



UNIVERSITÀ
DEGLI STUDI
DI PADOVA

DEPARTMENT
OF GEOSCIENCES

PROGRAMME 1 **SELF-ASSESSMENT**

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	PROGRAMME 1
1.1	Title
	Deep Earth Coordinators: Giorgio Pennacchioni, Fabrizio Nestola
1.2	Objectives and aims
	The global scale morphological features of the Earth's surface (e.g. mountain ranges, ocean basins) are the result of deep-seated processes occurring in the Earth's crust and mantle, and can be explained in the general framework of plate tectonics. In addition, the main "fabric" of many geological terrains (for example metamorphic or magmatic terrains) and of many rocks now exposed to the Earth's surface, was developed at depth during relatively high temperature and pressure conditions, and major geological processes (e.g. earthquakes, volcanism) have their origin in the Earth's interior. Regional scale processes, however, are governed by the grain-scale behaviour of minerals and fluids, that can be understood in terms of atomic properties. It follows that future advances in understanding the multi-scale rock fabric-forming process in the deep Earth and their role in the fundamental dynamic processes of the Earth's interior can only be achieved through an integrated, multi-disciplinary approach, combining knowledge and latest achievements in each of a wide range of relevant disciplines, many of which are present in the current research program "Deep Earth": Mineralogy, Petrology, Geochemistry, Structural Geology and Geophysics. These disciplines have been traditionally part of the Department of Geosciences at Padova, and have contributed to significant advances in specific topics of their own field of interest, which span the range of scales of investigation from the lattice-grain (10^{-9}-10^{-3} m), scale to the scale of mountain belt (10^3-10^6 m), as detailed below in the description of individual research projects. The main approach of several studies is by direct investigation of deep seated materials brought to the Earth's surface by exhumation processes, or recovered through drilling projects. In this Program, the study of rock materials adopts different techniques ranging from quantitative field analysis and mapping to sophisticated laboratory determinations (scanning electron microscopy; different techniques of X-ray diffraction: powder, single-crystal, texture goniometry; microchemical electron microprobe analysis; X-ray goniometry; Raman spectroscopy; different methods of radiometric rock and mineral dating; PIXE; LA-ICP-MS, SHRIMP, TEM). The direct investigation of natural materials is integrated with physical laboratory experiments (on rock and rock-analogue materials), theoretical and numerical modelling. At the megascale, the study of geodynamic processes has involved the monitoring of active tectonic systems by GPS networks and modern remote sensing analysis of multispectral satellite images; classic regional geological work has been integrated with modern computer techniques of 3D modelling of structures. In all cases these studies have prompted the development and upgrading of the laboratories at the Department of Geosciences, as well as of the research skill of teaching and technical staff, also through the numerous ongoing collaborations with national and international research centers. These highly-qualified and internationally recognized instrumental and human resources represent a primary wealth of the Department and have provided (and provide) a direct or indirect background to applied studies. In fact, despite many of these Deep-Earth studies have been traditionally mainly devoted to basic science or "academic" issues regarding the complex composition, mechanics and dynamics of the

Earth's engine. Most of this research has also an important social relevance in, for example, (i) assessing and mitigating geological hazards, (ii) exploring an exploiting natural ore resources, and (iii) developing industrial materials.

A better knowledge of the complex behaviour of geological processes concurring to the Earth's dynamics can only result from a multidisciplinary approach integrating the expertises of scholars from different research fields. Despite the research groups have followed independent lines in many cases, a close overlap in scientific interests and cooperation between subjects of the different disciplines is present in some fields of the Deep-Earth program. In an attempt for a better exploitation and integration of the research potential of the Department, an effort to coordinate the relevant different disciplines towards common major research projects has been undertaken in the last years. As a result, the recent funding of an "excellence project" on "Revealing the secrets of an earthquake: physico-chemical constraints from a multidisciplinary study of exhumed faults" by the Cariparo foundation brings together for the first time the largest group ever (11) of researchers from the Department to work on a coordinated project.

The program "Deep Earth" includes the following research projects which are detailed later in this document:

1) **Evolution of thermodynamic properties as a function of composition, temperature and pressure for geological materials.** The evolution of all the deep Earth geological processes can be understood in terms of physical, chemical and thermodynamic properties of minerals. In this light, the mineral physics plays a crucial role in determining and interpreting all the mantle and low-crust geophysical, geodynamic and seismological models, including subduction and convection processes. All such models can be constructed starting from the determination of stability fields for those minerals, which represent the largest volume of our planet as MgSiO_3 perovskite, α , β and γ -olivine $(\text{Mg,Fe})_2\text{SiO}_4$, ortho and clinopyroxenes $(\text{Ca,Mg,Fe})_2\text{Si}_2\text{O}_6$, garnet, spinel and feldspar structures of various compositions.

2) **Petrology and geochemistry of magmatic systems.**

This project is mainly focussed on two research lines. The first one is dedicated to the investigations of the relationships between the basic magmatism of Large Igneous Provinces and the break-up of Pangea. In the second research line the magmatism processes related to the continental collision (e.g. Eastern Alps, Italy; Morocco and Antarctica) are investigated.

3) **Metamorphic petrology.** Its main aim is the interdisciplinary characterisation, interpretation and modelling of important aspects of metamorphism, such as: deformation and reaction microstructures; phase equilibria and mass balance; thermobarometry and thermodynamic analysis; fluid-rock interactions; high-temperature conditions and anatexis; rock physics.

4) **Deformation mechanisms of shear zones:** it deals with deformation processes within the brittle and ductile faults across the lithosphere accommodating the tectonic displacements at all scales.

5) **Regional geology, tectonics and geodynamics of Mediterranean region:** it focusses on large scale tectonics of the Alps in the broad framework of Western Mediterranean geodynamics by integration of different approaches such as: field mapping and structural analysis; remote sensing investigation, interpretation of seismic sections, radiometric dating, 3D volumetric reconstructions, paleomagnetic analyses, GPS data processing and interpretation.

1.3	Projects
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1.3.1	Project 1: Evolution of thermodynamic properties as a function of composition, temperature and pressure for geological materials (Coordinator: Fabrizio Nestola)
	The evolution of all the deep Earth geological processes can be understood in terms of physical, chemical and thermodynamic properties of minerals. In this light, the mineral physics plays a crucial role in determining and interpreting all the mantle and low-crust geophysical, geodynamic and seismological models, including subduction and convection processes. All such models can be constructed starting from the determination of stability fields for those minerals, which represent the largest volume of our planet as MgSiO_3 perovskite, α, β and γ-olivine $(\text{Mg,Fe})_2\text{SiO}_4$, ortho and clinopyroxenes $(\text{Ca,Mg,Fe})_2\text{Si}_2\text{O}_6$, garnet, spinel and feldspar structures of various compositions. In order to define the stability fields of such phases it is crucial to determine their thermodynamic properties (e.g. molar volume, enthalpy, entropy, thermal expansion, compressibility) as a function of composition, temperature and pressure. However, some of these properties are extremely difficult to be measured as they request in situ experiments by using relatively complex technologies not always available for conventional laboratories. Aim of this project is to investigate under ambient and non ambient conditions minerals belonging to the main mineral families, studying phases representing the Earth's low-crust, upper mantle (down to 410 km) and transition zone (between 410 and 660 km). The main phases investigated are represented by spinels (natural and synthetic MgAl_2O_4, Fe_2SiO_4 ringwoodite), olivines (natural forsterite – faylaite – tephroite solid solutions), clino and orthopyroxenes (from pigeonites to augites, to Na-pyroxenes to Ca-Fe-rich enstatite, natural and synthetic), feldspars (from plagioclase to anorthoclase to synthetic compositions rich in Sr). The mineralogical group of the Department focused its scientific research in these last years on the determination of the crystal-structure and crystal-chemistry evolution as a function of temperature and composition (e.g. 1, 3, 5). The results obtained were very satisfying and a large number of international publications were produced. These investigations provided important information relatively to the conditions of formations of very common rocks (e.g. 40). At the same time, the determination of crystal-structure evolution with temperature and composition gave the opportunity to define the thermal expansion and the molar volume of the phases investigated. Recently, the mineralogical group started a completely new research line dedicated to the high-pressure crystal-chemistry studies capable to provide not only the crystal-structure evolution as a function of pressure but also the compressibility, a further thermodynamic property impossible to be determined by the previous research lines (e.g. 20, 34, 42). Therefore, using crystallographic tools, a complete thermodynamic dataset (determined as a function of pressure, temperature and composition) of the main rock-forming minerals can be now well determined in our laboratories. This was possible also to scientific support and strong high-pressure background of new scientists, recently acquired by the group and to the implementation of scientific instruments also dedicated to the new research line.
1.3.2	Project 2:

	Petrology and Geochemistry of magmatic systems (Coordinator: Giuliano Bellieni)
	The main scientific goals of the research projects of the years 2003-2007 were: Line 1) Magmatism in extensional tectonic settings This line covers research carried out on the LIPs (Large Igneous Provinces) connected with the break-up of Pangea. Of particular interest are those of basic magmatism related to the break-up of Pangea (CAMP: Central Atlantic Magmatic Province) and of the Red Sea (Eritrea). Moreover, research work on the Veneto Volcanic Province and on the Permian Alpine magmatism of the Central Alps is ongoing. Research on the CAMP have established that it is the largest basaltic province of the Phanerozoic, and that its products cover a total surface area of 7 million Km² (in North America, South America, Africa and Europe) over a period of 1.2 Ma. Geochemical data have revealed the temporal evolution of the magmas, ranging in composition from continental lithospheric to asthenospheric. Due to its extent and temporal location (from 198.9+/-0.9 Ma to 199.6+/-2.8 Ma), this magmatic event has been proposed as the main cause of the climatic variations and consequent biological crisis which took place at the Triassic-Jurassic boundary (199.6+/-0.3 Ma). This conclusion is the subject of further analyses in other regions of the CAMP (Morocco, Mauritania, Sierra Leone Brazil, Venezuela, Portugal). Comparative study between magmatisms of various ages in the South American platform has shown that the Jurassic tholeiites (200 Ma) of the CAMP and those of Cretaceous age (130 Ma) of the Paraná Magmatic Province have chemical and isotopic compositions similar to those of Late Archaean (2.7 Ga) and Proterozoic tholeiites (1.0 Ga). The geochemical and isotopic features of the Mesozoic and Precambrian tholeiites indicate that they derived from a heterogeneous mantle source (e.g., due to fluids and small volumes of melts, and metasomatism related to ancient subduction events). The location of this magmatism near the craton-mobile belt indicates that the geodynamics of edge drive convection in the upper mantle played an important role in magma genesis. Recently (2006), the investigations on the Tertiary basic (transitional, alkaline to tholeiitic basalts) and silicic (rhyolites and ignimbrites) volcanism from Eritrea (central Eritrean plateau, Amasien e Seræ) were completed. The results on these magmatic occurrences and comparison with similar coeval magmatic rocks from Ethiopia allowed extending to the North the knowledge of the magmatism related to the opening of the Red Sea and proposing a stratigraphic reconstruction of the volcanism in this part of Africa The composition of the mantle underlying north-eastern Italy was studied based on analyses of xenocrysts and xenoliths entrained in alkali-basalts from the Veneto Volcanic Province. The crystallochimic composition of Opx, Cpx and Ol allowed attainment of indications on the depth and characteristics of the sampled mantle. Similar constraints on a poorly hydrated and not metasomatized mantle are given by crystallochimic analyses and by Oxygen isotopic data on zircon and garnet xenocrysts hosted by the same basic lavas. Lastly, the cumulitic ultrabasic rocks overcropping in the Penninic basement of the Eastern Alps and studied and dated for the first time, were attributed to a subductive context. These rocks, of Late Carboniferous age, are interpreted as the first products of the type I calc-alkaline magmatism which gave rise to the granitoid plutons of the Central Gneisses of the Tauern Window.

