Geogr. Fis. Dinam. Quat.
30 (2007), 99-116, 14 figg.

PIERLUIGI BRANDOLINI (*), GIACOMO CANEPA (**), FRANCESCO FACCINI (*), ANDREA ROBBIANO (**) & REMO TERRANOVA (*)

GEOMORPHOLOGICAL AND GEO-ENVIRONMENTAL FEATURES OF THE GRAVEGLIA VALLEY (LIGURIAN APENNINES, ITALY)

ABSTRACT: BRANDOLINI P., CANEPA G., FACCINI F., ROBBIANO A. & TERRANOVA R., *Geomorphological and geo-environmental features of the Graveglia Valley (Ligurian Apennines, Italy)*. (IT ISSN 1724-4757, 2007).

This paper presents a review of geomorphological and geo-environmental studies conducted in the Graveglia Valley, where Bracco-Val Graveglia Unit and Mt. Gottero Unit formations outcrops appear. The Bracco-Val Graveglia Unit consists of serpentinites and peridotites, gabbros, ophiolitic breccias, basalts, cherts, limestones and clayey shales. The Mt. Gottero Unit is made up of clayey-arenaceous schists, slates, shales with marly-clayey layers, sandstones and clayey shales.

The geomorphological layout is conditioned by the geological and structural characteristics of the valley. The principal tectonic trends, which consist of two orthogonal systems, one trending N-S to NW-SE and the other NE-SW, have determined the drainage pattern and are responsible for the formation of some deep-seated gravitational slope deformation.

Investigations carried out on the gravitational processes affecting the slopes have led to the mapping of landslides involving monolithological deposits and mixed lithologies, both deposited by rockfalls and sliding. For the most part, these deposits are present in the upper part of the valley.

Along Graveglia Valley, which is marked by frequent meanders, terraced alluvial deposits prevail from the outlet to as far as Frisolino. The upper part is instead characterized by rock erosion. Level surface areas attributable to fluvial terraces (sometimes with ancient alluvial deposits) are present at higher altitudes on the slopes, while alluvial cones are observable at the confluence of the tributaries flowing into Graveglia stream. As concerns underground water, numerous springs exist throughout the entire basin. They constitute an important water resource.

Karstic modelling has developed in the extensive outcrops of limestones present in the upper valley. Microforms of corrosion and dolines represent some of the epigenic forms, among which the Pian di Oneto landform of tectonic-karstic origin is the most imposing of all. As for hypogenic forms, there are about thirty caves, both active and fossil.

Landforms attributable to anthropic activity are numerous and mainly distributed in areas with rocks of oceanic sequence. The most important ones are present in mining sites worked for manganese, iron and copper sulfides. Numerous stone quarries are found one after another in the limestones between Frisolino and Arzeno. The blocks extracted in these quarries are used for breakwaters and the crushed rock is used for construction purposes. In the past, quarries had also been opened in the serpentinites and in the basalts. Lastly, environmental and geotourism points of interest have been indicated on a geomorphological map presented here. These points are related to the geomineral aspects of the areas, as represented above all by the Mining Museum of Gambatesa, as well as to geological-geomorphological aspects, such as the quarry fronts, the gorges and meanders, the agricultural terraces and dry stone structures.

KEY WORDS: Geomorphological mapping, Environmental geology, Graveglia Valley, Ligurian Apennines.

RIASSUNTO: BRANDOLINI P., CANEPA G., FACCINI F., ROBBIANO A. & TERRANOVA R., *Caratteristiche geomorfologiche e geologico-ambientali della Val Graveglia (Appennino Ligure, Italia)*. (IT ISSN 1724-4757, 2007).

In questo lavoro sono presentati gli studi geomorfologici e geologico-ambientali effettuati nella Valle Graveglia, per la quale è stata preparata la carta geomorfologica in allegato. Le unità presenti nella valle, appartenenti al Dominio Ligure interno, sono l'Unità ofiolitica Bracco-Val Graveglia, affiorante nella sua parte medio-alta, e l'Unità flischoide del M. Gottero affiorante nella sua parte bassa e nel settore estremo nord-orientale.

La prima è rappresentata dal basso verso l'alto, da serpentiniti e peridotiti serpentinizzate, gabbri, brecce ofiolitiche inferiori, basalti massicci e a pillow, brecce ofiolitiche superiori, diaspri, calcari a Calpionelle e argille a calcari palombini.

La seconda è costituita, dal basso verso l'alto, da scisti argilloso-arenacei, ardesie, scisti zonati, arenarie di M. Gottero, argilliti varicolori. Le ofioliti compaiono spesso al nucleo di grandi pieghe coricate verso E-NE costituite dalle formazioni sedimentarie dei diaspri e dei calcari. Le indagini sui processi gravitativi di versante hanno permesso di distinguere e di cartografare corpi di frana a componenti monolitologici, a clasti arenacei, ardesiaci, calcarei, diasprigni, basaltici e serpentinitici e corpi di frana a litologia mista, tutti dovuti a fenomeni di crollo e scivolamento, ubicati per la maggior parte nella zona alta della valle, con numerosi cigli di distacco attivi e movimenti attuali negli accumuli.

La geomorfologia è chiaramente legata alla composizione delle formazioni ed alle strutture della vallata, ove le direttrici tettoniche principali sono rappresentate da due sistemi grossolanamente ortogonali, uno orientato tra N-S e NW-SE e l'altro orientato NE-SW. Sono state individuate tre zone interessate da deformazioni gravitative profonde (DGPV): quella di Pontori coinvolge i calcari e i diaspri, quella di Statale i diaspri, i calcari e le ofioliti, quella dei monti San Giacomo e Capenardo le ardesie; all'interno di tutte compaiono grandi coltri detritiche di vario tipo e ampi spezzoni strutturati di formazioni. Il reticolo idrografico della valle,

* *Università degli Studi di Genova, DISAM, via Balbi 2 - 16126 Genova.*
** *Geologist, c.so Garibaldi 58 - 16043 Chiavari (GE).*

riguardante il T. Graveglia ed i suoi affluenti, è legato alle direttrici tettoniche sopramenzionate, ove si è osservato che il bacino si sviluppa, dallo sbocco nel T. Entella, secondo un andamento W-E fino a Conscenti, ove riceve in destra il Rio Garibaldo, quindi si orienta a NE verso l'alta valle, fino al Ponte di Lagoscuro, ove riceve in sinistra il Rio Novelli ed il Rio Statale; dopo questa località la valle si orienta nella direzione N-S fino alla sommità. Depositi alluvionali terrazzati compaiono lungo l'asta del T. Graveglia, spesso ad andamento meandriforme, dallo sbocco finale fino all'abitato di Frisolino, mentre nella parte superiore è prevalente il processo di erosione nella roccia in posto, quali calcari, diaspri, basalti, serpentiniti. Sono state rilevate numerose spianate in quota sui due versanti della valle, attribuite a terrazzi fluviali, talora con presenza di scarsi residui alluvionali. Altri depositi dovuti al trasporto delle acque sono stati individuati in forma di conoidi alluvionali allo sbocco degli affluenti nel corso del T. Graveglia. Per quanto riguarda le acque profonde si sottolinea che le sorgenti presenti nell'intero bacino sono numerose e talora assumono grande importanza ai fini dello sfruttamento idrico.

Lo sviluppo della morfologia carsica è stato nel tempo favorito dai calcari a Calpionelle, che sono presenti nell'alta valle in estesi affioramenti, in serie diritta e rovesciata. Fra le forme epigee si trovano microforme di corrosione assimilabili alle scanalature ed ai karren, doline ed avvallamenti doliniformi, doline di crollo ed inghiottitoi, fra cui la più grandiosa è la dolina tettonico-carsica del Pian di Oneto. Fra le forme ipogee sono presenti molte grotte, attive e fossili, negli affioramenti di M. Chiappozzo, di M. Bianco, dell'alta Valle di Chiesanuova e lungo i versanti dell'alta Val Graveglia.

Le forme, i processi ed i depositi dovuti alle attività antropiche sono numerosi e diffusi soprattutto nelle aree interessate dalle formazioni della sequenza oceanica. Le più rilevanti si trovano nelle aree delle attività minerarie dei minerali di manganese, nei diaspri, e dei solfuri di ferro e rame nei basalti sui contatti con le serpentiniti. Pure vaste e grandiose sono le cave nei calcari che si susseguono nella valle tra Frisolino e Prato di Arzeno, dalle quali sono estratti blocchi per scogliere marine e per arginature dei torrenti e pietrischi per l'edilizia e per i fondi stradali; in passato sono state aperte cave anche nelle serpentiniti e nei basalti, oggi abbandonate. Nella carta geomorfologica allegata è indicata, con appositi simboli, la distribuzione delle emergenze ambientali, didattiche e geoturistiche, interessanti il campo geominerario, di cui in primo luogo il Museo Minerario di Gambatesa, inoltre gli aspetti geologico-geomorfologici, i fronti di cava, le forre e i meandri, le terrazze antropiche di grande rilievo e le costruzioni in pietra a secco.

TERMINI CHIAVE: Carta geomorfologica, Geologia ambientale, Valle Graveglia, Appennino ligure.

INTRODUCTION

The geomorphological map of Graveglia Valley was prepared as part of the MIUR-COFIN 2000 project entitled «La valorizzazione turistica dello spazio fisico come via alla salvaguardia ambientale» (National Coordinator: R. Terranova). The map was compiled for the specific purpose of contributing to more indepth knowledge of the area's geomorphological aspects, while also valorising the environmental and geotourism sites and features.

Owing to the consistency and the distribution of the mining sites, and the variety of the stone extracted, this valley has been of essential importance in Liguria's social and economic history. Moreover, in more recent times, interest has developed more towards its educational and recreational offerings, particularly with the geomineralogical, geological and geomorphological itineraries that have been designed (Faccini & *alii*, 2000; Brandolini & *alii*, 2004; Robbiano & *alii*, 2006).

Together with Sturla Valley and Aveto Valley, Graveglia Valley lies within the territory of the Regional Park of Aveto. This park was founded in 1995 to protect one of the most beautiful and important regions existing in the Ligurian Apennines and has been represented on the Protected Ophiolitic Areas Coordination Board since 2001.

More importantly, of the three valleys, Graveglia Valley stands out for the richness of its geological characteristics, offering one of the best districts for the valorisation and utilisation of geological assets and for the conservation of geodiversity.

GENERAL FRAMEWORK

Graveglia Valley covers an area of about 65 km^2, with the outlet at less than 5 km from the coast in the Prioria di Carasco locality, where Graveglia stream flows into Lavagna stream, forming the Entella River, one of the largest watercourses in Liguria with a basin covering 376 km^2 (fig. 1).

The climatic conditions of the area have been defined using precipitation and temperature data recorded at the meteorological stations of Cassagna (432 m), Reppia (564 m), Statale (570 m), Chiesanuova (110 m) and Panesi (26 m). The Panesi station is situated along the plain of the Entella River just beyond the fork with Graveglia stream and is therefore useful for compiling meteorological climate profiles regarding the lower valley (fig. 2).

