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Strike-slip contractional stepovers in the Southern Alps (northeastern Italy)

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Key words: Italy, Southern Alps, strike-slip faults, transpression, Valsugana fault, Schio-Vicenza fault

ABSTRACT

Strike-slip pop-ups are seldom recognized because they are sites of rapid uplift and erosion. In addition, they can easily be confused with shortening structures of different age and significance. In the Neogene central-eastern Southern Alps, the western termination of the ENE-trending Valsugana thrust is located at the intersection with the suborthogonal Calisio Line, which is an inverted Permian normal fault. Just west of the Calisio Line the Monte Cornetto di Folgaria structural and topographic high is a large-scale pop-up localised at the restraining stepover between the sinistral Calisio and Schio-Vicenza strike-slip faults, which trend at high angle to the thrust belt. This pop-up developed in post-Tortonian times, when the kinematics of these faults changed from dextral to sinistral. At a smaller scale, strike-slip restraining and releasing stepovers of pre-existing steep fault segments show that these inherited faults are kinematically linked and constitute an important mechanical anisotropy responsible for strain partitioning into strike-slip and dip-slip displacements. The analysis of the Monte Cornetto di Folgaria pop-up and related minor structures suggests that in fold-and-thrust-belts affected by strike-slip faults at high angle to the belt axis, contractional structures related to strike-slip restraining bends and stepovers may be more common than usually thought.

RIASSUNTO

I pop-up correlati a curvature e stepover di faglie trascorrenti sono raramente riconoscibili poiché sono sede di veloce sollevamento ed erosione. Inoltre essi possono essere facilmente confusi con strutture di raccorciamento di età differente, perché possono essere interpretati come ondulazioni di strutture non cilindriche. Nel settore centro-orientale delle Alpi Meridionali, il sovrascorrimento della Valsugana termina verso ovest a ridosso della Linea del Calisio (NO-SE), che è una faglia normale permiana caratterizzata da riattivazioni polifasiche successive. Appena a ovest della Linea del Calisio, l'alto topografico e strutturale del Monte Cornetto di Folgaria è un pop-up a scala plurichilometrica, sviluppatosi nello stepover contrazionale tra le faglie trascorrenti del Calisio e Schio-Vicenza, orientate ad alto angolo rispetto alla catena. Il pop-up del Monte Cornetto di Folgaria si formò nel post-Tortoniano, quando la cinematica di queste faglie cambiò da destra a sinistra. A scala più piccola, stepover contrazionali ed estensionali tra segmenti di faglie subverticali ereditate dimostrano come queste siano cinematicamente collegate tra loro. Queste anisotropie preesistenti sono responsabili della partizione della deformazione tra faglie trascorrenti pure ed inverse. L'analisi del pop-up e delle strutture minori ad esso correlate suggerisce che, nelle catene interessate da importanti faglie trascorrenti subortogonali, le strutture contrazionali associate a quest'ultime siano più diffuse di quanto normalmente si pensi.

1. Introduction

Strike-slip systems exhibit typical structures accommodating transfer of movements between different fault segments. Contractional (restraining) and extensional (releasing) structures developing at stepovers (Fig. 1a) have been described from field studies (e.g. Wilcox et al. 1973; Aydin & Nur 1982) and analogue models (e.g. Dooley & McClay 1997; McClay & Bonora 2001). Segmentation is often representative of early stages of a growing fault, which later preserves bends witnessing the linkage of different segments (Fig. 1b). Aydin & Nur (1982) listed 62 pull-aparts against 7 pop-ups in their worldwide compilation of strike-slip extensional and contractional structures. It is likely that this ratio has not changed. The reason is certainly due to the different potential of preservation. While pull-aparts are sites of subsidence and sedimentation, pop-ups are sites of uplift and erosion. Moreover, folds and reverse faults of contractional stepovers may likely be confused with other shortening structures in strike-slip systems developing at a high angle to fold-and-thrust-belts. Indeed, the trend of both the contractional and transpressive structures can be nearly the same and eventual slight differences in orientation may be interpreted as undulations of non-cylindrical structures.

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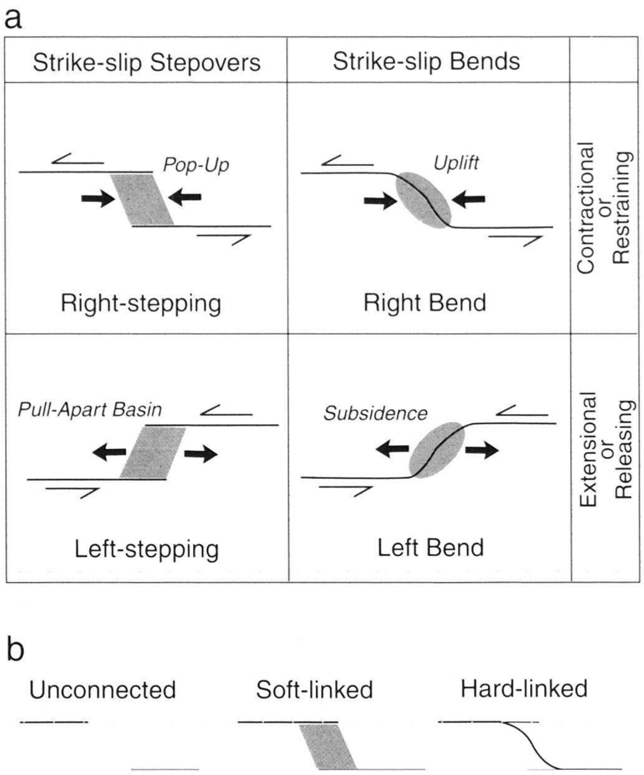

Fig. 1. Schematic diagram illustrating: (a) contractional and extensional stepovers and bends occurring in a strike-slip fault system with sinistral kinematics, (b) evolution of a growing strike-slip fault from two unconnected segments to a single fault with a double bend.

