GEOMORPHOLOGICAL MAPPING OF THE SAN LORENZO AREA SANT'ARCANGELO REGION SOUTHERN ITALY

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ABSTRACT

The study area is located in the Sant'arcangelo region, Southern Italy. The area was developed from late Pliocene to middle Pleistocene in the southern part of the Apenines chain. It has also been defined as a piggy back basin filled with siliciclastic deposits, controlled by sedimentary tectonic activity.

This article aims to identify the geological condition and generating geomorphological map for San Lorenzo area using aerial photo (scale 1:15000) and Panchromatic SPOT image (Scale 1:66000). Image interpretation was also done to identify morphological, structural and processes.

The Sant'Arcangelo region is composed of 4 cycles both marine and continental in origin, all deposited on different environments: The Caliandro, Agri, San Lorenzo and Sauro cycles. The study area consists of Sauro and San Lorenzo Cycle. Sauro Cycle is comprises of three heterotrophic units deposited in sintectonic discordance over the Agri cycle. San Lorenzo Cycle lying in unconformity over the precedent cycles is consisting of three units, namely conglomerates on the base part as well as on the top part of the sequence, and silty clays in the intermediate part. They form a syncline structure which ax has a NW-SE direction. The main structural features are represented by the San Lorenzo syncline and the Alianello fault. The San Lorenzo area has three principal origins: alluvial, denudation, and structural. Due to the geological-tectonic complexity, the structural landform is normally found as structural denudational landform. San Lorenzo area comprises of 41 landform units, namely 3 units of alluvial landform, 26 units of denudational landform and 11 units of structural denudational landform.

Keywords: Geomorphological mapping, San Lorenzo area.

INTRODUCTION

Geomorphology as a study of a given region implies the analysis and description of the landforms and their development processes together with the relationships between those forms and processes in their spatial arrangement over time. Normally, information pertaining the physical processes and terrain condition is depicted in a geomorphological map. This is particularly true where information is required concerning the distribution of landforms, soils, and rock materials, or features created by surface processes. The aim of geomorphological mapping is to record information on surface form, material (soil and rock), surface processes, and (in some cases) the age of landforms. Geomorphological mapping, in the context of environmental management, is carried out for three principal reasons: 1) to enable the geomorphologist to obtain a better understanding of the landscape before giving advice, 2) to provide a map record of landscape characteristics relevant to the project in hand, and 3) to provide an essential basis for derivative and special-purpose maps. (Cooke, *et al.*, 1990). Geomorphological approach and mapping is increasingly being applied in many areas, by for instance Agarwal, (1999), Garcia *et al.*, (1999), Mangunsukardjo., (1999), Nossin *et al.*, (1986), Pradesh *et al.*, (1999), Sartohadi, (1998), Stakenborg, (1986), Sutikno, (1994), and Verstappen, (1995).

The carry on of a geomorphology assessment involves a detail analysis based on the remote sensor imagery increase the efficiency. Higgit *et al.*, (1999) have argued that remote sensing techniques are providing fresh insights in geomorphology in four main ways:

a) They provide new applications for geomorphology;
b) They provide new and improved accuracy of measurement;
c) They provide new data that allow investigation of ideas that were previously untestable;
d) They involve development of data processing capability.

The study area (San Lorenzo) is situated near to Potenza city and between two small towns, Aliano town on the Northen part and Alianello town in the Southern part. The study area has particular climatic condition, that are influenced by its orographyc nature and by its proximity to two seas: Tyrrhenian and Gulf of Taranto. There is a typical Mediterranean climate characterised by scarce rainfall concentrated during the autumn-winter period and by heavy summer drought (Verstappen, 1983). There is a temperate-cold climate, with mild dry summers, while a cold and rainy climate is found at the higher zones and towards the Tyrrhenian Sea.

Regarding land cover, the study area is dominated by agriculture vegetation and pastureland. Some crops, such as fruit orchards and corn are planted on the mountainous and hilly parts of the area. On the middle part of the San Lorenzo area is cultivated with cereals, especially on clay-rich soils. The location of study zone in a hilly and mountainous area has soil degradation, erosion, and landslide as dominant denudative processes. Figure 1 shows the location of the study area.

