Geogr. Fis. Dinam. Quat.
Suppl. VII (2005), 163-177, 17 figg., 1 tab.

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STRUCTURAL ANALYSIS OF *ROCHES MOUTONNÉES* IN WESTERN OROBIC ALPS (LOMBARDIA)

ABSTRACT: GHISELLI A., BINI A. & ZUCALI M., *Structural analysis of* roches moutonnées *in Western Orobic Alps (Lombardia)*. (IT ISSN 1724-4757, 2005).

The structural characters of the *roches moutonnées* have been studied within four cirques of the Western Orobic Alps, for the purpose of identifying the relationship between structures and observed morphologies. The meso-structural analysis of the area has led to the identification and the chronological ordering of six deformation phases (three pre-Alpine and three Alpine) represented by many different structures both ductile (folds and foliations) and brittle (faults and cataclasites). Each exposed surface of the *roches moutonnées* has been analysed on the base of this structural model and the correspondence between morphological and structural characters has been evident. The investigated cases demonstrate that the exposed surfaces of the *roches moutonnées* are, in reality, structural surfaces. Therefore, it would seem that their *moutonné* appearance is not of glacial origin alone. The glacial action is likely to be limited to the removal of the higher rock portion weathered during interglacial periods.

KEY WORDS: *Roches moutonnées*, Structural analysis, Western Orobic Alps, Glacial morphology.

RIASSUNTO: GHISELLI A., BINI A. & ZUCALI M., *Analisi strutturale di rocce montonate nelle Alpi Orobiche Occidentali (Lombardia)*. (IT ISSN 1724-4757, 2005).

Nelle Alpi Orobiche Occidentali sono state studiate le caratteristiche strutturali delle rocce montonate affioranti all'interno di quattro circhi, allo scopo di indagare la relazione tra le strutture presenti e le morfologie osservate. L'analisi mesostrutturale dell'area ha permesso di individuare e ordinare cronologicamente sei fasi deformative (tre prealpine e tre alpine) rappresentate da numerose strutture sia di tipo duttile (pieghe e foliazioni) sia fragile (faglie e cataclasiti). L'esame della superficie esposta di ciascun dosso montonato, sulla base di tale modello strutturale, ha messo chiaramente in evidenza la corrispondenza tra i caratteri morfologici e quelli strutturali. I casi studiati dimostrano che le superfici esposte delle rocce montonate sono, in realtà, superfici strutturali. Perciò sembrerebbe che il loro aspetto montonato non sia solo di origine glaciale. L'azione dei ghiacciai potrebbe, quindi, essere limitata alla semplice rimozione della porzione superiore della roccia precedentemente alterata durante i periodi interglaciali.

TERMINI CHIAVE: Rocce montonate, Analisi strutturale, Alpi Orobiche Occidentali, Morfologia glaciale.

INTRODUCTION

Twelve glacial cirques in the Western Orobic Alps have been studied in order to compare the influence of glacial action and of structural actions control on the present-day morphologies.

A geological, geomorphologic and structural detailed mapping (scale 1:5,000) has been carried out and the structural field data have been elaborated. It is on this structural analysis that the observed shapes have been interpreted both on macro and meso scales.

Particular attention has been paid to the analysis of the *roches moutonnées* surfacing the cirque bottoms and close to their thresholds. Of the twelve cirques under examination only four are characterized by rock knolls that are likely to be defined *roches moutonnées* of glacial origin. These four are discussed in greater detail below.

GEOGRAPHIC AND GEOLOGICAL SETTING

The area stretches along the main ridge of the Western Orobic Alps, which constitutes the central part of the Southern Alps. The four cirques being analysed develop from 1,800 to 2,350 m a.s.l. and occupy the valley heads of Valle del Salmurano (Circo del Salmurano) on the southern side, Valle del Bitto di Albaredo (Circo di Passo San Marco) and Valle del Bitto di Gerola (Circo del

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Monte Ponteranica and Circo di Foppe di Pescegallo) on the northern side (fig. 1).

Bedrock lithology is constituted by a pre-Alpine (pre-Permian) metamorphic basement and a non-metamorphic or very low-grade metamorphic Permo-Triassic sedimentary cover.

Basement lithologies have been mapped on the base of their protolith composition (sedimentary or igneous) and not after the Servizio Geologico d'Italia distinction (Bonsignore & *alii*, 1971). In particular they are represented by:

- micaschist and paragneiss with quartz, feldspar, white mica, dark mica, chlorite, rare tourmaline and garnet; the main structure is characterized by one or two spaced foliations from 1 mm to 60-70 mm thick;
- orthogneiss with quartz, plagioclase, K-feldspar, biotite, chlorite, epidotes; the main structure is locally characterized by a spaced foliation 1 mm to 30 mm thick.

The sedimentary cover has been mapped on the base of authors' formational distinctions. It is constituted by, in stratigraphic order:

- *Conglomerato del Ponteranica* (Circo del Salmurano, Circo del Monte Ponteranica, Circo di Foppe di Pescegallo): grayish conglomerates with well rounded clasts, alternated with gray conglomeratic sandstones with rare clasts; generally the bedding is indistinct; the clasts are made up of volcanic rocks, rare basement fragments and quartz (maximum diameter 70 cm); the sandstones are primarily composed of volcanic fragments, rare quartz, feldspar and muscovite (Sciunnach, 2001).
- *Formazione di Collio* (Circo del Salmurano, Circo di Foppe di Pescegallo): gray siltstones and mudstones with fine intercalation of black pelite and local intercalation of green sandstone; conglomeratic sandstones and conglomerates with greenish matrix; sandstones have a very thin parallel bedding and they are composed of volcanic rock fragments, quartz, plagioclase, muscovite and feldspars; the matrix is not very abundant (Gianotti & *alii*, 2002).
- *Verrucano Lombardo* (Circo del Salmurano, Circo del Monte Ponteranica, Circo di Foppe di Pescegallo): red conglomerates alternating with sandstones and deep red mudstones; the conglomerates are composed of subrounded and rounded clasts of quartz and of volcanic rocks (diameter 2-64 mm, at times reaching 100 mm); the dark red sandstones are constituted by grains of quartz, volcanic rocks, feldspar and micas (Sciunnach, 2001).

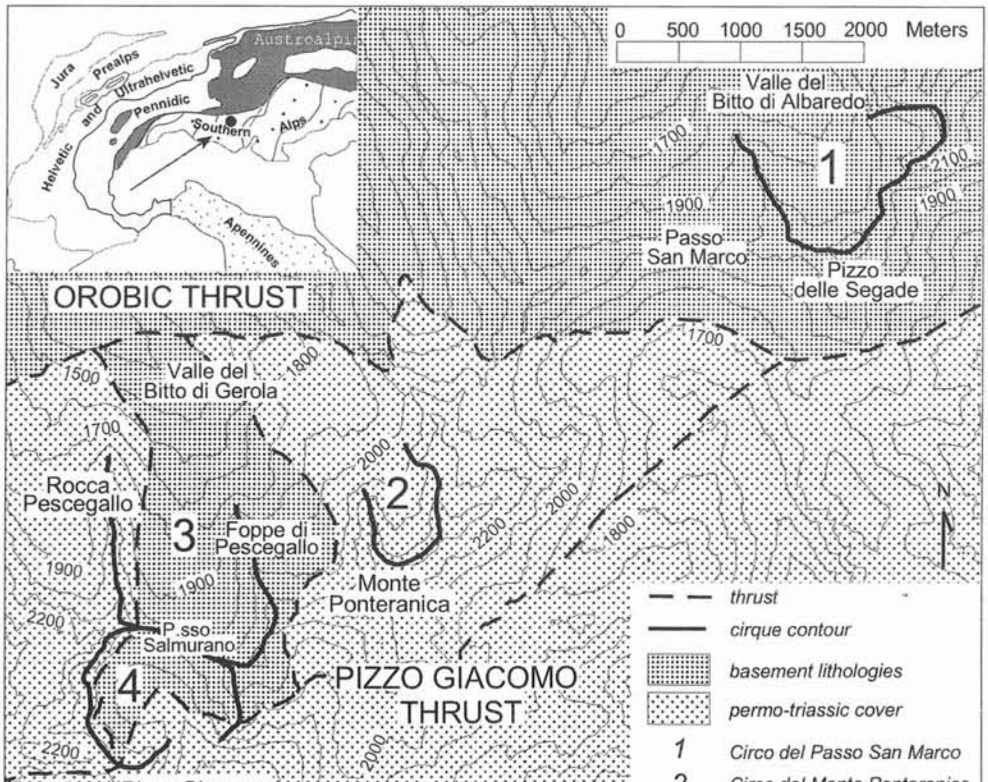


FIG. 1 - Simplified geological map showing the geological setting of the four analyzed cirques. Inset: geological sketch of the Alpine chain.

