OTTAVA GIORNATA RICERCA GIOVANI

7 giugno 2012

Dipartimento di Scienze della Terra, dell'Ambiente e della Vita, Università di Genova

Corso Europa 26 – Aula Perrier, ore 10:00

Seminari sulle attività di ricerca nelle Scienze della Terra svolte da dottorandi e assegnisti

PROGRAMMA

TUTELA E GESTIONE DELL'AMBIENTE E DEL TERRITORIO

chairman: Rosa Maria D'Acqui (Direttore Scientifico Agenzia Regionale per la Protezione dell'Ambiente Ligure)

Claudia Scopesi (Dipartimento di Scienze della Terra, dell'Ambiente e della Vita, Università di Genova):
Erosione del suolo e generazione di alluvioni con differenti scenari di uso del suolo in un sottobacino mediterraneo

Valerio Pucci (Dipartimento di Scienze della Terra, dell'Ambiente e della Vita, Università di Genova):
Monitoraggio ambientale attraverso geoindicatori. Esempio applicativo ligure

ASPETTI APPLICATIVI DELLE SCIENZE DELLA TERRA E MODELLIZZAZIONE SPERIMENTALE DEI PROCESSI MINEROGENETICI, PETROFISICI E LITOSFERICI

chairman: Giovanni Scottoni (Presidente Ordine Regionale dei Geologi della Liguria)

Giacomo Pepe (Dipartimento di Scienze della Terra, dell'Ambiente e della Vita, Università di Genova):
Studi geomeccanici della formazione del Flysch di San Remo

Silvia Torchio (Dipartimento di Scienze della Terra, dell'Ambiente e della Vita, Università di Genova):
Geologia strutturale, geomeccanica, telerilevamento e GIS: un approccio multidisciplinare per la realizzazione di gallerie

Enrico Cannaò (Dipartimento di Scienze della Terra, dell'Ambiente e della Vita, Università di Genova):
Isotopi del Boro in rocce femiche – ultrafemiche come traccianti del rilascio di fluidi nelle zone di subduzione. Dati preliminari

Eva Azzali (Dipartimento di Geoscienze, Università di Padova):
Evoluzione mineralogica e chimica dei precipitati ocracei correlati ai processi di Acid Mine Drainage nella miniera aurifera di Roşia Montană (Romania)

Matteo Padovano (Dipartimento di Scienze della Terra, dell'Ambiente e della Vita, Università di Genova):
Interazione tra percolazione di fuso e zone di taglio nelle peridotiti di Erro-Tobbio (Massiccio di Voltri)

Cristina Malatesta (Dipartimento di Scienze della Terra, dell'Ambiente e della Vita, Università di Genova):
Le zone di subduzione oblique attraverso modelli numerici 3D

MINERALOGICAL AND CHEMICAL EVOLUTION OF OCHREOUS PRECIPITATES FORMED DURING ACID MINE DRAINAGE PROCESSES AT THE ROŞIA MONTANĂ GOLD MINE (ROMANIA)

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The Roşia Montană gold mine (Apuseni Mountains, Romania) is characterized by active and intense Acid Mine Drainage (AMD) processes that cause the widespread circulation of Acid Sulphate Waters (ASW; *p*H ≤ 3), containing very high levels of Potentially Toxic Elements (PTE) deriving not only by the sulphide mineralizations but also from host rocks and gangue minerals (such as Zn, Cr, Cu, Ni, As, and Pb; Bird *et al*., 2005).

The studied area is located within the Roşia Montană mining site, which is a hydrothermal gold deposit hosted in andesites and dacites of Neogene age, piercing the prevolcanic sedimentary basement (Wallier *et al.*, 2006). In this study a mineralogical and geochemical characterization of the ochreous precipitates and associated waters forming within the Roşia river was carried out in order to evaluate the mineralogical variations starting from the lowest adit of the "Sf. Cruci din Orlea" gallery up to the confluence between Roşia and Abrud rivers; the partitioning of PTE between contaminated waters and secondary minerals was also investigated. The mineralogy of the precipitates was determined by means of XRPD, whereas the bulk chemistry by ICP-MS. Some selected samples, representative of the main mineralogical assemblages, were further analyzed by means of transmission electron microscopy (TEM) and microanalysis (EDX). Temperature, *p*H and Eh were measured *in situ*, whereas the chemical analyses on mine waters were made by means of ICP-OES, AAS, and chromatography.

