2nd Day

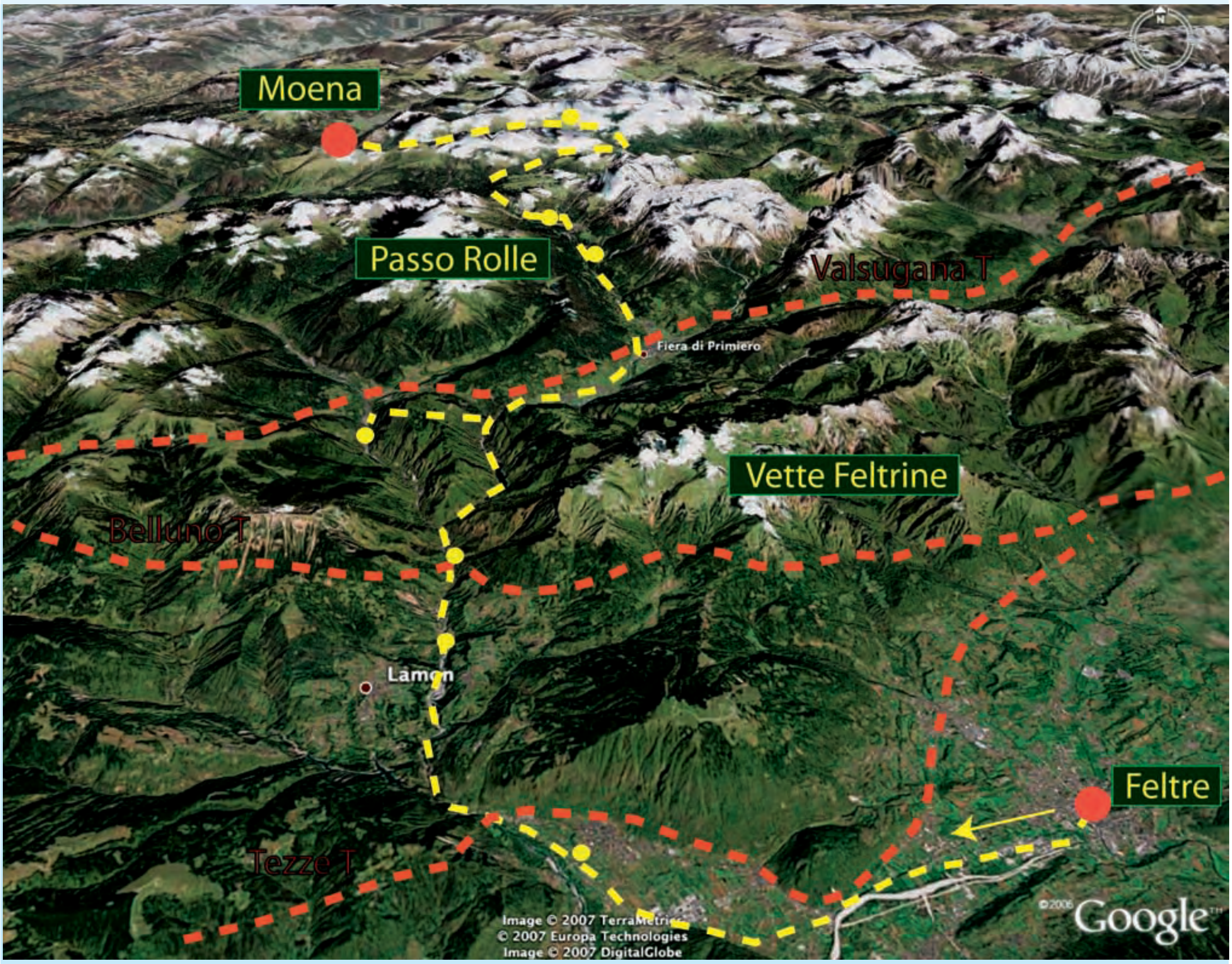


Fig. 2.0 - Itinerary: Feltre, Val Cismon, Passo Rolle, Passo Valles, Moena. Dashed red lines are the main thrusts.

Subject: Main structures of the fold-and-thrust belt, interference with the Mesozoic structures and stratigraphy

The daily excursion is a traverse through a typical cross-section of the eastern Southern Alps, characterized, in these areas, mainly by Neogene to present compressional deformation. We will observe the Tezze, Belluno and Valsugana thrusts, cropping out along the valley of the Cismon river. It will be shown that the Valsugana Line inherited and cut the system of Mesozoic horsts and grabens. In the Passo Rolle area, the control of Mesozoic (both structural and stratigraphic) anisotropies on the alpine compressional tectonics can be studied in detail. Again in the Passo Rolle area we will observe one of the most evident flower structures that can be observed in the field.

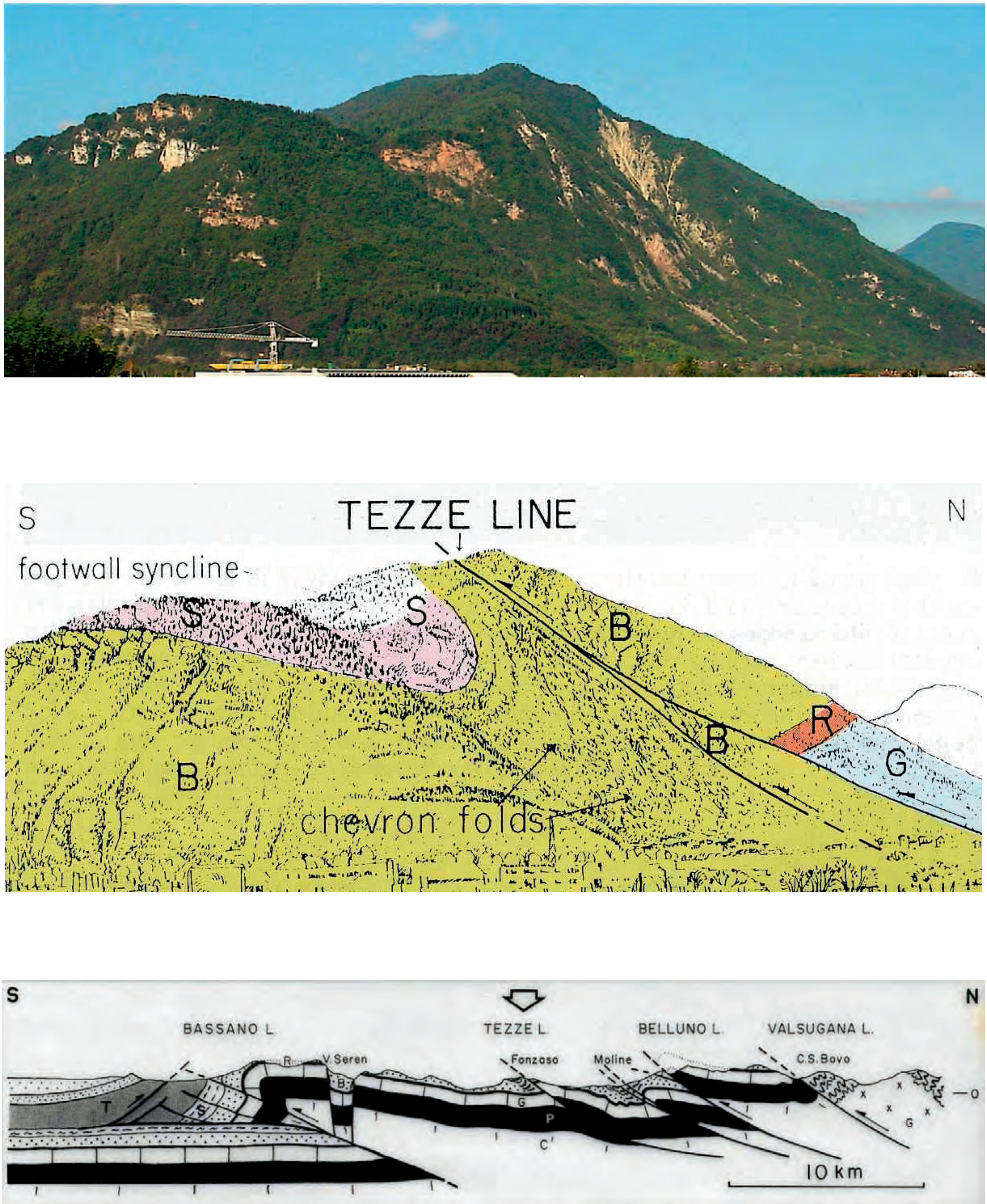


Fig. 2.1 - The Tezze thrust, near Fonzaso, west of Feltre. The syncline in the footwall suggests a fault-propagation-fold origin of the structure. Notice the chevron folds near the thrust fault. G, Calcari Grigi, Liassic; R, Ammonitico Rosso inferiore, Fonzaso Fm, Ammonitico Rosso superiore, Dogger and Malm; B, Biancone, Lower Cretaceous; S, Scaglia Rossa, Upper Cretaceous.

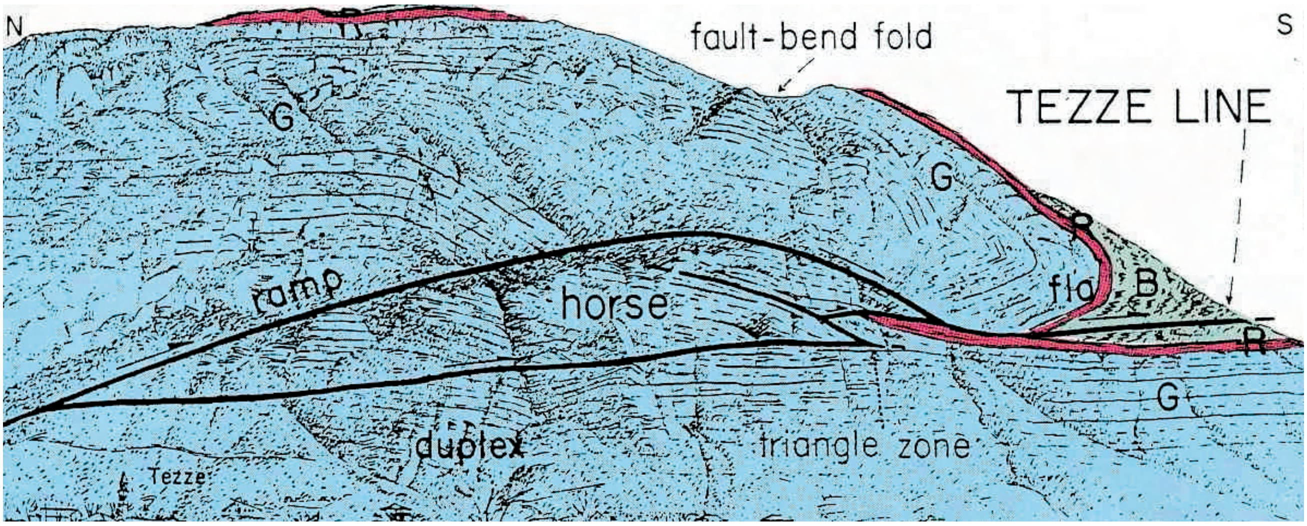


Fig. 2.2 - The Tezze thrust cropping out above the village of Tezze, in Valsugana. The frontal overturned limb of the fold suggests an origin by fault-propagation. This mechanism, however, was coupled to fault-bend folding, due to the ramp geometry of the fault in the Calcari Grigi (G) and the flat geometry at the bottom of the Biancone (B). Ammonitico Rosso inferiore, Fonzaso Fm, Ammonitico Rosso superiore (R).