• *Formazione del Servino* (Circo del Monte Ponteranica): the lower portion is composed of yellowish quartzitic sandstones, with rounded grains and ochreous alteration, intercalates of yellow-gray to green shale, marlstones and mudstones; the bedding is represented by thin parallel layers; the upper part is composed of reddish and yellowish siltstones which alternate with Dolomitic marlstone and green shale (Gianotti & *alii*, 2002).

Both crystalline basement and sedimentary cover belong to the Southalpine domain and were involved in Alpine deformation. In this section of the Orobic Chain the compressive Alpine phase lasted from Cretaceous to 30 Myr BP (Siletto, 1991) and generated a series of south vergent duplexes bounded by thrust planes whose dip direction is NNW. Two main structural lineaments outcrop in the area: the Orobic Thrust to the North and Pizzo Giacomo Thrust to the South (Schönborn, 1992) (fig. 1). These thrusts belong to the Orobic Line, a regional fault zone that causes the pre-Alpine basement overthrusting on the Permo-Triassic cover. Actually the thrust surfaces are numerous and take place at both the contact between basement and covers as well as inside the covers themselves. The resulting structure is characterized by imbricated slices of basement or covers, from 10 to 100 m thick, with the same dip as the bounding thrusts.

These thrust planes are associated with a rather brittle deformation that develops on the upper crust near the surface (Forcella, 2000). They are often characterized by cataclastic layers from 1 m to 10 m thick (Forcella, 2000). The tectonic transport direction is SSE with possible lateral movements: a dextral component has been reported by Siletto (1991).

MESOSTRUCTURAL ANALYSIS

The meso-structural analysis has been based upon the data collected both on the *roches moutonnées* surfaces and on the cirque walls. The intersection relationship between the structures observed on the field have been integrated with the processing and interpretation of the data through stereographic projections and kinematic evaluations (Nicolas, 1987).

This study has enabled six groups of structures belonging to six different deformation phases to be detected. It has also permitted a reconstruction of the relevant chronology. The first three phases are pre-Alpine and are only found to be recorded in the crystalline basement; the other three phases are Alpine and are recorded in both the basement and in the sedimentary covers. During the Alpine phases deformation develops on a more superficial level than during the pre-Alpine ones and the resulting structures are rather brittle (Siletto, 1991). In particular, there are five continuous fault systems developed at a macro-scale (A, B, C, D, E systems) and two systems represented by little discontinuous fault planes.

TABLE 1 - Age, location and structures of the six chronological ordered deformation phases

DEFORMATION PHASE	AGE	STRUCTURES	LOCATION
D1	Pre-Alpine	S1 foliation	Pre-Alpine basement
D2	Pre-Alpine	PA2 folds; S2 axial plane foliation	Pre-Alpine basement
D3	Pre-Alpine	PA3 folds; S3 crenulation cleavage of S1 and S2	Pre-Alpine basement
D4	Alpine	PA4 folds; thrusts dipping NNW (A system); cataclasites and S4 associated foliation; reverse-left lateral faults dipping NW or SE (B system); left lateral faults dipping W or SW	Pre-Alpine basement and Permo-Triassic cover
D5	Alpine	Left lateral faults dipping NNW; right lateral faults dipping ESE (C system)	Permo-Triassic cover
D6	Alpine	Reverse faults dipping S (D system); S6 associated foliations; normal faults dipping NNW (E system)	Pre-Alpine basement and Permo-Triassic cover

D1 phase is represented by S1 foliation, marked by thick quartz and feldspar-rich layers (fig. 2). S1 foliation is well developed in the meta-pelites while is often absent or less diffuse in the orthogneiss.

The structures belonging to D2 phase are: close folds involving S1 foliations, associated with asymmetric («S» or «Z» geometry) folds and an axial plane foliation S2. S2 foliation is marked by white mica and chlorite in micaschists and by tourmaline and black phyllosilicates in paragneiss. In the finer lithologies a fine planar division, not marked by a macroscopic compositional layering, may define S2.

D3 generated non-cylindrical, recumbent, tight to isoclinal folds, involving S1 and S2 with angular hinge, dm-sized and associated crenulation cleavage S3. D3 only occur within basement mica schists and paragneiss.

The D4 structures are the most evident and diffuse in the area. In basement lithologies they are represented by open to gentle folds involving all pre-existing structures (e.g. S1, PA2). Two fault systems and rare folds occur within the sedimentary cover. The first system (A) groups the NNW dipping thrusts that represent the regional duplexes system of southalpine domain described above.

FIG. 2 - S1 foliation marked by a thick quartz-rich layer folded and partly boudinated.

The major thrust planes localize within deformation bands, variously thick, constituted by cataclasites and minor mylonites (fig. 3). Anyway, the fault movement has been inferred from displacement markers represented by elongated quartz (fig. 4) or chlorite fibres and rare striae. In fine lithologies the S4 foliation associated with the thrusts is represented by diffuse slaty cleavage. Otherwise in conglomerates S4 is represented by irregular planes in the matrix and flattened clasts, and it is concentrated in bands, 1 to 10 m thick, close to the thrust planes. The B system is constituted by reverse-left lateral faults with NW or SE dip direction and 50° to 70° dip angle. The PA4 asymmetric folds, involving the Permo-Triassic covers, outcrop close to the A thrust planes and are in association with them. Their axial planes have the same dip of the thrust planes.

D5 structures involve the Permo-Triassic covers only and are represented by the C faults system. The C faults are right lateral faults with ESE dip direction and 70°-80° dip angle.

D6 deformation is recorded in both basement and in sedimentary cover and is represented by two fault systems and S6 foliation. The D system groups the reverse faults with S dip direction and 50°-60° dip angle. S6 foliation is associated with D faults and involves pelitic lithologies of sedimentary cover. The normal faults belonging to E system have a NNW dip direction and a 50°-60° dip angle, they are discontinuous and shortly developed.

ROCHEES MOUTONÉES DESCRIPTION

On the bottom of the four investigated cirques and in particular close to the threshold, *roches mountonnées* outcrop at heights between 1,850 and 2,150 m a.s.l. They have polished, more or less wavy and generally gently dipping surfaces. Besides the rock knolls with the typical appearance of the *roches mountonnées*, there are other ones which shapes do not always conform to the classical definition: «rock knobs with stoss and lee sides; the stoss (up-glacier) side has a polished, gently dipping surface, while the lee (down-glacier) side is shattered and steep» (de Saussure, 1786).

The rock knolls morphology and their structures are described below.

Circo del Passo San Marco

The cirque bottom is partially covered by glacial deposits from which many *roches moutonnées* outcrop (fig. 5). These knolls are made up of basement micaschists, and they extend in a N-S direction. The maximum length is 300 m, the width is 30 m. The exposed surfaces of the

FIG. 3 - Shear zone in the *Collio* mudstones near the tectonic contact with basement micaschists. The S4 foliation, associated with the A thrust, are represented by slaty cleavage. The characteristic S-C structures allow to determinate the sense of thrust movement.