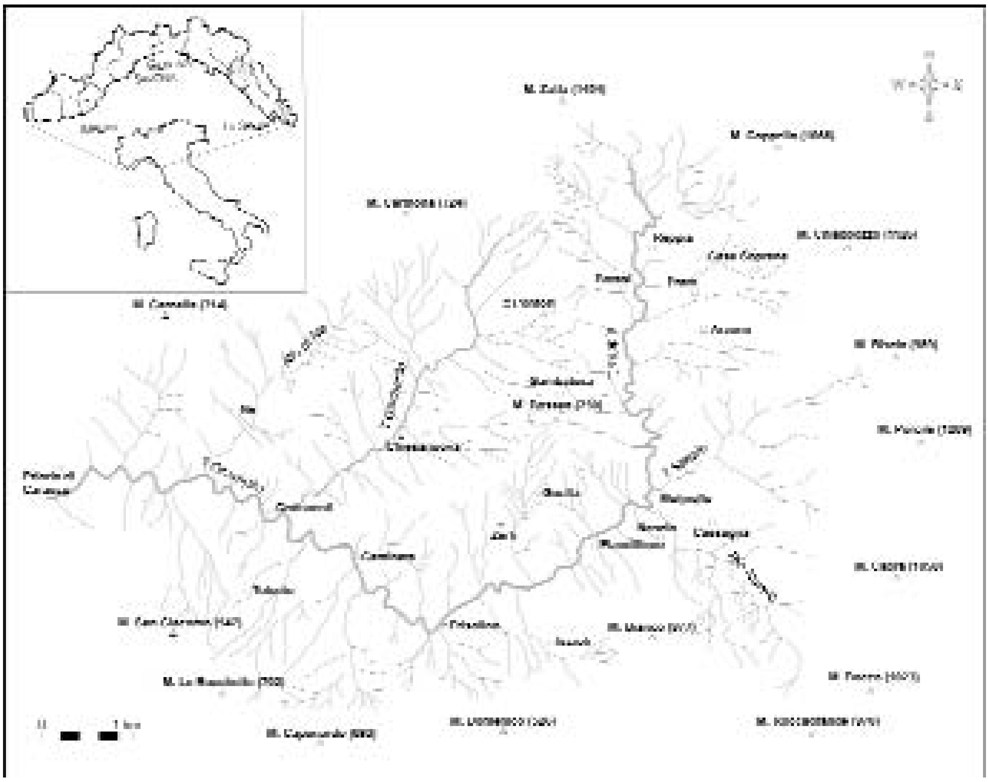
Owing to the geographical position and shape of the basin, the northern sector faces south, whereas the eastern sectors face west. Annual precipitation is affected by this exposure of the basin, which determines particular air mass circulation patterns. The latter are characterized by cool, moist sea breezes that are drawn directly into the valley through the Entella River channel.

The cold winds from the N, however, do not affect the valley owing to the orographic protection offered by the Mt. Zatta - Mt. Chiappozzo ridge. However, they do undergo warming by Föhn-type mechanisms. Due to these conditions, temperatures are relatively mild, with an average temperature of 12-13°C and frequent rain throughout the year.

Total annual precipitation increases directly with altitude. The annual maximum of 2100 mm is reached at the highest altitudes in the basin (i.e., Statale), whereas the Panesi station registers about half that amount (1100 mm).

The distribution of mean monthly precipitation is homogeneous among all of the stations. The monthly maximum proves to be in November (140 mm at Panesi, 190 mm at Chiesanuova, 195 mm at Reppia and 270 mm at Statale) and the minimum in July (42 mm at Panesi, 50 mm at Chiesanuova, 48 mm at Reppia and 84 mm at Statale). A submediterranean climate prevails in the lower and middle valley, while slightly different rainfall patterns exist in the upper basin, with a transition into a Mediterranean climate. In fact, the upper Graveglia Valley is characterised by high mean monthly rainfall in late autumn and in early winter owing to the orographic features and to snowfall, with snow cover varying in thickness and duration, depending upon altitude.

FIG. 1 - Geographical sketch map of the Graveglia Valley.



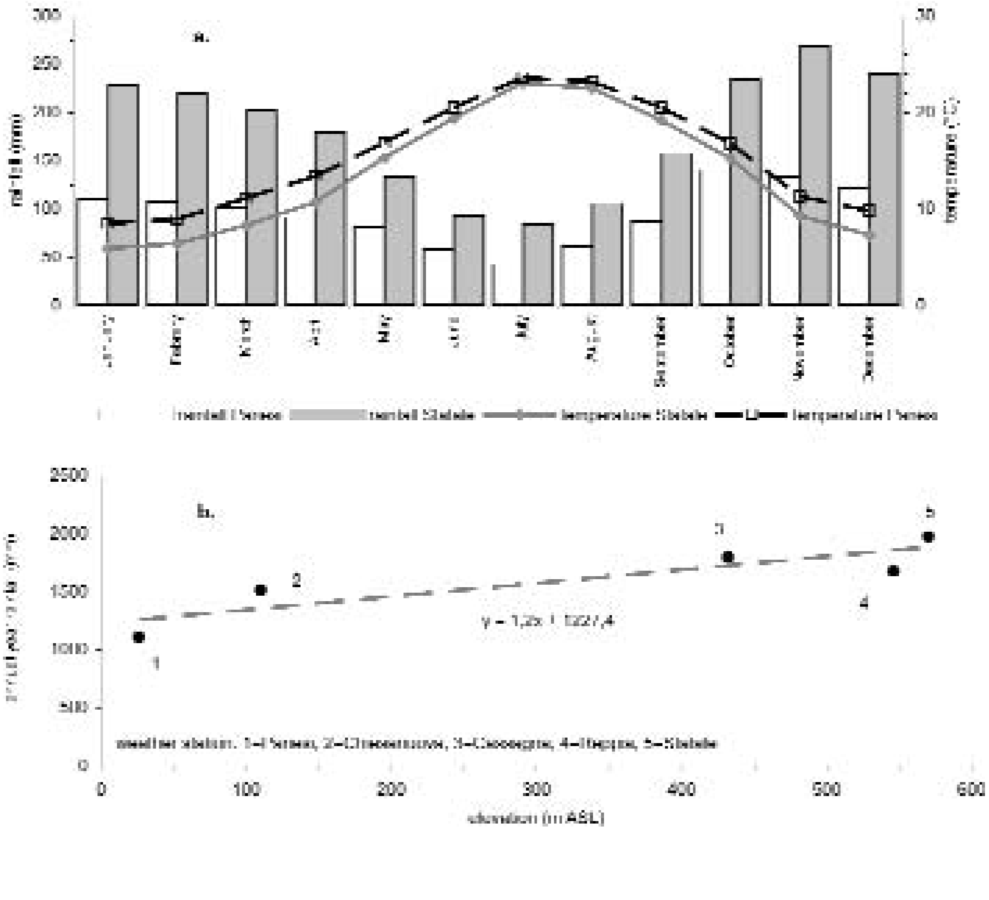


FIG. 2 - Climate diagrams referring to Graveglia Valley: a. climograph; b. rainfall vs. elevation linear regression.

Condensation phenomena contribute to increase precipitation. These phenomena occur in the vicinity of the divide, when the temperature of the air saturated with water vapour drops upon contact with the rocks. If we consider the exposure of the dividing range with respect to Vara Valley, thousands of litres can be estimated as a daily condensation rate, with an increased rate in the summer months due to the difference between the range of the air temperatures and the temperature of the bedrock. The overall contribution of the water resources can reach substantial levels. In fact, springs with high flow rates are observable in the vicinity of the divide. The resulting perennial regimen of the springs has led to continuous use of these waters since historical times and today they still supply aqueducts and industrial bottling plants (Acqua Fonti di S. Rita).

Heavy rainfall concentrated over short periods of time is frequent in the autumn months, when in just a few days, the rain often amounts to as much as half of the annual total. Records for the Statale station, for example, show about 950 mm of rain in December 1959, with an annual total exceeding 3000 mm, while the monthly total of 600 mm was exceeded many times in October and in November during the 1935-1998 period.

As mentioned above, snowfall also contributes to the annual total. Thickness varies considerably from one year to the next and the snow cover persists from October to May. However, snowfall is mainly concentrated between December and March, with peaks in January and February (e.g. 60 cm in February 1978, 90 cm in February 1986). Mean snowfall recorded at the Reppia and Statale stations amounts to 40 cm and 60 cm, respectively, during the 1974-1998 period.

The permanency of the snow accumulated on the ground depends upon altitude and local conditions, although it is generally of brief duration. There is permanent snow cover for periods exceeding 30 days only above an altitude of 1000 m ASL, with rapidly decreasing periods of time at lower altitudes until it becomes merely occasional in the lower valley.

The amounts of precipitation in the valley have an influence on slope modelling processes and affect the formation and development of surface and underground karst phenomena.

The mean monthly temperatures of the air decrease with altitude. Graveglia Valley is between the annual mean isotherm lower than 12°C at altitudes greater than 1000 m and the isotherm greater than 15°C at the confluence with the Entella River, at altitudes below 50 m.

The distribution of the monthly mean temperatures is homogeneous among the stations considered. There is a maximum in the summer months (July-August) with temperatures exceeding 22°C and a minimum in the winter months (December and January), with isotherms between 6 and 8°C.

With particular reference to the portions of the area at higher altitudes, the climate regime described above leads to marked thermal excursions. The latter determine frequent annual cycles of freezing and thawing, with consequent meteoric alteration of the bedrock (e.g. cryoclastism phenomena affecting the limestones of Mt. Chiappozzo).

GEOLOGICAL DATA

The geological layout and the stratigraphic sequence characterizing Graveglia Valley are now well known. They represent the typical ophiolitic sequence, with relative sedimentary rocks, and are characterized by low-grade metamorphism (Società Geologica Italiana, 1994); the formations present in the valley are attributable to the Ligurian Unit and are included in the ophiolitic Bracco-Val Graveglia Unit and in the Mt. Gottero Unit (fig. 3).

The Bracco-Graveglia Valley Unit is formed by: Shales with palombini limestones of Zerli; Limestones with Calpionella of Mt. Chiappozzo; Cherts of Mt. Roccagrande; Upper ophiolitic breccias of Mt. Bianco; Basalts of Ponte di Lagoscuro; Lower ophiolitic breccias of Mt. Capra, Ophicalcites of Iscioli; Gabbros of Case Moggia; Serpentinites of Mt. Bossea (Abbate & *alii*, 1980).

The Mt. Gottero Unit is formed by Shales of Giaiette; Sandstones of Mt. Zatta; Marly-clayey shales of Ne; Slates of Mt. Capenardo; Clayey and clayey-silty shales of Terisso (Terranova, 1966).

GRAVITATIONAL SLOPE FORMS, PROCESSES AND DEPOSITS

Our geomorphological surveys have identified many active and dormant gravitational phenomena extending particularly in the upper sectors of the drainage basin and involving various hamlets (e.g. Arzeno, Case Soprane, Prato, Reppia, Statale, Nascio, Pontori and Campo di Ne).