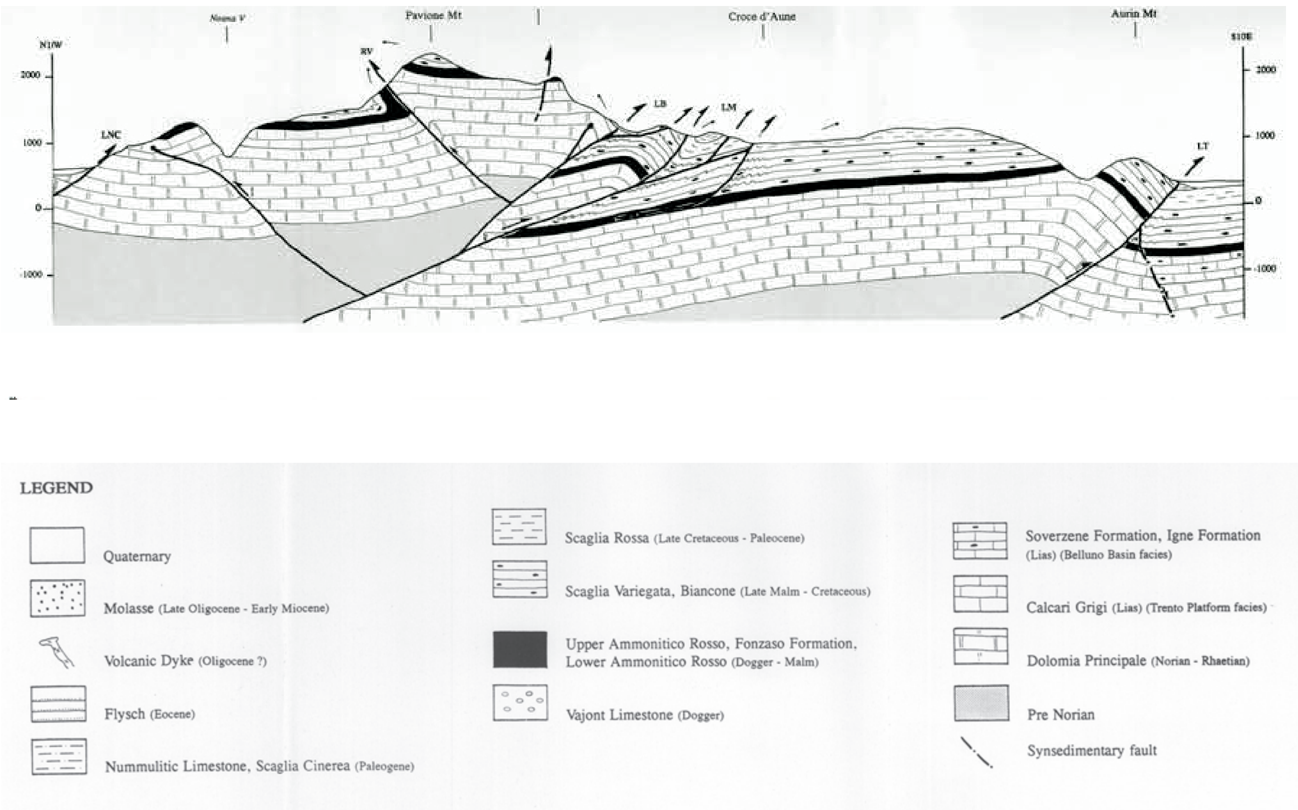
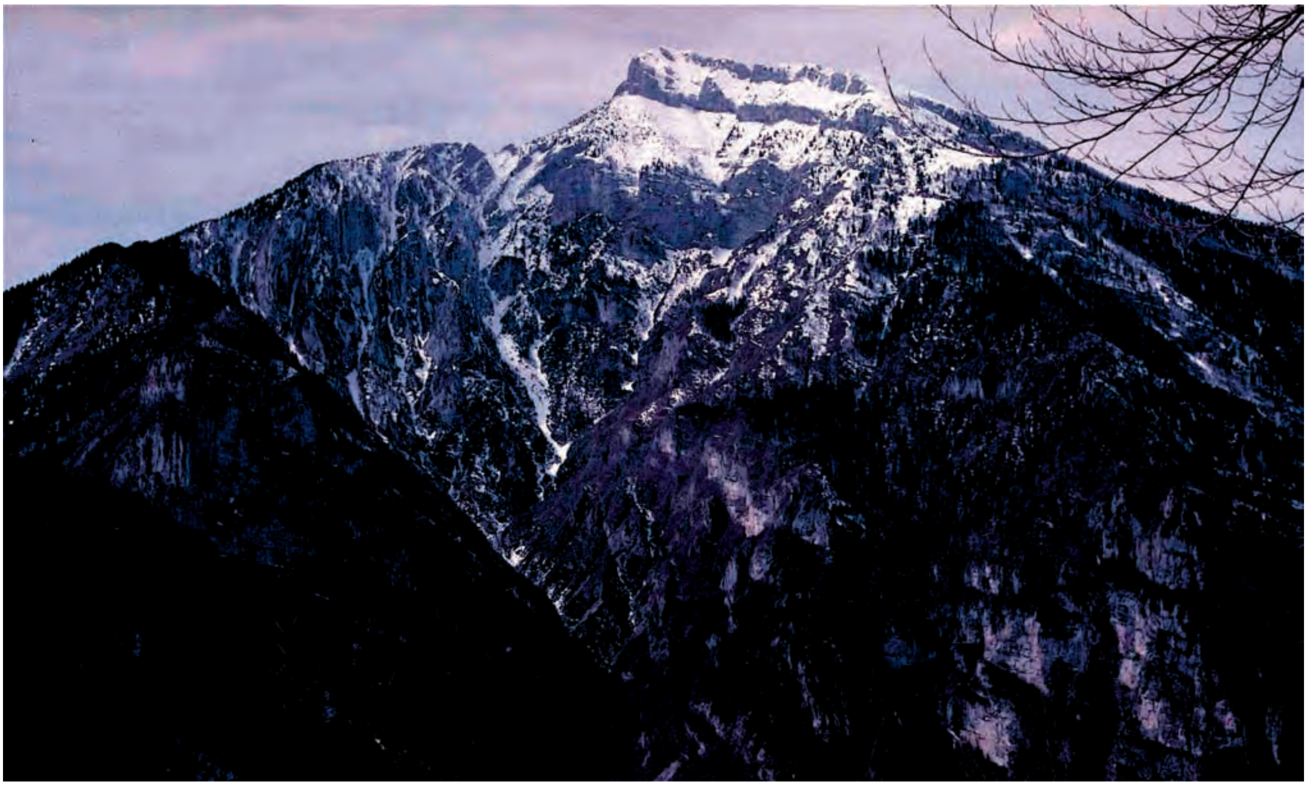


Fig. 2.3 - Cross-section of the Vette Feltrine, after D'ALBERTO *et alii* (1995).



