QUINTA GIORNATA RICERCA GIOVANI

26 Febbraio 2009

Dipartimento per lo Studio del Territorio e delle sue Risorse, Università di Genova

PROGRAMMA

<u>SESSIONE 1</u>: TUTELA E GESTIONE DELL'AMBIENTE E DEL TERRITORIO
Chairperson: Gianluca Gola

10.20 – *Sergio Aicardi*: Water catchment by deep reservoir in fractured rocks: the case of Bric Colombino (Western Liguria – Italy)

10.40 – *Anna Roccati*: Movements detection of deep gravitational slope deformations by means of PSInSAR™ data: the case study of some historical settlements in upper Aveto valley (Ligurian Apennine)

11.00 – *Ileana Balduzzi*: Submarine quarry of Albenga-Loano: a sand and gravel source for beach nourishment

11.20 – *Chiara F. Schiaffino*: Use of remote sensing to evaluate the shore protection work efficacy. The case of Levanto (La Spezia, Italy)

11.40 – Pausa caffé

12.00 – *Matteo Vacchi*: Mapping and assessing the underwater geomorphosites. The case study of Sigri bay (Lesvos island, Greece)

12.20 – *Alessandro Sacchini*: Climate as a georesource. examples from Ligurian region

12.40 – Pausa pranzo

<u>SESSIONE 2</u>: RICOSTRUZIOBE DEI PROCESSI GEOLOGICI ANTICHI E RECENTI
Chairperson: Ileana Balduzzi

14.20 – *Cristina Malatesta*: The exhumation of HP rocks (Voltri massif, Ligurian-Piemontese units): from natural evidences to numerical models

14.40 – *Roberto De Ferrari*: The reconstruction of the geometries of the sedimentary sequences in the Bojano basin (Campobasso province) by an integrated interpretation of geologic, geomorphologic and geophysical data

15.00 – *Matteo Padovano*: Modeling of the Variscan gneiss dome emplacement in NE Sardinia (Italy)

15.20 – *Ivano Rellini*: Preliminary observations about macroscopic and cryogenic structures in the soil and their paleoenvironmental significance (M. Beigua, Liguria, Italy)

15.40 – *Francesca Ferraris*: Long profile modeling: the case study of Piota river basin (Ligurian Alps)

16.00 – Pausa caffé

SESSIONE 3: MODELLI FISICI DEI FENOMENI NATURALI
Chairperson: Ivano Rellini

16.20 – *Andrea Zunino & F. Benvenuto*: Preliminary studies on nonlinear 3D magnetic inversion

16.40 – *Patrizia De Gaetano*: Calibration of the degradation model foam by new Mediterranean mineralization rates: evaluation of marine fish farm impact

17.00 – *Gianluca Gola*: Estimation of true formation temperature from bottom hole temperature data in the Po plain, Italy

WATER CATCHMENT BY DEEP RESERVOIR IN FRACTURED ROCKS: THE CASE OF BRIC COLOMBINO (WESTERN LIGURIA – ITALY)

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Water resources management linked to rock fracture framework aquifers, points out some difficulties involved with sampling hydraulic parameters and definition of aquifer properties.

Water reservoir geometry coincides with the fracture framework development, without hydraulic interruption, so that the water body boundary coincides with intact rock, where there is no fracture and where idraulic transmissivity is null.

Finally, the difficulties to fix dimension and hydraulic parameters of water reservoir and its boundary, cause similar problems in defining aquifer recharge.

Recharge depends actually on two variables: water body extension, like reservoir-boundary system, and water supplies availability.

The goal of this case of study is to fix the location of a water catchment by well and to valuate its performance in a rock outcrop area, near the Tyrrhenian – Po watershed, Bric Colombino – M. Mao ridge (Western Liguria, Italy).

Rock sequences object of this study area are included in inner parts of Briançonnais domain.

In particular we found:

- Monte Carmo Tectonic Unit formed by dolostones, limestones of the *Dolomie di S. Pietro dei Monti* Formation (middle Triassic) and by silico-clastic deposits of the *Quarziti di Ponte di Nava* Formation (low Triassic);

- Mallare Tectonic Unit formed by metamorfic rocks, derived by continental deposits and volcanic contamination, of the *Scisti di Gorra* Formation and *Porfiroidi del Melogno* Formation (Permian).

Alpine evolution involves poliphased tectonic deformation with both ductile and fragile components, associated with different stages with specific orientation and intensity.

These processes caused separation in elements settled down by traslation and thrust to build piled or rootless structure.

M. Carmo Unit is one of these elements that outcrops, in M. Mao, Rocche Bianche, Bric Colombino and Torre del Mare area, in a tectonic window (Menardi Noguera, 1981).

Thrust surfaces, fractures due to ductile and fragile deformation generate a framework in the rocks that is the principal way for water infiltration.

The main tectonic features of interest are two:

- Thrust surface that joins M.te Carmo, that is a cover unit, onto underlying metamorphic integument;

- Faults system outlined by reading Foglio n° 92 – Albenga Savona – of the Carta Geologica d'Italia scale 1:100000.

This last feature joins rock sequences by *Porfiroidi del Melogno* formation and *Scisti di Gorra* formation, in the Eastern sector of Mallare tectonic unit, to continue for a few kilometres towards NE.

These structural features are validated and checked by surface geological survey and measurements.

The rock fracture mash, joined with those two features, means a good target water reservoir. Reservoir/boundary geometry determination is pointed out by electrical resistivity tomography survey.

The experiment allowed to probe the M. Mao - M. Colombino ridge for a length approximately equal to 3.0 km and a depth of several dozens of metres, with minimal logistic needs.

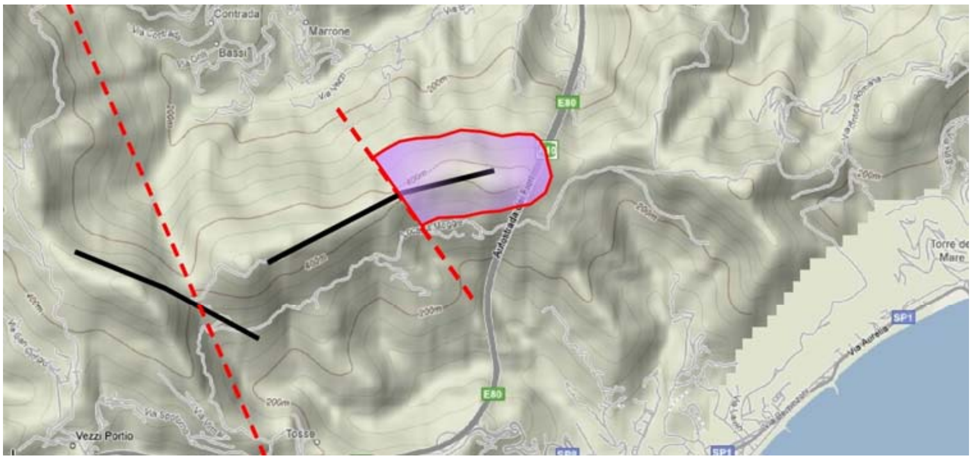

Fig. 1 – Targets (red line), ERT array (black line).