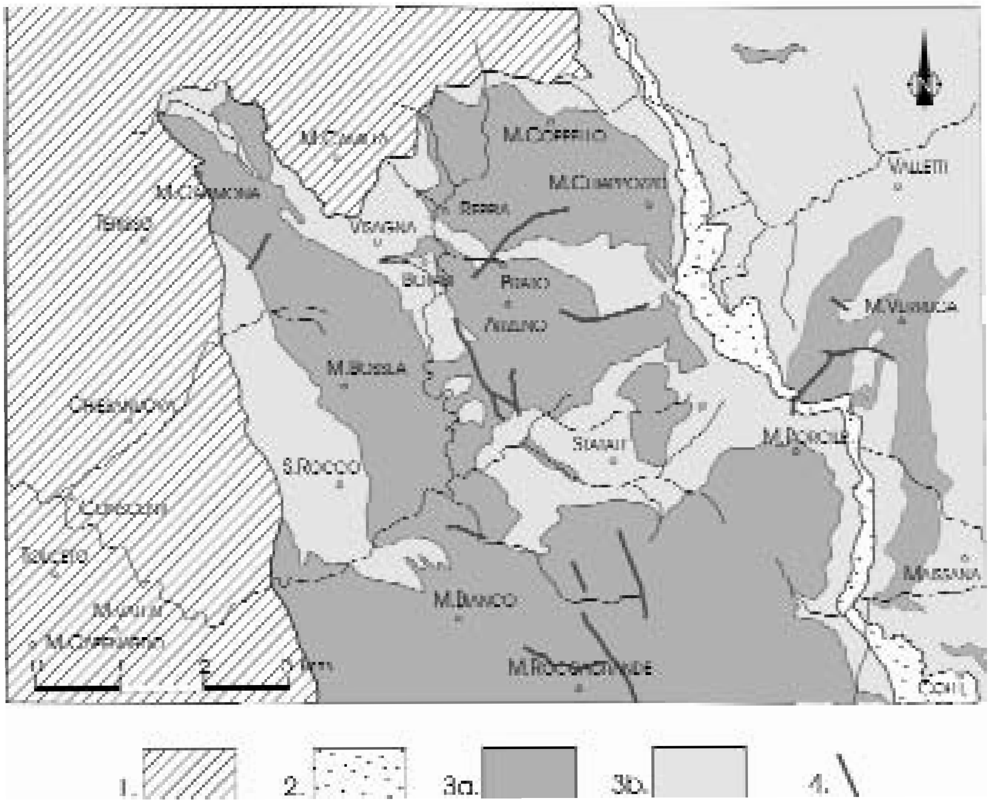
Approximately 20% of the valley is characterized by landslides, which are attributable mainly to rockfalls and rock slides, or to deep-seated gravitational slope deformations.

Causes leading to this situation of widespread geomorphological instability can be identified in the frequently unfavourable conditions of the geological and structural layout. There is also the high relief of the region, ranging from 30 m on the valley floor to 1400 m at the top of Mt. Zatta, and the erosive action of Graveglia stream and its main affluents to consider, as the latter are the determining elements responsible for the triggering and evolution of the landslide phenomena.

As concerns mass movements, a fair level of lithological uniformity of the clasts comprising many of the landslides has been observed (sandstone, slate, limestone, chert, basalt, serpentinite), whereas the dynamics of the landslide movement involve all the various typologies.

The distribution of the landslides shows a higher concentration in the northeastern sector of the basin. In fact, many landslides prevalently made up of limestone clasts, have been identified on the western slopes of Mt. Chiappozzo (1126 m). These clasts vary in particle size from

FIG. 3 - Geological-structural map of Graveglia Valley: 1. Mt. Gottero Unit; 2. Colli-Tavarone Unit; 3. Bracco-Val Graveglia Unit: a) ophiolites, cherts and limestones; b) shales with limestones; 4. Fault.



grains to fragments of diameters in the range of centimetres to decimetres, and blocks, produced by detrition affecting the Limestones with Calpionella, which outcrop below the summit of Mt. Chiappozzo under intense fracturing conditions (fig. 4). The landslides started from numerous scarps, some of which are active. They develop between 1050 and 900 m ASL, with movement converging westward towards the rustic cottages once used for sum-

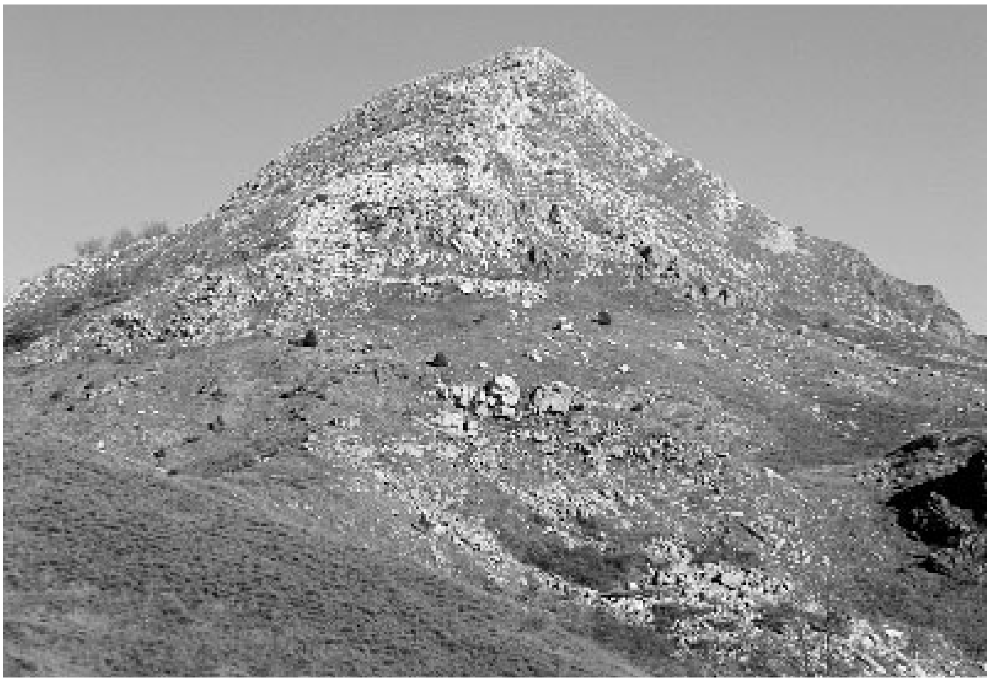


FIG. 4 - Panoramic view of limestones outcrop on Mt. Chiappozzo: the very fractured limestones, overlying the ophiolites, frequently feed the below scree slopes.

mer pasturing, known as Casoni di Chiappozzo, and towards Casoni stream, up to about 700 m, with an overall longitudinal extension of about 1.3 km (fig. 5).

A large landslide, where the Arzeno hamlet has developed, is supplied by the limestone ridge extending at about 800-850 m ASL and that marks the western margin of the tectonic-karstic basin of the Pian di Oneto. The basin is characterized by very fractured limestones, trenches, reverse slopes and an active landslide scarp. The landslide measures over 1 km from crown to toe. It represents the upper limit of the accumulation of limestone blocks that extends westward for about 1250 m, down to an altitude as low as 525 m, slightly below the Arzeno hamlet. With the contribution of serpentinitic debris, originating from the contiguous slopes, the landslide continues downslope for 650 m, with a mixed composition that is prevalently calcareous-serpentinitic, as far as Reppia stream (400 m), where it has deviated the river channel on the right bank.

The geomorphological evidence observed seems to indicate the presence of deep-seated gravitational slope deformation, also in higher areas nearing Mt. Chiappozzo and probably along tectonic lineations trending E-SE/W-NW, subparallel to the fault line identified slightly N of the limestone ridge.

Many landslides have been found clustered N of the ridge and SW of the crest of Mt. Chiappozzo. The landslide materials are composed of clasts of mixed lithologies. The hamlets of Reppia, Case Soprane and Prato are situated on these landslide areas. Genesis of the landslides appears to be of a complex nature, involving rockfalls and toppling, and originating from the supply of ophiolites.

The steep southern face of Mt. Zatta and the eastern slopes of Mt. Cian and Mt. Camilla are incised by deep valleys arranged along faults in the fractured bedding of sandy flysch, outcropping with a favourable dip direction (fig. 6).

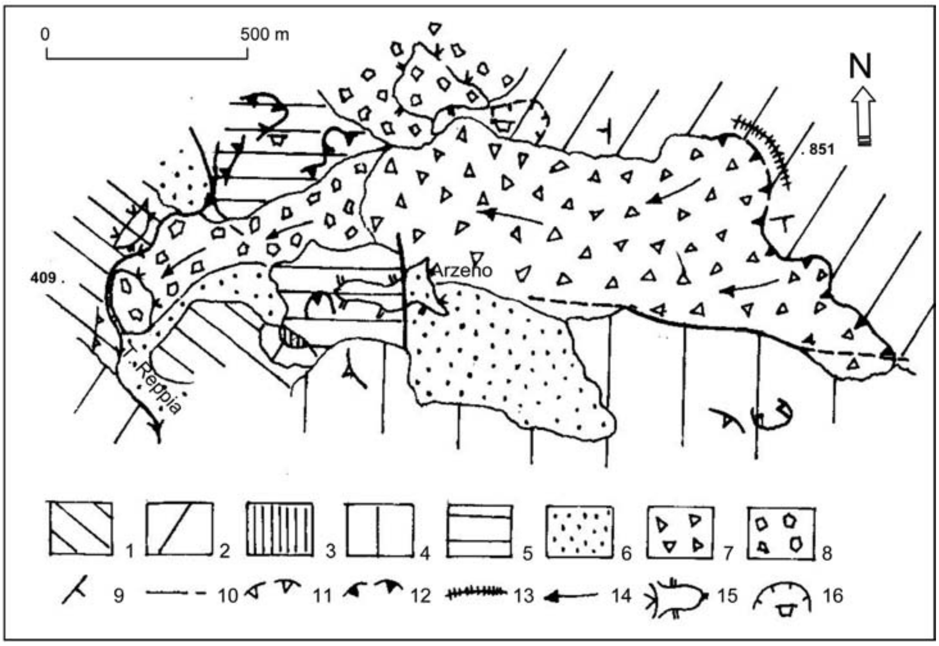


FIG. 5 - Geomorphological sketch map of the large landslide of Arzeno-Prato Oneto: 1. Shales with limestones; 2. Limestone with Calpionella; 3. Cherts; 4. Lower ophiolitic breccias; 5. Serpentinites; 6. Debris cover; 7. Landslide made up of calcareous clast; 8. Landslide made up of clasts of mixed lithology; 9. Bedding; 10. Fault; 11. Dormant landslide scarp; 12. Active landslide scarp; 13. Trench; 14. Direction of rock movement in the landslide; 15. Stream terrace; 16. Inactive limestone quarry.

