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Tectonics of the Dolomites

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The Dolomites are a part of the Alps, and therefore they recorded the subduction history of this orogeny (e. g. Kummerow et al. 2004; Castellarin et al. 2006). The Mesozoic passive margin sequences deposited on top of a hercynian basement were compressed during the alpine evolution. The passive margin history is recorded particularly by thickness variations of the sedimentary cover (about 2 km above the Trento Horst, and about 4.5 km in the Belluno Graben, Fig. 1). The thickness variations are spread-out over the entire late Permian, Triassic and Jurassic sequences, testifying an endless history of extensional-transtensional tectonics. The Dolomites are located half on the Trento Horst and half on the Belluno Graben.

Late Permian to Early Cretaceous crustal extension is well documented in the region (Bertotti et al. 1993) and it is generally believed that extensional tectonics in the Southern Alps are a manifestation of sinistral transtension during the Triassic to Early Cretaceous continental and subsequent oceanic rifting between the Adriatic and the European plate. Inversion of extension to compression in the Southern Alps is apparent from middle Cretaceous time, coincident with the opening of the North Atlantic and the general change of relative motion of Africa and Europe from sinistral transtension to dextral transpression.

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Summary of talks and contributions to the field trips given at the VSP/ASP annual convention, Ortisei, Italy, June 2007.

The Mesozoic extension is particularly evident already from the general geologic map of the Dolomites located in the hangingwall of the Valsugana Thrust (Bosellini & Doglioni 1986). In fact the crystalline basement is much higher in the western side of the Dolomites with respect to the eastern part (Fig. 1). Mesozoic extension generated mainly N-S trending normal faults, which separate the Trento Horst to the west and the Belluno Graben to the east. N70°-90° trending strike-slip transfer faults accomodated undulations of the extension.

During the growth of the Alps, the Trento Horst was probably the hardest lithospheric segment of the Adriatic plate. For this reason, the Dolomites are relatively well preserved by alpine tectonics, and the original Triassic platform-basin transitions are spectacularly preserved. Acting as a stronger crustal block, the Dolomites are in fact a recess of the alpine thrust belt, in which the Southern Alps (and the Dolomites) represent the retrobelt, i. e., that part of the double verging orogen, where thrusts and folds are directed toward the upper plate (the Adriatic plate). The Giudicarie Belt, to the west of the Dolomites, is the left-lateral transpressive system bounding the Dolomites recess, and transferring the deformation to the Milano-Lombardy salient, formed within the Lombardy Mesozoic basin. This structural undulation is one of the most prominent alpine features.

The Dolomites are now geographically and geologically located between the dextrally transpressive Pusteria Line to the north (a segment of the Insubric Lineament) and the SSE-vergent Valsugana Thrust to the south

(Fig. 2). These two main features have been active during Tertiary times. The Valsugana Line is the SSE vergent overthrust which marks the boundary between the Dolomites and the Venetian Prealps. Paleomagnetic data from the Venetian Prealps have indicated no significant rotation among thrust sheets and a generally concordance of Late Jurassic and Cretaceous data with the African apparent polar wander path (Channell et al. 1992). These low relative rotations between the Southalpine thrust sheets may be related to the deep roots in the basement of the thrust planes.

The Dolomites are located within an about 60 km wide pop-up, generated by the S-verging Valsugana thrust, and its conjugate N-verging thrusts (the Funes Line). The pop-up is confining a crustal-scale syncline where most of the Dolomites are situated (Fig. 2).

Particularly during Middle Triassic times, the Dolomites underwent a sinistral transpressive tectonic phase, concentrated along the N70° alignment of the Stava Line – northern limb of the Cima Bocche Anticline. Along this trend outcrop flower structures and high angle strike slip faults, cutting the entire basement and sedimentary cover up to Early Ladinian rocks. These features are cross-cut by the Late Ladinian - Early Carnian intrusions of Predazzo and Monzoni, supporting with other stratigraphic and structural data the Middle Triassic age of this deformation (Doglioni 1987). Minor similar alignments occur more to the north in the Dolomites along the Fedaia Pass and the Val Gardena Pass. The Middle Triassic volcanism occurring along the alignment is shoshonitic in character (Lucchini et al. 1982).