Survey is a specific use of tomography that matches with the hostility of the environment: steepness of the mountains, absence of pathways and shrubby vegetation.

The survey was performed using a Syscal Pro resistivity metre. The survey was composed of three lines located along a track close to the watershed. The survey lines cut the major geological features approximately at right angle. Two oh them have been disposed in continuity to allow the elaboration of a single dataset in order to maximize cover and penetration.

Each line was surveyed using a Pole-Dipole configuration. The current and voltage values collected are first reduced to apparent resistivity values and then inverted (Loke & Barker, 1996) to image the resistivity distribution along the surveyed section.

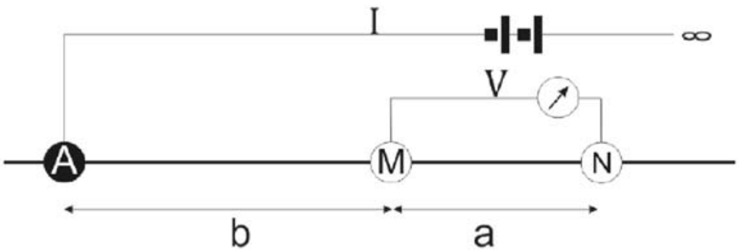

Fig. 2 – Pole-Dipole scheme.

In this survey the remote electrode was placed at 1.5 km far from the edge of each survey line. Each survey line was equipped with 48 poles spaced 20 m.

As well known, the electrical resistivity of rocks and terranes is mainly proportional both to their water content and salinity. ERT has been extensively used in many engineering and geotechnical applications and in particular in some karst terrains investigations (*e.g.*, Roth *et al.*, 2002; Atzemoglou, 2004).

The resistivity model obtained highlight a quite complex setting, reflecting the geo-structural arrangement. Along the section almost coincident with the watershed was inferred the presence of both sedimentary (dolostones) and metamorphic rocks covered by a soil blanket, like clay. These clayey components may severely affect the resistivity (Shevnin *et al.*, 2007), giving very low values due to ionization of clay minerals which behave like a metallic conductor.

The bedrock exhibits a complex framework of fractures and joints.

The interpretation of inverted ERT models leads to the following results

- identification of the tectonic contact between the M. Carmo tectonic Unit and the Permian metamorphic terranes

- identification of the tectonic contact inside the Paleozoic terranes between the *Scisti di Gorra* formation and the *Porfiroidi del Melogno* formation

Relying on the ERT results two drilling sites were established, reaching near 120 m depth from surface.

Idraulic pumping tests are performed into test wells.

Fig. 3 – Drilling test.

Pumping test has been performed by progressive lowering with data sampling during direct lowering and next raising, by conventional non equilibrium Jacob’s approach (Jacob, 1940).

Measurements during lowering and next raising have shown water comings separated from the main basal level.

This has not allowed to perform the test. The shift of the measured curve, from the theoretic one, suggest the presence of an impermeable limit. In spite of that a valuation of mean transmissivity (T) and mean permeability (K) is possible, by using raising data and by assigned water body thickness.

Potential use and management of water resource was defined in order to location and size.

Particularly by combining geological knowledge, geological survey, direct and indirect tests, water resources can be found even in deep fracture circulation.

The effectiveness of the ERT survey has been demonstrated. The method gave consistent results which combined with a careful geological survey allow the proper imaging of the water resource.

Water recharging remains an open question. Comprehension of this process allows to know the recharging time in order to perform real resource management.

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SUBMARINE QUARRY OF ALBENGA-LOANO: A SAND AND GRAVEL SOURCE FOR BEACH NOURISHMENT

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The increasing value of the beaches and the re-qualification of many sectors of urban waterfront required many studies and interventions in coast defence and re-naturalization of protected coasts (AA.VV., 2006). Between the most adopted solutions for the protection of beaches undergoing erosion, the beach nourishment is the most "soft" intervention if we accept the textural and compositional differences in placed sediment and smaller utilization of defence works.

The utilization of submarine quarries is one of the most recent techniques for the search of suitable sediment in beach nourishment. Actually, these deposits, that represent ancient shorelines now submerged, are originated from the Late Quaternary glacioeustatic events and they present textural and compositional characteristics compatible with actually beaches (Cattaneo & Steel, 2003; Corradi *et al.*, 1984).

Beginning from some geological marine data acquired since 1973 and available at the Genoa University, and some bibliographic sources, it has been possible to locate some different areas of interest characterized by transgressive deposits suitable for thickness and a poor Holocene muddy cover (Ivaldi *et al.*, 2006).

In this context, during two cruises financed by the Interreg IIIb "Beachmed" and Interreg IIIc "Beachmed-e" projects, a study of the most suitable continental shelf areas has been completed. The first one, carried out in 2004 on 3 areas of Western Liguria (340 km of geophysical survey and 40 vibracores), has permitted to locate two areas (San Remo and Albenga-Loano) where the Late Quaternary coastal deposits present a suitable thickness for the use of submerged quarries (AA.VV., 2004). These sedimentary bodies, corresponding to ancient shorelines and paleodeltaic deposits, lay at depths between 40 and 80 metres (Balduzzi *et al.*, 2008). The second cruise, in 2007 and carried out only in the Albenga-Loano area to define the dredging area, has allowed to obtain some seismostratigraphic lines with an high resolution.

The acquisition of 70 km of seismic lines consented to study the stratigraphy of transgressive relict bodies. The survey was carried out with a *Sub Bottom Profiler* (SBP – 4 and 8 kHz) to detect the detailed stratigraphy of highstand muddy sediments; a *Boomer* (*Boomer Plate Applied Acoustics* – 100 J) and a *Sparker Multi Tip* (*Squid 500 spk*, 200-300 J) have been employed to distinguish the entire stratigraphy of the transgressive deposits. These instruments allowed us to identified also the erosive surface that originated during the regressive cycle.

It is possible to recognize two different deposits: the first one lays at depth of about 40 metres (TST-2), the second one at depth between 60 and 80 metres (TST-1). The analysis of the data highlights that the deeper deposit, suitable for the dredge, is characterized by transgressive Versilian bodies that overflow the regressive and erosive surface (20-18 ky BP). In particular, we localized a transgressive complex deposit constituted by two different seismic units: TST-1A, defined by homogeneous sediment facies and, over those one and distinguished by a erosive contact, the TST-1B body, marked by a facies that abounds in internal reflections, indicating some coarse sediments.