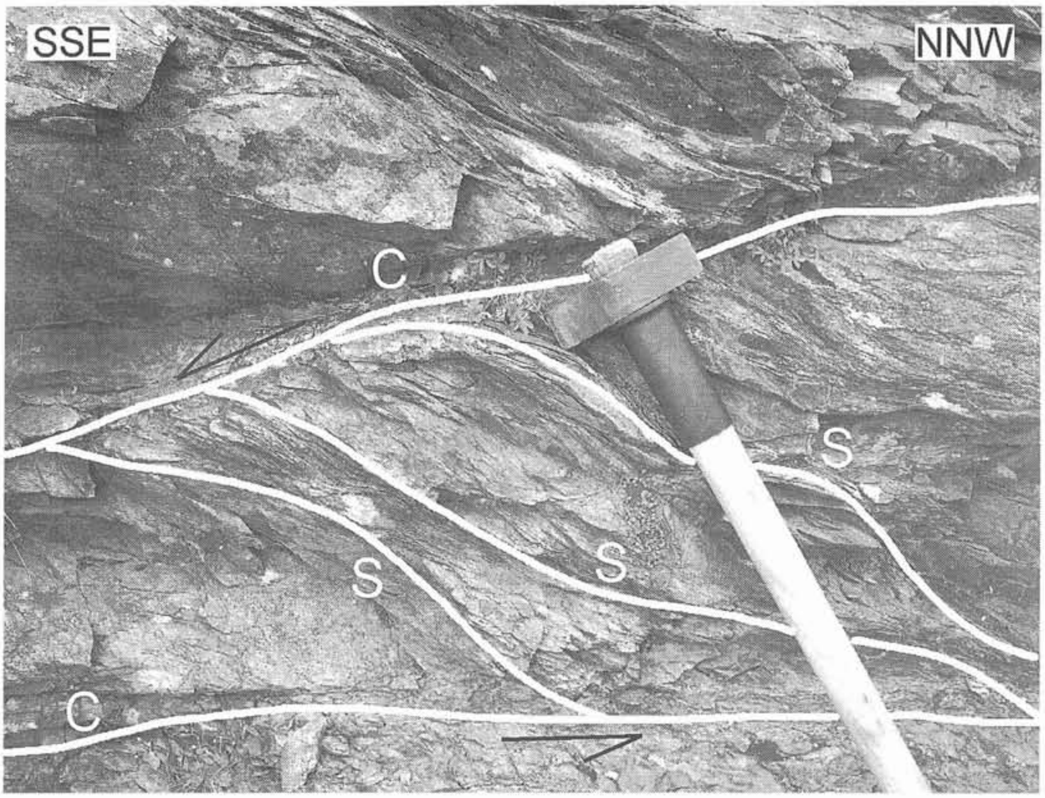


FIG. 4 - Displacement markers represented by elongated quartz fibres interrupted by small steps.

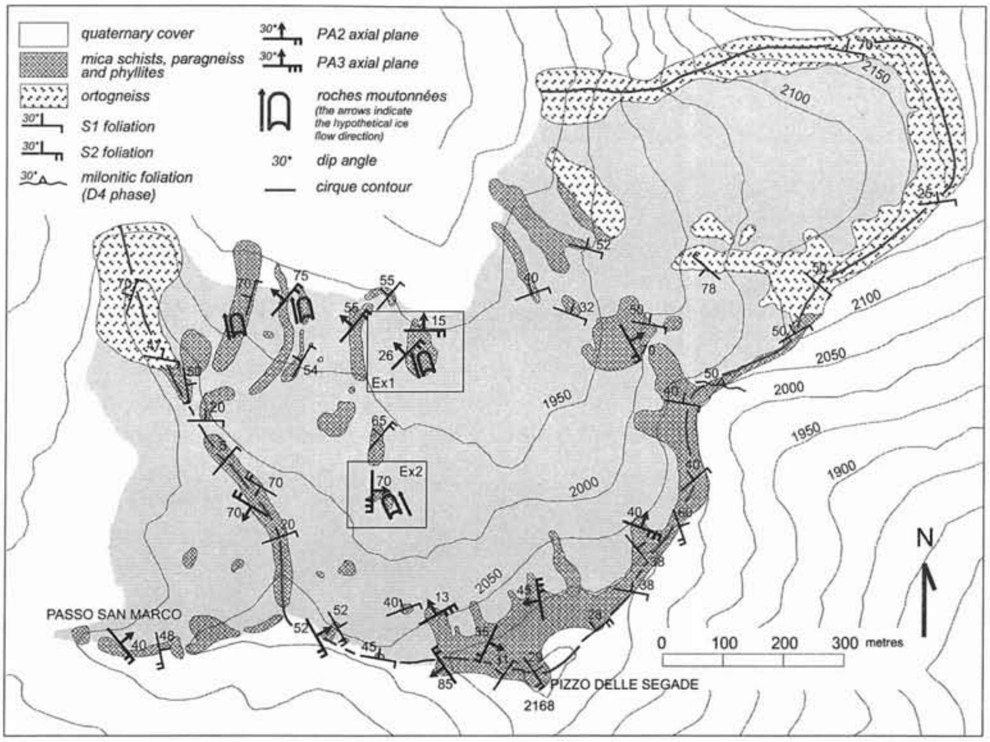


FIG. 5 - Simplified geological-geomorphologic and structural map of the Passo San Marco cirque. The two *roches moutonnées* examples described in the text are indicated in the squares.

north-western side is wavy, its dip direction is NNW and dip angle ranges from 25° to 80°. On the north-eastern side the dip direction is NNE and dip angle ranges from 30° to 60°. Since the cirque opens towards NNW (fig. 5) the ice flow direction would have been NNW. So the north-western side is the lee side of the *roches moutonnées*, while the stoss side doesn't outcrop because it's covered by glacial deposits.

These rock knolls are constituted by micaschists characterized by a composite foliation (S1+S2) marked by white mica and chlorite shape preferred orientation or quartz layers (figs. 6 and 7). D3 folds also bent S1+2 composite foliation producing metre-scale crenulation. The axial plane (PA3) dip direction is E and its dip angle is 70°; the fold axis isn't horizontal, but dips towards N. Such folding generates a macroscopic variation of the foliation dip direction: NNW with dip angle from 25° to 80° and NNE with dip angle from 30° to 60°.

Circo del Monte Ponteranica

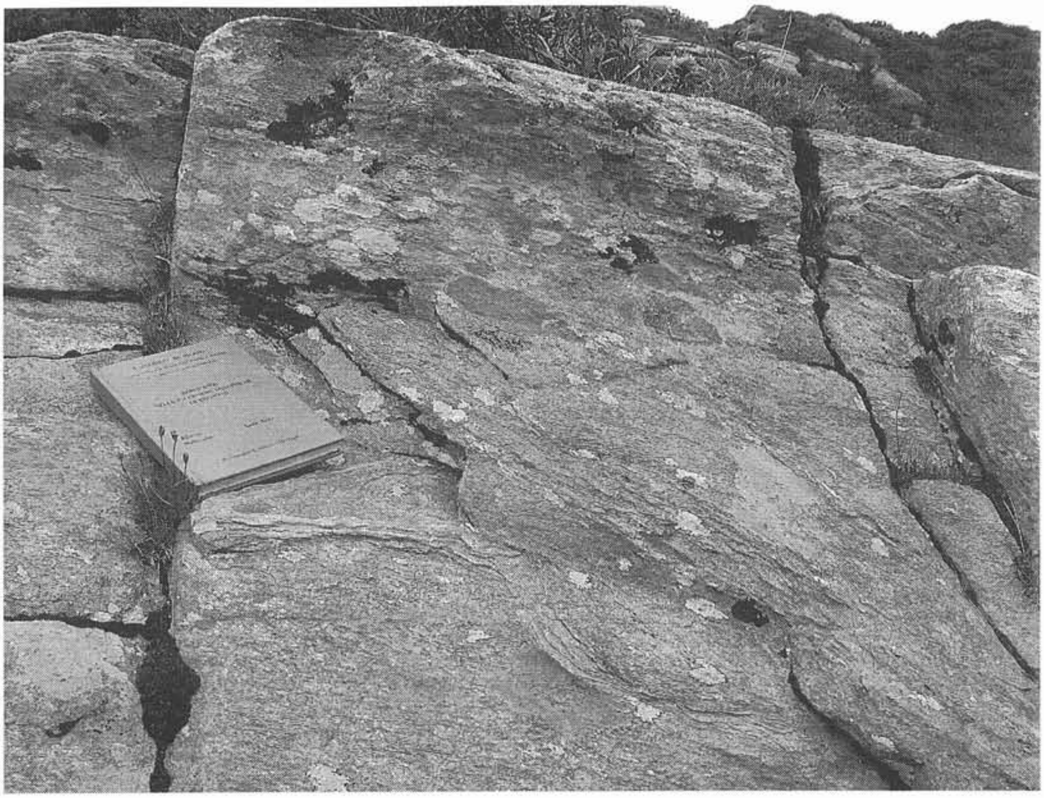
On the bottom of the cirque there is a *Conglomerato del Ponteranica* knoll that extends for 350 m in a NNW-SSE direction and for 100 m in a WSW-ENE direction (fig. 8). The exposed surface of its back is plain on a macro scale (fig. 9) but slightly wavy in its detail. Its dip direction is NNW and dip angle ranges from 30° to 37°. It is interrupted by small steps that have the same dip direction and a greater (60°-70°) dip angle. The western and southern sides are covered by slope debris, whereas the surface on the eastern side outcrops briefly (dip direction E, dip angle 60°-70°). Due to this morphology, this knoll does not conform precisely with the definition of *roche moutonné* and it's not possible to distinguish a lee side and a stoss side, but its polished and slightly wavy surface seem to be typical of the glacial modelling. Since the cirque opens towards NNW (fig. 8) the ice flow direction would have been NNW.

