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GEOMORPHOLOGY AND NEOTECTONICS OF THE VALLE SACRA IN THE ALTO CANAVESE (WESTERN ALPS, PIEDMONT, ITALY), AN EXPLANATORY NOTE TO THE «CARTA GEOMORFOLOGICA E NEOTETTONICA DELLA VALLE SACRA 1:12 500»

ABSTRACT: MALARODA R., *Geomorphology and Neotectonics of Valle Sacra in the Upper Canavese country, Western Alps, Piedmont, Italy*. (IT ISSN 1724-4757, 2004).

This Explanatory Note concerns the new 1:12 500 map of the Valle Sacra, a north tributary into the River Orco near its mouth into the Po Plain.

The Neotectonics is typically that of vertical faults causing different epeirogenetic movements between blocks. This was recognized mainly by anomalous contacts fresh rock/alterites, a method I have successfully applied in the Valle Gallenca at the opposite bank of the Orco.

An impressive mass exists of Middle Pleistocene sediments and alterites both bearing the same pedological stamp of the Riss-Würm Interglacials.

Fault scarps formed and repeatidly moving during the Riss-Würm times produced not only detritus, rockfalls, glaciers, alluvium and glacis (depositionals and erosionals) but also maroccoids (belts, flows and erratics), a new signe of neotectonic morphologies to be distinguished.

KEY WORDS: Maroccoids, Neotectonics, Glaciology, Quaternary, Weathering, Western Alps.

RIASSUNTO: MALARODA R., *Geomorfologia e Neotettonica della Valle Sacra nell'alto Canavese, Alpi Occidentali, Piemonte, Italia*. (IT ISSN 1724-4757, 2004).

Questo lavoro rappresenta la Nota Illustrativa della nuova carta della Valle Sacra, un affluente di sinistra dell'Orco che confluisce in esso presso il suo sbocco nella Pianura Padana.

La Neotettonica è, qui, tipicamente quella di un gran numero di faglie verticali che separano prismi nei quali producono effetti epirogenetici diversi. Questo, oltre che dai consueti troncamenti di scarpate di terrazzo, dalle ultrescavazioni e da altri fenomeni geomorfologici, è in prevalenza dimostrato dai contatti anomali fra rocce fresche e rocce alterate e alteriti, che consentono un metodo già da me applicato utilmente nella Val Gallenca, fronteggiante la nostra sulla riva destra dell'Orco.

Nell'area studiata abbondano sia le alteriti che i sedimenti alterati i quali presentano entrambi una identica alterazione che è quella tipica della pedogenesi degli Interglaciali Riss-Würm.

Originale è la scoperta che le faglie neotettoniche, con i loro ripetuti movimenti avvenuti essenzialmente, ma non solo, negli Interglaciali Riss-Würm hanno prodotto, oltre alle frane, al detrito ed ai frequenti glacis, anche dei maroccoidi (in fascie, colate ed erratici) nuovo nome col quale ho ritenuto di doverli distinguere anche perché rappresentano un significativo indizio di una contemporana attività neotettonica.

TERMINI CHIAVE: Marocche, Neotettonica, Glaciologia, Quaternario, Alterazione, Alpi Occidentali.

The map and its Explanatory Notes are a natural complement to my recent description of Val Gallenca, the other valley at the mouth of the River Orco (Malaroda, 1998). The similarities between the two valleys and their problems are such that the reader would be well advised to consult the two papers, especially their introductions and conclusions, together, since many useless repetitions have been avoided.

I have not, for example, repeated what was said in the Val Gallenca explanatory notes with regard to the fresh/weathered rocks ratio method [1] employed to identify neotectonic discontinuities, nor what I have written about the

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On the problems of Quaternary glaciations the shared advises of F. Carraro, professor of Geology of the Quaternary in the Turin University were helpful and appreciated for both the Val Gallenca and the Valle Sacra valleys.

[1] The value of these abnormal contacts is purely indicative and requires the support of geomorphological data. A significant example was the discovery, between the alterites to the left and right of a torrent of two small unweathered or lightly weathered tectonic gneiss slices in the San Grato area (P-8) NW of Colleretto di Castelnuovo. Examination of the valley floor between enabled them to be used as the markers of an otherwise unsuspectable, vertical E-W neotectonic fault that cuts into the valley floor alluvia and their terraces, and is bringing about the ultraexcavation of the torrent.

subdivision of the Quaternary and the conventions used to classify the glaciations (Malaroda, 1998, pp. 332-333).

