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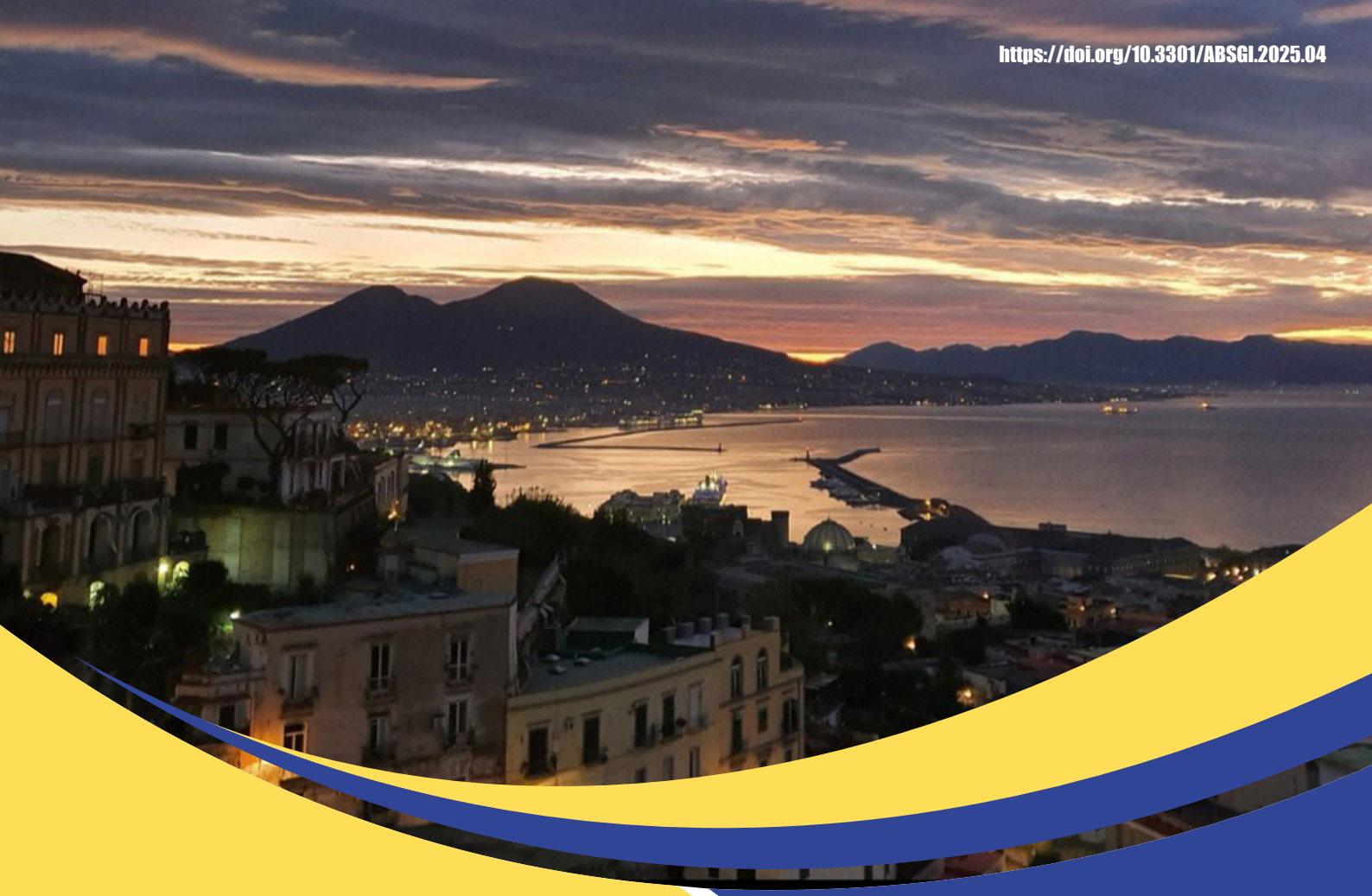

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ABSTRACT BOOK

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COVER IMAGE

Panoramic view of the city of Naples, with the Somma-Vesuvio volcanic complex in the background.

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PLENARY TALK

Inspiring Trust, Igniting Curiosity: ESA's current journey through AI, Immersive Technologies, and Earth Observation

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As the world becomes ever more data-driven, ESA is redefining how we see our planet, transforming complex Earth Observation science into experiences that inform, inspire and engage.

This session explores ESA's latest outreach initiatives that blend cutting-edge machine learning, immersive technologies, and emotionally resonant storytelling to bridge the gap between data and human understanding. Discover how ESA is turning information into impact and bringing the story of Earth closer to everyone. The discussion will also examine the challenges and ethical pitfalls of using generative AI in scientific communication, and how ESA navigates these to maintain authenticity and trust.

Multiscale Spectroradiometric and Prisma Hyperspectral Data for Mineral Exploration in the Igherm Inlier, (Western Anti-Atlas, Morocco)

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Keywords: Mineral Exploration , Prisma Hyperspectral, Spectroradiometry, Anti-Atlas.

Elongated in an E-W direction, the Igherm inlier is located on the northern margin of the West African Craton, south of the Anti-Atlas cratonic domain. It is composed of a crystalline basement of Proterozoic to Paleoproterozoic age, consisting of sandstone-pelitic formations, granites, basic dykes, quartzites, and conglomerates .This entire formation is overlain by the Paleozoic cover, which includes limestones, sandstones, pelites, and microconglomerates, collectively known as the Base Series. This sequence is capped by a thick succession of limestones and dolomites, all of which are intersected by a Hercynian basic dyke that is generally oriented in a NE-SW direction.

This study aims to enhance mineral exploration efficiency in the Igherm inlier integrating remote sensing data (PRISMA hyperspectral imagery), spectroradiometry reflectance, and fieldwork. By combining spectral signatures derived from PRISMA imagery with field-based reflectance measurements obtained using the ASD TerraSpec Halo Mineral Identifier, a rapid and robust workflow was developed for identifying weathering minerals and characterizing alteration zones, this workflow consists of PRISMA pre-processing (Removing unsuitable bands, georeferencing, radiometric and atmospheric correction, spectral smoothing, and vegetation and building masking) and PRISMA processing using the Spectral Angle Mapper (SAM) integrating spectroradiometry reflectance data. The TerraSpec Halo enabled near-instantaneous detection of diagnostic absorption features in dry samples, significantly improving the accuracy and speed of mineral identification. This integrated approach provides a comprehensive spatial understanding of alteration patterns, supporting more targeted and effective exploration strategies in the region.

Abundance maps revealed distinct spatial alteration patterns linked to lithological and structural features, marked by the presence of chlorite, epidote, illite, hematite, goethite, phengite, and dolomite. These findings underscore the potential of hyperspectral remote sensing in geological studies, providing valuable insights into mineral distributions and their tectonic controls.

Spectroradiometric analysis focuses on identifying and evaluating the mineral composition of various geological samples, primarily using the Halo Standard library. The spectral matches for multiple minerals, each rated on a star-based confidence scale. Key minerals identified include Dolomite, Goethite, Hematite, Calcite, Phengite and Fe-Mg Chlorite, among others. Several samples also indicate "No match found" or "VNIR - No match," suggesting areas where spectral signatures did not align with known mineral references. The analysis reveals a diverse mineralogical profile, with some samples showing complex mixtures of minerals, while others are dominated by a single mineral. The data provides valuable insights into the geological composition and potential mineralogical variations across different locations.

Positive inversion tectonics and cross-cutting relationships between thrusts and normal faults: the case of Mt. Vettore (Northern Apennine)

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Keywords: Sibillini mountains, positive inversion, cross-cutting relationships.

Mount Vettore massif hosts the highest peaks of the Sibillini Mountains and Umbria-Marche Apennine mountain chain. This area has been affected by a complex geological history divided into three tectonic phases. The first phase was an extensional regime during the Mesozoic-Cenozoic, lasting until the Paleogene, responsible for the formation and evolution of the Umbria-Marche basin. The second phase was a Neogene compressional event, generating several asymmetrical NE-verging anticlines "in the hanging wall of the Sibillini Mountains thrust, that moved several kilometers towards the Adriatic foreland. The final phase, starting in the Pleistocene, marked a return to extensional tectonics with NW-SE normal faulting that displaces pre-existing structures. This last phase is still active today, as evidenced by historical and recent seismicity, including the 2016 earthquake sequence. This series of tectonic phases created a complex structure that is still not well explored today. We provide a new structural model of this important area of Sibillini Mts, for which we have integrated field structural mapping with UAV photogrammetry.

Some Jurassic structural highs, with rhombocasmic shape elongated along NNE-SSW direction, have been identified in Mt. Vettore massif, surrounded by the deepest basinal area. From field and photogrammetry observations, there appear to be no cases of reactivation of the Jurassic faults. Furthermore, slip tendency analysis and numerical model were used to constrain the interpretation.

From the Pleistocene onward, a set of normal faults striking NW-SE formed, which is responsible for seismicity and the formation of Quaternary intramontane basins. The set is on the west flank of Mt Vettore, but some new normal faults have been identified on the east flank, such as Mount Torrone Fault. The field observations of the cross-cutting relationships between the compressional thrust structures (Linea Olevano-Antrodoco-Monti Sibillini) and the active extensional faults in the Mt. Vettore area show that the normal faults cut and displace the complex thrust system.

Analysis of the Susceptibility to rockfall along Monte di Procida coastal cliffs using "non-contact" detection techniques

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Keywords: Susceptibility, Cliffs, UAV photogrammetry.

The coastal cliffs of Monte di Procida, overlooking the Gulf of Naples, are both a striking natural feature and a fragile environment. Slope instability here poses a threat to beach tourism and limits local economic development. Given the challenging accessibility of the area, this study relies on remote sensing techniques, including aerial imagery, satellite data, and Unmanned Aerial Vehicle (UAV) surveys.

Two main sectors were identified as particularly critical: the northern cliffs in the Acquamorta area and the southeastern cliffs near Vitafumo. Both have experienced repeated rockfalls over the past 15 years, involving both isolated rock blocks and larger portions of rock mass. Detailed geological field surveys and high-resolution UAV-based analyses allowed for the mapping of geological-technical units and the identification of the main slope instability mechanisms. These efforts led to the production of detailed frontal engineering-geological and geomorphological maps.

Landslide susceptibility was assessed at two scales. At the point-scale, individual rock blocks defined by discontinuities were analyzed using Matheson's kinematic tests. The results showed that planar sliding and wedge failures are the dominant modes of instability. These findings were summarized in radar plots showing slope orientations susceptible to each failure mechanism, and in susceptibility matrices incorporating slope angle, dip direction, intersection geometry, dip angle, and friction angle of local tuff formations.

At the global scale, the Vitafumo sector was examined in detail due to the presence of a large-scale rock-slide that evolved into a rock avalanche. A geomechanical characterization was carried out using the Geological Strength Index (GSI), followed by a back analysis to validate shear strength parameters.

This involved comparing driving and resisting forces derived from historical topographic data and identified slip surfaces. The back analysis confirmed the adopted strength parameters, supporting future stability assessments and design of mitigation strategies.

The study concludes with practical mitigation measures, including metallic containment nets, rock bolts stabilized with cementitious grout, and protective geotextiles. These solutions aim to improve slope stability, control erosion, and protect populated areas, beaches, and critical infrastructure in Monte di Procida.

Future projection for an exquisite rarity. Species distribution modeling and conservation of the palinuro primrose

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Keywords: Climate Change, Conservation, Species Distribution Models, Paleobiology, Primula palinurid.

Global warming is threatening species worldwide. Despite some species reacting by habitat tracking, this is unfeasible within restricted areas, such as national parks and reserves, that often host species with narrow geographic ranges which are therefore vulnerable in terms of conservation status. Primula palinuri is an endemic angiosperm restricted to a small and heavily anthropized protected area in Southern Italy, the Cilento, Vallo di Diano, and Alburni National Park. This study aims to assess the current and future distribution of P. palinuri through Species Distribution Models (SDMs). Given the highly restricted geography of the species, we applied a recently developed algorithm, "ENphylo", specifically meant to deal with rare species. We further compared P. palinuri predicted responses to climate change to evaluate different management strategies. P. palinuri is particularly susceptible to current global change and excessive anthropogenic pressure. The development of innovative technologies for studying rare species makes it possible to implement more effective management strategies to mitigate extinction rates and preserve biodiversity and endemism.

Modelling the rock mass response to changing water inflow and thermometric conditions in the Bossea mountain karst aquifer

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Keywords: Rock temperature, Karst aquifer, Seismic effects, Heat transfer, Hydrodynamics.