The structures outcropping on the bottom rocks belong to the D4 and the D6 deformation phases; in particular. E system faults occur, which displace small boulders northward. The described *moutonné* knoll is characterized by small discontinuous normal faults with a NNW dip direction and a variable from 30° to 70° dip angle. (fig. 9).

Circo di Foppe di Pescegallo

The cirque bottom is almost entirely covered by glacial deposits and talus debris. Only a small basement micaschist *roche moutonné*, 30 m long and 30 m wide, outcrops (fig. 10). Its back is made up of a gently and wavy surface with a NNW dip direction and a dip angle of 56° (lee side) (fig. 11) cut off by little steps NNW dipping too. This surface ends with a higher step whose dip direction is NNW and dip angle ranges from 70° to 80°. The stoss side doesn't outcrop because it's covered by glacial deposits. Since

FIG. 6 - Passo San Marco cirque: polished surfaces of the *roche moutonné* corresponding to the folded foliation surfaces.



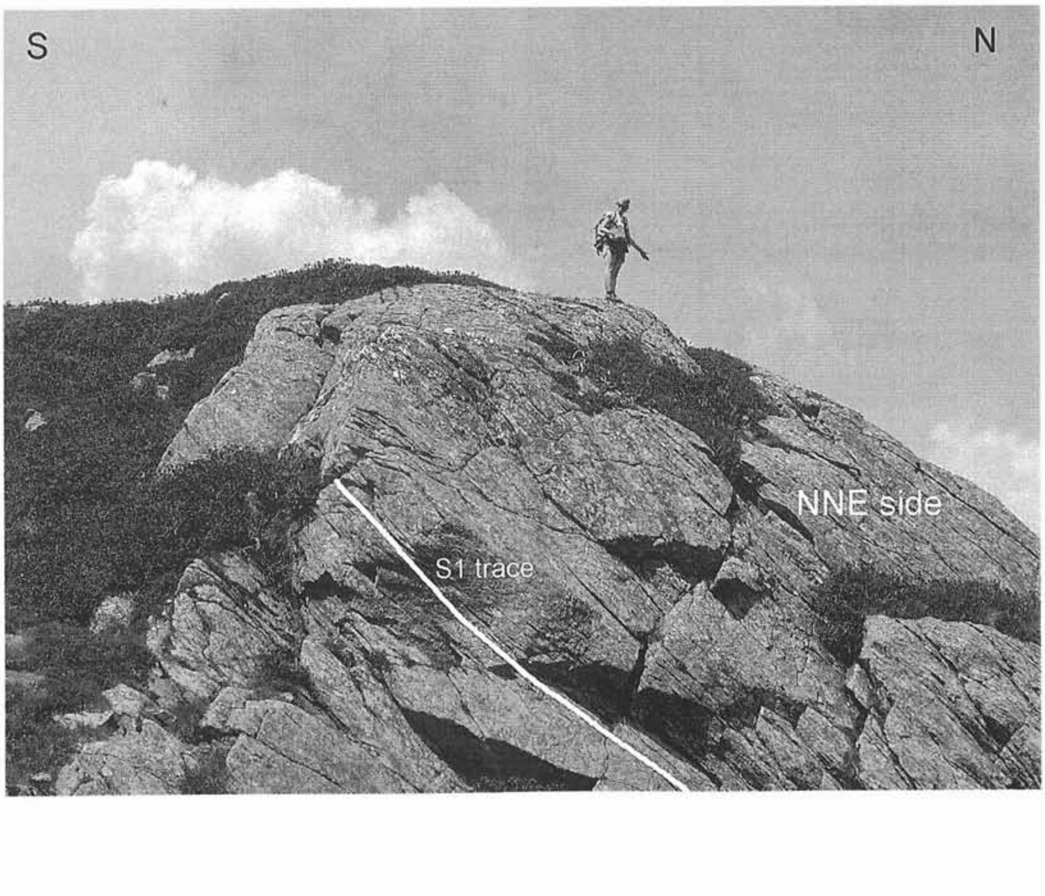


FIG. 7 - Passo San Marco cirque: metre-scale D3 phase fold; the *roche moutonné* north-eastern side corresponding to the NNE dipping folded S1 foliation is shown.

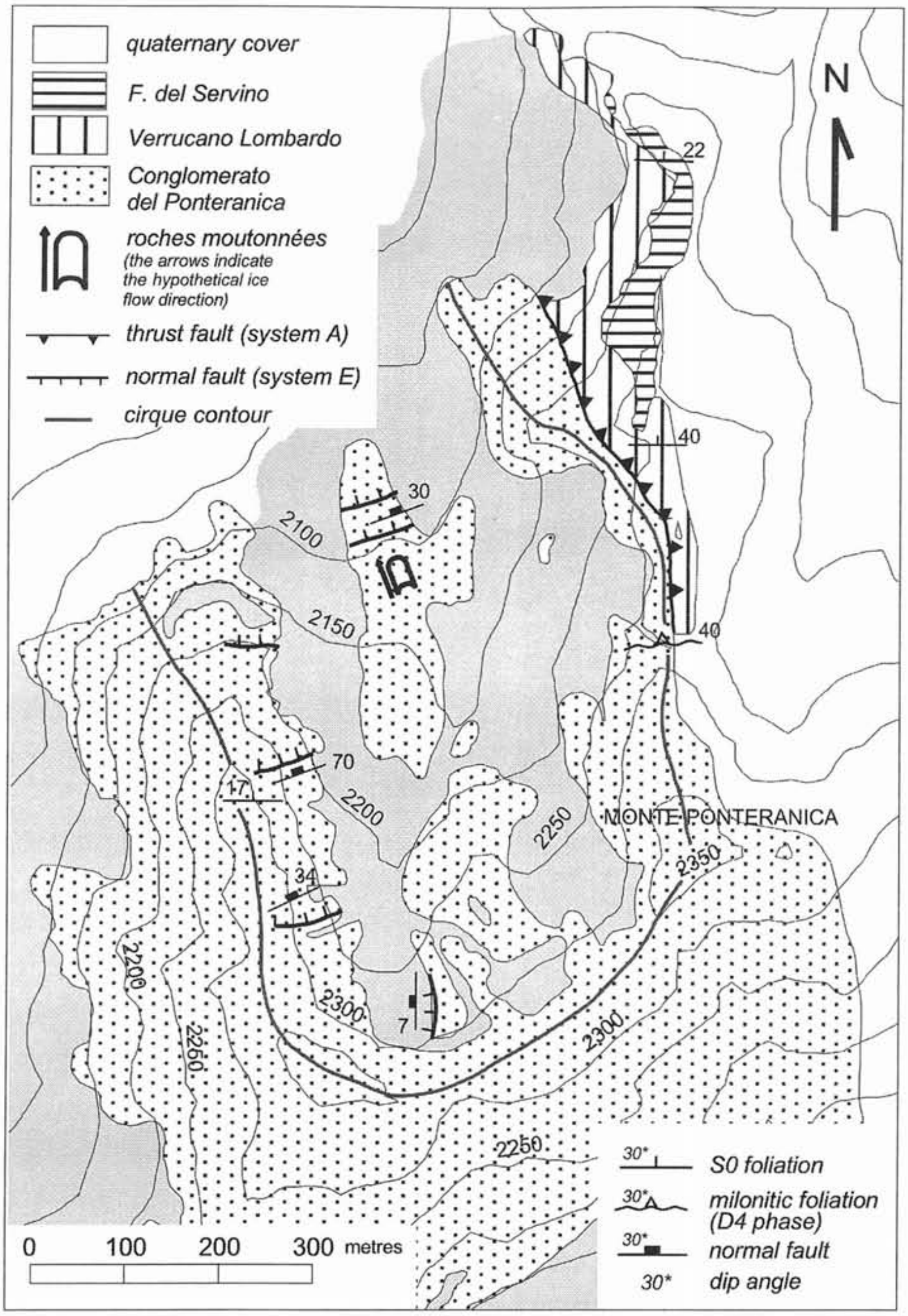


FIG. 8 - Simplified geological-geomorphologic and structural map of the Monte Ponteranica cirque. The indicated *roche moutonné* is described in the text and showed in fig. 9.

the cirque opens towards NNW (fig. 10) the ice flow direction would have been NNW.