Ochreous precipitates are characterized by high concentrations of PTE (in particular V, Zn, Cd, As, Pb) and consist of a mixture, in variable proportion, of K-jarosite and schwertmannite, which represent the stable secondary minerals along the investigated transect of Roşia river. Moreover a positive correlation between Fe and S with As, V and Pb suggests an effective control of schwertmannite and jarosite on the mobility of specific PTE. Waters flowing from "Sf. Cruci din Orlea" gallery (ASW) are characterized by the lowest *p*H values (2.7-3.1) and the highest Eh (460-484 mV), SO_4 (688-4800 mg/l) and PTE contents (Zn, Cr, Cu, Ni, Co, Cd). A remarkably different hydrochemistry is evident at the confluence between Roşia and Abrud rivers, being characterized by a significant increase in *p*H (6.3-7), decrease in Eh (≈ 300 mV), and a general reduction of dissolved SO_4 and metal load.

The results indicate that the role of secondary minerals as ''mitigating agents'' can be ephemeral because even minor *p*H-Eh oscillations can cause mineralogical transformations, via dissolution-reprecipitation or solid-state transformation, leading to trace elements mobilization in the environment.

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BORON ISOTOPES IN FEMIC-ULTRAFEMIC ROCKS AS TRACERS OF THE PROCESS OF TRANSFER AND RELEASE OF FUILD IN SUBDUCTION ZONES: PRELIMINARY DATA

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The subduction zones are the primary carriers for the transfer of water into the deep Earth, the recycling of crustal plates and the release of volatiles and fluid-mobile elements into the mantle, ruling Earth's mantle re-fertilization and triggering the arc magmatism in the so-called "subduction factory" (Tatsumi & Kogiso, 2003). In the subduction the consumption of the oceanic lithosphere of the lower plate and part of the upper plate takes place, and this process usually evolves with the collision between continental plates and the genesis of orogenic belts, in which material subducted at great depth is exhumated and emplaced in tectonic nappes recording the main events of dehydration and fluid/rock mass exchanges.

In some recently proposed models (deriving from numeric models; Malatesta *et al.*, 2012) exhumation of HP -UHP rocks occurs within low-viscosity channel located at the interface slab *vs.* mantle-wedge, generated by the rise of fluids from the slab and essentially made up of serpentines forming tectonic mélanges and/or nappes of material dominated by HP ophiolitic serpentinites (Hermann *et al.*, 2000). However, direct imaging of the plate interface is still missing and can be accomplished through detailed field, petrologic and geochemical studies of high-pressure rock complexes. The analysis of some isotope tracer, such as B (Leeman & Sisson, 1996) in mafic and ultramafic rocks can help to describe the exchange fluid/rock processes conditions of HP, to recognize the origin of the different tectonic elements (slab *vs.* mantle wedge) and to reconstruct the tectonic processes that govern these geodynamics environments.

I then performed analysis on HP ophiolitic rocks derived from different sectors of Western Alps, Lanzo and Voltri Massif, and Central Alps, Cima di Gagnone. The serpentinized peridotites of Lanzo show enrichments in B contents (2 to 30 ppm) respect to the depleted mantle (DM, 0.06 ppm; Salters & Stracke, 2004) and $\delta^{11}B$ positive values (up to 15 permil), indicating a possible derivation from hydrated mantle-wedge. The data set of the Voltri Massif offers content of B typical of oceanic serpentinites (12-41 ppm) and $\delta^{11}B$ values very high and variable $\delta^{11}B$ values (18-30 permil). The prograde garnet peridotites and chlorite harzburgites of Cima di Gagnone show enrichments in B (2 to 8 ppm) compared to the DM and $\delta^{11}B$ negative values (-7 to -9 permil) indicating a derivation from dehydration processes of the old serpentinites and/or interaction with fluids resulting from metasediments in subduction environment. Trace elements analysis on this rocks from Scambelluri & Rampone (unpublished) display enrichment in this element thus confirming the hypothesis of derivation from former serpentinites (Evans & Trommsdorff, 1978) and isotope Pb suggest an interaction with fluids derived from metasediments.