The analysis of the seismic *facies* allowed us to define the characteristics of the different detected layers. It was possible to recognize deposits that correspond to different levels of the regressive-transgressive cycles; they are characterized by some surfaces and regressive deposits, by the regressive ones and by some settling deposits of the Holocene muddy cover.

The seismic stratigraphic characterisation can be briefly described as follows (Corradi *et al*., 2004): a first horizon at the top, named Layer A, characterised by a moderately transparent reflection, and a B horizon almost always traceable under Layer A. It has a flat parallel to undulating parallel internal geometry. The Layer C is very similar to the layer above and it has an undulating parallel internal structure and good continuity. The Layer D is the most interesting in exploitation point of view. It has a medium to medium-high reflectivity which varies from sector to sector; Near the coast it has an extremely chaotic geometry and lenticular structures, whereas in the outer zones, near the shelf-break, it has a clinoform progradant geometry above all of an oblique tangential type. The last horizon, at the bottom of the deposit, is the Layer E and it presents some complex geometric characteristics. It is interesting for the quarry exploitation (Corradi *et al*., 2008).

The vibracores were carried out in both the surveys (2004 and 2007) and they allowed us to calibrate the seismic lines and the *facies*. The cores, realized on the TST-1B body, suggest some gravelly sand with a very low percentage of pelitic matrix.

In the drainage zone, constituted by the TST-1B and TST-2 bodies, the volume of the sediments is estimated at about 5 millions of m^3.

The deposits of the TST-1A body are estimated, only on the basis of stratigraphic analysis and of the seismic *facies*, at about 8.5 millions of mc; this deposit was not characterized because any cores reached it (AA.VV., 2008).

The littoral systems, that are be recognized, TST-1 and TST-2, are both overflowed by a thin muddy cover attributable to a transgression restarting. They are defined by sandy sediments with a growing pelitic component (Corradi *et al*., 1980).

At the top, the high-stand Holocene deposit almost uniformly recover many wide sectors of continental platform.

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THE RECONSTRUCTION OF THE GEOMETRIES OF THE SEDIMENTARY SEQUENCES IN THE BOJANO BASIN (CAMPOBASSO PROVINCE) BY AN INTEGRATED INTERPRETATION OF GEOLOGIC, GEOMORPHOLOGIC AND GEOPHYSICAL DATA

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The Bojano plain corresponds to an elongated basin with Apennine direction, delimited by the Matese massif to SW and by the Sannio hills to NE. This area was studied utilizing geologic, geomorphologic and geophysical data, acquired mainly for microzoning of the Bojano town.

Seismic reflection data reveal structural depressions nearby the centre of the town and two basins filled by recent fluvial-lacustrine deposits at the NW and SE sectors of the plain, respectively. Low angle tectonic structures correlate with the thrust of the Matese chain over the frontal more deformable sequences of the Sannio units, but any high angle active structure cutting the Matese thrusts at their eastern limit and in the first 1500 m has been imaged.

The seismic sections have been complemented by H/V measurements of the seismic noise utilizing a seismological network installed for sites amplification analysis with a reference station and by an accurate study of the geomorphology of the area. Analyses of the morphogenetic processes contribute to the description of the evolution of the plain and of the depocentres, with depressions and structural highs or divides which strongly influenced the rivers action and the arrival of the alluvial cones.

On the base of results obtained in this work and in agreement with INGV authors of Italian Database of Seismic Sources (DISS Working Group, 2007), there are no evidence about the existence, in the first 1500 m of depth of an active fault system within Bojano basin or at the contact with Matese mountain massif. Our dataset confirms the presence of a tectonic fault system that lead to overthrust of Matese massif on the basin deposits, with Adriatic vergence, as also reported by some authors in the Molisan Apennine area (Vezzani *et al.*, 2004).

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CALIBRATION OF THE DEGRADATION MODEL FOAM BY NEW MEDITERRANEAN MINERALIZATION RATES: EVALUATION OF MARINE FISH FARM IMPACT

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World aquaculture has grown fast during the last fifty years. We have passed from a production of less than a million tonnes in the early 1950s to 59.4 million tonnes by 2004. The average annual increasing rate is 8.8% and the mariculture represents 50.9% of the total aquaculture yield (FAO). This continuous expansion of marine aquaculture has been generating interest on predictive tools able to assess the possible impacts for coastal ecosystems. Indeed, several experimental studies have highlighted that the particulate waste originated by marine fish farm is the main cause of environmental impact (Hall *et al.*, 1990; Holmer & Kristensen, 1992; Karakassis *et al.*, 2000). In fact, the particulate products increase the organic load on the benthic environment and might result in changes in the structure and functions of the benthic communities (Tsutsumi *et al.*, 1991; Wu *et al.*, 1994; Vezzulli *et al.*, 2002, 2003; Pergent-Martini *et al.*, 2006; Holmer *et al.*, 2007; Hargrave *et al.*, 2008). Nevertheless, a classical sampling approach can not provide a complete information about dispersion pathways, settling, mineralization and burial of organic particles as uneaten fish feed or faeces, except with a huge experimental and costly effort. Therefore, the interest in tracking aquaculture wastes with mathematical models has been rapidly increasing in time (Henderson *et al.*, 2001; Cromey *et al.*, 2002; Panchang *et al.*, 1997; Dudley *et al.*, 2000).

Moreover, we recognize that following only the fate of the particles is not sufficient to correctly assess the organic load on the sea bottom. The modeling effort should consider the natural capability of the benthic environment in reacting and absorbing fluctuations in the organic load. For this aim, we improve the avvection-dispersion model POM-LAMP3D (Doglioli *et al.*, 2004) coupling with a new numerical benthic degradative module: Finite Organic Accumulation Module, FOAM (De Gaetano *et al.*, 2008).

FOAM is mainly based on the ideas expressed in the work of Findlay & Watling (1997) and uses the output of the other functional units of the modeling framework to calculate the organic load on the seabed. Different remineralization rates reflect the sediment stress levels and are used to compute the organic carbon concentration remaining on the seabed after degradation. The determination of the mineralization rates and the benthic metabolism activity is a key parameter in the accuracy of the model prediction. Nevertheless, the lack in literature of these values, specifically targeting Mediterranean conditions motivate us to perform two sampling campaigns in a typical Mediterranean fish farm in the warm and cold season. Biodeposition rates, background sedimentation, benthic O_2 respiration and CO_2 production were measured. Unlike what observed in Atlantic conditions (Findlay & Watling, 1997), we found that in the Mediterranean ones, the benthic response to the organic enrichment of the bottom depends on water temperature.