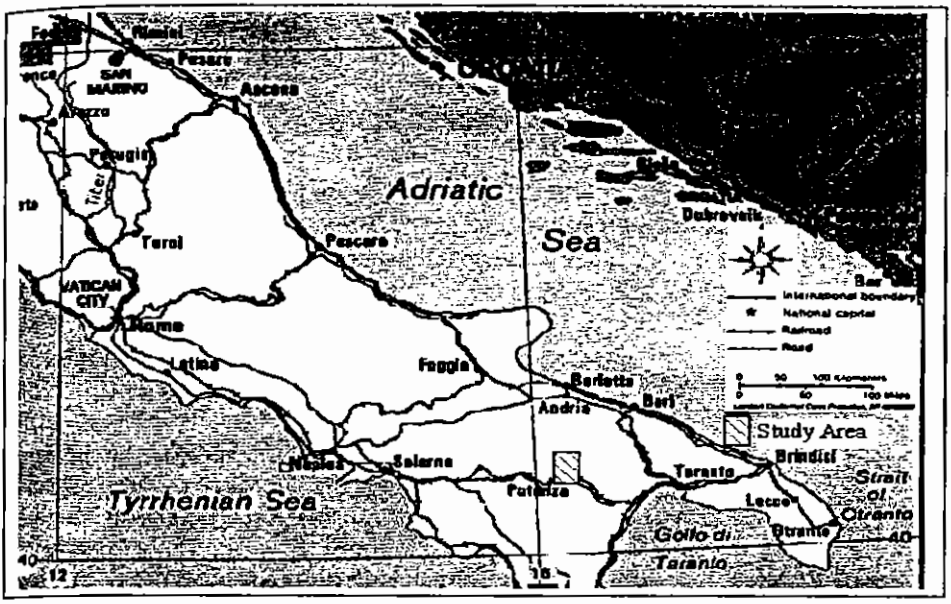

Figure 1. San Lorenzo area

Geomorphological hazard survey and mapping in Sant'arcangelo region Southern Italy was conducted by the Department of Earth System Analysis (Natural Hazard Specialisation, Earth Resources and Environmental Geoscience Program study) International Institute for Geo-Information Sciences and Earth Observation (ITC), Enschede, The Netherlands, in June 2002. The article is part of the survey and mapping specifically in the San Lorenzo area, for which remote sensing data aerial photo and supplemented by spot imagery were used. Fieldwork has been done to identify physical condition and map checking. This article aims to identify the geological condition and generating geomorphological map in San Lorenzo area.

METHOD

Images interpretation using aerial photo (scale 1:15000) and Panchromatic SPOT image (Scale 1:66000) has been done to generate the tentative map as a base for fieldwork. Image interpretation was also done to identify morphological, structural and generate preliminary map in which were also identified, both landslide and erosion process. Fieldwork has been carried out to check and evaluate the accuracy of the interpretation results. Re-interpretation base on the fieldwork data and generating the digital map of geomorphology map have been done using GIS software (ILWIS). To identify the geomorphological units in the digital processing, the legend of geomorphological map transferred into the digital

number code. The legend and digital number code of geomorphological map presented in Appendix 1.

RESULTS AND DISCUSSION

Geology condition

From the geological and structural point of view, The San Lorenzo area is located in the Sant'Arcangelo Basin, which was developed from late Pliocene to middle Pleistocene in the southern part of the Apenines chain. It has also been defined as a piggy back basin filled with siliciclastic deposits, controlled by tectonic activity.

The Sant'Arcangelo Basin is composed of 4 cycles both marine and continental in origin, all deposited on different environments: The Caliandro, Agri, San Lorenzo and Sauro cycles (Sabato 1997). Sauro Cycle is compound of three heterotrophic units deposited in tectonic discordance over the Agri cycle. These three units are Silty clay, Sands and conglomerates. The cycle represents a fan delta system with faces that is very heterogeneous type from proximal to distal. In the western part of the study area, it is possible to find the intermediate sandy within outcropping along the left side of the valley. Those sands have different characteristics, i.e. from coarse to fine grain, massive to flat parallel or oblique, the thickness of bedding layers is around 8 to 10 m and interlayer with levels of matrix-supported conglomerates and silts with macrofossils. This material represents the underwater part of a delta fan. The age of this cycle is early Pleistocene to middle –late Pleistocene.

