Geothermal resources exploitation from hydrocarbon wells using closed-loop geothermal systems: the potential of some Italian oilfields

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ABSTRACT BOOK

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COVER IMAGE

View from Monte di Procida, Campi Flegrei, Napoli (Italy) (Photo Simone Palumbo)

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On the applicability of the 2D linear upslope model for orographic rainfalls: a case studies in the pre-Alpine mountain range

Abbate A

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Keywords: orographic rainfalls, extreme weather, geo-hydrological hazards,depth-integrated-models.

In the field of geo-hydrological risk, rainfalls represent the most important triggering factor for superficial terrain failures such as shallow landslides, soil slips and debris flows (Longoni et al., 2016; Guzzetti et al., 2008). These phenomena are triggered over mountains regions where the density of the ground-based meteorological network is poor, and the local effects caused by mountains topography can change dramatically the spatial-temporal distribution of rainfalls (Abbate et al., 2021).

Trying to reconstruct a representative rainfall field across mountain areas is a challenge. We present a reanalysis of an ensemble of extreme rainfall events that happened across the central Alps and Pre-Alps, in the northern part of Lombardy Region, Italy using the Linear Upslope-Rainfall Model (LUM) (Abbate et al., 2021; Smith and Barstad, 2004)including airflow dynamics, condensed water advection, and downslope evaporation. The formulation extends the widely used ?upslope? model. Vertically integrated steady-state governing equations for condensed water are solved using Fourier transform techniques. Closed form expressions are derived for special cases. For more general cases, the precipitation field is computed quickly by multiplying the terrain transform by a wavenumber-dependent transfer function. Five length scales are included in the model: mountain width, a buoyancy wave scale, the moist layer depth, and two condensed water advection distances. The efficiency of precipitation in the model is sensitive to the decay of the forced ascent through the moist layer and to the advection of condensed water downwind into the region of descent. The strong influence of horizontal scale on precipitation pattern and amount predicted by the model is discussed. The model is illustrated by applying it to the Olympic Mountains in Washington State.”,”container-title”:”Journal of the Atmospheric Sciences”,”DOI”:”10.1175/1520-0469(2004. This model has been designed for describing the mechanism of orographic precipitation. In particular, we have pointed our attention to a better description of the rainfall microphysical process. We aimed to increase the accuracy of the LUM including some new features and tried to find some correlation with the meteorological index retrieved from radiosonde parameters. Moreover, we have extended the LUM to work automatically with a 2D digital elevation model. In the end, LUM was also tested in a piecewise-steady mode considering a sequence of stationary states as descriptive of each critical phases of the studied rainfall events.

The results obtained have shown that the LUM has been able to reproduce rather accurately the rainfall field both in 1D and 2D mode, giving a realistic reconstruction of the rainfall that occurred across the Alps. The application of the LUM model could help to address further information around rainfall phenomena (Kirshbaum et al., 2018) and giving insight into those ungauged areas where rain estimation could be critical for hazard evaluation.

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Smith R.B. & Barstad I. (2004) - A Linear Theory of Orographic Precipitation, J. Atmos. Sci., 61, 1377-1391.

Use of different flight configurations in a drone magnetometric system

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Keywords: Unmanned Aerial Vehicle, flight configurations, electromagnetic interference, pipelines, spectral analysis.

Over the past decade, the miniaturization of geophysical instruments, such as magnetometers, has recently opened new opportunities to install them on-board drones. Unmanned Aerial Vehicle (UAV) are becoming a desirable alternative or a complementary approach for remote sensing since they allow a high versatility and flexibility in comparison to traditional airborne systems or ground surveys. Magnetic sensors mounted on drones allow carrying out surveys with intermediate characteristics between traditional aero magnetism and ground surveys in terms of resolution, extension of the investigation area, elevation, and speed. One of the main problems related to the UAV-magnetometer system is the characterization and compensation of electromagnetic interference generated by the mobile platform. Most of the studies have concluded that the minimum distance to be maintained between the sensors and the mobile platform to avoid interference is 3 m. However, this strategy may compromise the stability of the system or create unwanted oscillations of the sensors that have the potential to introduce periodic variations in the data. In this study, magnetic measurements have been made over buried metal objects (probably pipelines and cables) whose position was unknown. Two different surveys were conducted using a multirotor UAV and a miniature cesium vapor atomic magnetometer (MFAM, Geometrics). During the first test, the magnetometer was fixed to the drone landing gear, at only 0.6 m distance between the rotors and the magnetometer; in the second investigation test, sensors were suspended through ropes 3 m below the platform. Spectral analysis shows that the target signal and the interference generated by the platform do not spectrally overlap, even when the distance between the drone and the sensors is minimal. The anomalies identified in UAV magnetic maps are comparable in terms of amplitude with those shown by a magnetic ground survey carried out in the same investigation area. Finally, the sources identified through modelling of the aerial surveys data are comparable in terms of position and depth with those located by the ground magnetic data. These results demonstrate the high quality of the drone-borne data acquired in the two flight configurations. Overall, this study shows the feasibility of different UAV-magnetometer flight configurations that may be chosen in function on the survey target and the flight conditions.

Coccolithophore distribution from water samples in the Ebro delta coastal area (Spain)

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Keywords: living coccolithophores, ecology, coastal area, Ebro Delta.

The present work focuses on the coccolithophore community ecological distribution in a coastal system. Coccolithophores are the most abundant group of calcifying phytoplankton and can be considered to be dominant in the pelagic system. For this reason, there is a lack of studies in coastal area. This work is focused on assessing their distribution in the coastal area of the Ebro Delta, discussing their environmental preference based on key parameters collected during the experimental sampling campaign. The results from water samples analysis (cell/coccosphere density (CD)) are also compared with the coccolith (individual calcite plates covering the cell) assemblage in the underlying surface sediments, to understand how the living community compares with the thanatocoenosis preserved into the sediment.

The most abundant coccolithophore species in all the stations is *Emiliana huxleyi*. Highest CD values occurred in the coastal area, associated with nutrient supply from river mouth and vertical mixing of the shallower environment. In the very coastal environments, neither a clear vertical distribution is observed in the assemblage, nor a significant variation in the environmental parameters, suggesting a rather homogeneous and mixed water column. Instead, a clear vertical zonation is observed in the offshore stations. The upper photic zone (UPZ) group (*Rhabdosphaera* spp., *Umbellosphaera* spp. and *Discosphaera tubifera)* occurs in the living community, while the deep-dweller *Florisphaera profunda* occupies the lower photic zone (LPZ). Temperature profile parallels the depth-related taxon distribution. This is in accordance with a more stable environment, with a water column thermally stratified and characterized by oligotrophic UPZ and nutrient rich LPZ. The study of thanatocenosis in surface sediments reveal a consistent pattern with the overlying photic zone structure.

Mapping soil properties in a lowland area of Lombardy region using terrain attributes and different predictive modelling approaches

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Keywords: digital soil mapping, terrain attributes, statistical predictive models.

Detailed and accurate soil maps that contain soil information such as soil properties and nutrients statuses and their spatial distribution are very important for decision making and planning towards sustainable soil management in order to improve agricultural production, environmental sustainability and land degradation management (Sachs et al., 2010). Generally, conventional soil maps are limited concerning the amount of information presented and regarding the spatial variability of soil properties of the soil information.

Digital soil mapping approaches provide a sophisticated alternative to conventional mapping methods since they are cost effective and fast (McBratney et al., 2003). The goal of this study is to investigates the potentials of terrain attributes to map the spatial distribution of the soil pH, top soil, Sand, Loam, Clay and soil organic carbon in an irrigated-lowland area in the western part of Lombardy region, Italy. For this study, 61 soil profiles were used to test different predictive models: i) Random Forest (RF), ii) multiple linear regression (MLR), iii) neural network (nnet), iv) Cubist, v) Bayesian Regularized Neural Network (BRNN), vi) Partial Least Squares (PLS), vii) generalized linear model (GLM) and viii) support vector machines with radial basis function kernel (svmRadial). 10-fold cross validation was repeated 1000 times and the performance of these models were determined using the Rsquare, root-mean-square error (RMSE) and mean error (MAE). The research helps to identify the best performing approach and to understand the robustness of the applied models. The triggering factors are characterized by the variable importance. The results yield valuable information for i) a sustainable land use in an area with a particular soil water cycle as well as for ii) future climate and socioeconomic changes influencing water content, soil pollution dynamics and food security.

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Geomorphological analysis of the Tifatini Mountains (Caserta)

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Keywords: Campania Plain, geomorphological map, sub-horizontal surfaces, collapse sinkholes, forms.

A morphotectonic analysis of the western sector of the Mt. Tifatini and Mt. Caserta has been carried out by integration of field work and detailed topographic maps analysis, which allowed to creating a geomorphological map and cross-sections. The study area is located in the north-western part of the Campania Plain coastal half-graben. The Campania Plain is considered one of the larger peri-Thyrrenian basin formed as a consequence of the extensional processes since the Early Pleistocene which affected the Southern Apennines (Sartori, 1990).

Particular attention has been devoted to the investigation of sub-horizontal surfaces on the horst blocks of the study area, in order to shed light on their origin and to the recognition of karst forms as collapse sinkholes. By integration of geomorphological, stratigraphic and structural data collection on the field, four types of forms have been recognized. Among these: (i) erosional, e.g., sub-horizontal erosional surfaces; (ii) depositional, e.g., alluvial fans, detrital and colluvial strata, Campania Ignimbrite plateau and alluvial plain surface; (iii) structural, e.g., fault slopes; (iv) karst forms, e.g., sinkholes and open fractures.

The stair-sequence sub-horizontal surfaces span between 90m and 180m above sea level (a.s.l.) along the study mountains and they have been classified in 8 orders. Even if no marine deposits associated to such surfaces, a marine origin is suspected. The distribution of the mapped collapse sinkholes shows a generic NW-SE alignment along faults in agreement with Di Crescenzo & Santo (2013). The geomorphological expression of the faults is also indicated by straight escarpments, open fractures and triangular facets. In addition, the geological-geomorphological analysis allowed the identification and characterization of the bedrock (pre-Quaternary) and Quaternary stratigraphic units, which have been summarized in geological sections. The new data provide constraints on the Quaternary evolution and vertical displacements along the western border of the Campania Plain.

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Di Crescenzo G. & Santo A. (2013) - Dati preliminari sull'assetto tettonico e fessurativo dei versanti carbonatici interessati da sinkhole nell'Appennino centro-meridionale. Mem. Descr. Carta Geol. d'It., 93, 219-238.

Estimation of the unconsolidated material-bedrock shallow interface depth by HVSR and MASW seismic survey for rainfall-runoff modelling

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Keywords: bedrock depth, MASW, HVSR, hydrological modelling.

The shallow unconsolidated material-bedrock interface represents a critical boundary in case of intense rainfall events, leading to more surface ponding and overland flow (Salciarini et al., 2012). The knowledge of more realistic spatial variations of unconsolidated material depth (UMd) would result in better hydrologic simulations, although it requires an intensive field survey which is difficult and expensive.

Since the shallow UM-bedrock interface can reasonably correspond to a seismic impedance contrast in the subsoil, in this study a fast integrated approach, based on passive (Horizontal to Vertical Spectral Ratio, HVSR) and active (Multichannel Analysis of Surface Waves, MASW) seismic surveys (Foti et al., 2011), were carried out in order to evaluate the possible presence and the relevant depth of this limit in the first meters of the subsoil. In particular, HVSR technique was performed to identify the resonance frequencies in the interval 10-50 Hz, while MASW analysis provided the shear wave velocity (Vs) estimate.

Another important parameter for the prediction of infiltration and runoff volume from storms, is the saturated hydraulic conductivity (Ksat), which was measured using a constant head "Aardvark" permeameter. The Green-Ampt equation (Green and Ampt, 1911) was implemented using the FLO-2D model (O'Brien et al., 1993) to simulate infiltration into porous media, where Ksat and UMd are two input data.

Different Mediterranean catchments affected by intense rainfall events (>50 mm/h), causing flood/debris flow, were analyzed. Preliminary results allow to evaluate, applying a rapidly seismic survey methods, how the spatial variations of bedrock depth may influence the hydrological modelling.

Foti S., Parolai S., Albarello D. & Picozzi M. (2011) - Application of surface wave methods for seismic site characterization. Surv. Geophys., 32(6), 777-825. https://doi.org/10.1007/s10712-011-9134-2.

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Experimental investigation of the kinetics of bridgmanite polymorphic back-transformation: implications for the ascent rate of superdeep diamonds and *impact*-induced shock

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Keywords: Bridgmanite, mineral inclusions, superdeep diamonds, high-pressure experiments, meteorites.

Mineral polymorphs that occur in rocks, mineral inclusions in diamonds and meteorites provide unique information on the pressure (P) and temperature (T) conditions at which they form. Among the ~5650 known minerals (Mg, Fe)SiO_3 bridgmanite, the high-P polymorph of orthopyroxene (opx), is of particular interest since it is experimentally proved to be the dominant mineral of the interior of Earth (Frost, 2008). In addition, there have been very few findings of bridgmanite in collected meteorites (Tomioka & Miyahara 2017) coexisting with other high-P mineral phases. Interestingly, this mineral has been never found trapped in natural sub lithospheric (i.e., superdeep) diamonds (SD). In contrast, $MgSiO_3$ glass or opx were both reported to coexist with (Mg, Fe)O ferropericlase (McCammon, 2001). This lack of observations might be either due to the rarity of the investigated SD (about 6% of the total investigated diamonds) or it can be explained as consequence of kinetic reactions that would not allow bridgmanite to reach the Earth's surface. Available data would suggest that the kinetics of bridgmanite-to-enstatite back-transformation can occur within 3 to 100 years at upper mantle conditions (Knittle & Jeanloz, 1987). However, these previous data do not consider the possible decompression-induced amorphization of bridgmanite or the effect of P and T in stabilizing intermediate polymorphs such as akimotoite and clino-enstatite. Here, we present preliminary results of experiments where synthetic bridgmanite was heated at different P withing minutes to hours by using the multi anvil press combined with synchrotron X-ray diffraction to monitor any structural change in real time. The texture and vibrational properties of the recovered run products were, then, investigated by scanning electron microscopy and Raman spectroscopy, respectively.

Our data are interpreted in light of the textural and spectroscopic features reported in the case of the natural and synthetic bridgmanite. Preliminary results support the possibility that 1) inclusions of opx are product oth the transformation of pristine Lower Mantle minerals, 2) most of the SD diamonds form as result of redox reactions involving ferropericlase rather than bridgmanite; 3) shock impact in meteorites must have taken few seconds to generate very high T (>1400 °C) and P to allow nucleation of bridgmanite.

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Tomioka N. & Miyahara M. (2017) - High-pressure minerals in shocked meteorites. Meteoritics & Planetary Science, 52(9), 2017-2039.

Deep Seated Gravitational Slope Deformations in the Apennine Mountains of Southern Italy: the Mt. Bulgheria case study

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Keywords: DSGSDs, DInSAR, geomorphological model, slope stability analysis.

Deep Seated Gravitational Slope Deformations (DSGSDs) have been recognized in a variety of geological conditions and are diffused in the Italian Alps and Apennines. They are characterized by a typical slow movement that makes the kinematics of such kind of landslides poorly constrained and can prevent their identification. In specific conditions, DSGSDs can form landslide cluster or, when associated with mechanically differentiated landslides, can form landslide complexes. In both cases, the mid-to-long term evolution of DSGSD slope is extremely complex and, under specific boundary conditions, a sudden slow to fast transition might be expected. On this basis, and considering the study of Guida et al. (1989), this research has the purpose of analyzing the kinematics of the DSGSDs affecting the Mt. Bulgheria in southern Cilento. Since these phenomena are extremely complex, a multidisciplinary approach has been adopted for the analysis. Considering the importance of the geological setting in the geomorphological evolution of the mountainside affected by these landslides, a preliminary analysis was carried out examining the geological formations cropping out in the study area and their tectono-stratigraphic relationships. Subsequently, a photogeological analysis of the area was carried out, allowing to draw up a geomorphological model focused on the identification of all diagnostic morphologies of these landslides. The interpretation of such data allowed to recognize all of the DSGSDs affecting the Mt. Bulgheria in southern Cilento. Once identified, the ongoing kinematics was analyzed using Persistent scatterer data derived by COSMO-Skymed image processing. Derived velocities of actively deforming slopes are in the range 4 to 10 mm/yr. The potential of satellite techniques in monitoring of surface deformations and in the interpretation of DSGSDs (Di Martire et al., 2016), has led to compare and validate all prior photogeological and geological understandings and to unravel the ongoing slow persistent movement of the identified DSGSDs. Finally, collected data used to support slope stability numerical modellings, allowing to extend our understanding of DSGSDs geometry at depth deriving a potential 3D shape of the analyzed DSGSDs.

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Early Cretaceous theropod and ankylosaurian tracks from Molfetta (Apulia, southern Italy)

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Keywords: dinosaurs footprints, late Aptian, early Albian, Apulian Carbonate Platform.

More than 800 dinosaur footprints are preserved on the upper Aptian-lower Albian surface of the San Leonardo quarry, near Molfetta (Apulia). The tracksite was recently accurately mapped by using aerial-based photogrammetry (Petti et al., 2018). Six well-preserved bipedal trackways, composed by tridactyl footprints, are attributed to medium- to large-sized theropod dinosaurs, as at least other two clearly recognizable isolated specimens. Only one clear but poorly preserved trackway and numerous isolated manus-pes sets have been attributed to quadrupedal dinosaurs. More than 20 tridactyl tracks, 8 isolated manus-pes sets and the whole quadrupedal trackway have been detected by using both traditional methodologies and close-range photogrammetry. The tridactyl ichnoassemblage is represented by large-sized, weakly mesaxonic (i.e., with low prominence of digit III in relation to digits II-IV; Lockley, 2009) and robust tracks. The clear digital pad impressions on each digit reveal the typical phalangeal formula of theropods. Morphological comparison with Late Jurassic and Early Cretaceous theropod tracks from surrounding areas, supported by the analysis of more than 2000 morphometric parameters, led to hypothesize a highest affinity with the specimens from North Africa (Bessedik et al., 2008; Mammeri, 2018). Nevertheless, a set of unique characters appears to justify the establishment of a new ichnotaxon for the tridactyl tracks. They can be referred to a theropod whose body length is estimated up to 6.5 m. The trackmaker's autopodium, reconstructed on the basis of characters identifiable on the 3D models, allows a reliable osteological match with the known hindlimbs of coeval theropods. The preliminary results (e.g., cluster analysis, PCA) to date suggest a basal carcharodontosaur as the most suitable trackmaker of the Molfetta tridactyl tracks. Additionally, the photogrammetric models of the quadrupedal trackway and four isolated manus-pes sets suggest they represent the same morphotype: pes is tetradactyl, wider than long and asymmetrical, with digits II and III forward oriented and digits I and IV slightly laterally directed; manus is highly digitigrade, tetra- or pentadactyl, displaying a similar pattern. These tracks share numerous morphological characters with both the ichnogenera *Tetrapodosaurus* Sternberg, 1932 and *Metatetrapodus* Nopcsa, 1923, and thus can possibly be attributed to a medium-sized ankylosaurian trackmaker.

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Phase equilibria and pre-eruptive conditions at low f(O_2) of pantellerites from Fastuca pumice fall unit

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Keywords: peralkaline rhyolites, pre-eruptive conditions, phase equilibria, Fastuca pumice fall unit.

The focus of this study is to use new phase equilibrium experiments to better evaluate the pre-eruptive conditions of pantellerites from Fastuca pumice fall unit in Pantelleria. New results at low oxygen fugacity (fO_2) and H_2O-saturated conditions help to better constrain the evolution and pre-eruptive conditions of evolved magmas from Pantelleria and peralkaline rhyolites in general. A better knowledge of the conditions of alkali feldspar crystallization is necessary because alkali feldspar can crystallize in large quantities and affect melt viscosity and hence volcanic eruptive style. We therefore conducted a series of cooling experiments on PANT01113 from Di Carlo et al., 2010 under water saturated conditions, buffered at ~FMQ-1 using a graphite filler rod in a cold seal pressure vessel at a temperature range of 680 °C - 880 °C, constant pressure between 20 MPa - 150 MPa and run duration of 72 - 312 hrs. The experiments show clinopyroxene as the first to crystallize at 750 °C together with Fe-Ti oxides in some cases, followed by alkali feldspar and finally quartz. A comparison of our study with Arzilli et al., 2020 PANT 15 (NNO +0.8) shows stability of alkali feldspar liquidus in Arzilli et al., 2020 at lower temperatures than this study (NNO -1). And again, comparing our study with Di Carlo et al., 2010 of the same oxygen fugacity (NNO -1) indicates the alkali feldspar liquidus of our study better constrained than Di Carlo et al., 2010 mainly because this study widely investigated lower pressure range under water saturated conditions than Di Carlo et al., 2010 who did fewer studies at lower pressures under water saturated conditions. Finally, we also observed delays of up to several days in alkali feldspar nucleation at water undersaturated conditions, which requires further investigations. Understanding the pre-eruptive conditions and phase relations of this magmatic composition brings insight into the time-scale of magmatic processes in Pantelleria as we relate experimental data to natural samples useful for evaluation of volcanic hazards.

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3D structural geomodelling in the complex metamorphic units of the Italian Western Alps (Aosta Valley, Italy)

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Keywords: 3D geomodelling, 3D geological structural model, structural geology, Aosta Valley, Western Alps.

Structural 3D geomodelling of metamorphic units that underwent a sequence of ductile and brittle deformation events is an extremely challenging task. In the context of the ongoing RESERVAQUA project, a 3D geomodel that runs along the Italian-Swiss border is being built. The Italian part of the area has an extension of c. 1,000 km^2 and crosses units of the Austroalpine, Penninic and Helvetic domains, showing a great variability of metamorphic environments and deformative style. In such a vast and heterogeneous setting, developing a conceptual model was necessary to define the scale of the problem and what level of detail to give to the 3D model. The first step in our analysis was to define homogeneous tectonic zones through an orientation statistics study. Progressing with the actual geomodelling phase, a first structural study in vertical cross-sections was followed by the usage of implicit algorithms (implemented in the software SKUA/Gocad, for this study). However, we tested different commercial software packages and some open-source research libraries to find that no one is capable of modelling Aosta Valley's complex structures out-of-the-box. This is not surprising since generally these codes are geared towards modelling gently deformed sedimentary sequences and not complex metamorphic tectonic settings. Nevertheless, it was possible to overcome a large range of obstacles by "fooling" the modelling algorithms to properly represent isoclinal folds, large volume variations of the lithological bodies, tectonic contacts between large-scale tectono-metamorphic units, lenticular bodies and many other complex geological geometries. For instance, we chose (1) to "cheat" on the geological meaning of some entities or (2) to build a "fake" stratigraphy where the same units were repeated several times. In this contribution, some of these modelling solutions are compared in terms of their straightforward implementation and their ability to generate models that properly fit the very detailed geological maps available in our study area (mapped at 1:5.000-1:10.000 with a dense set of structural and petrographic stations).

Evidences of Cretaceous syn-sedimentary tectonics in the Umbria-Marche-Sabina domain: insight from Mt. Soratte area

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Keywords: Cretaceous extension, sedimentary unconformity, neptunian dykes, Soratte, Umbria-Marche-Sabina domain.

Evidence for an extension-dominated tectonic phase in the Early Cretaceous has been identified at Mt. Soratte (40 Km N of Rome, Central Apennines) as a result of geological mapping performed on 1:5.000 scale. The Mt. Soratte ridge extends for about 5 Km in the Tiber Valley with an NW-SE axis; with an altitude of 691 m a.s.l. it represents the only relief between Sabini Mts. and Sabatini Mts. In the Mt.Soratte area mostly peritidal shallow-water carbonates cropping out, locally overlied in angular unconfomity by the Umbria-Marche-Sabina pelagic succession. These sectors of the Tethys ocean were affected by the Hettangian/Sinemurian extensional phase (Passeri & Venturi, 2005) which dismembered the depositional environment of peritidal shallow-water carbonate platform (Calcare Massiccio Fm.), leading to the structuring of a seafloor architecture with horst and graben connected to each other by submarine escarpments. This subdivision led to the establishment of structural lows and highs (Cecca, 1990; Centamore et al., 1971; Santantonio 1993; 1994) with different sedimentation rates (Marino & Santantonio, 2010; Fabbi & Santantonio, 2012). In the late Tithonian these paleotopographic differences were smoothed out by the Maiolica Fm., thus establishing a purely basinal and tectonically undisturbed depositional regime throughout this portion of the Tethys up to the Miocene compressive phase. In this work we focus on the presence of deposits from the Upper Cretaceous in angular unconformity stratigraphic contact with the Hettangian/Sinemurian calcareous bedrock, presumably following the Barremian extension-dominated tectonic phase described by Cipriani & Bottini (2019) at Mt. Cosce (about 20 Km NE of Mt. Soratte). The deposits are represented by chert-bearing limestones and marly limestones with planktonic foraminifera as Rotalipora spp. (Scaglia Bianca Fm., Cenomanian) and Globotruncana s.pl. (Scaglia Rossa Fm, Turonian - Early Eocene). These deposits were found in discontinuous patches with variable areal extension (SE side of Sant'Oreste city centre and along the SP30/b in the locality of "Il Casone"), in a neptunian dike hosted by Calcare Massiccio Fm. along the path between the Hermitage of San Silvestro and the Hermitage of Madonna delle Grazie, and as matrix of sedimentary breccia cropping out along Via Giovanni XXIII hosting clasts of variable size belonging to the Jurassic formations of a structural high.

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Tectono-Metamorphic Evolution of Serpentinites from Piedmont—Sesia-Lanzo Zone Boundary (Lanzo Valleys, Italy)

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Keywords: eclogitized serpentinites, Alpine subduction, multi-scale structural analysis, Piedmont Zone, Sesia-Lanzo Zone.

The contact between the metaophilites of the Piemonte Zone and the eclogitized continental crust of the Sesia-Lanzo Zone represents the dominant tectonic character of the Upper Tesso Valley (e.g.: Spalla et al., 1983; Gosso et al., 2015; Luoni et al., 2020). Here serpentinites, metabasites, calcschists, quartzites and fine-grained gneisses have been deformed by four superposed groups of ductile structures and the associated fabrics are marked by contrasted minerals assemblages. Different serpentinite types, Ol and Cpx bearing serpentinites, have been studied in detail. The pervasive mylonitic D2 structures developed under blueschist-epidote amphibolite facies conditions (T= 450 ± 50°C and P= 0,8 ± 0,3 GPa). The metamorphic peak conditions have been obtained from some pre-D2 relic minerals and indicate a re-equilibration under eclogite facies conditions (T=570 ± 50°C and P> 1,8 GPa). Post-D2 assemblages indicate a re-equilibration under greenschist facies conditions (T< 400°C and P< 0,5 GPa). The inferred PT path has been used to explore the geodynamic scenario under which these conditions could have been developed through a numerical model allowing some hypotheses concerning the time in which these structures have been generated. Model predictions for Pre-D2 mineral assemblages suggest that they developed at 60 to 90 km depth and 115 to 145 km from the trench during Paleocene or during the lower Eocene at 70 to 90 km depth and 135 to 160 km from the trench. This tectonic picture shows that this portion of the Piemonte Zone underwent a tectono-metamorphic evolution similar to that of the Zermatt-Saas metaophilites.

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New findings on mineral fibres characteristics and concentration in groundwater and their mobility through water flowing in Naturally Occurring Asbestos (NOA) rich settings

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Keywords: groundwater, NOA rocks, asbestos, hydrogeology, flow model.

In Naturally Occurring Asbestos (NOA) rich settings, water pollution by asbestos is likely to occur from weathering and erosion of asbestos-bearing rocks, such as meta ophiolites (e.g. serpentinite rocks and metabasites). Asbestos water dispersion may occur as a consequence of superficial and groundwater flow through rock formations containing NOA, depending on several characteristics of either the rocks (e.g. mineralogical composition, fracture grade) and hence the water (e.g. pH, speed).

Given the importance of groundwater resources as source of drinking water and for agricultural and industrial activities, groundwater asbestos pollution represents an environmental problem and could even constitute a risk for human health. In fact, waterborne asbestos can come into contact with human beings as airborne fibres after water vaporization, or by ingestion, especially if they are present in drinking water. While a lot is known about diseases caused by airborne asbestos respiration (IARC, 2012), not enough has been yet understood about potential noxiousness of its ingestion. For this reason, the necessity to set a Maximum Contaminant Level (MCL) for asbestos in potentially usable water is still debated (WHO, 2020).

To investigate asbestos occurrence in water due to natural environmental causes, we selected a study area in Piedmont, not far from Torino, a region surrounded by the North-Western Alps which are rich in NOA and also in naturally occurring asbestiform minerals non-asbestos classified (Compagnoni & Groppo, 2006; Belluso et al., 2019). There, sampling and analysis campaigns regarding the water system have been settled to investigate if, how and which type of mineral fibres (particularly asbestos ones) could occur in water, trying to correlate them to the local geolithology and hydrogeology.

The results of two surface water and groundwater sampling and analysis campaigns will be presented. The main aim is to investigate the principal aspects related to asbestos and asbestiform fibres presence in water, particularly groundwater, linked to hydrological and geolithological characteristics of the reservoir and to evaluate the seasonal variability. Additionally, following recent findings on asbestos mobility through soil (Mohanty et al., 2021), guidelines to create a flow model which describes mineral fibres mobility in acquifers will be presented following laboratory tests based on contaminated water circulation through packed columns.

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Depositional and diagenetic fabric of Paleocene Neo-Tethys Carbonates, Hazara Fold-and-Thrust Belt, Pakistan

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Keywords: Paleocene, Lockhart Limestone, microfacies, diagenesis, Pakistan.

The current research is based on microfacies studies and diagenetic history of the Lockhart Limestone of Hazara fold-and-thrust belt, Pakistan. Four microfacies have been interpreted in the Lockhart Limestone such as Pelagic Mudstone, Planktonic Foraminiferal Wackestone, Benthic Foraminiferal Wackestone and Bioclastic Packstone. The identified faunal assemblage of the Lockhart Limestone includes smaller benthic foraminifera (uniserial, biserial and miliolids), larger benthic foraminifera and echinoids. The identified larger benthic foraminifera includes *Discocyclina ranikotensis, Operculina salsa, Ranikothalia sahnii, Miscellanea miscella, Lockhartia conditi, Lockhartia haimei, Lockhartia tipperi* and *Assilina species*. On the basis of interpreted microfacies, the Lockhart Limestone indicates deposition in fore shoal mid ramp, mid ramp and deep marine depositional settings. On the basis of age diagnostic fossils like *Lockhartia*, *Miscellanea* and *Ranikothalia*, a Late Paleocene age is assigned to the Lockhart Limestone. The Lockhart Limestone is altered by several diagenetic processes including micritization, neomorphism, chemical compaction (stylolites, stylonodular fabric), mechanical compaction and calcite filled fractures. The diagenetic fabric demonstrates that the Lockhart Limestone has experienced diagenetic modifications in marine, meteoric and burial diagenetic settings.

A new Late Pleistocene fossil-bearing locality at Olduvai Gorge (Tanzania)

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Keywords: dating, fossil vertebrates, palaeoenvironment, Tanzania, volcano.

Olduvai is a dry river valley incised at the western margin of the East African Rift System at the edge of the Serengeti Plains (Tanzania). The rocks that crop out in the Gorge span the last 2 Ma and are very rich in palaeontological and archaeological remains, offering a glimpse of human evolution in the context of East African Quaternary environmental changes. The stratigraphic succession is divided into seven stratigraphic units (Bed I-IV, Masek Beds, Ndutu Beds and Naisiusiu Beds; Hay 1976). From bottom to top, the succession records the transition from (i) a wide saline-alkaline lake evidenced by lacustrine sediments interbedded with volcanic ash marker layers; (ii) fluvial environments formed after the progressive disappearance of Palaeolake Olduvai; (iii) the establishment of an environment similar to present-day dry savannah, marked in the succession by welded aeolian tuff (Hay 1976). Although research in Olduvai has been ongoing for over a century, not all stratigraphic units have been studied in detail. The older layers (Beds I-IV) -which yield Early Stone Age tools and archaic hominin species (australopithecines and early *Homo*)- have been investigated much more intensively than the younger ones. The field activities carried out by the THOR (Tanzania Human Origins Research) team led to the discovery of a very interesting Late Pleistocene palaeontological assemblage in Geolocality 83, preliminarily referred to the Ndutu-Naisiusiu Beds (NB-NaB). The assemblage includes some exceptionally-preserved fossils of large mammals, among which some carnivorans stand out. The total number of collected specimens (including some articulated skeletal parts) is about 200. According to our field analysis, the assemblage is largely composed of species that can be found today in East African savannahs. As far as the geological interpretation is concerned, the comparison of our outcrop with the type sections of the NB-NaB highlights several differences in lithology that will prompt further analysis in order to identify possible chronological and/or palaeoenvironmental differences. Literature data roughly agree that the NB would cover the interval between 400-32 ka, whereas the NaB would be referred to the latest Pleistocene (about 15 ka; Hay 1976). However, other data on the NaB would point to an earlier age (about 65-39 ka; Skinner et al. 2003). For these reasons, our study includes novel radiocarbon dating on fossils and $^{40}Ar/^{39}Ar$ dating on rock samples from Geolocality 83. In addition, several analyses (microfacies and petrographic interpretation on thin sections, XRD, EPMA, etc.) are in progress on geological samples from the site to help reconstructing its depositional history and palaeoenvironment.

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Geophysical characterization of Ceppo Lombardo Formation (Po Plain NE of Milan, Italy): new data from passive seismic surveys

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Keywords: Ceppo Lombardo Formation, HVSR, Po Plain, Geophysical characterization, Seismo-stratigraphic characterization.

The "Ceppo Lombardo Formation" (Riva, 1957) is a collection of Quaternary clastic conglomeratic units outcropping and sub-outcropping in an area of the Po Plain, North to the city of Milan (Italy). Due to the shallow depth and the areal extension of this formation, the geophysical characterization is of great importance for geotechnical engineering, land use and local seismic hazard studies.

The geophysical characterization of such clastic units shows several and not negligible issues, starting from its great areal extension to the great variability in the cementation and alteration parameters. The main geological, geophysical and geotechnical information about this formation, comes from a great amount of data and studies available from local administration and professional studies, these datasets were not ever integrated to have a more robust geotechnical knowledge.

To this aim, we gathered and analysed all available geophysical and geological datasets, resulting from well stratigraphies and geophysical soundings. Additional geophysical surveys were conducted, using the single station passive seismic (HVSR) technique on a single site investigation and two 10-km-long perpendicular transects. Geophysical data was integrated with boreholes information (e.g. core drilling and cutting from well drilling) for an efficient data validation.

The results show a strong seismic impedance contrast between the Ceppo Lombardo Formation and the overlying units having poor geotechnical characteristics. This formation has also been classified as overconsolidated soil ($Vs < 500$ m/s) with the exception of the Brembo unit that show Vs values comparable with a seismic bedrock ($Vs > 800$ m/s). Additionally, the great variability output of the HVSR tests, indicate that the top surface has irregular geometry with variable impedance contrasts up to about 30 m depth.

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May a tailing impoundment from an abandoned Pb-Zn mining activity be an environmental issue for water resources? Evidences from long-term groundwater monitoring

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Keywords: groundwater quality, mining contamination, long-term monitoring, potentially toxic elements, remediation.

Decommissioned mines represent a worldwide concern for the environment even for decades to hundreds of years since the activities ceased, and also in those areas located at long distances from the mining sites. The most important mining district of the Friuli Venezia Giulia region is the Pb-Zn Raibl mine, sited in the NE sector of the Julian Alps, near the border with Austria and Slovenia. The mine had a secular history since the first evidence of mining activity is dated to 1320 whereas it closure is dated back to 1991. Only in the 1976-1991 period, almost 4 million tons of mine tailings, products from milling and enrichment (flotation) processes of sphalerite (ZnS) and galena (PbS), have been stored in a tailings impoundment nearby the main stream flowing the area, the Rio del Lago creek. The tailings contain very high concentrations of base metals (Zn, Pb and Fe) and potentially toxic trace elements (PTEs: As, Cd, Tl, Sb). The site is currently under remediation to mitigate the impact on the environment, however, since the availability of such elements in the stream waters represent a concern for the freshwater ecosystem, the water quality is constantly monitored.

Ten years of groundwater monitoring results in several piezometers in the area conducted by ARPA FVG and the University of Trieste are presented. The time-series of the hydrochemistry evolution of tailings groundwaters has given the opportunity to observe the long- and short-term variations of elemental concentrations, thus suggesting the processes that lead the release of potential toxic elements (Tl, Zn and Pb) to groundwaters and some possible scenarios about future perspectives of contamination.

The short-term hourly data from groundwaters, entrapped in the tailing ponds, indicate high frequency relationship between hydrology and oxidation of sulfides that release PTEs. On the contrary, long-term hydrochemical series indicate that groundwaters inside the ponds are generally depleting in dissolved metals, due to both remediation actions and chemical depletion of the source. Groundwaters undergo a progressive enrichment of the main PTE concentrations, although this enrichment is limited to a few hundreds of meters downstream the impoundment.

Time-series analysis on the decay of PTEs performed with first-order rate constants (Newell et al., 2002), estimates that the dissolved metal contents in groundwater entrapped in the tailings could drop below the national law limits in a time interval from a couple of years to some decades. On the contrary, uncertain future scenarios about downstream enrichment have arisen.

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Carbon phases in Ureilites
The shock origin of diamond and the important role of Fe-Ni compounds

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Keywords: diamond, graphite, ureilite, meteorites, shock event.

The origin of carbon phases in meteorites is still a debated issue within the scientific community of planetary geology, with significant implications for the sizes of early Solar System bodies. The main expected outcome of this project was to have further insights on the origin and relationships among carbon phases in ureilites with the final aim to definitively clarify the diamond formation processes occurring for these achondrites. Ureilites are the second major group of achondrites (Goodrich et al., 1992), which consist of ultramafic rocks, mainly composed of olivine, pigeonite, minor carbon (graphite and diamond) and Fe-Ni compounds.

In this project, we used a multimethodological approach by Scanning Electron Microscopy (SEM), Micro-Raman Spectroscopy, Micro-X-ray diffraction (XRD) and Transmission Electron Microscopy (TEM) on different ureilitic fragments (from Almahata Sitta, NWA 7389, Y-74123 and Kenna). During this study we focused on their characterization and on the determination of their crystallite size and on the temperature recorded by graphite using the geothermometer by Cody et al. (2008).

Our results, which are reported in Nestola et al. (2020) and Barbaro et al. (2020, 2021), evidence that the mineral association of nano-, micro-diamonds and nanographite in ureilites was produced in an impact event at peak pressures not lower than ~15 GPa with the help of catalysis of Fe-Ni compounds. The observation that the graphite in all these ureilites is nanometric suggests that it records shock conditions occurred during the impact events involving the ureilite parent body. The temperature obtained from graphite, which ranges from 1180 to 1314 °C (±120°C), would represent the shock event temperature.

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High-pressure driven intrusion of molecules in natural erionite-K zeolite

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Keywords: Zeolites, synchrotron X-ray diffraction, adsorption, high-pressure, *in-situ* characterization.

Investigating the high-pressure behaviour of crystalline compounds with microporous structure, *e.g.* zeolites, has experienced a boosted interest in the last two decades, especially due to the *P*-induced intrusion of molecules and ions into the structural nano-cavities from the *P*-transmitting fluids (Gatta et al., 2018). Zeolites have a consolidated history of technological and industrial applications, but the understanding of these *P*-induced phenomena may further expand their utilizations, opening the way for new routes for tailoring functional materials. In this study, we have investigated the behaviour of the natural zeolite erionite when compressed in non-penetrating and potentially penetrating fluids: *i.e.* those fluids made by molecules having a kinetic diameter that may allow their *P*-mediated adsorption into the zeolite structural cavities.

Erionite is a zeolite with a wide chemical variability in nature, expressed as solid solutions among three end-members: erionite-Ca, erionite-Na and erionite-K.

The investigated sample, classified as erionite-K, has the following chemical formula: $K_{2.31}Na_{0.02}Ca_{2.15}Mg_{0.69}Ba_{0.04}Sr_{0.02}Al_{9.00}Si_{27.19}O_{72}\cdot 18.66(H_2O)$. Erionite crystal structure is characterized by the presence of large cages (23-hedron, called "erionite-cage"), superposed along the c-axis, hosting most of the extra-framework population.

In-situ high-pressure single-crystal X-ray diffraction experiments have been conducted at the Xpress beamline of the Elettra Synchrotron, using an ETH-type diamond anvil cell (DAC) and ruby as P-calibrant. We have performed two P-ramps using different P-transmitting media: the first one using the non-penetrating silicone oil, up to 2.60(5) GPa, and the second one with the potentially penetrating methanol:ethanol:H_2O = 16:3:1 (hereafter mew) mixture, up to 4.97(5) GPa. P-V data obtained by the silicone oil ramp were fitted by a II order Birch-Murnaghan equation of state, yielding the following refined isothermal bulk modulus: K_{V0} = 44(1) GPa ($\beta_{V0} = K_{V0}^{-1} = 0.0227(5)$, where β_{V0} is the bulk volume compressibility).

P-V data from the mew ramp show a marked decrease in compressibility, which unambiguously suggests the *P*-induced intrusion of H_2O (and possibly alcohols) molecules. This behaviour is somehow surprising if we consider that the magnitude of the intrusion process is comparable with that of synthetic SiO_2-ferrierite (Lotti et al., 2015) and $AlPO_4$-5 (Lotti et al., 2016) zeolites, but in this case has been observed in a natural sample of erionite, with structural cavities filled by extra-framework population.

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3D Slope stability analysis in the Agnano district (Naples, Italy) by means of a physically-based software

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Keywords: landslide, susceptibility, Naples, Scoops3D, GIS.

Landslide susceptibility assessment is a widely studied field in literature, especially by means of statistical and deterministic models (Pourghasemi et al., 2018). Deterministic models are being used for susceptibility analysis at local to relatively large scale, as function of data availability. Scoops3D (Reid et al., 2015), developed by the U.S. Geological Survey, is based on 3D slope stability models and can work also at basin scale.

In this work a susceptibility map depicting the computed Factor of Safety (FoS) in the Agnano area (Naples, Italy) has been produced using Scoops3D and GIS processing for input data preparation and output analysis.

The input data required by the software are the Digital Elevation Model (DEM) of the study area and layers representing the bottom elevation of the considered strata and the piezometric quota. Mechanical and physical parameterization of the identified soil layers is consistent with a Mohr-Coulomb failure criterion (i.e., cohesion, friction angle) and the unit weights of the partially and totally saturated material. To simulate different hydrological conditions, several depth values of the piezometric surface have been used. The analysis was completed considering only two layers: a cover layer and a bedrock layer. For consistency with field observations, the first layer thickness was set at 3 m, as most of the landslides in these types of covers are less than 2-m deep (Fusco et al., 2019).

The obtained results are minimum FoS values for each cell of the model representing the study area. Maps have been subdivided in five classes, taking in consideration the old Italian legislation (as the new one does not give determined limit values for the FoS): very high ($FoS < 1$); high ($1 < FoS < 1.3$); moderate ($1.3 < FoS < 1.5$); low ($1.5 < FoS < 10$) and very low susceptibility ($FoS > 10$). Results appear to be reliable, especially for those locations where physical and mechanical properties data are available. This analysis represents a first step toward a better assessment of the landslide susceptibility condition over the Agnano district and it can be improved by increasing the resolution of the model in terms of soil differentiation and related properties.

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Geomorphological evolution of an active Alpine rock glacier from 2012 to 2020

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Keywords: rock glacier, UAV, surface velocity, permafrost, Bulk Creep Factor.

Acceleration of rock glacier (RG) deformation has been documented in the European Alps for more than a decade in relation to an increase in ground temperature, combined with increasing liquid water content and local overloading by debris. However, the factors controlling RG acceleration are still not well understood, reinforcing the interest in studying RG.

In this work, we monitored the dynamics of an Alpine RG located in Valle di Fraele in the central Italian Alps by analyzing its surface creep rates.

The analysed were conducted using orthophoto of 2012 and four UAV (Unmanned Aerial Vehicle) surveys between 2016 and 2020. Moreover 18 ground control points were placed on the RG area and their coordinates measured by GNSS receivers in RTK mode.

RG creep rates were calculated over four intervals (2012-2016, 2016-2018, 2018-2019 and 2019-2020) using CIAS image correlation software (Fey & Krainer, 2020). To disantangle the contribution of material properties and geometry to the surface velocities, the Bulk Creep Factor (BCF) was calculated. BCF expresses the mechanical proprerties of the RG material and it allows to compare different RG areas with regard to its rheological properties (Cicoira et al., 2020).

The RG shows a high spatial variability of creep rates. In the rooting zone, the RG moved slowly downslope with a deceleration rate between 2016 (0.7 m/y) and 2019 (0.4 m/y). In 2019-2020 the maximum velocity peak was reached (0.9 m/y). The velocity was higher in the middle sector of the RG with displacements from 2.30 m/y (2012-2016) to 1.40 m/y (2016-2018). From 2018, an increase in creep rates was observed. Although the trend and the temporal evolution of the movements is in agreement with the middle sector, in the lowest part of the RG tongue the velocities are about twice as fast as in the previous sector. Following a phase of reduced displacement in 2016-2018, the RG entered a phase of velocities intensification, from 3.50 m/y in 2016-2018 to almost 4 m/y in 2019-2020. The RG shows a distinctly different BCF pattern. In the lowest part of the RG, where the highest velocities were detected, the BCF is the highest (~17). In the middle and in the rooting zones, a decrease in creep rates also correspond to a decrease in BCF values (5-8 and 2-4 respectively). The RG zones have the same rheological properties but show different creep rates due to their contrasting slope angles and BCF spatial distributions. The high BCF values and its discontinuity indicate a dynamical activity of the RG with a potential destabilization event.

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Segmentation pattern and morphotectonic anatomy of the 1983, M_w 6.9 Borah Peak earthquake (Idaho, USA)

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Keywords: 1983 Borah Peak earthquake, fault segmentation, surface rupture, rupture zone width, vertical separation.

Following the observations made in a survey campaign along the Lost River Valley (Idaho, USA), we integrate different data sets to obtain an extremely detailed segmentation of the fault that released the 1983 Borah Peak earthquake (M_w 6.9). The earthquake ruptured the topographic surface with a normal-oblique faulting mechanism, activating two SW-dipping segments (Thousand Springs and Warm Springs) and a branching SSW-dipping fault (Arentson Gulch Fault), and producing coseismic surface ruptures with throw up to 3 m. We augment the 1983 earthquake knowledge by investigating and interpreting high-resolution topography and scarps mapping obtained through structure-from-motion. A large dataset of quality selected vertical separation data, combined with rupture zone width (RZW) measurements, new fault/slip data, and an analysis of major and minor structural-geometric complexities, highlights a partition of the deformation and a segmentation of the fault up to the detail of four orders (*i.e.*, segments, sections, subsections, sectors), providing new useful details of the earthquake and new constraints for paleoseismic and seismotectonic studies. The fault/slip data show variations along the fault-strike that we interpret from the perspective of a kinematic partitioning, which supports segmentation. In 1983, the two main activated segments had completely different rupture behaviors, with important RZW in the southern portions and with the deformation concentrated along the main fault trace in the northern portions. We show that the distributed ruptures, in addition to being a large percentage of all deformation in terms of a total length of the ruptures (~19.5 km *vs* 31 km in total for the main ruptures) also accommodate most of the surface deformation (~66%). We also show that 83% of the deformation in terms of length of the surface faulting is located at the hanging wall of the main rupture, while at the footwall it is located the 17%, (80% and 20% respectively if in terms of vertical separation). We observe a significant correlation between vertical separation, rupture zone width, the position of the rupture (footwall or hanging wall), and fault geometry. From these correlations, we highlight, for example, the control of obliquity and kinematic partitioning in the surface expression of the earthquake propagation. We interpret the coseismic (*i.e.*, 1983) and long-term (*i.e.*, Quaternary) behavior, showing that the two segments activated had similar cumulated behaviors in distributing the deformation among synthetic and antithetic ruptures over time, even if with different geometries. We calculate ratios applying probability density functions, that are consistent with most of the literature but not spatially uniform. These results deserve to be considered in studies on active faulting hazard and suggest caution in establishing rules for land use planning close to active faults capable of rupturing the surface.

Layered deposits on Mars: geologic history of an impact crater (Meridiani Planum, Arabia Terra)

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Keywords: Mars, planetary geologic mapping, impact crater, equatorial layered deposits, water.

We know Mars as a cold and bleak wasteland, but many images our telescopes, orbiters and rovers have sent back show us many views suggesting that water has played a role in shaping the surface of the planet, particularly for early Mars. We wanted to investigate the issue of water on Mars, that is still intriguing and debated.

Our aim was the analysis of an unnamed impact crater on Mars led by remote sensing, using data provided from ESA and NASA missions to Mars. The study area is located in a volcanic plateau in Meridiani Planum region, where the first meridian crosses the equator. We produced a detailed planetary geologic map of the crater filling, a quasi-circular depression 52 km in diameter, to identify the lateral and vertical relations between geologic units and to reconstruct the stratigraphic framework. In particular, we investigated layered and light-toned deposits that are grouped under the informal name of equatorial layered deposits (ELDs). We selected the study area (longitude 0°83'W, latitude 3°83'N) because here ELDs can be observed and are well exposed; in addition, this area has good dataset coverage. We reconstructed the geometry of ELDs: they consist of high albedo faint to well-developed layers and mounds, and they form a kilometre-thick bulge inside the crater. They drape and onlap the plateau material of late Noachian age, according to Scott & Tanaka (1986), and their formation date back to the Hesperian, from 3.7 Gyr ago, while they are unconformably covered by more recent volcanic and volcanoclastic materials reworked by the wind.

We include ELDs in all that geologic evidence suggesting the widespread presence of liquid water for early Mars. In fact, we interpret these features inside the crater as evaporites formed in a playa setting originated by fluid upwelling through pathways likely provided by the fractures related to the crater formation.

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Comparing different approaches to set up SWAT model in a flat intensively irrigated area

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Keywords: SWAT, hydrological model, flat area, watershed delineation, Ticino River.

In the last years, hydrological models have been developed worldwide, to investigate hydrological processes and to assess the impact of climate change (e.g., Devia et al., 2015)we are going to discuss\\nbriefly about variable infiltration capacity model (VIC. However, especially in flat and cultivated areas with heavily modified drainage systems it is quite difficult to derive first order watersheds (Donmez et al., 2020)deriving hydrology-relevant information is complicated in flat data-scarce agricultural watersheds due to constraints in watershed delineation, flat topography, poor natural drainage, and irregular irrigation schedules by human intervention. The study aimed to improve the applicability of the Soil and Water Assessment Tool (SWAT. The aim of this study is to apply a numerical model, in a flat and intensely irrigated area, characterized by the Ticino River and other artificial irrigation channels, in Lombardy Region, Italy.

The hydrological model used in this study is the Soil Water Assessment Tool (SWAT), a physically based model operating at basin scale (Neitsch et al., 2011). SWAT subdivides the basin into sub-basins, which in turn are split up into Hydrological Response Units (HRUs), which represent areas with homogenous topography, soil and landuse. Therefore, SWAT's standard subdivision method works efficiently in large basins. However, as confirmed by other authors the application of SWAT is limited in flat areas, with a complex drainage networks and different agricultural activities (e.g., Donmez et al., 2020)deriving hydrology-relevant information is complicated in flat data-scarce agricultural watersheds due to constraints in watershed delineation, flat topography, poor natural drainage, and irregular irrigation schedules by human intervention. The study aimed to improve the applicability of the Soil and Water Assessment Tool (SWAT.

The main objective of this study is to investigate different approaches to apply SWAT in a lowland area without a natural channel network. Therefore, we compared SWAT results for two different watershed delineation approaches. For the first approach the model was set up in the "traditional" way supposing natural drainage conditions, creating streams and watershed based on Digital Elevation Model (DEM). However, this is not adequate for an accurate delineation of streams and watershed in an area with the characteristics described above. With this method, indeed, the channels delineated from the model do not reflect the real artificial drainage. Instead, in the second approach, we used a stream network and sub-basins, delineated based on geomorphological units (river terrace levels), the artificial drainage network and irrigation channels as well as administrative boundaries. The modelling units were defined separately using a GIS system and subsequently imported in the SWAT model. In conclusion, we show an alternative way to set up SWAT in order to better represent soil-water dynamics, in flat irrigated areas.

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Painted architectural terracotta fragments: do they belong to the ancient city of Caere? Petrographic analysis can help to give an answer

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Keywords: petrographic analysis, architectural terracotta, ceramic bulk, Southern Etruria, archaeometry.

In the first half of 2016 the Comando Carabinieri Tutela Patrimonio Culturale, with the precious cooperation of the Swiss authorities, recovered in Geneva and returned to Italy several boxes containing Roman, Magnogreek and Etruscan archaeological findings. During the same year, an agreement between MiBaCT (Ministero per i beni e le attività culturali) - today MiC (Ministero della Cultura) - and the Ny Carlsberg Glyptotek of Copenaghen agreed on the return to Italy of painted architectural terracotta fragments, which stylistically remind the typical painted architectural terracottas of the Southern-Etruria of the VI-V century BC.

The discovery, the subsequent placing in the clandestine market and the final recovery of the fragments under study influenced their scientific, stylistic and archaeological investigation; indeed, when archaeological findings are moved from the place of discovery, being decontextualized, without any appropriate documentation that guarantees to reconnect them to their original site, extremely important information are lost; so, it is necessary to resort to deepened studies in order to reconstruct the story, the provenance and to approve the authenticity (Russo et al., 2018). On the 38 fragments in study, a preliminary investigation through non-invasive and non-destructive techniques has been carried out by previous research (Barone et al., 2019). Non-destructive methods were used due to uniqueness and scientific importance of the archaeological finds. These analyses showed particular affinity concerning the painting techniques and the color palette between the studied materials and materials from Etruscan sites. Once assessed the chemical compatibility, it has been decided to proceed with petrographic and mineralogical analysis on the ceramic bulk, in order to obtain information about the ceramic fabric, thus on manufacturing techniques. Thanks to the comparison with reference materials - samples from the Banditaccia Necropolis in Caere from the Temple of Veii, from the locality of Quartaccio of Caere and from the Temple B of Uni-Astarte in Pyrgi - it has been possible to add new evidences to the hypothesis of local production, proposing the hypothesis of the presence of different workshops distributed on the South Etruria territory.

Here we show the results obtained by the petrographic investigations that, if on one hand provided very important information about the mineralogical phases and the texture of the ceramic bulk, on the other hand opened new questions for further researches, in particular regarding the use of different types of pigments, of whom it's necessary to assert the provenance.

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Coccolith size across the Early Aptian-Late Albian: What do they tell us about the mid Cretaceous paleoecology?

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Keywords: Cretaceous, calcareous nannofossils, morphometrics, OAE 1b.

Coccolithophore algae are among the most important calcifying organisms in the ocean system, and they are very sensitive to environmental conditions changes. In the geological record, evidence of variations in nannoplankton abundance, shape and/or coccolith size are attributed to different factors like altered carbonate chemistry, temperature changes and variation of nutrient content. Therefore, the study of calcareous nannofossils provides important information about the nannoplankton evolution and the long-term response to stress conditions in a natural system. This could improve current estimates of the amount of CO_2 exchange between the ocean and the atmosphere in the geological past.

In this research, we study the interval which encompasses the Early Aptian to Late Albian (early Cretaceous). This period is marked by profound climatic changes including a cooling event in the early late Aptian, and two "Ocean Anoxic Events", namely the OAE 1a and OAE 1b. A particular focus is dedicated to the Aptian/Albian boundary and the Oceanic Anoxic Event 1b. Studied samples are from ODP Site 1049 (North Atlantic) and the Piobbico core (Umbria-Marche Basin, central Italian Apennines).

Morphometrics on *Biscutum constans* from the Western Tethys documented relatively small sized specimens in the early late Aptian (Bottini & Faucher 2020) followed by average size increase after OAE 1b. The new morphometric analyses performed in the current work were conducted on *Watznaueria barnesiae* (oligotrophic species), *Rhagodiscus asper* (warm water species), *Zeugrhabdotus erectus* and *Biscutum constans* (mesotrophic species). The results have been correlated with the nannofossil abundance, temperature and fertility index in order to broaden the characterization of the nannoplankton response to short and long-term paleoenvironmental changes across the mid Cretaceous. The final aims of this work are to a) detect any species-specific response to paleotemperature and paleofertility changes, b) see any correspondence between size changes and OAE 1a and OAE 1b events, c) detect if coccolith size variations are also paralleled by changes in shape and if this may have impacted the total carbon budget.

Bottini C. & Faucher G. (2020) - Biscutum constans coccolith size patterns across the mid Cretaceous in the western Tethys: Paleoecological implications. Palaeogeography, Palaeoclimatology, Palaeoecology, 555, 109852, ISSN 0031-0182.

What makes a soil landscape robust? Land use changes in a southern Alpine valley (Ticino, Switzerland)

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Keywords: landscape sensitivity, alpine environments, pedogenesis, land use changes.

The sensitivity of a landscape to changes is expressed by the likelihood that a given change in the controls of a system will produce a sensible, recognizable and persistent response in the properties of the system (Brunsden & Thornes, 1979)over 102-105 years, to pertur- bations caused by high magnitude-low frequency events, environmenal change and internal structural instabilities, which initiate change. The responses to these impulses are complex and include damped, sustained and reinforcing changes taking place by ubiquitous, linear or diffusive propagation which reflect the sensitivity of the landscape to change. Results include the concepts of 1. A system can behave resilient or sensitive towards an external disturbance. Alpine soil landscapes can be considered as particularly sensitive to land use changes because their effects tend to be enhanced often extreme climatic and topographic conditions as well as intense geomorphological activity (Gordon, 2001). The aim of this study is to investigate the sensitivity of an alpine soil landscape in terms of land use changes that might affect soil properties.

The landscape in the Onsernone valley (Ticino, Switzerland) can be characterized by the following criteria: (i) the type of land use (pasture / meadow / cultivation / forest), (ii) the status of land use (active / abandoned), and (iii) the topography (artificial terraces / natural slope). The resulting 6 land use-terrain units are compared with the "natural" situation represented by forest cover and natural slope conditions. We measured the following key soil properties and soil water dynamics that are vulnerable to land use changes: saturated hydraulic conductivity, soil organic carbon, soil hydrophobicity and aggregate stability as well as surface runoff generation dynamics and related sediment transport. In mountainous regions, soil erosion is the main contributor to soil degradation reflecting the sensitivity of the soil landscape to land use changes. Based on statistical methods the changes and differences of these key properties and soil water dynamics were analyzed to detect changes in comparison to the natural conditions. We show that land use and land use change have a specific impact on soil formation and soil water dynamics. However, due to geological characteristics the soil landscape in the Onsernone valley seems to be resilient at least for the present-day climate variability.

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Construction of a chronostratigraphic database for the study of the eruptive periodicities of the volcanic districts of the Mediterranean area from the Pleistocene to the present

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Keywords: volcanology, statistics, volcanic hazard, tephrostratigraphy.

Tephrostratigraphy and chronostratigraphy allow to correlate the proximal and distal deposits with each other and with the related eruptions and allow to date in an absolute and relative way paleoclimatic and sedimentary events. This project has as its initial goal the creation of database of individual volcanic districts and a general database that, allowing a realistic reconstruction of the eruptive history of the volcanic districts in the Central Mediterranean area from the Pleistocene to the present, and an evaluation the impact on the consequent volcanic hazard. Through the study of the available records, it will be possible to study cyclical behaviors and non-stationarities of the various volcanic districts, correlating these behaviors with possible external factors and to identify the areas exposed to the highest hazards in a civil protection optic. In these first months of research, were created database of the most complete stratigraphic records present in the Mediterranean area, such as Lake Ohrid, Lake Monticchio and the Fucino basin (Giaccio et al., 2012; Lézine et al., 2010; Wulf et al., 2006). These database are the grouping of the layers found during the coring in these points of interest and have been divided and sorted according to their age, dating method, their thickness and their origin. One of the critical points work is the analysis of space-time completeness, due to the large amount of data present on a regional scale and the potential impact of high-altitude winds and the eruptive magnitude variability. To solve these problems, statistical analyzes are performed on high-altitude winds, useful for defining the statistics of the different directions and different wind intensities during the year through the Matlab programming language. These analyzes allow us to quantify, for each volcanic district, the probability that eruptions of different magnitudes can be recorded in the stratigraphic sequence in the areas of interest in the Mediterranean.

