QUARTA GIORNATA RICERCA GIOVANI

28 Febbraio 2008

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

PROGRAMMA

9.45 – PRESENTAZIONE SEMINARI: Gianluca Gola e Chiara F. Schiaffino

SESSIONE 1: RICOSTRUZIONE DEI PROCESSI GEOLOGICI ANTICHI E RECENTI
Chairperson: Ileana Balduzzi

10.05 – *Andrea Ciampalini*: The Plio-Pleistocene of Vado Ligure: preliminary data

10.25 – *Francesca Ferraris*: Quantitative geomorphology and Plio-Quaternary evolution of the NE Ligurian Alps, in the area between Genova and Savona

10.45 – *Ivano Rellini*: Late Quaternary loess of the Mount Beigua (Alpi Liguri): characteristics and paleoclimatic significance

11.05-11.25 Pausa caffé

11.25 – *Laura Federico*: First occurrence of syntectonic gold mineralization in transcrustal fault zones of the transantarctic mountains (Northern Victoria Land, Antarctica)

11.45 – *Davide Scafidi*: Seismotectonic analysis of the complex fault system named "Garfagnana–Nord" (northern Tuscany)

SESSIONE 2: STUDIO E MODELLIZZAZIONE DEI FENOMENI PETROFISICI
Chairperson: Ivano Rellini

12.10 – *Laura Buzzi*: Petrogenesis of Lower Permian andesitic magmatism from Southern Europe and geodynamic bearing on the post-Variscan collapse

12.30 – *Gianluca Gola*: Critical parameters for the thermal analysis of a sedimentary basin

12.50 – *Andrea Zunino*: A comparison between astronomical and magnetic image deconvolution targeting archaeological prospection

13.10-14.40 Pausa pranzo

SESSIONE 3: TUTELA DELL'AMBIENTE E DEL TERRITORIO
Chairperson: Laura Buzzi

14.40 – *Cristina Carbone*: Mineralogy and chemistry of varicolored stream sediments from AMD processes in Libiola mine

15.00 – *Evelina Isola*: Blastesis-deformation relationships in the evolution of the northen Apennine serpentinite

15.20 – *Ileana Balduzzi*: The search of submarine sediment sources suitable for Ligurian beach nourishment

15.40 – *Chiara Francesca Schiaffino*: Application of Argus video monitoring system to evaluate the evolution of submerged bars in the embayed beaches of Barcelona (Catalunya, Spain)

16.00 - 16.20 Pausa caffé

16.20 – *Claudia Dessy*: Gravel beach: litoral evolution after a shore nourishment

16.40 – *P. De Gaetano*: Dispersion and degradation model for marine organic pollutions: an evaluation of sediment impact due to a fish farm

17.00 – *R. De Ferrari*: The estimation of site effects using seismic noise: advantages, problems and limits

THE SEARCH OF SUBMARINE SEDIMENT SOURCES SUITABLE FOR LIGURIAN BEACH NOURISHMENT

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One of the most recent techniques adopted for the protection and restoration of beaches undergoing erosion is the so-called "*soft protection and restoration intervention*" which involves the artificial nourishment of the beach with sediments dredged from the seafloor. The search for and use of submarine quarries for both industrial purposes and beach nourishment has been increasingly used since the 1970s (http://www.maggnet.info, http://www.wwf.org.uk/filelibrary/pdf/ma_aggdred_wa.pdf). The first such nourishment in Italy was carried out along the Adriatic coast in the beginning of the 1980s (Preti, 2002); it was soon followed by work along the Tyrrhenian coast (Chiocci & La Monica, 1999) and then in the rest of Italy (http://www.beachmed.eu).

Research and dredging work along the northwestern coast of Europe has been carried out on both the nearshore seafloor, often to make port areas and access canals in macrotidal areas more navigable, and offshore, involving substantial quantities of sediment (in 2004 the UK concession supplied about 24,000,000 m^3 of sediment). Instead, research and dredging in Italy has been almost exclusively limited to the continental shelf and specifically related to transgressive relic deposits related to the last glacio-eustatic cycle (Cattaneo & Trincardi, 1999). The characteristics and volumes of these deposits depend on both paleoclimatic factors and the structural and sedimentary characteristics of the continental margins.

In Liguria, where the geological structure of the continental shelf has peculiar morphological characteristics as a consequence of the different evolutions of the "Alpine" and "Apennine" sectors, the transgressive Versilian deposits vary considerably in place, extension and volume (Corradi *et al.*, 2004).

The Ligurian continental shelf is a sedimentary construction shelf on which, over the past 2-3,000,000 years, sedimentary layers have accumulated on a substratum that dips step-like from the shelf break. Its genesis and development occurred entirely within the Plio-Quaternary, even if phases of precocious erosive reworking in some areas have been dated to the Late Miocene. The transgressive-regressive cycles related to Quaternary glacio-eustatic events have given the shelf its present structure, with aggradation and/or progradation processes occurring during various sea level high stands, erosive sheering and progradant processes occurring beyond the shelf break during low stands.

Due to these processes the evolutive and structural features of the Ligurian continental shelf are very variable: the Apennine shelf linked to the Tyrrhenian evolution and the Alpine shelf linked to the Provençal-Ligurian Basin (Corradi *et al.*, 1984). The continental shelf of the Apennine sector is generally a sedimentary construction shelf in which subsidence, sedimentary supply and transgressive-regressive cycles have played a decisive role in defining the features of the margin. Instead, the western Ligurian continental shelf is of limited width and subdivided by morphological features, tectonic alignments and canyons. It is primarily a rocky shelf with limited sedimentary deposits near the coast and Plio-Quaternary sediments off shore (Corradi *et al.*, 1984).

The study of the deposition during the last glacioeustatic trangressive-regressive cycle has enabled us to find and locate relic deposits (Federici, 1972; Bellotti *et al.*, 1994; Trincardi *et al*., 1996; Chiocci *et al.*, 1997; Cattaneo & Trincardi, 1999). In fact during the LGM lowstand (about 120 m below the

present sea level) the greater part of the present continental shelf was exposed and the littoral deposits consisted of progradant sedimentary lowstand system tracts (Fierro *et al.*, 1973; Corradi *et al.*, 1984; Fanucci *et al*., 1987). During the Versilian transgression (20-6 ky BP) the coastal zone migrated from the shelfbreak to its present position. During various slowdowns or halts in the transgression littoral and deltaic deposits accumulated (Correggiari *et al.*, 1999; Federici, 1972; Fanucci *et al*., 1974).

On a global scale it is possible to recognise at least two periods of stasis in the transgression (Federici & Scala, 1969; Corradi *et al.*, 1984; Fanucci *et al.*, 1984; Fanucci *et al.*, 1987). In Liguria it is possible to distinguish two phases and sedimentary deposits related to slowing down or stasis of the transgression (Fanucci *et al*., 1977; Fanucci *et al.*, 1979; Balduzzi *et al.*, 2005; Corradi *et al.*, 2005).