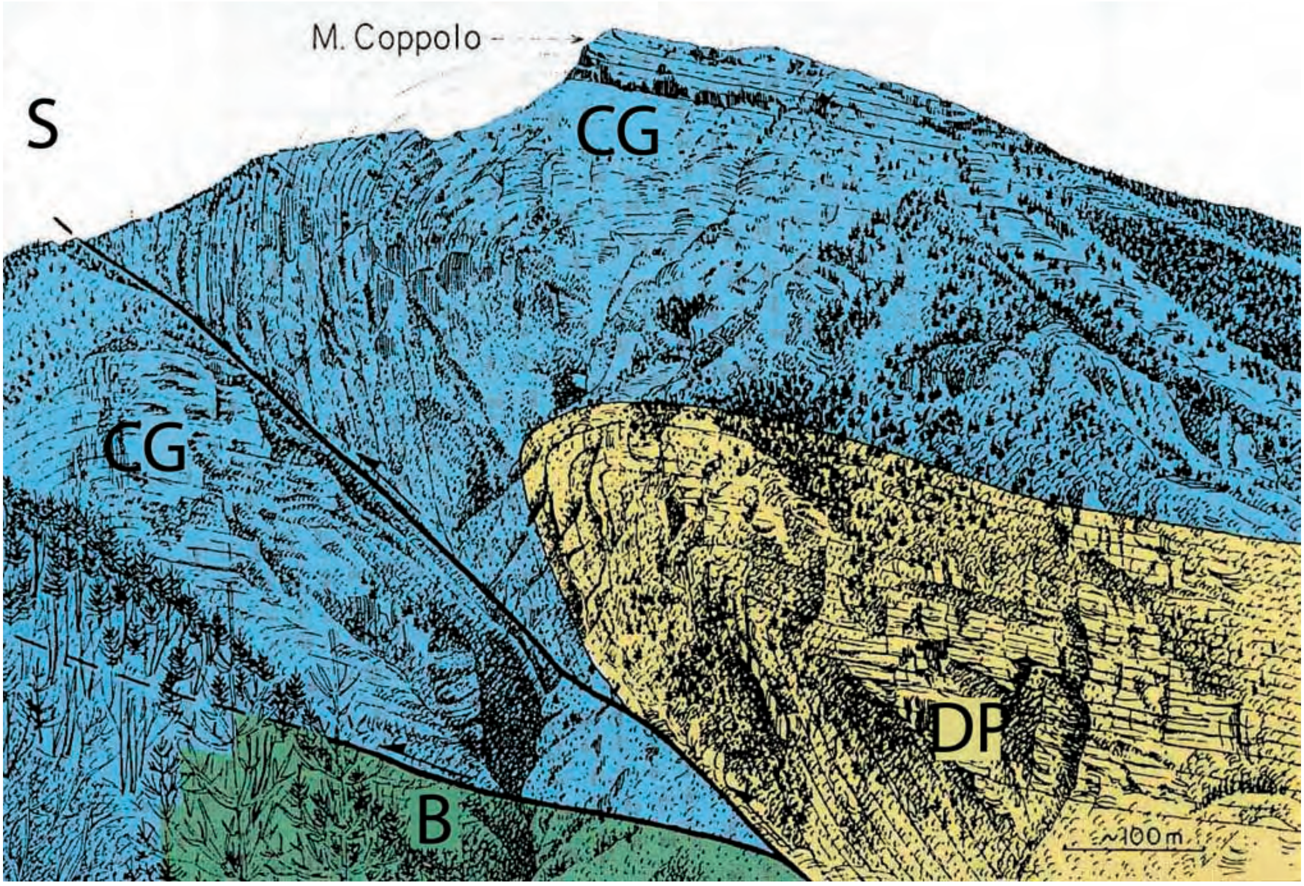


Fig. 2.4 - The Belluno thrust as it crops out along the western flank of the Cismon valley. The vertical and somewhere overturned external flank of the hangingwall anticline indicates folding by fault-propagation. DP, Dolomia Principale (Norian); CG, Calcari Grigi (Lias); B, Biancone (Lower Cretaceous).

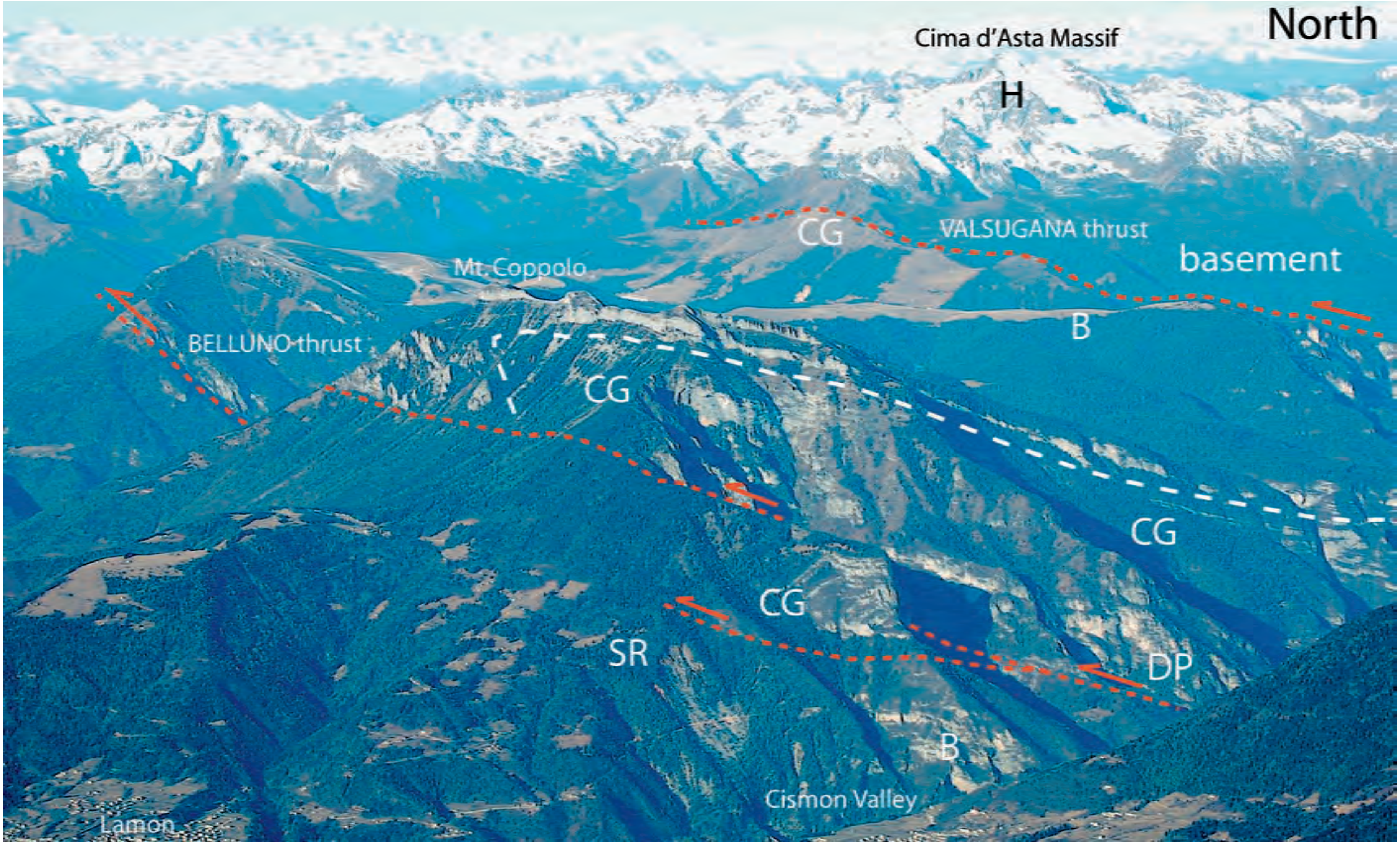


Fig. 2.5 - Same Belluno thrust as in Fig. 2.4. Note the short forelimb and the longer backlimb of the fault-propagation fold well exposed in the Coppolo mountain. To the north the Valsugana thrust where the crystalline basement outcrops in the hangingwall. H, Hercynian (Upper Carboniferous) intrusives and greenschist facies basement; DP, Dolomia Principale (Norian); CG, Calcari Grigi (Lias); B, Biancone (Lower Cretaceous); SR, Scaglia Rossa (Upper Cretaceous).

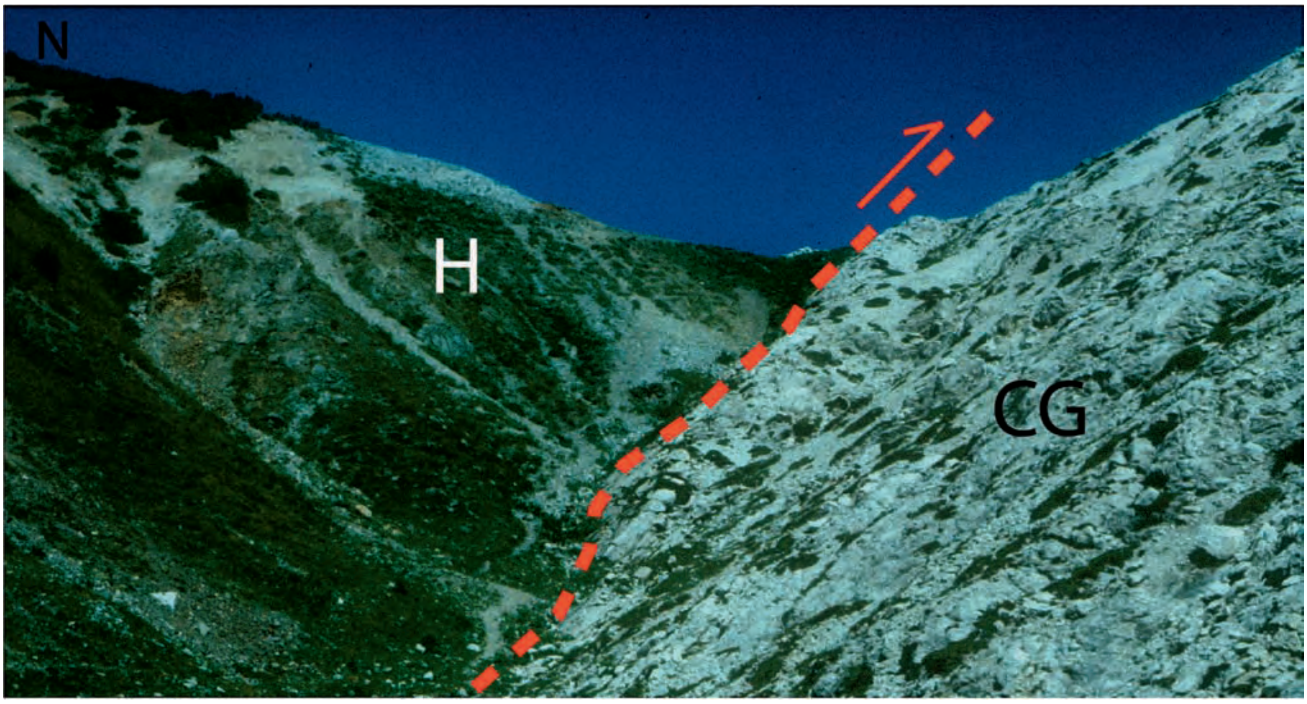


Fig. 2.6 - Valsugana thrust, north of Passo del Broccon. In the hangingwall the crystalline basement (H), here cropping out as an apophysis of the late-Hercynian Cima d'Asta granite. The basement is thrust towards the south over the Liassic Calcari Grigi (CG).

