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# Geological Field Trips and Maps

## The Geology of Monte Tignoso and Pian Dei Cavalli area (Val San Giacomo, Central Alps, Italy): a field trip along the tectonic boundary between the Tambo and Suretta Nappes

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**Geological Field Trips and Maps**

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# The Geology of Monte Tignoso and Pian Dei Cavalli area (Val San Giacomo, Central Alps, Italy): a field trip along the tectonic boundary between the Tambo and Suretta Nappes

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**Cover page figure:** The Monte Tignoso area (Campodolcino, Sondrio Province), on the northern flank of Val Starleggia, as seen from the south. The summit of the peak constitutes a klippe of Suretta nappe rocks, in tectonic contact with the underlying Tambo nappe cover rocks.

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## ABSTRACT

**The Monte Tignoso area, located along the western flank of Val San Giacomo (Central Alps), offers a unique and well-exposed cross-section through the tectonic contact of the Middle Penninic Tambo and Suretta nappes, as a result of the tectonic coupling during the final stages of the continental collision between the European and Adriatic plates.**
**The Permian-Mesozoic meta-sedimentary pile of the Tambo nappe is mainly made up of quartzites and successions of metacarbonates, and it is pinched between the poly-metamorphic basement rocks of the Tambo and Suretta nappes.**
**The one-day round trip illustrates a geological transect through the nappe stack, starting from the upper portions of the Tambo nappe basement, crossing the meta-sedimentary cover, up to the Suretta nappe basement, which forms a tectonic klippe on the top of Monte Tignoso. Furthermore, the field trip shows the main geomorphological and Quaternary peculiarities encountered along the way, as periglacial landforms, deep slope gravitative deformations and a well-developed karst system, all controlled, at least partially, by the distinctive geological and structural features that characterise the area.**
**The peculiar setting of the area, combined with a non-harsh environment, makes it suitable for an easy one-day field trip capable of condensing multiple geological evidence typical of the Central Alps.**

*Keywords:* Central Alps, Tambo nappe, Suretta nappe, structural geology, Quaternary geology.

## PROGRAM SUMMARY

Fourteen geological stops have been selected, along a 14 km long itinerary. The circular itinerary (Fig. 1) has an elevation gain of 650 m, and leads through a typical alpine environment made up of forests at the lower altitudes, and then an open mountain setting of grassy pastures alternated with rocky cliffs at higher altitudes. The itinerary hiking scale (SAC scale, Swiss Alpine Club) is T2-mountain hiking. The itinerary starts at an altitude of 1776 m a.s.l. and reaches its maximum elevation (2318 m a.s.l.) near Lago Bianco, located at the western end of the grassy, gently sloping Pian dei Cavalli area.
Itinerary lenght: 14 km; total travel time (estimated): 8 h

## SAFETY

In the field trip area, the use of appropriate equipment for mountain environment, especially hiking boots and long hiking pants is recommended. It's good to bring solar cream, hat and sunglasses, due to the sun exposition of the area. At the same time, it is recommended to bring wind jacket and water-proof clothes, because sudden rainfall events and storms are very common.
Pay attention to animals grazing in pastures, as horses and cows, and to dangerous species as snakes or ticks. Also pay attention to some poisonous flowers (e.g., *Aconitum napellus*). In the end, we recommend using a protective helmet in case of extended stops under rocky cliffs or dangerous slopes. Emergency telephone numbers in Lombardy: 112 (general emergency number); 113 (police); 115 (fire brigade).

**Table 1 - Location of stops of the field trip.**

| n. | Latitude (DD) | Longitude (DD) | Altitude a.s.l. (m) | Stop name |
|---|---|---|---|---|
| 1 | 46.409036 N | 9.319582 E | 1776 | The «Beola Verde» quarry of San Sisto: the quartzites of the meta-sedimentary cover of the Tambo nappe |
| 2 | 46.416278 N | 9.320676 E | 1920 | The chlorite and sericite quartz schists of the meta-sedimentary cover of the Tambo nappe |
| 3 | 46.417254 N | 9.318520 E | 2002 | The Monte Tignoso thrust and the tectonic breccias of Alpe Toiana |
| 4 | 46.418697 N | 9.318225 E | 2020 | Deep-seated gravitational slope deformations at the eastern side of Pian dei Cavalli |
| 5 | 46.421248 N | 9.315655 E | 2092 | The Pian dei Cavalli carbonate sequence |
| 6 | 46.424414 N | 9.312029 E | 2160 | The Tambo nappe meta-sedimentary cover and the Pian dei Cavalli karst system |
| 7 | 46.421455 N | 9.302995 E | 2177 | Periglacial features at Pian dei Cavalli: the Monte Tignoso rock glacier |
| 8 | 46.419488 N | 9.294906 E | 2206 | The Pian dei Cavalli thrust along Valle del Lago Bianco |
| 9 | 46.418837 N | 9.288297 E | 2323 | The Tambo nappe basement outcropping near Lago Bianco |
| 10 | 46.414961 N | 9.298167 E | 2270 | The carnieules of the carbonate cover and their geological meaning |
| 11 | 46.414103 N | 9.300141 E | 2265 | The quartzitic metaconglomerate west of Monte Tignoso |
| 12 | 46.413674 N | 9.300538 E | 2230 | Panoramic view of the morainic amphitheatres in Val Starleggia and Val Sancia, related to Lateglacial to Holocene stadials |
| 13 | 46.413393 N | 9.303102 E | 2210 | The quartzitic gneiss of the Suretta nappe basement and the Monte Tignoso tectonic klippe |
| 14 | 46.407418 N | 9.315827 E | 1820 | Panoramic views on Monte Tignoso and Val Sancia |

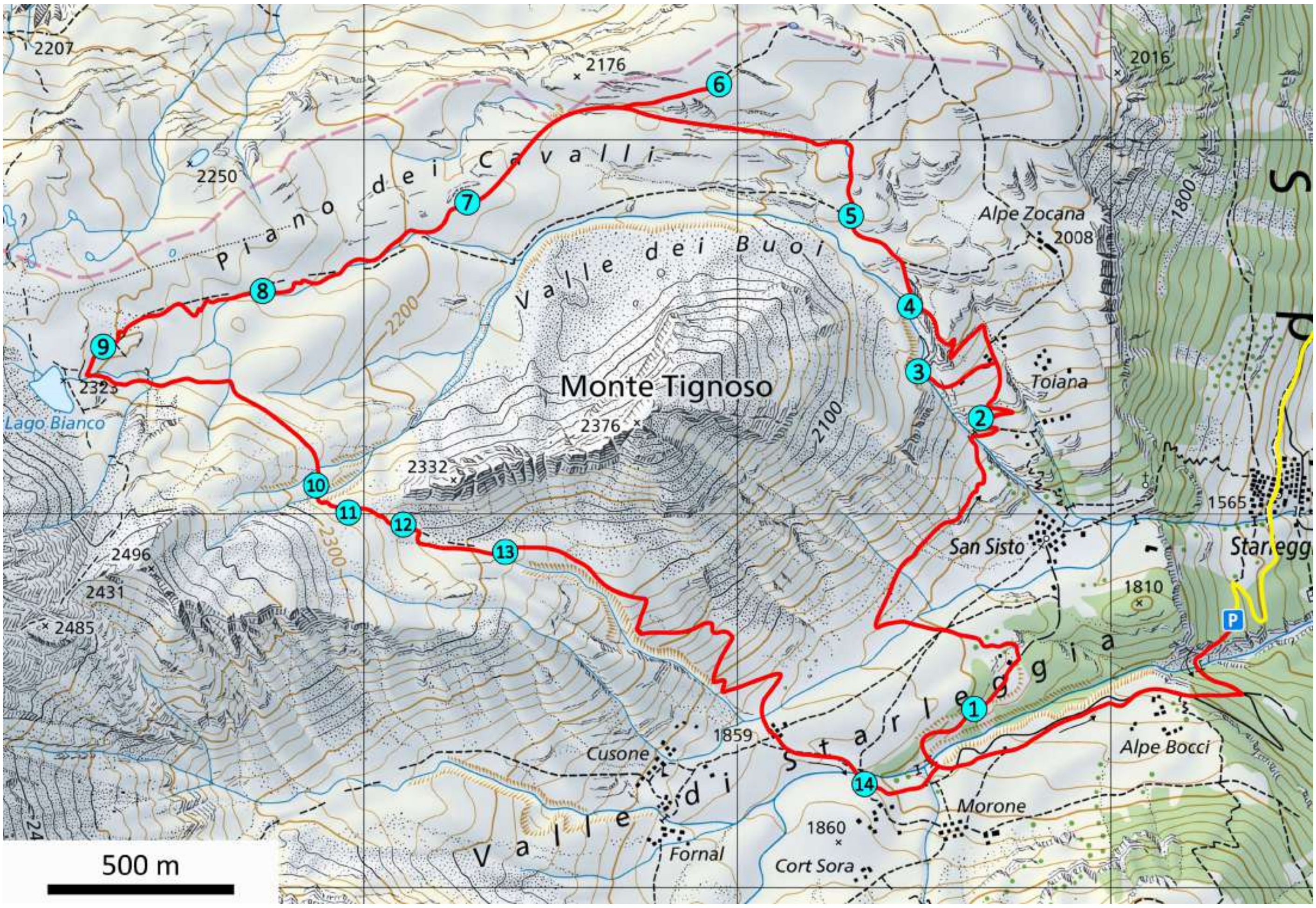


Fig. 1 - Field trip itinerary. Stops are marked by circles. Cartographic base: ©Federal Office of Topography swisstopo. Link to the online map: https://s.geo.admin.ch/0ovvg8cob5rt.

## HOSPITALS

Chiavenna Hospital, Via della Cereria 4 - 23022 - CHIAVENNA (SO), phone 0343 67111.

Morbegno Hospital, Via Morelli 1 - 23017 - MORBEGNO (SO), phone 0342 607111.

## ACCOMODATION

There are several hotels, B&B, camping and mountain huts in the area of the field trip https://booking.valtellina.it/it/valchiavenna/madesimo-campodolcino/campodolcino.

## TRAIL NETWORK

The hiking network in the field trip area is maintained by Club Alpino Italiano (CAI), Chiavenna and Vallespluga-Madesimo divisions. All the trails included in the field trip are marked by the «red and white» signals of the «Rete Escursionistica della Lombardia» (REL). A complete map of the trail network is findable at https://www.valtellinaoutdoor.it/it/map.

## BASE MAPS

Swisstopo CN 1:50,000 267, San Bernardino; CN 1:25,000 1275, Campodolcino;
Kompass 1:50,000 n.92, Valchiavenna, Val Bregaglia;
Carta Tecnica Regionale (CTR) della Lombardia 1:10,000 (B2c1, Pizzo di Curciusa; B2c2, Pizzo Quadro; B2d1, Madesimo; B2d2, Campodolcino).

## HOW TO REACH THE PLACE

The field trip area is located in Val San Giacomo (Fig. 2, Sondrio Province, Lombardy Region), and can be reached from the town of Chiavenna, via the SS36 “del Lago di Como e dello Spluga” road. From the village of Campodolcino, the Starleggia communal road and then the agro-pastoral road Starleggia-San Sisto lead to the starting point of the trip, up to the road bar near Starleggia riverstream, where it is possible to park the car.

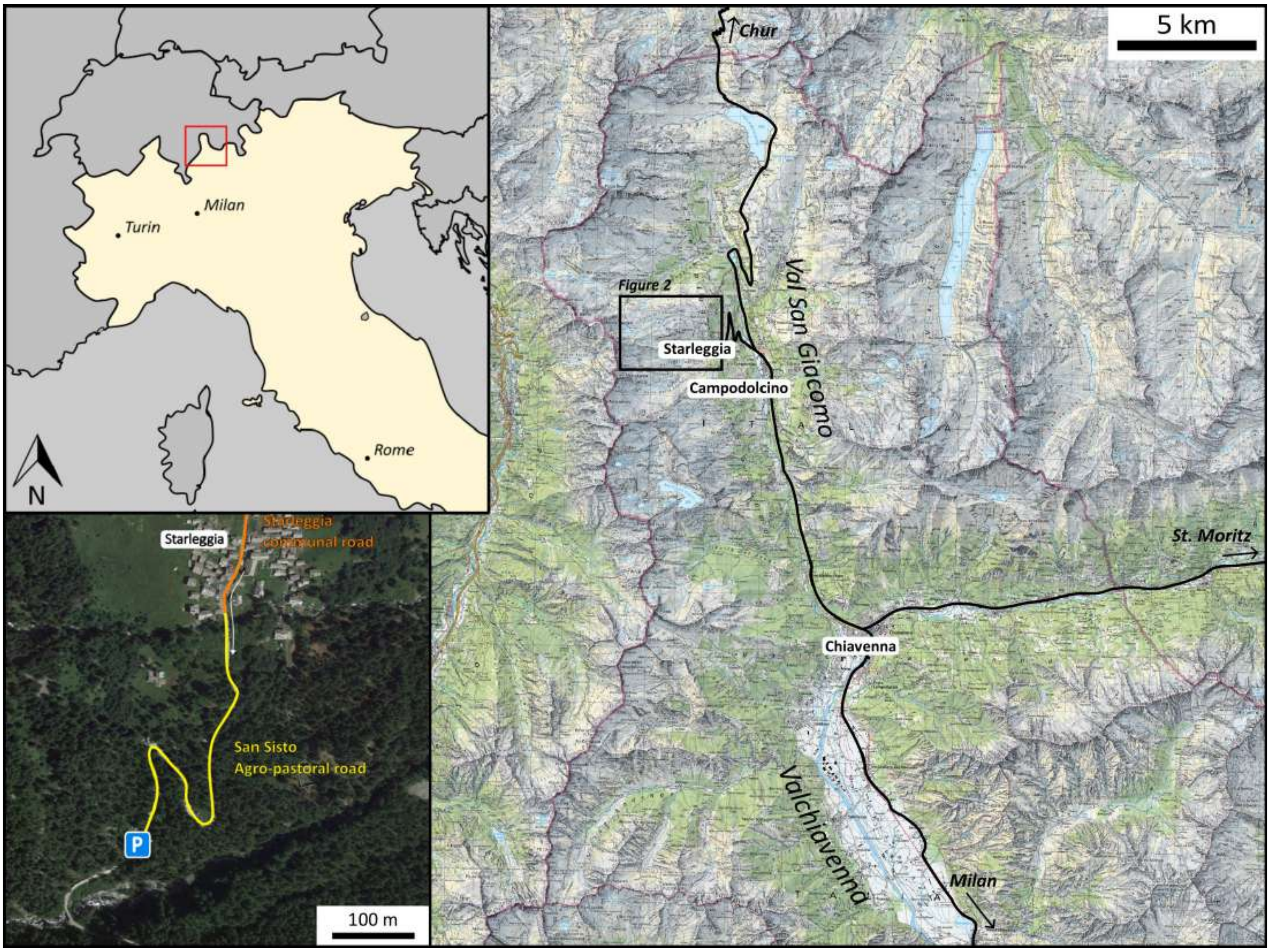


Fig. 2 - Location of the field trip area. Cartographic base: ©Federal Office of Topography swisstopo.

## GEOLOGICAL AND STRUCTURAL SETTING OF VALCHIAVENNA

The south-eastern portion of the Central Alps is characterised by a complex geological setting, due to the presence of many tectonic units (Fig. 3), mainly belonging to the Penninic and the Lepontic Domain of the Alps (Gouffon, 2024; Schmid et al., 1990). The Valchiavenna area is delimited by the Insubric Line to the south, and its geological structure is characterised by the Penninic nappe stack of a pre-Alpine polycyclic and poly-metamorphic crystalline basement, in the eastern portions of the Lepontine metamorphic Dome (Berger et al., 2005;

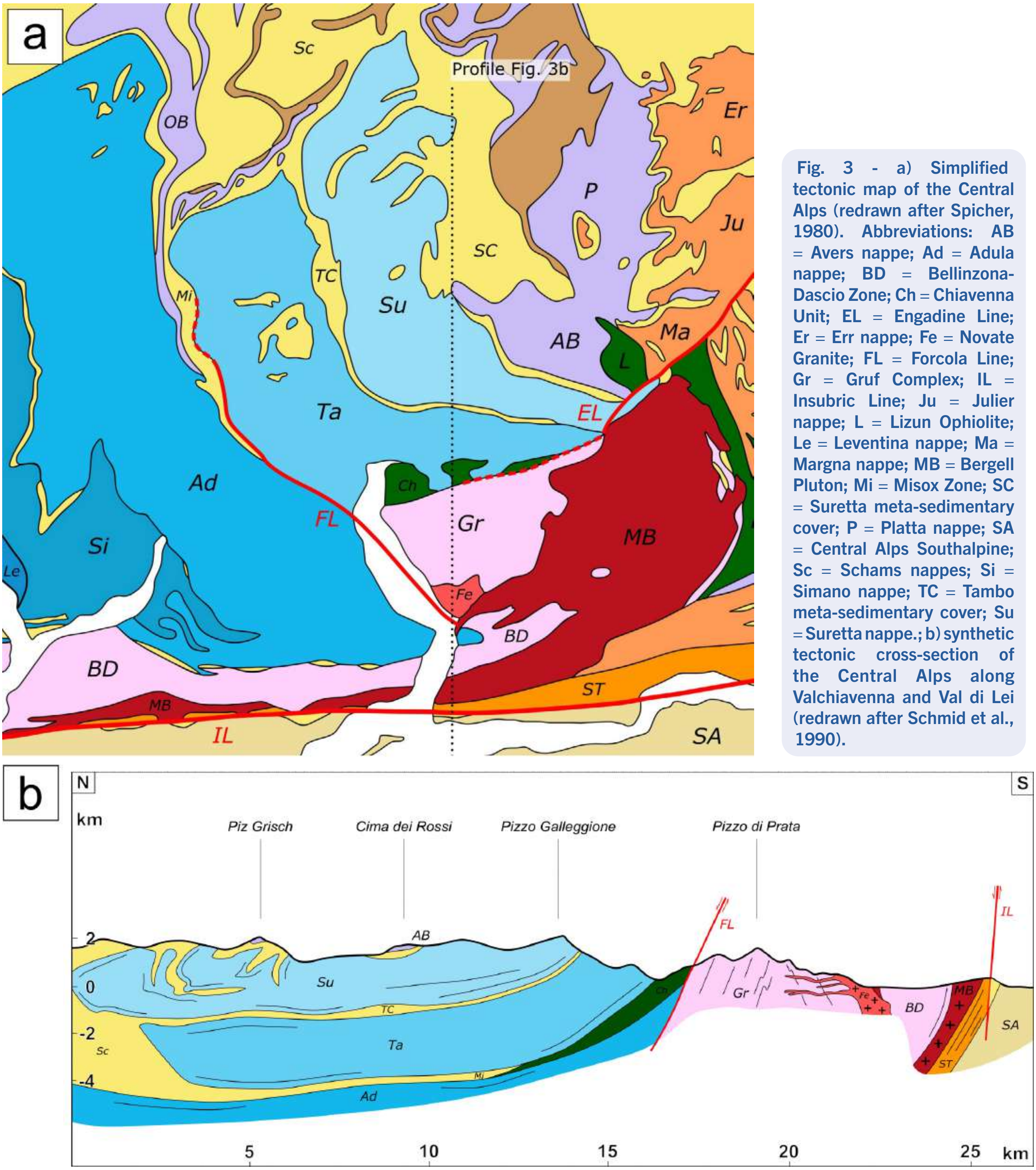


Fig. 3 - a) Simplified tectonic map of the Central Alps (redrawn after Spicher, 1980). Abbreviations: AB = Avers nappe; Ad = Adula nappe; BD = Bellinzona-Dascio Zone; Ch = Chiavenna Unit; EL = Engadine Line; Er = Err nappe; Fe = Novate Granite; FL = Forcola Line; Gr = Gruf Complex; IL = Insubric Line; Ju = Julier nappe; L = Lizun Ophiolite; Le = Leventina nappe; Ma = Margna nappe; MB = Bergell Pluton; Mi = Misox Zone; SC = Suretta meta-sedimentary cover; P = Platta nappe; SA = Central Alps Southalpine; Sc = Schams nappes; Si = Simano nappe; TC = Tambo meta-sedimentary cover; Su = Suretta nappe.; b) synthetic tectonic cross-section of the Central Alps along Valchiavenna and Val di Lei (redrawn after Schmid et al., 1990).

Nagel, 2008). The recent-published Tectonic Map of Switzerland 1:500,000 (swisstopo, 2024) gives an overall vision of the tectonic framework of the Central Alps area.
The Adula and Simano nappes (Lower Penninic, Nagel, 2008; Lepontic, Gouffon, 2024) are overlapped by the Medium Penninic nappes, including the Tambo and Suretta nappes, topped by the Upper Penninic Avers nappe. The nappes are separated by thin slices of meta-sedimentary rocks of Permian to Triassic ages and/or by tectonic mélanges (i.e., the Misox Zone, interposed between the Adula and Tambo nappes, and the Splügen Zone, interposed between the Tambo and Suretta nappes) that acted as a sliding surface between thick portions of more competent crystalline basement (Baudin et al., 1995).
According to palaeogeographic reconstructions, the Penninic Domain includes two oceanic basins (i.e., the Ligurian-Piedmont and Valais oceans), separated by the Briançonnais micro-continent; it is bordered by the continental margins of the Adria and Europe plates (Schmid et al., 1990).
The Briançonnais area constitutes a piece of thinned continental European crust, and the allocation of the Suretta and Tambo nappes to this palaeogeographic domain is now accepted due to the great similarities of their covers (Baudin et al., 1995). They represent crustal portions of the eastern margin of the micro-continent (Stampfli et al., 1998).

