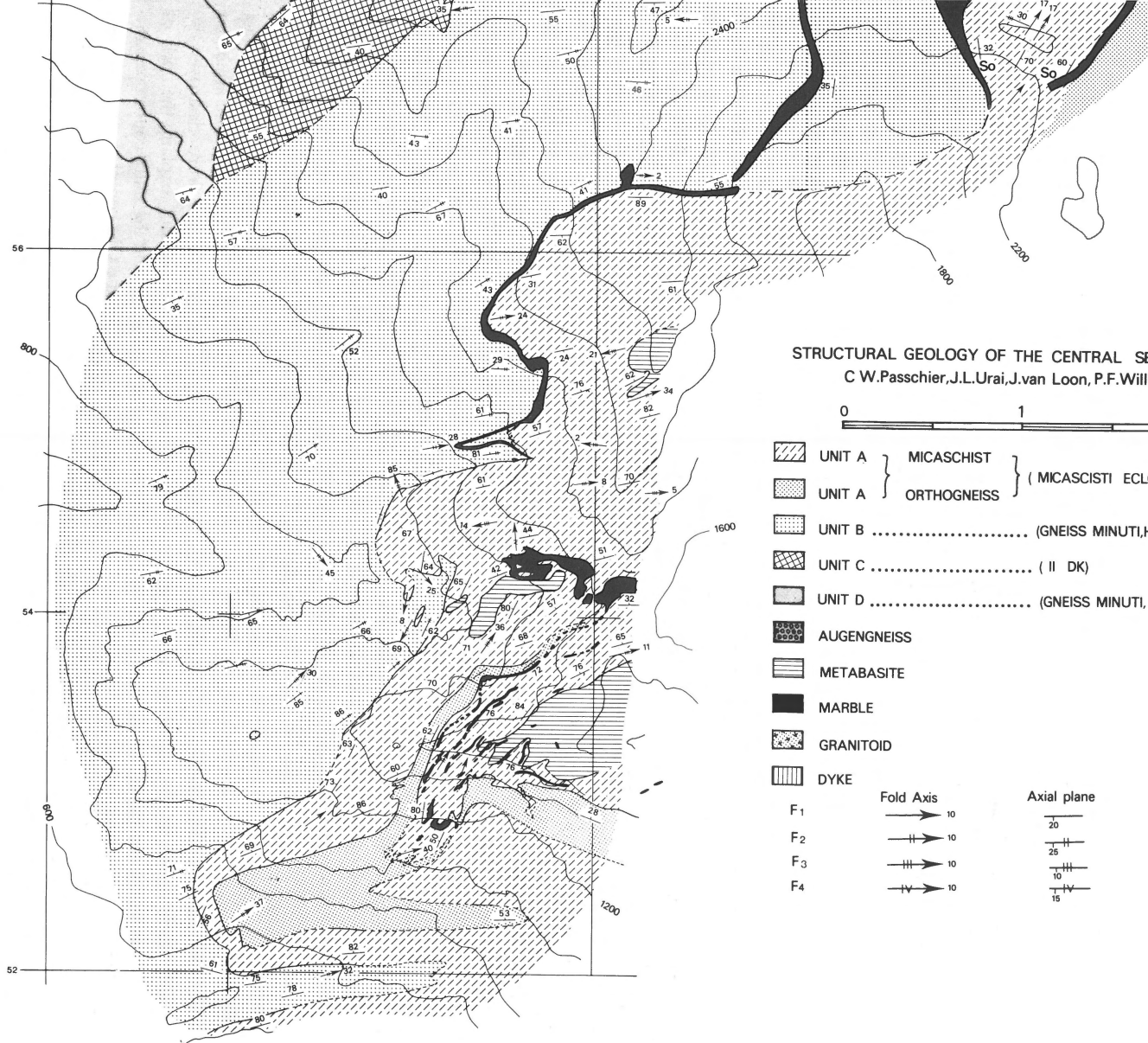
Event II is part of the high pressure/low temperature metamorphism that occurred throughout the western Alps in early Alpine, Cretaceous times. It culminated in eclogite facies assemblages and closed at 60-90 Ma (see BEARTH, 1967, 1974; BOCQUET 1974; COMPAGNONI, 1977; COMPAGNONI ET AL., 1977; DAL PIAZ, 1966, 1974-a, 1974-b; DAL PIAZ ET AL., 1972; ERNST, 1971, 1973, 1975; ERNST & DAL PIAZ, 1978; FREY ET AL., 1974; HUNZIKER, 1974).