The first Alpine phase of shortening in the Dolomites is Paleogene in age and is represented by WSW-vergent thrusts of the «Dinaric» phase (Doglioni 1987). The front of this thrust belt runs from NW to SE across throughout all the Dolomites (Fig. 3), but is rather the right-lateral transpressive transfer zone bounding to the east to the Dolomites recess, and transferring the deformation to the Belluno salient. The sedimentary cover in the Dolomites was shortened by at least 10-15 km during this deformation phase (mainly thin-skinned tectonics in this area). Ramps occurred at the margins of Triassic carbonate platforms and at the hinge zone between the Trento Horst and the Belluno Graben.

From Late Oligocene to Recent, the Dolomites and the Venetian Alps have been affected by deeper SSE-vergent thrusting of the «Southalpine» deformation phase, which deeply involved the basement (thick-skinned tectonics). The minimum total shortening in the Dolomites and Venetian Alps during this deformation phase is 40-50 km (Doglioni 1987). The Dolomites during this latest Neo-Alpine phase assumed the pop-up geometry due to the Valsugana Thrust and its conjugate back-thrust. The push-up is responsible for the wide syncline containing the sedimentary cover of the Dolomites, which adapted itself through flexural slip and flexural shear to the folding of the underlying basement. The inherited Mesozoic architecture (normal faults and strike-slip zones, carbonate platforms to basins transitions) acted as inhomogenities to the folding and controlled transfer zones and undulations of the Tertiary shortening. Some Mesozoic features might also have been reactivated or inverted (Doglioni & Carminati 2007). The previous NW-trending thrusts and folds have been folded and cross-cut by the deeper deformation (Fig. 4).

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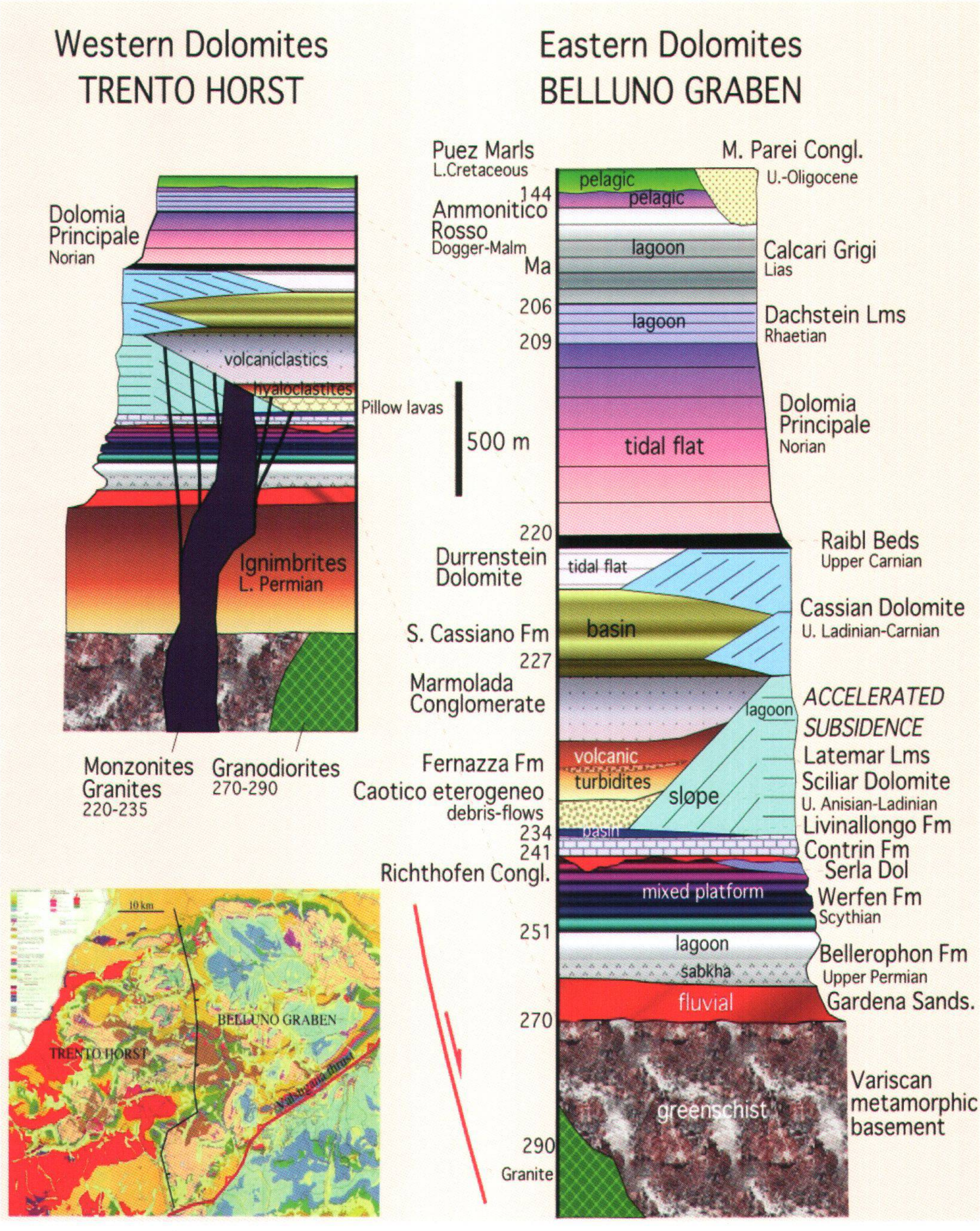

