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Alpine basement thrusts in the eastern Seengebirge, Southern Alps (Italy/Switzerland)

By MARKUS EDUARD SCHUMACHER[1])

ABSTRACT

In the basement area of the eastern Seengebirge between the Lake Verbano and Lake Como brittle fault zones of probable Alpine age were mapped and their sense-of-shear was determined mesoscopically. The individual faults can be linked to form a kinematically viable network. This network is characterized by a complex interference of structures caused by W-E and N-S compression. Transfer zones such as the Tamaro and the Maccagno-Tesserete zones connect south- with north-vergent and west- with east-vergent thrusts, respectively. A northern band of dextrally transpressive (Alpe del Tiglio zone) and dextrally transtensive (Musso pull-apart) structures manifest diffusion of movements along the Insubric wrench fault system.

ZUSAMMENFASSUNG

Im Kristallin des östlichen Seengebirges zwischen Lago Maggiore und Lago di Como wurden Bruchzonen auskartiert. Mesoskopische Schersinn-Kriterien im Bereiche bruchhafter Verformung wurden zur Bestimmung der Bewegungsrichtungen verwendet. Die einzelnen Bruchzonen lassen sich zu einem kinematisch funktionsfähigen Netz alpiner Bewegungszonen zusammenhängen. Charakteristisch ist eine komplizierte Interferenz von durch W-E und N-S Kompression bedingten Strukturen. Transferzonen, wie die Tamaro-Zone und die Maccagno-Tesserete-Zone, vermitteln zwischen süd- und nordvergenten bzw. west- und ostvergenten Überschiebungen. Ein nördlicher Streifen von dextral-transpressiven (Alpe del Tiglio-Zone) und dextral-transtensiven (Mussograben) Strukturen dokumentiert die Bewegungsdiffusion an der Insubrischen Linie auf deren Südseite.

Introduction

The relationship of the Southern Alps with the Western Alpine arc is a major problem in Alpine tectonics. To resolve this problem more detailed knowledge is necessary about the position and kinematics of the boundary zone of the Adriatic indenter, as both position and kinematics changed repeatedly during Alpine collision (e.g. LAUBSCHER 1988a). Particularly important are those elements located in the area of transition from the Orobic zone east of Lake Como to the Ivrea zone west of Lake Verbano near the internal hinge of the arc of the Western Alps (Figs. 1, 2).

The Orobic zone represents the northern basement thrust units of the W-E trending, generally south-vergent fold and thrust belt of the Bergamasc Alps (LAUBSCHER 1985; ROEDER 1989; SCHÖNBORN 1990), separated from the Central Alps by the W-E trending Tonale line. In contrast, west of Lake Verbano the Southern Alpine basement of the SW-striking western Seengebirge is bounded by the Canavese line, and

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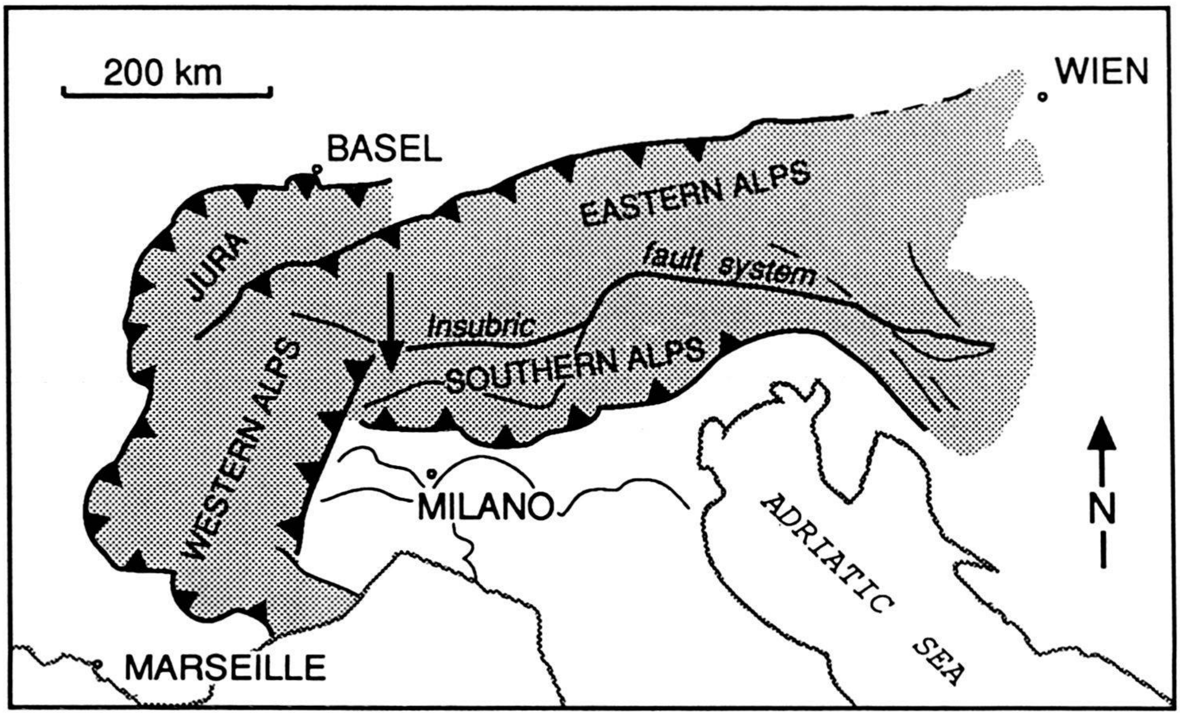

Fig. 1. Location of the Seengebirge in the Alpine chain. The particular location of the discussed area near the internal hinge of the Western Alps is indicated by the arrow.

both west-vergent obduction of the lower crust (Ivrea zone) (Laubscher 1971, 1984, 1988b) as well as post-Oligocene verticalization in conjunction with south-vergent folding and thrusting of the basement have been postulated (Handy 1986; Schmid et al. 1987, 1989). Despite its key position between the two contrasting areas, the eastern Seengebirge between Lake Verbano and Lake Como has remained a missing link of Alpine kinematics. This is certainly due in part to the many difficulties in working in this area. There are few good outcrops because of extensive Quaternary cover and dense vegetation, and easily identified key horizons are lacking. In attempting to analyse Alpine kinematics, one must be aware of numerous inherited pre-Alpine brittle structures, both late Paleozoic and early Mesozoic (Bernoulli 1964; Kälin & Trümpy 1977; Casati 1978; Bertotti 1990). As radiometric data are rare, timing of deformation can only be inferred by extrapolating from areas where the age of the structures is known.

This article is a preliminary digest of the results of my work, which is part of a project aimed at the kinematic analysis of the Southern Alps between Bergamo and Lake Verbano. It concerns the western half of this area, particularly its basement part, the eastern Seengebirge. Its basic mapping and description is due to Bächlin (1937), Graeter (1951), Reinhard (1953) and Spicher (1940). These authors had recognized elements of late, brittle dislocation zones although they made no attempt at mapping them in their own right. However, arguing from the important Alpine thrust belt in the sediments (Pieri & Groppi 1981; Laubscher 1985) it may be expected that an equivalent system should show up as a connected network of brittle faulting in the basement. This was the starting point for my own investigation. Thus my work centers