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OBLIQUE SUBDUCTION ZONES THROUGH 3D NUMERICAL MODELS

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Several past and present subduction zones (*e.g.*, Alpine subduction, Malusà *et al.*, 2011; Hikurangi margin, New Zealand, Upton *et al.*, 2003; Sumatra and Nankai subduction zones, Malod *et al.*, 1995; Tabei *et al.*, 2003) are driven not only by a trench-normal motion but also by a trench-parallel movement of the subducting plate, resulting in an oblique-type convergence.

Since classical 2D numerical models are not sufficient to reproduce this particular setting, I have therefore explored 3D simulations. Oblique subduction zones have been already studied in three dimensions through numerical models to highlight the pattern of small-scale convection within the mantle wedge (Honda & Yoshida, 2005). Here I want to focus on the influence that the trench-parallel component of velocity of the incoming plate exerts on subduction and exhumation dynamics. The numerical code that I have used is based on thermo-mechanical equations that are solved with the finite differences method and marker-in-cell techniques combined with a multigrid approach (Gerya, 2010).

The starting setup consists of a narrow oceanic basin (500 km-wide) delimited by continental margins. Two structures of the oceanic lithosphere have been tested in different models: the "layered" one is formed by layers of gabbros and basalts whereas in the "heterogeneous" oceanic lithosphere gabbros are limited pockets inside serpentinite peridotites and basalts forms a layer at the top. In both cases a sedimentary cover closes the sequence. Intraoceanic subduction is forced to start at a weak-zone in the mantle that defines the plate margins geometry; in each model the weak zone is at variable distance from the continental margins. The subduction process is afterwards free to evolve. An initial horizontal velocity is prescribed both to the lower- and upper-plates and it is normal to the lateral boundaries of the model; the trench-parallel component of subduction thus varies in each simulation according to the angle between plates' margin and model lateral boundaries. Moreover, I have tested the role of different plate-margin geometries on the dynamics of oblique subduction modifying the weak zone characteristics (*e.g*. continuous-, segmented-, steep-, shallow-weak zone). In particular, these models highlighted that the thermal structure of continental lithosphere controls subduction initiation in case of serpentinite-rich oceanic lithosphere: despite the initial starting point of subduction is regulated by the prescribed weak-zone, a younger and hotter upper continental plate favours the migration of subduction at the ocean/continental margin interface. On the other side, a constant thermal structure of the two continents' lithosphere promotes a stable intraoceanic subduction. As already done in 2D numerical models by Malatesta *et al.* (2012), I finally investigated the role of serpentinite rheology to set ulterior constraints on exhumation dynamics in oblique subduction zones.

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INTERACTION BETWEEN MELT PERCOLATION AND SHEAR ZONES IN THE ERRO-TOBBIO PERIDOTITE (VOLTRI MASSIF)

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The Erro-Tobbio (E-T) peridotites (Voltri Massif, Western Liguria, Italy) represent portions of the Adria sub-continental mantle (Chiesa *et al*., 1975) which were exhumed beneath the hyper-extended Adria continental margin during lithosphere extension of the Jurassic Ligurian Tethys basin. Despite their involvement in the subsequent Alpine orogenic cycle, the E-T peridotites mostly preserve records of the magmatic and tectonic processes linked to the continental extension and the continental rifting, describing their exhumation from deep sub-continental lithospheric levels to the Ocean Continent Transition (OCT) setting of the basin. Field and petrologic data evidence the formation of km-scale extensional shear zones which indicate that the E-T peridotites underwent decompression from garnet-peridotite facies conditions to spinel-, plagioclase-, and amphibole-chlorite-peridotite facies conditions (*e.g*., Hoogerduijn Strating *et al*., 1993 and references therein). The development of km-scale extensional shear zones enhanced lithospheric thinning and asthenosphere almost adiabatic upwelling. Asthenosphere melting under decompression generated silica-undersaturated MORB-type melts which percolated via porous flow through the extending lithospheric mantle and infiltrated into the shear zones (Rampone *et al*., 2004; Piccardo & Vissers, 2007). These melts reacted with the host peridotites during their ascent (dissolving pyroxenes and precipitating olivine), forming parallel bands of reactive harzburgites and dunites, characterized by isotropic textures, within the spinel-facies peridotite tectonites/mylonites of the shear zones. At shallower levels (plagioclase-facies conditions) the uprising asthenospheric melts impregnated large volumes of the shallow lithosphere, leading to abundant plagioclase enrichment. The plagioclase-rich impregnated zones became the sites were further strong deformation was localized, and the rocks were then transformed into plagioclase-rich tectonites and mylonites. The plagioclase-facies shear zones were in turn exploited by further uprising melts which originated metric to decametric bands of spinel dunites (replacive concordant dunites) running parallel to the shear foliation. The last event of melt/peridotite interaction is testified by the occurrence of centimetre- to metre-wide bodies of dunites which cut across the tectonitic/mylonitic foliation in form of channels (replacive discordant dunites).

