University of Milano-Bicocca
PhD Course in Chemical, Geological and Environmental Sciences
Call for Interest 39th cycle - session I - Curriculum Geological Sciences

Nr 1		**Supervisor**	**Pietro Sternai**
Title	**Assessing Alpine strain and exhumation dynamics through forward and inverse modeling of their geological and geophysical record**		
The European Alps have long served as a natural laboratory to investigate collisional orogenic dynamics. However, the main responsible mechanisms and timing of the strain and exhumation processes throughout the Alpine collisional history are still elusive. This project aims at constraining the partitioning between lithospheric/mantle and surface processes in driving the structural and exhumation history of the Alps. To this aim, the PhD candidate will focus on the interpretation of the available geological and geophysical data through extensive forward and inverse modeling techniques. The project involves a large collaboration with colleagues internal to the University of Milano-Bicocca and is co-supervised by colleagues/Prof. György Hetényi at the University of Lausanne, where the candidate is expected to spend between 12 and 18 months out of 36.			
Supervisor webpage: https://www.unimib.it/pietro-sternai			
Notes: *Project "Assessing Alpine strain and exhumation dynamics through forward and inverse modeling of their geological and geophysical record" in collaboration with the University of Lausanne (Switzerland)*			

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Nr 2		**Supervisor**	**Valter Maggi**
Title	**Innovative optical technologies in ice core science for an improved understanding of dust-climate interactions**		
Ice cores offer a unique opportunity to study the role of eolian mineral dust aerosol on climate evolution, as they preserve a pristine atmospheric input from the past. This information is somewhat altered at great depth where post-depositional processes likely occur. The aim of this research is to understand the microphysical properties of eolian mineral dust in ice cores which can be of use for reconstructing the atmospheric circulation in the past and climate variability at high southern latitudes. Traditional Coulter Counter techniques as well as Single Particle Extinction and Scattering Method (SPES) and the novel micro-holographic camera will be coupled with laser Abacus device in a continuous flow analysis system to extract key physical parameters from Antarctic ice core dust and to detect possible in situ formation of artefacts altering the pristine paleoclimatic sequence. Specific skills in microphysics of light are desirable. Laboratory work will be carried out at EUROCOLD laboratory of DISAT (UNIMIB) in collaboration with the Optics Group of the University of Milan.			
Supervisor webpage: https://www.unimib.it/valter-maggi			
Notes: *Shortlisted project on Polar Sciences*			

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Nr 3		**Supervisor**	**Roberto Colombo**
Title	**Modelling snow processes and ice melting by combining field experiments and thermal infrared remote sensing**		
The cryosphere is particularly sensitive to climate variability. Extreme events such as heat wave have the potential of triggering intense surface melting of snow and ice both in polar and alpine areas of the planet. Thus, monitoring the melting dynamics is an active field of research nowadays. Recent research suggests that Land Surface Temperature (LST) can provide useful information to retrieve snow surface properties such as density and to track snowmelt dynamics (Colombo et al., 2023). Although LST can be observed from space, its potential to improve snow and ice observations in alpine and polar regions remains underexplored. In this context, the main aim of the proposed research is to understand if LST and snow thermal inertia can be used for monitoring spatial and temporal evolution of melting of snow and ice in alpine and Polar regions. Possible test areas are the Greenland Ice Sheet, Svalbard archipelago, the Alps and the coastal areas of East Antarctic Ice Sheet. In this research, we will use a combination of snowpack physical models (e.g. CROCUS), thermal infrared satellite images, airborne imaging spectroscopy and field/lab experiments. We are planning intensive field campaigns in the Alps simultaneously to airborne overpasses, while for the other test areas we foreseen to exploit satellite data only. This research is conducted in collaboration with the University Grenoble Alpes in France, where we expect the candidate would spend his/her period abroad.			
Supervisor webpage: https://www.unimib.it/roberto-colombo			
Notes: *Shortlisted project on Polar Sciences*			

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Nr 4		**Supervisor**	**Mattia De Amicis**
Title	**Geomorphological maps realizations using innovative methodologies: from the field data acquisition to the database realization for applicative purposes** **Applicazione di metodologie innovative per la realizzazione di carte geomorfologiche: dall'acquisizione di dati sul terreno alla costruzione della banca dati a fini applicativi**		
Geomorphological maps represent a powerful tool to insight geological processes, to understand the territory as well as to apply mitigation strategies. Recently, ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale) published the new Italian guidelines for the geomorphological cartography introducing new symbolism and new procedures to complete landforms a geodatabase allowing the integration and harmonization with other thematic maps such as geological map and maps for application purposes. The aim of this PhD project is to explore all the steps of the geomorphological mapping in order to create a holistic methodology capable to enhance geomorphological maps following the ISPRA guidelines. The study sites of the project will focus on both Alps and Apennines, in two catchment sites that are characterised by distinct geological processes, in order to test the methodology in different environments. Field survey will be fundamental to understand the landforms and the associated processes and will be realized with traditional approaches and innovative instruments. In addition, the digitalization of the results will be done in a GIS system. Collaborations are planned with ISPRA, University of Camerino, at least 6 months are planned at Kazimierz Wielki University, Bydgoszcz (Poland).		
Supervisor webpage: https://www.unimib.it/mattia-giovanni-maria-de-amicis			
Notes: *Borsa PNRR - Infrastrutture di Ricerca (CUP: I53C22000800006)*			