	Line 2) Magmatism at convergent plate boundaries Research on magmatism linked to continental collision regarded the plutonic masses of acidic and intermediate-SiO₂ composition from the Eastern Alps (Italy), Morocco and Antarctica. In the Eastern Alps, the researches on the Alpine age plutons outcropping in Italy (Rensen, Vedrette di Ries, Cima di Vila), Austria (Polland) and Slovenia (Karavanke and Pohorje) were concluded recently. Results enabled us to define their composite nature and to place constraints on both the genesis of evolution of the original magmas and the significance which this magmatism has in reconstructing geodynamic events in collisional chains of Alpine-Himalayan type. We undertook a study on the Ordovician plutonic rocks of the Northern Victoria Land (Antarctica) which is related to a cratonic margin, the Pacific margin of Gondwana. In this area, also remnants of older (Grenvillian) plutonism were discovered and enabled formulation of a new hypothesis on the reconstruction of the super-continent Rodinia. Line 3) Classification and nomenclature of volcanic rocks The here considered activity was completed within the framework of the "Commission on the Systematics in Petrology" and "Subcommission on the Systematics of Igneous Rocks" and aims at unifying the various systems of classification and the nomenclature of volcanic rocks and developing user-friendly easily applicable diagrams to be used by the international scientific community. The result of these efforts was the definition of the chemical classification TAS (Total Alkali Silica) diagram which is based on the SiO₂ vs. (Na₂O+K₂O) contents (wt%) of volcanic rocks, recalculated to 100% on volatile-free basis. Recently the activity was focused on the applicability of the TAS diagram for the classification also of plutonic rocks. The preliminary results obtained for the subalkaline plutonic rocks were presented to the Italian scientific community and discussed and then approved by the I.U.G.S. Subcommission members and its improvement is presently in progress. The final goal of this International board is to define one single diagram to classify and define the nomenclature of magmatic rocks, crystallized in different conditions.
1.3.3	Project 3: Metamorphic petrology (Coordinator: Bernardo Cesare)
	The main aim of this project is the study of metamorphic processes by means of the characterisation, interpretation and modelling of important aspects such as: deformation and reaction microstructures; phase equilibria and mass balance; thermobarometry and thermodynamic analysis; fluid-rock interactions; high-temperature metamorphism and anatexis; rock physics. The project has numerous areas of overlap with the projects n. 1, 2, and 4, contributing to the integrated, multidisciplinary approach to the study of the Earth's lithosphere pursued in the DG. Emphasis of this project is on the dynamics of metamorphism, on the study of metamorphic minerals "in context", on the methodological development and on the <i>nano-to-mega</i> scale of analysis. On one hand, using state-of-the-art analytical and imaging techniques, this approach has brought to deepening of analysis at a progressively smaller scale ("nano-petrology"); on the other hand, basing on a sound traditional approach and on the groundwork of field and geochronological studies of crystalline areas, it has important bearings on large-scale processes such as geodynamics.

The main lines of research carried out in project 3 during the five-year period are:

Line 1) Processes and mechanisms in metamorphism

Core of the activity of the research group, this line has developed on several inter-related topics covering mainly the metapelitic system and using samples from characterized geological settings. Attention is devoted to the behaviour of minerals which play essential roles in metamorphic rocks (garnet, Al_2SiO_5 polymorphs, cordierite, spinel), and to the fluid-rock-melt relationships during the partial melting of graphitic systems, and particular efforts are devoted to understanding, with an “in-context” approach typical of “petrologic mineralogy”, the variations of chemical and physical characteristics occurring in micas with changing metamorphic conditions. The approach features multidisciplinary, high internationalisation of the working groups, and the use of avant-garde instrumentation which is not often used in metamorphic petrology, such as micro-PIXE, transmission electronic microscopy (TEM), advanced techniques of electronic microscopy (SEM-EBSD), and study of fluid and glass inclusions. The main topics are listed below.

Advanced methods for the study of metamorphic microstructures and minerals: concentrating mainly on garnets, minerals which more than others conserve memory of metamorphic processes, study has been devoted to nucleation mechanisms and growth of porphyroblasts, phenomena of coalescence and deformation, and chemical zoning of major and trace elements. From an analytical viewpoint, applications of accelerator-based techniques and μ -pixe have been used to characterise composition and age of minerals. (papers n. 6, 9, 17, 18, 27, 29, 38)

High-temperature metamorphism and crustal anatexis: using samples of partially melted metapelitic enclaves from SE Spain and granulites from the Kerala Khondalite Belt of India, attention focuses on processes of partial melting in the metapelitic continental crust, with particular regard to thermobarometric estimates, melting reactions of biotite, and modelling reaction coronae of garnet breakdown. Attention is also paid to the experimental measurement of rock-physical (seismic and electrical) parameters during crustal anatexis. Fluid and melt inclusion studies on the same rocks have led to a better understanding of fluid-melt-rock interactions and the role of graphite during anatexis, and to a new model for the origin of CO_2 in granulites. (papers n. 12, 13, 21, 22, 24, 25, 30)

Metamorphism of metapelites and stability of Al_2SiO_5 polymorphs: this project concentrated on the role of kinetics in the stabilisation of fibrolite, on the modelling of the andalusite-melt equilibrium and its relevance for the P-T position of the Al_2SiO_5 triple point, and on the occurrence and role of andalusite in peraluminous anatectic granites. (papers n. 5, 11, 14)

Thermobarometry in eclogites, granulites and garnet peridotites: this project aims at measuring or constraining the thermobarometric conditions occurring during metamorphism. Contexts were the high-pressure rocks of the Ulten Zone and the eclogitic metamorphism of the Eastern Alps. (papers n. 8, 10, 31)

Features of phyllosilicates as a function of crystallisation conditions: several lines are developed in this project. (i) Applications of the “illite crystallinity” and the qualitative geobarometry based on the parameter $d_{060,33\bar{1}}$; (ii) redetermination of the values of this parameter in very-high pressure, LT metapelites; (iii) implications of changes of crystal chemistry and compressibility of muscovite for the formation of slaty cleavage; (iv) multi-analytical approach to the study of Ti-rich biotites from HT metapelites, obtaining significant results both in the mechanisms of the Ti-substitutions and the petrological control on them (3 papers published in American Mineralogist, 2008); (v) studies on the factors controlling polytypism in natural muscovites (1 paper published in American Mineralogist, 2008). (papers n. 3, 16, 19, 20, 33)

Line 2) Studies on crystalline areas

These studies are the continuation, extension and deepening of the research carried out for decades in the former Department of Mineralogy and Petrology on the basements of the Alpine-Mediterranean chains. The aim here is primarily the advance of regional knowledge, from both petrological and tectonic viewpoints. This line, which involves field work and sometimes includes geological mapping, provides the solid basis for the previous types of research. Research developed in the following main themes.

Some topics of metamorphic petrology in the crystalline basements of the Eastern Alps and Western Mediterranean. Research focuses on specific aspects of metamorphism and anatexis in collisional chains, in order to supply constraints for modelling the genetic processes giving rise on one hand to the Alpine chain, with particular regard to pre-Alpine evolution, and on the other hand to the formation of the Betic chain and the Alboran domain. In addition to the above areas research has been undertaken also in Antarctica, Hungary and Slovakia. The granodiorite found in a borehole near Venice was also studied. (*papers n. 2, 4, 26, 28, 32, 34, 35, 43, 44, 45*)

Relation between tectonics and Cenozoic magmatism in the evolution of the Himalayan chain. This is a study on Miocene leucogranites intruding the High Himalaya Crystalline (HHC), and involves field and structural surveys, petrology and geochronology. Data obtained (chemistry, radiometric ages and thermobarometry) are used to constrain the model of extrusion of the high-temperature, partially melted crust that forms the core of the Himalayan chain. (*papers n. 1, 23, 46*)

Modelling of the petrographic and geochemical composition of the Austroalpine continental crust. This study was undertaken because knowledge of the chemical composition of the upper continental crust is essential in planning petrogenetic and geochemical models of various types. For the easternmost sector of the Austroalpine crust outcropping in Italy we produced: a) a model of petro-volumetric composition; b) petrologic and geochemical characterisation of all major lithotypes; c) a model of the abundances of chemical elements in the crust. (*papers n. 39, 40, 41, 42, 50*)

Constraints to the deposition age of the protoliths of the Southalpine Metamorphic Basement. This topic was studied from three viewpoints: 1) New U/Pb SHRIMP data on zircons from the Plan de Corones acidic gneisses (Brunico area) and from the Pre-Variscan acidic metavolcanism in the Levico and Val Sarentino areas; 2) First studies of well preserved Aeronian graptolites within fluorapatite-rich metamorphic boudins at Ponte Alto (Agordo area); other boudins in the same shear zone bear Middle Devonian corals; 3) New palynologic and petrographic study of the acritarch assemblage of Col di Foglia (Agordo area) we discovered in 1984; the new palynologic analyses indicate a Latest Cambrian age. The other Cambrian and Precambrian biostratigraphic ages mentioned in the Alpine literature do not have a firm palaeontological ground, and need to be reassessed. Therefore, the latest Cambrian age revealed by the present re-study, is the oldest biostratigraphic record in the whole Alps, as well as in the peninsular Italy. (*papers n. 15, 36*)

Studies on micas of the research line 1, and on the basements of the Eastern Alps and circum-Mediterranean areas of line 2, have been pioneered by the senior researcher (F.P. Sassi) who continued to co-operate until and after retirement, on October 2007, carrying out further research, and contributing to the organisation of a Symposium (GSA, 2006) and the editing of a Special issue "Petrologic Mineralogy - the study of minerals in context" (American Mineralogist, 2008) in honor of C.V. Guidotti.

An important activity in this Project has involved the work of the *SCMR Subcommittee on the Systematics of Metamorphic Rocks (a branch of IUGS Commission on Systematic in Petrology)*. The main aim of SCMR was to propose a simple but comprehensive terminology for common metamorphic rocks. A flowchart

	and guidelines for the use of the nomenclature scheme have been conceived, and a Glossary compiled. All results of SCMR (of which F. Sassi has been an active member), are now published on line and in a volume (Cambridge Univ. Press, 2007). (<i>papers n. 47, 48, 49</i>)
1.3.4	Project 4: Deformation mechanism of shear zones (Coordinator: Giorgio Pennacchioni)
	This research project focuses on the study of the micro- and meso-scale deformation mechanisms in ductile and brittle shear zones. The deformation in both the continental crust and lithospheric mantle is commonly localized to approximately tabular zones within relatively undeformed host rocks known as ductile shear zones (produced by dominant crystal-plastic deformation at relatively high temperature) and faults (produced dominantly by brittle deformation at low temperature). This process occurs at all scales from the scale of the thin section to that of the lithospheric plates. Shear zones can accommodate relevant tectonic displacement between adjacent tectonic units or plate margins and their rheology can control the deformation of the lithosphere in some cases. These zone and the associate second-order network of shears and fractures are preferential pathways for focussed fluid flow in the crust, assisting important mass transfer, or may instead represent barriers to fluid circulation. Therefore faults and shear zones play a major role in fluid migration and mass transfer processes in the entire lithosphere and control the location of economically relevant mineral or gas deposits. Faulting is also responsible for the seismicity and thus the study of faults has as a major social importance. The different research lines in this topic are: Line 1) Study of seismogenic pseudotachylyte-bearing exhumed faults. Line 2) Nucleation of ductile shear zone: the role of pre-existing structural and compositional heterogeneities Line 3) Study of microstructure and crystallographic preferred orientation in mylonites Line 1) Study of seismogenic pseudotachylyte-bearing exhumed faults Understanding the physico-chemical processes controlling faulting and earthquake generation is essential in seismic hazard assessment. Direct access to nucleation depths of large earthquakes (10-15 km) by drilling is impossible and monitoring active faults from the Earth surface, or interpreting seismic waves, yield limited information on earthquake mechanics. The indirect analysis of earthquakes is unable to provide tight constraints on fundamental mechanical parameters such as the dynamic fault strength and the energy budget of an earthquake. We adopted a novel and multidisciplinary approach to understand the mechanics of an earthquake which includes (i) the study of fossil seismic sources (faults containing pseudotachylytes, i.e., solidified melts produced during seismic slip) now exhumed at the Earth's surface, (ii) the analysis of the fault rocks in the laboratory which includes up-to-date techniques in microstructural analysis, mineralogy and petrology and, (iii) rock friction experiments using a unique apparatus (in Kyoto-Japan) that can simulate some of the extreme deformation conditions typical of earthquakes (e.g., slip velocities of ~ 1 m/s). The field study has mainly focussed on exceptional exposures of faults in the Adamello batholith (Southern Alps) and Sierra Nevada (California). The study of natural faults proceeded together with theoretical modelling calibrated on the basis of the field data, the mechanical data from rock-friction experiments and the analytical data of natural and experimental

deformation products. The integration of all data yielded estimates of seismic source parameters (e.g., dynamic shear stress, the seismic energy budget, all challenging issues for Earth scientists) and provided an insight into the mechanisms of earthquake propagation. For example the comparison between field structures and the theoretical dynamic stress field computed around propagating fractures was used to reconstruct the earthquake rupture directivity, rupture velocity and fracture energy of the fossil earthquakes in the Adamello [ref. 10]. The lubricating effect of the presence of friction-induced melts along a fault plane was demonstrated on the basis of field and experimental evidence [ref. 14]. Both the natural and lab data have been used to theoretically derive a constitutive relation to describe the fault behaviour under conditions of melt lubrication. Additional results of the study of frictional processes in faults has been the identification of silica gel lubrication as a fault weakening mechanism that may operate during earthquakes [*Di Toro et al.*, Nature, 2004]. The above study has implication also in the understanding of other friction-controlled processes important in Earth Sciences (e.g., rock landslides) as well as in industry.