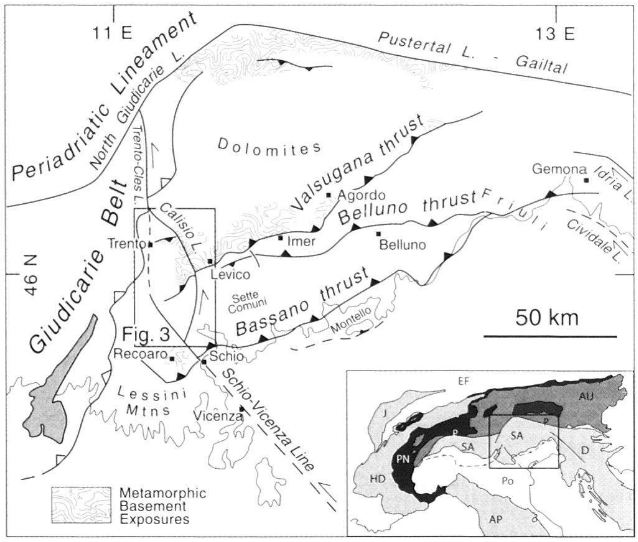

Fig. 2. Tectonic map of central-eastern Southern Alps showing the Messinian-Pliocene kinematics of the NW-trending strike-slip faults. Insets: principal tectonic domains of Alps. European Foreland (EF), Jura (J), Helvetic-Dauphinois (HD), Penninc (PN), Austroalpine (AU), Southern Alps (SA), Po Plain (Po), Appennines (AP), Dinarides (D), P = Periadriatic Lineament.

The Southern Alps are a south-vergent fold-and-thrust belt, separated from the Alpine collisional wedge by the Periadriatic Lineament, and extend southwards to the Padane plane where their frontal thrusts are buried under the Quaternary alluvial deposits (Bigi et al. 1990) (Fig. 2).

The aim of this paper is to unravel the role of the recent strike-slip activity of inherited faults in developing the transpressional structure of Monte Cornetto di Folgaria, in the central-eastern Southern Alps (NE Italy) (Fig. 2 and 3). This structure is located at the western tip of the Valsugana thrust, one of the main regional thrust faults, and is sometimes interpreted as the lateral ramp of this fault (Bosellini & Doglioni, 1986; Castellarin et al., 1992). This work shows that the Monte Cornetto di Folgaria could be better explained as a topographic and structural culmination related to a large-scale (over 10 km wide) pop-up of a strike-slip system which strikes at a high angle to the Southalpine thrust belt.

In our opinion Monte Cornetto di Folgaria is an outstanding example of a large-scale pop-up masked inside a fold-and-thrust belt. The correct interpretation of the uplift structure is a question of regional significance and may shed light on the importance of pop-ups.

2. Geological setting

The Southern Alps are one of the best preserved continental margins in orogenic mountain ranges (Bertotti et al. 1993). They are representative of the original Mesozoic northwestern passive margin of the Adria plate, which also included the Austroalpine domain. During Alpine orogeny, the central and western Southern Alps first constituted the slightly deformed hinterland of the Europe-vergent Austroalpine-Penninic collisional wedge (Late Cretaceous - middle Eocene Eoalpine phase). During the late Eocene - Oligocene Mesoalpine phase, only the easternmost sector was deformed by Dinaric SW-vergent thrusts. Later, from the Miocene onwards (Neoalpine phase), the whole Southern Alps were shortened as a shallow south-vergent fold-and-thrust belt, which developed as a retro-wedge (Doglioni & Bosellini 1987; Castellarin et al. 1992).

The Southern Alps are subdivided into two main sectors by the NNE-SSW-trending Giudicarie belt (Fig. 2). The western sector exposes a complete crustal section from the classic Ivrea lower crust to the post-Variscan Permian-Mesozoic cover (Bigi et al. 1990). The eastern sector exposes the upper crustal basement and Mesozoic cover sequences including the classic Dolomites (Bigi et al. 1990). To the east the Southern Alps are bounded by some NW-trending Dinaric Paleogene thrust fronts (Idria and Cividale Lines) reactivated during the Neoalpine phase as dextral strike-slip faults (Fig. 2). The main tectonic features of the eastern Southern Alps are the south-vergent Valsugana, Belluno and Bassano thrusts and to the west the NW-trending Schio-Vicenza and N-trending Trento-Cles strike-slip faults (Fig. 2).

Many pre-Alpine extensional structures have been unravelled from the analysis of syntectonic sediments (e.g. Castellarin 1972; Bertotti et al. 1993) and outcropping structures (e.g. Doglioni 1992; Zampieri 1995b). These normal faults trending N-S to NNE-SSW are derived from multiple tectonic phases, i.e. the early Permian-Triassic tectono-magmatic event (Cassinis & Perotti 1993; Dal Piaz & Martin 1998), the Jurassic extension of the passive margin of the Apulian microplate (Bertotti et al. 1993) and the Paleogene rifting coupled with magmatism (Zampieri 1995a). Major undulations of the Neogene SSE-vergent fold and thrust belt have been explained by inversion of the inherited normal faults (Doglioni 1992). The NNE-SSW-trending Giudicarie belt is oblique to the strike of the Southern Alps (Fig. 2) and is the main example of a transpressive fault zone controlled by pre-existing Jurassic normal faults (Castellarin et al. 1993; Prosser 1998 and refs. therein).