During two projects, the Interreg IIIb and IIIc Projects co-financed by the European Union, the Region Liguria and the University of Genoa (Beachmed 2002-04 and Beachmed-e 2005-08), Dip.Te.Ris has made a preliminary study of the stratigraphic and sedimentological characteristics of the relic sedimentary bodies and the possibility of their exploitation in beach nourishment.

Seismic surveys and core sampling have been performed on the western sector of Ligurian continental shelf between the mouth of the Centa River and the town of Loano.

In this sector, the continental shelf is wide and characterised by an internal sector in which the acoustic substratum is sometimes outcropping. The external continental shelf is characterised by thick, progradant sedimentary deposits.

The geophysical survey, 220 km of seismic lines (with a 3.5 kHz Sub Bottom Profiler and a 100-400 J Boomer or Sparker), has allowed us to distinguish two transgressive relic littoral deposits of substantial thickness, lying at depths of about 60 and 80 metres in areas with a limited Holocene muddy cover. The study has allowed us to identify five layers with different seismostratigraphic facies. The sedimentological data of twenty vibracores has enabled us to characterise the sedimentary deposits and calibrate the geophysical data.

The textural analyses of the core sediments indicate that under a thin muddy cover (maximum three metres), it is possible to find intermediate layers with a sand fraction between 38 and 77% and a gravel fraction between 22 and 59%.

The preliminary results of these projects have allowed us to estimate the quantity of usable sediments for beach nourishment at about 2,400,000 m^3.

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PETROGENESIS OF LOWER PERMIAN ANDESITIC MAGMATISM FROM SOUTHERN EUROPE AND GEODYNAMIC BEARING ON THE POST-VARISCAN COLLAPSE

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The post-Variscan sequences of southwestern Europe are characterized by the constant occurrence of a basal rhyolitic ignimbrite, followed by andesites, and by conspicuous dacite-rhyodacite products, intercalated within lacustrine sediments. The post-orogenic subalkaline andesite to K-andesite volcanism,

developed within intramontane basins after the collapse of the Variscan orogen, originated in a geodynamic environment significantly different from continental or island arc settings. In particular, geochemical features, as the trace element ratios and initial (t = 290 Ma) Sr (and Nd) isotopic compositions allowed excluding Andean-type and OIBs magmas, suggesting a complex genetic pattern.

The composition of Lower Permian andesitic lavas was modeled starting from two potential primary magmas: I) a picrobasaltic composition, considered in equilibrium with a garnet lherzolite (Kagami *et al.*, 1991; Ulmer, 1987), and II) an enriched MORB composition (Cocherie *et al.*, 1994), in equilibrium with an amphibole or spinel lherzolite. The fractionating assemblage for the parental picrobasalt consisted of 40 wt% olivine, 10 wt.% orthopyroxene, 40 wt.% clinopyroxene and 10 wt.% plagioclase. I assumed this melt, generated at some 3 GPa and ≈ 1400°C as the parental liquid, and added incremental amounts of a felsic granulite of the External Liguride Units issued from anhydrous anatectic melts extracted from restitic bodies of metasedimentary origin (Montanini & Tribuzio, 2001). The selected contaminant consists of 60 vol.% of feldspar, 30 vol.% of quartz, and 10 vol.% of garnet ($Alm_{56\text{-}60}Py_{34\text{-}42}$). Mingling and fractional crystallization (MFC) were then modeled (MELTS, Ghiorso & Sack, 1995; Asimow & Ghiorso, 1998) in a closed system under isobaric, isenthalpic conditions (P = 0.3 GPa). In the MFC model, olivine (Fo88) appear as the first phase on the liquidus at about 1250°C, followed by clinopyroxene at ~ 1152°C and orthopyroxene at ~ 1094°C. The computed residual liquid evolves to match closely the composition of Lower Permian andesitic lavas after ~ 34% crystallization by adding ~ 27% of contaminant to the parental magma.

The outpoured volumes of andesites are significantly different in Sardinia (the most conspicuous), Ligurian Alps and Southalpine domains. The initial ^{87}Sr compositions detected in andesitic lavas from the three domains suggest an increasing crustal contamination. The orogenic collapse, followed by wrench tectonics at the surface and by the partial melting of the lower crust, and, finally, of the lithospheric mantle at depth can account for the whole Lower Permian igneous activity.

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MINERALOGY AND CHEMISTRY OF VARICOLORED STREAM SEDIMENTS FROM AMD PROCESSES IN LIBIOLA MINE

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Acid mine drainage processes occur when unaltered sulfide mineralisations bodies and sulfide-rich waste materials are continuously exposed to the weathering agents and acid production exceeds the buffering capacity of the of host rocks or the surrounding soils (Jambor & Blowes, 1994; Jambor 2003). This causes the generation of acidic sulfate waters, release of heavy metals and other potentially toxic elements, and formation of large quantities of secondary minerals. Precipitates of Fe^{3+}, Al, and sometimes Mn, take place in a wide range of physico-chemical conditions, varying from strong acidic to slightly alkaline *p*H and T (Murad & Rojík, 2003) and provide a highly visible means of identifying mine-impacted waters. As a consequence, a large amounts of ochreous- to reddish- and milky-white-materials are accumulated as unconsolidated muds, within the stream beds (stream sediments), or as thick (millimetric/centimetric) crusts, or as efflorescent blooms, on the surface of the waste-rock piles.

In Libiola Mine (Fe-Cu sulfide ore) there are numerous evidences that the AMD processes are active (Marescotti & Carbone 2003, Carbone *et al.*, 2005) and acid sulfate waters (Dinelli & Tateo 2002; Marini *et al.*, 2003) are produced mostly by oxidation of pyrite and chalcopyrite processes that occur either within the underground excavations and within waste rock piles (Marescotti *et al.*, 2007). This causes a production of large quantities of stream sediments that occur both as soft crusts inside the mine adits and as loose suspensions associated with overland flow of mine drainage.

The aim of this study is to describe the formation, the chemical and mineralogical properties, and the microstructural features of the nano and microphase Fe-oxyhydroxides and Fe, Al, and Cu hydroxysulfates present in mine adits and effluents in the Libiola mine area. The samples, distinguished in ochre (10YR 5/6), milky-white (Gley 1 8/1), and greenish-blu (Gley 2 7/2) precipitates, have been investigated through diffraction powder analyses (XRPD) and transmission electron microscopy (TEM); moreover, for every sampling site, *p*H, *E*h and temperature were measured on-site, whereas chemical determinations of sediments were carried out by ICP-MS analysis.