Some experiments have also been conducted in order to interpret the different seismic signals in volcanic areas. Through comparison between the natural frequencies of volcanic earthquakes and tremors and acoustic emissions in experiments, it is possible to distinguish different physical processes (fracturing and magma transport in the volcanic edifice) active in magma chambers and preceding volcanic eruptions [ref. 15]. It is noteworthy that the experience accumulated on this topic formed the basis for the submission of a project about the chemical and mechanical processes occurring during the seismic cycle. The project, funded for 450.000 Euro in 2007 by the “progetti di eccellenza” of the Cariparo Foundation, brings together scientists with different backgrounds of the Dipartimento di Geoscienze of Padova as well as colleagues from different countries worldwide. Within the several scientific and technological goals, this project aims at developing a new dedicated laboratory which will allow Padova University to compete at top scientific level with the world’s leading institutions in the study of earthquake mechanics.

Line 2) Nucleation of ductile shear zone: the role of pre-existing structural and compositional heterogeneities

Ductile shear zones are most clearly developed within rocks considered to be effectively homogeneous and isotropic at the macroscopic scale such as granitoids. In these materials theoretical and numerical models, and rock-analogue experiments indicate that shear zones can develop due to rheology-dependent localization (especially in power law, strain-softening materials) assumed to initiate at point-like flaws, or weak inclusions and without the need for any pre-existing planar discontinuity. To check if these results can be applied to natural shear zones, we performed detailed meso-structural analysis and mapping in granitoid plutons. Selected examples are from the Alps and Sierra Nevada (California). The outcrops represent low-strain domains where the incipient stages of deformation are preserved and nucleation/initial growth of shear zones can be investigated. These studies invariably demonstrate a strong control by pre-existing planar compositional and structural heterogeneities on the nucleation of ductile shear zones [refs. 6, 7, 16]. In no cases individual shear zones were observed to propagate in the undeformed rocks despite the presence of grain-scale heterogeneities. The type of pre-existing planar anisotropy strongly control both the geometry of the development the typology of the developing shear zones. The results of the study indicate that shear zone patterns are a legacy of pre-existing or precursory planar heterogeneities and cannot be used to infer the geometry of the imposed bulk strain ellipsoid. This has implications, for example, in reconstruction of the geometries of deformation networks in ductilely deformed zones that can host mineral deposits.

	Line 3) Study of microstructure and crystallographic preferred orientation in mylonites Microstructure and crystallographic preferred orientations (CPO) in mylonites (highly deformed rocks by plastic flow) are proxies of several kinematic, rheologic and ambiental parameters during high temperature flow, e.g. : (i) the geometry of porphyroclast systems can yield information on the stress sensitivity of the strain rate of flow, (ii) the CPO can be used as a geothermometer, and (iii) the grainsize of dynamically recrystallized aggregates is a potential paleopiezometer. The comparison between microstructures and CPO of natural mylonites with the ones of experimentally deformed rocks and rock-analogue materials is the basis for the extrapolation of constitutive flow laws to natural rocks as well as the inference of deformation mechanisms occurring at depth in the Earth under geological strain rates. However this extrapolation is not straightforward as microstructure and texture in nature are the result of the complex interaction between different processes which are not taken into due consideration in simplified lab models. There is the need of a more detailed and quantitative analysis of natural mylonites to validate the lab and theoretical/numerical data and to perform new calibrated models. The microstructure and CPO of mylonites from different structural units pertaining to different lithospheric structural levels exposed in mountain belts have been investigated in by: optical microscopy, computer-integrated image analysis, scanning electron microscope (including electron back-scattered diffraction), transmission electron microscope, x-ray texture goniometry. The research in this topics has focused on a few issues and the main results are illustrated below. The systematic study of population of porphyroclasts in high temperature mylonites has demonstrated that classic models of rigid particle kinematics within a viscous fluid undergoing general, non-coaxial flow (an analogue for the deformation in ductile shear zones) are not adequate to describe the behaviour of porphyroclasts in natural mylonites. The new data on mylonites and new rock-analogue experiments indicate that non-coherent particle/matrix boundaries are the likely cause for the observed behaviour of natural porphyroclasts. Therefore the vorticity analysis of flow by study of stable positions achieved by porphyroclasts in mylonites appears unsuitable in many cases [ref. 1]. Quartz is one of the most common minerals in deformed regions of the Earth's crust and understanding their mechanical behaviour under geological conditions is critical for modelling crustal dynamics. Our studies have emphasized the dramatic bifurcation in microstructural evolution as effect of water-deficient vs. water-present conditions during deformation [ref. 4]. This is evidence that middle to lower crust is not inevitably weak due to its high temperature: water content also has an important influence [ref. 13]. The studies the have also highlighted does not behave as the main stress-supporting mineral in many low grade mylonites where micas and the alteration product of feldspar provide the main matrix component.
1.3.5	Project 5: Regional geology, tectonics and geodynamics of Mediterranean region. (Coordinator: Giorgio Vittorio Dal Piaz)
	The project is focussed on large scale tectonics of the Alps in the broad framework of Western Mediterranean geodynamics including the Late Cretaceous-Tertiary subduction-collisional stages of stacking of the tectonic units (or nappes) to the present

day kinematics of plate motion in the Alpine area. The study of the Alpine realm has a long-lived history in the DG with studies in all the structural domains of the Eastern, Central and Western Alps. During the period 2003-2007, a new research has been undertaken in the eastern Anti-Atlas (Morocco) with extensive mapping and structural analysis of the mapping Precambrian basement. This research project has integrated different approaches including classical field mapping, meso- and micro-structural analysis, remote sensing interpretation, analysis of deep seismic sections, radiometric dating, 3D volumetric reconstructions, paleomagnetic analyses, GPS data processing and interpretation. The principal lines of research in this project are:

Line 1) Geology and tectonics in the Italian Alps.

Line 2) Geodynamics of the Alpine Mediterranean region.

Line 1) Geology and tectonics in the Italian Alps

Alpine geology and tectonics have been traditional topics of our scientific community, since the beginning of the last century, from the discovery of nappe structure of the Alps to the first application of the global theory of plate tectonics to the Alpine mountain chain. In the last decade research in the Alps has mainly focussed on the subduction-related Austroalpine-Penninic collisional wedge, its Southalpine retro-wedge and their paleostructural restoration back to the Mesozoic Tethys.

An updated evolution history of the Alps can be found in the special presentation of the Italian geology for the Florence Congress [ref.3]. Some key areas have been mapped in detail in the frame of national CARG projects in the western Alps (1:10000 Geological Quadrants of Chatillon, Monte Cervino, Monte Rosa, Verres) and of the central-eastern Alps (Geological Quadrants of Asiago, Malè, Monte Adamello, Tione di Trento; Castellarin et al., 2005; Dal Piaz et al., 2007). These mapping project have triggered several research studies both devoted to regional aspects of Alpine geology and tectonics and to more process-oriented issues described in other projects (e.g. project 4).

A branch of Alpine studies has focused on dating some major kinematics and magmatic events. In the Helvetic Mont Blanc massif (western Alps) new systematic Ar-Ar dating of phengite in low-grade shear zones from across the whole massif have highlighted the similar age (16Ma) of the western and eastern thrust and back-thrust boundaries, resulting from a pop-up structure of the massif, in contrast with a two-stage evolution suggested recently [ref. 18]. In the Penninic Monte Rosa nappe (Western Alps) the subduction (eclogitic) metamorphism, earlier referred to as Late Cretaceous, has been dated at 44Ma [ref. 17]; this has major implications in the reconstruction of the early alpine dynamics of the orogenic wedge. In the Adamello (central-southern Alps), U-Pb dating of zircons in the central and northern intrusions has filled the information gap on the intrusion ages across the whole composite batholith [ref. 8] thus providing, together with the existing database, a detailed picture of the emplacement and cooling processes of the different intrusive bodies in the time range of 42-30Ma. Geochronological dating in the different areas has been integrated with structural, petrographic and geochemical analyses that have formed the basis of process-oriented studies (see project 4).

Another main issue in the Alpine studies has been the post-nappe tectonics and the final exhumation of the orogenic wedge nappes. This research is an extension of previous studies in the North Western Alps. The relationships between erosion, tectonic exhumation and topography have been investigated by low-temperature thermochronology and structural analysis in the western Lepontine Dome with the use of both surface and underground (Simplon railway tunnel) data. The overall data suggest that climate is the main controlling factor of erosion rates, rather than tectonics,

and show an abrupt increase in erosional exhumation rates in the Alps just after the onset of major climate change (northern hemisphere glaciation at 2.7Ma: ref.39). Post-collisional to active tectonics of different domains in the Alps has been studied by means of structural and seismotectonic analysis. The Alpine and South Alpine domains have been closely coupled within the framework of fault kinematics and geodynamic processes related to the indentation of the Adria plate against Europe. Our work have been focussed on fault linkages that developed from the Miocene onward both on the Alpine s.s. and South Alpine domains. In the Alpine domain, fault interplay enhanced tectonic unroofing of Penninic units in the Tauern window and a westward crustal stretching of the overlying Austroalpine units in the hanging wall Brenner extensional fault. In the Southern Alps, several fault linkages related to strike-slip reactivation of pre-existing normal faults were mapped, highlighting the strong control of rock lithology on the structural style of poly-deformed relay zones (refs. 5, 19). Rigid block rotation in the Venetian Alps has been investigated by means of paleomagnetic analyses on Upper Cretaceous-Tertiary rocks, finding that no major rotations occurred within the “unshortened” Adria block between the Giudicarie fault system and the Dinaric frontal thrusts (Marton et al., 2006).

As concerns active tectonics, the study of neo-alpine fault linkages has unravelled the existence of a complex shear zone (250 km long), which represents an incipient divide between the nearly stationary westernmost part of the North Adriatic indenter and the northward-pushing main body of the Adria plate (Massironi et al. 2006). Active movements have been estimated also through GPS measurements that lead to the compilation of strain rate maps of northern Italy (Caporali et al. 2003; see 5B) and allowed the assessment of the seismogenic source of the Merano earthquake (17 July 2001) constrained also by coseismic water table variations recorded in wells (Caporali et al. 2005).