A number of structural styles have been proposed for the Southern Alps. They include a fan system of basement imbricates bounded by listric faults (Pieri & Groppi 1981; Cassano et al. 1986; Doglioni 1990; Poli & Zanferrari 1992), basement ramp-flat geometries (Laubscher 1985; Schönborn 1999) and doubly-vergent thick- and thin-skinned thrust wedges (Roeder 1992). In the western part of the chain seismic data show flat thrust faults in the Mesozoic (Schumacher 1997; Schumacher et al. 1997) and ramps cutting down into the lower crust further north towards the Periadriatic Line (Pfiffner & Heitzmann 1997). The amount of overall shortening is in the order of 100 km (Schmid et al. 1997). In the eastern part of the chain, it is still questionable whether the fold structures were formed by uplift on steeply dipping faults or by compression on shallow- to moderately dipping faults. These contrasting styles result in different estimates of shortening of the belt, which has been estimated between 30 km (Doglioni 1990) and more than 50 km (Schönborn 1999). The Pre-Permian Variscan crystalline basement of the central-eastern Southern Alps has mainly been studied in the Agordo area (Fig. 2), where it is made up by metapelitic and metapsammitic units and minor acidic metavolcanics (Poli & Zanferrari 1992). The sedimentary layering of the late Paleozoic to Mesozoic cover is nearly parallel to the metamorphic foliation (Poli & Zanferrari 1992). North of the Valsugana fault the metamorphic basement is intruded by Permian granitoids, whereas Triassic and Tertiary magmatic intrusions are widespread to the southwest. All these intrusions disrupt the layered anisotropies of the basement and may have inhibited the development of thrusts with ramp-flat geometry. According to Doglioni (1990) and Poli & Zanferrari (1992), the late-Alpine deformations led to development of listric thrust faults rooted in the Variscan basement. The main decollement seems to be located at a depth of 15-20 kilometres and is connected with the high-angle reverse faults observed at the surface.

On the basis of fault kinematic data collected in the study area and surroundings Castellarin & Cantelli (2000) suggest that during the Neogene the maximum stress axis changed from N340° in Serravallian-Tortonian times (Valsugana Phase) to N310° in Messinian-Pliocene times (Adriatic phase). This reorientation of the stress axis has been referred to the relative motion of the European and African plates calculated by Mazzoli & Helman (1994).

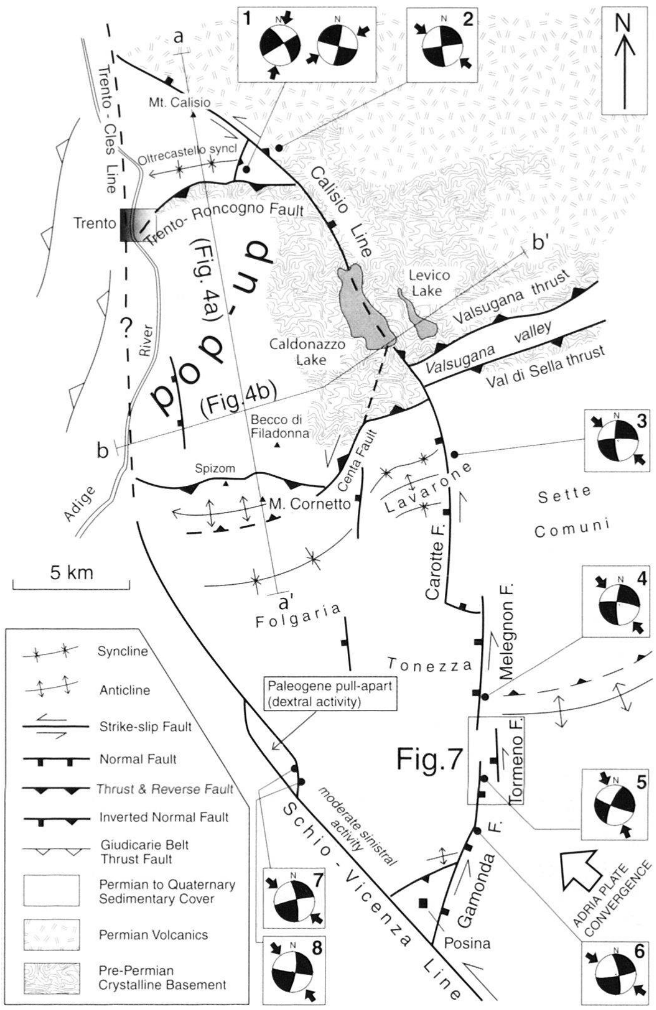

Fig. 3. Tectonic map of the study area between the Adige River and the Valsugana valley. The Monte Cornetto di Folgaria pop-up lies at the restraining stepover between the Schio-Vicenza and Calisio sinistral strike-slip faults. The Paleostresses are derived from fault slip data in Fig. 9.