Since these chemical precipitates are environmentally significant because they 1) add to the suspended sediment and bed load of receiving streams, 2) decrease the effective life of treatment systems (wetlands and limestone drains), and 3) play a major role in the binding and transport of toxic elements, the complete mineralogical characterisation of these natural mineral assemblages is necessary to establish and to predict the fate of the toxic metals dissolved in the circulating solutions.

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THE PLIO-PLEISTOCENE OF VADO LIGURE: PRELIMINARY DATA

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The aim of this study is a detailed analysis of the Plio-Pleistocene deposits outcropping along the coast from Bergeggi to Savona in order to reconstruct the stratigraphy and the paleogeographic evolution of this area. In this work preliminary data will be presented. The Plio-Quaternary deposits outcropping in the study area have a restricted extent and they are well preserved along the left side of the last part of the Segno stream.

Through geological surveys and facies analysis have been identified three different Allostratigraphic Units, one Pliocenic in age and two, probably, Pleistocenic in age.

It is not possible to observe the sequence base because of the bad quality of the outcrops. The Allostratigraphic Unit 1 is constituted, at the base, of sand-silt deposits with plane-parallel lamination and scattered millimetric clasts of quartz. Over this Allostratigraphic Unit outcrops a level, 30 cm thick, of clasts-supported, poorly sorted conglomerate with erosive base, without sedimentary structure. This conglomerate passes over gradually to a sand-silt gray level with orange specklings and small scattered clasts. The Allostratigraphic Unit 1 ends with 1,35 meters of gray mud-silt deposits with rare macrofossils. These deposits in according to recent study (Caldarola, 2005) would be ascribed to the Pliocene.

The Allostratigraphic Unit 2 lies on the Allostratigraphic Unit 1 with sharp but barely erosive base. This Unit has not an easily appreciable thickness due to the bad quality of the outcrops but it is estimable in 50-60 meters. The Allostratigraphic Unit 2 is constituted by an alternation of fine grained sand levels and gravel. The finest levels (sand-silt and silt) are 5 cm to 1 m thick and they are massive but sometimes they show a plane-parallel lamination. The color of these levels appears from ochre to red often indicating a secondary alteration, probably related to water circulation. Locally millimetric scattered clasts are present. Near Rio Termini some silty levels are observable containing a lot of small fossil coals and vegetable remains, probably roots, completely oxidized. The gravel layers are 10 cm to 80 cm thick. They

are clast-supported, massive and moderately sorted. The clasts are predominantly constituted by quartz fragments. The matrix is formed by ochre sands. Probably this unit is further subdivisible.

The Allostratigraphic Unit 3, 2 to 25 meters thick, lies with clear erosive base on the Allostratigraphic Unit 2 and on the pre-Pliocene substratum. It is constituted by a matrix-supported, poorly sorted and massive conglomerate, but, locally, it is clast-supported and the clasts appear embricated along the small axis. The clasts' roundness varies from sub-angular to moderately rounded. The composition of the clasts of this unit is more heterogeneous than the gravel of the Allostratigraphic Unit 2. The quartz clasts are not much dominant. The red sandy matrix shows evident traces of pedogenesis.

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THE ESTIMATION OF SITE EFFECTS USING SEISMIC NOISE: ADVANTAGES, PROBLEMS AND LIMITS

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In the last ten years, enhancements in instrumental sensitiveness and dynamics has leaded to elaborate new fast methodologies useful for evaluation of local seismic response using seismic noise instead earthquake records (Lermo & Chavez-Garcìa, 1993).

Seismic noise mainly consists in low-frequencies part (below 1 Hz) defined as microseism and high-frequencies part (above 1 Hz) defined as microtremor. The first is mostly produced by meteorological and oceanic far away sources and is only constituted by surface waves (Rayleigh's waves), which are the elastic waves produced by the constructive interference of the P and S waves in the layers near the surface. The second is generated by industries and vehicle traffic and is constituted both surface (Rayleigh's) and body waves.

Among methods developed and tested in last years based on analyses of seismic noise, Nakamura's technique (Nakamura, 1989) is based on spectral ratio between vertical and horizontal component of signal records (H/V ratio), allowing to obtain amplification function of a site. Using an accurate acquisition system constituted by a three component sensor, a digital analogic converter and a GPS is possible to record noise windows from which spectral ratios H/V are obtained by using appropriate processing recording techniques.

Such ratios provide different results depending on considered site, showing an amplification maximum related to fundamental frequency of a site.

The aim of this work is to evaluate the results obtained from application of Nakamura's technique in the course of surveys for evaluation of local seismic response carried out in some high seismicity urban areas of northern Tuscany. During the application of such technique some solutions about employed instrumentation and mathematical-analytical processing have been considered as accounted in the

"Bollettino Ufficiale della Regione Molise (Suppl. straordinario n. 1 al B.U.R.M.) del 16 Gennaio 2003 n. 17" and as reported in the guidelines published by SESAME ("Site EffectS assessment using AMbient Excitations, European Commission, n° EVG1-CT-2000-00026, Coordinator: Pierre-Yves BARD, May 1st, 2001 - December 31st, 2004").

This work aims to emphasize main advantages and limitations of this technique, his accuracy level and reliability of obtained results considering the problems pointed out in the application of this technique as reported by several authors (Lermo & Chavez-Garcìa, 1993; Lachet & Bard, 1994; Bindi *et al.*, 2000, Parolai *et al.*, 2001).

In particular the surveys realized by the staff of Laboratorio di Sismologia – Dip.Te.Ris – University of Genova considered in this work have allowed to validate the results obtained from Nakamura's technique by means of comparison with (1) experimental technique based on signal analyses of earthquake recordings, (2) geological-geophysical-geotechnical data available for analyzed sites (boreholes and downholes), and (3) numerical 1D analyses which provide theoretical transfer function.

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DISPERSION AND DEGRADATION MODEL FOR MARINE ORGANIC POLLUTIONS: AN EVALUATION OF SEDIMENT IMPACT DUE TO A FISH FARM

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My research concerns the marine pollutant dispersion and the numerical model development for the evaluation of the environmental impacts. The aquaculture represents an important application because it is the foodstuffs production activity with the most rapid growth in the world (44% of the consumed fish comes from farm) and in particular marine fish farm in intensive system (FAO, 2006). Therefore it is necessary to develop tools to predict environmental impact due to fish farm waste.

Several studies (Hall *et al.*, 1990; Holmer & Kristensen, 1992; Karakassis *et al.*, 2000) have identified in the release of particulate waste (uneaten feed and faecal waste) the main cause of environmental impacts due to the presence of marine fish farms. The particulate wastes increase the organic load on the benthic environment and might determine changes in the community structure and in the biodiversity of the benthic assemblages (Tsutsumi *et al.*, 1991; Wu *et al.*, 1994; Vezzulli *et al.*, 2002, 2003).

Therefore we are in need for predictive tools able to assess earlier whether or not, the establishment of a new farm or the permission for an increase in production of an already existing one, can result in a potential impact on the surrounding environment. Numerical models can represent the right tools to perform environmental impact predictions and to test different scenarios.