The Bossea Cave is a mountain karst aquifer located in the Ligurian Alps (Piedmont, NW Italy). It develops at the contact between a Permian impermeable meta-volcanic basement and an overlying Triassic meta-carbonate sequence. This upper layer is responsible for the drainage of infiltrating water, mainly related to rainfall and snowmelt processes occurring in the aquifer's feeding area. Since 2021, the temperature of the rock mass has been monitored through sub-hourly measurements with a resolution of one hundredth of a degree Celsius. The preliminary results suggest different behaviours across the cave: the rock mass close to the entrance is strongly influenced by meteoclimatic factors, with heat exchange between the external and hypogeal environment determined by the thermometric gradient, exhibiting both daily and long-term effects. In contrast, thermal variations in the innermost rock are less pronounced and are mainly attributed to the propagation of a seasonal heat wave. The thermal inertia causes a delayed temperature peak during the winter months. Moreover, the hydrodynamic behaviour of the aquifer system only affects the rock temperature locally: the main water-rock heat exchange is observed in the proximity of the main drain (Torrente Mora), while this phenomenon is less significant near the secondary vertical seepages.

In parallel, a preliminary study to assess the potential seismic signature of water inflows and related modifications in the rock mass stress is ongoing. After processing data from a seismometer located inside the cave, the effects of rainfalls and snowmelt are distinguishable at specific frequency values in the spectrograms obtained from East, North and vertical channels. These findings provide a basis for future monitoring and analyses about the triggering mechanism of induced deformations in the rock mass and the evolving dynamics of cave morphology.

Petrographic, mineralogical and geochemical features of heritage decorative stones: the case of ornamental stones from the Roman Thermal Baths of Chieti (Italy)

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Keywords: archaeometry, marble provenance, Roman baths.

The ancient Romans extensively utilised a wide variety of aesthetically valuable natural stones from numerous sites across the Mediterranean to create sculptures, artifacts and embellish their buildings. Depending on their decorative properties and consequent success, many rock types were transported over vast distances, leading to the spread of several commercial routes. To determine the provenance of white marbles, mineralogical-petrographic and isotopic analyses are commonly employed. In contrast, the origin of polychrome decorative stones is typically identified through qualitative analysis, or visual comparisons based on textural and structural attributes of mesoscopic specimens. This study focuses on white and polychrome marbles found in the thermal baths of Teate Marrucinorum, the current Chieti (Abruzzo, Italy). To enhance, extend, and validate mesoscopic comparisons for polychrome lithotypes various mineralogical, chemical, and textural analyses have been conducted. A total of 56 rock samples were examined; each type was characterized based on its mesoscopic textures and structures through autoptic analysis, distinguishing 6 types of decorative marbles: four polychrome stones, one grey-striped marble, and a group of white marbles. Mineralogical and chemical compositions were determined using XRPD, micro-Raman spectroscopy, and XRF-EDS. Additionally, thin-section analysis with Transmission Optical Microscopy (TOM) was employed to assess texture (including the number, abundance, colour, size, shape, and boundary of mineral phases) and structure (spatial arrangement). The isotopic signatures (δ18O, δ13C) of the white and grey-striped marbles were also analysed. The findings revealed that the four polychrome stones from Chieti correspond to Pavonazzetto antico (Marmor Phrygium), Cipollino Verde (Marmor Carystium), Portasanta (Marmor Chium), and Breccia di Settebasi (Marmor Scyreticum). The grey-striped marble was identified as Greco Scritto, while the white marbles were traced to two different sources: Carrara (Marmor Lunense) and Marmara (Marmor Proconnesium). Additionally, this study presents an analytical protocol that incorporates quantitative data to enhance the accuracy of provenance determination for both white and polychrome marbles through a multi-analytical approach.

Unveiling Roman Mortars through Images: combined approach on the Thermal Baths of Teate Marrucinorum (Chieti, Italy)

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Keywords: roman mortars, image analysis, μ-CT.

The archaeometric study of geomaterials and their artificial counterparts used in antiquity can be constrained through complementary mineralogical, geochemical, and textural analyses. This multidisciplinary approach helps determine raw material provenance, infer on ancient construction techniques, and evaluate durability of artefacts. Polished slabs and thin sections are commonly used to assess minerals or voids abundances, dimensions, size distributions, and orientations in the 2D domain. Morphotextural studies conducted on 3D images offer further information, such as volume fractions, surface areas, connectivity, and anisotropy. For this reason, a combined 2D and 3D image analysis approach was applied on ancient mortars from the public thermal complex of Teate Marrucinorum (nowadays Chieti, Italy) to obtain a detailed textural profile of these materials.

Teate Marrucinorum was a prominent Roman municipium. Its significance is evidenced by archaeological sites such as the Roman theatre, the Civitella's amphitheatre, sacred temple areas, and the thermal bath complex, with elaborate decorative elements. The public thermae, dating from the 1st–2nd century AD, was fed by a nearby cistern system; from the cistern walls, two horizontal core samples were taken, spanning the outermost to innermost layers. These semi-cylindrical specimens (15–30 cm long, 6 cm in diameter) were first imaged in 2D using a High-Resolution Scanner (HRS). Representative thin sections were analysed with Transmission Optical Microscopy (TOM) and Scanning Electron Microscopy (SEM) in order to characterize mineralogical phases across different scales. Then, the outermost portions of these specimens were examined using X-ray computed microtomography (μ-CT) with an EASYTOM XL230 system (RX Solutions, France). This combined 2D and 3D imaging approach enables a thorough characterization of pores, aggregate phases, and binder matrix, allowing for precise quantification of cement-to-aggregate ratio, as well as the shapes, sizes, and orientations of pores and aggregates.

This study enhances our understanding of ancient construction materials, highlighting the importance of integrating traditional 2D analyses with advanced 3D imaging techniques. In contrast to 2D observation techniques, 3D microtomography is proving to be extremely useful since, as compared to conventional methods, individual features can be studied in 3D space.

Basement inheritance impact on rift evolution and rifted margin formation

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Keywords: basement inheritance, rift evolution, rifted margin formation, tectonic inheritance.

The rifted margins of the North Atlantic are among the most thoroughly studied regions in the world, thanks to the abundance of geological and geophysical data. However, significant uncertainties remain, particularly in the deepest structures of the rift system, which are still difficult to access.

This study aims to better constrain the influence of inherited lithospheric structures on subsequent continental rifting and rifted-margin formation. It focuses on the northern North Sea and Mid-Norwegian continental shelf, where a complex basement architecture – initially shaped by the Caledonian orogeny and its post-orogenic collapse – was later reactivated during Mesozoic and Cenozoic rifting episodes.

Recent technological advances in seismic reflection imaging have enabled the acquisition of new deep seismic reflection profiles down to 16 s TWT (two-way travel time) along the Norwegian rifted margin, the Regional Deep Imaging (RDI) dataset. To assess the influence of basement inheritance on rift dynamics, this study combines interpretations of this deep seismic dataset with shallower datasets such as the North Sea Renaissance (NSR) and Mid Norway Regional (MNR) datasets.

Seismic facies analysis in Petrel is used to identify intra-basement structures based on the amplitude, frequency, continuity and spatial distribution of reflectors. In addition, gravity and magnetic data modelling is incorporated into the regional study. By integrating local geological observations with global analogues, this research aims to deepen our understanding of the links between basement inheritance and continental rifting – a key step towards better characterisation of rift systems.

Next Generation Palaeontology: new tools and methods available to young Paleontologists

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Keywords: phylogenetic comparative methods, species distribution models, three-dimensional virtual models, macroevolution, paleobiology.

Neglected and diminished for long time, paleontology had its heyday with Simpson's *Tempo and Mode* and the Modern Evolutionary Synthesis, when it was finally welcomed at the high table of quantitative sciences. The concept that the past is the key to the present granted paleontology a pivotal role in evolutionary biology (from which the term "paleobiology"), which became more and more prominent with the availability of large fossil databases, sophisticated statistical techniques and computational methods. In recent times, that same concept laid the ground for the new field of conservation paleontology, which uses knowledge from the past to predict the future and plan conservation acts accordingly. In this context, I am presenting a suite of algorithms written in R language which are meant to address some of the great questions in paleontology and evolutionary biology, and to pave the way for future conservation paleobiology. The algorithms condense in a suite of R packages covering different aspects of the modern paleobiology (as defined by Gould). The *RRphylo* package collects methods and tools to study the evolution of species-related characters in a phylogenetically explicit context. It was created to investigate the evolution of phenotypic characters on phylogenetic trees including extinct species, but it proved very reliable in dealing with several types of variables, such as ecological or genetic, and to work at all scales, from the very microevolution of viruses to the macro-evolution of entire taxonomic orders. *RRphylo* comes as the founder of the suite of packages, which now includes one package specifically meant to study the evolution or organismal shape in three-dimensions. This *RRmorph* toolkit includes tools to map phenotypic changes and patterns over 3D digital models, focusing on how and how much different portions of these phenotypes are involved in evolutionary processes. The last package of the suite, *RRgeo*, covers a different, yet very much related, aspect of evolution. It includes algorithms to model the distribution of species on Earth, taking into account both past e present climatic variability. Combining species distribution models with phylogenetic information, *RRgeo* is able to predict future geographical distribution for very rare species, and to find where on Earth a species was born. As it comes friendly, free and easy to use, the RR suite will help the next generation of paleontologists to dig deeper into their disciplines, making great discoveries in the years to come.

Stratigraphic Reconstruction of the Eocene Mount Calvarina Basaltic Shield Volcano Using RRIM from High-Resolution LiDAR Data (CARG Project, Sheet 124, Verona Est, Italy)

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Keywords: Red Relief Image Maps (RRIM), Digital Terrain Models (DTMs), CARG, Volcanic Stratigraphy, Lessini Volcanic District.

Over the past few decades, due to their increasing availability and resolution and decreasingproduction costs, Digital Terrain Models (DTMs) have been extensively and fruitfully used in volcanology as a complementary tool to support geological mapping and conduct morphological and morphometric analyses. Among the visualization techniques developed for interpreting such data, the Red Relief Image Map (RRIM) method - which is based on the integration of multipletopographic parameters (i.e., slope, positive openness, and negative openness) - has proven particularly effective in highlighting subtle morphologic variations in volcanic terrains. The identificationof volcanic landforms such as lava flows and eruptive vents through RRIManalysis, combined with field observations and geological data, supports geological mapping providing insights into the stratigraphic evolution of exposed volcanic sequences. Geological surveys are being carried out in the Lessini Mounts (Veneto, Italy) to create a new geological map (1:50,000 scale) within the CARG Project (Sheet 124, Verona Est). In the study area of the Mount Calvarina shield volcano, located between the Chiampo and Alpone valleys, the outcropping volcanic rocks are Eocene relatively homogeneous basaltic rocks currently classified as a single stratigraphic unit in the 1:100,000 map (Servizio Geologico d'Italia). This homogeneity, coupled with intense vegetation, poses challenges in reconstructing the stratigraphy using field observations alone. This study aims to subdivide the basaltic rocks of the Calvarina region into informal geological units with their own specific morphological features by means of RRIM. These units are then classified stratigraphically after targeted field ground truthing, combined with the identification of features that mark periods of volcanic quiescence, such as oxidized layers and volcaniclastic deposits. Specifically, the basal portion of the succession comprises basaltic lava flows and hyaloclastites interbedded with calcareous layers, indicating a marine depositional environment. In contrast, the upper portion is composed of subaerial basaltic lava flows. This enables a more detailed reconstruction of the area's volcanic evolution, reflecting a trend of progressive emergence.

Multiscale Lineament Identification through Manual Extraction from Multiple Visualizations of DTMs: the eastern Lessini Mountain, (CARG, Verona Est, Italy)

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Keywords: Digital Terrain Model, Remote Sensing, CARG, Lineaments, Lessini Mountain.

Remote sensing and Digital Terrain Models (DTMs) analysis are now well-established tools for landform mapping, especially given the increasing availability of national and global datasets. Within the framework of the Italian CARG Project for producing the Geological Map of Italy at a scale of 1:50.000, DTMs play a key role in improving geological interpretation by enhancing the understanding of surface structures and landscape evolution and supporting field geological mapping. However, lineament identification on remotely sensed data is often influenced by a high degree of subjectivity. As noted in previous studies, factors such as the operator's experience, observation scale, and DTM visualization method (e.g., artificial illumination azimuth) significantly affect the number, orientation, and length of extracted lineaments. Building on the methodologies of Scheiber et al. (2015) and Smith and Clark (2005), this study proposes a multiscale approach that employs multiple DTM visualizations to establish a reproducible workflow, aiming to minimize such subjectivity.

The study area is located in the eastern Lessini Mountains (Verona, Italy), characterized by Mesozoic and Cenozoic limestones in the west, Eocene volcanic rocks (mainly basalts) in the east, and Quaternary fluvioglacial deposits to the south. This area has undergone complex Alpine-related tectonic evolution, with the Castelvero Fault forming a major structural boundary between carbonate and volcanic units.

Lineaments were extracted from a 6-meter resolution DTM provided by the Veneto Region using GIS software at four scales (1:200,000, 1:100,000, 1:50,000, and 1:25,000) and through three visualization techniques (Ambient Occlusion, Hillshade with azimuth of 315° and 45°), resulting in twelve lineament maps. Rose diagram analysis of the lineament trends revealed two dominant orientations: NNW–SSE and WSW–ENE, with notable differences between volcanic and carbonate lithologies. Comparison with existing geological maps (Servizio Geologico d'Italia, 1967) revealed significant discrepancies, suggesting that not all tectonic features are clearly reflected in the DTM data. This highlights the need for further fieldwork to verify the actual orientation and nature of geological structures.