This rock knoll is characterized by D1 and D2 structures. The D1 phase is represented by S1 foliations, defined by thick quartz-rich layers, alternating to narrow mica and opaque-rich layers. The D2 phase is testified by a metre-sized gentle fold. Its axial plane has a WSW dip direction and a dip angle of 80°-90°, while its axis has a NNW trend and a plunge of 56°. The enveloping surface of folded S1 has a NNW dip direction and a dip angle of 56°. Numerous fractures with a NNW dip direction and a dip angle of 70°-80° occur.

Circo del Salmurano

Near the tight threshold of the cirque there are several *roches moutonnées* made up of the conglomerates of the *Verrucano Lombardo* formation (fig. 12). On the north-

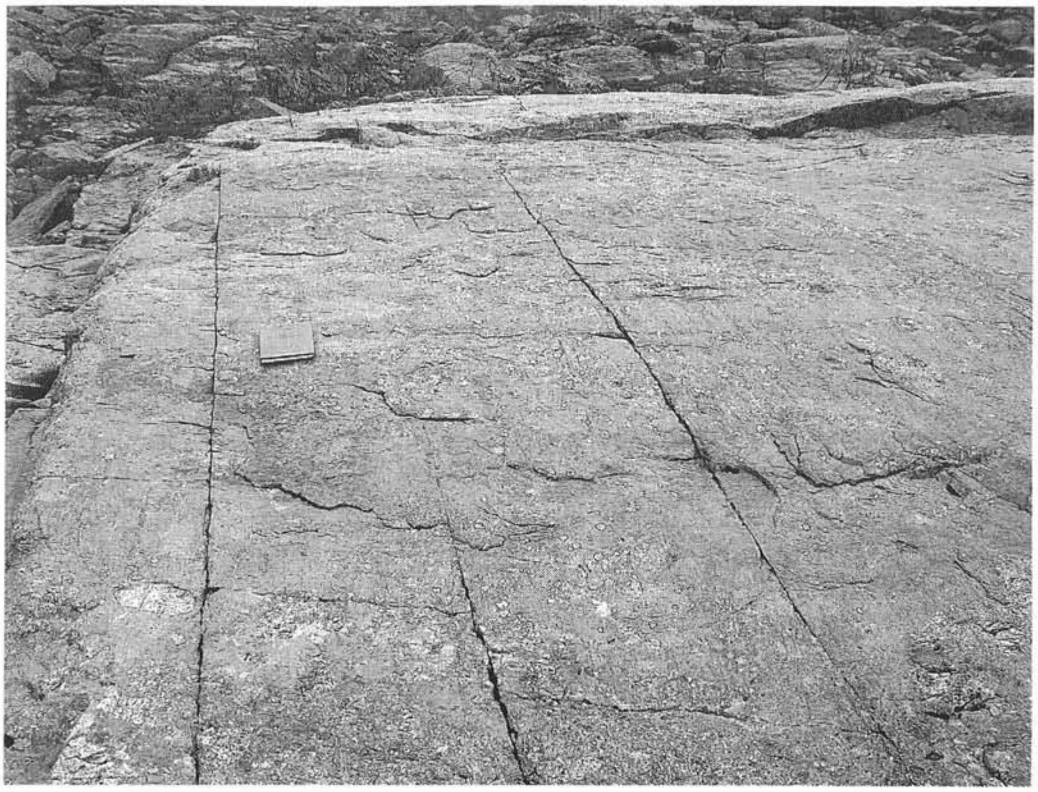


FIG. 9 - Monte Ponteranica cirque: polished surface of the back of the *roche moutonné* corresponding to a normal fault plane.

western side (stoss side) the dip direction of the exposed surfaces is NNW and the dip angle ranges from 40° to 50°. On the south-eastern side (lee side) the dip direction changes abruptly to SSE and the dip angle is steeper (60°-70°). To the north the *Verrucano Lombardo roches moutonnées* surfaces are covered by *Collio* Formation mudstones that have not *moutonnées* surfaces (fig. 13). Since the cirque opens towards SSE (fig. 12) the ice flow direction would have been SSE.

The meso-structural analysis on these rock knolls pointed out that *Collio* Formation mudstones and *Verrucano Lombardo* conglomerates are imbricated in four slices bounded by two major thrust surfaces belonging to the A system (D4 phase). Since these surfaces join both to the East and the West of the cirque threshold, the slices have been interpreted as horses (fig. 14). The dip direction is NNW, while the dip angle changes from 35° to 53°. In certain cases the contacts are wavy and folded, testimony to the complex morphology of surfaces that bind the slices.

Both mudstones and conglomerates are characterized by continuous S4 foliations with the same dip as the fault planes. There are some examples of asymmetric folds, belonging to the D4 phase,, near the contacts between the two formations, in *Verrucano Lombardo* conglomerates and sandstones (fig. 15). These metre-sized isoclinal folds are associated with A thrusts and their axial planes PA4 dip in the same direction as the contact surfaces. Many metre-sized faults belonging to D6 phase outcrop, and particularly reverse faults with a SSE dip direction and a dip angle that ranges from 40° to 90° (D system).

INTERPRETATION AND DISCUSSION

The detailed geomorphologic and structural mapping of *roches moutonnées* on the four examined cirque bottoms, together with structural analysis of the entire area, has made possible to determine the relationship between the existing structures and the morphologic characters of the knolls.

Circo del Passo San Marco

The polished surfaces of the rock knolls on the cirque bottom correspond to the wavy or folded micaschists foliation surfaces (fig. 6). Two particular cases demonstrate the relationship between the knoll exposed surfaces with the characteristic structures.

The first example (Ex 1 of fig. 5) is located just south of the cirque threshold where the section of the north side of the *roche moutonné* is exposed by the cut of the road. Its structure is characterized by a box-shap-