For this aim, we improve the avvection-dispersion model POM-LAMP3D (Doglioli *et al.*, 2004) coupling with a new numerical benthic degradative module FOAM, Finite Organic Accumulation Module (De Gaetano *et al.*, 2007). This module computes the sediment stress level based on the ratio between the quantity of oxygen supplied to the sediment carried by current on the bottom and the quantity of oxygen demanded by the sediment for the organic carbon degradation (Findlay & Watling, 1997).

Several simulations were carried out switching suitable parameters such as: i) the waste typologies (uneaten feed or faecal particles), ii) the release conditions (continuous or twice a day), and iii) the particle chemical-physical characteristics (settling velocity) depending on the reared fish and the hydrology of the site where the fish farm is located (in this case Sea Bass and Gilthead Sea Bream reared in the Mediterranean Sea; Vassallo *et al.*, 2006; Magill *et al.*, 2006).

In our results the uneaten feed are confirmed to be the primary cause of ecological impact on the sediment, according to Beveridge *et al.* (1991) and Vezzulli *et al.* (2003), while the faecal waste are almost completely degraded. Furthermore, the maximum impacts, in terms of both stress level and organic carbon concentration, are due to the quickly settling feed, released in periodical mode and during slow current periods. These results support the use of self-feeders that are already proposed by several authors in order to reduce the uneaten feed losses with no effect on growth rates (Azzaydi *et al.*, 1998). Moreover, the results show how the new and more complete modelling framework here presented is able to improve the objectivity in decision making processes and it may be successfully used for planning and monitoring purposes.

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GRAVEL BEACH: LITORAL EVOLUTION AFTER A SHORE NOURISHMENT

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In this work the attention is focused on the use of gravel as fill material of nourishment and on the consequent behaviour of the shoreline. An important aspect in a nourishment project is the one concerning the materials to use above all in the grain-size, both in its composition and quantity. Beaches which are generally defined as "gravel beaches" are not constituted by pure gravel, they contain instead a certain percentage of fine fraction. Most studies do not give a clear definition of gravel beach and of how much coarse and fine sediment it can be made of. To set with precision a percentage limit of sand, beyond which a gravelly beach might be considered mixed, wouldn't be of any use, since it could not be applied universally; the sediment characteristics in fact vary in space and time. The coarse material that composes the gravel beaches are represented from the range of gravels under Udden-Wentworth classification for sediment with a b-axis diameter comprised between 2 and 60 mm (Buscombe & Masselink, 2006).

Considering spatial and temporal variations of sediments, Jennings & Shulmeister (2002) classify the coarse beaches in three types: pure gravel beach, mixed gravel and sand beaches, which are homogenous in either the cross-shore and the long-shore direction, and the composite gravel beach, with the steep reflective berm, a pure gravel composition and the low-angle dissipative of the inter-tidal area characterized by sand. Besides Horn & Walton (2007) add to the previous classification a fourth type of beach, which is made of composite material of sand and gravel in the reflective upper beach, and of a sand dissipative flat in the low tide zone. Generally gravel beaches are reflective morpho-type in the emerged beach, while they assume a dissipative profile in the submerged field.

The use of coarse-grained sediments to replenish eroding beaches is increasing more and more because of the high hydraulic characteristics of the shingle. This one, if compared with a sand beach, is more permeable (Van Wellen *et al.*, 2000). Gravel beaches have high hydraulic conductivity rather than

fine sand; their advantage is that the loss of sediments due to back swash is smaller. Moreover the gravelly fraction forms a stable substrate over which the finer sediments are transported; where the percentage of gravel turns out to be dominant, the sand becomes usually an interstitial part both along the coast and perpendicularly to it (Horn & Walton, 2007).

The aim of this study is to analyze the beach profiles' variations and the sediment distribution before, during and after a beach nourishment along a mixed gravel and sand beach in the Liguria western coast, in Italy. The shoreline considered is that of Levanto beach, which was recharged between autumn 2004 and spring 2005. This beach is an arch pocket beach and is divided in three cells by two groins, the central cell is further protected by a submerged breakwater.

During this project 16.000 cubic meters of borrow coarse sediment have been distributed. The crushed and treated quarried material has a value of 30 mm on an average diameter size. Native material is still visible in the eastern part of the littoral, since it has not been subjected to the beach nourishment. The typical grain size of the emerged beach is 3.50 mm, represented by granules in the Udden-Wentworth classification, and 0.2 mm in the submerged field represented by fine sand (Calligaris *et al.*, 2007). The beach of Levanto can be defined as a mixed gravel beach that has coarse grained in the emerged part, with a slope of 13% in the steep berm, and a dissipative morphology in intertidale sand terrace. From January 2004 to January 2007 with the aim of estimating the morphodynamic evolution of the shoreline, the position of the coastline and beach profiles have been measured and sand samples have been collected either on the fore-shore surface and off-shore. After the process of beach nourishment some bathymetric measures have been carried out in order to reconstruct the morphology of the submerged beach. Afterward the beach profiles have been confronted and their evolution has been analysed. The cross-shore transect A has been survey in the first cell of the littoral, that in the western side, the transect B in the central cell, the C, D and E in the eastern cell that it have a greater extension. The borrow material spread out using earth-moving machinery to achieve the required profile in the first and in the second cell.

After the beach nourishment, from the analysis of the survey field comes out an accreted of the shoreline, not only in the cells affected by the recharge of the grained fill, but also of the area near of them. This is due to the addition of borrow sediments passing the groin. The following year in 2006, all middle-western shoreline has had a slightly retreat with an accreted in the eastern side part. It has had greater values of retreat specifically near the groin that separates the central from the eastern cell. This is brought about because since 2005 there has been a great strengthening of this work of defence, which has prevented afterward the migration of the sediments from west to east towards the littoral drift. The study shows that the shore hydrodynamics is dominated by the wave action that with the run-up transported the coarse sediment on the long-shore drift and the effect of the cross-shore current comes out to be less remarkable. In this case the works of strengthening of the groin has been decisive in order to preserve the borrow material.

In January 2007, two years after the program of nourishment, it has been possible to reach the natural profile of the beach and the shoreline is stable; the eastern side of the littoral is accreted in comparison with the original position, even though it has never received fill material directly. The sediment data suggest that the grain size is smaller from west to east, in agreement with the long-shore drift. They have similar dimensions in the first and second cell, a little smaller near this last one, and much smaller in the eastern part of the beach. Therefore the sediment grain size goes from the grains and medium-fine pebbles to the coarse sand, up to a medium and fine sand.