Line 2) Geodynamics of the Alpine Mediterranean region

The understanding of the intraplate tectonics of Central Europe requires a detailed picture of how stress is transferred by interaction of the Eurasian, Nubian and Anatolian plates to the Alpine, Carpathian, Pannonian and Dinaric regions, and of the role played by additional stress sources such as gravitational instabilities in the Vrancea seismic zone. The mechanics of coupling between crustal shortening and foreland basin development along the Alpine–Carpathian arc and back-arc deformation in the Pannonian Basin, and the interplay between lithosphere dynamics, active tectonics and the evolution of topography and drainage patterns require paleostrain rates and updated GPS velocities, strain rate maps and slip profiles be merged with geologic, geomorphologic and structural data. In particular GPS data provide the base for recent horizontal and vertical motions and allow a quantitative comparison of Late Miocene-Pliocene kinematics to the present-day kinematics. Systematic analysis of data from over 300 GPS stations, done in collaboration with other European Centres, has enabled horizontal velocities to be reliably estimated. Our first contribution [ref. 1] has consisted in the characterization of noise profiles of the time series of coordinates, whereby the presence of coloured noise has been quantified using spectral methods. The method of the Allan variance used in determining the stability of atomic frequency standards has been adapted to estimate the stability of time series of coordinates, which is useful in identifying slow signals such as creep deformation. The velocity data provide an updated picture of the regional evolution of the deformation at the surface, and hence an important boundary condition for 3 dimensional numerical models of the European geodynamics. The horizontal gradient of velocity field provides a direct estimate of the principal directions of strain at a regional scale and . In an algorithm for

	numerically computing the strain rate from a scattered velocity field was developed [ref. 2]. This algorithm to estimate horizontal strain rates and their uncertainties at a number of locations in Europe where sufficient data are available. When the implied rate of deformation is compared with the rate of seismic stress release in the corresponding area, quantitative inferences related to the seismic hazard of a province can be made: the most notable examples are the estimate of the ‘a’ value of the Gutenberg Richter scale, or the maximum expected magnitude [ref. 14]. The synergy between GPS geodesy, Seismology and Structural Geology has been crucial in the project of the INGV- Department of Civil Protection S2 ‘Stima della pericolosità sismica in Italia nei prossimi 30 anni’, coordinated by Prof. Caporali for Task 3 ‘Geophysical characterization of seismogenic areas’. Combined analysis of GPS data and water level in wells has proven very useful in the study of the 2001 Earthquake near Merano, where indications of pre-, co- and post- seismic motions were visible in GPS data and in the level of the water table, both well correlated with the fault plane solution obtained by classical seismic techniques [ref. 11]. Development on instrumentation based on GPS microwave interferometry has resulted on a new type of sensor [ref. 12] which has the potential to be sensitive to frequency bands lower than conventional seismometers, and is now extensively used in monitoring landslides, subsidences, dams and viaducts.
1.4	Human resources
	Project 1: Alberto Dal Negro – Full Professor Gilberto Artioli – Full Professor (partially) (since 2006) Susanna Carbonin – Associate Professor Paolo Nimis – Associate Professor (partially) Gabiella Salviulo – Associate Professor (partially) Luciano Secco – Associate Professor Fabrizio Nestola – Assistant Professor (since 2006) Ph.D. and post-graduate students: F. Liniero, L. Maini, F. Martignago, B. Lavina, S. Nazareni Project 2: Giuliano Bellieni – Full Professor Ester Justin Visentin – Full Professor (retired October 2004) Andrea Marzoli – Associate Professor Dario Visonà – Associate Professor (partially) Ph.D. and post-graduate students: T. Busà, T. Cuppone, A. Carraro, R. Merle Project 3: Francesco P. Sassi – Full Professor (retired October 2007, but operating through a personal research contract given by the University of Padova) Bernardo Cesare – Associate Professor Claudio Mazzoli – Associate Professor (partially) Raffaele Sassi – Associate Professor Richard Spiess – Associate Professor Dario Visonà – Associate Professor (partially) Paolo Nimis – Associate Professor (partially)

	Ph.D. and post-graduate students: A. Acosta-Vigil, A.M. Alvarez-Valero, M. Bavila, A. Carraro, T. Cester, R. Dibona, A. Ferri, S. Ferrero, L. Tajcmanova Project 4: Giorgio Pennacchioni – Associate Professor Giulio Di Toro – Assistant Professor (since January 2006) Ph.D. and post-graduate students: L. Menegon, L. Pittarello, S. Mittempergher Project 5: Giorgio Vittorio Dal Piaz – Full Professor (retired) Alessandro Caporali – Associate Professor Dario Zampieri – Associate Professor Giorgio Pennacchioni – Associate Professor (partially) Matteo Massironi – Assistant Professor Giulio Di Toro – Assistant Professor (partially) (since January 2006) Ph.D. and post-graduate students: A. Dalla Torre, S. Kalif Homran, C. Morini, P. Borin, A. Nardo, T. Pepi, E. Soldà, A. Duret
1.5	Financial resources
	See attachment DG 1.7
1.6	Links with other public or private organizations at local, national and international level
	<u>Project 1</u> Main collaborations with national institutes: Università di Trieste – Dipartimento di Scienze della Terra Università di Pavia - Dipartimento di Scienze della Terra Università di Torino – Dipartimento di Scienze Mineralogiche e Petrologiche Università di Perugia – Dipartimento di Scienze della Terra Università di Milano - Dipartimento di Scienze della Terra Main collaborations with international institutes: Virginia Tech (USA) Bayerisches Geoinstitut (Germany) University of Colorado (USA) University of Sciences and Technologies of Lille (France) University of Wien (Austria) Swedish Museum of Natural History of Stockholm (Sweden) ETH Zurich, (Switzerland) University of Technology Aachen (Germany)

Geological Institute of Copenhagen (Denmark)
 Centre for Science at Extreme Conditions Edinburgh (UK)
 Department of Earth Sciences, Cambridge (UK),
 School of Earth and Space Exploration, Tempe (USA),
 Institute of Geochemistry, Mineralogy and Ore Formation (Ukraine)
 University of Illinois (USA)
 ISIS-RAL (UK)
 Panalitycal, Delft (The Netherlands)
 CeSMEC, Miami (USA)
 CR2MF, Musée du Louvre, Paris (France)
 The Getty Conservation Institute, Los Angeles (USA)
 Russian Academy of Science, Institute of Earth's Crust, Irkutsk (Russia)
 Christian-Albrechts-Universität Kiel (Germany)
 Mineralogisches Institut, Universität Heidelberg (Germany)
 University of Arizona (USA)

Project 2

Main collaborations with national institutes:

Dipartimento di Scienze della Terra, Università di Milano.
 Dipartimento di Scienze della Terra, Università di Perugia
 Dipartimento di Scienze della Terra, Università di Trieste
 C.N.R. Istituto di Geoscienze e Georisorse, Padova Section
 C.N.R.-GRICES (Portugal): accordo di cooperazione scientifica
 C.N.R.-CNRSP (Morocco): accordo di collaborazione scientifica

Main collaborations with international institutes:

Laboratoire des Sciences de la Terre, UMR-CNRS ENS, Lyon, Francia
 UMR Geosciences Azur, Université de Nice, Francia
 Centre de Recherches Petrographiques et Geochimiques (CRPG-CNRS) Vandoeuvre-les-Nancy, France
 Berkeley Geochronology Center, Berkeley, USA.
 Curtin University, Perth, Australia
 Département de Géologie, Laboratoire de Pétrologie, Université Cadi Ayyad, Marrakech, Morocco
 Dipartimento di Mineralogia, Università di Losanna, Svizzera
 Sezione Scienze della Terra Università di Ginevra, Svizzera
 Centro de Geologia, Universidade de Lisboa, Portugal
 Dipartimento di Geologia, Università di Lubljana, Slovenia
 Instituto de Recursos Minerales, Universidad de La Plata, Argentina
 Instituto de Astronomia e Geofísica, Universidade Estadual de São Paulo, Brasil
 Laboratoire Pierre Süe, UMR9956, CEA Saclay, Gif-sur-Yvette, France
 Laboratoire des Géomatériaux, Université de Marne la Vallée, France
 Research School of Earth Sciences, Australian National University, Canberra

Project 3

Main collaborations with national institutes:

C.N.R. Istituto di Geoscienze e Georisorse, Padova Section
 Dipartimento di Scienze della Terra, Università di Firenze
 C.N.R. Istituto di Geoscienze e Georisorse, Florence Section
 Dipartimento di Scienze Geologiche, Università della Basilicata
 Dipartimento Geomineralogico, Università di Bari
 Dipartimento di Scienze della Terra e Geologico-Ambientali, Università di Bologna
 Dipartimento di Scienze della Terra, Università della Calabria
 Dipartimento di Scienze Geologiche, Università di Catania
 Dipartimento di Scienze della Terra, Università di Messina
 Dipartimento di Scienze della Terra, Università di Milano
 Dipartimento di Scienze della Terra, Università di Modena
 Dipartimento di Scienze Geologiche e Geotecnologie, Università di Milano - Bicocca
 Dipartimento di Geofisica e Vulcanologia, Università Federico II di Napoli
 Dipartimento di Chimica e Fisica della Terra, Università di Palermo
 Dipartimento di Scienze della Terra, Università di Parma
 Dipartimento di Scienze della Terra, Università di Roma3
 Dipartimento di Scienze Mineralogiche e Petrologiche, Università di Torino
 Dipartimento di Scienze della Terra, Università di Torino
 Dipartimento di Georisorse e Territorio, Università di Udine
 Istituto di Geoscienze e Georisorse del CNR, Firenze, Padova and Torino
 Istituto per la Dinamica dei Processi Ambientali del CNR, Milano

Main collaborations with international institutes:

Australian National University (Canberra, Australia)
 Ben-Gurion University of the Negev, Beer-Sheva (Israel)
 British Geological Survey, Edinburgh (UK)
 CNRS, Nancy (France)
 ETH-Geologie, Zurich (Switzerland): L.Burlini with B. Cesare, R. Sassi
 ETH-IMP, Zürich (Switzerland)
 Hungarian Natural History Museum, Budapest (Hungary)
 Hungarian Academy of Sciences (Hungary)
 Laboratory for Neutron Scattering, Paul Scherrer Institut, Villigen (Svizzera)
 Natural History Museum “Naturalis” (Leiden, The Netherlands)
 Memorial University of Newfoundland, Department of Earth Sciences (Canada)
 Obafemi Awolowo University, Centre for Energy Research and Development (Nigeria)
 Obafemi Awolowo University, Department of Physics (Nigeria)
 Obafemi Awolowo University, Natural History Museum (Nigeria)
 Oklahoma University (USA)
 Polish Academy of Sciences, Warsaw (Poland)
 Slovak Academy of Sciences, Geological Institute, Banská Bystrica (Slovak Republic)
 Universidad de Chile (Santiago), Departamento de Geologia)
 Universidad de Granada (Spain)
 University of Edinburgh, School of Geosciences, (UK)
 Universität Innsbruck, Inst. für Mineralogie und Petrographie (Austria)
 University of Calcutta (India)
 University of Leicester (UK)
 University of Liverpool (UK)
 University of Utrecht (The Netherlands)
 University of Maine (USA)

University of Portsmouth (UK)
University of Sao Paulo (Brasil)
University of Shizuoka (Japan)

Project 4

Main collaborations with national institutes:

Istituto Nazionale di Geofisica e Vulcanologia (INGV) – Roma
Istituto Nazionale di Geofisica e Vulcanologia (INGV) – Bologna
Dip. University of Pisa
Dip. Geologia, University of Perugia, Italy
CNR-IGG of Pisa, Italy
Dip.Te:Ris., Università di Genova

Main collaborations with international institutes:

Australian National University (ANU) – Canberra, Australia
Department of Geological and Environmental Sciences -Stanford University (USA)
Geowissenschaftliches Zentrum der Universität Göttingen (GZG), Germany
Eidgenössische Technische Hochschule Zuerich (ETH-Zentrum)- Geologisches Institut
CNRS, Geosciences Azur, Universite de Nice-Sophia Antipolis, Nice, France
PGP, Oslo
Kyoto University, Japan
University of Franche-Comte, Besancon, France
Instituto de Ciencias del Mar, Barcelona, Spain
Brown University, Rhode Island, USA
University of Durham, UK
University of Santa Cruz, CA, USA

Project 5

Main collaborations with national institutes:

Provincia Autonoma di Trento - Ufficio Geologico
Provincia Autonoma di Bolzano.
Regione Val d'Aosta - Ufficio Geologico (CARG project)
GEIE-BBT (Brenner Basis Tunnel project)
Università di Milano Bicocca
Università di Bologna
Istituto Nazionale Oceanografia e Geofisica Sperimentale (INOGS), Trieste
Istituto Nazionale di Geofisica e Vulcanologia (INGV), Roma, Bologna
Agenzia Spaziale Italiana (ASI)
Istituto Geografico Militare, Firenze

Main collaborations with international institutes:

Hungarian – Italian Intergovernmental S & T Cooperation Program

	Universit� de Marakesh Regione Veneto, Ufficio Cartografico Collaboration Institute for Environmental Studies, JRC, Ispra Universit� di Berna, Istituto di Astronomia ETH, Zurigo Bundesamt fuer Kartographie und Geodaesie, Francoforte Geoforschungszentrum (GFZ), Potsdam Institut Geographique National, Parigi CNRS, Geosciences Azur, Universite de Nice-Sophia Antipolis, Nice, France Technical University of Munich Technical University Delft. Ambrosius Technical University Darmstadt ESA-ESOC), Darmstadt Vrijes University, Amsterdam Politecnico di Bratislava MIT/Earth and Planetary Sciences Cambridge Harvard Smithsonian Astrophysical Observatory Cambridge NASA Goddard Space Flight Center NASA- CALTECH Jet Propulsion Laboratory, Pasadena (California)
1.7	Other activities relevant for the research Program <u>Project 1</u> <u>Invited seminars</u> 1) May 2006 In situ XRD studies in modern industrial materials – Lausanne, �cole Polytechnique F�d�rale de Lausanne, Laboratoire de Crystallographie (<u>G. Artioli</u>) 2) January 2007 Cement materials and processes. Problems and perspectives – MAPEI S.p.a., Milano (<u>G. Artioli</u>) 3) May 2007 BNL memories: HFBR, NSLS and more - Symposium in honor of �ke Kvick, ESRF, Grenoble (<u>G. Artioli</u>) 4) Dipartimento di Scienze della Terra, Universit� di Parma. Novembre 2006. Title: “From crust to upper mantle: trip among high-pressure phases using the diamond anvil cell”. (<u>F. Nestola</u>) 5) Dipartimento di Scienze della Terra, Universit� di Palermo. May 2007. Title: “Mineralogy of high-pressure minerals”. (<u>F. Nestola</u>) 6) Geological Institute of Copenhagen. High-pressure behaviour of Earth's crust and mantle silicate minerals. May 2006. (<u>F. Nestola</u>) <u>Organization activity, Conferences, School</u> 1) EGU Meeting April 2008 Wien. Session GMPV13: “Phase transitions in mineralogical systems: from theory to experimental and natural observations”.