Like Val Gallenca, Valle Sacra is essentially a longitudinal valley (Malaroda, 1998, f. 1). This and their contiguity explain their many coincident features.The post-Riss capture events for example, took place in the middle of both valleys and their terminal sections are deeply ultraexcavated. Fresh rocks, on the other hand, are more extensive in Valle Sacra, and the transverse lie of its initial section is more pronounced than in Val Gallenca.

BASEMENT GEOLOGY

Valle Sacra cuts into two Alpine tectonic units: the Sesia-Lanzo Zone and the Canavese Zone.

The Canavese Zone is uniformly represented in the valley's southern outcrops a short distance from the Orco River by a monotonous set of granite and migmatic-granite rocks with rare alternations of augen facies, all struck with an universal and intense cataclasis. In the area between Sant' Anna Boschi (S-9) and the reliefs to the east of Parrocchia and south of Bastiglia (T-7) the granitoid cataclasites outcrops clearly show that a fragile nappe (falda fragile) has overlain rocks displaying little or no tectonic disturbance. Other lithotypes represented in the Canavese Zone are metamorphites and migmatites deriving from sedimentary rocks, namely meta- and migma- conglomerates and sandstones, cordierite gneisses, fine-grained gneisses, porphyrites and porphyroids. There are distinct outcrops of Mesozoic rocks, i.e., calcareous shales, shales with interbedded limestones (Cretaceous?), black limestones (Jurassic) and phthanites (Jurassic). The limestones are mostly unfractured and have been extracted from small quarries for use as building materials in the past. Sandstones, Permian porphyroids and phyllites are uncommon. Particular mention may be made of the small strips of basic eruptive rocks that crop out in the short, meandering gully of the Villa di Castelnuovo stream that joins the Piova a little to the SE of Santuario di Piova (Q-10). These rocks are associated with carbonaceous phyllites (Carboniferous?).

In the Sesia-Lanzo Zone, on the other hand, the dominant lithotypes are micaschists and micaschist-gneisses that nearly always contain glaucophane and sometimes garnet. They are occasionally replaced by fine- and very-fine-grain gneisses, only sometimes rich in quartz. These gneisses are in general very pale and even white, and often contain glaucophane and garnet. These are most readily found in the Mt. Calvo area (F-11) to N of Castelnuovo Nigra and are transitional to greenish, grey or black (see the common place-name «Le Nere»[2]) compact quartzite-like migmatic rocks that appear to include Carboniferous materials. Some very particular conglomerate sandstone metamorphites and migmatites have been found at Fili (N-6) and Comunali (O-3) and along a strip going from Fili to the augen-migmatites of the eastern side of Mt. Sinseina.

All the rocks, in both zones, frequently display from large to small-scale folds, faults and sometimes small overthrusts, in general, preceding the weathering. Special emphasis must be given to the Mt. Calvo thrust (fig. 1), which has been uplifted as a neotectonic horst of poorly weatherable rocks in contact with greatly weathered micaschists (F-10).

WEATHERING

The map illustrates the extensive Quaternary weathering of nearly all these rocks and their sediments. It should be noted that while the intensity of their weathering is a function of the length of their exposure to the Pleistocene climates, two other factors are involved:

[2] The place name «Le Nere» assigned to a specific locality (D-11) on the map is also common throughout the area were similar geomorphological conditions exist.

FIG. 1 - Monte Calvo, a horst raising a slice of the Sesia-Lanzo cover composed of rocks that are less weatherable than those at the base. View from an altitude of 1730 m just below the yard of the abandoned quartzite quarries.

1) The depth of their burial under the alterite cover. This is so evident that in many cases the weathering can be distinguished in zones with a continuous sequence of alterites overlying weathered rocks and weathered rocks overlying fresh rocks. This is clearly the reason why fresh rocks nearly always crop out from the bottom of the streams at the base of weathered rocks, and at the higher levels where the products of weathering have already been removed.