Two stages have generally been found in the SLZ for event II: an eclogite stage followed by a blueschist stage. According to our observations (see also WILLIAMS & COMPAGNONI, in prep.), however, three stages can be recognized (see Fig. 4). The initial stage is characterized by glaucophane. It is followed by glaucophane-omphacite and jadeite assemblages which in turn are followed by glaucophane-almandine assemblages. Thus the pressure maximum is attained in the second stage. This corresponds to the first stage of event II of COMPAGNONI (1977) when a 17 kbar pressure is believed to have been reached. Glaucophane and omphacite assemblages are common in both units A and B, but jadeite + quartz assemblages have only been found in the SE part of unit A.

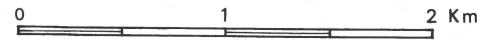
The event III greenschist facies metamorphism is similar in age (38 Ma) to the Lepontine metamorphic event of the central Alps (COMPAGNONI ET AL., 1977; HUNZIKER, 1974). It overprints older assemblages in all lithological units. The mineral assemblages of this event are best developed in units A, B and D. Oligoclase rims around albite of this age are only

Fig. 3
Geological Map of the Central Sesia – Lanzo Zone based on sheets 42 (Bard) and 29 (Challant) of the Carta d' Italia (1970). Altitude is in metres. The slice of Unit D in the NE-corner (see question marks) was sketched in from Gosso (1977, his figure 2) and shows the connection with the area described in this paper. Gosso (1977) defined this unit only as 'Gneiss Minuti' and it could therefore well be the equivalent of our Unit B. Mt Nery is shown by the 3000 m contour in the NE corner of the map.

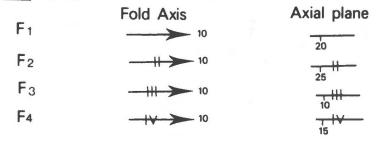




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- UNIT A } MICASCHIST
- UNIT A } ORTHOGNEISS } (MICASCISTI ECLOGITICI)
- UNIT B (GNEISS MINUTI, Hp-Lt)
- UNIT C (II DK)
- UNIT D (GNEISS MINUTI, No Hp-Lt)
- AUGENGNEISS
- METABASITE
- MARBLE
- GRANITOID
- DYKE



found in the north of the area (Fig. 1), suggesting that slightly higher temperatures were reached there.

Event III is followed by the emplacement of andesitic dykes which are 30-33 Ma old (HUNZIKER, 1974; LANZA, 1977).

DEFORMATIONAL HISTORY AND CORRELATION WITH METAMORPHIC EVENTS

On the basis of form surface mapping and overprinting five groups of folds have been recognized of which four (F_1 - F_4) are of Alpine age.

F_0 folds

These structures are found in only one locality in the south of the area. They occur in one of the pre-Alpine amphibolite lenses and the presence of recrystallized brown hornblende in a fold hinge indicates that folding took place under amphibolite facies conditions. It is therefore suggested that F_0 structures developed during the pre-Alpine, event I metamorphism (WILLIAMS & COMPAGNONI, in prep.).