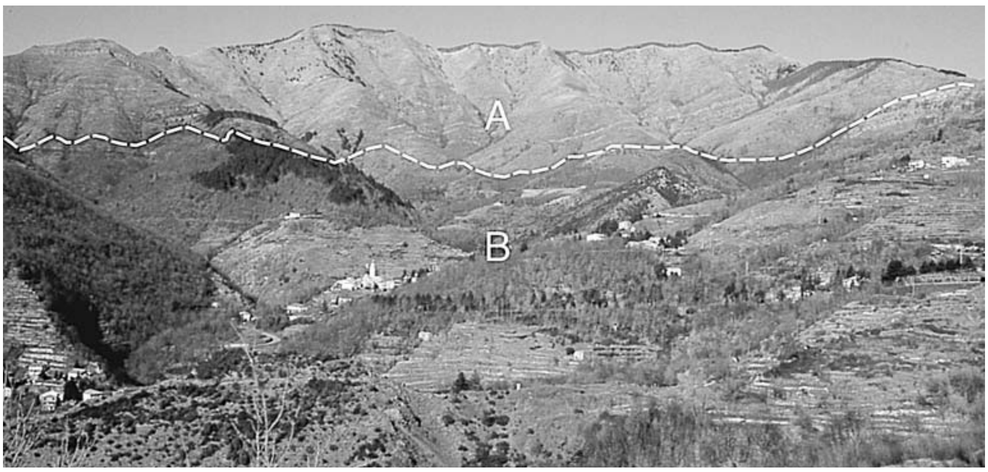


FIG. 6 - Panoramic view of morphological amphitheatre of Mt. Zatta: A. sandstones; B. ophiolites with cherts and limestones. There are numerous landslides and/or degradational scarps in this denuded rocky slope; following falls and toppling of sandy stone blocks, the scarps have led to constant slope retreat.

There are numerous active and dormant scarps in this denuded rocky amphitheatre. Following falls and toppling of sand stone blocks, the scarps have led to constant slope retreat. The material set into motion converges downslope to about 800 m ASL, where the lower inclination of the slope, along the shale formations, has led to the deposition of debris covers and landslide masses made up of clasts of mixed lithology.

The most significant example of a landslide mass made up of serpentinitic clasts is observable in the southeastern sector of the valley, on the northern slopes of Mt. Bocco. Just below the ridge aligned in a SW-NE direction and connecting Mt. Roccagrande (971 m), Mt. Bocco (1023 m) and Colle d'Arena (950 m), a scarp extends for a length of about 1.3 km. Sliding from this scarp continue to supply the taluses and the landslide mass below. The serpentinitic accumulation extends as far down as Novelli stream (700 m). The upper and middle parts, between 875 m and 925 m, present moderate steepness with several reverse slopes (known as the *Da Pria Grossa* area) that characterize the site. The base of the landslide is affected by reactivation, which is made evident by the active scarps found between 850 m and 750 m. The reactivation of the base is caused by erosion on the part of Novelli stream.

Four zones characterized by deep-seated gravitational slope deformation (DSGSD) have been identified: Mt. S. Giacomo, Mt. Le Rocchette, Statale and Pontori. They are all located in different sectors of the basin. The first two are found on the orographic left in the southwestern part of Graveglia Valley. The third zone is also on the orographic left, but in the outer eastern sector of the basin, while the fourth is on the orographic right in the central-northern portion of the valley.

A vast sector presenting evidence of DSGSD has been identified on the northern side of Mt. S. Giacomo (540 m). Slightly below the mountain ridge at an altitude of about 425-450 m, a level area known as the *Pian di Prato* is observable. It features small hollows and reverse slopes that form a trench that extends parallel to the ridge. The slope affected by DSGSD covers an area amounting almost 1 km^2, extending longitudinally for about 1250 m down to the bottom of the valley (35 m), where it ends along a meander of Graveglia stream in the locality of S. Lucia.

The Mt. Le Rocchette (700 m) slope facing north and situated E of Mt. S. Giacomo also presents reverse slopes below the ridge, at 590 m. It shows debris covers and landslide masses made up of slate clasts in the middle zone, where portions of a slate formation outcrop. Although the outcrop is altered and fractured, the formation still retains its original structure. With uncertain borders, this sector of the slope descends to about 250 m, to the Tolceto hamlet, over an overall surface area of about 1.1 km^2 and for a longitudinal length of 1650 m. Although the Mt. S. Giacomo and Mt. Le Rocchette zones are separated by a ridge consisting of slate bedrock that appears to be in place, they could be defined as a single DSGSD unit.

The western slopes of Mt. Biscia (989 m) and Mt. Porcile (1289 m), made up of cherts, limestones and shales, present landslide masses composed of mixed-composition clasts extending downslope to Statale stream to an altitude of 500 m, covering a length of about 2 km.

The landslide that affects Statale (600 m) has been assimilated into a deep-seated gravitational slope deformation. Among other morphological evidence, in the upper part, in the locality called Case Molinello (840 m), where very altered and fractured shales outcrop, there is a large reverse slope preceded by a stretch of level surface that disrupts the profile of the slope. This morphology resembles a trench parallel to the slope, arranged on a fault with a NW-SE orientation. Overall, the area believed to be affected by DSGSD covers a surface area of over 2.5 km^2.

The deep-seated gravitational slope deformation identified in the Pontori Alto area (fig. 7) extends over the southwestern slopes of Mt. Camilla (1000 m). The geological-structural layout of this zone is complex. In fact, the slope presents outcrops of the sandstones and the shales in contact due to thrust over the underlying shales with limestone. The latter are in tectonic contact with the basalts, the cherts and the limestones, followed by the lower ophiolitic breccias and the serpentinites. Lastly, the shales with limestone reappear on the valley floor along Nossiglia stream, once again, along a tectonic thrust.

Considering the tectonic aspects, the slope is thus affected by two faults, one oriented NW-SE and parallel to the slope, the other approximately orthogonal to the first one. Deep movement is thought to occur along the NW-SE fault, involving the slope between the limestone zone (550 m) and Nossiglia stream (300 m). This sector is covered by a landslide mass composed of limestone clasts deposited by collapse from the scarp above, which presents strongly altered and fractured bedrock. There is a reverse slope on the plateau of the Pontori Alto hamlet (435 m) that could reveal additional dislocation of the slope. A further conjecture would extend the slope area affected by DSGSD even further upslope, involving the cherts and basalts as well and reaching the tectonic contact with the shales with limestone above. The upper branch of Pontori stream flows along this fault. The depression incised parallel to the slope could be interpreted as an additional trench and thus evidence of deep-seated movement.

HYDROLOGICAL ELEMENTS AND RUNNING WATERS

The hydrographic basin is drained by a main watercourse of the sixth order, called Reppia stream, in the upper part, and by Graveglia stream in the tract that follows (Cortemiglia & *alii*, 1970).

Fluvial terraces of considerable dimensions are present in the lowest part of the watercourse, after the confluence of Graveglia stream with Garibaldo stream, a watercourse of the fifth order.

Upstream from the confluence, the extension of the fluvial terraces decreases and in the upper portion of the basin, depositional landforms are replaced by erosional landforms in the form of entrenched streams with mean-

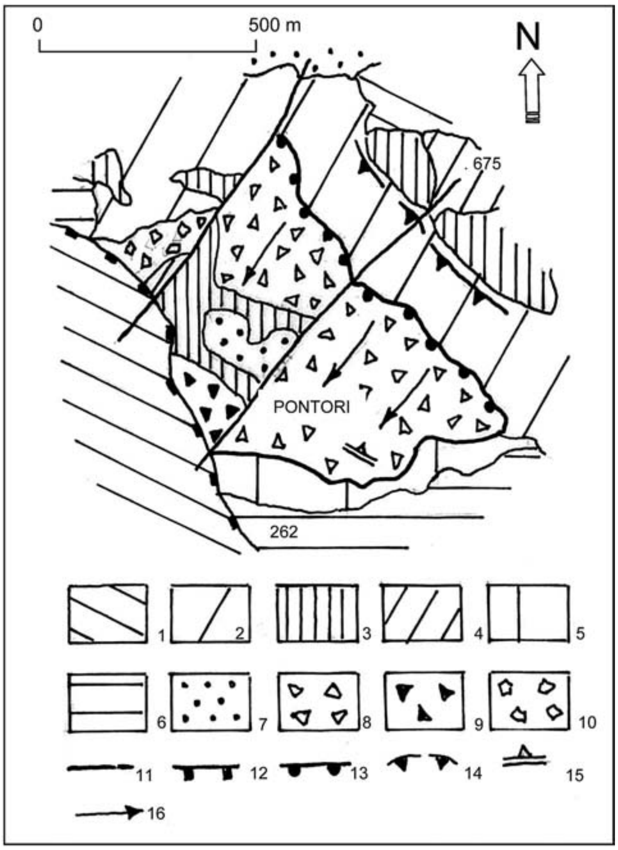


FIG. 7 - Panoramic view (up) and geomorphological sketch map (down) of the deep seated gravitational slope deformation of Pontori in the central-northern sector of the basin: 1. Shales with limestones; 2. Limestones; 3. Cherts; 4. Basalts; 5. Lower ophiolitc breccias; 6. Serpentinites; 7. Debris cover; 8. Landslide made up of calcareous clasts; 9. Lansdlide made up of chert clasts; 10. Landslide made up of clasts of mixed lithology; 11. Fault; 12. Traces of tectonic contact from overthrust; 13. Upper part of DSGSD; 14. Active landslide scarp; 15. Reverse slope; 16. Direction of rock movement in the landslide.

ders in the bedrock. Among the latter, the most significant are represented by the Novelli stream gorge, which is observable from Ponte di Lagoscuro (fig. 8), carved in the basalts and cherts, and by the meanders in the Reppia streambed in the tract where the limestones outcrop between Pian di Fieno and the locality known as Case Batesto.

The evolution of the profile of equilibrium proves to be slowed down by the slow rise in the base level of the lower tract that is still in progress today and that leads to episodes of flooding in the Entella River outlet zone.

The geological-structural layout of the basin gives rise to different erosive action connected with channel flow and also conditions mass transport.

The terraced alluvial deposits are almost level and conditioned by regressive erosion (fig. 9). Colluvial deposits overlie the fluvial terraces in the piedmont strip.

FIG. 8 - Ponte di Lagoscuro gorge: pillow lavas in the Graveglia valley (bridge in the foreground), extracted in the Molana quarry (on the right); the cherts outcrop in the Novelli stream climbs up to Nascio hamlet. At left of Nascio hamlet is the Novelli gorge, carved in the cherts and basalts, at the confluence of Graveglia stream.