(Convenor: **F. Nestola**)

2) SMEC Conference April 2007 Miami (USA) Session 11: “Minerals at high temperature and pressure: phase transitions, EoS, and applications”. (Convenors: **G. Artioli** and **F. Nestola**)

3) Scientific committee and organization for the International School in Mineralogy at Brixen – Bressanone February 2008 (organisation from January 2007): “HP-HT Mineral Physics: Implications for Geosciences”. (**F. Nestola** and **L. Secco**).

4) April 2006, Gargnano (Italy). International Workshop on “Surface reactivity in minerals”. Co-editor of the special theme issue of The European Journal of Mineralogy on the workshop topic (European Journal of Mineralogy, Vol. 19, N. 3, May 2007). (**G. Artioli**)

5) June 2006, Martina Franca (Italy). National School AIC (Crystallographic Italian Association) on “Diffraction on polycrystalline materials”. (**G. Artioli**)

6) July 2006, Scientific Committee of the XIV National Meeting of the Italian Society of Synchrotron Ligth. (**G. Artioli**)

L. Secco: member of the board of directors of the Gruppo Nazionale di Mineralogia (2003-2006); member of the organising committee of the Scuola GNM 2004 Otranto: “Proprietà e applicazioni dei minerali alla nanoscala”

Peer reviewing

Reviewers for the following international journals:

American Mineralogist, European Journal of Mineralogy, Physics and Chemistry of Minerals, Mineralogical Magazine, Acta Crystallographica A, Neues Jahrbuch für Mineralogie, Canadian Mineralogist, Journal of Physics and Chemistry of Solids, Inorganic Chemistry

Reviewing for research projects

- PRIN projects (A. Dal Negro)
- NSF projects (G. Artioli)
- The Leibnitz Foundation (G. Artioli)

Project 2

- IUGS “Commission on the Systematics in Petrology”, Chairman: (**G. Bellieni**)
- IUGS “Subcommission on the Systematics of Igneous Rocks”, Member: (**G. Bellieni**)
- CNR Istituto di Geoscienze e Georisorse, Sezione di Padova, Responsabile: (**G. Bellieni**)
- Dipartimento di Mineralogia e Petrologia, Head: (**G. Bellieni**)
- Consiglio di Corso di Laurea in Scienze Geologiche, President: (**D. Visonà**)

Peer reviewing for the following Journals):

- Earth and Planetary Sciences
- Journal of Petrology
- Geology
- G3
- Paleo
- Tectonophysics
- Journal of African Earth Sciences
- Lithos
- Chemical Geology
- Episodes
- Geophysical Research Letters
- Contributions to Mineralogy and Petrology
- AGU-monograph

Reviewing for research project:

- USA National Science Foundation (A. Marzoli)
- Fonds National Recherche Suisse (A. Marzoli)

Internationalisation of training for research

- Tempus Project N. IB_JEP-17072-2002 "Geomagnetic Measurements and Quality Standard" Skopje University, Stip (Rep. of Macedonia), Contact Person of Consortium member: Bellieni G.

Invited Lectures at:

- Amsterdam University (A. Marzoli, 2006)
- Perugia University (A. Marzoli, 2004)

Invited Paper at:

- IGC 32, Firenze, Italy. 20-28 August, 2005 (A. Marzoli)
GAC-MAC Annual Meeting, Vancouver, Canada, 2003 (A. Marzoli)

Project 3

Invited seminars and presentations

Invited talk at GSA 2006 (B. Cesare)
Invited talk at AGU Fall meeting 2006 (B. Cesare)

Invited seminar at University of Parma, 2004 (B. Cesare)
Invited seminar at University of Turin, 2005 (B. Cesare)
Invited seminar at University of Granada, 2006 (B. Cesare)
Invited seminar at University of Graz, 2007 (R. Spiess)
Invited seminar at ETH-Zurich, 2007 (B. Cesare)
Invited seminar at GFZ-Potsdam, 2007 (R. Spiess)

Invited lecture at Intensive seminars of Petrology, Venice, 2003 (R. Spiess)
Invited lectures at Intensive seminars of Petrology, Granada, 2004 (B. Cesare)
Invited lecture at Intensive seminars of Petrology, Canberra, 2005 (B. Cesare, R. Spiess)

Organization activity, Conferences, School

- Director of PhD School of Earth Sciences, Padova University, 2004-2007 (B. Cesare)
- Organisation of intensive international ISPET seminars: 1) "Microstructural Analysis of Metamorphic rocks" (Venezia Lido, Italy, 13-18/10 2003); 2) "High-temperature metamorphism and crustal anatexis" (Granada, Spain, 28/3-3/4 2004); 3) "High-pressure and ultra high-pressure metamorphism" (Monte Ortone, Padova, Italy, 20-25/6 2004); 4) "Advanced experimental and analytical techniques in petrology" (Canberra, Australia, 5-12/2 2005); 5) "Fluids in metamorphic rocks (Siena, Italy, 20-26/11 2005) (B. Cesare)
- Organisation of Special Session: V05 – Many facets of garnet: recorders of crust and mantle dynamics" AGU Fall Meeting, San Francisco, USA, 2003 (R. Spiess)
- Organisation of session "From atoms to lithospheres - microstructural influence and control on dynamic processes" 32nd IGC, Florence, Italy 2004. (R. Spiess)
- Member of Promoting Committee of 32nd IGC from 1996 to 2002 (F.P. Sassi)
- Member of Organising Committee of 32nd IGC from 2002 to 2004 (F.P. Sassi)
- Member of Advisory Board of 32nd IGC (F.P. Sassi)
- Organisation of session: "Melting and the rheology of the crust and upper mantle: what significance for geodynamics?", 32nd IGC, Florence, 2004 (B. Cesare)
- Organisation of field trip: "The periadriatic intrusion of Vedrette di Ries – Rieserferner (Eastern Alps): petrology, emplacement mechanisms and contact aureole", 32nd IGC, Florence, 2004. (B. Cesare)
- Member of Committee of MSA Grant For Student Research in Mineralogy and Petrology (2006-2008) (B. Cesare)
- Convenor of the Symposium "Volatiles in minerals and their petrologic implications", Frontiers in Mineral Sciences (Cambridge, UK, 2007) (B. Cesare)
- Auditor for the SIMP (Italian Society of Mineralogy and Petrology) (2003-04; 2004-05; 2005-06) (R.Sassi).
- Member of the Organizing Committee of the International Meeting "Micas @ Italy" (Rimini 9-10 febbraio 2005) (R. Sassi).
- Chairman of the International Meeting "Micas @ Italy" (Rimini 9-10 febbraio 2005) (R.Sassi).
- (2003-04, 2005-06, 2007-08). Secretary General of the "Commission on Systematics in Petrology" (CSP) of the International Union of Geological Sciences (IUGS). (R. Sassi).
- Since 2007, "Academic Co-ordinator" of the "Bilateral Agreement of Lifelong Learning Programme Higher Education – ERASMUS" (Trier University, Germany) (Ingegneria per l'Ambiente ed il Territorio). (R. Sassi)

Editorial Activity

- (2003) Editing of Volume: "The abundance of 55 elements and petrovolumetric models of the crust in 9 type areas from the crystalline basements of Italy, with some geophysical and petrophysical data". Scritti e Documenti, Accad. Naz. Scienze detta dei XL, vol. 32, 464 pp.
- Member of editorial committee of Bollettino della Società Geologica Italiana (F.P. Sassi)
- Member of editorial committee of Rendiconti della Accademia Nazionale dei Lincei (classe Sc. Fis. e Nat.) (F.P. Sassi)
- Member of the Advisory Board for the new, Springer, Rendiconti della Accademia Nazionale dei Lincei
- Guest Associate Editor of American Mineralogist (vol 93, no. 2-3 (pp.261-455)
- Guest Editor of Special Volume "A show case of the Italian research in metamorphic petrology", Periodico di Mineralogia, vol. 73 (2) 271pp (2004) (B. Cesare)

- Member of editorial committee of Periodico di Mineralogia, 2004-2007 (B. Cesare)
- Member of editorial Review Board of Journal of Metamorphic Geology since 2007 (B. Cesare)

Peer reviewing

- Reviewers for the following journals: Comptes Rendus de l'Académie des Sciences; Contributions to Mineralogy and Petrology; Eclogae Geologicae Helvetiae; European Journal of Mineralogy; Geochimica et Cosmochimica Acta; Geologica Carpathica, Geological Magazine; Geology; International Journal of Earth Sciences, Iranian Journal of Science and Technology; Journal of Metamorphic Geology; Lithos; Materials and Structures; Revista Geologica de Chile; Schweizerische Mineralogische und Petrographische Mitteilungen

Reviewing for research projects

- PRIN projects 2003
- Università di Siena projects 2003, 2005
- National Science Foundation projects
- European Science Foundation (2005)
- CIVR
- National Research Foundation of South Africa (2006)

Internationalisation of training for research

- Coordination of MIUR Interlink project "ISPET- International Seminars of Petrology", for intensive seminars for post-graduate students in topics of metamorphic petrology (2002-2005) (B. Cesare)
- Coordination of the FP6 Marie Curie Series of Events "Eurispet – European Intensive Seminars of Petrology" for the training of early stage researchers in Petrology. (2007-2010) (B. Cesare)

Other

One "Giuseppe Schiavinato" degree award (2005) of the Accademia dei Lincei (thesis in Mineralogical Sciences with petrological applications. (Student: D. Magaraci, supervisor: R. Sassi).

Project 4

Solicited/Invited seminars and presentations at international and national congresses

Di Toro, G., Pennacchioni, G., 2004. Induration of cataclasites as a mechanism for pseudotachylyte production. The Second International Symposium on Slip and Flow Processes in and below the Seismogenic Region, Tokyo (JPN).

Di Toro, G., Pennacchioni, G., 2004. The Gole Larghe Fault Zone (Adamello Massif, Italian Alps): a natural laboratory of an upper crust seismogenic source. European Geosciences Union First Annual Meeting, Nice (F). Geophysical Research Abstracts, Vol. 6, 03022, 2004. (abstract)

Di Toro, G., Pennacchioni, G., Teza, G., 2004. Can pseudotachylytes be used to infer earthquake source parameters? Limitations in the study of exhumed faults. International

Geological Congress 32 – Workshop: Geological Evidence of Earthquake Source Dynamics, Florence (I).

Mancktelow, N.S., **Pennacchioni, G.**, 2004. Single and paired shear zones: the influence of brittle precursors and associated fluid-rock interaction. Geoscience Africa 2004, University of the Witwatersrand, Johannesburg, South Africa, 12th - 16th July, 2004.

Di Toro, G., Hirose, T., Nielsen, S., **Pennacchioni, G.**, Shimamoto, T., 2005. Natural and Experimental Evidence of Melt Lubrication of Faults During Earthquakes. American Geophysical Union Fall Meeting, San Francisco (USA).