Studies of the structural and petrologic mantle features recorded by the Erro-Tobbio peridotites offer the possibility to unravel the evolution history of the interacting deformation and melt percolation processes, deepening the knowledge on the mutual enhancements of their effects. This would contribute to the understanding of the effects of melt-assisted extension on the rheology of the mantle lithosphere during the pre-oceanic continental extension of the *Ligure-Piemontese* realm.

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GEO-MECHANICAL STUDIES OF THE "FLYSCH DI SANREMO"

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In this study the geological strength index (GSI) method (Marinos & Hoek, 2000a, 2000b) were applied to rock masses from *Flysch di Sanremo* Formation (Sanremo-Monte Saccarello Tectonic Unit, Western Ligurian Alps). This formation is reported as compositionally heterogeneous and structurally complex (Sagri, 1984). The aim of this study was to carry out an evaluation of the mechanical behaviour (*i.e*., strength and deformability) and assess the influence of structural and petrographic features.

In particular, in this study petrographic and geo-mechanical tests were conducted. Thin sections analysis, uniaxial and triaxial compressive tests, and indirect tensile tests were carried out on rock core samples coming from borehole performed in the study area (from Capo Mele and San Remo, western Liguria).

Laboratory data, statistical analysis and software RocLab (Rocscience Inc., 2002) results allowed to describe both mechanical properties (such as UCS and m_i) and Hoek-Brown failure envelope (Hoek, 1983) of intact rock. Such intact rock was previously subdivided into six main classes of different grain size and calcium carbonate content. Rock mass parameters (such as GSI, m_b, σ_c, σ_t, σ_{cm}) were then determined based on: *i)* the Hoek-Brown criteria; *ii) in situ* geo-structural survey; *iii)* geo-mechanical surveys.

The results of this study clearly identified a correlation between the stratigraphic features and the mechanical properties of the four geological members. In fact, four main quality classes of rock masses were recognized to reflect the wide heterogeneity of the studied formation.

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ANALYSIS AND PLANNING OF THE GEOINDICATOR NETWORK IN LIGURIA. A RENEWED PERSPECTIVE IN ENVIRONMENTAL MONITORING

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The scientific picture of the research project is represented by global earth problems, like climate change and exploitation of resources, which need to promote sustainable development policies, as soon as possible. To this point Earth scientist can provide contribution in the knowledge and operative solutions of many questions. Geologists can apply their skills to environmental monitoring and only not for emergency occurrences. In fact, short time scale geological changes have been suggested as efficient indicators of environmental evolution as they provide data over periods of 100 years or less. They have been called, at first time, as "Geoindicators" by International Union of Geological Sciences (1996-2000) and characterized by 27 different geological phenomena's measures (arranged inside the IUGS Geoindicator Checklist).

The research hypothesis starts from these points:

- geoindicators establish baseline conditions and trends, so that natural- and human-induced changes can be identified;
- geoindicators are tools for assessing rapid environmental changes and over environmental monitoring beyond Civil Protection (emergencies) needs;
- it is possible to transfer the geoindicator technology for better monitoring environmental quality of Liguria .

The research method lies in a step-by-step process. Seven stages are expected, in order to elaborate some geoindicator time series analysis (from the present and available environmental databases or from field data), to compute specific forecast and an optimum deployment of new recording tools, if possible.