Fig. 1: General stratigraphy of the Dolomites. The eastern side underwent larger subsidence throughout the entire late Permian - Mesozoic. The differential subsidence was accommodated by a number of synsedimentary, roughly N-S-trending normal faults. The western side in the Trento Horst has a thickness reduced to about a half with respect to the Belluno Graben. Note that during the late Anisian - early Ladinian, the region had an accelerated subsidence (about 0.6 mm/year) that allowed the fast aggradation and growth of the Sciliar Dolomite (Marmolada Lms). Most of the Mid-Triassic calcalkaline magmatism (e. g. intrusions of Predazzo and Monzoni) and the lower Permian porphyry (Piastrone porfirico Atesino) concentrated in the Trento Horst (after Doglioni & Carminati 2007).

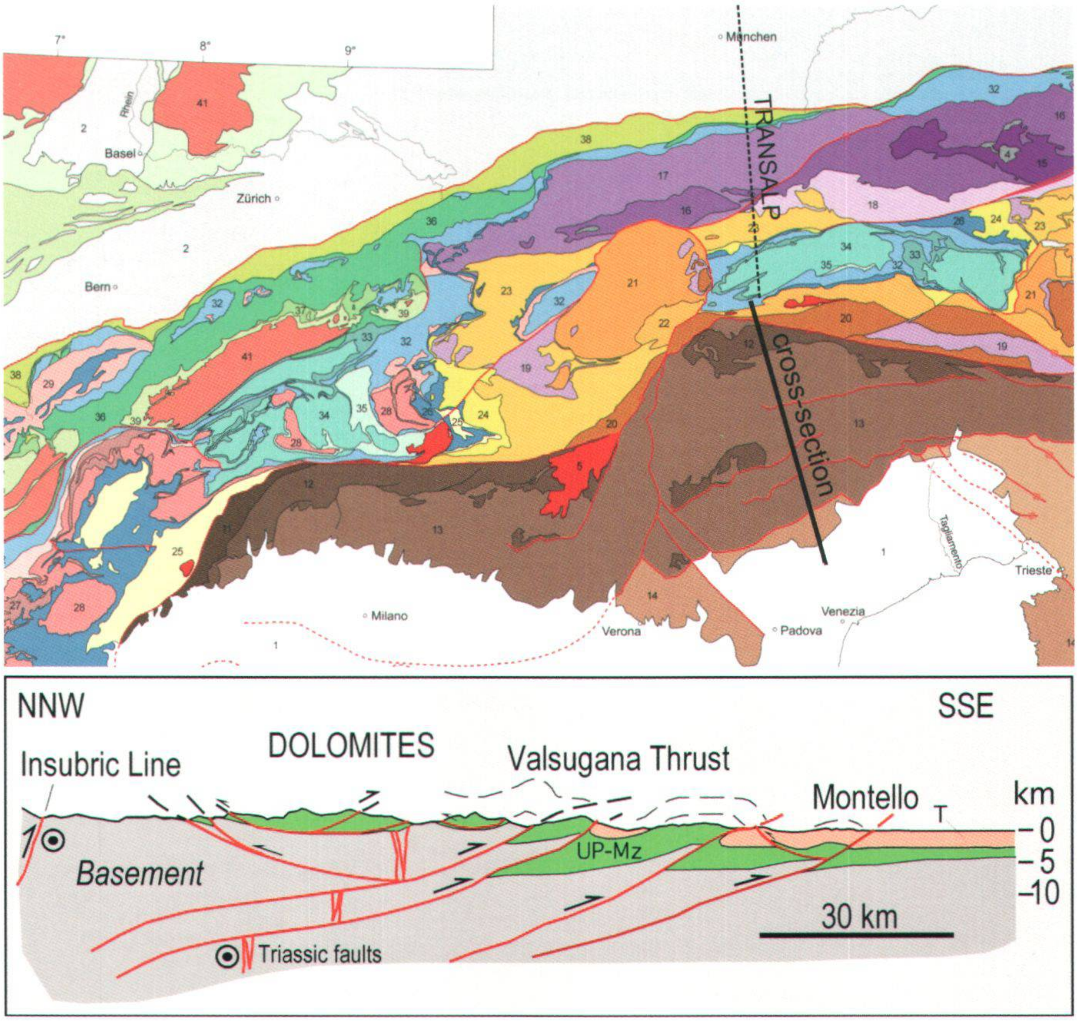

Fig. 2: Cross-section of the Southern Alps with the location of the field trip area (modified after Doglioni 1987). Map after Schmid, S.M. et al. 2004; UP-Mz: Upper Permian-Mesozoic, T: Tertiary.

