Geogr. Fis. Dinam. Quat.
19 (1996), 343-349, 5 figg., 1 tab.

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NOTES ON SOME LATERAL SPREADING PHENOMENA AROUND ROCCALBEGNA - Mt. LABBRO (Tuscany, Italy)

ABSTRACT: IOTTI A. & TARCHIANI U., *Notes on some lateral spreading phenomena around Roccalbegna - Mt. Labbro (Tuscany, Italy).* (IT ISSN 0391-9838, 1996).

In the area around Roccalbegna up to Mt. Labbro competent calcareus rocks (Calcareniti di Dubba and Calcareniti di Montegrossi) overlie lithotypes with duclite behaviour (Marne del Sugame and Argilliti di Brolio) with sub-horizontal setting.

Lateral spreading phenomena are indicated by the trenches observed on the different calcarenitic slabs; these tranches are the consequence of tectonic fractures evidently opened up in recent times by gravitational movements.

The activity of slope movements is connected to the recent uplitft due to the magmatic chamber setting in the Quaternary M. Amiata volcano. Toppling and rock falls are widespread along the edges of the calcarenitic slabs producing talus of debris at the base of the slopes; the talus are later removed by debris flows or landslips.

KEY WORDS: Contrast of competence, Landslide, Lateral Spreading, Roccalbegna, Tuscany (Italy).

RIASSUNTO: IOTTI A. & TARCHIANI U., *Fenomeni di espansione laterale nell'area di Roccalbegna - M. Labbro (Toscana).* (IT ISSN 0391-9838, 1996).

Nell'area circostante il centro abitato di Roccalbegna fino a M. Labbro, è presente una sovrapposizione di litotipi competenti (Calcareniti di Dudda e Calcareniti di Montegrossi), con giacitura suborizzontale, su litotipi a comportamento plastico (Marne del Sugame e Argilliti di Brolio).

La presenza sulle diverse placche calcarenitiche di trincee dovute all'apertura di tratture di origine tettonica, alcune delle quali con evidenti segni di recente apertura, indicano la presenza di fenomeni di espansione laterale in atto. L'attività è connessa al recente sollevamento dell'area conseguente alla messa in posto della camera magmatica del vulcano quaternario del M. Amiata.

Crolli e ribaltamenti interessano in maniera generalizzata i margini delle placche calcarenitiche dando luogo ad accumuli di detrito ai piedi delle scarpate; tali accumuli vengono poi rimobilizzati da colate di detrito o frane di scivolamento.

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Work carried out within the Murst Project 40. (Resp. Prof. P. Canuti) and U.O. 2.14 of Gndci. Publ. n° 1563 Cnr-Gndci.
We acknowledge Prof. P. Canuti for his suggestions and the critical reading of the manuscript, Dr. N. Casagli for his suggestions, Prof. V. Garduno for the help in the field survey and J. Flannagan and L. Abbazzi for the help in the traslation.

TERMINI CHIAVE: Contrasto di competenza, Frane, Espansione laterale, Roccalbegna, Toscana.

INTRODUCTION

This work is focused on the study and identification of deep-seated gravitational phenomena, in southern Tuscany (fig. 1), in an area of approximately 30 km^2, between Mt. Labbro to the North, and the town of Roccalbegna to the South.

In addition to the previous geological surveys, a new specific survey has been carried out in the scale 1:10,000 together with a detailed structural study of the different slabs. These studies have in particular shown some surface instability phenomena connected to the evolution of the marginal parts of the slabs.

GEO - STRUCTURAL FEATURES

In the area under survey, the Tuscan sequence ends with Polychrome Schists, on which the Ligurian units rest

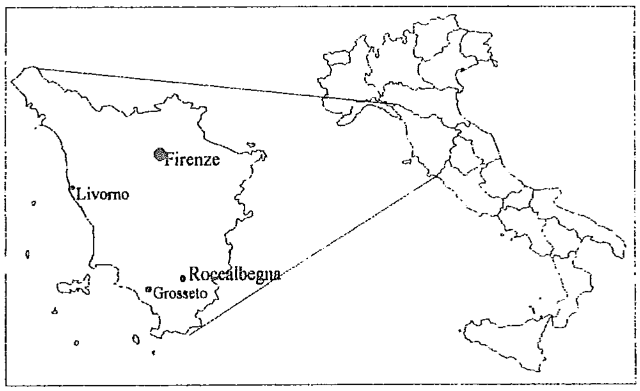

FIG. 1 - Site location of Roccalbegna.