2) The nature of lithotype[3]. The hydrothermal quartzites dikes that abound in the Sesia-Lanzo Zone are totally unalterables though their colour may change from white to yellowish, brown, pink or red due to seepage. This zone also comprises poorly weatherable glaucophanite, amphibolites in general and quartzite gneisses that form the vast horst area of Mt. Calvo and have resulted in its distinct separation from its surroundings. In the Canavese Zone the phthanites display few signs of weathering while the limestones are karstified, but unaltered. The structure of the granitoid cataclasites should have resulted in their rapid degradation.Their relatively slight alteration is evidently due to the young age and magnitude of their uplifting.

Significance must certainly be attached to the picture provided by the road that rises from Frera (C-10) to Roc, Roc Bian and the quartzite quarries (B-8). This always runs at the base of fresh rock cliffs, whereas its bed is composed of heavily and typically Rissian weathered detritus and rockfalls. In the absence of any neotectonic fault to mark the limit, these sediments may be supposed to have been stripped off from the cliffs as the result of erosion or rockfalls. One may thus postulate here the occurrence of a substantial epeirogenesis leading to the formation of maroccoids at the foot of the fault cliffs (see pag. 135), in this case topped by detritus.

[3] This is correct in statistical terms. It must be said however, that even the glaucophanites, other amphibolites and even the phthanites may be deeply weathered. Between the two peaks of Bric Filia (Q-12), in fact, phthanites, rocks that are, in general unweatherables, have been gradually transformed into brownish slates.

QUATERNARY

As in the Val Gallenca, there is an impressive mass of Middle Pleistocene sediments and alterites. The sediments include glacial, glaciofluvial and maroccoid deposits mainly bearing the pedological stamp of the Riss-Würm Interglacials. The few indications of earlier, or more recent, phenomena or sediments are negligible.

Glaciations in Valle Sacra and Val Gallenca can be usefully described in detail. Both valleys contain vast Rissian glacial and above all glaciofluvial deposits. Some have the typical tongue-and-ridge morphology. These, however, are of little account compared with the extensive subhorizontal (originally, at least) thick and extensive glaciofluvial deposits whose initial coverage can be further enlarged from the frequent discovery of erratics.

The present morphology is not in keeping with such an extension. One may thus suppose that some Rissian glacier had an Alaskan morphology with extensive front and formed belts parallel to the edge of the Alps.

The Riss Glacials have everywhere proved more intense and more extesive (though shorter) than those that preceded or followed them. The morphologies described above, however cannot be attributed to climatic factors alone. If, as I believe I have shown in a preceding work on the Canavese country, due significance is to be assigned to the essentially positive Würmian uplift, extension of the analogies to the Riss means that reliefs were then much higher, whereas during the Würm they sank first and rose later (fig. 2). Neotectonic fault-scarps must have formed the distinct boundaries of the pre-Alpine highlands from which Adamellian or Alaskan glaciers reached out and left enormous swathes of glaciofluvial deposits.

These covers, such as that now split in two by the neotectonic emergence of Belmonte in Val Gallenca, cannot be explained in any other way, especially since the composition of their rocks is closely linked to the slopes immediately behind them except at their boundary with the mouth of the Orco.