F_1 folds

Folds of this group are tight to isoclinal and may be rootless. They are mostly small, meter scale, but larger folds do exist (see Figs. 3 and 5). They are generally asymmetrical folds with sinistral vergence (looking down plunge) except for a few small dextral folds on the short limb of larger sinistral folds. The same observations regarding asymmetry have been made at Mt. Nery (GOSSO, 1977; GOSSO ET AL., 1979) in the northern extension of the area mapped here (F_1 coincides with IAD of GOSSO ET AL., 1979). F_1 folds vary considerably in orientation due, at least in part, to redistribution by later folding. They may or may not have an axial plane foliation (S_1). The foliation is best developed in schists and metabasic rocks. Where S_1 exists in the schists it is generally developed by transposition by microfolding of an earlier surface. This process involves kinking of elongate minerals such as micas and rotation of others. In some orthogneisses and related meta-pegmatites S_1 is a differentiated layering. In unit C a mylonite foliation of F_1 age is developed.

The F_1 deformation transposes an earlier foliation into a new penetrative layering and parallel schistosity both of which are parallel to the major thrust contacts. In terms of overprinting relationships this group of folds comprises at least two generations. The transposition is envisaged as an ongoing process associated with thrusting during which a steady state foliation has developed by non coaxial strain. This surface was continuously modified by the development of new folds which rotated the foliation out of its general orientation only to transpose it back into that orientation as the folds became isoclinal (for further discussion see WILLIAMS & COMPAGNONI, in prep.). In general the different generations of F_1 folds cannot

be distinguished and furthermore in view of the steady-state nature envisaged for the process we do not consider it useful to try to distinguish them from the point of view of understanding the regional geology.

F_1 folds locally deform metamorphic event II mineral assemblages (HP-LT) but elsewhere (units A and B) are overgrown by undeformed representatives of the same assemblages, indicating that some F_1 folds and HP-LT mineral assemblages were developing coevally (Fig. 4). This dates F_1 folds during and after the culmination of the HP-LT metamorphism of event II.

Deformation during F_1 folding was not equally penetrative in all areas. Thus areas of strong F_1 deformation with abundant F_1 folds enclose boudins, some of which measure hundreds of meters, that are comparatively undeformed during F_1 deformation. Moreover the major lithologic units comprise lenses of less deformed rock separated by thrusts which are simply zones or surfaces of more intense F_1 deformation. Thus the present juxtaposition of the various lithological units is a result of thrusting. Evidence in support of this interpretation is as follows:

- (1) The boundaries between the units are sharp. Locally between units A and B, and in unit C, relics of F_1 mylonites have survived later deformation and metamorphism (see WILLIAMS & COMPAGNONI, in prep.; PASSCHIER, unpubl. M.Sc. thesis, Leiden, 1978; URAI, unpubl. M.Sc. thesis, Leiden, 1980). A mylonitized marble layer follows the contact between units A and B (Fig. 3; PASSCHIER, unpubl. M.Sc. thesis, Leiden, 1978).
- (2) Lenses of some units occur in others, e.g. of A and C in unit B. (see Fig. 3).
- (3) Units with different metamorphic histories predating F_1 thrusting are in contact with one another. For example unit A contains relics of jadeite plus quartz whereas a few meters away in unit B there is no jadeite but albite. There is abundant glaucophane and omphacite in unit B right up to the contact with unit D. Pseudomorphs of chlorite, sericite and actinolite aggregates after glaucophane and omphacite locally also occur in unit B. Both these two minerals and their pseudomorphs are lacking in unit D, even though the composition of the units is essentially the same. The only simple explanation is that the contact between units B and D is a tectonic one. The argument that glaucophane and omphacite were destroyed by retrogression in unit D can not explain the lack of pseudomorphs in this unit, and the sharp contact separating units B and D. Thus the GM complex can be divided into a unit that underwent HP-LT metamorphism and a unit that did not.
- (4) The important translation on the thrusts is pre F_2 since the thrusts are themselves folded by F_2 .