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Sedimentological features of Sabellaria bioconstructions in Salento coastline (San Foca, southern Adriatic Sea, Italy)

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Keywords: Sabellaria spinulosa, sedimentology, erosion costs, bioconstruction.

Main aim of this work is to define the sedimentological features of some worm bioconstructions located along the San Foca coastline (southern Adriatic Sea, Italy). *Sabellaria spinulosa* is a gregarious reef-building polychaetae species that builds tubes by cementing together sand and shells fragments (Gruet et al., 1984). These worms contribute to create natural barriers against storm waves preventing coastal erosion in a natural way (Moretti et al., 2019). The reef of San Foca represents an important biodiversity hot-spot showing an unusual association between *Sabellaria spinulosa* and *Posidonia oceanica*.

This work is focused on the analysis of: reef changes in terms of areal distribution and thickness (Lisco et al, 2017), reef morphological variations (Griffin et al., 2020), textural and petrographic features of sands that form both the worm reef and the sea bottom of adjacent shallow marine environments (Zuffa,1980).

A multidisciplinary physical/biological approach has been used. Monitoring and sampling period corresponded to about eight months (from October 2019 to June 2020). Textural and petrographic analyses have been performed using classical and image analysis approaches.

Results show that the *Sabellaria spinulosa* reef of San Foca is relatively stable; large scale morphological variations are induced by physical processes (mainly storm wave action). Growth and degradation periods involve the entire reef, even if worms and fanerogams seem to show variations of different scale.

Sands of the adjacent beach have composition (they are hybrid sands) similar to the sand which are trapped in the reef. The polychaetae selects the particles based on both the grain-size and the morphometric parameters.

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An insight into the precious lustre decoration technology through chemical, mineralogical and statistical analyses

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Keywords: Lustre, Italian pottery, archaeometry, provenance study, firing conditions.

During Renaissance, Italian production of decorated majolicas reached its heights in terms of beauty and executive techniques. The towns of Gubbio and Deruta became the main manufacturing centres for stained lustred ceramics, a particularly sophisticated type of artworks decorated with painted pictures showing intense and brilliant iridescence effects (Padeletti et al., 2006). This high-level manufacturing technique, however, came from a lot far away. It developed in Mesopotamian regions during the IX century AD and then spread in Egypt, Syria and Spain (XIII century), where important arabesque production centres settled. The history of lustre thus represents an excellent example of technology exchange and stylistic contamination among different cultures, even if the original recipes have been often kept secret by craftsmen and still remain unknown.

Nowadays indeed we have only few and unreliable information about ancient technological procedures, mainly written in old manuscripts like "The three books of the potter's art" by Cipriano Piccolpasso (1557). For this reason, the actual knowledge about lustre mostly comes from archaeometric investigations. Scientific analyses have disclosed precious details regarding raw materials and craft procedures used to obtain such refined decorations (Pradell et al., 2008; Fermo & Padeletti, 2012; Sciau, 2012). For instance, it is known that lustre production required three different manufacturing steps and that the metallic iridescence is caused by the presence of copper and silver nanoparticles in the decoration outermost layer.

Aware of these considerations, we want to highlight the contribution of scientific analyses in reconstructing the ancient production technology of lustres and in supplying reliable criteria for provenance assignment.

In this work, 27 lustre ceramic fragments, coming from three Italian archaeological sites and belonging to two different decorative styles, have been investigated. The chemical composition of the ceramic body has been studied by Wavelength Dispersive - X-ray Fluorescence (WD-XRF) and has been submitted to Principal Component Analysis (PCA) in order to detect any clusters and determine the chemical elements best discriminating among groups. The mineralogical composition has been investigated by X-ray Diffraction (XRD) to reconstruct the firing temperature of the ceramic body. Finally, SEM-EDS analyses have been carried out on a cross-section containing the lustred decoration to obtain information about the materials and the firing conditions used for its realization.

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New insights on the dynamics of the Sumatra and Mariana complexes inferred from the omparative analysis of gravity data and model predictions

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Keywords: numerical modelling, gravity anomalies and Earth structure, subduction zone processes.

Subduction is responsible of surface displacements and deep mass redistribution. This rearrangement generates density anomalies in a wide spectrum of wavelengths which, in turn, causes important anomalies in the Earth's gravity field that are visible as lineaments parallel to the arc-trench systems. In these areas, when the traditional analysis of the deformation and stress fields is combined with the analysis of the perturbation of the gravity field and its slow time variation, new information on the background environment controlling the tectonic loading phase can be disclosed.

Here, we present the results of a comparative analysis between the geodetically retrieved gravitational anomalies, based on the EIGEN-6C4 model, and those predicted by a 2D thermo-chemical mechanical modeling of the Sumatra and Mariana complexes, representative of the two types of subduction: ocean-continent and ocean-ocean.

The 2D model accounts for a wide range of parameters, such as the convergence velocity, the shallow dip angle, the different degrees of coupling between the facing plates. The *marker in cell* technique is used to compositionally differentiate the system. Phase changes in the crust and in the mantle and mantle hydration are also allowed. To be compliant with the geodetic EIGEN-6C4 gravity data and to compare our predictions with the gravity at Sumatra and Mariana, we define a *model normal Earth* considering the vertical density distribution at the margins of the model domain, where the masses are not perturbed by the subduction process.

Model predictions are in good agreement with data, both in terms of wavelengths and magnitude of the gravity anomalies measured in the surroundings of the Sumatra and Marina subductions. Furthermore, our modeling supports that the differences in the style of the gravity anomaly observed in the two areas are attributable to the different environments - ocean-ocean or ocean-continental subduction - that drive a significantly different dynamic in the wedge area.

Channel morphology, sediment characterization and bedload transport of steep alpine streams. A case study in the Orobic Alps (Italy)

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Keywords: sediments size distribution, displacement length, steep-pool, floods, reservoirs.

Rivers are complex and dynamic systems with a strong influence on the territory. They transport water and materials and shape the landscape acting on different spatial and temporal scales. In particular, headwater catchments play a pivotal role influencing the whole drainage network (Wohl, 2010). Mountain regions produce a huge amount of sediments transported up to the ocean by the hydrographic network and provide the major water source (Milliman & Syvitski, 1992)runoff. Headwater channels control the denudation rate, the hillslope stability and the shaping of valleys and their actions are transmitted downstream affecting the whole catchment (Larsen & Montgomery, 2012). Moreover, mountain streams have been less affected by human development and, generally, constitute unique environments that host lots of species of conservation interest (Gomi et al., 2002)sediment transport models.

This project aims to describe the morphology of the Goglio and Sanguigno steep step-pool alpine streams (Valgoglio catchment ~30 km^2; Orobic Alps), characterize the grain size and composition of their sediments and to quantify the bedload transport to better understand the ecological implications of geomorphic changes on the stream functioning. The Goglio stream is regulated upstream by five high-reservoirs with hydro-electrical purpose whereas the Sanguigno is not.

Several cross-sections were measured along both streams, and for each fluvial bar a sediments' characterization was done through a pebbles-count. We quantified the sediment composition (the Valgoglio basin is characterized by vulcanites, conglomerates, sandstones, mudstones, siltstones and micascists) and the grain size distribution measuring the intermediate axis of the pebbles. Moreover, estimations of the bedload entrainment are being done by measuring the distance travelled by painted stones in response to flood events. Further a comparison between the two streams is being made in terms of bed channel stability and sediment dislocation to assess in which way high-reservoirs dab flood events and how the flow disturbance and the bedload transport differ between the two streams.

Our results will be useful to better understand the ecological effects of the geomorphology on the abundances of macroinvertebrates, the colonization pattern of phytobenthos and the streambed habitat availability, all data collected during the surveys.

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Morphostructural and lithological control on drainage pattern in Bognanco Valley (Piedmont, Northwest Italy)

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Keywords: Morphotectonics, drainage pattern, tectonic geomorphology, hydrographic network, Simplon Fault.

The E-W oriented, V-shaped Bognanco Valley is located in the Western Alps (Swiss-Italian Alps). It represents a well-exposed natural section across the continental metamorphic belt (Lower and Middle Penninic units) and the meta-ophiolite rocks (Antrona Unit; Lower Piedmont Zone) (Keller et al., 2005). After the last glaciation its main watercourse, the Bogna Stream, and tributaries flowed into the Toce Valley with parallel, angular, and dendritic patterns. By analysing the drainage network of the entire catchment area, extracted by a 5m resolution Digital Elevation Model (DEM) and hierarchized using GIS tools, it is possible to highlight the presence of anomalous angles, captures, fluvial elbows and knickpoints. To investigate the possible cause of these elements, geomorphological and geological field surveys have been performed. The structural analysis has been carried out to evaluate whether and how the regional tectonic drove the local fracturing status of rocks, discontinuity families and their spatial distribution. Despite the smallness of the basin (around 90 km^2 only), homogeneous domains were individuated as for litho-structural characteristics and related erodibility caused by superficial water. Preliminary results suggest that, especially in the central-northern sector of the investigated area, the Bogna basin landforms and its E-W watercourse directions are controlled by the regional-scale Simplon Fault (Mancktelow, 1985; Zwingmann & Mancktelow, 2004) and related structures. Where para- and orthogneiss crop out, N-S trending secondary structures might have influenced several captures. Here, the interaction between these two main discontinuity families might be responsible for the fluvial angular pattern. In serpentinite, due to the lithological characteristics, no clear influence of structures affects the pattern, which evolves as a dendritic type. Furthermore, evenly spread knickpoints seem to be connected to a paleolandscape, whose origin stimulates further investigations.

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Titanate: an indicator of Temperature-time evolution in the calc-silicate rocks. An example from the Valle Strona (Ivrea-Verbano Zone, Western Alps, Italy)

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Keywords: Titanite, U-Pb ages, trace elements, metacarbonate.

The Ivrea Verbano Zone (IVZ, Western Alps) is a well-exposed middle-lower continental crustal section of the pre-Alpine that escaped Alpine subduction. This crustal section is mainly constituted by the Kinzigite formation that is middle-high grade metapelites and metabasites with numerous marble lenses. In particular, this formation is best exposed in the Valle Strona, showing progressively higher T conditions with increasing crustal depth up to granulite facies. Several previous works have studied the P-T conditions of the amphibolite to granulite facies metamorphism based largely on the abundant metapelitic rocks from the Valle Strona d'Omegna.

The present study focuses on the metacarbonate rocks from Valle Strona d'Omegna, which metamorphosed from upper amphibolite facies up to granulite conditions. In this contribution, we present new petrological, geochemical and geochronological data with the purpose to reconstruct the Temperature-timing (T-t) evolution using the titanite from the calc-silicate and surrounding wall rocks.

Titanite ($CaTiSiO_5$) is a common mineral in the calc-silicates and mafic rocks. It may contain numerous important geochemical elements, such as Sr, REE, Pb, U, Zr and Nb. This suggest that titanite may be used as an important indicator of petrogenetic conditions. Kohn (2017) already demonstrated its petrological utility in the high-grade calc-silicate rocks from central Nepal Himalaya, they investigated (T-t) history of those lithologies using Zr-thermometry combined with geochronology.

In this study, we focus on the trace elements variation of the titanite. We characterized their chemical composition from rock with different content of carbonate and investigate their relationship with the temperature and age dating. Preliminary titanite data obtained from high temperature calc-silicate revealed a strong inverse correlation between the content of trace elements and content of carbonate in the rocks. A wide range of U-Pb dates mainly overlapping with the Permian-Triassic metamorphic events. Zr-in titanite estimate temperature ranging from 700 up to 900 °C that indicate recrystallization of the calc-silicate during metamorphic peak (~315 Ma, Redler et al., 2011). The trace element characterization of titanite grains showed a U concentration ranging from 30 to 300 ppm. The combination of trace elements composition may allow to better constrain the role of bulk rock and metamorphic grade on the titanite composition. The Zr-thermometer permit us to support that the temperature condition of this calc-silicate relate to Carboniferous metamorphism and cannot be linked unequivocally to the U-Pb ages.

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Relationship among geomorphodiversity, sediment connectivity and tree rings features in small mountain catchments

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Keywords: geomorphodiversity, sediment connectivity, dendrogeomorphology, mountain ecosystems.

The variety of geomorphic processes associated with climate conditions may play a relevant role in regulating mountain ecosystems dynamics and can affect the biotic components, among which arboreal vegetation. The high dynamicity characterizing mountain areas can be analysed in terms of sediment connectivity patterns between different landscape units. The connection between uphill and downhill areas may depend on the variety of geomorphological features (i.e., geomorphodiversity, Bollati & Cavalli, 2020). A useful tool to unravel the potential relation between connectivity and geomorphodiversity is represented by dendrogeomorphology (Germain et al., 2020). Specific indicators of disturbance in tree rings were analysed with the aim of verifying the role of tree rings as good archives of geomorphic instability events, in relation to geomorphodiversity and sediment connectivity patterns. The selected area for the analysis is the Buscagna valley (Veglia Devero Natural Park; Lepontine Alps), a hanging glacial valley that shows an evident altitude and relief-type difference between the two slopes due to different outcropping rocks. A relevant feature along the NW slope is represented by different polygenic cones, partially colonized by *Larix decidua*.

Increment cores were extracted from 42 trees of *L. decidua* on 3 polygenic cones and 1 snow avalanche corridor. Reference trees in undisturbed settings were also sampled. Tree rings were described and their width was measured using LINTAB and WinDENDRO softwares. Following the cross-dating procedures, the types and frequencies of events affecting trees in these geomorphic units were defined. Morphometric features of polygenic cones were also analysed using ArcGIS 10.1 software. The 4 sites show a spatio-temporal distribution of tree rings indicators that reflects the different sediment and snow fluxes along the surface as well as the age trend of such processes.

According to the obtained results and to other scientific investigations undergoing in the basin (Masseroli et al., 2020), the area represents an ideal location for proposing an interdisciplinary trail focused on the interactions between abiotic and biotic elements.

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The Early and Middle Pleistocene environment of Melka Kunture (Upper Awash, Ethiopia) as evidenced by stable isotopes analysis

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Keywords: Melka Kunture, stable isotopes, carbonates, palaeoecology, East Africa, Pleistocene.

Stable isotope analysis in mammal teeth from Pleistocene archaeological sites has proven highly informative regarding paleodiet and paleoenvironment in eastern Africa (Lee-Thorp *et al*., 2010).

Here, we present measurements of $^{13}C/^{12}C$ and $^{18}O/^{16}O$ isotopic ratios on fossil mammal teeth from Melka Kunture prehistoric site, located along the upper Awash River, in the Ethiopian highland at ~2000 m a.s.l. The chronological sequence, spanning over most of the Early and Middle Pleistocene, records hominin species, lithic artefacts, faunal remains as well as animal and hominin fossil footprints. In addition, fossil pollen records a diversified Afromontane vegetation that includes mountain forests, woodlands, wooded grasslands, and grasslands.

The specimens included in this study are representative of several *taxa*: *Hippopotamidae*, *Bovidae*, *Equidae*, *Suidae*, *Giraffidae*, and *Crocodylidae*. Faunal remains have been sampled using bulk and intra-tooth techniques, then pretreated and analyzed following the internal lab protocol of the AG Biogeologie (University of Tübingen, Germany) for isotopic analyses of carbonates from enamel teeth (Bocherens *et al*., 1996).

Isotopic results on bulk samples indicate that all herbivorous *taxa* consumed mainly C_4 plants, pointing to a C_4 grassland developing in some parts at least of the environment between ~1.6 Ma and 1.0 Ma. Nevertheless, C_3 plants were also present, as indicated by some lower carbon isotopic ratios of hippos and bovids. Between ~0.85 Ma and 0.6 Ma, carbon isotopic ratios indicate a more versatile feeding strategy for hippos and bovids that included both C_3 and C_4 plants. Intra-tooth analyses show uniform isotopic results with no significant variation in either carbon and oxygen isotopic ratios, indicating stable C_4 diet and water conditions during the growth of the analyzed teeth.

These data are consistent with the diversity of the Afromontane vegetation complex at Melka Kunture but also highlight that climate changed, notably during the Mid Pleistocene Transition (Mussi *et al*., 2016). Isotopic data help reconstructing past environmental fluctuations and testing hypotheses about habitat changes in Africa all over human evolution.

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Chemical and isotopic characterization of rainwater in volcanic, urban and industrial areas of Sicily (Italy)

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Keywords: rainwater, atmospheric deposition, trace elements, stable isotopes, volcanic emissions.

The chemical composition of rainwater depends on (i) the dissolution of gases and particulate matter emitted by different sources, (ii) the chemical and physical reactions occurring during local and regional scale transport, and (iii) removal processes. The source of major and trace elements dissolved in rainwater can be both natural (e.g. sea salts, volcanic emissions, geogenic dust, biogenic material) and anthropogenic (e.g. industrial plants, vehicular traffic, domestic heating, vessel traffic). A group of trace elements has been recently brought to attention, especially for their possible environmental impacts, the Technology-critical elements (TCEs): Ga, Ge, In, Te, Nb, Ta, Tl, the Platinum Group Elements and most of the rare-earth elements (REE). The current knowledge about the geochemical cycle of TCEs is still scarce and there are not many studies about the concentrations of them in the rainwater. Nevertheless, recent studies (e.g. Brugnone et al., 2020) evidenced a contribution from the volcanic activity for some of them (Te, Tl, and REE).

The main aim of this research is to produce an unedited geochemical database on major and trace element concentrations and bulk depositions, in different areas of Sicily: a volcanic area (Mt Etna), two urban (Palermo and Catania), and two industrial areas (Milazzo and Priolo) and a rural monitoring site representative of the regional atmospheric background (Cesarò, Nebrodi Regional Park). The samples will be collected monthly, for almost two years, through a network of 15 bulk collectors, most of which were installed at atmospheric monitoring stations of the "Agenzia Regionale per la Protezione Ambientale - ARPA Sicilia".

Moreover, the isotopic ratios of H and O in the rainwater will be investigated, while an innovative feature of the research will be the determination of the isotopic ratios of isotopes not investigated in previous similar studies: $^{34}S/^{32}S$, $^{11}B/^{10}B$, $^{87}Sr/^{86}Sr$. These isotopes have been studied in matrices such as groundwaters, river and marine waters, in which the above elements show higher concentrations than rainwater. Therefore, a new analytical methodology will be developed to measure these isotopic ratios in rainwater. The isotope fingerprint enables to distinguish the contribution of sea-salt from terrestrial and anthropogenic components, allowing to discriminate the different sources that contribute to the chemical and the isotopic composition of atmospheric bulk deposition in the Mediterranean basin.

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Thermogravimetricharacterization of local Sicilian clays and advanced geopolymeric materials

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Keywords: clay, thermogravimetric analysis, geopolymer.

This work has as its aim the chemical-physical characterization of natural clays and the subsequent preparation of new geopolymeric materials. Geopolymers are inorganic polymeric materials that possess an amorphous network of aluminosilicates; they are formed as a result of a geopolymerization process with an alkaline activating solution, leading to the formation of three-dimensional structures with Si-O-Al bonds. This study is part of the Sicilia Eco Innovative Technologies (SETI) project and in the first stage of this work various natural clays from different sites of the Sicilian territory have been characterized by thermal analysis (TGA).

Thermogravimetric analysis has allowed to deepen and investigate the degradation of a material subjected to heating in a controlled atmosphere. Sicilian clays are suitable for the production of geopolymers because of their compositional characteristics and high heterogeneity due to the different ratios of abundance between minerals, carbonates and silicates.

Thermal analysis carried out on the natural clays has allowed to verify their thermal stability; in particular, information on the various mass losses of each sample and the temperatures at which they occur have been obtained. These data have been correlated with the mineralogical nature of each samples and it has also allowed to compare the clays showing similar characteristics and/or differences between them.

Mortars of the ancient Roman aqueduct Aqua Traiana: an archaeometric study about the aggregate fraction

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Keywords: ancient Roman aqueduct, hydraulic mortar, aggregate, pozzolanic behaviour.

Ancient Romans achieved an advanced technological level in the field of constructions, and building remains are the tangible proof of it. Among the different materials, mortars played a fundamental role in the durability of these buildings. In order to obtain hydraulic mortars, ancient Romans mixed lime, used as binder, with an aggregate with pozzolanic activity, both natural (*e.g.* pozzolan, tuffs, glass) or artificial (*e.g.* grog), that were able to induce a reaction with lime, producing an amorphous gel of hydrated calcium silicates and aluminates with hydraulic properties (Torraca, 2009). In such mortars, aggregate did not simply have the function of reducing mortar plasticity and volume variations during the setting, but it was also responsible of hydraulicity, so it needed to be accurately selected.

Among the different ancient Roman buildings that employed hydraulic mortars, aqueducts are one of the most famous. However, there are only few scientific studies on the characterization of their mortars (Sabbioni et al., 2001; Rizzo et al., 2008; Maravelaki-Kalaitzaki et al., 2011). The focus of this research is the characterization of the aggregate present in the mortars of the ancient Roman aqueduct *Aqua Traiana*. It was built in 109 AD, at the behest of emperor Trajan, with the aim of supplying water to Transtiber, and it is still working (Pace, 2010). Mortar samples were collected from the inner duct of *Aqua Traiana*, at Trevignano Romano (RM), and they come either to the original construction and the restauration of pope Paulus V (XVII century). To obtain a petrographic characterization of the aggregate, thin sections were analized by optical microscopy (OM) and then metallized for scanning electron microscopy (SEM-EDS) analysis, to obtain further information on the morphology and chemical composition of the aggregate. Also X-ray powder diffraction (XRPD) analysis was performed on the mortar samples, to obtain information on the crystalline phases present. The archaeometric analyses performed allowed to distinguish among different materials with pozzolanic behaviour, mainly of natural origin, but in few cases also artificial. The very variable dimension of the aggregate seems to be one of the factors that favoured the hydraulic reaction in the original Roman mortars, and that can help distinguishing them from the restoration ones.

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Satellite thermal monitoring of volcanic activity: a comparison between VIIRS and MODIS data

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Keywords: remote sensing, thermal activity, VIIRS, MODIS, MIROVA

Volcanic activity is always accompanied by the emission of heat into the atmosphere and since 1985 satellite remote sensing has taken on a key role in monitoring parameters connected to that (Harris, 2013). This work aims to quantify the heat emitted during volcanic eruptions by using Visible Infrared Imaging Radiometer Suite (VIIRS) and compare the results with those routinely obtained by the Moderate Resolution Imaging Spectroradiometer (MODIS). For this purpose, VIIRS data acquired since 2012 over Stromboli and Erta Ale volcanoes were processed using the Middle Infrared Observation of Volcanic Activity (MIROVA) algorithm (Coppola et al., 2016) and compared with MODIS-derived time-series. The results obtained show an excellent correlation between VRP values of VIIRS and MODIS and a comparable trend of the total energy radiated by the eruptions. Moreover, the results suggest better performances for VIIRS which can detect a larger number of thermal anomalies of low amplitude. These results confirm the great potential of VIIRS to complement MODIS data for volcano thermal monitoring, and possibly to replace them, in view of a future end of NASA's EOS missions (Terra and Aqua).

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The Holocene coastal morphoevolution of the Bay of Cádiz (Southern Spain): a standardized RSL database

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Keywords: relative sea-level change, database, coastal environments, GIA models, vertical ground movements.

The Bay of Cádiz is made of low-lying coasts that during the Holocene were affected by erosional and progradational episodes, with the development of subsequent beach ridge systems (Gracia et al., 2008; Alonso et al., 2015). The Bay has an average length and width of 30 and 15 km and it is mainly made of marshes, extending several kilometers inland and separated from the sea by sand barrier systems.

The aim of this study is to reconstruct the Holocene coastal morphoevolution of the Bay of Cádiz in terms of relative sea-level (RSL) variations and related vertical displacements (VDs).

The RSL oscillations were reconstructed by developing a comprehensive database of sea-level index and limiting points. This includes newly produced sea-level data from unpublished boreholes carried out in the Bay, coupled to previously available data (Dabrio et al., 2000; Arteaga et al., 2008; Alonso et al., 2015; Caporizzo et al., 2021) standardized according to the recent international guidelines for RSL studies (Khan et al., 2019).

The database was developed using a specific web-application composed of two main modules: a database where data are stored, and a server-side software for data management and visualization. Finally, the collected sea-level data were further compared with a number of new GIA sea-level curves specifically created for the Gulf of Cádiz in order to disentangle the different components which influenced the sea-level evolution.

Then, the local VDs were calculated using a Bayesian statistical approach by determining the differences between observed and predicted RSL elevations together with their rates.

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The Earth crustal structure inferred by 3D Bayesian gravity inversion and interpretation methods for regional and local applications

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Keywords: Earth crustal structure, gravity field, 3D Bayesian inversion, applied geophysics.

The indirect investigation of the Earth crust by the exploitation of gravity field data is commonly used nowadays because it is able to provide spread information about the mass density distribution both at global and regional/local scales. The study of the Earth crust structure is fundamental to understand the geological evolution and actual characteristics of the shallower part of our planet. The crust is also the place where all the natural resources we need for living came from (e.g. oil&gas, geothermal energy, water or minerals etc.) and for this reason a deep understanding of it is crucial for both scientific and industrial related activities (Fairhead, 2016). The recently developed high resolution combined global gravity field models are a valuable source of information which can be exploited to infer the crustal structure at regional or local scales. The principal issue related to the gravity inversion is due to the fact that solution suffers for not uniqueness (different structures generate the same observations) and numerical instability (small errors in the observations propagates in the solution) (Sampietro et al., 2012). To overcome these issues the inverse problem has to be regularized introducing as much constrains as possible in order to reduce the space of possible solutions. We propose an algorithm to perform a complete 3D gravity inversion based on a probabilistic approach that, starting from a given a-priori model and a set of geological and conceptual constrains (from the geophysical/geological knowledge of the area), is able to adjust both the densities and geometries in order to be coherent with the gravity observations (Marchetti et al., 2019). The basic idea is to discretize the volume of the investigated area into a set of rectangular prisms, each one characterized by two random variables, namely r_i and L_i, representing the density and a categorical variable defining the geological material respectively. The algorithm by means of iterative approach, changes r_i and L_i of each voxel to fit the gravity. This inversion approach has been tested on various real case scenario from scientific research in the Antarctica continent to geophysical exploration activities in the Central Eastern Mediterranean Sea area and the results will be here briefly summarized.

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May FT-IR spectroscopy detect the presence of microplastics inside matrices with different mineralogical species as the river sediments?

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Keywords: microplastics, sediment properties, river sediments, FT-IR.

Microplastics (MPs), the tiny plastic debris which is smaller than 5mm in size, have recently been documented as emerging dangerous contaminants. They present in every type of environment worldwide, from water to sediments, from urban to remote areas, and from continent to the ocean. Microplastic impacts have also been well identified in many environments including air, soil, ocean and freshwater. Among them, MPs in the water environment have raised major concern in the scientific community due to their significant potential threat to the aquatic ecosystems and human health. Microplastics are essentially produced by the gradual degradation of synthetic polymers, such as polyethylene and polypropene, as a result of prolonged exposure to ultraviolet radiation and mechanical abrasion. Microplastics enter aquatic systems in more than one ways. Polyethylene, polypropylene, and polystyrene particles in cleaning and cosmetic products enter aquatic systems via domestic wastewater discharge. Microplastics from inland factory spills reach the beaches through primary routes such as rivers and streams. Abundance of microplastics in lakes, rivers, estuaries and beaches around the world have been documented in areas of high population density or areas with intense human activity. A variety of factors can affect the amount of microplastics present in the environment. These include human population density proximal to the water body, proximity to urban centers, proximity to major river inflows, precipitation events, surface movements of water currents, water residence time, body size water, type of waste management, amount of excess wastewater and atmospheric deposits. This study focuses on the identification of possible microplastics in a geological matrix, in particular river sediments. The method of analysis used to characterize river sediments and differentiate any microplastics present in them is FT-IR spectroscopy. The interpretation of the absorption bands allows to define the main minerals that make up the sediments and to determine the presence and type of microplastics, as plastic polymers are characterized by bands that are very distinct from those of minerals and by limited overlaps.

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Quartz c-axis fabric and kinematic vorticity analysis of the Main Central Thrust Zone and of the Lower Greater Himalayan Sequence in the Annapurna Range (central-western Nepal)

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Keywords: quartz c-axis fabric, kinematic vorticity analysis, meso and microstructural analysis, Himalayan Chain.

In the Annapurna Range (central-western Nepal) the metamorphic core of the Himalayan Chain, the Greater Himalayan Sequence (GHS), crops out. It is located between the low-grade rocks of the Tethyan Sedimentary Sequence (THS) to the north and the medium- to low-grade rocks of the Lesser Himalayan Sequence (LHS) to the south. The GHS is separated from the THS by the South Tibetan Detachment System (STDS) with normal kinematic and from the LHS by the Main Central Thrust Zone (MCTZ) with reverse kinematic. In the Modi Khola area other intra-GHS discontinuities are present. From top to bottom: the Modi Khola Shear Zone (MKSZ), the Sinuwa Thrust (ST), the Bhanuwa Fault (BT). In the MKSZ kinematic indicators at the mesoscale, pointing a top-to-the-S sense of shear, are present. The ST and the BT, previously recognized thanks to petrochronology, have a debated kinematics. Meso and microscale observations revealed, for the ST, top-to-the-S kinematic indicators. Furthermore, the asymmetry of the quartz c-axis fabric from a sample collected close to the BT, support a top-to-the-S thrust-sense kinematics. Quartz fabric analysis was also performed on three samples collected within the MCTZ. The asymmetry of the pole figures indicates a top-to-the-S sense of shear. The quartz fabric opening angle thermometer revealed deformation temperatures of ~525-618°C for the MCTZ and of ~635°C for the Lower GHS.

Deformation regime was characterized by kinematic vorticity analysis (stable porphyroclasts method) on two samples from the MCTZ and one from the Lower GHS. The obtained results show the presence of a non-coaxial flow with an important of the pure shear component (60-65%). Field mapping combined with mesoscale analysis, detailed microstructural and petrographic description, allowed to produce an updated geological map of the study area and a precise description of the tectonic discontinuities. Combining the results with previous literature data, it was possible to advance a tectono-kinematic model for the exhumation of the GHS. The ST, the BT and the MCTZ are active at different times and at progressively lower structural levels. This is consistent with the in-sequence shearing model documented for other sectors of the Chain (Montomoli et al. 2015; Iaccarino et al., 2017; Carosi et al., 2018).

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Sr-Nd isotopic features of the Cenozoic "subduction-related" igneous rocks from Sardinia (Italy)

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Keywords: isotopic ratio, subduction-related magmatism, Sardinia.

During the Late Eocene-Middle Miocene (38-12 Ma), an igneous magmatic cycle with calcalkaline affinity took place in Western Sardinia. This cycle was partly coeval with A) the separation of the Sardinia-Corsica microplate from Europe; B) the counter-clockwise rotation of the microplate; C) the opening of the Ligurian-Provençal back-arc basin. All of that caused also the formation of the Sardinian Rift (30-15 Ma). The peak of volcanic activity matches the maximum rotation rate (21-18 Ma) (Lustrino et al., 2009 and ref. therein). The rocks of this magmatic cycle range from calcalkaline basalts (HMB) to dacites, with more evolved rocks in the northern sectors; the mantle normalized patterns of the mafic rocks from all the districts are indistinguishable from those typical of the orogenic suites. The Mg-rich basalts of Montresta represent the most primitive magma of all the province, with the highest $^{143}Nd/^{144}Nd$ (0.5127) and the lowest $^{87}Sr/^{86}Sr$ (~0.704) values. The Monastir basaltic andesite dike has $^{87}Sr/^{86}Sr$ value (~0.704) similar to those of the Montresta HMBs.

The variations of $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ (0.704-0.711 and 0.5122-0.5126 respectively) and the positive correlation between SiO_2 wt.% and $^{87}Sr/^{86}Sr$ of the Sardinian volcanic rocks indicate significant open-system fractional crystallization (AFC). It is possible to calculate the ratio between the assimilation and crystallization velocities (r) for each district using the isotopic ratios. The degree of lower crust (Franciosi et al. 2003 and references therein) assimilation is variable: the Arcuentu magmas suffered the strongest contamination with r=0.3-0.5, the Siliqua ones show lower r values (0-0.3). The high amount of contamination required for the Arcuentu basalt/andesite transition is noteworthy considering their relatively restricted range of evolution.

The source of these basalts is an incompatible element-depleted source very slightly enriched by fluids coming from subducted Tethys oceanic lithosphere and sediments (Franciosi et al. 2003).

The rather limited mantle heterogeneity beneath Sardinia is at odds with the highly variable extent of fractional crystallization and crustal contamination evident even in contiguous districts (e.g., Cixerri, Siliqua and Arcuentu), pointing to a strong lithological heterogeneity of the crystalline basement of Sardinia.

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New insights from the Rocca Canavese Thrust Sheet Unit (Sesia-Lanzo Zone, Western Alps, Italy): peculiar lithological associations support the hypothesis of an oceanic pertinence

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Keywords: Rocca Canavese Thrust Sheet Unit, Sesia-Lanzo Zone, Western Alps, Omphacite veins, metarodingite.

The Rocca Canavese Thrust Sheet Unit (RCT; Pognante, 1989), located in the inner sector of the Sesia-Lanzo Zone in the Western Alps, represents a captivating example of a basement whose genesis has remained debated for years. Despite the RCT has been associated with a subducted-related mélange, relying on the presence of two different metamorphic peaks (Roda et al., 2018; 2019), there are still many open questions. This unit includes serpentinite and mafic rocks (glaucophanite and metagabbro) associated with a metasedimentary cover, i.e. lithological associations that are uncommon for a zone typically described as a continental crust. This work aims to analyze the main lithologies and the peculiar rocks never described before, and their field relationships. Serpentinite crops out mainly in the westernmost part of the unit and embeds plurimetric metagabbro bodies and pluricentimetric metarodingite dikes. Metasediments crop out in stratigraphic contact, although remobilized, with both glaucophanite and serpentinite and show strong outcrop-scale primary compositional variations from pelitic/felsic (micaschist and gneiss) to mafic (Wm-rich glaucophanite). Ortho-derived glaucophanite has been distinguished from the metasedimentary one basing on the absence of Wm and Cb. Omp + Chl + Ep s.s. veins occur in metagabbro only nearby or in contact with serpentinite. These mineral occurrences and the metarodingite dikes could be interpreted as metasomatic reactions during subduction. The observed assemblages and the related microstructures point to a metamorphic evolution common to the distinguished lithologies, characterized by a prograde Lws-blueschist facies event, an eclogite-facies peak followed by Ep-blueschist facies requilibration and subsequently, two greenschist-facies retrograde events. Based on the observed relationships between the distinguished lithologies and on their common evolution occurred during subduction and exhumation, the RCT could represent a preserved portion of an oceanic lithosphere with its related sedimentary cover. Our hypotheses could stimulate further investigations also on RCT relationship with the neighboring units (e.g. Lanzo Massif), which is still unknown and needs further constraints to be placed in the currently available paleogeographical models.

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Paleoenvironmental reconstruction in the highly polluted Bagnoli-Coroglio SIN (Site of National Interest): towards inferring paleo-ecological quality status and reference conditions using morphological and molecular benthic foraminiferal data

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Keywords: paleoenvironmental assessment, Bagnoli, foraminifera, bioindicators.

Benthic foraminifera have been widely used as bioindicators in environmental biomonitoring and more recently to define the ecological quality status (EcoQS) of marine areas. The morphology-based approach has been implemented by the application of the eDNA metabarcoding technique. The Bagnoli-Coroglio area (Southern Italy) was identified as a Site of National Interest since its high degree of contamination of soils and sea sediments nearby the dismissed steel plant. In this study, we reconstruct the paleoenvironmental conditions and the paleoEcoQS of the Bagnoli coastal area from the XIX century based on the analysis of benthic foraminifera along a sediment core. The analysed portion of the core dated back the 1825, which represents the *in situ* reference conditions (i.e., pre-industrialization). The sedimentological and chemical analyses of the core allow us to identify critical changes in the geochemistry of the Gulf of Pozzuoli. A marked increase in Polycyclic Aromatic Hydrocarbons and trace metals (i.e., Hg, Pb, Zn) concentrations is found from 1915, when the intensive industrial activities started in Bagnoli area. Since then, the pollution level has increased till the late '70s, when the plant operations reduced their magnitude. The effects of the anthropogenic impact (environmental stress: chemical contamination and coastal morphological interventions) on the aquatic ecosystem are reflected in the modifications of benthic foraminiferal assemblages over years. The historical trends of benthic foraminifera for both morphological and molecular datasets show congruent results. Foraminiferal changes (in terms of diversity and faunal turnover) permit to identify an industrial phase (1915-2000) characterized by the deterioration of the Paleo-EcoQS. After the industrial dismission, better paleo-EcoQS, testify a tendency towards an environmental recovery over the last 20 years, Our paleoenvironmental study provides important information about how the disturbance caused by the industrial activity in Bagnoli area deeply affected the aquatic communities (i.e., foraminiferal morphospecies and MOTUs) during the last century, also defining the ecological background conditions (i.e. the reference conditions) of Pozzuoli Gulf prior the start of the industrialization process of the area.

The impact of geodiversity on the value of agricultural products: a case study of the "Mela Rotella della Lunigana" and the "Moscatello di Taggia" (Italy)

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Keywords: **s**oil, ecosystem services, environmental, mineralogical, geological, economic approach.

Sustainable land use is currently one of the underlying themes of world policies (ONU, 2015). Soil is a non-renewable fundamental resource capable of providing goods and essential ecosystem services for human life that should be maintained by satisfying the needs of current generations without compromising those of future generations (WCED, 1987). About 95% of food products come directly or indirectly from the soil (FAO, 2015) and often, when purchased, they do not incorporate the cost of the exploited environmental good in the price (Turner et al., 1993).

In this work, an apple orchards ("Mela Rotella della Lunigiana"; Fivizzano, Massa Carrara) and a vineyards ("Moscatello di Taggia"; Ceriana-Terzorio, Imperia) were investigated using a multidisciplinary geological and economic approach.

In addition to the agronomic parameters, the agricultural soils were investigated to determine, geochemistry, lithology and mineralogy by means of *in situ* and laboratory analyses (Field Portable-EDXRF, Polarized-Light Optical Microscopy, Scanning Electron Microscopy and Microanalysis, X-ray Diffaction). The results allowed to determine the peculiar geo-pedological features that could represent the geological fingerprint of high-quality agricultural goods linking the product to its territory of origin and making it not delocalizable.

Since the results obtained are environmental goods and, therefore, not directly consumable and without market price, in order to calculate the total utility of the good, it is splitted down into different characteristics (called attributes) to which the consumer can attribute one or more utilities (Lancaster, 1966).

The economic approach (in collaboration with the Department of Economics of University of Genova) involved the creation of a questionnaire in which the different characteristics of the soils were separated using an experimental method (choice experiment). The results were statistically analyzed using the STATA's software.

The final purpose of the work was to combine the geological and economic results in order to determine the willingness to pay for agricultural products which have intrinsic value in terms of territorial uniqueness and to make consumers more aware of the purchase of goods. Moreover, the uniqueness of geological and geographical settings might represent an important tool for territorial marketing and to promote high quality agricultural products.

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Greenhouse Gases emissions in natural coastal wetlands: variations along a salinity gradient in the Adriatic Coast

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Keywords: coastal wetlands, GHG, salinity, methane.

Coastal wetlands provide highly valuable ecosystem services, and they are among the most productive ecosystems, storing 10 times more carbon (C) than temperate forests in the above- and below-ground biomass and in soils. These blue carbon sinks, play a crucial role in the global carbon sequestration and in mitigating climate changes. Nonetheless, coastal wetlands are suffering from degradation and challenges posed by global warming, sea level rise and increased extreme events, which may cause their shift from carbon sinks to net sources (Erwin, 2009). Such shift is mainly related to the balance between the amounts of carbon that these systems store every year with respect to the amount of greenhouse gases (GHGs) emitted due to organic matter degradation.

Methane (CH_4), a potent GHG, can be formed in the sediments of freshwater wetlands. However, it is known that wetlands exposed to high concentrations of sulphate (an anion present in seawater) emit methane at relatively low rates. In fact, the presence of sulphate in coastal wetlands soils allows sulphate-reducing bacteria to outcompete methanogens for energy sources, inhibiting methane production. Despite the importance of this process, there is still a limited knowledge on specific salinity or sulphate concentrations above which coastal wetlands emissions are negligible (Poffenbarger et al., 2011). Moreover, most studies focus on tropical or subtropical wetlands, leaving a knowledge gap on the behaviour of temperate coastal wetlands.

Our study takes place in a relatively small area with the presence of five natural wetlands with different salinities, along the north-east Italian coast. They are part of a larger European Union protected SCI/SPA area, characterized by a high biodiversity. This area is affected by land subsidence and ongoing processes of saltwater intrusion in the aquifer (Giambastiani et al., 2021). Here the salinization in soils is influenced by the thermo-pluviometric regime, and depth and salinity of the water table (Buscaroli & Zannoni, 2017).

The high variability of salinity within relatively small distances between sites gives us the perfect setup for monitoring fluxes of GHG gases along salinity gradients. CH_4, and CO_2 fluxes have been monthly assessed (April 2021-ongoing) in low-level waters and soils by a static accumulation chamber along with surface and ground water physical-chemical parameters (Eh, T, pH, EC, ions determination) and soil properties (organic matter, bulk density, granulometry). By this, we expect to assess which variable influence methanogenesis the most, and the potential influence of temperature and salinity as driving factors in shifting wetlands from sinks to sources of C.

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The response of the Apula plate to the advancing Calabrian and Hellenic wedges (Northern Ionian Sea): implications for subduction processes and tectono-stratigraphic evolution

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Keywords: Northern Ionian Sea, Calabrian Accretionary Wedge, Hellenic Wedge, Apulian foreland, transpressive tectonics.

In the Northern Ionian Sea, the Calabrian Accretionary Wedge (CAW) is facing directly the subducting Apula plate, mainly made of Mesozoic to Tertiary Carbonate Platform (Del Ben et al., 2010; Volpi et al., 2017). This contribution illuminates the structures and stratigraphic relationships between the frontal part of the orogenic belt, the foredeep and adjacent Apulian foreland. A detailed seismic facies analysis of four multichannel seismic profiles has been carried out to define the tectonic-sedimentary evolution of the study area but without exploration wells not available for these deep offshore area. Seismic interpretation allows us to identify four main structural domains: the highly tectonized CAW; the narrow foredeep basin filled by a Pliocene-Holocene subhorizontal succession laying above buried normal faults; the massive carbonate succession of the Apulian Platform showing reef and carbonate platform margin facies; the layered succession of the Apulian Platform characterized by ‘‘intra-platform’’ facies in the easternmost portion of the area. Three main regional unconformities with characteristic relationships with structural trends are recognized: i) the Messinian unconformity, related to a regional and significant erosion associated to paleokarst processes on the exposed Mesozoic Apulian Platform, is cut by an array of normal faults in the Apulian foreland and by thrust in the accretionary wedge; ii) the angular and erosive middle Pliocene Unconformity truncates the Lower Pliocene reflectors and is affected by normal faults in the foreland and by compressive tectonics in the CAW; iii) a Jurassic/Cretaceous unconformity in the Apulian foreland is marked by Cretaceous reflectors clearly onlapping the Jurassic carbonate platform. The CAW is characterized by compressive tectonics with several fore-thrusts forming a leading imbricate fan system near the orogenic front. The Mesozoic Apulian platform is affected by active extensional tectonics driven by flexural bending since Lower Pliocene (Argnani et al., 2001; Volpi et al., 2017; Maesano et al., 2020), that probably reactivated old normal faults related to the Permian-Triassic rifting stage. The structural map shows that transpressive and positive inversion tectonics is a common deformational style in the central sector of the foreland, suggesting that the Apulia plate is already part of the Calabrian/Hellenic belt. According to these observations, the compressive tectonics affecting the Apula plate is interpreted as related to shortening processes of both the CAW and Hellenic wedge whose interference plays an important role in defining the tectonic-stratigraphic evolution of the Apula Plate in the Northern Ionian Sea.

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Early Pleistocene chert artefacts from Pirro Nord site (Apulian region, Southern Italy)

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Keywords: chert, petrographic analysis, early European peopling, Pirro Nord, Pleistocene.

Pirro Nord in Southern Italy (Apricena, Apulia) represents the oldest occurrence of hominins in the Italian peninsula and even among the earliest records of European peopling (Arzarello, 2018). Palaeontological remains and related anthropic activities emplaced in fissures of the Pleistocene karst system opened at the top of a Mesozoic limestone formation, nowadays quarried as building stone (Arzarello et al. 2007; Arzarello & Peretto, 2010). Random distribution and post-depositional characteristics of both archaeological and faunal assemblages show that these materials were transported into the fissure probably by a chaotic process, such as mudflow or earthflow, and are not in primary deposition (Giusti & Arzarello, 2016; Cheheb et al., 2019; Berruti & Arzarello, 2020). Thanks to numerous faunal remains, that are representative of the late Villafranchian Mammal Age, the site has been biochronologically dated to 1.6-1.3 Ma.

The lithic assemblage, consisting of more than 400 artefacts, shows technological features that well fit the patterns observed in contemporaneous European and African Mode 1 sites. The lithic technology was essentially opportunistic, characterised by short reduction sequences and influenced by raw material morphologies. Hominins at Pirro Nord exploited chert cobbles and pebbles with different morphologies and sizes. From a first descriptive analysis, four main types of chert coming from the Gargano Cretaceous succession have been identified: brown oolitich flint, grey homogeneous flint, grey bedded flint, and a black flint with several inner fractures of tectonic origin. It has been suggested that these raw materials were collected in a secondary position (riverbeds or slope deposits) no more than 7 km from the P13 fissure (Arzarello et al., 2015).

This work aims to further investigate the characteristics of the different types of chert identified at Pirro Nord by using macroscopic, microscopic, and geochemical analyses. The results will allow to trace back the geological sources of these raw materials and try reconstructing the events that made them available to the hominins in the Early Pleistocene.

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Rockfall hazard assessment by means of integrated geomorphological analysis, heuristic-statistical landslide susceptibility, and numerical modeling: a case study from Celano Gorges (Abruzzo Region, Central Italy)

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Keywords: rockfalls, heuristic-statistical approach, susceptibility, hazard, numerical modeling.

Rockfalls are one of the main natural hazards in mountainous environments. In this context, Celano Gorges (Abruzzo Region, Central Italy) are a significant test site for rockfall analysis given the number of landslide events that occurred in recent times, likely concomitantly with seismic events. In this work, a mixed heuristic-statistical approach was adopted to define rockfall susceptibility and associated hazard degrees. A geomorphological survey was conducted to investigate lithological features and geomorphological landforms. It was integrated with geomechanical investigations to evaluate the fracturation degree of outcropping lithologies as well as the dimension of fallen blocks (I.S.R.M., 1978). A kinematic stability analysis was also executed based on the Markland test (Markland, 1972). This approach led to the identification of different rockfall-triggering parameters: slope, aspect, topographic curvature, presence of scarps, vegetation cover, lithology, degree of rock fracturing, karst incidence, distance from active faults, and distance from earthquake epicenters. These factors were evaluated by assigning appropriate expert-based weight accounting for their influence on slope instability. A data mining consisting of cluster analysis and a critical evaluation of detected parameters was performed to better delineate susceptibility classes. Subsequently, numerical modeling was performed by means of the software Rockyfor3D (Dorren, 2016). Detachment, transit, and accumulation areas were detected, and thematic maps were created depicting the number of passages and deposited blocks (Calista et al., 2020). Based on these results as well as on geomorphological features, a hazard matrix was created defining landslide hazard classes (Carabella et al., 2019). In conclusion, this integrated approach allowed us to realize a new zonation of rockfall hazard, which can be used in territorial planning and civil protection activities in mountainous environments.

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Incision history and emplacement dynamics of alkaline lava flows in the Western Meseta (Morocco)

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Keywords: Western Maroccan Meseta, uplift evolution, river incision.

Topographic (relict) surfaces provide information to constrain landscape evolution and to quantify fluvial incision and surface uplift. The Western Meseta (Morocco) represents a deeply dissected, uplifted region, at an elevation of more than 1000 m, characterized by a regional post-Cretaceous erosional surface and widespread late Miocene-Quaternary alkaline volcanism. This large-scale uplift is clearly documented by the occurrence of uplifted shallow-water marine deposits in the adjacent Middle Atlas Mountains and appears to be triggered by mantle-driven processes (dynamic uplift) associated with tectonic shortening. Conversely, the Western Meseta does not have any stratigraphic records that may allow deciphering this uplift history and does not display any evidence of Cenozoic tectonic activity. There, however, the presence of a transient state of river networks, of multiple phases of river incision across this regional erosional surface and of Quaternary lava flows, offers the opportunity to characterize the recent uplift history. In this study, we combine quantitative geomorphic analysis of topography and stream profiles with rheological modelling of lava flows emplacement to decipher the landscape evolution and incision history of the Western Meseta. Particularly, we use an empirical viscosity model to infer lava flow emplacement dynamics. The long- and short-term incision and pre- and post-emplacement surface gradients from the deeply incised valleys of the high-standing relict landscape and the Quaternary lavas provide important evidence for the late Cenozoic uplift. The inferred uplift rates from the high-standing relict landscape match the short-term rates obtained from lava incision and range between 100 and 150 m/Myr, suggesting constant rates since the late Miocene. However, in the Western Meseta fluvial incision is lower than the average long-term surface uplift rates of the Middle Atlas Mountains (170 - 220 m/ Myr). This discrepancy reflects different uplifted mechanisms (tectonic shortening vs dynamic uplift) that controlled the topographic resurgence of the Western Meseta and the Middle Atlas.

Background contaminants values in groundwater: methodological analysis in the case studies of Turin and Biella plains (NW Italy)

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Keywords: background values**,** diffuse pollution**,** chlorinated solvents**,** nickel.

Background Values (BVs) of diffuse pollutants in groundwater are a very important information to the correct comprehension of contaminant phenomena and constitute an operative tool for local authorities (Tedd et al., 2017).

In the European context, the BRIDGE methodology (Muller et al., 2006) has established a basic Community guide applicable in the various European countries, according to the level of knowledge.

The aim of the study was to highlight the criticalities of the SNPA (Sistema Nazionale per la Protezione dell'Ambiente) BVs determination methodology (SNPA, 2018) in the Piedmont plain shallow aquifer considering different chemical parameters.

More specifically, chlorinated solvents and nickel were considered at a local scale (two study areas in Biella and Turin provinces) and at a provincial scale (Metropolitan City of Turin).

Following the SNPA method, the conceptual model was built considering geological data, contaminants and contamination characterization. Then, a statistical procedure was applied for each area by imposing different conditions such as the subdivision of the area and the dataset. The concentrations data of the chemicals are derived from the Regional Monitoring network (RMRAS) for the Metropolitan City of Turin and from local analyzes of Agenzia Regionale per la Protezione Ambientale (ARPA Piemonte) in the two local sites.

The study highlighted numerous relevant criticalities.

The utilized SNPA method was resulted not exhaustive due to the non-attendance of specific indications on various contaminants. Moreover, the "statistical informations" provided were resulted sometimes incomplete and inapplicable.

The use of the RMRAS monitoring points was resulted inappropriate to define BVs in groundwater due to the low density of monitoring wells.

On the contrary, the analyzes in the local study areas made it possible to understand and characterize correctly numerous specific aspects, recognizing the diffuse pollution and identifying new potential punctual contamination despite the complex situation linked to historical and current contaminations.

In conclusion, the study made it possible to define the BVs in groundwater at a local scale and to propose possible improvements of analysis methodology.

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Eclogitic metamorphism in the Alpine far-west: new petrological constraints

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Keywords: Western Alps, tectono-metamorphic evolution, phase equilibria mdelling, P-T pseudosection.

The Alpine chain consists of tectonic units ascribed to different sectors of the collisional continental paleomargins (either Adriatic or European) and of their interposed oceanic domain (Ligurian-Piedmont ocean). These units recorded different tectono-metamorphic evolutions during the orogenic history of the Alps, with the axial sector of the Western Alps characterized by several continental and oceanic units recording eclogite- and blueschist-facies metamorphic peaks. In particular, the study of the lithostratigraphy and evolution of these HP metamorphic units and their distribution/transition in the Alpine collisional belt is fundamental in order to define large-scale tectonic processes driving subduction and exhumation, as well as to reconstruct the pre-collisional Alpine paleogeographic setting.

In order to give contributions to these latter points, the Susa and Chisone valleys (Cottian Alps) offer useful geological sections to be investigated. In these areas, an eastward increase of the alpine metamorphic peak conditions has been notably observed (e.g. Agard, 2021; Beltrando et al., 2010, for a review). At the uppermost structural levels of the tectonic pile, subgreenschist-facies conditions characterize the ophiolitic Chenaillet massif. Then, moving to the east, lawsonite- and epidote-blueschist facies conditions are recorded by the widespread oceanic Albergian and Cerogne-Ciantiplagna units, in turn resting on the eclogite-facies Orsiera-Rocciavré unit and Dora-Maira crystalline massif.

Exposed in the core of the blueschist-facies oceanic units, the small Banchetta-Rognosa tectonic unit is made of both continental and oceanic successions (Corno et al., 2019, 2021). New and original data supported by thermodynamic modelling allow to define for this unit a metamorphic peak typical of eclogite-facies conditions, hence higher than previously believed and higher than those registered in the neighbouring units. In detail, the results of phase equilibria modeling point to a metamorphic peak of 20-23 kbar and 450-520 °C, consistent among different lithologies of the continental succession. These data allow to extend westward the eclogite-facies metamorphism in this sector of the Alpine axial sector, and to postulate a more complex juxtaposition of units with different metamorphic peaks.

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On the applicability of a basin scale soil erosion model to pre-Alpine scenarios

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Keywords: sediment yield modeling, erosion modeling, geohazard, flood risk, depth-integrated models.

Smart cities improve quality of life by implementing sustainable strategies via advanced technology and innovation. According to the European Union and to the scientific community, the formulation of effective methods to deal with climate changes is one of the most important topics of research and technology. Hydrogeological instability is certainly among the effects of climate change with major impact on people and built environments security. Therefore, the development of tools able to predict extreme events is of great importance. In more detail, cities located downstream of mountain catchments are exposed to specific flood risks, in which sediment transport plays a significant role.

Soil erosion models are then important instruments for the identification of hazardous areas and risk management.

This work stems out from the above considerations and focuses on landslide and flood risk, providing an efficient simulation tool able to help institutions during the decision-making process, SMART SED (Gatti et al., 2021). Our model tries to overcome the limitations coming from simulation tools already available in literature, as the wide range of calibration parameters required and the a-priori identification of the riverbed. SMART-SED is implemented with a simple recasting of the classical SCS-CN model by means of rates in order to deal with multi-event simulations. The soil composition at catchment scale is assigned by a preprocessor tool (Gatti et al., 2020) that is able to downscale soil maps up to a desired resolution starting from coarser satellite data or from punctual data collected during geological surveys. Furthermore, the automatic identification of the wet or dry areas of the catchment was developed considering appropriate depth integrated models capable to simulate runout processes, to deal with dry regions and, at the same time, to ensure mass conservation. To face potential lake formations during flood events, SMART-SED solves the superficial runout dynamics via a semi-implicit finite-volume finite-difference classical numerical method. This numerical framework enables larger time steps compared to the classical finite-volume explicit schemes while guaranteeing full mass conservation.

The proposed model was tested on two catchments located in the Southern Alps, near the city of Lecco (Italy). Results were then compared to the ones gained from other classical tools already available in literature, as openLISEM. Another geo-hydrological tool, CRHYME, was tested on the same catchments for sensitivity analysis and validation. This model is based on Python script language and it was inspired by the PCRaster GLOBWB 2.0 model. CRHYME has the peculiarity of considering shallow landslide and erosion processes.

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Gatti F., Bonaventura L., Menafoglio A., Papini M., & Longoni L. (2021) - Preliminary Results from the SMART-SED Basin Scale Sediment Yield Model. In Workshop on World Landslide Forum. Springer, Cham, 241-248.

A multidisciplinary approach to unravel the rocks heterogeneities: link between deformation and metamorphic processes from lithospheric crust

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Keywords: Western Alps, rheological contrast, P-T-t-D-X path, fluid-rock interaction, heterogeneities rock pairings.

Lithosphere deformation involves a complex interplay between deformed rock, metamorphic reactions, and fluid flow. It has long been accepted that deformation and metamorphism are closely interlinked but quantifying these mechanisms and the consequent effect of tectonic deformation on the metamorphic processes is still debatable.

Notably, the interface between rocks with different chemical composition and rheology may be the site for intense and anomalous deformation, metamorphic and metasomatic processes (e.g., Schmalholz et al., 2020). Examples of such heterogeneous pairings are: (ultra)mafic rocks-metasediments, quartz-rich rocks-micaschist, orthogneiss-micaschist, metacarbonate-micaschists that occur both at the lens and at a regional scale.

The present project explores the link between metamorphism and deformation focusing on two major case studies located in the Alpine chain and representative of heterogeneous metamorphic associated rocks of diverse composition formed under different regional tectonic regime (compressive and extensional): the Cima di Gagnone from the Lepontine dome and the Ivrea-Verbano Zone. While the Cima di Gagnone area consists of metasediments enclosing lenses of (ultra)mafic rocks, the Ivrea-Verbano Zone represents a thinned continental crust were extensional shear zones developed mainly at the boundary between ultramafic/mafic rocks and felsic granulites.

In order to shed light on the geochemical and petrological processes (*P-T-t-D-X* path) occurring at the boundary of rocks with extremely different chemical composition, we use a multidisciplinary approach combining (micro)structural (SEM-EBSD), geochemical (EMPA and LA-ICP-MS), and petrological analyses (geothermobarometry, P-T-X pseudosections) with geochronological investigation (LA-ICP-MS; U-Th-Pb).

Our results indicate that in both case studies, the interface between rocks with high viscosity contrast are the preferential loci for deformation development, fluid flow and geochemical exchanges (Corvò et al., 2021). The final goal is to provide key information to interpret the tectonic evolution of the studied rocks.

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Alkaline Activation of Natural Pozzolans: Chemo-Physical Evolution

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Keywords: Alkali-Activated Binders, natural pozzolans, Multi-scale Analysis.

Over the years, a considerable interest has developed in sustainable construction and production of alternative materials to those normally used. The reason for this interest lies in the fact that, despite to traditional binders, such as lime and cement, provide excellent performances and adapt to different applications, their production is undoubtedly responsible for huge rates of CO_2 emissions into the atmosphere, due to high temperatures of processing. To overcome this problem, in the last decades non-traditional binders have been studied and designed such as those produced by Alkaline Activation which represent a group of cement-like materials formed by reacting silica-rich and alumina-rich solids with a solution of alkali salts, resulting in a mixture of gels and crystalline compounds that eventually harden into a new strong matrix (Verdolotti et al., 2008). The activation process of these materials not only takes place cold, therefore it is considered a Zero Impact effect, but uses waste materials therefore it represents an eco-sustainable production that favors the Circular Economy. The use of non-traditional binders in the geotechnical applications has an innovative character and is considered a very interesting topic as it could allow a real transition to materials that have a lower environmental impact. However, it is good to bear in mind that activation from aluminosilicate powders is a complex condition to complete, as multiple factors can affect the chemical reactions that characterize this process. Therefore, the primary aim of this study is to examine the factors that regulate the alkaline activation process of natural pozzolans and to understand how each of these can influence, in qualitative and quantitative terms, the dynamics of the kinetic reactions produced. Although, the chemical reactions during the experimentation, is different from a pozzolan to another, it is still possible to find common or "standard" dynamics through a statistical study of the processes described in the literature and confirmed by the observation of the chemo-physical evolution of some natural Pozzolans, such as two volcanic ashes from the Mount Etna and different types of Phlegrean Fields Pozzolans, that were studied. Moreover, thanks to the wide spectrum of analytical techniques used in the study of these binders, and to which the literature refers, is possible to provide a vision of the process at different observation scales: from that of the solid particle to that of the volume element. The approach adopted is of a multidisciplinary type, as the above investigations focus attention not only on the microstructure and basic mineralogy of natural pozzolans, but also on their geochemical component and on physical capabilities, highlighting the geotechnical characteristics and any cementitious properties.