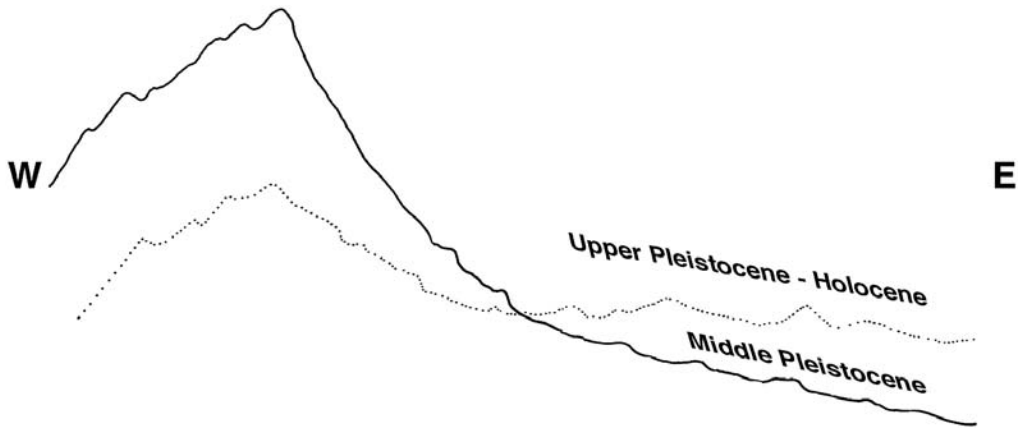

FIG. 2 - Proposal for the topographical profiles produced by epeirogenesis during the Middle Pleistocene and the Upper Pleistocene-Holocene in a W-E section at the height of the Orco Valley.

UPPER PLEISTOCENE GLACIALS AND INTERGLACIALS

The Würmian glaciers of the Orco have left some lateral moraine ridges and roches moutonnées along its left bank. A particularly significant feature is the extent to which these deposits have mingled with and overlain the Rissian moraines of the hill of Castello di Parrocchia and in the area to the W of Bastiglia.

Further up, in the inner part of Valle Sacra, the picture is complicated by the presence of maroccoids. Würmian moraines are evident down to an altitude of 1350 m to the SW of Confier (M-3) and at Comunali (O-3). Clear traces of the limited Würmian glaciers of the Piova are found at about 1400 m in the region at the head of the valley where two weak recessional moraines are evident at Frera, at an elevation of 1450 m (C-10), and traces of a tongue exist at 1750 m to the W of the large yard of the abandoned quartzites quarries (B-7). Würmian moraines of limited extent overriding the everywhere dominant Rissian moraines are also present down to 1200 m between Roc Bian, Frera, Capannone and Burio and to the W on the slopes of Comunali (O-3).

At intermediate elevations there are some traces of a W to E advance of Würmian glaciers towards Valle Sacra. To the W, glacial tongues evidently proceeding from Frassinetto valley have left deposits at 750 m to the W and down to Nava (620 m)(R-1) To the E, the ridge on which Villa di Castelnuovo (O-13) stands and some points around Sant' Anna Boschi (S-3) display a Würmian overriding the Rissian soil genesis. These can be associated with the morainal erratics (N-13) well represented to the N of Villa di Castelnuovo.

This limited presence of Glacial Würm is in sharp contrast with the massive abrasion-erosion associated with the epeirogenesis that shaped the sides of Valle Sacra during the Würm Glaciations. As in Val Gallenca a thick and complexe succession of terracings accompanied the uplift throughout the Upper Pleistocene and continued on a smaller scale during the Holocene.

MIDDLE PLEISTOCENE GLACIALS AND INTERGLACIALS

As already mentioned, the Valle Sacra glacial and glaciofluvial deposits that have only undergone the Riss-Würm Interglacials are impressive in both mass and extent. This is fully in keeping with the picture in Val Gallenca, all the more since they are not divided, here, by a recent epeirogenetic emergence like that of Belmonte between Val Gallenca and the adjacent and more internal pre-Alpine zone.

The ridges around Priacco and the ground moraine of the Parrocchia and Bastiglia hills with the ridges between Priacco (T-6) and Pianezza (S-6) were deposited by the Orco glacier.

In the inner Valle Sacra, however, true moraines with ridges are not common. Examples include those SE of Prato Forestiere (M-7) and nearby Ballaria (L-8), and especially those of the Sant'Elisabetta terrace: Mirauda (1350 m) (L-5) and Confier (1375 m) (M-3).

Heaps of Rissian moraine blocks that may indicate the stopping points of glacier snouts are found around 875 m, at Canton Quero south of Sant'Anna Boschi (U-8), and to the E and S of Cintano (O-11).

All the high reliefs are covered by Rissian slope deposits, though here their distinction from the maroccoids is problematical (see pag. 136).

The glaciofluvial deposits extend all the way from Cintano and Colleretto to the northern bank of the Orco. Others are present at higher altitudes in some of the pediments. They were dislocated by the Neotectonics as illustrated by the presence of isolate erratics in glacis.