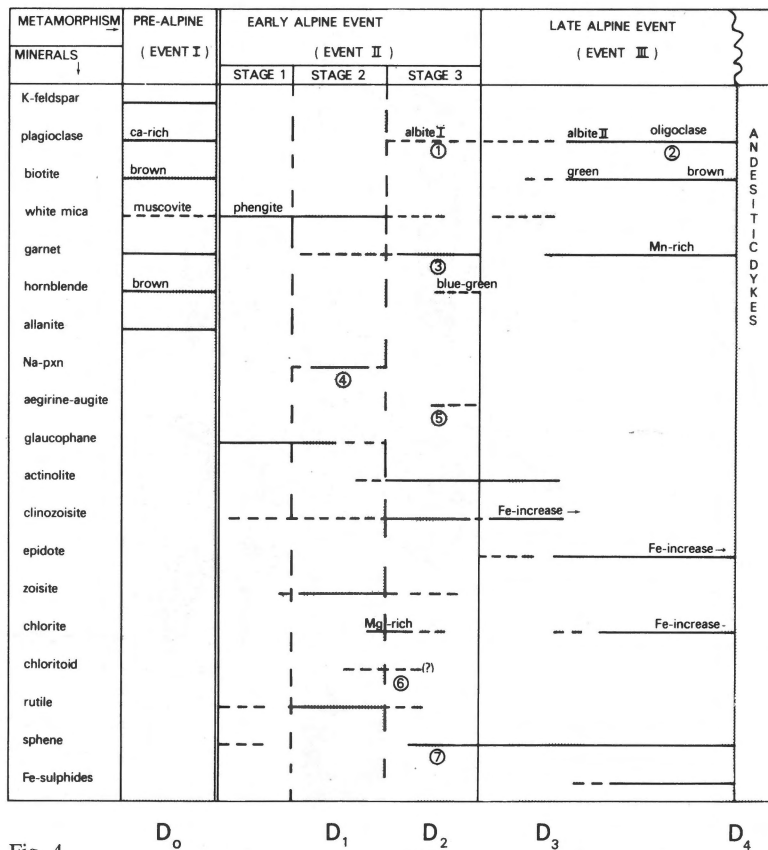


Fig. 4
Correlation scheme showing the relative ages of mineral assemblages and fold generations. Solid lines; periods in which a mineral grew throughout the area. Broken lines represent local growth of a mineral. After growth all minerals became unstable except allanite, chlorite, and albite which remained stable throughout the subsequent deformation history. 1- Albite 1 is recognized only in Units B and C (orthogneiss). 2- Oligoclase rims around albite occur only in the northern part of the area. 3- Garnet growth starts in the late stage of episode II, as opposed to Compagnoni (1977). 4- Locally jadeite (orthogneiss of Unit A), area of Williams (Fig. 1): in Units A and B omphacite. 5- Occurs only in Unit A, in metabasites. 6- In the areas of Williams and van Loon only (Fig. 1). 7- Sphene grows at the expense of rutile.

F₂ folds

These folds are close to tight and occur as microscopic to kilometer scale structures that deform the contacts between the various lithologic units (Figs. 3 and 5). Major folds are disharmonic and vary considerably in orientation. This irregularity is believed to be due partly to later folding and partly to a marked variation in the orientation of layering, prior to the F₂ deformation. The latter was a result of earlier folding and boudinage, and the irregular nature of plutonic igneous bodies. The vergence of F₂ folds is sinistral looking east or down plunge (Figs. 3 and 5) and style varies in different lithologies. Hinges tend to be rounded in gneiss and massive metabasite, and angular in schists. An S₂ mica foliation is developed locally in orthogneisses and in most schists. The development of S₂ partly erased S₁ in these rocks. S₂ foliation is rare in metabasic rocks and occurs as a millimeter scale differentiated layering in orthogneiss and particularly in

metapegmatite veins. In schists it is a crenulation cleavage. F₂ coincides with EPN of GOSSO ET AL. (1979) and developed during the late stages of the high pressure/low temperature metamorphism (Fig. 4).