## GEOLOGICAL AND GEOMORPHOLOGICAL SETTING OF VAL SAN GIACOMO

The Val San Giacomo is located in the Central Alps, between the Lepontine Alps, to the west, and the Rhaetian Alps, to the east. The valley is a northern tributary of Valchiavenna, which to the south connects to Adda and Como Lake valleys.
Most of the Tambo nappe basement is made up of paragneiss and micaschists, derived by sedimentary arenitic and clayey protholits (Baudin et al., 1993). These rocks locally preserve a pre-alpine mineral assemblage with staurolite, kyanite, andalusite, garnet, muscovite and biotite. The basement includes old orthogneiss (locally called Foppagneiss, Weber, 1966) and migmatites, both originated by a high-temperature event responsible for crustal anatexis (Marquer et al., 1998). In the central part of the valley and toward the north there are several amphibolite lenses. Locally, these amphibolites preserve evidence of pre-alpine pyroxene-garnet assemblages, indicating eclogite-facies conditions, or pyroxenitic rocks (Baudin et al., 1993). The Truzzo Granite, a Permian batholith dated at 268.0 ± 0.4 Ma (U-Pb dating, Marquer et al., 1998), is well exposed in the south.
The polycyclic basement of the Suretta nappe is composed of two main subunits (Milnes & Schmutz, 1978; Scheiber et al., 2012): 1) the Stella-Timun Complex (Milnes & Schmutz, 1978), exposed to the south, consisting of a heterogeneous polymetamorphic complex with paragneiss, augengneiss and amphibolite, and widespread evidences of pre-alpine migmatisation; 2) the Permian Roffna Porphyry Complex (Scheiber et al., 2012) well exposed to the north, and mainly developed in the frontal parts of the nappe. The Roffna metarhyolites have been emplaced at lower crustal levels at 268.3 ± 0.6 Ma (U-Pb dating, Marquer et al., 1998; Scheiber et al., 2013).
The most striking morphological feature of Val San Giacomo is the Liro valley, that clearly cuts the territory creating a NNW-SSE, 18 km long, almost rectilinear narrow valley. The Val San Giacomo drainage basin can be morphologically divided into two parts (Fig. 4): a southern part where the valley topography is influenced by the presence of the Truzzo Granite intrusion; here the slopes are steeper and the valleys are narrower due to the low erodibility of granite and gneiss. A northern and central part where the valley widens in the higher slopes featuring a gentler topography, with large flat plateau surfaces, whilst it remains narrow and more incised along the Liro valley (Tantardini et al., 2013).
This is due to the lack of the Truzzo Granite in the northern parts of the valley (it is buried under the structurally higher portions of the Tambo nappe, composed by paragneiss and micaschists and by rocks belonging to the meta-sedimentary cover; Fig. 4). In fact, the main plateaus of the upper Val San Giacomo have a meta-sedimentary carbonate substrate, as in the case of the Andossi, Motta and Pian dei Cavalli plateaus. This is mainly due to the presence of several structural surfaces that reflect the main thrusts that separate the Tambo nappe basement from its covers (Tantardini, 2016).
The Val San Giacomo (Fig. 5), as demonstrated by studies on perialpine sediments and on the structural evolution of the Central Alps (Bernoulli et al., 1993; Bersezio et al., 1993), already existed during the Miocene. Probably, it gained the present morphology already in the Late Miocene during the Messinian salinity crisis, as it is a tributary valley of the Como Lake which deepened during the Messinian, like most of the southern alpine valleys (Bini, 1994; Biella et al., 2001). Therefore, glacial erosion is not the main cause of the morphology of Val San Giacomo: weathering, denudation, slope dynamics and fluvial erosion have had greater impact on its formation (Tantardini et al., 2022).

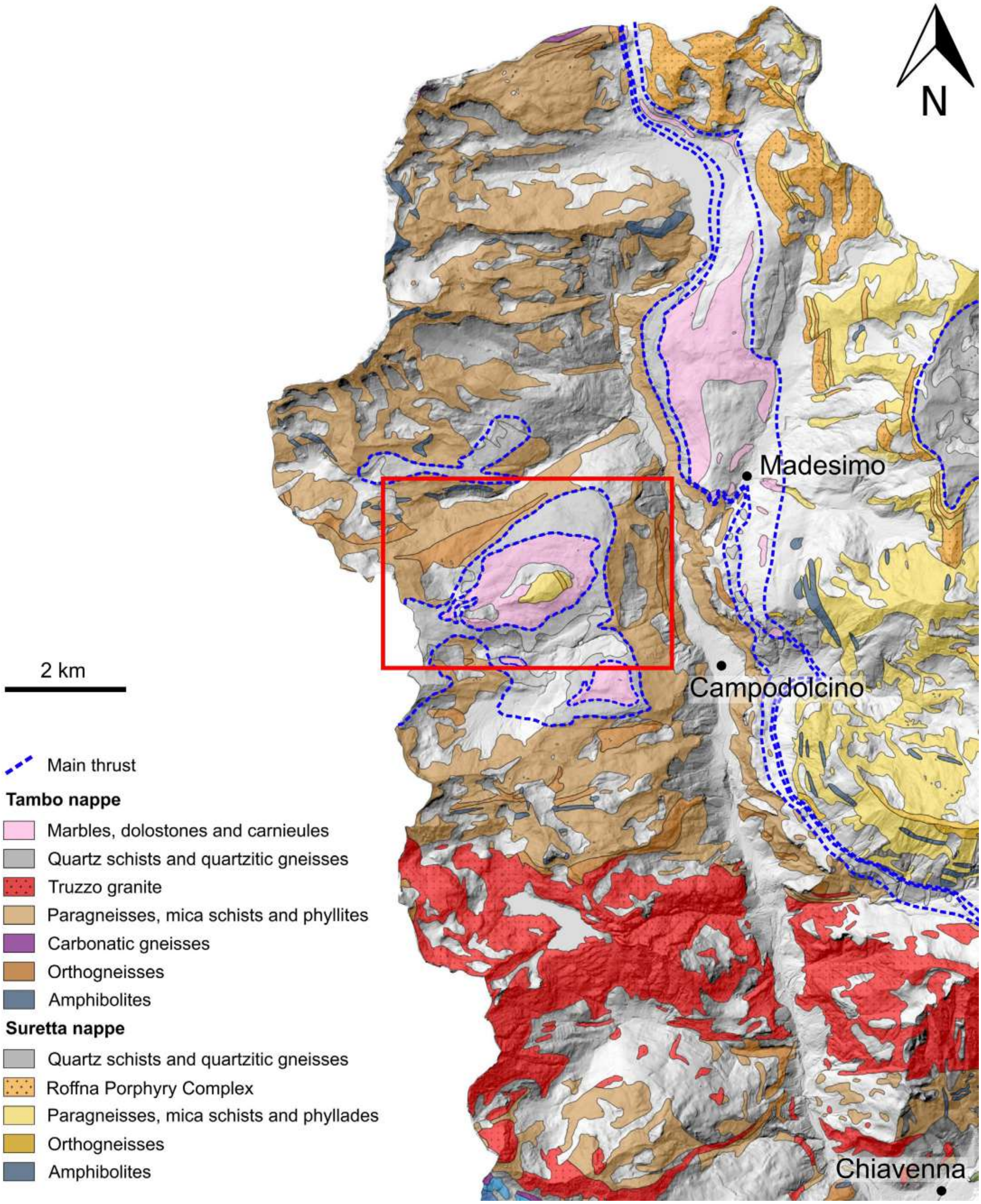


**Fig. 4 - Geological map of Val San Giacomo (modified after Montrasio et al., 1988).**

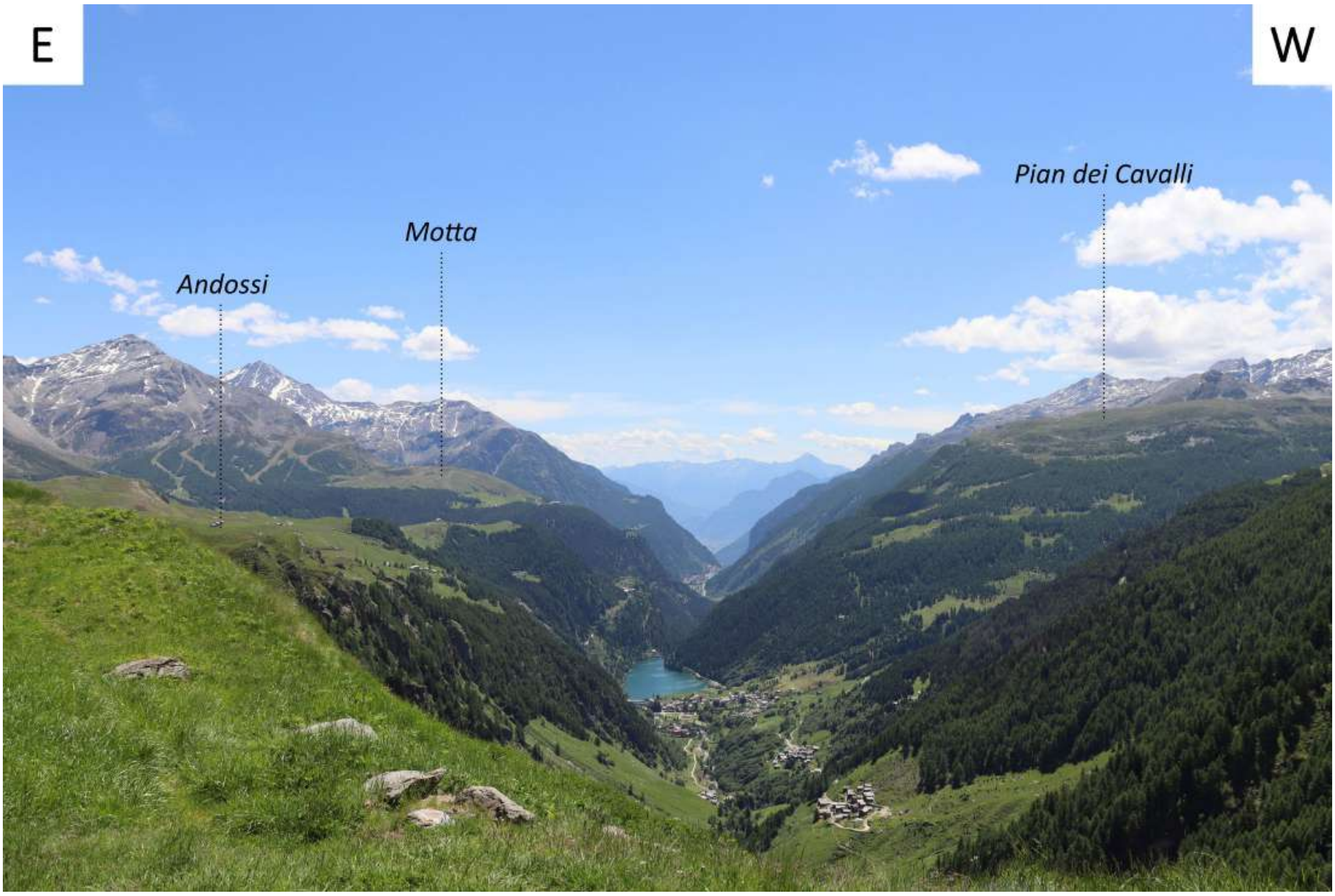


Fig. 5 - Panoramic view of Val San Giacomo seen from Alpe Mede (1920 m a.s.l.). The smooth, grassy valley shoulders on both sides of Val San Giacomo (Andossi, Motta and Pian dei Cavalli) are well recognizable. They mainly consist of the metacarbonates of the Tambo nappe.

## TECTONO-METAMORPHIC EVOLUTION

The basement of the Suretta and Tambo nappes underwent regional metamorphism during the Variscan Orogeny, between Carboniferous and Permian times (Engi et al., 2004). Nussbaum et al. (1998) indicate that the Suretta nappe experienced metamorphic conditions of at least 2.0 GPa and 700 °C, referred to subduction-to-collision, which suggests a pre-Alpine subduction-collision event. During the early Permian, post-collisional extension contemporaneously promoted ascent and intrusion of the Truzzo Granite and the Roffna Porphyry Complex, by the same magmatic event (Marquer et al., 1998).

Following the Mesozoic formation of the Ligurian-Piedmont and Valais basins, separating the Briançonnais micro-continent from the Adria and Europe, respectively, the Alpine convergence led to oceanic closure and continental collision. The Penninic thrusts took place with a NNW-directed stacking inside the Alpine orogenic wedge. The Suretta nappe was thrusted over the Tambo nappe during the early Eocene (56-48 Ma, Schmid et al., 1996). During the following phases of the continental collision, the stack was piled over the subducted European continental crust. The mafic rocks of the Suretta nappe indicates an alpine high-pressure and low-temperature metamorphism (1.0 GPa, 400-450°C, Nussbaum et al., 1998) caused by the subduction of the Briançonnais micro-continent under the Penninic accretionary prism. The continental collision was followed by the uplift of the orogen after the slab break-off of the subducted oceanic lithosphere. This led to exhumation, erosion and back thrusting of the Penninic Domain (Schmid et al., 1996).

According to Marquer (1991) and Milnes & Schmutz (1978), the deformation during the Alpine Orogeny that affected the rocks of the Tambo and Suretta nappes can be divided into four main phases. D1 is a ductile deformation phase that took place under eclogite-facies conditions, indicating a strong SSE-NNW oriented stretching lineation and by a top-to-the NNW shear. D2 is a ductile heterogeneous deformation phase linked to continental collision, showing a strong and pervasive eastward dipping foliation and an E-W stretching lineation. D3 and D4 phases are more localised and took place during lower grade metamorphic conditions (green schists-facies). The D3 phase was contemporaneous with the Oligocene Bergell Pluton intrusion and developed folds with an E-W trending axis and steep axial surfaces plunging southwards. The D4 phase developed several normal faults with NNW-SSE direction and plunging towards ENE at very steep angles. The main fault linked to D4 is the Forcola Line. D4 probably dated at 20 Ma and could be coeval with the transcurrent movements of the Insubric Line (Stampfli et al., 1998).

## THE GEOLOGY OF PIAN DEI CAVALLI AND MONTE TIGNOSO AREA

Within a few kilometres, the Pian dei Cavalli-Monte Tignoso area showcases different lithologies from the main tectonic units found throughout Val San Giacomo. Starting from the Liro riverbed, the right flank of the valley is composed of paragneiss, micaschist and a few orthogneiss lenses belonging to the Tambo nappe basement.

These rocks are characterised by a pervasive foliation, plunging towards east with medium to low angles (Fig. 6). From the village of Starleggia up to the small village of San Sisto, the crystalline basement gives way to the basal portion of the para-autochthonous cover of the Tambo nappe. This transition is marked by the main thrust running along both flanks of Val San Giacomo, responsible for the structural-morphological terrace of the San Sisto plateau (Fig. 6). The rocks cropping out in the area are mainly quartzitic gneiss, chlorite and sericite schists, quartzites and, in smaller quantity, marbles. From San Sisto up to Alpe Toiana (E of Monte Tignoso in Fig. 6), a second thrust develops within the meta-sedimentary covers, separating the meta-carbonatic series from the lower quartzites and quartz schists. In the field trip area, the carbonate cover is mainly composed of various types of marble, dolostone, tectonic breccia and carnieule. The Pian dei Cavalli area, north of Monte Tignoso (Fig. 7), forms an eastward-dipping plateau, which is characterised by several evidence of karst processes. In the middle of the field trip area, the Monte Tignoso stands in high prominence with respect to the surrounding smooth morphologies, due to the weakly erodible gneissic rocks belonging to the Suretta nappe that outcrops in the higher parts of the relief (Fig. 6 and 7). The latter constitute a tectonic klippe that lies directly on the carbonate cover of the Tambo nappe.

The lower part of the klippe is composed by quartzitic gneiss of the Suretta nappe basement, passing to paragneiss and biotitic micaschists towards the top. The Monte Tignoso klippe is the last remnant of Suretta nappe rocks cropping out along the right flank of the Val San Giacomo. Towards the western end of the valley, structurally lower rocks are cropping out, due to a general steepening of the eastward-dipping foliation, well visible west of Monte Tignoso (Fig. 6). The resulting geological setting shows then a concentric shape (Fig. 7), passing from structurally lower rocks in the peripheral parts (Tambo nappe basement and cover) to higher ones towards the center (Suretta nappe). This allows hikers to directly walk across the tectonic boundary of these two Middle Penninic units, which together form a part of the central-eastern alpine nappe stack.

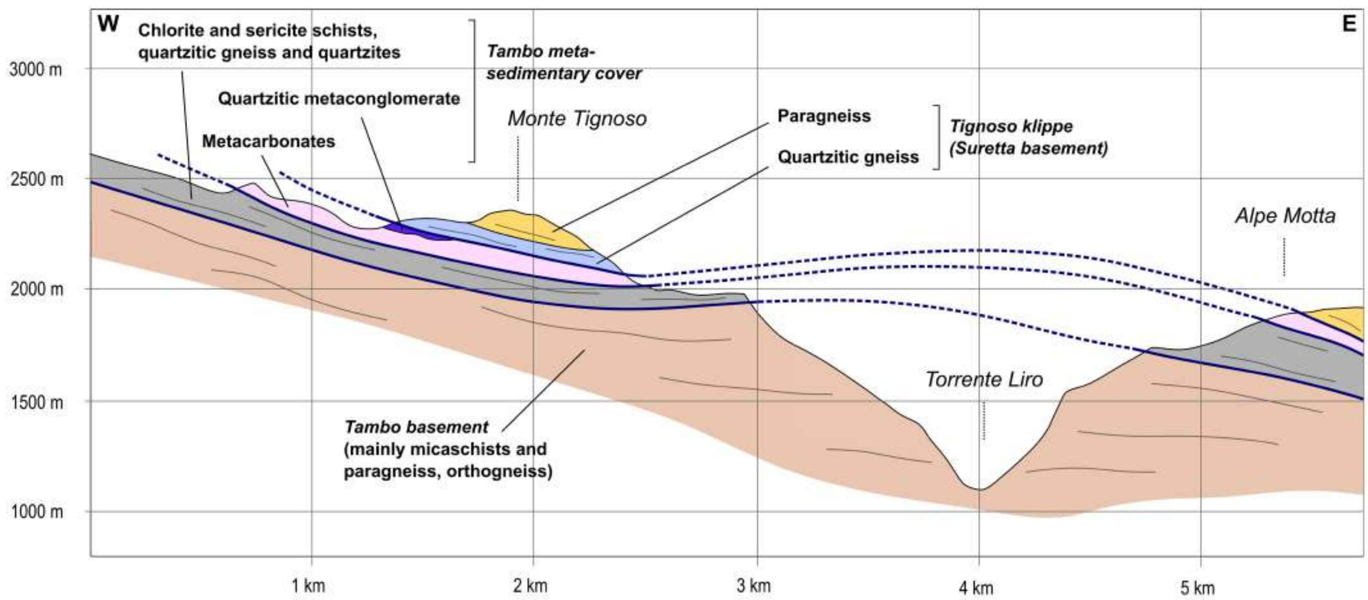


**Fig. 6 - Geological cross-section of Val San Giacomo through the Monte Tignoso area.**

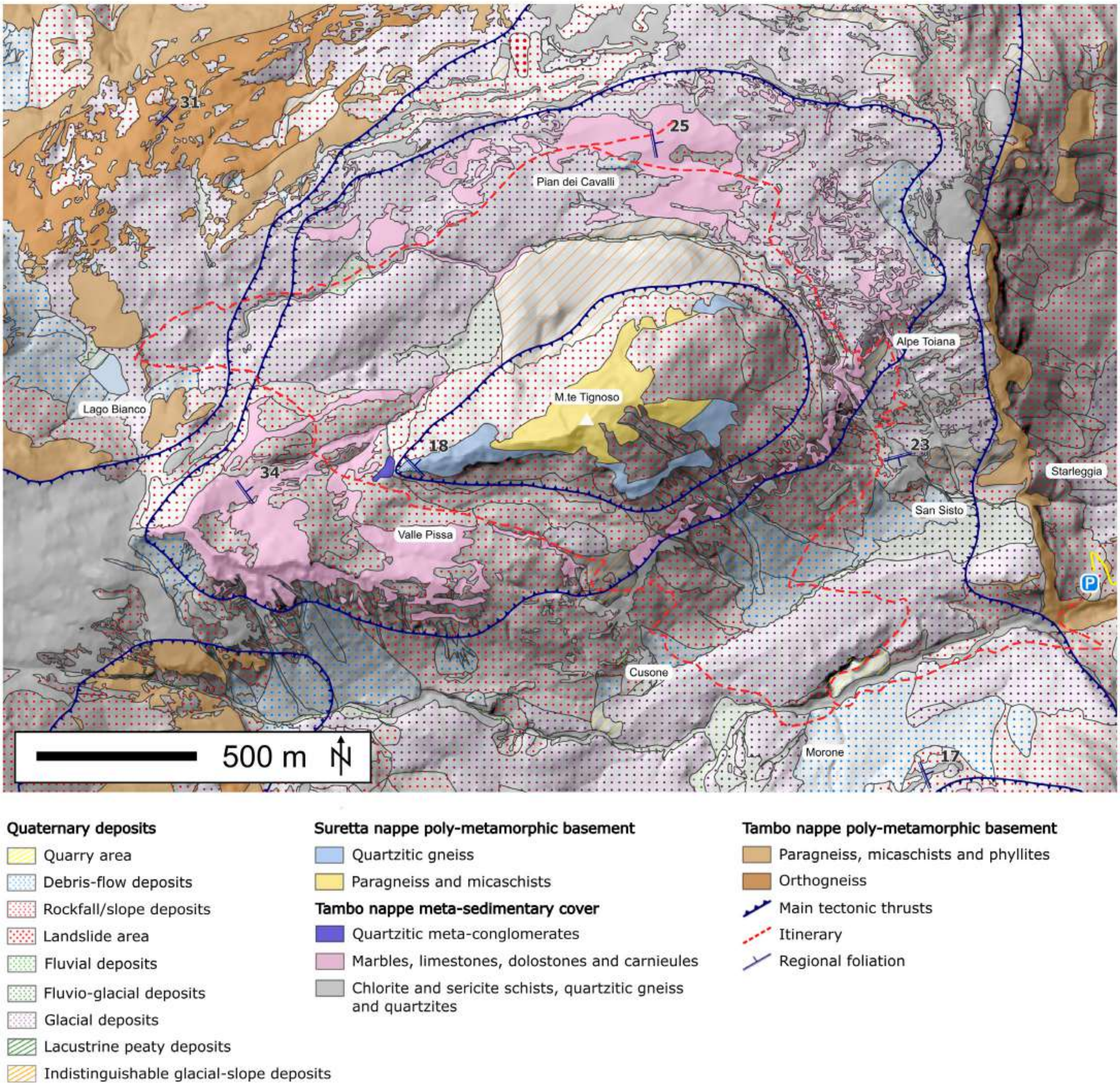


**Fig. 7 - Geological map of the Monte Tignoso area. Quaternary deposits after Tantardini, 2016; lithologies and tectonic units after Montrasio et al., 1988.**