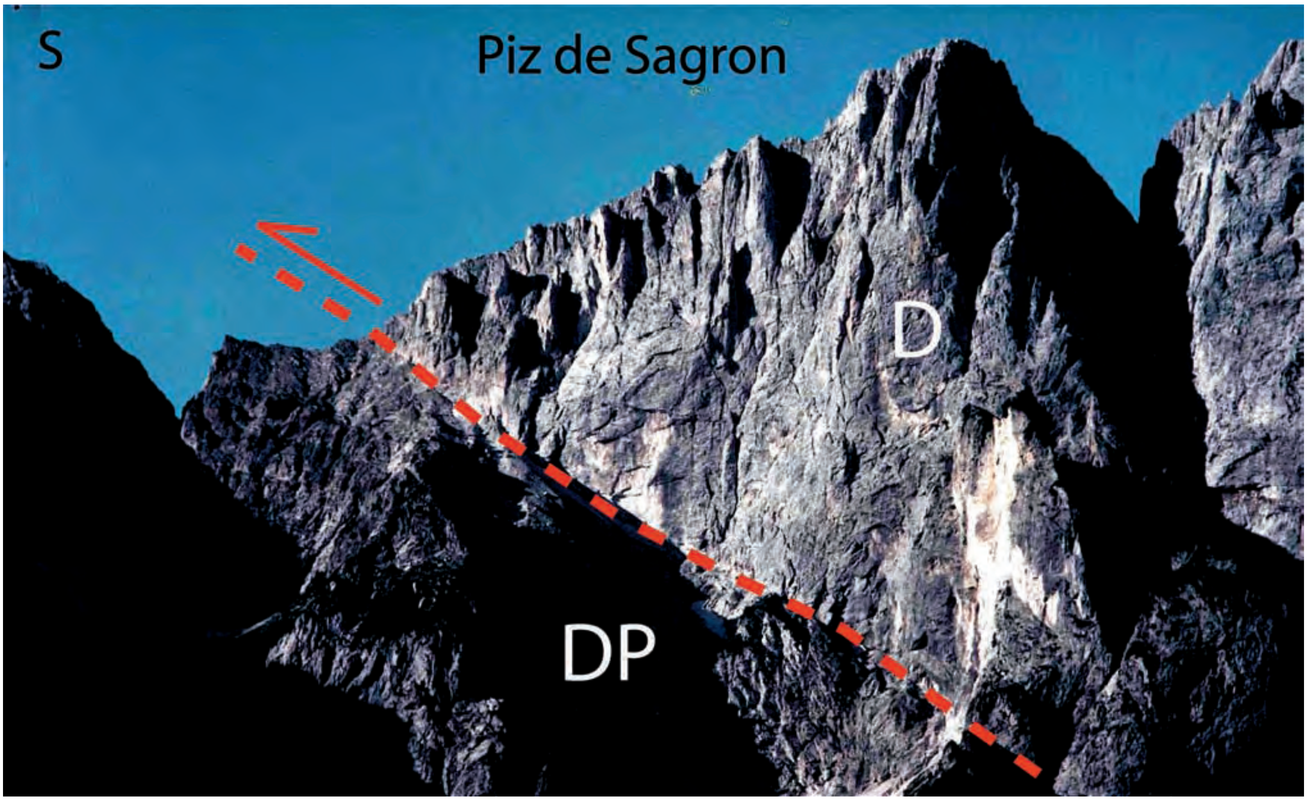


Fig. 2.7 - Same thrust as before, but more to the east: the Valsugana thrust outcrops with the Cassian Dolomite (Carnian, D) overriding the Dolomia Principale (Norian, DP).

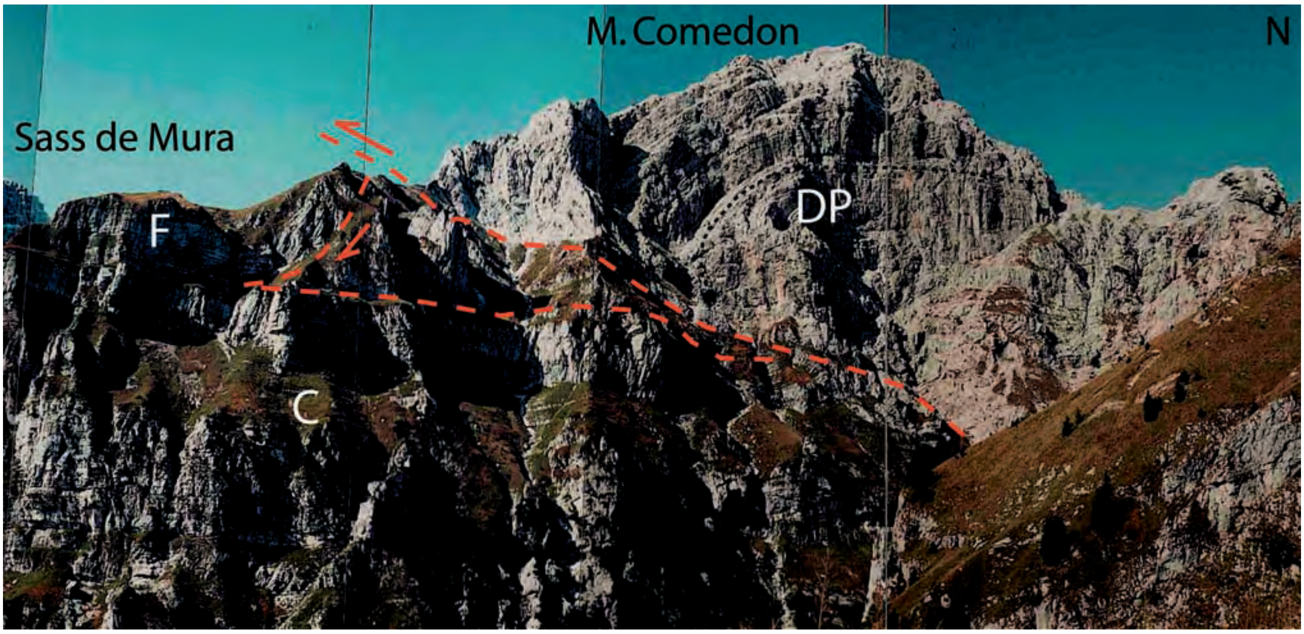


Fig. 2.8 - The Valsugana thrust in the southern cliff of the Mt. Comedon, Sass de Mura massif, Vette Feltrine. Note the triangle zone in the footwall. DP, Dolomia Principale (Norian); C, Calcari Grigi (Lias); F, Fonzaso Fm (Dogger); Photo by Lucio D'Alberto.

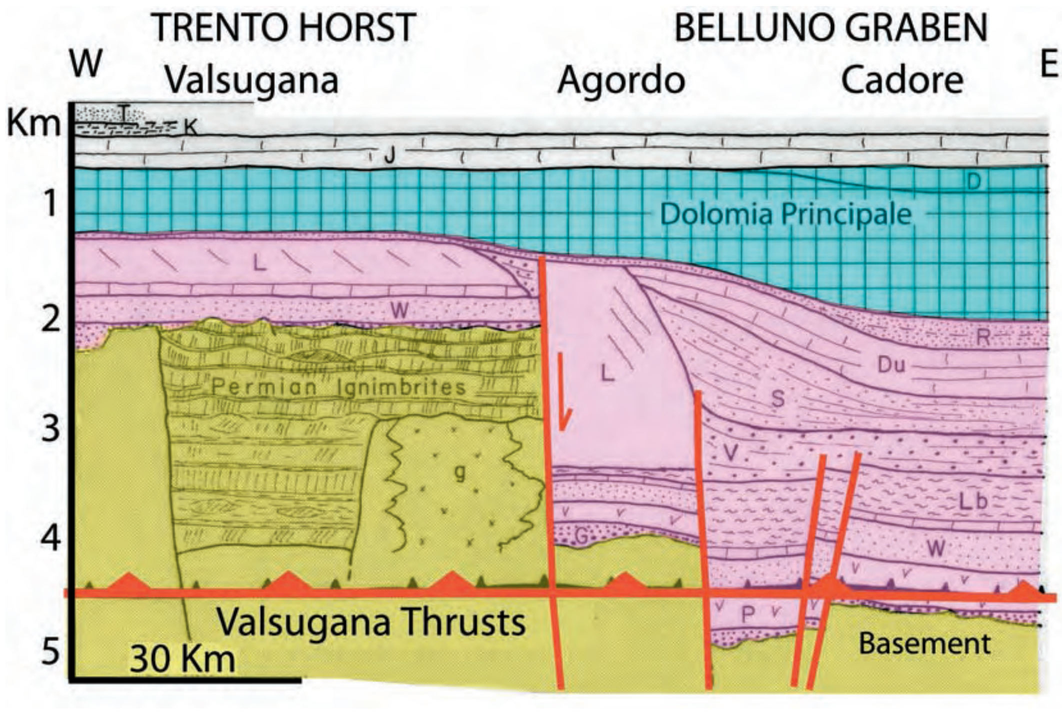


Fig. 2.9 - The Valsugana thrust cuts through inherited Mesozoic structures: the Trento (or Atesina) Platform and the Carnico-Bellunese Basin. This is evidenced by the thickness of the sedimentary cover that shows values around 2 km on the Trento horst and 4-5 km in the Carnico-Bellunese graben to the east (after Bosellini & Doglioni, 1986). The strike of the normal paleo-faults is always ca. N-S. Unlabelled yellow, crystalline basement; g, late-Hercynian granitoid; G, Gardena Sandstone (Upper Permian); P, Bellerophon Fm (Upper Permian); W, Werfen Fm (Scythian); Bricks, Anisian; L, Ladinian and Carnian carbonate platforms; Lb, Livinallongo Fm (Ladinian); V, volcanoclastic deposits (Late Ladinian); S, San Cassiano Fm (Carnian); Du, Dürrenstein Dolomite (Late Carnian); R, Raibl Fm (Late Carnian); DP, Dolomia Principale (Norian); J, Calcari Grigi (Liassic); D, Dachstein Limestone (Rhaetian); K, Cretaceous; T, Tertiary. One of the main Mesozoic extensional faults accommodating differential subsidence between the platform and basin realms is the Passo Rolle Line, later reactivated as a transfer (mainly strike-slip) fault between the Lagorai monocline and the Pale di San Martino syncline.