Moreover, we have distinguish three different sediment state categories on the basis of the respiratory quotient (Dilly, 2003). New simulation with the measured Mediterranean parameters have been performed considering two macro-periods, warm and cold season. Organic degradation for both uneaten feed and faeces is evacuate by changing release modality (continuous and periodical) and by varying the settling velocities. Our results clearly indicate different pathways, temperature dependent, of carbon oxidation, with higher oxygen demand, measured in warm season, associated to the same carbon input. Moreover, the extension of the impacted area and the organic carbon concentration remaining on the seabed vary seasonally, with a contraction in the warm period while in this season it is maximum the frequency of the high stress level of sediment.

We find that the introduced modelling framework successfully improves capability predictions. It can therefore represent an important tool in decision making processes, for planning and monitoring purposes.

Managers and policy makers may take care of these differences in planning the installation of new fish-farms or the expansion of existing ones. A balance among the organic matter spread or load and the occurrence of different sediment states may be accurately evaluated with the application of the model.

Further investigations may be necessary to characterized in systematic way the Mediterranean fish farms applying the entire model POM-LAMP3D and FOAM to several sites. Moreover, several sampling campaigns might be carried out in order to obtain a whole range of variations of FOAM parameters with temperature. Once the relationship with temperature has been fully understood, FOAM may handle the temperature variations coupling the hydrodynamic regimes with the matching temperatures on the sea-bed.

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LONG PROFILE MODELING: THE CASE STUDY OF PIOTA RIVER BASIN (LIGURIAN ALPS)

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In recent years the interaction between superficial processes and crustal processes has received a growing interest. Even if many aspects of dynamic response of bedrock channels to tectonic forcing are still unknown (Whipple & Tucker, 1999) the key role of bedrock incising channels in landscape evolution is today widely accepted as well the connection between channels characteristics and underlaying rocks and structures.

In this study the Piota river basin, one of the main drainage basin of Ligurian Alps, has been analyzed throughout quantitative, GIS-based, methodologies.

The Piota river basin belongs to the Po side of Ligurian Alps, the eastern most sector of Western Alps. The basin area is 112 km^2 and it is located in the southern most part of the Piemonte Region; a large sector of the regional Po-Ligurian divide is included in its watershed.

The basin forms mainly on the Ligurian-Piemontese Units of the Voltri Group, unconformably overlaid, in the northern part, by late- to post-orogenic deposits belonging to the Tertiary Piedmont Basin.

Its topographic and geological characteristics are peculiar compared with the surrounding area and its evolution represents a good example of interaction between tectonics and geomorphology.

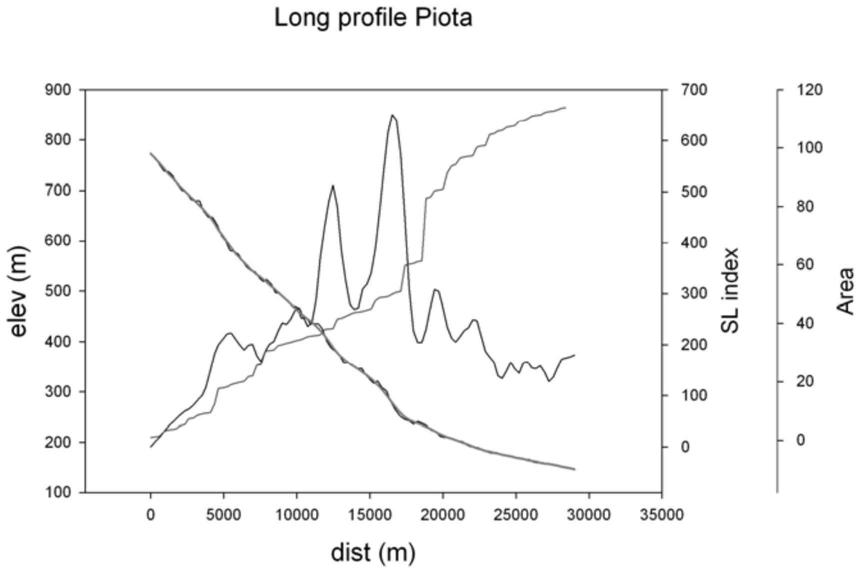
The morphometric analysis of the drainage network allowed to verify the influence of tectonics whereas through the azimuthal analysis of the ordered network the main morphotectonic directions have been highlighted. The analysis of the longitudinal profile of the trunk channel and the calculation of the Hack index (Hack, 1957) along it helped, moreover, to give a first characterization of the basin evolution processes.

Results of both azimuthal and morphometric analyses confirm the high structural control on drainage pattern, particularly clear in the southern sector of the basin, interested by deeply fractured metaophiolitic rocks.

The azimuthal analysis of the ordered Piota network showed N-S, E-W and NW-SE as the most representative directions of the channels. These results are consistent with existing geological studies of the region that demonstrate a pervasive fractures system oriented E-W and N-S that apparently have an effect in aligning channels in the basin.

Piota long profile shows a steep upper segment from the headquarters downhill to the contact between the Voltri Group and the TPB rocks, and a more gentle lower sector from the lithologic contact to the confluence with the Orba river.

The central sector of long profile shows anomaly increasing values of Slope and Drainage area and is interested by various knick-points, of these only the main one can be directly related to lithological reasons. In this sector of the river the Hack index (sensitive to changes in channel slope) seems to be totally uncoupled with rock resistance. It is in fact relatively low where the river crosses the hard rocks of the Voltri Group whereas it significantly increases in value on the soft rocks of the TPB. Since in landscape evolution processes streams profiles seem to adjust very quickly to rock resistance, these anomalous values allow to infer a relatively recent tectonic activity in the area.



Both different rocks erodibility and local structures seem to play an important role in the Piota river evolution, driving both incision mechanisms and geometry of streams. Anyway, trunk channel analysis provides evidences of the influence of regional tectonic as well, it affects in fact both the relative base level (with subsidence phenomena occurring in the TPB from Miocene; Carrapa *et al.*, 2003) and the headquarter area, apparently experiencing low rates of ongoing uplift.

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ESTIMATION OF TRUE FORMATION TEMPERATURE FROM BOTTOM HOLE TEMPERATURE DATA IN THE PO PLAIN, ITALY

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In sedimentary basins a large amount of thermal and geological data is generally available from petroleum wells. Unfortunately, borehole temperature data are often affected by a number of perturbations which make very difficult the determination of the true geothermal gradient. I analyze a wide set of time-temperature data from petroleum wells of western sector of the Po Plain, and propose temperature empirical corrections for mud circulation.

Two classical techniques for processing temperature data from oil wells are customarily used: (i) the method by Horner (1951), that requires two or more measurements of bottom-hole temperatures carried out at the same depth but at different shut-in time and (ii) the technique by Cooper & Jones (1959), in which several physical parameters of the mud and formation need to be known. Formation thermal parameters and their temperature dependence are taken into account (Pasquale *et al.*, 2008a).

