Short Abstracts

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The 23rd Annual Conference of the International
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Contents

S00 Plenary Session

International Association for Mathematical Geosciences (IAMG office)

S0001. Data-Driven Computational Modelling in Geodynamics

Alik Ismail-Zadeh (Karlsruhe Institute of Technology)
Room: D209 2025-10-10 09:00

Deep geodynamic processes and their surface manifestations, such as seismicity or volcanism, are of great scientific interest and of societal relevance. With great advances in understanding the geodynamic processes based on geological analysis, geophysical and geodetic monitoring, observations and data analysis as well as with novel mathematical methods and technological progress in computer simulations, data-driven computational models in geodynamics become feasible and important in recovering the past, analysing the present, and forecasting the future. If traditional geodynamic models are related to analyses of basic dynamical processes in and on the Earth without a direct linkage to observations, data-driven models try to assimilate Earth observations and relevant data models via physics-based numerical models to determine either optimal characteristics of the models or initial/boundary conditions. Data assimilation techniques, e.g., adjoint or quasi-reversibility, employed for analysis of geodynamic processes as well as AI methods used in computer vision, e.g., for identification of parameters of physics-based models based on geomorphological shapes, permit for utilising huge observations via models. During the talk I shall present case studies related to mantle-lithosphere dynamics, earthquake occurrence, and lava dynamics. These case studies enhance our knowledge on the dynamics of the planet as well as contributes to the solutions of societal challenges related to georesources and geohazards.

S0002. Data-knowledge dual-driven mineral prospectivity mapping

Renguang Zuo (China University of Geosciences, Wuhan)
Room: D209 2025-10-10 13:30

Mineral prospectivity mapping (MPM), as a computer-based approach to delineate target areas for a specific type of mineral deposits. MPM typically comprises knowledge-driven and data-driven models. Knowledge-driven MPM relies on expert knowledge, which is based on causal relationships but is not readily adaptable to dynamic changes. Data-driven MPM is capable of identifying underlying data patterns but involves poorly interpretable decision logic. This talk will focus on the state-of-art big data analytics and AI in MPM to devise a data-knowledge dual-driven model coupling AI with a mineral systems approach to MPM.

S0003. From Particles to Patterns: An Odyssey from Physics to Geostatistics and Beyond

Dionysios Christopoulos (Technical University of Crete)
Room: D209 2025-10-11 09:00

Are there useful connections between statistical physics and geostatistics? Does quantum many-body theory have similarities with random fields? Is it worth learning how to use kriging in the era of artificial intelligence (AI)? This presentation gives affirmative answers to the questions above. We show that the geostatistical framework fits nicely inside the framework of Gaussian process regression, thus connecting geostatistics with AI. On the other hand, Gaussian process regression (kriging as well) faces computational difficulties for very large datasets due to covariance matrix inversion. One solution to this problem exploits an idea from statistical field theory, namely the formulation of joint densities by means of field interactions. This change in perspective in contrast with the covariance-based formulation, emphasizes the precision (inverse covariance) matrix and avoids matrix inversion for spatial prediction and likelihood estimation. The stochastic local interaction (SLI) models derived by pursuing the above idea represent Markov random fields with physically inspired precision matrices that have significantly lower computational complexity compared to kriging. The range of interactions in SLI models is determined by adaptively controlling the bandwidth of user-selected interaction kernels. In the continuum limit, precision matrices are replaced by precision operators. We show that by combining a particular precision operator with yet another idea from statistical physics—smoothed particle hydrodynamics—we obtain the first representation of a continuum precision function. For data with non-Gaussian distribution, the idea of warped Gaussian processes (a close relative of Gaussian anamorphosis) is often useful. We present a flexible nonlinear transformation for warped Gaussian processes using mathematical tools developed for entropy generalizations. Finally, we consider the Ising model, a cornerstone in statistical physics and complex systems, and its potential impact in spatial data analysis. We conclude the presentation with remarks on future perspectives.

S0004. Data-driven traveling in deep time: a unique way of mathematical geologists for exploring the operation of early Earth

Guoxiong Chen (China University of Geosciences)
Room: D209 2025-10-11 13:30

A series of extreme geological events occurred in deep-time Earth—such as the GreatOxidation Event, Large Igneous Provinces, and large-scale mineralization events—have shaped the habitability of our planet. These events not only altered the trajectoryand processes of Earth's evolution but also laid the material and environmentalfoundations for human survival and development. Consequently, understanding themechanisms of extreme geological events and their resource-environment effects hasbecome a major frontier in the geosciences. Traditional efforts in this regard have beenlargely based on uniformitarian models and inductive methods, which, however, facegreat challenges due to the asymmetry of geological information from deep time,particularly given the singular nature of extreme geological events. Over the pastdecade, the rise of big data and artificial intelligence (AI) has driven a shift in thegeoscience research paradigm from experience-based to data-driven (abductive)approaches, offering new ideas and methods for the quantitative simulation andprediction of extreme geological events. In this talk, we will present our recent efforts toaddress these common key challenges in the transition to data-driven geosciencediscovery. Focusing on "sediment subduction and its extreme resource-environmenteffects," we propose novel data/AI-driven models to explore some fundamentalquestions that have plagued geologists, including: (1) when sediment recycling viasubduction became active on Earth; (2) how sediment subduction altered theatmosphere (notably during the GOE); and (3) the role of sediment subduction in theformation of ore deposits. These advances highlight the special role of mathematicalmodels, as well as the unique perspective of mathematical geoscientists, in deepeningour understanding of the habitable Earth evolution and the interactions among multiplegeospheres.

S0005. Unlocking Geological Resource Potential and Fostering Institutional Development through Cross-Border Collaboration: A lesson from Southern Namibia

Anna Nguno (Deputy Director at the Geological Survey of Namibia)
Room: D209 2025-10-12 09:00

Quality of geological mapping in Namibia various considerably; among the parts of the country only mapped at regional scales (1:100 000 to 1:250 000) was the Karas Region, situated along the border with South Africa. Moreover, existing maps were more than 40 years ago and due for revision employing modern research and mapping techniques, and scientific insights. Between 2013 and 2022, the “Southern Namibia Mapping Programme” (SNMP) was carried out by a joint team of mapping geologists from the Geological Survey of Namibia (GSN) and the Council for Geoscience (South Africa), supported by both Namibian and South African university students and academics.

The aim of SNMP was to produce more detailed, updated 1:50 000 scale geological maps of the area north of the Orange River to align with the geology already mapped to the south, in South Africa. These maps will contribute significantly to the economic development of the region, as well as to the long-term national geoscience objective of acquiring 1:50k geological map coverage for the entire country. Furthermore, the programme aimed to build mapping and research capacity at GSN.

To achieve this object, SNMP integrated field mapping, remote sensing, geochemical and geochronological analysis. Over the ten-year period, ninety-five 1:50 000 and four 1:250 000 scale geological maps (covering some 55 000 km2) of this geologically complex and highly prospective area in southern Namibia were completed. In addition, collaboration between governmental, parastatal and academic institutions from Namibia, South Africa and Canada resulted in 18 peer-reviewed publications in international journals, 34 conference abstracts, and 20 post-graduate research projects and degrees. The successful conclusion of SNMP shows that major mapping programmes provide a platform for government and research institutions to collaborate on common objectives, share data and exchange expertise, with enhanced capacity and know-how not the least of their many benefits.

S0006. Revealing Subsurface Petrophysical Properties Through Bayesian Learning

Dario Grana (Department of Geology and Geophysics, University of Wyoming)
Room: D209 2025-10-12 13:30

Estimating rock and fluid properties is essential for understanding subsurface processes that control fluid flow in applications ranging from hydrocarbon exploration and CO sequestration to near-surface groundwater studies. This research focuses on Bayesian inverse methods for the prediction of petrophysical properties, such as porosity, permeability, mineral composition, elastic stiffness, and fluid content, from geophysical measurements, including seismic and electromagnetic data. These approaches address nonlinear and non-Gaussian models, leading to a more accurate representation of the complex relationships between geophysical observations and petrophysical properties, as well as their multimodal distributions. By combining rock physics modeling, inverse theory, and geostatistics, these methods provide full posterior distributions of predicted properties, allowing for rigorous uncertainty quantification. Their effectiveness is demonstrated across multiple geological settings and data types, showing an improved predictive capability where direct observations are sparse. Furthermore, the integration of the probabilistic framework with deep learning opens new directions for robust subsurface characterization in both energy and environmental contexts.

S0007. Learning from Data, Learning from Planets: AI methods for Earth and Space Exploration

Anirudh Prabhu (Carnegie Institution for Science)
Room: D209 2025-10-13 09:00

AI methods have been at the center of many recent scientific discoveries and have opened up new frontiers in many areas of scientific inquiry. In this talk, I will take you through some of the most recent and exciting discoveries we've made and how AI methods played a central role in these discoveries. First, we will look at our work on data-driven biosignature detection, specifically how we combine pyrolysis-gas chromatography-mass spectrometry and machine learning to build an agnostic molecular biosignature detection model. Next, we will talk about how we used association analysis to predict the locations of as-yet-unknown mineral deposits on Earth and potentially Mars. These advances hold the potential to unlock new avenues of economic growth and sustainable development. I will also present our efforts in developing open-source tools to make crystallographic data AI-ready, enabling machine learning models to uncover patterns in atomic arrangements across minerals and materials. This work aims to identify structural motifs and the role they play in our understanding of mineral and material properties through data-driven analysis. Finally, we will set our sights on exoplanets—celestial bodies orbiting distant stars. The discovery of thousands of exoplanets in recent years has fueled the quest to understand their formation, composition, and potential habitability. We develop informatics approaches to better understand, classify and predict the occurrence of exoplanets by embracing the complexity and multidimensionality of exoplanets and their host stars.

S01 AI-driven Numerical Modeling and Data Assimilation in Geodynamics

Fan Xiao (Sun Yat-University),
Dunhui Xiao (Tongji University),
Zenghua Li (East China University of Technology),
Xiaohui Li,
Zhankun Liu (Central South University),
Xinguang He (Hunan Normal University)

The numerical modeling of geodynamics such as mineralization, diagenesis, and tectonic processes is based on the fundamental principles of mathematics, physics, and chemistry. Integrating geological data allows us to construct robust mathematical-physical models for quantitatively characterizing these geological processes. These models can be solved to simulate the complex geosystems and their spatiotemporal responses under extreme conditions within the inner Earth using numerical analysis methods such as finite element or finite difference and high-performance computing. This approach aims to investigate the mechanisms inherited in complex geological processes, and their evolutionary pathways, and to interpret the conditions of geological events. Nevertheless, geodynamics, including mineralization, diagenesis, and tectonic modeling, possess strong uncertainties due to dependence on unknown or ambiguous boundary conditions, initial conditions, and physical-chemical parameters. This requires the assimilation of observational data into physical-informed numerical models to improve the accuracy of solutions or predictions. In recent years, driven by the analytics of big data, computational science, and non-linear theories and methods in complex physical systems, significant progress has been made in the numerical modeling of geodynamics. Invited submissions for abstracts or/and full papers include (but are not limited to): (1) Numerical simulation of geological processes such as mineralization, diagenesis and tectonics; (2) Computational geochemistry; (3) Computational geophysics; (4) Numerical geotectonic and geodynamic modeling; (5) Data-driven numerical modeling approach; (6) High-performance and high-throughput computing for geoscience data; (7) Data assimilation techniques in geosciences; (8) Data-driven modeling and state estimation of Earth's dynamic systems. The full papers can be recommended to be published in the IAMG journal of Computers & Geosciences or Applied Computing and Geosciences.

S0101. Deep learning-based surrogate modeling for high-throughput computational simulation of mineralization dynamics

Fan Xiao (Sun Yat-University),
Ao Tang (Sun Yat-sen University)
Room: D209 2025-10-10 10:30

The mineralization system involves the interplay of various dynamic processes, including rock deformation, fluid flow, heat transfer, and chemical reactions. Numerical simulations of mineralization dynamics hold significant theoretical importance and practical value for understanding mineralization mechanisms, as well as for uncovering mineralization patterns and controlling factors. However, the concealed nature of mineralization environments and the complexity of mineralization systems make it challenging to accurately estimate parameters such as geometric models, physical property attributes, initial conditions, and boundary conditions. This complexity often leads to uncertainties in the results of mineralization dynamics numerical simulations. While 'trial-and-error' parameter optimization methods can help address these challenges, they require repeated computationally intensive numerical simulations and experiments, which significantly increases resource consumption. To tackle this issue, this study uses the multi-field coupled mineralization dynamics numerical model of the Fankou lead-zinc deposit as a case study. It proposes and validates a surrogate modeling approach based on sensitivity-optimized high-fidelity dataset generation and deep learning techniques. The goal is to enable rapid computation of high-dimensional, nonlinear, complex mineralization dynamics systems, providing an efficient model for parameter inversion and optimization in mineralization dynamics numerical simulations. This research has developed a surrogate modeling framework that leverages sensitivity-optimized high-fidelity dataset generation and deep learning for the rapid computation of high-dimensional, nonlinear, complex mineralization dynamics systems. It accurately reconstructs the spatiotemporal distribution of key mineralization variables, including stress, strain, fluid flux, temperature, and concentrations of mineralization elements. The findings not only offer computational models for the inversion and optimization of parameters in mineralization numerical simulations but also provide valuable methodologies for constructing surrogate models in other fields.

S0102. Structural controls on orogenic gold mineralization in the Jiaodong orogenic gold mineraliazation: Key insights from 3D numerical modeling

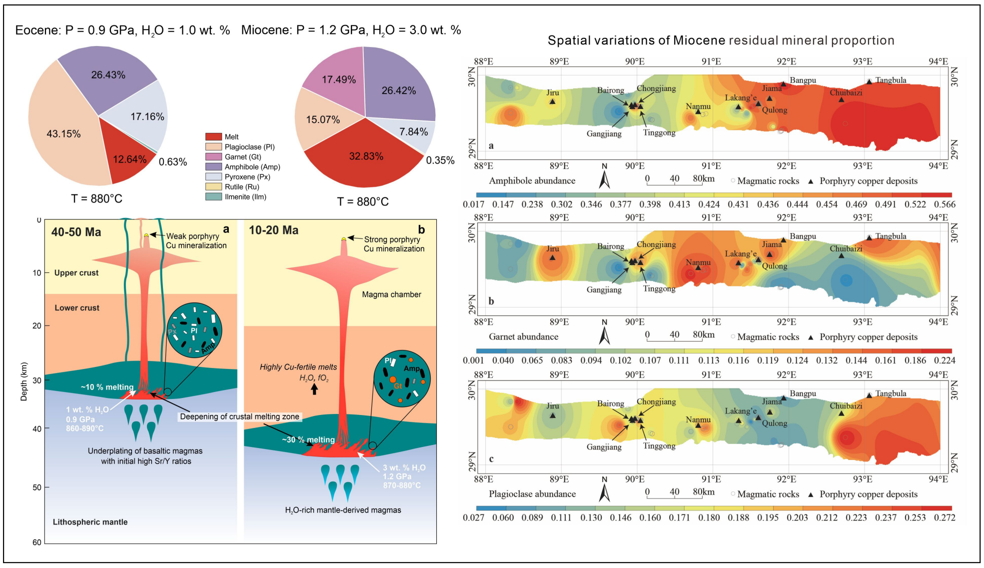
Zhankun Liu (Central South University),
Xiancheng Mao (Central South University)
Room: D209 2025-10-10 10:50

Hydrothermal disseminated gold mineralization is widely developed in the Jiaodong orogenic gold province, Eastern China, which is usually associated with the regional detachment faults. To investigate the structural controls on gold mineralization, we conducted 3D numerical modeling of coupled heat transport, tectonic deformation, and fluid flow, of which two sets of models, designed simple models and the actual models, were involved. The simple models were used to examine how general fault geometries influence dilation and fluid flow, and further control hydrothermal mineralization, and the actual model was carried out to further understand the structural controls and mineralization localization in a specific geology condition (at the Sanshandao gold belt, western Jiaodong). Following this, a series of numerical simulation experiments with variable paleo-stress on these two models were carried out in FLAC3D platform. The simulation results of the simple models show that long fault bend lengths, large absolute fault bend angles, and large changes in fault dip are more likely to promote dilation. The dilation zones are related to the small intersection angle of maximum principal stress and fault dip. As illustrated by the simulation results of the actual model, the gold mineralization distribution at Sanshandao is controlled by the coupling of fault strike–dip–bends. Specifically, the discontinuous mineralization in the vertical direction is caused by the local fluid focusing due to the fault dip changes, in particular where the bend length is long. In addition, the oblique orientation of ore shooting depends on the variable strain orientations relative to fault, which appears to be the fault strike variations. The results further determine the NNW–SSE directed compression as the paleostress regime at Sanshandao during the ore-forming period. Our work also illustrates the deep fluid flow pathways in the Sanshandao gold belt that may guide the next gold exploration.

S0103. Crustal thermal state controls the formation of post-collisional Cu-fertile magmas in the eastern Gangdese belt

Yuanzhi Zhou (China University of Geosciences, Beijing),
Yunzhao Ge (Zhejiang University),
Yuanzhi Zhou (China University of Geosciences (Beijing))
Room: D209 2025-10-10 11:10

The genesis of post-collisional porphyry copper deposits remains debated. The post-collisional magmas in the eastern Gangdese belt exhibit significant spatio-temporal variability in copper enrichment. There is broad consensus that all these magmas originated from partial melting of lower crust, yet the mechanisms driving their Cu fertility are unclear. Quantifying the thermal state and residual mineral proportion in magma sources may provide insight into geodynamic processes and the formation conditions of Cu-fertile magmas. Here, we compiled geochemical data for Eocene and Miocene magmatic rocks and simulated the P–T–X(H2O) conditions and mineral proportions of magma sources by using thermodynamic and trace element modeling. Our results indicate that the Miocene magma source exhibits higher pressure and H2O content compared to the Eocene magma source. The corresponding residual mineral assemblage also shows a transition from plagioclase to garnet and from pyroxene to amphibole. This implies the deepening of crustal melting zone and extra H2O addition during the Miocene. The high-pressure and high-water conditions favored the formation of highly Cu-fertile post-collisional magmas. Monte Carlo partial melting modeling delineates clearly the spatial variations in melting degree and residual mineral proportion from west to east during the Miocene. However, the high fertility might not be solely attributed to the effects of residual minerals (e.g., garnet and amphibole) in the lower crust but might also be partially inherited from the parent materials, which have been modified by prior subduction. These factors could be crucial for the occurrence of strong copper mineralization during the Miocene in the Gangdese belt. Our findings provide quantitative constraints for formation conditions of porphyry copper deposits in post-collision settings. This research not only enhances our understanding of the intricate petrogenetic mechanisms behind significant mineral deposits but also has considerable implications for future exploration in the collisional orogens.



S0104. First-principles and molecular dynamics simulations of In and Sn substitution for Zn in sphalerite: Implications for critical metal mineralization

Zongcong He (Sun Yat-Sen University),
Fan Xiao (Sun Yat-University)
Room: D209 2025-10-10 11:30

Indium (In) is a critical metal of strategic significance, playing an increasingly vital role in the global economic landscape. Indium is a dispersed element, rarely forming independent deposits and typically occurring as an associated mineral. Research indicates that indium primarily enriches in sphalerite through isomorphic substitution. In tin-polymetallic deposits, indium exhibits significantly higher enrichment levels compared to other deposit types, with its concentration process being closely associated with tin mineralization. Recent studies of numerous ore deposits have indicated that tin may exist as Sn2+ in sphalerite, with two key substitution mechanisms facilitating indium incorporation: In3++Sn2++Cu+→3Zn2+ and In3++Sn2++Ag+→3Zn2+. However, current research has not yet sufficiently constrained the physicochemical conditions governing these substitution mechanisms, significantly limiting our ability to develop a precise understanding of indium mineralization processes. Therefore, this study employs the first-principles molecular dynamics simulations to comprehensively analyze the substitution mechanisms of In and Sn co-replacing Zn with Cu/Ag in sphalerite. Based on the fundamental substitution equations of Sn and In replacing Zn, this study constructs two doping systems, namely Zn29InCuSnS32 and Zn29InAgSnS32. Through first-principles molecular dynamics simulations, the thermodynamic equilibrium configurations of these doping systems at various temperatures were obtained. We calculated the formation energy, electronic structure of each configuration to obtain detailed information about the microscopic structure. The results indicate that the substitution mechanism of In entering sphalerite via the reaction In3++Sn2++Cu+→3Zn2+ is more favorable. Temperature is a crucial controlling factor for both substitution reactions, which are more likely to occur at relatively low temperatures (200-225°C). This analysis provides deep insights into the enrichment mechanism of In into sphalerite for critical metal mineralization from a microscopic perspective, promoting the innovation and development of the theory and research methods for indium ore formation and exploration.

S0105. Influence of granite iron content on tungsten and tin Separation in hydrothermal solutions: A machine learning and numerical simulation study

Qi Hua (School of Earth Sciences and Engineering, Sun Yat-sen University, Zhuhai), Fan Xiao (Sun Yat-University)

Room: D209 2025-10-10 11:50

Tungsten and tin deposits in the world have regional decoupling characteristics, and most tungsten-tin deposits are related to highly evolved granite, with the evolution of major elements between tungsten-bearing and tin-bearing rocks. In response to this feature, scholars have proposed mineral-melt and melt-fluid separation crystallization models, but there are few studies on the coupled chemical behavior of tungsten and tin components in magmatic hydrothermal fluids. Our compilation of whole-rock geochemical data of tungsten-tin-related granites in the world 's major tungsten-tin metallogenic belts shows that there is a very strong correlation between the ore-bearing types of granites and the total iron content. From the ore-free rock mass, tin-bearing rock mass to tungsten-bearing rock mass, it decreases in turn, and the three types of rock mass are accurately classified by machine learning method. Incorporating the total iron content in the whole rock geochemical data compilation into the multiphase equilibrium thermodynamic model, it is found that the thermodynamic behavior of tungsten and tin and the iron content are the main controlling factors for the decoupling of tungsten and tin in magmatic hydrothermal fluids. Under the same pressure, the precipitation trend of wolframite and cassiterite is different. The precipitation of wolframite is higher than that of cassiterite between 200 °C-300 °C, and the precipitation of cassiterite is dominant between 300 °C-400 °C. With the increase of iron content, the temperature range of wolframite precipitation increases. The complete evolution sequence of ore-free-cassiterite-tungsten-tin symbiosis-wolframite in magmatic hydrothermal fluid is shown by data-physical double drive.

S0106. First-principles study on the charge compensation mechanism of In enrichment in sphalerite by Cu with different valence states

Ling Wang (Sun Yat-sen University),
Fan Xiao (Sun Yat-University)
Room: D209 2025-10-10 12:10

Indium (In), a critical metal and a dispersed element, has a very low crustal abundance and rarely forms independent deposits. It mainly enriches and mineralizes in sphalerite via isomorphic substitution. Numerous studies have identified various In enrichment mechanisms in sphalerite during natural mineralization. However, research on how these substitution schemes maintain crystal stability and electrical neutrality is lacking, limiting our understanding of In mineralization.

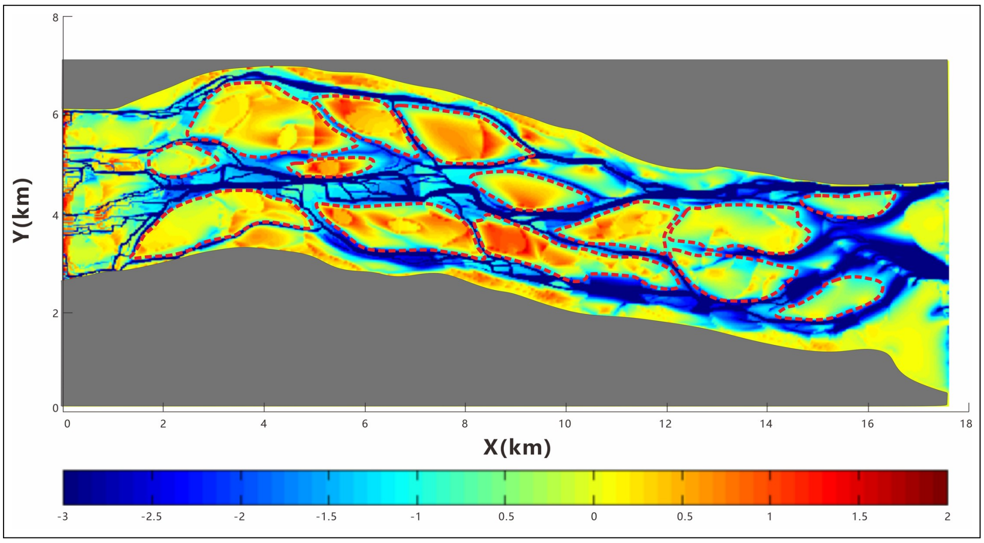
Therefore, this study takes the most common substitution mechanism Cu+ + In3+ → 2Zn2+ in the process of In enrichment and mineralization in sphalerite as an example. The substitution scheme of Cu2+ + 2In3+ + (vacancy) → 4Zn2+ is hypothesized for the substitution of divalent copper and indium in sphalerite, aiming to explore the influence of Cu with different valence states on the charge compensation mechanism during the enrichment of In in sphalerite. Using the first-principles calculation method based on density functional theory and the 2×2×2 supercell model of sphalerite, we constructed Zn30InCuS32 and Zn28In2CuS32 doped systems for the two substitution processes respectively. The formation energies, populations, and electronic structures of the two configurations were calculated.

The results show that: (1) The Cu+ + In3+ → 2Zn2+ substitution of In and monovalent Cu into sphalerite is more stable than the Cu2+ + 2In3+ + (vacancy) → 4Zn2+ substitution of In and divalent Cu. (2) The substitution processes of Zn by In and Cu with different valence states cause significant differences in sphalerite's electronic structure. (3) Based on population and bond-length changes, doped In and Cu with different valence states maintain electrical neutrality and crystal structure stability by adjusting the electron distributions of themselves and surrounding atoms. This study provides a computational-simulation basis for exploring the charge compensation mechanism of In enrichment and mineralization in sphalerite affected by Cu with different valence states.

S0107. Study on the Sedimentary Evolution Mechanism of Braided Rivers with Different Sinuosities Based on Numerical Simulation

Kanglong Wang (China University of Petroleum, Beijing),
Yuming Liu (College of Geoscience, China University of Petroleum (Beijing))
Room: D209 2025-10-10 12:12

The evolution of braided river sedimentary systems is of critical significance for understanding sedimentary basin filling processes and reservoir development. Sinuosity, as an important morphological parameter of braided rivers, its variation profoundly influences the flow dynamic characteristics and sediment transport and deposition processes. This study is based on the Delft - 3d numerical simulation platform, constructs flow and sediment models under different sinuosity conditions of braided rivers, and systematically investigates the influence mechanism of sinuosity changes on the sedimentary evolution of braided rivers. By precisely setting sinuosity parameters, the distribution characteristics of sedimentary bodies in braided rivers with different sinuosities are simulated. Simulation results show that with the increase of sinuosity, the flow kinetic energy is redistributed at the bend, leading to significant changes in sediment deposition rate and distribution pattern, and the morphology and migration patterns of sedimentary units such as channel bars and point bars exhibit unique evolutionary patterns related to sinuosity. This study reveals the quantitative relationship between braided river sinuosity and sedimentary evolution through numerical simulation, provides an important simulation basis for a deep understanding of braided river sedimentary dynamics, and has important theoretical guiding significance for related geological reservoir prediction and sedimentary environment analysis.



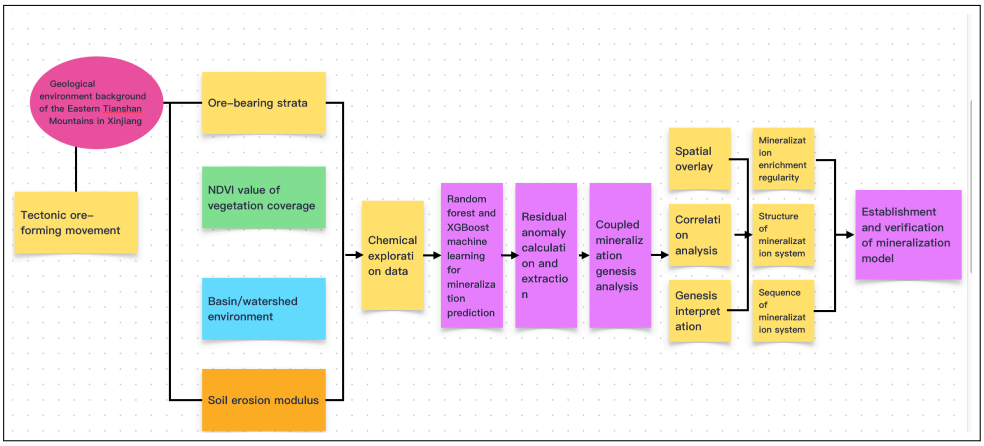
S0108. Identifying geochemical anomaly through machine learning and catchment basin modeling

HuiShan Bai (Sun Yat-sen University),
Fan Xiao (Sun Yat-University)
Room: D209 2025-10-10 12:14

This study focuses on the challenges posed by the complex geological background and coverage conditions of the copper mineral belt in the Eastern Tianshan Mountains of Xinjiang for mineralization prediction.

It proposes a method that deeply integrates multi-modal environmental data with machine learning techniques. By establishing a multi-condition fusion system, this approach incorporates various dimensions of data, including geological structures, ore-hosting surrounding rocks, catchment basin information and vegetation coverage, while conducting spatial analysis and modeling in conjunction with GIS.

Initially, the study cleanses and standardizes multi-source geological data. Geographically weighted regression is employed to identify the influences of key geological factors and quantify their spatial distribution. Subsequently, multiple statistical regression methods are utilized to screen core driving factors and construct a causal relationship model that elucidates element interactions. The research introduces random forest and GWRBoost algorithms combined with gradient boosting optimization technology to develop a high-precision spatial prediction model for copper minerals. This model leverages traditional algorithms' strengths in capturing spatial anomalies while addressing underfitting issues associated with conventional geographic regression when dealing with complex nonlinear data. Through interactive GIS visualization, this study presents insights into mineralization laws and driving mechanisms. It offers a novel theoretical framework for understanding regional mineralization processes as well as developing efficient predictive models and methodological systems. Furthermore, it demonstrates mathematical geology's potential in integrating multiple disciplines to address intricate geological problems while providing guidance and support for advancing resource exploration technologies.



S0109. Diagnostic implications of shortwave-thermal infrared characteristics of typical alteration minerals for mineral exploration in continental volcanic terrains: A case study of the Zhalong Cu-Sn polymetallic deposit, Tibet

Zizhuo Wu (China University of Geosciences (Wuhan)),
Shunbao Gao (Institute of Natural Resources Survey, China University of Geosciences),
Xin Chen (China University of Geosciences (Wuhan)),
Youye Zheng (China University of Geosciences (Wuhan))
Room: D209 2025-10-10 12:16

Shortwave infrared (SWIR) and thermal infrared (TIR) spectroscopy enable efficient reconstruction of hydrothermal systems by identifying alteration minerals. This study investigates the Zhalong Cu-Sn polymetallic deposit in western Gangdese, where cryptic alteration zoning and concealed mineralization hinder exploration. These characteristics render it an ideal testbed for SWIR-TIR integration. Through spectroscopic analysis of 656 surface samples and spectral parameter extraction, this study aims to (1) decipher alteration assemblage zoning patterns, (2) establish quantitative correlations between spectral parameters and mineralization environments, and (3) provide scientific guidelines for subsequent exploration. Key findings include: (1) Alteration zoning exhibits a concentric sequence: quartz + white mica → white mica + feldspar + kaolinite → kaolinite + montmorillonite + feldspar → chlorite + montmorillonite + feldspar + white mica, with ore bodies predominantly hosted in the strong silicified quartz + white mica zone; (2) Diagnostic spectral scalars—white mica Al-OH absorption wavelength position (Pos2200 $<$ 2206 nm), absorption depth (Dep2200 $>$ 0.3), and crystallinity (SWIR-IC $>$ 1.5); kaolinite crystallinity (SWIR-KC $>$ 1.1); quartz TIR absorption features (Pos9300 $<$ 9280 nm, Dep8625 $>$ 0.12); and plagioclase Na/Ca ratio (Hig9600/Hig9900 $<$ 1.3)—collectively indicate high-temperature, relatively acidic mineralization environments and serve as robust exploration vectors; (3) Integration of spectral scalar anomalies and alteration zoning, combined with metallogenic patterns of analogous deposits (e.g., Balong, Sinongduo) in Gangdese, reveals three hydrothermal mineralization centers at Zhalong deposit. Shallow Cu mineralization is structurally controlled by volcanic conduits, while deeper Cu-Sn polymetallic orebodies likely exist. This study demonstrates how SWIR-TIR synergy enables multi-parameter spectral scalar extraction as efficient exploration proxies, overcoming the limitations of single-technique approaches in hydrothermal system analysis. The methodology establishes a replicable framework for exploration strategy optimization and target delineation in comparable deposits, offering novel insights for mineral prospecting of Ag-Pb-Zn-Sn-Au-Cu deposit systems in western Gangdese and even global continental volcanic terrains.

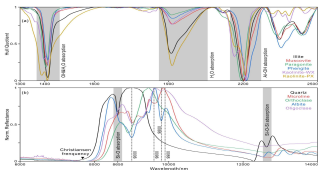


Fig. 4. Standard spectral curves of typical minerals identified by (a) SWIR and (b) TIR (according to the TSG library)

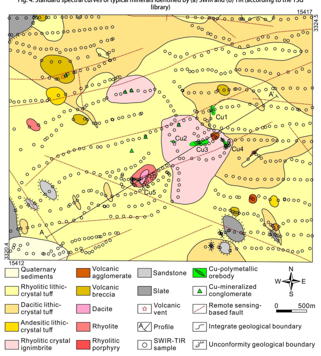


Fig. 2. Geological map of the Demingding deposit

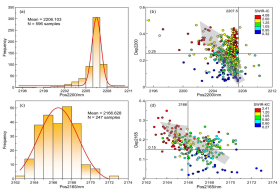


Fig. 8. (a) Histogram of Pos2200 frequency distribution and (b) scatter diagram of the relationship between Pos2200 and SWIR-IC of white mica; (c) histogram of Pos2165 frequency distribution and (d) scatter diagram of the relationship between Pos2165, Dep2165 and SWIR-IC of kaolinite in Zhalong deposit

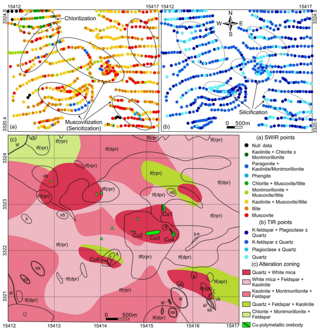


Fig. 6. Hyperspectral alteration mapping of the Zhalong deposit: (a) SWIR-based and (b) TIR-based mineral assemblages, and (c) schematic diagram of the alteration zoning

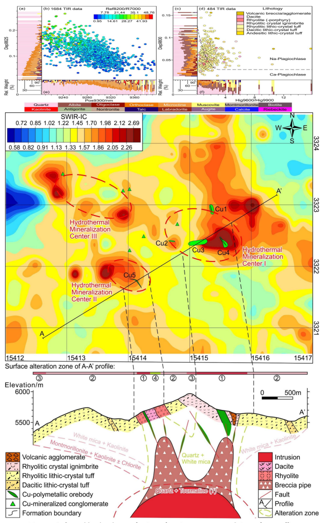


Fig. 14. Inferred hydrothermal mineralization centers and Cu-polymetallic alteration-mineralization model of the Zhalong deposit

S0110. Post-Collisional Magmatic Evolution and Metallogenic Drivers of the Giant Qulong Porphyry Copper System: Constraints from Felsic-Mafic Transitions and their Hf-Sr-Nd-O-Hg Isotopic Systematics

Chao Nan (School of Resources, China University of Geosciences (Wuhan)),
Chen Xin (China University of Geosciences (Wuhan)),
Zheng Youye (China University of Geosciences (Wuhan))
Room: D209 2025-10-10 12:18

Post-collisional porphyry copper deposits (PCDs) in thickened crustal domains remain poorly understood, particularly regarding the interplay between lithospheric tectonics, magmatic evolution, and metal enrichment. The Qulong deposit (Tibet), a world-class PCD in the Gangdese belt, provides a unique opportunity to unravel these linkages. This study aims to (1) reconstruct the spatio-temporal magmatic evolution from pre- to post-ore stages, (2) identify crust-mantle interaction mechanisms governing metal transport, and (3) establish a geodynamic model for PCD formation in collisional orogens. We integrate 10,000 m of drill core logging, whole-rock geochemistry, zircon U-Pb-Hf, apatite Sr-Nd-O, and Hg isotope analyses, coupled with zircon trace element thermometry and regional geophysical data. Three distinct pulses are identified: (1) Pre-ore (17.4 Ma): Biotite monzogranite derived from juvenile lower crust (depleted Sr-Nd-Hf; Δ199Hg: -0.12 to -0.02‰). (2) Syn-ore: Hybridized monzonitic granite porphyry with mantle-derived volatiles (positive Δ199Hg) and transitional granodiorite porphyry marking crust-mantle interaction. (3)Post-ore (14.8–14.7 Ma): Mantle-sourced diorite porphyry metasomatized by subducted components (enriched isotopes; Δ199Hg: -0.07–0.17‰). Near-zero Δ199Hg in sulfides (-0.05 to -0.04‰) confirms dominant mantle-derived Cu. High zircon ΔFMQ and H2O content highlight oxidized, hydrous magmas as critical Cu transporters. Slab tear propagation along the Yadong-Gulu rift induced mantle upwelling, lithospheric root erosion, and northward-migrating mineralization (Qulong→Jiama→Bangpu). This study establishes that post-collisional PCDs require: Syn-ore hybridization of crustal melts with mantle-derived volatiles/metals; Tectonic transition (compression→extension) enabling mafic underplating; Slab tear-driven mantle flow sustaining high fO2/H2O. The framework reconciles metal enrichment mechanisms in collisional orogens globally.