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The end-moraine system of the Pleistocene Moletta glacier (Susa Valley, NW Italy)

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Keywords: end-moraine system, glacigenic deposits, Lateglacial, Western Alps, Susa Valley.

A geological survey was carried out on the left side of the middle Susa Valley north of Bussoleno (NW Italy), with the aim of study the relationship between the tributary Moletta Glacier and the main Dora Riparia Glacier in the Last Glaciation.

The Moletta catchment is a 5,8 km² wide tributary south-facing valley, with maximum elevation of 2963 m a.s.l. (M. Palon - Rocciamelone Group).

It consists of oceanic crust made of serpentinite and prasinite (Piemontese Zone), oucropping in the upper sector of the valley and tectonically overlying (cargneule) on a continental crust made of paragneiss, micaschist and dolomite marble (Dora Maira Massif) outcropping in the lower sector (Cadoppi et al., 2002). The bedrock, with a diffuse subglacial abrasion shaping, is covered by Lateglacial (19-11.7 ka BP) glacigenic deposits (lodgement till, subglacial melt-out till, ice-marginal flow till, glacio-lacustrine and glacio-fluvial deposits) and by post-glacial gravitative deposits (talus debris and colluvial). The Bussoleno village is located on the T. Moletta alluvial fan which extends downvalley in the trunk valley floor.

Thick bodies of well stratified ice-marginal glacio-lacustrine gravelly sand, scattered on the trunk valley side, rest above the subglacial till and are referred mainly to the trunk glacier. Some geomorphological elements have been found on the valley side at the edges of the lower T. Moletta incision (a latero-frontal moraine ending at the valley side-valley floor border; N-S trending glacial-striae on roche moutonnée) and in the apex sector of the T. Moletta alluvial fan (a set of transversal scarps not due to river erosion; a cluster of 1-2 long serpentinite blocks; a big serpentinite erratic boulder). These elements are interpreted as the remnants of an end-moraine system largely buried under the alluvial fan deposits and referred to the Moletta Glacier.

This reconstruction attests that the Moletta Glacier joined the Dora Riparia Glacier during the Last Glacial Maximum and reached the main valley floor in the Lateglacial. A greater expansion of the tributary glacier is therefore recognized and reported on a new geological map compared to the previous extent reported in the Susa Sheet of the Geological Map of Italy (Cadoppi et al., 2002).

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ArcStereoNet: an ArcGIS® Python toolbox to analyse and plot 2D and 3D structural data

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Keywords: stereoplots, ArcGIS®, Python, rose diagrams.

ArcStereoNet (ASN - Ortolano et al., 2021) is a new ArcGIS® toolbox for 2D and 3D oriented data analysis and projection, entirely coded with Python 2.7 programming language. It merges the ArcGIS® built-in functionalities of georeferenced data storing and managing with the plotting algorithms of the mplstereonet Python package (Kington, 2016). This allows ASN users to semi-automatically draw stereographic projections and rose diagrams, and to link them to the geographic location of the processed data without ever leaving the ArcGIS® environment. This, in turn, is helpful to join or subdivide groups of structural stations with a simple selection procedure. Moreover, ASN includes the possibility of easily applying and comparing most of the common statistical methods for cluster and girdle analysis of data, such as Fisher (Fisher et al., 1993), K-means (MacQueen, 1967) and Bingham (Bingham, 1974) algorithms. Furthermore, a completely new algorithm for cluster analysis and mean vector extraction (i.e., M.E.A.D. - Mean Extractor from Azimuthal Data) was developed, enabling a greater background noise reduction through user-defined parameters, and a greater user awareness and control of the algorithm behaviour. Finally, the ASN applications are not only restricted to classic meso-structural data (e.g., bedding, lineations, fold axes, faults etc.), but can also include the analysis of oriented micro-structural data from rocks' fabric, obtainable by vectorization of minerals in thin section with image analysis techniques (e.g., Micro-Fabric Analyzer - Visalli et al., 2021), and potentially can be extended to any type of oriented data.

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The archaeometric study of pottery production from Sudan

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Keywords: pottery, archaeometry, petrographic analysis, Gash Delta, Sudan.

History has recorded, through the remains of the civilizations of the territory between and around Atbara e Gash rivers (Sudan), the events that testify to the presence of different sites and, probably, a developed trading network in this territory (Fattovich et al., 1988). Nowadays its extension and internal dynamics, during the time, are partially outlined, but can be resolved by means of an interdisciplinary approach that supports the archaeological research. In this context an archaeometric study of the pottery of the area, combining geology, mineralogy, and archaeology, via a minero-petrographic and chemical approach, may allow for the definition of the extension and internal dynamics of trade network. At the same time, it will be possible to provide a useful temporal evaluation of further socio-cultural and socio-economic aspects, highlighting their fluctuations related to the technological level of the various ceramic producers, along with possible correlations to particular historical events (Whitbread, 1995).

In a preliminary phase of a larger research study, 29 ceramic samples coming from different sites of the area and covering a time span from 3000 BC to 1800 BC, were analysed via polarized light microscopy. Inclusions of the same type (quartz, K-feldspar, plagioclase, amphibole, epidote, mica, opaque; furthermore, there are lithics of granites, quartzites, gneisses, schists and amphibolites/pyroxenites) were observed in all samples. These minerals and lithics are consistent with the local geological context and each type of inclusion varies in concentration according to the point of supply of the raw material within the area. It is also evident that the potters' intent was to provide specific properties to the artifacts through intentional additions of *chamotte* and/or vegetable fibers, but also through surface treatments such as burnishing and smoothing to waterproof the surface. Ceramic body of samples showing a more or less marked *black core* indicate a prevailing reducing firing atmosphere with an uncontrolled oxygen fugacity (fO_2), followed by cooling in an oxidizing environment. The matrix activity's range of the samples suggests that the maximum firing temperature (T_{max}) was quite low and the residence time at that temperature was poorly controlled.

The high cultural value of the samples is given by their area of origin, probably belonging to the ancient region of Punt, widely exploited by Ancient Egypt for the supply of raw materials. In fact, the archaeological interest of these populations was also related to the commercial relationship with Egypt, inseparably linked to a cultural influence (Manzo, 2020). We aim, moreover, to begin to delineate the extentions and dynamics with which the two populations have influenced each other.

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Frictional-viscous cycles in high pressure metagranitoids: the example of Gilba Valley (Dora Maira Massif, Western Alps)

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Keywords: mylonite, pseudotachylyte, cataclasite, Dora Maira Massif, Brossasco-Isasca Unit.

In this contribution the relationships between mylonite, cataclasite and pseudotachylyte, outcropping in the in the Brossasco-Isasca Unit localized in the south-western portion of the Dora Maira Massif (Cosca et al., 2005) Western Alps, have been analysed. This work is based on a multi-scale structural geology approach starting with the realisation of a geological-structural map of the area at the scale of 1:5000. Emphasis is given on the observations, and overprinting relationships, of the different types of sheared rock, at the mesoscale, followed by their microstructural/microtectonics characterization on eight thin sections of selected samples. The late structural evolution of the area (Henry et al., 1993), from the greenschist facies metamorphic re-equilibration associated to non-coaxial ductile shearing, up to the latest brittle structures, formed at very shallow conditions, was reconstructed. Different types of mylonitic rocks, developed under general flow conditions, determined through the study of kinematic vorticity (Kurz & Northrup, 2008), with a top-to-the SW/W sense of shear during greenschist facies metamorphism have been recognized and mapped. Cataclasite and pseudotachylyte, hosted in the mylonitic gneiss (Zechmeister et al., 2007; Cosca et al., 2005), nucleated often (but not always) on structural discontinuities precursors like the mylonitic foliation (Sibson, 1980). Interesting overprinting relationships between mylonite, cataclasite, pseudotachylyte veins and foliated/mylonitic pseudotachylyte are described and linked to different frictional-viscous cycles (Handy & Brun, 2004). The microstructural study allowed to infer useful information on the kinematics of the fault rocks, on their overprinting features and on the possible temperature range of mylonite and pseudotachylyte formation (Bestmann et al., 2011).

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Structural evolution of the Pietramorta Shear Zone (Stura di Viù Valley, Western Alps): kinematics and tectonic significance of a shear zone promoting eclogitic units exhumation

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Keywords: Western Alps, Viù Valley, shear zone, exhumation.

In the Stura di Viù valley (Western Alps) around Malciaussia Lake, a several hectometers -thick West-plunging polyphasic shear zone, here named Pietramorta Shear Zone (PSZ), juxtaposes the eclogitic-facies Internal Piedmont Zone (IPZ) in the footwall and the blueschist-facies External Piedmont Zone (EPZ) in the hangingwall. These two tectono-metamorphic units consist of both mafic-ultramafic rocks and metasedimentary successions mainly made up of carbonate and siliciclastic materials. They represent the remnants of the Jurassic Alpine Tethys, which experienced high-pressure metamorphic peak and polyphase deformation during the subduction and subsequent exhumation stages in the context of alpine evolution. Through detailed fieldwork, a 1:10.000 scale geological map has been produced and a structural analysis has been carried out, in order to characterize the main deformation stages and define their relative chronology, in this poorly studied area of the Western Alps axial sector. The Alpine structural evolution is characterized by four regional deformation phases (from D1 to D4) in the two tectonic units, while two shear events (T1 and T2) are recognized along the Pietramorta Shear Zone. This shear zone consists of a mylonitic calcschist matrix in which variably sized blocks (mainly metabasic rocks, marble, serpentinite and quartzite, sampled from both units) are embedded. The "blocks-in-matrix" structure is consistent with a tectonic mélange (*sensu* Festa et al., 2019). T1 event developed during early exhumation in ductile conditions and is responsible for the mélange structure and the mylonitic fabric. This fabric usually cuts the regional S2 greenschist foliation and shows a top-to-E sense of shear which is an "apparent inverse" kinematism as a result of the shear zone reorientation during D3 and D4 regional deformation phases. The T1 event is consistent with a relative extensional primary kinematic likely linked to the higher exhumation rate of the lower IPZ compared to that of upper EPZ. T2 event developed in brittle-ductile conditions during D4 deformation phase and is defined by shear planes with top-to-W extensional kinematics. This event shows a very pervasive development in the T2 core zone and gradually decreases towards the boundaries of the shear zone. T2 event allows the final uplift of the eclogitic units. The kinematic evolution of Pietramorta Shear Zone allows to be related to other first-order regional shear zones, along the Western alpine belt, namely the Susa Shear Zone (Gasco et al., 2013; Ghignone et al., 2020) and the Entrelor Shear Zone (Butler & Freeman, 1996; Malusà et al., 2005).

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Middle Holocene environmental reconstruction and climatic inferences through multi-proxy records from Seymareh lake sediments (Zagros Mts., Iran)

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Keywords: climate change, Lake overflow, Middle East, Seymareh landslide, Zagros Mountains, multi-proxy, Iran.

The Seymareh landslide is the largest rock slope failure (44 Gm^3) ever recorded on the exposed Earth surface. It detached ~10 ka BP from the northeastern flank of the Kabir-Kuh anticline (Zagros Mts., Iran) originating the natural dam responsible for the formation of a three-lake system (Seymareh, Jaidar, and Balmak lakes, with an area of 259, 46, and 5 km^2, respectively). The lake system persisted for ~3000 yr during the Holocene before its emptying phase due to overflow. A sedimentation rate of 2.12 cm yr^{-1} was estimated for the Seymareh lacustrine deposits, which increased to 10.26 cm yr^{-1} during the early stage of lake emptying because of enhanced sediment yield from the lake tributaries. To reconstruct the climatic and environmental impact on the lake infilling, we reviewed the geomorphology of the basins and combined the results with multi-proxy records from a 30 m thick lacustrine sequence in Seymareh Lake. Major analyses comprise grain size analysis, carbon and oxygen stable isotopes of carbonate-bearing sediments, and X-ray diffraction analysis of clay minerals.

Lake overflowing is largely accepted as the main response to variations in water discharge and sediment supply since the alternation from dry to wet phases enhances sediment mobilization along hillslopes decreasing the accommodation space in the downstream sedimentary basins. In this regard, during the early-middle Holocene, the Seymareh area, as well as the entire Middle East, was affected by short-term climate changes at the millennial-scale, as testified by both paleoecological and archaeological evidence. Indeed, several records from Iranian lakes (i.e., Mirabad, Zeribar, Urmia) well documented the temperature and the moisture conditions of the western Zagros Mountains during the Holocene. As regards the Seymareh area, a more irregular distribution of rainfalls and their increasing seasonality may support rhexistasy conditions, during which the scarce vegetation cover enhances both the hillslope erosion and sedimentation rate in the basins, most likely contributing to the overflow of Seymareh Lake.

Active faulting and deep-seated gravitational slope deformation in carbonate rocks (Central Apennines, Italy)

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Keywords: active faults, deep-seated gravitational slope deformation, slip surfaces, cataclasites, carbonates.

Active faulting and deep-seated gravitational slope deformation (DGSD) constitute common geological hazards in mountain belts worldwide. In the Italian Central Apennines, km-thick carbonate sedimentary sequences are cut by major active normal faults which shape the landscape generating intermontane basins (Elter et al., 1975; Barchi et al., 2000).

Previous geomorphological observations suggest that the mountains slopes affected by DGSD are often located in the fault footwalls (Moro et al., 2012).

We selected five mountain slopes affected by DGSD and exposing the footwall of active seismogenic normal faults exhumed from 2 to 0.5 km depth of active normal faults. We combined field structural analysis of the slopes with microstructural investigation of the slipping zones from the major and secondary slip surfaces. The interpretation of this dataset shows that DGSDs exploit pre-existing surfaces formed both at depth and near the ground surface by tectonic faulting and, locally, by gravitational collapse. The slipping zones of the fault surfaces are more texturally mature (i.e., well-developed ultracataclasites/cataclasites vs. cataclasites/protocataclasites), because of the larger displacement accommodated. The widespread traces of clasts indentation within the cataclastic matrix is consistent with clast fragmentation, fluid-infiltration and congruent pressure-solution mechanisms active at low ambient temperatures and confining pressures (Gratier et al., 2015) and, possibly, low slip rates (creep).

We conclude that in carbonate rocks of the Central Apennines, DGSDs commonly exploit pre-existing tectonic faults/fractures and, in addition, localize slip along newly formed fractures that accommodate deformation mechanisms similar to those associated to seismic faulting. Furthermore, the exposure of fault surfaces along mountain slopes in the Central Apennines is the result of both surface seismic rupturing and DGSD.

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Middle and Late Pleistocene stratigraphic architecture of the Po Plain

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Keywords: Po Plain, Late Quaternary, subsurface stratigraphy.

Middle-Late Pleistocene and Holocene stratigraphy has been reconstructed in a 7000 km^2-wide sector of the Po Plain through core and well data correlation.

In the study area Pliocene marine and Quaternary coastal to continental sedimentary units accumulated atop a system of blind thrusts and folds, which represent the most external structures of the Apennine chain.

Two Unconformity-Bounded Stratigraphic Units, the Lower and Upper Po Synthem (LPS and UPS, respectively) have been recognized and characterized in terms of facies architecture, and sedimentological characters.

Thickness and facies distribution of Middle and Late Pleistocene deposits reflects, in part, the location of the main structural highs. Particularly, LPS displays thicknesses ranging from a few meters above buried anticlines to more than 250 m in syncline areas. UPS thickness ranges between about 90 and 400 m.

In the westernmost areas, LPS is mainly composed of fluvial-channel-related, floodplain and swamp facies associations, with rare occurrence of subtle lagoonal horizons. To the east, thickness of alluvial deposits decreases, and swamp deposits are progressively replaced by coeval paralic and coastal deposits.

The UPS displays distinctive cyclic changes in lithofacies and channel stacking patterns. Each cycle is composed at the base of mud-prone swamp and floodplain deposits which grade seaward into paralic, coastal and shallow-marine deposits. The upper part of each cycle is composed of laterally extensive fluvial-channel sand bodies.

These vertical repetitive facies changes permitted to subdivide UPS in five subunits which are interpreted to reflect Middle-Late Pleistocene glacio-eustatic oscillations. Several pollen curves revealed that the base of each subunit accumulated during interglacials whereas the upper part in glacial periods.

Coastal sediments within interglacial intervals are encountered progressively at more distal locations toward younger units distinct stratigraphic levels. This overall trend reflects the progressive filling of the Adriatic foredeep, superposed to glacio-eustatic oscillation.

The work represents a robust basis for future in-depth studies, such as the definition of a clear chronostratigraphic framework, through absolute dating, and the reconstruction of the patterns of the sediment dispersal in key evolutionary stages of the Pleistocene-Holocene sedimentary history of the Po Basin through petrographic analysis and the creation of paleogeographic maps.

Evolution of Deep-Seated Gravitational Slope Deformations in relation with uplift and fluvial capture processes in Central Eastern Sardinia

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Keywords: deep-seated gravitational slope deformation, river capture, tectonic geomorphology, InSAR, UAV.

Connection between Plio-Pleistocenic tectonic activity and geomorphological evolution in the Pardu Valley and Quirra Valley (Ogliastra, East Sardinia) have been studied. An intensive Quaternary tectonic activity in Sardinia linked to the Tirrenian Basin opening, is known. In Eastern Sardinia it manifests with an Uplift, recording by geomorphological indicators such as deep-seated gravitational slope deformation, fluvial captures, engraved valleys, waterfalls and heterogeneous water drainage. The river networks geometry and gravity processes show a young conformation of the landscape, tipical of an active tectonic setting.

The evolutionary conditions of the Pardu Valley are associated with a cycle of undeveloped fluvial erosion, which suggests a relatively young age of engraving. The evolution of Pardu River is closely linked to that of Quirra River. Pardu River flows from the NW toward the SE and then abruptly changes direction toward the NE. At this point, a capture elbow adjacent to the current head of the Quirra River is well developed. The Quirra River in the upstream part flows at altitudes approximately 200 m higher than the Pardu River. It also shows an over-sized and over-flooded valley with respect to the catchment area upstream. This setting indicates that the Pardu River, previously flowing south along the Quirra River, was captured by Pelau River.

We analyzed long-term landslides with lateral spreading and sackung characteristics, which involve giant carbonate blocks and underlying foliated metamorphites on both valleys. The use of LiDAR, high resolution unmanned aerial vehicle (UAV) photogrammetry, and geological, structural, and geomorphological surveys enabled a depth morphometric analysis and the creation of interpretative 3D models of DSGSDs. These high-resolution data enabled the formulation of new hypotheses about DSGSDs evolution and kinematics. In addition, with the use of the acquired high-resolution topographic data and geological and geomorphological field surveys, we identified different evolutionary stages of DSGSD. Lateral spread affects the carbonate plateau edge, whereas sackung features are located in the middle slope on metamorphic basement.

Space-borne Interferometric Synthetic Aperture Radar (InSAR) data using ERS and Sentinel-1 satellites identified downslope movement of up to 20 mm per year on both Pardu Valley flanks. These data indicate up to 2 km^2 large slope areas identified as DSGSDs to be active in the past decades. While no movement is identified in Quirra Valley.

Multi-source and multi-scale data show that the state of activity of the DSGSDs is closely linked to the geomorphological evolution of the catchment areas of the Rio Pardu and Rio Quirra.

The intense post-capture erosion has given the Rio Pardu Valley morphometric features that are favorable to the current evolution of the DSGSDs. While the Rio Quirra Valley presents palaeo-DSGSDs fossilized by pre-capture terraced alluvial deposits.

Kinetic partitioning of major and trace cations between clinopyroxene and phonotephritic melt under convective stirring conditions: New insights into sector and concentric zoning

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Keywords: convective stirring, partitioning between clinopyroxene and phonotephritic melt, sector and concentric zoning, lattice strain and electrostatic energies, crystal field stabilization energy.

Within subvolcanic plumbing systems, along volcanic conduits and post-eruptive emplacement, mineral textures and compositions are governed by complex kinetic (undercooling) and dynamic (convective) processes that deviate from theoretical models and equilibrium criteria. In this perspective, we have investigated the partitioning of major and trace cations between clinopyroxene and phonotephritic melt under convective stirring conditions (from 1 to 10 s^{-1}) at high degrees of undercooling ($-\Delta T_{nominal}$ = 120-150 °C) and atmospheric pressure. We have integrated this novel data set with conventional static (no physical perturbation) clinopyroxene-melt compositions obtained under interface- and diffusion-controlled growth regimes. Results show that clinopyroxene growth kinetics and diffusion boundary layers caused by melt supersaturation are partly mitigated by the homogenizing effects of stirring. Because of continuous supply of fresh melt to the advancing crystal surface, the partitioning of major and trace cations is governed by local equilibrium effects, which are interpreted as the extension of equilibrium thermodynamic principles to non-equilibrium bulk systems. Major cations are incorporated into the clinopyroxene structure via the coupled substitution [^{M1}Mg, ^{T}Si] ↔ [^{M1}Ti, ^{T}Al] and in conformity with the thermodynamic mixing properties of $CaMgSiO_2$, $CaAl_2SiO_6$, and $CaTiAl_2O_6$ components. The complementary relationship between lattice strain (ΔG_{strain}) and electrostatic ($\Delta G_{electrostatic}$) energies of heterovalent substitutions is the most appropriate thermodynamic description for the accommodation of trace cations in the clinopyroxene lattice site (i.e., $\Delta G_{partitioning} = \Delta G_{strain} + \Delta G_{electrostatic}$). The excess energy of partitioning $\Delta G_{partitioning}$ changes principally with Al in tetrahedral coordination and determines the type and number of charge-balanced and -imbalanced configurations taking place in the structural sites of clinopyroxene. An important outcome from dynamic stirring experiments is that superimposition of convective mass transfer on melt supersaturation phenomena causes the formation of Cr-rich concentric zones under closed system crystallization conditions. However, these Cr-rich zones do not correlate with enrichment in other compatible elements and depletion in incompatible elements, as would be expected in natural open systems characterized by input of more primitive magmas. While the convective transport acts to reduce the diffusive length scale of chemical species in the experimental melt, fresh Cr cations are more easily incorporated into the concentric zones via the dominant control of crystal field stabilization energy (CFSE) over the lattice strain and electrostatic partitioning energetics (i.e., $\Delta G_{CFSE} > \Delta G_{strain} + \Delta G_{electrostatic}$).

Gas emission to the southwest of the Matese ridge: morfostructural setting and mineralogical analyses of altered soil

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Keywords: geomorphology, mineralogy, Southern Appennine, active faluts, CO_2 emissions.

Literature data (Ascione et al., 2018) suggest that natural degassing of massive amounts of CO_2 affects Middle Pleistocene fluvio-lacustrine deposits outcropping in the Ciorlano valley, to the west of the Matese ridge. Ascione et al. (2018) also pointed out that CO_2 degassing is concentrated along hundred meters long, N-S trending normal faults. In this study, a multidisciplinary approach, based on geological, geomorphological, and mineralogical analyses, has been adopted to detail the morphostructural setting of the Ciorlano valley and the mineralogical signature of gas emission

The geological analyses allowed to detail the outcropping Quaternary units, which consist of fluvio-lacustrine, alluvial fan and fluvial deposits. In addition, geomorphological analyses suggests that the morpho-evolution of the Ciorlano valley mainly proceeded through phases of river downcutting, as testified by two orders of river terraces affecting the fluvio-lacustrine unit.

Mineralogical analyses were carried out on the clayish materials composing the fluvio-lacustrine Quaternary unit outcropping to the west of the Ciorlano valley, nearby active gas vents. XRD and SEM analysis showed that kaolinite widely occurs in the analysed samples, and that it stays on the top of K-feldspar surfaces. In previous studies (Sinno, 1966; Adamo et al., 2001) conducted in the adjacent area of Ailano (to the south of the Ciorlano valley), kaolinite and halloysite deposits occurring in volcanoclastic rocks were considered genetically associated to the hydrothermal alteration of preexisting rocks, due to the circulation of CO_2-bearing acid fluids. Since the valley of Ciorlano and the area of Ailano share similar characteristics, it is likely that also the kaolinite detected in the current study is of hydrothermal origin and derives from the alteration of preexisting fluvio-lacustrine deposits.

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Evaluation of rainfall-induced shallow landslide susceptibility using a hybrid integration approach

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Keywords: susceptibility mapping, machine learning, runout modeling, hybrid approach, Cinque Terre National Park.

Rainfall-induced landslides represent a serious threat in hilly and mountain areas globally. Usually, shallow landslides are triggered by prolonged or severe rainfalls and frequently may evolve into potentially catastrophic flow-like movements. Because of the capacity of these phenomena to travel long distances, buildings and infrastructures located in areas improperly deemed safe can be affected.

Spatial and temporal hazard posed by flow-like movements is due to both source characteristics (e.g., location and volume) and the successive runout dynamics (e.g., travelled paths and distances). Hence, the assessment of shallow landslide susceptibility has to take into account not only the recognition of the most likely landslide source areas but also landslide runout (i.e., travel distance).

In recent years, a meaningful improvement in landslide detachment susceptibility evaluation has been gained through robust scientific advances, especially by using statistical approaches. Furthermore, various techniques are available for landslide runout susceptibility assessment in quantitative terms. The combination of landslide detachment and runout dynamics has been recognized by many researchers as an appropriate and comprehensive procedure for landslide susceptibility evaluation. Most of these studies focused on either landslide susceptibility mapping or mobility assessment by considering them separately. The coupled prediction of the potential for Landslide Detachment Susceptibility (LDS) and Landslide Runout Susceptibility (LRS) still remains a challenge for researchers.

In this study, the adoption of a hybrid approach allowed to estimate shallow landslide susceptibility to both detachment and potential runout. Such methodology is based on the integration between LDS assessment via Machine Learning techniques (using the Ensemble approach) (Di Napoli et al., 2020) and LRS evaluation through GIS-based tools (using the "reach angle" method) (Corominas, 1996). This approach has been implemented in the Cinque Terre National Park (Liguria, northwest Italy). This area is characterized by a high level of landslide hazard due to intense rainfalls that periodically affect its rugged and steep territory (Cevasco et al., 2015). Nine environmental variables were selected, while a database of about 300 rainfall-induced shallow landslides was employed as input. The obtained map may be useful for urban and regional planning, as well as for decision-makers and stakeholders, to predict areas that may be affected by rainfall-induced shallow landslides in the future and to identify areas where risk mitigation measures are needed.

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Geometric and kinematic evolution of faults associated with volcano-tectonic collapses

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Keywords: collapse faults, fault zone evolution, throw analysis, structural survey, Campi Flegrei.

Rock collapses triggered by magmatic chamber emptying or magma migration at depth are a common feature in volcanic areas (Holohan et al., 2011). Numerous analogue and numerical modelling experiments reproducing the collapse process have been carried out in the last decade, to better constrain the fault systems evolution and the strain accommodation mechanisms affecting the caldera collapses (Acocella, 2007). These experiments show that collapsing block subsidence can be accommodated by fault systems that are concentric in map view, and associated with normal and reverse fault segments in cross-section. However, there is discussion in the literature on how these normal and reverse faults are associated with one another in space and time. Thus, this work aims to deeply characterize, for the first time using field data, a fault array developed in the Campi Flegrei caldera (Italy) (Vitale & Isaia, 2014). The fault array affecting the Astroni deposits is interpreted to have developed to accommodate the collapse induced by magmatic activity at depth in recent times (Isaia et al., 2015). The outcrop structural analysis focused on defining the spatial and temporal relationships between the normal and reverse fault segments of the fault zone. This analysis was carried out using a multi-methodological approach based on (i) the geometrical relationships between fault segments with opposite kinematics, (ii) the angular relationships between fault segments and bedding, and the most important (iii) the throw partitioning. Based on the results, we suggest that normal and reverse faults simultaneously developed to accommodate the collapse. These finding can be of significance for the better understanding of strain localization mechanisms and processes within the volcanic-tectonic caldera evolution and represents an important tool for mitigating risks connected with geohazards and refining industrial application to the world of georesources such as for geothermal industry.

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Geological and structural characterization of the Vedra Valley Zn-Pb-Ag sulfide ore (Polymetallic Gorno Mining District, northern Italy)

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Keywords: ore deposits, structural geology, sedimentary basins.

The Gorno mining district is developed in the Lower Carnian units of the central Southern Alps. The high grade sulfide mineralisation is hosted in marly and shaly beds, known as the "black shales", placed at the base of the Gorno Formation, and in peritidal limestones and dolostones of the Breno and Calcare Metallifero Bergamasco (CMB) formations. The ore deposits are strata-bound and show typical characteristics of MVT mineral systems, such as mineralized breccias, ore-related dolomitization and quartz-fluorite-barite gangue (Mondillo et al., 2019). Field and petrographic evidences suggest a post-depositional, early precipitation of the ore deposits, which occurred in a shallow burial environment. N-S paleofault system, active at least since the Norian age (Zanchi et al., 2012), could have represented a feeder for the mineralizing fluids, which then expanded horizontally through the host rocks, below the impermeable layers of the Gorno Formation.

The mineral resource of the Vedra Valley reservoir was estimated in 2017 at 3.3 Mt @ 4.9% of Zn and 1.3% of Pb (27.2 ppm Ag) only for the western sector of the mine, by Alta Zinc Ltd, which owns the mining concession and exploration license (www.altazinc.com).

The Middle Triassic-Carnian units of the Vedra Valley are presently arranged into an antiformal stack consisting of some tectonic units, separated by thrust faults, which have been intensively displaced and deformed during the Alpine orogeny.

Two main deformation phases (D1 and D2) related to the Alpine compressional tectonics are recognized. The first stage of the D1 deformation phase (T1) is associated with the development of a km-scale deformation unit, here named *Pian Bracca Shear Zone*, characterized by a system of south-verging, NW dipping thrust faults. T1 caused the development of several thrust sheets mainly occurring along the marly and shaly horizons of the *Gorno* and the *CMB* formations and, to a lesser extent, between the much more competent layers of the *Breno* and *CMB f*ormations. The second deformation stage of the D1 deformation phase (T2), is defined by two large-scale tear faults, sub-vertical and striking N-S. These structures probably represent the reactivation of the pre-existing extensional fault system which affected the Lombardian basin from Norian to Jurassic. These tear faults caused the lateral continuity of the main thrust front and its associated units to break into several smaller tectonic units, which subsequently underwent different structural evolution.

The deformation phase D2 can be related, at regional scale, to the development of two sub-vertical south dipping major faults (Val Torta and Val Canale Faults) that caused the back-thrusting of the Upper Triassic unit over the Middle Triassic ones. Local back-thrusts are observed: they are characterized by shear planes opposite to the Sud-verging Alpine ones and associated to flower structures and ramp-and-flat systems with double verging fold systems.

The mineralized bodies of the Gorno mining district have been clearly deformed and displaced by the Alpine tectonics, which is the ultimate responsible of their presently complex distribution in the Vedra valley subsurface. The shale-hosted mineralization experienced intense deformation, as the main thrust faults of the study area developed mostly along these clay-marly horizons.

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Microstructure and isochemical phase diagrams constrain peak and retrograde P-T conditions in the Variscan Monte Filau Orthogneiss, SW Sardinia (Italy)

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Keywords: orthogneiss, microstructure, metamorphism; partial melting, Variscan Sardinia.

The Monte Filau Orthogneiss crops out in the External zone of the Sardinian Variscan chain. It was derived from a granitoid intruded at about 460 Ma and deformed during the Variscan orogenesis. It occurs into three different petrographic facies: i) a dark, biotite-rich facies and two leucocratic, ii) coarse-grained and iii) fine-grained facies. The orthogneiss shows a polyphasic deformation with two schistosities recognizable in the field: the first is a gneissic foliation, whereas the second is given by the orientation of andalusite-bearing aggregates in the fine-grained facies. The metamorphic evolution can be evaluated by the microstructural analysis of the mineral assemblage preserved in the fine-grained facies (Fs+Qtz+Wmca+Bt+And+Sill+Grt); hence, a combined petrographic, microstructural, and thermodynamic analysis was carried out to define peak P-T conditions and the retrograde path during metamorphism. Sillimanite and garnet only occur in the fine-grained samples, the former in the fibrolite variety, the latter as small single crystals and, more rarely, in clusters; andalusite is the main aluminosilicate, identified as prismatic, fractured crystals. Retrograde white mica grows on fibrolitic sillimanite, andalusite and K-feldspar. The peak mineral assemblage is Qtz+Pl+Kfs+Bt+Sill+Grt. The following microstructural features suggest that the peak assemblage formed under partial melting conditions: i) thin films of feldspars (mainly plagioclase) along K-feldspar boundaries, ii) cuspate and lobate quartz boundaries in contact with feldspar, iii) K-feldspar pseudomorphs over plagioclase, iv) volatile-rich phases (tourmaline) trapped in triple junctions and v) aggregates ("spindles", Mazzoli & Visonà, 1992) aligned with the schistosity with relics of peak metamorphic assemblage. All these features suggest the former presence of a melt-phase (Hasalova et al., 2008; Dyck et al., 2020). The presence of aluminosilicates denotes that muscovite- dehydration-melting was active, although contribution from water-fluxed melting cannot be completely excluded. Isochemical phase diagrams also suggest that the observed peak mineral assemblage formed under partial melting conditions, in the stability field of Sill+Bt+Grt+Melt. The growth of retrograde andalusite and white mica complete the path followed by the orthogneiss. Our data suggest a metamorphic peak at about 680°C/4-5kbar and retrograde condition of 400-450°C/2-3kbar.

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Fluoride in Campi Flegrei volcanic aquifer, south Italy: A comparison between water and rock composition

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Keywords: fluoride geochemistry, F/Cl ratio, empirical cumulative distribution function, water–rock interaction.

Campi Flegrei aquifer is situated in an area with a long history of volcanic activity. Although groundwater geochemistry has been studied since the late 20th century to characterize volcanic activity in the study area, limited information is available about fluoride geochemistry. To fill this gap, 44 groundwater samples were collected to determine concentrations of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-} and F^{-} using ion chromatography together with alkalinity, electric conductivity (EC), temperature and pH via portable devices. The results indicate a positively skewed distribution of F^{-} concentration, ranging from 0.02 to 0.72 meq/l (0.26 meq/l on average). The alkaline waters generally contain more fluoride than acidic waters, being consistent with fluoride desorption tendency at pH>7. However, previous studies showed significant heterogeneity of the groundwater body due to site-specific geochemical processes.

In the present investigation, the empirical cumulative distribution function of F^{-}/Cl^{-} molar ratio is used to determine a threshold value and categorize the groundwater samples in: Gr1 ($F^{-}/Cl^{-} < 0.065$), mostly characterized by chlorine-rich groundwaters with the highest values of Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, alkalinity, EC and temperature; and Gr2 ($F^{-}/Cl^{-} > 0.065$), mostly composed of bicarbonate-rich groundwaters with the highest F^{-} and pH values. The F/Clratios of whole-rock and water follow the decreasing order of: ignimbrites (pre-40 ka) > Campanian Ignimbrite (~39.3 ka) > tephra (post-15 ka) > Gr2 > Quarto Plain groundwater > rainwater > Gr1 > seawater. Composition of rock, Quarto Plain groundwater, rainwater and seawater was obtained from literature. Quarto Plain groundwater, which is a shallow meteoric component influenced by water–rock interaction, reveals F^{-}/Cl^{-} higher than rainwater, indicating that rock leaching increases F^{-}/Cl^{-}. The interaction is more significant in a subset of Gr2, mostly far from the area of intense hydrothermal activity, leading to elevated F^{-}/Cl^{-} in the other subset of Gr2 downstream. F^{-}/Cl^{-} of Gr2 is almost similar to post-15 ka rocks. On the other hand, low F^{-}/Cl^{-} in Gr1 might explain that different processes (e.g., water–rock interaction, precipitation of F-bearing phases, F^{-} volatility and the rising geothermal fluids) affect F^{-} geochemistry. Hence, empirical cumulative distribution function of F^{-}/Cl^{-} molar ratio can be an effective tool in distinguishing the groundwater samples that their F^{-} load directly relates to lithology and does not undergo significant changes. Careful interpretation of sulfate-rich groundwater geochemistry is required because low Cl^{-} content, high temperature and, in some cases, low pH probably influence their classification. It is worth mentioning that the highest F^{-} concentration was detected in Stufe di Nerone well (a member of Gr1) which might show geothermal contribution to F^{-} content of groundwater.

Analysing long time-series of groundwater levels in a paddy field area (Piedmont region, NW Italy): preliminary results

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Keywords: water table, groundwater hydrodynamic behaviour, trend, paddy fields.

The analysis of the time-series of groundwater level is extremely important to observe the behaviours of groundwater over time and to identify any critical situations (Lasagna et al., 2020).

The studied area is an agricultural district characterised by paddy fields, located in the eastern part of Piedmont region, on the border with Lombardy region. In this area long time-series of groundwater level, starting from the 1960s, have been collected in 20 wells.

Water table data have a good continuity (in the majority of the cases >90%).

Firstly, the groundwater hydrodynamic behaviour, based on water table levels, was investigated to highlight the response of groundwater to the irrigation. A basic statistical analysis was performed (mean, median, standard deviation, maxima, minima), and then trends of water table levels were evaluated in order to better observe the long-term behaviour of groundwater.

Trends were performed on average and maxima annual data, and also on the minima annual data, which are, most likely, the data less influenced by the watering of the paddy fields.

These analyses allowed to observe a groundwater hydrodynamic behaviour characterised by a repeating annual pattern (minimum in February/March and maximum in August/September) clearly linked to the phases of irrigation of the paddy fields.

Moreover, trend analysis highlighted the presence of both wells with a decreasing water table (with maximum lowering of 4.3 m in 60 years) and wells with an increasing water table (with maximum rises of 2.8 m in 35 years). Furthermore, in most cases, it can be observed that all three trends analysed agree on being positive or negative.

Future insights will be the comparison of these long time-series with the meteorological data, and the investigation of other factors (e.g. anthropic withdrawal, variations of cultivation practices and irrigation, geology of the subsoil) to better understand the causes of the water table fluctuations and trends.

Lasagna M., Mancini S. & De Luca D.A. (2020) - Groundwater hydrodynamic behaviours based on water table levels to identify natural and anthropic controlling factors in the Piedmont Plain (Italy). Sci. Total Environ. 716, 137051.

Assessment of mitigation measures and risk scenario of the museum collections exhibited in the Villa Frigerj National Archaeological Museum in Chieti (Central Italy)

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Keywords: risk management, seismic vulnerability assessment, protection cultural heritage, seismo-resistant exhibition.

Do we really know the seismic history of our region? Are we aware of seismic safety rules in our area? Are the cultural heritage goods kept in seismic-resistant buildings and exhibitors? Cultural Heritage is a precious memory inherited from the past and an unrevealed resource for the future. There is an urgent need to answer these questions to turn museums into centers of active, innovative and awareness culture through the risk mitigation. Civil society has the duty to protect it. It is a complex issue that concerns the hazard, the vulnerability, and the exposed value. A typical interdisciplinary topic. For this reason, it is necessary to divide the research by four interrelated aspects: a geological assessment including the effects of site amplification, the assessment of seismic hazard scenarios, the study of the vulnerability and dynamic response of the building and finally the assessment of vulnerability mitigation scenarios for both the building and the exhibitors. The 2009 L'Aquila earthquake produced extensive damage, caused by the instability of the museum buildings collapses of the exhibitors, breaking of glass shelves, overturning of objects, and movement of pedestals and hosting art master pieces. According to the procedure above described this work aims to risk mitigation of the National Archaeological Museum housed at Villa Frigerj in Chieti, selected as a case history, among others. The geological data available for this building and the characteristics of the building, allow us to hypothesize its improvement through innovative techniques such as the use of seismic energy dissipators and further calculation of residual shaking. Once the data has been acquired, 3D models can be created. After evaluating if the building is structurally seismo-resistant (minimum target no collapse level), exhibitor can also be made seismo-resistant. Then proceed with the ad hoc adaptation of the collections through the study and development of innovative and experimental isolation dampers/dissipators (passive electromagnetic, mechanical). The approach of this study reverse the logic of protection of cultural heritage turning it in an active preventive action. We must change the way of thinking of our society: do not act when the damage has happened, but make sure that does not happen!

Numerical taxonomy applied to Upper Triassic Megalodontidae: first attempts on the genera Neomegalodon and Triadomegalodon

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Keywords: paleontology, Megalodontidae, Triassic, taxonomy, statistics.

Fossil bivalves of the *Megalodontidae* family are among the most distinctive and studied skeletal components of Upper Triassic shallow-marine carbonates. Well-known examples of these extinct bivalves come from the carbonates of the Dolomia Principale and Dachstein Limestone Formations (Vegh-Neubrandt, 1982). Megalodontids typically occur as dissolved moulds, given the metastable nature of the original aragonitic shell. Accordingly, taxa classification is primarily based on geometrical rather than shell features. In the last century, paleontologists have examined Megalodontids by means of objective parameters without a formally accepted and unique criterion (Allasinaz & Zardini, 1977; Vegh-Neubrandt, 1982).

This study aims at deepening the knowledge about *Neomegalodon* and *Triadomegalodon* by means of numerical taxonomy, rarely applied before. These genera share an almost identical cardinal formula, though differ for some morphological characters (Allasinaz & Zardini, 1977; Vegh-Neubrandt, 1982; Yao et al., 2012).

The studied dataset included 41 taxa: 33 species assigned to *Neomegalodon* and 8 to *Triadomegalodon*, described by 7 morphological parameters (Tichy, 1980; Vegh-Neubrandt, 1982), were imported into MATLAB. To ensure data consistency some taxa were excluded. A *MANOVA* test revealed that the currently accepted separation between the two genera is not statistically significant ($p>0.05$). To analyze potential inter-data relationships, a hierarchical clustering algorithm (*UPGMA*) was performed after z-score normalization. The output dendrogram highlighted that the selected specimens can be still effectively separated into two clusters. The produced clusters include both *Neomegalodon* and *Triadomegalodon* species and, thus, they are not genus dependent. An additional *MANOVA* test supports that the distinction between the latter two clusters is statistically significant ($p<0.0001$). As shown by scatter plots, one cluster includes specimens with normally higher shell length/shell height ratio, lower furrow width/shell thickness ratio, and a less developed lunule with respect to the other cluster.

This work provides new insights on *Megalodontidae* via the application of statistical analysis and set the stage for further and more in-depth studies at the family level.

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Fault zone structure at different stages of evolution in carbonate rocks (Lattari Mountains, Italy)

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Keywords: petroleum geology, structural geology, tectonics.

The Lattari Mountains, situated in the Southern Apennines fold and thrust belt in the Sorrento peninsula, are interested by high-angle extensional systems of faults, thought to be related to foreland flexuring that took place during the early phases of convergence. The structure of one of these fault systems, cropping out on southern slope of the Mt. Catiello mountain, is the object of study of this thesis work. In this area, shallow-water limestones and dolostones of Lower Cretaceous age are cross-cut by four faults with pluri-decametric dip lengths and significant throws, comparable is size to faults that can be mapped in high-resolution seismic reflection data. Two areas of this fault zone were studied in detailed, by mapping them in details using an orthophoto as base map and by constructing detailed throw profiles. We found that one area (Area 1) is characterized by three main fault segments tipping out within the outcrop, defining two contractional dip relay zones associated with antithetic faulting. The other area (Area 2), in contrast, is characterized by several faults mostly synthetic with one another and linked to each other at branch points, and by minor isolated faults. Results suggest that these two areas are representative of different stages of fault zone evolution.

Ground deformation mapping over large areas by means of InSAR-based semi-automatic approach

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Keywords: InSAR, Sentinel-1, mapping capabilities, ground deformation.

The Advanced multi-temporal Differential SAR (Synthetic Aperture Radar) Interferometry (ADInSAR) is a microwave remote sensing technique playing nowadays a crucial role in the investigation of the Earth surface deformation phenomena in different geomorphological environments (Del Soldato et al., 2019). Huge SAR datasets has been collected starting from the '90s and several advanced InSAR processing algorithms have been developed in parallel allowing for the retrieval of spatial and temporal evolution of ground deformations with sub-millimeter accuracy (Crosetto et al., 2016). Such algorithms exploit long-time series of SAR images for the investigation of the surficial displacements by identifying a sparse grid of coherent points provided with average annual values of velocity, generally referred to as PS (Permanent Scatterers).

The launch of the European Space Agency's (ESA) Sentinel-1 constellation, has allowed to acquire huge volumes of freely accessible radar images with a worldwide coverage and an unprecedented temporal sampling (6 days considering the twin satellites). The combined use of efficient InSAR techniques with Sentinel-1 system peculiarities has made possible systematic displacement detection and analysis at large scale in reduced time frame (Montalti et al., 2019). In the framework of extensive exploitation of InSAR results at very large scale, a semi-automatic approach for the preliminary screening of wide territories affected by active or potential instability phenomena due to both natural hazards and anthropogenic activities is presented.

Taking into consideration the intrinsic constraints of any interferometric approach (only slow-moving deformations can be detected), the proposed semi-automatic algorithm relies on three main steps: (*i*) identification and analysis of PS with a velocity greater than a selected threshold; (*ii*) aggregation of the targets in different polygonal clusters, which are intended to define newly activated phenomena in the time-span of the input InSAR dataset; (*iii*) classification of the underlying natural or anthropic process which has triggered the observed surface deformation. The obtained results confirm the effectiveness of the adopted post-processing technique for large areas mapping.

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Application of a thermo-desorption technique for Mercury speciation on soil samples to support the risk assessment procedure of Mercury-contaminated sites

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Keywords: risk assessment, Mercury speciation, Grado Lagoon, contaminated site, thermo-desorption.

Mercury (Hg) contamination of soils and sediments represents a serious concern for human and ecosystem health. The mobility and bioavailability of Hg in the environment are function of its chemical form, so Hg speciation analysis represents a key aspect for assessing the fate of Hg and the environmental and health risk associated with Hg contamination. The occurrence of different Hg species in environment samples is usually assessed by means of multiple step extraction procedures, which, however, are time-consuming and characterized by low reproducibility and non-specific removal of species (Issaro et al., 2009). In this work, we evaluate the possible application of a thermo-desorption (TD) Hg speciation technique, which allows a prompt evaluation of Hg species according to their release temperature, for the risk assessment procedure at a Hg-contaminated site of Friuli-Venezia Giulia region by comparing results obtained through this approach with those derived from the commonly used selective sequential extraction (SSE) method (e.g. Bloom et al., 2003). For risk calculations, relative amounts of non-cinnabar compounds determined through TD and mobile Hg fractions obtained from SSE procedure were considered. The study site is a portion of the embankment of the Marano and Grado Lagoon, an area impacted by Hg as a result of past mining (cinnabar extraction) and industrial activities. In this work, 23 surface and deep soil samples were collected and analyzed for total Hg (THg) concentration and Hg speciation through TD, whereas SSE was applied only to four samples characterized by the highest THg contents. The THg concentrations found in this study ranged between 0.240 and 3.091 mg/kg, exceeding the Italian regulation limit (1 mg/kg) in the eastern part of the study area. However, the calculated risk resulted "acceptable" using both SSE and TD data, despite the higher abundance of potentially mobile forms of Hg found through the latter technique. Besides, TD data are referred to the results obtained from all the 23 soil samples collected in the study area, providing a major representativeness. Considering also its celerity, reproducibility, low costs and accuracy in Hg species discrimination, the TD technique could then represent a useful and low expensive tool for future risk assessments of Hg contaminated sites, particularly those characterized by the occurrence of cinnabar, easily discriminable through this technique.

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Mapping of the low enthalpy geothermal resources: a case study from South-Eastern Sicily

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Keywords: geothermal energy, low-enthalpy, Sicily, geothermal mapping.

The constant increase of energy demand requires a redefinition of the energy use according to unconventional forms of exploitation. In such a context, low-temperature geothermal energy underwent a major development, as it affects many important socio-economic sectors in which either small or big enterprises are involved. For this reason, the correct evaluation of the geothermal properties allows the optimization of the exploitation of shallow geothermal resources within suitable areas. In this study, geothermal properties of the south-eastern domain of Sicily (Hyblean sector) have been analyzed to obtain a steady-state thermal conductive model of the subsurface. In this regard, the detailed geological framework and the wide geophysical background have been used to reproduce a low-resolution geological model useful for the subsequent thermal analysis.

The thermal modeling started from the evaluation and analysis of stratigraphical and geophysical evidence of several exploration wells existing in the investigated area. In particular, the definition of the main geothermal parameters (thermal conductivity, geothermal gradient, heat flow) according to the lithological (density) and stratigraphic properties as well as the geophysical attributes (seismic wave velocities) allowed the identification of the thermal regime up to 1000 meters depth and to solve the linear variations in heat transfer. The interpolation of geothermal parameters has allowed the development of geothermal maps at different depths. The temperature distribution at 200-, 500- and 1000-meters of depth has been considered to obtain useful information on the low-enthalpy geothermal potential. Investigation of the thermal regime has enabled us to improves our knowledge of the geothermal potential of the Hyblean domain occurring at shallow-intermediate depths and allowed the definition of low-enthalpy geothermal mapping at several depths scales useful for exploration and exploitation of low-enthalpy resources. The geothermal maps provide new evidence of heat transfer properties of the south-eastern sector of Sicily as well the boundary conditions for more local and higher resolution thermal studies to investigate afterward.

Optimization and analysis of completeness of a seismic events catalog recorded by OTRIONS seismic network in the period 04/2013-12/2018

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Keywords: earthquake, seismic catalog, RSNI-Picker$_2$, ZMAP7.

The aim of this work is to create a new seismic database of the Gargano Promontory (Southern Italy) during the period from April 2013 to December 2018 (Filippucci M. et al., 2021). The seismic recordings belong to the Gargano seismic network which is composed by the seismic stations of the OTRIONS seismic network (international code OT), managed by the University of Bari Aldo Moro, and by the seismic stations of the National Seismic Network (international code IV), managed by National Institute of Geophysics and Volcanology (INGV) (Filippucci M. et al., 2020). In the work, the RSNI-Picker$_2$ (Regional Seismic network of Northwestern Italy) software was employed for automatic detection, picking and localization of earthquakes (Spallarossa D. et al., 2014). The main advantage of RSNI-Picker$_2$, respect to Seiscomp3 software, used by University of Bari Aldo Moro for automatic detections and localizations, is that RSNI-Picker$_2$ can detect S-waves arrival time and not only P-wave arrival times to locate earthquakes (Scafidi D. et al., 2018). The localization performed by RSNI-Picker$_2$ are based on NonLinLoc software. The collected automatic earthquake localizations were organized in a new seismic automatic catalogue, which was created by using a procedure written in Fortran77. For the period 23rd April 2013 to 30th April 2014, the manual picking of P and S waves arrival times was performed by using the SAC-Picker software. In this way, a new manual seismic catalogue was achieved and a comparison between the automatic and manual catalogue was performed. The seismic catalogues were analyzed by plotting the frequency histograms: frequency histograms of all the output parameters of the localizations to evaluate the quality of the database; frequency histograms of depth of earthquake foci to analyze the geo-tectonic state of the area; frequency histograms of origin time to determine the presence of antropic events as quarry's explosions in the catalogue. In order to evaluate the completeness of the catalogue, the manual seismic catalogue was then used as input file for Zmap7 software (Wiemer S., 2001); the M_C, a- and b-value of Gutenberg-Richter relationship were calculated automatically.

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Use of geophysical survey techniques to compare the engineering construction project with the realized infrastructure: laboratory and field tests

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Keywords: urban geophysics, infrastructure heritage, monitoring civil infrastructure, engineering project.

Most of the Italian infrastructural heritage dates to the thirty years 1955 - 1985. From the moment of construction to today, there has been a neglected and most of the time non-existent organization of maintenance works. The interventions on the infrastructural heritage were carried out only when there were already evident manifestations of structural failures and problems at an advanced stage that led to the non-viability, infinite construction times and various inefficiencies; unfortunately, in the best scenario, because cases of collapses or structural failures are reported more and more frequently during the phase of use of an infrastructure, clearly compromising the safety of citizens. Urban Geophysics is a new subdiscipline in the Applied Geophysics. It is going to be largely used to analyse the contribute, in terms of limits and potentialities, that geophysical methodologies can give for providing useful information about the subsoil, environment, buildings and civil infrastructures and supporting the public administrations in planning interventions in urban scenarios (Lapenna, 2017).

The first part of this work introduces a laboratory test that was performed at the Hydrogeosite CNR-IMAA laboratory of Marsico Nuovo (Basilicata region, Italy). The test consisted in a multisensor geophysical application on an analogue engineering model. Thanks to the possibility to work in laboratory conditions, a detailed knowledge of the structure and the engineering project was available, providing great advantages for assess the capability of the geophysical methodologies for analyze engineering issues, regarding the characterization and monitoring of the infrastructural critical zone placed at the interface soil structure, the geometry of the foundation structures and the disposition of the rebar for the reinforced concrete frame. For this purpose, geoelectrical and electromagnetic methodologies, including Cross hole Electrical Resistivity Tomography and Ground Penetrating Radar, were used.

In the field test we have applied the geophysical survey for the engineering characterization applied on an old railway tunnel located in Marsico Nuovo, Basilicata, Italy. The study aims to obtain as much information as possible about the engineering infrastructure and highlight the potential and any limitations of the use of geophysical techniques applied on the old tunnel without having any information of the engineering project.

3GEO - Geoclimbing & Geotrekking in Geoparks: a UNESCO IGCP project to promote global geoheritage through outdoor activities and multimedia approaches

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Keywords: geoparks, geotrekking, geoheritage, interdisciplinary tools, 3D modelling**,** geotourism.

Astonishing inland and marine landscapes have always been appreciated for leisure activities, but their geological heritage was only considered at the beginning of the last millennia. Since 2001, UNESCO has been working with geoparks leading to a holistic awareness of geological landscapes and geoheritage preservation, education, and sustainable development. Today, the Global UNESCO Geoparks Network counts 169 sites spread over 44 countries. However, the geological evaluation of many sites is still in constant development thanks to new studies and technological progresses. The fresh UNESCO IGCP 3GEO aims at boosting Global Geoparks through traditional geoclimbing and geotrekking techniques (Garlick, 2009; Ruban and Ermolaev, 2020) as well as through original drone photogrammetry and 3D outcrop modelling to raise geoheritage awareness. Although the UNESCO IGCP 3GEO project just started, numerous international geoparks (e.g., Kütralkura, Estrela, Psiloritis, Rocca di Cerere, Sesia-Val Grande) and geotrekking areas are participating to the project (Brazil, Chile, Greece, Italy, Oman, Portugal, South Africa, Spain) and several new collaborations are being evaluated. Apart from amazing panoramas, geoparks represent pivotal areas of study which lead to noteworthy global scientific geological discoveries. Moreover, from the perspective of the pandemic situation we have been living, a totally different way of teaching geology has born in the academia: new technologies, such as GIS platforms and 3D geological outcrops, have become essential. The main goal of 3GEO is to reconstruct 3D geological models of iconic geoclimbing sites along with geotrekking routes, included in a global network. Data will be shared through websites and social media to sustainably promote geoheritage, while specific educational applications (Bollati et al., 2018) will favour its preservation all over the World. The solid network among developed and developing countries allows to strengthen an aware geotourism, providing interactive tools which are necessary to appreciate and respect geosites and other connected natural features, as well as to become familiar with risks. The multidisciplinary and multicultural context of the UNESCO IGCP 3GEO project is the key to develop and improve a new experience of living at 360 degrees the geological heritage in Geoparks, from virtual reality to outdoor activities.

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Geological map of the eastern termination of the Mt. Kumeta-Alcantara Line (NE Sicily)

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Keywords: NE Sicily, Peloritani sole-thrust, Mt. Kumeta- Alcantara Line, orogenic system.

We present a new 1:10.000 scale geological map of the southwestern border of the Nebrodi-Peloritani Transition Zone (NE Sicily) (Pavano et al., 2015; 2018), a NW-SE oriented narrow belt characterized by Plio-Pleistocene, NW-trending, dextral strike-slip faults that accommodated the SE-ward migration of the Calabrian Arc, which originated during the Nubia-Eurasia collision to accommodate the retreat toward the southeast of the Ionian subduction zone (Ghisetti & Vezzani, 1982; Dewey et al., 1989). The study area extends for about 58 km^2 in the interference zone between two main regional tectonic lineaments. The SW-verging Peloritani sole-thrust (Catalano et al., 2018) that, crossing the NE Sicily, is responsible for the tectonic superposition of the Kabilo-Calabride Chain (European margin) on the Apenninic-Maghrebian Chain (African margin). In the footwall of the Peloritani sole-thrust, the Mt. Kumeta-Alcantara Line (Ghisetti & Vezzani, 1982) is a main E-W oriented oblique (dextral) thrust ramp bounding to the south the axial zone of the Sicily collision belt.

The geological map, which was realized using ESRI ArcGis and CorelDraw software, pictures the tectono-stratigraphic relationships between the different lithostratigraphic units outcropping in the area. The main target is the reconstruction of the polyphase history of the main tectonic features affecting the eastern sector of the Apennine-Maghrebian Chain and the definition of the geometry, deformation style and kinematics that characterized each stage of their evolution. Our study provides new insights on the tectonic structures involved in the overlapping of the orogenic edifice on the Apenninic-Maghrebian Chain and on the kinematic and the role of the Mt. Kumeta-Alcantara Line in the frame of the Nubia-Eurasia collision.

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Changes in groundwater trace element concentrations before seismic and volcanic activities in Iceland from 2010-2018

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Keywords: seismic precursors, volcanic precursors, hydrogeochemical anomalies, earthquakes, pre-seismic processes.

The aim of this study is the identification of possible correlations between trace elements of the groundwater and geological events in order to identify potential hydrogeochemical precursors. We analyzed temporal variations of trace element concentrations in groundwater from a borehole in northern Iceland and compared them with seismic and volcanic events that occurred in Iceland during the study period. In particular, since 2002, a hydrogeochemical monitoring system is running in northern Iceland consisting of two monitoring stations, at Húsavík (HU01) and at Hafralækur (HA01) with the main objective of identifying potential precursors of earthquakes. These monitoring sites have already given very promising results (interpreted as potential seismic precursors) before three large earthquakes (M_w > 5.0) that occurred in northern Iceland on 2002, 2012 and 2013 (Claesson et al., 2004, 2007; Skelton et al., 2014, 2019; Andrén et al., 2016). The samples analyzed in this study come from the borehole HA01 and cover the period 2010-2018. An increase of B, Al, V, Li and Mo concentrations started from eight months to one month before the 2014 Bárðarbunga eruption, while Ga and V concentrations began to increase one day and one month after the onset of the event, respectively. We also found that concentrations of some trace elements (Li, B, Ga, Mo, Sr, Rb and Fe) significantly increased before an M_w 5.0 earthquake that occurred ~80 km from the borehole in 2018. However, other notable hydrogeochemical changes were detected during the monitoring period without apparent correlation with the seismic and volcanic events in the region. This study shows that systematic long-term hydrogeochemical monitoring in seismic and volcanic areas is critical to advance the science of seismic and eruptive precursors. Furthermore, the use of statistical tools, such as principal component analysis (PCA) and change point (CP) analysis can help identify the most useful chemical elements and validate the trend variability of those elements in the time series.