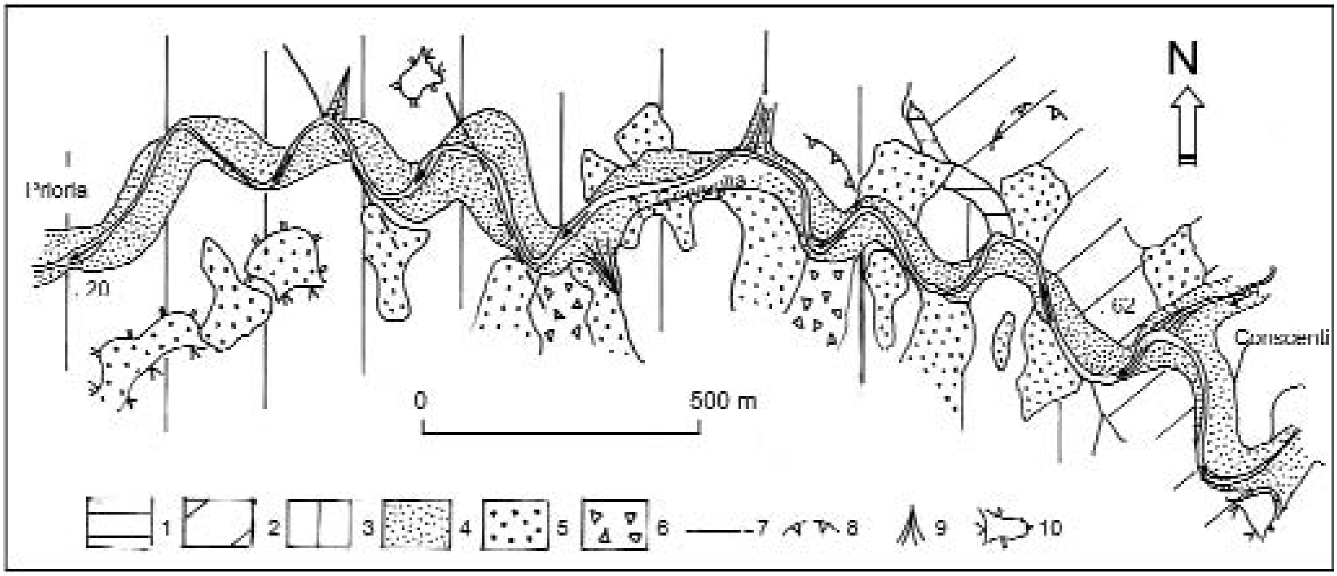


FIG. 9 - Geomorphological sketch map of lower Graveglia Valley showing the main fluvial forms and deposits: 1. Shales with red and green schist; 2. Sandstones; 3. Slates; 4. Recent alluvial deposits; 5. Debris covers; 6. Landslide made up of slate clasts; 7. Faults; 8. Dormant lanslide scarps; 9. Alluvial fans; 10. Fluvial terraces.

As concerns fluvial dynamics, in the course of time and during flood events, alluvial deposits have been incised over and over again in subsequent erosion phases, manifesting their erosive action prevalently along the outer river banks of the meanders, where streambed protection intervention projects have been implemented to restore conditions of safety in the basin.

Numerous fluvial erosion scarps also affect the secondary network on some slopes, with a particular distribution in the sandstones S of Mt. Zatta, in the serpentinites W of the Gambatesa mine and in the clayey formations N of the Mt. Capenardo-Mt. S. Giacomo alignment.

Erosion of the streambeds is a phenomenon sometimes associated with lateral erosion, or alternating and affecting mainly the watercourses in the upper section of the basin. These watercourses are characterized by a very steep riverbed and by the presence of erodible rocks.

The lithotypes most affected by this phenomenon are limestones and cherts, in which the tendency to deepen can also be linked to tectonic lineations affecting the drainage network. Incision phenomena and the deepening of the drainage network are present on the southern slope of Mt. Zatta.

Evidence of the quaternary evolution of the profile of the Graveglia stream and its main affluents also appears in other forms. The most apparent consists in the fluvial terracing identified at altitudes definitely higher than that of the current streambed. These are level surfaces along some secondary ridges and linked to the fluvial dynamics. They have been interpreted as terraces, as have other surfaces in the upper basin areas where the localities of Botasi, Prato and Arzeno are situated.

Traces of alluvial deposits have been observed in few cases on the surfaces at higher altitude, although lenses of suspended coarse-grained alluvial deposit have been reported and prove to be over 50 m higher in elevation than the current streambed. Suspended alluvial deposits are present in the upper part of the Reppia stream basin, downstream from Botasi bridge, and in the central sector at the beginning of the road to Iscioli.

Alluvial fans have been mapped in the vicinity of the confluence of several lateral valleys in the main stream, as in the case of the lower tract of Graveglia stream, before the confluence with the Entella River.

As concerns slope surface runoff, some areas affected by rill wash have been identified in the upper zones of the basin below the watersheds. These phenomena have been noted to be particularly frequent along the southern slope of Mt. Zatta and along the ridge connecting Mt. Chiappozzo and Mt. Biscia.

Colluvial deposits are significant in terms of their distribution and stratigraphical significance. These deposits are very often present in depressed areas and have been adapted for use as agricultural terraces.

In the case of the Pian di Oneto doline, the phenomenon is related to tectonic-karst landforms and these deposits take on geohydrological importance, also owing to their dimensions. The large marshy plain that surely was once all swamp, was drained by means of a series of canals, representing an example of a highly efficient drainage system.

As regards the dynamics of the underground water, it should be stressed that numerous springs exist throughout the entire basin. Some are also important as water resources, serving for aqueducts and for commercial or agricultural use, based on the high flow rates and the quality of the water supplied.

The most important examples are the «Fonti di S. Rita» springs in the upper Statale stream basin (eastern sector), utilised for natural mineral water classified as low in mineral content, and the «Tana della Madonna» springs in the upper Reppia stream basin, used for irrigation.

There are examples of almost all the existing types of springs classified in current literature, but the karst springs existing principally in the outermost eastern sector of the drainage basin along the Statale and Novelli streambeds merit special mention (Maifredi & Giammarino, 1968; Maifredi & Pastorino, 1970).

KARST GEOMORPHOLOGY

In addition to universally recognised mineral and geological aspects, Graveglia Valley is characterized by interesting surface and hypogenic karst phenomena. The many caves represent important elements for an understanding of the geomorphological evolution of the valley, testifying also to human presence in the area at least since the Middle Ages, including both temporary presences or settlements (Gardini & *alii*, 1992).

With Law no. 14/1990, the Region of Liguria established the guidelines for the protection and valorisation of the karst areas, and for the promotion of the development of speleological studies, nominating an official karst site under the name of «Alta Val Graveglia» and identified as GE36.

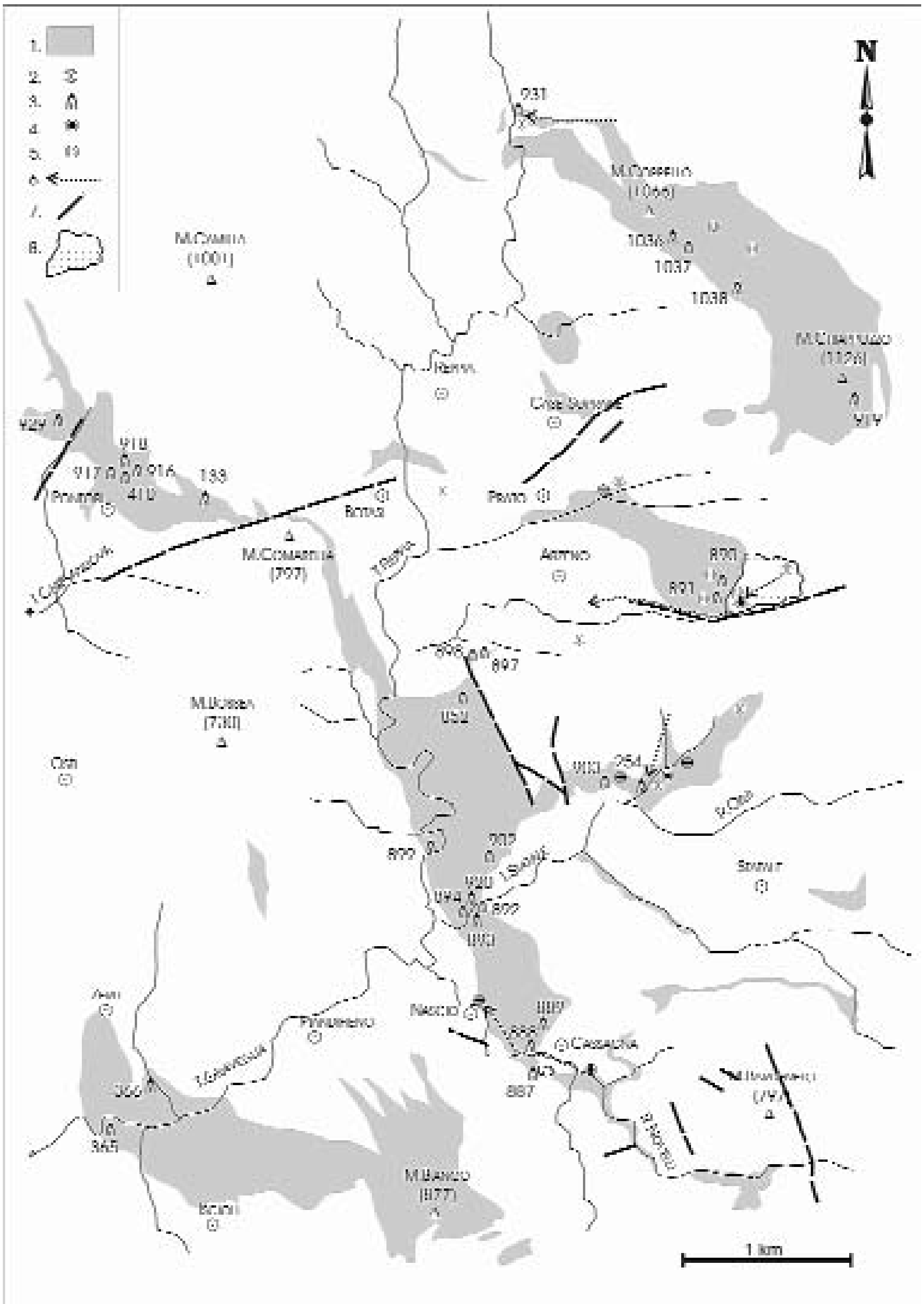
In Graveglia Valley the bedrock prone to karst modelling is composed of Limestones with Calpionelle, which maintain their original stratigraphic correlation, positioned between the cherts and the shales with palombini limestones, although the sequence is often reversed.

The Limestones with Calpionelle are made up of white and light grey limestone bedding varying in thickness (prevalently 30-40 cm). The limestone is very fine-grained and compact, characterized by conchoidal fracturing, as well as by bands and flint nodules intercalated at the bottom (Cobianchi & Villa, 1992). The limestone bedding is separated by very thin layers of marly clay (thickness range between several millimetres to a few centimetres), or sometimes by interlayers of red or greenish clayey shales.

On the basis of numerous studies, the main limestone outcrops can be defined as follows (fig. 10):

– a strip with an ENE-WSW trend that descends westward from the top of Mt. Bianco through Graveglia stream to the rocky ridge where the remains of the Zerli castle stand;
– a sector of the Mt. Carmona - Mt. Comarella alignment along the slope facing SW, above the Pontori hamlet, in upper Garibaldo Valley;

FIG. 10 - Map of karst phenomena in Graveglia Valley: 1. Limestones; 2. Resurgence; 3. Cave with bracket the number of speleological hand register; 4. Active swallow hole; 5. Inactive swallow hole; 6. Water flow underground direction; 7. Fault; 8. Doline.



– an area roughly oriented NW-SE that from the eastern slopes of Mt. Comarella, includes the western portion of Crocetta di Arzeno, and Castellaro ridge as far as Novelli stream, below Cassagna; a significant portion climbs Castellaro ridge, to reach the former Scrava mine through Orti stream;
– an extensive outcrop oriented NW-SE on the watershed ridge between Mt. Coppello and Mt. Chiappozzo;
– the secondary ridge behind the Arzeno hamlet, as far as the Pian di Chiappozzo, together with several isolated strips in the vicinity of Case Soprane, Statale and on the northern slopes of Mt. Porcile;
– several portions of a relatively modest extension, in the Statale area, on the southern slopes of Mt. Bardeneto and Mt. Porcile and in the vicinity of the Reppia stream springs.