San Lorenzo Cycle lying in unconformity over the precedent cycles is consisting of three units, namely conglomerates on the base part as well as on the top part of the sequence, and silty clays in the intermediate part. They form a syncline structure whose ax has a NW-SE direction. The units conform a Fluvio-lacustrine system and have been dated as early Pleistocene.

According to Pieri *et al.*, (1996), the lower unit represents the terminal part of an alluvial fan and consists of tabular layers of clast - supported by conglomerates with a thickness up to 10 m with levels of silty sand. In general, the thickness of this part is 150 m. In the lower part of the area, outcrops can be seen near to debouch of the San Lorenzo River. The intermediate unit is conformed by silty clays, clays and silts layers. The silt layer has a thickness of almost one meter. Total thickness on the intermediate unit is 200 m. Typical Characteristic and process of this area is undulate to flat-parallel rhythmic laminations, bio-turbation, and slumps. Inside the silty layers, it is possible to found gastropods and ostracods, vertebrata bones and plants. There are also intercalations of volcaniclastic and products a thickness from centimeters to decimeters. This member represents a continental environment with swampy to lacustrine. It outcrops took place along the lower part of the road to Aliano village via Alvanello.

The upper unit probably conforms the terminal unit of the lacustrine regression and represents an alluvial fan environment. It is made of conglomerates with reddish sandy matrix, sandy conglomerates, and sand layers on the base. The thickness of conglomerates

with reddish sandy matrix, and sandy conglomerates reaches almost 100 m. In this area, this member has been strongly removed from erosion, the remaining outcrop is near to Santa Maria stella. The quaternary is represented by thick Colluvial deposits from the numerous and complex denudative process taking place over the rocks of the different cycles. Detail information about geological condition and litho-stratigraphic log and main facies characteristics of the entire San Lorenzo Cycle is shown on Figure 2.

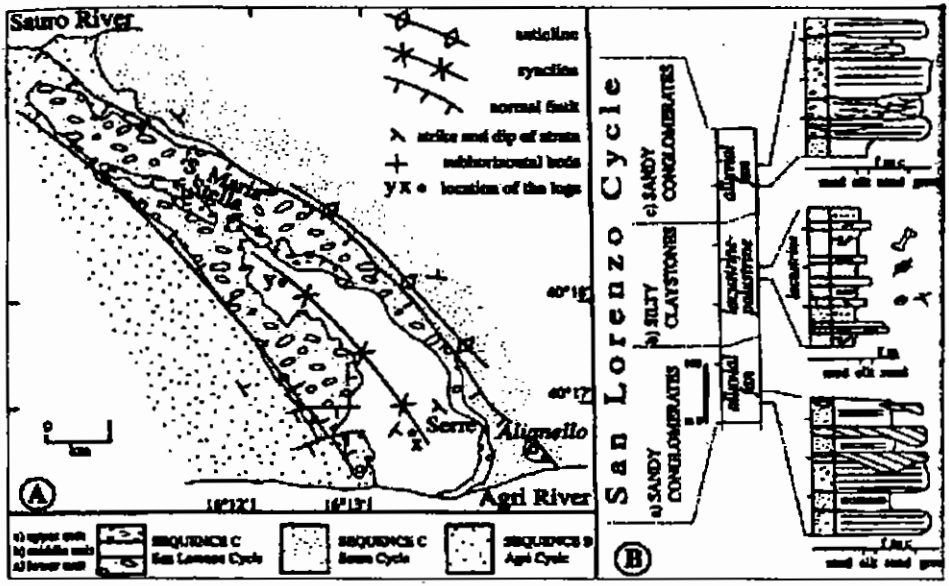

Figure 2. Geological map (A) and Litho-stratigraphic log and main facies characteristics of San Lorenzo Cycle Schema and Geological Column (B) (Pieri *et al.*, 1996).

Structural Features

The Sediments infilling the basin are affected by many structures, both of sedimentary compression and extensional type. In the study area the main structural features are represented by the San Lorenzo syncline and the Alianello fault. There are also several lineaments belonging to the major regional trends with N-NE, E-W, and N-NW directions.