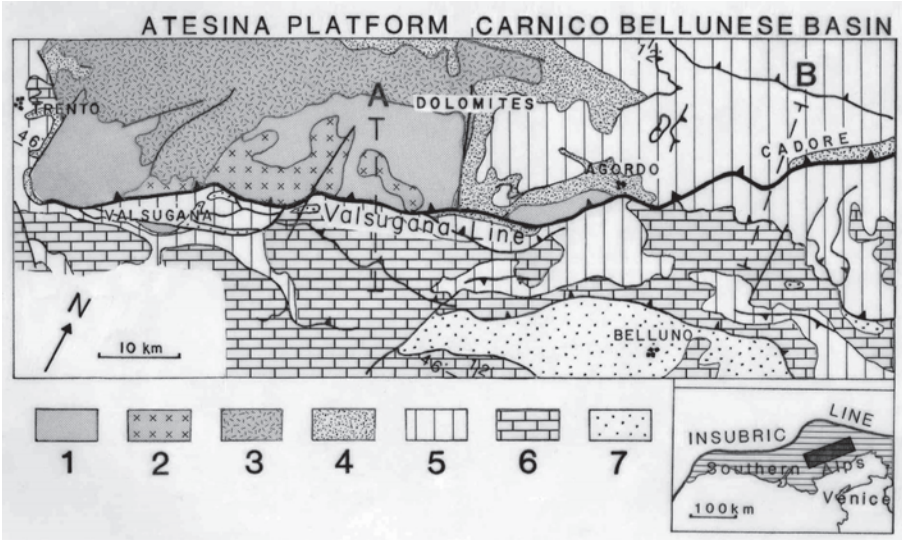


Fig. 2.10 - The Mesozoic structuration can be recognized also in geological maps that show a structural high of the basement in the hanging-wall of the Valsugana thrust between Trento and the Cismon Valley, developed along the Passo Rolle Line. To the east of this lineament, the Valsugana Line cuts mainly through sedimentary cover, since this area was structurally depressed before the onset of compression. A and B are the traces of the cross sections of the next figure. 1, crystalline basement; 2, late-Hercynian granitoids; 3, Permian ignimbrites; 4, Upper Permian and Lower Triassic; 5, Upper-Middle Triassic; 6, Jurassic-Cretaceous; 7, Tertiary.

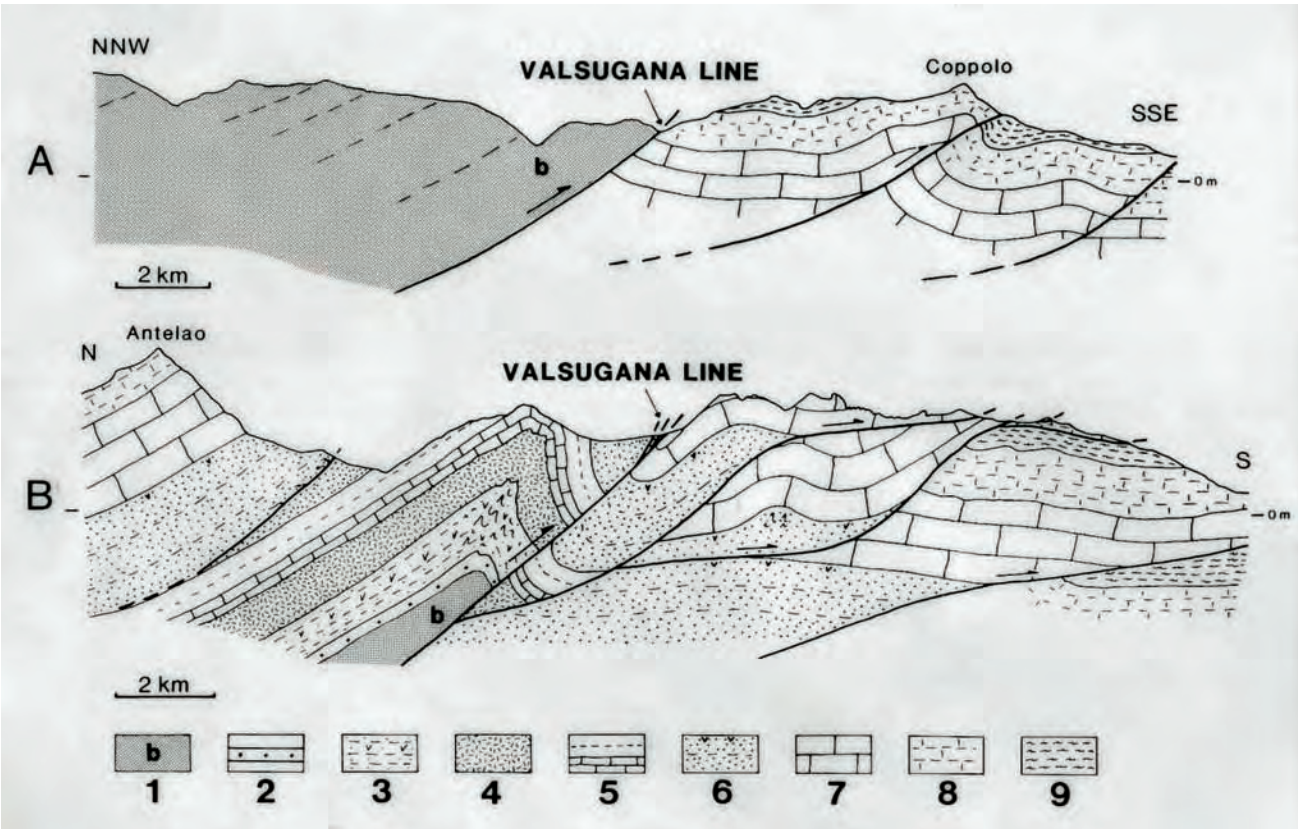


Fig. 2.11 - Geological cross-sections through the Valsugana Line: notice that along section A the basement (b) is more elevated in the hangingwall with respect to section B, although no significative differences of shortening occur between the two sections. This feature is explained by the fact that along section A the Valsugana Line cuts the horst of the Trento platform (or Atesina Platform) whereas in section B it cuts the Bellunese graben. 1, Undifferentiated crystalline basin; 2, Gardena Sandstone; 3, Bellerophon Fm; 4, Werfen Fm; 5, Anysian and Ladinian formations; 6, Carnian formations; 7, Dolomia Principale (Norian); 8, Jurassic limestones; 9, Cretaceous limestones and marls. The traces of the sections are shown in fig. 2.10.

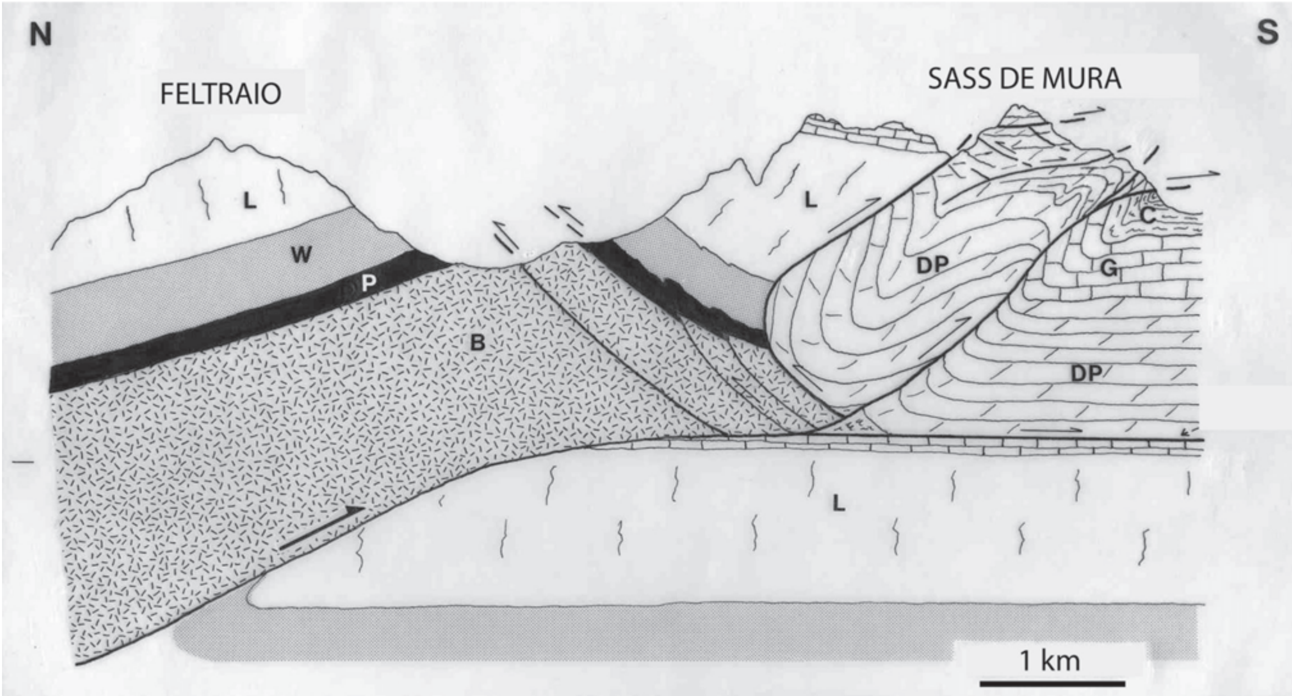


Fig. 2.12 - Cross-section across the Valsugana thrust, at the southern margin of the Dolomites, in the zone of Passo Cereda. The basement of the Dolomites (B) thrusts over and wedges within the sedimentary cover of the Venetian Prealps, developing a triangle structure. The basement shows a fault-bend-fold. The southern flank of the fold shows the Dolomia Principale (DP) wedging between the basement and Ladinian carbonates (L), generating thus another triangle structure, with the substitution of the cover at its bottom (direct contact between basement and Dolomia Principale. P, Upper Permian; W, Scythian and Anisian; G, Jurassic limestones; C, Cretaceous limestones and marls.