In conclusion, the multiscale identification and analysis of lineaments using DTMs significantly enhance geological interpretation in the Lessini Mountains. The study underscores the differences with previous surveys and points to lithology-dependent variations in lineament orientation, emphasizing the value of this approach for guiding future geological investigations.

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Taphonomical observations on Hippopotamus fossil remains from the Pleistocene of Maglianella (Rome, Italy)

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Keywords: hippopotamus, bones, Pleistocene.

Abundant fossil hippopotamus skeletal remains have been recovered during the first half of the 20th century, along the Via Aurelia, in the locality of Maglianella (Rome, Italy). Despite the abundance of material, only a small portion was previously described and assigned to the now-debated species Hippopotamus tiberinus. The entire collection is currently housed at the Natural History Museum of the University of Pisa (Calci, Italy), where a composite skeleton is also displayed. The assemblage is represented by approximately 530 specimens, including 19 cranial elements, numerous isolated teeth, postcranial bones and bone fragments. These remains are attributable to a minimum of five individuals, at different ontogenetic stage, as testified by the presence of a juvenile mandible and several molars at different stage of wear, as well as scapulae displaying variation in the development of the root of the scapular spine. The state of preservation of the specimens is extremely variable but a few observations enable to identify bite marks and traces of a short transportation in a fluvial environment. The former are mainly observable on ilium while the latter are mostly documented on long bone surfaces and are characterized by striae and grooves. Finally, despite reported as collected from diatomaceous deposits, no diatoms have been observed from sediment samples from the bones. These features provide valuable insights into the depositional and post-depositional processes that led to the formation of this remarkable hippopotamus bone assemblage.

Speleothem science: paleoclimate and geo-environmental applications

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Speleothems are secondary chemically-precipitated cave deposited (ie. stalagmites) mostly composed by calcite. They generate because the dripping and/or flow of CaCO3 rich meteoric water in karst underground environment, in turn fed by rainfall water that is enriched in soil-derived CO2 before entering the epi-karst zone. Accordingly, speleothems inherit the geochemical properties of the seepage, mirroring some key climate-controlled properties of the rainfall and the soil biological activity. δ18O and δ13C from speleothems' calcite are indeed excellent proxies to reconstruct past climates together with trace elements, growth rate and fabric. These mostly give qualitative indications about oscillations in temperature, rainfall amount-seasonality-source, vegetation status and more. However, new frontiers of speleothems science permit to analise the δ18O-δ2H in fluid inclusions trapped within the calcite lattice, which are remnants of the paleo-rainfall generation the CaCO3 deposition in cave. Through this, quantitative reconstruction of paleo-temperature are also possible. Speleothems paleoclimate proxies are anchored to solid chronologies by applying the U-series radiometric dating, which provides very accurate and precise absolute ages because cave calcite is most of the time "pure" (ie. no allogenic detrital particles). U-Th method allows paleoclimate reconstructions over the last 500000-600000 years, while U-Pb method can – theoretically limitless - extend records further back in time.

Furthermore, from a geological perspective, vadose speleothems attest that the karst network was drained during their formation; contrarily, some peculiar phreatic speleothems (and also phreatic cave morphologies) straightforward indicate the paleo-water level, either of the freshwater aquifer as well as marine level in coastal setting. If coupled with other geological and environmental evidences (ie. river terraces, sedimentary deposits around and/or inside the cave, and more), speleothems can be used as excellent tools to rigidly reconstruct in space and time the geological evolution of specific karst areas, as well as to constrain the oscillation of the sea level through time.

Through case studies, the talk will overview the multidisciplinary geoscience applications provided by speleothems, focusing on the importance of rigidly chronologically constrain paleoclimate variations to better understand 1) human evolution and 2) geo-environmental processes.

Multidisciplinary and multiscale investigations across crustal rheological boundaries: links between petrochronology and microstructures

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Keywords: shear zone, deformation, metamorphism, geochronometers, high-resolution analytical techniques.

Crustal rheological boundaries represent key structural and compositional domains within the lithosphere, characterized by the juxtaposition of contrasting rock types (ultramafics vs. metasediments). These boundaries exhibit heterogeneous rheological behaviors, acting as zones of stress/strain concentration that facilitate lithospheric deformation through the development of shear zones, faults, and boudinage structures. Beyond their mechanical influence, these domains are central to the interplay between metamorphism and deformation, controlling fluid-rock interactions and serving as channel for melt/fluid migration from the lithospheric mantle toward the Earth's surface. Consequently, they often host mineralization and ore deposits, making their study essential for understanding lithospheric dynamics and resource distribution.

Given the complexity of these interactions, a detailed characterization of crustal rheological boundaries is critical to deciphering the factors that govern rock rheology. We apply a multidisciplinary and multiscale approach, integrating microstructural, geochemical, and petrochronological analyses to investigate the evolution of these boundaries. By employing geochronometers, such as monazite and titanite, in combination with microstructural and petrological characterization, we constrain the evolution of these geological contexts.

Here, we present a series of case studies that explore the geochronometers interaction with deformation within mid- to lower-crustal shear zones of the Ivrea-Verbano Zone (Southern Alps, Italy). These structures exhibit prolonged deformation histories that are only partially constrained. By integrating high-resolution analytical techniques (SEM-EBSD, EPMA, LA-ICP-MS, APT), we investigate the microscale processes governing geochronometer record in shear zones. We demonstrate that mineral-scale compositional heterogeneities, intracrystalline deformation, and fluid-mineral interaction significantly influence geochronometer behavior. Moreover, the study highlights how variations in strain intensity (e.g., protomylonites vs. mylonites), local mineral assemblages (mm-scale compositional layering), and high- grade metamorphic conditions affect the reactivity of accessory minerals, ultimately allowing us to reconstruct the deformation history of shear zones.

Our findings underscore the importance of a multiscale and multidisciplinary approach in unraveling the geological processes that shape crustal rheological boundaries such as shear zones, offering new insights into the mechanisms that control lithospheric dynamics.

Structural variability and architecture of the Latakia Ridge, Offshore NW Lebanon

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Keywords: Plate boundary, Fault kinematics, 3D seismic modelling, Transpression, Strike-slip domain.

The Latakia Ridge, offshore northwest Lebanon, forms part of the Eurasian–Nubian plate boundary in the eastern Mediterranean. This study analyses its along-strike geometric and structural variability, to better understand related tectonic processes. The ridge links the Cyprus Arc System and the East Anatolian Fault, crossing a triple junction (Karliova) involving the Dead Sea Transform. A key feature is its strike change from NE–SW in the south to NNE–SSW in the north.

Using 3D seismic data from PGS Geophysical EAME Multiclient Group Lebanon, interpreted with Petrel software, key reflectors such as Top and Base Messinian were identified and modelled. These reveal thinning of stratigraphic units along the ridge core and thickening outward. Lithological data from nearby wells helped correlate seismic facies.

Structural analysis shows clear along-strike variability. In the south, shortening dominates with thrust systems showing fault-bend fold geometries. Northward, structures evolve into doubly verging steep reverse faults and anticlines forming pop-up structures, indicating transpressive kinematics. At the northernmost segment, a sub-vertical strike-slip fault truncates the anticline, marking a transition from pure compression to lateral shear.

The results suggest a spatial-temporal transition from a contractional phase, marked by the Main Thrust cutting Miocene and Messinian strata, to a later transpressive phase overprinting earlier structures. This evolution is controlled by the strike change, influencing dominant tectonic shortening regime in the south, transpression and strike-slip motion in the north.

In conclusion, Latakia Ridge's structural variability reflects changes in plate boundary kinematics. The shift from NE–SW to NNE–SSW governs the transition from thrust-related shortening to transpression and strike-slip motion. Ridge geometry controls fault behaviour and regional tectonic dynamics, linking spatial structural changes to evolving tectonic stresses along this key segment of the eastern Mediterranean plate boundary.

Combined rainfall estimation from rain gauges and meteoradar: implications for geo-hydrological risk assessment

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Keywords: Rainfall, Whether Radar, Rain gauges, Risk assessment.

Accurate quantitative estimations of precipitation are a critical challenge in hydrometeorology, with significant implications for hydrological modeling, water resource management, and prediction of geohydrological hazards (such as floods and landslides).

Rain gauge networks provide direct, high-quality "local" measurements of precipitation. Nevertheless, their spatial coverage can be unsuitable to capture the high spatial-temporal variability of rainfall events. This limitation is particularly evident in areas with complex orography and during convective meteorological events, which are typically short-lived and highly localized. In such scenarios, even dense rain-gauge networks may result inadequate for an accurate reconstruction of the precipitation, leading to inaccurate estimations of induced ground effects and related risk.

In contrast, meteoradar systems offer spatially continuous precipitation estimates, at high temporal resolutions, over large areas. Though, this type of remote measurements is indirect, as derived from reflectivity through empirical relationships subject to uncertainties that depend from various factors (e.g., radar calibration, beam geometry, atmospheric attenuation, and variability in raindrop size distributions). To overcome the limitations of each type of measurement system, integrating raingauge and meteoradar data can be adopted for improving the accuracy and resolution of quantitative estimations of precipitation.

In this work, an example of integration approach is tested in a study area in Liguria (Northern Italia), historically affected by severe geo-hydrological events. Employed rainfall data are provided from the rain-gauge network of the Regional Agency for Environmental Protection in Liguria (ARPAL), whereas meteoradar data are provided by the Italian National Civil Protection. By properly combining such data, the precipitation field was reconstructed with a spatial resolution of 1x1 km² and a temporal resolution of 1 hour.

Eight rain-gauge stations, evenly distributed across a region of 200 km², were considered. By employing a 7-years data set (from 2015 to 2021), the performance of spatializing the precipitation information from rain gauges alone was first evaluated, and then compared with the results of combining rain-gauge and meteoradar data. The implications of the proposed method for accurate interpretation of rainfall that triggered landslides in the same period are finally discussed.

Understanding Natural Variability In Fossil Species Through A Phylogenetic Comparative Approach

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Keywords: sexual size dimorphism, mammals, RRphylo, within-species variation, body size.

Sexual dimorphism (SD) refers to the morphological differences between males and females of the same species. SD, and especially sexual size dimorphism (SSD), has been, and it still is, a key topic in evolutionary and ecological biology because of its involvement in animal behaviour, and because it is informative of the selection regime differences between the sexes. Sexual dimorphism is a known consequence of sexual and natural selection and the reason why most male vertebrates tend to be bigger, or more peculiar, than their female counterparts.

Unfortunately, finding traces or evidence of SSD in fossil species is particularly hard, as they come limited in numbers and species limits are somewhat arbitrary. Here we present a study on the body mass of sexed adults for 1633 extant mammal species. We used a new method, based on the phylogenetic comparative tool RRphylo, which allows us to examine the consequences of SSD on macroevolutionary inference. The method proved reliable at recognizing SSD in our data, providing a strong linear relationship between measured (from input data) and predicted size dimorphism ($R2 = 0.927$; slope = 0.905; intercept = 0.028; p-value $<< 0.001$).

Our approach is promising in recognizing species variability at the intraspecific level and may help identifying fossil species that lived under intense SSD.

Development of a New 3D Conceptual Model for Environmental Risk Assessment in the Remediation of a Disused Industrial Site in Solofra (Southern Italy)

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Keywords: 3D model, uncontrolled landfills, Risk Assessment, Multivariate statistical analysis.

In Italy, the management of uncontrolled landfills presents a significant regulatory gap. As a result, the risk assessment approach is often incorrectly aligned with that used for contaminated sites. This project aims to define an effective management method for such landfills, minimizing their impact on the surrounding environmental matrices. The study area is located within an industrial site in Solofra (Avellino), used for the tannery's organic waste treatment to produce organic fertilizers. In 2016, a characterization campaign, involving 68 boreholes, was conducted after discovering illegally stored industrial waste. A total of 88 deep soil samples and 235 waste samples were collected and analyzed by the "Centro Ricerca Innovazione e Sviluppo" (Ce.R.I.S. srl) for concentrations of 16 Potentially Toxic Elements (PTEs). A 3D stratigraphic model of the study area was generated using Surfer (v.28 - Golden Software), based on stratigraphic logs obtained during the characterization phase. This model allowed the visualization of the volumes directly impacted by the waste body, within the geological-stratigraphic context. Concentration data for each PTE in both deep soil and waste were interpolated in 3D using the inverse distance power (IDP) method.