Di Toro, G., Nielsen, S., **Pennacchioni, G.**, 2005. Rupture dynamics frozen in exhumed ancient faults. American Geophysical Union Fall Meeting, San Francisco (USA).

Pennacchioni, G., Di Toro, G., Brack, P., **Menegon, L.**, Villa, I.M., 2005. Sequential brittle-ductile-brittle deformations during cooling of a composite batholith, Adamello, Southern Italian Alps. Meeting FIST (Federazione Italiana Scienze della Terra), Spoleto (I), September 2005.

Seminars at Italian and foreign Universities

Di Toro, G. Processi in faglie sismogenetiche: dal terreno al laboratorio. Istituto Nazionale di Geofisica e Vulcanologia (INGV), Roma (Italy), 15 May 2003.

Di Toro, G. Comportamento del coefficiente d'attrito di rocce silicatiche a velocità di scivolamento prossime a quelle sismiche. Istituto Nazionale di Geofisica e Vulcanologia - Osservatorio Vesuviano (INGV-OV), Napoli (Italy), 30 March 2004.

Di Toro, G. Coefficiente d'attrito su piani di faglia durante rotture sismiche: misure di laboratorio. Università di Padova (Italy), 13 March 2004.

Di Toro, G. Can pseudotachylytes be used to infer earthquake source parameters? Limitations in the study of exhumed faults. Laboratoire de Géophysique Interne et Tectonophysique (LGIT), Grenoble (France), 21 October 2004.

Di Toro, G. Impiego delle pseudotachiliti per la determinazione dei parametri meccanici di un terremoto. Dipartimento di Geologia, Paleontologia e Geofisica, Università di Padova (Italy) 3 February 2005.

Di Toro, G., Friction in rocks approaching seismic slip rates: experiments from the Brown University (USA). Department of Geology and Mineralogy, Kyoto University (JPN), 1 March 2005.

Di Toro, G., Application of natural pseudotachylytes in the determination of earthquake source parameters. Department of Geology and Mineralogy, Kyoto University (JPN), 4 March 2005.

Di Toro, G. Attrito e fusione: faglie scivolosissime, evidenze di terreno e sperimentali. Istituto Nazionale di Geofisica e Vulcanologia (INGV), Roma, 18 Ottobre, 2005.

Di Toro, G., Rotary torsion apparatus and investigation of rock-friction at semi-seismic slip rate. Department of Geology and Mineralogy, Kyoto University (JPN), 2 March 2006.

Di Toro, G., Pittarello, L., Bizzarri, A., Hadizadeh, J., Pennacchioni, G., *Seismic energy partitioning inferred from pseudotachylyte-bearing faults (Gole Larghe Fault, Adamello batholith, Italy)*. Mini-workshop “Deformation, Fluid Flow and Earthquake Generation”, Kyoto University, Kyoto, 3 March 2006.

Di Toro, G., Hirose, T., Nielsen, S., Pennacchioni, G., Shimamoto, T., *Lubrication of faults by seismic melts during earthquakes*, Mini-workshop “Deformation, Fluid Flow and Earthquake Generation”, Kyoto University, Kyoto, 3 March 2006.

Di Toro, G., *Anatomia di un terremoto dallo studio di una sorgente sismica esumata*, Dipartimento di Geologia, Paleontologia e Geofisica, Università di Padova, (Italy), 11 May 2006.

Di Toro, G., *I terremoti, le faglie e loro simulazione in laboratorio*, Liceo Scientifico Giordano Bruno, Mestre (Venezia, Italy), 18 May 2006.

Di Toro, G., *Pseudotachylytes and Earthquake Mechanics*, Dipartimento di Scienze Geologiche, Università di Roma Tre, Roma, 17 Novembre, 2006.

Di Toro, G., *Pseudotachylytes and Earthquake Mechanics*, Geological Institute, ETH, Zurich, 28 February, 2007.

Di Toro, G., *Pseudotachylytes and Earthquake Mechanics*, Brown University, Providence, Rhode Island, USA, 4 May 2007.

Di Toro, G., *Pseudotachylytes and Earthquake Mechanics*, Los Alamos National Laboratories, LANL, Los Alamos (New Mexico, USA), 7 May 2007.

Di Toro, G., *Lo studio dei terremoti al Dipartimento di Geoscienze dell'Università di Padova*. Liceo Scientifico Enrico Fermi, Università degli Studi di Padova, 1 October 2007.

Di Toro, G., How to prepare a talk for an international meeting - *Come preparare una presentazione per un congresso*. Dip. di Geoscienze. Università degli Studi di Padova, 8 November 2007.

Di Toro, G., *Seismic melts and earthquake mechanics*. Laboratoire de Géophysique Interne et Tectonophysique (LGIT), Grenoble (France), 17 January, 2008.

Mancktelow, N.S., **Pennacchioni, G.** - The Control of Precursor Brittle Fracture and Fluid/Rock Interaction on the Development of Single and Paired Ductile Shear Zones. ANU-Camberra (Australia) March 2004

Mancktelow, N.S. and **Pennacchioni, G.** - The Control of Precursor Brittle Fracture and Fluid/Rock Interaction on the Development of Single and Paired Ductile Shear Zones. ETHZ-Zurich 26. April 2004, 17.15 Uhr, NO G33

Di Toro, G., Pittarello, L., Bizzarri, A., Hadizadeh, J., Pennacchioni, G., Seismic energy partitioning inferred from pseudotachylyte-bearing faults (Gole Larghe Fault, Adamello batholith, Italy). Mini-workshop “Deformation, Fluid Flow and Earthquake Generation”, Kyoto University, Kyoto, 3 March 2006.

Di Toro, G., Hirose, T., Nielsen, S., Pennacchioni, G., Shimamoto, T., Lubrication of faults by seismic melts during earthquakes,). Mini-workshop “Deformation, Fluid Flow and Earthquake Generation”, Kyoto University, Kyoto, 3 March 2006.

Pennacchioni, G. -Post-intrusive deformation and paleoseismicity within the Adamello pluton (Southern Alps, Italy). Freiburg (D), Monday 15 January 2007.

Pennacchioni, G. -Nucleation and initial development of shear zone network: field constraints. Potsdam (D), Nov. 6, 2007

Pennacchioni, G. - Nucleation and initial development of shear zone network: field constraints. Goettingen (D), Dec. Friday 14, 2007

Organization of sessions at international meetings:

American Geophysical Union 2004 Fall Meeting – San Francisco, Session T20: “*High Velocity Friction and Earthquake Generation Processes*” (**G. Di Toro** with Toshihiko Shimamoto, David Goldsby and Jim Rice).

European Geosciences Union 2006 General Assembly – Vienna, Session Vienna, **TS1.4** “*Fluid-rock interaction and localization in shear zones*” (**Pennacchioni, G.**, Neil S. Mancktelow and Yann Rolland).

European Geosciences Union 2006 General Assembly – Vienna, Session TS4.1 - Frictional heating and earthquake rupture dynamics: integration of field, laboratory and theoretical studies (**G. Di Toro**, Toshihiko Shimamoto and Massimo Cocco).

European Geosciences Union 2007 General Assembly – Vienna, Session SM22/TS3.1 – “*Physics and mechanics of earthquake and faulting*”. (**G. Di Toro**, Jean Schmittbuhl and Karen Mair).

16th DRT (Deformation Mechanisms, Rheology and Tectonics) Conference – **Milano 26-27 September 2007**– “*Brittle and ductile reactivation of compositional and structural heterogeneities*” (**Pennacchioni, G.**, Ulf Bayer and Terry Engelder).

Organization of international schools

- **Meeting of Young Researchers in Earth Sciences (MYRES) II - Dynamics of the Lithosphere** (<http://myres.org/meetings.html>) - Verbania (Italy), 2-6th July 2006 (Laurent Montesi and G. Di Toro). The meeting was granted by NSF and ESF for 130.000 USD.
- **Scuola Piali** (<http://users.unimi.it/rockdef/scpiali/old/neves/index.htm>): “*Field trip to the Lago di Neves (Tauern Windows, Eastern Alps): Mesostructural analysis of deformation structures*” - 10-13 September 2006 (**G. Pennacchioni**,

and Neil S. Mancktelow):

Participation to international schools:

- **ISPET 2003-International Seminars of Petrology** - Venezia Lido (Italy), October 2003). Class taught “*Microstructural Analysis of Metamorphic Rocks*”. **G. Pennacchioni** and Neil S. Mancktelow.
- **ISPET 2005-International Seminars of Petrology** - Canberra (Australia), February 2005. Class taught: “*EBSD – theory and applications to unravel petrological processes*”(R. Spiess).

Organization of sessions at international meetings:

- **American Geophysical Union 2004 Fall Meeting** – San Francisco, Session T20: “*High Velocity Friction and Earthquake Generation Processes*” (**G. Di Toro** with Toshihiko Shimamoto, David Goldsby and Jim Rice).
- **European Geosciences Union 2006 General Assembly** – Vienna, Session Vienna, **TS1.4** “*Fluid-rock interaction and localization in shear zones*” (**Pennacchioni, G.**, Neil S. Mancktelow and Yann Rolland).
- **European Geosciences Union 2006 General Assembly** – Vienna, Session TS4.1 - Frictional heating and earthquake rupture dynamics: integration of field, laboratory and theoretical studies (**G. Di Toro**, Toshihiko Shimamoto and Massimo Cocco).
- **European Geosciences Union 2007 General Assembly** – Vienna, Session SM22/TS3.1 – “*Physics and mechanics of earthquake and faulting*”. (**G. Di Toro**, Jean Schmittbuhl and Karen Mair).
- **16th DRT (Deformation Mechanisms, Rheology and Tectonics) Conference** – **Milano 26-27 September 2007**– “*Brittle and ductile reactivation of compositional and structural heterogeneities*” (**Pennacchioni, G.**, Ulf Bayer and Terry Engelder).

Peer-reviewing:

- JOURNALS: Journal of Geology, Journal of Structural Geology, Tectonophysics, Tectonics, Memorie di Scienze Geologiche, AGU monographs, Periodico di Mineralogia, Geology, Nature, Science, Nature, GeoScience, Journal of Geophysical Research, Geophysical Research Letters, Earth and Planetary Sciences
- PROJECTS: USA-NSF proposal, Swiss-NSF (2005)

Editorial Activity

Abercrombie, R., McGarr, A., **Di Toro, G.**, Kanamori, H., 2006. *Radiated Energy and the Physics of Faulting*, **Geophysical Monograph Series** Vol. 170 (American Geophysical Union, Washington, D.C.).

Awards

- **Giulio Di Toro: 2003 GSA ID Travel Award**. Individual award based on scientific merits for attending the 2003 National Meeting of the Geological Society of America held in Seattle (USA), November 2003. 700 USD.
- **Giulio Di Toro: 2005 AGU Travel Award** based on scientific merits for

attending the 2005 Chapman Conference on Radiated Energy and the Physics of Earthquake Faulting held in Portland (Maine, USA), June 2005, 800 USD.

Project 5

Participation to meetings and workshops:

a) SOLICITED and INVITED TALKS AT INTERNATIONAL MEETINGS

1. A. Bistacchi, **G.V. Dal Piaz**, G. Dal Piaz, **M. Massironi**, B. Monopoli, A. Schiavo,. Brenner Basistunnel: 3D geological modeling and reliability estimates. 2004, 32nd International Geological Congress – Firenze.

Participation to international schools:

Meeting of Young Researchers in Earth Sciences (MYRES) II - Dynamics of the Lithosphere - Verbania (Italy), 2-6th July 2006 (organization of the field trip by Massironi, Dal Piaz). The meeting was granted by NSF and ESF for 130.000 USD.

2006 Erice School on Seismic Hazard (A. Caporali)

2006 COMSOL Workshop on Contact Problems in Geophysics by Finite Elements Method

Organization of sessions at international meetings:

2005 EUG General Assembly, Vienna, Session ‘Lithospheric Deformation’ (**A. Caporali**)

2003-2005 GNGTS (Gruppo Nazionale Geofisica della Terra Solida) - CNR Annual Meetings, Roma: sessione sulla Geodinamica del Mediterraneo (**A. Caporali**)

Organization of meetings and workshops:

2003, 7th bilateral Geodetic Meeting Italy – Poland, Bressanone, 22-24 Maggio: Prof. A. Caporali

2004 83th Summer meeting of the Società Geologica Italiana (Vipiteno, Passo di Vizze – ChemitzerHuetten): G.V. Dal Piaz and Pennacchioni

2005, Meeting of the Technical Working Group dell'EUREF (at the Dipartimento di Geoscienze): Prof. A. Caporali

2005, Workshop of “Centri Locali di analisi Dati dell'EUREF” (at the Dipartimento di Geoscienze) : Prof. A. Caporali

2005, National Meeting on “Rete Veneta GPS”, in collaboration with Regione Veneto (Aula Magna, Palazzo del Bò) : Prof. A. Caporali.