# ITINERARY

## Stop 1 - The «Beola Verde» quarry of San Sisto: the quartzites of the meta-sedimentary cover of the Tambo nappe

**Coordinates: Lat. 46.409036 N, Long. 9.319582 E**

Starting from the car parking near the roadbar, the first part of the itinerary runs along the unpaved road that leads to San Sisto (path N692 of the "Rete Escursionistica della Regione Lombardia"). Along the road, between Morone and San Sisto, on the left side of the Starleggia creek, the path crosses the wide yard of an old, abandoned quarry (Fig. 8b). The extracted material is locally known as «Beola Verde dello Spluga», a greenish to greyish quartzite rich in chlorite (responsible for the greenish appearance) and white mica (muscovite and phengite), with high amounts of quartz and subordinate K-feldspar, albite, pyrite and iron-rich carbonates (Fig. 8a, 8c).
These rocks belong to the basal part of the Tambo nappe meta-sedimentary cover, made up of quartzitic gneiss (Fig. 9a), quartzites and quartzitic meta-conglomerates, with several affinities to the classical "Verrucano Lombardo" facies (Baudin et al., 1993). In some areas, these rocks show a strong volcano-clastic trend, especially in layers with a gneissic texture, rich in feldspar and sodic plagioclase. The latter sometimes resembles some deformed types of the Roffna rhyolites, linked to a shallow-level intrusion of subvolcanic nature (Baudin et al., 1993).
The basal Tambo cover represents the base of the Permian-Mesozoic sequence linked to basin opening during the post-collisional extension of late Permian age (Stampfli et al., 1998). In the Monte Tignoso area, the meta-sedimentary cover can reach a maximum thickness of about 150 meters.
The more quartzitic varieties were used as dimension stones for buildings, roofs or ornaments, thanks to their good mechanical properties combined with their highly demanded colours. In the past, the extraction activity was very important to the economy of the valley, while nowadays there are only few operative quarries, as the Isolato quarry (Madesimo municipality, Fig. 9b), whose material is sold as high-level luxury stone. Some quarries were established at high altitudes, as in the case of the Cà Bianca quarry (2500 m, both on the Italian and Swiss side) and of the Cima di Verchenca quarry (2700 m).

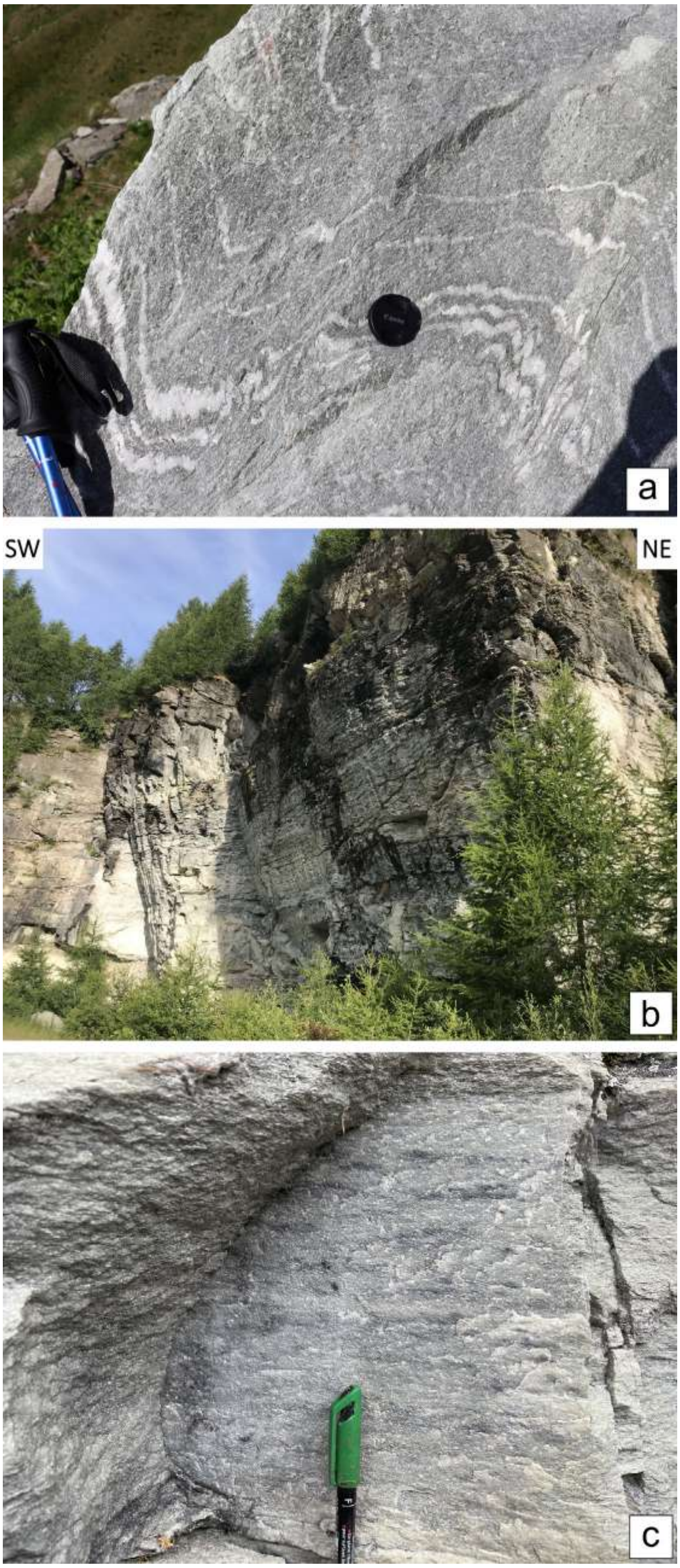


Fig. 8 - a) Typical greenish "Beola Verde dello Spluga" facies of the quartzites of the basal cover of the Tambo nappe; b) the abandoned open pit quarry at San Sisto (average quarry face height ~ 30 metres); c) detail of the San Sisto quartzite.

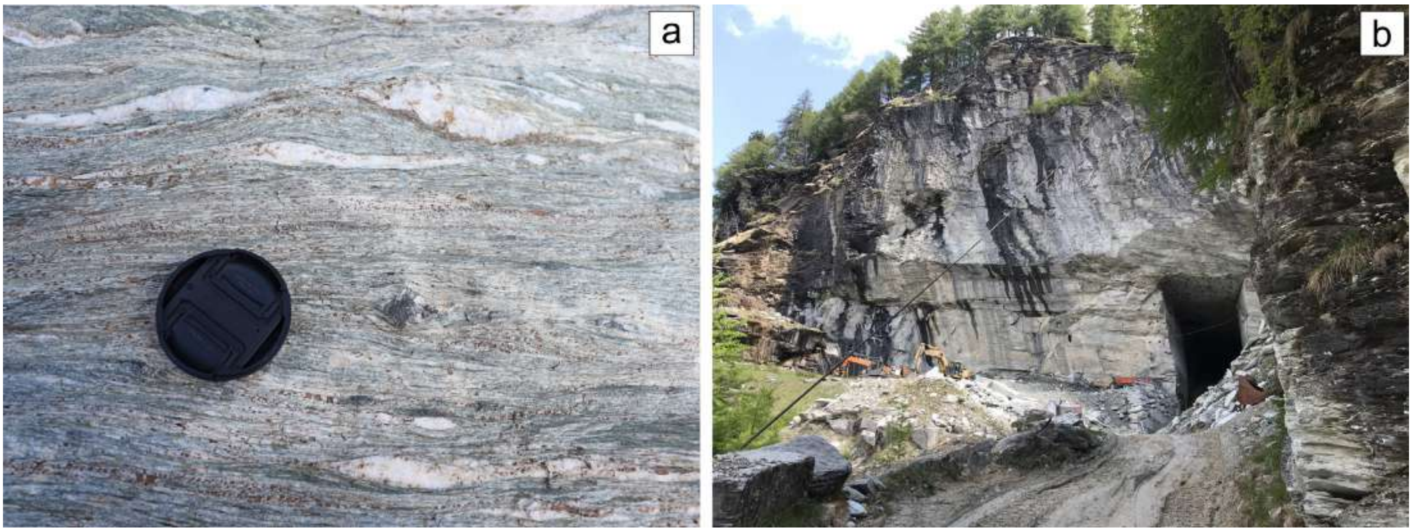


Fig. 9 - a) Iron-rich carbonate-bearing chlorite-sericite-quartz schist; b) the Beola Verde quarry (face height ~ 50 metres) near Isolato (3 km NE of the field trip area).

## Stop 2 - The chlorite and sericite quartz schists of the meta-sedimentary cover of the Tambo nappe

**Coordinates: Lat. 46.416278 N, Long. 9.320676 E**

After the first stop, the path continues to San Sisto, located at the base of the south-eastern flank of Monte Tignoso. From there, the path climbs up towards Alpe Toiana, and it crosses some slices of carbonate outcrops intercalated into the quartzitic basal cover. South of Alpe Toiana, a gneissic facies of the quartzites crops out, and, at higher altitudes, the texture gradually becomes more foliated, developing a pervasive schistosity that characterises a 30-meters thick level of mylonitic chlorite and sericite quartz schists (Fig. 10a). This mylonite shear zone is linked to a regional thrust that runs within the meta-sedimentary cover (Stop 3). These schists have a typical emerald-green colour, due to the chlorite abundance, and they are frequently altered as a consequence of post-orogenic fluid circulation. The fluids are responsible for the formation of quartz veins with iron-rich carbonates as ankerite and siderite (Fig. 10b). The low resistance to weathering and the penetrative foliation of the chlorite and sericite quartz schists is responsible for the bad mechanical quality of these rocks: this leads to the formation of trenches and fractures in the rocks and therefore to widespread gravitative collapses clearly visible in the landscape (Fig. 11a, b and c).

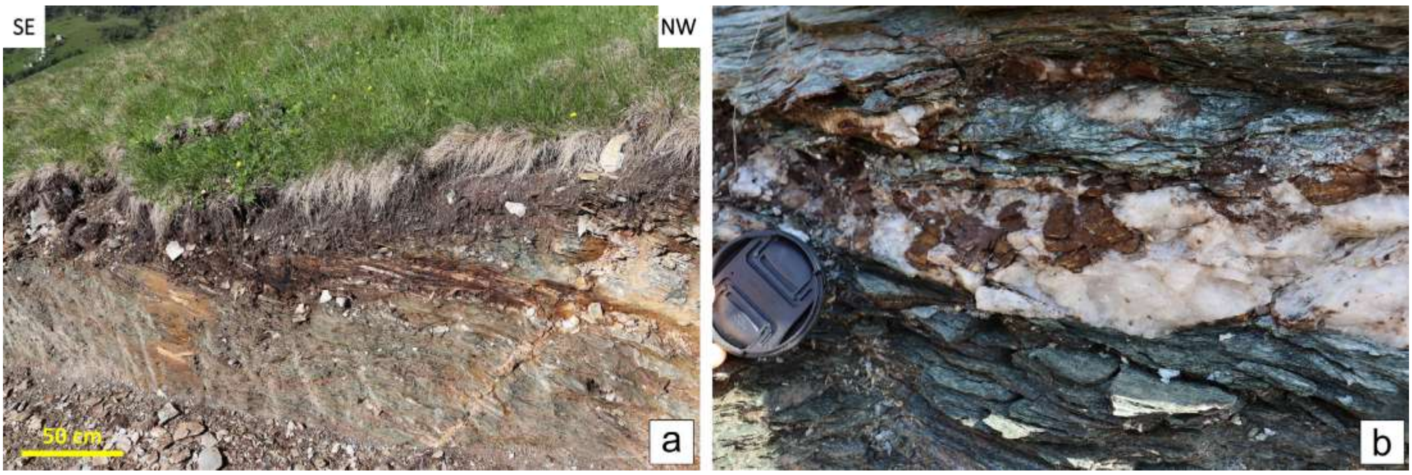


Fig. 10 - a) Chlorite-sericite-quartz schists cropping out along the Giumello roadcut; b) detail of the schistosity of the phyllosilicate-rich rock, with iron-rich carbonate-bearing quartz vein.

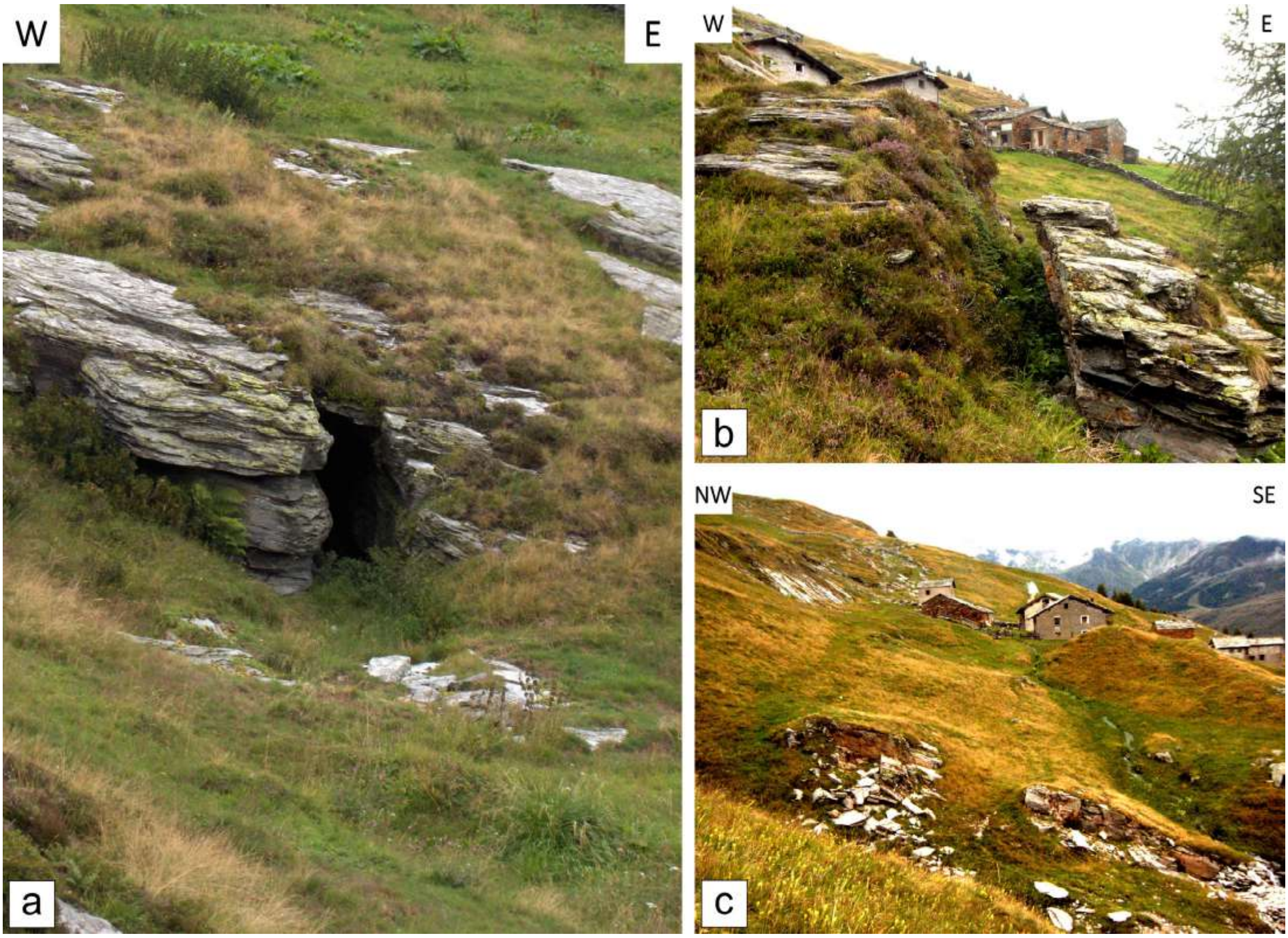


Fig. 11 - a) and b) Meter-sized open fractures on the slope south of Alpe Toiana; c) trenches at Alpe Toiana.

## Stop 3 - The Monte Tignoso thrust and the tectonic breccias of Alpe Toiana

**Coordinates: Lat. 46.417254 N, Long. 9.318520 E**

Within a few minutes, the next stop at Alpe Toiana can be reached. Here, the itinerary branches off from the main path toward the Valle dei Buoi creek, west of the last hut. The outcrops along the creek expose a clearly recognisable, 5-meters thick mylonite within a ductile shear zone (Fig. 12a) that marks the contact between the basal Tambo cover (Fig. 12b) and the overlying carbonates. From the base of the mylonite zone to its top, the quartzitic gneisses gradually pass into chlorite-rich mylonitic schists, very similar to those found at Stop 2. Inside the schists, several few-centimetres thick carbonate levels alternate with quartz veins (Fig. 13). At the top of the mylonite, a few-meters thick matrix-supported tectonic breccia is exposed. It consists of a fine-grained carbonate matrix and polygenic centimetric clasts (Fig. 12c). The clasts are mainly derived from the underlying autochthonous quartzitic cover (chlorite and sericite schists, quartzitic gneiss, and quartzites, Fig. 14 a, b and c).

The carbonate cover directly overlies the mylonite zone (Fig. 16). In the lower part, it is characterised by massive grey limestones representing the allochthonous portion of the meta-sedimentary cover of the Tambo nappe (Andossi Zone *Auct.*, Vezzoli, 1976), considered as the margin of a shallow sea carbonate platform. 50 meters above the Stop 3 (Lat. 46.418791 N, Long. 9.317726 E), along the creek bed, another complete and well-exposed sequence of the mylonite zone can be observed (Fig. 15b). Vezzoli (1976) gave a detailed description of the basal portions of the allochthonous cover, that starts with calcareous schists that grade into massive marbles and breccias towards the top, overlain by a thick layer of carnieules (Fig. 15a).

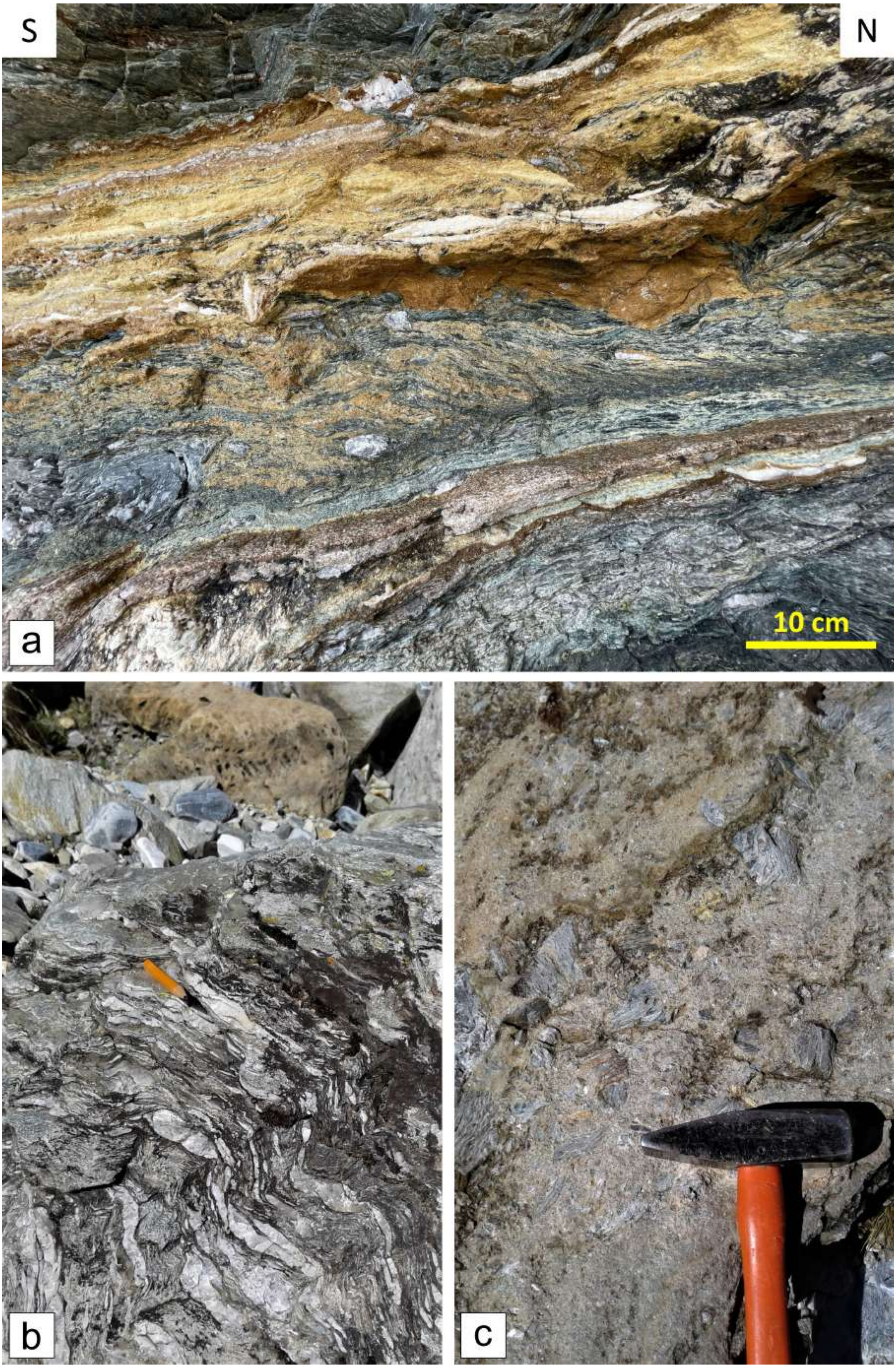


Fig. 12 - a) Five-meters thick mylonite belt developed between lower quartzitic gneiss (Fig. 12b) and overlying metacarbonates (not shown); b) highly deformed quartzitic gneiss at the top of the autochthonous cover; c) tectonic carbonate breccias at the base of the allochthonous cover.