Univariate statistical analysis was essential to determine the appropriate scale for the 3D models. Concentration data were log-normalized and summary box plots were generated for each PTE. Key statistical parameters – first quartile (Q1), median, third quartile (Q3) and upper whisker – were extracted and back transformed to define the scale limits for the 3D models. The results showed that, for some elements, the highest concentrations were concentrated in the volume corresponding to the waste body, suggesting a direct correlation between the waste and the detected contamination peaks. Principal Component Analysis (PCA) was applied to waste samples to identify element associations that influence the variability of geochemical data. PCA scores were then plotted, revealing areas characterized by different element associations, potentially corresponding to d ifferent waste typologies. A risk analysis conducted on deep soils indicated the absence of contamination.

Given the presence of industrial waste in a non-engineered catchment, alternative risk estimation methods were tested using evaluation data from waste samples. A deterministic method, typically used for regulatory waste disposal site assessments, was applied and adapted to the site's specific situation. Furthermore, a stochastic method was also proposed to compare the two approaches and evaluate which could be more effective in similar context.

Soft sediment deformation Structures in high density Turbidites: a case study from San Mauro Fm

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Soft-sediment deformation structures (SSDS) are typical syn-depositional features of deposits originated from high-density turbidity currents undergoing rapid deposition of the transported material, which is predominantly composed of massive, coarse-grained sandstone. Other types of SSDS are post-depositional and can be attributed to fluidization and/or liquefaction of the granular material due to external forces (e.g. wave action, seismic shocks, landsliding), leading to the overprinting of primary sedimentary structures.

Morphological convergence sometimes complicates their distinction in the field. SSDS such as pillars, dishes, injection tubes and sills are characteristic of some localized (meters-thick) stratigraphic intervals in the San Mauro Formation, part of the Cilento Group, which represents a thrust-top basin within the southern Apennine orogenic belt. The observed structures exhibit hierarchical organization and form a complex interconnected pattern comprising cm-thick coarse-grained horizontal and vertical injections, combined with systematic en-echelon arrangement of pillar arrays, which has contributed to the obliteration of primary sedimentary features.

These features are interpreted as syn- and post-depositional, respectively, with the latter attributed to harmonic ground vibration likely due to seismic shocks.

High-order cognition drove primate brain evolution

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Keywords: brain, anthropoids, no-anthropoids, frontal cortex, precuneus, DMN.

A distinctive trait of primate evolution is the relative expansion of their brains, which plays a major role in their outstanding cognitive abilities. Although it is well known that primate brains are exceptionally complex, it is intriguing to understand whether, and which, brain regions differentiate anthropoids from non-anthropoids. Here, by using a newly developed statistical tool to study the evolution of specific brain areas, I located the brain regions that underwent the most profound evolutionary changes during the evolution of the two groups. We found that the largest difference is concentrated in the frontal and posterior parietal cortex, with a marked expansion in the precuneus and medial the parietal cortex region, which are more developed in anthropoids. Intriguingly. These brain areas are involved in the default mode network (DMN) in primates. The DMN plays a key role in self-reference, social cognition, episodic and autobiographical memory, language and semantic memory, and mind wandering, suggesting performing such tasks influenced brain evolution in anthropoids.

Failure of Crater Rims and Generation of Deposit-Derived Pyroclastic Density Currents: Insights from Field Observations, Volcano Monitoring, and Slope Stability Assessment

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Keywords: volcanic crater rim failure, deposit-derived pyroclastic density currents (PDCs), slope stability, volcanic hazard mitigation.

The catastrophic failure of volcanic crater rims and the generation of deposit-derived pyroclastic density currents (PDCs) are frequent in mafic to intermediate volcanoes with steep slopes. These small-volume (103–107 m3) PDCs can travel several kilometres at high temperatures, posing significant hazards due to their unpredictability, particularly during effusive, Strombolian, or violent Strombolian activity. Such events often catch local communities and tourists unaware. Deposit- derived PDCs primarily occur through two mechanisms: (i) the collapse of hot material on volcanic slopes due to exceeding the angle of friction, undercutting, or overloading by fresh volcaniclastic or lava flows, and (ii) magma thrust. In the latter case, the transition from explosive to effusive activity increases magma density and pressure on the conduit walls, exerting a thrust that can lead to partial or complete crater rim collapse. Understanding hot rock failure is crucial for long-term hazard assessment and requires investigating both predisposing and triggering factors. Short-term risk mitigation depends on detecting predictive signals through monitoring systems. This study integrates field observations, monitoring data, and slope stability modelling, focusing on Stromboli and Vesuvius. A database of deposit-derived PDC events supports hazard assessment. Stability models, calibrated using Stromboli monitoring data, were applied to other volcanoes. The analysis employed a 2D limit equilibrium method (LEM), incorporating shear strength parameters from different failure criteria. Stratigraphic and mechanical characterisation of crater rims accounted for unit relationships and geometric configurations. Sensitivity analyses assessed the influence of slope angle, material strength, discontinuities, and deposit thickness. Comparing simulated critical zone slopes with observed failure zones highlighted areas most susceptible to destabilisation. The results align with field observations and monitoring data, demonstrating the broader applicability of this approach to steep volcanic terrains with proximal accumulations of unstable, high-temperature material.

Comparing different methods to ascertain diversification rates in Primates

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Keywords: Pyrate, equal splits, pradel, viversification rates, Primates.

Understanding species diversification rates is at the core of paleontological research ever since the pioneriing works by G.G. Simpson (1902-1984). Although during the early stages of research on diversification rates the calculation was mostly based on fossil occurrences through strata of different, consecutive ages, the later rise of phylogenetic comparative methods promised to derive diversification rates directly from phylogenetic trees. Recent studies, however, have suggested this is not always the case, and the range of applications and assumptions can be somewhat severe.

Here, we used an iconic group of mammals, Primates, to test the power of a tree-based (the equal split method) and two fossil record based (Pradel and Pyrate) approaches to retrieve diversification rates in Primates. The use of this clade is particularly appropriate because Primates are known to have undergone a major turnover across the Oligocene-Miocene boundary, and the fossil record of Oligocene Primates is exceedingly poor. We found the three methods to agree with each other, returning high and significant correlation coefficients between diversification rates estimates.

All the approaches suggest a drop in diversification occurring around 32–36 mya, coinciding with the demise of extinct Primates (i.e. Omomyoids and Adapoids), and a steep increase in diversification rates during the Miocene-Pliocene transition, when major clades of extant Primates started to thrive.

Simpson G.G. (1984) - *Tempo and mode in evolution*. Columbia University Press.

Archaeometric analyses of Western Greek amphorae from underground contexts in Naples

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Keywords: Western Greek Amphorae, Naples, provenance, XRF, petrography.

A selection of 37 samples of Western Greek amphorae, a category widely distributed throughout the Mediterranean basin during the Archaic period, were subjected to archaeometric analysis. These samples dated between the 6th and 4th c. BC have been classified according to the typological characteristics proposed by Sourisseau or Gassner for the variants of the rim shape. The samples come from excavations carried out for the construction of the Lines 1 and 6 metro station of the Naples underground, in Piazza Municipio (Municipio station), in Piazza Nicola Amore (Duomo station) and in Piazza Santa Maria degli Angeli (Chiaia station).

The main challenge with these amphorae is related to the difficulty in identifying the production centres of the Western Greek amphorae, which were produced in different centres in Magna Grecia, in Sicily, in the Ionian-Adriatic area, in the Aegean and in Massalia. The fragments were subjected to petrographic analysis via polarised light microscopy (PLM) and chemical analysis using X-ray fluorescence (XRF). By comparing the petrographic observations with the chemical data, it was possible to identify several groups related to their possible origin areas. Finally, the mineralogical analysis performed by means of X-ray powder diffraction (XRPD) along with scanning electron microscopy (SEM) provided data to estimate the firing temperatures of the amphoras.

The petrographic study identified seven petrographic groups with homogeneous characteristics and four samples with unique features, which were defined as outliers. The integration of the chemical data and the Hierarchical Cluster Analysis (HCA) supports the conclusions of the petrographic analysis. Most of the amphorae were produced with high-CaO clays (CaO > 6 wt.%), with the exception of few samples that are composed of low-CaO clays. Instead, there are some petrographic groups that show high concentrations of Cr and Ni. This represents an important marker of raw material characterisation as the presence of high concentrations of trace elements such as chromium and nickel can be typical of the Aegean and Ionian-Adriatic productions.

To develop hypotheses about the provenance of the amphorae more detail, the identified groups were compared with geological, chemical, and petrographic data available in the literature. The obtained results allowed the identification of a local production of Western Greek amphorae and productions related to the Paestum area, to the Calabria region, and to the Aegean/Ionian-Adriatic.

In-soil radon data collected throughout the 2015-2023 period at Mt. Etna: correlation with magma dynamics and potential use in volcano monitoring

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Keywords: Mt. Etna, Radon gas, Magma dynamics, Petrological data, Eruptive Activity.

In order to develop new techniques in volcano monitoring on Mt. Etna, we searched for new parameters able to catch subtle magma dynamics within the volcano or to predict the run-up of eruptions. Our research is based on the investigation of in-soil radon, a natural noble gas potentially effective in tracking magma dynamics and crustal/sub-crustal fluid movements along active volcano-tectonic structures. In this presentation, we show continuous in-soil radon data collected throughout the period 2015 - 2023 at a station on the southeastern flank of Mt. Etna that is part of the INGV-OE monitoring network. The approach proposed in this work is unique and really innovative, even in consideration that the time series of radon data analyzed is the longest one, to the date, on Mt. Etna and among the longest for active volcanoes worldwide. The choice of this period is strategic, considering the incredible record of volcanic eruptions with different behavior, i.e. from wholly effusive to strongly explosive eruptions. In order to constrain the radon signal from the influence of environmental cycles and to highlight those variations possibly linked to volcanic and tectonic activity, we have applied appropriate mathematical algorithms to this long-term data series. The filtered signal revealed variations, both long-term and mid- to short-term, that can be well correlated with the activity of Mt. Etna during the investigated period. Specifically, significant correlations were observed in conjunction with periods characterized by paroxysmal eruptions (i.e., the 2015-16 eruptions at Voragine Crater or the exceptional 2020-22 sequence at Southeast Crater) or in concomitance of intense seismic swarms caused by shallow magma intrusions within the volcano. To corroborate the interesting findings coming from the radon data, we have also integrated our record with important petrological datasets enlightening the major recharging phases occurred during the 2015-23 period. Integration of these data provided crucial insights into the dynamics of magma storage, transfer and interaction within Etna's plumbing system. Although the considerations here reported needs to be further pondered and examined in depth, this study preliminarily emphasizes the great potential of soil radon for tracking magma movements before eruptions, encouraging therefore its use as a further tool for continuous real-time monitoring of volcanic activity.

How to cope with a mass extinction: smarter or bigger?

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Keywords: Mass extinction, mammalian diversification, RRphylo, rate peaks, macroevolution.

Mass extinction events drastically modified life on Earth. It was estimated that more than 99% of the species ever lived on our planet have faced extinction. On one side, this means that mass (and background) extinctions irreversibly erase biodiversity, on the other side this great loss of species emptied ecological niches, allowing diversification. The scenario after mass extinction is represented by depauperate, unstable ecosystems where very few ecologically flexible taxa with small body mass survived.

Some of these survivors evolved key innovations such as novel reproductive modes, increased tooth complexity and larger, more complex brains. The latter played a fundamental role in mammalian diversification, giving therians the plasticity to cope with the harsh, post-extinction environmental conditions.

It is known that rapid body size evolution occurred in therapsid after the Permian-Triassic (~251 mya) mass extinction and in mammals after the Cretaceous-Paleogene (~66 mya) mass extinction, but here we are interested in investigating whether it was bigger bodies or larger brains that conferred high capability to cope with mass extinction. To this aim, we analysed endocranial volumes, body sizes, and the phylogenetic relationships of 1734 species (555 extinct, 1179 extant) therapsids, including extant) therapsids, including extant and extinct mammals.

All tests were run using the software R. Firstly, we computed rate of body mass evolution, rate of endocranial evolution and rate of endocranial evolution using body mass as predictor. Then, we tested the presence of trends in brain size evolution across therapsid species through time.

Furthermore, we developed a routine to find distinct peaks in the rate of evolution of each phenotype. Our results show that therapsid species experienced increased relative brain size altogether, but the trends differ among clades with Primates, Pan-Cetartiodactyla and Carnivoramorpha showing steeper slopes (faster relative brain mass increase) than others.

We found that endocranial volume evolution accelerates after each mass extinction event. Hence, our results show that body mass rate of change did not play a key role in diversification, while rapid evolution of larger brains had a major impact on therapsid diversification, especially after mass extinction events.

Exploring Sediment Contamination in a Polluted River Basin Using Multivariate Statistical Techniques

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Keywords: stream sediment, multivariate analysis, contamination sources.

Anthropic pressure within a river basin can manifest in various forms. Contamination phenomena may originate from localized sources but often extend downstream due to the natural transport dynamics of fluvial systems. Investigating surface water contamination is essential for understanding ongoing pollution processes.