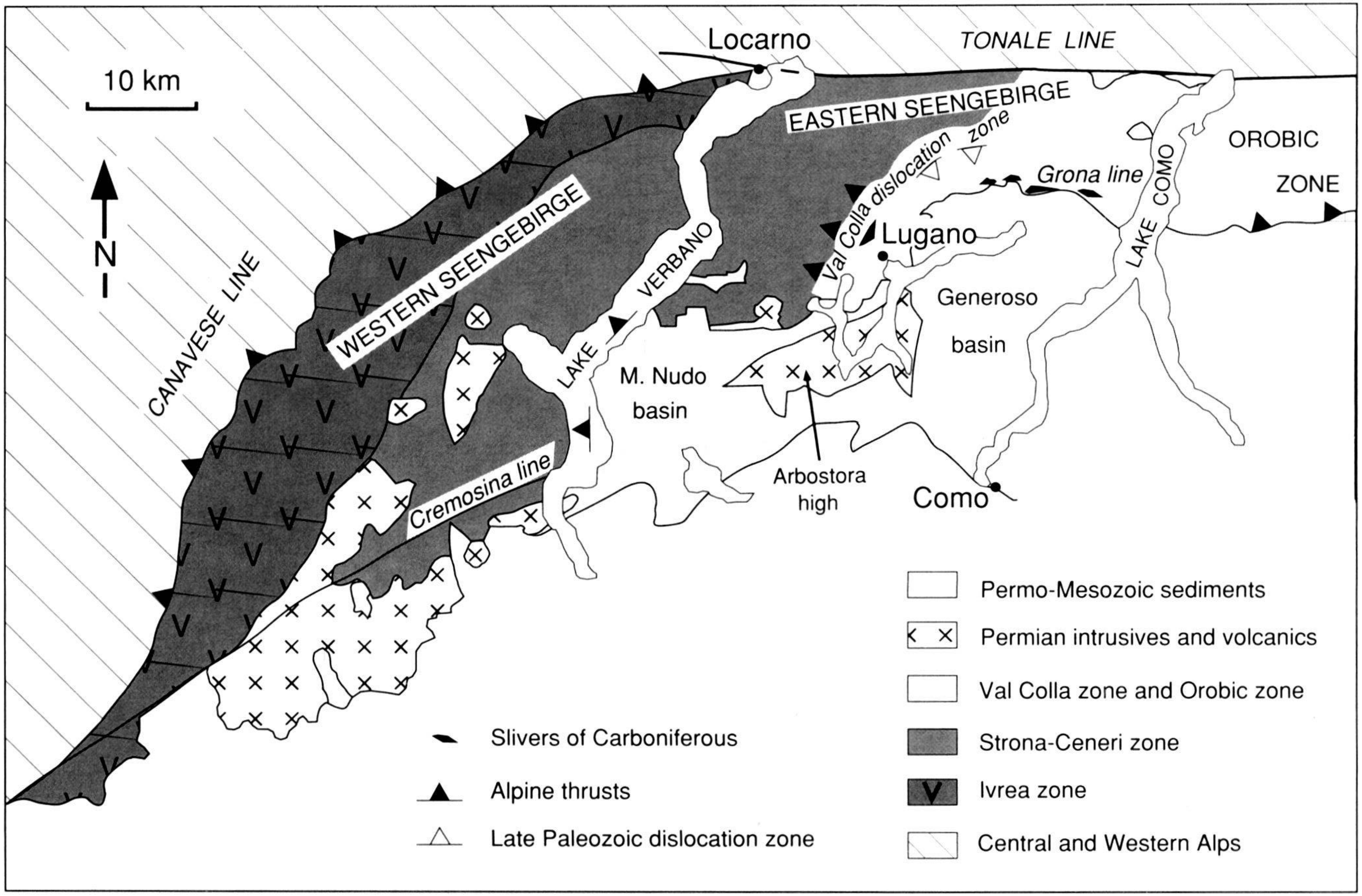

Fig. 2. Simplified map of the Seengebirge showing the main basement units and the adjacent southern Alpine sedimentary cover area (for location see Fig. 1). The basement outcrops of the Seengebirge suggest a cross-section through the deeper parts of the Adriatic crust, showing deeper crustal units to the west.

on an investigation of faults for which arguments in favor of an Alpine age exist. This is particularly so where tectonics in the Mesozoic sedimentary cover may be followed into brittle fault zones in the basement. To identify a network of brittle dislocation zones in the basement a special approach was chosen. Starting from elements already documented in previous publications, efforts were made to remap the dislocation zones in following them as far as possible, and also to pay special attention to such zones not previously recognized. In addition to mapping, sense-of-shear was established wherever recognizable in the field, in order to find out whether a consistent pattern was hidden in the rather unordered, or even chaotic distribution of faults reported in the past. The final goal was to order the mapped elements into a kinematically viable network that would reveal something about the role of this area in Alpine tectonics. No attempt was made, however, at a statistical approach to the distribution of structural elements as it was deemed of secondary importance for the solution of the problem at hand. The network includes a number of possibly late Paleozoic and early Mesozoic elements which have probably been reactivated during Alpine deformation.

In the basement of the eastern Seengebirge two main units are distinguished in the classical literature (REINHARD 1964; BORIANI et al. 1977). The Ceneri zone consists of amphibolite facies granitic gneisses, paragneisses, amphibolites and ultramafics. The Val Colla zone comprises micaschists, amphibole-bearing gneisses and phyllites tectonically associated with aplitic gneisses (Gneiss chiari or Bernardo Gneiss). In this zone, the amphibolite facies assemblages are overprinted by later greenschist facies metamorphism. The boundary between the Ceneri and Val Colla units is formed by greenschist mylonites that were interpreted by REINHARD (1964) as comprising a Paleozoic dislocation zone. However, inspection of the published maps of the area reveals that this "Val Colla dislocation zone" consists of two different segments (see Fig. 2). The southern segment (along the western slope of the Vedeggio valley) shows imbrications of Carboniferous conglomerates and aplitic gneisses. The mylonites dip to the west, and the Ceneri zone overlies the Val Colla zone. Along the northern segment (along the northern slope of Val Colla) the Ceneri zone lies beneath the Val Colla zone, and the south-dipping mylonite zone in between shows no imbrication with either Carboniferous conglomerates or aplitic gneisses. Carboniferous conglomerates and aplitic gneisses, however, are associated with the fault rocks along the Grona line (Fig. 2).

Sense-of-movement determination on basement fault using mesoscopic brittle deformation structures

There exist a number of sense-of-shear criteria for brittle deformation (see GROSHONG 1988, p. 1346–1347 for a recent review). Fault-surface features may be distinguished from fault-zone features. The mesoscopic fault-surface features used are summarized in Fig. 3. Synthetic extensional shears and drag folds proved to be very useful fault-zone features. Synthetic extensional shears (Fig. 4) are a brittle analogue of shear bands (or extensional crenulation cleavage) in mylonite zones. Figure 5 shows a folded cataclasite with fold-vergence indicating top to the left sense-of-shear. I interpret these features as sinistral drag folds (NEVIN 1953, p. 74) within a cataclastic zone.

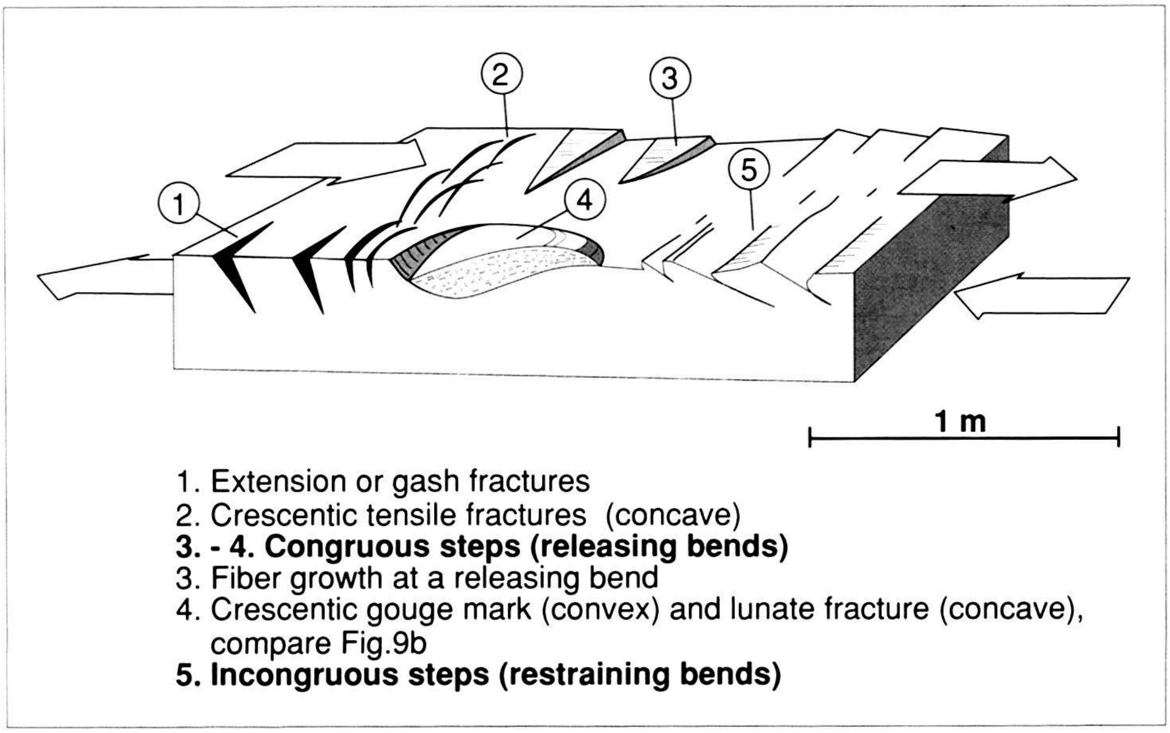

Fig. 3. Fault-surface features diagnostic for a dextral sense-of-shear. Crescentic features are concave and convex in the direction of slip of the opposing face, respectively.