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The Volcanological In-Situ Deformation Instrument

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Keywords: rheology, deformation, observation, magma, degassing.

A unique low load, high temperature apparatus was appositely designed to investigate magma rheology and directly observe deformation of the sample at temperatures of volcanological interest. The new apparatus that we call Volcanological In-situ Deformation Instrument (VIDI) is developed to perform vertical uniaxial deformation at high temperature (up to 1100 °C) on natural silicate melts. The base unit is a uniaxial press equipped with a furnace in which a sapphire window allows the visual inspection and camera recording of the sample subjected to deformation. This unique characteristic allows to characterize the rheology of the sample in a range of viscosity from $10^{8.5}$ to $10^{11.5}$ Pa s and directly relate rheological data to deformation mechanisms. Viscosity is calibrated by measuring cylindrical samples of variable dimensions (20-30 cm in height and 10-15 cm in diameter) of NIST Standard Reference Material® 717a Borosilicate Glass at a temperature between 540 and 625 °C and a strain rates between 5 x 10^{-5} and 1 x 10^{-3} s^{-1}. Viscosity standard values are reproduced with an error of ±0.21 log Pa s.

Due to its peculiar features, VIDI apparatus can be employed to perform accurate studies on bubble-bearing melt samples, by allowing a complete observation of the process occurring at temperatures above the glass transition (i.e., viscous softening, degassing and, possibly, outgassing) prior or during deformation. The first test of a foaming natural obsidian sample was performed on a cylindrical sample drilled from the Rocche Rosse lava flow in Lipari Island (Aeolian Arc, Italy). The experiment involves in-situ degassing at T =850 °C and subsequent deformation at T =800 °C under constant strain rates of 1 x 10^{-4} s^{-1}. The analysis of the strain partitioning on the sample during the deformation, allowed by in-situ observation, indicates a progressive increase of piston-sample contact area, while the sample maintains a cylindrical shape. This allows to choose the most appropriate model (i.e. "perfect slip" equation by Gent, 1960) to convert mechanical data to viscosity (8.77 $\log_{10}$ Pa s for the foamed rhyolitic sample with 64% bubble content).

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Extreme mass loss of Brenva glacier from UAV and satellite surveys

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Keywords: UAV, photogrammetry, glaciers, mass loss.

Debris covered glaciers are common in many parts of the world and contribute to the hydrological cycle and freshwater availability in arid regions. In the Italian Alps, some of the largest debris covered glaciers are located in the Mont Blanc group and among them Brenva glacier (5.95 km^2 in the latest glacier inventory, Paul et al., 2020) reaches the lowest terminus elevation on the southern side of the Alps at 1415 m a.s.l.. The debris supply originated from several rockfall events throughout the Holocene, with the most recent ones in 1920s and in 1997. In 2004, the ice flow was interrupted from the icefall to the glacier tongue, and this led to enhanced ice stagnation and mass wasting. To investigate the recent evolution of the glacier tongue, we carried out two UAV (Unmanned Aerial Vehicles) surveys in 2019 and 2020, acquired high resolution satellite images from the SPOT and Pleiades constellation from 2012 and 2020 and further DEMs (Digital Elevation Models) from the regional authority of Valle d'Aosta from 1991 and 2008. By comparing the DEMs and orthophotos generated from photogrammetric surveys, we were able to describe the rapid thinning of the ice tongue, which lost more than 40 m over one year only. Downwasting of the ice was faboured by the formation of epiglacial lakes, which enhance melt. By generating DEMs and orthomosaics from satellite data, we reconstructed the recent history of the glacier, showing an initial phase of mass transfer from the rockfall and the subsequent melt out of the ice tongue.

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Nanometric characterization of surface proprieties of phyllosilicates interacting with polypeptides and H_2O

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Keywords: Phyllosilicates, Polypeptides, H_2O, DFT, AFM.

The study at the nanometric level of the surface properties of minerals and their interactions with the external environment is crucial for its applications in many fields such as medical biotechnology, environmental and materials science. This work focusses on the possible role of these minerals in the origin of life. We analyze the interaction between simple biomolecules with the surface of the clinochlore $Mg_6Si_4O_{10}(OH)_{10}$, and H_2O molecules with the (001) surface of pyrophyllite and montmorillonite. The adsorption of biomolecules was investigated through Density Functional Theory (DFT) simulations and Atomic Force Microscopy (AFM). Following the promising results on the affinity between clinochlore and glycine and alanine monomers and dimers shown in previous works (Moro et al., 2015; 2019; 2020a; 2020b), we have extended the analysis using penta-glycine and penta-L-alanine. AFM observations of the interaction between a cleaved surface of clinochlore with the penta-L-alanine confirm previous results on monomers and dimers, *i.e.*, the preferential adsorption of the biomolecule on the exposed brucite-like layer of the mineral. DFT simulations provided the geometric configuration of the adsorbed molecules and we found that the adsorption energy of peptides normalized to the number of monomers decreases significantly compared to the single amino acids. The behavior of water on the surfaces (001) of montmorillonites, with different interlayer cations (Na^+ and Ca^{2+}) and the corresponding neutral pyrophyllite, was also investigated from a theoretical perspective. A specific organization, dependent on the surface electrostatic potential interacting with the molecules, has been found assuming an increasing coverage of H_2O molecules. Understanding how the solvent could mediate with the deposition and transport of biomolecules is of pillar importance in the formation of the first forms of life as well as to characterize the behavior of water in any other application.

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Evidences of carbonate preservation on the outer continental slope in the Western Ross Sea (Hallett Ridge and Central Basin, Antarctica)

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Keywords: Antarctica, Ross Sea, foraminifera, carbonate preservation, sedimentology.

Late Quaternary Antarctic Ice Sheet (AIS) changes can be investigated by analyzing marine sediments (gravity and box cores) collected on the continental shelves and along the continental margins of Antarctica. These sites are strongly influenced by the ice sheet/shelf sediment drainage and inflow/outflow of polar water masses. In this respect, the continental slope of the Western Ross Sea (WRS) is still poorly studied, in particular its history is affected by uncertainties due to the scarcity of well-preserved calcareous foraminifera preventing the production of reliable age models.

We present the results of a study made on one gravity core (KI13-C2; Melis et al., 2021) and three box-cores (KI13-bc2, bc3 and bc4; Torricella et al., 2021) located on the Hallett Ridge and in the Central Basin where the presence of carbonate-rich intervals offers the opportunity, to time-reconstruct the AIS evolving changes since the Marine Isotopic Stage (MIS) 2. These intervals correlated with other carbonate layers identified in cores collected along the WRS continental slope provide important insights about a large-scale break-up of the ice shelf/sea ice system.

This study has been conducted in the framework of the STREAM Project (Late Quaternary evolution of the ocean-ice sheet interactions: the record from the Ross Sea continental margin, Antarctica; period 2019-2021), funded by the Italian Ministry of Foreign Affairs and International Cooperation and the National Research Foundation of Korea, and thanks to a grant approved by the Department of Mathematics and Geoscience, University of Trieste.

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Walk to learn, learn to walk: an educational practice to reconnect geology with sustainability

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Keywords: environmental education, sustainability, transdisciplinary, experiential learning, trekking.

Despite the fact that, at the dawn of XXIst century, many scholars were predicting a central role of earth sciences (ES) in the education for future citizens (Orion, 2007) and in the scientific inquiries (King, 2008), the geology community has almost missed the opportunity to have a real impact in societal problems and to be considered at the centre of a new kind of education, where the geoscientists skills could be helpful to prepare for the future. In particular, the sustainability wave seemed to leave ES behind (Fildani & Hessler, 2021), as it's easy to understand considering the deep lack of geology classes in high ranked degrees and the decreasing number of students that applied for ES in the last years. Surely there's a problem with geosciences education in national curricula: nonetheless, it's time to change our approach as educators and give more importance to the complex and systemic abilities that we can develop. ES education needs a shift to move towards a sustainable, transdisciplinary and more experiential approach.

Walking can be a good starting point. If "educate", referring to the original Latin *educere*, means to experience "outside" in the world (Masschelein, 2010), it means also to be able to discover a territory with a sensorial approach. Geoscientists know, more than others, the importance of reading a territory as a complex system, where geological aspects are connected with others. Furthermore, the experience of crossing a territory in a group allows to go beyond the classic one-way transmission of notions and leads to a mutual exchange of shared knowledge on the same experiential level.

During may 2021 we propose to students a two-day workshop called Walking hills. The workshop consists in two different treks in Turin: the first one is a round-trip around Superga; the second in Western Monferrato, headed to the romanesque Abbazia di Vezzolano. During these two days we move on a territory with a high geological richness, where students can observe different typologies of outcrops. Nevertheless, we explore the historical and artistic landscape of the area. This workshop is an experience of a transdisciplinary educational project based on a systemic approach, to promote education as the discovery of interactions, a place where teachers and learners try to break conventional boundaries between scientific and humanistic approach, nature and culture, even body and mind.

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Petrogenesis and geochemical features of the Lar alkaline igneous complex (SE Iran)

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Keywords: Lar Igneous complex, alkaline magmatism, shoshonitic/ultrapotassic, Sistan Suture Zone.

We present a detailed geochemical and petrographic study on samples from the Lar alkaline igneous complex, which is located in the Sistan belt (SE, Iran), a poorly studied area of the Alpine-Himalayan orogenic belt. The complex is composed of intrusive and hypabyssal rocks of shoshonitic to ultrapotassic affinities with variable silica saturation degree. The most alkaline rocks include lamprophyres, nepheline-syenites and felsic dykes of phonolitic composition, whereas silica-saturated and over-saturated rocks are represented by syenites and monzonites. Lamprophyres and nepheline-syenites show petrographic textures suggesting subsolidus unmixing processes between nepheline and K-feldspar recalling the occurrence of pseudoleucite, and represent the most alkaline potassic rocks of the Oligocene magmatism in the Sistan-Lut collisional belt.

The application of a thermodynamically-constrained fractional crystallization model show clear comagmatic relationships among the most alkaline rocks, whereas silica-saturated and -oversaturated rocks have different origin but no parental mafic magmas were recognized within the Lar complex. Normalised incompatible trace element patterns show that all the studied rocks have geochemical features compatible with a subduction-related setting. The alkaline potassic and silica-undersaturated rocks are characterized by higher LREE/HREE fractionation (La_N/Yb_N from 12 to 22) with respect to the silica-saturated and -oversaturated rocks (La_N/Yb_N from 10 to 12). The Sr-Nd-Pb isotopic compositions are rather homogeneous suggesting a possible common mantle source for the Lar igneous rocks and that the crustal contamination/assimilation processes only affects the most differentiated products. A geochemical and isotopic-based modelling suggests that the metasomatic agents that modified the mantle beneath the study area are mainly constituted by melts derived from sediments rich in carbonate component, whereas melts from carbonate-poor sediments are subordinate.

This study shows that, in the general framework of the Alpine-Himalayan orogen, magmas of the Lar igneous complex show interesting geochemical similarities with those of the post-leucititic phase of the Neapolitan district in the Roman Magmatic Province, suggesting analogies in the magma genesis among different sectors of the Tethyan realm.

2D Hamiltonian Monte Carlo joint inversion of potential field data

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Keywords: Hamiltonian Monte Carlo, inverse problems, geophysical modeling, potential fields, applied geophysics.

In this work, we present preliminary results from an algorithm for joint inversion of gravity and total magnetic anomaly (TMA) data aiming to target the density distribution and the magnetization in the subsurface of the Earth by means of the Hamiltonian Monte Carlo method (HMC) (Neal, 2011; Fichtner et al., 2018).

The model parameterization is defined in terms of 2D polygonal bodies characterized by uniform density and magnetizations (induced and/or remnant) and the gravity and magnetic non-linear forward calculations are performed using the formulas of Talwani et al. (1959) and Talwani & Heirtzler (1962) respectively, the latter ones checked in detail recently by Ghirotto et al. (2021).

The main benefits using polygonal bodies are i) a huge reduction of the model space size for well-defined geological bodies compared to gridded approaches and ii) a computationally much cheaper algorithm in terms of both memory requirements and number of calculations.

The unknown parameters are represented by both the positions of the polygon vertices and their density and magnetizations, with the option of limiting the inversion to any of them.

Following the probabilistic approach to inverse problems, the goal of the HMC inversion strategy is to explore the posterior probability density of the model parameters (PPD), obtaining as a result a collection of models representing samples of the PPD. In addition, statistical analysis performed on this collection could provide useful measures of parameters uncertainty and plausible geophysical scenarios, which cannot be handled using traditional deterministic inversion methods.

To help steering the inversion process toward high-probability areas in the model space manifold, HMC requires the computation of the gradient of the PPD with respect to the model parameters, achieved here by employing the technique of automatic differentiation.

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Characterisation of mineralogical specimens from the abandoned Fe-Mn Montaldo Mine, Corsaglia Valley, Cuneo

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Keywords: mineralogy, Montaldo Mine, Cuneo Province, REE minerals, Fe-Mn ore deposit.

The study focused on the mineralogical analyses of samples deriving from the already known mining landfills, located in Frazione Oberti, Montaldo Mine (Cuneo), collected in five different sites located both on the left and on the right sides of the Corsaglia River (Kolitsch et al., 2011). The samples were subjected to several analyses: SEM-EDS, μ-Raman spectroscopy, and optical microscopy of thin sections, which allowed to determine a quite complex mineralogy: in a mineralized mass of braunite, Fe-Mn-oxides and -silicates (cryptomelane/hollandite series, hematite, muscovite), lesser quantities of other mineral species were detected, like: berzeliite, tilasite, montmorillonite, as well as traces of Rare Earth minerals (monazite, gasparite, chernovite, wakefieldite), other manganese species (ranciéite, ramsdellite romanechite) and accessories minerals (zircon, rutile, arsenogoyazite). Also considering the different data obtained by previous studies (Cabella et al., 1992; 1999), it was possible to suppose that the Montaldo reservoir was affected by different metamorphic/hydrothermal events, which followed the deposition of the "Calcari di Val Tanarello" and its quartzarenitic/conglomeratic intecalations. The high concentration of REE and accessories minerals (mainly arsenogoyazite, berzeliite/manganberzeliite, svabite and tilasite) in the montmorillonite, observed by Kolitsch et al. (2011) and during this study, could be explained by the cations exchange capacity of this clay, which in presence of certain pH adsorbs more easily incompatible elements on its surface (Li & Zhou, 2020; Liu et al., 2019). This study allowed to also classify numerous species in reference of the new rules dictated by IMA, such as As-rich fluorapatite and muscovite-celadonite series phases (Cabella et al., 1992; 1999), and to recognize some species not yet identified in the Montaldo mine: gasparite-(Ce), monazite-(Ce), ramsdellite, ranciéite and wakefieldite-(Ce), where the latter would also be the second discovery in Italy of this species (Tumiati et al., 2020).

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Quaternary geomorphological evolution of the Telesina Valley (southern Apennine)

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Keywords: geomorphology, fluvial terraces, structural terrace, active tectonics, Southern Apennines.

This study is addressed to the reconstruction of the Quaternary geomorphological evolution of the Telesina Valley in the southern Apennines.

Relevant for the aim of the research is the reconstruction of the stratigraphical and morpho-structural features of the outcropping Quaternary units. Moreover, 270 outcrops have been analysed during the field work, which allowed to collect new geomorphological and stratigraphic data useful for the reconstruction of the main Quaternary morpho-evolutionary events.

Field data have been integrated with subsurface data from 185 boreholes. Both the field and borehole data have been analysed in a GIS software (QGIS). Integration of both datasets is synthesised in a geological and geomorphological map, and in five geological cross-sections. Pre-quaternary units was largely derived from the literature and supplemented by field checks and verifications.

On the opposite, Quaternary deposits were distinguished during field surveys and were grouped into different morpho-stratigraphic units. These include fluvial deposit, slope and alluvial fan deposits, travertine deposits and volcanic units.

Worthy to note, lacustrine deposits have been largely recognised in the subsurface of the Telesina valley, whose age may be constrained to the Middle Pleistocene. As a result, the perimeter of the lacustrine basin has been hypothesised.

Overall data indicate a transition from a lacustrine environment to a fluvial environment, which occurred from the Middle Pleistocene to the Upper Pleistocene. The presence of river terraces testifies the recent morphoevolution of the Telesina valley, which experienced also vertical motion due to fault activity.

Fault activity is testified by small dislocations of the topographical surface during the Upper Pleistocene and the Holocene, i.e., after the eruption of the Ignimbrite Campana (40 ka - Giaccio et al., 2017), and conditioned the incision / aggradation processes. This hypothesis is also supported by the historical seismicity of this sector of the chain and suggests that some of the mapped faults may still be active and, therefore, require more careful investigation.

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Geothermal resources exploitation from hydrocarbon wells using closed-loop geothermal systems: the potential of some Italian oilfields

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Keywords: renewable energy, geothermal energy, mature oilfield, abandoned hydrocarbon well.

Clean energy production using affordable, sustainable, and reliable energy resources has become one of the central topics of European and National development policy visions. In this context, the current Italian energy paradigm, heavily relying on fossil fuels, turns to be increasingly unsustainable. Geosciences can offer a possible range of solutions to this issue, through the development of various options that could encourage decarbonisation and the transition to renewable energy sources at local and regional scales. Geothermal energy exploitation, as a weather-independent, environmentally friendly, and currently available renewable resource, represents an effective solution for power generation, heating and cooling buildings, and direct-use applications. Over time, petroleum systems in Italian sedimentary basins have been explored mainly for oil and gas extraction. However, geological and geophysical exploration campaigns have ascertained the coexistence of hydrocarbons and low to medium-temperature geothermal energy resources in the deepest regions of such geological contexts. As such, thermal energy production based on the exploitation of available geothermal resources associated with disused deep wells in Italian oilfields has considerable potential: it could solve problems associated with suspended wells near municipalities, allowing for their longer-term use, even at the end of the production cycles.

With the main purpose to analyse heat exchange mechanisms associated with deep wells in different Italian oilfields, emphasizing how the quantity of extracted thermal energy can vary based on geological context, information available from both the National Mining Office of the Italian Ministry for Economic Development (MISE) and the Italian National Geothermal Database was explored (Gizzi et al., 2021). The simplified heat exchange models (Coaxial and U-tube WellBore Heat Exchanger) described in Alimonti & Soldo, 2016 and Ruiz-calvo et al., 2015 were implemented in a Python environment and applied to three different Italian hydrocarbon wells, respectively located inside the Villafortuna-Trecate, Val d'Agri, and Gela fields. Depending on the closed-loop geothermal configuration selected, the surrounding rocks thermophysical parameters, the hydrocarbon wells' constructional features, a substantial difference in the potential amount of extracted thermal energy between analysed sites was defined. Unlike the Villafortuna-Trecate ones, the implementation of a WBHE system in the Val d'Agri and Gela fields hydrocarbon wells may not be energetically or economically worthwhile The analysis approach, with the associated simplified models proposed, could represent a useful methodological tool for allowing a preliminary definition of the possibility of a hydrocarbon well to be converted into a geothermal one, employing a closed-loop geothermal technology.

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Hydrogeochemical changes before and during the 2019 Benevento seismic swarm in central-southern Italy

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Keywords: groundwater, hydrogeochemistry, earthquakes, hydrosensitivity, deep fluids.

Insights on groundwater changes induced by seismic activity have been carried out in the last decades. However, detecting seismic precursors is still one of the most compelling challenges in Earth sciences. Indeed, a detailed and in-depth understanding of hydrogeochemical anomalies prior to earthquakes remains the goal of many research teams worldwide. In order to investigate the earthquake-groundwater relationship with the main aim of identifying potential precursors of nearby earthquakes in groundwater, between 2018 and 2020, we performed sampling surveys coupled with continuous multiparametric monitoring in Grassano spring fed by the Matese carbonate aquifer (central-southern Apennines, Italy). Relevant hydrogeochemical changes were observed before and

during the onset of the 2019 Benevento seismic sequence (main earthquake on December 16th, 2019: M_w 3.9 San Leucio del Sannio). Recorded variations included dissolved CO_2 increase, pH lowering, and anomalies in major ions (i.e., Ca^{2+}, Na^+, HCO_3^-) that later recovered to their typical concentrations. We argue that geochemical responses in groundwater were triggered by pre-seismic crustal dilation processes, which allowed and enhanced the deep CO_2 progressive upwelling along tectonic discontinuities, as testified by the C_{ext} behavior detected in Grassano groundwater during the 2019 year. Results highlight and confirm the occurrence of a potential pre-seismic geochemical process in the fractured carbonate aquifers, similar to the one proposed in literature for the stronger 2016-2017 Amatrice-Norcia seismic sequence (Barberio et al., 2017; Boschetti et al., 2019; Barbieri et al., 2020; Franchini et al., 2020). Therefore, despite the seismicity during the monitoring period was characterized by small-intermediate magnitude, this finding shed light on the possibility of having pre-seismic hydrogeochemical signals in springs and groundwater of Apennines not only for high-magnitude earthquakes, at least in the areas where deep fluids contribution to groundwater is evident. Thus, the setup of a standardized and diffuse monitoring network of groundwater would produce significant and useful information to the huge topic of the evaluation of seismic risk and related activities.

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Radon fluxes estimate from geochemical data and gamma radiation in Campania region (Italy)

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Keywords: radon fluxes, geochemical mapping, multifractal IDW, radionuclides, terrestrial gamma dose rate.

Radon is a ubiquitous radioactive gas proceeding from the decay of some naturally occurring radionuclides, mostly abundant in igneous rock and volcanic materials, including soils. It is the heaviest noble gas, thus chemically inert, and moderately soluble in water. The total amount of radon in nature derives from three unstable isotopes: ^{219}Rn (^{235}U decay chain), ^{220}Rn (^{232}Th decay chain) and ^{222}Rn (^{238}U decay chain). ^{222}Rn, whose half-life is 3.8 days, represents the most important in terms of risks posed to human health since its progeny (e.g. ^{212}Po, ^{214}Po, ^{218}Po, ^{210}Bi, ^{214}Bi, ^{210}Pb, ^{214}Pb) is chemically very reactive and decays emitting particles and large amounts of energy. Alpha particle radiation from Rn progeny is one of the main sources of natural radiation to which human beings can be exposed during their life and it is considered the second indirect leading cause of lung cancer after cigarette smoking.

An empirical method was applied to estimate the flux of ^{222}Rn across Campania, a region of the south-western sector of the Italian peninsula and whose territory is mostly characterized by the presence of volcanic lithotypes and sediments, by using radiometric and geochemical data recorded in two different prospecting campaigns completed in 2003 and 2015, respectively. The main objectives of the work were to compare the estimated ^{222}Rn fluxes, resulting from the two sets of data, to analyse and interpret any differences and to identify areas with a high exposure to Rn for humans.

As a first step, Terrestrial Gamma Dose Rates (TGDRs), which represent the gamma-radiation emitted by the decay of naturally occurring radioactive nuclides, were calculated from both datasets and, later, they were used as inputs to determine the ^{222}Rn fluxes across the region. Data were processed in a GIS environment and were interpolated by means of the Multifractal Inverse Distance Weighted (MIDW) method. The resulting raster flux maps were compared by mean of a software that allowed to analyse the similarity among the values of the two maps, pixel by pixel. Further, a regression analysis was performed to quantitatively assess the functional relationship among the determined fluxes and residuals were also used to generate a raster (MIDW) map of their distribution, which was classified trough the C-A method.

The results denote two areas with high flux in correspondence of the volcanic centers (Mt Roccamonfina, Mt Somma-Vesuvio, Phlegrean Field), an area with medium flux values roughly corresponding to the pyroclastic covers (overlapping the sedimentary formations) and areas with low values along the Apennines and south of the region. The analysis of the residuals and the similarities suggested the hypothesis of an underground contribution to the surficial ^{222}Rn flux due to the presence of deep volcanic thick layers and the presence of tectonic structures.

Provenance and dispersion of heavy metals in late Quaternary deposits of the Piombino area (Tuscany, Italy)

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Keywords: environment, heavy metals, natural pollution, sedimentology, geochemistry.

A combined sedimentological and geochemical characterization of late Quaternary deposits was undertaken around the promontory of Piombino, Tuscany. The sampling campaign includes forty-six sediment samples from fluvial, swamp, lagoon and floodplain facies associations. Samples were collected with manual drill, and sedimentary facies were analyzed. For the estimate of background values of potentially toxic elements beyond human influence, the depth of sampling was between 90 and 140 cm (Sammartino et al., 2007; Amorosi et al., 2014). Samples derive from two distinct provenance domains: Cornia river (to the east) and Campiglia (to the west), differentiated on the basis of drainage basin position and of literature petrographic data (ARPAT, 2017). Each sample was analyzed through X-Ray Fluorescence, a non-destructive analytical technique aimed at defining total chemistry. The results show that surficial deposits in the area are affected by heavy-metal pollution (As, Co, Cr, Ni, Pb, Sn, V and Zn) often exceeding thresholds (CSC) imposed by the Italian D.Lgs 152/2006. As and Sn exhibit high values throughout the area. Pb and Zn are mostly concentrated in the northwestern portion of the area (near Campiglia Marittima). Concentrations of these elements are controlled by sulphide mineralizations, scattered in the Metalliferous Hills that border the area. Minerals such as arsenopyrite, galena, stannite and sphalerite, leached by the surrounding rivers, account for these high concentrations. Other metals, such as Co, Cr and Ni, are abundant in the eastern zone (Campiglia domain), where they reach values significantly beyond maximum permissible limits. Such high values are due to leaching of outcropping serpentinized peridotites. Heavy-metal distribution is strongly influenced by sediment provenance in both domains. Moreover, Cr, Ni and V display a clear relationship with particle size. In this small-sized fluvial system, Cr and Ni are enriched into coarse sand, contrary to what can be observed in larger alluvial basins (Amorosi et al., 2002; Dinelli et al., 2012). Vanadium shows its higher concentrations in lagoon and swamp deposits, especially in the eastern Cornia river domain, where sediments are particularly fine-grained. This study demonstrates that high heavy-metal contents are due to geogenic (and not anthropogenic) factors, closely related to local geology. However, assessment of health and environmental risks linked to these metals, requires targeted studies of bioavailability.

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Using multi-proxy thermal maturity datasets to validate deformation styles from the Adjara-Trialeti fold-and-thrust belt to the Greater Caucasus (Georgia)

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Keywords: intra-continental deformation, Maikop, thermal maturity, Caucasus, Kura Basin.

We present a brand new multi-proxy dataset of thermal maturity indicators, which derive from the application of several analytical techniques on surface and subsurface sedimentary successions. The study area spans from the Greater Caucasus to the Adjara-Trialeti fold-and-thrust belt (FTB), comprising the intervening western Kura Basin, in Georgia, and represents a region of continental deformation in the hinterland of the Arabia-Eurasia collision zone. Original and published clay mineralogy, Raman spectroscopy and petrography on dispersed organic matter, and pyrolysis data are integrated for the first time in a coherent tectono-sedimentary scenario. Thermal maturity spans from the low diagenetic realm (60-80°C) in the Upper Miocene section of the Kura sedimentary fill, to the oil window in the Cretaceous to Lower Miocene successions of Adjara-Trialeti FTB, Kakheti ridge and Kura Basin (70-120°C), up to about 400°C in the Greater Caucasus core. Integration of different indicators, besides allowing the estimation of maximum burial temperatures acquired through time, enabled to draw the tectonic evolution of the area. Different maturity trends and thermal histories, coupled with structural and stratigraphic data, highlight that the study area comprises two domains derived from positive tectonic inversion: the E-W Adjara-Trialeti doubly-verging FTB from an Eocene back-arc rift basin and the SSW-verging Georgian Greater Caucasus from a Mesozoic rift basin. Between the two, thin-skinned south-verging thrusts deform the Kura Basin and the Kakheti ridge successions, originally deposited on an extensional structural high which was later flexured during compression. The similar thermal maturity degree in the Adjara-Trialeti FTB and the Kakheti ridge/Kura Basin areas has been acquired in different time spans: during Paleogene extension and during Miocene thin-skinned shortening, respectively. The results indicate that thermal maturation of the sedimentary successions in the Adjara-Trialeti FTB can be ascribed to burial during rift evolution. The same conclusion can be drawn for the axial zone of the Greater Caucasus, whereas tectonic overburden may have contributed to the thermal maturity of the rocks in the southern foothills of the Greater Caucasus: this area needs further work to assess its tectonic evolution.

Multi-sensor remote sensing approach for detecting and mapping the human-waterscape interactions during the early-mid Holocene in Tell Zurghul area

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Keywords: Lower Mesopotamian Plain, remote sensing, geoarchaeology, waterscape.

During the early-mid Holocene, the archaeological site of Tell Zurghul was part of the State of Lagash in the southernmost sector of the Mesopotamian Plain (Iraq). About 6000 yr BP, the Persian Gulf shoreline reached its maximum ingression up to the modern cities of Nasiriyah and Al-Amara (Lambeck, 1996; Kennett & Kennett, 2006), where the Tigris and Euphrates rivers developed a wide river-dominated delta system that guaranteed water availability for agriculture, settlements, and transport. Since 6000 yr BP, the delta progradation shifted the Persian Gulf shoreline up to the modern position, about 200 km southward. Therefore, the Lower Mesopotamian Plain represents the ideal study area for discovering and unravelling the interactions between human activities and the surrounding waterscape, characterized by a multi-channelized fluvial system, further complicated by a well-developed canal network (Jotheri, 2016; Jotheri et al., 2018). A multi-sensor remote sensing approach is a suitable method for detecting and mapping the main fluvial features and recognizing the associated morphogenetic processes, especially when international lockdowns due to the COVID-19 pandemic and local warfare occur and prevent extensive field-works. In order to reconstruct the waterscape surrounding the archaeological site of Tell Zurghul and define the human interferences, the multispectral analysis focuses on the NDVI (Normalized Difference of Vegetation Index) and Clay Ratio indices for discerning between active and abandoned fluvial landforms, while the topographic analysis of the micro-relief is a key method for enhancing the "above floodplain" framework of the active and abandoned landforms. Landsat 8 multispectral images and 30-meter spatial resolution DEMs like the optical DSMs from ALOS and ASTER, in addition to the extraction of a high spatial resolution DTM from COSMO-SkyMed data are the main materials for investigating the study area. Thanks to the field evidence provided by the Italian Archaeological Mission, the presence of water and the proximity of the sea during the early-mid Holocene has been furnished by fish vertebras belonging to a *Carcharhinus leucas*, several clay weights for fishing nets and clay sickles for cutting marsh reeds during the fishing and sailing. Moreover, the patron deity of Tell Zurghul was the goddess Nanshe of the sea and sea species (fish and birds), unravelling a strong relationship between water and the ancient settlement.

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Petrographic, microstructural and petrophysical study of asphaltic limestone employed in the Late Baroque Towns of the Val di Noto UNESCO site (south-eastern Sicily)

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Keywords: Pietra Pece, bitumen, porosity, Hyblaean Plateau, SE Sicily.

This paper reports the results of a petrographic and petrophysical study of asphaltic limestone rocks, known by the local name of "Pietra Pece" (i.e. Pitch Stone), from the Tabuna quarry, located in the city of Ragusa (south-eastern Sicily).

The earliest evidence of Pietra Pece processing is related to an ornamental use and dates to pre-Hellenic eras (Iurato, 2013). After the Val di Noto earthquake of 1693, the south-eastern territory of Sicily was affected by an intense reconstruction activity that saw a strong increase in the use of asphaltic stone alternating with white limestone: this style was recognized in 2002 as a UNESCO World Heritage Site "Late Baroque Towns of the Val di Noto" (https://whc.unesco.org/en/documents/141487). Since this limestone is impregnated with bitumen, Pietra Pece throughout history has also been affected by industrial processing for the extraction of hydrocarbon (Iurato, 2013).

Although the two selected samples show similar macroscopic petrographic and mineralogical characteristics, they are different in color, from total black to brownish with white veins, which we assume is related to the various percentage of bitumen. In addition, Pitch Stone is nowadays widely used as a stone material because of its good physical and mechanical properties (gelivity, external and internal physical durability, and high impermeable properties).

In order to (1) highlight the microstructural and petrophysical differences, such as fossil content and porosity, that may have influenced the bitumen permeability and (2) to correlate the mineralogical-petrographic and physical-mechanical characteristics of the rock with its excellent behavior as a building material, we performed optical microscopy, X-Ray CT tomography, SEM analysis, and ultrasonic investigation.

In summary, the present work made it possible to define: (1) how the fabric, the porosity and the bitumen content affect the sample's physical and mechanical properties; (2) the relationship between the porosity and the percentage of bitumen impregnation; (3) based on the fossil content, a relative dating of the samples.

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Stratigraphic and micropaleontological approaches for the Holocene paleogeographical evolution of the Sarno River alluvial-coastal Plain

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Keywords: micropaleontology, stratigraphy, paleoenvironmental reconstruction, Sarno River Plain, Somma-Vesuvius.

Stratigraphic and micropaleontological analyses were carried out with the aim of contributing to the reconstruction of the paleoenvironmental evolution of the Sarno River Plain in the time range between the Avellino (3950 BP, Di Vito et al., 2009; Sulpizio et al., 2010) and Pompeii (79 AD, Sigurdsson et al., 1985; Gurioli et al., 2005) Plinian eruptions. A total of 62 samples were used for the present study, 46 from cores drilled in front of Pompeii Archaeological Park, 12 from a core drilled in the southern part of the alluvial coastal plain (Messigno) and four samples collected from Pompeii Archaeological Park. Meiofaunal assemblages, with special regard to benthic foraminifers and ostracods, were used to reconstruct the depositional environments of the Holocene successions. Regarding the deposits buried by 79 AD volcaniclastic layers, six samples yielded microfossil assemblages of shallow marine waters while other four showed remains typical of continental waters. These data suggest the presence of marine shallow water environments very close to the Roman city. The presence of a thin paleosoil and traces of biological weathering at the top of the deposits suggest short-term subaerial conditions, probably due to ground-uplift movements that preceded the eruption. In order to evaluate the relative sea level movements, the marine deposits and their relative age were projected into an age-depth diagram, along with the Relative Sea Level positions during the last 5 ka BP for the Neapolitan coastline (Romano et al., 2013). The present study adds new paleoenvironmental data to the paleo-coastline reconstructions suggested in previous studies, and highlights the strong value of micropaleontology for paleoenvironmental reconstructions in volcanic and sedimentary sequences, also contributing to the knowledge of the deformative history of the Somma-Vesuvius complex.

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Sedimentary origin of the carbonate-rich components in the pyroclastic breccias from Cabezo Negro de Tallante volcano (SE Spain)

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Keywords: carbonatite, calcrete, volcanic basaltic rocks, petrology.

Cabezo Negro de Tallante (CNT; SE Spain) is a small Plio-Quaternary volcanic centre, part of the South East Volcanic Province of Spain (Cebrià et al., 2009). It is characterised by the presence of several metre-thick deposit of polymictic and heterometric pyroclastic tuff-breccia, agglutinated by a carbonate-rich component. The silicate magma has basaltic, hawaiitic and basanitic compositions, found as scoriaceous to massive, small lava flows and, in the pyroclastic breccia, as scoria and lava fragments.

Most studies on CNT volcanic products have focused on the abundant crustal and mantle xenoliths, found in the silicate portion, leaving only minimal interest on the whitish carbonate component of the breccia. This carbonate fraction has been recently interpreted as representing a mantle carbonatite component (Toscani et al., 2020). We reinterpret the breccia as an in-situ fragmented strombolian deposit, which undergone a subsequent carbonate precipitation. We suggest a secondary origin for the carbonate, led by an alternation of precipitation and dissolution phases in a vadose zone. The bacterial activity together with fungi, roots and meteoric water caused the development of calcrete-type deposits, largely diffused in the area of study (Alonso-Zarza et al., 1998). This conclusion is based on sedimentological (coated grains and root recrystallization), petrographic (occurrence of plagioclase in scoriae and absence of liquidus phases in calcite matrix), mineral chemistry (low BaO and SrO contents in calcite), whole-rock chemistry (low incompatible element budget in the pure carbonate fraction and negative correlation between trace elements and CaO), radiogenic isotopic systematics (correlations of Sr-Nd-Pb isotopic ratios vs. CaO), as well as stable isotope data (heavy $\delta^{18}O$ and light $\delta^{13}C$ composition of carbonates).

The CNT mildly alkaline sodic basaltic activity, part of the wider circum-Mediterranean anorogenic igneous phase (Pliocene-Present), is comparable to the other coeval Spanish volcanic provinces, despite some geochemical features (i.e., negative Rb and K anomalies) remind the orogenic signature of the Miocene calcalkaline to ultrapotassic magmatism particularly abundant in the area. CNT basalts may be interpreted as the product of a low-degree (2-6%) partial melting of an amphibole-bearing peridotite mantle, close to the lithosphere-asthenosphere boundary, due to small-scale, edge-driven convection.

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Sulaiman Fold and Thrust belt from Sentinel-1A interferometry

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Keywords: source fault geometry SFT, coseismic deformation, Dajal earthquake, flexural slip axial surface, restricted rupture propagation.

The continental collision at the western boundary of the Indian continent formed the tectonically complex transpressional zones of the Sulaiman Fold Thrust (SFT) and Kirthar Fold Thrust (KFT) belts. Seismic hazard around the SFT is considered elevated, but shortening across its eastern boundary is poorly understood because of the scarcity of moderate-sized earthquakes in the last decades. Here, we use Sentinel-1A interferometry to analyze the coseismic crustal deformation and source fault geometry associated with the 2015 moment magnitude (Mw) 5.7 Dajal earthquake that occurred on the boundary thrust in the SFT belt. The line-of-sight displacements amount to ~45 and ~50 mm for the ascending and descending interferograms, respectively, due to thrust-dominated slip over a blind fault. The inverted InSAR measurements fit well with USGS and ISC model parameters, except for the depth of the fault that is found to be shallower. A simplified fault model shows a dip of 41°, strike of 194° and rake of 79°, with a large aspect ratio of the seismogenic fault, due to a narrow ruptured fault width compared to the ruptured length. The InSAR inverted fault source parameters are used to determine the seismic moment ($Mo = 3.94 \times 10^{17}$ Nm), with the shear modulus ($\mu = 32$ GPa), corresponding to a moment magnitude Mw = 5.7 that is consistent with seismological estimates. We also perform the sensitivity analysis to understand the geometry of a possible ramp-décollement or décollement-ramp-décollement fault system using finite fault inversion. Finite fault modeling indicates the presence of a shallow décollement branching into a shallow ramp and décollement at approximately 7 km depth. We also incorporate the flexural slip over axial surface during coseismic deformation. The Dajal earthquake seems to have propagated along the base of the ramp and associated axial surface, that stops at the tip of the ramp. A few aftershocks occurred in the surrounding anticline. We suggest that folding of the shallow sediments by flexural slip at the eastern boundary of the SFT belt may have restricted the rupture propagation.

Chemical and textural analysis of short-term magma carbonate interaction experiments - implications for natural systems

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Keywords: magma, carbonate, limestone, CO_2, eruption.

The interaction between magma and solid wall-rocks is an unavoidable process in the Earth's system.

From the generation of magma at depth, during migrations through dykes and sills, storage in a magma chamber until the final ascent to the surface, magma is interacting with the surrounding country rocks.

Especially the interaction with carbonate-bearing wall-rocks (i.e., carbonate assimilation) is of paramount importance due to their ability to release CO_2 (e.g. Deegan et al., 2010). As several papers suggest (Deegan et al., 2010; Jolis et al., 2013; Blythe et al., 2015) the release of CO_2 can happen in syn-eruptive timescales (i.e., during an ongoing interaction). The additional CO_2 from carbonate assimilation might also drive the transition from effusive to explosive mafic eruptions (Freda et al., 2011). In a Merapi case study, Carr et al. (2018) calculated that the addition of as few as 1000ppm of CO_2 to a batch of magma might be enough to reduce H_2O solubility, force its vesiculation and generate enough vapour phase overpressure to cause this change in eruptive behaviour. Despite all these findings and their importance regarding hazard assessment, fundamental parameters influencing the rate of carbonate assimilation (like pressure, temperature, H_2O-content of magma) remain only poorly or not constrained at all.

Here we present the results of a new series of short-term (0-10min) magma carbonate interaction experiments with special emphasis on the chemical and textural changes around the interface. The results of our study confirm that CO_2-release is indeed a fast process and it is decoupled from the chemical dissolution of the carbonate clast. Furthermore, by comparing chemical and textural changes within the experimental products to natural samples from the Avellino eruption of Somma-Vesuvius we can draw first-order conclusions about interaction times and therefore magma ascent times.

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Ab initio thermodynamics of minerals at deep Earth's conditions: the case of ringwoodite

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Key words: Ab initio, DFT, thermodynamic properties, deep mantle, ringwoodite.

Since the deepest portions of the Earth's mantle still remain unsampled (especially below 400 km depth), ab initio calculations based on quantum-mechanical theory are one of the most reliable methods available to obtain information on thermodynamics, phase relations and rheological properties of mineral phases stable at deep mantle conditions. The most striking feature of the so-called density functional theory (DFT) is that it is able to accurately predict physico-chemical and thermodynamic properties of crystalline solids in a wide range of P - T conditions, without the need of any experimental data.

We performed *ab initio* calculations by means of the CRYSTAL computer code to determine thermodynamic properties of ringwoodite. Ringwoodite, with ideal formula Mg_2SiO_4, represents the stable polymorph of olivine in the Earth's lowermost mantle transition zone, where a dense, cubic, spinel-type structure is adopted by this mineral due to the extreme P-T conditions. Thermodynamic properties of ringwoodite that depend on vibrational frequencies (i.e., heat capacities, thermal expansion, isothermal bulk modulus, entropy, enthalpy, Gibbs free energy) have been computed in the framework of quasi-harmonic approximation by a full phonon dispersion calculation or, alternatively, by a modified Kieffer's model splitting acoustic and optic contributions (Kieffer, 1979). Both methods reproduce well the vibrational density of states, allowing an accurate determination of the equation of state parameters and thermodynamic properties as well. The calculated heat capacity in the low- to medium-T range is in excellent agreement with the few calorimetric investigations made so far on this phase (Akaogi et al., 2007; Kojitani et al., 2012).

The obtained results are then used to derive relevant phase equilibria of ringwoodite in the Earth's deep mantle, such as: i) the wadsleyite to ringwoodite phase transition occurring at 520 km depth in the mantle transition zone; ii) the disproportionation reaction of ringwoodite to give periclase (MgO) and bridgmanite ($MgSiO_3$), usually referred to as post-spinel phase transformation, occurring at the top of the lower mantle. Some possible geophysical implications for mantle seismic discontinuities and phase relations are finally outlined and discussed.

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Soils chronosequences in high-altitude environments: The case of Alpe Veglia (Lepontine Alps)

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Keywords: soil chronosequence, pedogenesis, mountain environment, climate change, Lepontine Alps.

Climate change has a huge impact on alpine environments. In high altitude environments, one of its most visible effects is glaciers retreat, which causes the progressive exposure of previously glaciated surfaces, where weathering processes promote soil formation. These areas are open-air laboratories where, substituting space for time, the effect of time factor on soil development can be isolated from the effect of the other soil-forming factors (Egli et al., 2006). However, isolating the effect of time from the other factors could be challenging when considering the high geomorphic activity featuring proglacial areas, where paraglacial dynamics are expected to control landscape changes and sediment supply even limiting the vegetation establishment (Temme et al., 2016).

The aim of our study is to evaluate soil evolution along a soil chronosequence in the Alpe Veglia area (Lepontine Alps). We performed a field and laboratory characterization of seven soil profiles sampled on different time-exposed surfaces, from the Aurona glacier proglacial area to the Alpe Veglia plain across different age glacial deposits.

Our preliminary results suggest major evidences of differentiation between younger soils of the proglacial area and the well-developed soils outside it, on Pleistocene-aged deposits. The results of physical and chemical analyses underline a time-trend of soil skeleton concentration, fine particles fraction, accumulation of soil organic carbon and acidification. On the other hand, some soil profiles developed outside the proglacial area s.s. do not show the same trend with time in their properties. In particular, two profiles deviate from the trend with a higher amount of clay and organic matter with respect of older profile, while another profile shows an unusual abundance of gravel in the surface horizon with slightly higher pH values. Hence, various soil forming factors might have induced a divergence from the chronosequence, probably depending on both the lithological heterogeneity of glacial deposits (calcschists, gneisses, prasinites) and the influence of different geomorphic dynamics such as surface processes. Moreover, differences in aspect and micro-climatological conditions may need to be considered.

Our results demonstrate that soil properties variability along the chronosequence can be mainly explained according to the soil-chronosequence approach, but other factors need to be considered in order to better evaluate how the landscape changes in such a sensitive and dynamic environment.

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Kinematics of the Afrera Linkage Zone (Afar) from InSAR, Seismicity and Structural data

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Keywords: InSAR, time-series, seismicity, rift systems, rift-linkage.

At divergent plate boundaries, discrete spreading segments accommodate extension through dominant magmatic activity and minor faulting. As plate divergence proceeds, such segments grow and interact through linkage zones that range in width from a few tens to several hundreds of kilometers and can eventually evolve to oceanic transform margins. However, the spatial and temporal distribution of displacements and the kinematics of linkage zones are poorly constrained as direct observations are difficult to make. The Afar depression in Ethiopia represents a perfect study area as it shows the mature phases of the rifting process exposed at surface.

Here, we present the results of an InSAR and seismicity study to investigate the plate-boundary kinematics of the Afrera linkage zone, the junction between the two active magmatic segments of Erta Ale (EA) and Tat Ali (TA) in Northern Afar (Ethiopia) (La Rosa et al., 2019; 2021). We used a ~9 years-long InSAR dataset spanning 2005-2010 and 2014-2019 from ENVISAT and Sentinel-1 satellites, respectively, to produce time-series of satellite Line-of-Sight (LOS) cumulative displacements. Co-seismic InSAR displacements were also observed in October 2007 and January 2018 and were inverted for the fault parameters. InSAR data were also combined with seismic and structural geology. Our results show that deformation in Afrera is accommodated by a series of active en-echelon faults striking ~NS and characterized by normal slip and a left-lateral strike-slip component. Faults have a varying behavior encompassing stick-slip (with abrupt fault displacements up to ~40 mm and $M_L > 5$ earthquakes) and creep (with cumulative LOS displacement up to ~30-40 mm over a ~5-year period and low-level seismicity). Some of the creeping faults are also spatially associated with hydrothermal springs.

We propose a kinematic model where the EA and TA segments interact through a right-lateral transfer zone where deformation is primary accommodated by oblique left-lateral slip along NS striking faults. The varying temporal behavior of the faults in the linkage zone could be controlled by the interplay between tectonic extension, high heat flows, and fluid circulation.

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Advanced Remote Detection and Analysis System-ARDAS. An innovative solution for hydro-morphological monitoring in a fluvial system

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Keywords: Fluvial geomorphology, hydrogeological hazard, UAV acquisition, change detection, near-real time.

Investigations in fluvial geomorphology are functional to describe and to understand river dynamics over time. The detection of channel morphologic changes allows us to observe the effects of environmental and anthropic conditioning and to assess the connected risks such as geomorphological dynamics hazard, flood hazard, induced flood hazard (Wohl, 2014). During the last decades, data fusion methodologies made the most of remote sensing potentialities in surface detection and extreme event observation. Advanced methodological systems apply analytical procedures using the integration of field observations and remotely sensed data (Rinaldi et al., 2016), but they don't enable an immediate access to a High-Resolution information about the channel alterations and the flood exposure, due to the complexity of the methods and costs to be incurred. Today, the effects of climate changes with increasingly frequent natural disasters require an accurate and promptly updated definition of action plan to minimize the harmful impact on human lives, facilities and productive activities (Arnaud-Fassetta et al., 2009). Therefore, the need to a near-real time analysis of river morphology and features along the more exposed reaches with a very high spatial resolution becomes essential. This work proposes an innovative and integrated system, ARDAS (Advanced Remote Detection and Analysis System), based on multi-technologies: Unmanned Aerial Vehicle-UAV systems for channel images acquisition, cloud computing environment for massive data processing, the Structure from Motion-SfM techniques for the generation of a Digital Elevation Model and the application of the Artificial Intelligence-AI for the automatic extrapolation of morphological features and parameters. ARDAS tries to satisfy the main requirements: (1) the recurrent detection of more exposed reaches with the availability of very high-resolution product as a HR-DEM; (2) the timely support to the hazard assessment through the quantitative analysis of hydro-morphological parameters. The partial experimentation of the system along some reaches of the Basento river (Basilicata, southeastern Italy), demonstrates the improved monitoring of the morphological alterations and the potential contribution to the activities of river management and land planning.

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Detailed study of Golja Ignimbrite (Main Ethiopian rift): eruptive and depositional mechanisms, characterization and reconstruction of the possible genesis of juvenile products

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Keywords: Main Ethiopian Rift, Golja Ignimbrite, eruptive and depositional mechanisms, mixing.

The Main Ethiopian Rift (MER) represents an ideal natural laboratory to analyze the evolution and dynamics of continental break and separation from the initial phase in the South to the continental break-up in the North (Hayward and Ebinger, 1996; Corti, 2009). The process that regulates the distribution of volcanic products is generally bimodal, with the absence or scarcity of products with intermediate composition, known as Daly Gap, still not fully understood (Gasparon et al., 1993). We describe here the stratigraphic, textural and compositional features of the Golja Ignimbrite (GI), a Low Aspect Ratio Ignimbrite (~1.2 Ma) which characterizes the recent volcanic succession of the Asela-Langano area. The main sequence of the GI, sourced from an uncertain position within the Rift, is characterized by a coarsening upward basal fallout, overlain by an obsidian fiamme-bearing vitrophyre, brecciated at the top. This basal portion of the sequence is followed by a weakly to partially welded ash flow, rich in lithics, obsidians, pumices, crystals and glassy fiamme, passing to a thick, unwelded deposit. We developed different types of analyses: measures of density and aspect ratio of the juvenile material to characterize the typical sequence from the sedimentological point of view, optical and SEM observations of thin sections to describe the textural characteristics of the matrix, bulk rock compositions, SEM-EDS data of glass and minerals in the different juvenile fractions, EMPA data on melt inclusions (MI) hosted in quartz and feldspar crystals. The presence of juvenile products with different characteristics (obsidian chips, black scorias, white and banded pumices) has aroused considerable interest, providing the prerequisites for hypothesizing a mixing process between magmas of various compositions. The data collected were discussed in terms of eruptive and depositional mechanisms, as well as of the possible processes of formation for the different juvenile fractions. We suggest that the evolution of these magmas was mainly driven by a complex process of fractional crystallization, which played a leading role in the transition from basaltic (MI) to trachyandesitic magmas (black scorias), while the observed trachydacytic compositions of the banded pumices could be the result of a mixing process between trachyandesitic and rhyolithic magma (white pumices and obsidians). Differently from other ignimbrites from this sector of the Rift, characterized by nearly homogeneous, peralkaline rhyolitic to pantelleritic compositions, the GI represents a clear example of an eruption that involved magmas of different compositions, generally not well represented in the products of the MER.

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Interpretation of seismic profiles for detection of the Messinian Salinity Crisis in the Adriatic Sea

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Keywords: Messinian Salinity Crisis, Adriatic Sea, evaporites, Apennine Chain.

During the Messinian Salinity Crisis (MSC), the Adriatic Sea was characterized by several depositional domains. The area represented the foreland of the Dinarides, active since the Eocene, of the southern Alps. The Apennines, in particular, played probably a primary role during the Messinian Salinity Crisis, conditioning the connections between the Adriatic, Ionian, and Proto-Tyrrhenian basins.

Following the intense oil exploration activity, many geological and geophysical data were acquired in the Adriatic area, subsequently made available to the scientific community through the Videpi project (https://www.videpi.com/videpi) and the SNAP website (https://www.snap.ogs.trieste.it). As part of this work, we analyzed the seismic profiles acquired from the Gulf of Trieste to the Strait of Otranto. We have interpreted the base of the Plio-Quaternary sequence (PQb), also analyzing data available in the literature, especially essential for the Balkan offshore. The PQb horizon, characterized by a high-amplitude reflector, represents the Messinian erosion surface and/or the top of the Messinian evaporites. Our analysis made it possible to highlight that:

- The Northern Adriatic reveals widespread canalized systems, suggesting subaerial erosion that sometimes reached the deeper Adriatic carbonate platform, generally buried below a Paleogene-Miocene cover. On the contrary, local evidence of evaporites would indicate some sectors submerged by water.
- The Central Adriatic shows a variable thickness of evaporites, from few tens to a maximum of 200 meters. There are canalized systems, which affected the evaporites in the last Messinian phase. The continuity of the top Messinian reflector suggests marine conditions in the western portion. Conversely, in the central portion of the basin, the previously originated Middle-Adriatic ridge, has erosional characteristics associated with emergence.
- In the Southern Adriatic, the Apulian carbonate platform is covered by a thin pre-Messinian sequence followed by a depositional hiatus, while in the deeper portion, the Messinian evaporites, although present, seem to be partially eroded within the Southern Adriatic basin.

The evaporites thickness variability is likely related to different factors, including: i) subsea erosion (channels), ii) subaerial erosion (discontinuous surfaces), iii) non-deposition (possible non-compliance), iv) deposition on a horizontal plane, v) deposition on an inclined foreland towards the surrounding chains. In this work, the incidence of these factors in the various sectors of the Adriatic Seais analyzed.

A possible multi-stage fault inversion in Central Apennines (Abruzzo, Italy)

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Keywords: structural geology, geological mapping, tectonics.

This work aimed at investigating the Celano-Ovindoli-Pezza extensional fault-system located in the Central Apennines chain, between the Fucino Plan and the Gran Sasso Massif, in the Abruzzo region.

The complex geological setting of this area is the result of the convergence between the Apulian and the African plates, that determined firstly a compressional tectonic phase during the Miocene followed by an extensional phase starting from the Pliocene. The main objective of the work was the recostuction of the geometry and the kinematics of the faults and the relationships between thrusts and normal faults. With this aim, a detailed geological mapping, a multiscale structural analysis and the measurement and analysis of 8 geological sections were performed. Combining the field observations with the already published literature I hypothesize that the normal faults reactivated the ramp of the ancient thrusts. In the northern portion of the investigated area such reactivation is not exposed and is supposed to be in the subsurface, while in the central and southern portions the reactivated faults are visible in outcrop.

In the southern portion, the Corniola formation is exposed and characterised by deep-water limestones of the Early Sinemurian. The Corniola formation does not belong to the Lazium-Abruzzi succession outcropping in this area, which is characterised by Meso-Cenozoic shallow-water limestones. I suggest that the presence of the Corniola is related to the opening of a narrow intraplatform basin, N-S oriented, during the Lower Jurassic. Moreover, it's possible that the Miocene thrusts reactivated the Jurassic faults in the eastern edge of the basin. In conclusion, a multiple reactivation of some structural elements in the studied area, during three main stages (Lower Jurassic, Miocene, Pliocene-Holocene) is plausible.

Back to the past: application of hydrogeological physical models to teaching and science popularization

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Keywords: physical models, hydrogeological conceptualization and visualization, didactic, popular science.

Groundwater circulation is an integral part of the natural hydrologic systems and ecosystems as well, therefore any effort to disseminate and communicate its processes is to be accomplished in order to increase its public awareness. Considering that understanding and visualizing hydrogeological processes is a difficult task for many undergraduate students and non-scientists, to support this comprehension is a challenging task for the academic community. The first steps in the comprehension of hydrogeological processes were based on physical experiments such as that used to demonstrate the famous Darcy's law (Darcy, 1856) by the simulation of water flow in porous media through a physical model under different values of hydraulic gradient. Even if numerical modelling and its graphical outputs are currently used for scientific purposes, they are not completely understandable by "beginner" hydrogeologists. In such a view, physical experiments are still significant due to their higher visualization and communicative capabilities. Analogously to the Darcy's experiment, hydrogeological physical models include laboratory tanks and columns packed with geological material in which groundwater heads and flows are measured and visualized directly (Anderson et al., 2015). The aim of this work is to design some hydrogeological physical models, showing their effectiveness for teaching and popular science. Even if this type of models are sold by specialized producers, this work wants to demonstrate how it is possible to build them with specific purposes and in a cost-effective way. The procedure employed for models' realization includes different steps: i) collecting of natural or artificial porous geological materials, selected by their hydraulic properties; ii) filling of a transparent plexiglass box, in order to re-create the sequence of different hydrostratigraphic layers; iii) realization of a closed hydraulic system to simulate water circulation, through an imposed hydraulic gradient between the lateral boundary of the box; iv) installation of points of sink and source; v) installation of piezometers for the water levels observation; vi) simulation of contaminant transport by colored dyes. Depending on the experimental setting, physical hydrogeological models allow to simulate both phreatic and confined conditions of aquifers. Recharge and discharge processes, and horizontal water flow can be visualized during the experiment. Once a steady-state flow has been established, dynamical perturbations can be recreated injecting or extracting water from the system, thus simulating the effects of artificial recharge and withdrawal from wells. Further possibilities regards visualization of interaction of groundwater circulation with surficial water-bodies and underground man-made structures such as basements, tunnel or other impermeable barriers. Moreover, the visualization of the propagation of pollutants in the aquifer represent another important experiment. In conclusion, despite their current scarce use to solve scientific issues, the physical modeling of hydrogeological processes has still a great capability in communication and visualization allowing students the direct observation of replicable experiments.

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Geogenic degassing from active tectonic areas of the Balkan Peninsula

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Keywords: geogenic degassing, Carbon dioxide, Helium, Methane, Balkan Peninsula.

During the last decades, great interest of the scientific community has been addressed to the estimation of geogenic Carbon degassing from tectonically active areas (Tamburello et al., 2018).

Due to its high solubility in water, CO_2 can be dissolved, transported and released to the atmosphere by groundwater. The quantity released by such process is probably of the same order of magnitude as that directly emitted from active volcanoes. The quantification of this contribution has a substantial implication for the modelling of the global atmospheric carbon cycle.

The Balkan peninsula, one of the geodynamically most active regions in Europe, is characterized by intense geogenic degassing. Until now, only scarce data exist about the chemical and isotope composition of the gas emissions of this area (Nisi et al., 2013; Kis et al., 2017; Daskalopoulou et al., 2019).

Aim of this PhD research is to investigate the possible presence of deep CO_2 degassing and its possible impact on regional aquifers of the Balkans. Here, we present the results of a preliminary geochemical characterization of gas manifestations from the main geothermal fields of the Republic of North Macedonia.

Gas samples are dominated by either N_2 (up to 989,000 µmol/mol) or CO_2 (up to 998,000 µmol/mol). The highest CO_2 values are found along major fault lines, suggesting a deep source of gases. Only few samples have also significant CH_4 concentrations (up to 20,200 µmol/mol). Helium shows a prevailing crustal source (R/R_A = 0.1-1.6), however a low but significant mantle contribution was found in most samples. Similarly, $\delta^{13}C_{CO2}$ displays a wide range (-15.7 to +1.0 ‰ vs. V-PDB) and the $CO_2/^3He$ ratio suggests a prevailing carbonate source together with a small mantle contribution. $\delta^{13}C_{CH4}$ and δ^2H_{CH4} values indicate a mainly thermogenic source; few samples may be related to an abiotic source or be the result of secondary oxidation processes.

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Integration of surface and subsurface data for the understanding of karst hydrogeology: caves as open windows to the water table

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Keywords: karst, hydrogeology, cave**,** pollution, water resources.