Fig. 13 - Meters-sized mylonite zone that marks the contact between the basal Tambo cover and the overlying carbonates. The core of the mylonite zone is composed of chlorite and white mica schists with intercalated carbonate slivers.

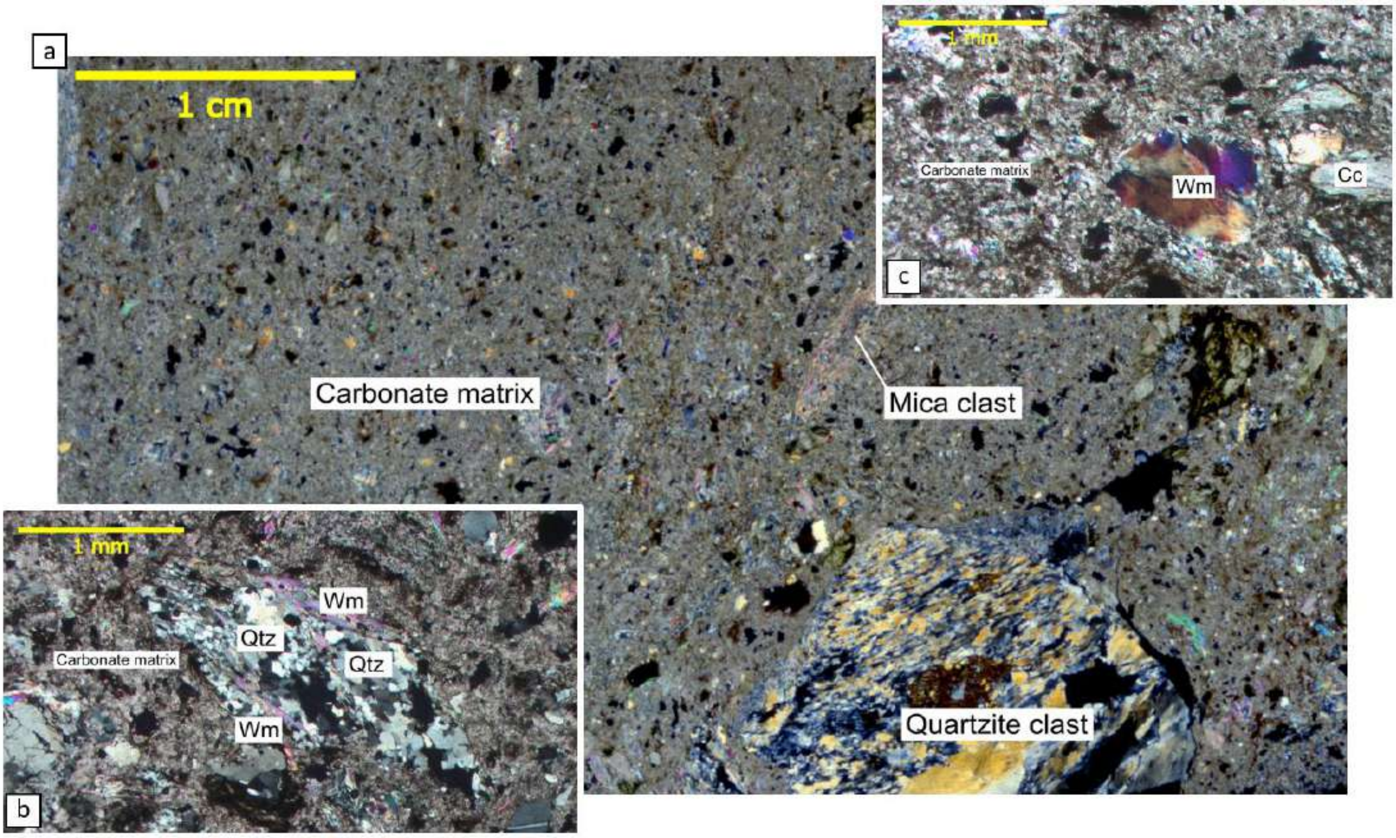


Fig. 14 - a) Thin section scan (crossed polars) of the Alpe Toiana tectonic breccias, with a cm-scale quartzite clast on the right; b) detail of a small clast composed by quartz grains and phengitic white mica (crossed polars); c) detail of a white mica mono-mineralic clast (crossed polars). Abbreviations: Cc = calcite; Qtz = quartz; Wm = white mica.


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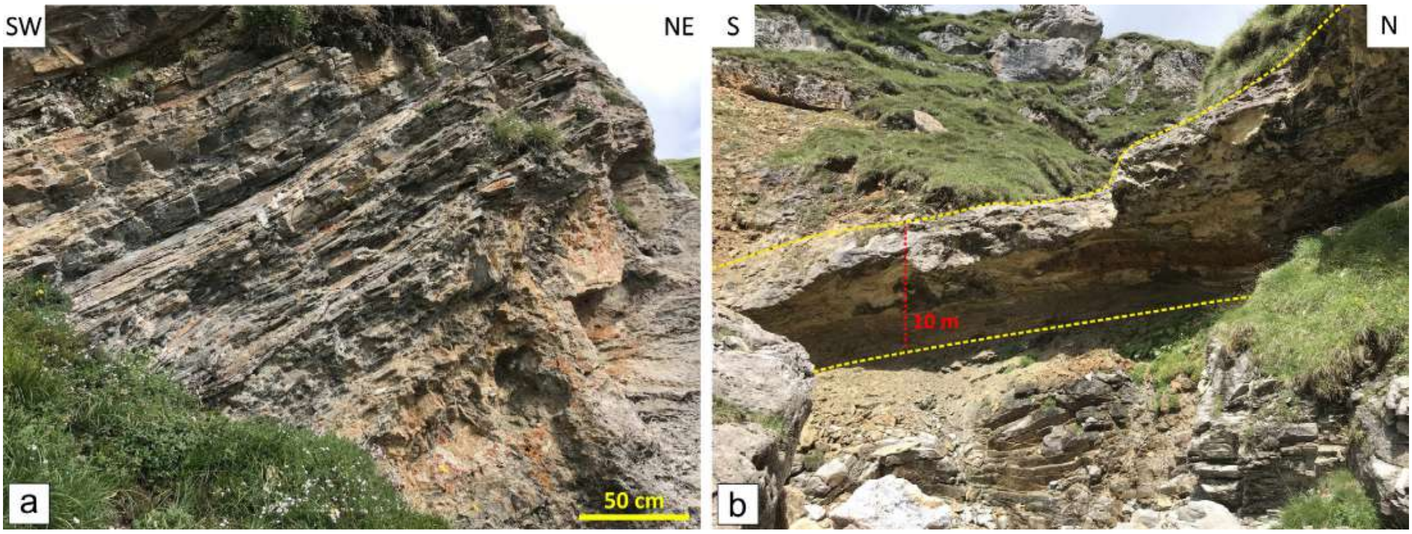


Fig. 15 - a) Detail of the carbonate series at the base of the cliff near Alpe Toiana; b) the tectonic thrust (marked by the yellow dotted lines) cropping out along Valle dei Buoi.


Fig. 16 - Geological scheme of the lower Valle dei Buoi area, near Alpe Toiana, with the base of the carbonate series overlying the quartzitic basal cover.

## Stop 4 - Deep-seated gravitational slope deformations at the eastern side of Pian dei Cavalli

**Coordinates: Lat. 46.418697 N, Long. 9.318225 E**

From Alpe Toiana, the itinerary follows the N689 path and climbs the slope north of the village to reach Pian dei Cavalli, a grassy plateau with gently rolling morphologies, strongly linked to the carbonate rocks cropping out in the area.

The eastern and north-eastern sides of Pian dei Cavalli are strongly affected by Deep-Seated Gravitational Slope deformations (DSGSDs) (Fig. 17). Several examples of deep instabilities affect nearby areas, as in the case of the Valle di Vamlera DSGSD, a few kilometres north of Pian dei Cavalli (Apuani et al., 2005).

The Pian dei Cavalli eastern side shows a long, metric to decametric–wide, NW-SE and N-S trending trenches (Figs. 19 and 20) and is displaced by the gravitative deep-seated movement (Fig. 18).

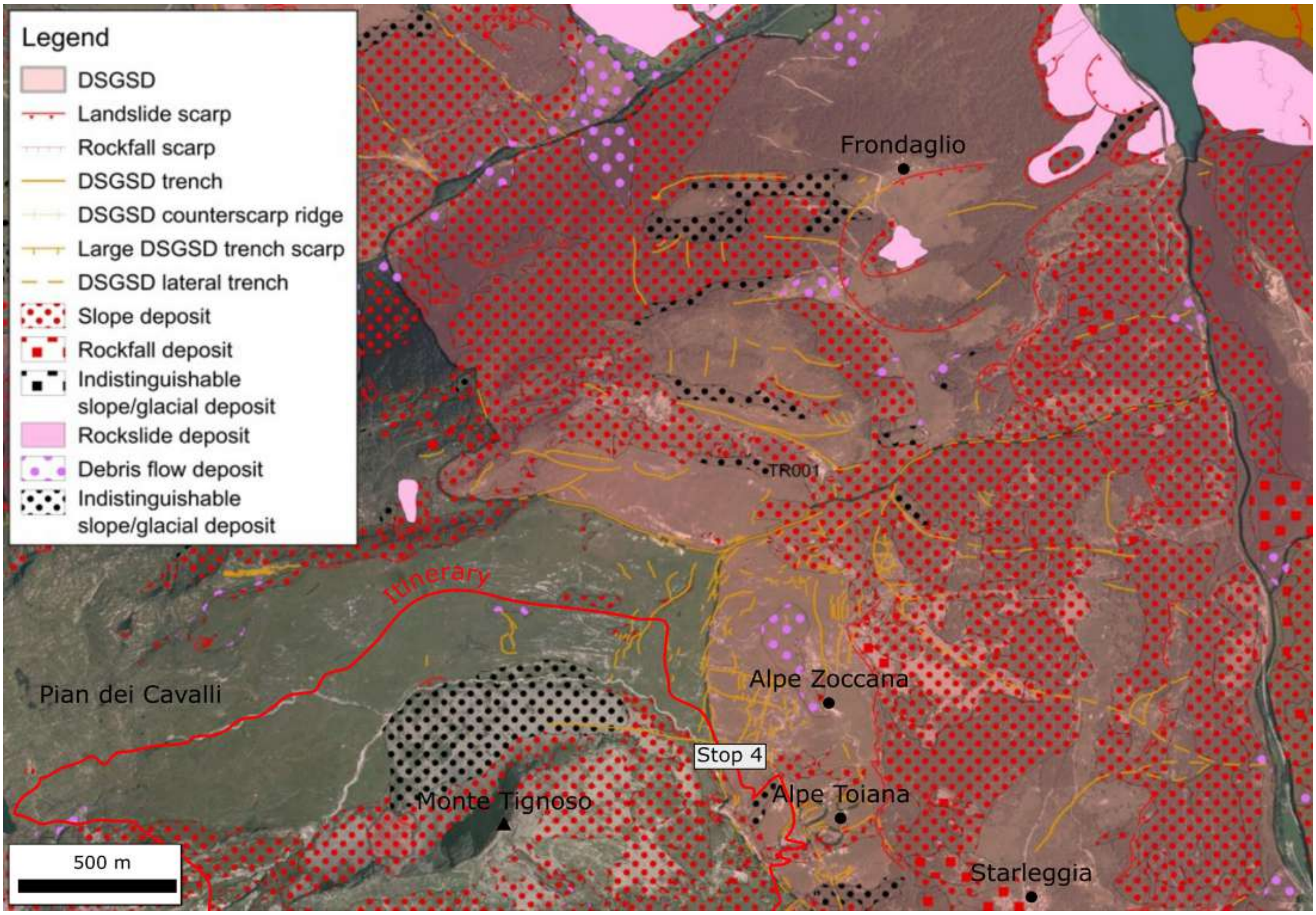


Fig. 17 - Map of slope dynamics deposits and landforms (redrawn after Riganti, 2012). Orthophotos from Lombardy Region, 2012.

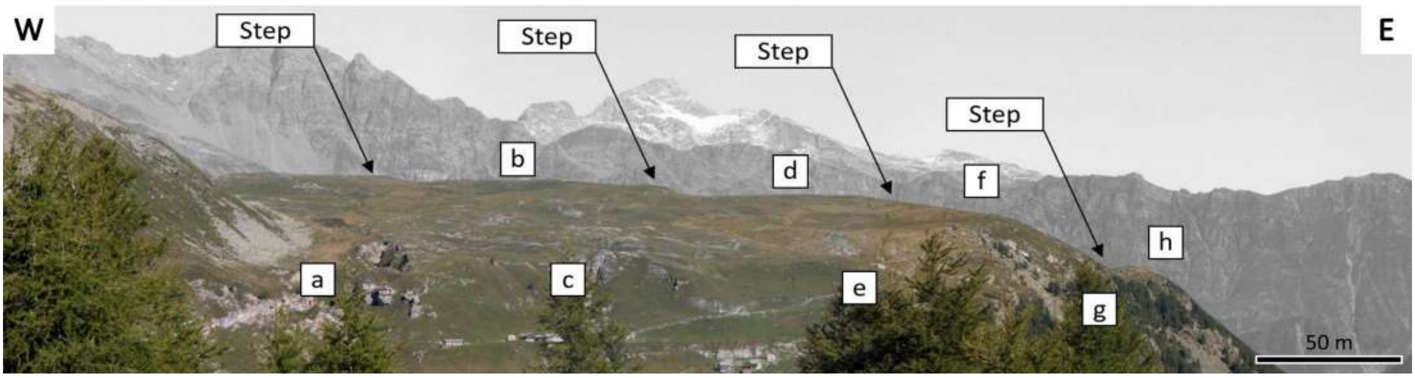


Fig. 18 - View of the eastern part of Pian dei Cavalli plateau from the south. a, c, e, g) N-S fractures due to DSGSD movement. a, c in Fig. 19. b, d, f, h) displaced volumes. Arrows indicate clearly recognizable morphological steps that shape the landscape.


Fig. 19 - DSGSD related trenches along the southern slope of Pian dei Cavalli area.

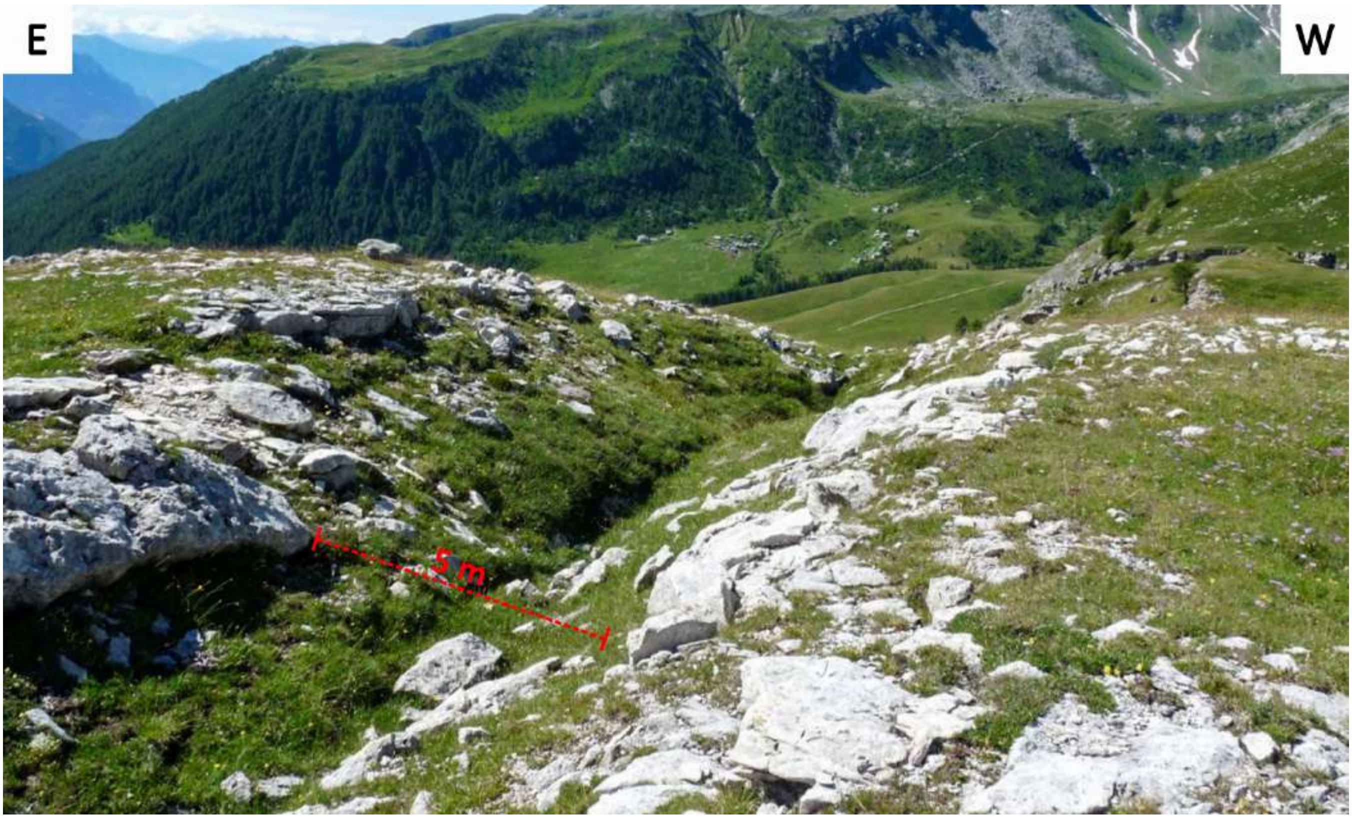


Fig. 20 - Detail view of one of the trenches in the SE part of Pian dei Cavalli area.

## Stop 5 - The Pian dei Cavalli carbonate sequence

**Coordinates: Lat. 46.421248 N, Long. 9.315655 E**

The strongly reduced carbonate series cropping out at Pian dei Cavalli (Fig. 22) shows a Briançonnais-type stratigraphy (Baudin et al., 1995). Stampfli et al. (1998) have shown the presence of a complete normal cover sequence, systematically overlying the Permian–Triassic cover mainly consisting of quartzites (Fig. 21). It shows strong similarities with other units of the Briançonnais, as the Barrhorn series (Sartori, 1990; Pantet et al., 2024). The stratigraphic sequence starts with a level of tectonic breccias (described in Stop 3), followed by a repeated alternation of yellowish dolomitic marbles (Fig. 23a) and light greyish layered calcitic marbles (Fig. 23b) and breccias (Middle to Upper Triassic). Irregular bodies of carnieules (Fig. 23c) are frequently associated with Triassic carbonates that are described in detail afterwards. The upper part of the sequence is mainly characterised by white massive calcitic marbles (Fig. 23d, Middle to Upper Jurassic) and carnieules. This stratigraphic succession is frequently affected by tectonic transposition, as witnessed by a metaconglomerate body at the top of the carbonatic sequence west of Monte Tignoso (described in Stop 11), probably transposed from a structurally-lower position along the main Tambo-Suretta thrust. In the Pian dei Cavalli area, the carbonate cover reaches a thickness of about 150 meters. These facies can also be found in the Suretta nappe, as well as in the Schams nappe (Schmid et al., 1990; Mayerat, 1994).