Sometimes sense-of-shear phenomena are ambiguous. Features of the latest movements are usually best preserved. In some cases earlier kinematic phases left traces that allow a chronological order to be inferred (e.g. multi-striated fault surfaces). In order to obtain a coherent result, the kinematic classification has to be done by extensive consideration of mutually independent criteria at numerous places along the fault.

The network of brittle basement faults in the eastern Seengebirge, geometry and kinematic implications

Figures 6 and 7 show the data obtained by mapping in a simplified form. The full documentation including a detailed map of the observed features accompanied by extensive comments will be given in my thesis. Figure 6 shows the actual geometry and orientation of the main cataclastic fault zones, and Figure 7 provides additional kinematic data obtained by mesoscopic sense-of-shear determination. The figures reveal some of the difficulties encountered by the mapping approach. Although many more cataclastic fault zones were found than known previously, there are still many gaps in the network and for a kinematic analysis it is necessary to interpolate through domains of no observation. Still, even in this first fragmentary form the maps as summarized in Figure 8 reveal some rather continuous features. These are, beginning in the northwest and following the numbers in Figure 8:

1) The Gambarogno thrust is a well-known south-vergent Alpine thrust (Überschiebung von Indemini, Bächlin 1937). Its western continuation is poorly exposed,

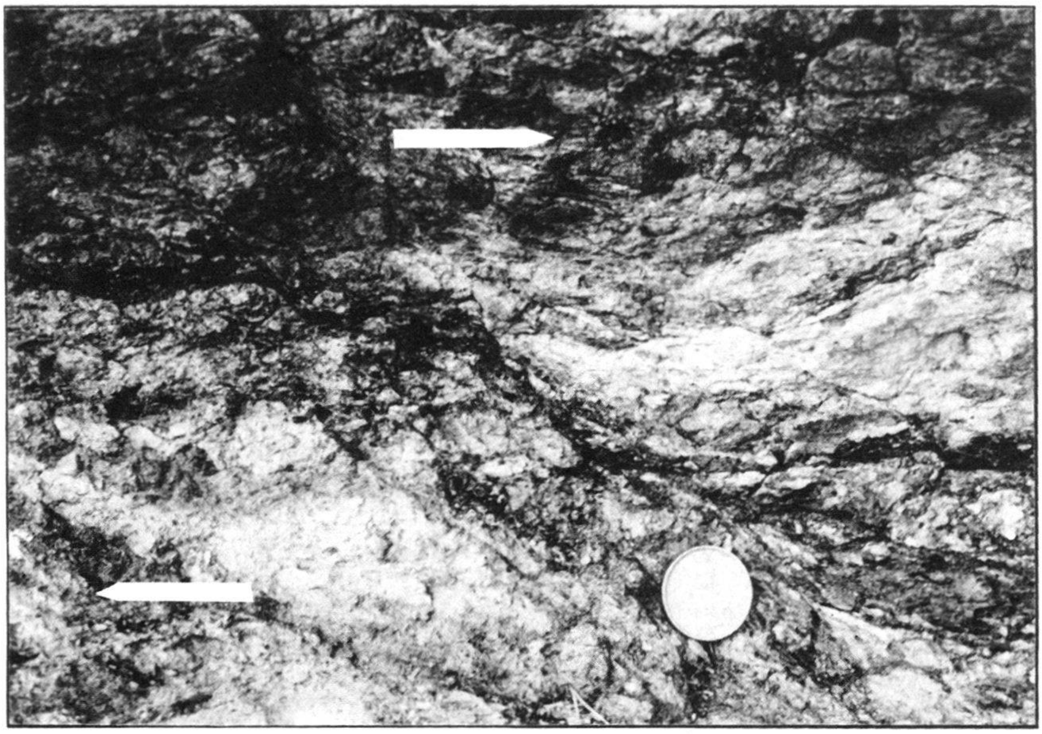

Fig. 4. Synthetic extensional shears indicating dextral shear. As the fault is subhorizontal the hanging wall moved to the south. Monteviasco thrust near Alpe Polusa (coordinates of Swiss topographic map 708 170/102 830). Coin is 27 mm in diameter.

Fig. 5. Drag folds caused by sinistral shear within a cataclasite zone. Gazzirola fault (coordinates of Swiss topographic map 726 170/108 510). Coin is 27 mm in diameter.

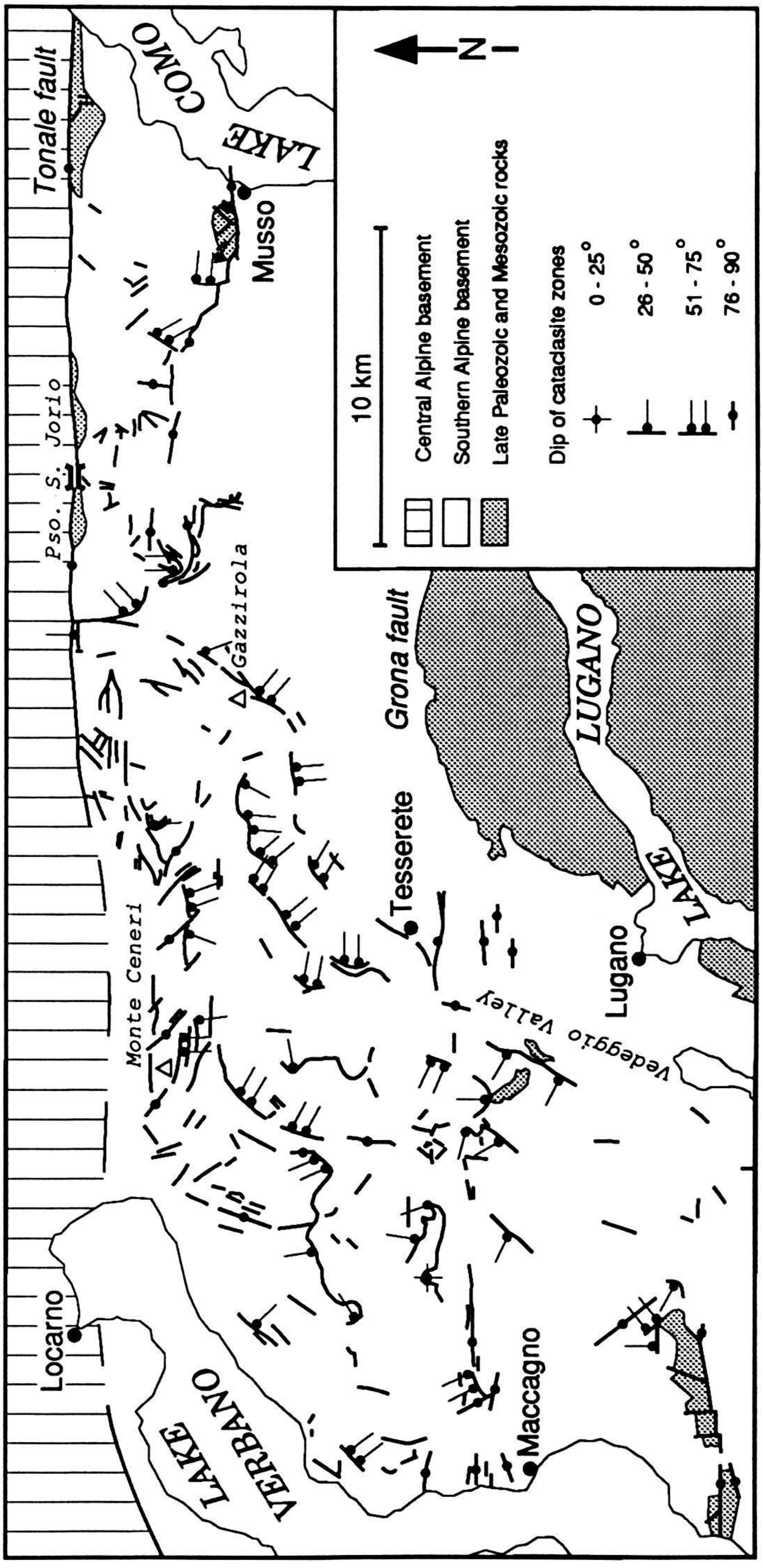

Fig. 6. Geometry and orientation of the cataclastic fault zones in the eastern Seengebirge.