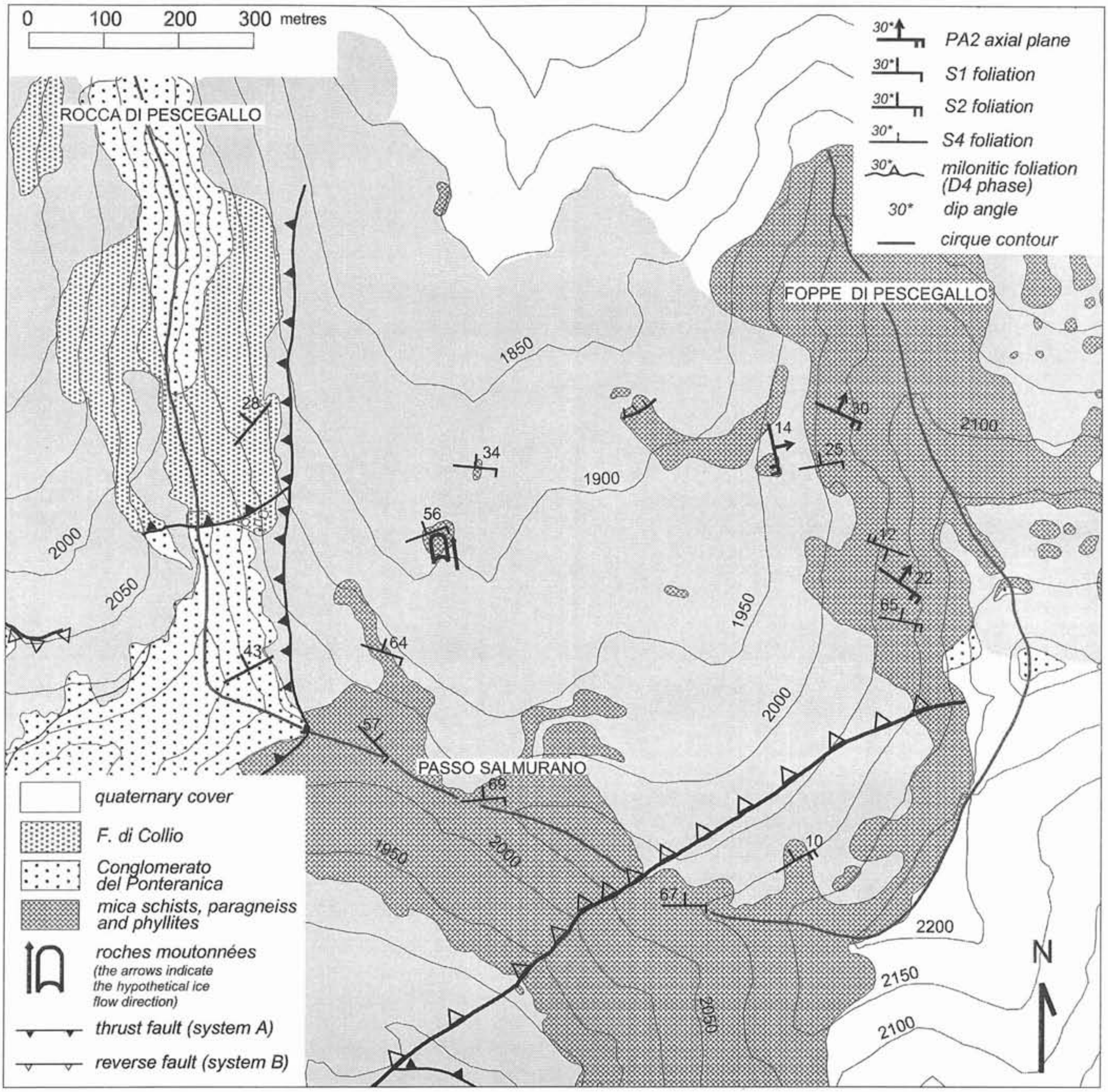


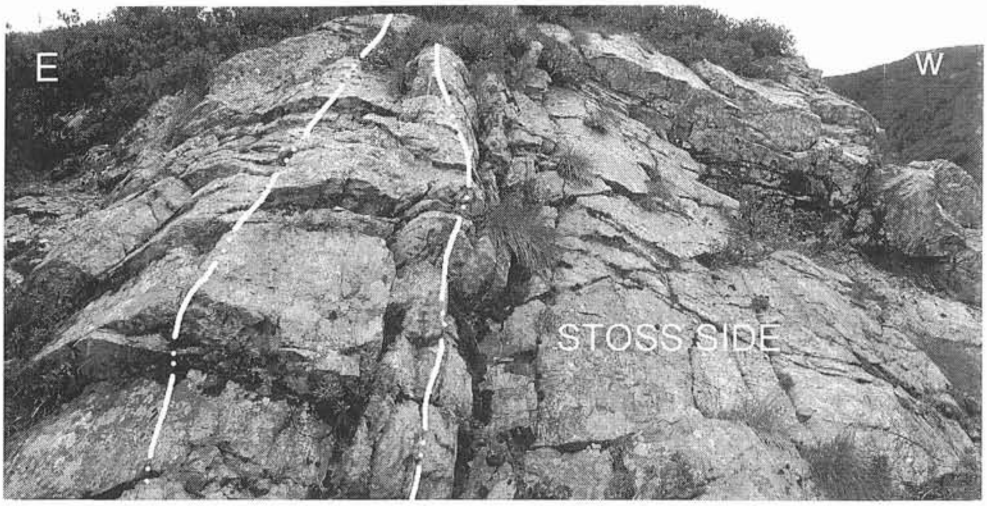
FIG. 10 - Simplified geological-geomorphologic and structural map of the Foppe di Pescegallo cirque. The indicated *roche moutonné* is described in the text and showed in fig. 11.

ed fold. This fold has a large hinge with two conjugated axial planes (PA2a and PA2b of fig. 16). The fold limbs dip in the same direction as the *roches moutonnées* flank surfaces which outcrop just south of the cirque threshold.

In the second case (Ex 2 of fig. 5), one *roche moutonné* on the cirque bottom is characterized by a m-scale D3 phase fold (fig. 7). This fold is shown by the S1+2 foliation. Since the fold has a N dipping axis, the two knoll flanks coincide with the fold limbs: the north-western side is the NNW dipping limb, while the eastern side is the NNE dipping limb.

Therefore the *roches moutonnées* surfaces reflect the fold geometry.

FIG. 11 - Foppe di Pescegallo cirque: surface of the *roche moutonné* stoss side corresponding to S1 surface folded by D2 phase folds; the fold axis (A2) are indicated on the exposed surface.



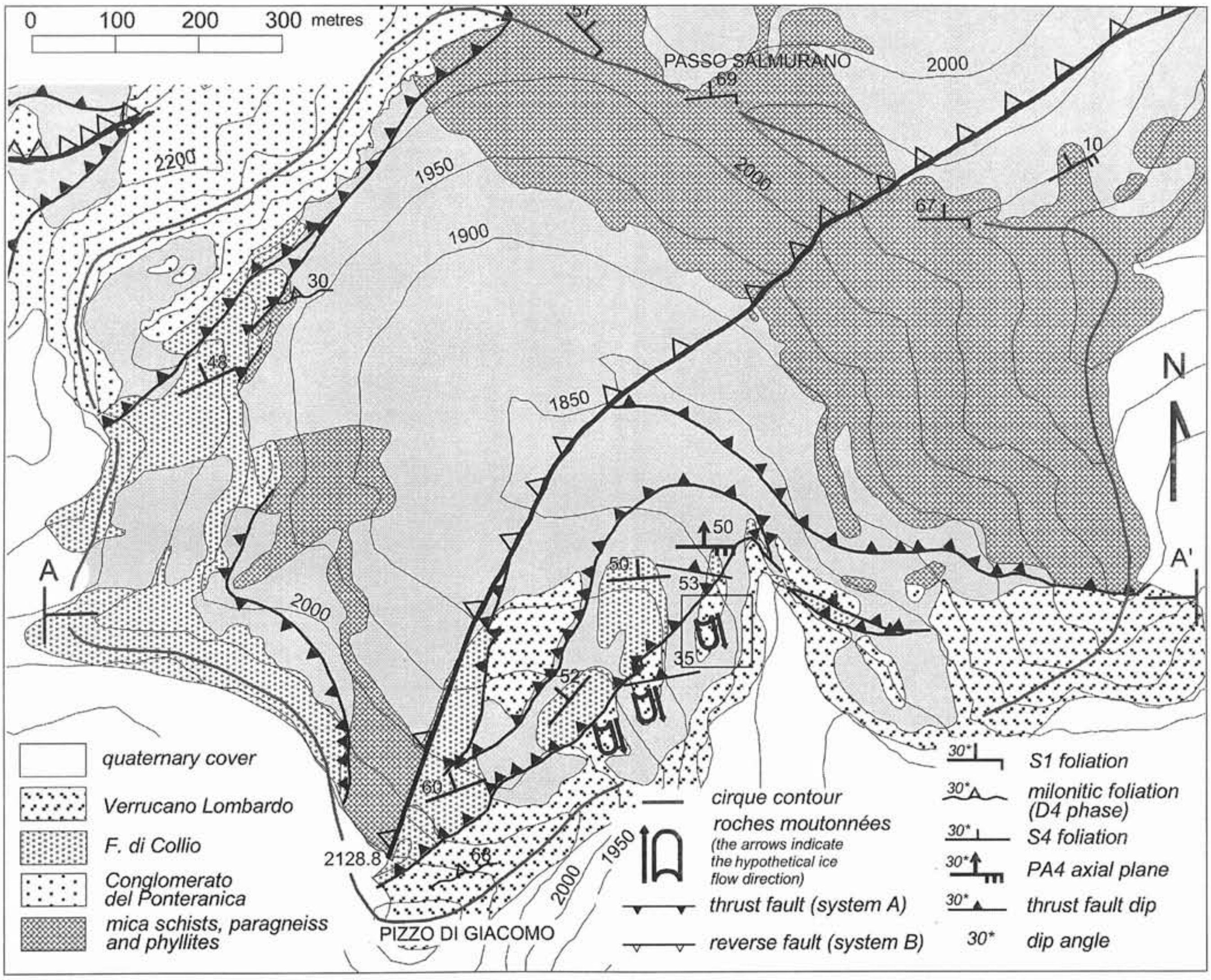


FIG. 12 - Simplified geological-geomorphologic and structural map of the Salmurano cirque. The square indicates the *roche moutonné* of fig. 13. A-A' is the trace of the fig. 14 section.