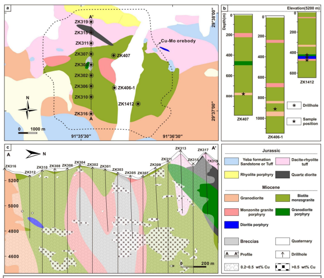


Fig. 1 (a) Geologic map of the Qulong porphyry Cu deposit (modified from Yang et al, 2009 and Zhao et al, 2016), ZK-numbers refer to different drillholes; (b) Simplified geological profile of the studied drill holes (ZK-numbers and depth indicated); (c) Cross section A to A´ (see (a)) showing the crosscutting relationship and Cu distribution along Exploration Line 3 of the Qulong deposit.

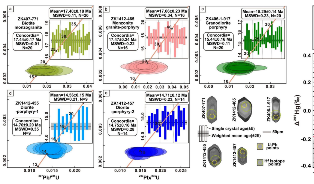


Fig. 2 Representative zircon cathodoluminescence images and age ranked plot showing all concordant 206Pb/238U dates for individual zircons from the different lithologies of the Qulong deposit. MSWD: mean square of weighted deviates; N: number of samples.

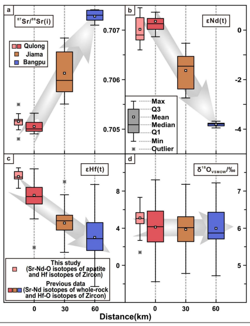


Fig. 6 Whole-rock Sr-Nd isotope compositions and zircon Hf-O isotope data are compiled for ore-forming plutons in three porphyry deposits: the Qulong monzogranite porphyry (Qin et al., 2014; Hu et al., 2015; Li et al., 2021), Jiama granite porphyry (Qin et al., 2010; Zuo et al., 2019; Sun et al., 2022; Wang et al., 2022), and Bangpu monzonite porphyry (Chen et al., 2012; Hu et al., 2015; Zhao et al., 2015), as well as the apatite Sr-Nd-O and zircon Hf isotope box plots of the Qulong deposit from this study.

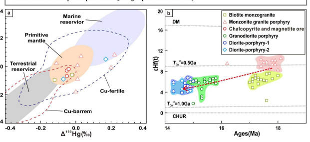


Fig. 3 (a) Plots of (a) Δ199Hg versus Δ201Hg of whole rock and (b) εHf(t) versus U-Pb age of zircon grains from the different lithologies of the Qulong deposit. Fields for marine reservoir, terrestrial reservoir, and primitive mantle are from Yin et al. (2022).

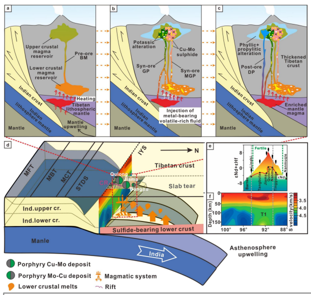


Fig. 5 (a-c) Schematic illustration showing the genetic model of the collision-related Qulong porphyry Cu deposit. (d) Interpretation cartoon showing the tearing of the Indian lithospheric slab beneath the Himalayan-Tibetan orogen (modified from Wang et al., 2022; Hou et al., 2023; Chen et al., 2024). (e) Comparative analysis of the isotopic characteristics of Miocene high Sr/Y granitoid magmatism, as measured by εNdi (whole-rock; red line) and εHfi (zircon) + εNdi (whole-rock) (modified after Hou et al., 2013). (f) Spatial distribution of the T1 tear structure within the E-W trending cross-sectional profile (at ~30°N latitude, near Lhasa, Tibet) from Li and Song (2018). Gray vertical lines mark the edges of T1 and include the most positive (unevolved) isotopic values in (e), as well most of the porphyry deposits. Acronyms: MFT - Main Frontal Thrust; MBT- Main Boundary Thrust; MCT - Main Central Thrust; STDS - Southern Tibetan detachment systems; IYS - Indus-Yarlung suture.

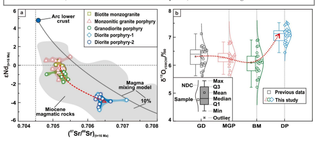


Fig. 4 (a) εNd(t) vs. initial 87Sr/86Sr ratios of apatite from the different lithologies at t = 16 Ma, which is the average age of the Miocene high Sr/Y granitoids. (b) Box-plot variation diagram showing the δ18O values of the intrusive rocks from the different lithologies of the Qulong deposit.

S0111. Numerical Modeling of ore-forming process of the Anqing Deposit, Middle Lower Yangtze River Valley Metallogenic Belt, China

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Room: D209 2025-10-10 12:20

The Anqing deposit is a large skarn Cu-Fe deposit within the Anqing-Guichi ore concentration area of the Middle Lower Yangtze River Valley Metallogenic Belt (MLYB), China. Its zoning pattern is different from classical pattern with respect to skarn minerals and metals, characterized by diopside and chalcopyrite are occurred at the proximal skarn near the intrusion, while andradite and magnetite are developed in the external skarn in contact with marble. In addition, metallic minerals are more abundant at the middle and upper part of the intrusion where the dip angle changes from gentle to steep, and gradually pinch out toward the bottom. The formation processes and controlling factor underlying this usual geologic phenomenon have not yet been effectively investigated. We employ numerical simulation based on finite element, coupled with heat transfer, fluid flow, material migration and chemical reaction, to quantitatively model the formation processes of diopside, andradite, magnetite, and chalcopyrite in hydrothermal stages, aiming at revealing the controlling factors of zoning pattern and ore body localization mechanism in the Anqing deposit. The modeling results indicate that the skarn zonation is governed by the coupled effects of limited permeability wall rock and chemical species mobility gradients induced by a low-fluorine magmatic-hydrothermal system, while the zonation characteristics of metals are mainly controlled by the permeability of wall rock. The mineralization reaction lifespan and flow flux at different positions of the contact zone control the spatial distribution of Fe ore body, and the grade and localization of Cu ore body are influenced by the low permeability characteristics of wall rock.

S0113. Machine learning-based hierarchical forecast reconciliation for multi-timescale precipitation forecasting

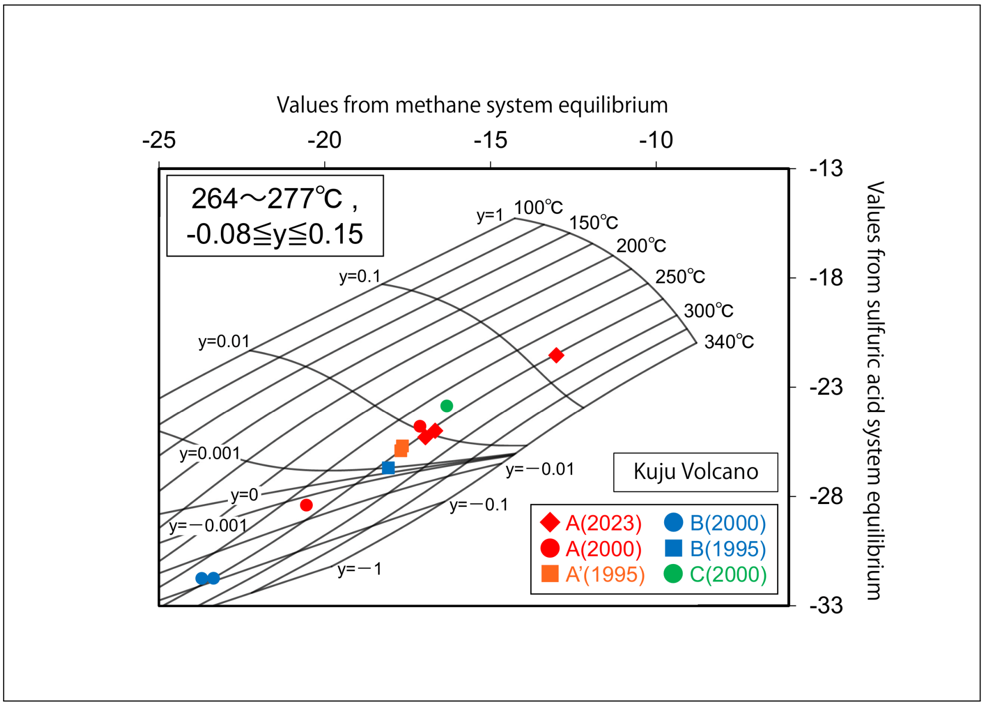
Mengjie Yang (Hunan Normal University),
Zhen Zhu (School of Geographical Sciences, Hunan Normal University, Changsha 410081),
Xinguang He (Hunan Normal University)
Room: D209 2025-10-10 14:30

Coherent precipitation forecasting across multiple timescales is essential for effectively managing water resource systems. Current studies generally produce forecasts independently at each timescale, ignoring the coherence constraint across scales. Several studies have attempted to address this by incorporating a regularization term into forecasting model loss functions to penalize inconsistencies and using temporal hierarchical reconciliation (THR) methods as postprocessing to enforce coherence. However, the former never fully enforces coherence due to its "soft" constraint, while the latter ensures coherence and improves accuracy but relies on linear reconciliation schemes that overlook nonlinear dependencies. Therefore, this study introduces three machine learning (ML) based reconciliation frameworks: (1) Machine Learning-Reconciliation (MLR), employing ML models to directly combine base forecasts across all timescales into bottom-scale forecasts, subsequently aggregating them upwards to ensure coherence. (2) Residual Learning-Reconciliation (RLR), utilizing residual learning models to estimate and correct the errors between bottom-scale base forecasts and ground truth, followed by upward aggregation to enforce coherence. (3) THR-based Residual Learning-Reconciliation (TRLR), using the residual learning model to integrate the THR and ML models. The three methods are used to reconcile monthly and seasonal precipitation at 189 stations in the Yangtze River Basin (YRB) and compared with three state-of-the-art THR methods. The results show that the TRLR method benefits from integrating the linear and nonlinear relations among base forecasts, thus effectively improving monthly and seasonal precipitation forecasts in YRB. In comparison, MLR, RLR, and traditional THR methods yield comparable but inferior performance, suggesting that linear or nonlinear modeling alone cannot correct systematic errors in base forecasts. Moreover, the three ML-based reconciliation methods exhibit better generalization ability than the THR methods. They also improve accuracy by more than 10% at a greater number of stations than the THR methods, with TRLR achieving the highest count of such stations.

S0114. Temperature Estimation of the Hydrothermal System in Active Volcanoes based on Heterogeneous Geochemical Equilibria of Low-Temperature Fumarolic Gas Composition

Takumi Akiyama (Kyoto University),
Shinji Ohsawa (Beppu Geothermal Research Laboratory)
Room: D209 2025-10-10 14:50

Not only the detection of volcanic seismic activity, ground deformation, and magmatic gas, but also the understanding of the behavior of hydrothermal systems within the volcano is essential to reduce human casualties from sudden phreatic eruptions. In this study, we focused on Kuju volcano, where geochemical observation data were available for high-temperature volcanic gases, low-temperature fumaroles linked to hydrothermal systems, and hot spring waters. Based on the theory of the physical chemistry of gas-liquid two-phase systems, we attempted to extract critical information about the volcanic hydrothermal system which causes phreatic eruptions, such as temperature and steam fraction, by analyzing gas compositions of fumaroles. Most previous studies on volcanic fumarolic gases have focused on high-temperature fumarolic gases presumed to originate from a single gas phase, so studies considering heterogeneous geochemical equilibrium based on a two-phase (gas-liquid) system have been limited. In this study, we targeted relatively low-temperature (approximately 95°C) fumarolic gases with low SO /H S ratios that were continuously emitted before and after phreatic eruptions from existing fumarolic areas (A, B, and C regions). We developed a new method to estimate the temperature and steam fraction of a hydrothermal reservoir within the volcano, on the basis of a gas-liquid two-phase system. This method is based on the chemical equilibria of CH + 2H O CO + 4H and H S + 4H O 4H + 2H + SO ^{2}, and takes into account the partitioning of gas species between the gas and liquid phases. As a result, we found that the reservoir was in a hydrothermally dominated state (steam fraction was approximately less than 0.1) both before and after the eruption, with temperatures ranging from 264 to 277°C.


Values from methane system equilibrium
-25
-20
-15
-10
264～277℃ ,
-0.08≦y≦0.15
y=1
100℃
150℃
200℃
250℃
300℃
340℃
y=0.1
y=0.01
y=0.001
y=0
y=−0.001
y=−0.01
y=−0.1
y=−1
Kuju Volcano
A(2023)
A(2000)
A'(1995)
B(2000)
B(1995)
C(2000)
-13
-18
-23
-28
-33
Values from sulfuric acid system equilibrium

S0115. Numerical simulation of multi-stage hydrothermal alteration processes in ore deposits: a case study of the Daiyingezhuang gold deposit, Jiaodong

Yanhong Zou (State Key Laboratory of Critical Mineral Research and Exploration, Central South),
Bo Wang (1 State Key Laboratory of Critical Mineral Research and Exploration, Central Sou)
Room: D209 2025-10-10 15:10

The Dayingezhuang gold deposit, located in the footwall of the Zhaoping fault zone, is a typical altered rock-controlled gold deposit characterized by multi-stage alteration and mineralization overprinting. The deposit exhibits distinct alteration zonation, including beresitization, chloritization, and reddenization. This study employs numerical metallogenic dynamics simulations to quantitatively analyze multi-stage alteration-mineralization processes.

To analyze different types of alteration-mineralization processes, hydrothermal-water-rock interaction simulations were performed for multiple mineralization stages . The simulations calculated the pH, logf(O2), and chemical equilibrium concentrations of ore-forming elements across four mineralization stages at different locations (Jiaodong Group, fault zone, and Linglong granite), generating 3D volume fraction maps for key alteration minerals. Results indicate that the Jiaodong Group and Linglong granite were under meta-alkaline and oxidizing conditions, promoting chloritization and reddenization, respectively, whereas the fault zone experienced acidic and reducing conditions, leading to beresitization. These findings are consistent with geological observations, confirming that gold primarily migrates as [Au(HS)2]- and precipitates near the fault zone, with an optimal mineralization temperature range of 200–300°C.

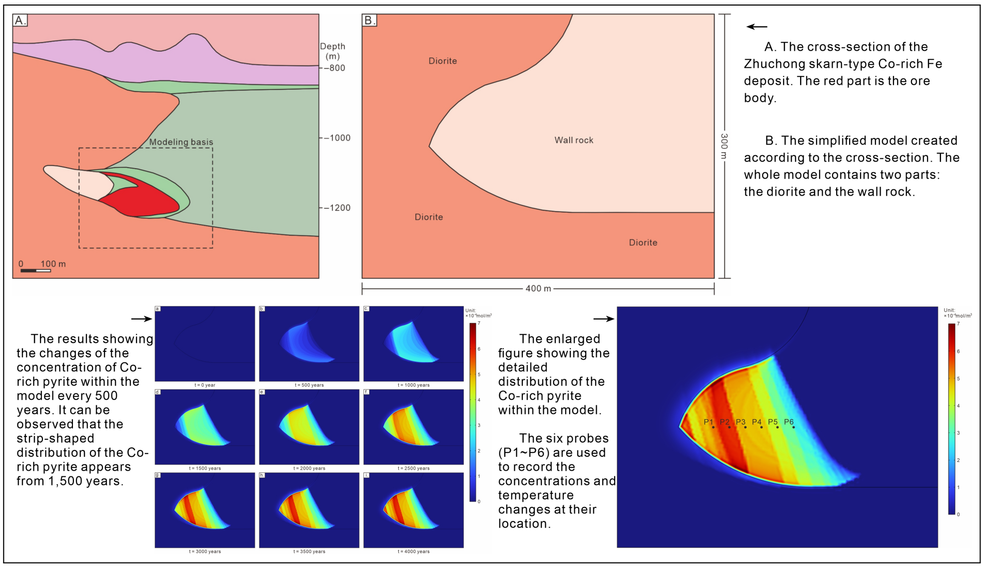
To investigate the impact of structural deformation and fluid migration on mineralization during different mineralization stages, multi-stage thermo-hydro-mechanical (THM) coupled numerical simulations were conducted The simulations quantified the spatial distribution of volumetric strain rate, shear strain rate, temperature gradient, and pore pressure gradient across different mineralization stages. Additionally, modern metallogenic rate theory was incorporated to couple the chemical equilibrium concentration of [Au(HS)2]- and compute the spatial distribution of metallogenic rates. Results indicate that during deformation of the Zhaoping fault, temperature decreased and pore pressure dissipated, generating positive volumetric strain and negative metallogenic rates at fault bends and undulating zones, forming favorable mineralization sites.

These findings contribute to a deeper understanding of the metallogenic dynamics of alteration-mineralization zonation and provide scientific support for the exploration of concealed ore bodies.

S0118. Cooling front controls Co mineralization within the Zhuchong skarn-type Co-rich Fe deposits, China: evidence from numerical simulation

Xunyu Hu (Fuzhou University)
Room: D209 2025-10-10 15:30

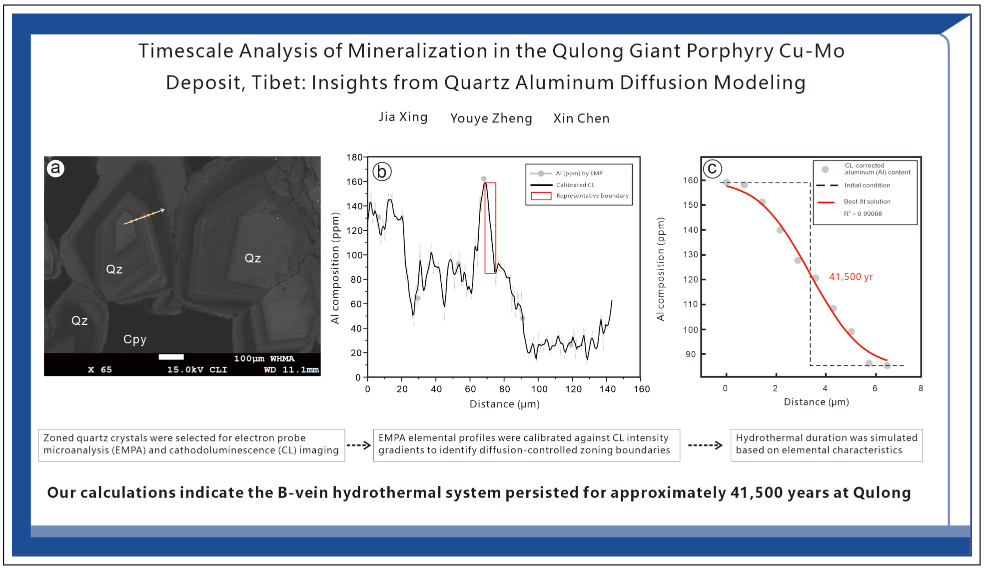
Cobalt is a type of the rare and precious metal with the demand for it sharply increasing these years. The Zhuchong skarn-type deposit, situated in eastern China, is a large Co-rich Fe deposit with over 50 million tons of iron ore (50.1%) and 10 thousand tons of associated Co. Previous studies indicate that temperature performs as a key ore-controlling factor during the formation of Co-rich pyrite. This study established a two-dimensional simplified geological model to simulate the formation of the Co-rich pyrite within the Zhuchong deposit, and analyzed the detailed thermal process and chemical reactions quantitatively and continuously. The numerical simulation process involves deformation, heat, fluid-flow, and chemical reactions, which recurrents the complex mineralization process of ore formation.The results of temperature and chemical reactions verified that the formation of Co-rich pyrite is controlled by temperature, which results in spatially differentiated distribution of Co concentration, matches the results of previous studies, and proves that the mathematical model presented in this study is reliable. Besides, the movement of cooling fronts, controlled by the morphologies of intrusion surfaces, can lead to different degrees of cobalt mineralization development in different parts of the model, which causes the strip-shaped distribution of the concentration of Co-rich pyrite. On top of that, it takes merely 4,000 years for the wall rocks to experience a single period of "heating and cooling", indicating that the duration of a single-period ore formation process within a magmatic-hydrothermal system could possibly be within 10,000 years or even thousands of years, which provides data support for related geochronological research.



S0119. Timescale Analysis of Mineralization in the Qulong Giant Porphyry Cu-Mo Deposit, Tibet: Insights from Quartz Aluminum Diffusion Modeling

Jia Xing (China University of Geosciences (Wuhan)),
Youye Zheng (School of Earth Resources China University of Geosciences),
Xin Chen (China University of Geosciences (Wuhan))
Room: D209 2025-10-10 15:32

Abstract Determining the duration of hydrothermal evolution is crucial for understanding the formation of giant porphyry Cu-Mo deposits. Current geochronological studies (e.g., molybdenite Re-Os and zircon U-Pb dating) demonstrate that these deposits form through multiple magmatic-hydrothermal pulses. These episodic events, occurring over 1,000 to 1,000,000 years, drive most metal enrichment and ore deposition. Thus, precisely constraining hydrothermal timescales is vital for deciphering mineralization processes. In this study, we integrate zircon U-Pb geochronology with diffusion chronology theory (a method that quantifies element diffusion rates to infer timescales) through finite-element mathematical modeling. This approach estimates the duration of hydrothermal activity at the Qulong Cu-Mo deposit (central Tibetan Plateau), achieving millennial-scale temporal resolution. Zircon U-Pb dating shows that the mineralized monzogranite porphyry crystallized at 16 Ma, followed by hydrothermal activity formed three vein types (A, B, and D) identified via cross-cutting relationships and mineralogical variations. We focus on the mineralization-critical B veins for diffusion modeling. Electron probe microanalyzer (EPMA) mapping of B-vein quartz reveals that CL intensity correlates more strongly with aluminum content than with titanium, indicating that Al diffusion provides robust constraints on the hydrothermal duration of this mineralization stage. Our calculations indicate the B-vein hydrothermal system persisted for approximately 41,500 years at Qulong.



S02 Advances in Spatial and Spatiotemporal Modeling

Dionysios Christopoulos (Technical University of Crete),
Yongze Song (Curtin University, Australia)

This session invites researchers to present the latest studies in spatial association methods and their practical applications. Accurate characterization of spatial association is fundamental for exploring spatial factors, improving spatial predictions, and supporting informed geographical decision-making. Models addressing spatial dependence, heterogeneity, geocomplexity, singularity, and similarity are central to describing spatial association. Moreover, recent developments in geospatial artificial intelligence have introduced powerful and precise approaches for analyzing spatial association. We welcome submissions from both theoretical and applied studies that contribute to the advancement of spatial association analysis.

The development of space-time methods remains at the forefront of current research in Spatial Statistics and Machine Learning. Flexible and interpretable models that can accurately capture the complex patterns of dynamic processes and reliably estimate uncertainties are needed. The key modeling challenges for the analysis of modern spatiotemporal data include the development of models that scale favorable with large data size, ability to handle heterogeneous data, multivariate dependence, multiple correlation scales, and the development of practical non-Gaussian probability distribution and non-stationarity.

This session aims to assemble contributions that will advance spatiotemporal methods in mathematical geosciences by introducing novel concepts and methodologies, computational algorithms, and innovative applications or studies that focus on interesting or challenging spatiotemporal datasets. Topics of interest include the development of novel space-time covariance functions (e.g., non-separable models, models on the sphere and manifolds, multivariate dependence, complex-valued models), covariance-free approaches (e.g., models based on stochastic partial differential equations and explicit precision operators), innovative simulation methods, and computational advances for big space-time datasets. The session also invites contributions that focus on causal inference, uncertainty quantification, applications of deep learning to spatiotemporal datasets, non-Gaussian space-time approaches and multiscale models. Interdisciplinary contributions that combine the spatiotemporal dimension with physics, machine learning, and applied mathematics perspectives are also welcome.

S0201. Characterization of space-time traits of nanoscale calcite dissolution through Multiple-Point Geostatistics

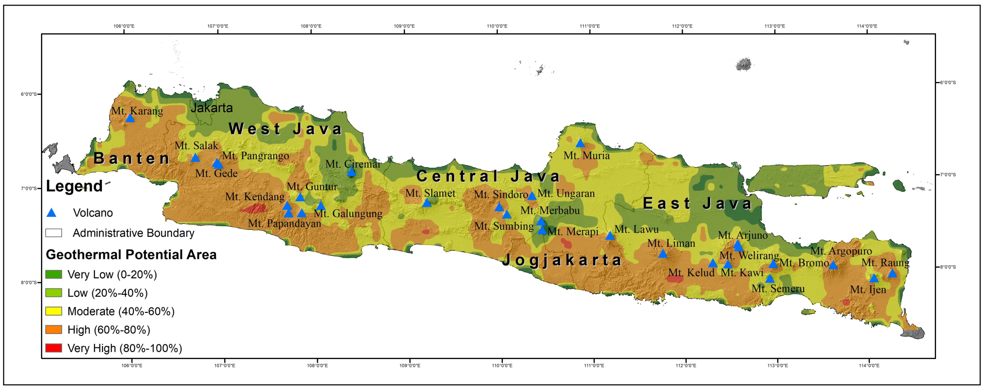
Maria Koltsidopoulou (Technical University of Crete),
Chiara Recalcati (Dept. of Civil and Env. Engineering, Politecnico di Milano),
Monica Riva (Dept. of Civil and Env. Engineering, Politecnico di Milano),
Alberto Guadagnini (Dept. of Civil and Env. Engineering, Politecnico di Milano),
Emmanouil A Varouchakis (Technical University of Crete)
Room: B228 2025-10-13 10:30

We provide a geostatistically-based assessment of space-time dynamics of dissolution rates imprinting self-organization of mineral-water interfaces. Our study is motivated by the recognition that geochemical processes govern chemical weathering of mineral-water interfaces in natural porous (or fractured) media at a fundamental level. Recent advances document that reaction rates display significant variations across the same mineral surface. This variability is related to the presence of molecular-level surface sites that are randomly distributed within the mineral system and drive the organization of the topography of the mineral-water interface. In this context, the topography of the mineral surface and the dissolution rates emerging from its space-time dynamics can be viewed as random fields. Here, we investigate the dynamic patterns associated with (i) surface topography and (ii) reaction rates at calcite-water interfaces undergoing dissolution. We focus on nanoscale heterogeneous patterns documented through a collection of experiments performed upon leveraging the capabilities of high-resolution Atomic Force Microscopy (AFM). We ground our analysis focuses on an approach based on Multiple-Point Statistics (MPS), which we employ to model the complex spatial and temporal structures observed in these nanoscale datasets. Doing so enables to explore the potential of encapsulating higher-order spatial relationships to capture the intricate features exhibited by the evolving interface. As such, our study moves beyond a traditional view based on two-point geostatistics. Our implementation focuses on characterizing structural features exhibited across the calcite/water interface through rotation and scaling of training images collected through AFM. We rely on synthetic examples and tailored experimental results to assess the potential of these geostatistical strategies to capture fine-scale heterogeneity typical of reactive mineral-water systems. Our findings highlight the versatility of MPS in simulating complex spatial structures and support the possibility to transfer of geostatistical approaches to nanoscale geoscience applications.

S0202. Delineating Geothermal Potential Zones in Java Island, Indonesia, through Multi-Sensor Satellite Imagery and Geophysical Data Analyses Using Fuzzy Logic and Geostatistical Techniques

Tedi Atmapradhana (Kyoto University),
Katsuaki Koike (Graduate School of Engineering, Kyoto University),
Asep Saepuloh (Bandung Institute of Technology (ITB))
Room: B228 2025-10-13 10:50

Indonesia, located along the geologically active Ring of Fire, is endowed with abundant geothermal resources. This potential is further amplified by the relatively cost-effective nature of geothermal exploration compared to other energy resources. In response to the growing need for efficient exploration methods, this study introduces an integrated approach that combines fuzzy logic and geostatistics, termed as Weighted Fuzzy Logic (WFL), to enhance the identification and delineation of geothermal prospect zones. The methodology leverages a diverse array of datasets derived from both remote sensing and geophysical data. These include multi-sensor satellite imagery from Landsat 8 Operational Land Imager (OLI), nightime thermal data from the ASTER Thermal Infrared Sensor (TIR), and geophysical datasets such as aeromagnetic, seismic, and gravity data. Additionally, field measurement spectral data of alteration minerals are incorporated as a ground-truth tool. ASTER TIR imagery is utilized to extract land surface temperature (LST), a key indicator of geothermal activity, while specific bands of Landsat 8 (bands 3,4,5,6, and 7) are used to analyze vegetation stress through an index, VIGS (Vegetation Index considering Greenness and Shortwave infrared). An aeromagnetic dataset provides insight into subsurface lithology and the distribution of magnetic anomalies associated with volcanic structures. The Bouguer gravity anomaly is related to the subsurface density variations, often linked to heat sources. Meanwhile, a seismic dataset is used to identify potential zones of permeability that could serve as pathways for geothermal fluids. Based on the spatial integration and analysis conducted using the WFL approach, this study identifies several zones with high geothermal potential. The most prominent areas, newly discovered, are located in the western part of Java, particularly around Mount Gede, and the eastern region near Mount Arjuna. Additional anomalies are observed in the northern part of the Island, notably around Mount Muria, indicating further prospects for geothermal exploration.



S0203. New Spatial Copula Model for Mapping Unconventional Resources Sweet Spots

Qian Zhang (Research Institute of Petroleum Exploration & Development, PetroChina), Shiyun Mi (Research Institute of Petroleum Exploration & Development, PetroChina)
Room: B228 2025-10-13 11:10

An unconventional resource "sweet spot" can be defined as an area in which commercial success in unconventional reservoirs is likely to result in. In order to map sweet spots, conventional kriged models can be used. The spatial correlation structure of unconventional resources is different depending on the distance of two wells in practical applications. It has been found that conventional kriged models tend to ignore variations in the spatial correlation structure of the unconventional resources data. As a means of overcoming this problem, in this study we developed a new method of sweet spots mapping based on spatial copulas in order to assess unconventional resources.

In the case of small sample sizes of unconventional resources data, an inaccurate marginal distribution of the unconventional resources can lead to a failure in fitting the spatial copula model. Fiducial Empirical Distribution (FED) was employed to model the marginal distribution of unconventional resource data. Vine copula is used to describe the spatial correlation structures.

We conducted a case study on mapping sweet spots for unconventional resources in the Barnett Shale production area. The comparative study shows that, compared to a conventional lognormal kriged model, the new method can express the whole and the local spatial correlation between the sweet-spots in a more effective manner, and sweet-spot mapping more accurately.

S0204. Research on the Response Mechanism between Urban Surface Energy and Physical Spatial Elements——Taking Beijing Capital Functional Core Area as an Example

Yue Ma (Capital Normal University)

Room: B228 2025-10-13 11:30

Abstract:Under the background of global climate change and rapid urbanization, the urban thermal environment problem is becoming more and more prominent, which affects the human habitat environment and sustainable development of cities. This paper takes Beijing Capital Functional Core Area (CFCA) as the research object, and systematically explores the response mechanism between surface energy and spatial elements of urban entities based on Landsat remote sensing images, results of Beijing's geographic national conditions, and vector data of house buildings. It is found that: (1) the surface energy in the core area of the capital city is significantly stratified, showing a "Λ" structure of "high in the middle and low inside and outside", and showing strong positive spatial correlation on the global spatial scale; (2) the land type of housing and buildings is the main heat source, and forest and grass cover and water area are the main heat source land types. forest and grass cover and watershed are the main sink categories, which have a significant moderating effect on surface energy; (3) the functional development category elements in the core area show strong circling differentiation characteristics, and building density and impervious surface coverage are the core spatial morphology indicators affecting the thermal environment, which are significantly positively correlated with the surface energy values (r=0.594, r=0.676); (4) the GWR model outperforms the OLS model, revealing that the spatial heterogeneity of thermal environment influencing factors, and the strongest response areas are concentrated in the districts of Dazhalan, Tsubaki, Dongsi and Financial Street Junction.

Keywords:thermal environment; surface energy; Capital Functional Core Area; spatial elements; geographically weighted regression

S0205. Spatiotemporal reconstruction of precipitation fields using the effective distribution methodology with compound Poisson gamma marginals

Anastassia Baxevani (University of Cyprus),
Anastassia Baxevani (University of Cyprus),
Dionissios T. Hristopulos (Technical University of Crete),
Christos Andreou (University of Cyprus)
Room: B228 2025-10-13 11:50

Modeling daily precipitation remains a challenge due to the intermittent, non-Gaussian, and spatially dependent structure of the process.

We propose a novel stochastic spatio-temporal precipitation generator which uses the compound Poisson gamma distribution (CPG) to handle simultaneously the intermittency and non-Gaussianity of daily precipitation combined with the effective distribution method (EDM) to model spatial dependence. We present an estimation approach for the model parameters from daily precipitation time series at a number of sampling locations. In addition, we employ EDM with computationally efficient simulation algorithms that account for intermittency and correlations at neighboring sites, in order to generate realistic precipitation fields.

The performance of the proposed CPG-EDM method is assessed by fitting the model to reanalysis datasets and calculating univariate and joint-dependence cross-validation measures.

S03 Ontologies, Knowledge Graphs, and Large Language Models in Geoscience: Construction and Application

Xiaogang Ma (University of Idaho),
Chengbin Wang (China University of Geosciences(Wuhan)),
Anirudh Prabhu (Carnegie Institution for Science)

As the geoscience community increasingly turns to advanced AI methods, the integration of ontologies, knowledge graphs, and large language models (LLMs) offers transformative potential for data management and knowledge discovery. This session aims to explore innovative approaches to constructing and applying these technologies within geoscience. We invite presentations that demonstrate the development of ontologies and knowledge graphs specific to geoscientific domains, showcasing how these models and frameworks can enhance data interoperability and semantic clarity. In particular, we welcome presentations that demonstrate how the machine-readable semantics are leveraged in reasoning and inference tasks that lead to new knowledge discoveries. Moreover, we encourage discussions on the utilization of LLMs for data science tasks in geoscience, such as automation of literature review, hypothesis generation, and enhanced data querying and analysis. Other presentations such as using knowledge graph to guide and advise LLMs in data-intensive research are also encouraged. By bringing together experts in geoinformatics, artificial intelligence, and mathematical geosciences, this session aims to stimulate interdisciplinary dialogue and identify best practices for leveraging these advanced tools. Join us in exploring and discussion how the synergistic application of ontologies, knowledge graphs, and LLMs can advance a variety of topics in geoscience.

S0301. Training Large Language Models to Think Like Geologists: Axiom-Based Reasoning for Complex Interpretation

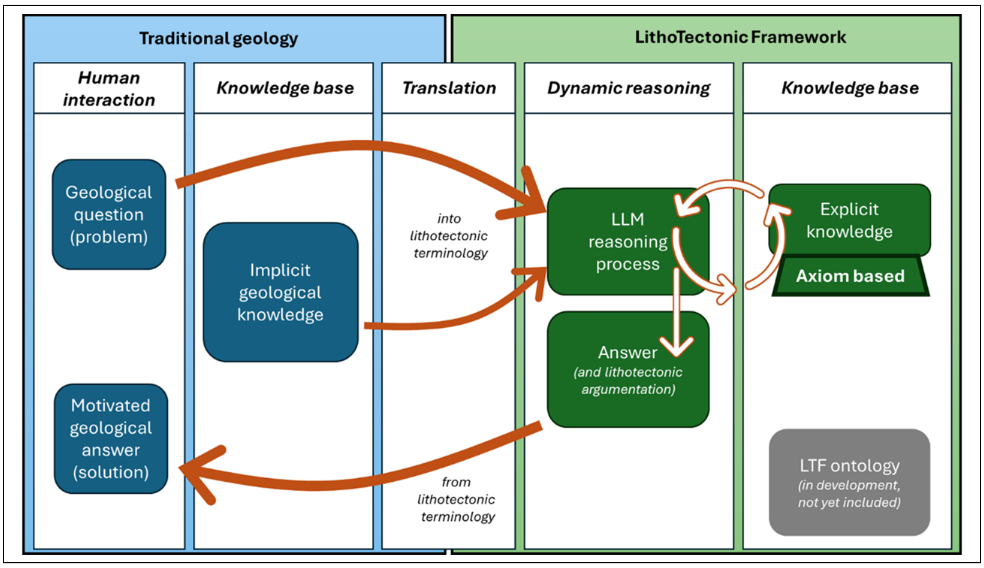
Kris Piessens (Geological survey of Belgium),
Jose Rodriguez (Geological Survey of Belgium)
Room: B210 2025-10-10 10:30

This poster presents our systematic development of axiom-based reasoning capabilities in large language models with the Lithotectonic Framework (LTF), a formal ontology for geological interpretation. Unlike agent-based approaches, we focus on developing "axiomatically-guided natural reasoning" where explicit axioms structure implicit reasoning processes of LLMs. The LTF employs five axioms that prioritize boundaries as defining features of geological units rather than traditional geographical or lithological characteristics.

Through our novel integration of explicit axioms with implicit reasoning, our methodology involves structured exercises where LLMs apply axiom-based reasoning to resolve complex geological questions. We've implemented a knowledge translation protocol converting standard geological terminology into the LTF's conceptual framework. The LTF functions as a domain ontology with formal semantics, implemented through SKOS vocabularies distinguishing between class-level concepts and instance-level concepts.

Initial results demonstrate successful reasoning about basement relationships and distinguishing true lithotectonic units from geographical features. For example, the AI correctly determined that different-aged unconformities indicate separate basement units and recognized that inliers represent geographical features rather than volumetric lithotectonic bodies. Our evaluation demonstrates progression from novice-level geological interpretation to advanced reasoning capabilities equivalent to graduate-level expertise.