These portions of the territory are distinguished by bedrock that is prone to karst modelling, even though the development of the morphological features appears to be limited, with respect to the considerable thickness of the limestone formation. In fact, in the case of Graveglia Valley, the considerable degree of fracturing characterizing the bedrock inhibits the formation of extensive karst phenomena.

More than solution sinkholes, the surface phenomena are limited to karst depressions. Underground, however, drainage is generally uniformly distributed in the discontinuity network, without preferential subsurface conduits. The concentration of the waters draining through the discontinuities causes progressive dissolution.

The more evident aspects are found in the outcrops in upper Graveglia Valley, along Orti and Novelli streams, in the Pian di Oneto zone and along the Mt. Chiappozzo - Mt. Coppello ridge. Although they are not as highly developed as karst phenomena in the Apuan Alps or the Ligurian Alps, the features present in this valley are of considerable interest, offering the possibility to use the geotourism itineraries recently designed by the Regional Park of Aveto (Faccini, 1999; Faccini & *alii*, 2000) or to visit environments rarely touched by mass tourism and discover underground caves that are still intact.

A total of about thirty natural caves of horizontal or vertical extension have been inventoried, and include both active and fossil caves and two important macroforms.

The following are caves that merit special mention owing to their scientific importance, often serving as keys for an interpretation of the geomorphological evolution of the valley: the Ciocca cave situated above Pontori; the Rocca Roncallo cave, with its entrance facing Cassagna; the Bossea cave situated along the axis of Graveglia stream (Faccini & Robbiano, 2001); the Cà Freghè cave in Statale Valley, which has recently become popular with tourists (Faccini, 1998; Faccini & *alii*, 2007); the Sorgente della Madonna cave at the foot of Mt. Coppello, which also serves an important function as the outlet for the waters draining from the carbonate Mt. Coppello-Mt. Chiappozzo massif (Benedettini & *alii*, 2002; Faccini & *alii*, 2005).

Among the macroforms, we note the well-known Pian di Oneto doline (fig. 11), the largest doline in eastern Liguria, also classified as a «natural monument» by the Regional Park of Aveto, and the Rocca Roncallo doline. The first one is a large karst depression near the Vara Valley watershed and it has been studied for some time (Maifredi & Pastorino, 1973; Faccini & *alii*, 2005). It presents an active swallow hole on the western side of the plain and a spring on the opposite eastern front. During the rainiest periods, the entire depression turns into a marsh, with growth of typical vegetation. The smaller Rocca Roncallo doline represents a sunken part of the cave roof opposite the cave that bears the same name. Various studies and surveys are still being conducted there.

The valorisation of the karst phenomena present in Graveglia Valley, for the purposes of geotourism, is certainly aimed at building towards a better understanding of the territory in this sector of the Ligurian Apennines. However, it is also a tool that must necessarily safeguard this environment, particularly regarding the management and planning of the water resources and the fundamental role of the karst aquifers.

FIG. 11 - Panoramic view of Pian di Oneto karst-tectonic depression; between the basalt of Costa Riasola (A) and limestones (B); active swallow hole (C). The geomorphological evidence observed from Costa Riasola to Casoni di Chiappozzo seems to indicate a deep-seated gravitational slope deformation.

ANTHROPOGENIC LANDFORMS

Human activity in Graveglia Valley is of wide scope, especially as concerns all of the various activities carried out in connection with the exploitation of minerals and stone characterizing most of the previous century. In fact, the manganese mines and to a lesser degree, the sulfide mines have been of great importance in the social and economic history of the valley - sometimes even determining the development of human settlements near the deposits, as in the truly exemplary case of the Cassagna hamlet. The development of historic villages, widely distributed throughout the area, and more importantly the development of main and secondary roads was influenced by the practical necessity of being able to reach the mining sites or areas suited to agricultural activity.

MINING SITES

All of the numerous manganese mines in the valley (Gambatesa, Molinello, Mt. Bossea, Cassagna, Statale, Pontori, Nossiglia, Mt. Porcile, Mt. Bianco) are found within the Cherts of Mt. Roccagrande: detrital green cherts, hematitic cherts, varicoloured cherts and pelitic cherts distinguished on the basis of chemical and mineralogical composition and genetic significance (Marescotti & Cabella, 1996).

The manganese mineralizations, which are found within the hematitic cherts, near the bottom, have been distinguished into four principal types (Marescotti & Frezzotti, 2000): striped, lenticular and in boudins, fractured and in thin films.

The most extensive and economically more important mineral deposits are found in the core of the plurimetric (lenticular) folds or along their limbs (in boudins). They vary in dimensions and sometimes reach substantial volumes, as in the case of the one exploited in the Gambatesa mine.

The discovery of manganese deposits of a certain importance in Graveglia Valley in the second half of the 1800s led to the petition for the first concession granted in 1876 to the french engineer August Fages; intensive extraction began only in 1901, following the completion of the infrastructures and roads required for transport of the extracted mineral. Over the years that followed, mining concessions were granted to various mining companies, among which Ferriere Voltri, ILVA, Ferromin and Italsider. In the period from 1876 to 1990, extraction from the group of mining sites in the valley amounted to over 1,300,000 t of the commercial mineral with a 28%-30% manganese content. Peak production levels (coinciding with a maximum of 620 employed mine workers) were recorded in the 1936-1946 wartime decade, and after an abrupt decline, also in the twenty-year period between 1950 and 1970.

Production between 1942 and 1952 represented about 80% of national production and in 1970 the 54,000 t extracted constituted the total domestic output. In 1974, the mine concession holder Italsider closed the mines and relinquished the concession. Sil.Ma s.r.l. was founded in 1976 and obtained a new concession. Extraction resumed, although in fewer mines (*i.e.*, Gambatesa, Molinello, Cassagna, Mt. Bossea and Mt. Bianco) and with a limited number of employed workers. Since 1976 only the Gambatesa, Molinello and Cassagna mines have been worked and since 1990 the total output of about 10,000 t/year has dropped to about one-tenth of that amount (Marescotti & *alii*, 2005).

Today most of the manganese extracted is transported to the Pian di Fieno plant for the crushing, washing and sorting production phases. The plant is also equipped with a «sink-float» manganese enrichment system, although it is currently out of use. This system exploits the difference in the specific weight of the mineralized rock and low-grade rock. The material to be separated is first ground and washed and then immersed in a fluid medium of known density, where the mineral grains, which are heavier than the medium, sink, and the non-mineralized grains, which are less dense than the medium, float, and can thus be easily removed.

Under Italsider s.p.a. management, the manganese extracted was utilised mainly for use in the steel industry, but also to colour glass and in the production of welding electrodes. The manganese extracted today is used solely for the production of welding electrodes.

The Gambatesa mine has now been reconverted into a mining museum and an educational tourist centre. All of the itineraries include the tunnels used for extraction purposes. Although they have been restored and altered to meet safety requirements, the original characteristics of the tunnels remain intact. The train used for the guided tour travels over the original tracks (fig. 12). The locomotives used by the miners and the passenger cars have been reconstructed with the same undercarriages used for the wagon cars that transported the ore extracted. Access to the mine is situated at 550 m, along one of the six main working levels. From there it is possible to observe a series of development chambers, the largest of which contains a massive orebody that has been completely worked. The ore consisted of a mass of minerals rich in manganese (above all braunite) and presented an irregular shape and dimensions on the order of 200 m in length, 40 m in height e 40 m in width. It supplied about 600,000 t of economically valuable minerals, with an average manganese content of 35%, maximum levels of 52% and minimums of 26%, proving to be the largest orebody ever exploited in Europe. Extraction is currently in progress at 530 m involving the sublevels at 520 m and 508 m.

In Graveglia Valley there are also numerous iron and copper sulfide mine sites, some of which developed over considerable areas underground, although they never reach extensions comparable to the Libiola site in Gromolo Valley nearby. These extraction sites are associated with the pillow-lava basalts and basaltic pillow breccias found along the contact with the serpentinites. The most representative of these sites are one below Mt. Carmona (Le Cascine), the Gambatesa site, where development first began precisely to extract the sulfide deposits, the site N of Reppia

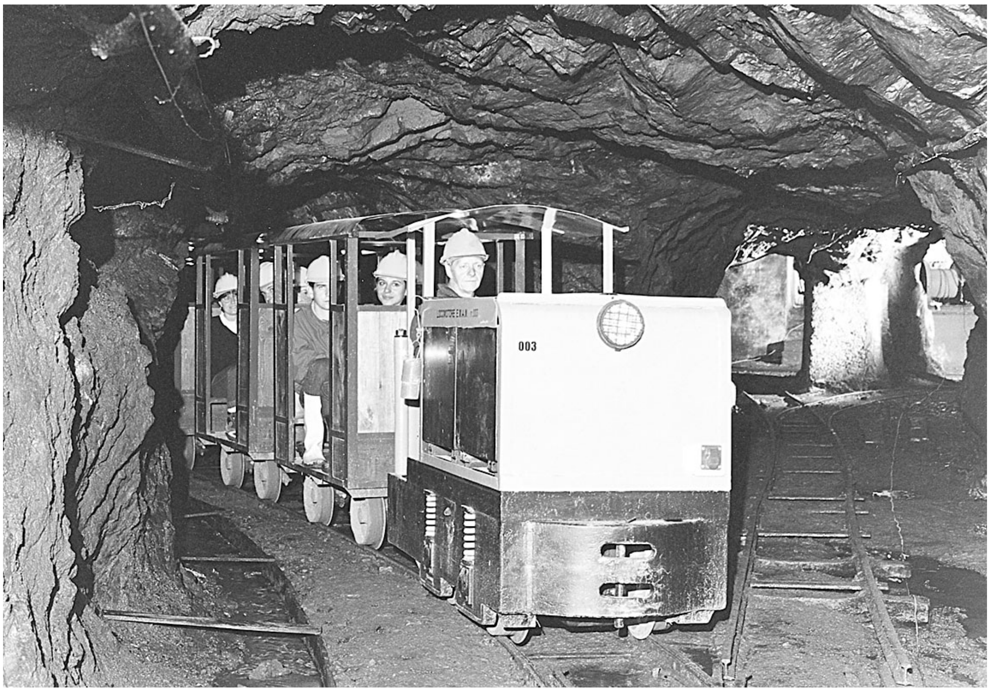


FIG. 12 - Gambatesa manganese mine in the cherts, reconverted into a mining museum and an educational tourist centre.

and the mines located in the sector between Mt. Bianco and Mt. Capra.

QUARRY SITES

Throughout Graveglia Valley there is also widespread quarrying of almost all of the outcropping rock types (Robbiano & *alii*, 2006).

The two most representative quarries in serpentinites consist of one in the locality of Arbisci, in the vicinity of the Reppia hamlet, and another along the road to Zerli, about 300 m beyond the fork at Ponte di Lagoscuro. The latter is currently undergoing environmental reconversion. Copper, iron, nickel and talc deposits varying in importance are often found in association with the serpentinite, which is used as construction material or as ornamental stone.