F₃ folds

F₃ folds are open to tight structures which vary in size from microscopic to hundreds of meters. In massive rocks such as gneisses and metabasites F₃ folds are parallel with rounded hinges and straight limbs. In strongly foliated rocks such as the schists they are kinks. The size and interlimb angle of the folds vary systematically with altitude. In the lower parts of the area (400-1000 m) the folds are mostly open and small whereas in the higher parts (2000-3000 m) they are mostly tight to isoclinal and large. Furthermore in the higher areas they have an axial plane crenulation cleavage which locally is the dominant foliation and which in leucocratic gneisses and meta-pegma-

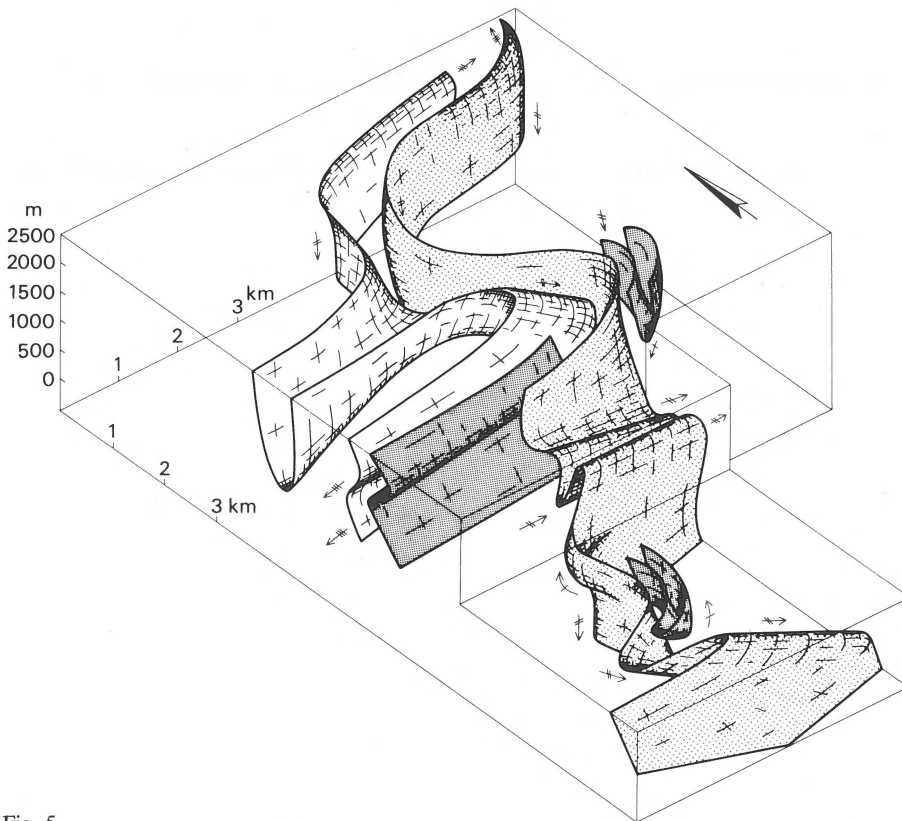


Fig. 5
Block diagram of the Central Sesia-Lanzo Zone. The coarse-stippled surface represents the thrust at the base of Unit A. Other surfaces are generalized from selected surfaces to give the best impression of the structure. Arrows indicate the plunge and generation of the major folds (see legend Fig. 3).

tites may be a differentiated layering. F_3 folds coincide with LPN of GOSSO ET AL. (1979) and are contemporaneous with the early stage of event III metamorphism. F_3 folds are usually recumbent: axial surfaces are generally shallowly dipping and fairly constant in orientation compared to those of earlier folds. F_3 hingelines, however, show considerable variation in orientation depending on their position relative to earlier, large folds. GOSSO (1977) and VAN LOON (in prep.) described F_3 axes as having a constant orientation but this appears to be a local feature since one of us (PFW) has examined the area north of Gosso and v. Loon and there the variation in orientation is also strong.

F_4 folds

F_4 folds occur as open to tight microfolds and as open folds on a meter scale. They have steeply dipping axial surfaces and axes vary considerably in orientation. In style F_4 and more open F_3 structures are indistinguishable. They may have an axial plane crenulation cleavage and locally a non penetrative axial planar surface is defined by closely spaced chlorite filled veins. F_4 folds are correlated with the last stages of stage III metamorphism and as discussed below are believed to be contemporary with, or later than intrusion of the andesitic dykes.