Along the watercourse, changes in the flow energy can promote sediment accumulation in specific areas, and, in contaminated environments, pollutants from the water phase can bind to solid particles and deposit on the riverbed. During extreme meteoric events, becoming more frequent under climate change, if polluted sediments are remobilized contamination can spread far downstream, with floodwaters potentially transferring pollutants far from the source. The chemical analysis of stream sediments represent a valuable tool for key information on the source, intensity, and persistence of contamination processes affecting a catchment basin.

An extensive environmental survey was carried out to explore the environmental impact of multiple anthropic stressors on a changing environment. Twenty-four sampling sites were selected along the main course of one of Europe's most polluted rivers, the Sarno River (Southern Italy), and along its tributaries. Stream sediment samples were examined to assess the concentration of some potentially toxic elements (PTEs) and additional metals, as well as several organic pollutants. The elements (Be, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd, Pb, U, V, Hg) in the sediments were quantified by solubilizing the samples using the microwave-assisted acid digestion procedure (EPA 3052).

Our findings highlight elevated Cr in the upper part of the basin near the industrial centre of Solofra, consistent with the high concentration of tanneries that use Cr salts in their production process. Conversely, highest Cu concentrations characterize the lower section, near the river mouth, which is an area influenced by intensive agriculture.

An attempt to identify the sources of contamination in the river basin was also made, applying principal component analysis (PCA), a multivariate statistical analysis technique. The PCA was performed on a selection of highly correlated elements and allowed to classify samples into two main groups: one affected by industrial pressure exerted by the tannery pole (Upper course) and another influenced by agricultural activities and urbanization (Lower course). No consistent correlation was found between sediment grain size and metal accumulation.

Future work will involve integrating in the multivariate analysis also the data of the organic compounds. This combined multivariate approach could improve the definition of the chemical profile of complex contamination sources and deepen the understanding of the environmental and health risks linked to the contamination scenarios.

Rapid Landslide Emergency Mapping Through Multi-Model Fusion of Sentinel-2 Data on Cloud Platforms

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Keywords: landslide detection, Google Earth Engine, Sentinel-2, machine learning, remote sensing.

Early and accurate landslide detection is indispensable for hazard mitigation, especially in geo-hydrologically threatened regions. This paper presents a cloud-based operational scheme that automates landslide detection by integration of three complementary methods: the Sudden Landslide Identification Product (SLIP), Tasseled Cap Transformation (TCT), and Convolutional Neural Networks (CNN). SLIP model relies on spectral change indices like Red band reflectance, NDVI, and NMDI for the quantification of pre- to post-event Sentinel-2 imagery differences enhanced by SRTM-derived slope filtering to identify landslide susceptibility. The TCT method generates high-speed-change RGB composites in terms of δTCTBrightness, δTCTGreenness, and δTCTWetness indices whose physically meaningful representations characterize surface change. CNN models, learned from mapped landslide inventories, enable robust pixel-wise feature learning from morphologically heterogeneous environments. This multi-model strategy is implemented entirely within Google Earth Engine (GEE), enabling scalable analysis with cloud-based data handling at ease, supplemented by Python integration via Google Colab for model adaptation and iterative refinement. The proposed method is validated by applications in two very different contexts: the Marche Region of Central Italy, which experienced extreme floods and landslides in 2022, and the monsoon-hit Chitral District of Northern Pakistan. Preliminary quantitative results demonstrate 87.7% overall accuracy and 66.7% recall for the combined SLIP-TCT approach, with the CNN component further improving detection reliability by 22% in F1-score (a balanced metric that considers precision (ratio of accurately predicted landslides) and recall (ability to detect actual landslides). This improvement is the CNN's capacity to reduce both false positives and false negatives). Model validation employs regional landslide inventories, predictions combined in a Bayesian setup that returns continuous maps of probability rather than binary labels. A threshold optimization loop estimates ranges of probabilities optimizing detection reliability (F1-score) and sensitivity (True Positive Rate) to support performance assessment. The preliminary results validate the operational efficiency of this hybrid approach, since the consistency of baseline detection by the SLIP model is coupled with integration of TCT and CNN, allowing increased sensitivity to heterogeneous landslide signatures. Cloud-native deployment of the framework achieves processing times that are consistent with emergency response deadlines and delivers a solution that can be transferred to landslide hotspots worldwide. By bridging novel analytical methods to operational requirements, this work delivers both scientific advancement and operational applicability for near-real-time landslide hazard estimation.

Hotspot Analysis for discriminating geochemical Anomalies and estimating Background levels in the Soils of an Intensely Anthropized Volcanic Region in Italy

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Keywords: spatial patterns, hotspot analysis, background thresholds.

Soils are the result of physical, chemical, and biological processes acting on rocks and their weathered products. Over historical times, these natural processes have been profoundly influenced by anthropogenic activities such as industrial production, vehicular emissions, waste disposal, and agricultural practices. Consequently, soils act as sinks for chemical elements and compounds, which exhibit high spatial variability across the Earth's surface.

Understanding the spatial distribution of contaminants, identifying anomalous concentrations, and determining the underlying drivers of variability are crucial tasks in environmental management. These efforts are particularly important when assessing ecological risks and impacts on human health, and when aiming at effective remediation strategies.

In recent years, the availability of large geochemical datasets has highlighted the need for advanced analytical approaches. Among these, spatial clustering methods have shown great potential for identifying hidden patterns in complex data. In this study, we applied the Getis-Ord Gi* statistic to more than 7000 topsoil samples (~7300) collected from the Campania region in southern Italy, focusing on 21 chemical elements. The analysis revealed statistically significant clusters of high (hot spots) and low (cold spots) concentrations.

The spatial patterns of elements showed strong correlations with regional geological features.

Elevated levels of As, Ba, Be, Bi, Cu, Sr, Th, Tl, U, and V were primarily associated with soils developed on volcanoclastic deposits, whereas higher concentrations of Co, Cr, Ni, and Mn characterized soils developed on siliciclastic units. Additionally, Cd, Hg, Pb, Sb, Sn, and Zn showed high concentrations in proximity to and across urban and industrial centres, highlighting the role of anthropogenic sources in their spatial distributions.

To further investigate the influence of anthropogenic contamination, elements typically associated with human activities were examined in greater detail. Hotspots indicative of potential contamination were isolated and excluded from subsequent calculations of the upper tolerance limit at the 95th percentile (UTL95%), providing an estimation of the geochemical background levels for these elements.

In this context, hotspot analysis proved to be not only an effective tool for identifying anomalies and revealing complex spatial patterns, but also a methodological support for refining background/baseline threshold determination in contaminated regions.

This approach provides a powerful framework for interpreting large environmental datasets and supports informed decision-making in land management and contamination mitigation.

Mount Etna Crustal Structure Through the Lens of P-Wave Anisotropic Tomography

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Keywords: Etna Volcano, Anisotropic Seismic Tomography, Volcano Dynamics, Crustal Structure.

Mount Etna (Italy) is an active and hazardous volcano shaped by the complex interplay of magma dynamics and tectonic forces. Seismic tomography has been a key tool for investigating its crustal structure; however, traditional isotropic models fail to fully capture the complexities of velocity distributions within the shallow-to-intermediate crust. To address these limitations, this study employs an innovative anisotropic seismic tomography approach, inverting P-wave travel-times to recover Pwave velocity and three anisotropic parameters: the magnitude, azimuth, and dip of the symmetry axis. This methodology provides a more detailed and accurate imaging of the volcanic structure, shedding light on both the regional tectonic influence and the intricate pathways of magma migration.

Our findings reveal a prominent high-velocity body located in the central and southern sectors of the volcano, extending from the surface to depths of over 6 km. This volume, characterized by low seismicity and high velocity, is interpreted as solidified magmatic bodies that have intruded the crust along tectonically weak zones. Additionally, several low-velocity anomalies are identified, interpreted as fluid-filled, pressurized rock volumes associated with the sedimentary substratum to the south, and tectonically complex areas to the north and west.

Incorporating anisotropy into the inversion significantly refines the velocity models, enhancing spatial resolution and reducing the strength of the anomalies compared to isotropic models. Anisotropic analysis reveals fracture and fault orientations, with slow axes in the high-velocity body suggesting radial fractures linked to magma ascent. These fracture patterns correlate with the distribution of volcanic cones, eruptive fissures, and dyke orientations, further supporting the relationship between magma dynamics and surface features. In the deeper crust (>6 km), we identify a high-velocity volume, deepening towards northwest, recognized as the collision-related subducting foreland units that appear to confine a low velocity anomaly, hypothesized to be the expression of a deep magmatic reservoir. A likely tectonic-origin discontinuity affects the subducting units, facilitating the transfer of magma from depth to the surface. This geological setting may explain the presence of such a very active basaltic strato-volcano within an atypical collisional geodynamic context.

This study emphasizes the important role of anisotropy in refining our understanding of the volcanic and tectonic processes beneath Mount Etna, offering a better perspective on magma ascent and guiding future volcanic monitoring efforts.

Age-clustered eruptive activity at La Palma (Canary Islands) during the last 4000 years: Evidence from paleomagnetic dating

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Keywords: La Palma, Paleomagnetic dating, Holocene, Basaltic eruptions.

The detailed knowledge of timing and dynamics of pre-historic eruptions is pivotal for volcanic hazard assessment. This is most relevant for inhabited lower slopes of active basaltic volcanoes such as La Palma (Canary Islands), where the 2021 Tajogaite eruption caused severe destruction. We paleomagnetically investigated eight La Palma Holocene eruptions which are currently loosely constrained either by few radiometric (K/Ar and 14C) ages, or by stratigraphic/archaeological evidence. The paleomagnetic directions gathered from 28 sites (300 oriented cores) were compared with updated reference models of the paleo-secular variation of the geomagnetic field direction during the Holocene. Overlapping paleomagnetic directions from the Fuego and La Fajana lava flows, along with geologic and geochemical evidence, imply that the two flows were emplaced during the same eruptive event falling within the 2000–1730 BC time window. Single paleomagnetic age windows – consistent with and narrower than available 14C age intervals - were obtained for the Malforada–Nambroque, Montaña Quemada, and Fuego–La Fajana lava flows. Conversely, the Martín, Birigoyo–La Barquita, and La Caldereta flows yielded multiple age solutions. Moreover, our data show that the flanks of the pre-historic San Antonio scoria cone are almost totally covered by pyroclastic products of the nearby AD 1677 Fuencaliente eruption. The updated chronologic framework of the pre-historic volcanic activity at La Palma demonstrates that the past four kyr are characterized by an early period with low-frequency eruptions (three lava flow eruptions between ca. 2000 BC and 300 BC), followed by a ca. 1000 yr-long quiescence period, and by a subsequent clustering of nine events during the last 1100 yr (about one eruption per century).

Geological survey of the Eocene Lessini Mountains volcanic district (Veneto, Italy) within the CARG Project

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Keywords: CARG Project, Geological mapping, Volcanic stratigraphy, Lessini Mountains, Eocene basaltic eruptions.

A new geological map is being produced for the Lessini Mountains of the Southern Alps (Italy) in the Veneto Region as part of the national geological mapping CARG Project (Sheet 124 – Verona Est). The study area comprises from Mesozoic-Cenozoic sedimentary rocks to Tertiary volcanic products and Quaternary deposits. Mapping is currently being performed at the 1:10.000 scale on rock types belonging to the Lessini Mountains volcanic district (within the Venetian Volcanic Province). Based on fieldwork, geomorphometric, and petrographic data, basaltic hyaloclastites (both in situ and reworked) to lava flows have been recognized.

Stratigraphic relationships between sedimentary and volcanic deposits show that volcanic activity started during the Eocene in submarine environments and evolved progressively towards subaerial conditions. Preliminary observations suggest, as initial volcanic manifestation, a typical basaltic fissural eruptive activity in submarine context, while a polygenic volcanism prevails in the successive subaerial environment. Such volcanic structures developed in the peculiar geodynamic setting of the Venetian Volcanic Province.

Volcanic activity shows indeed a complex interaction with (i) the pre-Eocene sedimentary succession, which is frequently crossed by cm- to m-thick dykes and sills, and (ii) tectonic structures (e.g., normal, high-angle faults), exploited by the rising magma. Finally, the great Castelvero normal fault shows to be syn- to post-volcanism on age. The base of the volcanic sequence, resting on the Upper Cretaceous Scaglia Rossa Fm, is indeed dissected by the Castelvero fault, cropping out at lower elevations in the eastern fault hanging wall, and small portions of volcanic products compose tectonic slices along the main fault zone.

Moreover, volcanic products display growth structures related to fault development during the Lessini Mountain volcanism.

Structural Evolution and Strain Characterization of the Ligurian Units in the Cilento area (Southern Apennines, Italy)

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Keywords: Ligurian Accretionary Complex (LAC), Deformation, Folding Events, Shear Zone, Accretionary Prism.

Comprehensive structural and microstructural observations from the Ligurian Accretionary Complex (LAC) in the Cilento region covering Pioppi, Punta Telegrafo, and Caprioli areas revealed a polyphase deformation history. Field studies identified two principal folding events: F_1 tight to isoclinal folds with axial-planar S_1 foliation, and F_2 isoclinal to open folds that refold F_1 structures, generating S_2 crenulation cleavage. Thrust faults and ductile shear zones are common, displaying S–C and S–C′ fabrics, rotated σ- and δ-type porphyroclasts, and boudinage, indicating top-to-the-NE vergence within a sub-simple shear and oblate regime.