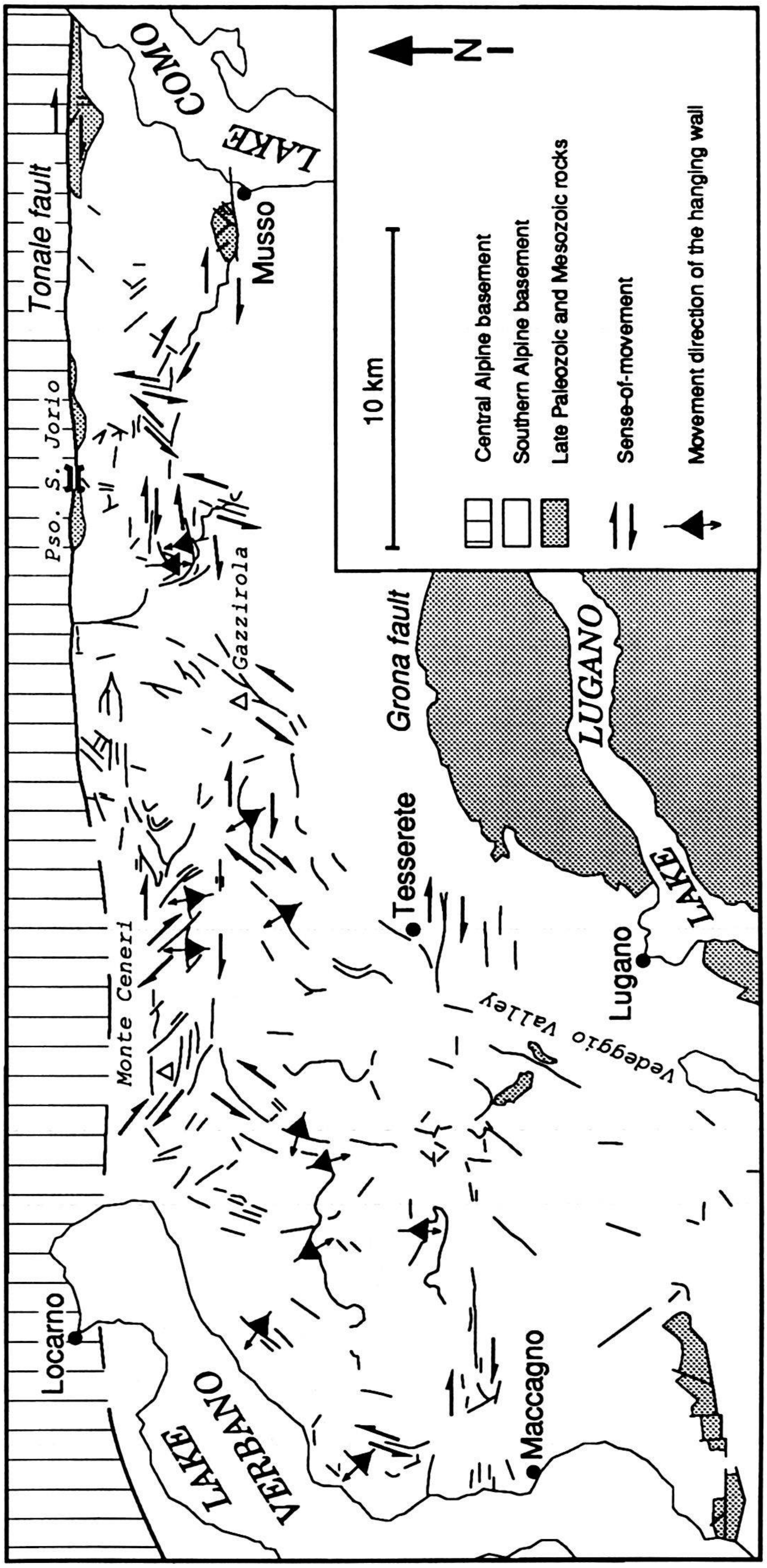

Fig. 7. Sense-of-movement of the cataclastic fault zones in the eastern Seengebirge determined on the basis of mesoscopic brittle structures.