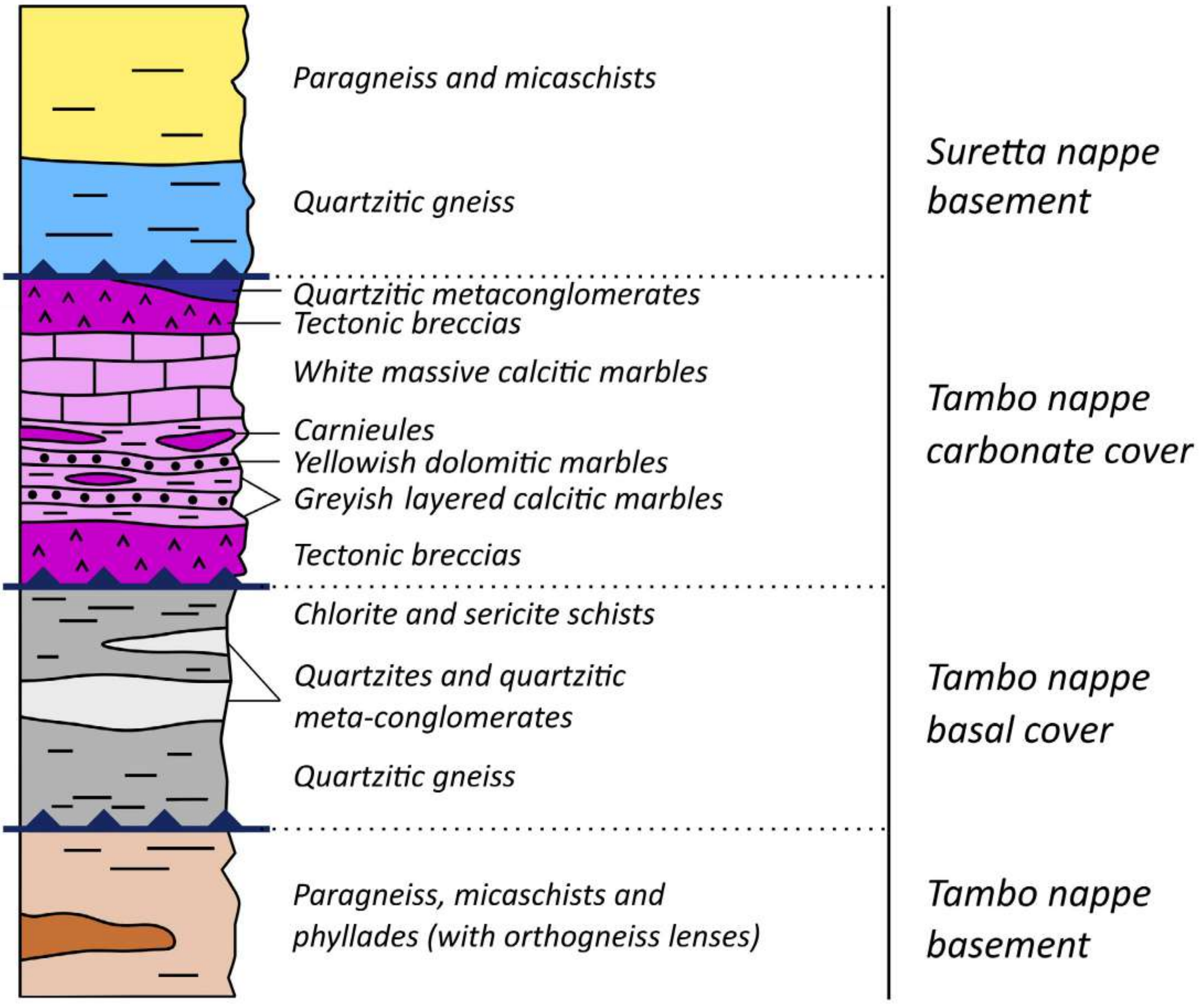


**Fig. 21 - Synthetic lithological section of the Tambo and Suretta nappes in the Monte Tignoso – Pian dei Cavalli area.**


Fig. 22 - Panoramic view of the Pian dei Cavalli area, with Fil dal Re di Cim (on the left) and Monte Bardan (in the middle) in the background.

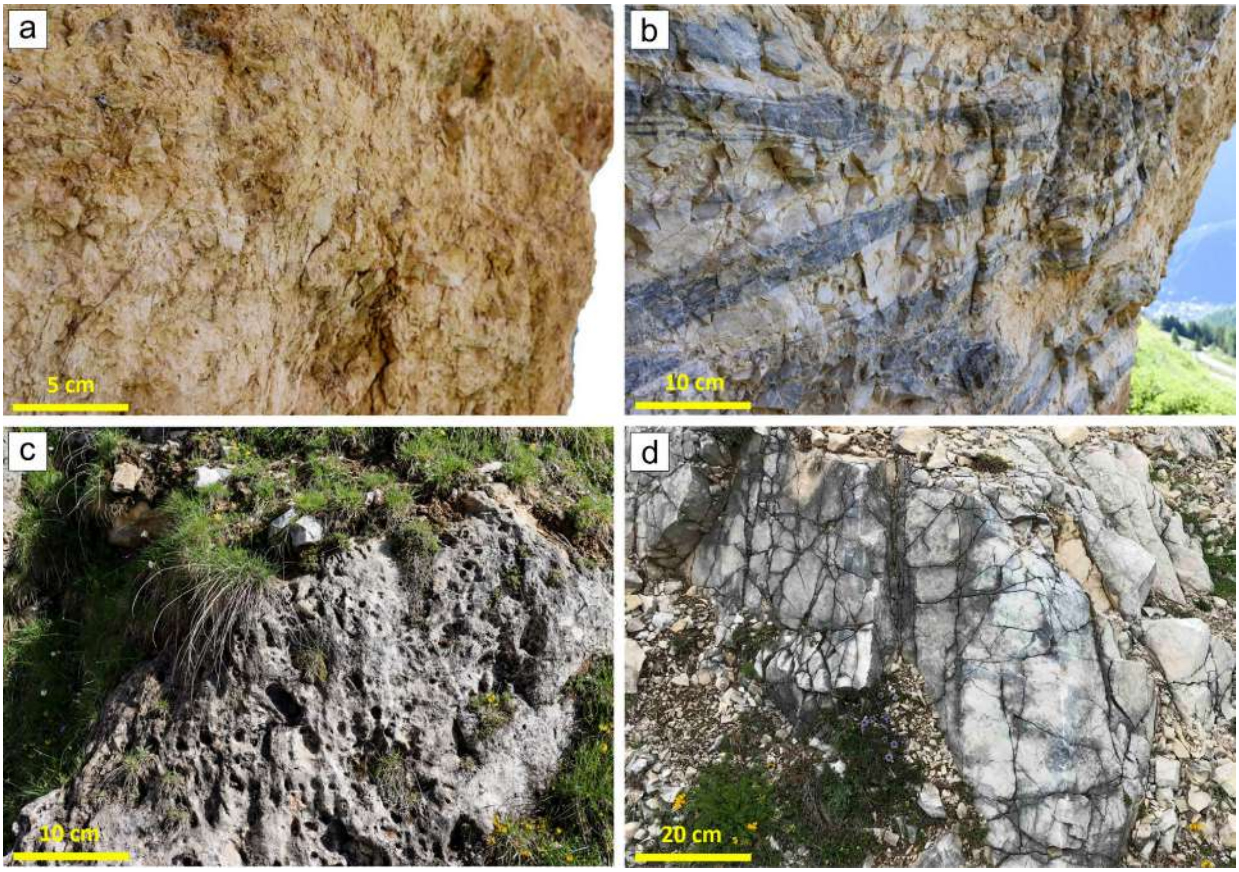


Fig. 23 - a) Yellowish dolomitic marbles forming a cliff along the path to Pian dei Cavalli; b) greyish layered calcitic marbles; c) greyish carnieule with its characteristic “cavernous structure” cropping out at Pian dei Cavalli; d) white massive calcitic marbles.

## Stop 6 - The Tambo nappe meta-sedimentary cover and the Pian dei Cavalli karst system

**Coordinates: Lat. 46.424414 N, Long. 9.312029 E**

At Pian dei Cavalli there are many large-scale karst landforms to observe (Fig. 24).

The peculiar lithology (metacarbonates) is prone to dissolution phenomena. The carbonate meta-sedimentary cover expresses an almost planar, low gradient topography, that discouraged the water runoff while promoting infiltration. Also, in its eastern and northern sides, Pian dei Cavalli is affected by large DSGSDs phenomena (Stop 4) evidenced by trenches due to extensional stress favouring the rock collapse, water infiltration, and the formation of sinkhole-like landforms.

The Pian dei Cavalli topography, at a small scale, is heavily controlled by the orientation of the thrust plane between the Tambo and the Suretta nappes (Fig. 25a). At a larger scale, the topography is heavily influenced by metacarbonate cleavage (Fig. 25b) that creates small monoclinal or tabular landforms.

Upon this tectonically-controlled topography, some karst landforms can be observed, especially in the eastern part of Pian dei Cavalli. There, metacarbonates crop out more frequently and the glacial till deposit is thin and discontinuous. Thus, in this area small scale slope deformations favour water infiltration and carbonate dissolution.

Karst landforms found in Pian dei Cavalli are large-scale, usually metric or decametric up to hectometric in size.

Metacarbonate outcrops are commonly affected by dissolution and collapse sinkholes (Figs. 26 and 28), whereas in the north-eastern part (where a thin till sedimentary cover is present) suffosion sinkholes are more common (Figs. 27 and 29).

Karst phenomena are favoured by the pervasive cleavage of the metacarbonates, and, in the eastern area, by small-scale slope dynamics (DSGSDs).

Karst landforms are connected to a diffuse fracture system. Some caves are present (Figs. 31 and 33). Caves and fractures direct water towards the San Sisto springs (Figs. 30 and 32).

## Stop 7 - Periglacial features at Pian dei Cavalli: the Monte Tignoso rock glacier

**Coordinates: Lat. 46.420553 N, Long. 9.304690 E**

At the foot of the Monte Tignoso north slope, a lobate-shaped deposit, about 0,2 km$^2$ wide, is observed (Fig. 34) (Scotti et al., 2013). It is interpreted as a rock glacier due to the presence of perennial springs on its east side, with cold waters even in summer, suggesting permafrost ice presence at its core. This deposit is fed mostly by talus deposits from the Monte Tignoso northern slope; a little contribution from till debris could be inferred, given that the rock glacier reworks a small moraine (Fig. 35).

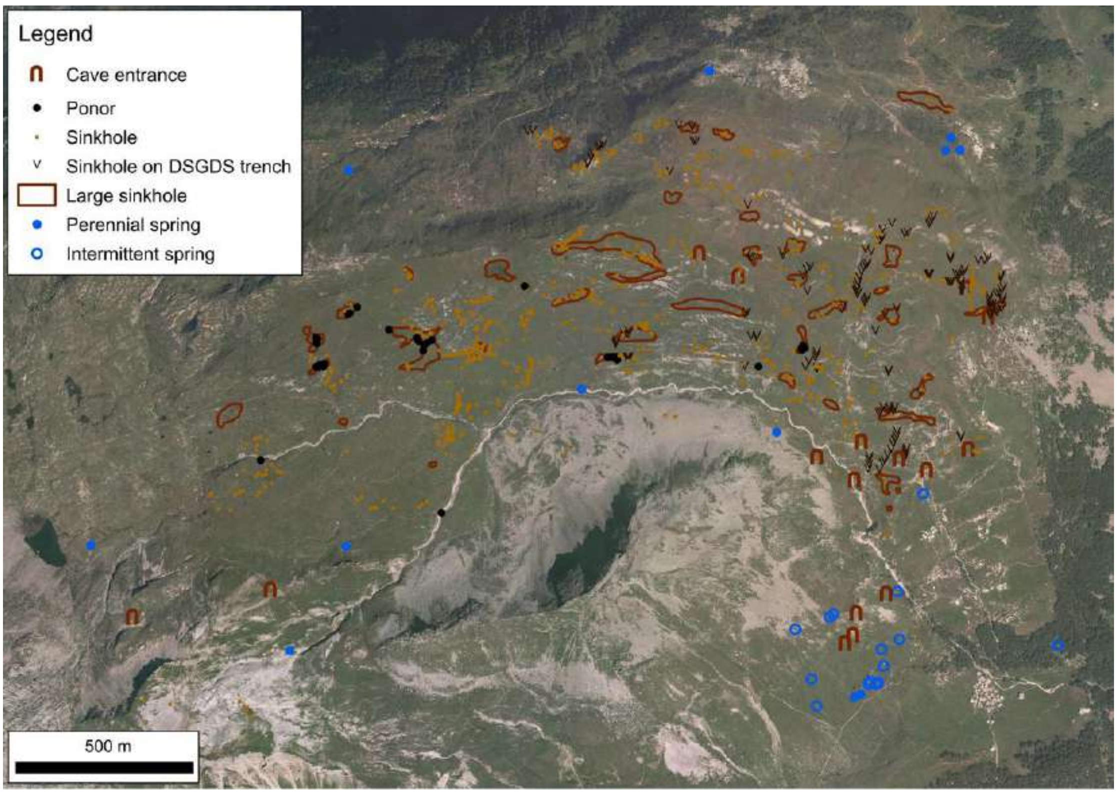


Fig. 24 - Map of karstic landforms and associated springs at Pian dei Cavalli (redrawn after Riganti, 2012). Orthophotos from Lombardy Region, 2012.

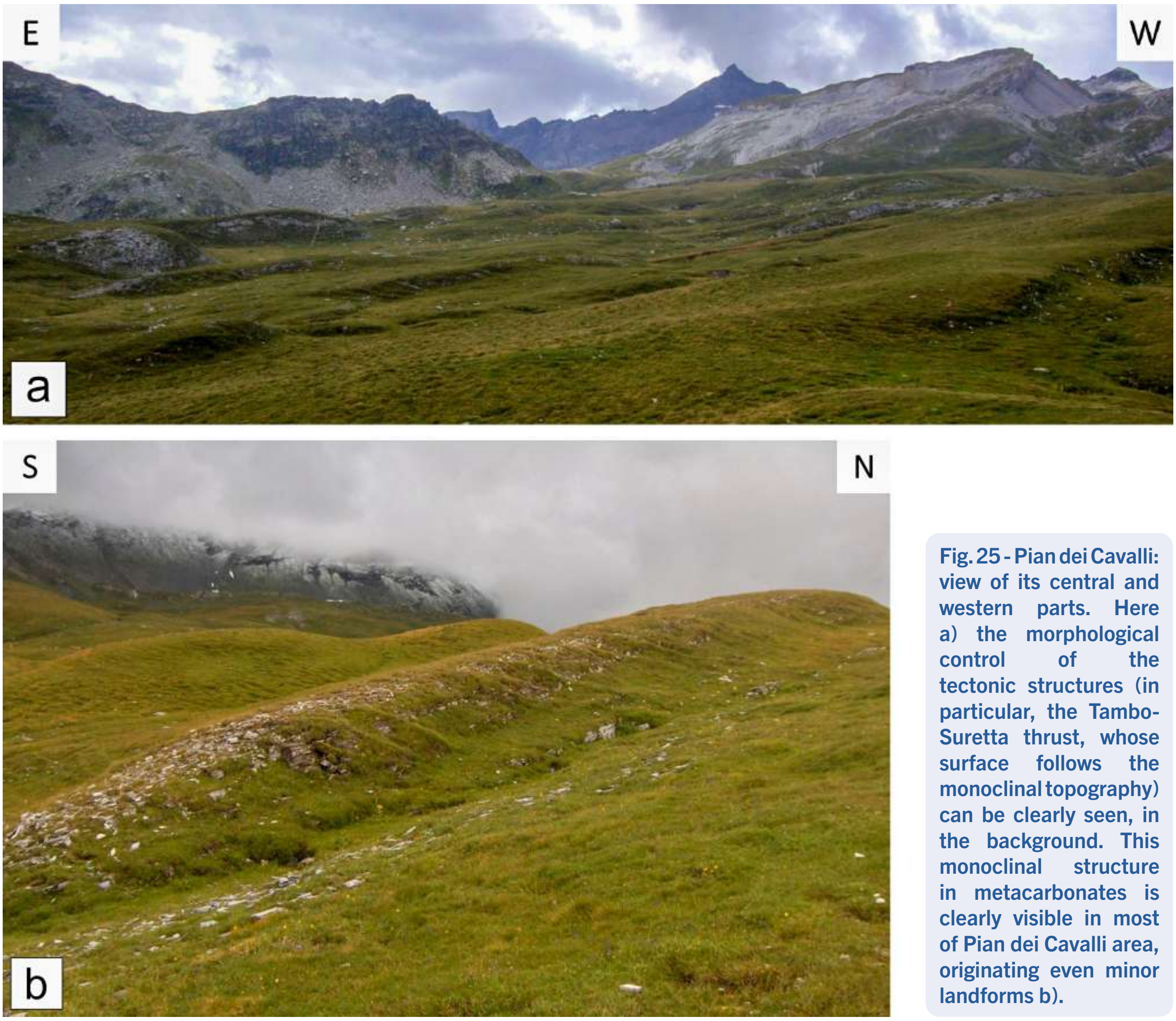


Fig. 25 - Pian dei Cavalli: view of its central and western parts. Here a) the morphological control of the tectonic structures (in particular, the Tambo-Suretta thrust, whose surface follows the monoclinal topography) can be clearly seen, in the background. This monoclinal structure in metacarbonates is clearly visible in most of Pian dei Cavalli area, originating even minor landforms b).


Fig. 26 - Metric / decametric dissolution sinkholes in the eastern part of Pian dei Cavalli.


Fig. 27 - Metric suffosion / collapse sinkholes in the central Pian dei Cavalli.

Fig. 28 - Metric collapse sinkhole in the central Pian dei Cavalli.


Fig. 29 - Hectometric steephead valley in the northern Pian dei Cavalli.

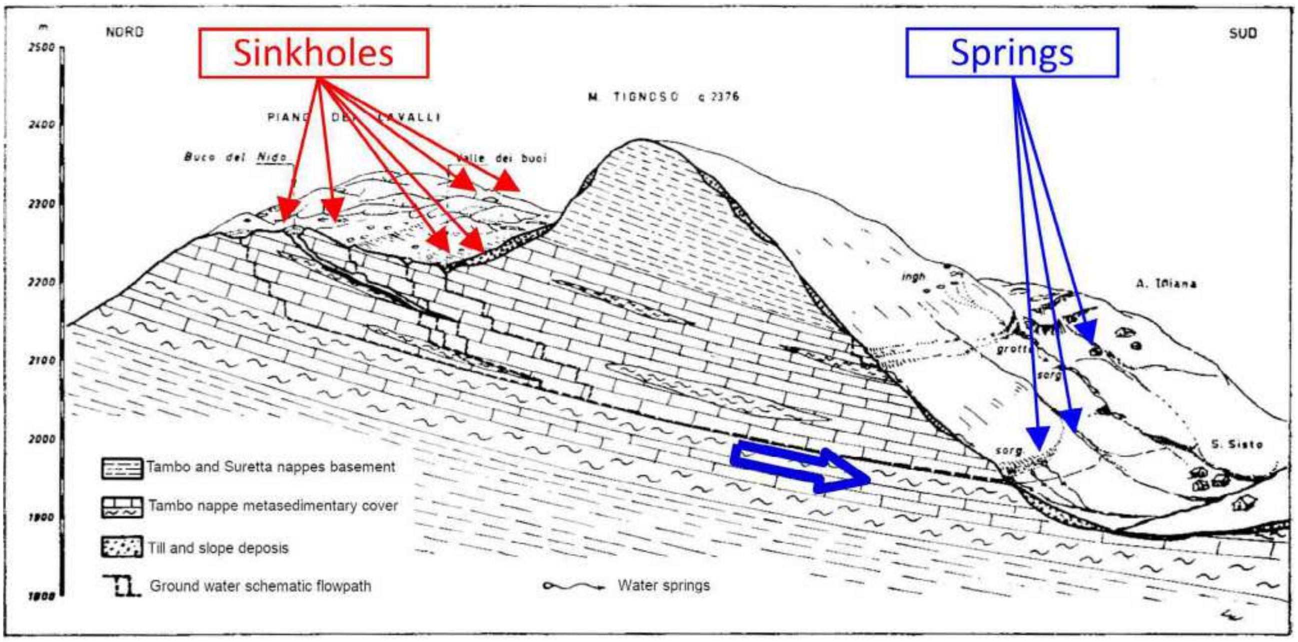


Fig. 30 - Schematic cross section of Pian dei Cavalli and Monte Tignoso, with inferred flowpath of ground waters (redrawn after Cappa & De Michele, 1963).

Fig. 31 - Buco del Nido cave entrance.

Fig. 32 - San Sisto springs.