At the moment we are reaching two important results:

- a methodical selection from IUGS geoindicator checklist has highlighted nineteen precise geoindicators for Liguria's area
- a first practical application by geoindicator surveillance. To this end an elaboration from the present ARPAL, SIRAL databases for Centa watershed's groundwater (2002-2011) has pointed out three areas with different trends of pollution and their different perspective of recovery and monitoring in the future.

Next efforts will be addressed to set up a geoindicator network for another specific site, in order to study new possible geoindicators and related results for different habitat. To this purpose we are selecting a suitable Liguria's national marine park.

SOIL EROSION AND FLOOD GENERATION UNDER DIFFERENT LAND COVER SCENARIOS IN A MEDITERRANEAN SUB-CATCHMENT (T. ARZOCCO, ITALY)

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Most geomorphic processes are governed by temperature oscillations, intensity of rainfalls, and human activities. Mediterranean catchments are particularly sensitive to these changes, above all due to the progressive decrease of the rural activities and the abandonment of terraced cultivations, the consequent re-colonization by shrubs and forests, that are more sensitive to forest fire and new scenarios of climate changes. All these factors imply significant environmental problems in terms of soil erosion and control of the meteoric waters.

The main aim of this research is to analyze the hydrological and geomorphological consequences of different land cover under the same climate scenario (Garcia-Ruiz *et al.*, 2008).

This study was carried out in the Torrente Arzocco catchment, a sub-catchment of the Torrente Teiro basin, which extends for 28 square kilometres in the province of Savona, between the municipality of Stella and Varazze, and it is representative for many ligurian basins.

We collected pedological, geological and environmental information. Soil depth and soil permeability was measured with a constant-head permeameter. These data were then used in a quantitative erosion model based on the ERU concept (Erosion Response Unit; Maerker *et al*., 2001).

Thank to two different G.I.S. system (ArcGis 9.2 and SAGA) we utilized the SCS-CN II erosion model (Soil Conservation Service, 1972) to estimate the temporal rate of sediment yield from rainfall events on T. Arzocco catchment under four different land cover scenarios: *i)* terraced slopes with cultivation, *ii)* abandonment of terraces, *iii)* forest and pinewood cover, and *iv)* post forest fire scenarios.

The results of this study show the differences in the hydrological response of the catchment with different scenarios and its effect on river discharge and flood generation.

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STRUCTURAL GEOLOGY, GEOMECHANICS, REMOTE SENSING AND GIS: A MULTIDISCIPLINARY APPROACH TO TUNNEL EXCAVATION

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The aim of my research is twofold: a) the comprehension of the geological setting of the area along the layout of the Terzo Valico dei Giovi Tunnel, and b) the geotechnical and geomechanical characterization of the rocks interested by the tunnel excavation. My research is particularly focused on fault zones.

Fault zones are characterized by highly deformed rocks, which show low rock strength values. Thus fault rocks have a different geomechanical behaviour with respect to the undeformed host rocks. In addition, fault zones play an important role in fluid flow, and fluid storage: the high concentration of fault and fracture surfaces and the cataclasis along these zones leads to complex hydrogeological behaviour.

From these statements can be inferred the importance of studying fault zone distribution and characteristics especially in relation to underground excavation.

The study area is located between the Varenna River (to the west) and the Polcevera River (to the east) and it spans from Erzelli to the south to Isoverde to the north. From a geological point of view, this area is mainly characterized by the occurrence of the Figogna tectomometamorphic Unit and by its tectonic contacts with the other units of the Sestri Voltaggio Zone.

The Figogna Unit is made up by serpentinites, metabasalts and metasediments (Pumpellyite-Actinolite facies; Capponi & Crispini, 2008). The structural setting of the area is very complex, due to the superposition of different folding phases. More recent fault systems superimpose the ductile structures and shape the landscape.

A significant amount of data have been collected and stored in a georeferenced database, linked to a GIS map. These data derive both from fieldwork and core drillings; they include for example fracture and fault sets orientation, stratigraphies, geotechnical and geomechanical properties of rock samples, hydrogeological parameters of rock masses and others.

Data will be elaborated through a GIS software, to perform different kind of spatial analysis and the results will be imported in a 3D software to build a three-dimensional geological model of the studied area. The expected result of my research is a 3D geological model, showing the location and orientation of the principal fault zones and the hydrogeological and geomechanical behaviour of fault rocks.

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