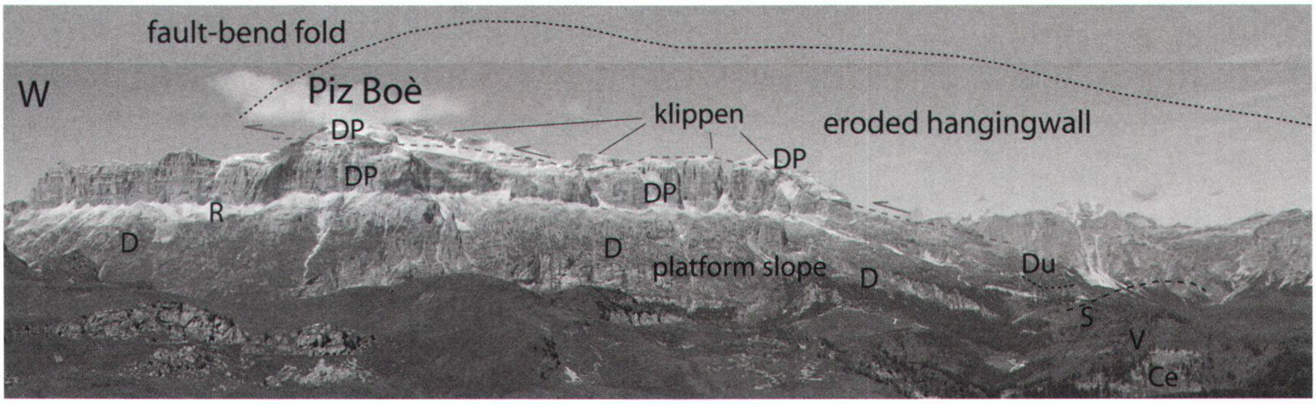

Fig. 3: View of the Sella Massif from the south. The basal part consists of Cassian Dolomite (D) of Middle Carnian age. The overlying debris in the middle consists of rocks belonging to the Upper Carnian Raibl Fm. (R). The upper cliff is made of Norian Dolomia Principale (DP). Du: Dürrenstein Dolomite, S: San Cassiano Fm., V: Volcanoclastic sandstones, Ce: Caotico Eterogeneo. The thrust followed the shape of the Carnian platform slope, it continued in ramp into the Dolomia Principale, and with a staircase trajectory arrived at the top of the Piz Boè with its classic upper klippe. The top klippe overlies a condensed Jurassic-Cretaceous succession. The thrust represents the leading edge of the WSW-directed thrusting of Paleogene(?) age in the Dolomites, later deformed by the younger (Neogene to present) SSE-directed deeper thrusts and folds (after Doglioni & Carminati 2007).