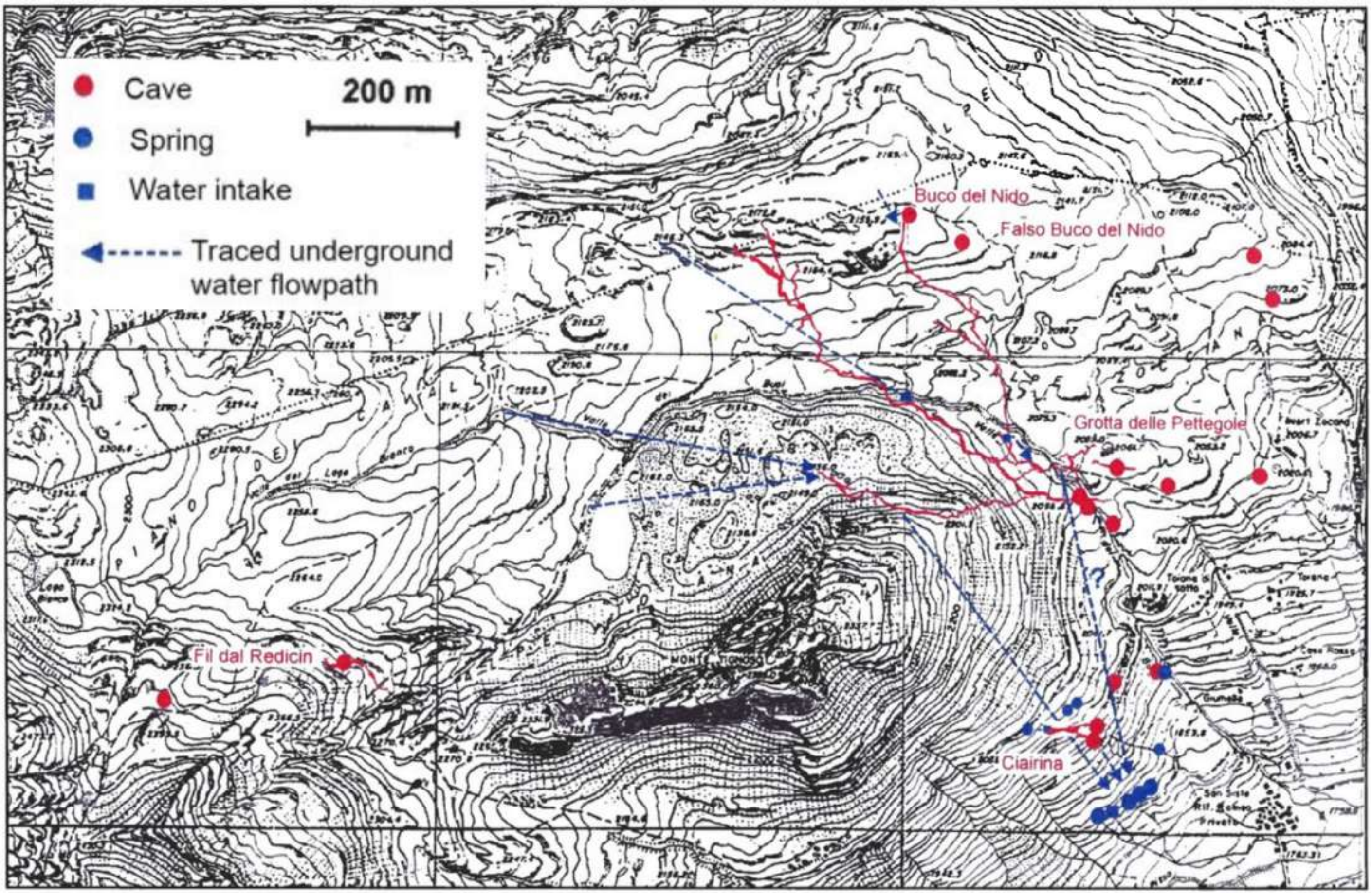


Fig. 33 - Plant map of caves at Pian dei Cavalli. Blue dashed arrows point to underground water pathways verified thanks to water tracing campaigns. Waters spring out NW of San Sisto (redrawn after Cella & Torri, 1999).


Fig. 34 - Monte Tignoso rock glacier seen from the north.

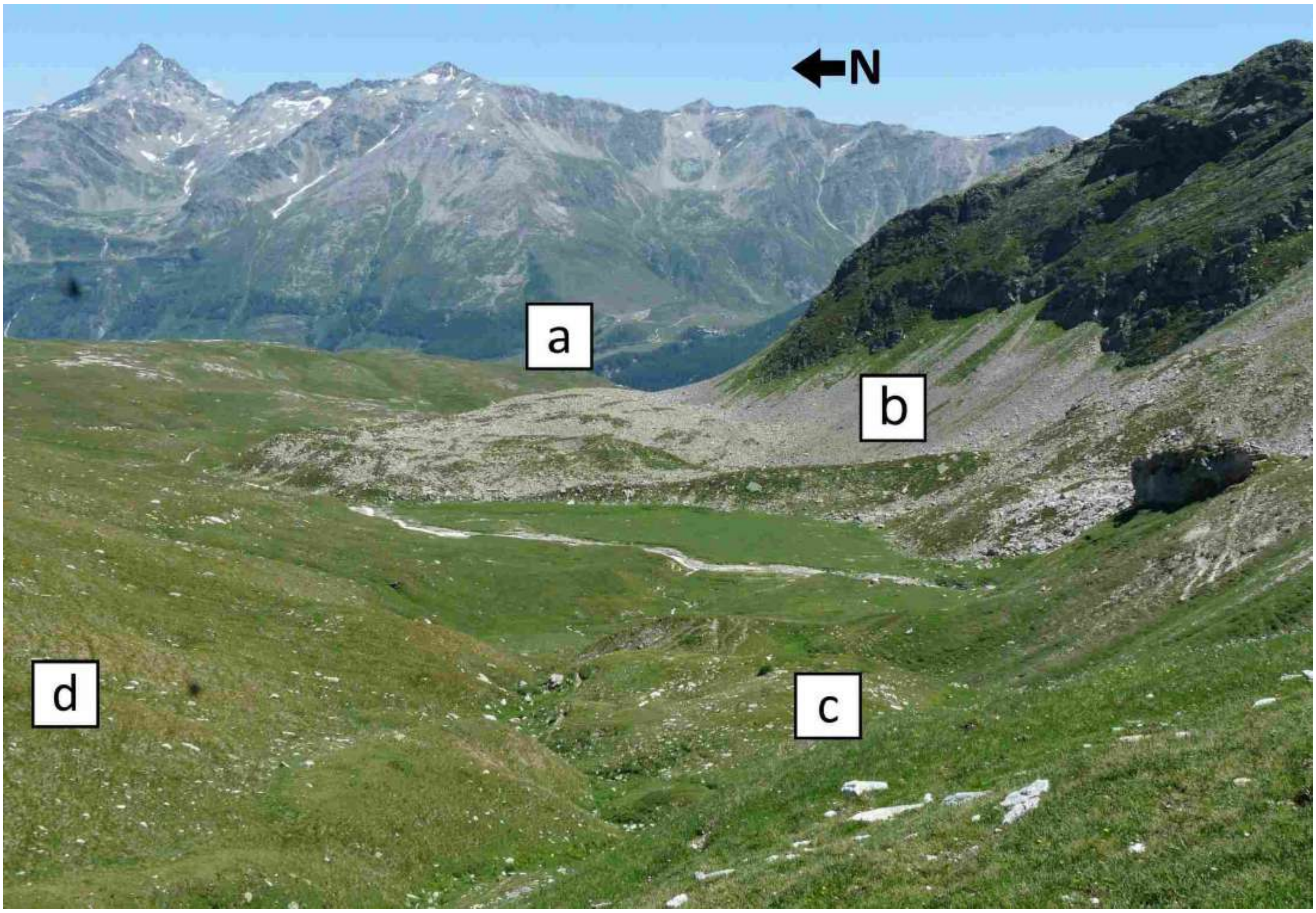


Fig. 35 - Monte Tignoso rock glacier seen from the west. During the Last Glacial Maximum (LGM) this small valley was occupied by a tiny local glacier that flowed eastward, coming in touch with Monte Tignoso rock glacier. a) rock glacier body. b) local moraine, reworked by rock glacier at its northern end. c), d) later local moraine and ablation till.

## Stop 8 - The Pian dei Cavalli thrust along Valle del Lago Bianco

**Coordinates: Lat. 46.419488 N, Long. 9.294906 E**

The itinerary traverses Pian dei Cavalli westwards, reaching the effluent creek from Lago Bianco. In the valley east of Lago Bianco, the same tectonic thrust seen above Alpe Toiana (Stop 3) crops out, exposing the lithological transitions previously described (Fig. 36). Here, the meter-sized mylonite is partially buried under fluvial and glacial deposits, but, if cropping out, it always shows its characteristic lithology made up of tectonic breccia.

## Stop 9 - The Tambo nappe basement outcropping near Lago Bianco

**Coordinates: Lat. 46.418837 N, Long. 9.288297 E**

To the west, in the area surrounding Lago Bianco (Fig. 38a), the general steepening of the east-plunging foliation leads to the exposure of the Tambo nappe crystalline basement, at the expense of the meta-sedimentary cover rocks.

The basement is manly composed of muscovite- and biotite-bearing paragneiss and schists (Fig. 37a), alternating with metaintrusive rocks. The latter are mainly orthogneiss of granodioritic composition, that gradually fades into the gneissic wallrock, known as “Foppagneiss” (Weber, 1966; Strohbach, 1965). The lack of geological datings leaves their origin unknown, but they are supposed to be Ordovician in age, and linked to crustal anatexis (Baudin et al., 1993). Scheiber et al. (2013) mainly obtained ages of about 490 Ma on orthogneiss lenses from the southern part of the Suretta nappe. Within the paragneiss, and bordering the main orthogneiss masses, tourmaline-bearing metapegmatite swarms are aligned along the main foliation (Fig. 37b), while recent quartzitic dykes develops along the main fracture set.

The Foppagneiss is mainly composed of quartz, K-feldspar and plagioclase (often with strong evidence of saussuritisation), biotite, an alpine white mica and epidote


Fig. 36 - Geological scheme of Valle dei Buoi, 500 meters NNE from Lago Bianco.

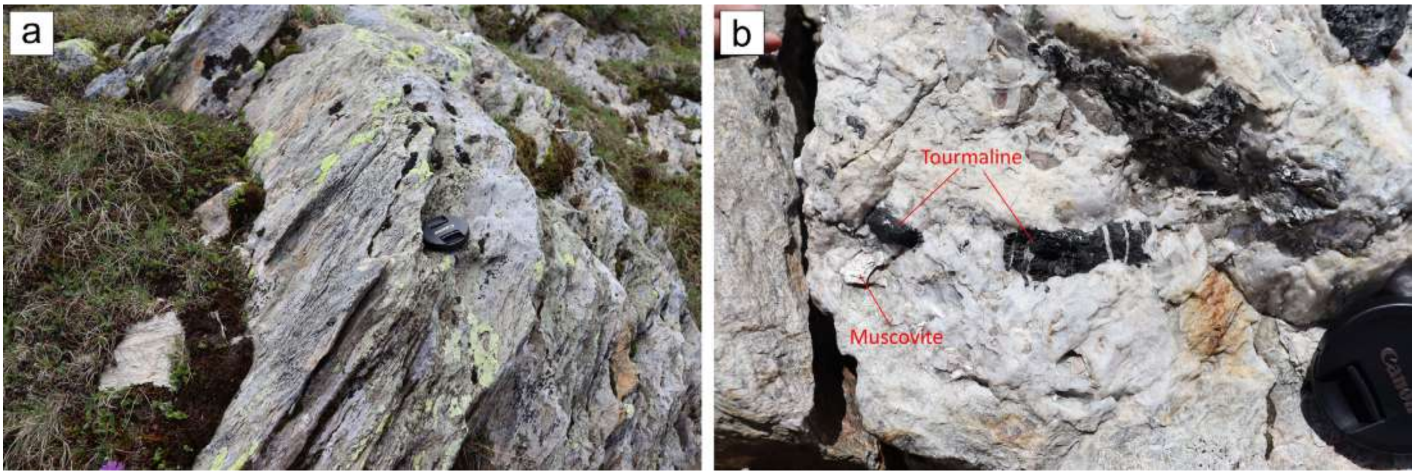


Fig. 37 - a) Foliated muscovite- and biotite-bearing paragneiss cropping out in the Lago Bianco area; b) meta-pegmatite dyke with cm-sized tourmaline crystals.

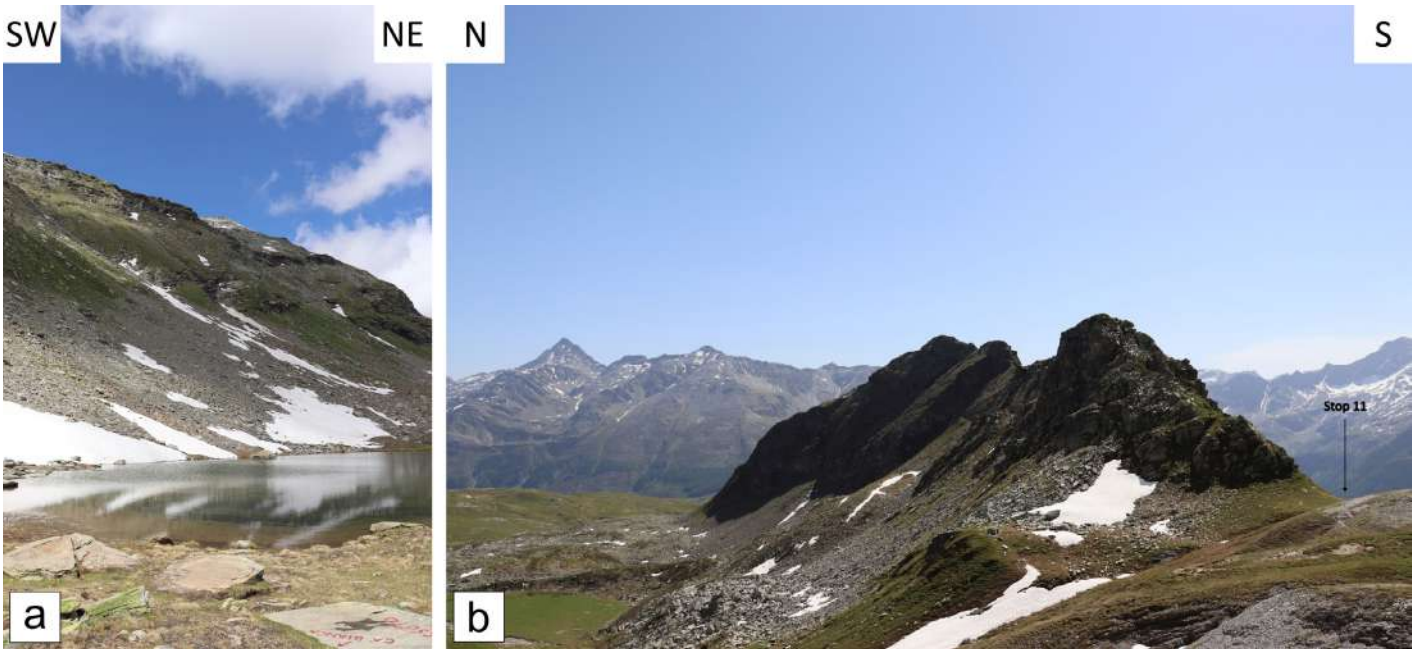


Fig. 38 - a) The Lago Bianco area and the eastern flank of Monte Bardan, made up of paragneisses from the Tambo nappe; b) Monte Tignoso area located south of Pian dei Cavalli. Location of Stop 11 is indicated.

The paragneiss is mainly composed of quartz, biotite, white mica, epidote, k-feldspar, and plagioclase. It locally shows garnet, often very altered (Fig. 39c), and tourmaline.

## Stop 10 - The carnieules of the carbonate cover and their geological meaning

**Coordinates: Lat. 46.414961 N, Long. 9.298167 E**

From Lago Bianco, the itinerary continues along the N688 path, which leads towards the pass located west of Monte Tignoso (Stop 11, Fig. 38b). The itinerary passes through a small canyon at the head of Valle dei Buoi, where mainly carnieules outcrop (Figs. 41 and 42). The term "carnieule" usually refers to vacuolar dolostones or dolomitic breccias. On their surface, the carnieules show a spongy appearance, with irregular vacuoles of variable diameters (from few millimetres to several centimetres), casually distributed (Fig. 43). The weathered rock colours are yellowish to greyish. Around the carnieule outcrops, the superficial deposit and the soil have an orange to brownish colour. The biggest carnieule outcrops are characterised by steep, bare slopes with badland-like morphologies, as in the case of the upper part of Valle dei Buoi. On fresh cleavage surfaces, the brecciated structure is always present and well visible.
As also observed by Metzeltin & Vezzoli (1977), the carnieules of the meta-sedimentary cover can be divided in two groups: 1) monogenic carnieules, with carbonate

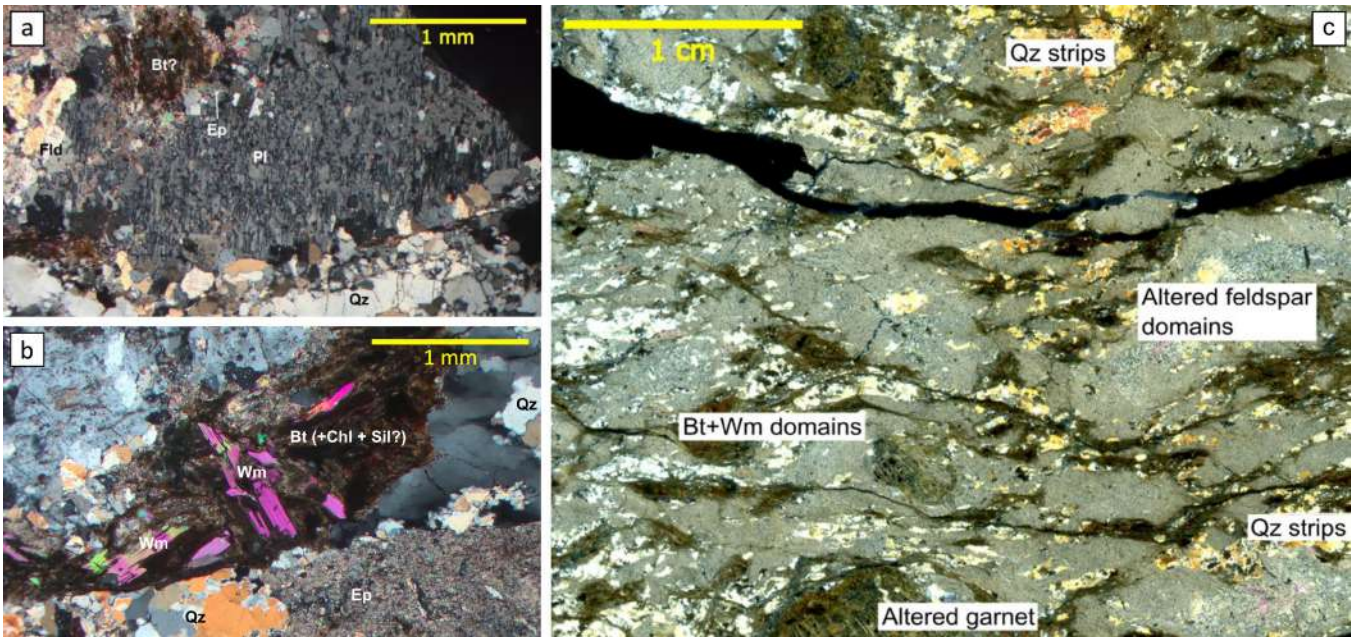


Fig. 39 - a) Photomicrograph of a migmatitic orthogneiss (Foppagneiss) from Splughetta (500m SE of Starleggia), along the roadcut (crossed-polars); b) Alpine white mica (phengite) nucleating over older biotite crystals in a migmatitic orthogneiss from Splughetta (crossed-polars); c) photomicrograph of a biotite and garnet paragneiss of the Tambo nappe basement (crossed-polars). Abbreviations: Bt = biotite; Chl = chlorite; Ep = epidote; Fld = K-feldspar; Pl = plagioclase; Qz = quartz; Sil = sillimanite; Wm = white mica.

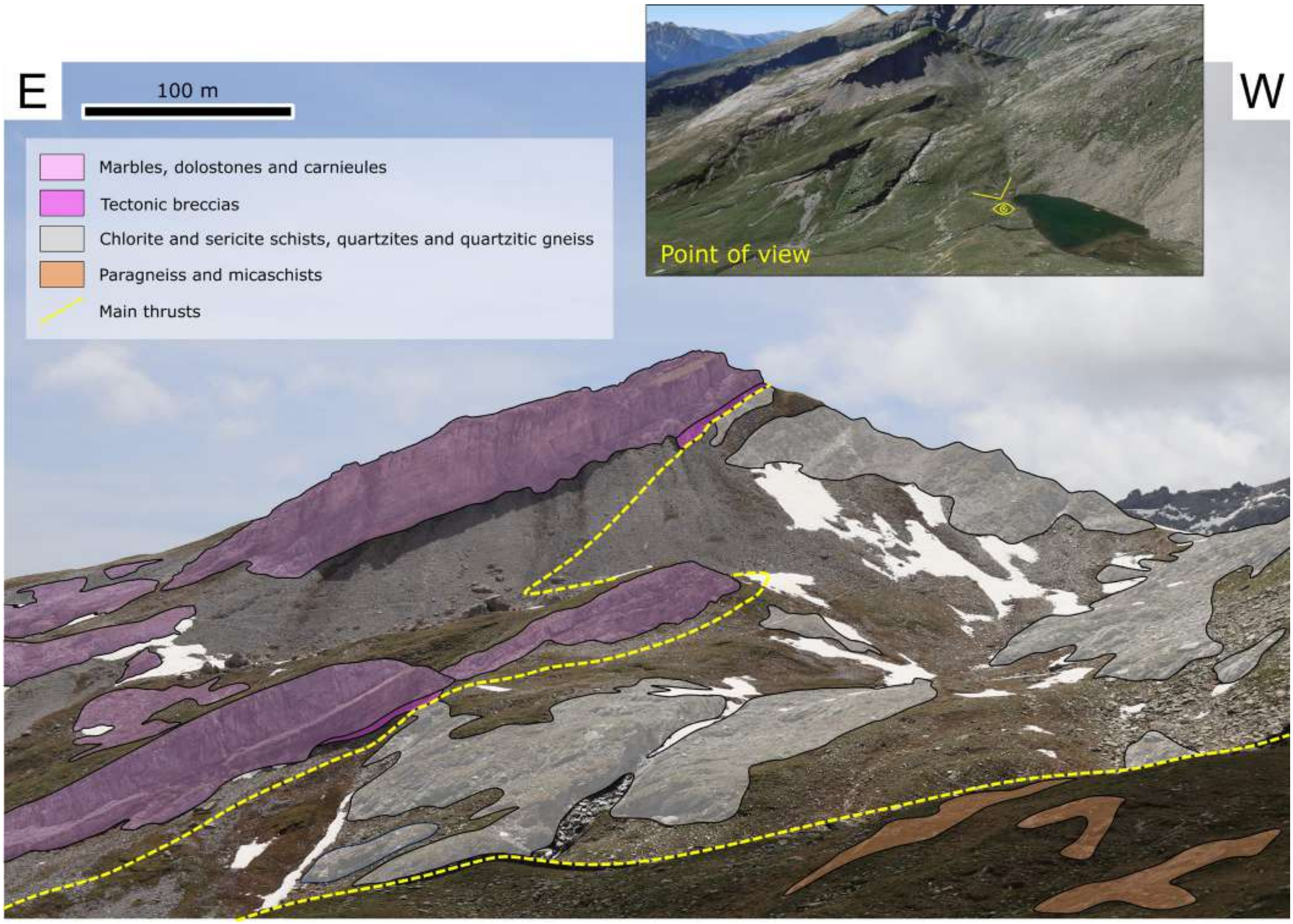


Fig. 40 - Panoramic view of the rocky cliffs cropping out south of Lago Bianco. As a consequence of the steepening of the thrust, and its associated foliation, structurally deeper lithologies are exposed to the west.