The ophicalcites in the Iscioli, Campuettin and Nascio quarries differ from the others existing further east and known by the name of Rosso di Levanto, because, in addition to the clasts made up of serpentinites, fragments of gabbros and basalts are present to a lesser degree, as described previously. Owing to their heterogeneous appearance with colours varying according to the nature of the fragments and the cementing fraction, the ophiolitic breccias are used as ornamental stone, in some cases of great value (Cimmino & *alii*, 2003).

Development in the basalts is prevalently localised in the pillow-lava basalts and is generally limited in extension, except for the case of the now environmental reconversion Molana quarry, near Ponte di Lagoscuro.

The products extracted from the basaltic rocks are used as flagstone, as crushed stone for railroads or as aggregate for construction, also constitute the raw material used for the production of mineral wool and glass wool.

Chert quarries are not common and are generally very limited in size. As relates to rustic buildings, an example of which can be seen in the Cassagna hamlet (Brandolini & *alii*, 2004), a characteristic type of plaster is used, obtained using fine chert gravel, mixed with lime, which for the most part is produced locally. This plaster imbues the buildings with a very particular reddish-brown colour, without any use of paints or pigments.

The limestone sites are the most important sites in Graveglia Valley in terms of the number of quarries and the amount of material extracted. Some of the most significant ones are the quarries in the area between Frisolino and Pian di Fieno, along Provincial road no. 26, where several are still operating, and the quarries in the Arzeno area (fig. 13). Given the high silica content and the level of preservation characterising the lithotype, these materials are suited for utilisation in the form of blocks for jetties to protect beaches, or for piers and harbours, and to protect railways, as in the case on the line between Lavagna and Sestri Levante. Finer material is used as aggregate in concrete (Campi & *alii*, 2004). In addition, in Graveglia Valley there is widespread use of these materials for roofing, especially for cottages and other rural structures. Consisting of irregular slabs and of stone tiles, obtained from the thinnest layers, this roofing features a very light colour tone.

There is only one active slate underground quarry, located on the southern slope of Mt. Le Rocchette. There are extraction sites of historical interest on the S. Giacomo and Capenardo mountains, along the watershed ridge behind the city of Lavagna. Extraction dates back to pre-Roman times. Utilisation as roofing slate is the most ancient

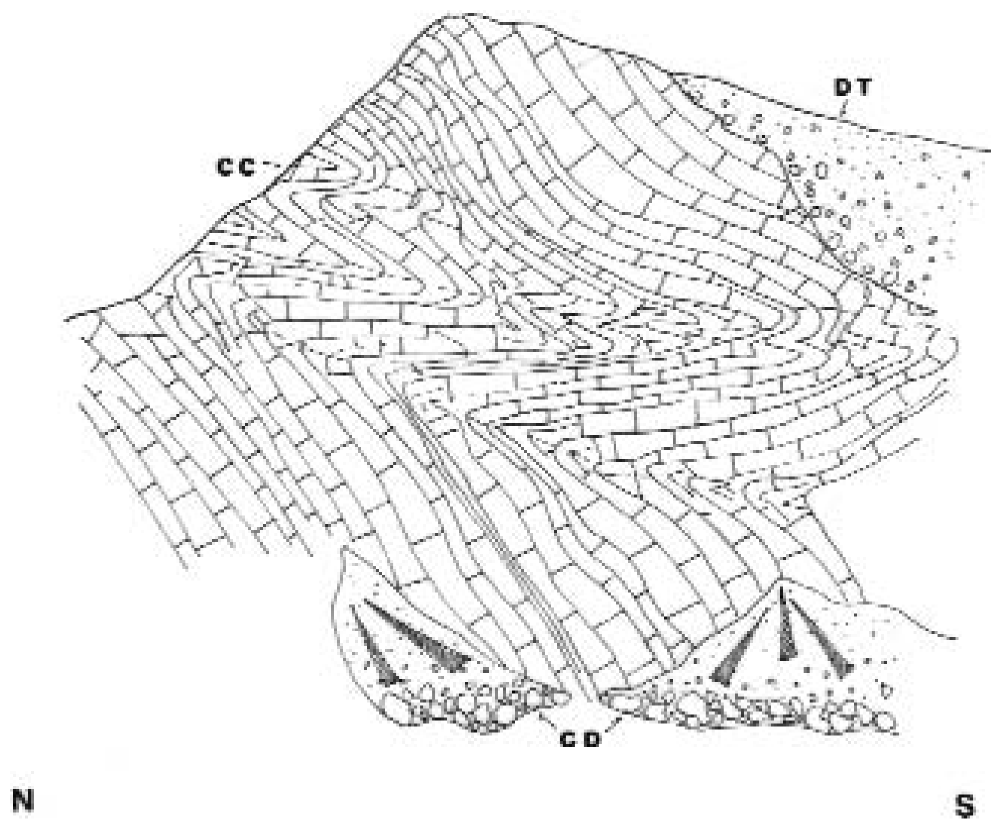


FIG. 13 - Drawing of the Maenche quarry in Prato di Arzeno: cc. limestones; dt. debris covers; cd. talus cone.

and most common use today; the tiles are flat and thin (about 6-7 mm). However, this stone has been used in a variety of ways (Brandolini, 1988; Terranova, 1994; 1996; 2000; Cimmino & *alii*, 2003; Brandolini & *alii*, 2005). In construction, the slate has been laid for thresholds, windowsills, lintels and pilastered doors. More recently, it has been utilised for billiard and pool tables and for decorative objects and accessories such as fireplaces, wells, tubs, benches, blackboards and writing tablets.

AGRICULTURAL TERRACES

Like most of Liguria, Graveglia Valley is characterized by extensive sectors in which the morphology has been modelled by man to obtain terraces for agricultural use. The dry stone terrace walls made of ashlar of varying dimensions and of local origin, sustain cover deposits that have been levelled to obtain level surfaces on steep slopes.

Abandoned terraced areas and those currently in use have been identified in Graveglia Valley. Above all, it is possible to note that the man-made terraces are located and developed on slopes characterised by extensive debris cover derived from clayey, marly, clayey-silty, and calcareous-clayey bedrock and sometimes from basaltic bedrock and very altered basaltic and interconnected breccia bedrock, whereas terraces are a rare occurrence on unaltered basaltic bedrock, and on substrata consisting of serpentinites, gabbros, cherts and sandstones, as the latter are not favourable for crop growth.

The variability of the lithotypes used for the construction of the dry stone walls is interesting to observe. Dry stone walls constructed with perfectly laid ashlar of *palombino* limestone of varying dimensions, shapes and dressings are distributed throughout upper Garibaldo Valley, in the area of Zerli (fig. 14), in Statale Valley, in the zone between the Botasi hamlet and the slopes of Mt. Camilla, and in the area that lies between Passo del Biscia and the slopes of Mt. Chiappozzo. Dry stone walls made with Calcare a Calpionelle ashlar appear around the remains of the Castello di Zerli, on the right-hand side of the lower part of Statale Valley, in the vicinity of the hamlets of Cassagna, Reppia, Case Soprane and Arzeno, as well as in the Casoni di Chiappozzo area.

The northern faces of the San Giacomo and Capenardo mountains are covered with terraces of moderate heights, sustained by dry stone walls built with blocks and slabs of slate and fine sandstones. Over the course of centuries these terraced areas, covering several square kilometres, were used for chestnut cultivation.

The right-hand side of Ne Valley presents many debris covers on the clayey shale and the sandstone bedrock, in favourable positions exposed to the sun; they have been terraced with supporting dry stone walls built with ashlar of sandstone with a sporadic presence of patches of clayey schists. Other areas with dry stone walls of the same type are found on the right-hand side of lower Garibaldo Valley, and on the right side of Graveglia Valley in the area between the hamlets of Conscenti and Frisolino (fig. 14).

FIG. 14 - Panoramic view of terraced slope in Graveglia Valley: in the centre the terraces supported by dry stone walls, on debris covers, utilized for wineyards and vegetables, appear; at outline chestnut-trees prevail.

In more limited areas there are walls in ashlar consisting of additional lithologies, built with limestones, serpentinites, ophicalcites and cherts. They are found in areas close to the contacts between the respective formations, as for example in the areas around the hamlets of Reppia and Iscioli.

As in the rest of Liguria now, but also in other parts of Italy, many terraced areas in a large part of the valley (especially in the areas that are farther away from the villages) have been abandoned and are often in very poor condition, owing to partial or total collapse phenomena, and to disjointing, settling and bulging of the walls. The terraces are also often covered with brush and weeds (Terranova, 2005).

In other zones, especially in the vicinity of towns or the road networks, the terraces and supporting walls are still in good condition and in use for cultivation purposes. Continuous maintenance is therefore carried out on a regular basis.

These terraced areas are of great environmental value because of their structural characteristics, state of preservation and extension, as well as their modelling effect on the slopes. They ensure effective soil erosion control and represent an asset also in terms of our historical and cultural heritage, for they are evidence of an extraordinary human effort to render land areas cultivable.

ENVIRONMENTAL AND GEOTOURISM EMERGENCE SITES

Graveglia Valley is one of the richest zones in Liguria in terms of environmental sites characterized by particular geological and geomorphological features.

These sites were once and are still visited and studied by secondary school students, university students majoring in geology, natural sciences, geography, mining engineering and to a lesser extent other majors as well, and by italian and foreign geologists.

Various sites ranging from geomining points of interest to dry stone structures are indicated on the geomorphological map included here. The geomining sites include the manganese mines in the cherts; among these, the tour of Gambatesa is particularly interesting.

The geological and geomorphological sites include an interesting example of slate outcrops in the locality of Ponte di Gaggia. The limestone are spectacular on the Costa Castellaro, appearing along the valley between the road fork for Statale and Botasi, where they are clearly evident also on the cliffs of the numerous quarries. The cherts are observable along the Provincial road, near Ponte di Lagoscuro where they cross through the valley and particularly in the rocky streambed below.

Spectacular views of the pillow basalt facies can be seen from the road near Ponte di Lagoscuro, where they are clearly visible thanks to the erosive action of Reppia stream.

The serpentinites represent an interesting topic for study and observation. Thus the route along the slopes of Mt. Bossea between Ponte di Lagoscuro and the Zerli hamlet.

As concerns the group of quarry fronts of interest for educational purposes and geotourism, the quarries in the Limestones with Calpionella throughout the valley between the hamlets of Frisolino and Botasi are interesting tour sites. The inactive ophicalcite quarry of Iscioli is a recommended site.

Interesting visits to see meanders and gorges include the George of Lagoscuro, where Reppia stream has incised the pillow basalts (fig. 8), a deep gorge cut into the cherts below Nascio.

Man-made terraces of great interest are found on the slopes of Zerli and Gosita, as well as in the Statale area with dry stone walls made of ashlar consisting of limestone, in the area of the Casoni di Chiappozzo with Limestones with Calpionella ashlar, in the area of Ne and Castagnola with sandstone ashlar, and in the area of Tolceto, Mt. San Giacomo and Case Galla with ashlar made of slate and sandstone.