Analyses show that formation equilibrium temperatures computed with the Horner method are well comparable to those obtained by means of the Cooper & Jones method for shut-in times > 25 hours. Horner method gives, on average, temperatures by 1°C lower only for shut-in times < 25 hours and the maximum difference reaches 6.7°C for shut in time < 15 hours. The corrected temperatures compared with temperatures measured during drill-stem tests show that the proposed corrections are rather accurate. The data set gives coherent results and the inferred average geothermal gradient is 25 mK/m in the studied sector of the basin (Pasquale *et al.*, 2008b). The Horner slope and Cooper & Jones slope data as a function of depth are then fitted with a second order polynomial and depth-time correction equations are calibrated for the area. Finally, I propose an empirical function for the estimate of the mud circulation time, which is a piece of information often unavailable. The correction equation derived by Horner slope data is function of depth, mud circulation time and shut-in time; the correction equation derived by Cooper & Jones slope data is function of depth, shut-in time and radius of well.

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THE EXHUMATION OF HP ROCKS (VOLTRI MASSIF, LIGURIAN-PIEMONTESE UNITS): FROM NATURAL EVIDENCES TO NUMERICAL MODELS

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The Voltri Massif (Ligurian-Piemontese Units, Ligurian Alps, Italy) is formed by several tectono-metamorphic units (Voltri Unit, Palmaro-Caffarella Unit, Angassino-Terma Unit), characterized by discordant metamorphic peak conditions, ranging from eclogite to blueschist facies.

Lenses of rocks with different metamorphic climax, completely wrapped in serpentinites, are pretty diffused in the Voltri Unit in particular between the Sestri-Voltaggio zone and the metasediment-outcropping area between Voltri and Rossiglione.

Recent studies on ophiolitic complexes in the Western Alps (Schwartz *et al.*, 2000; Guillot *et al.*, 2004) and on serpentinitic mélanges cropping out in the Ligurian Alps (Federico *et al.*, 2007) let suppose that the Voltri Massif could be an example of a km-wide subduction channel and that every unit could represent a slice of a subducted oceanic plate, coming from different depths and exhumed along the subduction channel.

In order to test this hypothesis I made fieldwork with the aim to analyze the structural relationships between the pluridecametric lenses of metagabbro and the associated serpentinites and/or metasediments which crop out in the Voltri Unit and in the Palmaro-Caffarella Unit.

The petrographic study of the collected samples allow to define in details the paragenesis and the metamorphic conditions registered in the different rocks that crop out in the area of interest.

The study of the outcrops was associated with the production of 2D numerical models, which use the finite differences method in order to solve equations describing the behavior of viscous, incompressible, heat-conducting media in the gravitational field. This simulations show the formation and the evolution of an intraoceanic subduction zone within a Ligurian-Piemontese ocean-like basin.

The comparison between 2D models results and field evidences (geometries and P-T-t paths) will allow the definition of the more likely mechanisms which control the subduction/exhumation processes of the Voltri Massif rocks.

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MODELING OF THE VARISCAN GNEISS DOME EMPLACEMENT IN NE SARDINIA (ITALY)

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The Variscan High Grade metamorphic Complex outcropping in Sardinia is made of gneissic rocks and different types of migmatites, with a metamorphic grade reaching the granulite facies. The Axial Zone of Sardinia could represent a Mantle Gneiss Dome (Elter & Corsi, 1995; Elter *et al.*, 1999; Corsi & Elter, 2006; Elter, 2007). Within this Gneiss Dome, apart from the migmatites, many other rock types crop out, such as: granitic-granodioritic Ordovician orthogneiss; metabasites with granulitic and eclogitic relics and calcsilicate nodules; rare wollastonite + diopside + garnet marbles (Elter & Palmeri, 1992); rare amphibole migmatites, coeval with kyanite gneiss (Cruciani *et al.*, 2008). All these migamatites are embedded in a HT shear zone N140 trending, 20 km thick (Pittolongu - Serra Tamburo - Capo Ferro Shear Zone). In this shear zone is possible to envisage centrimetric to kilometric size *pods* of the previously described lithologies. The regional schistosity in the migmatites strikes NE-SW, having a strong angular discordance with the NW-SE oriented shear zone.

Within the shear zone syntectonic granites, dated 320-300 Ma, outcrop (pre-syn-tectonic granites of Barrabisa, Capo Ferro and Cala Spada). The whole system, previously described, is intruded by the late-tectonic granites (300 Ma) and the post tectonic ones. The post-tectonic granites' emplacement could be related to an extension NW-SE oriented. Rare anorogenetic Permo-Triassic sienites also outcrop.

The cooling rate (Whitney *et al.*, 2004) estimated for the preserved migmatites into the shear zone, suggests *doming* processes with vertical transport and slow exhumation rate. This exhumation is well defined by the decompressive paths drawn in the P-T-t diagrams known in petrology (Franceschelli *et al.*, 2005, 2007; Cruciani *et al.*, 2008). Nevertheless, on the basis of recent bibliography (Yin, 2004), it is possible to notice that the only evidence of a decompressive process is not enough to understand the mechanism related to a gneiss dome emplacement.

Recent papers (Olivier *et al.*, 2004; Yin, 2004; Whitney *et al.*, 2004; Tirel *et al.*, 2004; Burg *et al.*, 2004), provided many models, either numerical or analogical, about the possible mechanisms originating a Mantle Gneiss Dome.

The geological and structural data and the analogical models described in this paper, show that a Mantle Gneiss Dome emplacement is possible also in environments dominated by a transpressive deformation. Nevertheless the transpressive deformation is followed by a transtensive tectonic, characterized by a shear zones system evolving from the amphibolite facies to the green schists facies. This evolution is well witnessed either by the structural data or by the vorticity number (Wm) valuation, distinct for the regional schistosity and for the mylonitc event.

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PRELIMINARY OBSERVATIONS ABOUT MACROSCOPIC AND CRYOGENIC STRUCTURES IN THE SOIL AND THEIR PALEOENVIRONMENTAL SIGNIFICANCE (M. BEIGUA, LIGURIA, ITALY)

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In the past years, several studies in the Beigua Massif (1287 m. s.l.m) highlighted the presence of landforms and deposits connected to permafrost during the Last Glacial. The discovery of blockfields and blockstreams (Firpo *et al.*, 2005, 2006), confirm the permafrost conditions (Harris, 1994). Moreover, reworked loess deposits recently have been identified along Massif slopes. Following up the loess field survey, different and weakly weathered deposits have been distinguished at the bottom of the loess. They are characterized by evident macroscopic and cryogenic structures.