Microstructural analysis supports these field interpretations, showing overprinting relationships between S_1 and S_2 foliations, which recorded progressive dominant non-coaxial deformation under ductile conditions. Finite strain data and vorticity indicators (Wk = 0.75–0.88) from shear zones confirm mixed simple and pure shear, consistent with deformation in an accretionary prism setting.

Collectively, these structural results indicate a tectonic evolution characterized by early ductile folding and thrusting, later refolding, and localized shearing. The integration of meso- and micro-scale evidence demonstrates that deformation within the LAC reflects the progressive frontal accretion and internal reworking of the oceanic-derived sequences during the Miocene evolution of the southern Apennines.

Influence of aggregate grain size on the hydraulic behavior of lime mortars

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Keywords: Hydraulicity Index (HI), Volcanic aggregates, Experimental mortars, GIS-based image analysis, Physical-mechanical properties.

The Baroque architecture of Catania (Eastern Sicily) is the result of a reconstruction that occurred after two devasting events, i.e. the 1669 eruption and the 1693 earthquake. Volcanic aggregates from Mt. Etna activity, specifically azolo and ghiara, are key components in historic lime mortars. Azolo, now obtained from finely ground basalt, was originally an incoherent pyroclastic rock, while ghiara is a reddish material derived from the thermal transformation of paleo-soils due to lava flows. provide aluminosilicates that, in the presence of moisture, promote the hydraulic reactions leading to the formation of calcium silicate (CSH) and calcium aluminate hydrates (CAH).

In this contribution, we present the results of a physical-mechanical study of mortar replicas reproduced in laboratory for conservation purposes by using the ancient recipes. Specifically, a 3:1 aggregate/binder ratio has been used for both azolo- and ghiara-based mortars. Two different formulations were prepared for each type: one with aggregate grain size in the range 2 - 0.063 mm and the other one comprising also the finer fraction (< 0.063 mm). After 28 days curing, minero-petrographic analyses (XRD, POM, SEM-EDS) have been performed along with physical-mechanical tests (water absorption, uniaxial compressive strength, perforation test) and accelerated degradation by salt crystallization.

Additionally, a GIS-based image processing approach (Q-XRMA software) was applied to assess the hydraulic properties of experimental mortars through multivariate statistical analysis of X-ray maps. Two micro-domains per mortar type were analyzed to evaluate the grain size influence on reactivity. High-resolution X-ray elemental maps revealed distinct hydraulic phases within the binder. Ghiara-based mortars showed higher Hydraulicity Index (HI) values (~90% of the binder falling in the 0.3–1.5 range, from moderately hydraulic lime to cement) than azolo-based ones (~90% in the 0–0.3 range, from aerial lime to moderately hydraulic lime).

Experimental results also highlighted that the fine aggregate fraction in ghiara-based mortars increases HI values by enhancing reactive surface area, reduces porosity and water absorption and improves mechanical strength. Conversely, in azolo-based mortars, the fine fraction has negligible impact on the mechanical performances but delays hardening.

Endocast shape variation in mammals through the lens of phylogenetic evolutionary rates

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Keywords: Mammals, brain evolution, cortical areas variation, primates.

The close link between cognition and brain evolution has drawn great scientific interest. Mammals have complex, highly convoluted brains, that are generally larger (relative to body mass) than those of other vertebrates except birds. This is the result of a long trend toward larger and more complex brains in the group. The neocortex of early mammals was smaller and simpler compared to today's species, which possess up to six layers of neurons, and highly gyrified brains. brains. In humans, in particular, the neocortex occupies about 90% of the entire cerebral cortex.

In this study, we analysed cortical shape variation within Mammalia by using a newly developed statistical tool to study the evolution of specific brain areas, pinpointing individual areas under selection across different mammal groups. We found that a general trend towards expansion of the frontotemporal area pertains to eutherians as a whole but not to marsupials. Primates stand out among other mammals for their highly derived cortical shapes. In primates, the large neocortex evolves frontally. In the human clade further expansion in the parietal and occipital areas gives the brain a globular shape.

Geological, environmental, and methodological factors affecting Radon concentration in the soil: first results from the Gioia Plain (Southern Calabria, Italy)

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Keywords: Radon, control factor, measurement technique, risk mitigation, Calabria.

Distribution of Radon-222 (Rn) in soils is affected by several factors, related to geological and environmental characteristics. Produced by the decay of Uranium-238 in the bedrock, Rn can migrate up to the surface, carried by fluids through pores and fractures. It can be found in extremely various amounts in the regolith, also depending on permeability, texture, moisture and organic content.

Environmental factors – such as temperature, atmospheric pressure and relative humidity – also affect release and migration of the gas. Seasonality plays a key role, as climatic conditions lead to different concentrations at the same sites. In addition, morphological and geo-structural characteristics – e.g., presence of faults and fractures – commonly represent preferential pathways for gas migration, leading to heterogeneous spatial distributions.

Rn concentrations in the soil tend to vary with depth, providing indications on gas-migration dynamics. An increase with depth is usually observed, due to intermediate layers with low permeability, and because deeper layers are less subject to atmospheric influences. At shallower depths, concentrations show daily and seasonal fluctuations. Soil structure and variations in groundwater levels can also influence the accumulation and release of Rn, resulting in a non-uniform distribution.

A further critical element affecting measured amounts of Rn concerns the measurement techniques and procedures. Only a pre-established sampling procedure, defined in detail and shared within the survey team, can enable correct sampling and, at the same time, obtain a homogeneous population of data. Moreover, the periodic maintenance/calibration of instruments is a crucial factor for reliable results. Conversely, discrepancies may arise from inherent characteristics of the instruments or slightly different operating procedures.

For an accurate acquisition of radon concentrations in soil, an integrated approach is therefore needed that considers: i) characteristics of the soil; ii) environmental and climatic dynamics; iii) underlying geological structures and stratigraphy; iv) rigorous and uniform measurement techniques and procedures.

A review of geological, environmental, and methodological factors affecting Radon concentration in the soil is presented. In addition, the first results of measurements in the soils of the Gioia Plain (Southern Calabria) are briefly described, with reference to the above controlling factors. The study area is characterized by Palaeozoic magmatic and metamorphic rocks, covered by Tertiary and Quaternary terrains, and is cut by regional faults systems, responsible for major historical earthquakes. Based on such preliminary results, effective strategies for monitoring and mitigating Rn-related risk can be defined for the study area.

Development and implementation of procedures and techniques for verifying the reliability of Reference Geological Models: preliminary study

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Keywords: Reference Geological model, Reliability, Tunnels.

Infrastructure development is vital for economic growth, social progress, and improved living standards. Among these, underground structures like tunnels, considered the silent marvels of modern engineering, play a pivotal role in connecting landscapes, facilitating transportation, and overcoming geomorphological and geographical obstacles. From ancient civilizations carving rudimentary passageways through mountains to the advanced, mechanized tunneling techniques of today, tunnels have evolved as a testament to human ingenuity and determination. The design and construction quality of tunnels depend entirely on the degree of understanding of the geological, geotechnical, geomechanical, and hydrogeological contexts of the project area. All this information is provided by Reference Geological Models. However, these models involve a certain degree of uncertainty due to the complex behavior of the natural environment. Reference Geological Models are simplified representations of surface and underground reality, used to guide the design and construction of infrastructures such as roads, bridges, tunnels, building foundations, offshore platforms, dams, quarries, etc. This study aims to compute and verify the reliability of reference geological models in the specific context of tunnel design and construction. To achieve this objective, two case study tunnels were chosen, each with different geological contexts. The first one is about 1.7 km long and crosses terraced alluvial deposits in three lithofacies characterized by polygenic and heterometric gravels, silty sands, and clayey silts. The second one is about 2.2 km long and crosses a deposit of Varicolored Clays in three lithofacies that include silty and sandy clays, stratified or massive limestones, and alternating clay and limestone layers. The tunnels were divided into 100 m sections in simple geological contexts and 50 m sections in complex geological contexts.

Reliability indices (R-index and Geological Model Rating) were calculated. The quantification and calculation of these two indices is based on three main parameters, including the investigation parameters, the system parameters and the interpreter's capabilities. The reliability of the models was verified by comparing the project's geological models with actual field data, such as more than 230 survey sheets of excavation faces in progress. The preliminary observations show that, in the first study case, which presents simplifications concerning lithostratigraphic complexity and the complexity of ductile and brittle deformations, the geological reference model successfully reflects the underground reality in most sections. On the other hand, the second, more complex case reveals a significant discrepancy between the predictions of the project's geological model and actual underground conditions.

Preliminary assessment of saltwater intrusion in the Volturno coastal plain (Southern Italy): a multidisciplinary case study

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Keywords: Saltwater Intrusion, transition, Coastal aquifer vulnerability, Integrated hydro-geophysical approach.

Saltwater intrusion represents one of the most serious and growing pressures on coastal aquifers globally, particularly in areas affected by intense urbanisation, extensive irrigated agriculture, and geological vulnerability. The phenomenon involves the progressive advancement of seawater into groundwater systems due to an imbalance between recharge and withdrawal rates. This process, further exacerbated by climate change (i.e., sea-level rise), local subsidence, and reduced natural recharge, can compromise the quality of water resources for human consumption, agriculture, and industry, with potentially irreversible consequences on soil productivity and coastal ecosystem integrity.

The Volturno coastal plain (Southern Italy) provides a representative example of these critical dynamics. Over the past decades, a combination of intensive groundwater abstraction, land subsidence, and anthropogenic alterations has led to a progressive deterioration of groundwater quality and a marked inland advancement of the saltwater wedge (Alberico & Matano, 2024).

Several previous studies using numerical modelling, geophysical surveys (Tarallo et al., 2023), geostatistical methods (Schiavo et al., 2023), and environmental tracers (Colombani et al., 2024) have highlighted the complexity of the local hydrogeological system and the coexistence of active marine intrusion with residual palaeosalinisation.

Against this backdrop, a new technical-scientific initiative has recently been launched with the SAL.WE. Project, funded by Basin Authority of Southern Apennines District - FSC 2014-2020 PED Acque. The objective is to enhance the spatial characterisation of saltwater intrusion through an integrated and replicable approach. Studies include analyses of coastal plain stratigraphy, hydrological features, subsurface hydrogeological setting and ecological features, as well as analyses of shoreline evolution, subsidence processes, meteorological, climatic and sea wave parameters.

Current activities include electrical resistivity tomography (ERT) surveys, groundwater and surface water sampling, and measurement of key physic-chemical parameters (e.g., conductivity, salinity) along selected coastal transects.

Preliminary results allow for an initial delineation of the areas most affected by saltwater intrusion and the construction of a baseline knowledge framework for vulnerability analysis. This will support the implementation of long-term monitoring systems and the design of sustainable groundwater management strategies. The study is presented as a case study potentially applicable to other Mediterranean coastal aquifers under similar hydrogeological stress conditions.

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Antropigene: a new approach to detect soil contamination and natural backgrounds. The case study of Campania region, southern Italy

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Keywords: Environmental geochemistry, antropigene, contamination.

The determination of the natural geochemical background is crucial for differentiating natural concentrations of chemical elements from anomalies due to the anthropogenic activities, thereby enhancing environmental monitoring and sustainable resource management. This study introduces the *Antropigene*, a new tool derived from the concept of the *geochemical gene* (Yan et al., 2018), applied for the first time in an environmental context to characterize urban and agricultural contamination in the Campania region of Southern Italy.

To construct a geochemical gene, five key steps are proposed: selection of elements, determination of reference values, spectral line and codes, calculation of similarity, and sequence of elements (Yan et al., 2018; Li et al., 2019; Gong et al., 2020). Following this methodology, the *Antropigene* was developed by analysing over 3,000 topsoil samples from the Campania region and selecting indicator elements specific to various contamination types: lead (Pb), zinc (Zn), mercury (Hg), antimony (Sb), and gold (Au) for urban pollution, alongside arsenic (As), copper (Cu), potassium (K), sodium (Na), and phosphorus (P) for agricultural contamination. A unique geochemical code was calculated for each sample based on the contamination type examined, and final maps of contamination patterns within the study area were produced, revealing distinct spatial distributions linked to both urban and agricultural impacts.

Preliminary results show that the urban gene identifies anomalies corresponding to the main urban areas in the region, while the agricultural gene highlights zones designated for cultivation, particularly vineyards on the island of Ischia and in the Phlegraean Fields area, as well as the Sarno Basin, known for its intensive agricultural production. Furthermore, through the calculation of similarity among the genetic codes of the samples, a more accurate distinction was made between anthropogenic anomalies and samples related to the natural background. The latter were subsequently used to determine specific background values for each geological context.