3. The Mt. Cornetto di Folgaria pop-up

The Valsugana thrust fault borders the Dolomites to the south and in the western sector transported the crystalline basement onto Late Triassic to Miocene sediments. The western tip of the Valsugana thrust has usually been located at the intersection with the NW-SE-trending Calisio Line, which is a Permian normal fault inverted during the Neogene shortening of the re-

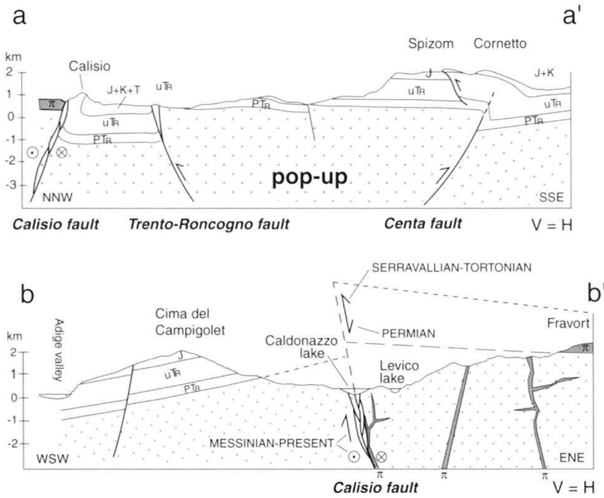

Fig. 4. Cross sections of Monte Cornetto di Folgaria pop-up (location in Fig. 3). π: lower Permian volcanics and dikes; PTr: Permo-Triassic; uTr: Upper Triassic (Dolomia Principale); J: Jurassic; K: Cretaceous; T: Tertiary; cross pattern: Pre-Permian basement.

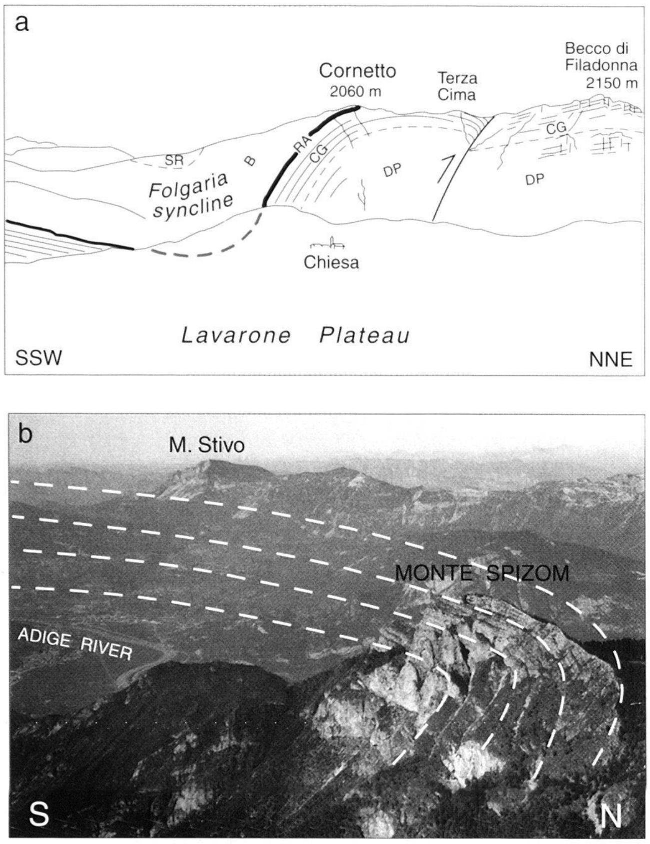

Fig. 5. (a) Line drawing of Monte Cornetto di Folgaria looking west. Note the steep reverse fault of Terza Cima. DP: Dolomia Principale (Upper Triassic); CG: Calcari Grigi (Lias); RA: Rosso Ammonitico (Dogger-Malm); B: Biancone (Lower Cretaceous); SR: Scaglia Rossa (Upper Cretaceous). (b) Mt. Spizom relict of the drag fold associated with the steep reverse fault antithetic to the Centa reverse fault. Dashed lines follow bed surfaces of the Liassic Calcari grigi.

gion (Doglioni 1990; Poli & Zanferrari 1992; Selli 1998). Nevertheless, west of the Calisio fault the crystalline basement is also uplifted and exposed at the Monte Cornetto di Folgaria high, a structural culmination lying between the Adige valley, to the west, and the Valsugana valley to the east (Fig. 2 and 3). The alignment of the basement exposure across the Calisio fault has suggested to some authors that this fault is not the true lateral ramp of the Valsugana thrust. Accordingly, some tectonics maps indicate that the Valsugana thrust front continues westwards to also include Monte Cornetto di Folgaria high (Bosellini & Doglioni 1986; Castellarin et al. 1992).

From the stratigraphic point of view, the main difference of the Monte Cornetto di Folgaria block with respect to the Valsugana area is the absence of Permian volcanics above the metamorphic basement. These volcanics accumulated within a Permian pull-apart (Cassinis & Perotti 1993) or half-graben (Selli 1998) basin, bounded westwards by the subvertical Calisio Line. According to the literature, the contractional evolution of this fault developed through a first phase of dextral transpression in Serravallian-Tortonian times, and a second phase of sinistral activity in Messinian-Pliocene times (Selli 1998; Castellarin & Cantelli 2000).