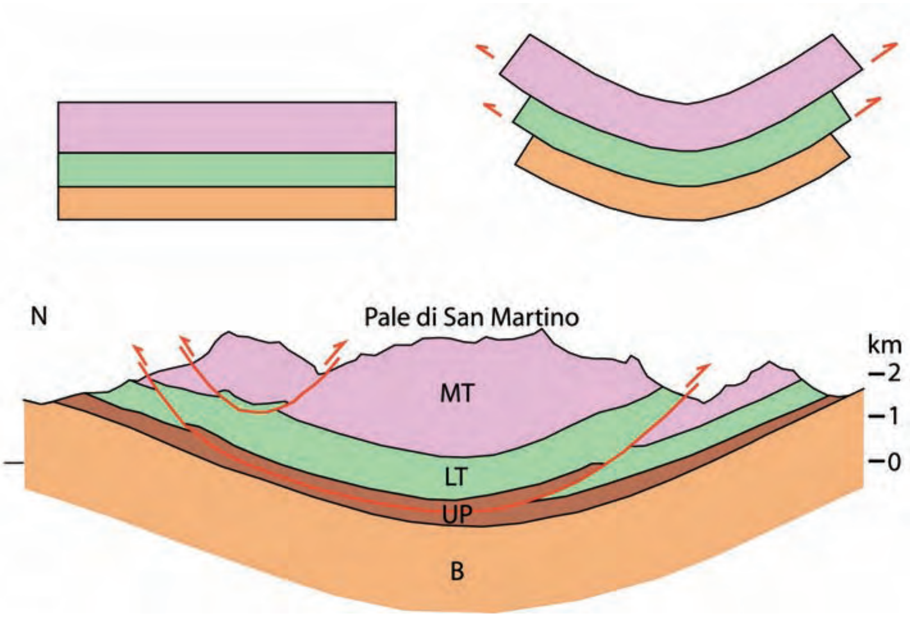


Fig. 2.13 - The Pale di San Martino are located at the core of a regional undifferentiated basement (B) syncline. The sedimentary cover accommodated the folding by flexural slip and shear, thus developing south-verging thrusts in the southern limb and north-vergent thrusts in the northern limb of the syncline. UP, Gardena Sandstone and evaporitic Bellerophon Fm (Upper Permian) which acted as a main decollement level between cover and basement (see next figure). LT, Lower Triassic; MT, Middle-Upper Triassic.

Fig. 2.14 - North-vergent en-echelon folds in the evaporitic Upper Permian Bellerophon Fm (B). The occurrence of gypsum and shales lowers the frictional resistance, thus enabling sliding. The outcrop is at the base of the Pale di San Martino massif, along the road to Passo Rolle from San Martino di Castrozza. Folds are confined within this formation made of shale, gypsum, marly limestone, and indicate a N-vergent decollement. Note the overlying unfolded Werfen Fm (W) and Marmolada Limestone (C). It testifies the flexural sliding (towards the north in this case, since the outcrop is positioned in the northern flank) of the sedimentary cover within the basement syncline.

Fig. 2.15 - Detail of the previous outcrop, Road from San Martino di Castrozza to Passo Rolle. The folds are within the Bellerophon Fm. Note the gypsum thickening in the hinge of the fold above to the left of the geologist.

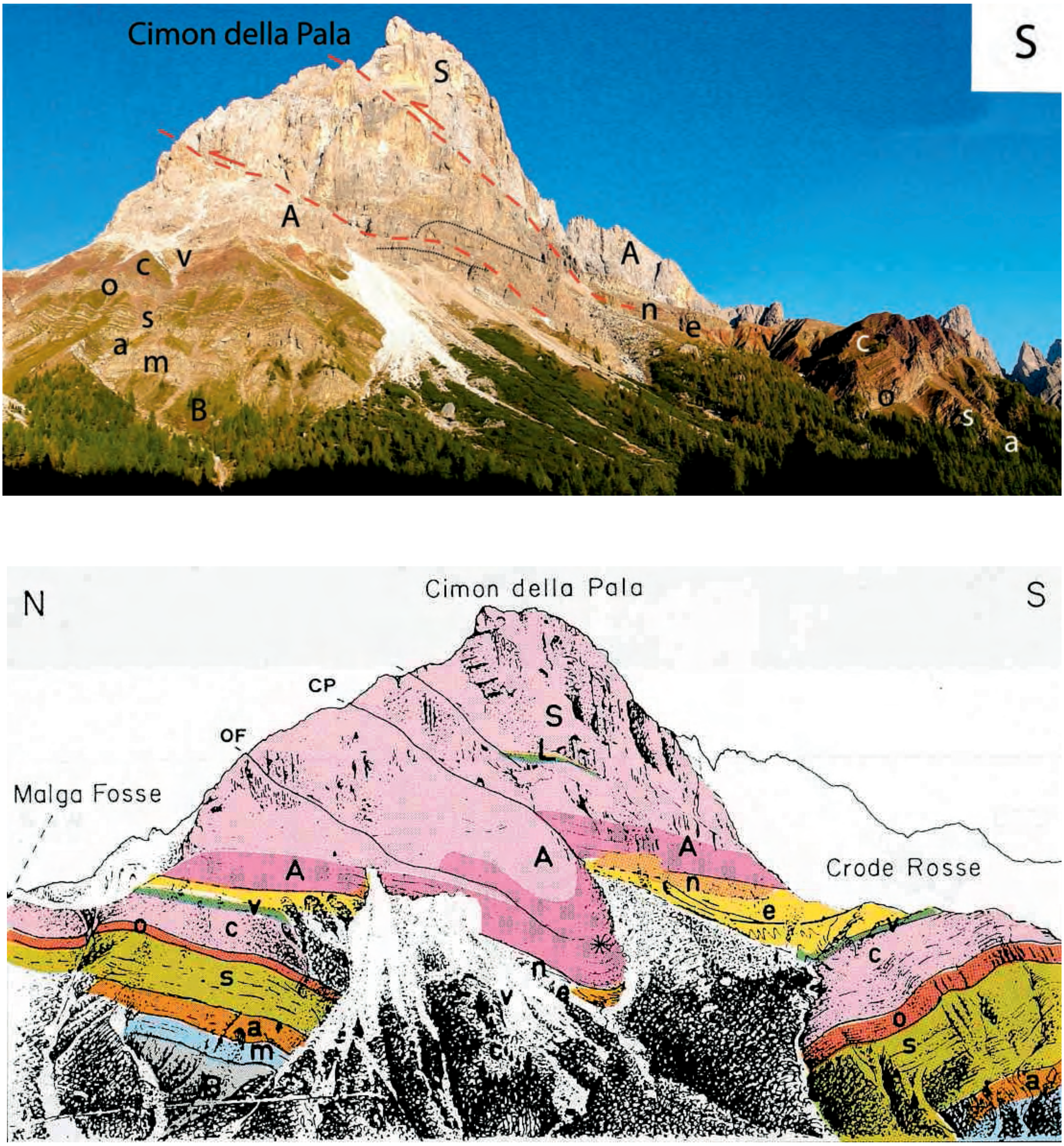


Fig. 2.16 - NW flank of Cimon della Pala massif, near Passo Rolle, at the northen margin of the Pale di San Martino regional basement syncline. Thrust faults verge northward due to the flexural sliding of the sedimentary cover accompanying the basement folding. Notice the thinning towards the left of the Werfen Fm, i.e., toward the Trento Horst: the Gasteropod Oolite (o) can be taken as a reference. This layer is much thicker to the right (40 m) than to the left (20 m). Also the other members of the Werfen Fm, in particular the Siusi (s), Campil (c), Cencenighe (e) and San Lucano (n) members, show lateral variations of thickness. In the right portion of the figure, the lower section of the Cencenighe Member is characterized by evaporites (gypsum) and shales; these lithologies enabled the localization of the detachment plane of the Cimon della Pala thrust fault (CP). Where the evaporites terminate, the thrust fault is characterized by a ramp. A thrust sheet comprising the external syncline (out-of-syncline thrust, OF) characterizes the footwall syncline of the Cimon della Pala thrust (Doglioni & Neri, 1988). S, Sciliar Dolomite (Ladinian); L, Livinallong Fm (Ladinian); A, Anisian formations (lower Serla Dolomite, Voltago Conglomerate, upper Serla Dolomite, Morbiac Limestone, Contrin Fm). Werfen Fm (Scythian): n, San Lucano Member; e, Cencenighe Member; v, Val Badia Member; c, Campill Member; o, Gastropod Oolite; s, Siusi Member; a, Andraz horizon; m, Mazzin Member; B, Bellerophon Fm.