This new approach demonstrated a faster and more practical method, as it considers the association of chemical elements related to specific contaminations, providing a comprehensive understanding of anomalies and enabling better identification of background samples compared to conventional methods. The *Antropigene* could serve as a valuable tool for environmental monitoring and the management of natural resources, contributing to a deeper understanding of geochemical dynamics and large-scale anthropogenic influences.

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Constraining geometry and kinematics in the Quaternary Fault System of the Campania-Lucania Arc: approaches and comparisons

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Keywords: tectonics, seismic lines, extensional fault, structural geology, 3D modelling.

The Campania-Lucania Apennines are of significant scientific interest due to their stratigraphic-structural setting, intense hydrocarbon exploration, and extensional seismicity associated with Pleistocene-Holocene normal faults. In the northeastern sector of the Alburni Mountains, east-dipping normal faults dominate the extensional structural setting, representing the expression of a regional synthetic detachment surface. The survey of key areas has provided new data that have been integrated into a database for the creation of a regional-scale geological-structural map, extending from the southern flank of the Picentini Mountains to the northwestern border of Mt. Pollino. These data constitute the surface constraints used to draw four shallow geological cross-sections.

The extensive availability of structural data in the northern sector motivates the expansion of investigations into the southern area, using various approaches focused on the interpretation of seismic lines, where coverage hinders a satisfactory surface analysis.

Particularly, this work aims to determine whether the deformational style observed in the northern sector can be generalised across the entire internal region of the Campania-Lucania arc, from the Sele Plain to the Mt. Cervati massif.

The integration of surface geological data with the logs from some calibration wells, available in the literature, enables the interpretation of a grid of 12 seismic lines provided by both Eni and the openly accessible Videpi database. The varied methods employed for interpreting seismic lines - whether on paper, through software like Move® and Kingdom®, or by converting raster formats into SEG-Y - are part of the multidisciplinary approach adopted for this highly complex region. Comparisons of results obtained using different software help refine the methodology. The conversion of the seismic dataset from two-way travel time to depth has resulted in a series of crustal sections that facilitate the comparison of both contractional and extensional structures across the study area. Seismic lines, interpreted down to the Apulian Platform Top, shed light on some significant aspects: the geometry of the extensional fault systems and the depth of their detachment surface; the hierarchy and the relationships between normal and reverse faults; last but not least, the shape of syn-tectonic Quaternary depressions and the thickness of their sedimentary infill.

Petrographic Characterization and Optimized Analytical Approach for Fluorite-grade evaluation: Quantitative Analysis of Geo-Complex Products from the Pianciano Mine (Italy)

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Keywords: Geo-complex products, Mineralogical analysis, Fluorspar, Ore Geology.

Geo-complex products consist of mixtures of two or more different raw materials, requiring the definition of ad hoc beneficiation methods for their characterization. In this case, the products studied, marketed by So.Ri. Co.M. Srl - Società Ricerche Coltivazioni Minerarie, consist of two different mixtures from the Pianciano mine: a low-grade mixture (from 30 to 50 wt% CaF2) and a high-grade mixture (from 50 to 70 wt% CaF2). The Pianciano-Castel Giuliano carbonatite-fluoritite sequence was first described by Mastrangelo (1976) as the main deposit in the Sabatini Mountains area, covering about 6-8 km2 and characterised by the presence of four different mineral facies: white carbonate rocks; yellow carbonate rocks; white fluoritite and grey fluoritite. The latter is the source of CaF2. The deposit has since been extensively studied and its facies have been interpreted as carbothermal residual carbonatites. This type of rock is interpreted in the late evolution of alkaline magmatism of the Roman Volcanic Province.

The Pianciano geo-complex is characterized by heterogeneous mineralogical assemblages, where fluorite (CaF2) occurs predominantly in grain sizes smaller than 200 μm. Accurate CaF2 quantification using conventional methods is hampered by this fine distribution. We propose a novel method based on granulometric spindle separation and targeted mineralogical evaluation. After primary quartering, the bulk material is homogenized with 120 vol% hydrogen peroxide (H2O2) to disaggregate the material. The resulting suspension is sieved at 200 μm and dried below 80°C. Both the <200μm and >200μm fractions are dried separately, quartered and analysed by X-ray powder diffraction (XRPD) for quantitative phase identification. Scanning Electron Microscopy with Energy Dispersive Spectroscopy (SEM-EDS) is used to aid qualitative characterization and phase control. Mineralogical analysis shows that the <200μm fraction typically consists of semi-pure mixtures of fluorite, calcite and barite. This methodological refinement allows a more reliable determination of the actual mineral content of the Pianciano end rock and its processed derivatives. Given the strategic role of fluorspar in reducing CO2 emissions during clinker production, accurate assessment of CaF2 content is essential to promote the sustainable use of geo-complex products and minimize industrial waste.

Key-factors in the genesis of pure Plinian vs. caldera-forming eruptions: experimental constraints

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Keywords: experimental petrology, volcanology, phase relations.

The advancement in understanding of physico-chemical conditions that characterise magma plumbing systems, is a main issue in volcanological investigations. In fact, the evolution of eruptive phenomena is strictly correlated also to pressure conditions (Bower and Woods, 1998), whose precise estimation is still subject of debate, (Masotta et al., 2013). In this view, the study of phase relationships and stability fields of mineral phases sensitive to variations of pressure, temperature and volatile content conditions could contribute to the resolution of this matter. During a recent geological survey in Ventotene Island (Pontian Island, Tyrrhenian Sea), primary analcime, that according to literature is stable at PH2O >200 MPa, was observed in Cala Battaglia unit (UCB2), that consists of a sequence of Plinian fall deposits, without associated pyroclastic currents. Conversely, this mineral phase does not occur in the deposits (both Plinian fall and pyroclastic currents) of the Parata Grande caldera-forming event. In order to investigate the influence of pressure and volatile content (H2O) on phase relations, of alkaline differentiated products (tephri-phonolite, MD1, from Parata Grande, and trachyte, UCB2 from Cala Battaglia unit), low-pressure (150 MPa) to high-pressure (600 MPa) experiments were conducted under water-saturated and water-undersaturated conditions. For the tephri-phonolite composition MD1, only the pressure condition 600 MPa was preliminarily explored, while the trachyte UCB2 was investigated at two different pressures of 150 MPa and 600 MPa. In the experiments, the temperature ranged between 700-1050°C. The main experimental results show that in the H2O-undersaturated experiments on MD1, the mineral assemblage consists of clinopyroxene+apatite+oxide at 1050 °C, followed by biotite, plagioclase and K-feldspar at decreasing temperature, while in the over-saturated one (950 °C) the paragenesis is composed of mica, clinopyroxene, oxide and apatite. Experiments on the UCB2 composition, in the high pressure set, a hydrous feldspathoid associated with plagioclase and biotite occurs at 900°C, followed by K-feldspar at lower temperature (750°C). Conversely, in the products of the low pressure set, the hydrous feldspathoid is absent and the mineral assemblage consists of K-feldspar, plagioclase, biotite and oxide. The experimental results suggest that hydrous feldspathoid minerals are unable to crystallise from a H2O-saturated trachy-phonolitic magma in shallow (≤150 MPa) reservoirs. This evidence supports the hypothesis that pre-eruptive magma system's depth is a primary factor controlling pure Plinian (e.g. Cala Battaglia) vs. caldera forming events (e.g. Parata Grande).

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Structural analysis of fracture systems and their interaction with intruded mafic dikes in the Montorfano Granite (Verbano-Cusio-Ossola, Italy)

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Keywords: mafic dikes, granitic pluton, structural analysis, petrological analysis.

Understanding the geological structures controlling rock mass stability and deformation over time is crucial for safety in quarrying and related activities. Quarry faces provide excellent exposure for structural investigations, revealing otherwise hidden geological features.

This study focuses on the structural analysis and post-crystallization deformation history of the Montorfano granitic pluton, part of the "Serie dei Laghi Massif" (Southern Alps). This composite Permian batholith (275–283 Ma) crops out along the Cossato-Mergozzo-Brissago (CMB) tectonic line, extending from Biella to Lake Maggiore. The research area includes the former Ciana-Tane Pilastretto Quarry and adjacent working yards. The study aims to: 1) map geological structures (fault planes, fractures, and shear zones), 2) investigate their relationships with mafic dikes intruding the granite. A multi-phase structural analysis was conducted, integrating field data, pre-existing studies, and remote sensing (DOM and morphostructural maps) for inaccessible structures. Stereographic projections and kinematic analysis enabled a paleo-stress reconstruction, revealing four tectonic regimes: one compressive, one extensional, and two strike-slip phases. However, the chronological relationships among these regimes remain uncertain.

The structural framework was integrated with petrological and geochemical analyses of the mafic dikes. Representative samples were analyzed using X-ray fluorescence (XRF) and scanning electron microscopy (SEM). Preliminary results indicate high alteration of dyke, with significant chlorite content and compositions ranging from basaltic to dacitic. The presence of apatite grains suggests potential for radiometric dating. Our findings indicate that compression was the earliest deformation phase, followed by extension. The role of strike-slip phases is less clear but aligns with a major right-lateral shear zone. A shear zone model with Riedel fractures suggests that reverse and right-lateral faults are subparallel, possibly indicating reactivation of pre-existing reverse faults. Compression may have facilitated dike emplacement, as intrusion appears syn-kinematic with reverse faulting ($\sigma 1$ parallel to dikes). Left lateral faults may represent antithetic R' faults or record stress field rotation.

Overall, the mapped faults likely correspond to multiple tectonic phases, including Alpine-related deformation (Insubric Line), Triassic-Jurassic extension, and Late Permian post-crystallization processes. Dating the mafic dikes is essential to constrain the geological, tectonic, and evolutionary history of the study area.

Seismicity and Surface Deformation: Insights into Fault System Geometry Along the Main Himalayan Thrust

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Keywords: seismic analysis, fault geometry, Main Himalayan Thrust, InSAR, coseismic deformation.

The spatial distribution of seismicity is widely used to identify the location and geometry of active tectonic structures and to assess their seismic potential. To ensure a correct link between seismicity and activated structures, accurate relocation of seismic events is essential. Recently, this approach has been successfully applied following the 2015 Gorkha Earthquake (Mw 7.8) (Yamada et al., 2020), which was caused by one of the world's most destructive thrust faults, the Main Himalayan Thrust (Wang et al., 2017). The precise hypocentral estimation of the sequence (Yamada et al., 2020) provides a valuable opportunity to examine the debated flat-ramp geometry along the activated segment of the Main Himalayan Thrust (Wang et al., 2017).

We have developed a new statistics-based Python tool that facilitates the rapid and efficient analysis of hypocenter spatial distribution to identify possible tectonic alignments, infer the geometry of the activated fault system, and correlate it with surface coseismic deformation. Our results reveal a fault system rooted in the Main Himalayan Thrust, consisting of both synthetic and antithetic high-angle splays. Their upward continuation closely matches the coseismic deformation recorded by InSAR data, suggesting their activation as reverse faults during the Gorkha earthquake. Thus, our findings highlight the important role of previously unknown hanging-wall splays in rupture propagation and their influence constraining surface deformation.

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DFT simulation study of structural, vibrational, and electronic properties of dolomite

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Keywords: Mineral Exploration, Prisma Hyperspectral, Spectroradiometry, Anti-Atlas.

Dolomite $CaMg(CO_3)_2$ is a double carbonate mineral crystallizing in the trigonal system, space group R3, with an hexagonal-like unit cell framework formed by Ca-Mg cations octahedrally coordinated (NC = 6) with the oxygens lying on the trigonal planes of the carbonate groups $(CO3)^{2-}$. Dolomite is substantially known as being the most abundant mineral in dolomitic rocks (dolomia) as well as present in all other carbonatic rocks therefore, being one of the main protagonists of the Earth's carbon cycle. This work aims at strengthening the knowledge of the minero-physical properties of this mineral using a novel multimethodology approach combining density functional theory (DFT) simulations with experimental investigations. The experimental knowledge was obtained from both existing updated literature and instrumental measurements performed on a natural sample of dolomite taken from Traversella mine nearby Ivrea, Turin (Italy). The assessment of the crystallographic and physico-chemical structure of dolomite was done with X-ray diffraction analysis (XRD), Environmental scanning electron microscopy coupled with energy dispersive spectroscopy (ESEM-EDS) at low vacuum conditions (70Pa) and vibrational analysis through FTIR (Fourier Transformed Infrared) and Raman spectroscopies. Ab initio DFT-simulations were performed with CRYSTAL23 code adopting Gaussian basis sets and 12 different Hamiltonians of the Jacob's ladder (LDA, GGA, meta-GGA, GH and RSH), in addition, D3 dispersive correction factor to include the weak van der Waals forces was applied when conceivable. All the simulated properties i.e., the optimization of the crystallographic structure, the electronic and elastic properties were performed at T= 0K. Vibrational frequencies were computed at the Γ point in the first Brillouin zone, and the LO-TO splitting was calculated. Overall, the cross-correlation between the experimental and theoretical data showed consistent results from the micro- and nano-scale down to atomic scale. Although the simulations were performed within harmonic approximations the results appear to be in line with the experimental data with a better agreement obtained with hybrid functionals. The crystal structure of the mineral calculated using the different DFT functionals was in line with that obtained by XRD analysis. All the simulated IR and Raman spectra have exhibited the internal modes of the carbonate ion with a relatively blue-shifted bands from most of the functionals due to the simulation conditions state above. The elastic properties calculated show intrinsically stiffer nature of the mineral due to the intrinsic athermic conditions of the study. Finally, the calculated electronic properties, i.e., band structures and density of states (DOS), showed a band gap of ~5.0 eV, in good agreement with previously reported data. These first analyses would lay the ground to build a solid model to calculate the thermodynamical properties of the mineral at PT conditions.