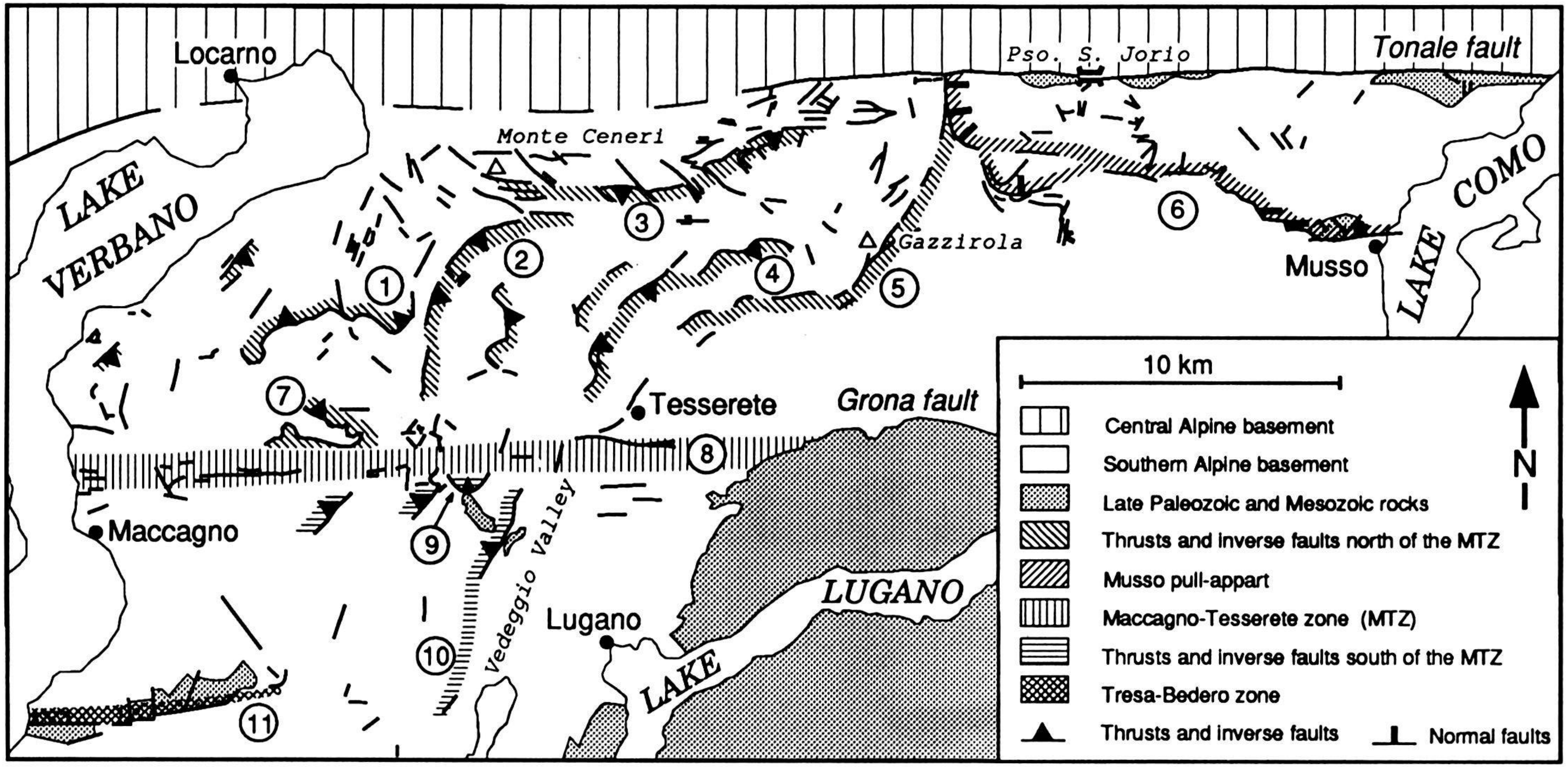

Fig. 8. The main elements of the network of brittle faults in the eastern Seengebirge extracted from the data in Figures 6 and 7. 1 = Gambarogno thrust, 2 = Tamaro transfer zone, 3 = Alpe del Tiglio thrust zone, 4 = Monte Bigorio-Gola di Lago and Cima della Screvia thrust zones, 5 = Gazzirola fault, 6 = Musso pull-apart system, 7 = Monteviasco thrust, 8 = Maccagno-Tesserete zone, 9 = Arosio thrust, 10 = Vedeggio thrust, 11 = Tresa-Bedero zone.

but there are several E- and SE-dipping, W- and NW-vergent cataclastic zones in the mountainside east of Lake Verbano that, if connected with the Gambarogno thrust suggest a later synclinal folding of the thrust. To the east the Gambarogno thrust may be followed into the sinistrally transpressive Tamaro transfer zone.

2) The Tamaro transfer zone is a subvertical to steeply SE-dipping fault zone that is well exposed along the Tamaro road, for example in the Valle della Luna (Fig. 9). As to kinematics this implies that to the east, shortening accomodated by the Gambarogno thrust was transferred sinistrally northwards into the Monte Ceneri area. There the Tamaro transfer zone joins the south-dipping Alpe del Tiglio thrust zone.

3) The Alpe del Tiglio thrust is an E-W trending, north-vergent, dextrally transpressive thrust zone. Sense-of-shear can be determined on several faults near Alpe del Tiglio (east of Monte Ceneri in Fig. 7). The thrust zone or zone of inverse faults is segmented by a number of NW-SE trending en échelon faults, synthetic with respect to the dextral Tonale fault (Fumasoli 1974; Heitzmann 1987).

4) The Monte Bigorio-Gola di Lago and Cima della Screvia thrust zones form an arcuate west- to north-vergent thrust system, cut by a series of dextral transverse faults, within an arc of basement units between Tesserete and Isone. The Monte Bigorio-Gola di Lago thrust zone, the southwestern segment, dips E to SE and verges W to NW, whereas the Cima della Screvia thrust zone, the northeastern segment, is a more or less steep SE- to S-dipping, dextrally transpressive, N to NW vergent fault. At some places bending or folding of cataclastic zones and the development of narrow kink folds in the hinge can be observed (Fig. 10). The new observations concerning the Cima della Screvia zone are at variance with Spicher (1940) who mapped a thrust fault in this area but described it as a south-vergent thrust.

5) The Gazzirola fault is a steep SE-dipping sinistral fault (Fig. 5) within the verticalized Late Paleozoic(?) Val Colla mylonites. It trends in a NNE direction towards the Tonale fault. In the north it follows partly the boundary between the Val Colla and the Ceneri zones, whereas in the south it seems to correspond to a W-E trending zone of cataclasite within the Val Colla zone.

6) The Musso fault appears further east near Lake Como 5 km south of the Tonale fault. It trends W-E and is vertical to steeply north-dipping. This geometry is well defined by a subvertical fault contact between a Paleozoic marble band (also subvertical) to the south and nearly flat-lying Upper Triassic Dolomia Principale (Repossi 1904) to the north. The bottom of this relict of the Southern Alpine Mesozoic cover, in turn, seems to be in tectonic contact with basement on the north side of the Musso fault. This bottom fault is apparently cut off by the Musso fault. The western continuation of the Musso fault within the basement is problematic. Mapping revealed two main W-E trending faults exhibiting both strike-slip and dip-slip features indicating a dextral down movement of the northern basement blocks. The two faults are thought to be part of a complicated dextral transfer system, that cuts through earlier south-ver-

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Fig. 9. Tamaro transfer zone. a) Fault-surface in the Valle della Luna, coordinates of Swiss topographic map 712 580/108 850. The arrow indicates location of Fig 9b. b) Crescentic gouge mark (right) and lunate fracture (left) indicating movement of the eroded upper block to the right. The gouge overhangs the void in the direction of slip of the opposing face and forms a congruous accretion step. Handle of the hammer on the lower right is approximately 50 cm long.

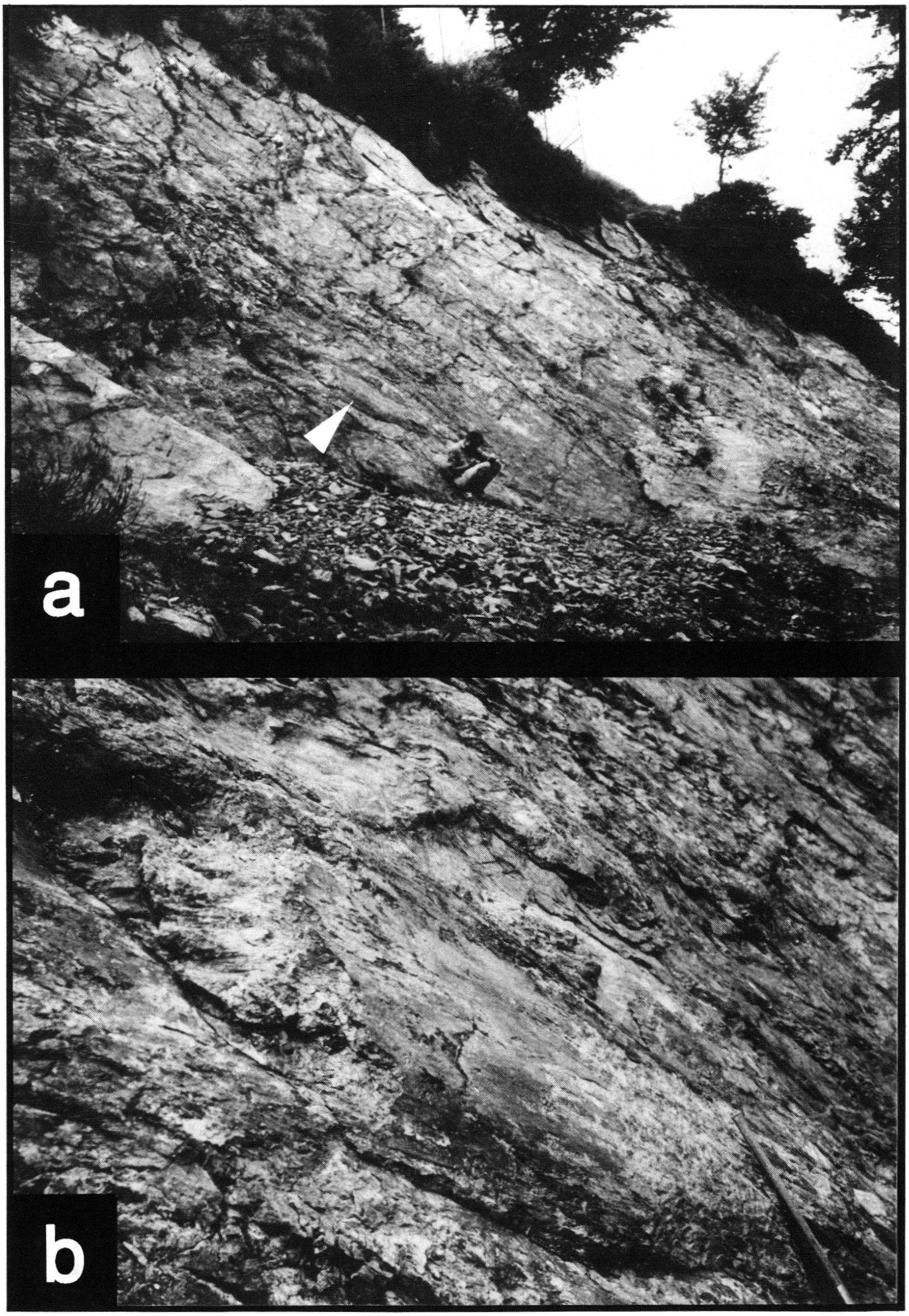
a
b

Fig. 10. Narrow kink folds which formed in the hinge of an Alpine fold south of Monte Bigorio, coordinates of Swiss topographic map 717 000/140 650. Pencil is 14 cm long.

gent thrusts. At its western end this system turns to the north where it joins the Tonale fault, and, at its eastern end, the Musso fault. These data suggest that in the west dextral movements along the Musso fault were transferred to the north at a releasing step (e.g. as in Christie-Blick & Biddle 1985 and Harding et al. 1985).