Peer-reviewing:

Tectonics, Journal of Geodynamics, SMPM, Eclogae Geologicae Helveticae, Terra Nova, Ofioliti, Tectonophysics, Geology, Geophysical Journal International, Geosphere, Bollettino della Società Geologica Italiana

PROJECTS: NSF Swiss, Austrian NSF,

Editorial Activity

Editorial Board of Ofioliti (**Dal Piaz G.V.**)

Associate Editor of Eclogae Geologicae Helveticae (**Dal Piaz G.V.**)

Associate Editor of Swiss Geosciences (**Dal Piaz G.V.**)

Associate Editor of Terra Nova (**Dal Piaz G.V.**)

Associate Editor of Journal of Asian Earth Sciences (2003) **A. Caporali**

Memberships of scientific committee and organizations

Member of the “Accademia Nazionale delle Scienze detta dei XL” (**Dal Piaz G.V.**)

National Member of the *Accademia Nazionale dei Lincei* (**Dal Piaz G.V.**)

Member of the Accademia della Scienze di Torino (**Dal Piaz G.V.**)

Member of the Istituto Veneto Scienze Lettere ed Arti (**Dal Piaz G.V.**)

1.8**Research products****Project 1**

G. Artioli and F. Nestola contribute for 2006 and 2007

Summary of research products

	2003	2004	2005	2006	2007	Total
A1	2	2	2	18	17	42
A2	0	0	1	1	0	2
F	3	3	8	24	12	50
Total	5	5	11	42	29	

List of research products

1. 2003 A1 MARTIGNAGO F., DAL NEGRO A., CARBONIN S. (2003) HOW CR3+ AND

			FE3+ AFFECT MG-AL ORDER-DISORDER TRANSFORMATION AT HIGH TEMPERATURE IN NATURAL SPINELS. PHYSICS AND CHEMISTRY OF MINERALS. 30, 401-408
2.	2003	A1	TRIBAUDINO M., PASQUAL D., MOLIN G.M., SECCO L. (2003) MICROTEXTURES AND CRYSTAL CHEMISTRY IN P2(1)/C PIGEONITES. MINERALOGY AND PETROLOGY. 77, 161-176
3.	2004	A1	NAZZARENI S., MOLIN G.M, SKOGBY H., DAL NEGRO A. (2004) CRYSTAL CHEMISTRY OF Ti3+-Ti4+-BEARING SYNTHETIC DIOPSIDES. EUROPEAN JOURNAL OF MINERALOGY. 16, 443-449
4.	2004	A1	TIBLIAS D., SCAVNICAR S., MOLIN G., SLAVKOVIC R. (2004) AUTHIGENIC MICA IN EARLY MIOCENE VOLCANICLASTIC ROCKS OF THE MACELJ AREA, HRVATSKO ZAGORJE, CROATIA. NEUES JAHRBUCH FUR MINERALOGIE-ABHANDLUNGEN. 2, 69-82
5.	2005	A2	SECCO L., BOSCARDIN M., DALLA FONTANA G., MARTINI B., PEGORARO S., SALVETTI A. (2005) WULFENITE E ALTRI MINERALI DI QUITTENG, VALLE DEL CERVO, BIELLA. RIVISTA MINERALOGICA ITALIANA. 2, 114-117
6.	2005	A1	STIMPFL M., GANGULY J., MOLIN G.M (2005) KINETICS OF Fe2+-MG ORDER-DISORDER IN ORTHOPYROXENE: EXPERIMENTAL STUDIES AND APPLICATIONS TO COOLING RATES OF ROCHS. CONTRIBUTIONS TO MINERALOGY AND PETROLOGY = BEITRAEGE ZUR MINERALOGIE UND PETROLOGIE. 150, 319-334
7.	2005	A1	TUMIATI S., GODARD G. MARTIN S., NIMIS P., MAIR V. BOYER B. (2005) DISSAKISITE-(LA) FROM THE ULTEN ZONE PERIDOTITE (ITALIAN EASTERN ALPS): A NEW END-MEMBER OF THE EPIDOTE GROUP. AMERICAN MINERALOGIST. 90, 1177-1185
8.	2006	A1	GATTA G.D., NESTOLA F., BROMILEY G.D., MATTAUCH S. (2006) THE REAL TOPOLOGICAL CONFIGURATION OF THE EXTRA-FRAMEWORK CONTENT IN ALKALI-POOR BERYL: A MULTI-METHODOLOGICAL STUDY. AMERICAN MINERALOGIST. 91, 29-34
9.	2006	A1	ARTIOLI G., DAPIAGGI M., FORNASINI P., SANSON A., ROCCA F., MERLI M. (2006) NEGATIVE THERMAL EXPANSION IN CUPRITE-TYPE COMPOUNDS: A COMBINED SYNCHROTRON XRPD, EXAFS, AND COMPUTATIONAL STUDY OF CU2O AND AG2O. JOURNAL OF PHYSICS AND CHEMISTRY OF SOLIDS. 67, 1918-1922
10.	2006	A1	DAPIAGGI M., ARTIOLI G., MAZZOCCHIA C., MERLINI M. (2006) STRUCTURAL CHARACTERISATION OF HIGHTEMPERATURE K-EXCHANGED SODALITE. ZEITSCHRIFT FUR KRISTALLOGRAPHIE. 437-442 PART: PART 2 SUPPL. 23.
11.	2006	A1	DEKOV VM, MOLIN GM, DIMOVA M, GRIGGIO C, RAJTA I, UZONYI I (2006) COSMIC SPHERULES FROM METALLIFEROUS SEDIMENTS: A LONG JOURNEY TO THE SEAFLOOR. NEUES JAHRBUCH FUR MINERALOGIE-ABHANDLUNGEN 183, 269-282
12.	2006	A1	DUBROVINSKY L., DUBROVINSKAIA N., KANTOR I., NESTOLA F., GATTA G.D. (2006) HIGH-BRILLIANCE X-RAY SYSTEM FOR HIGH-PRESSURE IN-HOUSE RESEARCH: APPLICATIONS FOR STUDIES OF SUPERHARD MATERIALS. HIGH PRESSURE RESEARCH. 26, 137-143
13.	2006	A1	GATTA G. D., NESTOLA F., WALTER J. M. (2006) ON THE THERMO-ELASTIC BEHAVIOUR OF KYANITE: A NEUTRON POWDER DIFFRACTION STUDY UP TO 1200. MINERALOGICAL MAGAZINE. 70, 309-317
14.	2006	A1	GATTA G.D., NESTOLA F., BOFFA BALLARAN T. (2006) ELASTIC BEHAVIOR, PHASE TRANSITION, AND PRESSURE INDUCED STRUCTURAL EVOLUTION OF ANALCIME. AMERICAN MINERALOGIST. 91, 568-578
15.	2006	A1	GATTA G.D., NESTOLA F., BOFFA BALLARAN T. (2006) ELASTIC BEHAVIOUR AND STRUCTURAL EVOLUTION OF TOPAZ AT HIGH-PRESSURE. PHYSICS AND CHEMISTRY OF MINERALS. 33, 235-242
16.	2006	A1	GATTA G.D., NESTOLA F., BROMILEY G., LOOSE A. (2006) NEW INSIGHT INTO CRYSTAL CHEMISTRY OF TOPAZ: A MULTI-METHODOLOGICAL STUDY. AMERICAN MINERALOGIST. 91, 1839-1846
17.	2006	A1	LAVINA B., CARBONIN S., RUSSO U., TUMIATI S. (2006) THE CRYSTAL STRUCTURE OF DISSAKISITE-(LA) AND STRUCTURAL VARIATIONS AFTER ANNEALING OF RADIATION DAMAGE. AMERICAN MINERALOGIST. 91, 104-110
18.	2006	A1	MARTIGNAGO F., ANDREOZZI GB., DAL NEGRO A. (2006) THERMODYNAMICS AND KINETICS OF CATION ORDERING IN NATURAL AND SYNTHETIC MG(AL,FE3+)(2)O-4 SPINELS FROM IN SITU HIGH-TEMPERATURE X-RAY DIFFRACTION. AMERICAN MINERALOGIST. 91, 306-312
19.	2006	A1	MERLINI M., GEMMI M., ARTIOLI G. (2006) LOW TEMPERATURE SR-XRPD STUDY OF AKERMANITE-GEHLENITE SOLID SOLUTION. ZEITSCHRIFT FUR KRISTALLOGRAPHIE. 419-424 PART: PART 2 SUPPL. 23
20.	2006	A1	NESTOLA F., BOFFA BALLARAN T., LIEBSKE C., BRUNO M., TRIBAUDINO M. (2006) HIGH-PRESSURE BEHAVIOUR ALONG THE JADEITE NAALS2O6 - NAFESI2O6 SOLID SOLUTION UP TO 10 GPa. PHYSICS AND CHEMISTRY OF MINERALS. 33, 417-425