Preliminary archaeometric analyses on artificial conglomerate blocks: the case of the Ugurgeri tower (Siena - Italy)

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Keywords: artificial stone, LiDAR, artificial stones, archaeometric analysis, medieval tower.

The Ugurgeri tower, datable to around the middle of the 12th century, stands in Siena, via Cecco Angiolieri, at the entrance to the alley leading to the Castellare of the homonymous family. Currently incorporated into the surrounding building fabric, the tower is distinguished by the extensive reuse of Roman material and the presence of artificial conglomerate blocks. The latter, of parallelepiped shape, are composed of angular lithic elements immersed in a mortar matrix. The aim of this study is to investigate the production processes of such material by making use of archaeometric analyses, to allow, in the future, adequate conservative restorations as well as laboratory reproduction with characteristics similar to the originals.

The methodology adopted for the archaeometric analysis and diagnostics of the state of conservation of the artificial conglomerate blocks is based on a multidisciplinary approach that combines non-invasive survey techniques and laboratory analytical investigations. In particular, the study was conducted using a three-dimensional photogrammetric survey with LiDAR (Light Detection and Ranging) technology, aimed at detailed mapping of the block surfaces, as well as through the collection of representative samples.

The analyses carried out include macroscopic observations for the determination of colour, X-ray diffraction (XRD) for crystal phase determination and polarizing optical microscope observation for mineralogical-petrographic characterization. Preliminary archaeometric analyses of the blocks attest to the use of local raw materials, offering significant data on building techniques and resource procurement methods in ancient times.

The study also highlighted a good general state of conservation of the material, suggesting the reproduction of the blocks in the laboratory with characteristics similar to the original ones, in order to understand the construction techniques and imagine their possible use.

Management of missing air pollution data within urban environments using machine learning regressions: a case study for Delhi, India

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Keywords: Horizontal to Vertical Spectral Ratio (HVSR), Seismic Site Response, Site Amplification, Seismic Monitoring.

Air pollutants including PM2.5, PM10, O3, NO2, SO2 and CO pose serious environmental challenges, especially in densely populated Asian metropolises like Delhi. Accurately assessing these hazards requires long-term, spatially distributed and complete monitoring data, which are often lacking. For instance, the World Air Quality Historical Database shows Delhi had only 4 stations in 2014 increasing to 45 by 2024, leads to inconsistent and incomplete records, hamper to evaluate urban air quality, policy effectiveness, and manage pollution levels. This study introduces a Monte Carl o-driven machine learning (ML) strategy to statistically cross-reconstruct missing daily pollution data for all six pollutants across 45 stations from 2014 to 2024.

For each station with gaps, the algorithm identifies its four most correlated pollution records form other city regions, assuming similar environmental conditions, then uses these as inputs in MATLAB's Regression Learner to test 35 ML regression models. The algorithm select the best-performing models by testing their reconstruction against the pollution record that needs to be filled and fills all possible missing points with the best ML prediction. This process is iterated until all data gaps for all 45 records are addressed. Our results show that Fine Tree, Bagged Trees, Optimizable Ensemble, Fine Gaussian SVM, Rational Quadratic, and Exponential models consistently outperform traditional multi-linear regression models. The reconstructed datasets enable the generation of ensemble mean records for each pollutant, offering a more realistic and bias corrected representation of Delhi's daily pollution dynamics over the decade. The final ensemble results reveals modest improvements in air quality between 2014 and 2024. Beyond Delhi, this statistical approach can be effectively applied to other cities and scenarios and it can be a powerful tool to study air condition in complex cities with missing data.

Preliminary analysis of the site response in sample sites of the INGV - Etna Observatory network

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Keywords: Horizontal to Vertical Spectral Ratio (HVSR), Seismic Site Response, Site Amplification, Seismic Monitoring.

The seismic site characterization of seismic monitoring stations represents an important information for the study of earthquake strong motion. Three stations of the Etna seismic network located in Fiumefreddo, Castiglione and Nicolosi were considered in this study. These seismic stations were preliminarily chosen because they are located in different geological- structural contexts.

In order to estimate the seismic site response, 527 earthquakes located by INGV in the eastern area of Sicily were checked, selecting from them 10 earthquakes with magnitude greater than 2.5 and station site distance less than 100 km. In addition, four one-hour segments of ambient vibrations time windows were selected for each station at different times of the year (March-May-August-November), to test the site response variability due to seasonal effects.

The data thus collected were processed using the Horizontal to Vertical Spectral Ratio (HVSR) technique.

The results obtained with the two techniques are comparable, with some differences in amplitudes, due to the different processing methodologies and the wavefield composition of the analyzed signal. The resonance frequencies identified at the three sites are mainly at low-frequencies (< 1.0 Hz), with amplitudes in the range 3-7 units.

From a preliminary interpretation of the spectral ratios, the observed site effects can be attributed to the different layers. In particular, for the low frequencies (<1.0 Hz) the resonance seems to be related to deep geological discontinuities (soft layer over the clay basement).

Comparison of electrical resistivity tomography and frequency domain electromagnetic methods for mapping seawater intrusion in shallow aquifers

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Keywords: Seawater intrusion, Electrical Resistivity Tomography, Frequency Domain Electromagnetics, Coastal aquifers, Climate.

Seawater intrusion into coastal aquifers is an increasingly pressing issue worldwide, primarily driven by climate change, rising sea levels, and unsustainable groundwater extraction. Addressing this challenge requires robust assessment and monitoring tools to support long-term water resource sustainability. While conventional hydrogeological methods like borehole logging yield precise but localized data, they often fall short in providing the spatial coverage needed for broader regional evaluations. In contrast, geophysical methods—specifically Electrical Resistivity Tomography (ERT) and Frequency Domain Electromagnetics (FDEM)—offer non-invasive alternatives with complementary strengths and limitations.

This study investigates the effectiveness of ERT and FDEM in delineating shallow seawater intrusion across four distinct locations along the northern coastline of Friuli Venezia Giulia, Italy. These sites vary in terms of salinity profiles, geological characteristics, and seasonal conditions. High-resolution ERT data served as the benchmark for evaluating subsurface conductivity. FDEM data were acquired using two instruments: a constant-frequency, multi-depth system and a multi-frequency, single-offset system, both selected for their capacity to collect rapid and extensive datasets.

To facilitate meaningful comparison, apparent electrical conductivity (ECa) values from FDEM were normalized against the ERT-derived conductivity profiles. Findings reveal that FDEM, while significantly faster to deploy, can yield dependable subsurface conductivity estimates without requiring site-specific calibration—provided appropriate normalization is applied.

The outcomes highlight the promise of FDEM as a practical, scalable technique for tracking seawater intrusion, offering new insights into coastal groundwater salinization and supporting the advancement of large-area monitoring strategies in environmental and water resource management.

From Earthquake Geology to risk-based solutions for strategic infrastructures – The Shaking spin-off initiative

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Keywords: Seismic Hazard, Fault Displacement Hazard, Earthquake Geology.

Shaking Srl (Seismic Hazard and Risk Assessing – www.shaking-srl.it) is a spin-off company of the University "G. D'Annunzio" of Chieti–Pescara (Italy), established in 2023. The company provides advanced consultancy services in the field of seismic hazard, adopting a modern earthquake geology approach and developing innovative methodologies and in-house software for hazard assessment.

Our core expertise lies in seismic hazard evaluations, encompassing the collection and analysis of active and seismogenic fault parameters, and the implementation of probabilistic models for both ground shaking and fault displacement hazard analysis. We support our clients in evaluating the seismic safety of existing or planned infrastructure, offering quantitative hazard analyses to inform risk-based design and mitigation strategies.

Our main fields of expertise include:

- Probabilistic Fault Displacement Hazard Analysis (PFDHA);
- Probabilistic Seismic Hazard Assessment (PSHA);
- Methodology & Innovation.

Our workflow typically follows three main phases:

1. Data Acquisition – Identification and characterization of active faults using state-of-the-art earthquake geology techniques, high-resolution geological and structural mapping, paleoseismological investigations, and the planning and execution of geophysical and geognostic surveys.
2. Data Processing – Assessment of seismic potential of faults (e.g., maximum expected magnitude, slip rates, expected displacement, recurrence intervals). PFDHA and fault-based and area-source based PSHA.
3. Data Visualization – Development of thematic maps in a GIS environment, fault zoning, and site-specific fault displacement hazard quantification to support risk-based approaches. Generation of probabilistic hazard curves and maps for both ground shaking and fault displacement.

In terms of methodology and innovation, our goal is to design and implement proprietary numerical codes for PFDHA, incorporating site-specific characteristics such as pre-existing discontinuities, fault ranking, soft soil cover, and lithological-mechanical properties.

In this contribution, we also present the results of recent case studies focusing on dams located on or in the vicinity of faults classified as active, either in the scientific literature or according to the most widely used databases of active faults and seismogenic sources.

Modelling of two active rock glaciers highlights effect of climate warming on permafrost in the Raethian Alps (Adamello-Presanella Group)

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Keywords: rock glaciers dynamic, zero curtain, numerical simulations, downslope displacement, Italian Alps.

Rock glaciers are key indicators of permafrost evolution in Alpine environments. Their deformation reflects the interplay between thermal, hydrological, and mechanical processes that respond sensitively to atmospheric forcing. In this study, we perform numerical simulations of two active rock glaciers in the Italian Alps, Amola and Maroccaro; using multi-year records of precipitation, near-surface ground temperature (~0.1 m), air temperature, and annual horizontal displacement derived from geodetic surveys.

All observations are reorganized by hydrological year (October–September) to capture both winter freezing and summer thaw cycles. Gaps between near-surface and ground-temperature records were smoothed using a cosine-blend interpolation to preserve realistic thermal transitions. "Zero-curtain" periods are automatically detected when $|T| < 0.3$ °C for at least three consecutive days, and their duration and timing are quantified. Downslope displacement rates (cm yr^{-1}) derived from annual geodetic data were interpolated to daily resolution to assess their relationship with thermal forcing and precipitation cycles.

Results reveal that the onset and duration of zero-curtain conditions vary widely between years, from short (< 2 weeks) to long (> 2 months) events, shifting by several tens of days depending on seasonal thermal conditions. Extended or repeated zero-curtain phases often coincide with enhanced or sustained horizontal motion, even without exceptional precipitation, suggesting that latent-heat exchange, liquid-water presence, and partial thaw control the rheological response of the active rock glaciers.

These results show that rock-glacier motion in the Adamello-Presanella Group is not steady but seasonally pulse driven. Zero-curtain metrics, combined with vertical-velocity trends and horizontal displacements, offer valuable indicators of evolving permafrost stability and can strengthen monitoring and early warning strategies for periglacial slope hazards under ongoing climate warming.

Oxygen-Driven Changes in Ostracod Assemblages from the IM-5 Agosto Section, Lucania Basin: Insights from Sapropel 19 (Early Pleistocene)

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Keywords: Ostracods, palaeoxygenation, sapropels, Montalbano Jonico, Early Pleistocene.

The study of ostracod assemblages from the IM-5 Agosto section, a partial interval of the Montalbano Jonico composite section in southern Italy, highlights the strong sensitivity of these microfossils to changes in bottom-water oxygen levels. Ostracods are known to be highly responsive to variations in dissolved oxygen, with their abundance and diversity showing a significant decline when oxygen concentrations fall below critical thresholds (typically < 3 ml/l). The IM-5 Agosto section features a 5.6-meter-thick, dark, locally laminated interval correlated to Marine Isotope Stage 25, interpreted as a maximum flooding surface, associated with sapropel 19 and insolation cycle 90, both orbitally tuned at around 954,000 years ago. Sapropels are cyclically formed as a result of orbital and climatic variations that cause changes in the water column structure, leading to stratification, reduced vertical mixing, and anoxic conditions at the seafloor. During the deposition of sapropel 19, high resolution benthic foraminiferal studies identify two main anoxic phases (phases A and C), separated by a brief period of temporary re-oxygenation (phase B). These anoxic phases are characterized by a drastic reduction in the abundance and diversity of ostracods, consistent with their tolerance limits to low O2 concentrations. The variations observed in the ostracod assemblages occur at a constant water depth (about 250–350 m, epibathyal environment), excluding bathymetry as a controlling factor and confirming that oxygen fluctuations are the main drivers of the observed changes in the faunal composition.

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