LOWER PLEISTOCENE GLACIALS AND INTERGLACIALS

No Mindelian ridge-moraines and morphologies have been preserved and small spots of ground moraines were seen only near Santuario (P-9) and north of Moie (M-6; N-6).There are vast outcrops of heavily ferrettised glaciofluvial deposits on the flanks of the Piova between Cintano (fig. 3) and Castelnuovo Nigra in the eastern part of the valley. Both isolated erratics (possibly maroccoids) and accumulations of erratics E of Colleretto Castelnuovo and especially that immediately at Bastiglia and south of this locality (T-6) are clearly of Mindelian age.

Infiltration of haematite along diaclases and leptoclases is normal during ferrettisation. Mention can also be made of the ascensional migration of hydrothermal haematite along a fault with a 30; SE 80 attitude to the W of Colleretto.

PLIOCENE

There are no Tertiary deposits. Heavily ferrettised and kaolinised zones ascribable to the Pliocene climate are visible here and there among the bedrock and the sediments. The main zones are at the southernmost edge of the area where diggings and equipments for the extraction of kaolin still exist (Cave Fabiana) (Marchetto, unpublished, pp. 13, 19-21).

Others are shown on the map at Bastiglia, Filia, Borgiallo, and Visitazione and especially between Castelnuovo Nigra and Villa di Castelnuovo, at Castagna (W of Chiesanuova) and the Sant'Elisabetta terrace (1350 m) to the S of Mirauda.

The kaolinised area of Frera (C-10) is of particular interest because it has been heavily cataclased by movements along N-S and E-W neotectonic faults.

FIG. 3 - Section through the Cintano sports ground: A) folded Sesia-Lanzo gneiss Lower Pleistocene alterites; M) debris and detritus composed of ferrettised blocks; R) debris with Riss-Würm Interglacial pedogenesis and partial reworking of the Mindelian ferrettised detritus.

MAROCCOIDS

I have decided to introduce this new term to indicate what I called «marocche» when dealing with Val Gallenca (Malaroda, 1998, pp. 336-337). These morphologies and deposits were evidently formed in a glacial or periglacial environment. While less impressive than the Val Lagarina, Sella di Nago and Valle Sarca (Trentino) rock-wastes and not obligatory bound to a glacial retreat, they none the less have a morphogenetic impact and a fairly generalised extension.

They are collapse rocksfalls often of great proportions. In some cases, the break-off point can still be discerned on their overhanging fault walls. Block flows are rare. The usual pattern is that of a more or less continuous belt parallel to the wall (see, for instance, the one to the NE of Nava (R-2). In addition to their uniform lithology and the angularity of their components, a feature of these landslides is the considerable and often exorbitant size of the individual blocks, which sometimes exceeds 100 m^3. Both weathered and fresh rocks are present; most of the alterites that may have been present on the fault scarp have been destroyed. Some of the fragmented rocks even display signs of ferrettisation. The landslides are thus composed of mixtures, though the fresh rocks nearly always prevail.

Besides belts, and rare flows, maroccoids are also present as individual erratics that have slid down the slope and travelled far from their source. This makes it very likely that the collapse took place when extensive ice, or snow covers still persisted[4]. We have also to take on account the importance of permagel recently put in evidence for the Alps by Guglielmin & Notarpietro (1997). The feature has already been described for Val Gallenca in the small Würmian affluent basin of the Buasca (Malaroda, 1998, p. 337).

The position of these landslides with respect to the walls, which are always neotectonic fault surfaces with no sign of glacial moulding (fig. 4), and their arrangement are compatible with seismic shearing. They can thus, perhaps, be regarded also as palaeoseismites.

The main question raised by these maroccoids is their age. Most of them lie on Middle Pleistocene glacis and were therefore presumably deposited during Middle Pleistocene or at the beginning of the Würm glaciations, others, may be, during the entire Upper Pleistocene and also (see below) the Holocene. A multistage origin may thus be postulated as I have already suggested for Val Gallenca where even a Lower Pleistocene age cannot be excluded (Malaroda, 1998, p. 336).

The chaotic nature of these rockfalls makes their deposits similar to moraines. Erratics are found on any substratum and are often of considerable size. In the absence of distinguishing features, such as rounding or scratching,

[4] Near Canton Ferina (between Sant'Anna Boschi and Filia) an isolated block of fresh phthanite rests on Rissian alterite debris at 485 m and about 2 km from the nearest phthanite outcrops. This can only be attributed to sudden epeirogenetic uplifting of Bric Filia.