San Lorenzo syncline with N20W trend is a compression structure, which was very active during the deposition of the San Sauro and San Lorenzo cycles, confirmed between others by some characteristics of the lacustrine deposits as slumps and other soft-sediments deformations structures. The ax of this structure is slightly remarkable in aerial photographs, but it was difficult to take any measure of the dip angle of the strata due to the uncertainty of *in situ* outcrops. Figure 3 is shown the block diagram of San Lorenzo area.

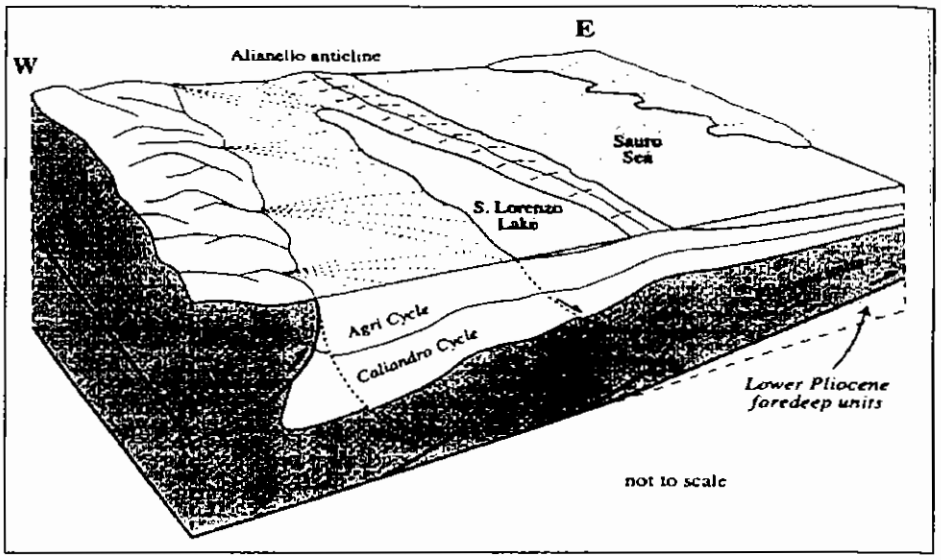

Figure 3 Block diagram of San Lorenzo area (Sabato, 1997)

In the Alianello Town is possible to observe a small anticline structure formed by the compression tectonic affecting to the region. The Alianello fault is N15W trending and affect event he youngest deposits of the San Lorenzo and Sauro Cycle. It shows main strike slip movement with left lateral component and reactivation during middle–late Pleistocene. In the area this fault has giving rise to the hills of bataglia ridge and constitutes the faulted contact between the Sauro and San Lorenzo cycles.

Geomorphological mapping

Geomorphology is the study which genetically describes the landforms and processes on the earth surface and investigates the interrelationship of these forms and process in their spatial arrangement and which seeks to explain the environment context in which they occur (Van Zuidam, 1976). From the geomorphic point of view, the study area is composed by three three principal origins:

- Alluvial (fluvial process)
- Denudative
- Structural

Due to the geological-tectonic complexity, the structural landform is normally found as structural denudational landform.

Alluvial Units

The alluvial form is found along the two small intermittent rivers on the area. The alluvial unit sited on the small part of the southern part of San Lorenzo area. The alluvial landform of the area comprise of three units, namely; *Alluvial high terraces (1.2.1.), Alluvial medium terraces (1.2.2.), and (Alluvial low terraces (1.2.3.).*

Denudation Units

These units constituted by the remains of the hilly and mountainous original relief, which are have been affected by mass wasting and erosion processes. These units are present mainly in San Lorenzo group members. The member of denudational hilltops comprise of; *Denudational Hilltops wide and predominantly flat (2.1.2.), and Denudational Hilltops moderately wide and sloping (2.1.3.)* are located on the upper left and lower right corners of the area, over top conglomerate and intermediate clay members of San Lorenzo Group. They exhibit convex, long and smooth slopes, with inclination angles between 5° and 30°. At the moment there are no evidences of mass wasting or erosion phenomena inside these units, the acting process are more related with weathering and surficial erosion (sheetwash or creep), but their outer boundaries have been wasted by retrograding of headwaters and slides scarps. The landuse correspond to agricultural activities, wheat crops, and isolated shrubs.