FINAL REMARKS

The geological heritage of Graveglia Valley is of great interest, offering opportunities for a deeper understanding of geomorphological and geo-environmental topics with a scientific and/or applicative focus. In addition, the presence of the ophiolites lends intriguing originality to the landscape, while the geomorphological processes are characterised by a simultaneous array of attributes of a scientific, cultural, socioeconomic and scenic nature.

The rock outcrops found in this overall surface area of 65 km^2 vary greatly in age and composition: serpentinized peridotites, pillow basalts, cherts rich in manganese minerals, karstified limestones, slate extracted in underground quarries, and massive sandstones.

The geomorphological dynamics have determined particularly characteristic landforms and deposits prevalently in relation to gravitational processes, running waters, karst processes and lastly, but not in terms of importance, in relation to human activities.

The cultural value of this area is connected with the ancient settlements in the valley. These settlements were built along the main communication routes, with models of lithology applied to the buildings, structures and dry stone walls built in the area. The remains of castles and other important settlements and infrastructures dating from the Middle Ages are also numerous.

The valley, however, was to gain European renown especially in the 19th century owing to the development of the large mining complexes, which have also left their mark on the economic and historical importance of the valley.

With Graveglia Valley also being so close to the coast, tourism in more recent times has also seen major development, in connection with the well-known geological and geomineral aspects characterizing the area.

Use of all the emergences described is being made possible through the creation of several different guided tour itineraries differentiated on the basis of their geodiversity value. Some have already been designed and completed, such as the Mining Museum of Gambatesa and the educational karstological trail in upper Graveglia Valley. Others have been designed, but are not yet completed, as in the case of the geomineral and geomorphological tour route through the Novelli stream valley and the geological tour route along the Provincial road to Reppia. Additional trail routes can be proposed for tours covering all aspects related to the slate quarries, following the mountain ridge line over the San Giacomo, Le Rocchette and Capenardo mountains, covering aspects related to the Iscioli ophicalcite quarries with a loop trail around Mt. Bianco, and additional historical-cultural and geomineral aspects by means of the itinerary between Statale and Mt. Porcile, the reopening of the old trail used by miners between San Rocco di Zerli, the Mining Museum of Reppia, and also including the Gambatesa mine site.

The geological, geomorphological and geomineral elements are already protected because a portion of the territory has been included in the Regional Park of Aveto and is represented on the Protected Ophiolitic Areas Coordination Board.

Keeping in mind the already existing Mining Museum of Gambatesa as the primary emergence and acknowledging the international uniqueness of the geological and mineralogical elements in this territory, it is hoped that the area will be recognised as a UNESCO geopark for it would provide for further, definitive valorisation of all these aspects.

REFERENCES

ABBATE E., BORTOLOTTI V., GALBIATI B. & PRINCIPI G. (1980) - *Carta geologica delle ofioliti del Bargonasco e dell'alta val Gravegli*a. L.A.C., Firenze.

BENEDETTINI A., BONARIA V., FACCINI F. & ROBBIANO A. (2002) - *Osservazioni e ricerche idrogeologiche presso il complesso carbonatico di M. Coppello-M. Chiappozzo. Grotta sorgente della Madonna (Li 931 GE) - Alta Val Graveglia, Comune di Ne, Provincia di Genova (Liguria Orientale).* Atti del Convegno Nazionale sull'ambiente e sviluppo sostenibile «Le acque sotterranee - risorsa preziosa, poco conosciuta, a rischio», 12-14 Settembre 2002, Rossiglione (GE).

BRANDOLINI P. (1988) - *L'utilizzazione dell'ardesia in Liguria*. Studi e Ricerche di Geografia, 11, 31-85.

BRANDOLINI P., FACCINI F., ROBBIANO A. & TERRANOVA R. (2004) - *Valorizzazione turistica di emergenze geomorfologiche e geominerarie: l'itinerario del Rio Novelli in Val Graveglia (Appennino ligure).* Atti del 2° Convegno Nazionale Geologia e Turismo, «Opportunità nell'economia del paesaggio», Bologna 3-4 Novembre, Vol. 2, 142-144.

BRANDOLINI P., LAGOMARSINO R., NICCHIA P. & TERRANOVA R. (2005) - *Recupero e valorizzazione turistica di emergenze geomorfologiche ambientali e storico-culturali nelle aree delle ardesie interessate da attività estrattive nell'Appennino ligure*. In: R. Terranova, P. Brandolini & M. Firpo (eds.), «La valorizzazione turistica dello spazio fisico come via alla salvaguardia ambientale», Pàtron, Bologna, 41-86.

CAMPI G., CIMMINO F., FACCINI F. & ROBBIANO A. (2004) - *Il Calcare a Calpionelle, una tipica georisorsa ligure.* Quarry and Construction, 8, 95-99.

CIMMINO F., FACCINI F. & ROBBIANO A. (2003) - *Stones and coloured marbles of Liguria in historical monuments.* Periodico di Mineralogia (Special Issue 3: a showcase of the Italian research in applied petrology), 73, 71-84.

COBIANCHI M. & VILLA G. (1992) - *Biostratigrafia del Calcare a Calpionella e delle Argille a Palombini nella sezione di Statale (Val Graveglia, Appennino ligure).* Atti Ticinensi di Scienze della Terra, 35, 199-211.

CORTEMIGLIA G.C., MARCONI G. & TERRANOVA R. (1970) - *Lineamenti geomorfologici dell'alta Val Graveglia (Liguria orientale)*. Ferrari-Occella, Alessandria, pp. 31.

FACCINI F. (1998) - *Ambienti carsici nell'alta Val Graveglia: la tana di Cà Freghé*. Canessa, Rapallo, pp. 16.

FACCINI F. (1999) - *Zone carsiche: l'esempio della Val Graveglia per la tutela e la fruizione a fini scientifici e naturalistico-didattici*. Atti del 4° Convegno sulla montagna ligure e mediterranea «Il mare in basso», 22-30 Ottobre 1999, Torriglia.

FACCINI F., MARESCOTTI P. & ROBBIANO A. (2000) - *La Val Graveglia, un tesoro geologico nell'Appennino ligure*. Ente Parco dell'Aveto, Fassicomo, Genova, pp. 112.

FACCINI F. & ROBBIANO A. (2001) - *La grotta Bossea PMD1 nel quadro dell'evoluzione geomorfologica della Val Graveglia (Appennino Ligure).* Rivista di Storia e Cultura del Territorio, 5, 225-235.

FACCINI F., BRANDOLINI P., ROBBIANO A. & TERRANOVA R. (2005) - *Valorizzazione turistica e salvaguardia ambientale dei siti d'interesse carsico nella Val Graveglia (Appennino Ligure).* In: R. Terranova, P. Brandolini & M. Firpo (eds.), «La valorizzazione turistica dello spazio fisico come via alla salvaguardia ambientale», Pàtron, Bologna, 160-188.

FACCINI F., BENEDETTINI A. & SIVORI L. (2007) - *Pericolosità geomorfologica, ambiente carsico e fruizione turistica: il caso della tana di Ca' Freghé (alta Val Graveglia, Appennino ligure).* In: M. Piccazzo, P. Brandolini & M. Pelfini (eds.), «Clima e rischio geomorfologico in aree turistiche», Pàtron, Bologna, 207-222.

GARDINI A., ODETTI G. & PASTORINO M.V. (1992) - *Piccola cavità frequentata nel medioevo in Provincia di Genova*. Studi Genuensi, 10, 17-25.

MAIFREDI P. & GIAMMARINO S. (1968) - *Osservazioni idrogeologiche sulle risorgenti del Rivo Orti nell'alta Val Graveglia (Provincia di Genova).* Atti dell'Istituto di Geologia dell'Università di Genova, 6 (1), 3-20.

MAIFREDI P.& PASTORINO M.V. (1970) - *Nuove ricerche sulla sorgente Molinello (alta Val Graveglia, Provincia di Genova).* Atti dell'Istituto di Geologia dell'Università di Genova, 7 (2), 402-413.

MAIFREDI P. & PASTORINO M.V. (1973) - *Contributo allo studio morfologico delle depressioni carsiche in Liguria: 2) Il «Prato d'Oneto», nell'alta Val Graveglia (Liguria orientale).* Atti XI Congresso Nazionale Speleologia, Memorie. Rassegna Speleologica Italiana, 281-284.

MARESCOTTI P. & CABELLA R. (1996) - *Significance of chemical variations in a chert sequence of the «Diaspri di Monte Alpe» Formation (Val Graveglia, Northern Apennine, Italy).* Ofioliti, 21 (2), 139-144.

MARESCOTTI P. & FREZZOTTI M.L. (2000) - *Alteration of braunite ores from Eastern Liguria (Italy) during syntectonic veining processes: mineralogy and fluid inclusions.* European Journal of Mineralogy, 12, 341-356.

MARESCOTTI P., LUCCHETTI G. & PATRONE F. (2005) - *Valorizzazione dei siti minerari dimessi: il Museo Minerario di Gambatesa (Val Graveglia, Liguria), un'esposizione sotterranea di mineralogia e storia mineraria nel più importante giacimento italiano di manganese.* In: R. Terranova, P. Brandolini & M. Firpo (eds.), «La valorizzazione turistica dello spazio fisico come via alla salvaguardia ambientale», Pàtron, Bologna, 145-158.

ROBBIANO A., BRANDOLINI P. & FACCINI F. (2006) - *Valenza geoturistica delle attività estrattive nella Val Graveglia (Appennino ligure).* In: S. Salgaro (ed.), «Scritti in onore di Roberto Bernardi», Pàtron, Bologna, 283-298.

SOCIETÀ GEOLOGICA ITALIANA (1994) - *Appennino ligure-emiliano. Guide geologiche regionali.* BE-MA, Milano, pp. 382.

TERRANOVA R. (1966) - *La serie cretacea degli «argilloscisti» fra le valli dei torrenti Entella e Petronio (Appennino Ligure).* Atti dell'Istituto di Geologia dell'Università di Genova, 4, 109-174.

TERRANOVA R. (1994) - *Le ardesie della Liguria: dalla geologia agli aspetti ambientali e culturali.* Atti VIII Congresso del Consiglio Nazionale dei Geologi, Roma, 313-324.

TERRANOVA R. (1996) - *Le cave di ardesia in Liguria: geologia, coltivazioni, lavorazioni e utilizzazion*i. Memorie della Società Geologica Italiana, 51, 1165-1177.

TERRANOVA R. (2000) - *Lithologie appliquée aux constructions en pierre seche de la zone des ardoises cretacées en Ligurie orientale (Italie).* Actes du VI Congres International sur la pierre séche «Pierre seche: regards croises». Carcés, Le Val (France), 24-27 septembre 1998. Supplemente N° 8 au Caire de l'Aser, 21-24.

TERRANOVA R. (2005) - *L'abbandono dei versanti montani terrazzati e i dissesti geomorfologici: una grave perdita di valori ambientali di grande pregio.* In: R. Terranova, P. Brandolini & M. Firpo (eds.), «La valorizzazione turistica dello spazio fisico come via alla salvaguardia ambientale», Pàtron, Bologna, 129-143.

(Ms. received 30 April 2006; accepted 30 December 2006)