7) The Monteviasco thrust is a well exposed south-vergent thrust segment on the southeastern side of the Veddasca valley. The south-vergent movement of the hanging wall is well documented by extensional shears (Fig. 4) and south-vergent drag folds.

8) The Maccagno-Tesserete zone is composed of a whole series of steep, W-E trending fault segments further south. To the east, this rather diffuse zone eventually joins the Grona fault. North of the Maccagno-Tesserete zone there are ESE dipping and WNW vergent thrusts, whereas to the south there are WNW dipping and ESE vergent thrusts. Thus, in spite of its diffuse nature, the Maccagno-Tesserete zone is obviously an important transfer zone.

9) The Arosio thrust segment is a south-vergent thrust that turns up to the east. A possible continuation towards the SSW in the Malcantone area remains unclear at present. It seems probable, however, that the Arosio thrust represents a south-vergent thrust that was folded later during E-W compression.

10) The Vedeggio thrust is the main ESE vergent thrust south of the Maccagno-Tesserete zone. It follows the western slope of the Vedeggio valley between Bedano and Cademario, where outcrops can be found along the roads. In this area it coincides

approximately with the "Taverne-Caslano Line" mapped by Graeter (1951). However I have found no continuation of the thrust at Monte Caslano and therefore prefer another name for the thrust.

11) The Tresa-Bedero zone is another conspicuous W-E trending fault zone. It consists of a band of Permian and Lower to Middle Triassic sediments wedged into the basement (Harloff 1927). This complexly fractured wedge shows signs of both strike-slip movement and squeezing in NNW-SSE direction. Neither to the west across Lake Verbano nor to the east of the Dumentina fault (see Fig. 11) can a direct continuation of the Tresa-Bedero zone be observed.

Towards modelling Alpine kinematics of the eastern Seengebirge

The schematic tectonic map of the eastern Seengebirge in Figure 11 is an attempt at connecting the individual elements of Figure 8 into a kinematically viable network. In doing this, the diagnosed kinematics of the individual structures have to be integrated with kinematic requirements of the adjacent areas (Pieri & Groppi 1981; Laubscher 1985; Schmid et al. 1989; Zingg et al. 1990) and of the regional tectonic

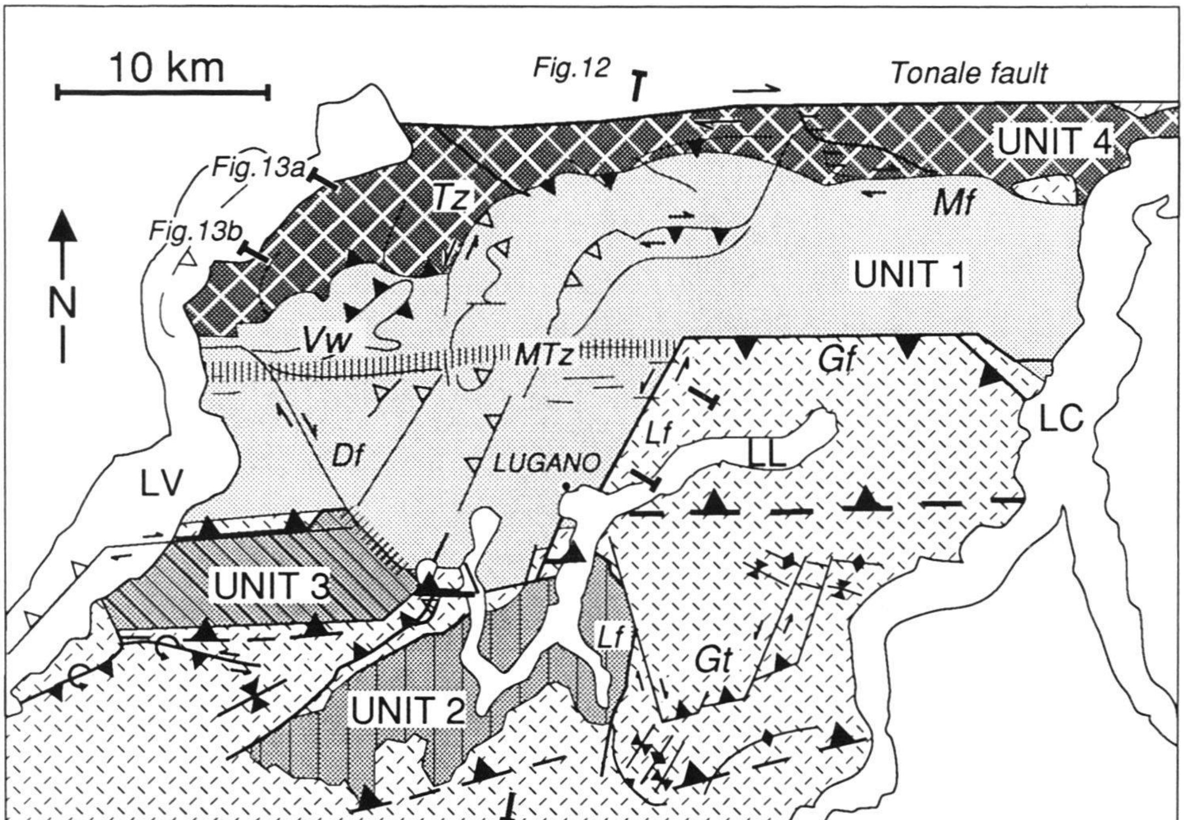

Fig. 11. Schematic tectonic map of the eastern Seengebirge. Dark barbs: south- and north-vergent thrusts; dark barbs and bent arrows: overturned north-vergent thrusts; light barbs: east- and west-vergent thrusts; random dashes: Mesozoic cover. Subsurface structures are marked by broken lines. Df = Dumentina fault, Gf = Grona fault, Gt = Generoso thrust, LC = Lake Como, Lf = Lugano fault, LL = Lake Lugano, LV = Lake Verbano, Mf = Musso fault, MTz = Maccagno-Tesserete zone, Tz = Tamaro transfer zone. (Hatching see Fig. 12).

framework (e.g. Laubscher 1983, 1988a, 1990a). In order to provide a three-dimensional view, the map of Figure 11 is supplemented by the cross-sections in Figures 12 and 13. Finally, the sequence of movements is sketched in Figure 14.

In the map Figure 11, four tectonic units are distinguished in the basement.

Unit 1 is regarded as the western continuation of the upper Orobic basement thrust unit (San Marco unit of Schönborn 1990). The southern front of this oldest thrust unit is believed to lie under the sediments of the northern Generoso basin (Laubscher 1985). The northern Generoso basin was steepened and back-thrust along the Grona fault probably during a later phase, when the northern segment of the Lugano fault acted as a sinistral transfer zone (for the detailed geometry of the Alpine imbricated northern part of the Generoso basin and the inherited Mesozoic structures see Lehner 1952 and Bertotti 1990). To the south and west of Lugano a repeatedly interrupted band of Permian and Lower to Middle Triassic sediments (M. San Salvatore, M. Caslano, Tresa-Bedero zone) marks the southern limit of unit 1 (frontal ramp fold).