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Nr 5		**Supervisor**	**Andrea Bistacchi**
Title	**3D geological modelling: structural analysis of complex case studies in sedimentary basins and modelling with innovative open-source algorithms** **Modellazione geologica 3D/4D con software open-source: sviluppo software, workflow e algoritmi innovative, e casi di studio**		

Project 1:
Over more than 20 years, 3D geological modelling has been developed almost exclusively by the industry, aimed at petroleum geology, mining, and a few other applications. Recent open-source projects and new applications are changing this scenario, accelerating a widespread diffusion of 3D geological modelling in many other geoscientific disciplines.
The PhD candidate will participate in the PNRR Geosciences IR project (https://geosciences-ir.it/), with the main goal of developing innovative structural analysis and 3D geological modelling in complex tectonic environments typical of mountain belts.
The candidate will carry out advanced structural analysis in the field and in the lab, in order to fully characterize one or more case studies, which will be used to reconstruct 3D geological models of complex structures, and to contribute to the development of innovative workflows and algorithms in the framework of the PZero project (https://github.com/andrea-bistacchi/PZero). The PhD candidate will work within a multidisciplinary team, including researchers from different universities and research centers, and will spend one/two period(s) abroad, hosted by partner universities and research centers.

Project 2:
Over more than 20 years, 3D geological modelling has been developed almost exclusively by the industry, aimed at petroleum geology, mining, and a few other applications. Recent open-source projects and new applications are changing this scenario, accelerating a widespread diffusion of 3D geological modelling in many other geoscientific disciplines.
The PhD candidate will participate in the PNRR Geosciences IR project (https://geosciences-ir.it/), with the main goal of developing innovative stratigraphic and structural analysis, and 3D modelling in complex sedimentary basins.
The candidate will carry out advanced analysis in the field and in the lab, also using geophysical and wells data, in order to fully characterize one or more case studies, which will be used to reconstruct 3D geological models of complex sedimentary sequences and structures, and to contribute to the development of innovative workflows and algorithms in the framework of the PZero project (https://github.com/andrea-bistacchi/PZero).The PhD candidate will work within a multidisciplinary team, including researchers from different universities and research centers, and will spend one/two period(s) abroad, hosted by partner universities and research centers.

Supervisor webpage: https://www.unimib.it/andrea-luigi-paolo-bistacchi

Notes: *Numero due borse PNRR - Infrastrutture di Ricerca (CUP: I53C22000800006)*

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Nr 6		**Supervisor**	**Federico Agliardi**
Title	**Automated characterization of alpine mass movements integrating geomorphology, remote sensing and artificial intelligence**		

Alpine glacial, paraglacial and periglacial environments are affected by different types of mass movements (e.g. rock and debris slides, rock glaciers) that evolve at different rates, rapidly changing due to global warming, and threaten human lives and infrastructures. To manage related risks, we need capabilities to rapidly map and classify processes over large areas and assess their evolution and impacts. Current analyses rely on geomorphological mapping supported by remote sensing to capture processes and their evolution. These approaches are accurate but time consuming and difficult to update over wide areas. On the other hand, artificial intelligence applications are still few and missing robust process-based constraints.
This PhD project will develop geomorphologically-constrained libraries of remote sensing data (InSAR, optical, thermal) to train a deep-learning model, able to classify different types of mass movements over wide portions of the Alps to support their characterization and monitoring in a risk mitigation perspective.
We seek for a candidate with a geomorphological and engineering geological background, motivated to work with a multi-disciplinary team to take advantage of remote sensing and artificial intelligence for the development of an innovative approach to tackle with mass movements. The research will be carried out in collaboration with researchers of the CNR-IMATI (Itay) and the WSL (Switzerland), where the PhD student will spend at least six months.