directly (fig. 2). The oldest terms of the Tuscan sequence do not outcrop but are present in the Enel deep borehole Roccalbegna 1 (CALAMAI & *alii*, 1970), and in the mine close to the Banditella Hill. In the same investigations the Mesozoic substratum, consisting of Triassic and Liassic siliceous limestone, appears generally dipping to the South. The substratum has been actually found at about 900 m asl in Mt. Labbro and at about 100 m asl in Roccalbegna. The 800 m difference in height over 3.5 km distance corresponds to 13° mean slope, and it is very likely that it was the consequence of a fault system aligned NW-SE.

The small Lower Pliocene outcrops, presently observed at an altitude of about 1000 m asl around Roccalbegna-Mt. Labbro point out the important late uplift of this area (BALDI & *alii*, 1974; AMBROSETTI & *alii*, 1978), probably connected to the setting of the magmatic chamber of the Mt. Amiata volcano (GIANNELLI & *alii*, 1988).

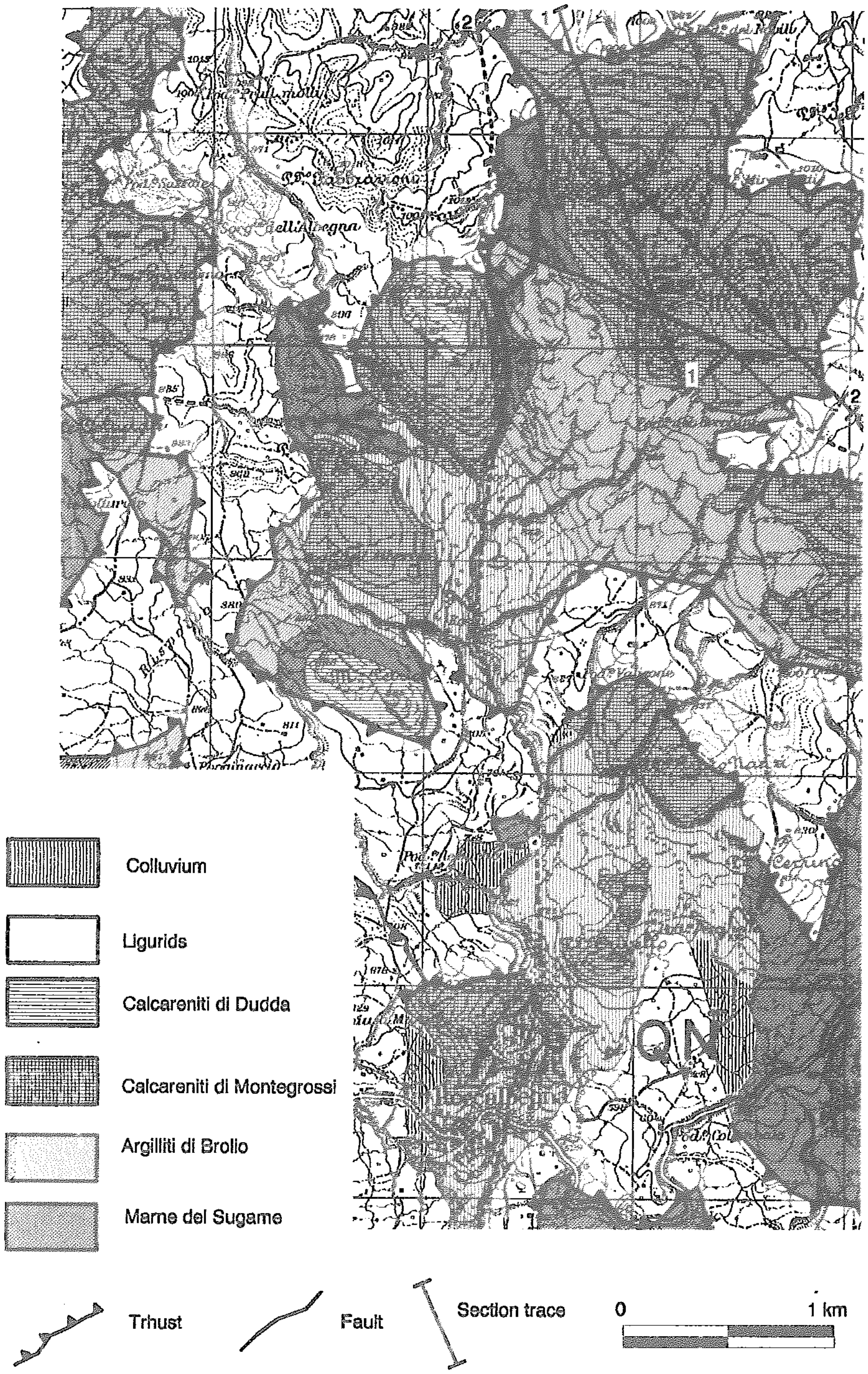

FIG. 2 - Geological map of the study area.

The Polychrome-Schists formation has been divided in four different lithofacies, according to CANUTI & *alii*, (1965), BOCCALETTI & SAGRI (1966), CANUTI & MARCUCCI (1971), FAZZUOLI & *alii*, (1985):

a) *Argilliti di Brolio* (Cretaceous): argillites and marly argillites, with colours ranging from red to greygreen, with a typical scaly texture. Fine grained calcarenites are seldom found, but are mainly located in the upper part of the sequence. Maximum outcrop thickness is in the range of 25-35 m.

b) *Marne del Sugame* (Paleocene-Eocene): calcareous marlstones and marlstones, in layers from decimetric to metric, with local calcareous and calcarenitic levels; diaspre levels are also found in the upper part of this lithofacies. Thickness ranges from a few metres in the Roccalbegna area up to a probably hundred metres, due to the evident ductile deformations in the unit.

c) *Calcareniti di Dudda* (Palaeocene-Eocene); it is an irregular decimetric alternation of fine calcarenites, calcilutites and micritic limestones, often siliceous, with argillitic and (reddish-yellow-brown) marlstone levels.

d) *Calcareniti di Montegrossi* (Eocene): calcarenites and calcirudites, sometime siliceous, in layers of 1-2 m average thickness; the contact with the Calcareniti di Dudda is of the transitional type, with gradual thickening of the calcarenitic levels and progressive decreasing of the argillitic and marlstone levels.