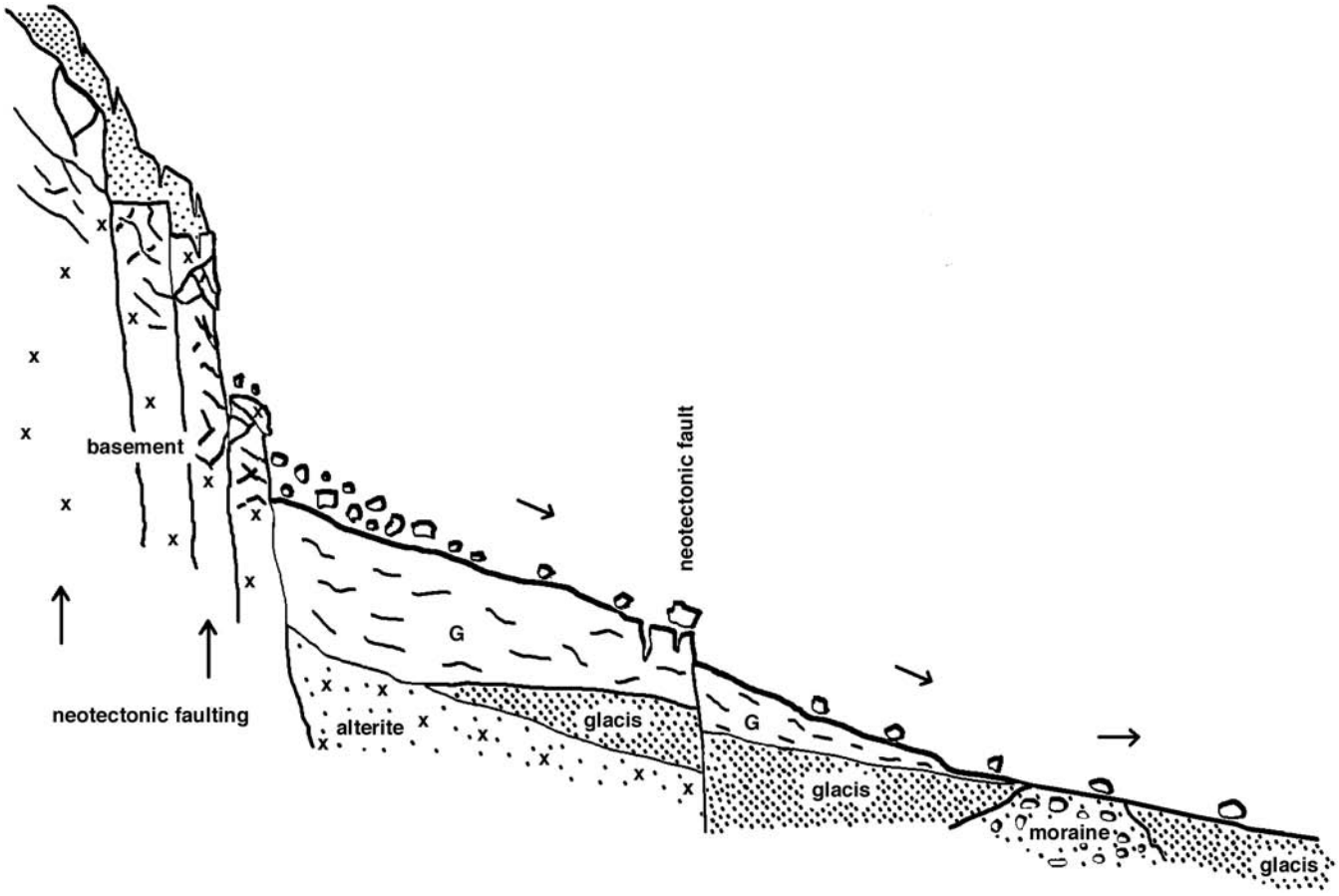

FIG. 4 - Proposal for the genesis of a maroccoid: situation prior to melting of the glacier-snowfield perhaps only prior the melting of permagel, both marked with the letter G.

one cannot tell, very often, whether they are erratics of maroccoids or of morainal origin.