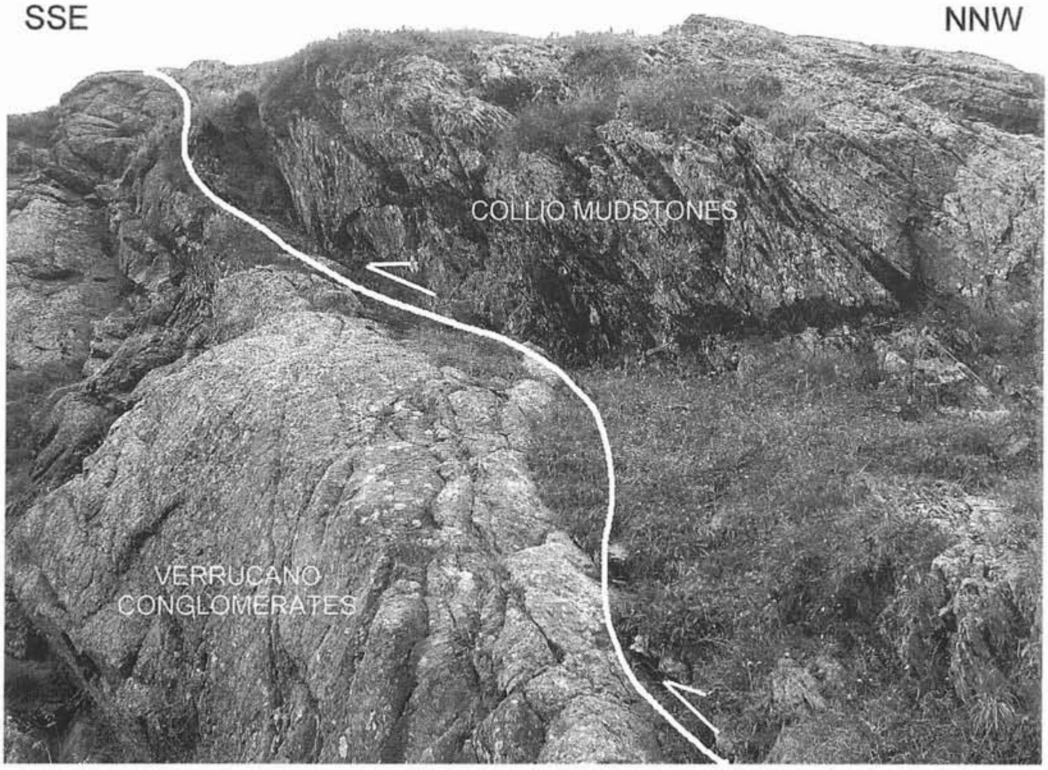


FIG. 13 - Salmurano cirque: exposed surface of the *moutonné Verrucano Lombardo* stoss side that corresponds to the thrust plane.

Circo del Monte Ponteranica

The surface of the back of the knoll on the cirque bottom (fig. 9) appears to be polished by the subglacial abrasion on the bedrock. Elongated quartz fibres, interrupted by steps, are present on the planar segments. These mineral fibers indicate a normal movement along the plane. The wavy and polished surface corresponds with that of normal fault plane belonging to the E system. Therefore this surface is both structural and erosive.

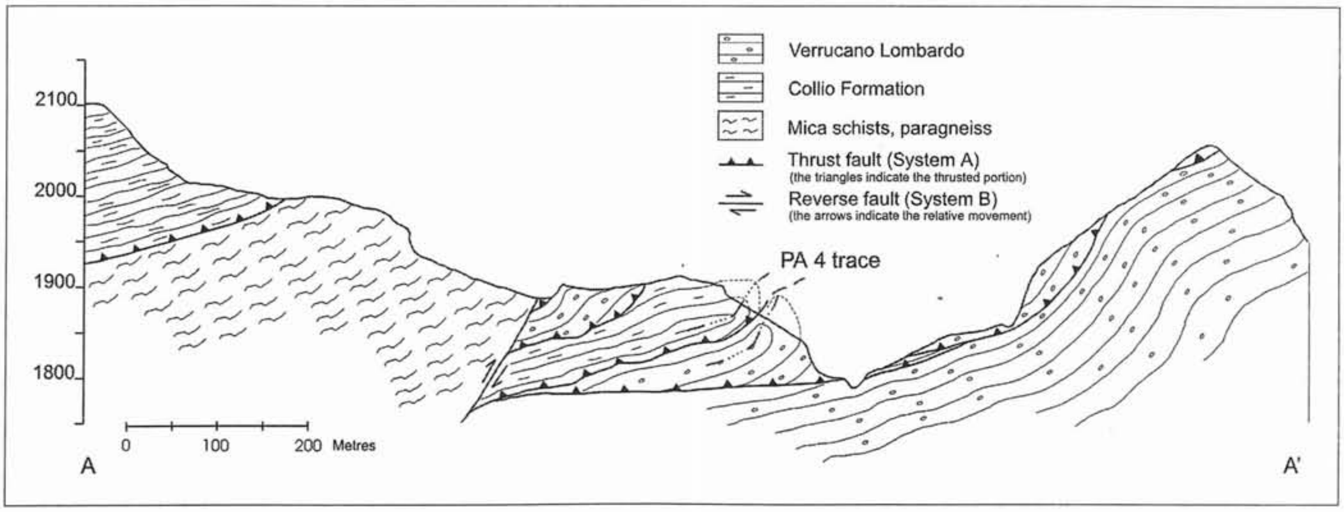
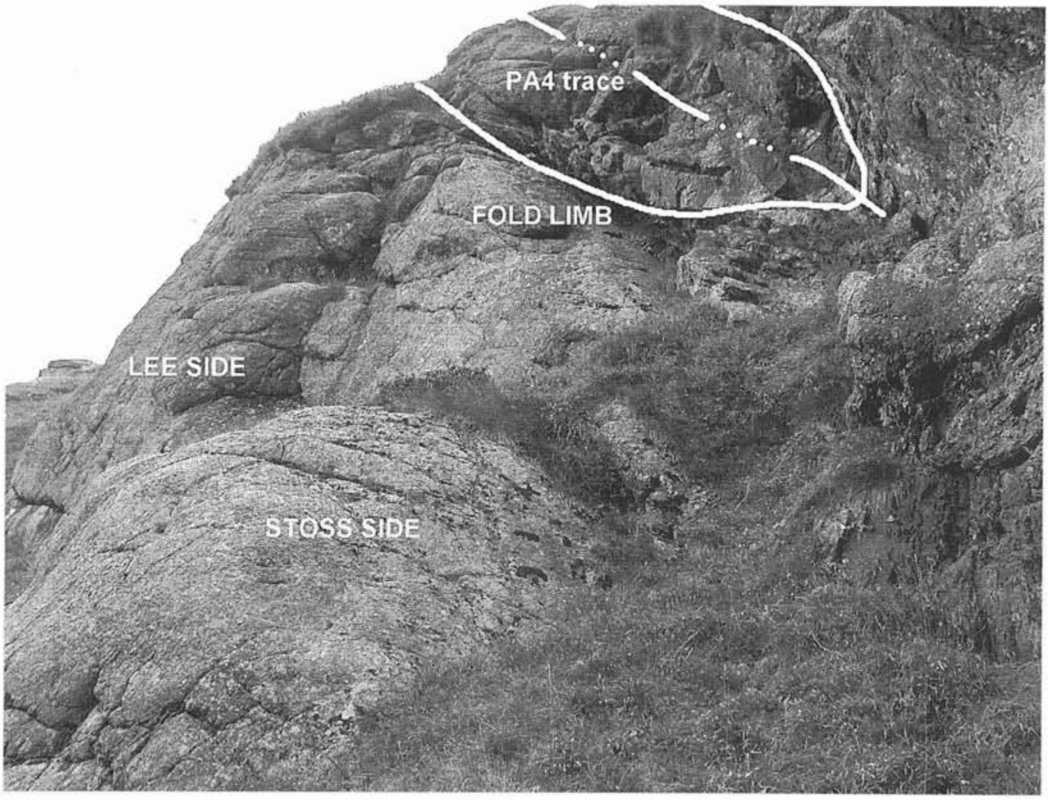


FIG. 14 - A-A' section showing the four horses of *Collio* Formation mudstones and *Verrucano Lombardo* conglomerates near the cirque threshold.