In analogy to the basement anticlines of the Bergamasc Alps (Orobic and Trabuchello anticlines) I interpret the Arbostora anticline as a frontal ramp-fold of a lower basement thrust unit 2 (see Fig. 12).

West of Lake Lugano the out-of-sequence unit 3 is placed between unit 1 and unit 2. At its front it caused verticalization or even overturning of the sediments in the Monte Nudo basin (van Houten 1929). The geometrical relation (younger upon older) of these sedimentary units can be explained by overturning of older, north-ver-

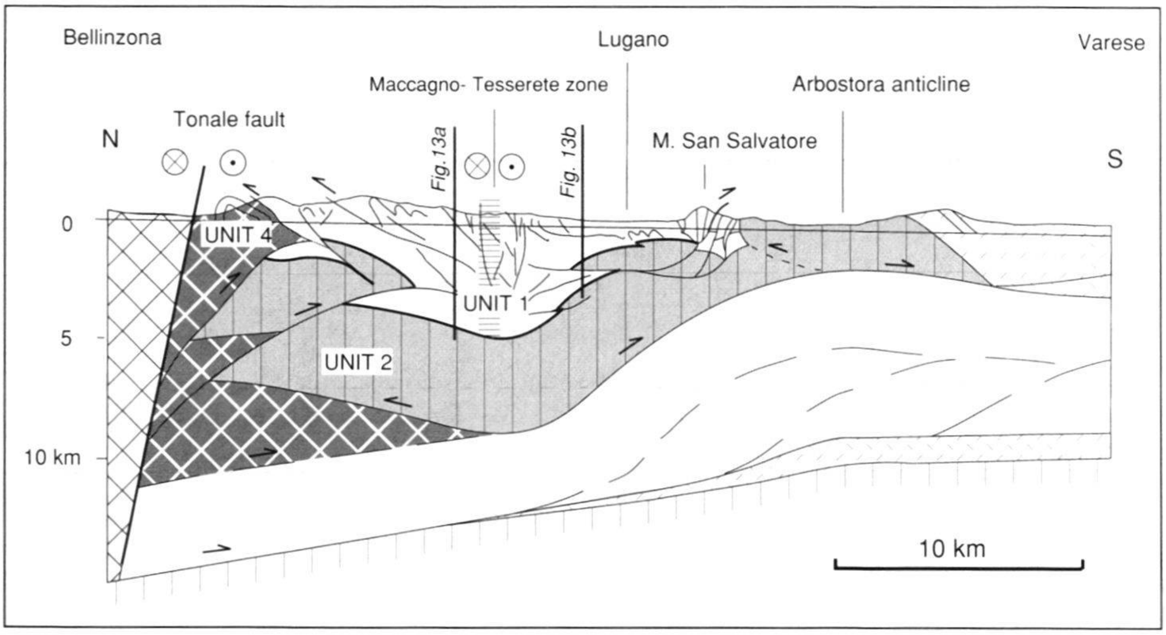

Fig. 12. Cross-section through the Southern Alps between Bellinzona and Varese (for location see Fig. 11). Distinguished are pre-Adamello (light grey and medium grey with vertical hatching), Insubric (dark grey with white cross-hatching) and Lombardic elements (white). Sediments are random dashed and the Central Alpine area north of the Tonale fault is black cross-hatched. The location of the basal autochthonous (Adriatic plate) marked by vertical hatching on white ground can be estimated from the seismic data of the Swiss geotraverse (Frei et al. 1989) in connection with the subsurface data from the Po plain (Pieri & Groppi 1981). The thickness of the basement units is estimated to be about 4 km, a value, which is reported from many places.

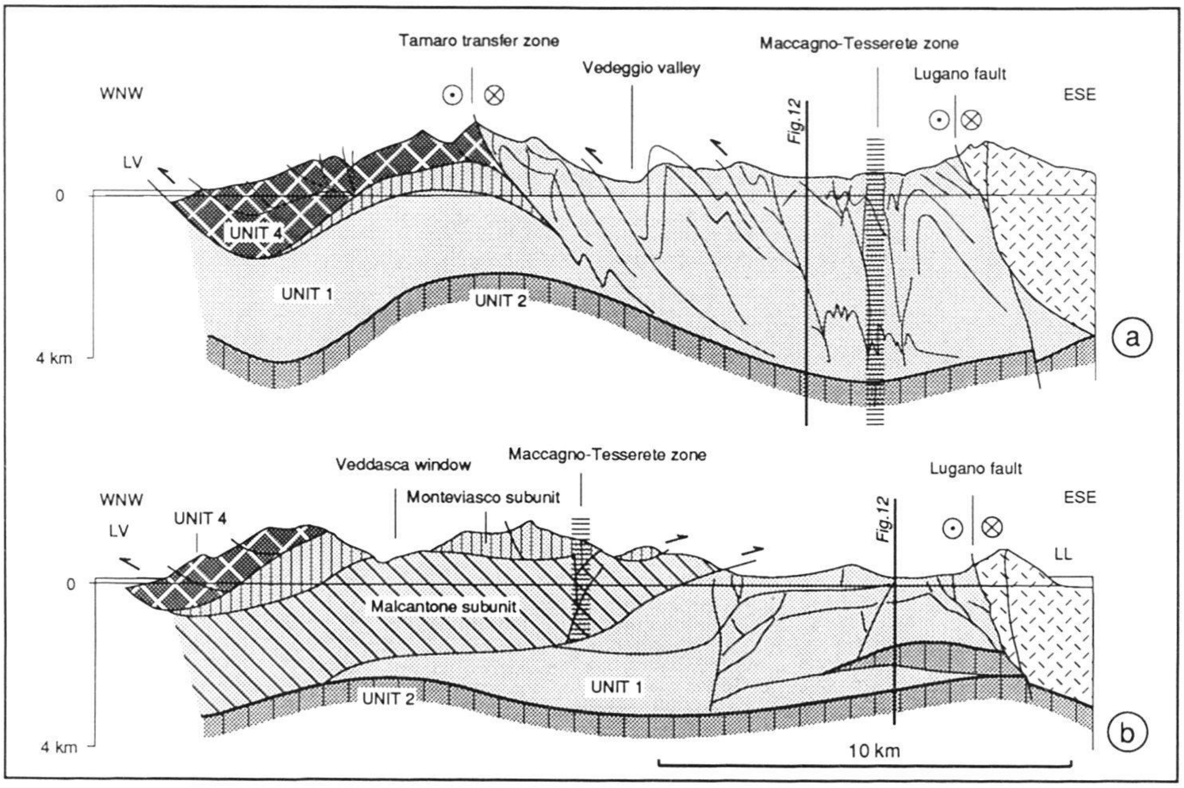

Fig. 13. Cross-sections through the upper units of the eastern Seengebirge between lake Verbano (LV) and lake Lugano (LL) (for locations see Fig. 11). Grey: pre-Adamello tectonics; narrow vertical hatching: Monteviasco subunit; oblique hatching: Malcantone subunit; white cross-hatched: Insubric tectonics; random dashes: sediments. a) through the Tamaro zone and the west-vergent area north of the Maccagno-Tesserete zone. b) through the Veddasca window and the east-vergent area south of the Maccagno-Tesserete zone.

gent thrusts or inverse faults. At the same time the Arbostora anticline (unit 2) acted as an oblique lateral obstacle causing sinistral transpression.

Unit 4 comprises a belt of transpressive and transtensive deformation due to late wrench fault tectonics along the Insubric line (Laubscher 1990b).