The member of denudational Steep slopes comprise of; *Denudational Steep slopes with active erosion (2.2.1.1), Denudational Steep slopes with active erosion and landslides (2.2.1.2.), and Denudational Steep slopes without active processes (2.2.1.4.),* are occur preferable on sands and clays of the Sauro formation. They have straight to concave forms with slope angles between 15° and 30° and moderate lengths (50 – 100 m). The 2.2.1.2 unit has gullies in stabilization process. They are used for agricultural activities.

The member of Denudational moderately steep slopes comprise of; *Denudational moderately steep slopes with active erosion (2.2.2.1.), Denudational moderately steep slopes with active erosion and landslides (2.2.2.2.), Denudational moderately steep slopes with active landslides (2.2.2.3.), and Denudational moderately steep slopes without active processes (2.2.2.4.).* All the units have short to moderate slopes (0-100m), with slopes angles between 15° and 30° sometimes until 45°. They are conformed specially from conglomerates of the top and base member of San Lorenzo Group and sands from intermediate member of Sauro Group. The unit 2.2.2.1; 2.2.2.2; and 2.2.2.3 show surficial erosion processes and mass movements type slide, some of them active, the others in dormant state or in stabilization processes. Due to this unstable condition the land mainly used for shrubs and bushes, which grow on the bodies of the old and recent landslides contributing in a certain way to their stabilization.

The Denudational gentle slopes comprise of; *Denudational gentle slopes without active processes (2.2.3.4.).* This unit located on Sierra Bataglia highest parts, in the middle of the study area. It is formed by rounded convex shapes, with smooth and uniform slopes, few degrees of inclination (< 20°), constitute primordially by clays and sands of the intermediate member of San Lorenzo Group. This unit as a whole does not exhibit mass wasting phenomena is shows progressive wasting of the outer boundaries due to successive and retreating slides in the nearest and deepest slopes. The landuse is composed of olives trees, wheat, and other agricultural activities. The Unit of *Denudational gentle slopes with paleolandslides (2.2.3.5.)* is a wide unit, which is constitutes of the nucleus of San Lorenzo syncline, conformed by sands and clays of the intermediate member. It has along (>250 m) and gentle convex slopes (between 5° and 20°), over which have been deposited thick bodies of old flows and slides, probably occurred during the general uplift of the basin or the folding of the syncline structure. Farmers constantly and deeply reshape those deposits with bulldozing and other methods in order to adapt them for productive landuse (wheat cropping). Nowadays there are not active mass movements on the slopes, just some gully incision, and falls due to the cut on the base of the slope for roads. The Unit *Denudational niches (small catchments) without active processes (2.3.4.)* is a small semicircular unit, on the lower right corner of the area, formed over clays and sands of the San Lorenzo Group due to incision process of the runoff water. When these small streams reach their base level, they become stable. The continuous and gentle dipping slopes make these units apt to support crops like wheat.

The member of Denudational valleys comprise of; *Denudational valleys deeply incised with active process on sides (2.4.1.1.), Denudational valleys deeply incised without active process on sides (2.4.1.2.), and Denudational shallow valleys (2.4.2.)* are formed on sands and clays of the Sauro and San Lorenzo Groups. There are small inner valleys with severe and fast dissection processes that have removed the soil layer. Those acting processes encloses rills, piping, and gulling erosion stages due primarily to intrinsic properties of the rocks, differences in permeability between layers, structural disposition of the beds, drastic changes on temperatures through the year and severe modifications of the land cover. They are suffering from advancing, widening, and incising processes. The barren surface, lacked of organic matter, is not able to support any vegetation despite some resistant species of bushes adapted to the semiarid conditions of the area. Figure 4 is shown to give an example about denudational unit in San Lorenzo area.

Figure 4. Denudation units on Sauro Group rocks

Accumulation and building up of new units generally conformed by debris coming from mass wasting phenomena. Among other are: *Scree slopes with active processes (2.5.1.1.), and Scree slopes without active processes (2.5.1.2.).* The units conformed by accumulation of materials, deposited by gravity process at the foot of the scarps. Due to the high porosity, they are suitable to support agricultural activities. Some of them exhibit rill erosion processes due to the cohesionless materials conforming.