The studied profiles (Fig. 1A) show structural patterns of ice segregation in the forms of lenses or veins within fissures formed by dissecation (ice-lensing), including foliated and platy structures, and angular or short prismatic structures formed by reticulate segregation ice (Fitzpatrick, 1976; Van Vliet-Lanoe & Langhor, 1981; Van Vliet-Lanoe, 1998).

These structures are strongly developed in fine sediment (silty-sands), while are weakly developed or absent in coarse material (gravels), because the most frost susceptible materials are fine grained and heterogeneous in particle size distribution ones (maximal capacity for ice segregation, Vliet-Lanoe & Langhor, 1981; Van Vliet-Lanoe, 1998). The size of the aggregates progressively increase with depth and the superficial shapes are distinctly foliated ("ice gneiss"), placing these profiles between the active layer and permafrost table (Van Vliet-Lanoe & Langhor, 1981).

On the other hand, it is more acceptable to identify these structures as permafrost (upper part) instead of fragipan, because of the their physical and morphological characteristics. In fact, even if they present some fragipan properties (compactness and low inner porosity, absence of biological activity, etc.), there is not the typical polygonal pattern due to vertical bleached streaks connected to coarse prismatic structures. The bleached areas are distributed along the horizontal fissures between the aggregates, with evident disjoined manganese accumulation in the deeper massive sediments. These hydromorphic processes could be contemporary to the permafrost formation (Fedorova & Yarilova, 1972) or related to the following wet Holocene phases (fluctuating groundwater tables). Besides, some cryogenic structures, typical of very slow freezing in water saturated clayey grounds (Van Vliet-Lanoe & Langhor, 1981), have been identified in horizons of paleosols outcropping on palaeosurfaces (Fig. 1B).

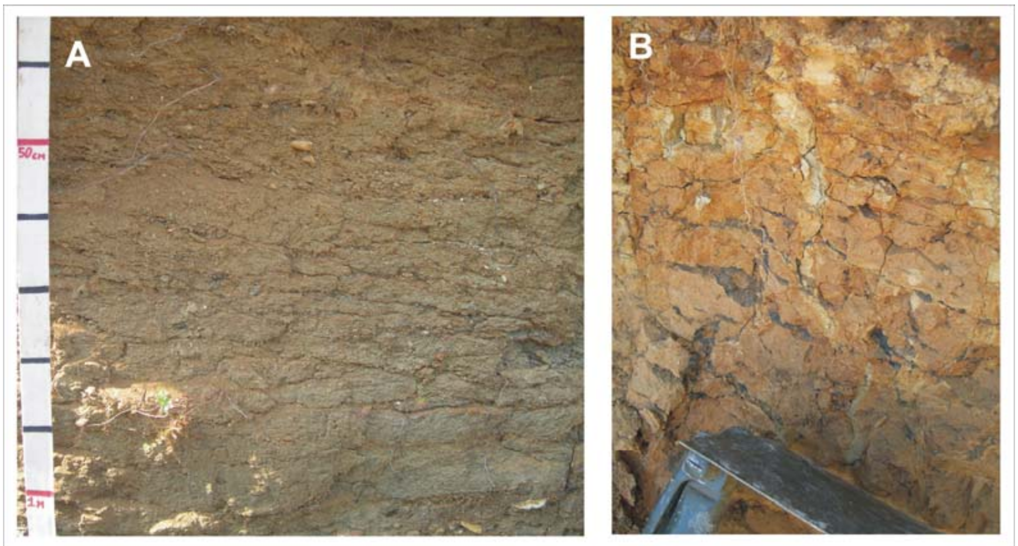

Fig. 1 - Structural patterns of ice segregation in the forms of lenses or veins within fissures formed by dissecation.

These patterns are characterized by a strongly developed angular blocky up to prismatic structure, with very hard aggregate and with manganese coatings on the their surface. These horizons are located near the erosional surfaces, which truncated these soils during the glacial periods. The evidences discussed in this paper, if confirmed by more detailed analyses (*i.e.*, micromorphology), could confirm the hypothesis that during the wet/cold phases of the Last Glacial, characterized by the growth of the alpine glaciers along the southern slope of the mountain range, the Ligurian Alps (even at low altitude, 500-600 m) were clearly characterized by periglacial environment with the presence of permafrost (probably discontinuous) which could have promoted blockfields and blockstreams formation through gelifluction or frost creep, while the following dry phases could have permitted the sedimentation of high amount of loess, which did not record permafrost signs but only deep seasonal freezing (Cremaschi & Van Vliet-Lanoe, 1990).

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MOVEMENTS DETECTION OF DEEP GRAVITATIONAL SLOPE DEFORMATIONS BY MEANS OF PSInSAR™ DATA: THE CASE STUDY OF SOME HISTORICAL SETTLEMENTS IN UPPER AVETO VALLEY (LIGURIAN APENNINE)

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This work investigates the geomorphological setting of the mountain area bounded by Mt. Penna, Mt. Aiona, Mt. degli Abeti and Gramizza river (Upper Aveto Valley), in order to reconstruct the morphological and morphogenetic framework of this area and define the characterization (origin, kinematic mechanism and state of activity) of landslides and mass-movements which affect this region. The investigation focused on the NW-sector, where the hamlets of Cerisola, Magnasco, Villanoce and Villa Rocca stand.

The studied area is characterized by a complex geological and tectonic-structural setting with turbiditic deposits, ophiolitic and ultramafic masses, associated with heterogeneous breccias and olistolithes, detached from their original substratum (Tectonic Unit Ottone - External Ligurides) (Terranova & Zanzucchi, 1983; Regione Liguria, 2005a, 2005b). In detail, multidecametric olistolithes of massive and brecciated basalts outcrop in the Mt. Penna - Mt. Cantomoro group; ultramafic complex (peridotites with tectonic fabric, which may be more or less serpentinized) forms Mt. Aiona (Marini &

Terranova, 1980; Terranova & Zanzucchi, 1982; Casnedi *et al.*, 1993). Chaotic complex, composed of ophiolitic sandstones, mono and polygenic breccias with clayey or sandy cement and ultramafic olistolithes (Casanova Complex), outcrop along the orographic left of Gramizza river, associated with shales intercalated by olistostromes lens with limestone clasts and shaly matrix , polygenic breccias and ophiolitic masses (Mt. Veri Palombini Shales); marls, marly limestones and clayey marls, sometimes with argillitic and arenaceous layers (Ottone Flysch), occur in the northern sector of the investigated area (Marroni & Perilli, 1990).

Mt. Penna-Mt. Aiona area is characterized by two different geomorphological types: very steep slopes and rocky scarps, locally with sub-vertical profile, and gentle-slope surfaces covered by deposits of various thickness and type, sometimes multimetric. The complex geomorphological setting of these sectors is due to the variety of forms and processes occurred (gravity, running and shallow waters, structural elements and crionival processes), which caused landslides and mass movements, sometime associated with deposits of different type. They are also favoured by the different geomechanical properties of the bedrock, highly fractured and jointed, due to the heterogeneous nature and the structural features of the rock mass.