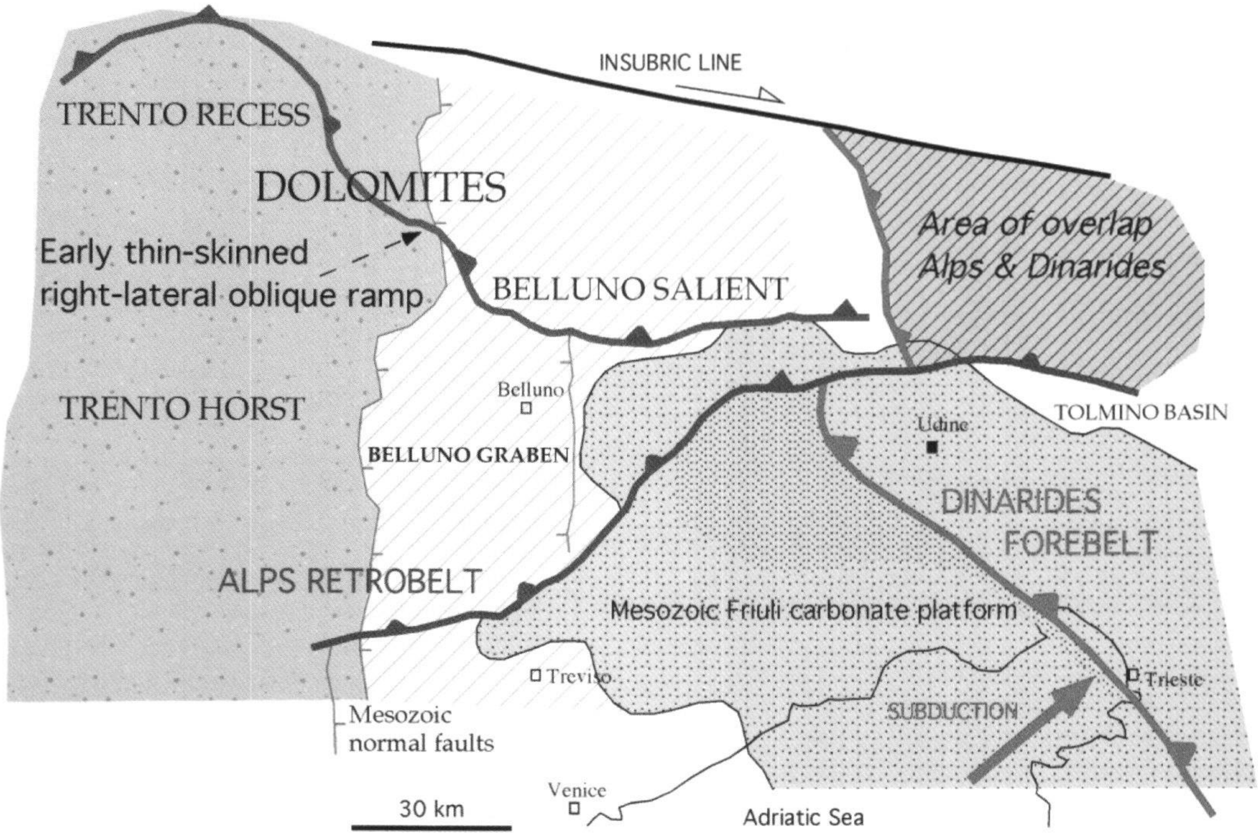

Fig. 4: The WSW-verging thrusts in the Dolomites are here interpreted as the oblique right-lateral transpressive ramp of the advancing Eocene alpine thrusting between the Trento recess and the Belluno salient. In this view the area of Alps-Dinarides overlap is more restricted to the east.

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