Karst groundwaters are the main hydric supply in many countries of the world (Stevanovic, 2015), and represent a precious resource to be protected and properly managed. They are extremely vulnerable to pollution (Goldscheider & Drew, 2007; Ford & Williams, 2007; Parise & Gunn, 2007), since karst landforms such as sinkholes are the preferential sites for pollutants entry, putting in direct contact the surface with the vadose zone. Marine intrusion has to be added in coastal areas as a further source of contamination for water quality (Masciopinto et al., 2017), locally with significant impact on society. A good knowledge of the geological and hydrogeological features, obtained through collection of lithological, petrographic, structural, geomorphological and hydrogeological data, is the necessary starting point to plan and develop the best practices and actions toward protection of underground water resources. In karst, this can be reached through integration of traditional geological approaches at the surface with direct exploration and surveying within the caves, by means of speleological techniques (Liso et al., 2019, 2020; Parise et al., 2020). In Apulia, one of the more extensive karst areas in the Mediterranean Basin, freshwater resources are stored within the fractured and karstified limestones making up the backbone of the region (Maggiore & Pagliarulo, 2004; Cotecchia, 2014; Liso & Parise, 2020). However, in contrast with the high number of surface sinkholes, dolines and poljes distributed over the Apulian karst landscape, among the over 2000 caves registered in the Regional Inventory, only two directly reach the water table. They are therefore a sort of open windows to the water table, ideal sites where to study hydrogeology. In this contribution we present our efforts, performed through direct explorations and in cooperation with cavers, to combine surface/subsurface data to enrich the available information about hydrogeology of Apulian karst systems, and to contribute to a better understanding of its main features.

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Interaction between low-angle normal faults and hydrothermal circulation during Early Permian extension in the central Southern Alps (Northern Italy)

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Keywords: Permian tectonics, hydrothermal event, structural control, U ore deposit.

Starting from the late Carboniferous, several episodes of crustal thinning affected the Variscan orogen, leading to the development of intracontinental basins at the Europe-Adria boundary, now-day preserved in the central Southern Alps (cSA). In this period, a megashear zone with dextral kinematics led to the transition from Pangea A to Pangea B configuration. During the later Alpine compression, the favourably oriented normal faults inherited from Permian tectonics played an important role, being frequently inverted as S-verging thrusts. Nevertheless, several Permian structures along the northern border of the Permian Orobic Basin still preserve their original features, since they exceptionally escaped the Alpine deformation (Zanchi et al., 2019). They are Low-Angle Normal Faults (LANFs) mainly developed at the interface between the Lower Permian sedimentary cover and the Variscan basement. Two major Permian LANFs are exposed at the head of the Brembana Valley (BG) and are characterized by cataclastic bands sealed by centimetric layers of dark aphanitic tourmalinites (Zanchi et al., 2019) and locally by U mineralizations. These rocks derive from rich in B fluids, preferentially channelled along high permeability shear zones and are associated to further exposures of Permian LANFs in other sectors of the cSA, testifying to the regional importance of this fluids circulation.

Intrusive bodies of 285 Ma occur close to the Trompia Valley (BS), where microcrystalline tourmalinitic breccias cutting the basement have been studied from the mineralogical point of view (De Capitani et al., 1999). We performed whole rock analysis both on tourmalinites and granitoids of this area, and it came out that they are geochemically related, demonstrating that the rich in B fluids are a product of the Permian magmatism.

Several authors genetically linked the cSA tourmalinites with the U mineralization of Novazza-Vedello district (De Capitani et al., 1999) but this correlation has not been proved so far. Bulk analysis of tourmalinites from different sectors of cSA indicates low U concentration, however new observations on rocks nearby the U mineralization district indicate the presence of tourmaline crystals combined with minerals likely relatable to the metallogenic event. Our main goal is to provide a better characterization of the regional hydrothermal event and to relate it with the structural setting, which influenced the fluids circulation in this intracontinental extensional configuration.

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Genesis and Depth of Formation of Ferropericlase Inclusions within Super-Deep Diamonds

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Keywords: diamonds, ferropericlase inclusions, host-inclusion relationships, geobarometry.

Diamonds containing fluid and mineral inclusions are the only natural samples capable of probing the deepest portions of Earth's mantle (down to ~800 km depth). In order to precisely interpret the mineralogical and geochemical information they provide, it is important to understand the growth relationships between diamonds and inclusions (i.e., whether they formed before or during diamond formation) and the depth at which the inclusions were trapped.

Ferropericlase [(Mg,Fe)O] is the most abundant inclusion within super-deep diamonds (i.e., those forming at > 300 km depth). Experiments and numerical models using a pyrolitic bulk composition indicate that ferropericlase, comprising 16-20% of the mantle phase assemblage, is stable at depths between 660 and 2900 km and is Mg-rich with X_{Fe} ranging from 0.10 to 0.27 (Lee et al. 2004, Akaogi 2007). However, ferropericlase represents 48-53% of the inclusions reported within super-deep diamonds and has a more variable Fe content, with X_{Fe} between 0.10 and 0.64 (Kaminsky 2012). Despite numerous studies, the reasons for this key discrepancy and our understanding of the origin of ferropericlase-bearing diamonds remain unclear.

Here we performed in-situ single-crystal X-ray diffraction analyses on a set of ferropericlase inclusions in superdeep diamonds from Juina (Brazil) and Kankan (Guinea), to determine inclusion-host crystallographic orientation relationships. These analyses were coupled with synchrotron X-ray tomographic microscopy in order to apply elastic and elasto-plastic geobarometry and to determine the depth of diamond formation. Electron microprobe analyses on a set of inclusions that were released from the diamond hosts were also conducted to investigate possible relationships between crystallographic data and chemical composition. We assess the most likely scenario for the genesis of ferropericlase inclusions in superdeep diamonds, their depth distribution in the Earth's mantle and their implications for mantle geochemistry.

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Beach Topography-Based Method for Shoreline Identification

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Keywords: shoreline, beach, UAV, GPS, structure from motion, QGIS plugin, topography.

The monitoring of coastal areas is very important and meaningful to safeguard the benefits that these areas bring to the environment and to the human activities. Monitoring starts with the control of the shoreline, which is the line where the land meets the sea. Shorelines are idealized as the dynamic interface between water and land (Dolan R. et al., 1980).The definition of shoreline is not the same for all contexts, and it is often a subjective matter. Different methodologies exist for coastal monitoring, which are based on direct and remote acquisition systems. Direct shoreline surveys are normally conducted using the DGPS technique of post-processing or of real-time methodology (Kelly and Gontz, 2018). The main drawback of this method lies in the amount of time required to cover large stretches of coastline. Remote sensing for the correct positioning of the shoreline can be distinguished by observation of satellite images, Unmanned Aerial Vehicles (UAV) (Pitman et al., 2019), historic aerial photos, and cartography (Bini et al., 2008).

The aim of this work is to find and promote a new and valid beach topography-based algorithm, able to identify the shoreline. We apply the Structure from Motion (SfM) techniques to reconstruct a high-resolution Digital Elevation Model by means of a drone for image acquisition. The algorithm is based on the variation of the topographic beach profile caused by the transition from water to sand. The SfM technique is not efficient when applied to reflecting surfaces like sea water resulting in a very irregular and unnatural profile over the sea. Taking advantage of this fact, the algorithm searches for the point in the space where a beach profile changes from irregular to regular, causing a transition from water to land. The algorithm is promoted by the release of a QGIS v3.x plugin, which allows the easy application and extraction of other shorelines.

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Geochemistry and radiogenic isotopes of surface waters and suspended solids from the Valdinievole sub-basin (Tuscany, Central Italy)

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Keywords: water geochemistry, heavy metals, isotopes, Valdinievole.

The Valdinievole sub-basin is located in the western part of the Arno River Basin (Tuscany, Central Italy) and is fed by Nievole, Pescia di Collodi, and Pescia di Pescia rivers as well as by a network of artificial canals that collect urban and industrial wastewaters from a densely inhabited and industrialized area. Nevertheless, these rivers and canals are tributaries of the Padule di Fucecchio, a protected swampy zone that has an important role in the migratory routes of several bird species. The Usciana River reclaims the waters of the Padule di Fucecchio and, after 25 km, it flows into the right bank of the Arno River. The complex ecosystem of the area is characterized by heavy anthropogenic impact such as paper mill industries, flora-nursey farms, thermal spas and one of the most productive Italian tanning districts that make this zone one of the most polluted area of the Arno River Basin. In order to evaluate the anthropogenic and natural contributions in the surface waters and suspended solids, this PhD project is aimed at determining the seasonal variations in terms of main, minor, and trace elements by Ionic Chromatography (IC) and Inductively Coupled Plasma Mass Spectrometer (ICP-MS), respectively. Additionally, Sr and Pb isotopic ratios by Thermal Ionization Mass Spectrometer (TIMS) on water and suspended solid load samples are to be analyzed to discriminate between natural and anthropic sources. Preliminary data have evidenced a relatively wide variability of the main water chemistry, with composition ranging from $Ca^{2+}(Mg^{2+})$-HCO_3^- to Na^+-$Cl^-(SO_4^{2-})$ with concentrations of N-bearing species up to 36 (NO_3^-), 2.4 (NO_2^-) and 11.5 (NH_4^+) mg/L, suggesting, as expected, the strong anthropogenic pressure acting on the Usciana Basin that, inevitably, also reflects into the surface waters of the Arno River.

From natural UHP Fluid Inclusions to Thermodynamic-modelled speciation of subduction fluids

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Keywords: electrolytic fluid modelling, impure marble, Dora-Maira Massif, UHP metamorphism, fluid inclusions.

Subduction fluids are a key component of long-term chemical cycles (i.e., H, C, S, N Cycles) and their reliable characterization is of primary importance to understand the processes related to mantle wedge metasomatism, oxidation and melting (e.g., Plank & Manning, 2019). H, C and S - due to their abundance - and C and S - due to their range of valence states - hold a great potential impact on the mantle wedge redox state. Both direct (fluid inclusion -FI- studies) and indirect (thermodynamic modelling, TM) approaches to study these fluids have reliability issues due to the complexity of the investigated processes. The chemical fingerprint of UHP FI can be easily modified by post-entrapment processes (Frezzotti & Ferrando, 2015), while TM of solute-bearing fluids at UHP conditions is in its infancy (Connolly & Galvez, 2018).

In this work, we apply and compare the data obtained by both these approaches on UHP FI trapped within peak diopside from a chemically simple marble (CMFS-COHS system), that experienced multiple carbonated dissolution-reprecipitation events (Ferrando et al., 2017), from the UHP Brossasco-Isasca Unit (BIU) of the Dora-Maira Massif (Western Alps). Classical molecular-fluid TM allowed to model post-entrapment reactions between FI and host diopside. Electrolytic-fluid TM allowed to model the chemical composition of the peak solute-bearing COHS aqueous fluid generated by progressive rock dissolution and dehydration reactions. The comparison between the modelled composition with that reconstructed by FI study allows to recognize the type and the extent of post-trapping chemical re-equilibrations occurred within UHP FI and to obtain the real composition of subduction fluid circulating in carbonate system at UHP conditions.

Building from these results, forward TM along the prograde UHP BIU PT-path (up to 4.3 GPa and 730°C), as a function of fO_2, allowed to model the composition, speciation, and redox state of subduction fluids in the fO_2 range of -2< log ΔFMQ <+2. The modelled fluid geochemistry allows to evaluate whether the redox potential, the transport mechanism and the solubility of C and S - as a function of P, T, and fO_2 - in H_2O-dominated subduction fluids, are coupled or not and the C and S potential redox impact on the mantle wedge.

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Laboratory scale research of a DNAPL contamination plume in a pozzolanic ash soil, using frequency and time domain resistivity and induced polarization methods

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Keywords: electrical resistivity tomography, induced polarization, normalized chargeability, contaminated soil.

The aim of this study is to explore potential and limits of electrical resistivity tomography (ERT) and induced polarization (IP) method for detecting a contamination plume through a laboratory small-scale investigation. The electrical tomography can be diagnostic for the detection of Dense Non Aqueous Phase Liquid (DNAPL) contaminants, since they are often characterized by high resistivity and high polarizability.

In this work, both direct current (DC) and alternate current (AC) measurements were carried out on two different electrode lines equipped with 48 and 12 electrodes respectively, in a cylindrical tank filled by partially-saturated pozzolanic ash.

Time-lapse measurements were performed before and after (at different time steps over a period of 21 days) the contamination with a continuous flux of HFE7100, an engineered colourless fluid having chemical and physical properties similar to trichloroethylene/tetrachloroethylene (TCE/PCE), which are common groundwater contaminants that persist in the environment. Recorded DC dataset has been inverted using the VEMI software (De Donno and Cardarelli 2017) to achieve time-domain resistivity and chargeability, while frequency-domain inversion for AC measurement was performed with the same software for each frequency in the range between 10 mHz and 1 kHz using amplitude and phase of the complex-valued resistivity as model parameters.

In addition to the magnitude of the resistivity and capacitive effects, a spectral inversion using the four-parameter Cole-Cole model was performed by means of the procedure after Kemna (2000), in order to obtain the relaxation time and the frequency-exponent, which are linked to the type of polarization and to the grain size distribution respectively.

Results show that the contamination plume is clearly visible with good resolution using both methods, as we are able to trace the evolution of the contamination process that follows a preferential path. Polarization signatures, which could clearly indicate the presence of contamination, are also highlighted in the phase spectra.

In conclusion, this study confirms the applicability of the AC/DC electrical tomography methods for investigation of a contaminated site and can be also extendable to different applications of applied geophysics for environment protection.

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Paleomagnetic dating of pre-historic lava flows from the urban district of Catania (Etna volcano, Italy)

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Keywords: volcanology, paleomagnetism, geophysics, petrology.

Determining the ages of past eruptions of active volcanoes whose slopes were historically inhabited is vitally important for investigating the relationships between eruptive phenomena and human settlements. During its almost three-millennia-long history, Catania— the biggest city lying at the toe of Etna volcano—was directly impacted only once by the huge lava flow emplaced during the A.D. 1669 Etna flank eruption. However, other lava flows reached the present-day Catania urban district in prehistoric ages before the founding of the city in Greek times (729/728 B.C., i.e., 2679/2678 yr B.P.). In this work, the Holocene lava flows of Barriera del Bosco, Larmisi, and San Giovanni Galermo, which are exposed in the Catania urban district, were paleomagnetically investigated at 12 sites (120 oriented cores). Paleomagnetic dating was obtained by comparing flow-mean paleomagnetic directions to updated geomagnetic reference models for the Holocene. The Barriera del Bosco flow turns out to represent the oldest eruptive event and is paleomagnetically dated to the 11,234-10,941 yr B.P. and 8395-8236 yr B.P. age intervals. The mean paleomagnetic directions from the San Giovanni Galermo and Larmisi flows overlap when statistical uncertainties are considered. This datum, along with geologic, geochemical, and petrologic evidence, implies that the two lava flows can be considered as parts of a single lava field that erupted in a narrow time window between 5494 yr B.P. and 5387 yr B.P. The emplacement of such a huge lava flow field may have buried several Neolithic settlements, which would thus explain the scarce occurrence of archaeological sites of that age found below the town of Catania.

Low P partial melting of metapelites during contact metamorphism in the Forcel Rosso-Mount Ignaga zone of the Adamello Massif (Northern Italy)

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Keywords: metapelite, partial, melting, metamorphism, Adamello.

Partial melting of crustal lithologies contributes to the geochemical differentiation of the continental crust. This process commonly occurs in regional metamorphic terranes and in thermometamorphic aureolas of deep seated mafic intrusions, while shallow felsic plutons usually lack the heating power necessary to cause it. The contact aureole of the Eocene-Oligocene Adamello pluton at Forcel Rosso-Mount Ignaga overprinted a continental to marine sedimentary succession of Permian to Triassic age producing disorganized melt patches and aplitic-pegmatitic dykes and veinlets in the Permian Verrucano Lombardo formation metapelites. This indicates that diffuse partial melting occurred up to 500m from the contact. In the study area, metamorphic grade increases from phyllites and schists at sub-greenschist and greenschist facies on the top of mount Foppa and in the Fumo valley, to upper amphibolite facies migmatites near the Western Adamello Tonalite (WAT) intrusion. Petrological and geochemical variations together with phase equilibria modelling are used to investigate the metamorphic conditions that determined the formation of the migmatites. Peak mineral assemblages are composed of crd+sil+bt+kfs+plg+q +tur+mag indicating a maximum P-T condition of 3.5 kbars and 700°C. The interpolation of these data suggests that migmatites from this region are the result of open system processes in which fluid assisted melting played a major role. Mass balance calculations allowed the estimation of the partial melt fraction and the degree of melt extraction in migmatites, as well as constraining melt composition. Geochemical evidence suggests that primary compositional variations characterizing the Verrucano Lombardo pelitic layers control both the amount of melt that was formed and its composition. Metatexites containing abundant deformed paleosome and cordierite have melt-depleted compositions (up to 20% volume of produced and extracted melt). The diatexites are composed of k-feldpar, high An86-96 plagioclase, high aspect ratio biotite schlieren, fibrolitic sillimanite, back-reacted cordierite and euhedral schorl-dravitic tourmaline with minor quartz. They represent cumulate products of fractional crystallization in melt accumulation and transfer zones. This indicates that the produced melt was efficiently extracted from the source rocks and successively accumulated in less fertile psammitic zones where it underwent further fractionation. This process can be observed through the enrichment in Cs, Sr and Li in the biotites of the rocks composed by fractionated residuals compared to the biotite of the low grade metapelites. The highly fluxed (Li, B, P, H_2O rich) melts were extracted following decompression caused by the opening of dilating fractures related to the strain regime. This event led to the formation a swarm of similarly oriented barren to Li enriched pegmatites that preliminar data attributes to direct anatexis of the Verrucano Lombardo metapelites.

Timing of eruptive activity at La Fossa caldera of Vulcano (Italy) during the last 1100 years unravelled by tephro-chronology, radiocarbon and paleomagnetic dating

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Keywords: tephro-stratigraphy, paleomagnetic dating, radiocarbon, Vulcano island, Vulcanello.

During the past millennia, several eruptions have occurred within the La Fossa caldera on the island of Vulcano (Aeolian Islands, Italy), with some of them being also described in historical documents dating back to the Republican Roman times. However, the timing of such activity has remained controversial, due to contrasting ages provided by radiometric and paleomagnetic methods. Here we try to solve the controversial reconstructions through the application of a standard paleomagnetic methodology to eight eruptions from the intra-caldera vents of La Fossa cone and Vulcanello, coupled to new radiocarbon dating and to a detailed tephro-chronological work. We find that between the IX and XV century AD, both La Fossa and Vulcanello eruptive centres were characterized by intense activity. The new dataset confirms that the lavas exposed above sea level at Vulcanello were erupted between X and XI centuries, and not during Republican Roman times as previously suggested by the majority of authors. In this same time interval, La Fossa was characterized by long-lasting basaltic explosive activity followed by a sustained rhyolite explosive eruption. Between AD 1050 and 1300, the activity focused at La Fossa cone, with alternating explosive and effusive eruptions which emplaced four lava flows of rhyolitic and trachytic composition resulting in a significant growth of the cone. After the violent, phreatic event of the Breccia di Commenda (XIII century) the eruption continued with a substantial, long-lasting emission of fine ash until the activity temporary ceased. Magmatic explosive activity resumed at La Fossa at the beginning of XV century. This phase lasted until mid-XVI century and produced at least seven explosive eruptions of intermediate magma composition and also a couple of lateral explosions (Forgia I and II). During this time interval, Vulcanello emplaced the third of its cinder cones and issued the latitic lava flows of Punta del Roveto and Valle dei Mostri. From XVII to XX centuries, volcanic activity again concentrated at La Fossa cone producing namely felsic explosive eruptions and one rhyolite lava flow (Gran Cratere cycle). The work confirms that Vulcanello island formed in Medieval times between AD 900 and 1050, and not in Roman Republican times as several works have previously suggested. It moreover highlights that between X and mid-XVI centuries, La Fossa caldera was the site of at least 19 eruptions with an average eruption rate of one event every 34 years. This rate is considerably higher making the volcanic hazard higher than that suggested by previous works.

The Low-Chron 27r event: a turning point in the evolution of Danian calcareous plankton

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Keywords: Danian**,** calcareous nannofossils, biological pump recovery, low-Chron 27r event.

The integrated stratigraphic study of the Danian Bottaccione section (Gubbio, Italy) enabled the identification of orbitally induced sedimentary cyclicity driven by the long eccentricity periodicity (405 kyr) and the compilation of a high-resolution magneto-biostratigraphy. Based on astrochronology, a sharp increase in sedimentation rate and a concomitant increase of bulk δ13C values occur across the so called "low-Chron 27r event" (LC 27r), 2.7 Myr after the K/Pg boundary (Galeotti et al., 2015). Similar occurrence at ODP Site 1262 succession (mid-Atlantic Ocean) and Zumaia section (Spain) (Dinares-Turrel et al., 2014), suggests a global significance for this event. Since the benthic-δ13C records from ODP Site 1209 (tropical Pacific Ocean; Westerhold et al., 2011) and Site 1262 (Barnet et al., 2019) successions do not show a corresponding increase, the LC 27r could be interpreted as an increase of the surface-to-benthic δ13C gradient, possibly related to an important step of oceanic carbonate productivity recovery. In agreement to this hypothesis, the analysis of calcareous nannofossil from Site 1209 reveals significant changes in the calcareous plankton community structure across the LC 27r event. A critical review of literature data from ODP Site 1262 and the Bottaccione sections shows data that point to a similar interpretation. Therefore, the LC 27r event seems to embody a key step in the evolutionary trajectory of calcareous plankton during the Danian, that could be linked to a major bio-geochemical reorganization of the global oceans, contributing to the final steps of the carbonate production following the K/Pg mass extinction.

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Seismic noise for reconstructing a 3D *Vs* Velocity Model of Ischia Island (Italy)

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Keywords: Ischia island, 3D Vs velocity model, H/V technique.

This study provides a contribution to the definition of the complex structural asset of Ischia volcanic island, Southern Italy. The aim is to reconstruct a 3D shear wave velocity (*Vs*) model of the island up to 2 km depth by using seismic noise signals recorded at seismic stations installed after the M_D 4.0 (M_w 3.9) Casamicciola earthquake. The proposed procedure consisted of two steps: the first step was based on the inversion of the horizontal-to-vertical spectral ratio (HVSR) curves, and on the definition of their frequency peaks, assessed at 19 station sites to get the corresponding 1D *Vs* models. The second step was aimed to retrieve a pseudo 3D *Vs* velocity model of the island by extrapolating thicknesses and velocities of the individual velocity models for the areas where measures are not available to highlight possible lateral variations of the seismic layers characterized by a high-impedance contrast. For the sites located along the northern coast of the island, the top of the high-impedance contrast interface appeared deeper than that identified by the sites located in the central part of the island. We attribute this difference in depth to the intra-calderic resurgence of Mt. Epomeo (Orsi et al., 1991). The obtained pseudo 3D velocity model is consistent with the geomorphological variations of the deep layers and well agrees with geological (Sbrana et al., 2011) and geophysical literature studies (Di Giuseppe et al., 2017).

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Paleoenvironmental reconstruction of the Eocene Nummulitic Limestone (Western Italy and Southern France): relationship between carbonate producers and clastic sedimentation

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Keywords: Eocene, foreland basin, large benthic foraminifera, red calcareous algae, acervulinids.

The paleoenvironmental reconstruction of four different Eocene carbonate successions within the Nummulitic Limestone of the Alpine Foreland Basin was performed in a wide area encompassing NW Italy and SE France. This basin formed due to the convergence of the European continent with the Adria microplate and its basement is constituted by Late Cretaceous units, separated by a major angular unconformity from the overlying Paleogene deepening-upward succession, consisting of *Microcodium* bearing deposits, nummulitic limestones, *Globigerina* marls and deep-water terrigenous sandstones (Sinclair et al., 1998; Varrone & D'Atri, 2004). This study integrates paleontological and sedimentological analysis to obtain a complete reconstruction of the depositional environment and examine the relationship between carbonate assemblages and terrigenous sedimentation. Clastic input was investigated with both petrographic observations and X-ray diffraction analyses, while the paleoenvironmental reconstruction was based on foraminiferal and skeletal assemblages. In every succession the skeletal assemblage was quantified using point counting technique while foraminiferal assemblages were studied with area counting, focusing on parameters like the ortofragminids/nummulitids and the large rotalids/miliolids ratios. These parameters provided paleobathymetric indexes, useful for the comparison of the different section (Beavington-Penney & Racey, 2004; Ćosović et al., 2004). Thus, the resulting paleoenvironmental reconstruction was based on quantitative data, providing more reliable and straightforward interpretations and allowing the creation of a coherent paleobathymetric model for all the successions. The observed carbonate assemblages deposited along a ramp and testify the progressive deepening of the basin. Six main biofacies were recognized: the nummulitid biofacies and the acervulinid and coralline algal biofacies related to shallow water; the nummulitid and orthophragminid biofacies and the coralline-algal branches and large benthic foraminifera biofacies related to intermediate depth; the orthophragminid biofacies and the orthophragminid and coralline algal biofacies related to deeper settings. These biofacies can be grouped into two major carbonate factories, one dominated by free-living benthic foraminifera and related to high terrigenous input, the other dominated by encrusting acervulinids and coralline algae and favored by low terrigenous input. Benthic foraminifera were the most siliciclastic-tolerant group of the Nummulitic Limestone, whereas red calcareous algae displayed less tolerance to terrigenous fluxes than one would expect based on the distribution of their Neogene counterparts, suggesting that Paleogene algal assemblages might have been relatively different and probably less adaptable than those of the Neogene.

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Morphodepositional and archaeological indicators to reconstruct the ground movements in the Campi Flegrei offshore caldera

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Keywords: sea-level indicators; morphodepositional markers; volcano-tectonics; vertical deformation.

Appraisal of morphodepositional markers tied to ancient sea-levels in high-resolution seismic profiles together with archaeological indicators surveyed along the coast of the Pozzuoli Bay provided insights into the vertical deformation of the submerged part of the Campi Flegrei caldera (Southern Italy).

The collapse of the central part of the Campi Flegrei caldera is associated with the eruption of the Neapolitan Yellow Tuff (NYT) at ~15 ka (Deino, 2004). The NYT caldera collapse was followed by central dome resurgence associated with alternations of fast uplift and subsidence displacements. Previously, the evolution of ground movement in the Campi Flegrei caldera has been reconstructed using marine deposits uplifted onland or archaeological evidence (Isaia, 2019; Bellucci, 2006). However, a complete reconstruction of post-collapse deformation suffers from the limitation that nearly two-thirds of the caldera are submerged beneath the Pozzuoli Bay.

We contribute to fill this gap by providing a reconstruction of offshore and coastal deformation through estimation of the vertical displacement of morphodepositional markers in high-resolution seismic profiles and archaeological markers. Our interpretation reveals the occurrence of different sediment stacking pattern whose provides evidence of rapid and oscillating ground movements. The most prominent markers identified in seismic profiles are several generations of Prograding Wedges (PWs), developed in the Pozzuoli Bay since the post-NYT. PWs represent shore-parallel, progradational sedimentary bodies developed along the inner shelf, between the mean fair-weather wave-base and the storm-wave-base levels (Casalbore, 2017).

The multi-dataset analysis has allowed disentangling the signal related to the post-caldera dynamics from a broader deformation signal that affects this part of the extensional margin of the Apennines. The integration of offshore data in this study bears a significant contribution reconstruction of high-risk resurgence calderas.

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Rock-magnetism as indicator of paleoclimate at the Norian/Rhaetian boundary

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Keywords: Upper Triassic, paleomagnetism.

Rock magnetic investigations of lacustrine and marine sediments are known to provide paleoclimatic information (e.g., Vigliotti et al., 1999, Abrajevitch et al., 2013; Chang et al., 2018). In the attempt to obtain information about the climatic perturbation around the Norian/Rhaetian boundary (Upper Triassic) we investigated the magnetic properties of the marine carbonatic sequence of the Pignola-Abriola section (Lagonegro basin, southern Italy). The late Norian-early Rhaetian is indeed characterized by a major biotic turnover involving marine and terrestrial fauna, such as ammonoids, conodonts, bivalves and theropods (see Rigo et al., 2020 and references therein). The Norian-Rhaetian biotic crisis occurred in concomitance of a general $\delta^{13}C_{org}$ perturbation that led to a negative carbon isotope excursion at the NRB, associated with the disappearance of bivalve *Monotis* and the first appearance of conodont *Misikella posthernsteini*. The cherty-limestone sequence of Pignola-Abriola section, candidate GSSP for the Rhaetian Stage (Rigo et al., 2016), has been broadly studied for both biostratigraphy and carbon geochemistry (e.g., Giordano et al., 2010; Maron et al., 2015; Rigo et al., 2016; Zaffani et al., 2017; Rigo et al., 2020). The rock-magnetic data here presented (ARM, IRM, χ, etc.) provided new paleoclimatic information (about weathering, runoff, microbial activity, etc.), that have been compared to the latest geochemical data (CIE, Ce/Ce*, V/Cr, Mo/U, etc.) from Pignola-Abriola.

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New insight into the Hyblean mantle metasomatism from oxy-thermobarometric estimates and noble gases measurements

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Keywords: metasomatism, ferric iron, oxygen fugacity, noble gasses.

The knowledge of the Earth's mantle redox state through the mineralogical and chemical analyses of peridotite rocks is of fundamental importance to model the speciation of volatiles (e.g. C, H, O, N) in depth and their role in processes like magma genesis and metasomatism. On the other hand, measurements of noble gases retained in fluid inclusions of minerals like olivine provide unique information on the source of ascending fluids.

This work aims to reconstruct the origin of the metasomatism of the mantle underneath the Hyblean Plateau (Sicily) combining thermodynamic estimates of the oxygen fugacity (fo_2) and analyses of the noble gases (He, Ar, Ne) from spinel peridotite nodules.

We selected 7 spinel peridotites (2 harzburgites and 5 lherzolites) from the Miocene Hyblean diatreme of Valle Guffari. Chemical and textural analyses were performed by scanning electron microscopy and electron microprobe; while the Fe oxidation state of spinel was determined by either in situ synchrotron (ESRF, Grenoble) or conventional Mössbauer spectroscopy (Sapienza University, Rome). Noble gases were analyzed on ~ 1 gram of olivine grains by single-step in-vacuo crushing coupled with mass spectrometry (INGV, Palermo) for simultaneous analysis of He, Ne and Ar. Geothermobarometric estimates on the crystal-chemistry of the coexisting minerals (olivine, orthopyroxene, clinopyroxene and spinel) result in pressure (P) and temperatures (T) of equilibrium ranging between 0.9-1.2 GPa and 950-1050 °C (Perinelli et al., 2008). The $Fe^{3+}/\sum Fe$ ratio in spinels ranges between 27% and 30%, which appears slightly higher compared to spinel peridotite xenoliths distributed worldwide. The estimated fo_2 varies between 0.4 and 2 log units (normalized to the fayalite-magnetite-quartz buffer; Ballhaus et al., 1991). Analyses of the noble gases are reported as $^3He/^4He$ (R/Ra), $^4He/^{40}Ar^*$ and $^4He/^{20}Ne$ and agree with data for the Hyblean peridotite rocks previously studied (Correale et al., 2012). A positive correlation was observed between fo_2 determined for our studied samples and R/Ra. Our preliminary results show evidence that the Hyblean peridotites are among the most oxidized mantle rocks worldwide falling in the field of lightly metasomatized xenoliths on geochemical basis. The analyses of the noble gases supported by thermodynamic modelling of the C-O-H fluid speciation suggest an HIMU (deep plume-like) mantle and contribution of the metasomatic fluids that might have occurred at several steps. Further investigations are ongoing on the distribution and composition of trapped fluid inclusions in order to establish a relation between Hyblean mantle redox state and (deep-mantle driven) metasomatism.

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Relationships between vegetation characters and saturated hydraulic conductivity at catchment scale

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Keywords: hydraulic conductivity, root reinforcement, LAI, vegetation load, shallow landslides.

Shallow landslides susceptibility assessment by physically based methods relies on the parametrization of both hydraulic and geotechnical features of soils. Among these, saturated hydraulic conductivity (*Ks*) influences infiltration rates, runoff, groundwater recharge and drainage processes, which makes it of particular concern in the prediction of natural hazards, including catastrophic floods and shallow landslides (Hao et al., 2019).

Moreover, it is well known that vegetation plays a role towards slope stability and over the last decades many efforts have been done in order to quantify the effects of the vegetation towards protection from shallow landsliding (Giadrossich et al., 2017). Basically, two main vegetation effects may be considered: hydrological (e.g., modification of the pore water pressure through tree rainfall interception) and mechanical ones (increase of the soil strength due to the root effects and increase of the subsurface shear stress due to the vegetation load).

Soil *Ks* is expected to be an important factor that influences plant growth, plant-available water, root system and root biomass and, therefore, this work focuses on the quantitative assessment of the relationship between vegetation characters and hydraulic conductivity.

Study areas affected by shallow landslides were chosen in the Garfagnana and Alpi Apuane regions (Northern Apennines, Italy), as well as in the Mt. Amiata volcano (Southern Tuscany, Italy), where field measurements (about 200) of below-ground vegetation (Root Area Ratio - RAR), above-ground vegetation (Leaf Area Index - LAI and vegetation load) and *Ks* were carried out inside, in the neighbour and far from shallow landslide locations. Acquisition of data within landslides areas was possible taking advantage of a multi-temporal landslide inventory already available for the study areas. Below-ground vegetation data were collected in trench profiles, while above-ground vegetation data were acquired by means of both digital relascope and digital cover photography. Measurements of *Ks* were carried out by means of both constant and falling head approaches. Results show that *Ks* related to RAR and soil depth, with decrease of *Ks* as the depth increases and root area decreases. Moreover, *Ks* varies with different vegetation types, indicating that shifts in aboveground vegetation features may impact the water dynamics of soil. The weight of above-ground vegetation plays a "mild" negative role on slope stability. Instead, root reinforcement to soil in terms of root-related cohesion plays a relevant role for the depths involved in shallow landslides.

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Internal structure of a crustal-scale seismogenic source: The Bolfin Fault Zone (Atacama Fault System, Chile)

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Keywords: seismogenic faults, fault architecture, fault zone rocks, fluid-rock interaction, earthquakes.

Fault zone structure is one of the controlling factors of earthquake nucleation and arrest, seismic sequence evolution (i.e., foreshock and aftershock), rupture speed and length, and ground motion and seismic radiation pattern. Here we describe the internal structure of the Bolfin Fault Zone (BFZ), a >40-km-long seismogenic, splay fault of the sinistral strike-slip Atacama Fault System (Chile). The BFZ consists of multiple segments nucleated along precursory anisotropies, represented by magmatic foliations of plutons (northern and central segments) and andesitic dykes (southern segment) and linked throughout splay and horsetail faults. These results in the sinuous geometry cutting through the Mesozoic magmatic arc of the Coastal Cordillera. Seismic faulting occurred at ≤ 310 °C and 5-7 km depth in a fluid-rich environment as documented by extensive propylitic alteration and chlorite-epidote veining. The BFZ includes multiple fault core strands consisting of chlorite-rich cataclasites and ultracataclasites and associated pseudotachylytes. The multiple fault core strands are surrounded by strongly altered rock volumes including protobreccias to protocataclasites and highly veined host rocks over a zone as wide as 75 m. The damage zone includes variably fractured and brecciated rock volumes associated with epidote-rich fault-vein networks. The latter are characterized by (i) small-displacement (< 1-2 m) normal dip-slip and strike-slip faults decorated by epidote-bearing slickenfibers and smooth (i.e., highly-reflective) surfaces, and (ii) veins and breccias sealed by epidote ± prehnite ± quartz and showing multiple episodes of fracturing and sealing. Overall, the internal structure of the BFZ, considering possible along-strike exhumation level and structural variations related to fault segmentation and linkage, presents similar distribution of the fault core strands and their associated alteration damage zone of that of the Alpine Fault (New Zealand), as revealed by drilling-derived and geophysical observations. Additionally, the epidote-rich fault-vein networks may represent an exhumed analogue of dilatant, high-flux fault-vein networks, which is in agreement with seismological observations of fluid-driven swarm sequences.

Analogue modelling of strike-slip tectonics from basin to structural-scale comparing quartz sand and new rock-analogue materials experiments

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Keywords: analogue modelling, granular materials, rock mechanics, fault damage zone, strike-slip tectonics**.**

Strike-slip fault zones commonly display complex 3D geometries, with high structural variability along strike and with depth and their architecture and evolution are difficult to analyse. In this regard, analogue modelling represents a powerful tool to investigate the structural, kinematic and mechanical processes in strike-slip fault systems at various scales. In detail, dynamically scaled experiments allow the direct comparison between model and nature. The geometrical scale factor defines the model resolution, in terms of model/prototype length equivalence, and depends on the mechanical properties of prototype and model material. Therefore, the choice of the analogue material is critical in scaled analogue experiments.

Granular materials like quartz sands, showing non-linear strain-dependent deformation behaviour similar to brittle rocks, are ideal for the simulation of upper crustal deformation processes. Nevertheless, comparing the geometrical scaling factor of the common analogue materials applied in tectonic models, we identified a model resolution gap for the simulation of fault-fracture processes corresponding to the outcrop scale (1 m - 100 m).

We developed a new Granular Rock-Analogue Material (GRAM, Chemenda et al., 2011) for the simulation of fault-fracture processes at the structural scale. GRAM is an ultra-weak sand aggregate composed of quartz sand and hemihydrate powder capable to deform by tensile and shear failure under variable stress conditions. Based on dynamical shear tests, the new GRAM is characterised by a similar stress-strain curve as dry quartz sand and has a geometrical scaling factor $L^* = L_{model}/L_{nature} = 10^{-3}$ (1 cm in model = 10 m in nature).

We performed strike-slip experiments at two different length scales, applying as model material dry quartz sand and the new GRAM. Digital Image Correlation (DIC) time-series stereo images of the experiments surface allowed the comparison of the developed structures at different stages of dextral displacement above a single planar basement fault. The analysis of fractures localisation and growth in the strike-slip zone with displacement and strain components enabled the comparison of the different structural styles characterising dry quartz sand and GRAM models. The application of the developed GRAM in scaled experiments will provide new insights into the multi-scale investigation of complex deformation processes with analogue modelling techniques.

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First steps toward the definition of deep structure and dynamic of the circum-Mediterranean orogens

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Keywords: 1D Minimum velocity model, AlpArray project, Geodynamic of central-Mediterranean.

The Alp-Array project is a European initiative to advance our understanding on the deep structure and dynamics of the circum-Mediterranean orogens elucidating the interaction between the Alps and the surrounding Apennines, Dinarides and Carpathians orogens. Still today, there are many debates and open questions on the deep geometry and links between those belts. One of the controversies is the slab origin and polarity beneath eastern Alps, between the opposite models of Adria (Kissling et al., 2006) or Europe subduction (Mitterbauer et al., 2011).

Some broad tomographic images of the circum-Mediterranean orogens are already present in the literature but those models have an intrinsic low resolution. So, the goal of our study is to obtain a high-resolution tomographic model to better solve the dynamic and the deep geometry of these belts. The main idea is to compute models of Vp and Vp/Vs perturbations to directly temperature and compositional variations in the mantle. In this way, it will be possible to have more constraints for geodynamic processes in the central Mediterranean.

In this study, we present a preliminary analysis of a huge data set collected from recordings at 628 Alp-Array seismic stations, which is the biggest broad band seismic network ever operating in Europe. These stations recorded in continuous for two years (2016-2018). We selected only seismic events with a value of magnitude (Mw) $\geq$ 3.5, recorded by all the seismic stations operating in the area. This dataset has been extended with some relevant (Mw>4) seismic events recorded between 2014-2021 from the Italian National Seismic Network (RSN).

Here, we present the computed one-dimensional Minimum velocity models for sub-regions and for the entire Italy, obtained inverting selected events with the VELEST procedure (Kissling et al., 1994). The entire Italy was divided in four sub-regions: Alps, Northern Apennines, Southern Apennines and South Italy. These velocity models were used to relocate the Italian seismicity of the past 5 years (2015-2020). The goal is to use this velocity model as the reference model to compute 3D tomographic images in future applications.

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A GIS-based approach to evaluate the hazard by lava flow invasion at Mount Etna volcano (Sicily, Italy)

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Keywords: Etna, lava flows, volcanic hazard, GIS.

Lava flows of Mount Etna are one of the most spectacular scenarios given by the volcano, but at the same time the less known as risk perceived by resident population. Yet the ability of lavas to spread across urban and rural areas, burning and burying buildings, infrastructures and fields, results in high volcanic hazard and risk. At Etna, effusive eruptions occurring from vents and fractures located at low altitude on the volcano flanks are those more prone to produce dangerous scenario because of their proximity with residential areas. The aim of this study is to investigate the lava flow hazard through a GIS-based approach, in which we adopt a statistic and probabilistic methodology. Starting with a literature investigation, we have created a dataset including the last 2500 years of lava flows, which also incorporates significant volcanological data, such as the duration of the eruption (years), vent position, length of the flow (Km) and covered area (Km^2), erupted magma volume (m^3) and the eruptive rate (m^3/s) where available (Branca et al., 2011; 2015; Tanguy et al., 2007). The GIS software has been used to draw both lava flow distributions and vent locations throughout the Etnean area, in order to obtain a reference map of the flows and their 2D geometries. Another step of this study implies the partitioning the whole selected volcanic area into twelve domains that have been distinguished on the basis of the altitude and the flank position. We performed a spatial and temporal analysis of the lava flow invasions for each identified domain. The relationship between areas invaded by lavas in a given sector with respect to the total inspected area allows us to define a threshold for evaluating the hazard associated to lava flow invasion. Based on the obtained parameters, the increasing hazard on the map is shown through a green-to-red colour scale. Moreover, the hazard map is here developed considering different time interval (500 years each) of the Mt. Etna volcanic record. This study may provide a useful tool for assessing the lava flow hazard in potentially dangerous volcanic areas, as it allows a proper and easy assessment of the spatial and temporal distribution of vents and lava flows, which finally will serve to discriminate between spatial domains of different hazard.

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Integrated infrastructures monitoring system using advanced DInSAR techniques and in-situ measurements

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Keywords: landslides, infrastructure monitoring, DInSAR, COSMO-SkyMed.

Urbanization has rapidly increased the development of large linear infrastructures such as roadways, railways, tunnels and pipelines. Therefore, the correct planning of the monitoring campaigns allows identifying any critical issues affecting the infrastructure networks to plan maintenance work on time. In the last decades, DInSAR techniques have been widely used for detection and monitoring of landslides and subsidence, which affect civil infrastructures limiting their functionality (Di Martire et al., 2018)such as landslides and subsidence, is one of the main causes of damage to linear infrastructures, such as roads, bridges, railways and retaining walls, resulting in important socio-economic and human losses. To this aim, the frequent and accurate monitoring of surface displacements plays a key role in risk prevention and mitigation activities. In the last decade, a considerable interest towards innovative approaches has grown among the scientific community and land management institutions. In particular, Differential Interferometry Synthetic Aperture Radar (DInSAR. This work investigates the possibility of monitoring slow gravitational movements using X-band COSMO-SkyMed (CSK) radar images taking into account their high spatial and temporal resolution of images that made it possible to identify a large number of reflectors to estimate ground movements. The study area corresponds to the middle part of A-16 highway (South Italy) in the Campania Region. The road track, with East-West development, crossing the Appenninic chain and hilly slopes with low-medium gradient, is widely affected by several erosional and gravitational phenomena: among them, landslides hold a top-rank position. As shown in the official landslide map released by the Hydro-geomorphological Setting Plan (HSP) of River Basin Authority in 2017, many phenomena have been surveyed as interacting with the highway and classified as translational/rotational slides and debris flows. About that, many instruments for displacement monitoring were installed along the highway by the managing body.

In this study, the slides' motion is monitored with CSK Single Look Complex (SLC) SAR images in ascending and descending geometry covering the period between 2017 and March 2020. The linear and nonlinear displacement terms and the DEM error have been estimated by using the SUBSIDENCE software (UPC, Barcelona, Spain). Moreover, to increase the visibility of the structures from the satellite and the availability of good-quality PS, especially in areas where it is limited by topography, vegetation, and road orientation, low-cost artificial Corner Reflectors (CR) were designed and deployed. In particular, the research was focusing on the identification of suitable CR geometries, in order to minimize their size and weight, and also to lower the maintenance requirements. Within this frame, the use of active transponder CR (Mahapatra et al., 2015)using interferometric synthetic aperture radar (InSAR has been considered. Furthermore, inclinometers measurements recorded in specific control point around the highway have been considered for validation and calibration of processing SAR data results. The results of this study indicate that the DInSAR approach can be a powerful tool to characterize displacement rates and the extension of landslides surrounding strategic infrastructures.

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Displacement analysis of a rock glacier system in South Tyrol (Eastern Italian Alps) between 2000 and 2015

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Keywords: rock glacier, multitemporal displacement, Italian Eastern Alps, ice melting.

Rock glaciers are alpine landforms related to the presence of permafrost in high mountain regions. They consist of unconsolidated rock debris, generally derived from talus or till, held together by internal ice. Rock glaciers are characterized by a downslope movement through a process defined as “creep”, caused mainly due to the influence of gravity and the interaction of many other factors, such as the topography, the slope and - none the less - by the physical properties of the ice changing with temperature conditions. The rock glacier creeping leads to lobate structures with depressed areas and uplift zones, creating a typical surface morphology defined as “ridges and furrows”. This study focused on the analysis of a rock glacier system located in the Pfitsch/Vizze valley (South Tyrol), in the Eastern Italian Alps. The analysis involved the study of rock glacier displacements between the years 2000 and 2015. The evaluation was carried out using tools implemented in SAGA GIS and ArcMap 10.7.1. Horizontal movements were detected and analyzed, and a point interpolation was performed in order to obtain displacement maps. Image correlation presented some limitations, e.g., concerning interpolation algorithms, orthophoto quality or availability. Preliminary results indicate an increase in the velocity of the rock glaciers during the analysed time periods. The instability may be caused by either melting of the remaining internal ice or a warming of it. Warmer ice is more ductile, and it deforms more easily, causing the movement. We collected data from two climatic stations near the study area and they all mark an increase in air temperature. This trend, widely observed in the last decades across the Alps, has likely caused an accelerated melting of ice in the less protected - in terms of solar radiation - rock glaciers, as is the case for our study area, causing the instability. Therefore, the monitoring of rock glaciers is fundamental to anticipate future changes in the type and magnitude of natural hazards originating at high elevations, in relation with the present and future climatic trends that foresee a further increase in temperatures, particularly in high-elevation mountain regions.

Carbonate reservoir characterization for carbon storage purpose

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Keywords: dolomitization, carbonate reservoir, mineralogic texture, petrophysical characteristics.

Most of carbonates rocks hold the largest known natural gas and hydrocarbon reserves being characterized by medium to high quality reservoirs due to their high primary porosity, fracturing and, frequently, a complex secondary porosity system. Recently, researchers realized their potential value as tools in addressing climate change. Recent studies investigated the impact of CO_2 injected in carbonate reservoir rocks. CO_2 leads to a disequilibrium of both fluid chemistry and pore pressure triggering a series of geochemical reactions thatresult in a new minerals assemblage and arrangement of petrophysical properties. In particular, when carbonate minerals are involved, these variations are enhanced due to their high reactivity with water-saturated CO_2, with respect to a siliciclastic component (Siqueira et al., 2017). Different processes of dissolution and precipitation of new minerals may occur, modifying texture and interface contacts between the different phases within the reservoir. Understanding both the influence of dolomitization on the physicochemical properties and the detailed distribution of the petrophysical characteristics within the carbonate reservoir rocks could represent a key point for employing Carbon Capture and Storage technologies. The case study here presented refers to dolomitized units cropping out in the Castel Manfrino area (Central Apennine, Italy), which offer an opportunity for studying the reservoir quality as a function of different dolomite textures, resulted from several dolomitization events (Mozafari et al., 2019). A multidisciplinary approach, coupling petrographic analysis and techniques as X-ray Powder Diffraction and synchrotron X-ray phase-contrast microtomography, was carried out. To visualize and improve information, the collected data were analyzed by using the Pore3D software library developed at Elettra (Brun et al., 2010). The quantitative data provided by the 3D analyses, combined with the other techniques, allowed us to distinguish between high and low-quality reservoirs focusing on different parameters such as mineral textures, pore size distribution and connectivity of the inter-crystalline porosity. Furthermore, a strong control on the type of dolomite texture and size of crystals by the original facies of the precursor limestone has been highlighted.

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Merging regional and small-scale petro-structural studies: From Gran San Bernardo to Sesia Lanzo zone (Western alps)

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Keywords: Western Alps, Gran Paradiso Massif, ophiolites.

The Western Alps have been studied for over 150 years and countless hours have been spent on the field by generations of geologists. We have a large heritage of geological maps produced over the years, but due to the complex anatomy of the alpine belt many of them are not easily comparable to each other and use their own lithological and deformative events classification.

The studied area is composed of a wide variety of rocks exhumed from the alpine accretional wedge, ranging from greenschist to eclogite metamorphic facies, deformed both during the Ligurian-Piedmont ocean subduction and the African-European continental collision.

We merged 10 different geological maps from Rhemes valley to the Sesia Lanzo zone, crossing the Gran Paradiso massif, to produce a geological map and two cross-sections using maps at different scales.

With our work we are able to provide a united interpretation about the deformative phases, the internal structure of the different nappes and the description of outcropping units.

The cartographical part is supported by the study of thin sections, sampled from some of the domains crossed by the geological cross-sections.

We also present a detailed petrographic study of the Piedmont Zone in Upper Soana Valley, on the north-eastern border of the Gran Paradiso Massif and near the trace of the geological sections. The petrographical analysis concerns a small portion of a unit (Colle della Rosa Dondena) described by previous authors as belonging to the Combin type ophiolites. In the succession are found garnet-chloritoid bearing leaden micaschist, equivalent to those described in previous works (Battiston et al., 1984) in the adjacent Rosa dei Banchi klippe (Monte Nero unit), that suggest the presence of eclogite-facies flakes inside Colle della Rosa Dondena unit.

With this work we hope to provide a uniformed and unified vision of the geological setting of the Gran Paradiso massif, to use as a starting point for future detailed and local studies in this area.

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The record of the end-Triassic mass extinction in the Southern Apennines carbonate platform (Italy)

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Keywords: Triassic-Jurassic boundary, mass extinction, carbon isotope stratigraphy, ocean acidification, Western Tethys.

The end-Triassic mass extinction is one of the big five of the Phanerozoic. It is associated with severe perturbations of the global carbon cycle, recorded by the worldwide occurrence of a series of negative carbon isotope excursions (CIEs) in both the inorganic and organic marine carbon record. The massive injection of isotopically light CO_2 into the atmosphere/ocean system from the paroxysmal volcanic activity of the Central Atlantic Magmatic Province has been invoked as the cause of the CIEs, of abrupt climate change, ocean acidification and mass extinction.

In many areas of the Tethyan ocean, carbonate platform sedimentation was terminated around the T-J boundary. In the resilient carbonate platforms that were able to survive the crisis (e.g. the southern Apennine carbonate platform in southern Italy), fossiliferous limestones with corals, sponges, chetetids, large megalodontid bivalves and rich and diverse benthic foraminiferal associations, change abruptly into unfossiliferous peritidal and/or oncolitic-oolitic limestones around the T-J boundary. We have sampled in detail a 244m thick section exposed near the village of Valle Agricola, in the Matese Mts, about 65 km north of Naples (southern Italy). The lower interval (0-205m) is made up of peritidal cycles, consisting mainly of wackestone-packstone with benthic foraminifers and dasycladalean algae and wackestone to floatstone with large megalodontids, corals and chetetids, capped by microbial laminites and supratidal facies with microkarstic cavities. The upper interval (205-244m) is entirely made up of unfossiliferous grainstone-rudstone with ooids, oncoids and intraclasts. We use carbon isotope stratigraphy, tied to benthic foraminifera biostratigraphy, to correlate the Valle Agricola section with other previously studied sections in the southern Apennines, including the Monte Cefalo carbonate platform section and the Pignola-Abriola section in the Lagonegro basin, which has been recently proposed as the GSSP candidate for the base of the Rhaetian. These correlations allow us to elucidate the sedimentary dynamics and evolution of the southern Apennine carbonate platform and of the adjoining Lagonegro Basin across the latest Norian to earliest Hettangian time interval. We then perform a high-resolution correlation with the classical Val Adrara/Italcementi quarry section in the Lombardy Basin, and with other reference sections like the base of Hettangian GSSP of Kuhjoch (Austria) and the St Audrie's Bay section (UK), aiming at interpreting the evolution of the Apennine carbonate platform in the framework of the end-Triassic events. Finally, we attempt using stratigraphic changes in minor and trace elemental concentration, measured with a portable XRF device, to build a high-resolution orbital cyclostratigraphy for the Valle Agricola section.

Geomorphological and multitemporal GIS analyses aimed at redevelopment of network geotouristic paths in the area of Campitello Matese (CB - Molise, Italy)

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Keywords: geomorphology, geotourism, photointerpretation, GIS.

The growing interest on studying mountain areas and their geotouristic redevelopment led us to look at the area of Campitello Matese, (CB - Molise, Italy) through the approach of the geomorphological analysis. According to the recent increase about mountain tourist attraction we propose the reassessment of network of geotouristic paths in a geological way, which can help to spread this kind of knowledge.

For this purpose, we analyzed the area paying special attention to the multiple aspects and geomorphological phenomena which characterize it. The feasibility closed to the redevelopment of geotouristic paths, which must be accessible to people and at the same time must not show critical issues, implies a meticulous and accurate assessment of the critical issues in the area, represented by the interaction and coexistence of the different geomorphological processes typical of mountain environments. Among these we recognize gravitative processes, surface and run-off water, karst phenomena and tectonic activity. Furthermore, an important role is played by the anthropic activity, as evidenced by the Ski Resort of Campitello Matese.

The study was based on data available for remote observations, through the multitemporal photogeological interpretation of aerial photos, integrated with morphometric, orographic and hydrographic GIS analysis by means of raster and vector data, involving the entire ridge-slope-valley system. Through the detail given by the scale of the available data it was possible to map punctual, linear and areal forms, classified following the most recent national guidelines; in this way we evaluated the evolution of the area as a system subject to different geomorphological processes which have modeled it. At the same time, with the integration of the historical data series, the transformations due to the presence of anthropic activities were also considered. Finally, to characterize the areas of greatest interest, multiple profiles were built in order to evaluate the interaction between geology, geomorphology, orography, hydrography, vegetation, anthropic activities and paths network.

A key outcome of this work was to discriminate various sectors in the study area evaluating the different entities of criticality associated at the interaction between natural processes and anthropic activities. Processing the results obtained from the analysis carried out, we divided the network of geotouristic paths that cross the entire area on the basis of altimetric zones, with the purpose to assess the influence of the elevation on the forms and deposits of different nature. In addition, the multiple geomorphological evolution of the area allowed us to design the structure of the geotouristic network differentiating the various paths by the different nature of the processes encountered.

High Ba-Sr granites in the Adamello Batholith (Southern Alps, Italy): the Corno Alto unit as a modern analogous of the Archean Sanukitoids

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Keywords: High-Ba Sr granitoids, Adamello batholith, continental crust.

Modern analogues of the Archean granitoids are unique rocks for investigating processes of continental crust formation and their variations through Earth's evolution.

A new and detailed field work on the Corno Alto unit of the Adamello batholith (Southern Alps, Italy) revealed the occurrence of three types of granitoid rocks: i) muscovite-bearing biotite granodiorite; ii) subordinate tonalite; iii) epidote-bearing biotite granodiorite. The latter is typical of the Sostino apophysis. Plagioclase is the dominant phase in all these rock types and is ubiquitously characterized by oscillatory zoning and the occurrence of ghost cores testifying conditions of intense chemical disequilibrium.

The whole rock composition of the Corno Alto granitoids is quite uncommon for the I-type and S-type granites, revealing particular features compared to the rest of the Adamello batholith: highest SiO_2 contents ($61.0 \leq SiO_2 \leq 71.5$ wt%), K_2O+Na_2O up to 7.2% and a strong enrichment in Sr and Ba (Sr + Ba ≈ 1100-1900). Other geochemical features include relatively high LREE/HREE ratios ($[La/Yb]_N > 20$) and Nb negative anomaly.

Their unique composition likely resembles those of a peculiar group of Phanerozoic rocks known as high Ba-Sr granites which are considered as modern analogues of the Archean sanukitoids originated from the interaction between mantle peridotite and a component from the subducted sediments (Martin et al., 2005).

Major and trace elements together with Sr isotopic compositional traverses across plagioclase grains of the studied rocks reveal abrupt chemical variations associated with enrichment in radiogenic Sr. On selected samples, U-Pb zircon geochronology and Hf isotopes were also carried out, revealing ages ranging from 44 to 39 Ma and a wide variety of isotopic compositions ($\varepsilon Hf_{(t)}$ vary from +1 to +13) related to different textures of zircons.

Microscale elemental and isotopic variations, as well as the occurrence of multiple age clusters, contrast with an origin of the studied rocks either in closed system or from a simple assimilation and fractional crystallization process. Mixing of melts with different geochemical signatures and recycling of older crystals is suggested.

Deciphering the origin of the different components active during the petrogenesis of the alpine high Sr-Ba granitoids may help to settle critical issues about sanukitoids, in particular concerning their mantle origin and how they differentiate at shallow crustal levels.

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Restoration work of the decorated paving stone from the "Palazzo Centrale dell 'Università di Catania", Sicily

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Keywords: restoration, stone decay, protective, cultural heritage.

The building of "Palazzo Centrale dell'Università" of Catania (Sicily) dates back to the end of 1600, and it was rebuilt in Baroque style by the architects Francesco and Antonino Battaglia and Giovan Battista Vaccarini, after the earthquake of 1693. The palace is currently the seat of the Rectorate, the offices of the central administration of the University and the Regional Library "Giambattista Caruso".

The decorative paving stones adorning the cloister pavement is certainly one of the most precious jewels of the Etnean city. It was realized by Francesco Fichera at the beginning of the 1900 on the drawing of Vaccarini. The pavement is made by black gravels of volcanites and white slabs of limestone. The volcanic stones with a rounded shape are inserted one by one like mosaic tiles showing a fine figurative design with floral and geometric motifs typical of the Sicilian Baroque.

Despite the recent conservation-restoration intervention in 2017, the paving is currently affected by biological decay due to the attacks of microorganisms, such as mosses and lichens that adhere to the stone surface.

In the framework of the project Advanced Green Materials for Cultural Heritage (AGM for CuHe) which aims to develop new technological and sustainable products in the field of restoration, the pavement has been selected among other buildings as a case study for testing new protective materials.

After a preliminary study of the materials and the degradation forms which affect the pavement, three different biocide products were tested in different areas, to evaluate their effectiveness. Then, the stone surfaces have been cleaned mechanically using a brush, a sponge and a solution of surfactants. Macroscopic observations and colorimetric analyses have been carried out with the aim to evaluate the efficiency of the cleaning treatments. In parallel, laboratory tests have been carried out by using the newly developed consolidating and protective coatings on several types of Sicilian limestone in order to evaluate their effect on the stone substrate. This study will lead to the choice of the best product to be applied *in situ*.

Nomenclature issues in the roméite group: towards a new nomenclature of the pyrochlore supergroup

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Keywords: roméite group, pyrochlore supergroup, nomenclature.

Pyrochlore supergroup minerals have general chemical formula $A_{2-m}B_2X_{6-w}Y_{1-n}$ (Atencio et al., 2010). Phases having B = Sb^{5+} belong to the roméite group, currently formed by five mineral species: fluorcalcioroméite (Atencio et al., 2013), hydroxycalcioroméite (Atencio et al., 2010), hydroxyferroroméite (Mills et al., 2016), oxycalcioroméite (Biagioni et al., 2013), and oxyplumboroméite (Hålenius & Bosi, 2013). Chemical formulae of these species show some inconsistencies. For instance, Atencio et al. (2013) wrote the simplified formula of fluorcalcioroméite as $(Ca,Na)_2Sb^{5+}{}_2O_6(F,OH)$ and its end-member formula as $(Ca_{1.5}\square_{0.5})Sb^{5+}{}_2O_6F$. In other formulae, the symbol # was used to indicate additional generic A-constituents (e.g., Hålenius & Bosi, 2013).