A «key level» has been identified (IOTTI, 1992) in the upper part of the Calcareniti di Montegrossi, in the outcrops of Mt. Labbro and Roccalbegna. It consists of a low elaborate poligenic breccia, where siliceous and carbonatic clasts are found, generally eterometric from angular to rounded. Clasts of medium and low level metamorphic rock are also found in the guide level (phillades and micaceus schists). Similar levels have also been identified in the outcrop of the Polychrome Schists in the nothern and southern part of the area (DALLAN, 1966; HEIN, 1982). The Calcareniti di Dudda are found again on top of the Calcareniti di Montegrossi.

The Calcareniti di Dudda and the Calcareniti di Montegrossi, which have together about a hundred meters in thickness, form steep-wall reliefs, with a sharp break in slope at the contact with the underlying Marne del Sugame.

The pelitic facies in the Polychrome Schists formation (Argilliti di Brolio, Marne del Sugame) are highly deformed and show strong slipping and bending phenomenon. The deformation in those units can be connected to the detachment of the overlying calcareous-torbiditic competent sequences.

The rock slabs formed by the Calcareniti di Dudda and the Calcareniti di Montegrossi show rigid deformations, with the formation of a tectonic thrust, separated by an inverse fault, with a flat-ramp-flat geometry, as observed around Roccalbegna. Furthermore, the calcarenitic slabs have been later separated into several blocks by normal fault systems. The blocks underwent downhill, rotational and mutual spread displacements. Identification of the ruditic key level inside the Calcareniti di Montegrossi allowed the measure of the throw of the faults and the reconstruction of the relative displacements among the blocks.

The more competent lithotypes (Calcareniti di Dudda and Calcareniti di Montegrossi), are characterized by an intense fracturation observed in all the outcrops of the area. This fracturation does not appear in direct relationship with the directions of the structures connected with regional tectonic processes. Statistical analysis of the fracture directions shows a great spread from block to block and also inside each block.

Mt. Labbro (1192 m asl) is the highest peak of a small mountains group, dismembered in blocks. It consists of Calcareniti di Montegrossi and Calcareniti di Dudda resting, sometimes in tectonic contact, on Marne del Sugame and on Argilliti di Brolio.