The member of Coluvial slopes, namely; *Coluvial slopes with active processes (2.5.2.1.) and Coluvial slopes without active processes (2.5.2.2.)* are accumulations of material, in the media and lower part of the slope, coming from large magnitude mass movements affecting the area trough the geological time. Some of these deposits have been reshaped and adapting by bulldozing, since the last decades, for agricultural activities losing their original and characteristic features, making difficult lacking the recognition and assessment of states, distribution, and styles and rate of activity.

The member of Footslopes, namely; *Footslopes with old debris flows (2.5.5.1.) and Footslopes with active debris flows (2.5.5.2.)* are deposits material. Old (2.5.5.1) and recent (2.5.5.2) deposits conformed by progressive accumulation of alluvial fans, on the intermediate part of the slope, from reworked Colluvial deposits from old slides (now in dormant state). After a few time vegetation growths and consolidate on its organic rich fine deposits. Figure 5 shows the deposits material on the Footslopes unit.

Figure 5. Debris flows deposits

Another denudational landform units, among other are; *Large backscarp (2.6.1.) ,Large backscarp with active erosion (2.6.1.1.),Large landslide area (2.6.2.), and Large flows area (2.6.3.)* are remains of big magnitude ancient slides occurred during the uplift and fold of the entire San Lorenzo Group. Nowadays they are stabilized or dormant, and just exhibit gully erosion processes and reactivation in small sectors of the main scarp (2.6.1.1), possibly caused by the cutting for a road to Aliano. Due to the deep slopes, they have not been adapted for agriculture and the landcover is conformed by shrubs and bushes, just the large flows unit have been reshaped and extensively cropped with wheat. Furthermore, badland unit (2.6.4. *Badland area)* is extensive phenomena involving soil and surficial material been removed by runoff and overland flowing water. Badland area with severe processes of rill, gulling and piping erosion developed on the clay member of the San Lorenzo Group. The processes of rill, gulling and piping erosion preferable on faceslopes units moderately steeping, with high exposure to sunlight but also in slopes with gentles dips. This kind of terrain is bulldozing and ploughed by farmers trying to stop the process and recover them for agricultural activities, but in many cases, they become barren areas with some bushes on the inner dipslopes. On the Sauro Clay member, they developed on sharp cliffs that are almost absolutely lacking of vegetation.

Structural Denudational Units

Structural denudationals are units with strong influence of geologic structures in their origin, development, and appearance. The influence of such geologic structures ranges from larges features, which exert a dominant influence on the form of the entire landscape, to small features, which affect individual landforms and the geomorphic processes operating on them.

In the study, area they are related to the tectonic settlement of the whole Sant'Arcangelo basin, and are manifestation of the active tectonic processes which were taking place such as uplifting, faulting, and folding, which control the present mass wasting and erosion processes of the slopes. The member of Structural denudational, namely; *Structural denudational dipslope (3.1.1.), Structural denudational dipslope with active rill erosion (3.1.1.1.), and Structural denudational dipslope without active processes (3.1.1.2.)* are conformed by asymmetric ridges related to backslope of strata sets in folded and faulted formations. These units have symmetric shapes and sharp edges, moderately to long straight slopes (100-250 m), moderately dipping (between 20° to 45°) are shown on Figure 6. Developed on sands and clays of the Sauro Group, they are very prone to be affected by large and shallow mass movements like translational slides and complex flows, which bodies slide controlled by bedding planes and accumulate in the lower part of the structural valley slope. Those debris deposits are not removed very fast due to the lack of permanent streams or flowing water trough the year, but in rainy seasons they are very prone to be removed and the whole slide can be reactivated.

In those units with active or very recent slides the landuse is constituted by bushes and shrubs. The bushes and shrubs are progressively cover the remaining bodies helping to their protection against rill and gully erosion. But, in those already stabilized or without processes is possible to find agricultural activities and olive trees cultivation.

Figure 6. Sharp edges and dipslopes of structural denudational units

The structural unit, namely *Structural denudational slopes without active processes (3.1.1.4.)* is related in origin with stratified and uplifted formations, but they do not develop bedding or preferential pattern of landscape (like dip or face slopes), but the mass wasting and erosion processes are related weakness of the rock units due to faulting and joints. They show few slides and the existing ones are dormant or already stabilized. The landcover consist on agriculture.