The Monte Cornetto di Folgaria uplift is bounded by two conjugate reverse faults: the Trento-Roncogno fault, to the north, and the Centa fault to the south (Fig. 3). The geometry is that of a "pop-up" (cf. Stone 1995). In the hanging wall of the Trento-Roncogno fault, the cover section is deeply eroded and the metamorphic basement is exposed (Figs 3 and 4). In the footwall of the Trento-Roncogno fault, the Oltrecastello syncline contains Eocene sediments (Trevisan 1941). The steep northeastern limb of this fold probably developed when the Calisio fault experienced dextral transpressive movement and inversion (Valsugana phase). Owing to erosion, the overall geometry of the Trento-Roncogno fault is poorly constrained.

The Centa fault is better preserved. The fault generally dips steeply to the NW and its throw increases eastwards. The geometric analysis shows that a south-vergent fault-propagation anticline developed above the tip of the steep reverse fault. The anticline is better exposed at Monte Cornetto di Folgaria where, because of its westward plunge, the Triassic-Early Jurassic sedimentary cover is preserved. Towards the south, the anticline is coupled with the Folgaria syncline (Fig. 5a), which developed at the transition to the footwall block. In addition, on the northern side of the Monte Cornetto di Folgaria a south dipping and downward steepening reverse fault is present (Fig. 3 and 5).

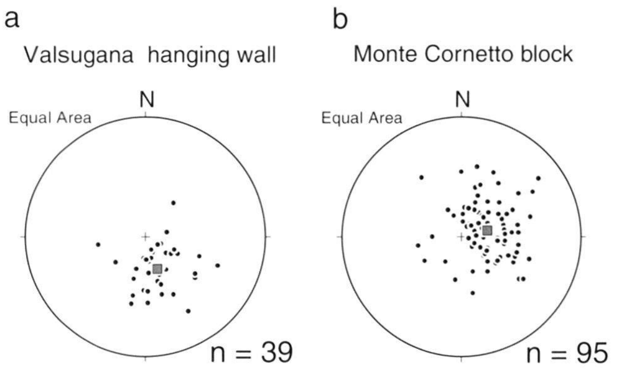

Fig. 6. (a) Attitudes of 39 poles of foliation planes (Schmidt net, lower hemisphere) of metamorphic basement close to the Valsugana thrust between Levico and Imer. Square is the mean vector. Plot has a strong similarity to that of Agordo basement shown by Poli and Zanferrari (1992). It suggests a NNW block tilting of the Valsugana hanging wall consistent with rigid-body rotation on a listric reverse fault. (b) Attitudes of 95 poles of foliation planes (Schmidt net, lower hemisphere) of metamorphic basement from Monte Cornetto di Folgaria block, west of Calisio fault. The westward dip may be due to tilting during the post-Tortonian uplift.

Basement highs have been interpreted as ramp anticlines (Poli & Zanferrari 1992; Selli 1998; Schönborn 1999); nevertheless, the inferred basement folding clearly contrasts with the attitude of the metamorphic foliation. In fact, in the hanging wall block the basement foliation always dips northwards even in proximity to the thrust fault. This is evident from published geological maps (i.e. Feltre Sheet; Serv. Geol. d'Italia 1970) and has been demonstrated by field measurements (Fig. 6a). Basement ramp anticlines have not been postulated since the basement may have passively transported and rotated the sedimentary cover. The latter may have been folded only above the tip of the basement. Rigid-body rotation on listric faults has been recognized as the fundamental explanation for backlimb rotation on some thrust-related fold in the Rocky Mountains (Schmidt et al. 1993), where only few low-angle thrust faults show thrust-related anticlines (Erslev & Rogers 1993).

The Monte Cornetto di Folgaria uplifted block dips gently towards the west and the basement outcrops on its eastern side, i.e. on the most uplifted part. Foliation planes in the basement show a mean attitude clearly different from that of the Valsugana hanging wall (Fig. 6). Taking into account the data of the hanging wall in the Agordo area (Poli & Zanferrari 1992), which are consistent with our data collected from Levico to Imer, the basement foliation shows a NNW dip over a distance of more than 60 km along-strike (Fig. 2). This suggests a NNW block tilting consistent with a rigid-body rotation on a listric fault during the Serravallian-Tortonian. The dip of the Monte Cornetto di Folgaria basement foliation may be due to westwards tilting during the post-Tortonian uplift.