DISCUSSION AND CONCLUSIONS

Detailed analysis of structure and metamorphism have made it possible to reconstruct the large scale structure and the deformational and metamorphic history of a portion of the SLZ.

Deformation was a continuous process under changing external conditions. Its progression fits well into the reinterpretation given by HOMEWOOD ET AL. (1980) for the structural history of the Western Alps. A correlation of the central SLZ with other studies in the Western Alps is hindered by the lack of comparable data nearby. The picture that emerges for the central SLZ is as follows:

A block of continental crust that had previously been subjected to amphibolite facies metamorphism and to at least one generation of folding (F_0) was involved in eo-Alpine (Cretaceous) metamorphism and deformation (F_1). The deformation resulted in transposition of earlier discontinuities such as layering and discordant pegmatite veins into a single Alpine foliation except in large lenses or boudins of relatively undeformed material where earlier relationships are preserved to a lesser or greater extent. During this same period of deformation an anastomosing array of thrust planes developed parallel to the transposition foliation.

The Sesia has previously (COMPAGNONI ET AL., 1977) been

divided into two 'tectonic elements' or nappes, an upper II DK nappe and lower Eclogitic Mica Schist nappe (EMS). WILLIAMS & COMPAGNONI, in prep.) suggested that the EMS should be further divided into an upper EMS nappe and lower GMS nappe because of the metamorphic hiatus between units A and B. According to earlier workers (DAL PIAZ, ET AL., 1971; GOSSO ET AL., 1979) the II DK nappe occupies the core of a major synform in the SLZ (F_2 , according to GOSSO ET AL., 1979). WILLIAMS & COMPAGNONI, in prep.), however, suggested that the II DK has the form of a lens bounded by two thrust planes which join to form the thrust between the GM and EMS nappes (Fig. 2). The mapping presented here supports this conclusion. It can now be shown (Fig. 3) that the thrust of WILLIAMS & COMPAGNONI in prep.) is part of a zone of anastomosing thrusts which is continuous with the lens of II DK. This lens which has been extended southeasterly to join up with another outcrop of II DK is simply one of the lithologic units delineated by the thrusts; it is part of the imbricated thrust zone (Fig. 3).

Some F_2 folds in units A and B and in the thrust which separates them were formed under conditions prevailing during the HP-LT metamorphic event, as was pointed out above (Fig. 4). Part of the thrusting, however, with associated F_1 must postdate the culmination of the HP-LT event. Unit D never underwent HP-LT metamorphism, but is nevertheless in contact with unit B, containing HP-LT mineral assemblages. Thus the two units must have been brought into juxtaposition at a relatively shallow level in the crust. This means that HP-LT mineral assemblages in unit B must have been formed before juxtaposition, and thus this part of the F_1 thrusting postdates the HP-LT culmination we observed. Unit A contains jadeite and quartz assemblages, unit B only omphacite and glaucophane in similar lithologies. Thus unit A was brought into juxtaposition with unit B above the level at which jadeite can form. In summary, F_1 folding started under HP-LT conditions in units A and B. During continuous F_1 deformation unit A was thrust from below the jadeite + quartz isograd into unit B above the isograd, and both units were then thrust onto unit D at an even shallower level. The position of unit C in this movement picture is uncertain due to a lack of good control on its metamorphic peak conditions. However, it appears to have been spatially more closely related to unit B than to unit D. Thus HP units were emplaced onto lower pressure units as a result of F_1 thrusting causing a jump in metamorphic grade between units A, B and D. It must be emphasized that the HP-LT metamorphism may have continued in deeper parts of the SLZ after upheaval of all the units in the rock volume considered.