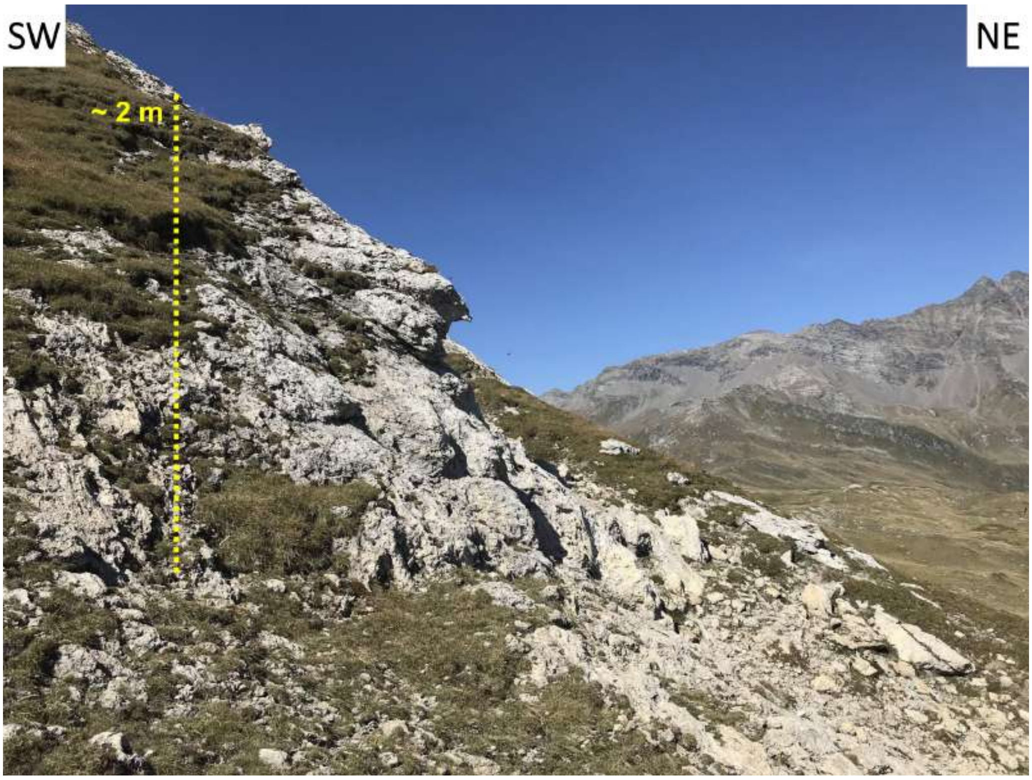


**Fig. 41 - Carnieule outcrop in the upper part of Valle dei Buoi, along the path to Monte Tignoso.**

or phyllitic clasts, depending on structural/stratigraphic position; 2) polygenic carnieules, with mixed crystalline clasts, or with both crystalline and carbonate clasts. Sometimes, the carnieules have a massive texture, while in other cases they show a layered texture, without evidence of erosion at the top or bottom of the layer. Sometimes, carnieule pockets or levels can be found inside marbles or limestones of the sedimentary sequence, with gradual transition from the latter to the carnieule, and with clasts of the nearby lithologies (Fig. 44).

Several authors gave a Triassic to Early Jurassic age to the carnieules, based on analogies with fossil-bearing carnieules of other Alpine nappes (e.g., the Acceglio Zone; Baudin et al., 1995), since the Tambo cover rocks don't show the presence of any kind of fossil.

Even if the carbonate rocks of the meta-sedimentary cover are affected by a low-grade metamorphism, that caused a widespread recrystallisation of calcite, carnieules are the only carbonate rocks of the sequence with no evidence of metamorphism at all.

As the carnieules show both sedimentary as well as tectonic features, they represent a key lithology to solve the open questions concerning the meta-sedimentary sequence of the Permian-Mesozoic cover. Then, their genetic meaning could affect the interpretation of the regional palaeogeographic setting (Metzeltin & Vezzoli, 1977).

The presence of a layered texture, combined with a spare evidence of laminated or gradational structures, and the lack of clast deformation, play in favour of a sedimentary origin of the carnieule horizons. In contrast, there are several evidences that support a tectonic origin: the concomitance with fault planes or thrust horizons; the sporadic discordancy with respect to the succession layering (pockets and lenses); irregular distribution and imbrication of the clasts, which occasionally are of exotic provenance, along with the absence of metamorphism even if they are part of metamorphosed successions (Metzeltin & Vezzoli, 1977). The most accepted explanation of this duality takes into account two distinct events, the first one sedimentary, and the second one tectonic.

As far as the origin of the vacuoles, which characterise the carnieules, Metzeltin & Vezzoli (1977) argued that the presence of surface vacuoles could be ascribed to surface weathering, that caused the preferred dissolution of the dolomitic elements of the breccia compared to the calcareous groundmass.

On the other hand, most carnieules and their typical vacuoles could usually form during the hydration of anhydrite into gypsum upon contact with meteoric water, and subsequent gypsum dissolution typical of such karst systems. Since anhydrite hydration and gypsum dissolution are secondary and post-orogenic processes, they do not exclude a prior tectonic or sedimentary origin of the carnieules.

However, within the carbonate sequence of the Monte Tignoso area, there is a lack of gypsum or anhydrite, while at the scale of the entire carbonate cover of the Tambo nappe, only two small evaporitic outcrop occur in Val Scalcoggia, near Madesimo, on the other side of Val San Giacomo (Zurfluh, 1961; Vezzoli, 1976), as well as northwest of Soglio, in Val Bregaglia (Switzerland, Staub, 1926; Blanc, 1965).


Fig. 42 - Carnieule outcrop in the upper part of Valle dei Buoi, 250 m east of Monte Tignoso.

Fig. 43 - Detail of the vacuolar texture of a polygenic carnieule cropping out near Monte Tignoso. On its surface, the carnieules have a spongy appearance, with irregular vacuoles of variable diameters (from a few millimetres to several centimetres), casually distributed.

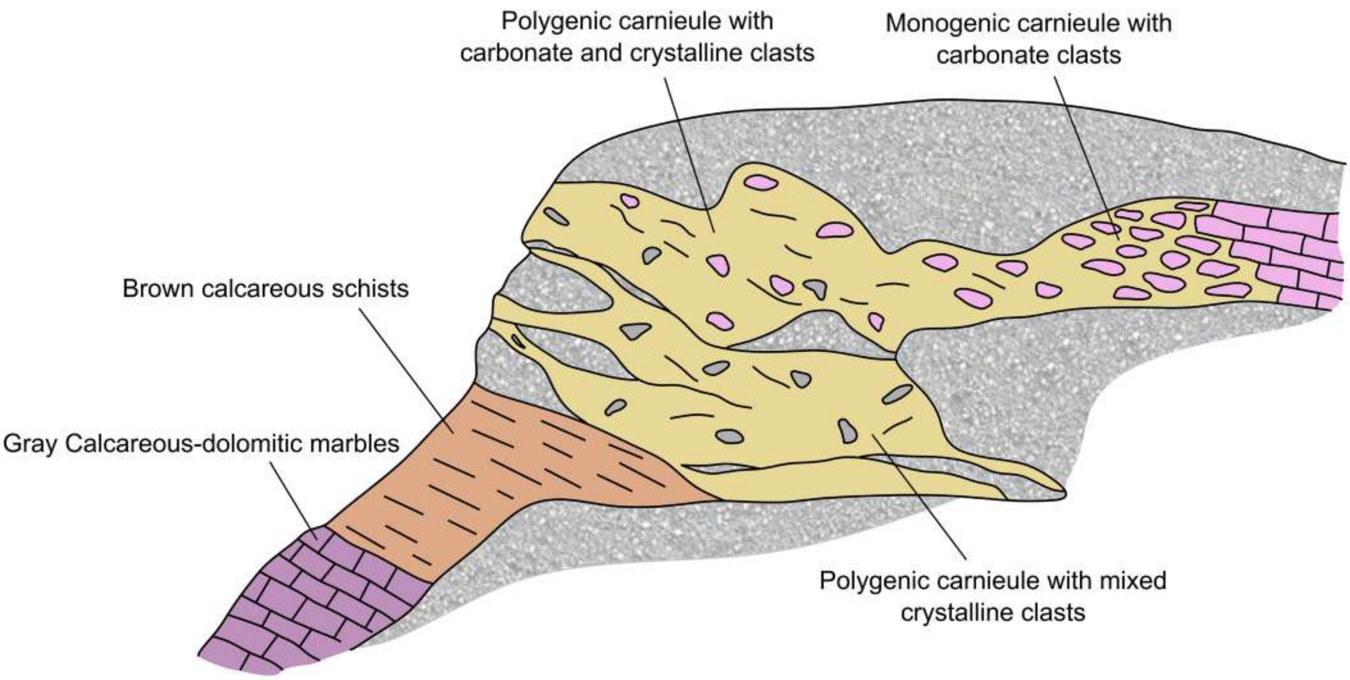


Fig. 44 - Geological simplified scheme of a typical carnieule outcrop of the meta-sedimentary cover of the Tambo nappe, redrawn after Metzeltin & Vezzoli (1977).

## Stop 11 - The quartzitic metaconglomerate west of Monte Tignoso

**Coordinates: Lat. 46.414103 N, Long. 9.300141 E**

The itinerary proceeds towards the pass (2270 m a.s.l.) that joins the Pian dei Cavalli area with Val Starleggia. In the upper part of the pass, the uppermost marble and carnieules outcrops of the meta-sedimentary cover crop out. However, a few meters to the east there is a smooth and rounded outcrop of a quartzitic metaconglomerate (Fig. 45), structurally overlying the metacarbonates. This quartz-rich rock represents another geological enigma in this area, since it doesn't match any lithostratigraphic significance in both Tambo and Suretta nappes. The metaconglomerate is supposed to be Permian in age, since its clear similarities with other metaconglomerate bodies cropping out in other areas of the Tambo nappe cover, characterised by quartz-rich conglomerates usually compared to the South alpine "Verrucano Lombardo" facies. This body could have been tectonically transposed at the top of the meta-sedimentary cover, along the main Tambo-Suretta thrust at the base of Monte Tignoso. The thrust zone is buried under glacial and slope deposits around the whole Monte Tignoso, so the tectonic relationships and features between the Tambo and Suretta nappes are not directly visible. Nevertheless, the geological structure of the klippe is well visible. The quartzitic metaconglomerate shows a clastic support and a medium-grained quartz-rich matrix, with minor amounts of feldspar (Fig. 46a). The clasts are centimetric in size and mostly composed of quartz (Fig. 46b). Sporadic hematite coating affects both matrix and clasts.

A different explanation for this metaconglomerate body takes into consideration its afference to the Suretta nappe meta-sedimentary cover. To justify this view, since the upper parts of the Monte Tignoso klippe are composed by rocks of the Suretta nappe crystalline basement (Stop 13), then the metaconglomerates must have been structurally inverted. The structural inversion could have been related to the post-nappe backfolding of the frontal part of the Suretta nappe


Fig. 45 - The quartzitic metaconglomerate outcrop east of Monte Tignoso Pass.


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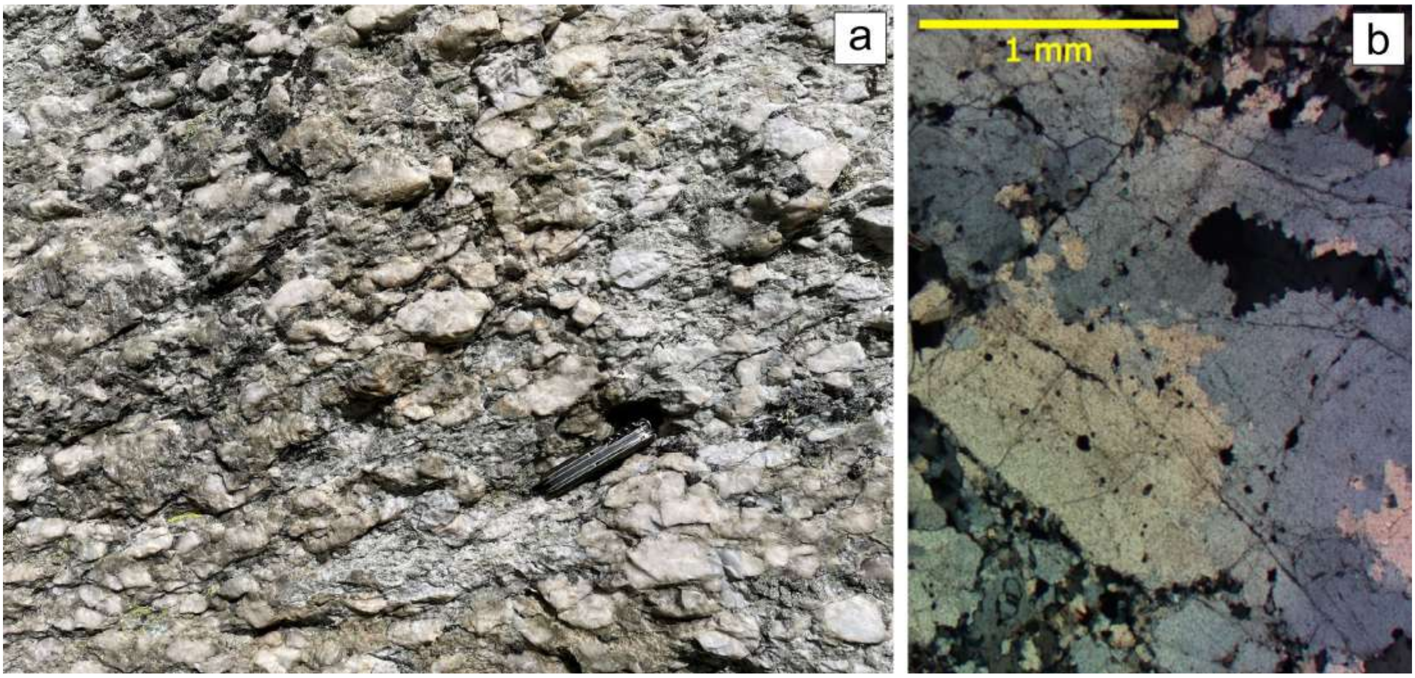



Fig. 46 - a) Detail of the quartzitic metaconglomerate east of Monte Tignoso Pass; b) photomicrograph of the metaconglomerate showing the coarse grain size of quartz porphyroclasts (crossed-polars).

(Niemet-Beverin phase, Milnes & Schmutz, 1978), linked to a top-to-the-S backshearing and to a vertical shortening combined with top-to-the-E shearing (Milnes & Schmutz, 1978; Scheiber et al., 2012).

However, this explanation would take into account a complex geological scenario that would have affected also nearby areas, but with lack of further evidence in addition to the structural position of these rocks.

Metzeltin & Vezzoli (1977) proposed that the quartzitic metaconglomerate could have formed via hydraulic fracturing and fluid circulation along the thrust, not taking into account a structural inversion of the stratigraphy, representing then hydraulic breccias rather than quartzites of sedimentary origin.

## Stop 12 - Panoramic view of the morainic amphitheatres in Val Starleggia and Val Sancia, related to Lateglacial to Holocene stadials

**Coordinates: Lat. 46.413674 N, Long. 9.300538 E**

From the pass, there is a very clear panoramic view of the glacial landforms in Val Starleggia. From downstream upwards, in figures 47 and 48 there are: a) lateral moraines outlining a local glacier tongue, made up of upper Val Starleggia and Val Sancia Glaciers that joined near Cusone and reached Val San Giacomo; b) morainic amphitheatre, partly eroded, built by the Val Sancia (major) and upper Val Starleggia (minor) glacier tongues; c) Val Sancia glacier morainic amphitheatre; d) upper Val Starleggia moraines. The glacial landforms clearly draw the glacier dynamics during the Last Glacial Maximum deglaciation: the glacier gradually shrank (a, b in figures 47 and 48) and split into two distinct bodies (c, d in figures 47 and 48). The Val Sancia glacier has existed until the LIA and to the last decades of the past century; now, it is almost completely melted.

No chronological constraints are available for the area, but from the literature of the surrounding regions (e.g., Scotti et al., 2017), the moraines located at b) and c) in figures 47 and 48 could be attributed to the Egesen and Kartell/Kromer stadials.

## Stop 13 - The quartzitic gneiss of the Suretta nappe basement and the Monte Tignoso tectonic klippe

**Coordinates: Lat. 46.413393 N, Long. 9.303102 E**

The itinerary now descends towards the village of Cusone, following the left flank of Val Starleggia. The path runs along the side of Valle Pissa, up to 2200 m a.s.l. and crosses some slope deposits at the base of the southern rocky cliff of Monte Tignoso (Fig. 49a). The boulders lying in the area have a quartzitic gneiss lithology (Fig. 49b), very similar to the ones cropping out in the basal portions of the Suretta nappe in the nearby Val Rabbiosa, along the left flank of Val San Giacomo. They are also very similar to the least-foliated facies of the quartz schists cropping out along Lago di Lei. These rocks are mainly composed by quartz, feldspar and white mica, with frequent carbonate lenses along the


https://doi.org/10.3301/GFT.2025.04

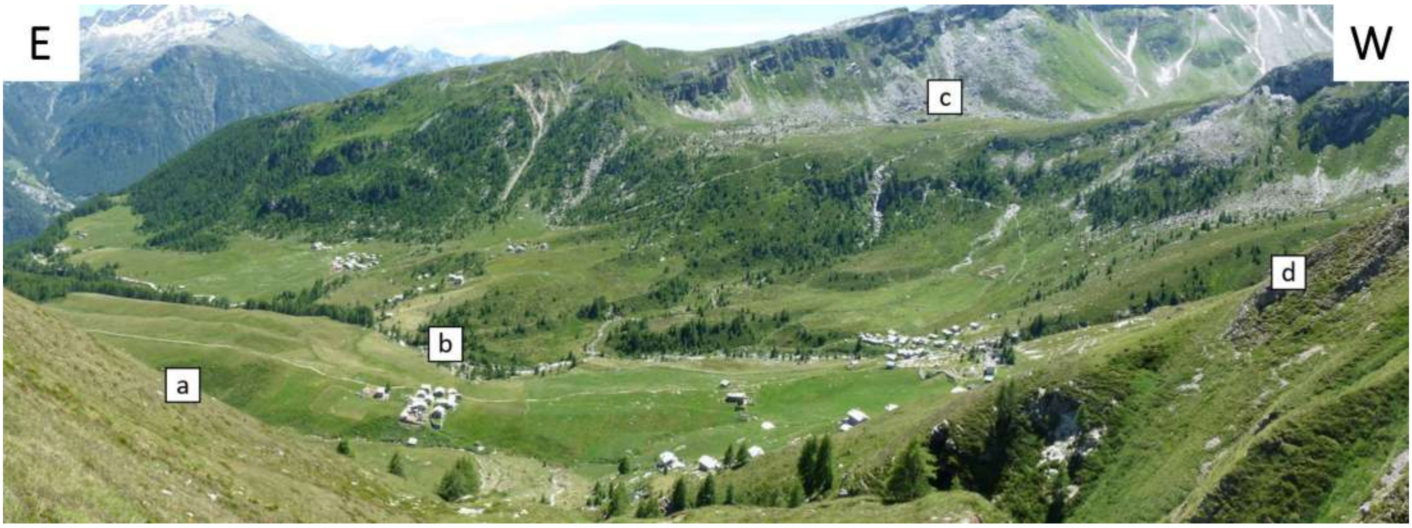



Fig. 47 - Southward panoramic view of Val Starleggia from the pass east of Monte Tignoso. Details for labels a-d are provided in the text.