An important N-S fault, in coincidence with the upper course of the Albegna river, puts in contact the Liguridi with the Calcareniti di Montegrossi at Roccalbegna. The Mt. Farleto block to the North has been lowered about of 100 m with respect to the western part of Mt. Labbro (1153 m asl). Another fault with the same N-S direction splits Mt. Labbro in two blocks, the western one lowered of about 60 m. A main normal fault system, NW-SE oriented, is observed in the southern slope of M. Labbro down to Roccalbegna. This fault system has dismembered the calcarenitic slabs (CESTARI & *alii*, 1979) into blocks arranged along different bands, NW-SE oriented, stretching to the West up to the N-S ridge of Poggio le Volturaie-M. Bucceto. The throw of the different faults has been reconstructed from the local guide level consisting of a sinsedimentary poligenic breccia (IOTTI, 1992).

The blocks in the step fault system are:

1) SW block of Mt. Labbro, 50 m lower than the NE one (1193 m asl);
2) Mt. Farleto, Poggio Pietriccione and Poggio le Volturaie blocks, 140 m lower than Mt. Labbro;
3) Poggio Carletto, 60 m lower than the previous one;
4) Mt. Petricci and Podere Prato Nanzi blocks, 70 m lower than the previous one;
5) Poggio Crivello, 75 m lower than the previous one;
6) Poggio Piantuma, immediately above Roccalbegna, 30 m lower than the previous one;

An additional E-W fault system is also observed on Mt. Labbro and it is causing a dismembering of the slab with progressive lowering of the blocks in the Northern part. The steps are due to the post-Pliocene uplift of the Mt. Labbro ridge, along the N-S and NW-SE tectonic directions. The maximum lifting centre seems to coincide exactly with M. Labbro, which constitutes a structural peak. The recent uplift is also confirmed by the strong cutting phase, with high solid transport, shown by the Albegna river in this section.

GEOTECHNICAL CHARACTERISATION

Some geotechnical classification tests shown in tab. 1 have been carried out on the pelitic levels of the Argilliti di Brolio. The materials mainly consist of sandy silts with clay and argillous silts with sand, with low and intermediate plasticity.

TABLE 1 - Pelites main characteristics: SF: sandy ratio; MF: silty ratio; CF: argillous ratio; LL: liquid limit; Pl: ductility index; AC: colloidal activity index; CaC03: carbonatic ratio

sample	SF (%)	MF (%)	CF (%)	LL (%)	Pl (%)	Ac (-)	$CaCO_3$ (%)
SP1	54	24	24	42	24	1.0	27
SP2	33	16	16	45	26	1.6	23
SP3	34	15	15	35	16	1.1	3
SP4	41	21	21	34	15	0.71	2
SP5	27	16	16	31	13	0.81	2.5
SP6	43	29	29	40	21	0.72	1

The rock layers consists of limestone and marly limestone with calcium carbonate content ranging from 65% to 98%. The point load tests gave strength indices values ranging from 1.3 and 7.8 MPa (which approximately correspond to uniaxial compressive strength ranging from 30 and 190 MPa) and anisotropy indices values ranging from 1.1 and 1.5.

These data show the marked contrast in the competence between the two main lithotypes.

GEOMORPHIC INDICATORS OF THE INSTABILITY

Identification of an instability condition due to a deep-seated gravitational slope deformation is made by means of the integration of the geological structural data with the geomorphologic survey. Several geomorphologic indicators of instability have been identified in the area under examination: in the different calcarenitic slabs there are open fractures (gulls) which show the differential displacements of the walls. In addition there are some flat-bottom trenches formed in different periods as it appears from their preservation and from the amount of soil or debris on the bottom. Trench orientation is different from block to block.

The geometry of the different calcarenitic slabs is influenced by their structural elements. The tilting and toppling phenomena are anyway observed on the slab edges, while the trenches are mainly located in the central areas.

The lower units of the Polychrome Schists Formation (Marne del Sugame and Argilliti di Brolio) outcrop between the different calcarenitic blocks resulting in a smooth morphology, with erosive processes, mainly due to channelised waters and small landslips.