This work represents a crucial step toward transforming geological AI systems from passive data repositories into active reasoning partners. By bridging explicit axiom-based knowledge with implicit learning capabilities of LLMs, we demonstrate how AI can apply expert-level domain reasoning using principled frameworks rather than pattern matching alone. This approach foreshadows a future where geoscientists collaborate with AI systems that actively reason with geological knowledge rather than merely storing it, potentially revolutionizing complex geological interpretation.


Traditional geology
LithoTectonic Framework
Human interaction
Knowledge base
Translation
Dynamic reasoning
Knowledge base
Geological question (problem)
Implicit geological knowledge
into lithotectonic terminology
LLM reasoning process
Explicit knowledge
Axiom based
Answer
(and lithotectonic argumentation)
Motivated geological answer (solution)
from lithotectonic terminology
LTF ontology
(in development, not yet included)

S0302. Geoscience Ontology, Corpus and knowledge Domesticate an LLM for Geoscience Research

Chengbin Wang (China University of Geosciences(Wuhan))
Room: B210 2025-10-10 10:50
School of Earth Resources, China University of Geosciences, Wuhan, China 430074

In recent years, the development of artificial intelligence and big data technologies has led to the advancement of tools and solutions for transforming the geological and mineral survey paradigm, which requires a large amount of geological knowledge in a complex and arduous working environment. The large language model (LLM) has a significant advantage in in knowledge management and service. However, the knowledge Illusion of LLMs restricts the application and promotion of large models in the field of geoscience. In this study, we employ the geological corpus, ontology and knowledge in the mineral deposit domain to domesticate a customized LLM for geoscience Research. The results indicate that geological corpus addresses the limitations of publicly available data, ensuring the professionalism and comprehensiveness of training data and providing a solid data foundation for LLM development. The infusion of ontology and knowledge graph to train a credible LLM and addresses common challenges of accuracy and contextual relevance faced by general-purpose LLMs in specialized fields. Th guilds from the ontology of mineral deposits can promote the creation of prompt learning that employs the an LLM to transform the text into the knowledge graph.

S0303. GeoAgent Network for Emergence of Geoscience Intelligence

Linshu Hu (Zhejiang University),
Xiang Zhao (Shool of earth science, Zhejiang University),
Jie Feng (School of Earth Sciences, Zhejiang University),
Chao Wang (School of Earth Science, Zhejiang University),
Sensen Wu (School of Earth Science, Zhejiang University),
Zhenhong Du (Zhejiang University)
Room: B210 2025-10-10 11:10

Geoscience plays a fundamental role in understanding Earth systems and supporting sustainable development. With the rapid growth of Earth observation and simulation technologies, geoscientific research is becoming increasingly data-intensive, interdisciplinary, and cognitively complex, demanding intelligent tools for knowledge discovery and decision-making. The emergence of Artificial Intelligence (AI), has given rise to Geoscience Intelligence—an integrated approach that combines geospatial data with intelligent methodologies. Generative AI , especially Large Language Models (LLMs) offers new possibilities for addressing the challenges of heterogeneous data fusion, complex spatiotemporal modeling, and interpretable scientific reasoning in geoscience.

To this end, we propose a geoscientific agent paradigm, where LLM-powered GeoAgents are designed to perform domain-specific tasks such as knowledge Q&A, literature analysis, and intelligent spatiotemporal computation. However, single agents often face limitations in coverage, scalability, and cross-domain reasoning.

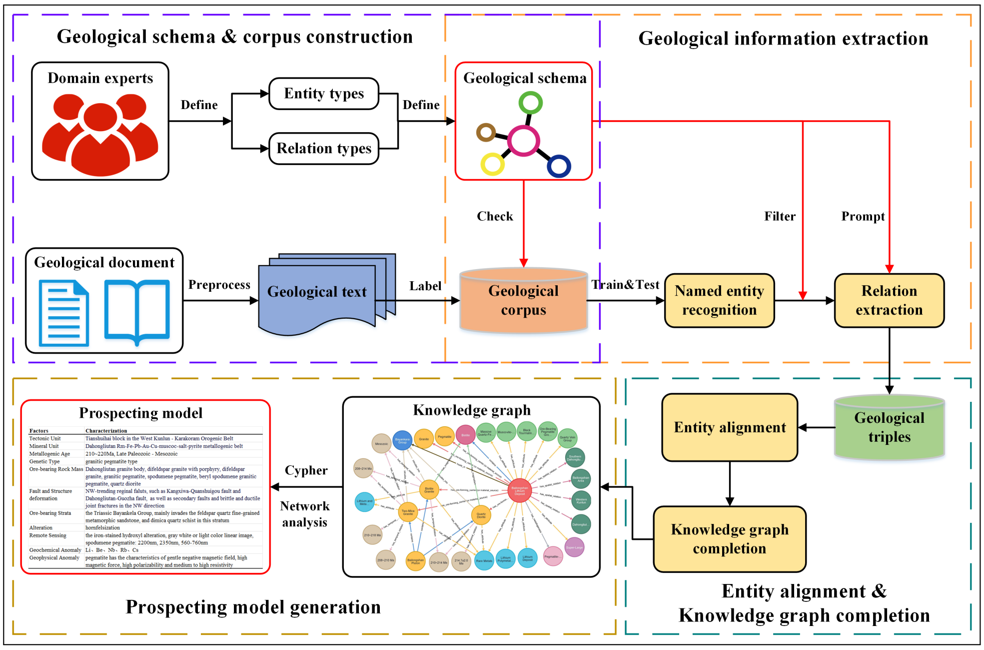
We therefore introduce the concept of a GeoAgent Network—a hierarchical and collaborative framework composed of domain-specific agents, designed to support the continuous emergence and evolution of geoscientific intelligence. Our contributions include: (1) developing a suite of GeoAgents for core tasks such as geoscience knowledge retrieval, literature mining, and spatial modeling; and (2) constructing a layered network architecture that enables inter-agent communication, task coordination, and dynamic knowledge sharing.

We hope this work can provide a novel paradigm for building intelligent systems in geoscience and offers foundational support for the broader vision of sustainable geoscience intelligence.

S0304. Construction of a Mineral Prospecting Model Based on a Knowledge Graph: A Case Study of Granitic Pegmatite-Type Lithium Deposits in Xinjiang

Jintao Tao (Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences,),
Nannan Zhang
Room: B210 2025-10-10 11:30

Traditional methods for constructing prospecting models rely heavily on geological experts and require extensive interpretation of unstructured geological reports, making it difficult to efficiently process large-scale datasets. With the increasing availability of multi-source, heterogeneous geological data, conventional manual retrieval and knowledge induction methods face significant challenges. The emergence of knowledge graphs offers new opportunities for the rapid acquisition of prospecting information and the development of intelligent prospecting models. This study focuses on granitic pegmatite-type lithium deposits in Xinjiang and explores the construction of a geological knowledge graph and the intelligent generation of a mineral prospecting model. First, scientific literature and geological survey reports related to granitic pegmatite-type lithium deposits in Xinjiang were collected to construct an annotated corpus containing 22 entity types and 16 relation types. A geological knowledge-constrained entity and relation extraction method was then proposed to extract mineral exploration-related information from geological texts. Subsequently, a graph convolutional network method combining entity type and semantic information was employed for entity alignment and knowledge graph completion. Finally, based on the constructed knowledge graph, a prospecting model was developed using Cypher query language and network analysis techniques. Experimental results demonstrate the effectiveness of this knowledge graph-based approach for the intelligent construction of mineral prospecting models. This research provides a novel methodological framework for prospecting model development and contributes to the automation and intelligent advancement of mineral resource prediction and exploration.



Geological schema & corpus construction
Geological information extraction
Domain experts
Define
Entity types
Relation types
Define
Geological schema
Check
Filter
Prompt
Geological document
Preprocess
Geological text
Label
Geological corpus
Train&Test
Named entity recognition
Relation extraction
Prospecting model
Knowledge graph
Cypher
Network analysis
Entity alignment
Geological triples
Knowledge graph completion
Prospecting model generation
Entity alignment & Knowledge graph completion

S0306. Scalable fine-tuning of LLMs for automating data science workflows in geoscience

Jiyin Zhang (University of Idaho),
Weilin Chen (University of Idaho),
Xiaogang Ma (University of Idaho)
Room: B210 2025-10-10 11:50

The integration of Large Language Models (LLMs) into geoscience research is transforming automated data analysis through agentic, task-oriented workflows. While proprietary models like ChatGPT-4o offer strong performance, their high cost and resource demands limit widespread adoption. To address this, we present a scalable approach for customizing open-source LLMs (Llama 3.1) to perform geoscience data analysis tasks. Using the self-instruct method, we generate synthetic training datasets that support fine-tuning without the need for extensive human annotation. Our workflow enables modular integration of LLM agents to tackle increasingly complex analysis tasks and serves as a generalizable framework for other scientific domains. Comparative evaluations show that the fine-tuned Llama 3.1 achieves performance on par with proprietary models in targeted geoscience workflows. Overall, this work demonstrates the viability of open LLMs for cost-effective, domain-adapted data analysis.

S04 AI-driven Mineral Prospectivity Modeling

Emmanuel John Carranza (Univ. of the Free State),
Renguang Zuo (China University of Geosciences, Wuhan)

Mineral prospectivity modeling as a computer-based approach to delineate target areas for exploration of certain mineral deposits in a mineral system has evolved from being knowledge driven to artificial intelligence (AI)-driven. The applications of AI in mineral exploration are ever increasing nowadays to address the complexity of relationships among datasets and with known deposit occurrences. The session welcomes submissions for presentations of: (1) novel AI algorithms and applications for recognition and integration of geo-anomalies to support mineral exploration, in 2D or 3D; and (2) novel AI algorithms and applications for analysis and synthesis of a variety of geoscience datasets to model mineral prospectivity and associated uncertainty, in 2D or 3D.

S0401. Metallogenic Geographical Setting and Potential of Ion-Adsorption Rare Earth Element Deposits in Shitouping, Ganzhou, Jiangxi A Study Based on Multi-Source Geographical Data and Machine Learning

Jinping Lu (EastChinaUniversityof Technology),
Mangen Li (East China University of Technology)
Room: D209 2025-10-11 14:30

Rare earth elements (REE) are critical strategic metal resources. However, researches on the metallogenic geographical setting and mineralization potential prediction in the Shitouping region of Ganzhou, Jiangxi, remain insufficient. This study identifies the metallogenic geographical setting and predicts the potential for ion-adsorption rare earth elements (iREE) mineralization in the region by employing multi-source geographical data. Key findings include:

(1) Topographic characteristics, such as low elevation ranging from 339 m to 640 m, moderate slopes from 7° to 12°, east to southeast-facing slopes from 0° to 137°, high plan curvature, low profile curvature, minimal terrain elevation from 0 to 3.50, shallow surface incision from 0 to 1.72, low roughness from 0 to 1.06, slope variability from 44.28 to 51.47, and aspect variability from 141° to 173° are conducive to the iREE accumulation.

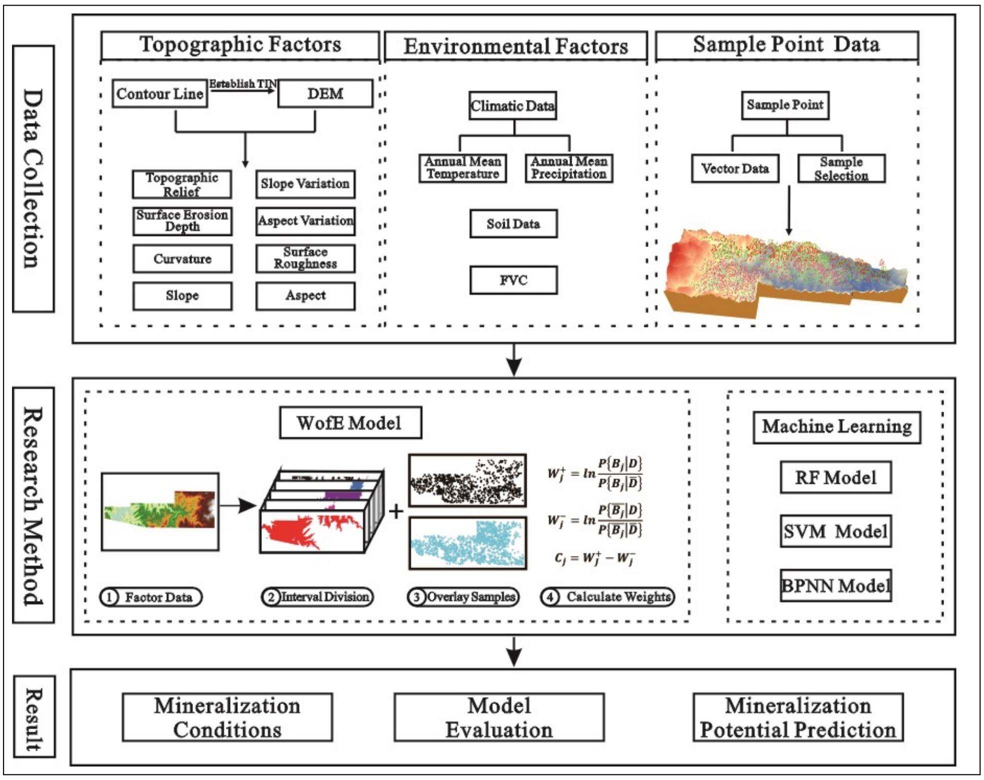
(2) Moderate fractional vegetation coverage ranging from 0.34 to 0.47, annual precipitation ranging from 1,291 mm to 1,313 mm, soil moisture levels between

298 cm^3/cm^3 and 341 cm^3/cm^3, and slight to mild soil erosion significantly support mineralization.

(3) Among the predictive models employed, the Random Forest model achieved the highest accuracy (AUC = 0.968), followed by the Back Propagation Neural Network model (AUC = 0.903) and the Support Vector Machine model (AUC = 0.841). While the Weight of Evidence model demonstrated a lower overall accuracy (AUC = 0.733), its superior recall rate (0.933) highlighted an advantage in identifying mineralized zones.

This study contributes valuable insights into the mineralization potential of iREE in the Shitouping region of Ganzhou, Jiangxi, and offers a robust framework for future exploration and resource management.

Keywords: Shitouping iREE deposits; multi-source geographical data; metallogenic geographical setting; mineralization potential prediction; Ganzhou, Jiangxi



S0402. Gold prospectivity mapping in the Hatu area, Western Junggar, NW China: A multi-model evaluation using geochemical, geological, and geophysical datasets

Yanzi Shang (Xinjiang University),
Bowen Zhang (Xinjiang university),
Chunya Zhang (Xingjiang University)
Room: D209 2025-10-11 14:50

The Hatu area of the Western Junggar region in Xinjiang, covering approximately 2,872 km^2, is characterized by abundant gold mineralization but remains insufficiently explored due to its complex tectonic framework. This study aims to develop and evaluate the performance of three predictive models—Random Forest (RF), Graph Convolutional Network (GCN), and Deep Graph Attention Network (DeepGAT)—for delineating gold prospectivity zones by leveraging integrated multi-source geoscientific datasets.

The input data consist of high-resolution 1:50,000-scale geochemical surveys with 20,796 sampling points, geological maps of lithologies and stratigraphy, geophysical anomaly layers, and a compiled inventory of 128 known gold-related deposits and mineralized occurrences. A spatial graph was constructed using sampling coordinates, with geochemical, structural, and geophysical attributes encoded as node features.

Preliminary results from the GCN model yielded a test-set classification accuracy of 0.8792, successfully delineating several high-prospectivity zones that spatially correlate with known gold occurrences. Feature importance analysis from the RF model further reveals that fault-related variables—such as fault density and proximity to major structures—are among the most predictive. This highlights the significant structural control on gold mineralization in the Hatu region, where regional fault systems likely acted as conduits for ore-bearing hydrothermal fluids.

In addition, DeepGAT—an enhanced graph attention network architecture designed to capture multi-scale spatial dependencies—is being investigated to further improve prediction accuracy in structurally complex settings. Comparative experiments among the three models are ongoing, with the objective of identifying the most effective approach for gold prospectivity mapping in the study area.

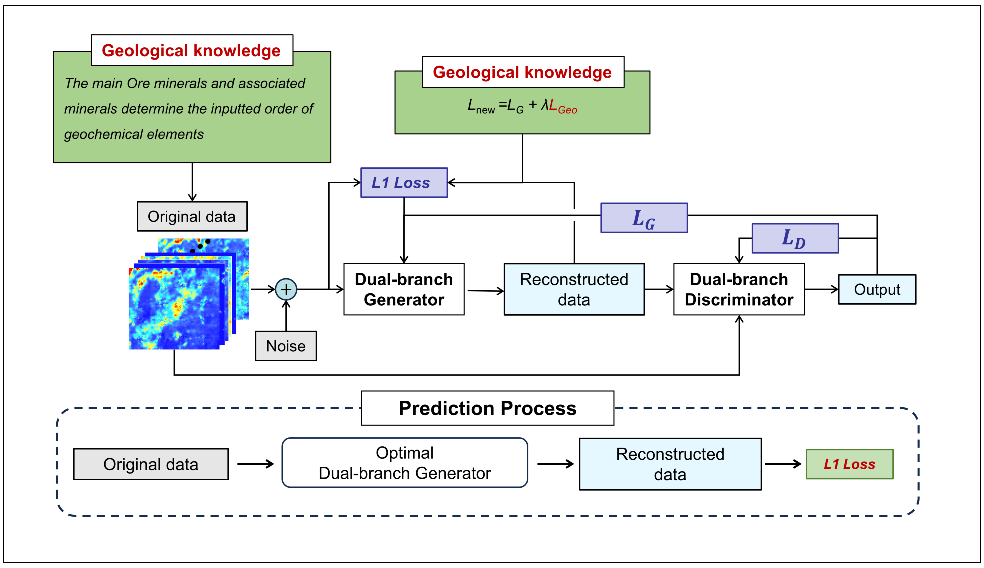
This work demonstrates the potential of integrating spatial machine learning and graph-based modeling techniques for mineral prospectivity analysis. The outcomes are expected to support intelligent target delineation and data-driven exploration strategies in the Western Junggar orogenic belt.

S0404. Geological knowledge-guided dual-branch deep learning model for identification of geochemical anomalies related to mineralization

Ying Xu (China University of Geosciences (Wuhan))
Room: D209 2025-10-11 15:10

Due to the combined effects of geological processes, geochemical behavior, and human activities, the spatial distribution of geochemical anomalies is diverse and complex. Data-driven unsupervised deep learning algorithms have powerful feature extraction capabilities and can discover intrinsic structures and patterns in data, which have been successfully applied to identify geochemical spatial patterns. However, there are still some challenges in geochemical spatial pattern recognition and anomaly extraction based on unsupervised deep learning: (1) single branch models often cannot fully capture the spatial features (anomaly size, shape, and orientation) and spectrum features (element concentrations and element associations combination) of geochemical data at the same time; (2) the scarcity of high-quality, comprehensive training datasets; (3) limited interpretability of geochemical anomaly identification results.

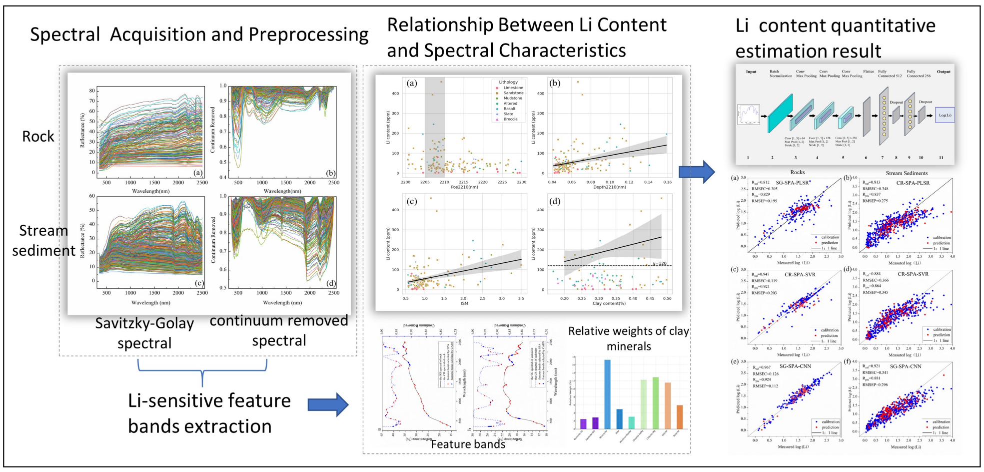
In this study, based on a generative adversarial network framework, we proposed an unsupervised spatial–spectrum dual-branch deep learning method for geochemical anomaly identification, namely dual-DL, which consists of a convolutional autoencoder (CAE) and a recurrent neural network (RNN). The spatial branch was constructed using the CAE, which can effectively capture spatial geochemical patterns and extract spatial relationships between neighboring pixels. The spectrum branch consists of an RNN that can study geochemical elemental assemblies within a single pixel. The geological knowledge was added into the model, including selecting the input order of geochemical elements and constructing the loss function of the model. A case study was conducted to recognize geochemical anomalies associated with gold polymetallic mineralization in Hubei Province, China. The results demonstrated that (1) the unsupervised dual-DL model has superior performance in identifying mineralization related to geochemical anomalies, (2) the geological knowledge-guided unsupervised dual-DL model can improve the accuracy and interpretability of geochemical anomaly identification.



S0406. Reflectance Spectroscopy Analysis and Lithium Content Estimation in Lithium-rich Rocks and Stream Sediments: Insights from Tuanjie Peak, Western Kunlun, China

Hao Zhang (Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences),
Nan nan Zhang,
Chao Liu (Geological Survey Academy of Xinjiang),
Li Chen (Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences),
Jinyu Chang (Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences),
Jintao Tao (Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences)
Room: D209 2025-10-11 15:12

Lithium, a rare strategic metal, has attracted increasing global attention. This study investigates the visible-near infrared to short-wave infrared (VNIR-SWIR, 350–2500 nm) spectral properties of 222 rock and 614 stream sediment samples from the Tuanjie Peak area, Western Kunlun, Xinjiang, to explore their quantitative relationship with lithium concentration. After VNIR-SWIR spectral measurement and lithium content analysis, spectral data were preprocessed using Savitzky–Golay smoothing and continuum removal. Key spectral parameters—absorption positions (Pos2210nm, Pos1910nm), depths (Depth2210, Depth1910), and Illite Spectral Maturity (ISM)—were extracted. Feature wavelengths sensitive to lithium were selected using the Successive Projections Algorithm (SPA) and genetic algorithm (GA), and combined with three regression models—PLSR, SVR, and CNN—to construct lithium prediction models. Results show lithium mainly exists in montmorillonite and illite, correlates positively with illite maturity and Al–OH absorption depth, and is linked to clay content. SPA outperformed GA in feature selection. The optimal rock prediction model was SG–SPA–CNN (Rp = 0.924, RMSEP = 0.112), while for sediments it was SG–SPA–CNN (Rp = 0.881, RMSEP = 0.296). Rock samples showed higher prediction accuracy, indicating better suitability for lithium estimation. CNN outperformed PLSR and SVR. This work demonstrates the potential of hyperspectral technology for identifying sedimentary clay-hosted lithium resources.



S0408. Data-Driven Mineral Prospectivity Mapping Based on Known Deposits Using Association Rules

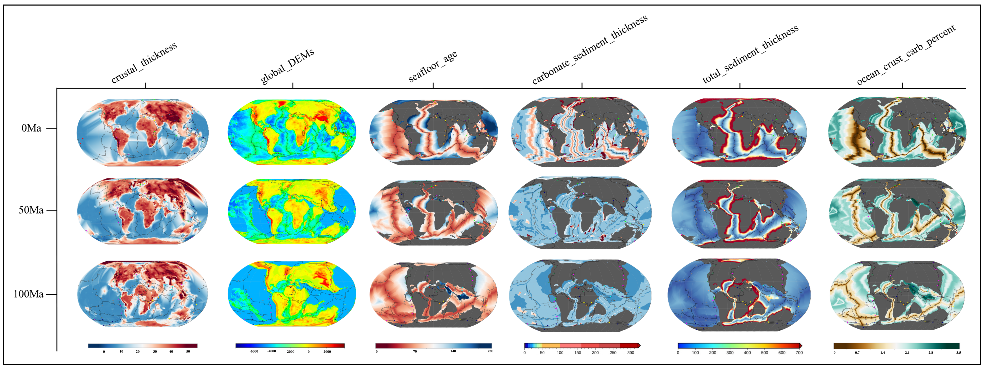
Xiaotong Yu (Institute Of Geochemistry, Chinese Academy of Sciences),
Xiaotong Yu (State Key Laboratory of Ore Deposit Geochemistry, Institute of Geochemistry, Chi)
Room: D209 2025-10-11 16:30

Machine learning methods have been recently utilized to mine correlations between geological variables and deposits because of their significance in mineral prospectivity mapping (MPM). However, characteristics of known deposits are often overlooked in supervised approaches to MPM, because only spatial coordinates of known deposits are used as positive training samples. We propose an interpretable method using association rules to predict the prospectivity of the Pangxidong district to incorporate characteristics associated with deposits into MPM. Specifically, association rules are a type of data-driven equivalent of ore-controlling factors in knowledge-based exploration and warrants a broader consideration in modern data-centric exploration. The detailed procedures are as follow: (1) two strong association rules related to deposits were extracted using the Apriori algorithm based on the known Ag-Au and Pb-Zn deposits in Pangxidong; (2) the weights of the variables in the data filtered by the strong association rules were defined using entropy weight method (EWM); (3) the probability of finding undiscovered deposits was calculated for further prospecting. The Apriori algorithm delineated 57.3% and 52.6% of the known Ag-Au deposits and Pb-Zn deposits within 3.91% and 1.48% of the study area, respectively. In addition, after the EWM, high-probability areas of Ag-Au deposits and Pb-Zn deposits cover 1.05% and 0.43% of the study area, respectively. Therefore, the method is effective and efficient in MPM and has the potential to be applied more broadly.

S0409. Spatio-temporal prediction of porphyry copper deposits in the Gangdese belt using machine learning

Yuepeng Zhang (China University of Geosciences),
Guoxiong Chen (China University of Geosciences)
Room: D209 2025-10-11 16:50

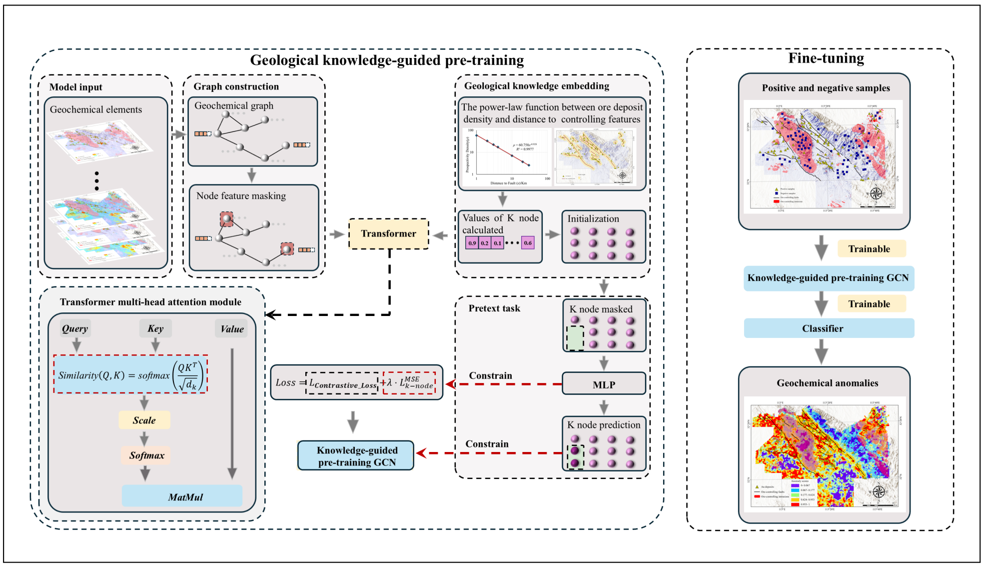
Porphyry copper deposits, accounting for 65% of global copper reserves, are typically associated with arc magmatism induced by subduction zones. However, the link between subduction dynamics and porphyry formation remains poorly understood. This study develops a deep-time machine learning model using plate motion reconstructions and oceanic crust age grids to derive subduction-related features. The goal is to clarify how subduction zone evolution and slab parameters influence porphyry copper mineralization and to identify high-prospect regions. The model reconstructs the spatiotemporal kinematics of convergent boundaries and extracts key features of the subducting plate, such as sediment thickness and oceanic crust properties. Using ten subduction parameters and nine semi-supervised learning methods, we predict porphyry copper prospectivity in the Gangdese Belt from 120 to 60 Ma and identify the most influential features. Results show that the model achieves 99% precision and accuracy, with strong generalization beyond the training data. Most known deposits fall within high- or medium-prospect zones. Subduction angle emerges as the most critical factor; steeper angles enhance slab dehydration and overlying crustal melting, providing the heat and fluids necessary for ore system development. In summary, this work presents a deep-time ML approach to reconstruct subduction processes during porphyry formation, highlights key geodynamic controls, and offers guidance for porphyry copper exploration in convergent settings.



S0410. Geological-knowledge-guided graph self-supervised pretraining framework for identifying mineralization-related geochemical anomalies

Zhiyi Chen (China University of Geosciences (Wuhan)),
Renguang Zuo (China University of Geosciences, Wuhan)
Room: D209 2025-10-11 17:10

The identification of geochemical anomalies related to mineralization is crucial for predicting the presence of mineral resources. Graph neural networks are essential tools in identifying geochemical anomalies associated with mineralization owing to their ability to process spatially correlated data. However, the performance and generalizability of supervised learning models are often constrained by the limited availability of labeled data. As such, graph self-supervised learning (SSL) has received considerable attention because of its ability to strengthen representation learning by capturing the intrinsic structure and distribution of data, even in scenarios in which labeled data are scarce. The existing SSL methods often fail to effectively incorporate domain-specific knowledge during the learning process, restricting both the generalization and geological interpretability of SSL models. Therefore, a geological-knowledge-guided graph with self-supervised pretraining (GKGP) framework was proposed in this study. The GKGP framework substantially enhanced the SSL model's ability to capture important spatial relationships and geochemical features by embedding the power-law relationship between the spatial density of mineral deposits and their distance to ore-controlling factors into the pretraining phase of the SSL, which is combined with a transformer-based multi-head attention mechanism. Case studies show that the GKGP framework can effectively identify ore-related geochemical anomalies in the South Tianshan region of Xinjiang, China, and maintain robust predictive performance even under high data disturbance. Furthermore, the integration of prior geological knowledge improves the accuracy and interpretability of the SSL model, ensuring its robustness under complex conditions.



S0411. A Bayesian Approach to Absolute Prospectivity: Integrating Exploration Intensity and Expert's Insight

Tianyuan Zhang (SRK Exploration Ltd),
Ehsanollah Baninarjar (SRK Exploration),
Niall Tomlinson (SRK Exploration)
Room: D209 2025-10-12 10:30

Prospectivity mapping plays a critical role in addressing the inherent uncertainty of mineral exploration by estimating the potential for undiscovered mineralisation and guiding new discoveries. Traditional data-driven prospectivity mapping methods (e.g., machine learning) typically require large amounts of training data and often fail to incorporate all available information (such as geologists' expertise and exploration intensity). Moreover, known deposits are sparse and usually fall within a positive-unlabelled framework, where only positive instances are available, and confirmed non-deposit data (areas thoroughly explored and verified as non-prospective) are lacking. Additionally, the absence of discoveries does not necessarily indicate low prospectivity; it may simply reflect a lack of exploration effort in those areas.

To address these challenges, a hierarchical Bayesian framework is proposed to quantify "Absolute Prospectivity", which estimates the probability of discovering deposits of varying magnitudes within a target area. The prior model is derived using a novel machine learning approach that incorporates geologists' opinions or available mineral system models relevant to the commodity of interest. This prior map is then updated using evidential layers, including known mineral deposit data and exploration activity within the terrane. The method applies signal detection theory to account for exploration intensity across the study area. Hit rates and false alarm rates, calculated from the discovered deposit data, are used to derive the posterior absolute prospectivity. The resulting probabilities represent actual likelihoods of discovery for deposits of different magnitudes.

The proposed method demonstrates how geological prospectivity can be assessed using exploration intensity. It supports informed decisions on ground selection, project valuation, and capital allocation, while also quantifying exploration uncertainty. This enables optimal allocation of exploration expenditure across both mature terranes and greenfield areas.

S0413. Identificating favourable reservoir areas of coalbed methane with deep learning model

Yuhua Chen (China University of Mining and Technology)
Room: D209 2025-10-12 10:50

Identificating favourable reservoir areas of Coalbed methane(CBM) is significant for improving economics of CBM project. However, accurately identification of favourable areas from CBM reservoir with strong heterogeneity of reservoir parameters is challenging. In previous researches, some traditional models were applied to identify favourable areas of CBM reservoir, however there is a widely gap between the evaluation result and reality distribution of high-yield areas of CBM reservoir. For solving above problem, identifying favourable reservoir area with strong heterogeneity is conducted with deep learning and multifractal theory. Furthermore, a deep learning model is constructed with the genetic algorithm and door circulation unit to identify favourable reservoir areas of CBM and is verifyed with the block of Fanzhuang-Zhengzhuang located in the Qinshui coalfield of China. And also, to identify the key features of favourable areas, an interpretable residual graph convolutional neural network model(I-RGCN) was designed for the classification of CBM production types and the identification of key features. The model constructs topology graph structures using inter-well interference and utilizes the Dynamic Time Warping (DTW) algorithm to assess the similarity between CBM well points, incorporating these as edge weights in the model for accurate classification of CBM production types. Subsequently, the GNNExplainer ranked the importance of features during the model's decision-making process. Experiments conducted on datasets from the Fanzhuang-Zhengzhuang block demonstrate that the I-RGCN achieves the accuracy of above 84% and the F1 score of about 65%, which is superior to other baseline models.

S0414. Quantification of Uncertainty in Data-Driven 3D Modeling of Mineral Prospectivity: A Machine Learning Framework

Zhiqiang Zhang (Hebei GEO University),
Gongwen Wang (China University of Geosciences (Beijing)),
Emmanuel John Carranza (Univ. of the Free State),
Jingguo Du (School of Earth Science and Resources, Chang'An University, Xi'an, 710054, Peopl),
Yingjie Li (School of Earth Sciences, Hebei GEO University, Shijiazhuang, 050031, People's R),
Xinxing Liu (School of Earth Sciences, Hebei GEO University, Shijiazhuang, 050031, People's R),
Yongjun Su (Tianjin Center, China Geological Survey, Tianjin, 300170, People's Republic of C)
Room: D209 2025-10-12 11:10

Uncertainty in 3D mineral prospectivity analysis is derived from (a) uncertainty in conceptual model of mineral system derived from relevant geological knowledge, (b) aleatoric uncertainty due to variability of and noise in multi-source geoscience datasets as a result of collection and processing, and (c) epistemic uncertainty introduced by an algorithm for predictive modeling. Quantification of the uncertainty in 3D mineral prospectivity analysis is a precondition for using a predictive model to guide exploration. Earlier researches on mineral prospectivity analysis focused mostly on tackling uncertainty in conceptual model of mineral system. Some researches focused on quantifying aleatoric and epistemic uncertainties in 3D mineral prospectivity analysis. This research purports a innovative framework for machine learning to measure uncertainty and to describe aleatoric and epistemic uncertainties in 3D mineral prospectivity analysis by random forest modeling. One more novelty of this framework is the use of the accuracy–rejection curve to specify a threshold quantifiable uncertainty for delineation of exploration targets. The hyperparameters of the random forest framework for uncertainty measurement were automatically tuned using Bayesian hyperparameter optimization. The practicality of the proposed framework is proved in a case study of 3D mineral prospectivity analysis to delineate exploration targets in the Wulong gold district (China). The results indicated that the 3D model of Early Cretaceous dykes was the main source of aleatoric uncertainty in the 3D model of mineral prospectivity. The delineated 3D exploration targets according to the random forest framework for uncertainty measurement can be used to guide subsurface exploration for gold mineralization in the study area.

S05 Fractals and Singularity in Geosciences

Wenlei Wang (Institute of Geomechanics, Chinese Academy of Geological Sciences),
Fan Xiao (Sun Yat-University),
Qiuming Cheng (Sun Yat-sen University),
Guoxiong Chen (China University of Geosciences),
Vijay Prasad Dimri (CSIR-National Geophysical Research Institute)

As a significant branch of no-linear science, the fractal concept has been widely used in geosciences. Fractal and multifractal models have been successfully employed to characterize the irregularity of geological features such as mineral textures, crystal structure, and grain size; the spatial distribution of geological objects such as mineral deposits, veins, and faults or/and fractures; multi-scale anomalous signals of geophysical survey data including gravity, magnetic and seismic; the singularity geochemical anomalies associated with mineralization, and many other properties of geological, geophysical and geochemical events or/and processes. In recent years, these studies have achieved many progresses or/and updated their applications. The focus of this session is to continue to advance research on topics relating to the theory, model, algorithm, and application of fractal analysis in geosciences. Topics that are invited for submission include (but are not limited to): (1) Fractal modeling and singularity analysis of extreme geological events; (2) Fractal filtering of geophysical data; (3) Fractal solutions for complex geophysical models; (4) Fractal modeling of geochemical data; (5) Fractal analysis in mineral prospectivity mapping; (6) Fractal analysis of ore deposit, minerals and rocks; (7) Fractal modeling of faults or/and fractures; (8) Fractal analysis in geological data fusion; and (9) Fractal modeling of geological or/and geochemical process.