FIG. 15 - PA4 thrust folds in *Verrucano Lombardo* conglomerates near the contact with the *Collio* mudstones; the fold limbs have the same dip direction as the exposed surface of the *roche moutonné* stoss side.



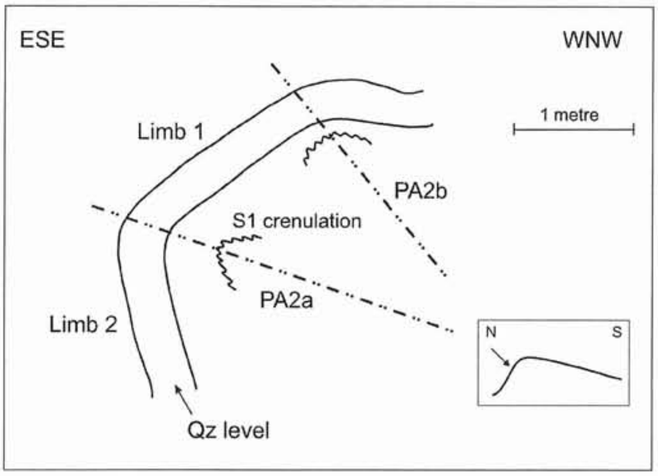


FIG. 16 - Section of the *roche moutonné* north side showing the box-shaped fold; the quartz level corresponds to the folded S1 foliation; in the phyllosilicates levels S1 is crenulated at the millimetric scale; PA2a dip: 0°/15°; PA2b dip: 320°/26°; limb 1 (north-eastern side) dip: 70°/50°; limb 2 (lee side) dip: 300°/78°. Inset: position of the section with reference to the knoll shape.

Circo di Foppe di Pescegallo

The wavy and polished surface of the lee side of the *roche moutonné* on the cirque bottom may be interpreted as the result of a glacial abrasion. In reality, this surface corresponds to an S1 surface that is folded by D2 phase folds (fig. 11). Otherwise the steps that cut off this surface correspond to the planes of the numerous fractures that characterize the rock knoll.

Therefore the knoll shape is modelled on its original structure and not simply generated by the glacial action on the bedrock.

Circo del Salmurano

On the north-western side of one of the *roches moutonnées* at the cirque threshold, a coincidence can be observed between the exposed polished *Verrucano Lombardo* surface and the plane along which the intensely foliated mudstone of *Collio* Formation overlaps with *Verrucano Lombardo* conglomerates (fig. 13). In addition, *Verrucano Lombardo* conglomerates are involved in the PA4 quasi-isoclinal thrust folds whose limbs have the same dip direction as the thrust plane and the exposed surface. Therefore, the stoss side surface corresponds both with the PA4 fold limb and with the thrust plane that bounds one of the four horses and its polished appearance is not due to glacial abrasion but rather to the hanging wall sliding along the foot wall (fig. 15). As a result of these observations, the north-western side surfaces of the other *roches moutonnées* at the cirque threshold may also be interpreted as structural surfaces.

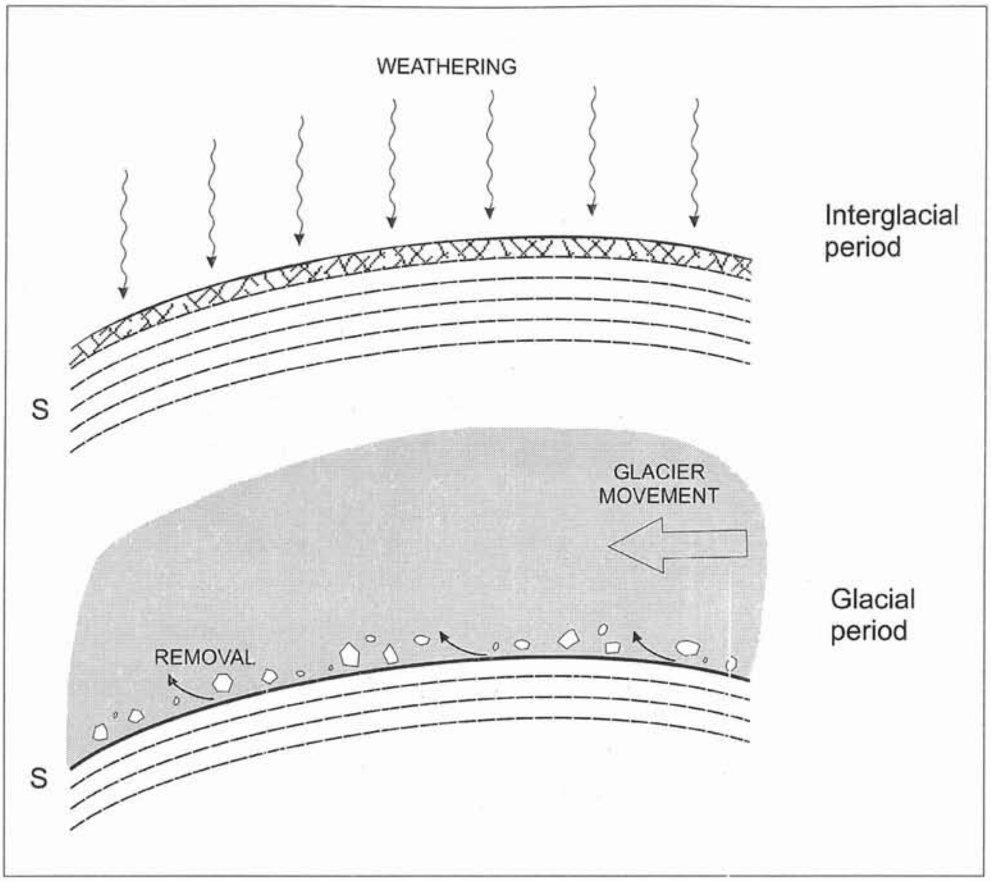


FIG. 17 - Proposed genetic model (S = structural surfaces).

However, on the south-western side (lee side), exposed surfaces of the knolls display the same dip direction of the south dipping reverse faults of the D system. Even though the clean and wide fault planes that correspond with the flanks of the knolls do not outcrop, the control of these structures is evident relative to the development of the fractures with which the exposed surface coincide. In this case too, there is a clear and strong relationship between the morphologic and the structural surfaces.

CONCLUSIONS

The investigated cases demonstrate that the exposed surfaces of the *roches moutonnées* are actually structural surfaces: in Circo del Passo San Marco the surface of the *roches moutonnées* reflects the geometry of the D3 folds; in Circo del Monte Ponteranica they are fault surfaces and their polished appearance is due to the movement of the hanging wall above the foot wall; in Circo di Foppe di Pescegallo the surface of the *roches moutonnées* reflects the geometry of the D2 folds; in the *Circo del Salmurano* the exposed surfaces correspond in part with the horse binding surfaces and in part with the associated fold limbs.

Therefore, it would seem that the *moutonné* appearance of the analyzed rock knolls is not of glacial origin alone. The glacial action is likely to have been limited to the erosion and the transport of the higher rock portion weathered before. This model is similar to that one proposed by Bögli (1964) for the *Schichttreppenkarst* where the glacier would only have freed the previous structural surfaces.

A possible genesis is suggested for the *moutonné* surfaces of the rock knolls within the analyzed cirques: during the interglacial periods (fig. 17) the rock below the structural surfaces may have been weathered for a variable thickness by a physical process (due primarily to intense cold in high mountain area) and also by chemical and biological processes. During the next glacial period (fig. 17) the advance of glacier would remove the weathered rock portion up to the first preserved structural surface freeing it.

At the moment these morphologies can't be dated because the studied cirques have been involved in more than thirteen glaciations (Bini, 1997; Bini & Pellegrini, 1998).

Further studies will be carry out in the area to verify the proposed genetic model.

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