The member of Structural denudational slopes, namely; *Structural denudational slopes with active erosion (3.1.1.5.) and Structural denudational slopes with scarps (3.1.1.5.)* are units formed especially on Sauro Group rocks. Those units are consistent in deep, sharp and straight escarpments (more than 50 m high), like remains of severe mass wasting and erosion, retrograding of the valley sides, or by undercutting of the former and original slope. On the faces of the escarpments, rill and gulling erosion and rock falls are taking place adding an extra hazardous element to the area. These units are between other surrounding the locality of Aliano and progressively have been destroying the infrastructure (roads, electric connection and poles etc) and isolating the oldest part of the village. Figure 7 illustrates the condition in structural scarps near to Aliano village.

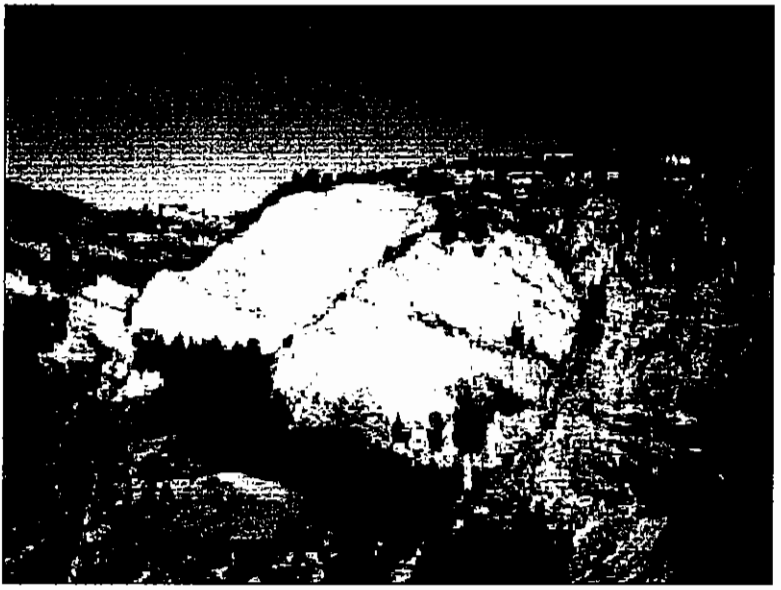

Figure 7. Structural scarps near to Aliano village

Unit *Structural denudational faceslopes (3.1.2.) and Structural denudational faceslopes with active erosion (3.1.2.1.)* show almost the same features as the previous ones but are developed on the faceslopes of stratified rocks (sands and clays) of Sauro Group. It is formed by sharp, deep (between 50-100m high) and barren cliffs with active processes of riling, gulling and translational slides, and rock falls. Some of them are relatively stabilized and can hold bushes or shrubs vegetation especially along the contacts of different rock units where some percolating water can be found. The retrogressive advance of these units has wasted the upper units located on faceslopes and increasing the instability in the surrounding areas.

Unit *Structural fault scarp with active erosion (3.1.3.1.) and Structural fault scarp without active processes (3.1.3.2.)* are developed on the face of the scarp left by normal faulting (Allianello fault). The slope of the units is moderate (500-100 m) with constant and steep dipping (up to 50°) They are related to differences in lithology due to the contact between sauro and San Lorenzo formations. The unit 3.1.3.2. and 3.1.3.2. have no active mass wasting process, it is maybe due to high slope angles in which the soil layer is thin or inexistent, or the soil layer have been already removed.

Unit *Structural denudational slope related to lithological differences* (3.2.1.) is a small unit located on the base of the intermediate member of the San Lorenzo Group. It is compose by thick and massive beds of sands and clays dipping towards Norwest (axe of the San Lorenzo syncline). The soil has been removed and the bare rock is exposed. Processes like rock fall and translational slides take place along bedding surface. The Geomorphological map of San Lorenzo area is shown on Figure 8.