S0501. Fractal Frontiers in Geosciences: Integrating Novel Multifractal Models for Enhanced Spatial Analysis

Behnam Sadeghi (CSIRO Mineral Resources, Australian Resources Research Centre)
Room: B210 2025-10-11 14:30

This research is to introduce a reference in mathematical geosciences by Behnam Sadeghi, published by Elsevier in May 2024. The book seamlessly synthesises traditional multifractal methods with innovative models developed by the author, providing a robust framework to analyse complex spatial patterns and quantify uncertainty in geochemical data. It details a comprehensive approach that integrates advanced data pre-processing with multifractal modeling techniques, enabling researchers to extract subtle features and detect anomalous signals with unprecedented clarity.

At its core, the book addresses the dynamic interplay between variables and spatial distances, offering novel multifractal models that adapt to changes in relationships among geoscience datasets. By incorporating Gaussian simulation techniques and uncertainty modelling alongside established methods like concentration-area, spectrum-area, and singularity analyses, the work significantly enhances the reliability of geochemical anomaly maps. It provides clear criteria for selecting the optimal combination of data treatments and modelling strategies, ensuring improved sample classification and spatial interpolation stability. Aimed at mathematical geoscientists, geostatisticians, exploration and environmental geochemists, computational geoscientists, geo-data scientists, compositional data analysts, GIS professionals, and decision-makers in the mining and mineral industries, this book bridges the gap between theoretical fractal geometry and practical applications. Its innovative perspective not only deepens our understanding of spatial heterogeneity in geoscience data but also offers strategic insights for follow-up sampling and exploration initiatives. This presentation will highlight the book's key contributions and transformative potential, inviting a dynamic discussion on the future of multifractal applications in the geosciences.

S0502. Multifractal and Empirical Mode Decomposition Analysis of Geophysical Well-log Data of Gulf-of-Suez

Enamundram Chandrasekhar (Indian Institute of Technology Bombay, Mumbai), Aref Lashin (Petroleum and Natural Gas Department, College of Engineering, King Saud Universi)

Room: B210 2025-10-11 14:50

The nonlinear geophysical well-log data sets exhibit not only their scale-invariant properties, but also some varied degrees of heterogeneities, associated with subsurface lithologies, as a function of depth. Therefore, nonlinear data analysis techniques must be employed to understand and characterize the nature of the subsurface lithologies, vis-à-vis their degree of heterogeneity. In this study, we apply multifractal detrended fluctuation analysis (MFDFA) and empirical mode decomposition (EMD) technique on gamma-ray and neutron porosity log data sets of several wells in the Gulf-of-Suez region, to characterize and compare the subsurface hydrocarbon zones. While the MFDFA technique provides a comprehensive understanding of the multifractal behaviour of nonlinear well log data through multifractal singularity spectrum and the Hurst exponents, the EMD technique facilitates to decompose the well-log data into oscillatory signals of different wavelengths, called intrinsic mode functions (IMFs), which represent different frequency characteristics of the signal and which in turn helps to calculate the degree of subsurface heterogeneity. Preliminary results suggest that the Gamma-ray (GR) log data sets of all the wells in the Gulf-of-Suez show a relatively higher degree of heterogeneity in them compared to that of Neutron Porosity (NP) log data sets, suggesting the presence of a geologically complex environment with variable lithology, likely with significant changes in the shale or clay content. While the higher heterogeneity in the GR log could reflect rapid lateral changes in lithology, such as transitions from sandstone to shale or limestone to shale, the less degree of heterogeneity in NP logs in all the wells implies the fluid present in the pore spaces is relatively uniform in the entire lithology. Results will be discussed in the light of subsurface lithological differences vis-à-vis the hydrocarbon yield from all the wells in the study region.

S0504. Effects of Subduction Zone Heterogeneity on Natural Earthquakes: Insights from the Sunda Plate

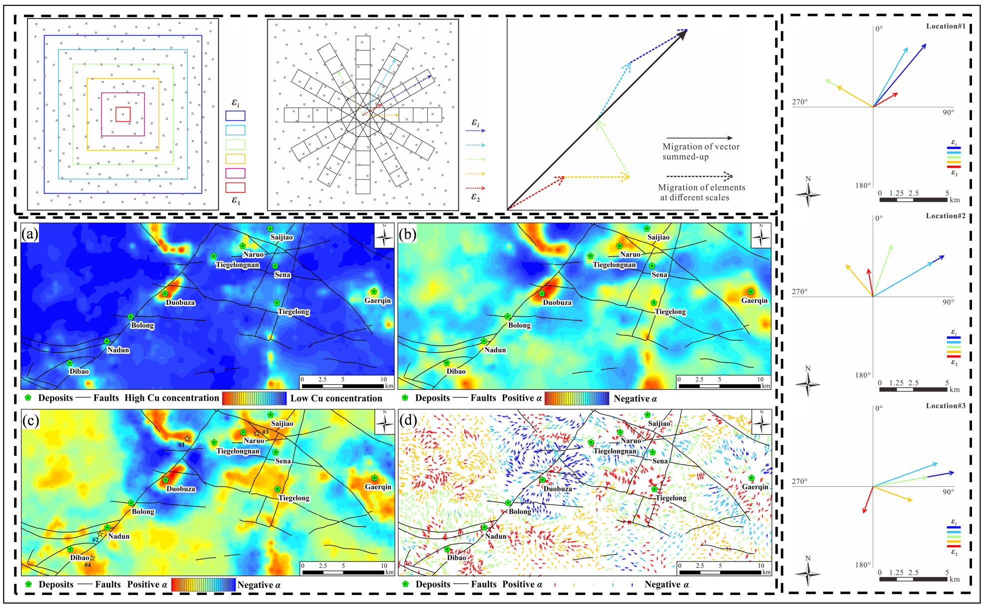
yufei ZHANG (Sun Yat-sen University),
qiu ming CHENG (Sun Yat-sen University)
Room: B210 2025-10-11 15:10

The spatiotemporal distribution characteristics of seismic events and their singularity analysis provide a crucial approach to understanding regional tectonic activity. Although previous studies on seismic events have been extensive, the exploration of their distribution patterns over large-scale regions and long-term sequences remains insufficient due to the inherent spatiotemporal unevenness of earthquake occurrences. The singularity of seismic events effectively characterizes their spatial clustering features, unaffected by spatiotemporal heterogeneity, offering a novel perspective for investigating the long-term evolution of seismic activity. This study focuses on the Sunda Plate, particularly its eastern and western subduction zones, employing singularity analysis to examine the spatiotemporal variations in seismic singularity and their relationship with plate tectonic dynamics. The research emphasizes the influence of differences between the eastern and western subduction zones on seismic singularity, while further exploring potential remote correlation effects between seismic activities on both sides. The findings aim to elucidate the regulatory mechanisms of subduction zone heterogeneity on the distribution characteristics of seismic events. The results may contribute to a deeper understanding of the dynamic processes of seismic activity in the Sunda Plate and provide theoretical support for regional seismic hazard assessment.

S0505. A Novel Anisotropic Singularity Algorithm for Identifying Geo-Chemical Anomalies within Covered Areas

Jie Tang (Chinese Academy of Geological Sciences),
Wenlei Wang (Institute of Geomechanics, Chinese Academy of Geological Sciences)
Room: B210 2025-10-11 16:30

In the field of mineral resource assessment, accurate and effective identification of geological anomalies holds critical importance. As a crucial information carrier for geological bodies, geochemical data represent one of the most direct and effective sources for the quantitative analysis of regional geological evolution and ore-forming prediction research. This study primarily focuses on resolving the challenging problem of separating anomalies from background within geochemical datasets. In response to the attenuation of anomaly signals in geochemical data analysis caused by traditional statistical methods that overlook spatial heterogeneity and scale-dependent variations in spatial statistical characteristics, this study proposes a novel algorithm for estimating anisotropic singularity indices by integrating fractal/multifractal theory with the anisotropic properties of geological bodies. By comparing with the isotropic singularity index, this novel method objectively identifies anisotropic geochemical signatures and explores the non-linear behaviors of ore-forming elements, thereby enhancing its practicality and effectiveness in geo-anomaly extraction. Furthermore, by leveraging multi-scale vector arrow marking technology, this method is capable of dynamically characterizing the gradient variation features of geochemical elements across various spatial domains. It can also intuitively illustrate the migration pathways and differentiation trends of mineral elements within the study area through the integration of comprehensive vector directions. This novel method not only provides high-precision technical support for deep mineral prediction but also further refines the theoretical comprehension of the fractal dynamics mechanism of ore-forming elements, thereby promising to significantly transform our understanding of mineral formation and distribution within the Earth's crust.



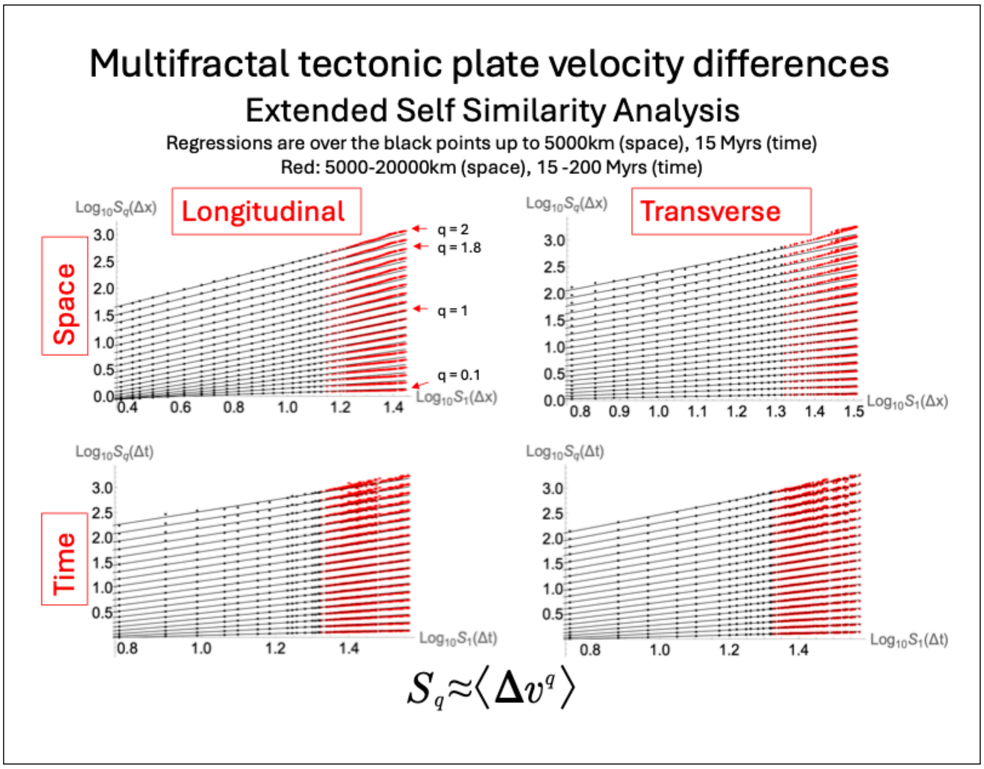
S0506. Multifractal tectonics: multifractal analyses and a convective - diffusion multifractal model

Shaun Lovejoy (Physics, McGill University),
Andrej Spiridonov (Department of Geology and Mineralogy, Faculty of Chemistry and Geosciences, Viln)
Room: B210 2025-10-11 16:50

Fluid turbulence and seismicity have many common features: nonlinearity with huge numbers of degrees of freedom. They are both riddled with scaling laws in space and in time and they both displaying power law extreme variability and – we can now add – multifractal statistics.

To demonstrate this, we analyse the GPlates data base of 1000 point trajectories over the last 200 Myrs, analyzing the statistics of the dynamically important longitudinal and transverse vector velocity differences where Dr is the great circle distance between two points and Dt is the corresponding time lag. The longitudinal scaling of the mean longitudinal difference follows the scaling law <Dv(Dr)> Dr H with H = 1 as theoretically predicted. This high value implies that mean fluctuations vary relatively smoothly with distance. Yet at the same time, the multifractal intermittency exponent C1 is extremely high (C1 0.55) implying that from time to time there are enormous quake-like "jumps" in plate velocities (c.f. the values in fluid turbulence of H = 1/3 Kolmolgorov and C1 0.07). Our study thus quantitatively shows how smooth fluid-like behaviour (H = 1) can co-exist with highly intermittent quake-like behaviour. For both longitudinal and transverve velocity differences we find that the outer spatial scale is near the size of the Earth (15000km) and the outer time scale 50Myrs.

In time, the mean fluctuations follow <Dv(Dt)> Dt H for both longitudinal and transverse components H ½. We also quantify the probability of extremes finding them to be power laws (Guttenberg – Richter type laws). On this basis we propose a convective – diffusive model that uses two the theoretically derived exponents (H = 1, ½) as well as a single intermittency exponent and unique index of multifractality. The model reproduces the observed statistics including the longitudinal-transverse correlations.


Multifractal tectonic plate velocity differences
Extended Self Similarity Analysis
Regressions are over the black points up to 5000km (space), 15 Myrs (time)
Red: 5000-20000km (space), 15 -200 Myrs (time)
Longitudinal
Transverse
Space
Time
q = 2
q = 1.8
q = 1
q = 0.1
$\mathrm{Log}_{10}S_q(\Delta x)$
$\mathrm{Log}_{10}S_1(\Delta x)$
$\mathrm{Log}_{10}S_q(\Delta t)$
$\mathrm{Log}_{10}S_1(\Delta t)$
$S_q \approx \langle \Delta v^q \rangle$

S0507. Unlocking automated mineralogy for accurate and consistent nomenclature of igneous cumulate rocks

Behnam Sadeghi (CSIRO Mineral Resources, Australian Resources Research Centre),
William Smith (CSIRO Mineral Resources, Australian Resources Research Centre, Australia)
Room: B210 2025-10-11 17:10

Automated mineralogy (AM) is a rapid, non-destructive technique that quantifies the mineralogical and textural properties of geological materials using Scanning Electron Microscopy coupled with Energy Dispersive Spectroscopy. Beyond determining modal mineralogy, AM software can characterize grain size distributions, two-dimensional shape properties, mineral and bulk-rock chemistry, and the spatial relationships between mineral phases.

The terminology used to describe cumulate igneous rocks in layered mafic–ultramafic intrusions and sill complexes has been debated for over fifty years, largely due to the genetic implications embedded in traditional naming conventions. Cumulate rocks are typically defined as a framework of touching cumulus crystals, surrounded by intercumulus phases derived from residual silicate melt that was trapped between the cumulus crystals. These rocks may also display poikilitic textures, where smaller chadacrysts are enclosed within larger oikocrysts. For example, a harzburgite comprising equal proportions of olivine and orthopyroxene could be classified as a granular harzburgite (cumulus olivine and orthopyroxene) or a poikilitic harzburgite (cumulus olivine with poikilitic orthopyroxene). Accurate classification requires attention to both mineralogical and textural considerations. However, the complexity and subjectivity of these terms have led to widespread inconsistencies in naming, perpetuating misconceptions in geological interpretations—"an inaccurate or misleading name is worse than no name" (Irvine, 1981).

It is proposed that AM data can be harnessed for the objective classification of igneous cumulate rocks when combined with grain-scale multifractal analysis. Using an in-house AM database of cumulate rocks, we are documenting the shape properties, mineral associations, and mineral chemistries that are representative of cumulus, intercumulus, and poikilitic crystals. The goal is to develop workflows that synergize with AM software to facilitate the accurate and consistent classification of igneous cumulate rocks while potentially appending descriptors related to grain size distributions, degree of alteration, or the presence of mineralization.

S0508. From Eons to Epochs: intermittent, scaling, multifractal Geological Time and a compound multifractal-Poisson model

Shaun Lovejoy (Physics, McGill University),
Andrej Spiridonov (Department of Geology and Mineralogy, Faculty of Chemistry and Geosciences, Viln),
Raphael Hebert (Alfred-Wegener Institute Helmholtz Centre for Polar and Marine Research, Telegra),
Fabrice Lambert (Geography Institute, Pontificia Universidad Catolica de Chile, Vicuña Mackenna 4)
Room: B210 2025-10-11 17:12

Geological time is punctuated by events that define biostrata and the Geological Time Scale's (GTS) hierarchy of eons, eras, periods, epochs, ages. Paleotemperatures and macroevolution rates, have already indicated that the range 1 Myr to (at least) several hundred Myrs) is a scaling (hence hierarchical) "megaclimate" regime. We apply analysis techniques including Haar fluctuations, structure functions trace moment and extended self-similarity to the temporal density of the boundary events (r(t)) of two global and four zonal series. We show that r(t) itself is a new paleoindicator and we determine the fundamental multifractal exponents characterizing the mean fluctuations, the intermittency and the degree of multifractality. The strong intermittency us determination to show that the (largest) megaclimate scale is at least 0.5 Gyr.

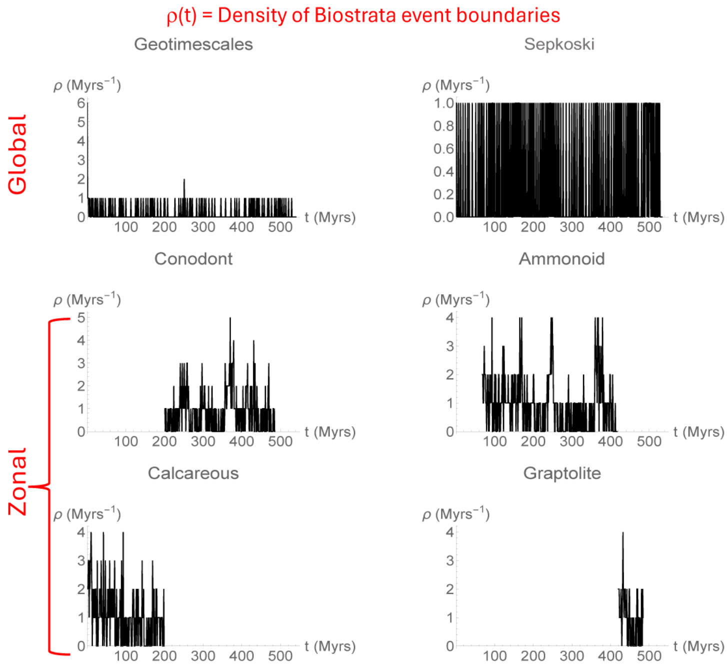
We find that the probability distribution of the intervals ("gaps") between boundaries and find that its tail is also scaling with an exponent qD 3.3 indicating huge variability with occasional very large gaps such that it's third order statistical moment barely converges. The scaling in time implies that record incompleteness increases with its resolution (the "Resolution Sadler effect"), while scaling in probability space implies that incompleteness increases with sample length (the "Length Sadler effect").

The density description of event boundaries is only a useful characterization over time intervals long enough for there to be typically one or more events. In order to model the full range of scales (and low to high r(t)), we introduce a compound Poisson-multifractal model in which the multifractal process determines the probability of a Poisson event. The model well reproduces all the observed statistics.

Scaling changes our understanding of life and the planet and it is needed for unbiasing many statistical paleobiological and geological analyses, including unbiasing spectral analysis of the bulk of geodata that are derived from cores.

From Eons to Epochs: intermittent, scaling, multifractal Geological Time and a compound multifractal-Poisson model

Shaun Lovejoy,
Andrej Spiridonov,
Rhisiart Davies ,
Raphael Hebert,
Fabrice Lambert



S06 Machine Learning Applications in Geoscience Research

Enamundram Chandrasekhar (Indian Institute of Technology Bombay, Mumbai), Sang-Mook Lee (School of Earth and Environmental Sciences, Seoul National University, Seoul, Ko), Byung-Dal So (Department of Geophysics, Kangwon National University, Korea)

The geoscience data are inherently heterogeneous, encompassing spatial, temporal, and multiscale information. The steady penetration of machine learning (ML) and deep learning (DL) techniques into geoscience research has been emerging as a transformative force, providing a unique ability to detect patterns, make predictions, and enable new insights and methodologies across various applications in geophysics, geology and atmospheric science. This session aims to explore the innovative use of ML/DL techniques in geoscience research from subsurface imaging to environmental monitoring to predicting mineral prospecting zones and natural hazards. We invite contributions in all areas of geosciences that showcase cutting-edge research, case studies and advancements in ML/DL algorithms addressing challenges in geoscience research. Contributions to this session include but not limited to timeseries modelling, geospatial analysis, pattern recognition, data automation and uncertainty quantification.

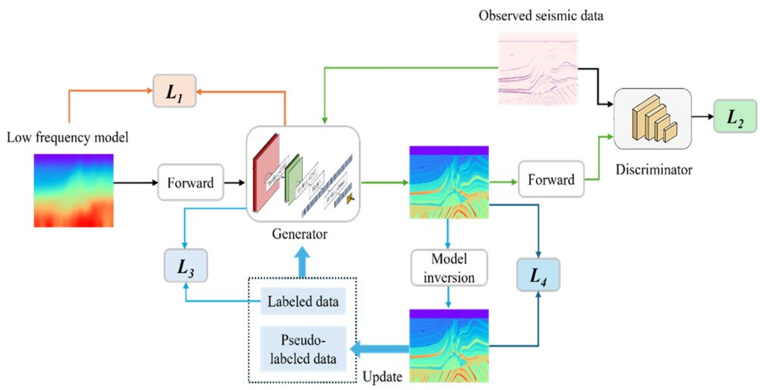
S0601. Seismic inversion based on GAN joined with geophysical constraints

Jianguo Yan (Chengdu University of Technology), Wenlu Huang (Chengdu University of Technology)
Room: B210 2025-10-10 14:30

Deep-learning algorithms have great potential in interpreting complex geo-datasets, e.g., unveiling subsurface geological structures and properties by seismic inversion with deep-learning methods. However, it is realized that the lack of geophysical constraints seriously affects the feasibility and accuracy of the inversion results. To address the above problem, we designed an improved generative adversarial network (GAN) and added new geophysical constraints to form an optimistic seismic inversion method based on joint GAN and GC (Geophysical Constraints). The established method includes using conventional seismic inversion to expand training data sets with “pseudo-labels” and adding inversion and forward objective function terms to form a new GC. We tested the proposed method on the Marmousi model and the field data, and the results show that the subsurface structure and seismic impedance predicted by this method have higher reliability.

The proposed workflow with the method is (1) the result of deep learning network inversion is used as the initial model for conventional seismic inversion, and the result of the conventional seismic inversion is used as the expanded ”pseudo-label”; (2) In the network parameter training, the original loss function is reconstructed with inversion and forward objective functions; (3) final results are obtained by iterative processing with optimizing deep learning network prediction and updating ”pseudo-labels” and ”joint loss functions.”

One of the critical parts of the proposed method is that we construct a new joint loss function, which is mainly composed of four parts: network loss (L1), seismic loss (forward loss L2), pseudo-label loss (L3), and conventional inversion loss (L4). The whole loss function can be expressed as an equation: >0 are the weights to adjust the three parts. The schematic structure and workflow of the proposed method are also shown in the accompanying figure.



The schematic structure and workflow of proposed network inversion with forward + inversion joint constraints

S0602. A Spectral-Preserving Resampling for Spatial Upscaling of Hyperspectral Imagery

Yuxin Tian (Sun Yat-sen university),
Yuxin Tian (Sun Yat-sen university)
Room: B210 2025-10-10 14:50

Multi-scale hyperspectral imagery enables effective characterization of mineralogical signatures at varying spatial resolutions, thereby enhancing the accuracy of mineral identification. However, conventional scale transformation methods often induce spectral distortion and information degradation during the spatial upscaling of hyperspectral data, negatively impacting identification performance. To mitigate information loss during spatial scale transformation, this study proposes a spectral-preserving resampling (SpePR) method for hyperspectral imagery upscaling. Multi-scale hyperspectral imagery was initially acquired using unmanned aerial vehicles (UAVs). To quantitatively analyze the key spectral absorption features of pegmatite samples, various spatial scales were simulated through spatial upscaling. Subsequently, a comparative evaluation was performed across seven widely used interpolation algorithms: Average, Bilinear, Cubic, Gaussian, Lanczos, Mode, and Nearest Neighbor. Resampling performance was evaluated using Spectral Angle Mapper (SAM), Spectral Information Divergence (SID), Spectral Gradient Angle (SGA), and correlation coefficients. Results indicate that the proposed SpePR method exhibits improved spectral fidelity and scale adaptability relative to conventional methods, indicating its promise for mineral identification and related remote sensing applications.

S0603. The Spatiotemporal Characteristics of Volcanic Thermal Activity in the South China Sea Marginal Area Based on Remote Sensing Big Data Analysis

Yilin Yang,
Qiuming Cheng
Room: B210 2025-10-10 15:10

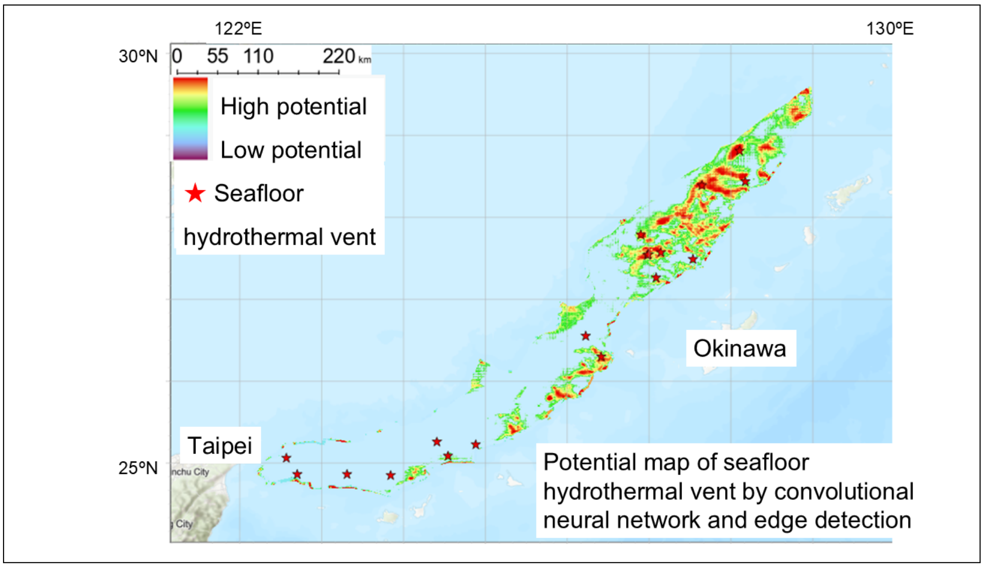
The South China Sea is located at the junction of the Indian Plate, the South China Plate, the Philippine Sea Plate, and the Australian Plate, with complex geological structures and frequent volcanic activity. Although various remote sensing monitoring methods have been employed to detect volcanic thermal activity, most studies focus on individual volcanoes or short-term anomaly patterns, lacking systematic research on volcanic thermal activity in large-scale, geologically diverse, and heterogeneous regions. To address this scientific issue, this study proposes a framework combining remote sensing LST time series and machine learning methods to extract surface thermal anomalies induced by deep geological processes.

The research utilizes the Google Earth Engine (GEE) platform to process MODIS daily-resolution data and Landsat data from 2003 to 2024. First, regions of interest (ROI) around the volcanic craters are selected, followed by data cleaning, calibration, quality control, and the removal of seasonal cycles and noise. A comparison with ground-truth volcanic thermal activity records indicates that the proposed algorithm demonstrates a certain level of accuracy. Building on this, the study applies statistical methods such as wavelet analysis and singularity analysis to extract temporal patterns of volcanic thermal signals, revealing the periodic characteristics and anomaly event patterns of volcanic activity in the South China Sea region. These analyses capture the temporal dynamic variations of thermal anomalies on multiple scales and identify the suddenness of these anomalies and their association with deep geological activities. Furthermore, the study combines unsupervised machine learning classification methods to perform spatial clustering of the extracted thermal signals, uncovering the thermal anomaly characteristics and spatial distribution patterns of different volcanic activity areas. Through time-space integrated analysis, this study not only reveals the temporal characteristics of volcanic thermal signals in the South China Sea region but also demonstrates the relationship between thermal activity variations and geological processes.

S0604. Specifying Control Factors on Formation of Seafloor Hydrothermal Deposit and Presence Potential Mapping Using GIS and Machine Learning Methods

Yusuke Hashimoto (Department of Urban Management, Graduate School of Engineering, Kyoto University),
Katsuaki Koike (Graduate School of Engineering, Kyoto University),
Taiki Kubo (Department of Urban Management, Graduate School of Engineering, Kyoto University)
Room: B210 2025-10-10 16:00

Seafloor hydrothermal deposits are known to be rich in base and precious metals such as copper and zinc, but their distribution and control factors on the deposit formation have not yet been revealed accurately because of difficulties in drilling investigation and geophysical exploration in the deep seas. Based on this background, this study aims to specify the control factors and estimate potential of undiscovered deposits by targeting the Okinawa Trough and Izu-Ogasawara Sea areas in the southwest and south of Japan and the Havre Trough area in the north of New Zealand, located on the plate subduction zones. GIS and machine learning methods with seven types of data were used for the purpose: hypocenter, location of seafloor hydrothermal vent, seafloor topography, Bouguer gravity anomaly, heat flow, and magnetic anomaly. Two methods were adopted for the deposit potential mapping, a combination of convolutional neural network and edge detection (CNN-ED), which can extract nonlinear features and recognize complicated patterns from the input data, and presence-only prediction (POP) based on the maximum entropy approach, which needs only the data of existing deposits. One feature detected by the CNN-ED mapping result common to the three sea areas is that ridge pattern of the seafloor topography and Bouguer gravity anomaly is the strongest factor on the vent location, which can be interpreted that the hydrothermal deposits tend to be formed on a mound in caldera above the magma intrusion. More plausible potential mapping result was obtained through POP by considering all the datasets. All the vent sites were evaluated to be the maximum presence potential and high potential vent spots were located mostly in the ridge pattern of the topography and gravity anomaly common to the three sea areas. The very high potential zones of vents are partly regarded as actual formation of hydrothermal deposit.

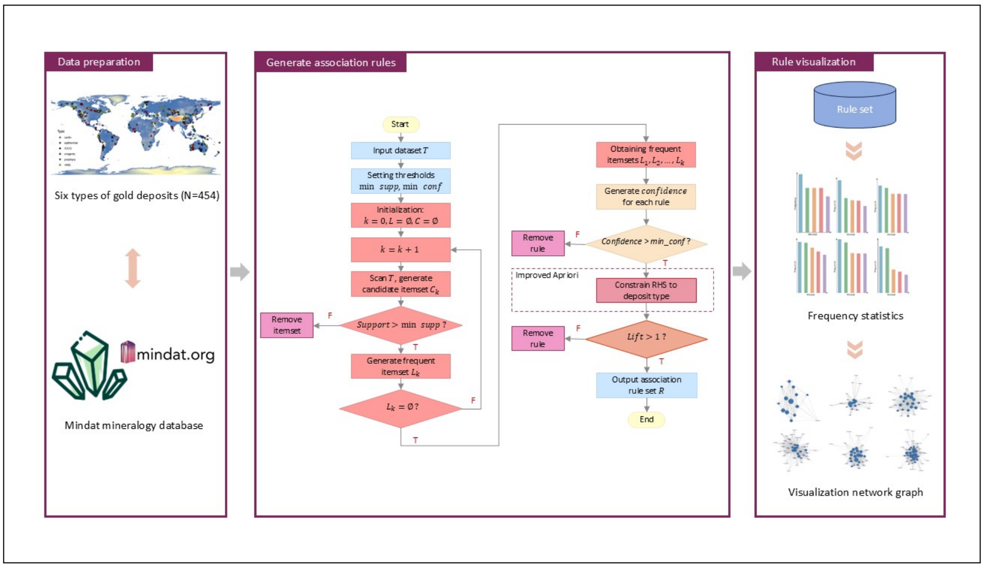


122ºE
130ºE
30ºN
25ºN
0 55 110 220 km
High potential
Low potential
Seafloor hydrothermal vent
Okinawa
Taipei
Potential map of seafloor hydrothermal vent by convolutional neural network and edge detection

S0605. Uncovering the mineral assemblages of six major gold deposit types—a machine learning approach to big data analytics of a global mineralogical database

Bin Wang (China University of Geoscience (Wu Han)),
Renguang Zuo (China University of Geosciences, Wuhan)
Room: B210 2025-10-10 16:20

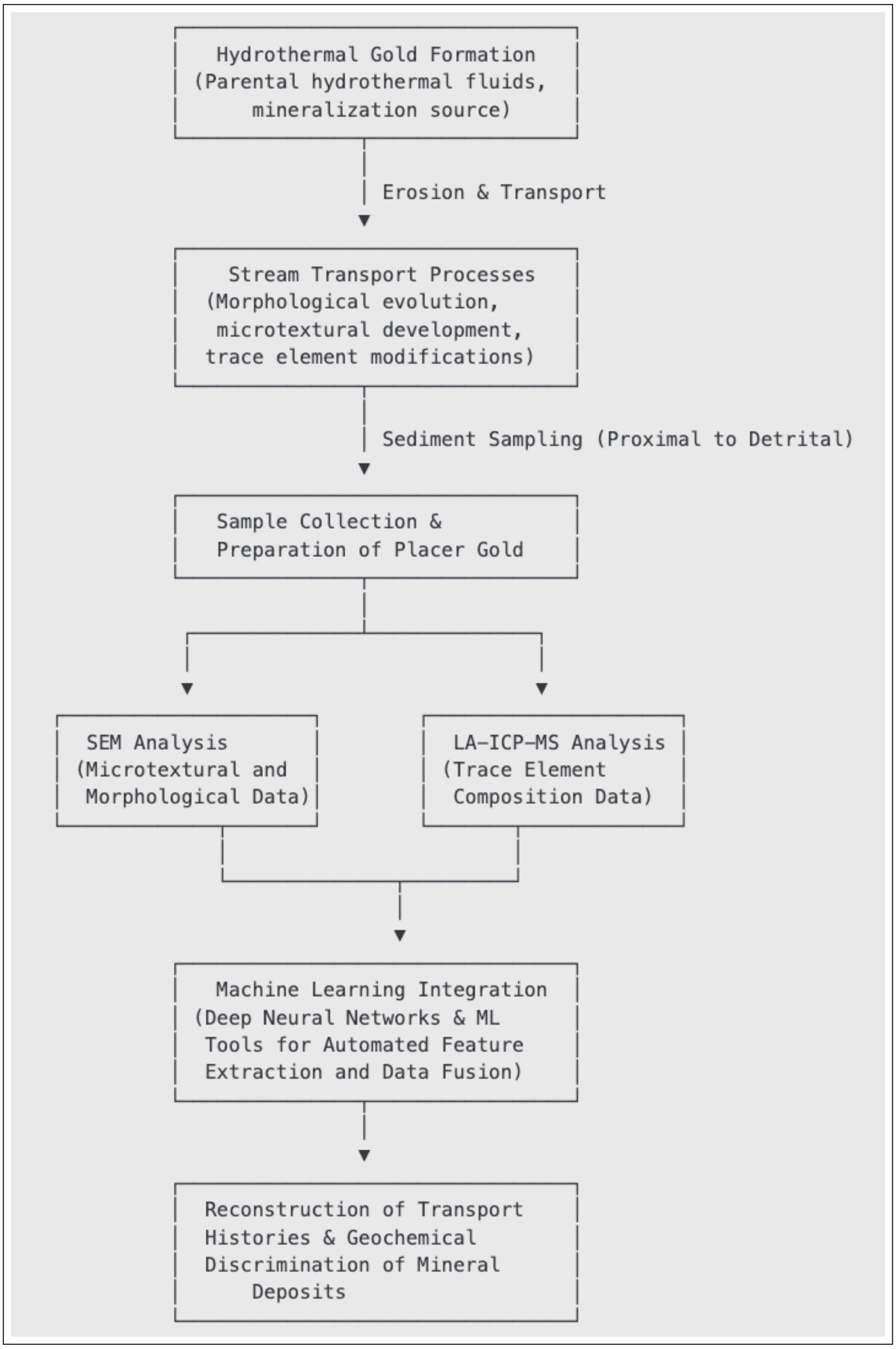
Identifying mineral assemblages is crucial for developing a better understanding of ore genesis and improving mineral exploration efficiency. Traditional geological methods have provided significant insights into the classification of the many different gold deposit types and their genesis, but they typically occur at the deposit to thin section scale and focus on small, local datasets. This study developed a data-driven approach, leveraging machine learning and big data to determine the characteristic mineral assemblages of six globally significant gold deposit types: orogenic, epithermal, porphyry, Carlin, iron oxide-copper-gold (IOCG), and volcanogenic massive sulfide (VMS). Employing association rule mining (ARM) with an improved Apriori algorithm (constraining association rule consequents to deposit types) on a global database of 454 gold deposits, we reveal characteristic mineral association patterns for each deposit type. For instance, Carlin-type deposits exhibit low-temperature assemblages of realgar–orpiment–cinnabar, porphyry deposits strongly associate with intermediate-high temperature molybdenite-bornite-quartz combinations, while orogenic types demonstrate metamorphic alteration assemblages of chlorite-sericite-pyrite. Visualization through bipartite and unipartite network analysis uncovers critical relationships between minerals and deposit types: (1) Ubiquitous minerals (e.g., pyrite) coexist across multiple types but exhibit distinct combinatorial patterns; (2) Type-specific minerals (e.g., uranium minerals in Carlin-type) show strong exclusive associations. The research demonstrates that machine learning approaches leveraging global mineralogical big data can not only identify established mineral associations but also reveal previously unrecognized mineral relationships. As such, our approach, which links geology and big data, offers new opportunities for mineral exploration targeting and gold deposit research.