Since the upper units of the SLZ are the more internal ones, this is consistent with the general picture in the Alps, where the grade of metamorphism generally decreases from the internal to external zones (e.g. ERNST 1971, 1975). The inverted pressure sequence recorded in the SLZ is analogous to the inverted temperature sequence recorded in similar areas where there is a better control on temperature than

pressure. Such a situation has been described by ZWART (1974) and WILLIAMS & ZWART (1977) for the Seve-Köli nappe of Sweden and a similar explanation based on thrusting has been proposed. While alternative explanations can be found for temperature inversion it is difficult to find an alternative explanation for the pressure inversion so that the data presented here are strong evidence for the general model for the development of inverted metamorphic zonation by thrusting. The history of increasing pressure associated with thrusting is consistent with both metamorphic assemblages and structure having developed in a subduction zone with underplating of internal units by more external ones during Cretaceous times (for further discussion see WILLIAMS & COMPAGNONI, in prep.).

F_2 folds have been interpreted as representing a continuation of crustal shortening after the thrust zone ceased to be active and underplating involved units external to the Sesia rather than occurring within the Sesia itself (WILLIAMS & COMPAGNONI, in prep.). Because the ultimate mutual configuration of units was reached at comparatively low P conditions during F_1 , F_2 formed at low P conditions. This is supported by mineral parageneses that were stable during F_2 (Fig. 4). Isostatic adjustment associated with the thickening and continuing underplating resulted in uplift of the SLZ. As it rose above the general level of its surroundings it was able to settle vertically by spreading laterally. This has been suggested by WILLIAMS & COMPAGNONI, in prep.) as an explanation for the recumbent F_3 folds. The work presented here adds credence to this explanation since the higher parts of a mountain chain are less constrained laterally than the deeper parts which are below the crustal surface. Thus F_3 folding might be expected to be better developed at higher levels in the crust than at lower levels and this is consistent with our observations. A further possible explanation of F_3 is that it is a product of continued crustal shortening after development of F_2 and is in fact due to the 'retrocharriage' of French writers. While this possibility cannot be overruled there is nothing in our structural observations to support it since the style of folding suggests vertical shortening rather than development of recumbent folds in a thrusting environment.

Little can be said from our work about the F_4 deformation. However, this folding may be related to the formation of the 'rootzone' and to the uplift of the SLZ relative to the Ivrea zone.

LANZA (1977) measured the natural remanent magnetization in andesitic dykes in the SLZ that postdate the Lepontine metamorphic event (event III). He found two main directions of magnetization corresponding to dykes in the SE and NW parts of the SLZ (inner and outer group). The two groups are rotated with respect to one another around a horizontal axis that trends 018° , parallel to the Canavese line and the 'rootzone' of the Pennine nappes (MILNES, 1974; KLEIN, 1979). LANZA (1977) argued that the outer group of dykes was still in its original orientation, while the inner group had been reoriented after intrusion. The internal group orientation requires a rotation of 40° anti-clockwise looking north to be

coincident with the external group orientation. LANZA (1977) believed that this difference in orientation is due to a late stage folding that rotated the internal SLZ clockwise looking north.

AHRENDT (1972) found that the SLZ was uplifted at least 3.5 km along the Canavese line after deposition of the andesitic cover, which is considered to be of the same age as the dykes (LANZA, 1977). This uplift may well be related to the rotation effect postulated by LANZA (1977). Such a structure would be analogous to the 'root zone', but the complexity of the SLZ makes it difficult to recognize such a structure. In the present area F_4 folds are generally younger than the andesitic dykes and may be related to the same tectonic event. They vary considerably in orientation as remarked above. However, their axes tend to plunge in the NE quadrant. In conclusion, F_4 folding is possibly coeval with a large scale folding of the SLZ after metamorphic event III that is part of the same structural event that caused the 'root zone' fold (see KLEIN 1979) of the Pennine Nappes. A comparison of the orientations of structures preceding F_4 throughout the SLZ should be undertaken in order to prove the existence of such a large scale structure in the SLZ. The present area is totally covered by the outer group of Lanza and cannot be used alone for such a study. Brouwer, in an unpublished report, Leiden, recognized F_3 folds in an area covered by the inner group of LANZA (1977). The orientation of F_3 axial planes were identical to those in the central SLZ. Thus the major F_4 structure, if existent, must be a complex one.

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