Supervisor webpage: https://www.unimib.it/federico-agliardi

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Nr 7		**Supervisor**	**Marcello Campione**
Title	**Study of the carbonation reaction of serpentine minerals under hydrothermal conditions and microwave irradiation**		
Mineral carbonation is a widely investigated method for CO2 mitigation enabling its capture and storage with production of secondary raw materials in the form of hydroxy-carbonate hydrates. Weathering of serpentine minerals is a well-known natural process allowing for the long-term capture of CO2 under environmental conditions. This research program consists in a laboratory focused activity aimed at the study of enhanced weathering processes of serpentine minerals under mild hydrothermal conditions and exploiting thermal and non-thermal effects triggered by irradiation with microwaves. Model synthetic mineral samples will be purposely prepared for evaluating the influence of stoichiometry and composition on the carbonation mechanism and kinetics. Optimized processes developed with synthetic samples will be tested on natural serpentine samples salvaged from quarries in the territory of Italy and Austria. Carbonation reaction will be carried out with a dedicated apparatus enabling pressure, temperature, and irradiation energy programming and monitoring, whereas the characterization of the products will be performed by X-ray diffraction, infrared spectroscopy, electron microscopy, and scanning probe microscopy methods. The microscopy analyses will be performed in collaboration with the Politecnico di Milano. A six-month period to be spent at Montan University, Leoben, Austria (Prof. Philip Hartlieb, Chair of Mining Engineering an Mineral Economics) is envisaged.		
Supervisor webpage: https://www.unimib.it/marcello-campione			

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Nr 8		**Supervisor**	**Giancarlo Capitani**
Title	**Development of advanced electron microscopy techniques and application to minerals**		

The project focus on the development of two advanced transmission electron microscopy techniques and their application to selected mineral groups relevant for geological processes or mineralogy applications. The first of these techniques is the Continuous Rotation Electron Diffraction Tomography (CR-EDT). The method allows the acquisition of 3D electron diffraction data with quasi kinematic intensities, which in principle can be employed for structure solution of crystals smaller (tens of nm) than usually required for single crystal X-ray analysis (tens of μm). CR-EDT is therefore effective for systems were crystalline domains occurs almost exclusively at sub-microscopic scale, such as clays, serpentine minerals, micas or systems were exsolutions or syntactic intergrowths occur at a comparable scale, as in spinel and REE-fluorcarbonates, respectively. CR-EDT is also suitable for the characterization of very small reaction products that may occur during mineral alteration, either in nature or in laboratory, as for instance carbonation reaction in CO2 sequestration experiments.
The second technique is the Time Resolved Transmission Electron Microscopy (TR-TEM), which adds a further dimension, the time, to the nanoscale information currently delivered by TEM. The technique allows the study of ultrafast transient states of mater using sub-picosecond electron pulses generated by a laser and may be suitable for the study of phase transitions and ordering processes in minerals. A large number on minerals such as feldspars, pyroxenes, silica polymorphs, show ordering processes and phase transitions induced by changes in pressure and temperature that convey important information on the history of the host rock and related geological processes. Most of these processes pass through a number of metastable or unquenchable states that may complement the information. With TR-TEM is possible to shed a light on these transient states.
The instrumental equipment necessary for the project is fully available at the Platform of Microscopy of Milano-Bicocca, as well as the research samples. Stages at Italian and foreign macroscopy facilities are envisaged. Possible centers could be the Department of Earth Science, University of Pisa (ITA), the Institute of Physics, Czech Academy of Sciences of Prague (CZE), the École Politecnique Fédérale de Losanne (CH)…

Supervisor webpage: https://www.unimib.it/giancarlo-capitani

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Nr 9		**Supervisor**	**Nadia Malaspina**
Title	**A transitional metal stable isotope (Fe, Zn, Cu) study of metasomatised mantle wedge in subduction zones and its role in the redox processes occurring at the slab-mantle interface**		
It is widely accepted that the lithospheric mantle wedge above subduction zones is apparently more "oxidised" (i.e., records higher fO2) than other mantle domains as a result of metasomatism by slab-derived fluid phases. Nevertheless, the dispute about the process responsible for this relative oxidation and the actual oxidising capacity of slab-derived metasomatic fluids at sub-arc depths is still going on. Non-traditional stable isotope variations in elements (e.g., Fe, Zn and Cu), complement trace element observations in sub-arc environments and their fractionation is also influenced by the redox state of the fluid phase. This project aims to compare the elemental and isotopic composition of orogenic peridotites from different subduction depths to identify and characterise the relative effects of subduction related processes on mantle peridotite composition and oxidation. Samples will be spinel and garnet peridotites from Dabie-Shan (China), Ulten zone and Duria area (Italian Central Alps), Alpe Arami (Swiss Central Alps) and Bardane (Norwegian Western Gneiss Region) and will be analysed in collaboration with Dr. Baptiste Debret (IPGP, Paris). The data will be also complemented with traditional back titration analyses of the bulk peridotites to measure the Fe2+ content, synchrotron Mossbauer analyses at ESRF (Grenoble) of the mineral assemblages to measure the Fe3+ content and thermodynamic forward modelling. A six-months period will be spent at IPGP (Paris, France).			
Supervisor webpage: https://www.unimib.it/nadia-malaspina			