Large scale mass movements are located close to the southern edge of the calcarenitic blocks; important heaps due to rock falls are observed in particular around Poggio Carletto and Poggio Prato Nanzi. The Poggio Piantuma-Roccalbegna was affected by a large rock falls which produced a great amount of debris which now slowly crees downhill.

a) *Mt. Labbro slab*

This is the larger (about 1.6 km^2) and thicker (about 100 m) slab and it shows trenches of different dimensions, mainly oriented SW-NE and E-W (fig. 3). Trenches due to

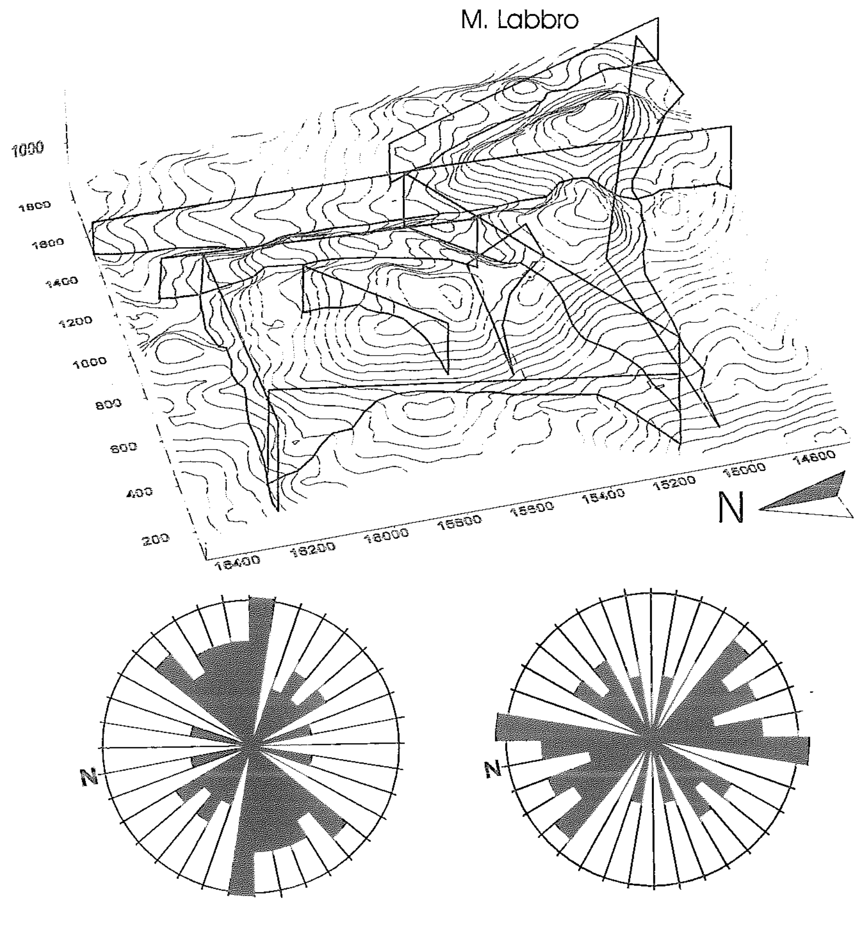

FIG. 3 - Mt. Labbro slab with the main structures present and rose diagram of the discontinuity planes distribution, a) western sibe, b) estern side.

periods of diverse activity are observed, in fact there are forms with round-profile and sharpedges. The slab appears surrounded by a series of cliffs evidently connected to tectonic features.

From inspection of Mt. Labbro the rock appears divided into totally separated elements (fig. 4). Trenches are evident from block to block and they correspond to *graben* or open joint structures. An evident trench runs under top of the mount: it is 150° N oriented, 30 m long approx inside the calcarenites, and its walls are vertical.

b) *Poggio Carletto slab*

This slab is smaller (0.25 km^2) and shows rock falls in its N and NE part while in the central part there are well preserved trenches oriented at 70° N (fig. 5).

c) *Poggio le Volturaie slab*

This slab, with a 1.25 km^2 surface, is located on the western edge of the area under survey. It shows an elongated shape (NNW-SSE oriented), with 400 m maximum width and perpendicular fracture systems (fig. 5). The trenches are very wide with rounded edges and filled in the bottom with pedogenised debris, as a proof of the substantial stability of the slab. This inactivity is probably due to the evolution of the slab towards the present small outcrop in coincidence with the almost horizontal ridge line. Some small-dimension fractures are observed at the edges of the slab and their sharp walls parallel to the ridge prove that the spreading phenomenon underwent a change in direction, due to a changed morphology that drove the maximum relief direction in the local horizontal stresses.