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FIRST OCCURRENCE OF SYNTECTONIC GOLD MINERALIZATION IN TRANSCRUSTAL FAULT ZONES OF THE TRANSANTARCTIC MOUNTAINS (NORTHERN VICTORIA LAND, ANTARCTICA)

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All the former Pacific margin of Gondwana is characterized by Paleozoic gold mineralizations (Goldfarb *et al.*, 2001), for instance in what is now eastern Australia, the South Island of New Zealand and southern South America. Here we describe for the first time gold-bearing quartz veins in northern Victoria Land (Antarctica) that was part of this margin during the Paleozoic.

Northern Victoria Land can be subdivided into three NW-SE trending domains known as the Wilson, Bowers and Robertson Bay terranes. The terrane arrangement is increasingly interpreted as a fossil arc-trench system resulting from a westward-directed subduction at the paleo-Pacific margin of Gondwana during the Early Paleozoic Ross – Delamerian orogeny (Federico *et al.*, 2006) and therefore the three terranes should represent the continental magmatic arc, the forearc/back-arc and the trench sedimentary sequence, respectively.

The mineralized veins occur inside the Bowers terrane, not far from the contact with the outboard Robertson Bay terrane, known as Leap Year Fault. Wall-rocks are primarily greenschist to low-greenschist metabasalts with slices of metasandstones of Middle Cambrian age. Regional structural setting is characterized by NW-SE-trending folds, with subvertical axial plane, and by NW-SE and N-S fault systems linked to a transpressional regime of deformation. Quartz-carbonate veins occurs in a brittle-ductile high strain zone superimposed on the earlier regional metamorphic foliation and folds. The high strain zone is characterized by foliated fault rocks with S-C structures, widespread veining, and hydrothermal alteration of the host rocks. The quartz-carbonate veins are extensional and shear veins, often with ribbon/banded appearance and texture typical of crack and seal processes (Ramsay, 1980). The vein network is surrounded by an alteration halo approximately up to 500 m wide, which ranges from a chlorite zone, to a sericite-carbonate zone and a sericite-pyrite zone approaching the core of the vein system. Carbonates are ankerite inside the veins and both ankerite and siderite in the wall-rock.

Preliminary chlorite thermometry (Cathelineau & Nieva, 1985), provides temperature estimates ranging from 270 to 280°C in the chlorite-altered metabasalts and from 290 to 310°C in the more altered samples.

Gold occurs as coarse-grained (up to some millimeters) native gold, associated with pyrite and arsenopyrite.

Available data are discussed with the aim to understand the origin of the gold deposit, its role in the tectonic evolution of northern Victoria Land and its relevance for correlations at the scale of the paleo-Pacific margin of Gondwana.

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QUANTITATIVE GEOMORPHOLOGY AND PLIO-QUATERNARY EVOLUTION OF THE NE LIGURIAN ALPS, IN THE AREA BETWEEN GENOVA AND SAVONA

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The sector of Ligurian Alps that marks the link between the Apennines and the Alps has a short and steep marine slope through South and a more gentle and wide one through North. The Po-Ligurian divide lies at a high altitude, often above 1000 m above sea level, and runs almost parallel to the coastline, only 6 km from it in the neighbourhood of Arenzano. The strong asymmetry of the range has not yet been completely related to the tectonic and climate forcing leading to the building and modeling of the Ligurian Alps.

Through quantitative analysis and long profile modeling of 9 rivers (6 on the Ligurian flank, 3 on the Adriatic one) the recent landscape evolution has been investigated, focusing, in particular, on their erosion mechanism and on the correlations between tectonics and hydrographic networks. Results from the opposite flanks will eventually help in understanding the divide migration process.

Using ArcGis 8.3 and 9.2 three swat profiles of the study area, which covers 760 km^2, have been extracted. They highlight the asymmetric trend of the range and show particularly high values of Local Relief (E_{max} - E_{min}) along the Ligurian flank, within a distance of 5-6 km from the drainage divide.

Carrying out an analysis of first order channels slopes (Frankel & Pazzaglia, 2005) an interpolation map from the obtained punctual data has been created. It shows, moving from W to E, a growing trend of river incision, probably related to different rates of tectonic uplift.

The longitudinal profiles of the 9 main trunk channels have been analyzed by creating Slope/Area plots, using the power law S = ks A - θ (Flint's law; Hurtrez *et al.*, 1999). This analysis allows modeling the values of steepness, ks, and concavity, θ in order to verify the influence of lithology and tectonics in the erosion mechanisms.

The high values obtained for the Ligurian basins for both indices, especially in the central sector, suggests a high rate of erosion in the middle part of the basins. However, this high erosion doesn't coincide with a fast retreat of the watershed divide, probably because of the presence of the hard metaofiolitc rocks of the Voltri Group within this sector. The high erodibility of the sedimentary rocks of the Piedmont Tertiary Basin, which characterize the main gaps of the range, favour instead the retreat of the escarpment and the widening of the S flank throughout fluvial captures.

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CRITICAL PARAMETERS FOR THE THERMAL ANALYSIS OF A SEDIMENTARY BASIN

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The *in situ* bulk thermal conductivity of rocks, which directly controls the temperature distribution at equilibrium state, is a key parameter for the implementation of thermal models of sedimentary basin evolution. In transient conditions, the temperature field is controlled by the thermal diffusivity, *i.e.* the ratio between the thermal conductivity and the volumetric heat capacity (density × specific heat). These physical proprieties, representing the capacity of a rock to transmit heat, vary with lithology.

To measure directly the *in situ* thermal proprieties in a basin is not often possible, and the usual approach is to assume thermal conductivity and volumetric heat capacity based on published data of different rock types. If the conductivity and diffusivity cannot be accurately predicted, even the most sophisticated and appropriate modelling techniques are not sufficient for accurate temperature predictions.

The aim of this paper is to remedy the existing deficiency of thermal proprieties data of sedimentary rocks by making a series of laboratory measurements on several bottom core samples,

available at the Eni E&P core-house. The core samples were recovered from petroleum explorative wells, and are representative of the main sedimentary rocks recognized in the western Po Basin (sandstones, shales, marls and carbonates).

A number of measurements of thermal conductivity, thermal diffusivity and volumetric heat capacity were performed perpendicularly and transversely to the core axis at the geophysical laboratory of the University of Genova. Samples were considered as structurally isotropic materials. Index properties (porosity, bulk density and matrix density) and mineralogical composition of samples were determined at the petrophysical laboratory of the Eni E&P (Pasquale *et al.*, 2008a).

The matrix thermal conductivity of a rock is that of the solid portion, and it may be expressed as a function of the conductivity of each rock-forming mineral and of its relative abundance. Among several mathematical models proposed for multicomponent systems, the geometric distribution model is the most accurate to estimate the conductivity. We experimentally verify the first-order control of mineralogy, porosity and fluid content on bulk conductivity, and we demonstrate that the computed matrix conductivity can generally differ by less of 10% to the measured matrix conductivity, as long as isotropic samples are used and the mineral content is reasonably well estimated (Pasquale *et al.*, 2008b). This approach does not care for any effect on the structure, such as crystal orientation, or grain boundaries. The bulk density and specific heat are modelled through a weighted mean between the solid and fluid components.