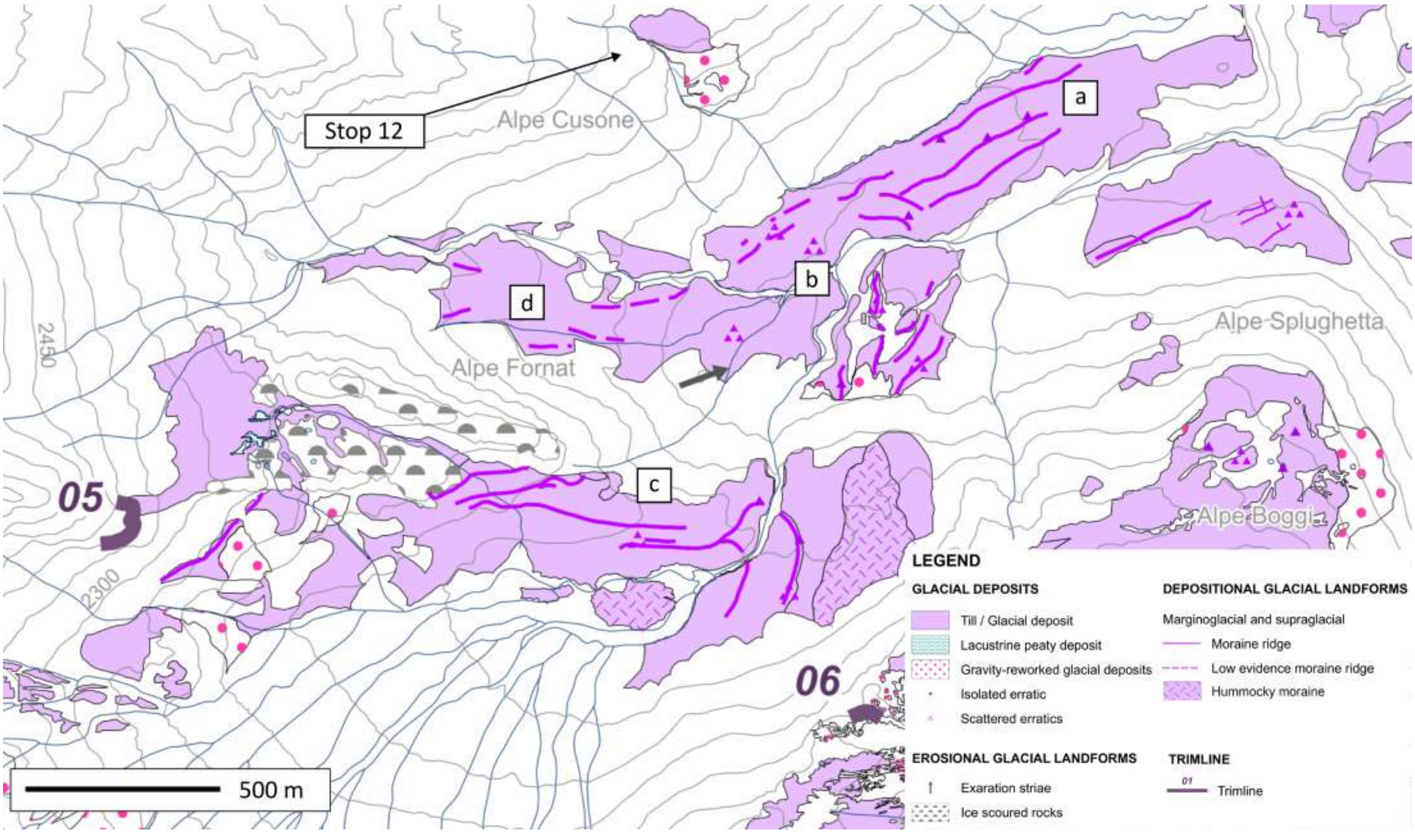



Fig. 48 - Map of glacial landforms in Val Starleggia and Val Sancia (extract from Tantardini et al., 2022). Details for labels a-d are provided in the text.

main foliation, and they could constitute the basal horizon of the Permian meta-sedimentary cover on the Variscan crystalline basement of the Suretta nappe, that in this area could lie with an inverted structural polarity (Stop 11).
Above the quartzitic gneiss there are some biotite-rich paragneiss and garnet mica schists (very similar to the ones cropping out around Passo di Angeloga, at the core of the Suretta nappe). They compose the upper part of the Monte Tignoso, as well as the highest portion of the klippe (Fig. 50). They show a widespread brownish surface weathering, and in general are characterised by a lower mechanical quality, with respect to the underlying quartzitic gneiss. Within the slope talus, occasional biotite orthogneiss boulders can also be found.

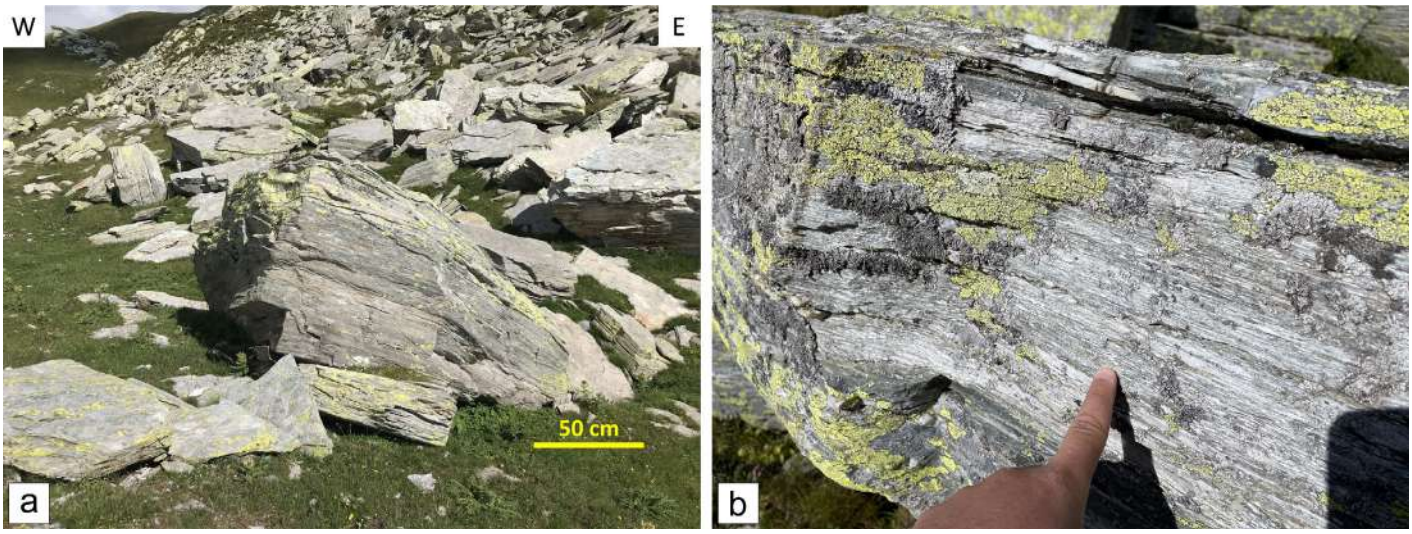



Fig. 49 - a) Quartzitic gneiss boulders at the base of talus deposits of the southern cliff of Monte Tignoso; b) detail of the quartzitic gneiss texture.

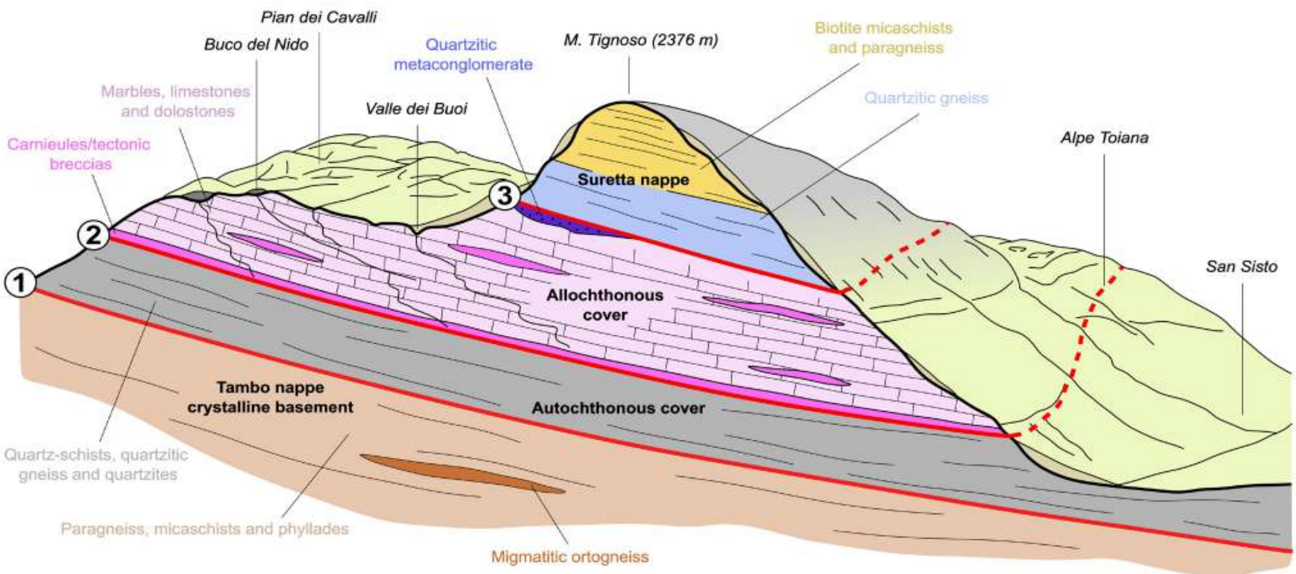



Fig. 50 - Three-dimensional geological sketch of the Monte Tignoso and Pian dei Cavalli area, redrawn after Cappa & De Michele (1963). The main tectonic thrusts of the area are well visible, dividing, from below, 1) the crystalline basement of the Tambo nappe from its autochthonous cover; 2) the autochthonous from the allochthonous cover of the Tambo nappe; 3) the allochthonous cover from the Suretta nappe (Monte Tignoso klippe).

## Stop 14 - Panoramic views on Monte Tignoso and Val Sancia

**Coordinates: Lat. 46.407418 N, Long. 9.315827 E**

The itinerary now descends along the southern flank of the Monte Tignoso, reaching the village of Cusone. The N688 path continues from the southern end of the village and leads to Morone along a well-visible moraine on the left side of Starleggia creek, until it reaches a small bridge. This area benefits from a good view on both Monte Tignoso, to the north, and Val Sancia, to the south. The rocks cropping out here are quartzites and quartz schists of the meta-sedimentary cover of the Tambo nappe, at altitudes between 1650 and 2100 m a.s.l.

The panoramic view of the southern slope of Monte Tignoso offers a perfect view on the geological structure of the area (Fig. 51). The two main thrusts, the first one dividing the autochthonous from the allochthonous cover, and the second one dividing the allochthonous cover from the Suretta nappe rocks, are underlined by the presence of two structural morphological surfaces.

Towards southwest, the Pizzo Quadro summit dominates the head of Val Sancia. In this area (Fig. 52) rocks belonging to the Tambo basement crop out, in particular the subunit

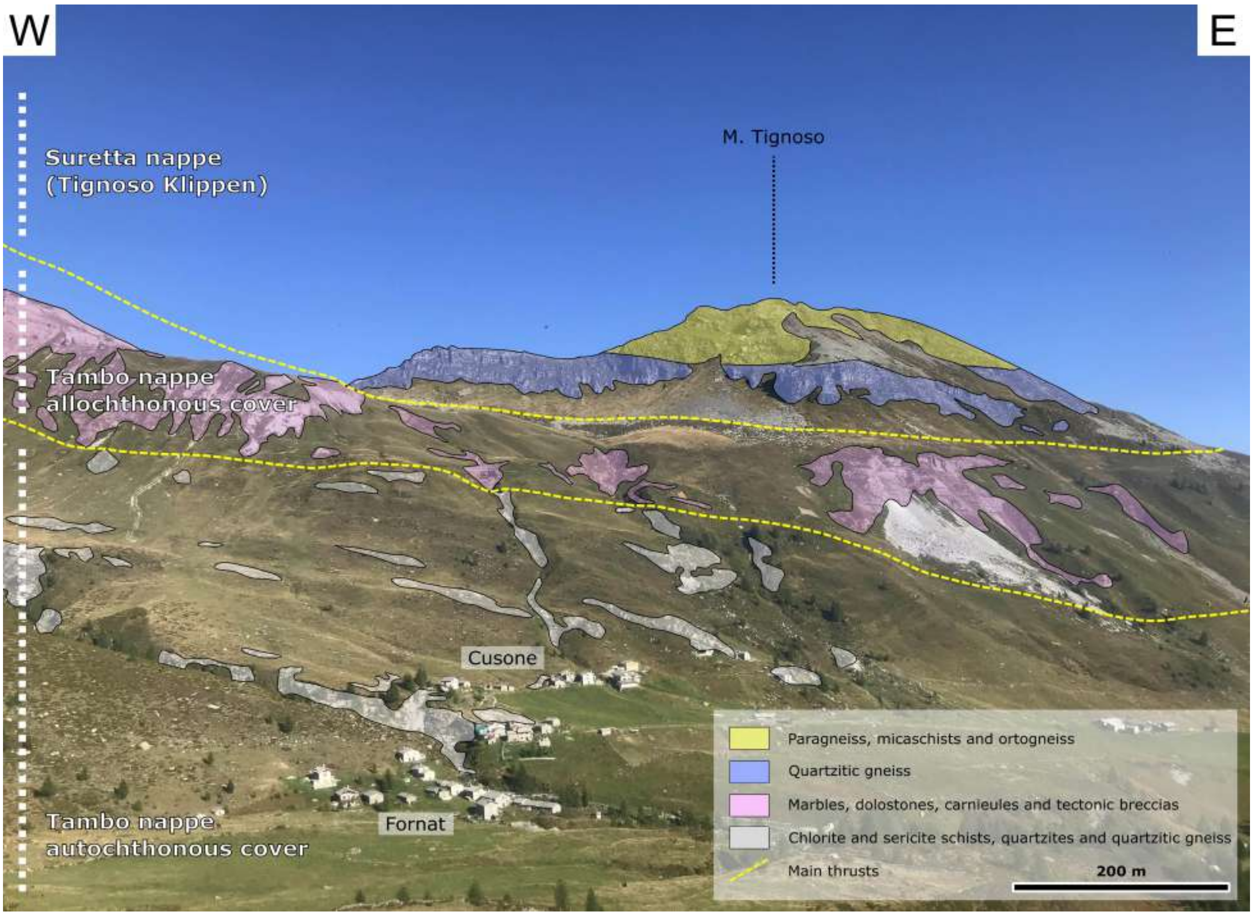



Fig. 51 - Panoramic view and geological scheme of the Monte Tignoso area. The two main thrusts (yellow dashed lines) are underlined by two morphological surfaces.

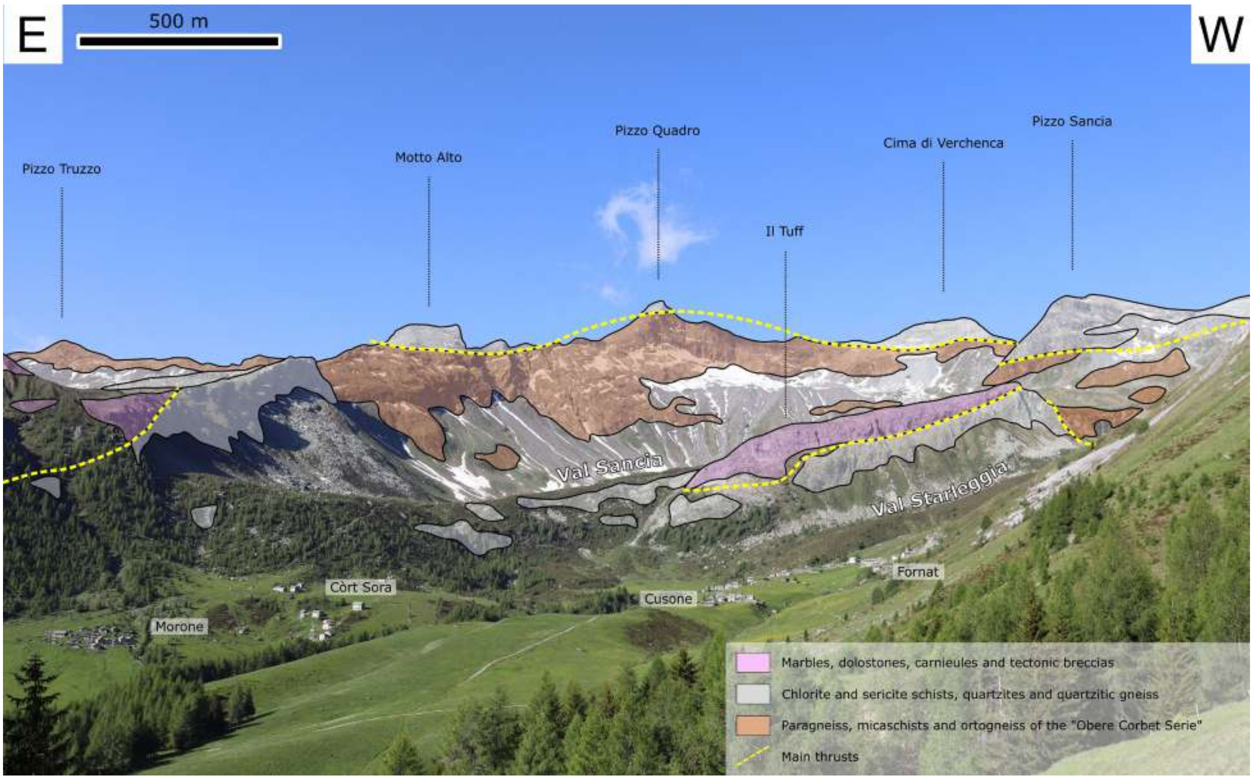
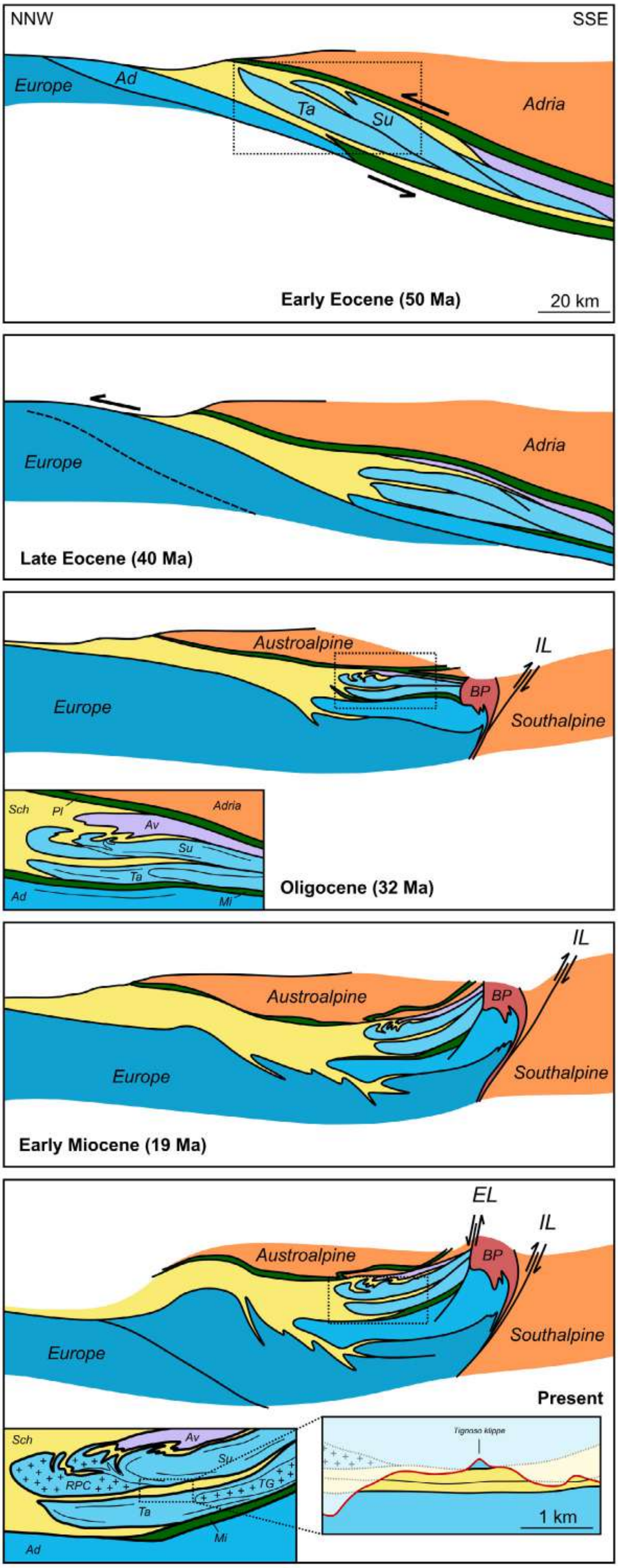



Fig. 52 - Panoramic view of Val Sancia, as seen from the southern slope of Monte Tignoso.




called "Obere Corbet Serie" by Weber (1966). These rocks are mainly composed by white mica-rich, locally garnet-bearing, paragneiss and mica schists. This subunit underlies the meta-sedimentary cover, that crops out only in the higher parts of the rocky ridge between Motto Alto to Pizzo Quadro. The meta-sedimentary cover reappears at Cima di Verchenca, to the west. In the foreground, the kilometre-sized rocky cliff called "Il Tuff" is composed by marbles and limestones of the Tambo nappe allochthonous cover, overlying the quartz schists.

From here, the itinerary returns to Morone, concluding with a descent along the dirt road in the direction of Starleggia, to the car parking.

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**Fig. 53 - Sketch of the tectonic evolution of the Central-Eastern Alps, from early Eocene to present time, with a focus on the nappe stack emplacement in the Val San Giacomo area (redrawn after Schmid et al., 1996, Nussbaum et al., 1998). Abbreviations: Ad = Adula nappe; Av = Avers Bundnerschiefer; BP = Bergell Pluton; Mi = Misox Zone; Platta = Platta nappe; RPC = Roffna Porphyry Complex; Sch = Schams nappes; Su = Suretta nappe; Ta = Tambo nappe; TG = Truzzo Granite.**

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