A completely separate question is posed by the massive landslide blocking the end of the small glen between the two hills of Parrocchia and Bastiglia (V-7; box 14).This, too, has all the characters of a palaeoseismite and is composed of enormous blocks of black Jurassic limestone, like the wall of the glen itself. By analogy with the prevalent maroccoids, it could be of Middle Pleistocene age, though it is more likely to be Würmian or Holocene.

DEBRIS DEPOSITS AND BLOCK DETRITUS

Würmian and Holocene detritus, often in the form of blocks, is nearly always present at the foot of the walls and especially in gullies between them. It overlies moraines and maroccoids and is generally not very extensive.

Middle and Lower Pleistocene debris, mainly classified according to its weathering, is also present and distinguished as such on the map. However, since the characteristics of the components of the debris that is continually being formed under walls composed of weathered rocks or alterite are those of the walls themselves, very little significance can be attached to these chronological attributions.

The lithology of the erratics is essentially of local origin, except for the area closest to the point where the Orco debouches into the plain. Less weatherable rocks, such as quartzites, glaucophanites and amphibolites in general are always dominant. The augen migmatite erratics are distinguished on the map because they are exact indicators of origin. There are two facies: the more frequent was brought down from the Gran Paradiso Massif by the Orco glaciers.The other comes from an intercalation within the gneisses of the flank of Punta Quinseina overlooking Ca' Nera.

Areas with no outcrops, of only eluvium, are hatched (as shown in box 29). They occasionally carry furrows. As a thin eluvium of the Rissian silt is found at the top of the glacis I suggest that these areas represent a stage connected to the formation of the glacis.

GLACIS (or pediments)

They are much more extensive than in Val Gallenca. In the middle part of the valley, indeed, they are particularly impressive and its most distinctive feature because they almost totally override the Rissian glaciofluvial.

They are prevalently depositional and usually level or slightly inclined though they also occupy steeper slopes and are often riven by countless escarpments that are, presumably at least, partly separated by minor neotectonic step faults.

Their surface morphology is smooth and their grass cover is occasionally pierced or covered by erratics. They are often associated with springs (L-8) and solifluction (P-5).

When examined in section, a glacis always displays a thin layer of brown-orange silt near the surface, followed (though not always) by an underlying layer of alterite or glaciofluvial conglomerate debris that may be of metric thickness.

ALLUVIAL DEPOSITS

These are fairly extensive and diversified on the left side of the Orco. Elsewhere they are limited and especially interesting because their genesis and fractionation are certainly attributable to neotectonic epeirogenesis. Along the Piova they are mainly found around, chiefly south, of Santuario (P-10) of Cintano and correspond to many Würmian-Holocene episodes.

TERRACES

The whole of Valle Sacra is heavily terraced. Scarps have been cut in both fresh and weathered rocks and alterites, as well as in Rissian glacial and glaciofluvial deposits. For this reason, and bearing in mind what has been said on the subject with reference to Val Gallenca (Malaroda, 1998, pp. 341-342), excluding the morphologies over the higher terrace of Sant' Elisabetta (fig. 5), can be attributed to Würmian glacial or fluvial erosion.

Since Valle Sacra is furrowed by countless subtransverse neotectonic faults (i.e. between N 45°W and N 45°E, often definitely N-S), and since the present altitude of the terraces cannot be taken into consideration for the reason set out above, the fact that they are commonly found in groups of 3 or multiples of 3 in a prism produced by the neotectonic epeirogenesis suggests that they may correspond to the 3 generally accepted Würm glacials moreover that in the extreme southern area similar terraces are cut in Würmian alluvium.

Where the number of significant scarps is more or less than 3, undetectable antagonist neotectonic faults (i.e. those of the NE-SW system) would suffice to explain both the repetition of the terraces and the differences between individual prisms.

NEOTECTONICS

There can be no doubt that the gradient of both sides of Val Sacra was rejuvenated with scarps and erosion and ultraexcavations of its watercourses by a positive epeirogenesis that persisted during the whole of the Würmian glaciations and must have promoted the extensive development and partial fractionation of the pediments.