In the framework of a review of Sb minerals, roméite-group minerals have been reexamined and their end-member formula was derived by applying both the dominant-valency rule and the site-total-charge (STC) approach (Bosi et al., 2019). Some issues have been found.

The end-member formula of fluorcalcioroméite, currently written as $(Ca,Na)_2Sb_2(O,OH)_6F$, is (CaNa) Sb_2O_6F; on the contrary, Atencio et al. (2013) gave the formula $(Ca_{1.5}\square_{0.5})Sb_2O_6F$. In this case, the same name would correspond to two different end-member formulae (i.e., two different species).

The end-member formula of hydroxycalcioroméite is $Ca_2(SbTi)O_6(OH)$. Since the belonging of a pyrochlore supergroup mineral to different groups is based on the dominant B-constituent, this does not fit in the current classification.

Consequently, we propose a classification procedure based on the dominant B-constituent, followed by the application of the STC approach at the A and Y constituents. Further studies are required to extend this procedure to the other groups of the pyrochlore supergroup.

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Philosophy of geosciences: theoretical models and applications

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Keywords: philosophy of science, history of science, methodology, paradigms, hermeneutics.

In Italy, the philosophy of geosciences does not have a long academic history and is practiced by humanists and scientists who are passionate about these issues. Nevertheless, philosophy of science can contribute as an extension of theoretical science, thanks to the collaboration between scientists, philosophers and historians on the same issues (Barrotta & Montuschi, 2019). The twentieth century saw the rise of Plate Tectonics, a unifying theory for all Earth sciences. It is precisely the history of science that investigates the complex mechanisms that lead to the transition from one theory to another (Frankel, 2012). Instead, it is philosophy that proposes methodologies of analysis to interpret the reconstructed histories of changing paradigms (Laudan, 1978; Lakatos & Musgrave, 2008; Kuhn, 2012; Feyerabend, 2013). Philosophical reasoning can be used to evaluate the correlations among different hypotheses, e.g., by using the Method of multiple working hypotheses, which was theorized by the geologist Chamberlin at the end of the 19th century (Chamberlin, 1890). Investigations into the nature of reality can help researchers increase their awareness of the nature of the hypotheses or reality (Rittmann, 1981). Finally, a recent case is given by Frodeman's hermeneutic reflections to examine the nature of geological reasoning (Frodeman, 2014). All these possible ways can improve the clarification of the scientific language developed by scientists and contribute to a more precise explanation of reality.

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Trigger of Messinian sapropel deposition: clues from stable isotopes on benthic foraminifers

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Keywords: sapropel, stable isotope, Messinian, calcareous nannofossils.

Sapropel deposits represent an important perturbation of the carbon cycle; despite more than 50 years of intense studies, the triggering mechanism of sapropel deposition is still under debate. In particular, two models explaining the mechanisms promoting the Messinian sapropel deposition were proposed: the first relies on the Pleistocene-Holocene sapropels depositional model, which invoked humid and warm conditions as necessary for the sapropel deposition (Sierro et al., 2003); the second points to a cold and highly productive environment as a trigger for the sapropel deposition (Mancini et al., 2020).

We applied a multiproxy approach and studied samples collected in Pollenzo and Govone sections (Northwestern Italy) to explore the paleoenvironmental dynamics that drove the sapropel deposition at the MSC onset in order to develop a conceptual model for the Messinian sapropel deposition. Stable carbon and oxygen isotopes on planktic and infaunal benthic foraminifera belonging to two different size ranges (63 - 125 and > 125μm) were analyzed, covering a time interval of about 270,000 years (from about 6.2 Ma to 5.95 Ma) and straddling the Messinian salinity crisis onset. These data were integrated with a detailed calcareous nannofossil relative abundance analysis and compared with previously published foraminiferal assemblage data (Lozar et al., 2018). Oxygen and carbon isotopes show a precession-driven fluctuating trend in accordance with the calcareous nannofossil and foraminifera assemblage trends. Our results show an increase in primary productivity related to the instauration of a prevalently cold climate during the sapropel inception, and a progressively warmer climate during their deposition. Our isotopic and micropaleontological records also show that there is no evidence of an increase in water salinity during and after the MSC onset. This finding suggests a reevaluation of the paleoenvironmental processes that promoted both the cyclical sapropel deposition and the MSC onset.

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Magmatic intrusions north-east of Roccamonfina volcano (Italy): evidence of tectonic control on dike swarm emplacement and implications for the Late Pleistocene volcano-tectonic activity

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Keywords: volcano-tectonics, dike intrusion, Roccamonfina volcano, Apennine tectonics.

Magmatic dikes are sub-vertical magma-filled fractures that cross-cut the host-rock and possibly feed an eruption. Their emplacement is particularly favoured in extensional tectonic settings (Gudmundsson, 2012). This is the case of the Garigliano graben in southern Italy, where many examples of volcanic activity along structural lineaments are reported (e.g. Di Girolamo et al., 1991; De Rita & Giordano 1996). In this work, we analyzed a large magmatic dike beautifully exposed in the Mt. Cesima quarry north east of the Pleistocene Roccamonfina volcano. The country rock consists of cataclastic Mesozoic carbonates covered by a lower Pleistocene breccia. The dike contact with the fractured limestone is quite sharp, with a well-developed thermometamorphic aureole showing a transition from decarbonized limestones to marbles. Many limestone xenoliths are found along the dyke margin, as well as dike segments, namely dike horns (i.e. aborted dike paths) and magma fingers (Gudmundson, 2011; 2020). On the other hand, the contact with the Pleistocene breccia is strongly irregular, with many apophyses with a rounded shape. This dike reached the surface and fed an eruption, as testified by the presence of proximal Strombolian pyroclastic sequence. This consists of scoriaceous lapilli, with upward increasing degree of welding, with frequent dense scoriae bombs and blocks. Structural data of faults, mechanical and cooling joint have been collected in the field and remotely by means of VOM (Virtual Outcrop Models) retrieved by drone surveys. The data indicate that the dike is characterized by a segmented geometry with a dominant E-W direction, although locally conditioned by pre-existing NE-SW trending fault zone, which deviated the dike trajectory. The dike and the tephra are dislocated by E-W and N-S trending faults, with normal to transtensional kinematics. The thickness of the dike varies both along its dip and strike, ranging between ca. 6 and 25 m, with a general increase toward the surface (Geshi et al., 2010), whereas minor dike fingers are ca. 1-2 meters thick. The magmatic assemblage, composed of Clinopyroxene and Plagioclase phenocrysts, accompanied by Leucite, Biotite, and Oxides in the groundmass, is consistent with the magma feeding the Roccamonfina volcano (Peccerillo et al., 2017). Stratigraphic evidences points out that the dike fed an eruption younger than the Yellow Trachytic Tuff of Roccamonfina volcano (Giannetti, 1995), and the structural investigations suggest a significant fault activity of the graben-bounding faults in the Late Pleistocene.

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Back-trajectories analysis and stable isotope signatures of single meteoric events in central-western Italy (Tuscany)

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Keywords: precipitation, water isotopes, moisture origin, air mass trajectories, Mediterranean.

The hydrogen and oxygen isotope composition of atmospheric precipitation is widely used to track processes within the hydrological cycle and understand atmospheric patterns from local to global scales (Clark & Fritz, 1997). The stable isotope signature of precipitation is affected by both factors related to the source of moisture and the rain-out history, geographical factors (e.g. latitude, altitude, distance from the coast) and meteorological variables such as precipitation amount and air temperature (Dansgaard, 1964). Although the dependence of the precipitation isotopic signals from meteorological and geographical factors is documented over monthly or annual timescales (Dansgaard, 1964; Rozanski et al., 1993), further efforts are required to investigate the isotopic variability among single precipitation events and the relationships with the moisture sources, air masses trajectories and synoptic weather patterns. In the western Mediterranean the investigations about these relationships are of crucial importance to evaluate the influence of different moisture sources and synoptic patterns on the isotopic signal of precipitation, which has direct implications for understanding the aquifers recharge mechanisms. In this work, we present the preliminary results of a study aimed to investigate the isotopic variability of single meteoric events in northern Tuscany (central-western Italy) which is a key area of western Mediterranean to understand the processes governing the isotopic composition of precipitation since the complex morphology and orography that imply strong climatic and meteorological gradients. To this aim, several single meteoric events were sampled from March 2020 to May 2021 at two stations placed at different altitudes: the Versilia plain at 4.5 m and the Apuan Alps at 660 m a.s.l. Two PALMEX Tube-Dip-In-Water rain collectors (Groning et al., 2012) were used to collect total cumulative amounts of each event and air temperature was also measured at both sites. Samples were analyzed to determine the isotopic ratios of hydrogen and oxygen. A HYSPLIT back-trajectory analysis was performed for each event based on one-degree meteorological GDAS (Global Data Assimilation System) data, and trajectories were initialized at prefixed temporal step over the total duration of the event. The isotopic variability registered among the meteoric events has been explained by the different role of air temperature, precipitation amount, moisture sources and trajectories.

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How does seismic attenuation correlate to rheology of crustal rocks? First results from a numerical approach

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Keywords: rocks' rheology, seismic attenuation, Burgers model.

Intrinsic anelasticity of crustal rocks causes energy dissipation of seismic waves when they propagate through the media. This dissipated energy can be quantified in terms of a seismic quality factor (, which can be used as a potential attribute for subsurface characterization. This parameter depends on the seismic frequency, as well as on temperature, water content, and grain size of the rocks (e.g., Karato & Spetzler, 1990; Jackson & Faul, 2010). On the other hand, the viscous deformation of crustal rocks occurs through different anelastic mechanisms including diffusion creep, numerous mechanisms of the dislocation creep, pressure solution that exhibits dependency on their structure, composition, and fluid content, as well as on their P-T conditions (e.g., Burov, 2011). Therefore, it is likely that seismic attenuation and the viscous modes of deformations of rocks can be correlated, based on their dependency on the aforementioned conditions, as expressed by an Arrhenius-type equation (Farina et al., 2019).

In this study, we investigate the quantitative relationships between seismic attenuation and viscous rocks' rheology, especially across the domain where rocks transition from a dominant brittle to a more ductile deformation mode (Brittle Ductile Transition, BDT). We rely on a Burgers mechanical model to derive shear wave attenuation (), for several dry and wet crustal rheology, thermal conditions, and different strain rates values. This allows us to establish geothermal and mechanical conditions at which the BDT occurs and to cross-correlate this transition to computed shear seismic wave attenuation values. In particular, we observe a relatively significant reduction for strain rates of 10^{-13} s^{-1}, despite the assumed rock's rheology and thermal conditions. These first results confirm our hypothesis that variations in the factor can be effectively used to identify the BDT's depths in tectonically active areas. Ongoing and future works will focus on a further validation of the modelling implications by systematic analyses of observations derived from rocks' laboratory experiments, which can add constraints on the relationship between seismic attenuation and rheological flow laws.

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Dynamics of periglacial environment. An approach by the study of rock temperature in alpine zones at mid-high altitudes

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Keywords: geomorphology, bedrock temperature, glacier, Western Alps, climate change.

The present study is based on an introductory geomorphological analysis within an area located in the western Alps, called Alpi Graie, in the ambit of which have been made fieldwork measurements now storaged in a previous database. Such data regards the local atmospheric temperature and bedrock temperature (outcropping and under the snow cover) of two different lithologies: prasinite and calcescisto. The study was inserted in the ambit of the research projects *GeoClimAlp* held by CNR-IRPI section of Turin, related on the impact that the global climate change, aimed at the mean temperature increase, can entail on the microclimate at high altitudes zones. We investigated the circadian cycles and, presumably, the seasonal cycles developed through a solar year, correlated to freeze-thaw processes (Matsuoka et al., 1998) and natural instability processes mostly rockfalls (Nigrelli et al., 2018), relating to both parameters, analyzing the type of reciprocal correlation. The surveys have also given the possibility to improve the use of instrumentations like a meteorological station pre-installed from Arpa Piemonte, a webcam arranged on a glacial moraine or a temperature micro data logger. The whole for the monitoring of some parameters such as air and rock temperature and the snow cover thickness. Other aim of the work was to investigate the effects that these phenomena could have on the abandoned permafrost (Fischer et al., 2006) and so on the most glacial and periglacial morphologies, such as rock-glacier, observable in the study area.

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The enigmatic chloritoid + biotite + garnet assemblage: a phase diagram modelling study

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Keywords: chloritoid+biotite assemblage, thermodynamic modelling, P-T-X relations, Himalayan belt.

Forward thermodynamic modelling approach is among the most powerful methods currently applied for unravelling the P-T-X evolution of metamorphic rocks (Lanari & Duesterhoeft, 2019). In the last decades, this approach has been widely and successfully applied on metapelites from different geodynamic settings, because this lithology is often characterized by low variance mineral assemblages providing tight P-T constraints. However, certain uncommon mineral assemblages observed in metapelites have still proved difficult to be constrained (e.g. Sengupta, 2012), remaining an exciting conundrum to be solved. This contribution presents the results of a phase diagram modelling study of the enigmatic chloritoid + biotite + garnet assemblage, aimed at understanding the influence of both intensive (P, T) and extensive (X) variables on its stability. The studied samples are chloritoid + garnet + staurolite ± chlorite two-micas schists from the Upper Lesser Himalayan Sequence in eastern Nepal Himalaya. We performed a detailed petrographic, microstructural and mineral chemical analysis, highlighting the equilibrium relations between chloritoid, biotite and garnet, as well as between chlorite and staurolite. Two representative samples have been modelled using PerpleX_6.9.0 (Connolly, 1990) and testing two internally consistent datasets and solution model packages (Holland & Powell, 1998, 2011). P-T pseudosections calculated in the MnNKCFMASHTO system failed in modelling the observed equilibrium relations between chloritoid and biotite, predicting biotite appearance at higher temperatures than the chloritoid stability field. The influence of compositional parameters (XFe_2O_3 and XH_2O) on the stability of chloritoid + biotite has been further investigated using P/T-X pseudosections. Preliminary results suggest that XFe_2O_3 has a negligible influence on the stability of the observed assemblage; vice versa, slightly under-saturated H_2O conditions seem to enhance the biotite stability, allowing a good fit between the modelled and the observed mineral assemblages.

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Calcareous nannofossil assemblages during the Miocene Climatic Optimum: new biostratigraphic remarks

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Keywords: calcareous nannofossil, biostratigraphy, Miocene Climatic Optimum.

The Miocene Climatic Optimum (MCO; ca. 17 to 14.7 million years ago; e.g. Holburn et al., 2015) is a warm interval of the Miocene epoch that has risen scientific interest due to its strong similarity to the present-day increasing warm condition. It is considered an excellent analogue to assume not only current global changes but also the future ones (Steinthorsdottir et al., 2021).

In an ongoing study on calcareous nannofossil assemblages variability within the MCO interval, using deep-sea sediments from different oceanic areas, we focus on the occurrence of the biostratigraphic marker *Reticulofenestra pseudoumbilicus*. This species is a characteristic taxon of the middle Miocene to lower Pliocene nannofossil assemblages and shows a variable distribution pattern throughout its stratigraphic range, characterized by a temporary disappearance in the late Miocene (from 8.8 to ca. 7 Ma; Backman & Raffi, 1997). The very base of *R. pseudoumbilicus* range has never been precisely reported, while the beginning of a common occurrence has been observed at several locations starting from the middle Miocene, and calibrated at 13.53 Ma (Backman et al., 2012). In the data here presented (from IODP Site U1338 - equatorial Pacific and ODP Site 959 - tropical Atlantic) specimens of *R. pseudoumbilicus* already occur in lower Miocene sediments, within the lower part of *Sphenolithus heteromorphus* Zone (CNM6; Backman et al., 2012). This appearance is followed above by a temporary disappearance which delineates the beginning of an absence interval similar to what observed in the upper Miocene and could be included as additional biohorizon in the biostratigraphy scheme. Preliminary results suggest that this distribution variability of *R. pseudoumbilicus* could be related with the paleoenvironmental and paleoclimatic variations typical of the MCO.

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Structural and geochemical characteristics of peridotite and pyroxenites mantle-wedge xenoliths from the Northern Andes (Mercaderes area, Colombia)

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Keywords: peridotite, pyroxenite, xenoliths, mantle, Colombia.

Pyroxenite and peridotite xenoliths of the Granatifera Tuff pleistocenic body (Mercaderes - Rio Mayo area of Southern Colombia) offer a direct view of the supra-subduction mantle underneath the Northern Andes (Weber, 1998; Rodríguez-Vargas et al., 2005; Bloch et al., 2017). They range from subordinated garnet peridotite to dominant garnet websterite and clinopyroxenites. Moderately deformed granular structures (evident in garnet pyroxenite) are shown by few xenoliths that retain evidence of melt-rock interaction (e.g., anhedral interstitial garnet and pyroxene overgrowing coarse, deformed pyroxene grains). Most peridotite and pyroxenite xenoliths show a coarse granular mineral assemblage (ortho-, clinopyroxene and garnet porphyroclasts) overprinted by porphyroclastic to mylonitic textures (orthopyroxene + clinopyroxene + olivine matrix). Considering the whole sample set mineral compositions define large intervals in terms of Mg-value (82-92) and Na contents in clinopyroxene (0.70 - 1.60 wt%). However, the major elements compositions of minerals are very homogeneous within a single xenolith, without core-to-rim or porphyroclast-matrix variations. This trend is also reflected by the trace elements mineral abundances; with higher REE concentrations in clinopyroxene and garnet of more fertile (i.e. with lower Mg-value) xenoliths. Pressure-temperature estimates (performed using two pyroxene and garnet-pyroxene calibrations) range in the intervals 24-37 kbar and 1100°C-1250 °C. The homogeneous composition of porphyroclasts and matrix in major- and trace-elements indicate that pervasive re-equilibration affected all xenoliths during mylonitic deformation. Comparing microstructural, mineral chemistry and thermobarometric data on the studied samples with a recent geodynamic model of the area (Wagner, 2017) we infer that the Mercaderes xenoliths derive from a heterogeneous highly deformed mantle-wedge domain near the lithosphere-asthenosphere boundary. Despite the geodynamic location of the studied xenoliths, no modal metasomatism has been observed yet.

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The contribution of seismic methods to the stuctural analysis of monumental buildings: an application to the National Archaelogical Museum "Gaio Cilnio Mecenate" (Arezzo)

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Keywords: structural health monitoring, site effects, monumental and historical buildings, resonance frequencies.

The main contribution to Structural Analysis given by the analysis of ambient noise measurements (Nogoshi & Igarashi, 1970; Nakamura, 1989) consists in identifying the resonant frequency of a site, as a function of the elastic and geometric properties of the soil, which could produce a double resonance effect on a building if it is in agreement with its modal frequencies. The ground shaking determines, infact, the input vibration that propagates inside the building, that will respond with an oscillation ruled by its elastic properties, related to its geometry and construction materials. The analysis of ambient vibrations can be applied for identifying the modal properties of monumental buildings (e.g. resonant frequency), through a non-invasive monitoring network composed by accelerometers or velocimeters installed on different levels of the building. When continuous monitoring goes on for long time, the variation of modal parameters can be estimated in order to evaluate its dependence from environmental or anthropogenic factors (Clinton et al., 2006).

In this study, the seismometric monitoring is applied to the National Archaeological Museum "Gaio Cilnio Mecenate" in Arezzo (Italy), an historical structure built on the remains of an ancient Roman amphitheatre. The survey, started on December 2019 and still operating, is aimed to estimate the dynamic properties of the building from ambient vibrations. Monitoring network consists in four seismometric stations installed on the four levels of the building, on the recorded data (referred to the period 4th February - 9th April 2020) have been applied spectral analysis, HVSR and SSR techniques, in order to estimate the fundamental modal frequency. The continuous feature of the monitoring campaign allowed to observe the variation of the value of the modal frequencies and of the amplitude of oscillation, that seems to be related to the set of cultural activities: a reduction of the amplitude, in fact, is observed during then night hours and the week-ends. Confirm on the effect of anthropic activities as principal source of vibration has been deducted by the observation of a substantial reduction of the vibrations during the lockdown due to the pandemic emergency CoVid-19 occurred from March 2020. An interesting aspect is that related to the effects of small earthquakes and transients on the natural frequencies of the building. Both of them, in fact, produces small variations that lasts only during the occurrence of the input forces. The result of this analysis will constitute crucial data to calibrate the numerical models describing the dynamical behaviour of the building.

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A reappraisal of the tectono-metamorphic evolution of the Sardinian Variscan basement along the Baronie Region

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Keywords: Variscan belt, mylonite, Barrovian metamorphism.

The Baronie Region (Carosi & Palmeri, 2002; Carosi et al., 2020), in the Sardinian Variscan belt, offers a well-exposed and continue structural section of the metamorphic basement, starting from the Low- to Medium-Grade up to the High-Grade Metamorphic Complex (L-MGMC and HGMC; Carmignani et al., 1994). The Posada Asinara Shear Zone (PASZ; Carosi et al., 2020) is a regional scale transpressional shear zone, marking the boundary between these two complexes. PASZ activity was related to the exhumation of the metamorphic rocks. A detailed petrographic and microstructural study has been conducted along two transects orthogonal to the PASZ, where mostly amphibolite-facies mylonitic micaschist and gneiss are present, showing a northward increase in the metamorphic field gradient. We investigated the distribution of index-minerals, the relationships between mineral growth and deformation, combined with new P-T estimates, to provide new P-T-D paths. Blastesis-deformation relationships suggested how the mineral assemblages, corresponding to a Barrovian metamorphism, grew from the late collisional stage (D1 phase) to the beginning of transpressional shearing along the PASZ (D2 phase). We focused on three specimens of staurolite-garnet-bearing and staurolite-garnet-kyanite-bearing mylonitic micaschist, belonging to the MGMC. Evidence of a later, low pressure heating stage was also found, as suggested by the post-kinematic growth of andalusite. The metamorphic evolution has been reconstructed with the aid of two different methods: the inverse method and the forward modeling (calculating P-T pseudosections). In addition to previous petrological investigations of the area (Franceschelli et al., 1989; Carosi & Palmeri, 2002), the detection of minerals connected to a late heating stage allows to update and refine the shape of P-T-D paths. These new data, coupled with the ones from the geological literature (see Cruciani et al., 2015 and Carosi et al., 2020 for a review) shed new light on the tectono-metamorphic evolution of the MGMC in this portion of the Sardinian Belt.

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Landslide hazard in the Abruzzo Region (Central Italy): landslides case studies in different geomorphological/morphostructural environments

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Keywords: landslides, geomorphological mapping, GIS analysis, landslide hazard assessment, Abruzzo Region.

Landslides are considered, worldwide and in Italy, as one of the most important and frequent natural hazards responsible for several casualties and damage (Kjekstad & Highland, 2009). Abruzzo Region (Central Italy) is largely affected by different types of landslides from mountainous to coastal areas (Miccadei et al., 2019; Esposito et al., 2021). It is located in the central-eastern part of the Italian peninsula, and it is framed in a complex geological and geomorphological context. Landslide occurrence is generally controlled by the dynamic interaction between predisposing factors (i.e., morphology, lithological and structural setting, vegetation cover, land use, climate, etc.) and triggering ones (i.e., heavy rainfall events, earthquakes, wildfires, human activity, etc.) (Aleotti and Chowdhury, 1999; Calista et al., 2020). Selected landslide case studies have been chosen as representative of the main active geomorphological processes affecting different morphostructural environments, with reference to the predisposing and/or triggering factors. This work illustrates the results of multidisciplinary analyses carried out in recent years in different geomorphological environments, involving literature data and landslide inventory analysis, morphometric analysis, photogeological analysis, and field mapping. It outlines the importance of combining geological-geomorphological approaches with integrated field-based and laboratory analysis to better characterize landslide distribution and occurrence and their role in landscape evolution. Furthermore, this work could represent a scientific tool in geomorphological studies for landslide hazard assessment at different spatial scales, readily available to interested stakeholders, to support sustainable territorial planning and land management activity.

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Lead anomalies in the Lake Accesa (Tuscany, Italy): possible evidences of human activities from the Early Copper Age

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Keywords: trace elements, Pb isotopes, lake sediments, southern Tuscany.

The Lake Accesa is a small karstic lake (~0.15 km^2) located in southern Tuscany, about 5 km from the town of Massa Marittima. The catchment area of the lake covers ca 5 km^2 and is surrounded by sulfide polymetallic deposits exploited at least since the Etruscan times for the extraction of silver and lead (Lobell, 2002).

Here, we present a high-resolution and continuous geochemical record for lead, from a sediment core of the Lake Accesa collected in 2005 from the deepest part of the lake. The core is about 8 meters long and covers a time spanning from today to 11000 cal. BP (Vannière et al., 2008)organic-content analyses, and pollen counts to provide data about sedimentation and vegetation history. A comparison between fire frequency and lake-level reconstructions from the same site is used to address the centennial variability of fire regimes and its linkage to hydrological processes. Our data reveal strong relationships among climate, fire, vegetation, and land-use and attest to the paramount importance of fire in Mediterranean ecosystems. The mean fire interval (MFI. Lead was analyzed along the core (260 samples) by X-ray fluorescence (XRF). In addition, 9 samples were analyzed for Pb isotopic composition by Multi Collector-Inductively Coupled Plasma-Mass Spectrometry (MC-ICP-MS).

The results obtained from XRF analyzes indicate that Pb concentrations varied from below the detection limit to ~362 ppm, with a mean of 33 ppm and a median of 4.4 ppm. The distribution of Pb with depth shows that the highest values were mainly localized around 5500 cal. BP (3550 yr BC) and in the uppermost part of the core, starting from 1200 cal. BP (from 750 yr AC). Pb isotopic compositions fit with the composition of polymetallic ores of southern Tuscany (e.g., Lattanzi et al., 1997) indicating that Pb is of local origin and related with the mineralization of this area.

The highlighted peaks of Pb could thus be related to human activities, which seem to be particularly intense during the Copper Age and since the Middle Age. Surprisingly, there is no evidence of Pb anomalies during Etruscan and Roman times. The high values of Pb could be related to mining activities, that favored the accumulation of slags enriched in Pb, and operations related with the land-use management, such as deforestation, that favored soil erosion in the exploited areas. Further analyses on other trace elements could be helpful to discriminate the process of formation of these anomalies and their origin.

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Provenance study of Sahara Desert: a remarkable case of sediment recycling

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Keywords: Sahara Desert, recycling, sand petrography, heavy minerals, detrital zircon geochronology.

Provenance studies of large deserts are a tackling effort considering extreme climatic conditions and poorly studied sediment pathways in some of the largest and oldest sedimentary basins of Earth. We here present the results of a provenance study on dune sand of the Sahara Desert, that applies petrography, heavy mineral analysis and detrital zircon U-Pb dating,and aims to capture provenance signals of a remarkably homogeneous dataset of quarzose sediment, with poor heavy mineral suites enriched in ultra-stable minerals such as zircon, tourmaline and rutile.

Few samples consistently display compositional differences, with more feldspars, amphibole, epidote, garnet, or staurolite, occurring closer to basement outcrops as in the Air Mountains, or carbonate grains, clinopyroxene and olivine near basaltic fields (as in Libya). Relatively varied compositions also characterize sand along the Nile Valley and the southern front of the Anti-Atlas fold belt in Morocco. In the star dunes field of Grand Erg Oriental there is a selective enrichment of garnet in the heavy fraction. These signatures are nevertheless negligible considering the overall markedly quartzose compositions and abundance of durable minerals in the depleted heavy mineral suites. Moreover, the main cluster of the total concordant ages (77%) is distributed between 0.48 and 1.1 Ga and dominates the age spectra of the whole desert.

In addition, our samples present an extreme similarity with Cambro-Ordovician sandstones that were deposited in sedimentary basin formed after the Pan-African orogeny, that remobilized mainly Archean and Paleoproterozoic terranes from Arabian-Nubian shield to West African Craton. The relative tectonic quiescence that followed this Neoproterozoic to Ordovician event imposed the dominance on sediments of multiple recycling events, testified to by the homogeneous quarzose bulk composition and similar detrital zircon age spectra yielding a dominant Pan-African age peak. These sandstones are the main source of the present-day detritus, preventing major provenance consideration from the early stages of sediment production, but representing a remarkable example of extensive recycling both in terms of spatial and temporal extension.

This hampers the assumption that, in provenance studies, zircon ages may give direct source to sink information, often leading to hypotheses on ancient routing systems, wiping out any consideration over the inheritance from multiple stages of rock formation and erosion.

Trace element behaviour along the water column and mobility at the sediment-water interface in a stratified estuarine environment (Gulf of Trieste, northern Adriatic Sea)

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Keywords: trace elements, estuary, water quality, sediment-water interface.

Sediments are considered reservoirs of contaminants, but they can also act as a secondary source of contamination since remobilisation processes at the sediment-water interface (SWI) may affect the water quality (Caplat et al., 2005; Petranich et al., 2018). The estuarine system of the Timavo River is located in the Gulf of Trieste (northern Adriatic Sea). The innermost sector of the estuary was recognised as the most critical area showing high concentrations of potentially toxic elements (PTEs) in sediments and scarce water circulation which led to a permanent oxic-hypoxic interface along the water column (Pavoni et al., 2020).

Field activity was performed before (June) and after (September) the forced aeration of a system of porous pipes laid on the bottom aiming at re-oxygenating the water column in summer. Sampling was carried out along the water column, short sediment cores were collected to investigate both solid phase and porewaters and *in situ* benthic chamber experiments were conducted at the SWI. The primary aim of the work was to understand if and how biogeochemical processes may affect PTE (As, Cr, Hg, Fe, Mn, Ni, Pb, V) mobility and and related fluxes at the SWI.

The water column was found to be oxygen stratified and hypoxia occurred at the bottom, mostly in June (2.29 mg/L) when reductive conditions were also observed (-58 mV). As a result, dissolved PTEs increased with depth reaching maximum values at the bottom due to dissolution/desorption processes of Fe and Mn oxy-hydroxides (Dellwig et al., 2010). This evidence was confirmed by the benthic chamber experiments highlighting a gradual oxygen depletion inside the chamber due to organic matter remineralisation with subsequent increase of dissolved PTEs.

The porewater profiles were found to be different between the two campaigns showing the highest PTE concentrations in June, mostly at the top of the sedimentary sequence suggesting that release of PTEs at the SWI is promoted in hypoxic conditions.

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Application of morpho-structural and geophysical surveys for the characterization of the Stradella Fault (Southern Lombardia)

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Keywords: North Apennines, Emilia Arc, morphological relief, resistivity profiles, seismic history.

The examined area is placed within the structural context of the buried Apennine folds. In this area it is possible to observe the result of the compressional strengths of the northern sector of Apennines which is due to the anticlockwise movement of the Adria plate, which led the Apennines to approach the Southern Alps. The result of this compression is noticeable at the San Colombano Hill, standing out from the Po Plain and related with the Emilia Arc, which trends NE-SW till San Colombano, and then proceeds with a NW-SE strike till the Sillaro Line (Pieri & Groppi, 1981). This is one of the three main buried structural arcs which characterize the northernmost part of the Apennine sector, and it was mainly active during the Pliocene (Turrini et al., 2016).

The morphological relief of Stradella presents a nearly constant E-W strike from Stradella to Castel San Giovanni, where it shows a 1 km offset towards S.

The morphological relief has been investigated through the integration of field surveys and the aid of an Unmanned Aerial Vehicle (UAV), the DJI Spark, followed by geophysical studies to create resistivity profiles of the area.

Along the structure, which is almost 18 km long, it is possible to follow a main escarpment, ranging from 9 m to 20 m in height, and a lower parallel one, ranging from 0.55 m to 4 m in height.

The results obtained from the electrical resistivity surveys, performed into two different areas, show the presence of structures that correspond with the morphological evidence identified through the support of UAV and the analysis of high-resolution Digital Elevation Models (DEM). Both resistivity profiles exhibit the presence of a sub-horizontal high-resistivity structure, which plunges towards S and, in the northernmost portion, sub-vertical low-resistivity structures, which prolong at depth. We interpret these data as a fault splay also due to the detection of saline waters (low resistivity bodies) associated with the Vogherese Fault in an area adjacent to the one in study (Torrese & Pilla, 2015). The presence of structural elements enables waters to rise the structures themselves. Due to the features of the terrains in the area (clays and sands) it appears impossible to identify a clear kinematics.

In response to the identification of structures in the studied area, it has been restored the seismic history of the main villages along the structure. This part of the study, performed through the analysis of the Italian Parametric Catalogue of Earthquakes (CPTI15 v3.0) and the Italian Seismological Instrumental and Parametric Data-Base (ISIDe), had the aim of examine the possible link between historical and recent earthquakes with our structure. Because of limited availability of data for the area and due to the low magnitude that features the extracted events, it was not possible to affirm that the structure has been active during historical period, although the morpho-structural data suggest a possible recent (Holocene?) age.

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Potential risks to human health associated to short-term exposure to gaseous fumarolic emissions at the "La Fossa" crater, Vulcano Island (Italy)

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Keywords: gases hazard, vulcanic gases, fumarolic emission.

Vulcano is the southernmost island of the Aeolian archipelago (Italy). Indeed, since the last eruption in 1888-1890, the most evident activity on the island is the emission of fumarolic gases in the summit area of La Fossa and in peripheral areas in the Bay of Levante (e.g. H_2O, CO_2, SO_2, H_2S). Volcanic activity constantly releases large quantities of gases into the atmosphere, with high concentrations that are potentially toxic to human health, even for short periods of exposure. The spectacular activity attracts hundreds of tourists per day, who climb to the summit area, and walk through the fumarolic field to observe the wonderful and ephemeral sulphur efflorescences.

This study aims to assess the potential risk to tourists who expose themselves, often unknowingly, to fumarolic gases. To this end, a field survey was carried out in June 2019 to measure the concentrations of fumarolic gases (CO_2, SO_2 and H_2S) in the atmosphere, using a MultiGAS made by the LabVulc laboratory of Palermo (DiSTeM, University of Palermo). The spatial-temporal survey was carried out by measuring in real time (1hz) the gases at about breath-level (1,5 m above ground) during 11 walking transects, mainly in the crater fumarolic area; at the same time, prevailing wind directions, air temperature and atmospheric pressure, relative humidity and GPS measurements were recorded. The highest concentrations of volcanic gases were measured in fumarolic areas, significantly higher than atmospheric concentrations representative of the local background: CO_2 concentrations vary between about 500 and 2000 ppm in the summit crater zone, reaching maximum values of more than 13000 ppm in the vicinity of active fumaroles; SO_2 and H_2S concentrations range from a few ppm to maximum values of about 300 and 100 ppm respectively in proximity of fumarolic vents.

Considering that most tourists pass through the fumarolic field, stopping for several minutes inside the areas with high gas flows, it is clear that they are exposed to a high risk of intoxication.

Peak concentrations for both sulfur gases at or even above the immediately dangerous to life limit (100 ppm) for healthy adults are reached only very close to the fumaroles. But levels dangerous to people affected by bronchial asthma or lung diseases (0.2 ppm for SO_2 and 2 ppm for H_2S) were measured widely in the crater area. In conclusion, tourists visiting the fumarolic field of Vulcano are unconsciously exposed to a high risk of intoxication, especially the most vulnerable people (asthmatics, people with respiratory and cardiovascular diseases), also considering that there is no assistance and no signposts explaining the associated risks, and any instructions on how to protect themselves (e.g. use of suitable masks).

Cu- minerals from the Vesuvian Collection of the Royal Mineralogical Museum of Federico II University (Naples, Italy)

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Keywords: Cu-minerals, Somma-Vesuvius, fumarolic minerals.

Arcangelo Scacchi, Director (1844-1892) of the Royal Mineralogical Museum of Naples University (Italy) and famous mineralogist, collected a great variety of copper minerals from the Somma-Vesuvius volcanic complex. In this locality, copper is associated to an active magmatic-hydrothermal system and occurs in different minerals: halides, sulfates, sulfides, silicates, oxides, vanadates and carbonates. For the present study, a set of more than seventy Cu-bearing samples from the Vesuvian Collection of the Royal Mineralogical Museum of Naples has been considered up to now. The first two groups currently under investigation belong to vanadates and silicates; the samples have been investigated by X-ray powder diffraction (XRD), scanning electron microscopy (FESEM-EDS Merlin VP Compact Zeiss coupled with EDS Oxford X-Max 50, and SEM-EDS Jeol JSM 5310 coupled with EDS Oxford Inca x-act). The V-bearing phases are found in the so-called "vesbine" samples, term now discredited that indicated a mix of vanadates, typically occurring as yellow and green-yellow patinas. Our investigation shows that those phases are composed by complex mineral assemblages, mainly consisting of mottramite $PbCu(VO_4)(OH)$ and descloizite $PbZn(VO_4)(OH)$, but with higher amounts of wulfenite $PbMoO_4$ and vanadinite $Pb_5(VO_4)_3Cl$, compared to those recently investigated by Balassone et al. (2019). In these samples, Ba, Zn, Mn and REE-bearing phases have been observed and are still under investigation. The second group of samples under study is represented by litidionite-bearing rocks; this Cu-bearing silicate names a mineral group composed of litidionite *s.s.* $CuKNaSi_4O_{10}$, calcinaksite $CaKNa(Si_4O_{10})\cdot H_2O$, manaksite $MnKNaSi_4O_{10}$ and fenaksite $Fe^{2+}KNa\ Si_4O_{10}$. At Somma-Vesuvius, litidionite was first described by E. Scacchi in deep blue shiny crusts on thermally-modified lapilli of the 1872 eruption. Our investigation allowed to detect very complex mineral assemblages in the litidionite-bearing samples, ranging from litidionite *s.s.* to amorphous materials. Albeit Cu-minerals at Somma-Vesuvius do not possess economic relevance, their study could represent an advance in the understanding on the mineralogical systematics of volcanic copper deposits.

Rare mineral as a window on future critical metal resources in Italy

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Keywords: Rare Earth Elements, critical metals, alkali-syenites, Roman Region.

'Rare' is a relative concept in nature, depending largely upon understanding the geological processes that produce the conditions suitable for mineral deposits' formation. Nowadays, there is a desperate need for new approach in the mining industry and in social and economic impact assessment, related with the green economy that implies substantial environmental respect. Another issue is the politically incorrect distribution of income because of the exploitation of the resources of underdeveloped countries by monopolistic attitude of multinationals. It is now clear that we must overcome these problems with a new sustainable use of resources and that society must accept this revolution, where the role of the geologist must change, respecting human health first. For thirty years, with the discovery of carbonatites, it has been known the robust link between ultra-alkaline mantle magmatism and critical metals deposits' formation. Carbonatites contain up to 50% of the world's reserves of indispensable materials for the ecological transition. However, this potential is underestimated and only a few attempts have been made so far to assess it (Stoppa et al., 2016). What are the main indicators of the presence of economic resources at depth? What are the cut-off and problems in prospecting and exploiting these deposits? The surface distribution of mineralized subvolcanic rocks, the indirect indication through geochemistry of eruptive rocks and a new vision of Italian magmatism and tectonic context, can answer the above questions. A complex variety of REE, Nb, Zr, V-bearing minerals have emerged from ejecta in the Roman Region. We studied silicates (thorite, stillwellite-(Ce), vicanite, hellandite, gadolinite, allanite, zircon), phosphates (monazite, britholite, apatite, brockite), vanadates (wakefieldite), oxides (pyrochlore, baddeleyite), borates (peprossiite-(Ce)), and carbonates (bastnasite). This association reveals the main deposits formation mechanism, related with the migration of highly evolved carbothermal fluids from the carbonatite intrusion, modifying the associated rocks (Guo and Liu, 2019; Stoppa et al., 2019). This complex association leads us to believe that Italy could reach a position like that of other producing countries. This would happen only if the Italian scientific world would consider a change in its interpretation of Italian magmatism, thus attracting the mining industry.

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Investigating subsidence induced by groundwater exploitation in Apulia Tavoliere with the aid of persistent scatterer SAR interferometry

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Keywords: persistent scatterers SAR interferometry, subsidence, ground water depletion.

In the Apulia Tavoliere (south Italy), the growing demand of water for agricultural purpose since the 1950s has caused a costant lowering of aquifer water table (Cotecchia et al., 1958) and thus a potential phenomenon of subsidence. The purpose of this work is to investigate the spatio-temporal evolution of ground deformation phenomena using Sentinel-1 derived Interferometric Synthetic Aperture Radar (InSAR) time-series from both ascending and descending orbits and subsequently implement a groundwater model. From a first analysis on the Persistent scatterers, a subsidence bowl was identified with an extension of 100 square kilometers and with an average value of the lowering speed along the LOS (Line of Sight) of 10 mm / yr. An analysis was carried out on the PS points in ascending and descending orbit to derive the vertical component of the displacement. Comparing the PS data with the geological, hydrogeological cartography and land uses of the territory it was possible to note that the subsidence bowl develops in correspondence with an area characterized by alluvial deposits. In these deposits a superficial aquifer is found from which farmers extract water for irrigation purposes.

Therefore, the analysis that are being carried out concern the acquisition of piezometric data for the definition of the variations of the water table.

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Multiscalar geomorphological mapping of the Kurdistan Region of Iraq: insights on Late Quaternary dynamics and evolution of archaeological landscapes

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Keywords: arid zone geomorphology, fluvial network, geoarchaelogy, Late Quaternary, landscape evolution.

We present a multiscalar approach for geomorphological and Quaternary geology mapping of the Kurdistan Region of Iraq (KRI) aimed at understanding the Late Quaternary evolution of surface processes and their interaction with human agency. In the region, the interplay between tectonic activity of convergence between Arabian and Eurasian Plates and Quaternary climate influenced the evolution of landforms and the rate of geomorphological processes. We performed our mapping using data derived from the combination of remote sensing (recent and historical satellite imagery) and field surveys. At the more general scale, we performed the geomorphological mapping of the NW range of the Zagros, between Tigris and Great Zab Rivers (Forti et al, 2021), and we draw the geomorphological map of the Erbil Plain between Great Zab and Small Zab Rivers. At the meso-scale, we reconstructed the fluvial pattern of the part of the Tigris River that today is submerged under the Mosul Dam Lake. Finally, at the scale of detail we analyzed the evolution and preservation of the archaeological landscape between Tell Helawa and Tell Aliawa (Southern Erbil Plain).

Regional geomorphological mapping highlights that weathering, erosional and depositional processes in the mountain and flat areas are strongly connected to the interplay between neotectonics, litho-structural characteristics of the local bedrock, and Quaternary climatic fluctuations. At the mesoscale, the analyses of declassified CORONA imagery acquired in the 1960ies of the area of the Mosul Lake permitted to reconstruct the pristine pattern of the Tigris River and the seasonal variations of its riverbed and related landforms. At the scale of detail, geomorphological mapping, supported by field observations and remote sensing, of the area between Tell Helawa and Tell Aliawa permitted us to outline the environmental context of the two archaeological sites. The area is characterized by the interplay between large (paleo-)channels whose riverbeds are incised by extant wadis, distal bajada sedimentation from the Khurmala Anticline, and human exploitation of the channel network. Moreover, a more detailed geomorphological and geoarchaeological mapping of the two sites helped to understand how current geomorphological processes influence the preservation of the archaeological record. The correlation between natural and anthropogenic processes is evident looking at the building up and continuous reshaping of a complex landscape.

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Classification of coralline algae using deep learning techniques on SEM images

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Keywords: coralline algae, CNN, deep learning, SEM.

The taxonomy of calcareous red algae continues to undergo revisions, especially since the spread of molecular techniques (Pezzolesi et al., 2019; Caragnano et al., 2021). Genetic analyses challenged the morphological approach to species identification, that relies on thallus organization, morphology of cells and reproductive structures observed with high magnification scanning electron microscopy (SEM), or in thin sections under optical microscope. Recently, a growing attention is also given to the calcified structures and to the shape of the crystallites composing the cell walls, which are diagnostic at the level of family (Auer and Piller, 2020). Looking for new identification tools therefore represents a current challenge, which could have crucial implications in paleontology. Convolutional neural networks (CNN) have successfully been applied for the classification of fish, bivalves, and foraminifera (de Lima et al., 2020). To the best of our knowledge, there is no literature about CNN for species identification using SEM images. We tested the potential of CNN to classify SEM images taken from different species of coralline algae commonly found in Mediterranean waters: *Lithothamnion corallioides* (P. Crouan & H. Crouan) P. Crouan & H. Crouan 1867, *Mesophyllum philippii* (Foslie) Adey 1970 and *Lithophyllum racemus* (Lamarck) Foslie 1901. The model provided promising results in terms of accuracy, considering the small set of images used (~40 per species). SEM acquisition, indeed, has significant costs that limit the number of images available for cross-validation. Further efforts should focus on enhancing the image dataset to improve the CNN classification capability and on the interpretation of the features determining the classes.

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The Phlegrean Fields volcano - seismic monitoring network.

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Keywords: seismic network, the Phlegrean Fields, Pisciarelli.

In this research, the Campi Flegrei seismic network dataset has been studied focusing on the seismic event dated the 12th of March 2018. Seismic data have been processed with the NonLinLoc software. In the general approach, the location of an earthquake is solved by calculating the probability distribution for the space-time coordinates of the hypocenter in a predefined discretized volume. This technique is implemented in the numerical code NonLinLoc (NLL). The NLL localization code follows the probabilistic inversion formulation. Based on this formulation, the knowledge of the parameters of a given model is described through probability density functions. The network, which is run by the Osservatorio Vesuviano on INGV, Napoli (Italy), is composed of 22 seismic stations located all around the Campi Flegrei caldera. The analysis of the seismic sequence shows that in the week between March 6th to March 13th 2018, 42 earthquakes, mainly of low magnitude, were recorded in the Phlegrean Fields area. The strongest one, of Magnitude 2.4, occurred on March 12th 2018 at 14:09 and was Located in the middle of Pisciarelli and Solfatara area at depths between 1.1 and 2.6 km. It is to note that those are the main areas of hydrothermal activity, supporting the strong correlation between seismic activity and gas emissions at Campi Flegrei.

The dark layer at the Messinian Zanclean boundary: a glimpse on the refilling of the Mediterranean at the end of the Messinian salinity crisis

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Keywords: Messinean-Zanclean bundary, dark layer, Zanclean Mediterranean infill, paleoenvironmental evolution.

The Messinian salinity crisis (MSC) was a geological event characterized by the deposition of huge volumes of evaporites in the Mediterranean basin. After decades of scientific debate, the consensus model (CIESM, 2008) proposed a new stratigraphic framework, and the MSC was subdivided in three stages (Manzi et al., 2013; Roveri et al., 2014). Stage 3 started at around 5.53 Ma, and its uppermost part corresponds to the "Lago-Mare" phase (LM), characterized by the occurrence of brackish shallow water ostracods of Parathetyan origin. These deposits are sharply overlain by Zanclean open marine fine-grained sediments recording the establishment of open marine condition at the end of the MSC at 5.33 Ma. The interpretation of such abrupt transition is debated: it could be a catastrophic reflooding of the Mediterranean according to some authors or a gradual refilling of the basin according to others. In many Mediterranean sections, the Messinian-Zanclean boundary is marked by a poorly investigated dark layer (DL), that can provide insights on the mechanism responsible for the refilling of the Mediterranean at the end of the MSC. We investigated DL in six sections along a W to E transect of the Apenninic foredeep trough an integrated micropaleontological, petrographic and ichnological approach.

Preliminary results show that, although the texture, structure, and lithological composition of the DL change from section to section, this is always interbedded between the uppermost Lago Mare and the basal Zanclean sediments through a sharp and conformable boundary, arguing against a catastrophic refilling of the Mediterranean. Moreover, the DL is strongly bioturbated, with crypto and large burrows filled with Pliocene basal mud (*Reticulofenesta zancleana*), which suggests starved condition at early Zanclean. Finally, the preliminary results on the association of benthic foraminifera and on the P/B ratio, indicate a gradual increase in bottom oxygen content and in depth from the top of the DL to the lowermost Pliocene.

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A multi-temporal landslide mapping approach in clay-rich terrain of the Northern Apennines

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Keywords: landslides, multi-temporal landslide mapping, recurring activity, source-to-sink pathways.

In the Northern Apennines, clay-rich lithologies are affected by widespread and recurring earth flows and earth slides, which in these settings are the dominant processes of sediment transfer. Landslides are important in terms of landscape evolution and sediment management, but often they cause also hazard and risk to lives and infrastructures.

In the Emilia-Romagna (E-R), the regional Geological Survey has compiled and has been managing a region-wide landslide inventory. The degree of completeness of the E-R inventory is unknown and the way it is updated, without a systematic multi-temporal approach, does not provide information about landslide occurrence and recurrences.

To address this shortcoming, the existing E-R inventory was compared and integrated with a systematic high-resolution multi-temporal landslide mapping approach, focus on four selected sites of the Sillaro River basin (139 km^2). In detail, this work aims to explore the advantages of multi-temporal landslide mapping, with specific reference to landslide geometry, activity, and landslide sediment transfer.

The multi-temporal landslide mapping was performed through visual interpretation of thirteen sequential aerial photo sets from 1954 to 2020, combined with fieldwork. For each landslide, the following attributes were recorded: (i) photo year of occurrence, (ii) landslide type, (iii) morphologic position at initiation, (iv) lateral confinement, and (v) sediment delivery target at landslide terminus. For recurring landslides, was also detected: (i) headscarp upslope migration or revegetation, (ii) temporal pattern of revegetation and/or the development of gully channel incision on landslide depositional features, and (iii) downslope stream channel changes.

Results show that the multi-temporal mapping can enhance the degree of completeness of the existing inventory (e.g., detection of previously undetected landslides), (ii) reduce mapping uncertainties on existing polygons, (iii) improve estimation of landslide area, (iii) provide information on landslide occurrences and recurrences, and (iv) identify sites of sediment production and delivery, and consequently the sediment transfer pathways. In addition, this mapping approach allows to define most likely scenarios of evolution at the site scale.

This work, as part of the projects BEDFLOW and BEFLOW PLUS, is partially funded by Fondazione Cassa di Risparmio in Bologna.

Completing the eruptive record of Deception Island (South Shetland Islands, Antarctica) by describing the ash layers located in proximal marine sediment cores

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Keywords: volcanic ash, marine core, Deception Island.

Deception Island, located in central Bransfield strait (South Shetland Islands, Antarctica), is a horseshoe-shaped composite volcano, whose central part is occupied by a collapse caldera (8.5 x 10 km). It is considered to be among the most active volcanoes in Antarctica where a future eruption is very likely to happen, affecting the military and scientific research stations located nearby. The characterisation of volcanic ash layers found in marine sediment cores outside Deception Island can provide valuable information to: (i) determine the size and explosiveness of past eruptive events, (ii) assess the extent of their related hazards; and (iii) complete the eruption record of the island. Here, we present results of the characterization of the ash layers found on five marine sediment cores (TG-40, 41, 43, 48 and 50) drilled proximal to Deception Island (less than 40 km) during the Antarctic Campaign of the MAGIA project (ANT-584/97). The final aim is to trace isochronous tephra horizons between the studied cores and try associating them to their respective eruptive events on the island. First, we carried out a granulometry analysis of each sampled layer and quantified the morphology of the fragments. Results obtained indicate that most of the layers are moderate to well sorted coarse ash. Minor amounts of lapilli and fine ash appear in the shallower (0 to 50 cm depth) layers. The granulometry and the morphology indicate that the layers have been reworked by turbiditic currents after the eruption, but not enough to destroy the information necessary for correlation. The petrographical study via optical microscope has highlighted the presence of three different types of volcanic glasses based on: (i) the colour of the ash particles under non-crossed polarized light; (ii) microcrystal content; (iii) texture; and (iv) vesicle abundance. Type 1 glasses, with black colour and generally shard shaped, show a low content in microcrystals and vesicles. Type 2, with brown colour and more spherical shapes, have a higher content in microcrystals and the fragments usually have a fluidal texture; the vesicle abundance is variable. Type 3, with yellow colour and variably shaped, are usually rich in microcrystals and vesicles, and have fluidal texture. In all families, the mineralogy of the microcrystals is mainly plagioclase (90%), pyroxene and olivine. The longest core (TG-48, 120 cm long) contains 15 layers, the deepest ones (113, 115 and 120 cm depth) may be correlated to the ones found in previous studies associated with a period of abundant volcanic activity around 2000 years BP.

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Volcano-tectonics analysis of the active faults affecting eastern slope of the Mt. Etna: the case study of "Ripe della Naca" fault system

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Keywords: Mount Etna, volcano-tectonics, fault system, flank dynamics, geophysical data .

The eastern part of the Etna volcanic complex is affected by the presence of several active fault systems (Monaco, 1997; Monaco et al., 2010), which generate tectonic instability, strictly connected to the regional stress fields, acting on a larger scale (Ellis & King, 1991; Lo Giudice & Rasà, 1992; Gvirtzman & Nur, 1999; Doglioni et al., 2001). In this work, we focus on the secondary the Ripe della Naca fault system (RNF), located on the North-eastern sector of Mount Etna, oriented about NE-SW. Although this sector is characterized by weak seismic activity (Hirn et al., 1997), i it has been affected by a historical eruptive event, dated 1928. While studies related to the eruptive event have already been carried out (Branca et al., 2017), to date there are no works that focus directly on the Ripe della Naca fault system.

By analysing structural-geology, tectonic, and rock-physics data, as well as geodetic and seismic information, this work aims to verify the volcano-tectonic behaviour of the RNF. The crustal, geological cross section allowed us to compute the tensional state on the fault plain at three different depths (1 km, 2 km, 3.2 km) (Griffith, 1990; Labuz & Zang, 2012). The Geodynamics & GeoMatic Laboratory Working Group provided ground velocity field and displacement monitored by discrete geodetic network (UNICT-Net), quantifying the aseismic deformation along the RNF system during the 2018 December unrest period.

This information provides new knowledge to understanding the volcano tectonics processes. This all with a view of being able to make reliable forecasts as to the likely course of events or scenarios during unrest periods of Etna volcano.

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UAV-UGV imagery for natural disaster scenario mapping

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Keywords: UAV, UGV, photogrammetry, disaster response, emergency mapping.

In the last decade, UAVs (Unmanned Aerial Vehicles) have been used for several applications, overcoming several limitations of the traditional methods and providing High-Resolution data, also in dangerous environments. This makes these platforms them suitable for emergency response in hazardous scenarios. This study is focused on integrating data collected by an aerial and terrestrial unmanned system. In fact, coupled with aerial vehicles, UGVs (Unmanned Ground Vehicles) provide ground-based data capable of detecting those elements which are incomplete or not visible using UAVs, such as facades, complicated structures, interiors.

Within a joint industrial PhD research project, a low-cost UAV-UGV system has been developed and employed in the photogrammetric survey of a disaster scenario in Pomarico (MT). The aim is to remotely perform low-cost mobile photogrammetric surveys in emergency, mapping natural and anthropogenic elements in areas affected by paroxysmal events such as landslides, earthquakes or floods, without exposing crew members to danger.

The developed system consists of a UAV and a UGV robotic platform, equipped with RGB and IRT sensors, and a ground station. The system has been tested in different environments and employed in a case study. The study area is located in the municipality of Pomarico, where a landslide occurred in January 2019, affecting the sandy clayey deposits of the western part of the hill, causing the collapse of a road and destroying or damaging several buildings.

UAVs have been used to obtain the traditional photogrammetry products, while the UGV has been used to perform mobile terrestrial photogrammetry and thermography, focusing on vertical and sub-vertical surfaces. Datasets were processed using the SfM-MVS technique and open source software, resulting in photogrammetric products which have been employed in GIS environment to carry out a spatial analysis. Dense clouds have been aligned and merged to obtain a multi-scale model, while the IRT survey resulted in the 3D thermal model of the buildings.

Contour lines were extracted, the updated topographic profile of the slope was reconstructed and it was possible to compute the total surface of the landslide (34000 m^2) and its perimeter (1.8 km). The change detection analysis carried out using DTMs allowed the computation of the total volume of collapsed sediment (about 165000 m^3) and the estimation of the volume of debris resulting from the collapse of the buildings and the road (about 25000 m^3). Photogrammetric products obtained from UGV surveys, have been compared with reference models, obtained with terrestrial stationary photogrammetry survey, in order to assess their accuracy, obtaining an average accuracy of 5 cm.

The developed methodology, based on remote mobile photogrammetry, represents a low-cost solution for safe disaster scenario mapping activities, providing consistent products which can be used for damage assessment or employed for spatial analyses.

The southernmost occurrence of the volcanic-rich layer of 5.5 Ma in the Northern Apennines: clues on its deposition

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Keywords: tephra, density current, XRPD, EPMA, SEM.

A 5.5 Ma aged volcanic-rich horizon crops along the Northern Apennines chain for about 200 km, in the post-evaporitic sedimentary sequence. Its thickness ranges between 30-200 cm and has been interpreted either as a primary fallout or a giant gravity flow in seawater (Trua et al., 2010). Here, we focus on the two southernmost occurrences in Abruzzo (Italy): Castiglione a' Casauria (CAC) and San Vittorino (SVT) villages.

The SVT and CAC deposits are lithified and 80 and 220 cm thick, respectively, mildly fractured and greyish to light brown. Four (SVT) and fifteen (CAC) coaxial to the field samples, were cut and polished to expose a plenty range of their vertical mesoscopic surfaces. The oriented thin sections and powders were prepared according to mesoscopic features.

The XRPD (X-ray powder diffraction) spectra show the presence of a peculiar bulge reflecting significative silicate non-crystalline phase, i.e. volcanic glass, plus faint Bragg reflections indicative of minor amounts of quartz, two feldspars (anorthite and sanidine), clinopyroxene, biotite and montmorillonite. The latter mineral results from post-emplacement and secondary crystallization. In addition, calcite and dolomite XRPD peaks occur with intensity inversely proportional to that of the bulge, reflecting the abundance or paucity of sedimentary *versus* volcanic fractions in sub-layers.

The microscopic 2D textures plus compositional features were investigated by SEM and EPMA. Both layers are very rich in fine-grained (largest particles averaging on 200 μm) and highly sorted glass shards, while minerals are < 5 area% in agreement with XRPD outcomes. Lithified ashes are mainly blocky shaped and un-broken. The ashes plot in the rhyolitic TAS field overlapping those relating to other Northern Apennine sites. The amount of volatiles ($H_2O + CO_2$) from EPMA average on 6 wt.%, in agreement with the amount of LOI determined on both bulk samples.

Field observations and analysis on mesoscopic polished rock slices and thin sections do not show any significant vertical size gradation and sorting, or fossils content. By contrast, both volcanic-rich deposits show: sedimentary- and volcanic-rich sub-layers, cm-sized volcanic clasts dispersed prevalently on the uppermost sedimentary sub-layers, cm-sized convolute laminations and slumped pseudo-beds. All these features demonstrate mass transport, soft-sediment deformation and fluid escape in seawater. The absence of rounded shards, lithic sedimentary rocks and classic Bouma sequence features (as in adjacent deposits) mirrors for local remobilization of poorly consolidated to loose carbonate and tephra material. In parallel, the high sorting of fine ashy clasts suggests a distal fall primary deposition. The location and features of both SVT and CAC volcanic-rich layers extend the previously inferred distribution of this ancient volcanic eruption.

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F/OH ratio in a rare fluorine-poor blue topaz from Padre Paraíso (Minas Gerais, Brazil) to unravel topaz's ambient of formation

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Keywords: topaz, gemology, mineralogy, petrology.