d) *Poggio Prato Nanzi slab*

This slab is approximately a 300 m side square, generally dipping SW, with 60 m and 40 m high slopes on the SW and SE sides respectively. There are two joint systems parallel to the above referred slopes and the trenches show sharp edges without debris inside. They are probably recently opened. The cliffs show falls and tilting phenomena. The large amount of debris accumulated at the base of the SW wall has a morphology with two large steps. This morphology has been considered as due to slump phenomena in the debris layer, with a slip surface probably located inside the argillites of the substratum close to the contact with the debris layer. The large steps should therefore be the crowns of two subsequent landslip phenomena. Due to the different preservation of the crown, it seems that the slipping phenomenon evolved retrogressively. The landslip phenomenon was probably started by the Albegna river erosion, which cut the base of the debris talus, together with the continuous piling of other debris on top of the talus as a consequence of the active rock falls in the cliffs of the Poggio Prato Nanzi.

e) *Poggio Piantuma-Poggio Crivello slabs*

The two slabs stand above Roccalbegna, on the two sides of the Albegna river. The Poggio Piantuma slab has a subvertical SE cliff. The joint systems divide this wall into blocks, up to decametric dimensions; the fractures appear more persistent in comparison to the other ones probably because the slope runs along the line of the fault of the Albegna which is a regional fault as previously mentioned. A pinnacle is totally separated from the wall and is unstable. The cliff is not exactly parallel to the fault and this could

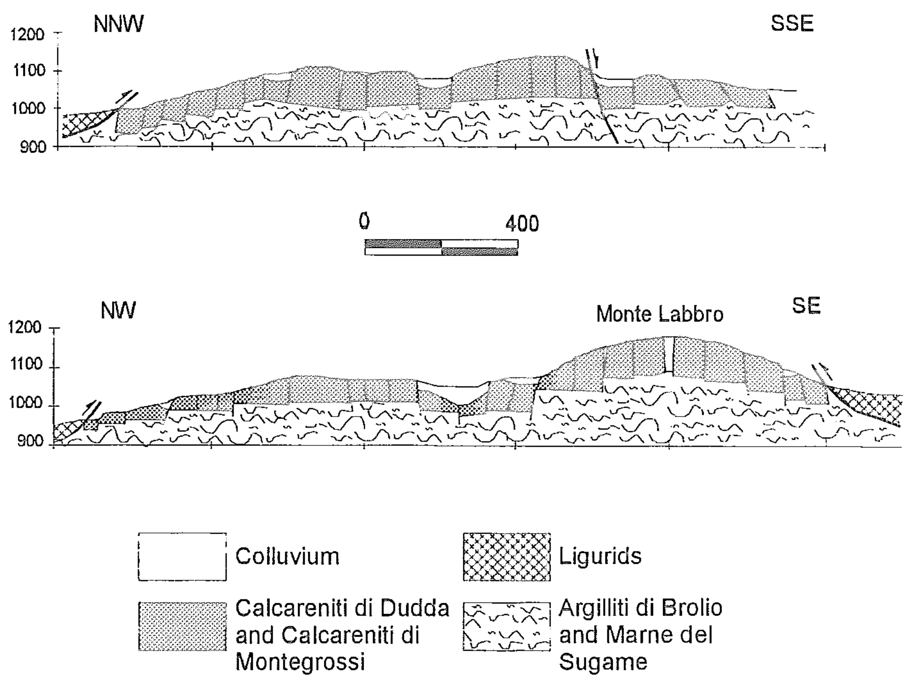

FIG. 4 - Schematic sections of the Mt. Labbro area showing the superimposition of the rigid plate on the plastic material, and tilting of the blocks.