Such a geological and structural setting favoured the development of large-scale gravity-driven phenomena (known as deep-seated gravitational slope deformation) which have affected large ridge portions of the whole area; several are the morphological evidences such as ridge splitting, trenches, ridge sackung, scarps and morphological steps, reverse slopes, rock falls, lateral spread and block slide, closed depressions.

The slope where the hamlets of Magnasco, Cerisola, Villanoce and Villa Rocca were built is affected by some major situations of geomorphological instability, already recorded in the main tools for land-planning and management, (such as the Italian landslide inventory map - IFFI - and the hydrogeological risk management plan - PAI), where landslides are classified, sometimes with different interpretation regarding their origin, kinematic movement, state of activity and boundaries (Autorità di bacino del Fiume Po, 1999; Bottero *et al.*, 2004; Federici *et al.*, 2004). These mass movements are responsible for widespread structural damages and cracks of the buildings and infrastructures observed in the hamlets.

The Permanent Scatterers (PS) technique, a multi-image interferometric approach, is carried out for landslide investigation in this area; dataset of SAR images acquired, both from ascending and descending orbits, by the ERS 1-2 and ENVISAT-1 satellites between 1992 and 2008 is collected (Allievi *et al.*, 2003; Bottero *et al.*, 2006).

The PS approach allows millimetric precision in the radar target ground position (PS), the average deformation rates per year along LOS direction and the displacement Time Series of single PS. Deformations are measured along the sensor-target Line of Sight and thus they represent only the component of real displacement vector measured along LOS direction (Perissin *et al.*, 2004; Farina *et al.*, 2006).

The investigated area shows topographic features of the site (gentle slope and a prevailing N-NE exposure), kinematic mechanism of the slope movements (slow and non intermittent deformations), typology and spatial density of radar target (man-made structures, exposed rocks, sparsely vegetated areas) compatible with PSInSAR capabilities, due to the particular data acquisition conditions and satellite orbit.

Displacement rates range from 1-5 mm/year, at Villanoce and in the external sector towards the ridge between Rezzoaglio and Gramizza rivers, to over 30-35 mm/year in the middle portion of the large landslide bodies where Magnasco, Cerisola and, partially, Villa Rocca hamlets stand.

A preliminary comparison between radar scenes acquired both from ascending and descending orbits shows how the same movement can be measured with different sign and magnitude by the two dataset: for example, the signs of the measured displacement vectors are in all concordant at Villanoce (positive values indicate movement towards the satellite) while they are contrary at Magnasco and Cerisola, with positive values for descending orbit and negative values (*i.e.*, movements away from the satellite) for the ascending one. Displacement vectors with contrary signs on the same slope suggest complex kinematic mechanisms, with prevalent E-W direction of horizontal movements.

In order to examine the PS nature and significance, then the reliability of acquired data, a preliminary inventory of radar targets has been carried out, particularly in the built-up area: they usually correspond to buildings and man-made structures which may respond in different ways to the ground deformations, for the same geometric features: in fact, deformation rate varies depending on structural features and the PS position on the building.

The inventory of structural damages and cracks on the buildings and infrastructures of the hamlets has been carried out at the same time, with particular regard to some factors (age and conditions, building materials, foundations type, damage level and type, etc.); sometimes displacements appear incompatible with the cracks situation and the consistency state of bearing structures of buildings.

The deformation rate vector projected along the highest slope direction has been calculated by combining in a work-sheet the LOS information (direction cosine and deformation rate along LOS direction, different for ascending and descending orbits) with topographic feature (slope and exposure) at single PS.

The preliminary results and observations suggest the presence of complex phenomena, characterized by kinematic mechanisms different from the motion along the highest slope direction: by combining ascending and descending datasets, it may be possible to resolve displacement vectors in their horizontal and vertical components in order to obtain further information about their direction, sign and value and then about the kinematic mechanisms which affect this territory.

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CLIMATE AS A GEORESOURCE. EXAMPLES FROM LIGURIAN REGION

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In this study climate is considered as a geographical resource, as it is renewable, differently distributed on the Earth surface, varying in time and space and central to many human activities, such as agriculture, the use of water and forest resources and tourism. Giving the growing importance of tourism to the economic conditions of a region, a sustainable tourism can create opportunities for people living marginal areas, so that climate, like geotopes, can be considered a georesource, in the aim of the exploitation of these areas and for soil protection purposes.

Some of the most used climatic indicators on tourism were applied to Liguria, The problem of the goodness of meteorological data bases used for the study suggested also the creation of new indicators that can be tested in other regions.

The examples from Ligurian stations confirm the excellent and well-known climatic conditions of the whole coast not only for the balnear season but also for climatic comfort in summer and mild winter together with the wide opportunity to practice surfing and other water sports for the favourable average conditions of wind and sea.

However the climatic analysis emphasized also the goodness of the hinterland, rich from an historical and architectonical point of view, for the comfort of its summer season together with the attitude of the mountain for sporting activities, hiking, trekking, climbing and activities related to winter snow.

As a conclusive remark, in terms of climate the entire region may be affected by a sustainable cultural, environmental and sporting tourism in every season, not only in the world famous coastal towns whose sustainability is now often at the limit of saturation.

One possible development of this study is a more detailed climate analysis to more restricted area, like protected areas or mountain parks.

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USE OF REMOTE SENSING TO EVALUATE THE SHORE PROTECTION WORK EFFICACY. THE CASE OF LEVANTO (LA SPEZIA, ITALY)

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In order to carry out a coast functional preservation and conservation, it is of overriding importance to gather detailed information about the hydrodynamic process and the morpho-sedimentary mechanisms that control the littoral itself.

Video monitoring is a method that has spread out worldwide for the morpho-dynamic analysis of both the beach face and the intertidal beach. Nowadays video monitoring is used when it is necessary to gather information and data about the shoreline both very frequent and on a temporary large scale (Holland, 1997; Davidson *et al.*, 2004), as well as a complement to surveys carried out according to classic methods (Elko *et al.*, 2005).

Video monitoring in such cases was mainly applied to sand beaches, whereas in the specific case concerned in this research, a system made of two web-cams was installed on the gravel beach of Levanto during the spring of the year 2005. This system was used to monitor the nourishment intervention that was being carried on there. This made it possible to evaluate the opportunity to apply this method to beaches which are characterized by different hydro-dynamism than the sand ones (Horn & Walton, 2007; Pedrozo-Acuña *et al.*, 2006), which therefore react in another way to the waves variations and to the installation of artificial structures.