21.	2006	A1	NESTOLA F., GATTA G.D., BOFFA BALLARAN T. (2006) THE EFFECT OF CA SUBSTITUTION ON THE ELASTIC AND STRUCTURE BEHAVIOR OF ORTHOENSTATITE (MG ₂ Si ₂ O ₆) UP TO 10.2 GPa. AMERICAN MINERALOGIST. 91, 809-815
22.	2006	A1	PISTORINO M., NESTOLA F., BOFFA BALLARAN T., DOMENEGHETTI M.C. (2006) THE EFFECT OF COMPOSITION AND CATION ORDERING ON THE COMPRESSIBILITY OF COLUMBITES UP TO 7 GPa. PHYSICS AND CHEMISTRY OF MINERALS. 33, 593-600
23.	2006	A1	PRINCIVALLE F., MARTIGNAGO F., DAL NEGRO A. (2006) KINETICS OF CATION ORDERING IN NATURAL MG(Al,CR ₃ ⁺)(₂ O-4 SPINELS. AMERICAN MINERALOGIST. 91, 313-318
24.	2006	A1	SANSON A., ROCCA F., DALBA G., FORNASINI P., GRISENTI R., DAPIAGGI M., ARTIOLI G. (2006) NEGATIVE THERMAL EXPANSION AND LOCAL DYNAMICS IN CU ₂ O AND AG ₂ O. PHYSICAL REVIEW B, SOLID STATE. 73 (21): ART. NO. 214305
25.	2006	A1	SMYTH J.R., FROST D.J., NESTOLA F., HOLL C.M., BROMILEY G. (2006) OLIVINE HYDRATION IN THE DEEP UPPER MANTLE: EFFECTS OF TEMPERATURE AND SILICA ACTIVITY. GEOPHYSICAL RESEARCH LETTERS. 33, L15301
26.	2006	A2	GUASTONI A., CARBONIN S., NIMIS P. AND ZORZI F. (2006) MESOLITE, PECTOLITE, THOMSONITE - STUDIO SUI CAMPIONI DELLA COLLEZIONE GASSER, MUSEO DI MINERALOGIA DELL'UNIVERSITÀ DI PADOVA. RIVISTA MINERALOGICA ITALIANA. 3, 186-189.
27.	2007	A1	ARTIOLI G, LATTANZI P (2007) FOREWORD: SURFACE REACTIVITY OF MINERALS. EUROPEAN JOURNAL OF MINERALOGY 19, 295-295
28.	2007	A1	BENNA P, NESTOLA F., BOFFA BALLARAN T, BALIC-ZUNIC T, LUNDEGAARD L.F, BRUNO E. (2007). THE HIGH-PRESSURE STRUCTURAL CONFIGURATIONS OF CA _{0.2} SR _{0.8} AL ₂ Si ₂ O ₈ FELDSPAR: THE 11 - 12/C AND 12/C - P21/C PHASE TRANSITIONS. AMERICAN MINERALOGIST. 92, 1190-1199
29.	2007	A1	DAPIAGGI M, ARTIOLI G, RIGHI C, CARLI R (2007) HIGH TEMPERATURE REACTIONS IN MOLD FLUX SLAGS: KINETIC VERSUS COMPOSITION CONTROL. JOURNAL OF NON-CRYSTALLINE SOLIDS 353, 2852-2860
30.	2007	A1	GATTA GD, RINALDI R, KNIGHT KS, MOLIN GM, ARTIOLI G (2007) HIGH TEMPERATURE STRUCTURAL AND THERMOELASTIC BEHAVIOUR OF MANTLE ORTHOPYROXENE: AN IN SITU NEUTRON POWDER DIFFRACTION STUDY PHYSICS AND CHEMISTRY OF MINERALS. 34, 185-200
31.	2007	A1	GEMMI M, MERLINI M, CRUCIANI G, ARTIOLI G (2007) NON-IDEALITY AND DEFECTIVITY OF THE (A)OVER-CIRCLEKERMANITE-GEHLENITE SOLID SOLUTION: AN X-RAY DIFFRACTION AND TEM STUDY. AMERICAN MINERALOGIST. 92, 1685-1694
32.	2007	A1	KULKARNI SR, MERLINI M, PHATAK N, SAXENA SK, ARTIOLI G, GUPTA S, BARSOU MW (2007) HIGH-TEMPERATURE THERMAL EXPANSION AND STABILITY OF V ₂ AlC UP TO 950 DEGREES C JOURNAL OF THE AMERICAN CERAMIC SOCIETY. 90, 3013-3016 SEP 2007
33.	2007	A1	MERLINI M, ARTIOLI G, MENEGHINI C, CERULLI T, BRAVO A, CELLA F. (2007) THE EARLY HYDRATION AND THE SET OF PORTLAND CEMENTS: IN SITU X-RAY POWDER DIFFRACTION STUDIES. POWDER DIFFRACTION 22, 201-208
34.	2007	A1	NESTOLA F., BOFFA BALLARAN T, BALIC-ZUNIC T, PRINCIVALLE F, SECCO L, DAL NEGRO A. (2007). COMPARATIVE COMPRESSIBILITY AND STRUCTURAL BEHAVIOR OF SPINEL MGAL ₂ O ₄ AT HIGH-PRESSURES: THE INDEPENDENCY ON THE DEGREE OF CATION ORDER. AMERICAN MINERALOGIST. 92, 1838-1843
35.	2007	A1	NESTOLA F., LONGO M, MCCAMMON C, BOFFA BALLARAN, T. (2007). CRYSTAL-STRUCTURE REFINEMENT OF NA-BEARING CLINOPYROXENES FROM MANTLE-DERIVED ECLOGITE XENOLITHS. AMERICAN MINERALOGIST. VOL. 92, 1242-1245
36.	2007	A1	NESTOLA F., ROTIROTI N, BRUNO M, TRIBAUDINO M, VAN SMAALEN S, OHASHI H, REDHAMMER G. (2007). LOW-TEMPERATURE BEHAVIOR OF NAGASi ₂ O ₆ . AMERICAN MINERALOGIST. 92, 560-569
37.	2007	A1	NESTOLA F., TRIBAUDINO M, BOFFA BALLARAN T, LIEBSKE C, MRUNO M. (2007). THE CRYSTAL STRUCTURE OF PYROXENES ALONG THE JADEITE-HEDENBERGITE AND JADEITE-AEGIRINE JOINS. AMERICAN MINERALOGIST. 92, 1492-1501
38.	2007	A1	PERRILLAT, J.P, NESTOLA F., SINOGEIKIN S.V, BASS J. (2007). SINGLE-CRYSTAL ELASTIC PROPERTIES OF CA _{0.07} MG _{1.93} Si ₂ O ₆ ORTHOPYROXENE. AMERICAN MINERALOGIST. 92, 109-113
39.	2007	A1	PRENCIPE M, NESTOLA F. (2007). MINERALS AT HIGH PRESSURE. MECHANICS OF COMPRESSION FROM QUANTUM MECHANICAL CALCULATIONS IN A CASE STUDY: THE BERYL (Al ₄ Be ₆ Si ₁₂ O ₃₆). PHYSICS AND CHEMISTRY OF MINERALS. 34, 37-52
40.	2007	A1	SECCO L, GUASTONI A, NESTOLA F., REDHAMMER G, DAL NEGRO A. (2007). CRYSTAL CHEMISTRY OF SYNTHETIC AND NATURAL AEGIRINES AS AN INDICATOR OF DIFFERENT P-T FORMATION CONDITIONS.

			MINERALOGICAL MAGAZINE. 71, 249-255
41.	2007	A1	SMYTH J, MIERDEL K, KEPPLER H, LANGENHORST F, NESTOLA F., DUBROVINSKY L. (2007). CRYSTAL CHEMISTRY OF HYDRATION IN ALUMINOUS ORTHOPYROXENE. AMERICAN MINERALOGIST. 92, 973-976
42.	2007	A1	TARAN M, NESTOLA F., OHASHI H, KOCH-MLLER M, BALIC-ZUNIC T, OLSEN L. (2007). HIGH-PRESSURE OPTICAL SPECTROSCOPY AND X-RAY DIFFRACTION STUDIES ON SYNTHETIC COBALT ALUMINUM SILICATE GARNET. AMERICAN MINERALOGIST. 92, 1616-1623
43.	2007	A1	GUASTONI A, NESTOLA F, MAZZOLENI G., VIGNOLA P. (2007) MN-RICH GRAFTONITE, FERRISICKLERITE, STANNICKITE AND MN-RICH VIVIANITE IN A GRANITIC PEGMATITE AT SOÈ VALLEY, CENTRAL ALPS, ITALY. MINERALOGICAL MAGAZINE, 71, 579-585
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Project 2

Summary of research products

	2003	2004	2005	2006	2007	Total
A1	3	3	3	2	4	15
A2	3	1	1	0	0	5
B1	3	1	0	0	1	5
D	1	2	2	4	3	12
F	10	7	2	2	2	23
Total	20	14	8	8	10	

List of research products

Line 1

1.	2003	A1	BENNIO L., BROTZU P., D'ANTONIO M., FERAUD G., GOMES C.B., MARZOLI A., MELLUSO L., MORBIDELLI L., MORRA V., RAPAILLE C., RUBERTI E., (2003). THE THOLEIITIC DYKE SWARM OF THE ARRAIAL DO CABO PENINSULA (SE BRAZIL): ⁴⁰ AR/ ³⁹ AR AGES, PETROGENESIS, AND REGIONAL SIGNIFICANCE. J. SOUTH AMER. EARTH SC., 16, 163-176.
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7.	2005	A1	COLTORTI M., FERAUD G., MARZOLI A., PERETTO C., TON-THAT T. (2005). AGE AND PALEOCLIMATIC SIGNIFICANCE OF PLEISTOCENE ARCHAEOLOGICAL SITES OF CENTRAL ITALY. QUATERNARY INTERNATIONAL, 345, 183-151.
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Project 3

Summary of research products

	2003	2004	2005	2006	2007	Total
A1	9	2	7	1	7	26
A2	1	5	2	1	2	11
B1	0	0	0	1	3	4
B2	5	1	1	0	0	7
E	1	1	0	0	0	2
F	18	17	17	10	13	75
Total	34	26	27	13	24	

List of research products

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| 1. | 2003 | A1 | BORGHI, A., CASTELLI, D., LOMBARDO, B. AND VISONA', D., (2003) THERMAL AND BARIC EVOLUTION OF GARNET GRANULITES FROM THE KHARTA REGION OF S TIBET, E HIMALAYA. EUROPEAN JOURNAL OF MINERALOGY., 15, 401-418. |
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Project 4

Summary of research products

	2003	2004	2005	2006	2007	Total
A1	2	3	5	4	2	16
A2	0	0	0	1	0	1
E	0	0	0	1	0	1
F	13	8	22	18	20	81
Total	15	11	27	24	22	

List of research products

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|----|------|----|--|
| 1. | 2003 | A1 | CERIANI S, MANCKTELOW NS, PENNACCHIONI G. (2003). ANALOGUE MODELLING OF THE INFLUENCE OF SHAPE AND PARTICLE/MATRIX INTERFACE LUBRICATION ON THE ROTATIONAL BEHAVIOUR OF RIGID PARTICLES IN SIMPLE SHEAR. JOURNAL OF STRUCTURAL GEOLOGY. VOL. 25, PP. 2005-2021 ISSN: 0191-8141, ISI:000185851600003. |
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52.	2005	F	MENEGON, L., HEILBRONNER, R., PENNACCHIONI, G., PITTARELLO, L., 2005. DEVELOPMENT OF QUARTZ CPO IN NATURALLY DEFORMED GRANITOIDES (AROLLA GNEISS, WESTERN ALPS). GEOLOGICAL SOCIETY OF AMERICA ANNUAL MEETING, SALT LAKE CITY, 16 - 19 OCTOBER. (POSTER PRESENTATION)
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65.	2006	F	DEL GAUDIO, P., R. HAN, DI TORO, G., HIROSE, T., SHIMAMOTO, T., COCCO, M., 2006. DYNAMIC STRENGTH OF PERIDOTITE DURING FRICTIONAL MELTING AT SEISMIC SLIP RATES: EXPERIMENTAL RESULTS. EUROPEAN GEOSCIENCES UNION ANNUAL MEETING, VIENNA (A). (POSTER PRESENTATION)
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72.	2006	F	MENEGON, L., PENNACCHIONI, G., STÜNITZ, H., 2006. FLUID-ASSISTED NUCLEATION AND GROWTH OF MYRMEKITE DURING DEVELOPMENT OF DUCTILE SHEAR ZONES IN METAGRANITES. EUROPEAN GEOSCIENCES UNION ANNUAL MEETING, VIENNA (A). GEOPHYSICAL RESEARCH ABSTRACTS, VOL. 8, 08211, 2006. (ABSTRACT) (POSTER PRESENTATION)
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74.	2006	F	MENEGON, L., PITTARELLO, L., PENNACCHIONI, G., HEILBRONNER, R., 2006. EVOLUZIONE MICROSTRUTTURALE E TESSITURALE DEL QUARZO DURANTE LA DEFORMAZIONE DUTTILE DI GRANITOIDI. GRUPPO ITALIANO DI GEOLOGIA STRUTTURALE (GIGS) ANNUAL MEETING, CHIETI, 27 - 28 FEBRUARY. (TALK PRESENTATION)
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82.	2007	F	DI TORO, G., NIELSEN, S., HIROSE, T., PENNACCHIONI, G., PITTARELLO, L., SHIMAMOTO, T., 2007. ANATOMY OF A 30 MA OLD EARTHQUAKE FROM AN EXHUMEDFAULT (GOLE LARGHE FAULT, ADAMELLO, ITALY) GEOPHYSICAL RESEARCH ABSTRACTS, VOL. 9, 04942, 2007. EUROPEAN GEOSCIENCES UNION ANNUAL MEETING, VIENNA (A) 2007. (TALK PRESENTATION)
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84.	2007	F	GRIFFITH, A., DI TORO, G., PENNACCHIONI, G., POLLARD, D., 2007. PSEUDOTACHYLYTES IN FAULTS OF THE MT. ABBOT QUADRANGLE, SIERRA NEVADA. IMPLICATIONS FOR SEISMIC SLIP. GEOLOGICAL SOCIETY OF AMERICA ABSTRACTS WITH PROGRAMS, VOL. 39, NO. 6, P. 374 (138-4), DENVER, OCTOBER 2007. (TALK PRESENTATION)
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93.	2007	F	MENEGON, L., PENNACCHIONI, G., SPIESS, R., 2007. THE ROLE OF DISSOLUTION-PRECIPITATION CREEP ON THE DEVELOPMENT OF CRYSTALLOGRAPHIC PREFERRED ORIENTATION OF K-FELDSPAR IN GRANITIC MYLONITES. EUROPEAN GEOSCIENCES UNION ANNUAL MEETING, VIENNA (A) 2007. GEOPHYSICAL RESEARCH ABSTRACTS, VOL. 9, 06886. (TALK PRESENTATION)
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Project 5

Summary of research products

	2003	2004	2005	2006	2007	Total
A1	4	0	1	0	2	7
A2	3	2	1	2	0	8
B1	1	0	0	2	1	4
F	0	3	5	4	9	21
GM	3	5	1	0	8	17
Total	11	10	8	8	20	

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