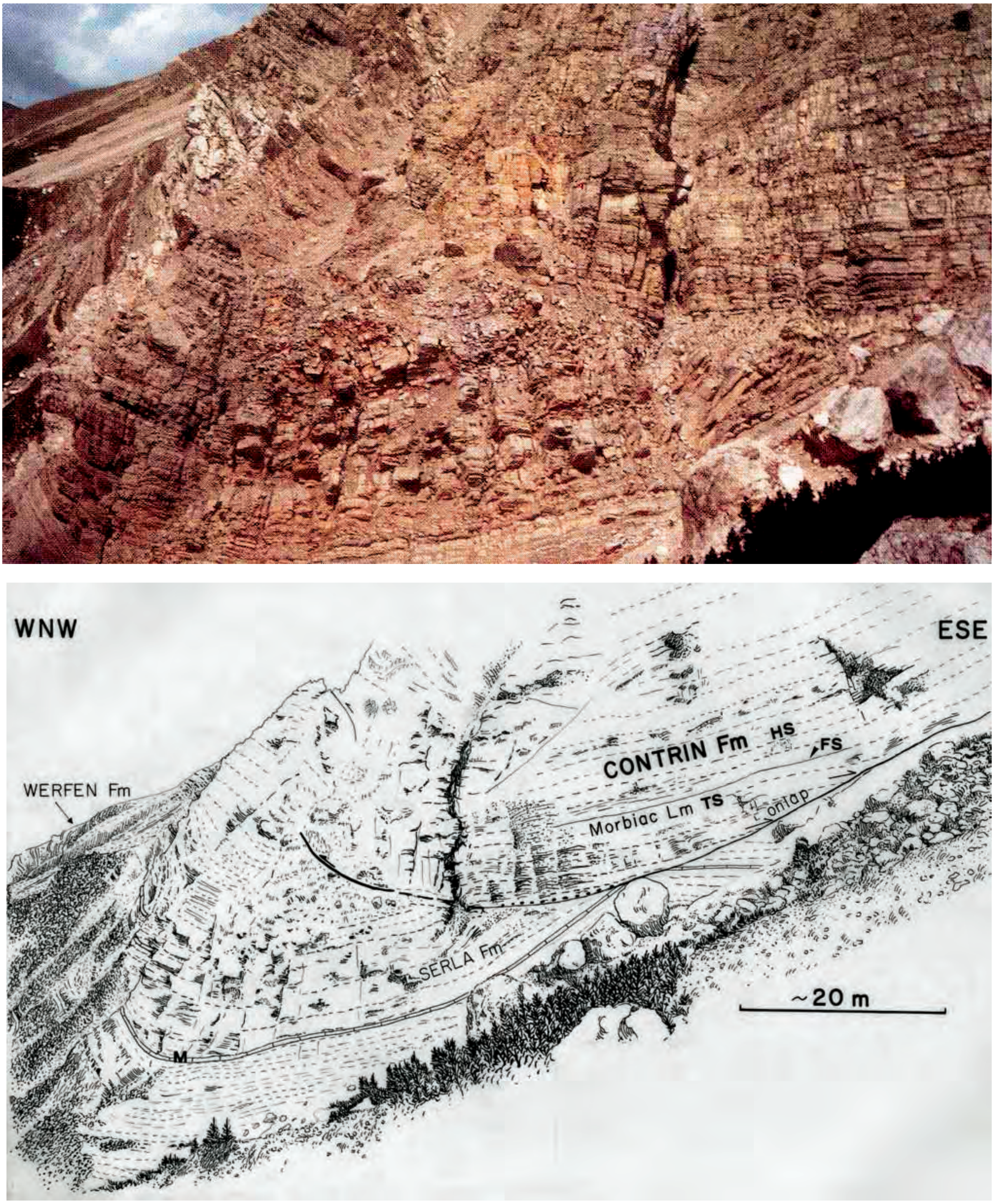


Fig. 2.17 - Geological drawing of the NW slope toe of the Cimon della Pala Mt. A N30-40°E trending anticline involving Pelsonian rocks is eroded and covered unconformably by conglomerates pockets and marly limestones of the Morbiac Limestone, which onlaps the unconformity. In terms of sequence stratigraphy we interpret the Morbiac Limestone as a transgressive system tract (TS) and the Contrin Formation as the highstand system tract (HS) of the Illyrian cycle. The boundary between the two units is the maximum flooding surface (FS). To the left the unconformity has been used as detachment plane by an out-of-syncline thrust located in the footwall of the Cimon della Pala thrust. M, marker bed.

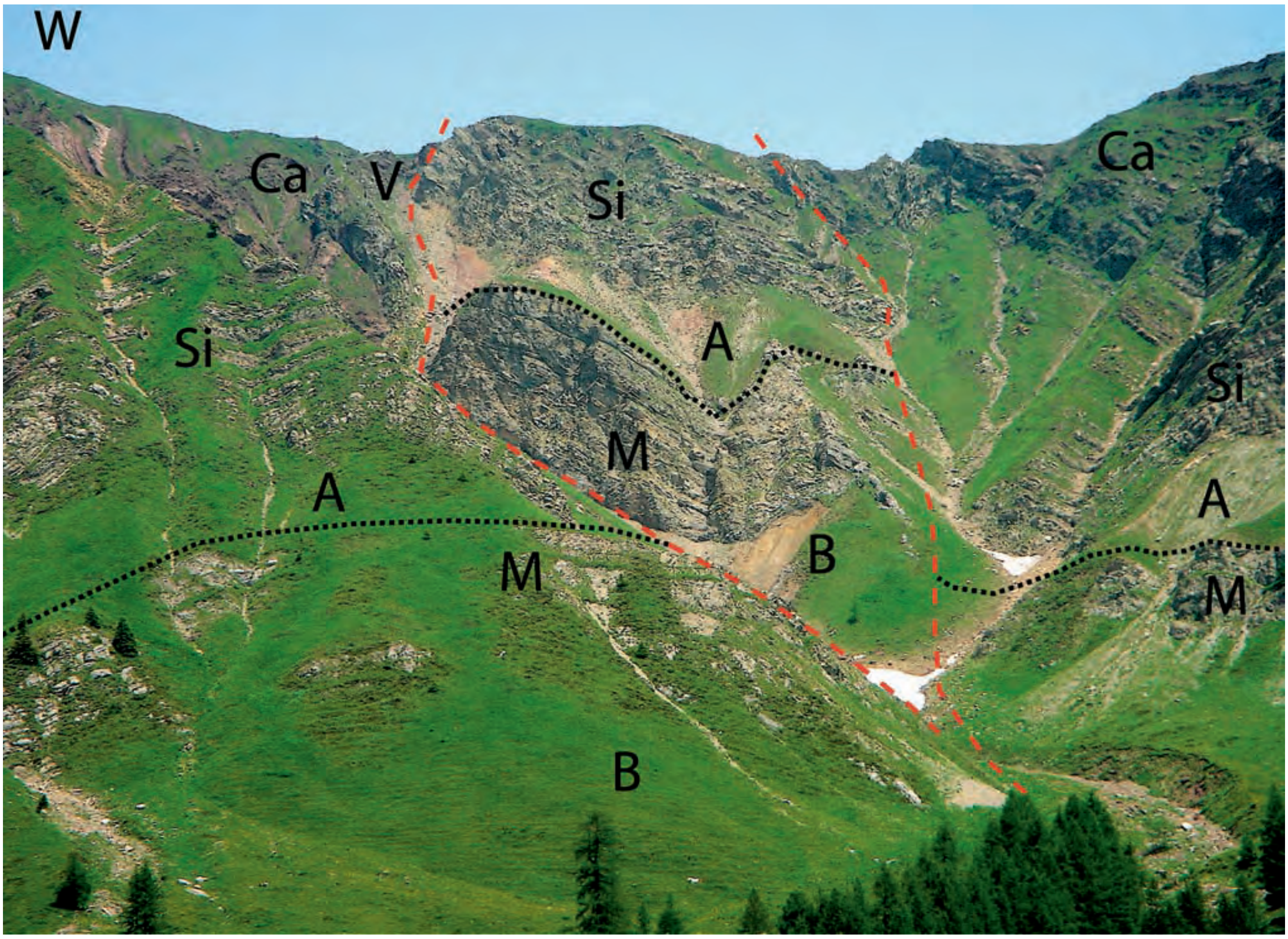


Fig. 2.18 - Positive flower structure cropping out near Passo Rolle (locality Malga Fosse). Notice the uplifted wedge between two high angle faults which branch at the bottom of the picture. The structure is oriented N5°-10°E and shows a sinistral shear. Note that moving up along the faults the undulated geometry determines either normal or reverse offset. A, Andraz horizon that, as reference level, marks the vertical throws. The outcrop shows various levels of the Werfen Fm (Scythian). At the bottom of the flower structure, the faults converge in the Bellerophon Fm (B) evaporites (Upper Permian). A dark Ladinian volcanic dyke (v) is subparallel to the western fault. Legend: M, Mazzin Member; A, Andraz horizon; Si, Siusi Member; Ca, Campil Member; V, volcanic dyke.

Fig. 2.19 - Upper Permian Gardena Sandstone near Malga Fosse, Passo Rolle. They represent fluvial facies reworking the underlying ignimbrites. The faults show extensional movement later reactivated into left-lateral transpression. This kinematic evolution is consistent with 1) the regional setting of Mesozoic extension between the Trento Horst to the west and the Belluno Graben to the east, and 2) the Alpine reactivation of this hinge separating the regional NNW-dipping monocline of the Lagorai massif in the hangingwall of the Valsugana Thrust with respect to the S-dipping northern limb of the Pale di San Martino syncline.

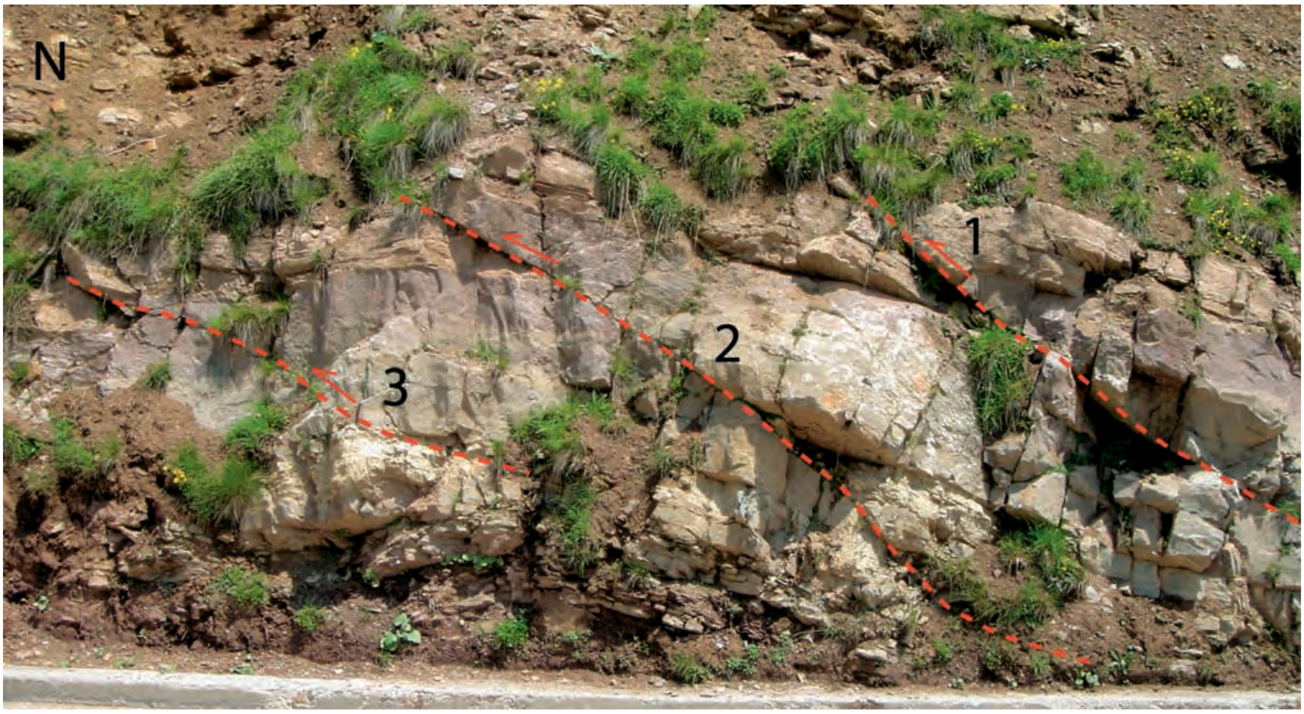


Fig. 2.20 - System of mesoscale thrust faults near Passo Rolle. The imbricated fan propagated from right to left. The kinematics are indicated by the dip of the fault planes: the fault to the right (1) is more inclined and reflects the transport along the ramp of the thrust in the middle (2). The distance among fault planes is constant since the lithologies (oolitic limestones, marly limestones and siltstones of the Siusi Member of the Werfen Fm, Scythian, Lower Triassic) cross-cut by the faults do not change laterally. Micro- and meso-structures, slickenlines, small conjugate backthrusts, pressure solution and other features make of this small outcrop a miniature of a fold-and-thrust belt such as the Southern Alps.