To determine the reaction of the Levanto beach to the anthropic interventions that were being carried out was also one of the project goals. This study planned to use video-derived images as the main data source to monitor the space and time evolution of that coast portion. The beach morphological variations were related to the environmental conditions: this comparison was necessary to understand the natural adjustments and the human induced ones.

The littoral studied is wide of about 900 m, and has an average width of 35 m. The Levanto beach is a part of the physiographical unit included between Punta Mesco and Punta Picetto, and it is limited on the sides by two promontories: Punta Mesco and Punta Levanto. The coast portion has a prevailing wind exposition of 180° (from 164° to 344°), and therefore is exposed to waves and currents generated from SW and partly from S and SE. The outcomes of the environmental conditions on the coastal area are confirmed in "Wind and wave atlas of the Mediterranean sea" (2004). Over the years many defence structures was built to protect the coast. Among these are 3 groins, which break the beach continuity and subdivide it in 3 different cells, and a submerged breakwater put in the central cell about 65 m off the shoreline. The last intervention on this beach was the nourishment carried on in the year 2005: this foresaw the poring in the central and west cells of 16000 m^3 of quarry material that had previously been crushed and treated.

Following both a monthly as well as an annual analysis of the shore line, it was concluded that the beach remained in a condition of general stability. The sediment pouring was sufficient to realize the seasonal profiles and also for the coast portion correct adaptation to the sea conditions. In particular, the nourishment efficacy is optimal in the west cell, whereas in the central one some modest signs of retreat were seen. This condition is probably to be ascribed to the strong influence carried on by the anthropic structures on the morpho-dynamic of this sector.

As far as the east part of the beach, it was not included in the intervention because always stable in the previous years. After 12 months from the beginning of the monitoring, a regression of the sector was noticed. This condition is probably due to a lack of sedimentary fill material in the sector by the E-directed drift, which is totally intercepted by the transversal structures.

During the study, the attention was also focused on the dynamics of the central cell which, even though it had been undergone a nourishment, it showed a slight regression rate. This survey want to evaluate the effective influence and alteration provoked on this cell by the anthropic structures. According to Ranasinghe & Turner (2006) the flow of the waves that are incident on the coast passes over up the breakwater until it interacts with the long-shore current. The meeting of these two currents provokes a loss in the sediment transport capacity, and as a result their depositing on the beach face. The water accumulation close to the shore is then eliminated by means of return flow on the lack created by the breakwater and the groins.

In the Levanto gravel beach the alteration of the coastal morpho-dynamics by means of the submerged breakwater was studied through the analysis of the salient morphology and its development stages. Through the observation of the snapshots images it was discovered that the sedimentary depositing is strictly connected to the environmental conditions.

On the basis of such considerations, three different development phases of the salient morphology were identified. These can be related to the wave height:

- A waves less than 0.5 m high cannot move the sediment that form the salient, so it do not alter the morphology, which than results to be always present.

- In case of waves heights between 0.5 m and 1 m the salient development must be related with the different waves conditions and its variation ways.

- In environmental conditions characterised by a huge wave motion and waves higher than 1 m, the salient is destroyed, and this determines the shore line to be uniform.

From the morphological study of the Levanto beach, the waves height of 1 m can thus be assumed as the maximal limit for the submerged breakwater efficacy. In case of lower heights the defensive works interacts with the waves, thus bringing about diffraction that favour the sediment deposit and the salient formation. If the waves are higher than 1 m the breakwater is no longer able to contrast with the waves action, and the sediment previously deposited on the shoreline is dispersed on the submerged beach. This aspect is fundamental to understand the sedimentary dynamics of the sector studied. The material moved can be partly carried offshore by the return flow. After a waves height decrease, the dispersed sediment will be hindered in its coming back on the beach just by the breakwater presence. This will determine a sediment loss of the littoral portion.

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MAPPING AND ASSESSING THE UNDERWATER GEOMORPHOSITES. THE CASE STUDY OF SIGRI BAY (LESVOS ISLAND, GREECE)

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The valorisation and conservation of the geological heritage have gained, in the last years, a growing importance, leading to place side by side biodiversity and geodiversity concepts (Brilha, 2002). Coasts are the most diverse and dynamic environment found anywhere on earth (Morang *et al.*, 2003). Many geologic, physical, biologic, and anthropomorphic (human) factors are responsible for shaping the coast and keeping it in constant flux. A complete and accurate mapping of the coastal geoheritage necessarily includes both the description of the shore and the description of the underwater side of the coastline. However, while information on mapping of the "on land" coastal features are largely available, methods for the underwater geoheritage mapping and assessment are seldom reported (Orrù *et al.*, 2005), especially if not focusing on benthic communities (Bianchi *et al.*, 2003). A limit in underwater mapping approaches is related to the diving time and thus, to the logistic of diving itself (air in the bottles, safety diving rules, etc.). The presented experience is based on a simple methodology for mapping the geoheritage in shallow waters (about 5 m depth) through snorkeling surveys. The surveys were carried out in Sigri bay (Lesvos Island, Greece), presently included in the proposed Western Lesvos Marine Geopark (Zouros, 2007). The underwater transects, divided in territorial parcels, allowed to characterise the submerged beach (sediments sampling and granulometric analyses), to identify geomorphosites (beach rocks, tafoni structures, sea notchs), shallow waters habitats (seagrass meadow), as well as exceptional forms (underwater fossil trunks). Every parcel was scored with scientific and the additional values. The experience resulted in a relevant amount of data useful to create a map of the area, in a relative simple way. In addition, during the survey, sites of particular interest were identified, that are not only scientifically relevant but that can be suitable for touristic underwater enjoyment purposes and included in a geoheritage-geotouristic map.

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PRELIMINARY STUDIES ON NONLINEAR 3D MAGNETIC INVERSION

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Magnetic anomaly data are acquired most of the time by magnetometers that measure the modulus of the total magnetic field. The inversion of magnetic anomaly data is usually performed using a linearized version of the forward model. Actually the relation between the sources (susceptibility) and the modulus of the field is nonlinear because it involves the square root of the sum of the square of the three components. Because of this reason we study the case of the nonlinear forward model and its inversion (Tarantola & Valette, 1982). Using a maximum likelihood approach, we perform the inversion through an accelerated gradient projected minimization algorithm. We impose the constraint of non-negativity to the solution and use a quadratic stabilizing functional. The functional to be minimized results non-convex, so some problems arise about the uniqueness of the minimum and hence the solution.

We attack the 3D problem in the underdetermined case, facing this by means of properly constructed weighting functions (Zhdanov, 2002). The results of this work are still preliminary. The comparison of linear and nonlinear inversion reveals that the latter gives more focused solutions and that the susceptibility values are closer to the real ones with respect to the linearized case.

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