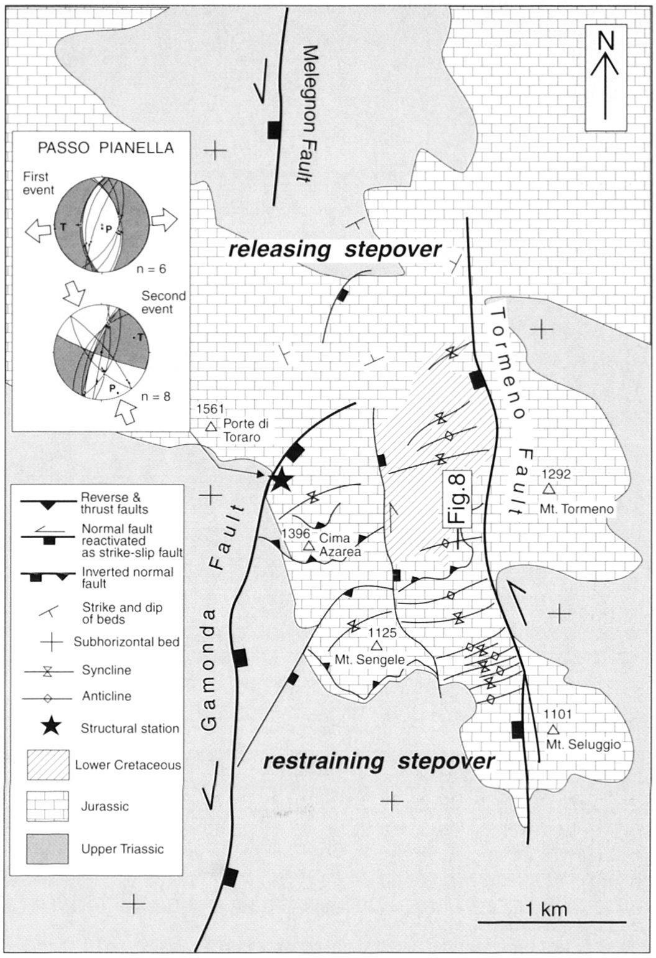

Fig. 7. Restraining and releasing structures at the stepovers of the Gamonda, Tormeno and Melignon faults. Location in Fig. 3.

4. The Mt. Tormeno restraining stepover

Southwards the NW-trending Calisio Line links with an array of steep N- to NNE-trending faults crosscutting the Lavarone and Tonezza plateaux to join the Schio-Vicenza fault near Posina (Serv. Geol. d'Italia 1968; De Vecchi et al. 1986). From the north, these are the Carotte, Melegnon, Tormeno and Gamonda faults (Fig. 3). Barbieri (1987) described this fault system as the Posina fault and interpreted the prominent segmentation in terms of sinistral offsets related to the superimposition of an inferred pervasive network of NW-trending faults. In fact, segmentation of the N- to NNE-trending faults can be attributed to the inheritance of a Liassic-Paleogene normal fault system, similar to that recognized in the adjoining Lessini Mountains (Fig. 2) (Zampieri 2000). The extensional origin of these faults is readily seen in the Schio sheet of the Carta Geologica d'Italia (Serv. Geol. d'Italia 1968), where it is also possible to recognize the westward dip of the Carotte, Melegnon

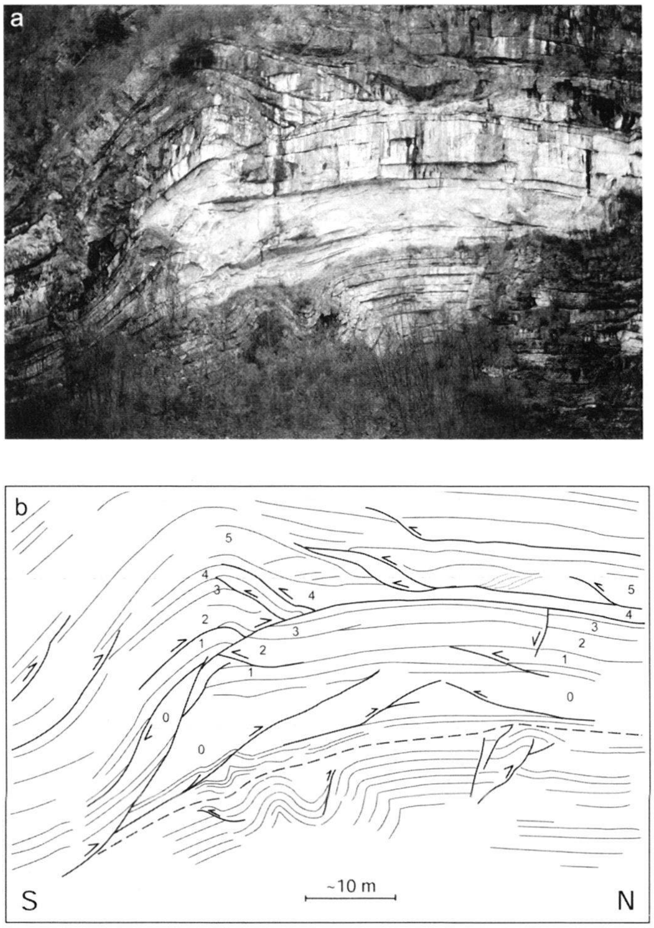

Fig. 8. (a) Core of the anticline fold between Cima Azarea and Mt. Tormeno (looking west). Shortening was accommodated by brittle flexural-slip thrust-related folds. (b) Ramp-flat geometries and duplexes are outlined.

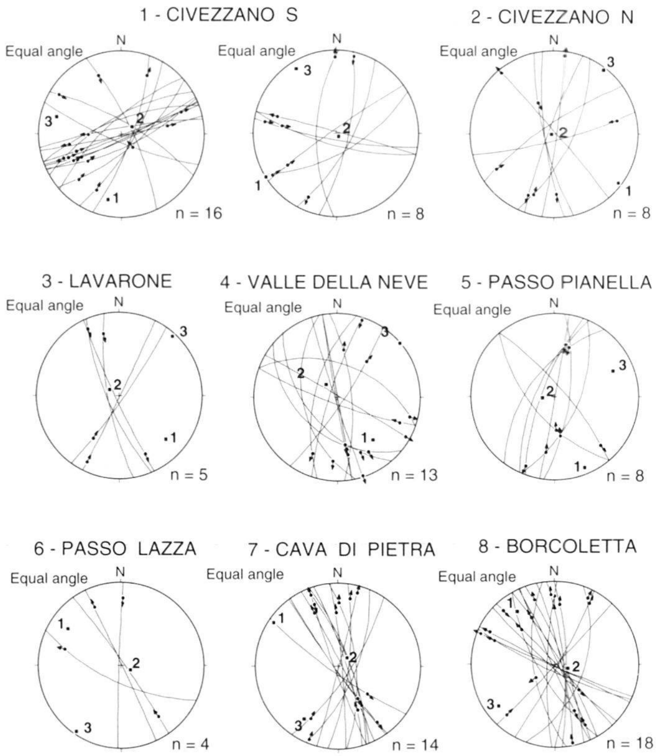

Fig. 9. Stereonet plots (lower emisphere) of fault slip data collected at the stations shown in Fig. 3 and paleostress axes computed by FaultKin program (version 3.8a) of Allmendinger et al. (1994).