Topaz is one of the principal fluorine-bearing silicates that occurs as an accessory mineral in fluorine-rich silicate rocks (rhyolites and granites) associated with pneumatolytic/hydrothermal events, and in ultrahigh-pressure rocks (Wunder et al., 1993; Alberico et al., 2003; Zhang et al., 2011). Its composition ranges from a nearly OH-free end member, $Al_2SiO_4F_2$, in acid igneous rocks, to $Al_2SiO_4F_{1.4}(OH)_{0.6}$, with XOH = OH/(OH+F) = 0.30, in hydrothermal deposits (Barton 1982). Higher OH content was reported for topaz found in ultrahigh-pressure (UHP) -rich topaz-kyanite quartzites from Hushan (west of Dongai), (XOH=0.35), and southern Sulu (XOH = 0.40-0.55), eastern China. In this work we fully characterized blue topaz from Padre Paraíso (Minas Gerais, Brazil) by means of in situ synchrotron X-Ray and neutron powder diffraction measurements (temperature range 298-1273 K) combined with EDS microanalyses. The fluorine content estimated from neutron diffraction data is ~1.03 a.f.u (10.34 wt%), in agreement with the chemical data (on average 10.0 wt%). The XOH [OH/(OH+F)] (0.484) is close to the maximum XOH value (0.5), and represents the OH-richest topaz composition so far analysed in the Minas Gerais district. After reaching 1010 K, it is possible to notice a sudden change in the trend underlying structural modifications induced by the defluorinization. At 1170K the main diffraction peaks associated with the topaz phase declined fairly rapidly with continued heating, indicating a rapid decomposition of the sample. A second phase appeared to grow at the same rate as the peak from the previous phase declined thus revealing the formation of mullite $Al_{4+2x}Si_{2-2x}O_{10-x}$. On the basis of this behaviour, it is possible to interfere that this temperature may represent the potential initial topaz's crystallization temperature from supercritical fluids in a pegmatite system. The $\log(fH_2O/fHF)$fluid (1.27 (0.06)) is coherent with the fluorine activity calculated for hydrothermal fluids (pegmatitic stage) in equilibrium with the forming mineral ($\log(fH_2O/fHF)$fluid = 1.2-6.5) and clearly different from pure magmatic (granitic) residual melts [$\log(fH_2O/fHF)$fluid = <1]. The modelled H_2O saturated fluids with the F content not exceeding 1 wt% may represent an anomalous water-dominant/fluorine-poor pegmatite lens of the Padre Paraíso Pegmatite Field.

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Efficiency of fractured networks for CO_2 storage

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Keywords: Discrete Fracture Networks, fluid flow, CO_2 storage.

In the field of the mitigation action to a low-carbon energetic system, the CCS (Carbon Capture and Storage) technology can give a great contribution, quantified around the 14% of the total emissions IEA, 2004; IPCC, 2005). Many oil, gas, geothermal and water supply reservoirs form in fractured rocks, therefore are considered a great resource also in the field of storage. Fracture networks exist at a wide range of scale in the earth crust and strongly influence the hydraulic behaviour of rocks, providing either pathways or barriers for fluid flow (Odling et al., 1999; Nelson, 2001).

The main challenge is the development of numerical models that describe adequately the fracture networks and the constitutive equations governing the physical processes in fractured reservoir (Agosta et al., 2010; Watkins et al., 2018).

The hydraulic properties of fracture networks, derived from Discrete Fracture Network (DFN), models are commonly used to populate continuum equivalent models at reservoir scale, to reduce the computational cost and the numerical complexity. However, the efficiency of fracture networks to fluid flow is strongly tied to their connectivity and spatial distribution, that continuum models are not able to capture explicitly.

In this work through field data and synthetic models we want to introduce a new method to evaluate the efficiency of fracture networks to fluid flow, reflecting a range of variability in fracture network characteristics (e.g. fracture intensity, number of fractures, stress field). The simulation of fluid circulation is performed on the synthetic DFN models, measuring the behaviour of fracture network with respect to the total amount of injected / flowed gas through the model. This allows to obtain different efficiency factors for several values of fracture intensity that can be applied to outcrop or aquifer scale volumes to infer their storage potential.

This alternative method allows to model fractured systems at reservoir scale, in a variety of geological settings, using exclusively a DFN approach.

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Geomorphology as a key factor influencing pedogenesis in high mountain soils

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Keywords: geomorphological processes, geopedological analyses, mountain environments, Buscagna Valley.

By its classical definition, soil is an independent natural body with a proper morphology, which derives from a combination of factors: climate, organisms, topography, parent material, and time (Jenny, 1941). In high mountain environments, geomorphological dynamic is a key factor to the development of soils (Bollati et al., 2019), and influences the soil formation interacting with climate, vegetation cover and lithology.

The main aim of this work is to assess the influence of geomorphology on pedogenesis in the Buscagna Stream hydrographic basin (Veglia-Devero Natural Park, Lepontine Alps) and to pursuit a more detailed geopedological characterization of the area, increasing the already published data by Masseroli et al. (2020). Field and laboratory characterizations were performed on 5 soil profiles selected in different morphological contexts, on the two valley slopes.

The preliminary results confirm the influence on soil development of the geomorphic dynamics dissimilarities between the valley slopes, reflecting their lithological diversity (calcschists on the SE slope versus ortogneiss, micaschists and spots of ultramafic rocks on the NW slope), as previously found. On the SE side, characterized by gentle slopes, soils show a good degree of development, testified by the presence of an incipit of the podsolization processes. Whereas, on the NW slope, where the lithology poses by its nature a higher relief energy, the soil profiles are less developed and have recorded the action of gravity, water and snow that have contributed to landscape evolution in term of sediment, erosion and deposition. The presence of two soil units in the profile located in an abandoned branch of the Buscagna riverbed possibly mirrors the past fluvio-glacial geomorphic dynamic that affected the study area, testifying different degradation/aggradation phases.

Overall, the present study contributes to demonstrate the deep influence of geomorphology on soil evolution in high mountain environments. Moreover, the results underline how soil investigation manages to reveal past geomorphic dynamics not always preserved as landmark evidence. In this light, this work is consistent with Masseroli et al. (2020) in emphasizing the role of soil as archive and its usefulness in reconstructing landscape evolution.

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Suldenferner (Vedretta di Solda Italy)

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Keywords: lateral moraines, debris-covered glaciers, clast shape, glacier fluctuations, sedimentology.

Lateral moraines are key features of glacial landscapes in high-alpine mountain areas (Lukas et al., 2012). Research on lateral moraine formation is mostly limited to clean-ice glaciers; lateral moraine formation at the margins of debris-covered glaciers is currently poorly understood in an Alpine and sedimentological context (Kellerer-Pirklbauer et al., 2008). This research focuses on the reconstruction of processes of lateral moraine formation at the debris-covered glacier Suldenferner (Vedretta di Solda, NE Italy).

The studied lateral moraines at Suldenferner glacier reach heights between 110 and 130 m above their bases and are up to 3 km wide. The eastern lateral moraine is characterised by a pronounced cross-profile asymmetry, with gentle distal slopes (14°-30°) and steeper proximal slopes (40°-60°), while the planform of the western lateral moraine is only slightly asymmetrical (50°-60°). Clasts within the western lateral moraine are exclusively dolomite, while the clasts within the eastern lateral moraine contain mainly micaschist with minor contributions of paragneiss.Sediments within the lateral moraines are divided into three lithofacies associations: lithofacies association 1 (LFA 1) is a silty-sandy, matrix-supported diamicton (DgMm3-2), lithofacies association 2 (LFA 2) comprises a clayey- silty, massive diamicton (DgFm2-2) and a clayey-silty, matrix-supported diamicton (DhMm3-2) and lithofacies association 3 (LFA 3) is a sandy-gravelly, clast-rich diamicton (DmCm1-1, DmCm2-1). These lithofacies associations are interpreted as reworked, glaciofluvial deposits (LFA 1), subaerial debris flows that have been stacked in an ice- marginal position (LFA 2) and debris flows that have incorporated distinctive amounts of micaschist (LFA 3). Clast shape analysis reveals that the sediment delivery towards the lateral moraines contains a signal of mixed sources: within the western lateral moraine, the main mode of clast transport consists of subglacial and englacial sources (active transport). Contrarily, the main mode of clast transport within the eastern lateral moraine is exclusively dominated by supraglacial sources (passive transport). The presented conceptual model for high-alpine, lateral moraine formation implies that lateral moraines have a complex formation history (multiple glacial advance and retreat cycles).

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Analysis of earthquake swarms fluid induced in Northern Main Ethiopian Rift - Fentale-Dofan magmatic segment

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Keywords: earthquake swarms, relocalization, b-value, frequency analysis, hydrothermal, fluid induced.

The aim of the study is to understand the link between rift valley faulting and fluid flow, by investigating the spatial, temporal and waveform characteristics of local seismicity from the northern sector of the Main Ethiopian Rift (MER), and also mapped out surficial hydrothermal alteration.

The seismic database contains the events that occurred from October 2001 to January 2003 acquired by the EAGLE Project. The earthquakes have been relocated with NLLoc using a new 3D velocity model. The seismicity is mainly concentrated in two areas: near the Ankober border fault and within the rift in the Fentale-Dofan magmatic segment. On the border fault, events mostly occur down to 20 km depth, with an average depth of ~ 12 km. Within the rift, the events mostly happen down to 15 km depth, with an average depth of ~ 9 km. The seismicity is divided into several clusters aligned parallel to the rift direction, and in cross-section the clusters are mostly dipping steeply. The analysis of the temporal-spatial distribution of earthquakes shows that some of the clusters are strongly concentrated in time and in space, and therefore swarm-like B values were calculated for the identified clusters using the Maximum Likelihood method, with results showing B values of higher than 1. We have conducted a waveform cross correlation on waveforms cut 10 seconds before and 60 seconds after P waves arrivals in order to individuate similar events and group similar earthquakes into families. Most of the earthquake clusters are composed of several swarms within which earthquakes are highly correlated, but with different swarms not correlating well with each other. Finally, the cross-correlated P arrivals were used in a new relocation with the HypoDD double-differencing software. We interpret the spatial-temporal characteristics of the earthquake swarms as most likely induced by deep (mid-crustal) flow.

After to seismic analysis we have focused in an area ~50 km-wide and 40 km-long of the Fentale-Dofan magmatic segment, and with a remote sensing technique have mapped the surface hydrothermal alternations. The hydrothermal mapping was performed with a lithologic surface classification on Landsat data. The hydrothermal deposits mapped by us are mainly focused in two areas: on the western side of Dofan volcanic complex, in an area intense faulted by NNE-SSW faults; and around the Fentale volcano with a circular pattern on southern side of volcanic edifice. We conclude that the elements that mainly influence the hydrothermal pattern are the faults pattern, areas mainly faulted and fractured encourage the hydrothermal circulation; the lithologies, with their fracturing capacity and porosity; and the contact between volcanic and sedimentary rocks.

When combined, the surface distribution of hydrothermal alteration does not particularly correlate with the seismicity. This may suggest that shallow hydrothermal circulation is likely an independent system to deeper crustal fluid flow.

Deep-sourced fluids released in central-western Europe: new evidences of active degassing in Serbia region

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Keywords: helium, degassing, carbon dioxide, geodynamic, Serbia.

Identification of transfer of mantle-derived fluids (e.g. CO_2, N_2, noble gases) in continental regions is critical for developing exploration strategies of natural resources (i.e., hydrocarbons, ore deposits, heat sources) and also to investigate the processes that control the deep and shallow evolution of Earth such as subduction, volcanism, natural degassing vs. active tectonic and earthquakes (e.g., O'Nions & Oxburgh, 1988; Caracausi et al., 2013; Labidi et al., 2020). Recently the outgassing of deep-mantle volatiles has been verified in different crustal segments of central-western Europe, but the geological and tectonic controls on migration of these deep fluids remain to be fully understood. To figure out the source of these volatiles can furnish new elements to the understanding of the complex regional geodynamic evolution and for the exploitation of natural resources. Furthermore, that region is also characterized by an high heat flow (< 150 mW/m^2) that highlights an high geothermal energy potential that is coupled to seismicity trough the overall crust (Horwarth et al., 2015). Here, we report on the results of an extensive geochemical survey of gas manifestations in the Serbian part of the Vardar zone, a mega-suture zone between Eurasia and Africa plates. Based on their chemical compositions (C, He, Ne, Ar), the studied gases are clustered into three distinct groups (CO_2-, N_2- and CH_4-dominated). The He isotope ratios identify a weak (<20 %) but persistent regional mantle-derived component, with the lowest $^3He/^4He$ values reflecting radiogenic He production from nearby granitoid intrusions. The combined analysis of He, C(CO_2) abundances and isotopic composition demonstrates which there are two main processes that control the chemistry of the outgassing volatiles:1) mixing between crustal and mantle-derived volatiles and 2) the partial dissolution of volatiles in groundwater. Finally, we estimate the mantle He flux at 9.0 x 10^9 atoms $m^{-2}\ s^{-1}$, or up to 2 orders of magnitude higher than the typical fluxes in stable continental areas, suggesting a tectonic control of fluid migration through the crust.

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Composite magmatic evolution in Eastern Adamello plutons

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Keywords: Southern Alps, Eocene magmatism, Adamello batholith, crustal anatexis, Alpine geology.

Large felsic plutons often display mafic satellite bodies, apophyses and small-sized enclaves. Such bimodal associations may infer either variations in the magma source or compositionally distinct magma pulses owing to the involvement of various sources and complex magmatic processes. Geochemical and petrological data and observations are good implements to constrain the pluton evolution and the involved magmatic processes. Understanding how these processes act in large reservoirs allow to reconstruct the mechanisms of pluton formation and growth. A full comprehension and interpretation of these magmatic processes may also lead to the identification of the mantle and/or crustal materials that played a role in the formation of granitoids. In this frame, modern techniques like phase equilibria modelling are very useful tools to detect the nature of possible crustal contaminants. The Adamello batholtih is the largest Tertiary pluton of the Alps, and is mainly formed by granitoids. Nonetheless, Adamello comprises different units showing mafic - felsic associations; Corno Alto and Monte Ospedale are among them (Bianchi et al., 1970). Corno Alto is a bowl-shaped felsic pluton made up of trondhjemites with minor tonalites and granodiorites. It also includes dioritic enclaves and mafic to felsic dykes (Zattin, 1995). The nearby Monte Ospedale complex exhibits a bimodal mafic - felsic association comprising diorites, tonalites and granites that crop out over a narrow area (Tornielli, 1995). This geochemical heterogeneity reflects a composite magmatic evolution with multiple components contributing to the differentiation of a mantle-derived picritic melt (Ulmer, 1988). During its evolution, this melt is contaminated by either injections of new picritic melt and assimilation of lower crustal melts producing different magma batches. Different mixtures of these components generate chemically heterogeneous batches (Relvini, 2021). Injections of picritic melts from the mantle often remobilize the dwelling batches, thus promting their upward migration. Differentiation proceeds at shallower depths causing the crystallization of felsic rocks.

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Refining the Holocene eruptive activity at Tenerife (Canary Islands): The contribution of paleomagnetism

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Keywords: paleomagnetic dating, ^{14}C, Holocene, Tenerife.

The timing of Holocene volcanic activity of Tenerife (Canary Islands) is poorly constrained and despite the Teide-Pico Viejo (TVC) volcanic complex, which represents the last volcanic phase of the island, having been very intense, is still insufficiently investigated. Most of the recent eruptions are dated only by a single radiometric dating, or the ages are simply stratigraphically determined. We apply paleomagnetism, increasingly used in recent years, to date Holocene volcanism, to improve the knowledge of the recent volcanic history of Tenerife. We report on the paleomagnetic dating of nine mainly effusive Holocene eruptions, chosen based on volumes, length and width of involved sectors. We compare our results with those previously obtained by ^{14}C method, when available. Four of the studied eruptions were previously dated by ^{14}C, four only stratigraphically constrained, and one was never dated so far. Concerning the first group, for two eruptions the paleomagnetic and ^{14}C ages agree, while for the others we obtained older or younger ages than the previous data. Ages characterized by short incertitude age ranges (35 - 545 yrs) were found within the second group. Finally, we provided the first age (789-723 BC) of the Mña Grande eruption. We conclude that paleomagnetism can be considered an excellent complement to the ^{14}C dating method, because it is applicable on rocks with nearly all compositions and provides higher resolution dating, at least where reliable geomagnetic reference curves are available. The improved framework of the Holocene volcanic activity of Tenerife shows alternating periods with low and high eruptive frequencies, with the last 3 ka characterized by high eruptive frequency and dominated by basaltic eruptions. Furthermore, the Mña Grande eruption, which occurred near the historic eruption of Arafo (1705 AD) requires a re-assessment of the volcanic hazard, especially along the east coast of Tenerife, which is not currently considered a probable location for future vents opening.

Magnetic signatures of fluid-rock interaction in shear zones: an example from the Northern Apennines (Italy)

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Keywords: rock magnetism, fluid-rock interaction, fault rocks.

Fluid-rock interaction along intraplate shear zones strongly influences the mechanisms of deformation during the seismic cycle. The circulation of hot fluids during the co-seismic phase commonly triggers thermochemical transformations in a fault zone, producing potential changes of the magnetic properties. The thermal anomalies associated with seismic slip events may induce thermal decomposition or dehydration of certain phases, promoting the generation of newly formed ferromagnetic minerals. Thus, magnetic minerals are suitable indicators of the fluid migration path and changes in the physicochemical conditions within a shear zone.

Here, we are presenting preliminary results from a magnetic investigation of the wall rocks of an exhumed analogue of actual intraplate shear zones, cropping out in the Northern Apennines, Italy. Geochemical signatures of tectonic veins suggested cyclical variations in permeability and fluid sources during the seismic cycle.

Our findings reveal changes in magnetic properties depending on the distance from the basal décollement. Temperature dependent remanence experiments show the occurrence of goethite and magnetite assemblages with variable relative abundance, following characteristic trends with increasing distance from the main thrust. Variations might be related to spatial and temporal changes of the physiochemical conditions induced by the migration of hot fluids along the main faults during the co-seismic phase. Heating laboratory experiments at specific increasing temperatures revealed significative thermal generation of newly formed magnetic phases above 350 °C. The detected heating signature of the thrust wall-rocks may constraints the thermochemical reactions occurred within the fault zones.

We suggest that changes in thermomagnetic properties might provide insights into the complex fluid related processes (alteration, leaching and neoformation of minerals) during seismic cycles and then improving our understanding of the geodynamic evolution of intraplate shear zones.

High-resolution electrical resistivity and induced polarization tomography for mapping saline water intrusion in coastal aquifer: a case study from the Pontina Plain (Lazio, Italy)

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Keywords: coastal aquifer, salinization, Electrical Resistivity Tomography, Induced Polarization, model appraisal.

During the last decades, saltwater intrusion into the coastal aquifer has been recognized as a major issue for groundwater management, as a result of human activities and climate change. However, currently in Europe and particularly in Italy, only a limited number of maps are available for areas subjected to salinization, even though it is well-known that large parts of the coastal territory have been damaged due to salinization.

In this study, we demonstrate that the combined use of Electrical Resistivity Tomography (ERT) and Induced Polarization (IP) techniques can be an effective and non-invasive method to mapping areas prone to salinization at the Pontina Plain (Fogliano Lake). The near surface geological setting is dominated by sandy deposits, which host different silt/clay content for thin layers at different depths and distance from the sea throughout the Plain. Five ERT/IP lines were executed normally to the seashore, with 48 electrodes spaced 5 m apart and a multiple gradient array. Resistivity ρ and chargeability η models are then obtained through an inversion procedure using the linear approximation of Oldenburg & Li (1994), as implemented in the VEMI algorithm (De Donno & Cardarelli, 2017).

The resistivity and normalized chargeability (MN=ρ/η) models provide complementary information about both the lithostratigraphy and the geometry of the salt wedge front at the study site. In fact, resistivity is a straightforward proxy of the saline intrusion since in coastal saltwater aquifer it is lower than 10 Ωm. On the other hand, the additional contribution given by the normalized chargeability helps us to overcome interpretative ambiguities that can arise for complex lithology. Given the high polarization response of clay minerals, this parameter allows us to distinguish surface conductivity phenomena related to clayey fraction from those due to the presence of high salt content.

The model appraisal (resolution and depth of investigation indices) gives a further contribution for better delineating the geological formations and delimitating the salt-water intrusion inland. The combination of depth of investigation and resolution indices allows to go beyond the first approximation models and provides a quantitative assessment of the model quality.

Therefore, the combined use of the geophysical techniques supported by the resolution indices can be an effective tool for mapping the vulnerability of groundwater, preventing the salinization process and planning a sustainable use of the groundwater resources.

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Integrating exploratory AMS data with field and microstructural investigations in late Variscan granitoids emplaced at upper crustal levels (Serre Batholith, southern Italy)

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Keywords: granites, anisotropy of magnetic susceptibility, microstructures, post-collisional magmatism, Calabria.

The Serre Batholith, in central Calabria (southern Italy), makes up the intermediate portion of an almost continuous and complete late Variscan crustal section. At its upper crustal levels, the batholith is composed by two-mica granodiorites and granites (BMG; c. 295 Ma) passing upwards to biotite ± amphibole weakly peraluminous granodiorites (BAG; c. 292 Ma), whose mutual relationships and emplacement mechanisms are still debated. Field relationships between these rocks are not easy to define and no intrusive contact has been observed in the studied areas. Microstructural investigations revealed a wide range of deformation microstructures developed during cooling of the two granitoid rock units. Chessboard pattern in quartz crystals documents submagmatic deformation conditions at T> 650 ° (Guillope & Poirier, 1979). Grain boundary migration recrystallisation in feldspars indicates high-temperature deformation < c. 600°C, while deformation twins developed at T of 400-500 °C (Passchier & Trouw, 2005). Finally, bulging recrystallisation of quartz crystals, kinked biotite and mica fish are indicative of temperature below 400 °C. No specific relationships between emplacement depth, age or composition and the type of deformation microstructures developed in the rocks have been found from the comparison between BAG and BMG. Preliminary anisotropy of magnetic susceptibility (AMS) data reveal an internal magnetic fabric for the studied granitoids, represented by a prevailing slightly oblate magnetic ellipsoid. The comparison between BAG and BMG magnetic stereograms suggests a similar influence of the local stress field, while magnetic foliations and lineations arrays provide hints about post emplacement tectonics or, alternatively, they could depict the peripheral architecture of the batholith roof levels. This study sheds new light on the Serre upper crustal granitoids and emphasizes the importance of AMS in obtaining constraints on the relationship between tectonics and magma emplacement from apparently isotropic rocks.

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Rheological investigations of volcaniclastic debris flows

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Keywords: rheology, debris flows, FT4, volcanoclastic, Campanian Plain.

Volcaniclastic debris flows occur when a mixture of loose pyroclastic fallout and current deposits and water flow down slopes, very commonly after intense and/or prolonged rainfall (Sulpizio et al., 2006). These phenomena represent a short and long-term hazard in all the circumvolcanic areas and this is the case of the area surrounding the Somma-Vesuvius and the Phlegrean Fields volcanoes in the Campania region. Here the slopes of the volcanic edifices and the Apennine reliefs are mantled by loose pyroclastic fallout and current deposits that can be easily remobilized (Pareschi et al., 2002; Zanchetta et al., 2004; Bisson et al., 2013; Sulpizio et al., 2006, Di Vito et al., 2019).

In the last five years, more than 500 sites among archaeological excavations, stratigraphic trenches, drill cores and outcrops have been reviewed and analysed, paying particular attention to the debris flow deposits related to the sub-Plinian AD 472 eruption of Somma-Vesuvius. Several samples have been collected and analysed to characterize their grain size distribution.

The aim of this work is to combine field studies and experiments since few studies on the rheology of debris flows have been carried out, and very few using volcanic materials, that display a wide range of components, grain size, density and shape. The FT4 powder rheometer developed by Freeman Technology Ltd has been used on several samples with the diameter of the particles less than or equal to 0.710 mm.

Shear tests, compressibility tests and wall friction tests have been performed to obtain physical parameters that can be useful in numerical simulations, such as the angle of internal friction and the flow function coefficient.

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Laboratory test results of a new developed low-cost and open-source inclinometer based on MEMS technology

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Keywords: inclinometer, Arduino®, inclination monitoring, landslides, continuous monitoring.

The stationary or in-place inclinometers are the main high-performance solutions in landslide monitoring applications. Despite their capability and the general need of data for understanding landslide behavior, the high cost of these instrumentations, in most cases, limit or prevent their use. On this basis, we started developing a low-cost and open source, modular MEMS-based inclinometer that uses multiple Arduino boards as processing units. Although MEMS accelerometers have many advantages in comparison with traditional high-precision electromechanical sensors, they are very sensible to temperature variation.

In order to compensating the thermal drifting, we using a specific thermal analysis and an associated simple compensation strategy (Ruzza et al., 2018; Ruzza et al., 2019).

The developed inclinometer system is composed by two main electronic systems: 1) the first one, which is installed within each measuring module, is composed by multiple electronic devices (i.e. a MEMS accelerometer, an IMU reading interface and a communication board); 2) the second one, the external master control unit, this also based on the Arduino platform coupled with a dedicate developed interface board. The master unit reads tilt value from each measuring module through a communication interface. Such unit was developed to allow interfacing additional digital or analog sensors (e.g. water content, etc.).

A steel casing for measuring components was designed and built. For each measuring unit, a squared-section case, consisting of a 30 cm long tube equipped with 4 elements that allow the installation the instrument within a standard inclinometric tubes, was prepared and assembled.

After system assembling, displacement of the inclinometric column was first simulated by a laboratory test. In particular, we used a supporting frame that allowed to vertically align the modules. The auxiliary frame was specifically designed to allow displacement along a selected axis and to register the maximum displacement at the head of the inclinometric column. In this way, the lower module is kept fixed. This test permitted to obtain a number of different synthetic deformation curves that form a basis for checking the accuracy of the instrumentation measurement. The results of the tests indicated a final displacement measuring accuracy of 0.37% of the length of the inclinometer chain. The obtained results highlighted the potential of using our system for real monitoring application (Ruzza et al., 2020).

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Spatial-temporal migration of the central-southern Apennine belt and foreland basin system (Italy): new high-resolution Sr-isotope dating constraints

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Keywords: foreland-basin-system, forebulge, foredeep; Strontium-isotope-stratigraphy, Central-Southern Apennines.

The Apennines form an active fold and thrust belt that develops as part of the W-Mediterranean subduction zone. The evolution of the collisional system is driven by the retreating subduction of the alpine Tethys, which has caused the migration of compressive fronts and the opening of the Liguro-Provençal and Tyrrhenian back-arc basins, along with the rotation and translation of the Sardinia-Corsica and Calabria blocks. The Apennines make the northern limb of the Apennines-Calabria-Sicily orocline, developed due to the differential SE-ward retreat of the subduction system. In such a context, the central-southern Apennine system develops a foreland basin floored by a subaerial forebulge unconformity developed due to bulge uplift and erosion. This unconformity is overlain by a diachronous sequence of three lithostratigraphic units made of: (i) shallow-water carbonates, (ii) hemipelagic marls and shales, and (iii) siliciclastic turbidites. Typically, the latter have been interpreted regionally as the onset of syn-orogenic deposition in the foredeep depozone, while little attention has been given to the underlying units. Accordingly, the rate of migration of the southern Apennine foreland basin-belt system has been constrained, so far, exclusively considering the age of the turbidites, which largely postdates the onset of sedimentation in the foredeep depozone.

In this work we provide a new regional dataset of high-resolution ages obtained by strontium isotope stratigraphy applied to calcitic bivalve shells sampled at the base of the first syn-orogenic deposits overlying the forebulge unconformity. In this regard, we have investigated a transect of the Apennine belt extending from inner to outer sectors (i.e. from Northern Calabria to South Majella massif) in order to constrain the timing and style of migration of the orogenic belt and foreland basin system. This dataset indicates progressive rejuvenation of the strata sealing the forebulge unconformity toward the outer portions of the belt. Moreover, integration with previously published data on syn-orogenic sediments of the area demonstrates that, among the different lithostratigraphic units of the foreland basin megasequence, dating the base of the post-bulging carbonates is the best tool to constrain the style and rate of the foreland flexuring.

A new approach for estimating CO_2 emissions in active fault zones based on geophysical surveys and numerical simulations

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Keywords: geophysical methods, numerical simulations, CO_2 degassing, active fault zones.

Characterization of complex geological systems, such as active fault zones, subsidence areas, volcanic districts, in terms of volumetric distribution of geophysical parameters is helpful in reconstructing their architecture and in understanding the processes that govern their dynamics (e.g. fluid migration within fault damage zones, land-surface elevation lowering, magma or volcanic fluid uprising). On the other hand, the numerical modelling has proved to be an indispensable tool to study the time evolution of such complex systems. In this framework, we propose an integrated approach based on geophysical surveys and numerical simulations for studying complex geological systems characterized by intense CO_2 degassing. Over the last decade, numerous geophysical methods have been successfully applied to the study of CO_2 degassing phenomena, both in volcanic and non-volcanic areas (e.g. Revil et al., 2011; Byrdina et al., 2014). In this work, a combined use of geoelectrical investigations (i.e. self-potential and resistivity tomography surveys) is proposed to reconstruct the architecture of tectonically active systems and localize preferential CO_2 migration pathways which, thanks to geological information available for the study area, allows to build an accurate 3D petrophysical model of the investigated system to be used for the subsequent numerical modeling. The latter, based on discrete dynamical models, is used to simulate the rising fluid dynamics (i.e. the time evolution of CO_2 flows and gas saturation degree). The proposed procedure can be helpful in many geological research fields, such as geothermal exploration and gas hazard assessment, due to the possibility of defining with high accuracy geometry and physical characteristics of fault systems, whose knowledge is fundamental to identify possible preferential paths for gas movements, as well as gas storage reservoirs. The effectiveness of the suggested approach is tested in some areas located in the Southern Apennines (Italy), where, associated with fault segments, diffuse non-volcanic CO_2 degassing occurs.

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Recycled carbon in the lithospheric mantle beneath central Mexico and the Canary Islands: Inferences from mantle xenoliths

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Keywords: lithospheric mantle, subducting carbon, mantle xenoliths, fluid inclusions, carbon isotopes.

Subduction is the geodynamic setting that governs the ingassing of carbon into the Earth's mantle. During subduction, carbon is released from the slab by metamorphic processes resulting in the formation of carbon-rich fluids, which have the potential to modify the pristine mantle composition. This carbon is recycled into the mantle for Ma or Ga and, due to the Earth geodynamics, is able to influence the mantle composition even far from the settings of occurrence of subduction. One of the ways to identify and quantify this recycling derived from paleo-subduction processes is through the study of carbon isotopic composition of CO_2 (expressed as $\delta^{13}C$ values; V-PDB) in fluid inclusions trapped in mantle-derived rocks. In this work, we investigate the $\delta^{13}C$ of CO_2 (coupled with noble gas systematics) of fluid inclusions trapped in mantle xenoliths collected from two different geodynamic environments: (i) central Mexico, a continental rift setting driven by the subduction of the Farallon plate beneath north America and (ii) El Hierro (Canary Islands), an oceanic island formed by mantle plume-derived intraplate volcanism. In total 10 peridotites were studied including 6 spinel lherzolites and 4 spinel harzburgites. As a result, xenoliths from Mexico and El Hierro exhibit Rc/Ra values ($^3He/^4He$ ratios corrected for atmospheric contamination) within the MORB range: 7.39 ± 0.14Ra and 7.45±0.26 Ra, respectively. Ne-Ar systematics revealed that fluid inclusions are contaminated by air-derived fluids suggesting the existence of atmospheric components recycled in the local lithospheric mantle (likely inherited from paleo-subduction episodes) beneath central Mexico and El Hierro. On the other hand, the isotopic composition of CO_2 of mantle xenoliths from both regions reflect $\delta^{13}C$ values well above the MORB mantle range ($-8‰ < \delta^{13}C < -4‰$; Sano and Marty, 1995). In the case of Mexican xenoliths, the $\delta^{13}C$ values and the $CO_2/^3He$ ratios vary in a narrow range, from -0.97 to -2.86‰ and from $3.38x10^8$ to $3.82x10^9$, respectively. On the other hand, mantle xenoliths from El Hierro show a systematic difference between pyroxenes and olivines; the $\delta^{13}C$ values ranges from -2.38 to -1.23‰ ($CO_2/^3He$ ratios from 4.65×10^8 to $1.48x10^9$) in pyroxenes and from -0.19 to +0.96‰ in olivines ($CO_2/^3He$ ratios from 4.19×10^9 to $2.03x10^{10}$). Values of $\delta^{13}C$ in mantle xenoliths moving from MORB range to that of limestone ($\delta^{13}C=0±1‰$, Sano and Marty, 1995) or even higher, indicate the mixing between mantle and crustal carbon materials, which suggests the existence of recycled crustal carbon components in the lithospheric mantle beneath Mexico and the Canary Islands. We propose that such components are associated with mantle metasomatism driven by fluids carrying carbon from recycled subducted sediments, altered oceanic crust (AOC) and/or oceanic lithosphere (OL).

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Coexistence of highly heterogeneous domains in the upper mantle: Nd-Hf isotopes of abyssal peridotites from the Doldrums Fracture Zone (7-8ºN, Mid Atlantic Ridge)

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Keywords: Mid Atlantic Ridge, abyssal peridotites, Nd-Hf isotopes.

Abyssal peridotites (AP) from mid-ocean ridges are commonly thought to represent residues of adiabatic decompression melting occurred at the ridge axis. However, the combination of detailed petrological investigation with long-lived radiogenic isotopic compositions of Cpx is now revealing a long-term history depletion and re-fertilization events. The Doldrums Fracture Zone (DFZ), at 7-8 °N in the Equatorial region of the Mid Atlantic Ridge (MAR), represents a tangible laboratory for the study of the evolution of the abyssal mantle, here exposed as a result of the tectonic forces active in a large-offset transform system (630 km by length). Extensive sampling of the north-western part was conducted during two R/V A. N. Strakhov expeditions (S06 and S09) in the 80', and by the 45th A.N. Strakhov expedition (Skolotnev et al., 2020). Major and trace elements compositions allow to defining different families of peridotites, ranging from purely residual peridotites to melt-modified samples showing evidence for interaction with melts occurred at lithospheric levels (Sani et al., 2020).

New Nd-Hf isotopic data show that the melt modified samples preserve highly radiogenic values (Hf up to 101) rarely reported in literature (Stracke et al., 2011) and though to be signature of ancient (>1 Ga) melting events. On the contrary, the residual samples have MORB-like Nd-Hf isotopic compositions that, coupled to markedly depleted character, require a combination of ancient metasomatism and melting below the present-day ridge axis. Our study conducted on the Doldrums FZ peridotites show the existence of different isotopic domains that are coexisting in the upper mantle forming the current heterogeneity.

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Record of shallow levels tectonics in low-grade continental units: Insights from the Marguareis Massif (southwestern Alps)

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Keywords: Marguareis Massif, low-grade, continental units, shallow tectonics.

We present and discuss the results of a geological survey performed in the southwestern sector of the Marguareis Massif and aimed to unravel the deformation history of the units deformed at shallow crustal levels during alpine collision. The study area is located at the boundary between Maritime and Ligurian Alps covering about 50km^2 along the Italian-French border. In the study area, a SW-ward stacked nappe pile composed of low- to very low-grade Helminthoid Flysch and Europe-derived continental units (i.e. Briançonnais Units) occurs (Sanità, 2019; Sanità et al., 2020 and reference therein). We focus on the structurally highest Marguareis Unit which is characterized by Meso-Cenozoic cover rocks that sedimented as a passive continental margin (i.e. Europe margin) progressively involved in a convergent setting.

We performed a multidisciplinary approach including high-resolution geological mapping and micro- to map-scale structural analysis of the Marguareis Unit whose exceptional exposure allow us to decipher its finite strain pattern.

According with Sanità et al. (2020) the Marguareis Unit recorded an intricate deformation history dealing with superposition of different generations of fold systems (D1, D2, D3 and Post-stacking folds) and faulting developed at different crustal depths. The firsts (D1, D2 phases) took place at deeper crustal levels and they are characterized by development of penetrative granular-scale foliations (S1 and S2) and related isoclinal folding systems (F1 and F2), up to km-scale amplitude, with scattered (A1) and NW-SE trending (A2) fold axes and NW-SE trending axial planes, called AP1 and AP2, showing dips toward SW and toward NE, respectively. The third event (D3) imposed thrusting of Marguareis Unit onto the underlying Helminthoid Flysch Unit, and it produces a knee-shaped km-scale fold (F3) with NW-SE trend developed at shallower crustal depth and unable to produce diffuse granular foliation. However, this folding event is responsible of an important re-orientation moving from NE toward SW of the pre-existing structural features. The post-stacking (PS) folding event is shared by all the units and developed at very shallow crustal levels. PS folds superimpose all the previous structures, including the unit-bounding shear zones. Finally, this structural architecture was segmented by faults that play a not-significant role in the deformation history of the unit.

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Pyroclastic stratigraphy and volcanology of the Pre-Caldera Miliscola Volcano (Campi Flegrei)

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Keywords: pre-calderaPhlegrean volcanism, proximal pyroclastic deposits, Miliscola volcano.

Campi Flegrei is a large active volcanic field characterized by the presence of diffuse monogenetic volcanic cones and two nested calderas associated with the Campanian Ignimbrite (39 ka; Rosi & Sbrana, 1987; Perrotta et al., 2006) and the Neapolitan Yellow Tuff (15 ka; Scarpati et al., 1993) eruptions, respectively. Because of dense urbanization and calderic collapses, the youngest products of the Campi Flegrei are well-exposed and generally better known than those of the older, pre-caldera deposits. To contribute to the reconstruction of the ancient eruptive Phlegrean history toward a better definition of the volcanic hazard, our research focuses on the Monte di Procida cliff, in the southwestern sector of Campi Flegrei. In this area thick pyroclastic sequences, separated by several paleosol horizons, are well exposed along the steep walls of Monte di Procida, covering all the volcanic activity of Campi Flegrei. In this scenario a field survey was performed on the pyroclastic sequence of the tuff cone of Miliscola. Although the absolute age of this ancient volcanic edifice is unknown, the Miliscola sequence is capped by pyroclastic products erupted in the nearby island of Ischia which has an age between 74 and 55 ka (Vezzoli, 1988), suggesting for Miliscola vent a volcanic activity older than ca 70 ka. The succession, thick up to 20 meters, consists mostly of alternating matrix supported, massive or stratified ash layers and thick pumice lapilli deposits with large blocks and scattered bombs. The facies variations observed in deposits testify to explosive volcanic activity with a sustained eruptive column that accumulated pumice lapilli and blocks fall alternating to repeated column collapses emplacing unsteady and non-uniform pyroclastic density currents. Additional features of the deposits, such as the presence in some horizons of diffuse ballistic clasts (respectively up to 18 cm and 10 cm in diameter for pumice and lithic clasts), indicate that the Miliscola vent was presumably located close to the Monte di Procida shore, but at present the edifice is partially demolished by marine erosion. The style of the eruption was mainly magmatic with episodic phreatomagmatic pulses. Lithic-rich horizons indicate that erosion or partial collapse of volcanic conduits occasionally occurred. The research provides new insights to the knowledge and the risk assessment of the Campi Flegrei activity. In fact, it shows that, although the pre-caldera Phlegrean volcanism is represented by monogenic and scattered vents with a confined distribution (Perrotta et al., 2010), some eruptions such as the Miliscola's eruption show complex dynamics conditions that changed during the single event.

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Imaging and morphological setting of Amorphous Lake (Victoria Land, East Antarctica) by means of Ground Penetrating Radar

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Keywords: GPR, Antarctica, glaciology.

Amorphous Lake (74° 42' S, 163° 58' E) is the unofficial name given to the largest perennial frozen pond of the Amorphous Glacier area. It is located in the Northern Foothills area, an undulating upland terrain in Northern Victoria Land, East Antarctica, about 2 km west from the Italian Antarctic Station (Orombelli et al., 1990*)*. The lake lies on the northern side of a frontal morainic ridge (Guglielmin et al., 2002), taking up a morphological bowl. In this work, we present the analysis and interpretation of a 2 km-long Ground Penetrating Radar dataset collected in 2014 on and around the Lake, in order to reconstruct the dynamics and the morphological setting of this area. GPR is extremely effective in glaciology and has proved to be a valid tool to provide high resolution imaging of the subsurface and to characterize frozen materials due to their low overall electrical conductivity (e.g. Santin et al., 2019). On the basis of the responses to the EM signal and the strength of amplitude reflections, we first identified several EM facies, including the lake bottom, the frontal morainic ridge, the snow cover, the interconnections with the Amorphous Glacier and its underlying bedrock. Later, we reconstructed, both in 2D and 3D, the geometry and morphology of the lake, which resulted partially lying on the frontal morainic ridge and partially on the glacier. An evident and high amplitude EM layered facies was identified between the lake bottom and the top of the moraine, with a mean thickness of 2.5 m and an extension equal to about 40% of the whole lake. This peculiar unit and the evidence of a localised incision flowing down along the moraine, suggested the hypothesis of a past sedimentary activity, which formed the layered unit, which can be interpreted as a sort of fluvial delta, built during a warm period of the Antarctic climatic history.

Further investigations including additional GPR surveys and ice coring within the lake will hopefully be performed during the next Antarctic Expedition in order to better insert this study in the wider geomorphological context of the Northern Foothills area.

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Cooling rates in glass-forming melts: a DSC model

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Keywords: conventional scanning calorimetry, flash scanning calorimetry, fictive temperature, cooling rate, parallel shift factor.

Since the heat amount available in a volcanic system strongly impacts eruption dynamics and deposit characteristics, the study of pyroclastic material is fundamental to get information on their thermal history and ultimately address the hazard potential of both effusive and explosive events.

Relaxation geospeedometry techniques using a Differential Scanning Calorimeter (DSC) on glasses are the prevailing techniques for retrieving cooling rates applied. This methodology allows accessing the thermal history of glassy phases by revealing the cooling kinetics across the glass transition recorded by the glass fictive temperature (T_f; i.e., the temperature at which the liquid structure appears frozen on the timescale of observation). Conventional DSC (C-DSC) devices explore limited cooling rates (below 0.5 K/s) and often need extensive extrapolations to be applied to those affecting natural volcanic materials. This study introduces a universal technique for retrieving cooling rates by combining Conventional and Flash DSC (F-DSC). The latter is a novel apparatus that allows gaining information on the glass transition kinetics under ultra-fast cooling rates (from 3 to 30000 K/s).

We test and expanded over six orders of magnitude of cooling rates, the T_f evaluation technique using the so-called "unified area-matching approach" (Guo et al., 2011). This methodology can be used to determine and parameterize the fictive temperature as a function of cooling rate.

Analysis of standard and synthetic glasses allow us to successfully model cooling rates up to 1000 K/s. We also provide a composition- and cooling rate-independent shift factor that allows us to relate cooling rates with silicate and fluorophosphate melts' viscosity. Therefore, the proposed strategy represents a significant improvement in the study of fast- and hyper-quenched samples, better capturing and constraining the cooling rates experienced by volcanic materials following both sub-aerial and submarine eruptions.

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Landslides inventory in Canelli (AT) area between 2008 and 2018: update and integration of the information system performed by ARPA Piemonte

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Keywords: geomorphological mapping, landslides, GIS, civil protection.

New collection and analysis about recent landslides have been realized, between 2008 and 2018 period, interesting the municipal area of Canelli (AT) in south Piedmont-Langhe hills, to update and integrate the information system SIFraP - Sistema Informativo Frane in Piemonte performed by ARPA - Agenzia Regionale per la Protezione Ambientale.

The Langhe hills form the southern part of the Piedmont Tertiary basin, composed by Oligocene-Miocene sequence of terrigenous rocks: marls, mudstones, sandstones. The sequence forms a monocline with a regional dip of 10-12° toward the northwest.

The study was approached on different levels: looking for the previous landslides inventory made by ARPA, to define the strategy to be applied and realize the inventory. To retrieve information, the planning of inventory phase involved the local authorities such as civil protection and firefighter's department, Comune di Canelli, Provincia di Asti, as well as the recovery of satellite, aerial imagery, and journalistic reports.

The most important recorded landslide, called ''Reg. Braglia rotational landslide'' and occurred on vineyards near Canelli, was deeply studied. A geomorphological map of the landslide area has been realized and, after an historical investigation, information on reactivation was obtained and included in the report paper.

The results of the inventory have been put in a GIS database for statistical analysis: the acquired information offers an evident correlation between local geomorphology, type of landslides and previous bibliography data. Of the 59 surveyed events, 68% are translational slides mostly involving clay-soil materials and mainly located along local roads, 25% are rotational slides in bedrock and soil materials, mainly located on vineyards slopes, and a 5% of rock falls, that interested the steepest slopes formed by the bedrock.

Collected information will be uploaded into SIFraP database, freely accessible by a WebGIS on ARPA Piemonte website, while the report of Reg. Braglia landslide is already available.

Through the landslides mapping, the work aims to offer strategic support for territorial planning and civil protection activities, to deepen the Langhe natural hazard and try to reduce them.

Remote analysis of andesitic-to-dacitic lava flows, Central Andean Volcanic Zone: A new proposed morphology-based classification

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Keywords: lava flow, Central Andean Volcanic Zone, morphology, intermediate lava.

Lava flows are the most common erupting magmatic products at the Earth and extraterrestrial surfaces. Thus, understanding lava flows processes provide valuable information regarding the formation of extant lavas and their associated hazards. The morphology of a lava flow records the eruptive dynamics that governed its emplacement and evolution and the rheological properties of the erupting magma. Although the eruptive dynamic and a robust morphological classification for mafic flows have been well constrained, studies and laboratory simulations focused on intermediate to silicic-rich lavas are scarce. This study presents a remote characterization and proposes a morphological-based classification for lavas flows with a broad spectrum of features in the andesitic to dacitic transition. We analysed a dataset of 49 flows from the Central Andean Volcanic Zone (CVZ) and quantified the maximum wavelength and the folding patterns of the lava flows and their relationship with thickness distribution, pre-surface slope, composition, and rheology. Furthermore, we introduced a Fourier analysis for quantifying the plain-view shape of the lava flows and a novel method based on an S-transform spectral analysis of grayscale satellite image data to assess the folding pattern. We propose a classification for andesitic-to-dacitic lava flows that result from the combinations of different eruptive dynamics. Type 1 lavas have highly arcuate ridges with convex surfaces, large thickness, and one rounded frontal lobe. Type 2 lavas are parasitic flows with characteristics between lava flows and domes. They have relatively simple shapes with lengths that do not exceed their widths significantly, their vents are located inside the flow, and prominent ridges and crumble breccias are observed. Type 3 lavas range from short to long flows, have the simplest shapes, are highly channelized, and have a unique frontal toe of maximum thickness. Type 4 lavas range from thin to thick flows, have the most complex shapes with lateral and frontal breakouts, poorly developed levees, and fronts with increasing width and thickness. Transitional lavas are common between the different types and exhibit intermediate features, folding patterns, and shapes. The recognition of the characteristic features of the different lava types represents a first step for the interpretation of the main processes controlling the effusion at the surface of magmas with largely different compositional features.

A geochemical contribution to the study of autism spectrum disorders (ASDs) in South Sardinia: the role of environmental factors

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Keywords: Autism Spectrum Disorders (ASDs), geochemistry, metals, metalloids.

The Autism Spectrum Disorders (ASDs) are a group of disorders that develop during the infant life, between the pre-natal stage and the third year, affecting the child's social and behavioral development as well as their physical health, influencing the development of their immune and nervous systems. In the last decades, the number of ASDs patients has steeply raised worldwide: in USA 1 in 56 children (ADDM, 2020), in Europe 1 in 89 (ASDEU, 2018), in Italy 1 in 77 (ISS, 2021). The scientific community agrees that the onset of ASDs is the results of multiple contributing factors, both genetic and environmental: virus, exposure to chemical compounds, metals, metalloids, unbalanced homeostasis of trace elements and essential minerals, parental age etc. Many multidisciplinary research have studied the relationship of the human-environment interaction (environment defined as the complex media of soil, water and air), but only few have further investigated the associations of ASDs and the environment's geochemical characteristics. In Italy, and particularly in the Sardinia island, despite the growing social attention and support, only few studies have been carried to further examine the environment's influence on ASDs (Valera et al., 2013). Especially in Sardinia, due to the homogeneous genetic background of the population, the growing numbers of ASDs patients can't be easily explained by genetics only, suggesting the presence of external factors. Throughout the last century, since the mining exploration was the main economic activity of the region, large amount of information have been gathered on the mining deposits and their surrounding territories. Additionally, extensive prospecting research have been carried since the 1970s (Marcello et al. 1978), culminating in the development of a still growing region-wide database of soils, rocks and stream sediments analytical data, and in the development of the geochemical baseline of the whole Sardinian territory (Marcello et al., 2003).

The following ecological study aims to highlight and evaluate, on the basis of the geochemical and clinical data available for the South Sardinia region, the possible correlation between a set of elements and the responsibility of these factors in the frequency fluctuation of the ASDs, with the goal of providing a new supporting tool in the medical studies on the contributing environmental factors that could be involved in the onset of these disorders.

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Application of palaeomagnetism in deciphering the contacts between plutonic body and volcanic sequences: preliminary results from the Valganna, Southern Alps (Italy)

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Keywords: emplacement dynamic, intrusions, paleomagnetism, magnetic fabric.

Deciphering the contact between intrusive bodies and volcanic sequences along with the stratigraphy and/or structural relations among them is quite challenging using field data and structural interpretations. Paleomagnetic techniques enable us to unravel the nature of natural remanent magnetization (NRM) and the possible tectonic control in the nature of the contact between them. Moreover, changes in the anisotropy of magnetic susceptibility (AMS) ellipsoid among different lithologies enable us to deduce emplacement processes and deformation history.

Here, we are presenting the preliminary findings obtained from the rock magnetic and palaeomagnetic analyses to unleash the ambiguity of contact history between the intrusive body and volcanic sequences of the Valganna region of western Southern Alps, Italy. This study includes two transects across the contact between the Permian intrusive body and the overlying Lower Permian volcanic and volcanoclastic sequence, cropping out in the Western Southern Alps, in order to characterize its nature and the emplacement history.

The variability in the magnetic fabric reveals partial preservation of the original magmatic and volcanic nature with significant evidence of a possible structural control during the emplacement and/or a subsequent reworking by the faults. Furthermore, paleomagnetic data revealed the potential control of tectonic events in the contact between them and possible alteration processes by the change in natural remanent magnetization (NRM) nature.

Barrovian metamorphism in the Lesser Himalayan Sequence of Central Nepal seen through the eyes of aluminous metapelites

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Keywords: metamorphic evolution, aluminous metapelites, phase diagram modeling, Himalaya.

The Lesser Himalayan Sequence (LHS) of the Nepal Himalaya is a thick Paleo- to Meso-Proterozoic sedimentary sequence originally deposited on the northern margin of the Indian plate (Upreti, 1999). Although it is well known that, during the Himalayan orogenic cycle, the LHS developed a Barrovian inverted metamorphism, its metamorphic history is still poorly documented and constrained, the general belief being that it experienced a low-grade metamorphism (De Celles et al., 2001; Kohn, 2014). However, garnet, staurolite and/or kyanite-bearing assemblages are sporadically reported from the upper structural levels of the LHS (Catlos et al., 2001; Kohn et al., 2001; Groppo et al., 2009), which are in contrast with the supposed low metamorphic grade of the LHS.

As a contribution towards a more precise understanding of the LHS metamorphic evolution, this study aims at constraining the peak P-T conditions experienced by the upper-LHS in central Nepal. The study focuses on aluminous metapelites, because these lithologies are more prone to the development of low-variant assemblages compared to other LHS lithologies. The detailed microstructural, petrographic and minerochemical investigation of six aluminous metapelites allows recognizing that the most common aluminous minerals (garnet, staurolite and/or kyanite) show variable relationships with the main foliation (i.e., they can be pre-, syn-, or post-kinematic with respect to the main foliation in different samples). Phase diagram modeling succeeded in reproducing the observed blastesis-deformation relationships. Combined with isopleths thermobarometry, this approach allowed constraining the P-T evolution of the upper-LHS, which is characterized by peak-P conditions of 9-10 kbar, at T = 590-600°C, followed by heating decompression at 620-630°C, 8-9 kbar.

Catlos E.J., Harrison T.M., Kohn M.J., Grove M., Ryerson F.J., Manning C.E. & Upreti B.N. (2001) - Geochronologic and thermobarometric constraints on the evolution of the Main Central Thrust, central Nepal Himalaya. J. Geophys. Res., 106, 16177-16204.

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The multidisciplinary study of regional-scale shear zones, a powerful tool for improving paleogeographic reconstructions

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Keywords: East Variscan Shear Zone, Variscan Orogeny, structural analysis, vorticity analysis, petrochronology.

A fundamental contribution to paleogeographic reconstructions derives from the study of regional-scale shear zones by combining detailed field work with structural and microstructural analysis, petrology and petrochronology. Those data are fundamental in order to verify the compatibility of structures cropping out in crustal fragments that were probably in lateral continuity and are now separated because of subsequent geodynamic events. This is the case of the Southern European Variscan Belt in the Mediterranean area that was partially overprinted by the Alpine cycle (Stampfli & Kozur, 2006). A main debate is the connection among the Corsica-Sardinia Block (CSB), the Maures-Tanneron Massif (MTM) and the future Alpine External Crystalline Massifs (ECM) and if these sectors were connected by a network of shear zones of regional extent, known as the East Variscan Shear Zone (EVSZ). The multidisciplinary study of shear zones cropping out in the CSB (the Posada-Asinara shear zone), in the MTM (the Cavalaire Fault) and in the ECM (the Ferriere-Mollières and the Emosson-Berard shear zones) revealed a striking similar evolution of such structures (Carosi et al., 2020; Simonetti et al., 2020a; 2020b). Kinematic and finite strain analysis allowed us to recognize a transpressional deformation and a general flattening deformation. Syn-kinematic paragenesis, microstructures and quartz c-axis fabrics revealed that shearing occurred under decreasing temperature from amphibolite- up to greenschist-facies. U-Th-Pb monazite petrochronology constrained the time of deformation between ~340-330 and ~320 Ma. The striking similar features of the studied shear zones suggest that the studied sectors werein lateral continuity during late Variscan time. This case study demonstrates how paleogeographic reconstructions could benefit from datasets obtained from large-scale structures (i.e., shear zones) investigated by integrating independent techniques in order to unravel their tectono-metamorphic evolution.

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Tectonic significance of the wedge - top Epiligurian Units for the Northern Apennines evolution as constrained by multiscalar structural analysis

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Keywords: Northern Apennines, Epiligurian Units, wedge-top basins.

The Northern Apennines are an accretionary wedge formed in response to the Late Cretaceous-Eocene closure of the Ligurian-Piedmont ocean and the Oligocene-Miocene collision between Adria and Europe plates. The wedge is shaped by WNW-ESE-striking, SW-dipping thrusts accommodating a top-to-the NE tectonic transport. Since the Late Miocene, thrusting in the belt external domains acted coevally with extension in the western hinterland domain, where crustal thinning is accommodated by NW-SE normal faults. Atop the deformed accretionary wedge occur the Epiligurian Units, which consist of middle Eocene-upper Miocene bathyal to shallow-water siliciclastic deposits infilling wedge-top basins. Our study focuses on the multiscalar and multitechnique characterization of the tectonic structures affecting selected Epiligurian Units, with the aim to provide a comprehensive syn-to-post accretion evolutionary model for these basins during the Oligocene-Miocene convergence. The mesoscale analysis shows that extensional and compressional fault arrays affect the entire Epiligurian stratigraphic succession. Top-to-the NE, WNW-ESE-striking thrusts/reverse faults are defined by commonly slickensided planar surfaces decorated by thin damage zones. Top-to-the SE, ENE-WSW-striking thrusts/reverse faults are, instead, generally devoid of well-developed damage zones. These contractional faults are systematically cut by NW-SE and NE-SW-striking normal and oblique faults systems, characterized by mutually intersecting fault planes accommodating centimetric to metric throws. Cataclastic and disaggregation deformation bands locally occur along major extensional structures cutting across upper Eocene coarse-grained sandstones as either single bands or clusters. A remote sensing analysis of the tectonic structures affecting the Epiligurian Units was performed, with the aim to define whether orientation and density of normal and reverse faults vary as function of the affected stratigraphic units. This analysis confirms a variable orientation and density for both normal and reverse faults within different stratigraphic units, probably reflecting the interaction between regional and local tectonic stress conditions. Our preliminary results suggest that the current framework of the Epiligurian wedge-top basins reflects a polyphase tectonic evolution during progressive frontal accretion and the switch from syn-to post orogenic conditions of the underlying wedge. We suggest that the Epiligurian Units can be used as a powerful structural-stratigraphic gauge to track down the variation of the tectonic regime and state of stress of the Apennines wedge during the Adria-Europe continental collision.

Geological features of an aspiring Geopark (aUGGp): the MurGEOpark

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Keywords: Alta Murgia National Park, UNESCO Geopark, geosite, Adria Plate, colluvial breccia.

The main geological features of the *Alta Murgia National Park*, which applied to be included in the UNESCO Global Geoparks in 2019, have been illustrated in a Master's Degree Thesis. The geological uniqueness of this park, essential for becoming a geopark, is represented by the fact that the study area is the only remaining part of the Adria Plate, i.e. the old continent that played an important role in the geodynamics of the Mediterranean area (van Hinsbergen, 2014). Furthermore, since the dossier submitted must also highlight the importance of the development of sustainable tourism, a new itinerary connecting two previously-known geosites of the National Park has been proposed. The itinerary starts at *Castel del Monte* and ends in the *Murgetta Rossa*, covering an overall distance of 56 km. *Castel del Monte* is a 13th Century Norman-Swabian castle included in the UNESCO World Heritage List since 1996; the *Murgetta Rossa* is a disused bauxite mine, having national importance. In particular, the itinerary aims at illustrating some peculiar geological aspects of the two sites, unknown to tourists who normally visit these sites for purely historical and architectural reasons (Castel del Monte) or landscape and chromatic impacts (Murgetta Rossa). The relief on which *Castel del Monte* lies is linked to the Tertiary tectonics acting in the northwestern Alta Murgia Cretaceous plateau and may be due to the presence of extensional faults that produced a horst (Quarto & Altomare, 2015); the Cretaceous bauxitic deposits of the *Murgetta Rossa* developed due to a tectonic phase affecting an interior area of the Mesozoic Apulia Carbonate Platform, and recent studies have suggested an allochtonous origin for these residual rocks (Mongelli et al., 2014). In addition, this study proposed the institution of a new geosite to add to the list of those already existing in the National Park area. The geosite regards a succession of Quaternary continental deposits located at *Minervino Murge*, where slope-breccias, composed exclusively of Cretaceous limestone fragments, crop out into an urban area. This geosite presents steep and short fans, often coalescing and forming a long string bordering the northwestern part of the Alta Murgia escarpment (Caldara & Ciaranfi, 1988). The facies analysis has shown that these deposits belong to rockfall depositional processes in a colluvial depositional system (*sensu* Blikra & Nemec, 1998), whose origin can be related to the interaction of active tectonics with climate changes. In conclusion, the *Alta Murgia National Park*, geologically well-known for its karst features, dinosaur tracks, and the presence of a Neanderthal skeleton embedded in a speleothem, offers many other interesting and intriguing reasons to aspire to become a UNESCO Geopark, and one of these "yet-to-be discovered" elements is represented by the Minervino Murge geosite.

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Minero-petrographic characterization of marble archaeological finds from P.A. Garda Museum (Ivrea, To): a case of interdisciplinary studies on ancient stone

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Keywords: cultural heritage, petrography, ancient white marbles, archaeometry, stable isotopes.

The ornamental marble stones of monuments and historical artifacts today bear witness to the past and are an integral part of the historical, artistic and cultural heritage of our territory. Therefore, their conservation is essential, especially from the diagnostic point of view. The studies of historical marble finds can also be useful for geoconservation, that is, the conservation of the geological heritage and the enhancement of historical buildings.

The work provides a minero-petrographic characterization of the main white marble finds of the Museo Civico P.A. Garda of Ivrea (Piedmont, Italy). A multi-analytical approach based on petrographic (optical and scanning electron microscopy), electron microprobe and stable isotope analysis of Piedmont white marbles has been performed in order to carry out a detailed description, summarizing their main microtextural, mineralogical and isotopic features. The electron microprobe analysis has provided the chemical composition of the main mineral component (calcite and/or dolomite), and the chemical composition of subordinate or accessory minerals useful for discriminative purposes.