S0607. AI-based extraction of detrital indicator mineral information and its application for mineral exploration

Haiming Liu (Chinese Academy of Geological Sciences),
Yang Song (Chinese Academy of Geological Sciences),
Yang Wang (China University of Geosciences Beijing),
Yan Nie (Chinese Academy of Geological Sciences)
Room: D209 2025-10-11 11:30

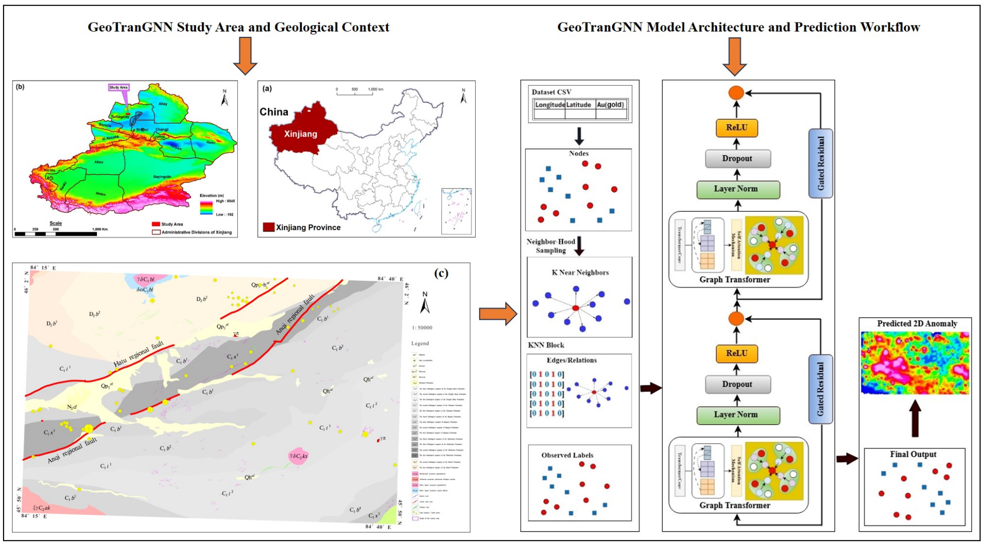
Placer gold is a significant indicator mineral for gold-bearing deposits. The chemical composition of placer gold in diverse geological settings is a function of the composition of its parental hydrothermal fluids in diverse geological settings. Thus, trace elements contained in placer gold could present a particular geochemical signature that can be used to discriminate placer gold grains from different mineralization types and to trace the source of placer gold. As placer gold particles are transported across Earth's surface in stream sediments, their morphologies evolve, and microscopic surface textures develop as well as the trace element compositions change. Since transport mechanisms differ among depositional processes, the shape and characteristic micro-textures on gold surfaces integrating with geochemical signatures can offer valuable insights into their transport histories and depositional processes. In this study, we applied a deep neural network model to extract grain morphological information and used various machine learning tools to investigate geochemical compositions of placer gold from proximal to detrital locations to predict unknown gold deposits in the Duolong porphyry-epithermal ore district, western Xizang, China. This study characterizes the composition of placer gold grains from stream sediments and yields geochemical discrimination models for application to mineral exploration for gold deposits. The micro-textures of placer gold grains were investigated by scanning electron microscopes (SEM). Trace element contents of placer gold grains were measured in-situ by laser ablation ICP-MS (LA-ICP-MS) to identify systematic changes in gold compositions associated with different transportation environments, and, where possible, to identify the distinctive geochemical signature of Au in different transportation distances. Our results demonstrate the robustness and versatility of the model in rapidly and automatically constraining the transport histories recorded in individual grains of placer gold through their morphological and geochemical features.


Hydrothermal Gold Formation
(Parental hydrothermal fluids,
mineralization source)
Erosion & Transport
Stream Transport Processes
(Morphological evolution,
microtextural development,
trace element modifications)
Sediment Sampling (Proximal to Detrital)
Sample Collection &
Preparation of Placer Gold
SEM Analysis
(Microtextural and
Morphological Data)
LA-ICP-MS Analysis
(Trace Element
Composition Data)
Machine Learning Integration
(Deep Neural Networks & ML
Tools for Automated Feature
Extraction and Data Fusion)
Reconstruction of Transport
Histories & Geochemical
Discrimination of Mineral
Deposits

S0608. A Hybrid Deep Learning Framework for Geochemical Anomaly Prediction Using Transformers and GNNs

Muhammad Atif Bilal (College of Geoexploration Science & Technology, Jilin University),
Yongzhi Wang (Jilin University),
Muhammad Pervez Akhter (Department of Computer Science, National University of Modern Languages, Faisala)
Room: B210 2025-10-10 16:40

Automatic mineral resources exploration, like geochemical anomaly prediction, is influenced by complex geological processes and geochemical data, which limits the performance of deep learning models to accurately predict locations. Deep learning models such as Transformers and Graph Neural Networks (GNNs) have been used for mineral resource exploration. Transformers have shown superior performance when extracting long-range relations from sequential data. GNNs perform better when processing graph-structured data to extract spatial features. In this study, we propose a GeoTranGNN, a novel hybrid deep learning model by integrating the strengths of the Transformers and GNNs to predict geochemical anomalies. The proposed model can make use of both local spatial connections and global contextual information to improve predictions about geochemical anomalies. Using a comprehensive geochemical dataset from a mineral-rich area, Hatu (Xinjiang Uygur Autonomous) region, we merged topographical and geochemical features related to gold. The proposed hybrid model was tested against traditional Transformer and GNN models in several configurations, including different depths, batch sizes, dropout rates, and multi-head attentions. Our model outperforms the baseline models with an AUC score of 93.3 and displays improved anomaly prediction ability. Furthermore, GeoTranGNN's efficiency is underlined by its capacity to produce accurate 2D anomaly maps that are closely related to recognized gold deposit locations. Our results show the potential of GeoTranGNN in mineral resource exploration and more consistent prediction of geochemical anomalies.



S0609. Prediction of Ionospheric Total Electron Content Data Using Spatio Temporal Residual Networks

Enamundram Chandrasekhar (Indian Institute of Technology Bombay, Mumbai),
Nayana Shenvi (Department of Electronics & Telecommunication Engineering, Goa College of Engine),
Hasanali Virani (Department of Electronics & Telecommunication Engineering, Goa College of Engine)
Room: B210 2025-10-10 17:00

We present a novel deep-learning-based model to predict the ionospheric total electron content (TEC) using the spatio-temporal residual network (ST-ResNet). The novelty in our network is that in addition to the convolutional neural networks, it uses an additional GRU (gated recurrent unit) and suitable interplanetary magnetic field (IMF) data, such as, the magnetic field components, By, Bz, the plasma flow speed (Vp) and the proton density (Np) as exogeneous parameters for improved accuracy in TEC prediction. The TEC data used in the study were obtained from 185 GPS receiver locations, covering the latitude region from 100N to 800N and the longitude region from 1100W to 340E. We considered TEC data of 154 days each corresponding to the solar maximum (2014) and the solar minimum (2020) years for training the network together with the exogeneous IMF data. A total of 44,352 maps (collected @ 288 maps/day) were pre-processed by grouping them into near-time, short-term, and long-term trends in the TEC data. The objectives of the study are: i) To develop and evaluate the performance of the ST-ResNet model, ii) to assess its performance on TEC data corresponding to mid-latitude region, under different solar conditions and iii) to compare the efficacy of our ST-ResNet model with other network models developed earlier by others. For the entire study region, the RMSE between the observed and predicted TEC was 3.13 TECU for the solar maximum year and 1.23 TECU for the solar minimum year. Similar trends were observed in the mid-latitude region (300N-600N), with RMSE values of 2.31 TECU and 1.58 TECU for the solar maximum and solar minimum years respectively. Our results suggest that the ST-ResNet model showed an improved accuracy of more than 30% over those obtained by the long short-term memory (LSTM) deep learning network and IRI-2016 model.

S0611. Quantifying Spatio-temporal Variations in Crustal Thickness Using Machine Learning

Kunyi Wang (Sun yat-sen University),
Pengpeng Yu (Sun Yat-sen University),
Qiuming Cheng (Sun Yat-sen University)
Room: B210 2025-10-10 17:02

The spatio-temporal variation of the thickness of the crust is a key parameter that can be used to reveal regional crustal dynamics and tectonic processes. Although pairs of proxies have been proposed to quantify crustal thickness (e.g., Sr/Y, La/Yb(n), etc.), the application of these proxies to regional or even smaller scale investigations often suffers from significant errors and limitations. In this study, we propose an algorithm for machine learning based on Random Forest regression that can be combined with the LOWESS method to quantify the spatio-temporal variation of crustal thickness. The models were trained on geochemical compositions (including major and trace elements and ratios) and corresponding crustal thicknesses of 2,072 juvenile intermediate to felsic rocks related to subduction and collisional orogeny on a global scale. The validation of the model indicates that it offers more robust estimates of crustal thickness than geochemical proxies. The implementation of this model in the Central Andes has demonstrated its efficacy in forecasting crustal thickness modifications across disparate geologic epochs. These alterations encompass a notable thickening during the Late Cretaceous period. In spatial terms, this model demonstrates the variation in crustal thickness across the boundary between the Puna and Altiplano plateaus. The model's results indicate that crustal thickening occurred in the southern region of the Puna plateau (24-27°S) during the Neogene period. These findings indicate that this model may serve as an effective tool for reconstructing the spatio-temporal evolution of crustal thickness at the regional scale.

S0619. A New Approach for Automatic Lithological Identification Using pXRF and Machine Learning

ZHAOXIAN YUAN (Hebei GEO University),
SHUBIN ZHOU (China University of Geosciences (Beijing)),
SHENGYUAN ZHANG (Hebei GEO University)
Room: D209 2025-10-11 10:30

Lithological identification and classification are fundamental tasks in geological research and core logging. Traditional approaches, such as field observation and microscopic examination, are time-consuming and heavily reliant on expert experience. In this study, we propose a novel method for automatic lithological classification by combining portable X-ray fluorescence spectroscopy (pXRF) with machine learning techniques.

Three drill cores from the Caosiyao Mo deposit in Inner Mongolia, China, were selected. Based on conventional geological methods, three lithologies were identified: granite porphyry, diabase, and metamorphic rocks. A total of 807 geochemical data points were collected using pXRF, covering 34 major and trace elements (Ag, Al, As, Au, Ba, Bi, Ca, Cd, Cl, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Nb, Ni, P, Pb, Pd, Rb, S, Sb, Se, Si, Sn, Sr, Ti, V, W, Zn, and Zr). Core ZK0403 was measured at intervals of 0.5–2 meters, while ZK1203 and ZK1603 were sampled every 5 meters. Both unsupervised K-means clustering and supervised random forest algorithms were employed for data analysis. For the random forest method, two training strategies were compared: a randomly selected training set (R-T method), and a fixed training set based on the densely sampled ZK0403 core (F-T method).

Using K-means clustering, the classification accuracies were 87% for granite porphyry, 95% for diabase, and 79% for metamorphic rocks. The random forest method achieved accuracies of 90% (granite porphyry), 92% (diabase), and 95% (metamorphic rocks) with the R-T method, and 100% (granite porphyry), 80% (diabase), and 99% (metamorphic rocks) with the F-T method.

These results demonstrate that the integration of pXRF analysis with K-means clustering and random forest modeling can achieve lithological classification accuracies of up to 100% for granite porphyry, 95% for diabase, and 99% for metamorphic rocks. This study offers an efficient and automated alternative for drill core logging and lithological interpretation.

S0620. From Points to Sequences: A Spatial-Aware Transformer with Sliding Window Stratigraphy for Lithology identification

Xu Yang (College of Science, China University of Petroleum (Beijing)),
Shaoqun Dong (China University of Petroleum (Beijing)),
Guohao Xiong (China University of Petroleum (Beijing)),
Huangshuai Kong (China University of Petroleum (Beijing)),
Xinqi Li (College of Science, China University of Petroleum (Beijing), Beijing, China. 102)
Room: D209 2025-10-11 10:50

Machine learning techniques provide powerful solutions for lithology identification. However, in lithology identification studies, sample construction often relies heavily on single-point feature extraction, neglecting the spatial continuity and layering structure of the lithology. Inspired by the Transformer model's outstanding sequence processing capabilities, this study systematically evaluates different sample processing methods and sequence model construction approaches in well log lithology identification. In terms of sample construction, we analyze sample construction based on single-point geological features, sample clustering based on geological feature similarity, and stratigraphic sequence construction based on sliding windows. Additionally, we consider Transformer models consisting solely of an encoder, encoder-decoder structures, and encoder-decoder Transformer models with residual connections. To validate the proposed method, experiments were conducted using complex lithological datasets from the Zagros Basin in Middle East. Results demonstrate that the sliding window sample construction method, which considers the spatial stratigraphic relationship, is relatively superior, leading by approximately 3%. Additionally, the encoder-decoder Transformer model improves performance by 2%. As the lithological datasets size increases, the advantages of the encoder-decoder Transformer model with residual connections become more pronounced. Finally, the impact of the window length on the sequence is discussed, with a window length of 8 being more suitable for sample construction.

S0621. The constraints of Paleozoic to Cenozoic igneous rocks on the paleoclimate response in the Tibetan Plateau

Xinwei Liu (Sun Yat-sen University),
Qiuming Cheng (Sun Yat-sen University)
Room: D209 2025-10-11 11:10

Integrating machine learning, we reconstructed Tibetan Plateau atmospheric CO -O evolution since the Early Paleozoic, revealing a carbon-oxygen negative feedback system: volcanic pulses drive CO surges, while intensified silicate weathering triggers O drawdown, forming a prominent "seesaw" effect during rapid uplift since 100 Ma.

Long-term records show synchronous 45-Myr CO -O cycles, with CO leading O by 45 Myr—indicating carbon cycle forcing of oxygenation. Wavelet analysis confirms statistically significant ($p<0.05$) 45-Myr periodicity in magmatic activity (volcanism/plutonism), temporally coupled with atmospheric changes. The observed tripartite cyclicity (CO release → O adjustment → magmatic resurgence) implies deep Earth processes (e.g., mantle upwelling) periodically drive decarbonation, where metamorphic/magmatic CO outgassing alters atmospheric chemistry, subsequently regulating oxidative weathering and O reservoirs.

S0623. Development of a SWIR Spectral Database and Machine Learning-Based Interpretation for Mixed Minerals

Yang Wang (China University of Geosciences Beijing),
Jingjing Dai (Institute of Mineral Resources,Chinese Academy of Geological Sciences)
Room: D209 2025-10-11 11:50

Short - wave infrared (SWIR) spectral data are of great significance for mineral exploration. However, two major issues hinder their effective application. Firstly, there is a lack of a specific regional SWIR spectral database. Data from different regions vary in format, accuracy, and storage methods, which restricts cross - regional data sharing, comparative analysis, technology promotion, and the generalization ability of models. Secondly, traditional linear mixture models (such as TSG) face difficulties in interpreting complex mineral mixture spectra. For minerals altered by multi - stage fluids, problems such as mineral particle scattering, surface reflection distortion, and overlapping absorption peaks can lead to large interpretation errors.

In this study, we use machine learning techniques to address these challenges. In the Zhule - Mangla - Luobu continental volcanic rock area of Tibet, we designed a specialized database system to manage the multi - dimensional, multi - format, and large - scale SWIR spectral data in the study area. A spectral unmixing model based on a machine learning was developed. By training with a large number of spectral samples with known mineral compositions, this model can separate the end - member spectra in mixed pixels. In addition, we combined the linear spectral mixture model with the regularization method to invert mineral abundances, taking into account spectral characteristics such as absorbance and absorption peaks.

The research results show that this method can accurately interpret SWIR spectral data, providing a new approach for mineral exploration in volcanic rock areas and helping to improve exploration efficiency and accuracy.

S0624. Stochastic simulation of continuous geoscientific variables based on spatial dependence: a data-driven perspective

Jian Wang (Research Institute of Petroleum Exploration and Development),
Jinfeng (J.) Yang (Research Institute of Petroleum Exploration and Development)
Room: D209 2025-10-11 11:52

Geostatistical simulation techniques such as sequential Gaussian simulation provide valuable approaches for quantifying spatial variability in geoscientific variables, thereby facilitating risk assessment across various decision-making contexts. Traditional geostatistical paradigms, however, are constrained by assumptions of stationarity, specific data distribution requirements, complex variogram modeling, and computationally intensive matrix operations—limitations that become particularly problematic with large and high-dimensional datasets. The growing prominence of data-driven methods across various scientific domains suggests potential avenues for transforming stochastic simulation frameworks. Nevertheless, the effective encoding of spatial dependence and its application within data-driven simulation frameworks warrant further investigation. This preliminary study explores artificial neural network-based models to address these issues. Initial simulation experiments are being conducted to explore and validate the proposed models. Preliminary results suggest that various methods, including spatial lag features, neighboring observations, Moran eigenvector maps, multi-resolution basis functions, rotary position embedding, and direct location encoders, offer promise for representing spatial dependence under stationary and isotropic conditions. Furthermore, data-driven methods appear relatively less sensitive to non-stationarity and non-Gaussianity in capturing spatial relationships compared to traditional kriging. The potential of purely data-driven neural network-based simulation models as alternatives to conventional algorithms is being evaluated, with an emphasis on their flexibility and ability to generate stochastic realizations that reproduce lower-order statistics, potentially with reduced computational demands.

S0625. Quantitative Modeling of Soil Component Disturbance by Chinese Aeolian Sand Enabled through Integration of Machine Learning Algorithms and the Environmental Kuznets Curve Model

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Weihang Zhou (State Key Laboratory of Geological Processes and Mineral Resources (GPMR), Facul)
Room: D209 2025-10-11 11:54

Quantitative modeling plays a pivotal role in analyzing the aeolian sand-soil geochemical relationship and assessing its environmental impact. Contemporary investigations of desert-soil systems predominantly concentrate on isotopic signatures and major element characterization, whereas systematic quantitative frameworks for assessing aeolian sand perturbation mechanisms in pyrochemical composition remain underdeveloped in environmental geochemistry research. This study innovatively integrates machine learning regression with the Environmental Kuznets Curve (EKC) modeling to establish an optimized quantitative assessment system for aeolian sand-soil geochemical interactions. Our experimental results reveal that Support Vector Regression (SVR) and Random Forest Regression models demonstrated superior predictive performance, significantly outperforming other machine learning regression models across diverse desert and sandy land datasets. The EKC theory indirectly suggests that aeolian sand may influence and interfere with soil chemical composition through factors such as parent material, weathering processes, climate conditions, and their varying intensities. Mathematically, the overall dataset of desert and soil samples follows a cubic polynomial relationship, establishing a relatively stable quantitative model to characterize the degree of aeolian sand interference on soil chemical composition. This indicates that the EKC theory can be applied to geochemical data, offering significant scientific and practical value for exploring the driving mechanisms of surface element distribution in deserts and their surrounding regions.

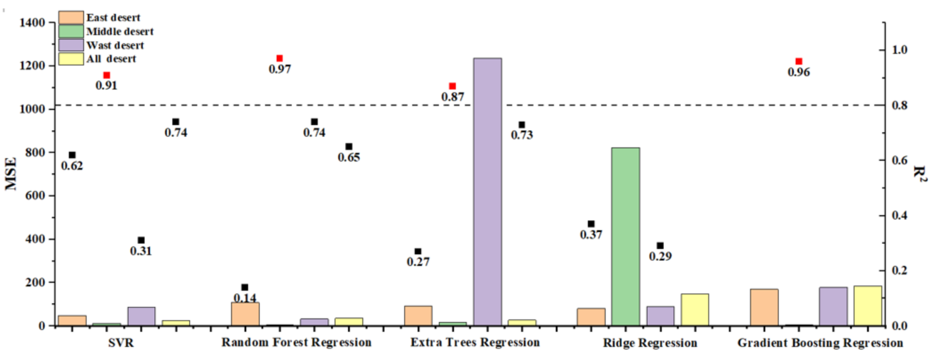


Figure. Evaluation Figure of Model Performance Parameters in Different Desert Regions

Table. Statistical Table of Environmental Kuznets Curve Trends and Impact Intensity in Different Desert Regions

Desert Area	Trend	Inflection point x-value	Disturbance extent	Trend	Inflection point x-value*	Disturbance extent
1 Hunshandak	↗↘↗	$x \approx 350.0$	*High*	↘↗↘	$x \approx 60.0$	*High*
2 Horqin	↗↘↗	$x \approx 248.3$	*High*	↘↗↘	$x \approx 46.7$	*High*
3 Hulun Buir	↗↘↗	$x \approx 223.1$	*High*	↘↗↘	$x \approx 59.3$	*Moderate*
4 Badain Jaran	↗↘↗	$x \approx 711.1$	*Moderate*	↘↗↘**	$x \approx 142.9$	*Moderate*
5 Ulan Buhe	↗↘↗	$x \approx 691.7$	*Moderate*	↗↘↗**	$x \approx 64.4$	*High*
6 Mu Us	↗↘↗	$x \approx 788.9$	*Moderate*	↘↗↘**	$x \approx 160.3$	*High*
7 Hobq	↗↘↗	$x \approx 716.7$	*Moderate*	↘↗↘	$x \approx 155.0$	*Low*
8 Tengger	↗↘↗	$x \approx 666.7$	*Moderate*	↘↗↘**	$x \approx 850.0$**	*Low*
9 Kumtag	↘↗↘	$x \approx 111.1$	*Low*	↗↘↗**	$x \approx 958.3$**	*Low*
10 Gurbantunggut	↗↘↗	$x \approx 583.3$	*Low*	↘↗↘	$x \approx 230.0$	*Low*
11 Taklimakan	↘↗↘	$x \approx 95.2$	*Low*	↘↗↘	$x \approx 163.3$	*Low*
12 Qaidam	↘↗↘	$x \approx 133.3$	*Low*	↗↘↗**	$x \approx 650.0$**	*Low*

↗: Function is monotonically increasing, ↘: Function is monotonically decreasing; *: Fitted curve after removing outliers, **: The value(or trend) is unobservable within the practical range

S0627. Mineral informatics of detrital rutile as indicators for mineral exploration using machine learning: a case study from the Duolong porphyry district, Western Xizang, China

Nie Yan (Chinese Academy of Geological Sciences),
Yang Song (Chinese Academy of Geological Sciences),
Haiming Liu (Institute of Mineral Resources, Chinese Academy of Geological Sciences),
Hao Sun (Institute of Mineral Resources, Chinese Academy of Geological Sciences)
Room: D209 2025-10-11 11:56

Detrital minerals, formed through the weathering of rocks in continental erosion zones, are commonly recovered from stream sediments during geological survey These minerals record interactions between source rocks and their geological environments, offering insights into regional geological evolution, geochemical processes, and mineralization. In areas of intense erosion, detrital minerals are particularly valuable for mineral exploration because they can indicate the presence of concealed mineralization. Rutile, a typical detrital mineral, can be liberated from various host rocks and is highly resistant to weathering, making it an excellent indicator mineral for provenance studies.

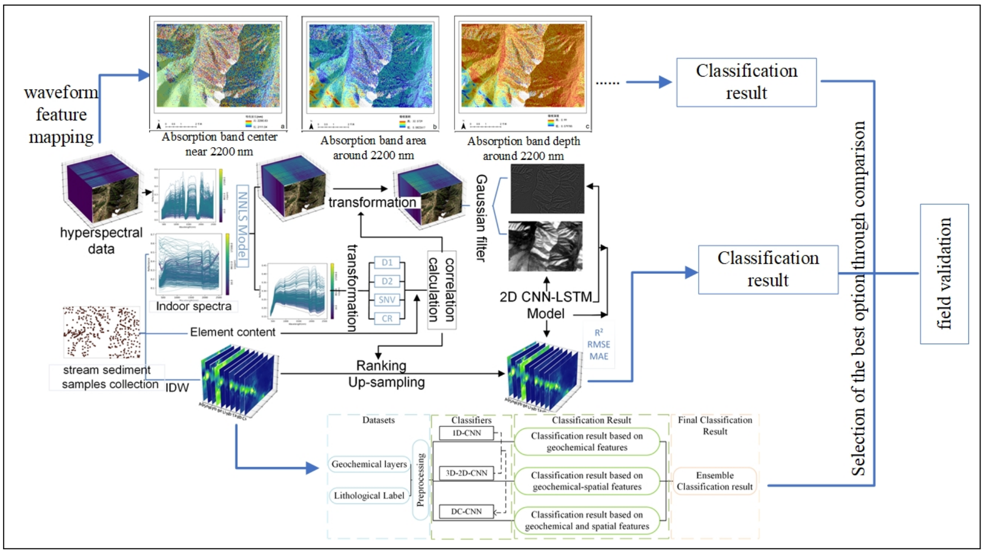
The Duolong porphyry district, located in the northwestern Tibetan Plateau, is part of a globally significant porphyry-epithermal Cu-Au metallogenic belt. Continuous uplift and erosion in this region have resulted in limited bedrock exposure and a shallow, yet variable, surface cover, presenting substantial challenges for traditional exploration methods.This study investigates detrital rutile collected from stream sediments within the Duolong porphyry district. Based on their spatial distribution, mineralogical and morphological characteristics, we applied a deep neural network (DNN) to capature the morphological variations of rutile grains collected at different distances from the ore body . In addition, a random forest (RF) algorithm was employed to classify rutile from different deposit types by comparing with geochemical compositions from a worldwide collection.

Our findings indicate that detrital rutile in the Duolong porphyry district is sourced from porphyry-epithermal metallogenic system. These results not only confirm the exploration significance of detrital rutile but also demonstrate a novel strategy for identifying porphyry Cu-Au potential in strongly eroded terrains.

S0629. Deep Learning–Based Identification of Ore-Bearing Pegmatites

Li chen (Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences),
Nannan Zhang
Room: D209 2025-10-11 11:58

Lithium metal, with its excellent ductility, high thermal conductivity, corrosion resistance, and high-temperature stability, is widely used in high-tech industries such as artificial intelligence, clean energy, and biotechnology. The Dahongliutan area in the Western Kunlun of Xinjiang represents a geologically and economically significant rare-metal pegmatite district in western China. Integrating AI methods with multisource data to enhance pegmatitic lithium exploration here is crucial for driving geological innovation and supporting a new wave of mineral-discovery breakthroughs.This study first reviews the advancements and trends in remote sensing and geochemical applications for pegmatitic lithium exploration. Focusing on Deposit 509 in Dahongliutan, we evaluate different deep-learning strategies—using hyperspectral imagery, geochemical data, and their fusion—to identify lithium-bearing pegmatites and explore novel techniques for improving detection accuracy. Results indicate that: Hyperspectral-based models are well suited for early-stage prospecting to locate pegmatite clues; Geochemical data effectively delineate mineralized pegmatite swarms, aiding detailed follow-up surveys;Fused remote-sensing–geochemical data provide superior recognition of exposed pegmatite vein morphology.Depending on data availability and exploration objectives, tailored strategies can thus be employed for efficient identification of lithium-bearing pegmatites.



S0636. How to choose the training samples in supervised remote sensing image classification?

Jinxin He (Jilin University),
Jinxin He (Jilin University)
Room: D209 2025-10-11 12:00

Machine learning has become the most popular scheme to classify remote sensing image, and training samples are of great significance in supervised learning. Howerver, how to choose the training samples in supervised remote sensing image classification? Can a small number of training samples achieve relatively higher classification accuracy? Hence, we were going to get to the bottom of this problem from the uncertainty of classifcation model to the uncertainty of remotely sensed data. Based on the experimental results, the balance can be kept to a certain extent between the training sample size and the classification accuracy.

S08 Data-Driven Innovations for Mineral Exploration Decision-Making: Addressing Present and Future Challenges

Behnam Sadeghi (CSIRO),
David Zhen Yin (Senior Research Scientist, Department of Earth and Planetary Sciences, Stanford University, USA),
Rian Dutch (Head of Applied Science, Datarock Pty Ltd, Melbourne Victoria 3000),
Putra Sadikin (Product manager, IMDEX, Australia),
Richard Scott (Principal Data Scientist, BHP, Australia)

This session welcomes all data-driven ideas to address the current and future challenges in energy-transition minerals exploration and development, especially the need for rapid and accurate information to make better decisions in addition to sample or survey optimization through data-driven and machine learning methods. Following the landmark Paris Agreement on Climate Change, a multitude of nations committed to a substantial reduction in greenhouse gas emissions. Central to this ambition is the advancement of clean energy technologies. However, the successful deployment of these technologies hinges on the availability and sustainable management of critical minerals like copper, lithium, nickel, cobalt, and rare earth elements. These minerals are fundamental in the manufacture of a wide range of clean energy products, from the batteries that power electric vehicles to the components essential for energy-efficient lighting and advanced electronics. The rising demand for critical minerals, essential for clean energy technologies like electric vehicle batteries and wind turbines, offers economic opportunities but also poses environmental and geopolitical challenges. Addressing this requires global collaboration to implement sustainable mining, enhance recycling, and foster innovation in alternative technologies while investing in infrastructure and workforce development. Recent progress in data science and machine learning has shown great potential to accelerate the discoveries of mineral deposits, improve resource efficiency, and sample/survey optimization. Such data-driven approaches can more effectively ingest geochemical, geological, geophysical, remote sensing, environmental data, and beyond, thereby proving better-informed mineral exploration. Our session will cover the latest data science and machine learning advancements in combining such multi-disciplinary data to enhance sustainable and efficient decision-making in mineral exploration. We encourage studies using new data-driven approaches for geochemical data analysis, geological modeling, geophysical inversion, mineral prospectivlity mapping, decision-making under geological uncertainty, and more.

S0801. Identification of high purity silica in legacy core

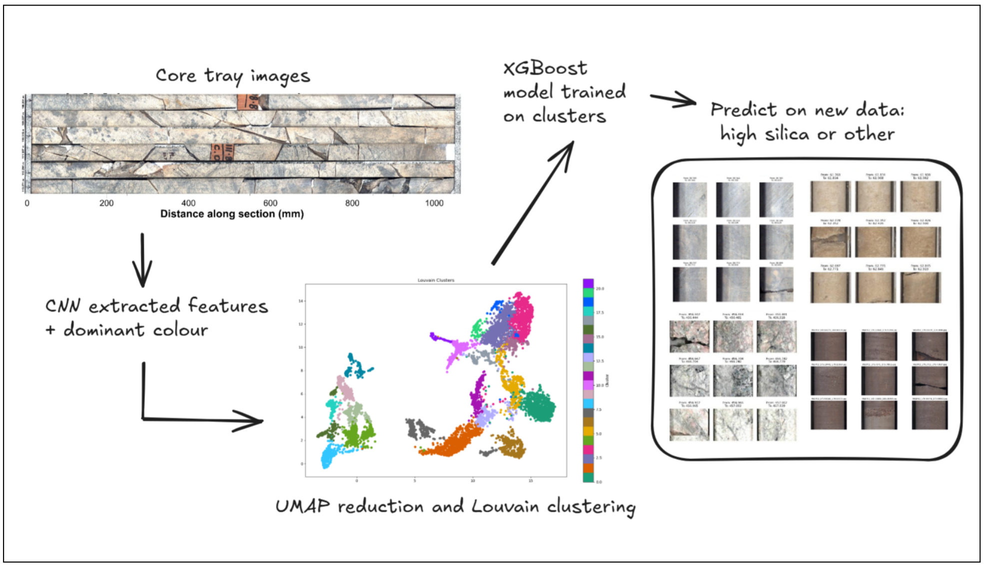
Katie Silversides (Datarock),
Rian Dutch (Head of Applied Science, Datarock Pty Ltd, Melbourne Victoria 3000)
Room: D205 2025-10-12 10:30

High purity silica is a critical component for technologies such as solar panels and semiconductors. It may be found in lithologies such as quartz veins, pegmatite, quartzite or light sandstone. These lithologies may have already been drilled as part of historical mineral exploration, and reexamining legacy core can be an efficient way of locating prospective areas for additional study. However, silica was not always consistently logged and an efficient way of locating potential high silica areas in the data is required.

The test library consisted of cores from South Australia that have been scanned by HyLogger and made publicly available in the National Virtual Core Library (NVCL). A training dataset that had known intervals of high silica was selected. The cores were split into 5cm core images. For each image, the dominant colour was extracted. Then 512 features that describe the texture in each image were extracted using transfer learning, from a pre-trained Convolutional Neural Network (CNN) model. The dominant colour and extracted features were combined and evenly weighted. A Uniform Manifold Approximation and Projection (UMAP) was then used to reduce the dimensionality to 20. The Louvain community detection algorithm was applied to the UMAP network to determine clusters of similar images. The clusters were cleaned up, grouped and compared to the logged lithologies to create a training library that included groups of high silica and other lithologies.

An XGBoost model was trained on the cleaned clusters identified by the Louvain. The labels and probabilities provided by the XGBoost were used to locate intervals with a high percentage of a quartz rich material. These intervals were then ranked to indicate those that should be investigated further.

The results of this study were used as a screening tool to identify intervals for detailed manual sampling, saving time and increasing efficiency.



S0802. Data-Driven Innovations for Enhanced Decision-Making in Mineral Exploration

Behnam Sadeghi (CSIRO Mineral Resources, Australian Resources Research Centre),
David Zhen Yin (Senior Research Scientist, Department of Earth and Planetary Sciences, Stanford University, USA)
Room: D205 2025-10-12 10:50

Data-driven innovations are transforming mineral exploration decision-making by integrating advanced analytics, machine learning, and geospatial data. As traditional exploration methods often rely on historical data and qualitative assessments, they may fall short in identifying untapped resources and managing uncertainties. In contrast, data-driven approaches enhance the accuracy of resource estimation, mitigate geological risks, and optimize decision-making processes. The significance of adopting data-driven strategies lies in their ability to address key challenges such as high exploration costs, complex subsurface conditions, and the integration of diverse data sources. By leveraging predictive models and data integration techniques, these approaches deliver deeper insights into geological formations and improve resource allocation, ultimately reducing operational risks and accelerating exploration timelines. This paper presents several successful exploration case studies from Australia, Sweden, Cyprus, the Central African Copper Belt, and Brazil where data-driven decision-making has significantly improved exploration efficiency and resource discovery. These examples demonstrate the practical benefits of embracing data-centric approaches, including enhanced targeting precision, reduced uncertainties, and streamlined workflows. In conclusion, this study advocates for a paradigm shift towards data-driven innovations in mineral exploration. By overcoming the limitations of conventional methods, these advancements hold the potential to shape the future of exploration practices and drive sustainable resource management.

S0803. Unlocking the Power of Spatial Geoscience Data: Integrated Data Management, Analytics, and Dissemination with LithoSurfer

Fabian Kohlmann (Lithodat Pty Ltd),
Wayne Noble (Lithodat Pty Ltd),
Moritz Theile (Lithodat Pty Ltd),
Xinyan Zhang (Lithodat Pty Ltd),
Romain Beucher (Lithodat Pty Ltd)
Room: D205 2025-10-12 11:10

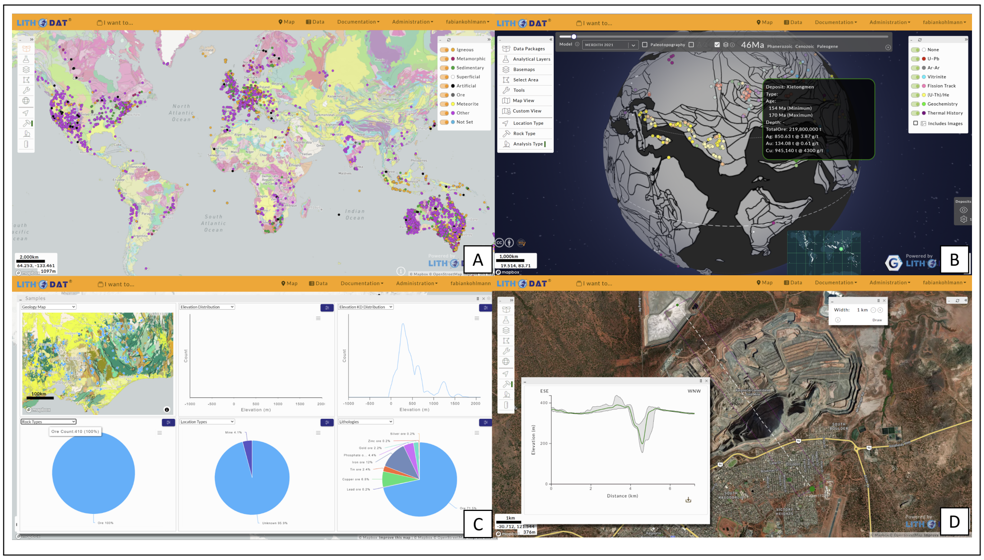
The growing global demand for energy-transition minerals, including copper, lithium, nickel, cobalt, and rare earth elements, underscores the need for rapid, precise, and sustainable mineral exploration. Traditional geoscientific workflows frequently suffer from fragmented and inconsistently structured datasets, limiting the effectiveness of exploration and accurate geological interpretations.

Here, we present LithoSurfer, a cloud-based data platform designed specifically for the integrated management, standardisation, and analysis of geoscientific datasets. LithoSurfer incorporates a relational database structure with comprehensive and detailed data models tailored for various geological, geochemical, and geophysical data types, alongside extensive analytical metadata. A key strength of the platform is its ability to preserve legacy data from outdated analytical techniques and instrumentation, facilitating their integration into modern exploration workflows.

LithoSurfer supports spatially enabled data integration, providing efficient aggregation and consistent accessibility across multidisciplinary datasets. The platform's dissemination capabilities include minting Digital Object Identifiers (DOIs) for data packages and Persistent Identifiers (PIDs), such as International Generic Sample Numbers (IGSNs), for sample-specific data, enhancing the traceability, transparency, and reproducibility of geoscientific research.

Importantly, LithoSurfer forms the foundational data infrastructure for multiple publicly funded Australian geoscientific initiatives, such as AusGeochem and Isotopes.au, demonstrating its scientific reliability and practical utility. Continuous agile development ensures LithoSurfer evolves dynamically, integrating feedback from the geoscientific community to continually refine and expand its capabilities.