In order to estimate the thermal conductivity and diffusivity of sedimentary formations at the basin scale, it is necessary to define precisely the matrix thermal conductivity and volumetric heat capacity of the main lithologies and pore fluids. Porosity is the major parameter controlling the petrophysical proprieties, and so it is necessary to assess carefully the void index before modelling the thermal conductivity, density and specific heat along a vertical section. Porosity was modelled using a generalized porosity-depth function formulated by Sclater & Christie (1980), which states that the porosity decays exponentially with depth of burial. The increases in temperature and pressure with burial depth are further determining factors in the estimation of the effective thermal conductivity and diffusivity. The temperature dependence of thermal conductivity was taken into account assuming that the matrix conductivity is proportional to the reciprocal of the absolute temperature (Deming & Chapman, 1988) and the water conductivity follows a polynomial law obtained by least squares fit of Kreith's data (1973). The pressure effect is linked to the compaction curve (porosity vs. depth) of each lithology. Moreover, it plays an important role in the modelling of physics properties versus both depth and time, because during a burial event, subsidence occurs and the sedimentary units move down. The temperature gradient controls the surrounding thermal conditions, while the lithostatic load consolidates sediments and decreases their porosity. These phenomena control the effective thermal proprieties of rocks, and thus appropriate corrections for *in situ* conditions must be applied to matrix thermal conductivity and diffusivity.

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BLASTESIS-DEFORMATION RELATIONSHIPS IN THE EVOLUTION OF THE NORTHEN APENNINE SERPENTINITE

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Northern Apennines ophiolites represent slices of the Jurassic Ligurian-Piedmont oceanic basin separating paleo-European and Adria continental blocks. The peridotitic basement was involved in two cycles of ocean floor metamorphic events: the first one corresponds to the uplift to the ocean floor; the second one is related to the effusive activity and to the hydrothermal alteration on the basement and the volcano-sediments (Cortesogno & Lucchetti, 1984). During Late Cretaceous - Early Cenozoic orogenic events, the ophiolites were deformed and metamorphosed in prehnite-pumpellyite facies conditions (Lucchetti *et al.*, 1990). As a result, Apennine serpentinites are extensively tectonized and characterized by several generations of fractures.

Studied samples belong to Jurassic Ophiolitic Units ascribed to the "Val di Vara" Supergroup, Internal Liguride (Petronio Valley, Graveglia Valley, Vara Valley, Levanto) and to the External Liguride Ophiolitic Units (Upper Taro Valley). Dismissed quarries and natural outcrops were object of microstructural and petrological analysis. On the basis of textures, mineralogical composition and geometric ratio it is possible to recognize different microstructures corresponding to the Jurassic oceanic and to the Apennine orogenic phases respectively.

The pristine lherzolite is characterized by granular and schistose fabric. Clinopyroxene is preserved, whereas olivine is rare. The pre-oceanic phase is preserved as iso-oriented orthopyroxene, sometimes in polycrystalline aggregates, with gently bent cleavages. Plagioclase (generally < 3% in volume), during serpentinization, undergone an exchange reaction whit orthopyroxene consequently transformed in chlorite, and mantle orthopyroxenes exsolve in orthopyroxene and lamellar diopside.

Serpentinization process gives a lizardite, chrysotile and magnetite paragenesis. In massive domain and in polyphasic fracture sets, serpentine minerals are frequently microcrystalline and microscopically intergrown. In addiction to chrysotile, also fibrous diopside and tremolite, and chlorite are present. Orthopyroxene porphyroclasts (diameter between 1–3.5 mm) are replaced by lizardite in bastite textures within a serpentinitic matrix characterized by mesh and ribbon textures.

Mesh textures (static blastesis), hourglass and ribbon textures (sin and post kinematic blastesis) and pseudomorphic substitutions of orthopyroxene by serpentine (bastite) characterize the early oceanic stages. Lizardite is the most common polymorph, developed on protolith olivine fracturing micro-sites, instead of chrysotile, which crystallizes along fractures. Chrysotile growth is favoured in brittle conditions, along micro-fractures in $P_{tot} = P_{H2O}$ conditions, where it crystallizes with antitaxial and/or sintaxial structures (Ramsay & Huber, 1987), with crack–seal mechanism (Ramsay, 1980; Andreani *et al.*, 2004). Lobate rim veins and cryptocrystalline vein filling seem to show a fluid-dominated regime with $P_{H2O} \geq P_{tot}$ (P.sso dei Ghiffi).

The orogenic phase is characterized by brittle deformation structures. Studied serpentinites are interested by several vein generations that cut the older fabric. Metamorphic tremolite veins, referred to the orogenic event, are consistent with prehnite – pumpellyite facies conditions.

Locally (P.sso dei Ghiffi), chrysotile syn-orogenic veins present a pervasive fracture – cleavage or an extensive "brecciated" texture (Bargonasco).

Bastite porphyroclasts are affected by an extensive micro-fracturing and syn-kinematic recrystallization, that results in a "chessboard" structure.

As a whole, the blastesis–deformation relationships allows associating the different serpentine textures to the genetic and evolutionary phases of the Apennine.

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LATE QUATERNARY LOESS OF THE MOUNT BEIGUA (ALPI LIGURI): CHARACTERISTICS AND PALEOCLIMATIC SIGNIFICANCE

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In the framework of a larger study, focused on the Quaternary evolution of selected areas of the Ligurian Alps (Northern Italy), one representative loess-paleosol sequence has been identified and characterized in detail, by mineralogical and micromorphological analyses, in order to clarify his genesis, and to discuss his palaeoclimatic significance in relation to the Quaternary climatic fluctuations of the Ligurian Alps.

The final aim of this study is essentially to establish a chronological succession of pedological and sedimentary events in order to decipher and interpret the enviromental significance of each phase. These successive events have affected the soil at different levels. Most of the transformations appear to have been recorded at the microscopic scales and consequently soil micromorphology can be considered as the most efficient approach for studying the loess-paleosol sequence. The following phases of erosion, deposition and soil formation were recognized by detailed examination of thin section.

The micromorphological evidences supported by the mineralogical analyses, suggest a polygenetic origin for the profile, affected by different superimposed processes, acting in different environmental conditions on distinct parent material: in fact the deeper unit was produced by a strong pedogenetic phase, involving the bedrock parent material and leading to the development of pedogenetic body showing characteristics like present day strongly weathered subtropical to tropical area soils (*i.e.* fersiallitic to ferrallitic soil, *sensu* Duchaufour, 1977), while the upper units, is clear that multiple erosional events, followed by depositions of material developed from loess blankets, have took place. These materials

shows features which are comparable to Lateglacial interstadial soils of the middle Europe, which were not erased by the present day pedogenesis.