Intense, non-homogeneous uplifting took place throughout the Upper Pleistocene. The reasons raised with regard to the topographical elevations in Val Gallenca are equally

FIG. 5 - Sant'Elisabetta, a preglacial Pliocene terrace (in the background) covered by a grassy glacis and sectioned by erosion. View from an altitude of 1615 m below the abandoned quartzite quarries.

applicable to those of Valle Sacra. The raising, when also different from point to point, during the Upper Pleistocene was of nearly 200 m.

SPRINGS

The valley's numerous springs often display significant flow rates and many are currently used to supply aqueducts. They are widely, though not uniformly distributed, and generally associated with faults and cataclastic areas or, when drowned, with pediments or others Quaternary deposits. Those in the following areas are of major significance: Pian delle Vesche and Comunali; Le Moie; flanks of Mt. Calvo; slopes of Punta Quinseina around Ca' Bianca and Ca' Nera; Prato Forestiere).

ULTRAEXCAVATIONS

The alternation of thalweg segments in equilibrium with ultraexcavated segments is a clear sign of a non-homogeneous prism-type epeirogenesis that developed during the Würmian glaciations and is probably still in progress. Rapids and waterfalls mark the point where a watercourse is crossed by a neotectonic fault, whereas heavy and more uniform excavation is evident when it runs in the same direction as the fault.

The stream to the SW of Sant' Elisabetta, all those that flow into the Orco between Salto and Priacco, all those to the E of Cintano and Castelnuovo Nigra, and all the glens to the E of Val Sacra are deeply and continuatively ultra-excavated.

Neotectonic rapids are also present in the bed of the Orco to the W of Piova.

EROSION DUE TO HUMAN ACTIVITIES

This is entirely due to the abandonment of paths and mule tracks extensively used in the past. Some are flanked by stone walls and even cobbled. The longest runs down from Guiardi (1040 m) (G-9) to Camagna (870 m) on the right side of the Piova. There are others to the S of Cantello (N-11), at Colleretto Castelnuovo, along the slope between Cappella Belice and Piloni (Q-4) and at Le Moie.

HYDROTHERMAL QUARTZITES DIKES

The rocks of these dikes abound and are exclusive of the Sesia-Lanzo Zone and were emplaced during a late-Alpine distension tectonic phase. They constitute one of the most conspicuous deposits has been greatly exploited, till nearly twenty years ago.

Stripping, layout and storage operations, together with the construction of a road for heavy traffic, have altered the morphology of the «Le Rocche Bianche» ridge between Val Sacra and Val Savenca. Large quartzite blocks have fallen from this ridge onto the slope below, including the enormous «Roc» (C-8; unnamed on the map) a true natural monument which has fortunately escaped demolition an can even be seen from the Orco valley floor. The quartzite has often lost its whiteness and acquired fine yellow, orange, brown-orange, pink or red hues due to seepage evidently ascribable to weathering processes. Other dikes located elsewhere produce residual debris covers and are the origin of certain place names.

REFERENCES [5]

BAGGIO P. (1965) - *Caratteri stratigrafici e strutturali del Canavese s. s. nella zona di Montalto Dora (Ivrea).* Mem. Ist. Geol. Min. Univ. Padova, 25, 25 pp., 2 ff., 2 tabb., 1 geol. map. 1:10.000.

GUGLIELMIN M. & NOTARPIETRO A. (1997) - *Il permafrost alpino. Concetti, morfologia e metodi di individuazione.* Quad. Geodinam. Alpina Quat., 5, 5-117, 15 ff., 3 tabb.

MALARODA R. (1998) - *Geomorfologia e Neotettonica della Val Gallenca ed aree limitrofe nell'alto Canavese*. Il Quaternario, 11, 331-346, 14 ff., 1 geol. map 1:12.500 (with a complete bibliography).

MARCHETTO E. (unpublished) - *Notizie sulle cave di argilla nel comune di Castellamonte e sulla utilizzazione dei materiali da esse estratti.* Natural Sciences Degree Thesis, Univ. Turin, 1980-81, with small geological map and figures.

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[5] For a more complete bibliography see Malaroda, 1998.