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Nr 10		**Supervisor**	**Nadia Malaspina**
Title	**Micro-to-submicron scale interface processes in natural and synthetic microreactors for mineral carbon capture and storage**		
A useful approach to model fluid/mineral interactions in the inaccessible parts of the inner Earth employs multiphase fluid inclusions as natural microreactors that can disclose information on the nature and composition of fluids produced from low to at high/ultrahigh pressures and of their interaction with their mineral hosts, treated as simplified solid systems. This project aims to study the nanoscale processes that drive the fluid/mineral interactions during carbonation of mafic and ultramafic natural and synthetic minerals by sophisticated high resolution analytical techniques: synchrotron XRD at ESRF (Grenoble), Raman, fluid inclusion extraction for carbon isotope analysis (University of Bologna), TEM at the microscope platform of Milano-Bicocca and EELS (University of Jena). Results will evaluate the crystallinity of the carbonation products and enable to compare them with those precipitated from different synthetic and natural systems and at different redox conditions. Synthesis will be performed at ANTICARB lab (Milano-Bicocca) and at the Experimental Labs (Milano Statale). The carbonation reaction dynamics will be quantified by a controlled dissolution and precipitation mechanism undertaken on the basal surface of single crystals and by the characterisation of natural carbonate-silicate/oxides interfaces of geological samples (Western Alps; Dabie-Shan, China, Almirez, Spain, Erro Tobbio, Italy). A six-months period will be spent at the University of Jena (Germany).			
Supervisor webpage: https://www.unimib.it/nadia-malaspina			

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Nr 11		**Supervisor**	**Alessandro Tibaldi**
Title	**4D imaging of magma-induced faults and of shallow magma pathways as a key tool for volcanic hazard assessment**		
The PhD project aims to study, in space and time, the surface deformations induced by the movement/emplacement of magma at very shallow levels in the Earth's crust, with the final aim of obtaining a fracturing identikit that can be associated with a dike that is approaching the surface, and therefore capable of producing a potential eruption. The parameters that guide the scenario in which a dyke propagates towards the surface and then arrests, without therefore leading to an eruption, will also be taken into consideration. The study will focus on a series of magmatic events on Etna that gave rise to surface deformation in historical times (e.g. 1928, 1947, 1971, 2002, 2018, 2022), where it is therefore possible to create ad-hoc structural maps of high detail through historical aerial photos (IGM), pre- and post-event, quantifying offsets from 3D models obtained through photogrammetry applied to drone images and historical aerial photos, classic field surveys, and surface geophysics to characterize the geometry of the volcanotectonic structures in the subsurface. To better understand the processes and parameters that link the rising or arrest of magma in relation to the deformation of host rocks and surface, numerical models will also be conducted using Comsol Multiphysics. Two sites located in the Northern Volcanic Zone of Iceland will also be taken into consideration. Collaboration is expected with the National Italian Institute of Geophysics and Volcanology and it is expected also a period of research at a university in Iceland.		
Supervisor webpage: https://www.unimib.it/alessandro-tibaldi			

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Nr 12		**Supervisor**	**Stefano Zanchetta**
Title	**An evolving orogenic wedge in space and time: 3D modeling, Geochronology and Thermochronology of the Eo-Alpine Eastern Alps orogen**		

The Eastern Alps orogenic wedge was active since the Late Cretaceous, well before the Europe-Africa collision that led to the Alpine orogenesis. Tectonic and geodynamic interpretation of the Eo-Alpine phase are still debated, and more data are mandatory to characterize in details its temporal and structural evolution. The western sector of the Eastern Alps is the area that best preserves the record of this orogenic phase as major tectonic contacts exist here, dividing the Eo-Alpine tectonometamorphic units from ones chiefly preserving their pre-Alpine features.
This project is aimed to define the geometry and the structural evolution of the main tectonic boundaries, together with their reconstruction in 3D, starting from field structural analysis to software modelling. The reconstructed tectonic framework will then be integrated with geochronological (U-Th-Pb and Ar/Ar) and thermochronological data (Apatite Fission Track analysis) to constrain the time of nappe-stacking and subsequent exhumation.
Activities in the field will consist of detailed structural mapping of key areas, sample collection and regional mapping of the main tectonic features. Sample analyses in labs will take about the 40% of the total activity.
The project will be held in collaboration with the Department of Geology of the Innsbruck University (Austria), where the PhD candidate is expected to spend a period of 12 months.

Supervisor webpage: https://www.unimib.it/stefano-zanchetta