and Tormeno faults and the eastward dip of the Gamonda fault. The later strike-slip reactivation superimposed on dip-slip movements is revealed by the analysis of geological structures of the stepovers and also corroborated by the kinematic analysis of outcropping fault planes (Fig. 7).

The most impressive evidence of the soft linkage between fault segments is observed at the right step between the two conjugate Gamonda and Tormeno faults (Fig. 7). In the overlap zone, Jurassic to Early Cretaceous sediments inside a narrow graben have been deformed by compression subparallel to the strike of the normal faults. Given the sinistral movement expected during the Neogene on these N to NNE-trending faults, the step must have acted as a restraining zone. Only within the narrow (1 km) relay zone have the sedimentary rocks accommodated shortening, developing an array of E to ENE-trending folds with an amplitude of ca. 150 m, associated with thrusts and reverse faults (Fig. 7 and 8). On the contrary, where fault segments form left steps, releasing zones developed in terms of tectonic basins. This is the case of the steps between the Tormeno Melignon and Carotte faults (Fig. 3).

5. Kinematic analysis

Throughout the entire area the outcropping faults are steeply dipping (dip>45°), with low-angle slickenlines (Fig. 9). Only few faults show polyphase activity, i.e. dip-slip striations overprinted by strike-slip slickenlines (e.g. some of faults in Fig. 7 stereoplots), but the last deformation frequently masked earlier movements. This is consistent with the tectonic evolution of the region, which experienced Permian to Paleogene extensional tectonic pulses before Neoalpine contraction, and final transpression. Regarding the strike-slip kinematics, the NW-trending fault system (Schio-Vicenza and Calisio faults) record both dextral and sinistral movements, while the N-trending system (Gamonda, Tormeno, Melegnon, Carotte faults) shows only sinistral movements. The dextral activity of NW-trending faults is consistent with the ESE to ENE-directed extension axes (σ_3) of the Permian (Selli 1998), Mesozoic (Bertotti et al. 1993) and Paleogene (Zampieri 1995a) extensional tectonics, and also with the N340° maximum principal stress axis (σ_1) of the Serravallinan-Tortonian compression (Castellarin & Cantelli 2000). The sinistral activity of the NW-trending faults agrees with the Messinian to Present N300° maximum principal stress axis. On the contrary, the sinistral activity of the N-trending faults is consistent with both the N340° and N300° maximum principal axes recorded in this area and surroundings.

6. Discussion

The Monte Cornetto di Folgaria pop-up is located at the right step of the two NW-trending Calisio and Schio-Vicenza Lines (Fig. 3). Many authors suggested that the post-Tortonian kinematics of the Schio-Vicenza Line is sinistral (Semenza 1974; Pieri & Groppi 1981; Zanferrari et al. 1982; De Vecchi et al. 1986; Castellarin & Cantelli 2000).

It is questionable whether or not the Schio-Vicenza Line is directly connected with the N-trending Trento-Cles Line along the Adige valley, as suggested by Semenza (1974). If so, the Trento-Cles-Schio-Vicenza fault system would be a regional structure displaying a prominent right bend. From the kinematic point of view, the Schio-Vicenza Line has been identified as a sinistral transfer fault system between the Giudicarie and Bassano (Pedemontana) structures (Castellarin & Cantelli 2000). The role of the Trento-Cles Line in partitioning the sinistral strike-slip component of the transpressive North Giudicarie Line from the Miocene has recently been discussed by Prosser (1998). According to this interpretation, the Trento-Cles-Schio-Vicenza structure would be a regional sinistral strike-slip fault with a right bend at the Monte Cornetto di Folgaria latitude (Fig. 2).

In any case, the Monte Cornetto di Folgaria pop-up is due to shortening localized either at a restraining stepover of the Calisio and Schio-Vicenza faults or at a restraining bend of a single regional fault (Trento-Cles-Schio-Vicenza). We prefer the first solution, because it explains field data without additional assumptions.

The Alpine front between Schio and Gemona (Fig. 2) is the site of active thrusting related to the Neogene convergence between Adria (and Africa) and Europe. Interpretations of seismic reflection and refraction data across the Alps suggest that a wedge of Adriatic lower crust was forced into the European crust in Neogene times (Nicolas et al. 1990; Fantoni et al. 1993; Pfiffner & Hitz 1997; Schmid et al. 1997; Lammerer & Weger 1998). From 7.9 Ma onwards the northeastern part of the Adriatic plate moved NW-wards, bordered to the northeast by NW-trending dextral strike-slip faults (Idria and Cividale Lines) and to the southwest by the NW-trending sinistral Schio-Vicenza Line (Fig. 2). The Schio-Vicenza fault acted as a transfer fault, connecting the Bassano and Montello frontal thrusts with the Giudicarie belt, where post-Tortonian out-of-sequence reactivation occurs (Castellarin & Cantelli 2000).