The interference of structures caused by N-S and W-E compression, respectively, is the most striking feature of the eastern Seengebirge. It is at least partly an expression of the adaptation of the western Southern Alps to the internal hinge of the arc of the Western Alps. For several fault zones such as the Lugano fault (Bernoulli 1964), the Tresa-Bedero zone and the Tamaro zone it is evident (stratigraphic control) or plausible (transpression zones demand pre-existent inhomogenities, geometric orientation is analogous to older, well established regional fault directions) that they were inherited earlier Alpine or/and pre-Alpine structures with various kinematic functions (see Fig. 14) during Alpine deformation. It should not be forgotten here to take into account reorientation of earlier structures by later rotation and folding (e.g. folding of earlier Alpine thrusts along approximately ENE-WSW trending axis in the area between Locarno and Tesserete). A more detailed analysis of this interference is the subject of current work but two ideas have emerged so far:

The Seengebirge west of lake Verbano may be visualized as an east-vergent thrust with the Cremosina line as a dextral transfer fault to the south (Boriani & Sacchi

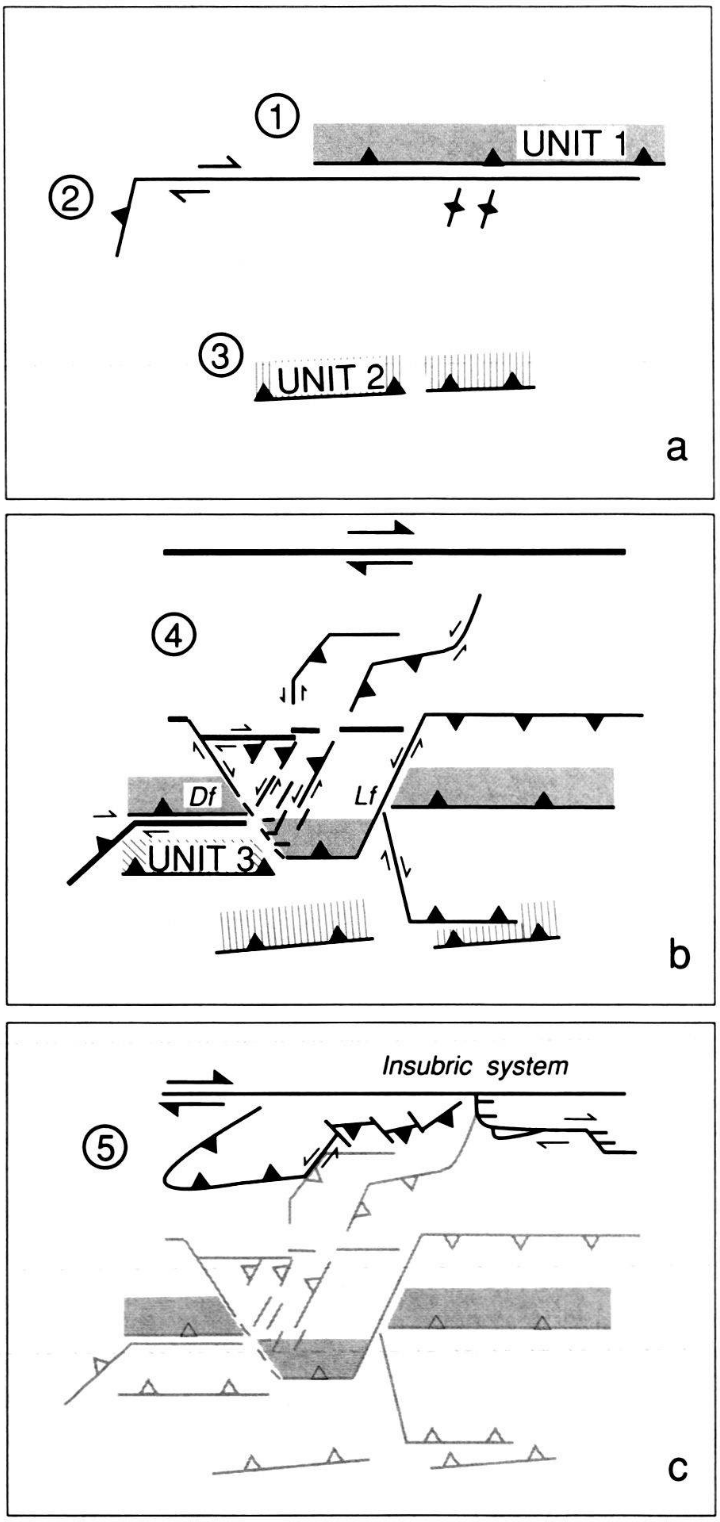

Fig. 14. A possible sequence of Alpine movements in the eastern Seengebirge. a) phase 1–3 (Orobic phase): 1. thrusting of unit 1, 2. early E-vergent thrusting, 3. thrusting of unit 2. b) phase 4 (phase of interference): S-vergent out-of-sequence thrusting, N-vergent back thrusting, E-vergent thrusting and W-vergent back thrusting. c) phase 5 (Insubric phase): late wrench fault deformation along the Insubric system (older, kinematically inactivated structures to the south are marked in grey).

1974). East of Lake Verbano east-vergent thrusting was transferred along the dextral Tresa-Bedero zone to the eastern front of the Malcantone block (Fig. 13b). The Malcantone block is limited in the north by the Maccagno-Tesserete zone, another dextral transfer zone. North of this zone, W-E compression was absorbed by W-vergent thrusts and folds (Fig. 13a).

The Insubric wrench fault system (Laubscher 1983, 1988a, 1990b) influenced the Seengebirge north of the Maccagno-Tesserete zone. Transtensive features like the Musso pull-apart were subsequently compressed. Wedging of basement units that split off from the Insubric wrench fault system may be responsible for steep folding and north-vergent back thrusting of the northern part of the Seengebirge (Fig. 12).

A possible sequence of five phases of Alpine movements resulting in the network of Figure 11 is summarized in Figure 14.

Phase 1: The oldest movements took place along the south-vergent thrust of unit 1. It is connected with the Orobic thrust system, which was sealed by the Adamello intrusion (Brack 1981). Hence phase 1 is older than 30–43 my and could well be Cretaceous (Eo-Alpine, Doglioni & Bosellini 1987).

Phase 2: Early east-vergent thrusts in the western Seengebirge were dextrally transferred to the east along the Tresa-Bedero zone near the front of unit 1. A connection with early NNE-SSW trending fold axes in the southern Generoso block (Bernoulli 1964, p. 126) is possible.

Phase 3: South-vergent in-sequence thrusting of unit 2 with the Arbostora anticline as a frontal ramp-fold began before interference with elements due to E-W compression became important.

Phase 4: During phase 4, east- and west-vergent thrusts interfered with south- and north-vergent out-of-sequence thrusts. Dextral transfer of east-vergent thrusting along the Tresa-Bedero Zone went on while the front of unit 1 was dissected by pushing the basement wedge between the Dumentina fault (Df) and the northern part of the Lugano fault (Lf) to the south. As a consequence of transpression along the northern margin of the Adriatic indenter various basement wedges were emplaced beneath unit 1 and unit 2 (see Fig. 12).

Phase 5: Finally, dextral movements along the Insubric wrench fault system (Tonale fault and precursors) diffused several kilometers into the Southern Alps and, like the latest deformations, affected the northernmost belt of the eastern Seengebirge. Transpressive and transtensive domains along the Insubric fault system changed in space and time.

Phases 1–3 are supposed to belong to the Orobic phase (Laubscher 1990a), whereas phase 5 is believed to comprise later stages of the Insubric phase (Laubscher 1990a, 1990b). Phase 4 lies in between, however, deformation subsumed under this phase of interference may be due mainly to earlier stages of the Insubric phase. During the Late Miocene Lombardic phase (Laubscher 1990a) the most frontal parts of the Southern Alps (Milan belt) as documented by subsurface data from the Po plain (Pieri & Groppi 1981) were formed meanwhile the Seengebirge and the Insubric fault system were passively transported to the south and became kinematically inactivated. However, deformation of the Gonfolite Lombarda (southern Alpine "molasse") at the front of unit 2 documents post-Oligocene/Lower Miocene deformation for this more internal part of the Southern Alps as well (Bernoulli et al. 1989). For a short summary of further stratigraphic indications for Cretaceous, Eocene, Oligocene and Miocene deformations see BERNOULLI et al. 1990.

Conclusions

In a first step towards an analysis of Alpine kinematics in the eastern Seengebirge, structures in the sedimentary cover were pursued into brittle fault zones in the basement, and a kinematically viable network of such fault zones was synthesized as a basis for further modelling. W-E compression at the front of the Adriatic indenter in the Western Alps affected the Southern Alps as far east as the Vedeggio valley and dextral wrench fault tectonics along the northern boundary of the Adriatic indenter diffused southwards into the Southern Alps and was accompanied by other W-E trending fault zones even further to the south.

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