In conclusion, the present work on loess-paleosol sequences along Ligurian Alps is very important because it extends the eolian sedimentation studied by Cremaschi (1990a, 1990b, 1990c) in basin between the Alps and the Mediterranean region, already described in Spain and France, and because such sequences are regarded as some of the best terrestrial equivalents of marine-sediment records of quaternary environmental change (Catt, 1991).

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APPLICATION OF ARGUS VIDEO MONITORING SYSTEM TO EVALUATE THE EVOLUTION OF SUBMERGED BARS IN THE EMBAYED BEACHES OF BARCELONA (CATALUNYA, SPAIN)

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This research is a preliminary study carried out to analyze the morphology of the submerged bars which characterize the embayed beaches of Barcelona (Spain), by means of the application of the Argus video monitoring system (Holman *et al.*, 1993, 2003; Holman & Stanley, 2007). The importance of this research lies in the function that these heaps of sand have to help preserve the beach stability in the evolution of the morpho-dynamic beach profiles (Wright & Short, 1984).

The beaches on the waterfront of Barcelona were monitored through an Argus video system since November 2001 (Ojeda & Guillen, 2006). On two of these beaches, Bogatell and La Barceloneta, there is a single shore-parallel bar (Ojeda *et al.*, 2007). For the description of the submerged bars the Argus images set between the 19/10/2001 and the 31/12/2002 were examined. The description of the nearshore bars observed in Bogatell and La Barceloneta has been realized through the images Argus time exposure and the wave data provided by buoy WANA 2065051.

Two lines of research have been undertaken: these have entailed an analysis of the change of the submerged bar position on annual and daily scale, in order to show its mobility and its acting causes, such as the adaptability to the sea conditions or the erosive process in progress. In order to study the homogeneity of the structures' movements and the ways and conditions in which they take place during the year, analysis have been carried out by subdividing the beaches into sectors with equidistant transects. The bar movements have been surveyed considering the intersection of the bar offshore limit and the

corresponding transect. For each zone the variability has been calculated, that is the difference between the nearest point to the shoreline reached by the bar and the most distant one.

The research showed that the bars of both beaches are active, they adapt to the wave conditions thus helping the beach create its morpho-dynamic profiles and protect itself against withdrawing and loss of material. The bar movements have been most clearly noticed in the medium-term analysis, as a consequence of the forming of seasonal beach profiles.

As regards the zones' analysis of the beach La Barceloneta, a regular and plain bar movement was noticed; data concerning the bar displacement are almost the same in every part of the beach, even though it is possible to notice a displacement decrease in the centre-north zones. On the other hand, on the beach of Bogatell, a non-uniform bar motion was noticed, which shows maximum displacements especially in the most northern zone, in comparison in the most southern one.

The study of the tendency lines, obtained from the intersection variation of the offshore bar limits and the transects, made possible the analysis of the bars' morphological variation throughout the year. As far as La Barceloneta beach is concerned the tendency lines are linear. The concavity they show indicate the year's periods in which there maximum movements took place. The Bogatell beach bar, instead, shows a less regular movement, with undulations. The distance of the different bar zones from the seashore line changes increasing from south to north, as it was been noticed by the variance analysis. This movement allows the hypothesis that the structure is not parallel to the shore, and that there is an angle of inclination with it.

The medium-term observations show an inshore bar movement in conditions of waves low energy, and an offshore movement with high energy. From the achieved data the influence that the hard protection structures have on the bars' morphology was put in evidence. Both in La Barceloneta and in Bogatell, the bar part which is more protected by the groin north from the beaches has a lower reaction to the wave conditions, thus showing a poor variability both in position and morphology; this action is not noticed in the southern zone which is not protected. Further observations allowed to notice that in both beaches the presence of groins helps the creation of a rhythmic bar (Wright & Short, 1984).

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SEISMOTECTONIC ANALYSIS OF THE COMPLEX FAULT SYSTEM NAMED "GARFAGNANA–NORD" (NORTHERN TUSCANY)

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Garfagnana–Lunigiana is one of the most seismically active areas of the Italian peninsula. It is characterized by a complex faults system, only partly mapped, with a not well known seismotectonic regime and depth extension. The aim of this work is to improve the seismotectonic knowledges of the area integrating different seismological methodologies.

The potential of the system is instead well known: this region was interested by a major earthquake on the 7 September 1920 (Mw 6.4). The most recent damaging earthquake (Ml 4.9) has occurred on the 10 October 1995. The seismicity is under constant monitoring by the Seismic network of North–Western Italy (RSNI managed by Dip.Te.Ris., University of Genova) and by the National Central Seismic Network (RSNC managed by the National Institute of Geophysics and Volcanology, Roma). This lead to a good concentration of seismic stations, and to the availability of several seismograms, that enable us to reveal, record and localize earthquakes down to very low magnitude threshold (inferior to Ml 1.8) and with extremely contained errors in the hypocentral parameters.

The dataset used in this study consists of 953 earthquakes obtained linking the waveforms of both RSNI and RSNC seismic networks, in order to achieve a good completeness. The best quality of data is ensured by a comprehensive manual phase repicking both for P and S arrival times (14893 P phases and 9865 S phases). Making use of the resulting database, several analysis were conducted to determine the shape, size, extension with depth and associated seismicity of the seismogenic lines. The methodology applied consists in seismic tomography, precise location algorithms NonLinLoc and HypoDD and computation of focal mechanisms, all combined with the constraints provided by geological knowledge.

Local seismic tomography is used to obtain accurate 1D and 3D velocity models. The tomographic problem for both Vp and Vp/Vs ratio is approached via the widely used code "SIMULPS" (Thurber, 1983), a software designed to linearize and to solve the coupled velocity-hypocentre problem in a three dimensional model subdivided into layers and nodes. This software simultaneously solves a direct problem where the unknown parameters are the locations of the earthquakes, and an inverse problem where the three-dimensional seismic velocity model is the parameter to find. The resulting velocity models, in particular the three dimensional one, are able to better simulate the real behaviour of an inhomogeneous volume of the Earth, that is a key point to achieve reliable results in locating earthquakes.

Accurate locations of seismic events are calculated, on the basis of the obtained velocity models, both with a probabilistic location methodology (NonLinLoc developed by Lomax *et al.* (2000; http://www.alomax.net/nlloc), and with a relative location methodology (Double-Difference Hypocentre Locations – HypoDD, developed by Waldhauser & Ellsworth (2000)).

The first methodology is based on a global search of the solution procedure that can be obtained using three different algorithms. We choose to use the "Oct–Tree Sampling Importance" (Lomax & Curtis, 2001) algorithm, after convenient comparative tests, first of all because of its good and reliable results, and also because of its ease of setup and of its velocity of execution.