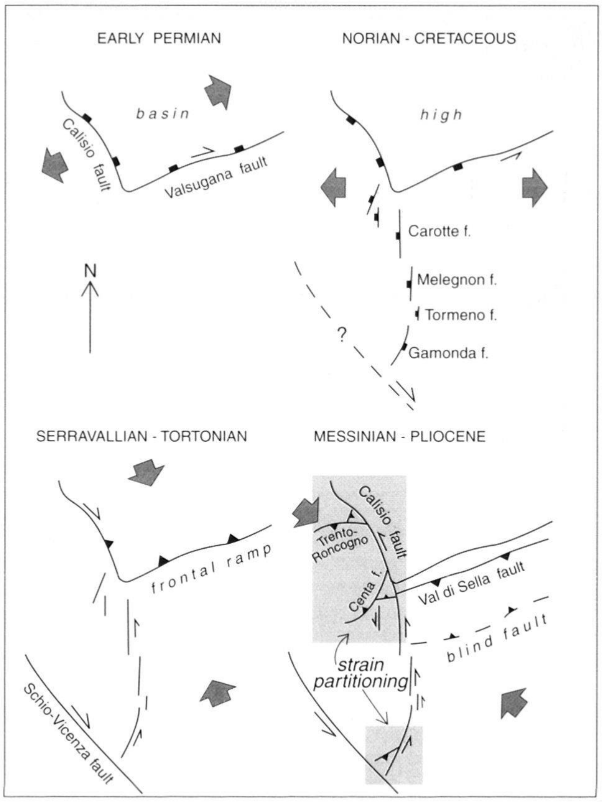

Fig. 10. Summary of structural evolution of the western termination of the Valsugana Line from the Early Permian to the Pliocene. Paleogene extensional tectonics is omitted, although some Paleogene oblique extension reactivated pre-existing N-S trending faults.

The triangular area between the southern edge of the Giudicarie belt and the Schio-Vicenza Line corresponds to the Lessini Mountains block (Adige embayment of Laubscher 1996), which was slightly affected by Neogene compression (Cantelli & Castellarin 1994; Zampieri 2000).

The map expression of the Monte Cornetto di Folgaria is similar to the pattern produced by the restraining stepover models of McClay & Bonora (2001). Nevertheless, some important differences may be recognized, mainly due to the complex inherited grain of the Monte Cornetto di Folgaria structure. The most prominent pre-existing feature is the presence in the southern part of north-trending Mesozoic normal faults (Fig. 3). Pre-existing structures are an important mechanical anisotropy which can be responsible for strain partitioning into strike-slip and dip-slip displacements on different structures (e.g. Tikoff & Teyssier 1994). The normal fault systems played a key role in absorbing the sinistral strike-slip component of transpressive deformation occurring in the stepover region (Fig. 10), while the Centa and newly-formed Trento-Roncogno reverse faults absorbed the shortening component. Smaller reverse faults, which accommodated the shortening component, have been also recognized in the northernmost part of the structure, between the Trento-Roncogno fault and the Calisio Line, and in its southernmost part, north of Posina (Fig. 3). In this way, the segment of the Schio-Vicenza Line north of the Gamonda fault decreased its activity during the post-Tortonian sinistral reactivation of the structure.

7. Conclusions

Contractional stepovers have not been recognized previously in the central-eastern Southern Alps, although the large-scale Monte Cornetto di Folgaria pop-up and related minor structures turned out to be striking examples. The analysis of these structures and the critical evaluation of literature data allowed us to draw the following conclusions on the regional structural pattern and kinematics, and on some general inferences:

(1) The western lateral ramp of the Valsugana thrust is the Calisio fault. This steep normal fault of Permian age was reactivated with dextral kinematics during the Serravallian-Tortonian (Valsugana phase) and once again during Messinian-Pliocene times (Adriatic phase) as a sinistral strike-slip fault.

(2) The Monte Cornetto di Folgaria pop-up is the result of Messinian-Pliocene contraction at the restraining stepover between the sinistral strike-slip Schio-Vicenza and Calisio faults. The structure originated during the Adriatic compressional phase and reactivated the Serravallian-Tortonian dextral Schio-Vicenza fault as a sinistral fault.

(3) Sinistral strike-slip movements occurred along pre-existing features, such as the array of N- to NNE-striking late Triassic to Paleogene normal faults crosscutting the Tonezza and Lavarone plateaux and showing a prominent segmented pattern with dextral and sinistral stepovers. The development of contractional features as folds and thrust faults at dextral stepovers, and extensional basins at sinistral stepovers caused the linkage of the fault segments.

(4) The inherited normal faults were an important mechanical anisotropy responsible for strain partitioning during the post-Tortonian transpression along the western termination of the Valsugana thrust. Although shortening structures are prominent in the area, coeval strike-slip and contractional processes may better explain the recent tectonic evolution of this sector of the Southalpine belt.

(5) In fold-and-thrust belts affected by strike-slip activity along faults at high angle to the belt axis, strike-slip related contractional features may be significant, but hardly recognizable since they can be interpreted as undulations of non-cylindrical structures. These features are likely to be localized along the lateral strike-slip dominated borders of wide transported blocks, especially if oblique inherited faults create bends or stepovers along the transcurrent zones.

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