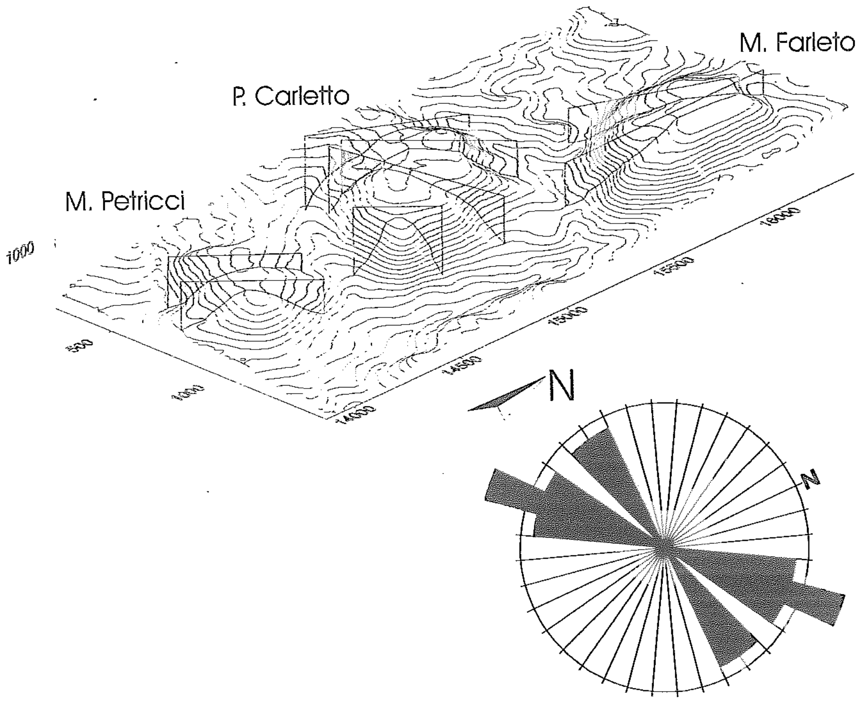

FIG. 5 - Mt. Petricci, P. Carletto and Mt. Farleto slabs with the mains structures present and rose diagram of the discontinuity planes distribution.

be related to the rock fall and toppling phenomena in the same fault. The pile-up of debris at the base of the slope has a stepped profile similar to the one of the SW cliff of Poggio Prato Nanzi. Also in this case the slumps, with the slip surface inside the Argilliti di Brolio, seem to have been started by the erosion by the Albegna river at the base of the debris talus (PAŠEK, 1974).

Small blocks are continuously falling on top of the debris talus triggering slipping phenomena. The continuous increase of the load at the base of the slope should therefore be taken into consideration as it can induce undrained load phenomena in the argillites of the substratum, with consequent activation of the slips.

At Poggio Crivello trench orientation is NW-SE and NE-SW. This slab is the smaller but nevertheless at its base, over Roccalbegna, there is a considerable talus of debris subject to slipping phenomena. The southern side is covered by high vegetation which proves its substantial inactivity. The western side, the one over the Albegna river, is in continuous activity. This activity is observed along the slope, where rock falls constantly take place, and inside the debris heap as well.

In April 1996 a debris slide partially dammed the course of the Albegna river. The displaced blocks range in dimension up to 100 m^3. In low water conditions some sections of the river flow under the blockage after having removed the fine materials which went to fill some depressions downstream. It is likely that in a future flood the course of the river will be displaced in the left part of the blockage. This change could produce new slipping phenomena as the talus could be more deeply eroded.

CONCLUSIONS

The geologic, lithologic and structural conditions herein described highlight the present evolution processes mainly due to landslip phenomena both of deep and superficial types.

The course of the rivers and streams appear to deepen, continuously triggering slipping phenomena after undercutting at the base of both the argillitic lithotypes and the debris talus produced by rock falls from the calcareous slab.

In the area between M. Labbro and Roccalbegna, there are different calcarenitic slabs lying over marly argillitic terrains, which are affected by block - type slope movements. Lateral spread caused the opening of fractures of tectonic origin. The tectonic differential uplift has also produced the general monoclinalic south-dipping features of the substratum. In a smaller scale each slab shows spreading phenomena as evident from the trenches and open fractures. This proves that the rocky mass was subject to tensile stresses after the stress relief occurred during the phases of valley cutting.

Stream erosion, which produced deep valleys in the argillites, caused the relief of the horizontal stresses thus inducing the progressive widening of pre-existing fractures. Slabs show cliffs in critical stability conditions, with falls and toppling in continuous evolution supplying material to the debris talus at their base. Those talus are later subject to slipping phenomena with a slipping surface located in the argillites.

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