On the basis of the mineralogical-petrographic characteristics of the marbles analyzed, it was possible to create a first database for archaeometric purposes and to make a possible comparison with the Italian and Greek marbles reported in the literature.

The analyzes made it possible to discriminate the origin of the marbles: they were generally of local origin (Alpine), but also from more distant areas as in the case of Apuan or Greek marbles. This suggests that *Eporedia* (the old name of Ivrea) in Roman times was a center of some importance, with trade and trade routes; stone materials were therefore used not only of local origin, but also of Mediterranean origin.

The Pietra di Vico quarry (Vicoforte, CN): description and interpretation of the sedimentary succession

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Keywords: Times: Pietra di Vico, sandstone, cementation, sedimentary structures.

The "Pietra di Vico" is one of the most interesting Heritage Stones used for historical constructions in southern Piemonte, specifically in the Monregalese area. The most famous example of use of the "Pietra di Vico" is in the sanctuary of Vicoforte, national monument and one of the most significant buildings of the Piemonte region. The "Pietra di Vico" is a relatively recent sedimentary rock and is part of the San Paolo Formation, deposited in the Tertiary Piemonte Basin during early Miocene (16 to 23 million years ago). After its formation, it has undergone an important localized process of cementation. This project not only describes the "Pietra di Vico" and its uses but aims to investigate how, where and when this Heritage Stone was formed. "Pietra di Vico" is a gray-beige sandstone with medium-coarse grain size, well sorted, consisting of quartz grains and reddish lithic fragments with a carbonate cement. Sedimentary structures such as trough cross bedding or water escape structures can be observed on both natural outcrops and the walls of the sanctuary. The detailed stratigraphic study of the sedimentary succession shown on the outcrops of the quarry of "Pietra di Vico" helped to define the geological contest and the paleo-environment situation at the deposition.

Cross bedding documents that deposition occurred in an environment characterized by water currents and rapid sedimentation which in turn resulted in the formation of water escape structures. The absence of fossils of marine organisms leads to infer a deposition in a continental, fluvial, environment, although the observed sedimentary structures could be also found in coastal marine settings. The geological-petrographic study carried out on the outcrop and in the laboratory on the "Pietra di Vico'' has allowed us to assert that this Heritage stone refers to a cemented portion of the San Paolo Formation. This lithification is not homogeneous as it is localized in masses of decametric dimensions with abrupt passages between the completely lithified and unconsolidated volumes. The petrographic study, performed under a normal optical microscope and in cathodoluminescence, showed that the lithification is due to the precipitation of a dolomitic cement which is unusual in siliciclastic sandstones. The fabric of these sandstones exhbits a limited degree of compaction that suggests that cementation occurred under a small lithostatic load. It is suggested that the dolomite cement may be related to the circulation of hydrothermal fluids that were propagated along faults and fractures, probably connected to a deformation phase of the southwestern edge of the Tertiary Piemonte Basin during the early Miocene. These fluids probably flowed preferentially in sedimentary bodies with a coarser grain size, and thus greater permeability, where the precipitation of a cement was consequently favoured (Storti, 2019).

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Stratigraphic analysis and petrographic characterization of Piani Resinelli sulphide deposits (Valsassina, LC)

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Keywords: Alpine type-deposits, metallogenesis, Southalpine domain, Gorno district.

Piani Resinelli plateau (Valsassina, LC) hosts several, mainly Zn/Pb, sulphide deposits, that were mined in the past since Middle Age up to the post-war period. These deposits are classified as *Alpine type-deposits* (APT). The ores are hosted in the Triassic carbonate stratigraphic succession of the Southalpine Domain, and represent the western continuation of the Zn/Pb Gorno district (BG).

The present study aimed to investigate these deposits through geological mapping, stratigraphic analysis and a petrographic characterization. A detailed geological mapping, focused on the mineralized interval of the succession, produced a geological map of the study area at a 1:10.000 scale. The main object of the stratigraphic analysis was the identification of the stratigraphic interval affected by the mineralizations, which was sampled during the field work for the petrographic characterization. The exploration of several abandoned mines in the area allowed a more detailed observation of the geometry of the mineralized bodies.

The petrographic analysis mainly focused on the study of the Zn/Pb sulphides (sphalerite, galena) and diagenetic processes typically associated with this kind of deposits (dolomitization, silicization, brecciation) through different techniques (transmitted light microscopy, reflected light microscopy, cathodoluminescence, SEM-EDS).

The acquired data allowed to gather the following information: i) a strong stratigraphic control of the mineralizations, located in correspondence with the Ladinian-lower Carnian tidal flat successions.; ii) recognition of several generations of breccias and ores; iii) the precipitation of ores in still very porous sediments; iv) recognition of saddle dolomite cements in the host rock pores, associated with the mineralization. The confinement of the ores in a precise stratigraphic interval confirms the stratabound nature of the deposits; the recognition of different events of brecciation and precipitation indicates the polyphasic nature of deposits; the occurrence of saddle dolomite documents that the ores precipitated from hot fluids with T>70°C. Together with several evidence of shallow burial setting, this documents the hydrothermal nature of the fluids and suggests that sulphide precipitation occurred shortly after the host rock deposition, i.e. in the Carnian. This interpretation permits to propose a new metallogenic model: sulphide deposits precipitated from hydrothermal fluids upflowing through faults and associated fractures, which were enriched in metals during their interaction with basement rocks in the deepest portion of the hydrothermal system. The precipitation of the ores occurred at a shallow burial setting within the Triassic carbonate succession, where the upflow of the metal-rich hydrothermal fluids was arrested by the presence of a mud-rich horizon acting as an aquitard, and a mixing with others fluids enriched in sulfide ions by means of organic matter degradation processes occurred.

Diagenesis modelling of Illizi-Ghadames basin (North Africa)

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Keywords: diagenesis, microthermometry, thermochronology, modelling.

The study of pore network modification in reservoir rocks due to diagenesis is an important aim for hydrocarbon research. Unfortunately, this is not easy to achieve because of the high number of variables driving the time and space modifications of pores with heat-flow, which is probably the trickiest one to challenge. With this respect, here we present an example of integrated study performed on Paleozoic and Triassic reservoir sandstones from the Ghadames-Illizi Basin, one of the most prolific hydrocarbon regions in North Africa (English et al., 2017 and reference therein). In this region, it is still discussed the possible thermal effect on the petroleum system of the Cenozoic magmatic activity that occurred in the neighboring Hoggar Dome. This study (Di Giulio et al., 2021) aimed at solving that problem by combining different techniques: (i) petrography to reconstruct the relative timing of diagenetic events; (ii) fluid inclusions microthermometric analyses to measure the cements precipitation temperatures; (iii) low-T thermochronology on detrital apatite grains to unravel the thermal constraints; and (iv) vitrinite reflectance and spore analyses to assess the organic matter maturity profile. This composite experimental dataset was compared and interpolated with the simulations of the thermal evolution of the studied rocks according to three different thermal scenarios. Measurements from organic matter and fluid inclusions exclude a thermal scenario with heating only by increasing burial depth, for this reason a following Cenozoic heating overprint is necessary. We then considered two different overheating events during the Tertiary, one occurred in the Early Cenozoic (65 Ma) and a second in the Late Cenozoic (5.4 Ma). Between these two scenarios, the Early Cenozoic thermal event seems to fit better with the experimental data, although a younger thermal peak cannot be completely excluded. Whatever the case, it is important to note that the predicted age of each cement precipitation phase, significantly changes as a function of the adopted thermal model and this has relevant consequences on the exploration activity. To finally constrain the correct Cenozoic overprints, we run the datasets into a diagenesis modelling software, Touchstone (by Geocosm). To have prediction models, this software can help in finding which thermal scenario best fits with the data previously obtained, working out also major differences in the pore network histories predicted according to different thermal models.

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Depositional Setting and Paleogeographic Reconstruction of the Salento Peninsula from Late Cretaceous to Pleistocene

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Keywords: Salento Peninsula, paleogeographic reconstructions, sequence stratigraphy.

The Salento Peninsula is in the southern portion of the Apulia region, and is part of the Apulia Carbonate Platform. The latter constitutes one of the carbonate banks developing in the southern sector of the Tethyan Ocean, being part of the Adria microplate that represents the Neogene-Quaternary foreland area of two opposite-verging chains: the northeast-verging Southern Apennines and the southwest-verging Dinarides. The Salento Peninsula is almost exclusively composed of a thick (3-5 km) Upper-Triassic to Upper Cretaceous shallow-water carbonate succession, capped by a thin cover of Tertiary and Quaternary terrigenous and carbonate deposits. The best-preserved Paleogene sediments crop out along the eastern margin of this structure, whereas in the internal sector the Miocene deposits are better preserved . The Pliocene-Pleistocene sediments occur predominantly around the margin of the Salento Peninsula. We focused on the emerged portion of the Salento Peninsula by analyzing more than 150 wells and through field data, in order to produce a total of 117 stratigraphic correlation panels. We utilize the flattening procedure to restore the original relationship among the different lithostratigraphic units and to produce a series of paleogeographic schemes of this area from the Oligocene to Pleistocene. These data allowed me to evaluate how paleogeographic evolution changed during this period of time due to the west and east coeval propagation of the Apennines and Dinarides respectively and under the influence of three main factors: the tectonic uplift, the subsidence and the relative sea-level changes. Carbonate production rates are hardy to evaluate considering that Tertiary and Quaternary carbonate deposits reaching a thickness less than 100 m. These data allowed the recognition of a different general trend that together with the field investigations allowed me to produce a sequence-stratigraphic scheme of Salento Tertiary and Quaternary deposits. At the present a detailed investigation of the offshore sector of Salento Peninsula has been made by utilizing several seismic sections and wells, to recognize the main lithostratigraphic units occurring landward in the submerged sector bordering the Salento Peninsula both on Adriatic and Ionia. The focus is to produce a more detailed paleogeographic reconstruction of the the whole area integrating data derived from the emerged and submerged sectors of the Salento Peninsula and to better define the sequence stratigraphic scheme of the post Cretaceous sedimentary succession.

Stability analysis of Cuma lava dome

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Keywords: rockfall, cultural heritage, geomechanical analysis, kinematic analysis, Phlegrean Fields.

The province of Naples is known for its cultural heritage, expression of the history of the city and its surrounding zones. Over the years, many archaeological areas have been the subject of historical, geological and archaeological studies in order to enhance them and make them safe to use. Specifically, the Phlegrean Fields area is known for its exposure to landslide hazard (Di Martire et al., 2012; Di Napoli et al., 2020), essentially due to the steep slopes covered by pyroclastic soils presence and sub-vertical tuff and lava walls highly fractured like Cuma mount, located in the in the Phlegrean Fields Archaeological Park. Cuma is one of the most important sites in the area and the first Greek settlement in the western Mediterranean, which still retains Greek archaeological features such as the cave of the Cumaean Sibyl, the temple of Jupiter and Apollo and the Roman Crypt. Given the considerable importance of the historical site of Cuma, this paper presents the analysis of the susceptibility to rockfall of the western slope of the Cumae Mount, already affected by rockfall events located near the railroad station and one of the main access roads to the park. A recent event occurred in August 2019 when a 0.5 m^3 boulder detached from the northern slope of the Cumae Mount and reached the local road immediately downslope (De Stefano et al., 2021). Due to the high speed with which they occur, rockfall events can cause catastrophic consequences, causing damage to infrastructures and above all threatening the safety of human lives. For this reason, it is extremely important to be able to identify the type of landslide, to circumscribe and accurately assess the spatial distribution of the phenomenon and the possible trajectories of the falling blocks. To this purpose, a geo-mechanical analysis was carried out using an open-source software, Cloud Compare (RANSAC Shape Detection), starting from obtained data with innovative techniques: digital terrestrial photogrammetry and laser scanning. Subsequently, Markland test showed the potential of slope instability at the site, in the form of toppling, wedge and planar slides Finally, the susceptibility analysis was carried out using two methodologies: Qproto, through which the rockfall susceptibility map was obtained by identifying the areal distribution of the phenomenon; and RotomapGis, through which a trajectory analysis of the falling blocks was obtained. This study underlines the importance of the use of innovative techniques in areas of difficult access such as Cumae Mount, obtaining a product able to support development of management plan oriented to an increased safety in the site in fruition perspective.

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Reconstructing the RSL of the I century BC in Campi Flegrei area: the case study of the archaeological ruins at Torregaveta

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Keywords: Gulf of Naples, Campi Flegrei, relative sea-level change, archaeological sea-level markers, bradyseism.

Torregaveta promontory is located along the western side of the Campi Flegrei volcanic area and is constituted by a high coast sector made of Neapolitan yellow tuff interrupted to the east by a low coast sector, characterized by gravel and sandy sediments of pyroclastic origin.

This coastal sector hosts the ruins of an ancient Roman maritime villa belonged to the Roman consul *Publio Servilio Vatia Isaurico* and ascribable to the half of the I century BC (Caputo, 2006).

During a direct underwater survey carried out in the study area, different structural features belonged to the villa were detected, measured, and interpreted as archaeological sea-level markers. In particular, in the northern sector, the submersion of the lowest level of *crepido* belonged to the ancient fish tank of the villa was measured at -2.94 m MSL and interpreted as sea-level index point (SLIP). Considering this submersion value, after a correction with respect to a functional clearance (Fc) of 0.2 m and an Indicative Range (IR) between the MHW and the MLW, a RSL of -3.34 m MSL was deduced for the half of I century BC. On the other hand, along the southern border of the promontory, the tufaceous platform found at the base of the apsidal area of the *nymphaeum* of the villa was interpreted as a Terrestrial Limiting Point (TLP), helping to establish an upper limit for the positioning of the RSL during the I century BC at -2.44/-2.94 m MSL, considering for this particular type of coastal building a Fc of 1.0/1.5 m.

The RSL calculated from the archaeological site of Torregaveta was compared with RSL data from the Roman fish tank at the Dragonara Cave (Caporizzo, 2021) and the *pila* of the Nisida Roman Harbour (Mattei et al., 2018). Then, the three RSL values were further compared to the GIA models available for the study area (Peltier, 2004; Lambeck et al., 2011) in order to assess the component of the vertical ground movement related to the local volcano-tectonic activity.

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Application of probabilistic fault displacement hazard analysis to The Anghiari - Città di Castello fault, upper Tiber valley, Italy

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Keywords: PFDHA, active fault, natural hazard.

Faulting of the ground surface is a localized hazard due to the occurrence of slip along active fault during a strong earthquake. It is an important issue especially for infrastructure like lifelines, power plant, dam and emergency facilities.

Generally, the approach to the fault displacement hazard is the avoidance of site characterized by fault and their nearby.

In Italy, the only tool that consider the fault displacement hazard is the seismic microzonation (Gruppo di Lavoro ms, 2008). Several authors provided a probabilistic known as probabilistic fault displacement hazard analysis (PFDHA), to evaluate the conditional probability of exceedance of a given displacement value for different style of faulting (Youngs et alii, 2003; Petersen et alii, 2011; Moss & Ross, 2011; Takao et alii, 2013; and Nurminen et alii, 2020).

In this work, the earthquake approach proposed by Youngs et alii (2003) have been applied to the Anghiari fault, (Northern Apennines, Sansepolcro basin, a NW-SE striking, NE dipping active normal fault belonging to the Anghiari-Città di Castello master fault. The occurrence of both principal and distributed faulting has been explored for two different rupture scenarios, for different locations along the strike and for different distances from the principal fault. The results are expressed in terms of hazard curves and maps for different probabilities of displacement exceedance in 200 years.

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Granitoids and pyrite bodies exploited similar crustal traps in the Gavorrano Intrusive Hydrothermal Complex (Tuscany, Italy)

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Keywords: crustal traps, pyrite deposits, magmatic-hydrothermal complex.

The 3D reconstruction of magmatic and ore bodies plays a major role in understanding the origin and emplacement mechanisms for magmas and hydrothermal fluids in the upper crust. The Gavorrano Intrusive-Hydrothermal Complex (GIHC, Tuscany, Italy) is an excellent case study in which intrusive and hydrothermal rocks, as well as sulfide ore bodies, are spatially associated.

The evolution of the GIHC starts in the early Pliocene with the sequential emplacement of a cordierite-biotite monzogranite and a tourmaline microgranite at the contact between the Paleozoic basement (metapelites) and the overlying Mesozoic limestone-dolostone formations. The small size of the Gavorrano intrusion (ca. 3 x 1 x 0.5 km) and its shallow emplacement level (ca. 5 km) resulted in a thin contact aureole (< 100 m) made of phlogopite-olivine marble and biotite-andalusite pelitic hornfels. A thin and discontinuous layer of vesuvianite-garnet exoskarn overprinted the marble along with the intrusive contact. An episode of hydraulic brecciation affected the host rocks and skarn.

The last stage is characterized by chloritization-silicification of the wall rocks and formation of ~30 Mt pyrite exploited during the XX century. The pyrite shows variable textural settings, from microcrystalline to coarse decimetric crystals in veins and it is associated with variable amounts of adularia, fluorite, and sulfide/oxide minerals as: pyrrhotite, magnetite, chalcopyrite, marcasite, sphalerite, and galena. Pyrrhotite and magnetite are also found as metric masses within the main pyrite bodies.

Surface and underground mapping, integrated by mining reports and drill logs, allow us to reconstruct the attitude and shape of magmatic and hydrothermal bodies. The GIHC has an overall asymmetric character. The western side is the location of the main ore bodies and the maximum thickness of the magmatic bodies (0.8 km) with an overall sub-vertical, west-dipping attitude. The ore bodies mantle the top and the west flank of the intrusion displaying, in vertical section, a sigmoidal shape with a steep west-dipping thick portion connecting upper and lower tails gently dipping to the west. The eastern side has sub-horizontal thinner microgranite multiple bodies with steep west-dipping offshoots.

The collected data point out the GIHC western side as the focus zone for both magmas and hydrothermal fluids. The overall geometries of the intrusive units and pyrite bodies suggest a sense of movement top-down-to-the-west. This close spatial and shape relationship between intrusive rocks and hydrothermal bodies suggests a common extensional tectono-magmatic regime capable to produce crustal traps (dilational structures) for magmas and ore fluids.

Evolution of the Tibet-Indochina orogenic system since 60 Ma: from NE India corner indentation to collapse and eastward flow of Tibet crust

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Keywords: Tibet, GPS, paleomagnetism, active deformation, crustal flow.

Existing models describing continental crust deformation require the coexistence of strike-slip faults and crustal blocks rotating between them, although the offset and the location of the faults are mostly unconstrained. A great amount of data collected in Tibet show that the central Plateau is undergoing horizontal dilatation with an E-SE-ward crust drift between the Sichuan and the EHS rigid buttresses (Clark & Royden, 2000). Conversely, others described the India-Eurasia collision as accommodated by the eastward extrusion of mega-blocks, bounded by continental-scale strike-slip faults, with a hundred km of lateral offset (Tapponnier et al., 1982). Paleomagnetism proved as a valuable tool to constrain the displacement of the major strike-slip faults and the crust behaviour of SE Tibet-Indochina. Several authors proposed that the upper crust is composed by hundreds of km wide microplates escaping since Oligo-Miocene (Li et al., 2017), while others related the scattered paleomagnetic rotations to the presence of 2-5 km wide blocks, which underwent independent rotation (Todrani et al., 2020). In this work we synthesized and re-evaluated the reliability -with modern and homogeneous criteria- all paleomagnetic data from Tibet-Indochina, evaluating the rotation values with respect to East-Asia. We focused on SE Tibet, comparing the vertical axis rotations with the present-day geodetic data, which show an active large-scale CW rotation around the EHS, at odds with the paleomagnetic rotation pattern. The Jurassic-to-Oligocene localities W of EHS show a prevalence of CCW paleomagnetic rotations, while the E-SE is mainly characterized by CW rotations in agreement with the current geodetic behaviour. However, we suggest that the widespread CW rotations from northern Indochina have been acquired since Oligocene, while Plio-Holocene localities show negligible rotations. Therefore, we concluded that the revised paleomagnetic rotations agree with a diffused deformation, mainly active between ~25-13 Ma, and are at odds with the present-day geodetic CW rotation and drifting of the crust around the EHS.

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Partitioning and bioavailability of trace metals on bottom sediments from two very different water reservoirs, Ridracoli and Conca Reservoirs

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Keywords: sequential extractions, leaching test, polycyclic aromatic hydrocarbons.

Ridracoli and Conca are both Reservoirs for the storage of drinking water in the Emilia-Romagna region of Italy but they differ in many ways. The Ridracoli reservoir is located upstream near the source on Apennines, it can store $33.06 \cdot 10^6$ m^3 of water and shows the formation of a seasonal anoxic layer on the bottom in late summer (Toller et al., 2020). The Conca reservoir instead is located downstream in the Romagna plain almost at the mouth near the Adriatic Sea and can store a volume of $1.2\ 10^6$ m^3 of water. Environmental conditions of Conca reservoir vary due to the management, which opens and closes the bulkheads seasonally, leaving the sediments submerged for half the year and dry for the other half.

After a general characterization of the sediments of the two study sites, representative samples were then selected for further investigation thanks to the Leaching test (EN 12457-2, 2002), the BCR sequential extraction according to the three-step methodology proposed by the European Community Bureau of Reference (Rauret et al., 1999; Sahuquillo et al., 1999) and Soxhlet extractions for polycyclic aromatic hydrocarbons (PAHs) (Fabbri et al., 2013).

Overall, the sediments have good quality standards in both sites, even if differences in partitioning and bioavailability for selected elements emerge between the two sites and within each reservoir. The most interesting elements, as Fe, Mn, Cu, Cr, Ni, Pb, and Zn, were then explored and environmental assessments were carried out.

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Formation mechanisms of inflated lava tubes: the case of La Corona System (Lanzarote, Canary Islands)

Tomasi I.[1], Massironi M.[1], Meyzen C.M.[1], Sauro F.[2], Pozzobon R.[1], Penasa L.[1], Santagata T.[3], Martìnez-Frìas J.[4] & Mateo Mederos E.[5]

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Keywords: volcanic caves, lava tubes, Inflation, planetary geology, analogues.

Multidisciplinary efforts are currently boosted by an urgent need to improve our understanding of Earth's lava systems in the perspective of their future exploration on other rocky bodies of the Solar System.

Among the many structures documented in lava fields, the lava tubes are the most enigmatic. They constitute a peculiar type of caves dug by channels of molten lava. These roofed conducts are very efficient thermal structures enabling channelizing lava transport over long distances. The longest lava tubes are found on volcanic islands (e.g. Hawai'i, Canaries, Iceland, etc.) or volcanic plateau characterised by a gentle slope (<2°). These structures are easily recognizable from the surface by skylights and collapses of the roof forming pits chains, which allow to reconstruct of the path of the duct. Analogous conformations of aligned collapses have been seen on the surfaces of Mars and the Moon (Haruyama et al., 2012). This discovery has led to a growing interest as these structures could be suitable sites for future exploration and/or permanent human settlement.

Located in the north-eastern part of the island of Lanzarote (Canary Islands), the La Corona lava tube system, with its 7.6 km of total length (~8.9 km of cave development) and 10-20 m diameter, is one of the world's largest volcanic cave complex. It is one of the most studied, due to the particular geological context in which it arose. Indeed, the Canarian archipelago represents both long-term and spatially focused volcanic activity over a poorly mobile tectonic plate [less than ~20 mm/yr, during the last 30 Ma (Gaina et al., 2013)]. This environment identifies the Canaries as one of the best terrestrial analogues of the Martian one-shell plate volcanism (Meyzen et al., 2015).

What makes this inflated lava tube so interesting is a pyroclastic layer, derived by the initial Strombolian activity of La Corona vent (Carracedo et al., 2013) and interleaved within the lava flows crossed by the tube. The layer follows the tube for at least one third of its extent and we speculate that it could have been pivotal for the inception of the inflation process. By analogy, similar geological settings could be favourable for the formation of lava tubes on rocky bodies like Mars and the Moon, where weak layers of pyroclastic deposits or fine regolith are thought to be common.

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Morphostructural evolution of rocky cliffs and relationships with coastal processes: examples from Adriatic coast in Marche region (Italy)

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Keywords: coastal cliffs, geomechanics, remote sensing, geomorphology, wave erosion.

Rocky coasts represent landscape units with high economic, socio-cultural, and touristic values. Both hard and soft rocky cliffs characterize the central Adriatic coastal sector in the Marche region (Italy). Here, either active or relict landforms occur and, a strong litho-structural control on the gravitational morphodynamics has been recognized (Troiani et al., 2020). In such landscape contexts, the assessing of rock slope instabilities is possible using different traditional and advanced structural and geomorphological investigation techniques; furthermore, these techniques can take advantage of the use of DEM-based land surface quantitative analysis and, of remote sensing.

The complex morphodynamics, characterized by processes which act at different space and time scales, brings to various evolutionary scenarios of the coastal slope instabilities. In particular, the geometries, spatial distribution, and frequency of the fractures play an important role in the weathering processes especially for the loss of tensile strength of the rock mass. In this way, analysing the behaviour of the limestone, marl and sandstone lithologies outcropping along different cliff sectors, indicate the role and the magnitude of the mechanical and physical proprieties of the rocky mass related to the weathering processes.

Furthermore, the Adriatic Sea is a semi-enclosed basin where coastal orography can play a major role in wind forcing and in the wave regime. The wave energy is linked to the low bathymetric gradients and coastal geometry dominates the onshore wave propagation and transformation as well as the eventual impact on the rocky cliffs.

Based on preliminary studies, the cliff erosion rates seem to change in different lithologies with various strengths of the rock mass rather than as a function of the spatial variations in wave energy.

Rocky coasts in the central Adriatic Sea offer a rare opportunity for better understanding the predisposing role of the morphological and structural setting on coastal slope instability (Torre, 2019; Troiani et al., 2020) and quantify the wave energy impact on the rocky cliffs.

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Variations in the recent volcanism of central and southern Afar: new insights from geochemistry and petrography

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Keywords: Afar depression, Stratoid Formation, Gulf Basalts Formation, continental break-up, rifting.

Unravelling the spatial and temporal evolution of basaltic magmatism at continental rift system is crucial to understand the role of magma and the variations in the mantle source during the break-up process. In the Afar depression the Stratoid and Gulf Basalts Formations, ranging from ~4.5 to ~0.6 Ma, preceded the ongoing rift segments activity and represent ideal targets to study the magmatic evolution during continental break-up. The Stratoid Formation covers 70% of Afar and is dominated by sequences of flat lying fissural basalts reaching 1500 m high, with sialic products from central volcanoes in the uppermost part (Barberi & Santacroce, 1980). Based on age and morphological observations (changes in texture and freshness), Kidane et al. (2003) divided the Stratoids in Lower and Upper and distinguished them from the Gulf Basalts. Nevertheless, the geochemical characteristics and origin of these two formations are still debated. In this work we present petrographic and major and trace elements analyses of 24 Stratoids and 15 Gulf Basalts samples collected during the February 2020 campaign while 10 are from the Afar repository of the University of Pisa. Overall, our datasets encompass the Karrayu, Tendaho, Dobi, Eli Adda Do and Dulul grabens. The samples are Hy-Ol normative with some Qz normative, ranging from basalts to rhyolite and mostly aphyric. The study of 32 mafic samples (MgO% from 4 to 8.5) incompatible elements indicate variations in the magma source and in the primitive melts. The Gulf Basalts and the Stratoid Formations differ in highly incompatible elements ratios (e.g., Th/Ta, Nb/U) indicating differences in the primitive melts, possible related to variation in the degree of partial melting or in the source composition. Variations of HREE and HFSE ratios sensitive to partial melting in the garnet stability field (e.g., Zr/Y, Tb_N/Yb_N) indicate a shallower melting column depth for the Lower Stratoid and the Gulf Basalts respect to the Upper Stratoids. The shallower melting column of the Gulf Basalts respect to the Upper Stratoids supports the idea of the Gulf Basalts being the first products associated with strain localization (Stab et al., 2016). The shallower melting column of the Older Lower Stratoids respect to the younger Upper Stratoids may indicate two spatially distinct sources with similar composition but different depth of melting.

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Lithostratigraphy and the structural setting of the middle Maira Valley (Western Alps, Italy)

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Keywords: Western Alps, Maira Valley, Liguria-Piemonte unit, continental margin unit.

The E-W striking Maira Valley offers a spectacular geological section of the southern part of the Western Alps, from the Dora-Maira internal crystalline massif (to the east) to Liguria-Piemonte and Briançonnais units (Piana et al., 2017). Based on original field mapping (Toso, 2021), the present study illustrates lithostratigraphy and the structural setting of the middle Maira Valley between Prazzo and Lottulo villages. Main geologic features of this area are in Franchi (1898), Michard (1967) and Servizio Geologico di Italia (1971).

In the investigated middle Maira Valley two different units were distinguished in this study, i.e. a continental margin unit (here reported as Maira-Elva unit) in lower structural position and an overlying Liguria-Piemonte oceanic unit (here mapped as Costa Cavallina unit).

The continental margin unit consists of Lower Triassic quartzite and minor sericite-rich schist, followed by a platform succession (up to 400-500 m-thick) of Middle-Upper Triassic marble and dolomitic marble with intercalated calcareous schist and micaschist. Then, up-section Norian dolomitic and Rhaetian-Hettangian calcareous schists are unconformably covered by Cretaceous carbonate-micaschist and phyllite.

The Liguria-Piemonte oceanic unit consists of prevailing glaucophane-bearing carbonate-micaschist embedding metric to pluri-decametric bodies of serpentinite and metabasite. The carbonate-micaschist laterally can pass to two-micas micaschist and phyllite and contains discontinuous levels and bodies of marble and quartzite up to metric in size.

Field data suggest four deformation phases common to the two mapped units. The D_1 and D_2 phases are recorded by folds and pervasive axial plane foliations (reported as S_1 and S_2) marking the transition from blueschist-facies to green-schist-facies metamorphic conditions. The tectonic contact between the two units is parallel to the S_1 foliation and folds related to the D_2 phase are typically E-verging. Later folds and crenulations are mainly characterized by NW-SE and ENE-WSW trending axes and usually high-angle axial planes. Peculiar top-to-W-SW S-C fabrics have been often recognized in particular in the schists. The most pervasive post-metamorphic faults are high angle normal to strike-slip faults trending E-W/ENE-WSW, NW-SE/WNW-ESE, and N-S.

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Using chemical fingerprint to assess proximal to distal correlations of Campania tephra in the last 200 ka

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Keywords: pre-Campanian Ignimbrite, tephra markers, $^{40}Ar/^{39}Ar$ dating, Sr and Nd isotopes, eruptive history.

Tephrochronology can be a fundamental tool to obtain high-resolution records for past events. However, its use is strongly influenced by the availability of accurate reconstructions of the eruptive history of a volcanic source. When such reconstructions are at our disposal, we can achieve robust correlations between distal and proximal deposits. However, where the volcanic area is still active and at the same time subject to rapid urbanization, well exposed proximal-intermediate outcrops of deposits from old eruptions can lack, because of their erosion or burial. This is the case of the eruptions older than the Campanian Ignimbrite (CI; 40 ka), whose record is very fragmentary in the Campania Plain.

In this study, we try to get around the problem by working on tephra levels embedded within the successions of two boreholes. The two drilled sites are located at different distances from the potential volcanic sources, respectively at the proximal site of Camaldoli della Torre (Di Renzo et al., 2007), on the southern slopes of Somma Vesuvius, and in a medial-distance site in Sarno alluvial plain (Santo et al., 2019). In the frame of the FUTURE research project (PRIN 2017), a multi-methodological approach was carried out making the first attempt to correlate the volcanic products older than the CI embedded within the deposits and tephra markers widely spread in the Mediterranean Sea and intermountain basins of Southern-Central Apennines.

A complete chemical fingerprint has been provided by acquiring major and trace elements data on the glasses extracted from the tephra layers. In addition, we obtained $^{40}Ar/^{39}Ar$ age on sanidine from two layers of the Sarno drill hole. The joined determination of Sr and Nd isotopic compositions can play a key role in recognizing the volcanic source and, even in some cases, the eruptive event that produced the investigated level. Therefore, the $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ were determined on glasses and minerals (feldspar and pyroxene). Despite the relative proximity of the two boreholes (20 km in a straight line), we found that the records are not fully overlapping, covering time spans of different lengths. However, this fact has not precluded us from recognizing some tephra markers from Campania volcanic sources. These markers are widespread in different Late Pleistocene marine and terrestrial archieves providing new insights to the still incomplete reconstruction of the eruptive activity of Campania volcanoes.

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Surface faulting and ESI 2007 intensity accompanying the Dec. 26, 2018, Mw 4.9 Fleri earthquake, Mt. Etna volcano, Italy

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Keywords: earthquake, Mt. Etna, ESI-07 intensity scale, fault rupture, structural analysis.

The Dec. 26, 2018, Fleri earthquake is the strongest seismic event recorded on the Etna volcano in the instrumental era. It was the mainshock of a seismic crisis which accompanied an eruption on the eastern flank at the end of December 2018. We collected and mapped the earthquake environmental effects (EEEs) starting from the morning after the mainshock. The effects observed were mostly ground ruptures along the Fiandaca Fault, permanent ground deformations and some small landslides. We used the collected data for evaluating the macroseismic field using the Environmental Seismic Intensity scale (ESI-07) (Michetti et al., 2007). Maximum intensity is I_{ESI} IX between Pennisi (CT) and Santa Maria La Stella (CT). We compared our intensity results with the macroseismic data measured with the European Macroseismic Scale 1998 (EMS-98) for the same earthquake and others that occurred in the same area. For the EMS-98, maximum intensity is I_{EMS} VIII between Pennisi and Fleri (QUEST WG, 2019), showing disagreement with the ESI-07 data. It is important to note that the intensity of the traditional macroseismic scales might be affected by the introduction of new building codes, resulting in a decrease of macroseismic intensities for earthquakes occurred in the last decade (Ferrario et al., 2020). The collected data allow us to suggest that the ESI-07 works better than traditional macroseismic scale in the seismotectonic environment of Mt. Etna volcano, where damage is concentrated along the trace of surface faulting. As already observed at Ischia (Nappi et al., 2021), the ESI scale seems to provide a more authentic description of the effects of shallow-focus volcanic earthquakes, allowing a consistent comparison of other local seismic events occurred in the last centuries.

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After the Ice: geomorphological evolution of the Leone and Aurona proglacial areas (Lepontine Alps) in relation to local geodiversity

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Keywords: proglacial areas, multitemporal analyses, remote sensing, geodiversity, Alpe Veglia (Lepontine Alps).

Proglacial areas, defined as the surfaces left free form ice since the Little Ice Age (LIA) (Carrivick & Heckmann, 2017), represent one of the most sensitive environments to climate change, where the interplay of different geomorphic processes produce a great variety of landforms and features (i.e., geodiversity). One of the most impressive landmarks within this context is the presence of imposing moraine ridges dating back to the LIA. Besides these prominent features, glacial snout retreat allow permafrost dismantling and the increasing of different types of paraglacial processes (Ballantyne, 2002), related to water- and gravity-activity. In this framework, peaks of sediment yield could be recorded due to the presence of loose or poorly consolidated glacial deposits in glacier forelands, having effects, in terms of geomorphic risk scenarios, even far from sediment source. Running waters action contributes to these dynamics favoring unconsolidated sediments dismantling and genesis of proglacial lakes in correspondence of morphological hollow, later becoming potential sediment sinks. The highly geodiversity of such environments hence complicate the analysis of sediment connectivity which could reflect very local patterns (Mancini & Lane, 2020).To perform a multitemporal evaluation of dynamics affecting a proglacial region, the focus has been put on the last seventy years evolution of the adjoining Aurona and Leone proglacial areas, in the Alpe Veglia area (Lepontine Alps, Italy), characterized by different geomorphological features and approachable along a glaciological trail (Zanoletti et al., 2017). A multitemporal analysis on the historical archives allows to identify the main evolution stages of the proglacial areas, individuating the hot-spots of changes in the time span 1952-2018, among which LIA moraines, permafrost-related debris bodies, proglacial lakes. A quantitative estimation of these changes is ongoing to be performed through a combination of field survey and remote sensing activities (photointerpretation, digital photogrammetry, Structure from motion), as well as through in-site instrumentation for sediment yield measuring. These results will be considered in a wider framework of analysis, in comparison with other selected proglacial areas featured by even more different geomorphic traits in the Central Western Italian Alps.

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Geomorphological characterization of the coastal area between Agropoli and Ogliastro Marina (Campania, Italy)

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Keywords: **c**oastal changes, sea level variations, geomorphological map.

In the Agropoli-Ogliastro coastal area, the beauty of the landscape is the evaluable result of a complex long-term geological and geomorphological evolution. This area is part of the northern Cilento promontory along the Tyrrhenian coast of Southern Italy and falls in the "Cilento, Vallo di Diano and Alburni National Park" in Campania region. In this attractive coastal landscape, depositional and erosional landforms, located both above and below sea level, provide the basis for the reconstruction of the main coastal changes that occurred during the Quaternary period and related to relative sea-level variations. Since the 1950s, several authors focused their studies on the main evolutionary stages that characterized both the emerged (e.g. Blanc & Segre, 1953; Cinque et al., 1994; Iannace et al., 2001 and references therein; Bini et al., 2020) and submerged coastal areas (Aiello, 2019 and references therein) of the northern Cilento.

However, the interpretation of the large amount of depositional and erosional landforms scattered along the whole coastal sector can be still considered a challenge of scientific interest, in order to reconstruct the geomorphological evolution of this area under sea-level-change conditions. Therefore, this paper aims at giving a further contribution to this issue by providing a geomorphological map at 1:25,000 scale of the coastal and marine areas of the northern Cilento Promontory. The map covers an area of about 500 km^2 and is the result of the integrated analysis of different types of data provided by literature, aerial photos, on-site investigation, remote sensing and high-resolution bathymetric maps. The detected landforms were grouped based on the main controlling factors that drove their Quaternary evolution. In particular, several landforms generated by coastal erosion processes, which probably occurred between the Upper Pleistocene and the Holocene, were recognised and mapped. The result is the geomorphological characterization of the Northern Cilento coastal-marine area and the definition of the main active geomorphic processes in the area. This can be considered an intermediate step of a study aimed at reconstructing the long- and short-term evolutive model of the whole Cilento coastal sector.

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The Onset of the Messinian salinity crisis recovered from a new drill core: sedimentological, geochemical and bio-cyclostratigraphical evidence for the pre-salt evaporitic-carbonate paleoenvironment in the Caltanissetta Basin (Sicily, IT)

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Keywords: Tripoli Formation, Calcare di Base, onset of the MSC, Caltanissetta Basin.

After more than 50 years of research, the Messinian Salinity Crisis (MSC) stratigraphy is still controversial. The early Messinian phase (7.2 - 5.97 Ma) preceding the MSC has already been investigated in the Caltanissetta Basin. Although the Tripoli Formation and "Calcare di Base" (CdB) have been extensively studied, the stratigraphic reconstruction and the comprehension of the Messinian events still remain open questions. This is particularly the case of the CdB that, despite few studies have investigated its large spectrum of depositional facies, it has been at the centre of a fiery debate between different 'schools of thought' about its genesis, environmental conditions and timing of deposition. The CdB was commonly considered as the first evaporitic unit of the Messinian succession in Sicily. The variable ages obtained at the base of the CdB beds was considered indicative of a diachronous start of the MSC (Rouchy and Caruso, 2006). However, Manzi et al. (2011) suggest that the CdB does not correspond exclusively to the beginning of the MSC and that it rather consists of three carbonate facies characterizing different stages of the MSC.

The present study aims to reveal the petrographic, mineralogical and geochemical characteristics of the MSC sediments from the freshly drilled core 3AGN2S04, in order to reconstruct the environmental changes leading to the MSC during the transition from the Tortonian marine conditions to the Messinian evaporitic environments. We also carry out a detailed facies characterization of the evaporitic limestones of the CdB, to unfold the significance of this complex facies.

The sedimentological and mineralogical analysis revealed that core 3AGN2S04 consists of the marginal facies of the Tripoli Formation transitionally passing to the typical facies of the CdB. The stable isotope signals, the variation of the carbonate fraction and the presence of halite pseudomorphs and gypsum relics within some beds of the brecciated facies of the CdB suggest the occurrence of hyperaline conditions alternating with short input periods of fresh water. The high amount of organic material in the core, the brecciated structure of the evaporitic limestones and the diagenetic processes seem to be closely linked. The local transition between the upper part of the Tripoli Formation and the CdB reflects a worsening of marine connections between the Mediterranean and the Atlantic Ocean, indicating that during the late Messinian the stressful environmental conditions were constant in the central Mediterranean shelf zones. Marine inputs were not important enough to balance the effects of climate fluctuations and the evaporation / precipitation ratio in the semi-enclosed basins assumed in this paper.

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Improving seismic hazard models using Greek and Roman monuments

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Keywords: earthquakes, historic monuments, probabilistic seismic hazard analysis (PSHA), seismic risk.

Italy's history is marked by destructive earthquakes. These can cause extensive socioeconomic damage, as recently illustrated by the 2009 L'Aquila and 2016/17 Central Italy sequences. The occurrence of earthquakes in a certain time interval - and the associated shaking at a specific site - can be estimated probabilistically with Probabilistic Seismic Hazard Analysis (PSHA). PSHA is used to develop national or international seismic hazard models on times scales typically ranging from 50 to 2500 years, such as the MPS04 (esse1-gis.mi.ingv.it, 2004) for Italy or SHARE for Europe (Woessner et al., 2015; www.share-eu.org). Here we verify the reliability of these two hazard models in the long term (~2500 years) using monuments from Greek and Roman times (i.e., columns and temples) that either have or have not suffered damage from historical earthquakes. These data have not been used to construct these hazard models and serve as an independent verification of their estimates. (A similar method was recently proposed by using precariously balanced rocks as geological indicators to improve a hazard model (Rood et al., 2020).)

To verify the reliability of the hazard models, we estimate the probability of collapse for selected monuments at several sites (e.g., Siracusa, Selinunte, Capo Colonna) using two different methods: 1) calculating the risk integral over the models' hazard curve (i.e., demand) and the monuments' fragility function (i.e., capacity), and 2) using the probability-based Demand and Capacity Factor Design (DCFD) method (Cornell et al., 2002). The probabilities of collapse are then compared to an acceptable risk threshold and the actual structural damage due to historical earthquakes (i.e., the presence or absence of damage). These comparisons allow us to assess whether the seismic hazard estimates at those sites are realistic and eventually help to improve the hazard models.

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Study of the Monte Amiata mafic enclaves: a window into the evolution of its volcanic system

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Keywords: Monte Amiata, Central Italy, enclaves, petrography.

Monte Amiata is a Pleistocenic volcano located in southern Tuscany at about 40 km NW of Vulsini volcanoes, where the Tuscan and the Roman magmatic provinces overlap. It is composed by trachydacitic to olivine latitic lava flows and domes emplaced in a very short time (between 305 and 231 ka; Laurenzi et al., 2015) and grouped into the "Basal Trachydacitic Complex" (BTC), the "Dome and Lava flow Complex" (DLC) and the "Olivine Latite final lavas" (OLF; Conticelli et al., 2015).

The three main petrographic features are: 1) the presence of sanidine megacrysts, mostly visible in the rocks emplaced during the second phase of the volcanic activity (Ferrari et al., 1996); 2) the occurrence of abundant rounded fine-grained magmatic enclaves, which suggest that a possible mingling process occurred at Monte Amiata; 3) the presence of mafic olivine latitic lava flows, characterized by an intermediate composition between the early silica-rich volcanic rocks and the most mafic enclaves hosted in Monte Amiata volcanic,rocks.

Here, we report the preliminary data about the origin, the evolution and the distribution of the magmatic enclaves hosted by Monte Amiata lavas. In order to do this, thin sections were studied under the optical microscope, chemical analyses were performed, and statistical survey on the distribution of the magmatic enclaves and their variations in size was made. These preliminary results suggest that Monte Amiata mafic enclaves vary in composition and increase in size and abundance from those hosted by domes and lavas with the highest silica contents to those with the lowest silica contents.

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Thermal decomposition of cement-asbestos at 1100 °C: how much “safe” is “safe”?

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Keywords: cement-asbestos, thermal treatment, reuse, nanoparticles, leaching tests.

Asbestos minerals, namely chrysotile, and fibrous amphiboles, have long been used as components in construction materials, as for instance in cement-asbestos slates used in roofing, where asbestos fibers increase mechanical strength. Since the banning in Italy in 1992 of asbestos-containing material (ACM), the current legislation provides for the following remediation strategies: i) encapsulation, ii) confinement and iii) removal and landfilling of ACM. None of these solutions represents an ideal one, since the risk of fiber dispersion in the environment still remains high and it is lost forever a potential secondary raw material (SRM). Inertization of ACM and recycling represent therefore a smarter solution, in a contest of circular economy. In this respect, a stock of cement-asbestos panel fragments (about 40 kg) was thermally treated in air at 1100 °C and characterized mineralogically and chemically by the means of SEM-EDS, TEM-EDS, XRF, and XRPD techniques, to ascertain the effective deactivation of the harmful asbestos fibers and to determine any potential hazard represented by the inert SRM. On the one hand, the results confirmed the deactivation of the harmful asbestos fibers. On the other hand, the SRM, milled in view of future applications, when analyzed by dynamic laser scattering (DLS) revealed a trimodal grain size distribution with a significant nanometric fraction, possibly inherited from the recrystallization process, which may cause health and environmental concerns. Moreover, leaching tests revealed that the SRM is capable to release significant quantities of anions and trace metals, mainly SO_4^{2-}, F^- and Cr^{6+}. These may have adverse effects on the environment and human health in case seepage water could reach drinking water supplies, and also as regard potential reuse in the ceramic and cement industries. Since the nanometric fraction other than being a potential problem by itself also cause higher elemental release in solution (higher surface/volume ratio), possible routes to control the grain size distribution through adjusted thermal treatment conditions and microwave assisted grinding are under study within the frame of the present project.

Application of Rock Engineering System (RES) for debris flow susceptibility mapping in Alpine basins (Western Alps)

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Keywords: landslide susceptibility mapping, rock engineering system, OpenGeodata, debris flows.

Hazard mapping and risk assessments are fundamental tools for local authorities to support the development of protection plans and the design of appropriate risk mitigation measures. The spatial probability of landslide occurrence in a given area (Brabb, 1984) is expressed by susceptibility map, which identifies sectors prone to triggering. In mathematical terms, susceptibility can be defined as the spatial probability of occurrence of landslide, given a set of geo-environmental conditions (Guzzetti et al., 2005; Reichenbach et al., 2018).

In the alpine environment, debris flows are one of the most dangerous natural events with a high potential of destruction due to high kinetic energy and velocity. The scope of this study is to propose a quantitative, rapid and low-cost methodology for mapping debris flow susceptibility at the regional scale using available open-access data and geodatabases.

Bedrock lithology, quaternary deposits, slope, hydrological network, degree of fracturing, landslide activity, land use and curvature were selected as predisposing factors. Their mutual interactions were described and quantified using the Rock Engineering System (RES) methodology (Hudson, 1992). The method is based on a matrix approach capable to qualitatively coding the mutual interactions between the parameters and returning a "Debris flows susceptibility index (DfSI)".

The illustrated approach can represent a useful standardized tool, universally applicable as it is independent of the type and characteristics of the basin.

The prosed methodology has been applied to produce a susceptibility map of the Upper Susa Valley (Torino, Western Alps), where a number of debris flow events were recorded.

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Wehrlitization process and hypothesis on the composition of the metasomatic agent in the mantle Xenoliths of the Mt. Vulture (Basilicata)

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Keywords: wehrlites, metasomatism, mantle xenoliths, orthopyroxene.

This work focuses on the petrographic and geochemical characterization of mantle xenoliths suite from Mt. Vulture (Basilicata). Through the study of the textures, we characterize the interaction between the mantle peridotite and a metasomatic agent. Main features are reabsorption gulfs, intergranular glass, fluid inclusions, spongy structure, reaction coronas and the presence of intercrystalline veins. Notably, corona textures of olivine and clinopyroxene surround relict orthopyroxene. In addition, there is an extensive presence of neo-genetic vermicular spinel (Pettinella, 2020). Apatite, amphibole and phlogopite complete the metasomatic assemblage. These features suggest a pervasive interaction between peridotite and the metasomatic fluid. The presence of relict orthopyroxene indicates that the metasomatic process ceased before the wehrlitization was complete (Patkò et al., 2020). In fact, in different xenoliths we observed progressive growing of the reaction corona around the orthopyroxenes. During early stage, the orthopyroxene preserves his original habitus, during late stage the orthopyroxene is completely substituted by clinopyroxene. The glasses show a huge compositional variety, particularly in the reaction coronas. The amounts of SiO_2 and Al_2O_3 decrease outwards the reaction coronas, instead the amounts of Na_2O and CaO increase. The voids testifies the presence of fluids and vapor during the subsolidus dissolution of the orthopyroxene (in particular, OH^- and K to crystallize the phlogopite). The wehrlitization process can be summarized as follow: $4MgSiO_3$(enstatite) + $CaMg(CO_3)_2$(dolomite) = $2Mg_2SiO_4$(forsterite) + $CaMgSi_2O_6$(diopside) + $2CO_2$ Through the analysis of the glass phases and the petrographic features of the xenoliths we assume that the metasomatic fluid is SiO_2-undersaturated and CO_2-enriched (probably with an alkali carbonatitic composition) (Rosatelli et al. 2007). The wehrlitization process occurred in the spinel stability range, probably between 0.8 GPa and 1.7 GPa (Jones et al., 2000).

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Geopolymer foams obtained starting from Sicilian volcanic precursors

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Keywords: geopolymer foams, volcanic precursors, porous geopolymeric foams.

In the last years, a particular attention has been paid to "green" materials. Among these there are geopolymers, inorganic polymeric materials obtained by mixing a solid aluminosilicate precursor with an alkaline solution (Davidovits, 1991). They represent innovative products in terms of recycling and sustainability since their synthesis is carried at low temperature and involves the re-use of waste materials from human activity (Mina, 2014). Moreover, they produce low emissions of CO_2 and energy consumption compared to Portland cements (McLellan et al., 2011). Recent innovations in geopolymer technology have led to the development of various types of geopolymeric products, including highly porous geopolymer-based foams, which are formed by the addition of foaming agents to a geopolymer matrix (Zhang et al., 2014). The hardened structure which results in the formation of a low-density material can be used for applications in acoustic panels or for thermal insulation purposes. This study was carried out within the project "Advanced Green Materials for Cultural Heritage" (AGM for CuHe), carried by the University of Catania, which aims to use and valorize local raw materials as precursors to produce geopolymers. This study focused on analysing the mechanisms of formation and the structure of geopolymer foams by using different local volcanic materials that are available and suitable in terms of chemical, mineralogical, mechanical and aesthetic compatibility, as required by good conservation practices (Barone et al., 2020; Occhipinti et al., 2020). The samples obtained were analysed under X-Ray powder diffraction (XRD) and scanning electron microscope (SEM), in order to evaluate their chemical, textural and structural features. Preliminary results have shown that the porosity of geopolymers - whose pore volume and shape is varied, according to the kind and percentage of the foaming agent used - can be artificially tailored for the final application without losing the structure of the polymeric matrices. This allows to obtain binders with low dry unit weight and controlled porosity that may have good adaptability to the substrate and good breathability. This may open the way to the synthesis of alternative light materials, highlighting their potential role in Cultural Heritage preservation where homogeneous, compact amorphous matrix and a colour - which has to simulate the original stone - is required.

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Late Quaternary paleoenvironmental reconstruction of Faideh fluvio-lacustrine sequence in the Kurdistan Region of Iraq: a palynological approach

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Keywords: palynology, Late Quaternary, paleoenvironmental reconstruction, geoarchaeology, Ancient Mesopotamia.

We present preliminary results derived from the palynological analysis of the Faideh fluvio-lacustrine sequence located in the north-western Kurdistan Region of Iraq (KRI), in the proximity of Mosul Lake along the Tigris River. The study is part of a multidisciplinary project aimed at reconstructing the evolution of the Late Quaternary landscape of Upper Mesopotamia. In this multidisciplinary approach, the palynological analysis helped in adding information on the local environmental setting during the first attempts of cereal cultivation and the beginning of urbanization. Moreover, our approach permitted to distinguish among climatic and anthropogenic factors controlling changes in the vegetation and land use shifts.

The sequence is composed of 5m of sediments and in this study, we considered the upper portion of the sequence (0 to 2.5m), which is radiocarbon dated between 29991±100 years and 9040±40 years BP. In detail, this part of the sequence is composed by fine sand to silt-clay layers with thin layers of organic matter and calcium carbonate nodules, interpreted as the result of sedimentation along an oxbow lake. Preliminary results show that the vegetation appears to be dominated by herbaceous plants indicating an open steppe environment. A decline of the species representing humid environments (hygrophilous trees such as *Populus*, Cyperaceae and *Typha* among the hygrophilous herbs and aquatic plants such as *Hydrocharis*) and the increase of species representing the arid ones (mostly herbs such as Asteraceae, Poaceae and Chenopodiaceae) is registered towards the top of the sequence. In the uppermost layers of the sequence, cereal pollen and other anthropogenic indicators (Behre, 1986; Mercuri et al., 2013) represent a set of species that became the cultivated cereals with their associated wild flora of segetal and ruderal species when agriculture has developed.

These results are very important as they show the climatic trend moving towards the aridification of the area and then, with the introduction of the agriculture, the anthropogenic contribution to this natural change that varies the land use of the territory.

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What steers deformation in carbonate multilayer systems? New perspectives from the Belluno Thrust, Italian eastern Southern Alps

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Keywords: mechanical stratigraphy, carbonate rocks, fold, Alps, aseismic-vs.-coseismic deformation.

The understanding of deformation modes in carbonate fold-and-thrust belts has made giant strides in recent years by means of multidisciplinary and multiscalar studies. This notwithstanding, the mechanics of the early increments of localization by folding and thrusting remain poorly known due to the obliterating effects by the later structural evolution of mature belts. Aiming to better elucidate the incipient deformation history of such contractional belts, we analysed the carbonate multilayer footwall of the Belluno Thrust (BT), one of the most external and S-verging thrusts of the eastern Southern Alps (Italy). The BT footwall is formed by a c. 600 m thick Meso-Cenozoic carbonate multilayer characterized by significant compositional heterogeneities, with calcite, phyllosilicate minerals and chert as principal components. Its current structural framework is complex as documented by coexisting i) south-verging asymmetric folds, ii) faulted folds, cut by slip planes with centimetric to metric throw, iii) SC-C' fabrics in marly layers, and iv) fault-related cataclasites. We find evidence of the early shortening in mesoscopic upright folds. Further shortening formed asymmetric folds with gently N-dipping backlimbs and steeply S-dipping (or overturned N-dipping) forelimbs. Strain is well distributed within the marly layers, which act as multiple decollements during the formation of discrete fault planes, forming duplex structures and SC fabrics. Thrust faults, mostly along gently dipping backlimbs, are not associated with fracturing or cataclasis, suggesting distributed strain by layer-parallel shearing. Cataclasis and veining localise instead where thrusts/reverse faults cut across the steeply dipping (locally even overturned) forelimbs.

We propose that deformation progressively evolved from layer-parallel shortening to folding and layer-parallel shearing (initial phases) and, finally, to faulting and cataclasis (final phases) as a function of the dynamic interplay of the following factors: i) the geometrical relationships between fault orientation, fold attitude (in the forelimb and backlimb domains) and stress field, ii) the lithotype, which we account for by referring to the ratio between the cumulative thickness of the outcrop marly layers and the total measured stratigraphic thickness, iii) the vertical organization of the marly beds regarding their spacing and frequency, iv) the involvement of fluids during deformation, v) the mineral assemblage of the involved layers.

We conclude that these parameters, especially (i) to (iii), play a significant role in steering strain localisation and partitioning during continuous shortening within fold-and-thrust belts, governing the transition from overall aseismic creep (on backlimbs) to coseismic rupturing (on forelimbs) at the scale of mesoscopic structures and, possibly, of entire belts.

Deep Seated Gravitational Slope Deformations in Southern Apennine: the case study of Sannio-Matese mountains

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Keywords: DSGSDs, landslide deformation, DInSAR, slope stability modelling.

Deep Seated Gravitational Slope Deformations (acronym DSGSDs) move with velocities of between mm/yr and cm/yr, mobilizing significant rock volumes, even of the order of km^3, in a relatively long time. Due to their variable size and in relation to the characteristics of the involved materials, it could be very difficult to exactly identify landslide geometry, especially at depth. A further element of complexity is represented by the frequent existence of a band of distributed strain within the mass, rather than a well-defined failure surface. In the intricate geological frame of Southern Apennine, characterized by structurally complex setting, areal distribution and geometric relations of different tectono-stratigraphic units result in an even complex reconstruction. On this basis and considering the presence of several DSGSDs in the southern sector of the chain that have been previously identified, but not comprehensively studied, in this work, the DSGSDs identified by Di Nocera *et al*. (1993) and Budetta et al. (1994) in the area of San Lupo (Sannio-Matese mountains, Benevento Province) were analysed with the aim of providing new data about landslide geometry, kinematics and geologic control. In this perspective, a modern approach to the study of these phenomena has been adopted in this work, acquiring new data through field surveys and by using photogeological interpretation, geomorphological analysis and interferometric SAR techniques to detect and localize the entity of deformations. Interferometric data, obtained from acquisitions of ERS 1/2, ENVISAT and COSMO-SkyMed satellites, have been compared to results of photointerpretation and field data to produce a geomorphological map. The whole dataset (literature and field data) has been used to achieve stability modelling of the studied phenomena. The analyses indicated that: i) in the area three major DSGSDs are present, ii) these landslides involve mainly the "*Coltri Sannitiche*" terrain (Selli, 1962) iii) the presence of faults is a predisposing condition for DSGSDs development, iv) the average annual velocity range between 3 mm/y and 8 mm/y, v) the expected geometry of the basal sliding band/surface accommodating deformation is substantially circular or planar.

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Preliminary data of noble gases in fluid inclusions of ultramafic xenoliths from Montaña Roja (Tenerife, Canary Islands)

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Keywords: noble gas, fluid inclusions, Tenerife, Canary Islands.

We report on the first geochemical characterization of noble gas concentrations and isotope compositions in Fluid Inclusions (FI) trapped in olivine - and pyroxene - host ultramafic xenoliths embedded in lavas/scoriae from Montaña Roja (Tenerife, Canary Islands), a monogenetic volcanic structure (age, 948-750 Ka) located in the southern part of Tenerife island (28°01'40''N - 16°32'42''W). Our aim is to identify the processes (magmatic degassing, crustal and atmospheric contamination) that control FI compositions, and to derive constraints on the origin of these ultramafic xenoliths, how their compositions relate with volcanic gases of Teide, and their implications for the Tenerife island magmatic plumbing system.

The FI from the Montaña Roja ultramafic xenoliths span a wide range of He/CO_2 and He/Ar* ratios ($1x10^{-5}$ and ~1, respectively), indicating the entrapped fluids are the end-product of magmatic degassing. The $^{40}Ar/^{36}Ar$ isotopic ratio varies between 296 and 1057, implying an atmospheric component in the nodules that could reflect an intra-crustal crystallization. The helium isotopic composition varies between 4,84 and 6,84 Ra, at the lower range of He isotope compositions measured in Teide's fumaroles between 6,7-7,5 Ra (Meliàn et al., 2012). The FI also have more radiogenic He compositions than Tenerife lavas composition (Gurenko et al., 2006). We therefore conclude that the studied ultramafic nodules, being more radiogenic than the $^{3}He/^{4}He$ signature of the magma source under Tenerife island (7-7,5 Ra), are likely crustal cumulates formed with the intra-crustal magmatic plumbing system. In this interpretation, the modest but detectable radiogenic ^{4}He addition to Montaña Roja FI would have occurred during magma storage in the crustal plumbing system.

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