The HypoDD technique (described in detail in Waldhauser & Ellsworth, 2000) takes advantage of the fact that if the hypocentral separation between two earthquakes is small compared to the event-station distance and the scale length of velocity heterogeneity, then the ray paths between the source region and a common station are similar along almost the entire ray path. In this case, the difference in travel times for two events observed at one station can be attributed to the spatial offset between the events with high accuracy.

Fig. 1 shows the accurate earthquake relocation of the whole dataset calculated with the software NonLinLoc (circles), the epicentral position of the 1920 earthquake (star) obtained by an instrumental relocation (Solarino, 2005), and the epicentral position of the 1995 earthquake (rhombus). Similar image has been obtained also using the HypoDD methodology, supporting the reliability and the accuracy of the results. The seismicity has a NW–SE orientation, coincident with the supposed direction of the main fault systems of the area. There is also a concentration of hypocentres around the epicentral area of the 1920 earthquake and around the southern limit of the Garfagnana North fault.

The superimposition of the seismicity cross–sections obtained with NonLinLoc to the tomographic images of the Vp/Vs ratio distribution (Fig. 1) shows that the seismicity is confined to the border between high Vp/Vs areas (dark gray in Fig. 1) and low Vp/Vs areas (light gray in figure). The dip of the earthquakes distribution suggests that the dip of the Garfagnana North is of about 30° with NE immersion, and with a depth extension of about 15 km.

Finally, the transtensive character of the Garfagnana North area comes out from the study of the focal mechanisms calculated with the first arrivals methodology for earthquakes with Ml ≥ 3.0. Only the 1995 earthquake has a strike slip mechanism, that suggests that the epicentral area of this earthquake could be a junction zone of the NW – SE fault systems.

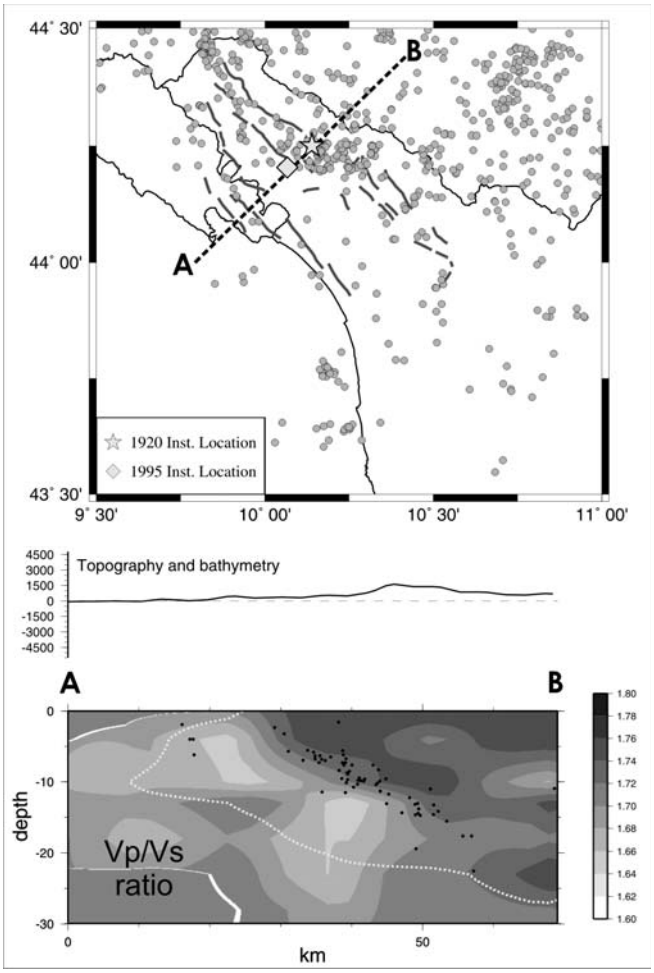

Fig. 1 - Horizontal distribution of the earthquakes relocated with the software NonLinLoc (circles), superimposed to the epicentral position of the 1920 earthquake (star) obtained by an instrumental relocation (Solarino, 2005), and to the epicentral position of the 1995 earthquake (rhombus). The bottom panel shows an anti–Apenninic cross–section of the Vp/Vs ratio distribution overimposed to the relocated seismicity.

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A COMPARISON BETWEEN ASTRONOMICAL AND MAGNETIC IMAGE DECONVOLUTION TARGETING ARCHAEOLOGICAL PROSPECTION

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Magnetic prospection is routinely employed in archaeological site surveying to map buried stone/brick foundation structures, roads or graves and to outline the locations of kilns, hearths and ferric objects. In archaeological magnetic prospection most of the buried targets may be simply modeled by a single layer of constant depth and thickness (Tsokas & Papazachos, 1992).

Starting from the assumption that magnetic sources are held only in a single layer and sampling points are taken equispatially over it, it is possible, from the mathematical point of view, to trace an analogy between the acquisition of magnetic data and the process of image formation (Bertero & Boccacci, 1998). The impulse response of above described single layer magnetic system is space-invariant, hence we can express the forward problem as a convolution product between the impulse response and the magnetized sources. So the measured magnetic field is a blurred and noisy image of the true buried magnetized object. The comparison between image processing and magnetics is given by: data image *vs.* measured magnetic field, point spread function (PSF) *vs.* impulse response function, Poissonian noise *vs.* Gaussian noise.

The inverse problem consists in recovering the magnetization distribution (or susceptibility) of the buried layer from magnetic surface measurements. Because of the presence of noise, the inverse of detected data, that is usually called the generalized solution has no physical meaning. This is an ill-posed problem described by a first kind Fredholm integral that requires regularization techniques to be solved. In analogy with the image reconstruction theory, the solution showing the resolved subsoil features can be considered as the focused version of the blurred and noisy magnetic rough data image.

In view of these considerations and taking into account an additive Gaussian noise, we apply to the magnetic inverse problem two iterative image deconvolution methods, Landweber and ISRA. The inverse problem becomes an optimization problem that we solve through the minimization of a functional derived

by the Maximum Likelihood (ML) approach which is based on modeling of the noise corrupting the detected data. The subsoil is parametrized as a layer of prismatic cells of constant magnetization. The resulting algorithms have been implemented in Python language and several tests have been performed.

Generally archaeological targets present a blocky structures (like walls for example) so it is important to obtain non-smooth reconstructions, as instead results applying the classical Tikhonov regularization. From this point of view, the regularization term can take into account some "a priori" information on the solution, in fact, we perform the optimization using edge-preserving regularization (like Total-Variation) obtaining enhanced and more stable results (Portniaguine & Zhdanov, 1998; Vogel, 1997).

The described inversion scheme represents a simple and effective "recipe" for magnetic archaeological prospection in case that the single layer assumption holds true, like when the targets are foundation structures, roads and graves. In this case piecewise constant (blocky) magnetization distributions in the subsoil should be expected.

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