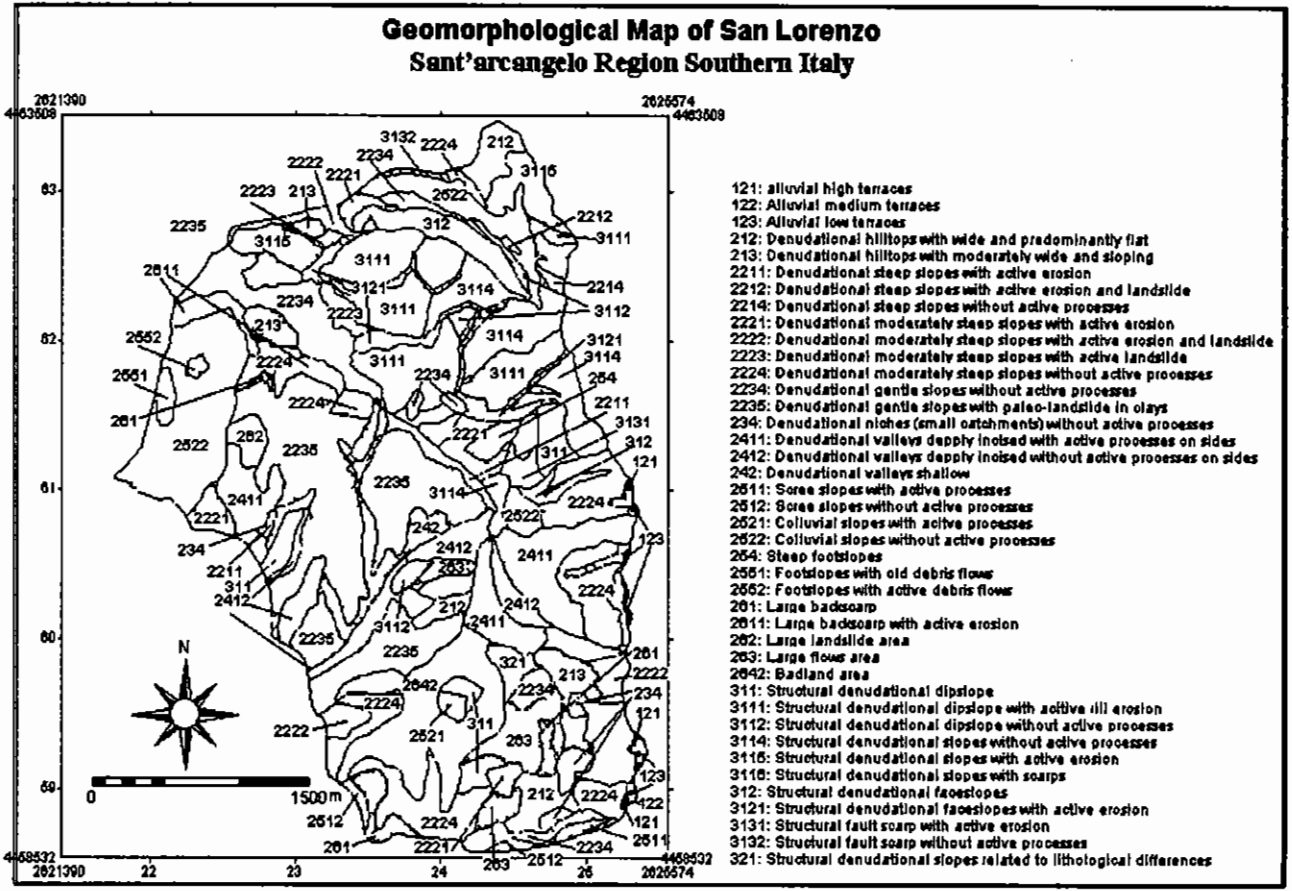

Figure 8. Geomorphological maps of San Lorenzo area

CONCLUDING REMARKS

Geomorphology analyses cover many topics related to landforms, their development processes and their environmental conditions. The geomorphology map has appropriately shown the information concerning the distribution of landforms, soils, and rock materials, or features created by surface processes, which is very necessary for environmental assessment. Aerial photo and spot imagery as a remote sensing data is very helpful in geomorphological survey and mapping. This is due to the advantages of remote sensing data, which can provide information without directly contacting with the object itself.

The study area consists of Sauro and San Lorenzo Cycle, which is compound of three heterotrophic units deposited in sintectonic discordance and in another place (San Lorenzo cycle) is consisting of three units, namely conglomerates on the base part as well as on the top part of the sequence, and silty clays in the intermediate part. The San Lorenzo area comprises 3 units of alluvial landform, 26 units of denudational landform and 11 units of Structural denudational landform with the dominant processes are landslide and erosion.

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