Fig. 2.21 - A Ladinian latit-basaltic dyke at Passo Rolle cross-cutting the Upper Permian Gardena Sandstone. The alpine deformation concentrated in the dyke where mesoscale N0-10° trending left-lateral strike slip faults can be observed.

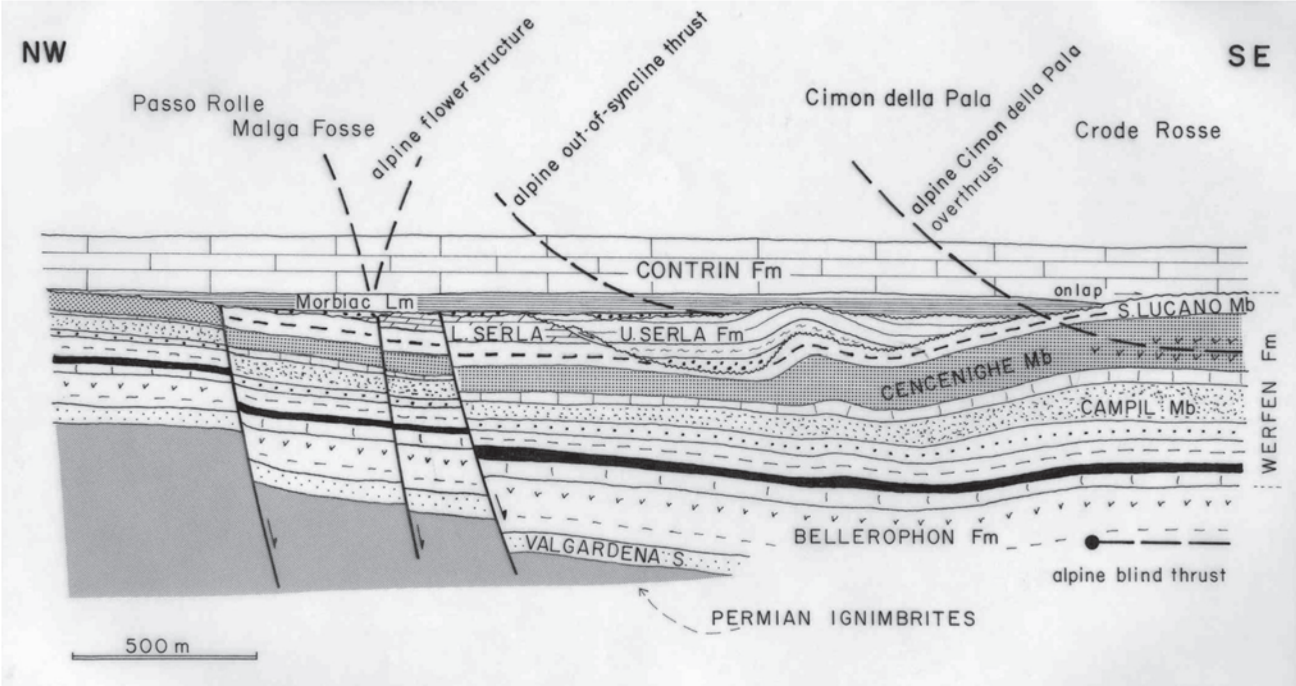


Fig. 2.22 - Geological reconstruction of the Passo Rolle area in the Anisian. Notice that the area is located in the tensional hinge zone between the Trento Horst and the Belluno Graben. This is evidenced by the occurrence of the extensional fault system of the Passo Rolle Line, by the thinning of the Scythian and Anisian formations and, at places, by the lack of some levels of the series towards the north-west (Doglioni & Neri, 1988). The Anisian unconformities are sutured by late Anisian formations. The alpine compressional deformation inherited this complex architecture: for example, the thrust fault of the Cimon della Pala becomes horizontal in the evaporitic level of the Cencenighe Member. The flower structure of Malga Fosse (Fig. 2.18) is probably related to sinistral transfer motions along the Passo Rolle Line and re-sheared a Mesozoic tensional structure. Moreover, the Upper Permian Bellerophon Fm is characterized by a blind thrust that generated an accommodation fold in the overlying cover, now visible between Crode Rosse and Malga Fosse.

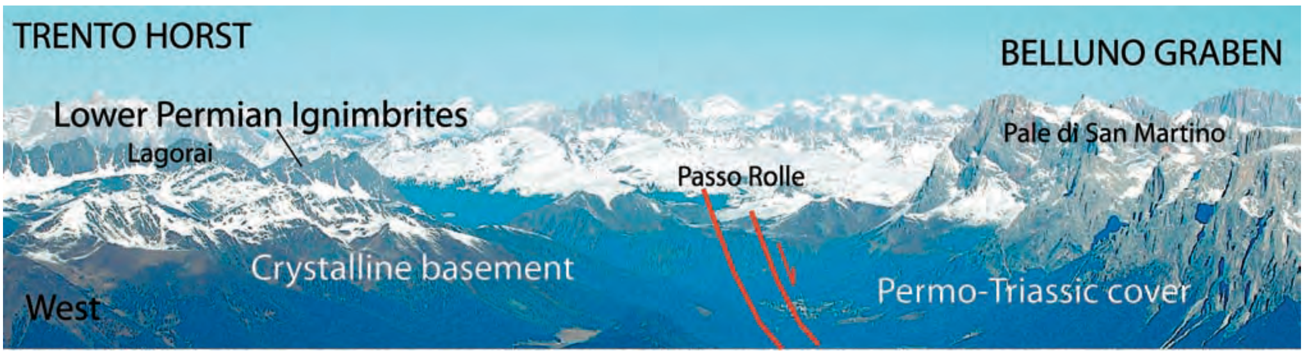


Fig. 2.23 - The about N-S trending Cismon Valley, with the Passo Rolle at its head, is the seat of normal faults separating the Trento Horst and the Belluno Graben to the east. Since the Permo-Triassic thickness of the sedimentary cover in the Trento Horst is about half (2 km) of the cover to the east, this supports a long lasting history of this hinge, acting as one of the major hinge zones during the Tethyan rift. During the Alpine shortening, the hinge was reactivated as a left-lateral strike-slip transfer zone. In the hangingwall of the Valsugana thrust, to the west the basement dips steadily northward about 30°, parallel to the deep thrust plane. To the east, the basement and the cover are folded within the Pale di San Martino syncline.

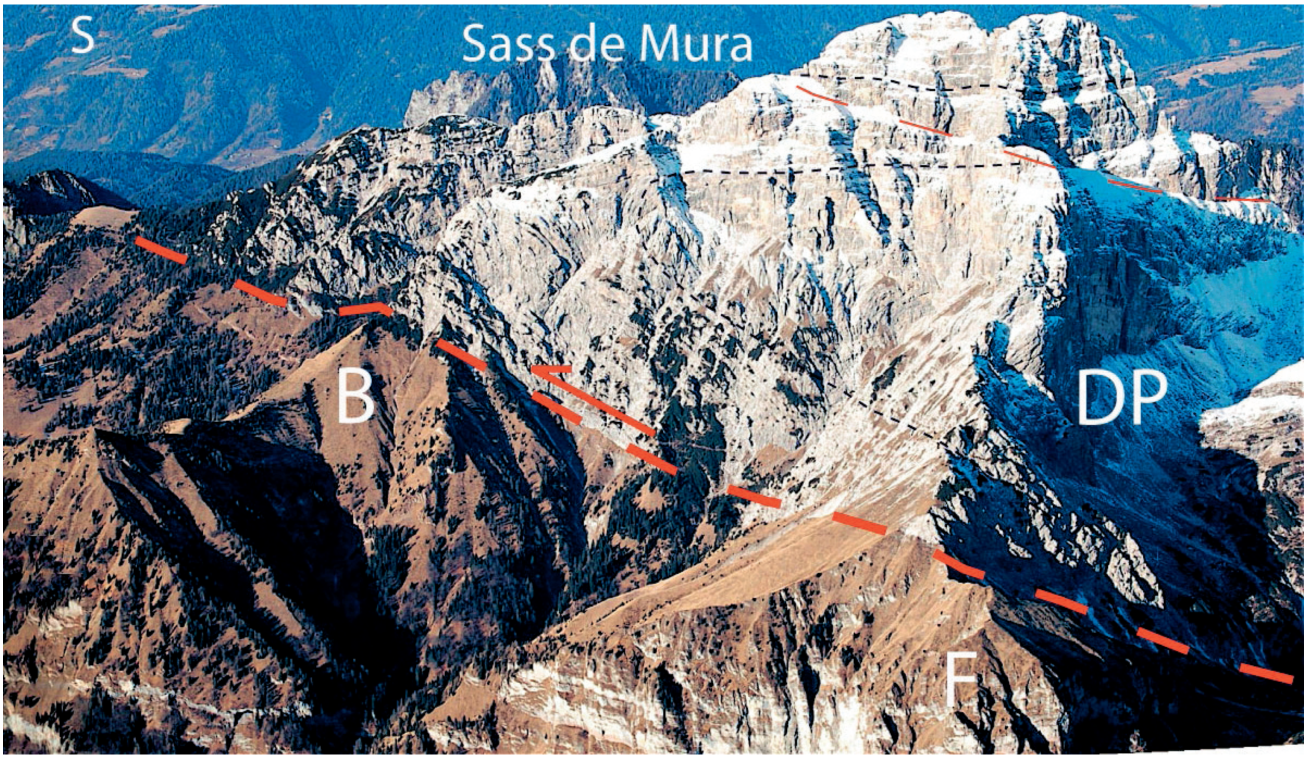


Fig. 2.24 - South of the Pale di San Martino, the S-verging Valsugana thrust carries the fault-propagation fold of Norian Dolomia Principale (DP) over the Lower Cretaceous Scaglia Variegata, Biancone (B) and the Middle-Upper Jurassic Fonzaso Fm (F). Note the long overturned forelimb.

Fig. 2.25 - Valsugana thrust footwall syncline affecting Liassic Calcari Grigi, south of Agordo in the Mt. Cielo.