By facilitating integrated, standardised, and analytically rigorous spatial geoscientific data management and dissemination, LithoSurfer directly addresses contemporary challenges in mineral exploration, supporting informed decision-making and sustainable resource management critical for energy transition.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S0804. Characterization of mineral assemblages with multiple-point statistics

Guillaume Pirot (The University of Western Australia),
Stephen Centrella (The University of Western Australia)
Room: D205 2025-10-12 11:30

Characterizing the mineralization footprint plays an important role in understanding mineral systems and facilitating mineral exploration. Recent advances in compositional mapping enable to visualize fluid-rock interactions at the sample scale, to estimate pression temperature (P-T) conditions and quantify mass transfer. However, the accuracy of such estimates relies on the representativeness of the mapped area, whose acquisition are time and cost consuming.

Here, to estimate compositional maps without excessive time on data acquisition and with quantified uncertainty, we propose to use a multiple point statistics (MPS) algorithm called Direct Sampling. The algorithm is trained on a given set of acquired and estimated data (BSE, phase, density and compositional maps) to extrapolate phase, density and compositional maps from BSE images for rocks sharing similar mineral composition.

The use of a MPS algorithm is effective and efficient to estimate phase, density and compositional maps from BSE, provided that the overlap of BSE values between different phases is not too ambiguous. It enables saving time on data-acquisition and possibly deal with representativeness as non-stationarity can be guided by auxiliary variables.

This work is supported by the ARC-funded Loop: Three-dimensional Bayesian Modelling of Geological and Geophysical data (LP210301239), and by the Mineral Exploration Cooperative Research Centre through the Australian Government Cooperative Research Centre Program (CRC Document 2025/31).

S0805. Data-Driven Gold Prospectivity Mapping in Qinling Orogenic Belt: A Machine Learning-Based Decision-Making Framework

Haicheng Wang (Survey Center of Comprehensive Natural Resources, China Geological Survey),
Ruiwen Shen (China Geological Survey),
Yun Bai (Survey Center of Comprehensive Natural Resources, China Geological Survey),
Shengyuan Zhang
Room: D205 2025-10-12 11:50

In the context of increasing resources consumption, there is an urgent need to adopt advanced technological approaches to enhance exploration efficiency. In recent years, supervised machine learning methods have emerged as powerful tools for mineral prospectivity modeling, which can fully leverage the metallogenic knowledge of known deposits to train predictive models. This data-driven approach has demonstrated strong adaptability and robust results in various metallogenic belts, providing a new paradigm of mineral exploration workflows.

The qinling orogenic belt is one of the most important gold metallogenic zones in China, characterized by complex tectonic evolution and intense mineralization. Numerous gold deposits have been discovered in this area, indicating a significant potential for further exploration. Following a data-driven framework, this study integrated critical geological determinants for deposit, geochemical anomalies, geophysical anomalies, and the known gold deposits in the qinling belt. The known gold deposits within the study area were used as positive training samples, while areas with no known mineralization were carefully selected as negative samples to form a supervised training dataset. Random Forest was employed to model for comprehensive prediction of gold prospectivity mapping. The results show that stratigraphy, structures, lithological boundaries, and geochemical anomalies exhibit significant roles in controlling gold mineralization. A comprehensive evaluation index was proposed to delineate potential prospectivity areas, which closely matched historical exploration results and further refined the target areas, demonstrating its strong generalization capability and practical value. The field reconnaissance was conducted in delineated potential areas, revealing distinct mineralization indications.

This study effectively integrated metallogenic insights with the advantages of machine learning to develop a data-driven gold prospectivity prediction model, thereby improving efficiency and prediction accuracy. An intelligent decision-making framework for gold exploration is proposed, offering new ideas for future strategic deployment and target selection in mineral resource exploration.

S0807. Uncertainty Quantification of Deep Learning Algorithm for Lithological Mapping

Ziye Wang,
Renguang Zuo (China University of Geosciences, Wuhan)
Room: D205 2025-10-12 12:10

Lithological mapping is the foundational process of identifying and classifying different types of rocks in a particular area. Recent advances in deep learning algorithm have evolved lithological mapping from traditional manual to automatic discrimination supported with high-resolution remote sensing data. However, it is worth noting that commonly used deep learning algorithms suffer from uncertainty issues due to fixed parameters and network architectures. More importantly, model uncertainty can transfer to the final resulting lithological mapping and may prone to produce overconfident predictions. For lithological mapping tasks, in addition to outputting the probability of each lithology category, the level of confidence is also deserved emphasizing. This study integrates three uncertainty modeling methods, namely bayes by backprop, Monte Carlo dropout, and deep ensemble, into a convolutional neural network to quantify the uncertainty of lithological mapping. Bayes by Backprop uses Bayesian variational inference to approximate probability distributions over weights to estimate uncertainty; Monte Carlo dropout captures uncertainty by leveraging dropout as a stochastic approximation to Bayesian inference; deep ensemble trains multiple models independently with varying initialization parameters and random samples to achieve uncertainty estimation. The uncertainty modeling methods are illustrated by lithological mapping studies in Cuonadong dome, Tibet, China using ASTER remote sensing data. Several quantitative metrics, including mean, variance, entropy, confidence, expected calibration error, and uncertainty kernel density curves, are employed to quantify uncertainties, indicating that uncertainty mainly concentrated at lithological boundaries and transition zones. Uncertainty quantification transforms deterministic deep learning algorithm into a more trustworthy model to avoid overconfident predictions and improves the reliability of geological maps that enables to robust geological interpretations and decision-making.

S09 The 3D/4D geological modeling and targeting for mineral exploration

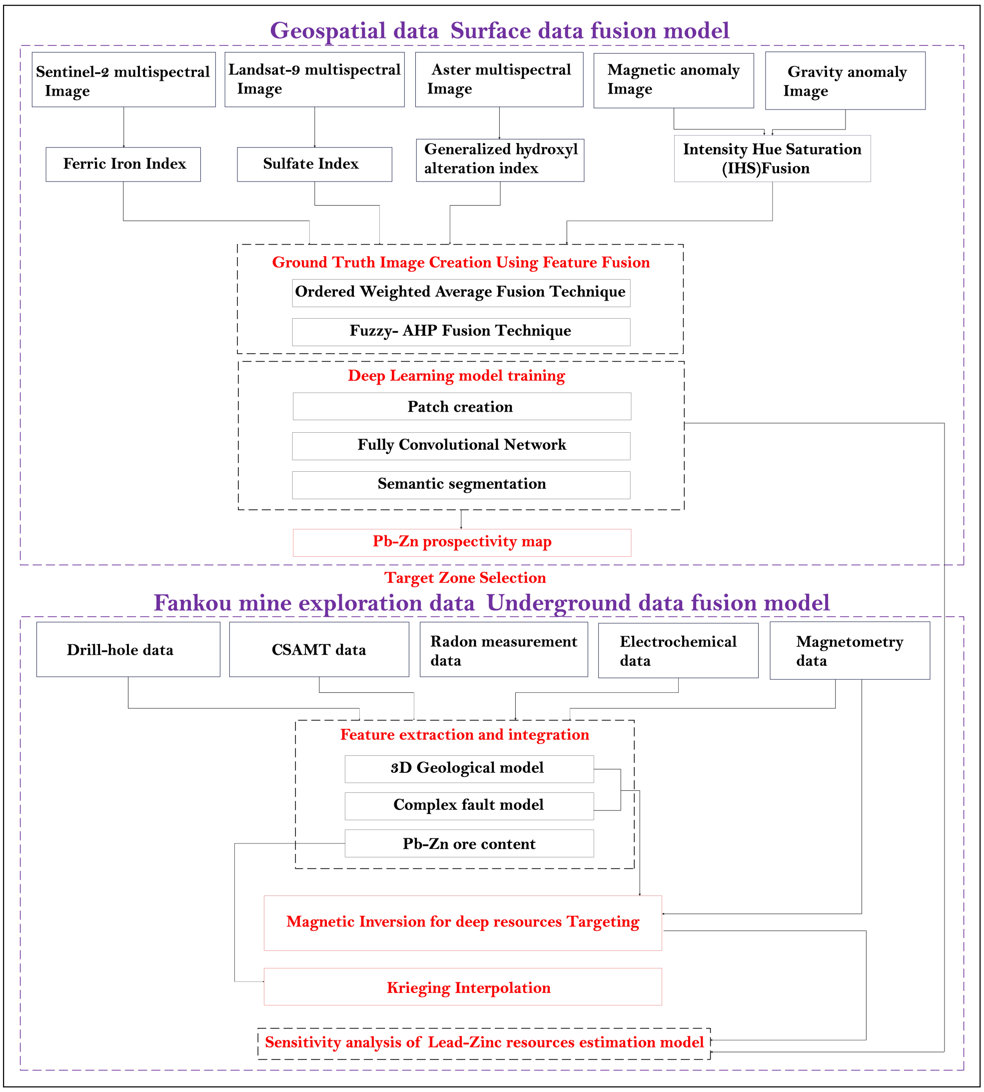
Gongwen Wang (China University of Geosciences (Beijing)),
Emmanuel John Carranza (Univ. of the Free State),
Deng Hao (Central South University),
Zhiqiang Zhang (Hebei GEO University)

All the authors are International Association for Mathematical Geology (IAMG) Life Member. They have some 3D targeting projects communication and cooperations each others. Professor John Carranza is Editor-in-Chief of NRR IAMG, and he is key memeber of EIS (2024).

S0901. GEODATA FUSION AND MINERAL RESOURCES APPLICATION: A CASE STUDY FROM FANKOU Pb-Zn DEPOSIT

Joel Paterne Kouame (State Key Laboratory of Geological Processes and Mineral Resources & Ministry of),
Joel paterne Kouame (State Key Laboratory of Geological Processes and Mineral Resources & Ministry of),
Jianguo Chen (State Key Laboratory of Geological Processes and Mineral Resources & Ministry of)
Room: D209 2025-10-12 11:30

The assessment of mineral resources is crucial for sustainable resource management and economic planning. With the growing quantity of geological exploration datasets, traditional methods of resource estimation are being increasingly supplemented by advanced data fusion techniques, which provide a suitable interface for integrating and exploiting various data types to create comprehensive models of mineral resource potential. However, the problem of uncertainty in data interpretation is always persistent. Furthermore, the challenges posed by heterogeneous data necessitate the incorporation of appropriate data fusion techniques. This paper examines the development of data fusion models for assessing surface and deep-seated lead-zinc resources, with a particular focus on the Fankou lead-zinc deposits and its adjacent areas. First, the remote sensing and geophysical dataset is used to detect the surface mineral assemblage characteristics and subsurface anomalies. Indices obtained through geodata processing were fused using Ordered Weighted Averaging (OWA) and Fuzzy-AHP fusion techniques, yielding Area Under Curve (ROC AUC) values of 0.764 and 0.938, respectively. A semantic segmentation-based Fully Convolutional Network (FCN) model was employed to map mineralization potential zones, achieving an overall accuracy of 0.91. Based on the potential zones highlighted, the Fankou mine was chosen for the depth evaluation. Well-logging, CSAMT, radon measurement, electrochemical, and magnetometry data were analyzed. The geological features derived from these data were then merged and integrated using Geomodeller software to create a three-dimensional lithological model. Subsequently, a litho-constrained 3D inversion model was developed to identify potential zones of mineralization at depth. Finally, lead-zinc and associated mineral contents were interpolated using the kriging method to observe Pb-Zn ore distribution with higher precision. Therefore, his paper assesses mineral resources in two dimensions by integrating multi-source geological data, and the outcomes facilitate the identification of new targets and the consistent evaluation of the mine's lead-zinc mineral resources.



S0902. Integrating Spatial Constraints and Dynamic Evolution Mechanisms:For MPM

Guohao Li (China University of Geosciences (Beijing)),
Gongwen Wang (China University of Geosciences (Beijing))
Room: D209 2025-10-12 11:50

In mineral prospectivity mapping (MPM), inadequate characterization of negative sample spaces and the absence of dynamic evolution mechanisms in models result in constrained geological rationality and interpretability of prediction outcomes. This study proposes a novel 3D modeling framework integrating spatial constraints and dynamic feedback mechanisms: (1) To address sample bias, we develop an L1 distance-information entropy co-optimized negative sample screening model, constrained by kernel density estimation to ensure spatial distribution similarity (KDE-SIM 0.82); (2) To resolve the prediction-evolution decoupling issue, we design a bidirectionally coupled Random Forest-Cellular Automata (RF-CA) architecture, establishing an alternating iterative mechanism for probability field recalibration and neighborhood state transitions (optimized via the Alternating Direction Method of Multipliers, ADMM). A case study of the Sanshandao super-large gold deposit in the Jiaodong Peninsula integrates borehole data, geophysical/geochemical profiles, and LiDAR point clouds to extract six-dimensional ore-controlling factors: structural, lithological, geochemical, geophysical, radar (fracture network density), and hydrothermal activity indices. Experimental results demonstrate: (1) The proposed sampling method enhances negative sample spatial coverage by 37% while reducing training time by 28%; (2) The RF-CA coupled model achieves an AUROC of 0.93 ± 0.02, outperforming traditional methods by 6.4% ($p < 0.01$); (3) 78% of high-probability anomalies spatially align with borehole-verified alteration zones or gold mineralization bodies, demonstrating robust geological rationality and engineering verifiability. This work provides a methodological advancement for addressing spatial bias and mechanistic interpretability in 3D mineral exploration targeting.

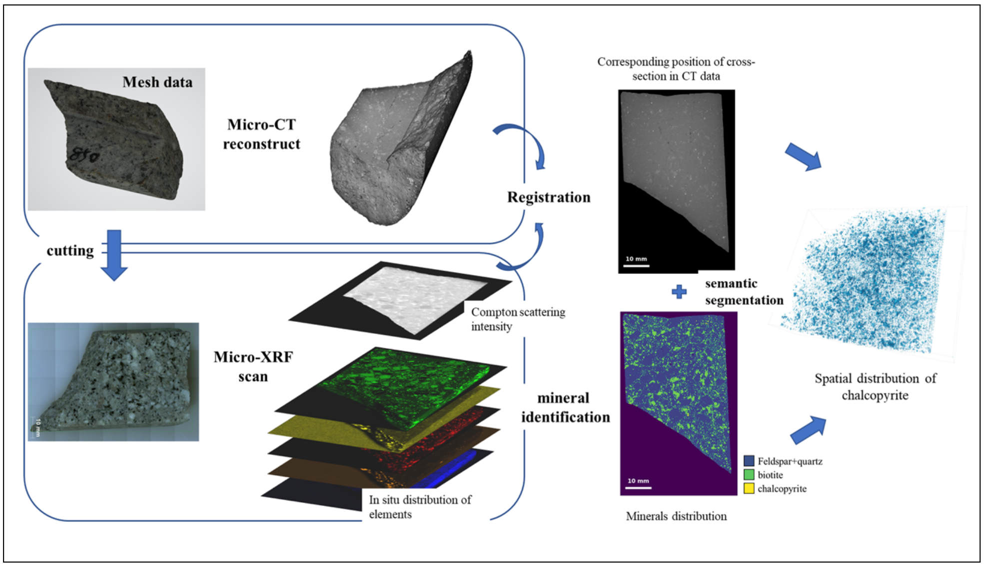
S0903. Integrated Micro-CT and Micro-XRF Imaging for 3D Minerals Characterization of Irregular Geological Samples

Yiming Wang (China University of Geosciences (Beijing)),
Jie Yang (China University of Geosciences, Beijing)
Room: D209 2025-10-12 12:10

Accurately knowing the distribution and proportion of a certain mineral in a sample is crucial for testing and analysis. Although X-ray micro-computed tomography (micro-CT) has transformed 3D analysis of heterogeneous rock matrices through non-destructive visualization, its mineralogical discrimination capacity remains constrained by inherent limitations in elemental specificity. Complementary micro-X-ray fluorescence (micro-XRF) spectroscopy offers high-resolution surface elemental mapping, but lacks depth resolution. To address these analytical challenges, this study proposes a multimodal integration framework that synergistically combines textural information from micro-CT with chemical signatures derived from micro-XRF, enabling automated 3D mineral segmentation in granitic samples.

Our methodology implements a two-stage workflow: (1) Development of a precision image registration workflow that spatially aligns 2D micro-XRF elemental maps with corresponding 3D micro-CT datasets through coordinate system transformation. This cross-modality fusion enables precise localization of sample cross-sections within volumetric data, thereby generating pixel-wise labeled training datasets with mineralogical ground truth. (2) Implementation of a deep learning architecture based on convolutional neural networks (CNNs) for high-precision multi-class mineral segmentation. Subsequent volumetric extrapolation across the complete CT dataset facilitates comprehensive 3D mineral reconstruction and quantitative analysis. Ultimately, we successfully reconstructed three-dimensional spatial distributions of feldspar-quartz assemblages, biotite, and chalcopyrite in granite samples.

The developed framework demonstrates robust capability in crystal boundary identification and 3D feature extraction, including morphological parameters and spatial distribution patterns of constituent minerals. This multimodal approach establishes a novel paradigm for non-destructive mineralogical characterization, with significant potential for adaptation to advanced analytical instrumentation and diverse geological materials.



S0904. Integrating model-agnostic meta-learning with SHAP interpretability techniques for mineral prospectivity mapping

Nini Mou (Development and Research Center, China Geological Survey)
Room: D209 2025-10-12 12:12

In recent years, machine learning techniques have been successfully applied to the mineral prospectivity mapping (MPM). Efficiently extracting potential mineralization information from data and improving the interpretability and transparency of prediction results are crucial for enhancing the predictive ability and accuracy of data-driven MPM. The formation process of ore deposits is extremely complex and a low-probability event. Additionally, the diversity of geological, structural, and mineralization processes leads to significant individual differences among similar types of deposits within the same mineralization system. This project uses model-agnostic meta-learning methods to extract common features between deposits through multi-task and cross-task learning, reducing the impact of deposit differences on prediction results. It also combines SHAP-based interpretability techniques for quantitative analysis of the prediction model, deeply examining how deep learning, after integrating model-agnostic meta-learning, further enhances mineral prediction results. This project tackles the challenges posed by variations in deposits in data-driven MPM in the Mila Mountain copper district of Tibet, China. It comprehensively applies meta-learning and interpretable machine learning techniques to systematically design a framework that is expected to further improve the performance of machine Learning based mineral quantitative prediction with limited deposit data. Thereby enhancing the credibility of machine learning algorithms and their reliability in applications.

S0905. Research on the Quality Evaluation Index System for 3D Geological Models

Yue Song (Integrated Natural Resources Survey Center, CGS),
Zhenji Gao (Integrated Natural Resources Survey Center, CGS)
Room: D209 2025-10-12 12:14

With the advancement of computer technology, geographic information systems, and 3D geological modeling techniques, 3D geological models are playing an increasingly vital role in digital earth construction, smart mining development, and the three-dimensional investigation and management of natural resources. However, due to factors such as variations in data accuracy, inherent errors in source data, the complexity and variability of geological conditions, and the diversity of modeling methods, 3D geological models exhibit multidimensional uncertainty in quality. This poses challenges for model quality assessment and limits their broader application.

Currently, although extensive research has been conducted on the uncertainty of 3D geological models both domestically and internationally, much of it remains project-specific, lacking a comprehensive index system to guide quality evaluation. As a result, it is difficult to provide effective references for assessing the accuracy, quality, and applicability of various types of 3D geological models in practical applications. To address this issue and improve the usability and reliability of 3D geological models, this study establishes a quality evaluation index system from four aspects: source data, geological rationality, model accuracy, and topological relationships. The aim is to provide a systematic evaluation method for assessing the quality of 3D geological models, thereby promoting their application and development across various fields.

S0906. Three-Dimensional Modeling of Geological Structures Using Gradient Enhanced Radial Basis Function with External Drift

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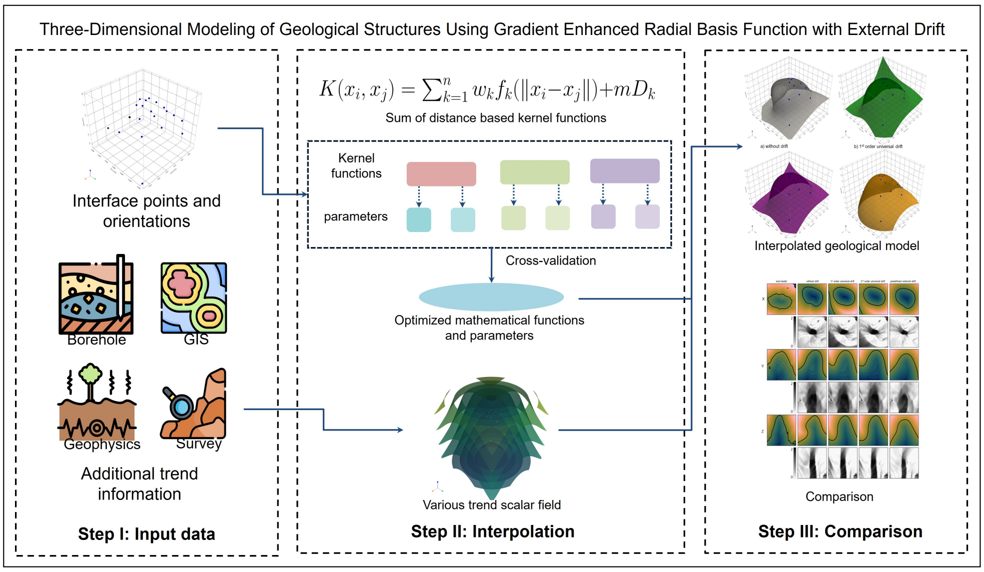
Friedrich Carl (Chair of Engineering Geology and Hydrogeology, RWTH Aachen University),
Peter Achtziger-Zupančič (Fraunhofer Research Institution for Energy Infrastructures and Geotechnologies,),
Florian Wellmann (Chair of Computational Geoscience, Geothermics and Reservoir Geophysics, RWTH Aa)
Room: D209 2025-10-12 12:16

Three-dimensional (3D) geological modeling is essential for visualizing subsurface structures and assessing associated uncertainties, with applications ranging from resource exploration to environmental management. Among various modeling methods, implicit approaches have become prominent due to their computational efficiency and capability to integrate diverse geological datasets. While techniques such as dual kriging have effectively incorporated drift terms to enhance modeling accuracy, radial basis function (RBF) methods have typically lacked this feature, limiting their effectiveness in complex geological scenarios. This study introduces a novel approach that integrates geometric external drift functions into the RBF framework, enabling RBF models to align closely with geological expert knowledge. Consequently, this integration significantly improves the accuracy of modeling geological structures, including planar strata, folded rocks, and salt domes. The proposed method is evaluated using two case studies—a synthetic fold model and a real salt dome model—and its performance is compared to traditional methods. The results demonstrate substantial improvements in accuracy and computational efficiency. These findings indicate that integrating external drift into RBF methods enhances their versatility and provides a robust solution for subsurface modeling, especially when the general geometrical configuration of the subsurface is already understood.



S0907. Three-dimensional mineral prospectivity mapping via deep multimodal fusion and domain adaptation

Deng Hao (Central South University),
Yang Zheng (Central South University),
Xiancheng Mao (Central South University)
Room: D209 2025-10-12 14:30

Three-dimensional mineral prospectivity mapping (3D MPM) is vital for locating deep-seated orebodies, but its effectiveness is limited by two key challenges. First, integrating geological frameworks and computational simulation outputs is difficult due to their differing data sources, formats, and abstraction levels, creating a cross-modal gap. Second, models trained on shallow-zone data struggle to predict deep targets, as metallogenic conditions and spatial controls change with depth.

We propose a framework combining deep multimodal fusion and spatially aware domain adaptation to address these issues. The fusion module uses a dual-branch neural network: one branch processes 3D geological data (spatial context, lithology, structures), while the other handles simulation outputs (geodynamic drivers). Canonical correlation analysis (CCA) aligns their latent features, enabling a shared representation that integrates spatial and dynamic mineralization clues. For transferability, we treat shallow and deep zones as distinct domains and introduce the Spatial-Associated Maximum Mean Discrepancy (SAMMD) criterion. SAMMD measures differences in feature and spatial distributions between domains. A domain adaptation network minimizes this discrepancy, ensuring the model extracts robust mineralization features across depth variations.

Tested in China's Jiaodong gold province, our approach outperforms unimodal and basic multimodal methods in prediction accuracy and mineralization delineation. The CCA-enhanced fusion improves feature integration, while SAMMD-based adaptation boosts performance in deep, data-scarce zones, reducing false positives and sharpening targeting efficiency. This method excels in both shallow, well-sampled areas and deep, poorly characterized domains, meeting a critical need in mineral exploration.

S0908. Case Study of 3D Exploration Targeting for Gold by Machine Learning Integration of Geological-Geophysical Datasets: Sanshandao–Cangshang District, China

Meng Gao (Frontiers Science Center for Deep-time Digital Earth, China University of Geosci),
Gongwen Wang (China University of Geosciences (Beijing)),
Emmanuel John Carranza (Univ. of the Free State),
Wen Zhang (Shandong Institute of Geological Survey),
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Room: D209 2025-10-12 14:50

Integrating positive, negative and unlabeled samples for 3D modeling of mineral prospectivity demand using a variety of mathematical models. Here, support vector machine (SVM) learning is demonstrated for comparing the impact of using dissimilar types of samples on results of predicting mineral prospectivity. We used a 1-class SVM (1CSVM) model that is suitable for positive-only samples, a SVM model that is suitable for both positive and negative samples, and an algorithm for bagging-based positive-unlabeled learning with SVM base learner (BPUL-SVM) that is suitable for positive and unlabeled samples. These models were demonstrated 3D modeling of mineral prospectivity in the Sanshandao-Cangshang offshore and onshore gold district, which hosts large and super-large gold deposits, which signify the district's huge prospect for gold mineralization. According to the evaluation methods used (i.e., receiver operating characteristics curve, F1 score, and prediction–area plot), the performances of the models were in the following high-to-low sequence: BPUL-SVM13 SVM12 weights-of-evidence 1CSVM. The performance of the BPUL-SVM model, which is suitable for positive and unlabeled samples, showed that it was the most optimal among the SVM models used. Markov chain Monte Carlo simulation and return-risk evaluation were then utilized to appraise the best-performing BPUL-SVM model and ultimately identify I-level exploration targets with high return but with low risk. The identified exploration targets mostly exhibit spatial proximity to the Sanshandao–Cangshang fault. In combination with consistency of mineralization, the deeper and peripheral continuation of the known deposits are significant for exploring undiscovered gold-bearing orebodies. The outlined exploration targets are significant for exploring onshore and offshore orebodies of gold in the district.

S0909. Multi-Source Data Integration and AI-Powered 3D Prospectivity Modeling for Gold Exploration in the Jiaolai Basin, Eastern China

Qingming Peng (China University of Geosciences Beijing),
Gongwen Wang (China University of Geosciences (Beijing))
Room: D209 2025-10-12 15:10

This study presents a data-driven framework for 3D mineral prospectivity modeling in the Xintai gold district, located in the Jiaolai Basin, Eastern China. The research integrates geological, geochemical, geophysical, and drilling datasets into a unified geoscience database, from which high-resolution 3D geological models—including stratigraphy, faults, and ore bodies—were constructed using the SKUA-GOCAD platform.

Key predictive variables include stratigraphic architecture, proximity to fault structures, interpolated geochemical anomalies (e.g., Au, As, Hg), and resistivity models derived from electromagnetic surveys. These features were used to train a suite of machine learning models for mineral potential mapping.

A custom deep learning framework incorporating Transformer-based attention mechanisms was developed to better capture long-range spatial dependencies and complex feature interactions in the 3D geodata. The Transformer-enhanced model outperformed traditional classifiers—including logistic regression, PU learning, and random forest—achieving high spatial precision in identifying deeply concealed mineralized zones.

The integrated modeling approach delineated three high-potential target zones (T1–T3), which show strong spatial agreement with known ore distributions and geochemical enrichment. Model performance was evaluated using ROC-AUC analysis and spatial cross-validation, confirming the effectiveness of attention-based architectures in subsurface mineral exploration.

This research demonstrates the potential of combining 3D geological modeling with Transformer-augmented deep learning to enhance mineral prediction in structurally complex terrains. The workflow offers a scalable methodology for intelligent targeting in mature mining districts and contributes to the advancement of AI applications in mathematical geosciences.

S0911. A framework integrating Graph Attention Network and Post Hoc Interpretability for Three-Dimensional Mineral Prospectivity Mapping

Zhongzheng Wang (China University of Geosciences, Beijing),
Gongwen Wang (China University of Geosciences (Beijing)),
Qingming Peng (China University of Geosciences Beijing)
Room: B222 2025-10-13 10:30

Mineral prospectivity mapping (MPM) is recognized as a crucial method for mineral exploration. Owing to their outstanding capabilities in extracting nonlinear features from data, many deep learning algorithms, including convolutional neural networks (CNNs) and graph neural networks (GNNs), which can model complex spatial relationships between mineralization and evidence layers compared to traditional statistical and machine learning approaches, have been widely applied to two-dimensional MPM. However, few studies have used them in three-dimensional (3D) MPM due to the constraints imposed by evidence layers based on 3D geological models. Specifically, CNNs rely heavily on regular grids, making it difficult to apply them to irregular 3D geological models with oblique XYZ coordinate axis and elevation variation. The construction of graphs for GNNs, transformed from 3D geological models, typically results in large-scale structures that impose significant computational and hardware burdens. Moreover, the opaque internal mechanisms of deep learning algorithms have hindered the applications of data-driven MPM. To address these challenges, a novel 3D MPM framework that integrates Graph Attention Networks (GAT) and post hoc interpretability has been proposed in this study. In the proposed framework, neighborhood cubes are used as inputs to the GAT, allowing for the capture of spatial relationships among voxels while effectively reducing the size of the constructed graph. More importantly, the post hoc interpretability module not only emphasizes the feature contributions within the evidence layers, but also introduces a novel spatial perspective for mineralization by visualizing the 3D attention vector fields of the neighborhood cubes. Here, the integrated framework was utilized to produce a 3D interpretable prospectivity model in the Lannigou gold district, China. The results demonstrate that the integrated framework delivers superior performance while enabling the inspection and interpretation of prediction outcomes. This study provides a promising direction for integrating deep learning and geoscientific interpretability in practical exploration scenarios.

S0913. Machine learning-based 3D mineral prospectivity modeling for targeting Cu-Mo mineralization within Duobaoshan district, northeastern China

Xiumei Lv (China University of Geosciences Beijing),
Gongwen Wang (China University of Geosciences (Beijing))
Room: B222 2025-10-13 10:50

The Duobaoshan area, located in the northeastern segment of the Central Asian-Xing'an-Mongolia orogenic belt, represents a typical porphyry Cu-Mo metallogenic system. Both the Duobaoshan superlarge and the Tongshan large-scale porphyry Cu-Mo deposits have been discovered in this region, indicating significant mineralization potential. However, due to the complexity of the geological structures, the difficulty of mineral exploration increases substantially with depth. To address this challenge, three-dimensional mineral prospectivity modeling (3DMPM) based on machine learning has been widely adopted for delineating deep-seated and concealed mineralization.In this study, multiple exploration datasets from the ore district, including borehole and profile data, were integrated to construct a 3D prospectivity model. Four key indicators-regional structures, regional stratigraphy, density, and magnetic susceptibility-were selected as the primary mineralization features. Advanced machine learning algorithms such as XGBoost and 3D convolutional neural networks (3D-CNN) were employed, and model accuracy was improved through cross-validation using multiple algorithms. Furthermore, repeated random sampling and Bayesian optimization were used to fine-tune and optimize model parameters. The results demonstrate that deep learning algorithms effectively identify favorable mineralization zones. C-V fractal analysis was applied to delineate and classify the prospectivity zones, defining both I- and II-level targets. These target areas show strong spatial consistency with known Cu-Mo deposits and are characterized by favorable geological conditions. The established 3D targeting model provides valuable technical support and theoretical guidance for future Cu-Mo exploration in the Duobaoshan area.

S0914. Deep Subdomain Adaption Network for Three-Dimensional Mineral Prospectivity Modeling with Imbalanced Data: A case study of the Damiao-Hongshila Fe-V-Ti belt, China

Zhiqiang Zhang (Hebei GEO University),
Gongwen Wang (China University of Geosciences (Beijing)),
Emmanuel John Carranza (Univ. of the Free State)
Room: B222 2025-10-13 11:10

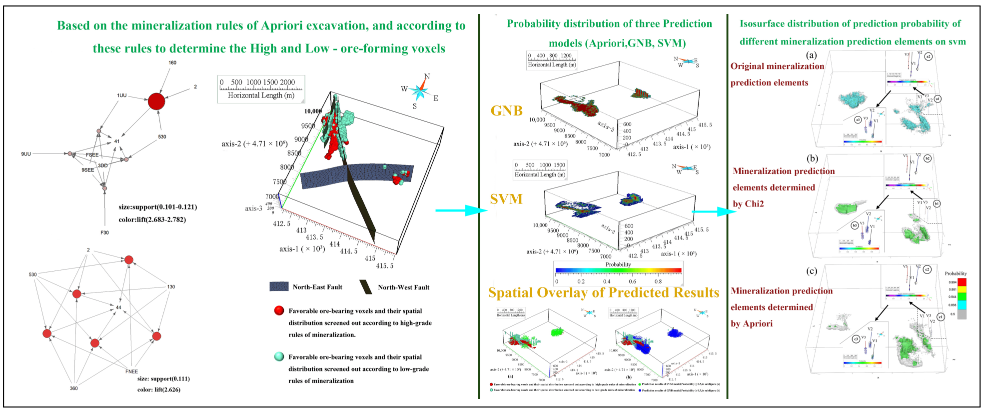
3D mineral prospectivity modeling (MPM) aims to identify deeper and peripheral targets in known mineral deposits. However, the complex mineralization processes often lead to variations in the 3D digital features of critical ore-controlling factors at depth compared to shallower areas. Additionally, the rarity of mineralization results in an imbalance between positive and negative samples in 3D MPM. Global domain adaptation methods can misclassify samples due to imbalanced subdomain shifts. To address this issue, we introduce a fine-grained multi-kernel maximum mean discrepancy (MK-MMD) loss function and develop a deep subdomain adaptive network (DSAN) based on it. In our approach, deep features are extracted using a backbone network (e.g., 3D LeNet or ResNet), and the MK-MMD loss is computed using multiple Gaussian kernels with varying bandwidths to capture complex differences between feature distributions. To address class imbalance, we apply a bidirectional sample weighting mechanism to the MK-MMD. Specifically, in our loss function, the weights for source domain samples are determined by the ratio of ore to non-ore bodies, while the weights for target domain samples are estimated based on class probabilities predicted by the MPM model. This fine-grained alignment, enabled by the weighting mechanism, facilitates class-level distribution matching between the source and target domains. In a case study of the Damiao Fe-V-Ti belt for 3D MPM, we evaluated the performance of random forest, 3D LeNet, conventional domain adaptation networks, and the proposed DSAN model. The results demonstrate the superior performance of DSAN in identifying prospective zones and highlight the significant mineralization potential beneath the Damiao anorthosite complex.

S0915. Apriori Algorithm-Based Three-Dimensional Mineral Prospectivity Mapping—An Example from Meiling South Area, Xinjiang, China

Jinyu Chang (Xinjiang Institute of Ecology and Geography , Chinese Academy of Sciences)

Room: D209 2025-10-12 12:18

Mineral Prospectivity Mapping (MPM) is shifting toward intelligent deep mineralization searches. In comparison 1,we use the Apriori algorithm to mine ore-forming information and determine the ore-forming voxel positions based on spatial distance and angle analysis. Then, we compare the ore-forming voxel positions determined by Apriori with the ore-forming voxel positions predicted by the mathematical model based on the conceptual model of mineralization, and these mathematical models include Gaussian Naive Bayesian (GNB) and Support Vector Machine (SVM). In comparison 2, the optimal prediction model is SVM, which is trained using the elements of mineralization prediction determined by the conceptual model of mineralization. Then, two sets of new elements of mineralization prediction are extracted from the original elements of mineralization prediction using the Apriori and Chi-square methods and then input into the SVM model for training. After we obtain the mineralization prediction results, we compare them with the original mineralization prediction results. The preceding comparison produced the following results. (1) Using the Apriori algorithm, the distribution characteristics of the high and low-grade ore bodies and the association rules between ore-bearing information were determined. (2) The prediction results of the GNB and SVM models displayed corresponding trends on the high and low-grade ore-bearing voxels identified by Apriori,which matched the rules mined by Apriori. (3) In comparison to the mineralization predictionelements screened by Chi-square and the original mineralization prediction elements based on the conceptual model of mineralization, the elements of mineralization prediction chosen based on Apriori have the best prediction effect in SVM when tested in new drill holes. Based on the mineralization prediction elements screened by Apriori, the number of accurate ore-bearing voxels (prediction probability greater than 0.5) predicted by the SVM model is 6, 5, and 1 in drill holes V1, V2, and V3, respectively.



S0916. 3D Prediction and Evaluation of Lujing Uranium Deposit

Yun Bai (Survey Center of Comprehensive Natural Resources, China Geological Survey),
Chunying Guo (th),
Pengfei Zhu (Corresponding author),
Haicheng Wang (Survey Center of Comprehensive Natural Resources, China Geological Survey),
Dawei Wang
Room: B222 2025-10-13 11:30

The Lujing uranium deposit is located at the border of Hunan and Jiangxi provinces and is a large granite type uranium deposit. It is one of the important uranium mining areas in southern China and has great potential for prospecting. Based on the understanding of the geological background genesis and mineralization laws of the Lujing uranium deposit relevant basic geological and drilling construction data and information related to the Lujing uranium deposit were collected and preprocessed. Based on the three-dimensional geological modeling theory and technical means SKUA-GOCAD was used A three-dimensional geological model of the Lujing uranium deposit was established using software including terrain structure rock mass strata and ore body. The ore-forming characteristics of the Lujing uranium deposit were analyzed including the spatial relationship and structural features of the rock mass strata and ore body. Beneficial information for mineralization was quantitatively extracted and analyzed including inter group interface information structural information and triangular favorable zones. The contribution of ore-forming elements to prospecting was determined. Based on the three-dimensional evidence weight method and three-dimensional information quantity method a three-dimensional quantitative prediction was made and the ore-forming favorable area was delineated according to posterior probability and information quantity. It was speculated that there were similar ore-forming environments in the lower part of the ore body and the resource quantity was estimated. Through three-dimensional visualization mineralization potential analysis and prediction research were carried out providing further exploration and resource evaluation for the Lujing uranium deposit. Based on scientific evidence and technical support.

S10 Recent developments in constructing geological structures: Beyond conventional methods

Weisheng Hou (Sun Yat-sen University),
Mathieu Gravey (Austrian Academy of Sciences),
Baoyi Zhang (Central South University),
Nan Li,
Yanshu Yin,
Jiateng Guo (Northeastern University),
Qiyu Chen (China University of Geosciences (Wuhan)),
Xiaohui Li

The artificial intelligence (AI), multiple-point statistics (MPS), and other methods have significantly enhanced 3D geological modeling, overcoming the limitations caused by sparse data and complex shapes. This session bring together researchers in AI, MPS, stochastic simulation, and conventional geological modeling who have a common research question: detection, characterization, and reconstruction of patterns and structures of geological and geophysical data. We invite contributions showcasing novel methods with applications in mineral perspective, gas and reservoir, engineering geology, digital twins, regional geological investigation, and beyond, for which can be valuable additions to the methodological toolbox for reconstructing geological structures.

S1001. Digital Reconstruction of Porous Media Using Latent Diffusion Models

Fabio Ramos,
Danilo Naiff (Federal University of Rio de Janeiro),
Bernardo Schaeffer (Federal University of Rio de Janeiro)
Room: B222 2025-10-10 14:30

Three-dimensional digital reconstruction of porous media remains a fundamental challenge in geoscience, requiring both fine-scale pore structure resolution and representative elementary volume capture. We present a novel computational framework that addresses this challenge through latent diffusion models within the Energy-based Diffusion Models (EDM) framework.

Our approach reduces dimensionality via a custom Variational Autoencoder trained on binary geological volumes, improving computational efficiency and enabling generation of larger volumes than previously possible with diffusion models. The key innovation is our controlled unconditional sampling methodology, which enhances distribution coverage by first sampling target statistics from empirical distributions, then generating samples conditioned on these values.

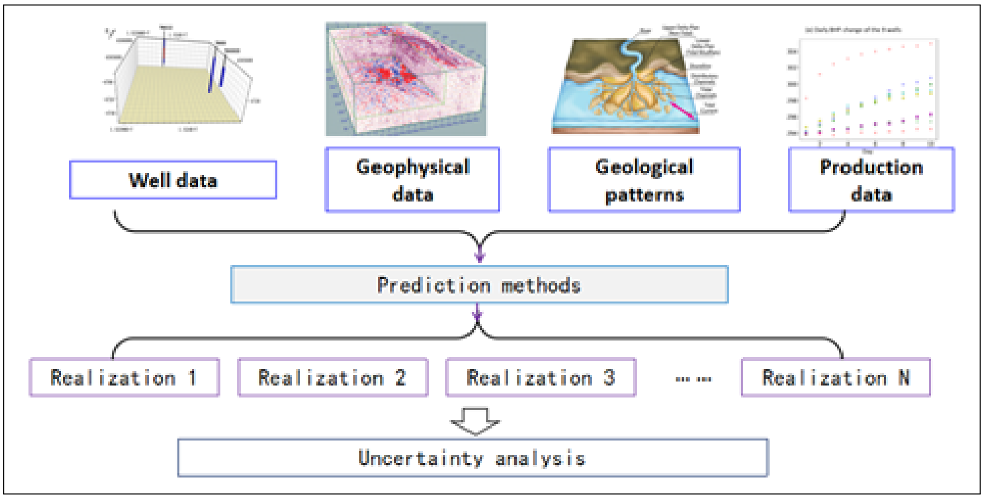
Extensive testing across four rock types demonstrates that conditioning on porosity—a readily computable statistic—sufficiently ensures consistent representation of multiple complex properties including permeability, two-point correlation functions, and pore size distributions. Our framework achieves superior generation quality compared to pixel-space diffusion while enabling significantly larger volume reconstruction (256^3 voxels) with substantially reduced computational requirements.

This work establishes a new state-of-the-art approach for digital rock physics applications, effectively balancing the need for detailed pore structure representation with computational feasibility in generating representative elementary volumes.

S1002. Conditional Generative Adversarial Networks (cGANs) Inversion method for Low-Uncertainty Hydrocarbon Reservoir Modeling

pengfei xie (Yangtze University),
yanshu yin (yangtze universoty),
Xun Hu (Yangtze universoty),
lixin Wang (Yangtze universoty)
Room: B222 2025-10-11 10:50

Reservoir prediction methods face three core challenges: data sparsity, multimodal data integration, and uncertainty. This study proposes an integrated intelligent workflow to address these issues: (1) a geological knowledge base mitigates data sparsity by incorporating sedimentary simulations, outcrop scanning imaging, mature field architecture analysis, and object-based stochastic modeling to generate 2D/3D training datasets; (2) a conditional generative adversarial network (cGAN), enhanced with a progressive growing architecture and a data fusion module, integrates multimodal well logs, seismic data, and facies proportions for conditional reservoir modeling; and (3) an inversion-based sampling method reduces prediction uncertainty by matching observed data through stochastic realizations. The proposed framework establishes a standardized workflow for robust, data-driven reservoir prediction, demonstrating improved accuracy in case studies.

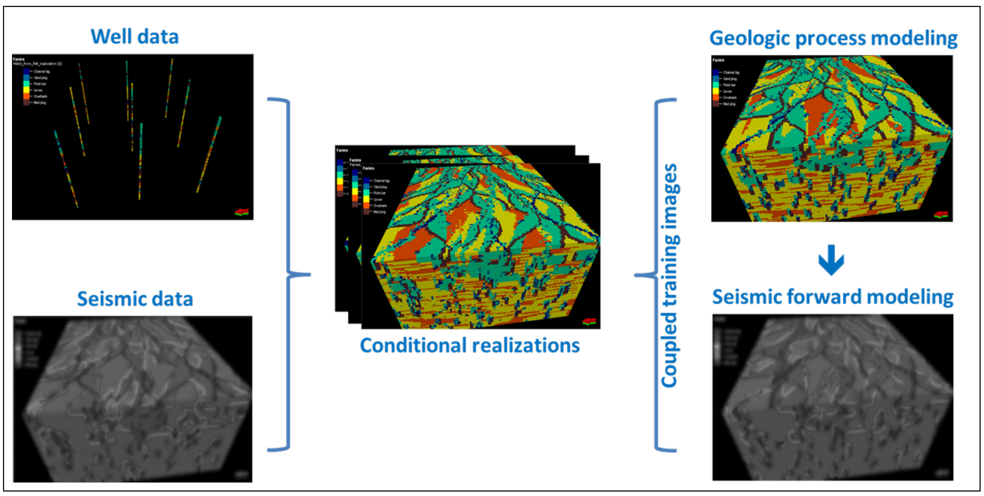


S1003. Statistical Pattern Learning, Drawing and Morphing for Conditional Simulation of Subsurface Heterogeneity

Linying Hu (Aramco Beijing Research Center),
Yupeng Li,
Wisam Al Kawai (Saudi Aramco)
Room: B222 2025-10-10 15:10

Geologic process models follow the physicochemical laws of deposition and diagenesis. These models appear geologically realistic and attractive, but do not necessarily honor quantitative information from wells, seismic volumes, and production history. This is because the data are not directly integrated into the model but rather indirectly used to infer a set of its input parameters. Conditioning geologic process models to quantitative information is critical for field applications and has been challenging for decades. The traditional approach to conditioning a geologic process model is to tune its input parameters by trial-and-error or through an automated inverse scheme. This can improve the model calibration to data but can hardly reach a fully satisfactory result. This paper presents a statistical pattern recognition approach for integrating well, seismic and production data into geologic process models.

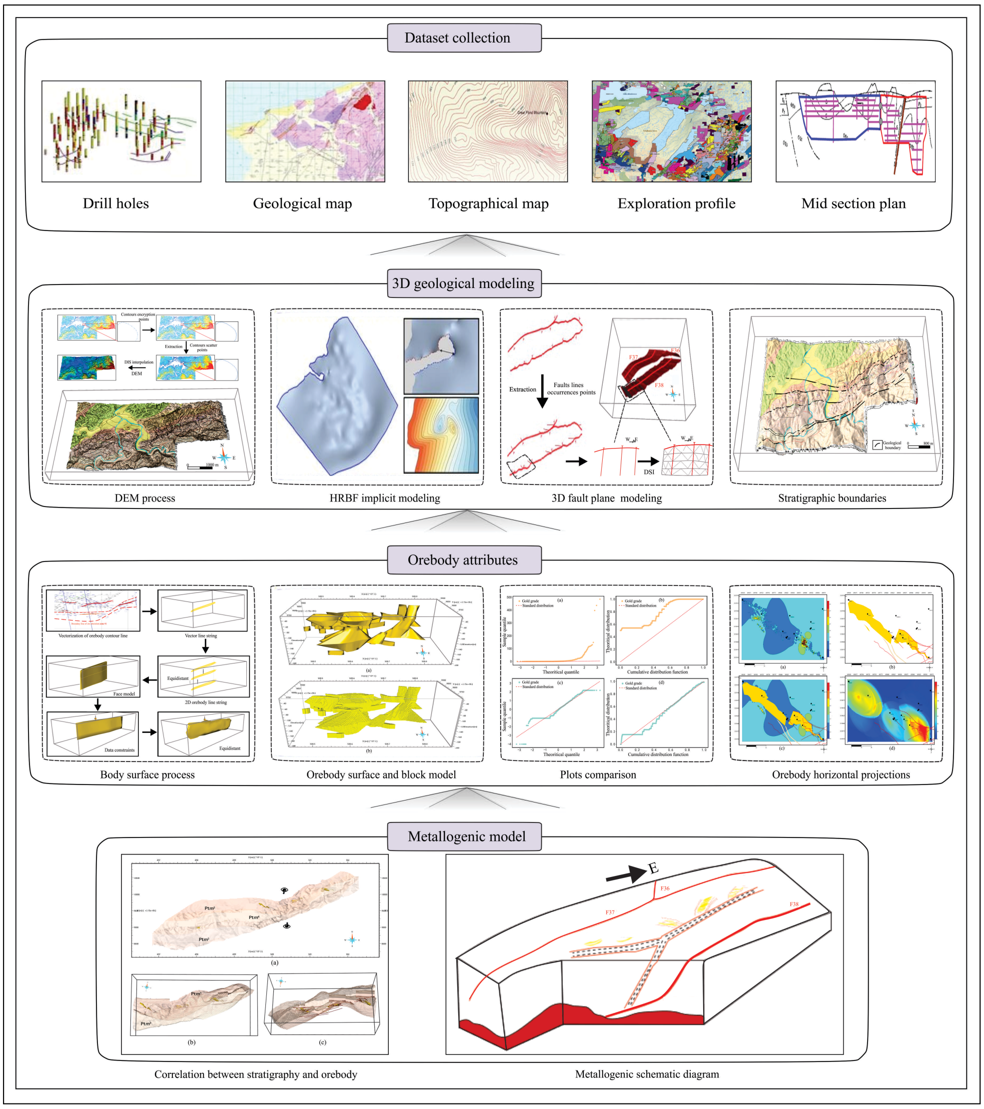
We start with a geologic process model (of deposition and/or diagenesis) whose input parameters are already tuned to reach a certain degree of data conditioning. To further condition the model, we adopt the regionalized multiple-point statistics (MPS) approach where the geologic process model and its corresponding seismic attributes are used as coupled training images for geologic pattern learning and simulation. The regionalized MPS method is based on Bayes' law and Gaussian kernel approximation of conditional probability instead of a probability combination scheme or a heuristic rule. It can calibrate the geologic process model to well and seismic data while preserving its geologic patterns. Moreover, the regionalized MPS method can also be implemented as a transformation from a uniform random field (or latent space) to a geologically meaningful model, and hence the gradual deformation method can be applied for history matching. Ultimately, the regionalized MPS method becomes a vehicle of geo-consistent integration of well, seismic and production data into the geologic process model.



S1004. Advanced 3D Modeling and Geostatistical Analysis for Metallogenic Reconstruction: A Case Study of the Guanzhuang Gold Deposit

OR AIMON BROU KOFFI KABLAN (Central South University),
Baoyi Zhang (Central South University)
Room: B222 2025-10-10 16:00

Understanding spatial characteristics and metallogenic growth of mineral deposits demands the use of modern 3D modeling and geostatistical techniques. While existing modeling tools are useful for visualizing geological formations or property parameters in low-variability environments, they face limitations in complex regions, which can lead to poor modeling performance. This work presents a hybrid approach that combines Hermite Radial Basis Function Interpolation (HRBF) with explicit modeling to develop an advanced 3D geological model. Using the Guanzhuang gold deposit as a practical case, HRBF modeling, incorporating attitude and attribute data from surface geological maps, was used to interpolate stratigraphic units. Explicit modeling of fault structures and lithological contacts was conducted through human-guided interpretation of exploration profiles and mid-section maps. The discrete smooth interpolation (DIS) algorithm was used to build a digital elevation model, which was enhanced with topographic texture mapping for better visualization. The geostatistical approach included outlier capping, Box-Cox transformation, standard normal score transformation, and variogram analysis depending on orebodies' spatial arrangement. Sequential kriging interpolation generated detailed grade attribution models for the three main ore blocks, with total metal content calculated for Zhengjiashan (299.07 kg), Jinzhuwan (1,710.11 kg), and Xianglu (988.58 kg). Spatial analysis of cumulative grade, thickness, and grade-thickness product showed that regional fault structures primarily control mineralization occurrence patterns. Notable differences in strike and stratigraphic distribution between eastern and western ore bodies suggest distinct regional metallogenic origins, despite a shared fold zone genesis. Fracture core density mapping and quantitative structural analysis using K-means clustering indicated the deep southern region as a potential mineralization source. This study demonstrates that data-driven 3D modeling, combined with geostatistical analysis, effectively reconstructs metallogenic history and provides a basis for future exploration strategies in structurally complex ore environments.



Dataset collection
Drill holes
Geological map
Topographical map
Exploration profile
Mid section plan
3D geological modeling
DEM process
HRBF implicit modeling
3D fault plane modeling
Stratigraphic boundaries
Orebody attributes
Body surface process
Orebody surface and block model
Plots comparison
Orebody horizontal projections
Metallogenic model
Correlation between stratigraphy and orebody
Metallogenic schematic diagram

S1005. Synthesizing geometry, topology, kinematic, and geomechanics in a graph-based fracture model

Ana Paula Burgoa Tanaka (University of Neuchâtel),
Philippe Renard (University of Neuchâtel),
Jefter Natan de Moraes Caldeira (University of Lausanne),
Celia Trunz (University of Neuchâtel)
Room: B222 2025-10-10 16:20

Identifying the preferential fluid flow paths through a fracture network starts with the detection, characterization, and modeling of the fractures. In structural geology, faults and fractures can be analyzed through a range of complementary approaches such as geometry, topology, kinematics, age relationships, geomechanics, and tectonics. However, it is a challenge to combine and easily access the data in a scale independent fracture model, because most of the studies describe and model the different aspects separately. Therefore, we propose an integration of geometry, topology, kinematics, and geomechanics, in a graph-based fracture model. We apply the method to the fracture network of Tsanfleuron, an aquifer system in the western domain of the Swiss Alps, where the fracture network plays a major role in groundwater circulation and karstification. In this study, we gather in one graph, stored as node and edge attributes, all the measurements and analyses available for geometry (length, azimuths, dips), topology (degrees and centralities), kinematics (type of displacement), and geomechanics (aperture related to the stress). To circumvent the scale dependency and easier the access to the data we apply a non-gridded graph approach, that maintains a reliable connectivity based in the topology of the interpreted fracture network. To build the graph, we remotely detect and measure fractures from digital elevation and digital outcrop models. We verify the interpretation and collect more measurements in the field from outcrops and scanline. In the resulting graph, the nodes and edges represent the intersections and branches of the fractures, respectively. We identified four main sets and the most important nodes in the network, which indicate preferential flow paths of NE-SW, ENE-WSW, and E-W directions for the study site.

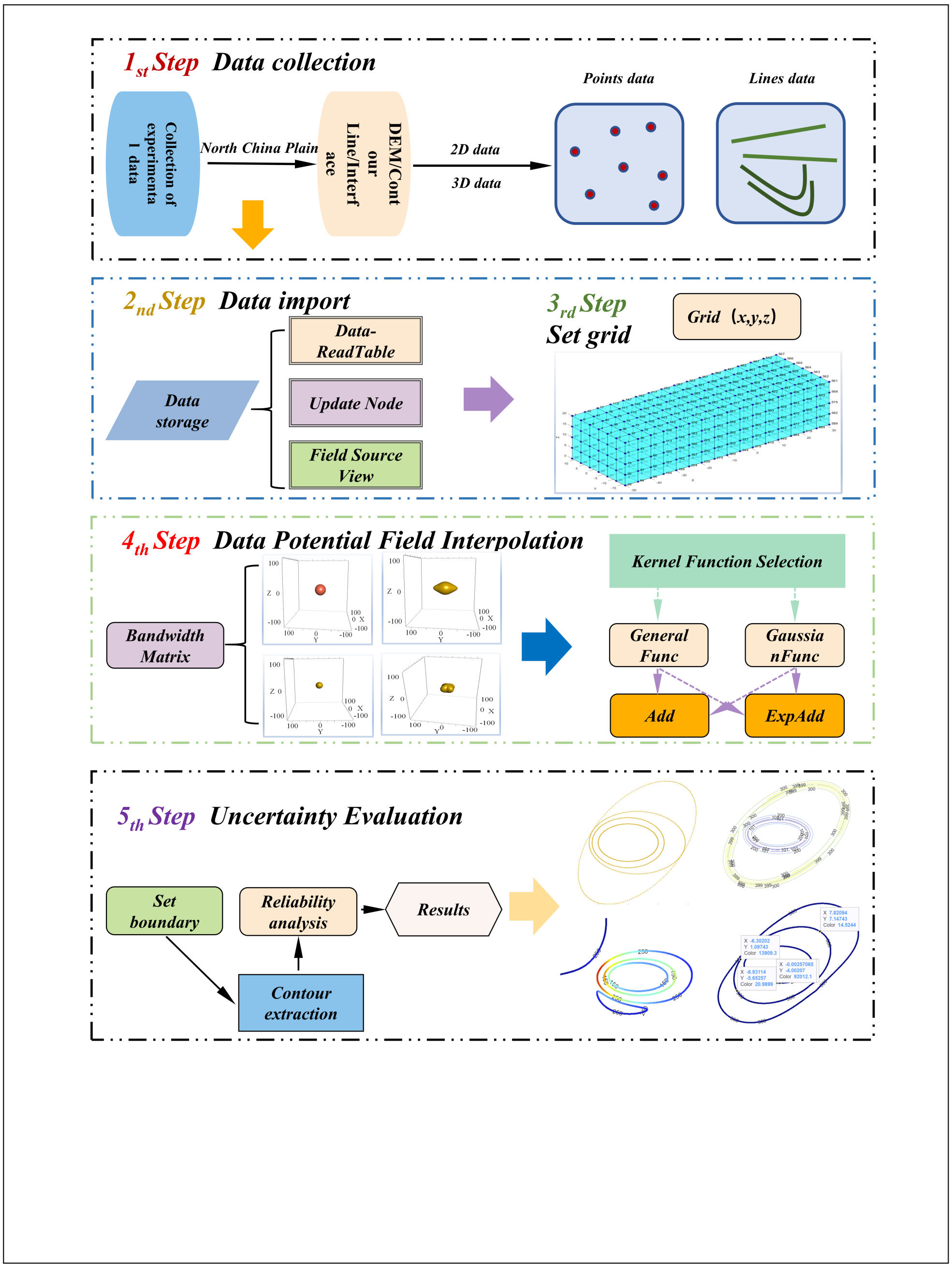
S1006. A Data Potential Field Interpolation-Based 3D Geological Implicit Modeling Method and Uncertainty Evaluation

Zhenxi Fang (Central South University),
Baoyi Zhang (Central South University)
Room: B222 2025-10-10 16:40

Three-dimensional geological models are critical for geospatial analysis, interpretation of geological phenomena, and numerical simulation of geological processes. However, existing implicit modeling methods, such as radial basis functions and universal co-kriging, require repeated data perturbations to calculate the information entropy of geospatial element uncertainties, which consumes significant computational resources and fails to accurately reflect the impact of data density on model quality. This study proposes a novel 3D geological implicit modeling method based on data potential field interpolation. By treating stratigraphic interfaces as iso-surfaces of a scalar field, the method avoids self-intersections of geological layers and ensures consistency in geological contact relationships. The method defines geological boundary points and lines as field sources, simulates their spatial influence using a potential function, and controls the decay rate of the data potential field through a bandwidth matrix. Weight coefficients for interpolation are derived from the normalized potential values of these field sources, enabling the reconstruction of stratigraphic potential fields. The total data potential field distribution, obtained by superimposing all field sources, quantitatively evaluates the uncertainty of the 3D surface model. Regions closer to field sources exhibit higher potential values and lower uncertainty, while sparse regions show the opposite. Experimental results demonstrate that this method efficiently integrates point and line data, constructs smooth geological interfaces, and evaluates model uncertainty in a single computation, outperforming traditional methods that rely on multiple stochastic simulations. The proposed framework provides a robust solution for reconstructing complex geological structures and offers practical value for engineering applications.

This study was supported by grant from the National Science and Technology Major Project of Deep Earth Probe and Mineral Resources Exploration, China (Grant No. 2024ZD1001201).

Keywords: 3D geological implicit modeling; data potential field interpolation; uncertainty evaluation; stratigraphic potential field; bandwidth matrix; iso-surface extraction.


1st Step Data collection
Collection of experimental data
North China Plain
DEM/Contour Line/Interface
2D data
3D data
Points data
Lines data
2nd Step Data import
Data storage
Data-ReadTable
Update Node
Field Source View
3rd Step Set grid
Grid (x,y,z)
4th Step Data Potential Field Interpolation
Bandwidth Matrix
Kernel Function Selection
General Func
GaussianFunc
Add
ExpAdd
5th Step Uncertainty Evaluation
Set boundary
Reliability analysis
Results
Contour extraction

S1007. Fast 3D Reservoir Modeling Through Spatial Clustering of Multiple Well Logs

Yupeng Li (BRC of EXPEC ARC, Aramco),
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Room: B222 2025-10-10 16:42

In conventional reservoir facies and rock type modeling, facies or rock types are initially interpreted from well log curves and subsequently employed as categorical variables in spatial modeling. This traditional approach comprises two distinct and separated steps: facies interpretation from well log curves and 3D facies spatial modeling. Consequently, crucial geological stacking and vertical transitional information, such as the information presented by log curve shapes, are often lost or not fully integrated during the 3D facies modeling process.

This study presents a novel approach that integrates these two steps using machine learning by treating multiple well logs as time series and performing a two-step clustering process. Specifically, well log curves from each well within the target spatial domain are clustered on a zone-by-zone basis. The Bag of Symbolic Fourier Approximation Symbols (BOSS), which is widely used in time series classification, is implemented for well log curves feature extraction and clustering. Through those clustering, all wells in the modeling areas are grouped into different types according to the similarity of their log curve features, characterized by multiple log curves. The final 3D spatial reservoir facies model is obtained through spatial interpolation of the clustered well groups. The final obtained 3D facies model offers valuable insights into the depositional background by revealing lateral geological heterogeneity features, as stratigraphic and petrophysical features are integrated into the final model.

A small synthetic dataset is employed in a case study to demonstrate the effectiveness of the proposed method in characterizing spatial heterogeneity. The results indicate that the spatial segmentation technique can serve as a rapid geological modeling approach, effectively integrating the geological heterogeneity features embedded in multiple well logs.

S1010. A Multi-Scale Growth and Attention-Enhanced SinGAN Method for Sedimentary Facies Conditional Simulation

Ce Zhang (China University of Geosciences),
Gang Liu (China University of Geosciences),
Qiyu Chen (China University of Geosciences),
Hongfeng Fang (China University of Geosciences)
Room: B222 2025-10-11 10:30

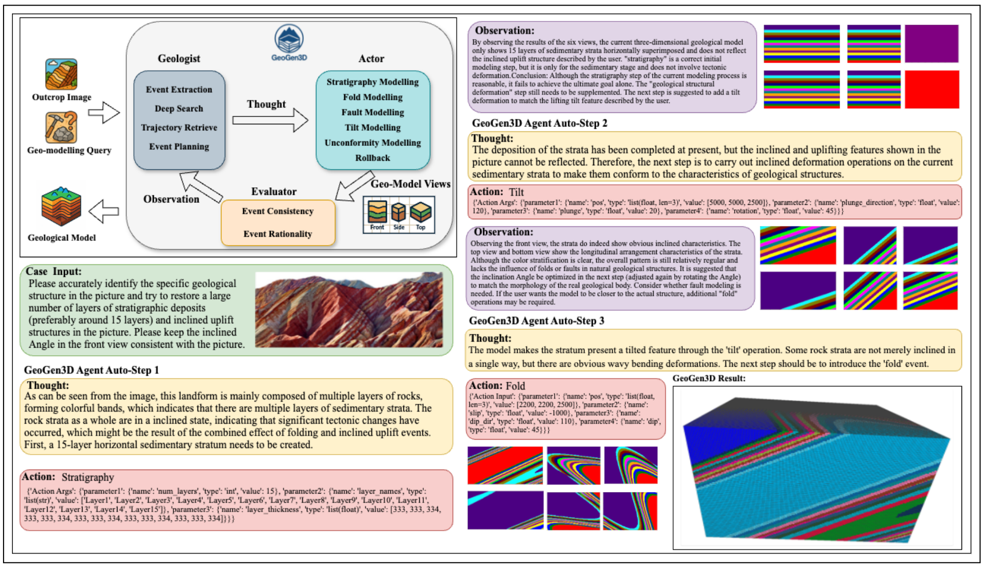
Conditional sedimentary facies modeling can accurately characterize the spatial distribution patterns of sedimentary facies, providing essential scientific support for the refined evaluation and efficient development of natural resources. Traditional multiple-point geostatistical methods rely on the assumption of spatial pattern replicability within local regions, while deep learning-based approaches are constrained by the need for stable network architectures and large volumes of high-quality training data. However, spatial patterns in different geological blocks often exhibit significant heterogeneity, and reliable training images are both scarce and costly to obtain, limiting the applicability of existing methods. To address these challenges, this study proposes a Multi-Scale Growth and Attention-Enhanced SinGAN (MSGA-SinGANc) method for conditional simulation of sedimentary facies. This method is based on a single training image, employing a progressive generator growth strategy combined with a hybrid attention module to improve network stability and accelerate convergence during training. Meanwhile, sparse well facies data are incorporated into the model to condition the simulation results, effectively reducing simulation uncertainty. A series of comparative experiments and multi-metric evaluations on various types of sedimentary facies models demonstrate the practicality and superiority of the MSGA-SinGANc method in conditional sedimentary facies simulation, offering an effective technical approach for modeling complex sedimentary facies distributions.

S1011. GeoGen3D: Agent for MultiModal-Driven Generation of 3D Geological Model

J.T. Guo (Northeastern University),
Junkun Li (Northeastern University, China),
Zhibin Liu (Northeastern University, China)
Room: B222 2025-10-10 14:50

Abstract: As digital carriers for geological research, 3D Geological Models(3DGM) enable intuitive visualization of the spatial distribution of subsurface strata, structures, and orebodies through coupled representation of geometric structures and attribute parameters. Traditional geological modeling methods heavily rely on borehole data, geological cross-sections, or geophysical survey data, requiring strict point-line-surface constraints for model construction. However, in theoretical geological studies, the scarcity of exploration data is common, and researchers often have to infer corresponding 3D geological structures based only on textual descriptions or outcrop images. To advance research on geological structures under limited data scenarios, this paper proposes GeoGen3D, an intelligent Agent for text-image multimodal-driven 3D geological modeling. (1) Based on an improved ReAct agent framework, and by constructing a comprehensive collection of Noddy-based agent tools, we leverage the deep text and image understanding capabilities of large multimodal models (LMMs) to enable intelligent generation of 3D geological models from textual or visual inputs. (2) We introduce MMGM-Eval, a multimodal 3D geological model generation benchmark, to systematically evaluate the ability of LMMs to generate geological models from multimodal prompts. The benchmark includes both text-based and synthetic image-based test sets. Experimental results demonstrate that GeoGen3D significantly outperforms direct prompt engineering approaches combining LMMs on the MMGM-Eval benchmark. GeoGen3D thus provides an efficient and intelligent modeling paradigm for multimodal-driven 3D geological model generation, especially suitable for research scenarios lacking sufficient professional exploration data.

Keyword: 3D geological modelling, LMM, Agent, generative AI, geological structure



S1012. Reconstruction of 3D Geological Structures Using Vector-Based Spatiotemporal Semantic Constraints by Integrating Deep Learning and Multiple-Point Statistics

Shuwan Ye (School of Earth Sciences and Engineering, Sun Yat-sen University), Weisheng Hou (Sun Yat-sen University),
Songhua Yang (School of Earth Sciences and Engineering, Sun Yat-sen University, Zhuhai 519082)
Room: B222 2025-10-11 11:10

Three-dimensional (3D) geological modeling is crucial in various fields. However, the representation and constraint of spatiotemporal relationships among geological blocks pose a significant challenge in modeling process. It is challenging to incorporate essential constraints such as stratigraphic sequences and fault contacts in the modeling process because conventional knowledge graphs are typically represented as undirected graphs, resulting in low quality and accuracy of the modeling results. To tackle this issue, this study, on a modeling framework that integrates deep learning (DL) with multiple-point statistics (MPS), proposes an innovative diagraph-based spatiotemporal semantic constraints method to guide pattern selection for constructing the initial model. The proposed mechanism represents the contact relationships among geological units in the X, Y, and Z directions using a diagraph, where each directed edge is determined based on the topological and temporal logic derived from geological sections during their integration into the 3D model. It allows for the explicit encoding of spatiotemporal associations within geological structures. Two synthetic datasets—a sedimentary layer model and a complex overthrust structure with thrust faults—were used to validate the effectiveness of the proposed method. The modeling results demonstrated that with the geological relationship constraints provided by the proposed method, the structures became more reasonable and smoother, and the accuracy of the final model improved by over 10% compared to the conventional MPS method. Additionally, the proposed method was applied to construct 3D geological structures at the Longzelu Metro Station in Guangzhou, southern China. This study is the first to systematically construct a directed graph-based spatiotemporal representation framework for geological modeling, which enhances the representation of temporal knowledge and addresses the key challenge of embedding semantic information into the modeling workflow.

This research was jointly supported by the NSFC (No. 42372341 and 41972302) and the Guangdong Province Introduced Innovative R&D Team (No. 2021ZT09H399).

S1013. A 3D stratigraphic modelling approach integrating bilinear interpolation and multiple-point geostatistical simulation

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Gang Liu (China University of Geosciences (Wuhan)),
Qiyu Chen (China University of Geosciences),
Ce Zhang (China University of Geosciences)
Room: B222 2025-10-11 11:30

Three-dimensional (3D) geological models provide a visual and quantitative description of complex geological structures and phenomena, which can support subsurface space development and utilization, geological disaster prediction and evaluation, etc. Image processing methods are expected to be applied to the generation of geologic profiles, but cannot incorporate the constraints of geologic knowledge. Multiple-point geostatistics (MPS) shows prospects in the automatic characterization of heterogeneous structures and phenomena, but complex geological structures hardly meet the stationarity assumption of MPS. In this work, we present a novel 3D stratigraphic modelling approach integrating bilinear interpolation and multiple-point geostatistical simulation, named 3D-BIMPS. The bilinear interpolation is used to rebuild crude cross-sections quickly. Edge detection is performed on these cross-sections to select regions that defy geologic rules. Further, precise MPS simulation is performed on these regions. Multiple connected fine cross-sections forms a entire 3D model. In our approach, bilinear interpolation is used for rough generation of geological cross-sections, and the MPS algorithm is used to correct cross-sections. Various synthetic experiments are performed to verify the performance of 3D-BIMPS. Multiple experiments show that 3D-BIMPS can efficiently and accurately reconstruct 3D models using a small number of cross-sections. 3D-BIMPS mitigates the negative influence of the strong non-stationarity of complex geological structures in MPS methods and improve modeling efficiency, so as to extend the application scope of MPS to 3D stratigraphic modeling.

S1014. Fault representation in structural geological modelling with implicit neural representations

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David Nathan (Institute of Computational Geoscience, Geothermics and Reservoir Geophysics, RWT),
Florian Wellmann (Chair of Computational Geoscience, Geothermics and Reservoir Geophysics, RWTH Aa)
Room: B222 2025-10-11 11:50

Implicit neural representations have been demonstrated to provide a flexible and scalable framework for computer graphics and three-dimensional modelling and, consequently, have also found their way into geological modelling. These networks are feature-based and resolution-independent, making them practical for modelling geological structures from scattered interface points, units, and structural orientations. Despite the advantages of current implicit neural representation approaches, effectively modelling geological faults remains a notable challenge.

In this work, we present a fault feature encoding approach to represent faults in implicit neural representations, where the discontinuous information is concatenated as additional features of observation points and query points for network input. Specifically, for infinite and semi-infinite faults, we employ binary fault features to explicitly differentiate the hanging wall from the footwall. In the case of finite faults, we introduce an ellipsoid to represent the displacement zone and subsequently encode fault features as normalized distances of points relative to the centre of this ellipsoid, and only the points inside the ellipsoid have non-zero fault feature values. Moreover, we explore the effects of ellipsoid geometry and fault feature variogram on the final predicted geological structures.

The modelling results demonstrate the method's capacity to generate a well-defined implicit scalar field while preserving sharp transitions at fault locations. Moreover, this work mentions the advantages of the presented approach over using Boolean operations and discontinuous activation functions. Furthermore, we discuss the potential opportunity to integrate prior domain knowledge and geophysics datasets into structural modelling by embedding them as model input features or incorporating them as constraints by loss functions.

S1015. Enhanced Methodology for Determining the Coefficient of Resource Scale Variation in Reservoir Size Sequential Analysis: Application to Tight Gas Reservoirs in the SC Basin

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Qian Zhang (Research Institute of Petroleum Exploration & Development, PetroChina),
Qiulin Guo (Research Institute of Petroleum Exploration and Development, PetroChina),
Shiyun Mi (Research Institute of Petroleum Exploration and Development, PetroChina),
Hongjia Ren (School of Computer Science and Engineering, Yanshan Univeristy),
Shuangling Chen (Exploration and Development Research Institute, PetroChina Southwest Oil & Gasfi)
Room: B222 2025-10-11 12:10

1 Objective

The sequential analysis of reservoir size is grounded in the Pareto principle. A critical challenge in this method is determining the coefficient 'k', which describes the gradient of resource scale variation, as it significantly impacts the method's effectiveness.

2 Methods

This study introduces an optimized methodology that calculates the ratio of discovered resource scales and applies potential sequential numbers. The method involves:

(1) Establishing a cross-plot with sequential numbers on one axis and 'k' values on the other, based on the calculated ratios.

(2) Identifying and locating data point combinations that form an approximately straight and vertical line against the 'k' axis.

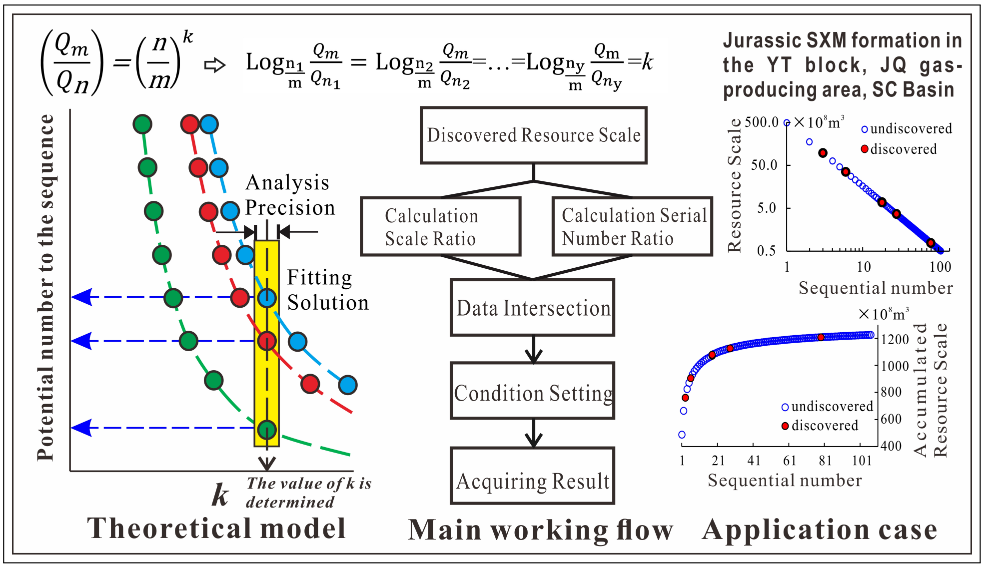
(3) Determining the intersection value on the 'k' axis, which serves as the solution for 'k'. Further principles for optimizing and validating the results to meet resource assessment needs are also suggested.

3 Results

Re-analysis of classic datasets from published literature demonstrates that this method effectively determines the coefficient 'k'. An actual application to the tight gas reservoir in the 6th group of the Jurassic SXM formation in the YT block, JQ gas-producing area, SC Basin, China, supports the method's validity. The linear fit between forecasted outcomes and actual data is favorable, and the calculated resource scale aligns with current recognitions in tight gas exploration in the SC Basin.

4 Conclusion

This methodology offers several advancements, including low dependency on geological experience, no requirement for setting analytic step sizes, and avoidance of complex determinant and matrix manipulations. It effectively reduces subjectivity and computational complexity in determining key parameters. The corresponding algorithm can be coded into computer programs, enhancing efficiency. This approach is beneficial for further applications of the reservoir size sequential method.



$\left(\frac{Q_m}{Q_n}\right)=\left(\frac{n}{m}\right)^k \Rightarrow \mathrm{Log}_{\frac{n_1}{m}}\frac{Q_m}{Q_{n_1}}=\mathrm{Log}_{\frac{n_2}{m}}\frac{Q_m}{Q_{n_2}}=\ldots=\mathrm{Log}_{\frac{n_y}{m}}\frac{Q_m}{Q_{n_y}}=k$
Potential number to the sequence
Analysis Precision
Fitting Solution
k
The value of k is determined
Theoretical model
Discovered Resource Scale
Calculation Scale Ratio
Calculation Serial Number Ratio
Data Intersection
Condition Setting
Acquiring Result
Main working flow
Jurassic SXM formation in the YT block, JQ gas-producing area, SC Basin
Resource Scale
500.0
50.0
5.0
0.5
$\times10^8m^3$
undiscovered
discovered
1
10
100
Sequential number
$\times10^8m^3$
1200
1000
800
600
400
Accumulated Resource Scale
undiscovered
discovered
1
21
41
61
81
101
Sequential number
Application case

S11 Advancing the Education of Next Generation Mathematical Geoscientists

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Zhijun Chen (China University of Geosciences (Wuhan)),
Gongwen Wang (China University of Geosciences (Beijing)),
Yalin Li (China University of Geosciences (Beijing)),
Weisheng Hou (Sun Yat-sen University),
Yongzhi Wang (Jilin University),
Zhifang Zhao (Yunnan University),
Hanting Zhong (Chengdu University of Technology),
Francisco Tognoli

With advancements in artificial intelligence (AI), machine learning (ML), and big data analytics, the field of mathematical geosciences is rapidly evolving. These innovations have significantly enhanced our ability to model, analyze, and understand complex geological processes. It is crucial to equip the next generation of mathematical geoscientists with the skills and knowledge necessary to address the urgent challenges facing our planet. This session aims to explore innovative approaches in education and training within mathematical geosciences, focusing on integrating cutting-edge technologies into the curriculum.The session will concentrate on several key objectives: 1 Curriculum Development: Discussions and presentations will feature innovative curriculum designs that integrate AI, ML, and big data analytics, ensuring students are well-versed in both traditional geological principles and modern computational techniques. 2 Pedagogical Strategies: The aim is to explore teaching strategies that foster critical thinking, problem-solving abilities, and data literacy among students. 3 Interdisciplinary Learning: The importance of interdisciplinary education will be emphasized, combining geosciences with mathematics, computer science, and other relevant fields to provide a comprehensive learning experience. 4 Practical Applications: The practical applications of mathematical geosciences in real-world scenarios, such as mineral exploration, environmental monitoring, and resource management, will be highlighted to demonstrate the field's relevance and impact. 5 Skill Enhancement: Focus on the essential skills required for the next generation, including programming, data analysis,modeling, virtual simulation and visualization. Discuss methods to enhance these skills through hands-on training and projects. The session will cover a range of subjects, from innovative curriculum models that integrate AI, ML and big data analytics to digital tools and platforms for teaching. It will also include data-driven learning, interdisciplinary collaborations, skill development workshops, career preparation and innovative assessment methods. The target audience includes educators, researchers, and professionals in the field of mathematical geosciences, as well as students and early-career scientists eager to enhance their skills. Policy makers and industry representatives interested in the development of the next generation of geoscientists are also welcome. In summary, educating the next generation of mathematical geoscientists is a critical investment in the future of our planet. This session will bring together experts to explore innovative methods in curriculum development, teaching strategies, and skill enhancement, preparing students for the complex challenges of the AI era. We cordially invite you to participate in this important discussion and contribute to the future development of mathematical geosciences education.

S1101. Landslide Assessment Using Geoinformatics: A Student-Led Initiative in Response to Brazil's 2024 Extreme Rainfall

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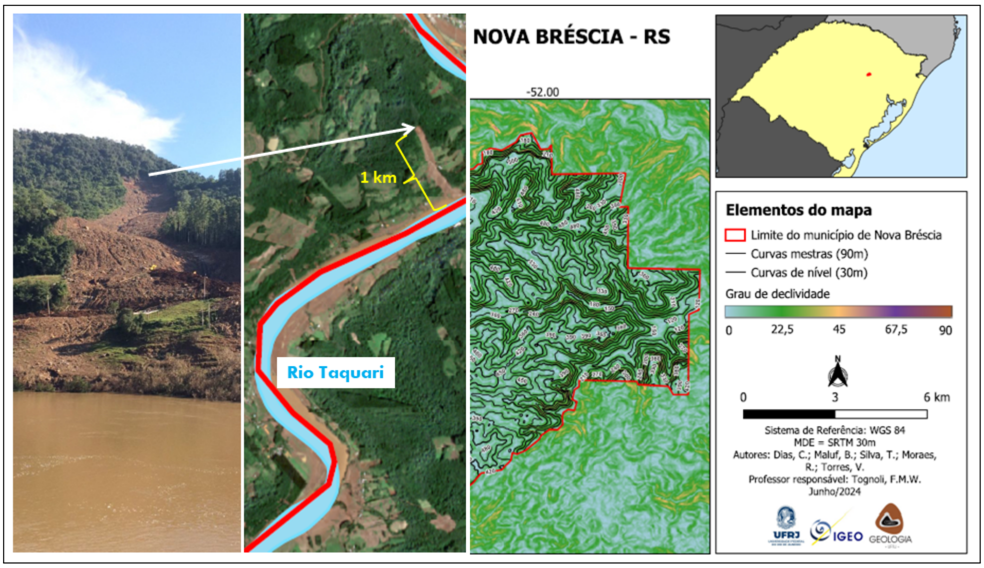
Andrea Brum (Federal University of Rio Grande do Sul),
Alexia Batista (Federal University of Rio de Janeiro),
Beatriz Maluf (Federal University of Rio de Janeiro),
Brenno Botelho (Federal University of Rio de Janeiro),
Carolina N G Dias (Federal University of Rio de Janeiro),
Gisella Roza (Federal University of Rio de Janeiro),
Iago C Jaques (Federal University of Rio de Janeiro),
João P C Amaral (Federal University of Rio de Janeiro),
João V Torres (Federal University of Rio de Janeiro),
Luiz H Melo (Federal University of Rio de Janeiro),
Marcelo Nery (Federal University of Rio de Janeiro),
Ruan Pereira (Federal University of Rio de Janeiro),
Thiago Pereira (Federal University of Rio de Janeiro),
Leticia Pataro (Federal University of Rio de Janeiro),
Victor E Martins (Federal University of Rio de Janeiro),
Maria Eduarda Candida Francklim Francisco (Federal University of Rio de Janeiro)
Room: B222 2025-10-10 10:30

April–May 2024 will be unforgettable for many Rio Grande do Sul (RS) residents in southern Brazil. The Taquari River Valley (TRV) experienced the most severe hydro-meteorological disaster on record, driven by a combination of extreme rainfall intensified by El Niño, geological vulnerability and anthropogenic factors. Over three days (April 30–May 2), cumulative rainfall exceeded 500 mm across an area of 11,674 km^2, reaching over 600 mm in a concentrated region of 427 km^2 near the TRV. This event is the most intense three-day rainfall episode ever recorded in Brazil at spatial scales ranging from 2,000 to 100,000 km^2. In addition to widespread flooding, more than 15,000 rupture points and associated mass movements were recorded in the region known as Serra Gaúcha. During this period, a group of undergraduate Geology students (Geoinformatics course) at the Federal University of Rio de Janeiro (UFRJ) was searching for a topic for a practical assignment based on the principles of problem-based learning. Given the unprecedented tragedy and the impossibility of accessing the affected areas in person, a faculty member and a volunteer geologist helped students develop actions to support the civil defense authorities and municipal departments in 15 municipalities within the TRV. The students integrated geospatial data and computational tools to produce hypsometric, topographic and slope maps using remote sensing imagery, Python programming, Google Earth Engine and GIS software. These maps were designed to assist volunteers in creating a landslide inventory, facilitating the assessment of impacted areas and supporting informed decision-making. The final products were exported in GeoPDF format, enabling anyone to use them in offline mobile mapping apps (e.g., Avenza®) in the field. The maps were distributed through civil defense and municipal departments of environment, planning and public works, accompanied by a user-friendly tutorial written in plain language.



S1102. Virtual Simulation Experimental Teaching Course of Crystal Morphology Analysis and Mineral Identification

Yanjun Guo (School of Earth and Space Sciences, Peking University),
Shan Qin (School of Earth and Space Sciences,Peking University),
Jinjiang Zhang (School of Earth and Space Sciences,Peking University,),
Bin Chen (School of Earth and Space Sciences,Peking University),
Mei Li
Room: B222 2025-10-10 10:50

The course is designed to align with the objectives of cultivating morality and talents in the context of ”Double First-Class” construction and the ”14th Five-Year Plan.” This course aims to explore higher education revolution by integrating virtual reality and augmented reality technologies into curriculum construction. By virtual simulation technology, the course addresses the limitations of traditional micro-level experiences in curriculum development. Cloud computing is utilized to facilitate the sharing of high-quality educational resources, ensuring equitable access to education for all learners. The course offers an immersive learning experience, tightly integrating AR/VR/MR and 3D printing technologies. Students engage in micro world operations such as crystal structure splitting and morphology analysis. They learn to analyze crystal monomer types, determine their symbols, derive potential monomers within fixed point groups, and submit internship reports. Mineral identification experiments are divided into mineral examples and self-directed learning, followed by assessments and report submissions. Incorporating virtual simulation technology, the course fosters new teaching content and establishes a three-dimensional interactive classroom. Cloud technology supports large-scale online open teaching, enabling widespread access to the course. The collaborative development of a virtual simulation course platform by both teachers and students facilitates comprehensive assessment of students’ academic progress and evaluation of the course. The course represents a paradigm shift in teaching, manifesting five innovative transformations: moving from ”static abstraction” to ”three-dimensional intuition” in curriculum design, from ”indoctrination” to ”interaction” in teaching methods, from ”imparting” to ”cooperation” in the teacher-student relationship, from ”single score” to ”comprehensive evaluation” in assessing student performance, and from a ”teaching-centered” to a ”learning-centered” approach in the overall teaching model. Through these innovations, the course achieves a profound and innovative reform in undergraduate geoscience curriculum, in a new course of immersive, interactive, and student-centered education.

S1103. Digital Technology in the Protection of Geological Heritage — A Case Study on the Porcelain Clay and Stone Mine Sites from Jingdezhen City, Jiangxi Province, China

Zhijun Chen (China University of Geosciences (Wuhan))
Room: B222 2025-10-10 11:10

Geological heritage carries rich earth scientific information and cultural values. Digital technology provides important high-tech means for the protection and restoration of geological heritage, demonstrating diversity. Jingdezhen city is world-famous as ”the Porcelain Capital”. The transformation of Jingdezhen’s ceramic production from a single raw material to a “binary” body formula of “porcelain stone + kaolin” was a significant revolution in the history of porcelain making in China and even the world, earning Jingdezhen the reputation of a thousand-year porcelain capital. In modern times, with the depletion of high-quality porcelain stone and kaolin raw materials for porcelain production, protecting the mining relics left by predecessors, promoting the long-standing history and culture, and exploring a revitalization path through transformation have become inevitable choices for Jingdezhen’s urban development. By studying the effective integration of different digital technologies, the scientificity and systematicness of geological heritage protection have been effectively improved. Based on the field geological survey of the porcelain stone deposits and the kaolin deposits in the town of Yaoli, Jingdezhen city, multi-view image 3D reconstruction technology was used to carry out high-precision 3D modeling of various types of identification specimens and cave mining sites, and drone technology was used to carry out panoramic image acquisition. The practice of the Jingdezhen porcelain clay and stone mine sites has shown that digital technology effectively can improves the efficiency and scientificity of geological heritage protection, promote the long-term protection and sustainable development of geological heritage.

S1104. The Development of Scientific Research Platforms for Mathematical Geosciences and the Implementation of Talent Cultivation Practices

Bingli Liu (Chengdu University of Technology)
Room: B222 2025-10-10 11:30

The Mathematical Geology Key Laboratory of Sichuan Province is affiliated with Chengdu University of Technology was approved to establish in 2010. Over the 15-year construction and development period, guided by national and Sichuan provincial science and technology development plans, the laboratory has centered on the national economy's demand for mineral resources and focused on frontier areas in mathematical geoscience. It has conducted applied basic research involving deep integration of mathematics and geosciences, established widely influential research teams, and cultivated multidisciplinary innovative talents. Anchored in Sichuan while serving the Qinghai-Tibet Plateau and surrounding regions, and extending its influence nationwide, the laboratory provides theoretical foundations, technical support, talent resources, and scientific consultation for fundamental and public-interest mineral resource research. Through years of development, the laboratory has evolved into a western China research base in the field of mathematical geosciences.

S12 Mining geostatistics, optimization and geometallurgy

Raimon Tolosana Delgado (Helmholtz Institute Freiberg for Resource Technology HIF-HZDR),
Jörg Benndorf (Technische Universität Bergakademie Freiberg),
K. Gerald van den Boogaart (Helmholtz Institute Freiberg for Resource Technology HIF-HZDR),
Julian Ortiz

The sessions aims to bring together all aspects of mining-relevant mathematical methods, along the whole mining cycle from exploration targeting to mine closure and on all scales from microstructure characterization to the long term mine planning and multi mine site operation planning. Important areas are: quantification and modelling of rock microstructures, geostatistics of geometallurgical variables incl high-order methods, modelling of beneficiation processes, structural modelling with uncertainty, stochastic mine planning, real time mining updating, and predictive process optimization. Contributions from all fields of application or development of geomathematical methods for mining are welcome.

S1201. Kernel Embedding of High-Order Spatial Statistics: A New Framework and Its Applications

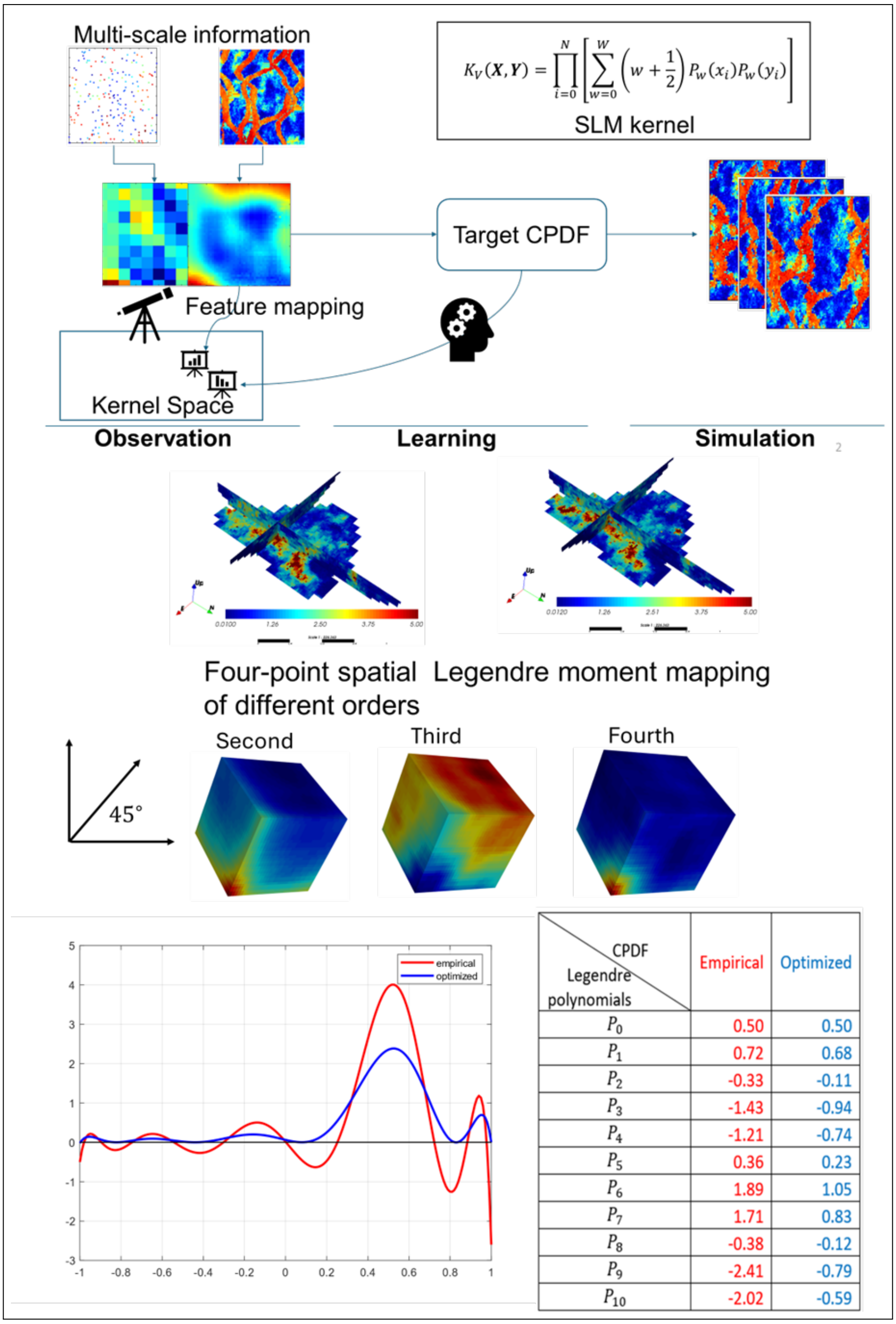
Lingqing Yao (Norda Stelo),
Roussos Dimitrakopoulos (COSMO – Stochastic Mine Planning Laboratory, Department of Mining and Materials Engineering, McGill University)
Room: D205 2025-10-10 14:30

High-order spatial statistics and related simulation methods have been developed to overcome the limitations of conventional geostatistical techniques in capturing and reproducing complex spatial patterns of natural attributes. Just as variograms serve as key signatures of Gaussian random fields in conventional geostatistics, high-order statistics have been introduced to characterize interactions among multiple locations, often manifesting as intricate spatial structures. These statistics enable the modeling of non-Gaussian random fields and skewed distributions commonly observed in Earth sciences.

This work introduces a new framework for encoding high-order spatial statistics in a feature space via kernel embedding. Specifically, a kernel space is constructed where high-order spatial statistics—whether derived from non-Gaussian multi-point distributions or observed data—are represented as elements. The kernel function measures the similarity between these elements based on their high-order spatial statistical behavior.

This framework opens new avenues for leveraging high-order statistics in a variety of applications. First, kernel moment mapping is presented for spatial pattern analysis in kernel space, facilitating the characterization of complex spatial structures from data. Second, a high-order simulation is carried out in kernel space via statistical learning, aligning the probability distribution of the underlying random field with observed data and training images. Finally, the stabilization of conditional probability density estimation using polynomial bases within high-order simulations is achieved through convex optimization in kernel space.

These applications highlight both the flexibility and effectiveness of the proposed kernel-based framework.



CPDF / Legendre polynomials	Empirical	Optimized
P_0	0.50	0.50
P_1	0.72	0.68
P_2	-0.33	-0.11
P_3	-1.43	-0.94
P_4	-1.21	-0.74
P_5	0.36	0.23
P_6	1.89	1.05
P_7	1.71	0.83
P_8	-0.38	-0.12
P_9	-2.41	-0.79
P_{10}	-2.02	-0.59

S1202. A Scalable Algorithm for High-Order Spatial Cumulant Computation via Dynamic Tree Optimization

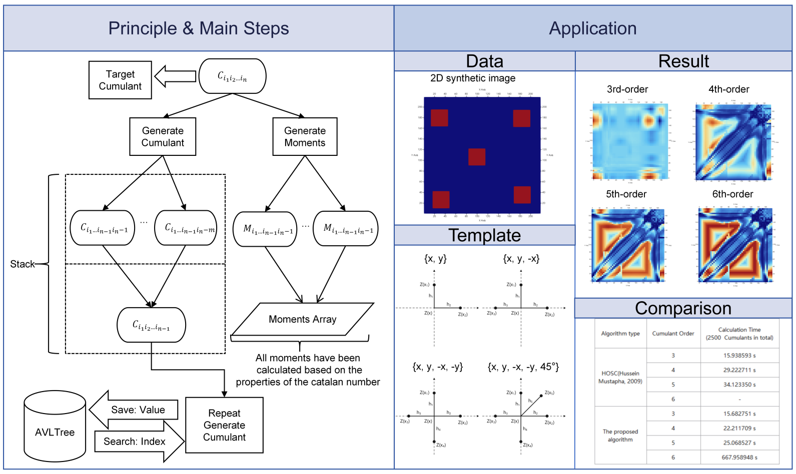
Zhanglin Li,
ziquan dai (China University of Geosciences (Wuhan)),
Xialin Zhang ( ),
Zhengping Weng ( ),
Zhiting Zhang ( ),
Gang Liu (China University of Geosciences)
Room: D205 2025-10-10 14:50

High-order spatial cumulants(HOSC) offer a theoretically grounded and general framework for capturing complex geological characteristics, including curvilinear structures, spatial heterogeneity, geometric relationships, and the connectivity of extreme values. Despite their potential, practical application has been limited by the computational burden associated with increasing cumulant order.

This study presents an efficient algorithm for computing arbitrary-order spatial cumulants. By transforming recursive calculations into an iterative process using stack-based storage, and introducing a dynamically balanced binary search tree indexed by lag distance, the algorithm avoids redundant computations. Additionally, the use of Catalan number properties ensures that each unique generating moment is computed only once, significantly improving efficiency.

The method was tested on 2D synthetic image and 3D geological image. The geological image is derived from the Ashele Cu-Zn deposit in China, characterized by strong nonlinearity and non-Gaussian features. Results show that third- to fifth-order spatial cumulants computed using the proposed algorithm match existing methods in capturing anisotropic geometry, while achieving a 1.36× increase in computation speed. Sixth- and seventh-order cumulants further enhanced the detection of ore body boundaries and multi-point spatial interactions, accurately reflecting spatial variations in ore grade.

By enabling fast and accurate computation of arbitrary-order cumulants, this work expands the practical utility of high-order spatial statistics in geological modeling. It provides a robust, scalable tool for detailed 3D characterization of mineral deposits, advancing the application of spatial cumulants from theoretical models to engineering practice.


Principle & Main Steps
Application
Target Cumulant
Generate Cumulant
Generate Moments
Stack
Moments Array
All moments have been calculated based on the properties of the catalan number
AVLTree
Save: Value
Search: Index
Repeat Generate Cumulant
Data
2D synthetic image
Template
{x, y}
{x, y, -x}
{x, y, -x, -y}
{x, y, -x, -y, 45°}
Result
3rd-order
4th-order
5th-order
6th-order
Comparison
Algorithm type
Cumulant Order
Calculation Time (2500 Cumulants in total)
HOSC(Hussein Mustapha, 2009)
3
15.938593 s
4
29.222711 s
5
34.123350 s
6
-
The proposed algorithm
3
15.682751 s
4
22.211709 s
5
25.068527 s
6
667.958948 s

S1203. Microstructure Aware Stochastic Geometry Models for Comminution Modelling

Raimon Tolosana Delgado (Helmholtz Institute Freiberg for Resource Technology HIF-HZDR),
Felix Ballani (Helmholtz Institute Freiberg for Resource Technology HIF-HZDR),
K. Gerald van den Boogaart (Helmholtz Institute Freiberg for Resource Technology HIF-HZDR)
Room: D205 2025-10-10 15:10

For most mining operations, comminution is the most energy-intensive part of minerals processing. The ore microstructure and the way they break during comminution determine their liberation and, consequently, the amount that can be recovered through physical concentration processes. Currently two types of comminution models exist: (1) quickly computable stochastic models that ignore ore microstructure and (2) those that can consider a given microstructure through very computation intensive numerical models of continuum and break mechanics. This contribution attempts to combine the advantages of both approaches through stochastic models that can consider the ore microstructure and be fitted to actual milling operations through a few parameters that capture the processing-relevant aspects of the comminution behavior of certain rock types across local variations of the ore within a deposit.

Our models combine a random marked mosaic modelling the crystalline structure of a multimineral ore with a second random mosaic model modeling the comminution process. The rules for generating the second mosaic from a point process can be modified in several meaningful ways depending on the existing microstructure, for example incorporating a tendency to break through certain mineral phases, or along mineral boundaries or certain types of crystallite interfaces. These modifications can be combined with more general, parametrisable versions of the point process-based mosaic models that we presented at IAMG 2024 for microstructure modelling. For example, point intensity can be used to parameterise particle sizes, regularity parameters can be used to modify the roundness of the resulting particles and mark distributions can be used to modify the variability of particle sizes. Such comminution models can be used to model individual comminution steps and can be applied iteratively for multiple-step comminution, comminution circuits, or combined with parametric microstructure models to create a flexible model of particle populations.

S1204. JuliaFlow: A Particle Process Modelling Software in Julia

Felix Ballani (Helmholtz-Institute Freiberg for Resource-Technology, Freiberg, Germany),
Raimon Tolosana Delgado (Helmholtz Institute Freiberg for Resource Technology HIF-HZDR),
K. Gerald van den Boogaart (Helmholtz Institute Freiberg for Resource Technology HIF-HZDR)
Room: B210 2025-10-11 10:30

Geometallurgical optimisation of processing requires fast simulations of physical and mechanical separation processes that can consider complex populations of multi-mineralogical particles. Models for individual steps typically combine property calculations for individual particles with process models, which may be based on formulae from literature, statistical model fits or machine learning. Most fitting algorithms of such models to observed process data require hundreds to thousands of simulations to be computed within a single operation of the fitting algorithm. To incorporate uncertainty into such models, e.g. for stochastic optimisation, does also require such amounts of simulations to be computed and evaluated with varying material and processing parameters. Existing process modelling software such as HSC Sim, Espen Plus, etc. is typically neither capable of working with complex populations of multi-phased particles nor of incorporating different kinds of models in the same run. Furthermore, such commercial software suites are not designed to be used interoperably within other algorithms.

We have therefore developed a toolbox for the particle-based modelling of physical separation processes under uncertainty within the Julia programming language, which combines the speed of native computation with the capabilities of a high-level programming language. The toolbox can handle complex networks of mechanical and physical processing units in steady state, transient operation and batch mode, describing these processes at the level of particle properties instead of by using property bins or population balance models, and can be seamlessly integrated with other codes available in Julia, R, python or C/C++.

S1205. Evaluating a locally varying linear regression approach for geometallurgical modeling

Alvaro Riquelme (Universidad Adolfo Ibañez),
Julian M. Ortiz,
Raimon Tolosana Delgado (Helmholtz Institute Freiberg for Resource Technology HIF-HZDR)
Room: B210 2025-10-11 10:50

In most mining operations, the ore body is characterized by abundant sampling of grades and elemental concentrations, and limited minerals characterization and metallurgical tests. The latter are usually done in limited locations of interest. Understanding the relationships of these responses to the characterized variables is important in forecasting the project's performance. However, this task is hindered by the non-linear relationship of geometallurgical responses when aggregating samples. We propose a spatial statistical approach to analyze local geometallurgical relationships. We consider as a working hypothesis that within small regions, relationships between primary properties—e.g. elemental and mineral abundances—and geometallurgical responses can be approximated by a linear regression.

By calibrating a linear regression model at each sample location, a collection of local models is generated that decomposes the global non-linear behavior across the domain. Attention is given to the geometric properties of the resulting regression planes to ensure rigorous statistical and geostatistical analysis. For example, a key consideration is the geometric interpretation of the regression planes. Unlike linear classification problems, where hyperplane orientation defines specific categories, the orientation of a regression plane —that is, which side is assigned with a unit normal vector— lacks meaning in the regression problem, and an equivalence relation is needed. To address this, we employ Riemannian geometry, mapping the models onto a Grassmann manifold to isolate meaningful geometric properties while discarding arbitrary orientation effects. This enables statistical analysis, Gaussianization of probability distributions using adapted iterative methods, and spatial interpolation of the models. By treating the geometallurgical response model as a regionalized variable, we achieve plausible predictions in under-sampled zones. Additionally, uncertainty quantification and scenario generation is enabled through classical Gaussian simulation methods. This framework bridges classical machine learning techniques with geostatistical principles, providing a rigorous methodology for geometallurgical modeling. The approach is demonstrated through an illustrative case study.

S1206. Geostatistical Modeling of Iron and Sulfur in Mine Tailings: Comparative Evaluation of Co-Kriging Methods for Mitigating Acid Mine Drainage (AMD)

Artur Korniyenko (Nazarbayev University),
Nasser Madani (School of Mining and Geosciences, Nazarbayev University),
Mohammad Maleki (Department of Metallurgical and Mining Engineering, Universidad Católica de Nort),
Annika Parviainen (Departamento de Edafología y Química Agrícola, Universidad de Granada, Avda. Fu)
Room: B210 2025-10-11 11:10

Reprocessing mine tailings is increasingly valued for recovering critical minerals and reducing environmental risks like acid mine drainage (AMD). AMD occurs when pyrite (FeS) oxidizes, producing sulfuric acid and releasing heavy metals, which can contaminate ecosystems. Mitigating AMD requires spatial modeling of Fe and S, key components of pyrite. Advanced geostatistical methods, such as kriging and cokriging, are widely used, with cokriging particularly effective for heterotopic sampling patterns.

This study compares three cokriging methods—simple cokriging (SCK), ordinary cokriging (OCK), and ordinary cokriging with related means (OCK-RM)—to model Fe and S in the Haveri mine tailing deposit, Finland. The dataset shows a strong correlation (0.845) between Fe and S. Models were assessed based on RMSE from cross-validation and their ability to reproduce the original means of 10.0184 for Fe and 3.1046 for S. SCK produced the closest means (8.9410 for Fe, 3.0713 for S), followed by OCK (9.8148 for Fe, 3.0522 for S). OCK-RM deviated the most (1.4023 for Fe, 0.8000 for S). However, all methods showed a smoothing effect, overestimating low grades and underestimating high grades, impacting accurate prediction.

For RMSE, OCK achieved the highest accuracy (1.3894 for Fe, 0.7915 for S), followed by OCK-RM (1.4023 for Fe, 0.8000 for S), while SCK had the highest RMSE (1.4344 for Fe, 0.8199 for S). Despite its superior accuracy, OCK failed to estimate 417 blocks, creating gaps in the block model. In contrast, OCK-RM provided complete spatial coverage while maintaining competitive RMSE values, making it more practical for application in mineral resource estimation.

While OCK is the most accurate, its lack of full coverage limits its usability. OCK-RM balances accuracy and coverage, making it ideal for modeling Fe and S distribution, supporting sustainable tailings management, and mitigating AMD effectively.

S1207. An innovative implicit geological modeling using Dirichlet-based multi-output Gaussian Processes

Rustam Zhanabayev (School of Mining and Geosciences, Nazarbayev University), Nasser Madani (School of Mining and Geosciences, Nazarbayev University)
Room: B210 2025-10-11 11:30

Geological modeling in mining creates 3D models of ore bodies and geology to support resource estimation and mine planning. Two main approaches are explicit and implicit modeling. Explicit geological modeling is time-consuming and challenging to replicate, as it depends on manual digitization. In contrast, implicit modeling is faster and better suited for capturing complex geological structures. It offers models with fewer artifacts and allows for dynamic updates directly from raw data.

In this research, we propose using a Dirichlet-based Gaussian Processes (GPs) classification algorithm to build an implicit geological model. The model is a multi-output GP regression method, where a latent GP represents each lithology class. The GP model transforms class labels using a Dirichlet distribution to estimate the probability of each rock type at every location in 3D space. The method uses a deep feature extractor to capture complex geological patterns, and Reinforcement-Learned Kernel Search to find the most suitable kernel functions (or equivalently covariance functions) for the lithological data.

The methodology is applied to modeling three rock types in a copper Porphyry deposit. It generates a block model that accurately represents lithological distributions. The Dirichlet Classification Likelihood maps categorical lithology labels to Dirichlet-distributed targets using log-space regression with a Gamma approximation. A shared-kernel multi-output GP is then trained to model all lithology classes jointly. Predictions are made by applying a softmax transformation to the GP outputs, yielding normalized class probabilities, from which the most likely rock type is assigned to each block.

Model performance was evaluated using random sub-sampling validation with 5 runs and 70/30 training/testing sets. The average accuracy across runs was calculated by comparing predicted and true lithology labels. The Dirichlet-based GP approach achieved 96.5% average accuracy, outperforming Indicator Kriging, which gained 92%. These results demonstrate the method's effectiveness, supporting better resource estimation and mine planning.

S1208. From Feasibility to Accuracy Optimization: SLAM-based wheeled Robots for Underground Geomonitoring

Jing Li (TU Bergakademie Freiberg),
Jörg Benndorf (TU Bergakademie Freiberg)
Room: B210 2025-10-11 11:50

Simultaneous Localization and Mapping (SLAM) has revolutionized autonomous navigation in GPS-denied environments and has demonstrated robust performance in both indoor and outdoor surface scenarios. Underground geomonitoring is critical for safety but requires long-term, continuous and repeated measurements, highlighting the need for autonomous and AI-driven solutions. This work bridges SLAM and geomonitoring, providing a systematic investigation into the use of SLAM-based robots for underground geomonitoring. It covers multiple phases, from feasibility analysis to accuracy optimization, and summarizes the key findings from three related research studies. In the first phase, a quantitative SLAM accuracy evaluation method was proposed. A LiDAR-based and a vision-based SLAM were evaluated at the designed real underground test site to determine the feasibility of SLAM-based wheeled robots in underground geomonitoring. Results showed that visual SLAM suffered from instability and inaccuracy, whereas LiDAR-based SLAM achieved centimetre-level accuracy but remained insufficient for high-accuracy underground geomonitoring. Given the limited research on underground SLAM and the unique challenges of such environments, including their complexity and limited accessibility, SubSurfaceGeoRobo, a comprehensive underground dataset featuring multi-sensor recordings and a joint calibration framework, was introduced in the second phase. This dataset enables researchers to test and develop underground SLAM algorithms, thereby supporting advancements in underground geomonitoring and mapping. To further optimize SLAM accuracy under the constraints of underground geomonitoring, the third phase focuses on a mine surveying-oriented evaluation of various state-of-art LiDAR-Inertial Odometry, LiDAR-Inertial-Visual Odometry, and radar-based SLAMs. Key parameters influencing underground SLAM performance were identified, and the most suitable SLAMs for underground geomonitoring and mapping applications were determined. This work demonstrates the potential of SLAM-based wheeled robots as an efficient solution for underground geomonitoring, while identifying key factors affecting their accuracy. The presented datasets and methodologies provide a solid foundation for future developments in autonomous underground surveying and intelligent monitoring systems.

S1209. Assessment of Hybrid Machine Learning-Kriging Frameworks for Improved Spatial Interpolation in Mineral Exploration

Hosang Han (Kangwon National University),
Geonwoo Lee (Kangwon National University),
Jangwon Suh (Kangwon National University)
Room: B210 2025-10-11 12:10

The selection of new exploration target areas is crucial for maximizing efficiency and success rates within limited time and budget constraints. Recent endeavors to enhance exploration accuracy by combining geostatistical (GS) methods with machine learning (ML) models have primarily focused on evaluating the performance of hybrid models, without providing practical recommendations for candidate sites. To address this gap, this study aims to proposes additional mineral exploration zones by deriving the best interpolation model through diverse combinations of ML models and GS methods. A total of 272 aluminum concentration samples were split into training (70%), validation (20%), and test (10%) sets. Among ML models, three tree-based models (Random Forest, XGBoost, AdaBoost) and three neural network (NN)-based models (ResNet1D, U-Net1D, Spatial Transformer) were employed for training and prediction. The prediction residuals (predicted − observed values) from each ML model were interpolated using ordinary kriging (OK) and universal kriging (UK), then summed with the ML predictions to construct 12 ML–GS hybrid models. Hyperparameters were optimized via RandomizedSearchCV and NeuralNetRegressor, each conducting five-fold cross-validation. Model performance was assessed using root mean square error (RMSE) and coefficient of determination (R2). Based on test dataset predictions, new exploration candidate sites were delineated. Results showed that all hybrid models consistently outperformed single models, with UK-combined models exhibiting superior predictive power over OK-combined ones. The XGBoost–UK hybrid model emerged as the best performer, its gradient-boosting error minimization synergizing with UK's polynomial trend modeling of global spatial patterns to significantly enhance interpolation accuracy. The proposed interpolation framework supports efficient, economical exploration by guiding the selection of an optimal ML–GS hybrid according to data characteristics and objectives.

This work was supported by the Energy & Mineral Resources Development Association of Korea (EMRD) grant funded by the Korean government (MOTIE) (2021060001, Data science-based oil/gas exploration consortium).

S1210. Machine Learning Mineral Resource Estimation with the Correct Scale and Block Variance

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Gamze Erdogan Erten (Centre for Computational Geostatistics (CCG), Department of Civil and Environmen),
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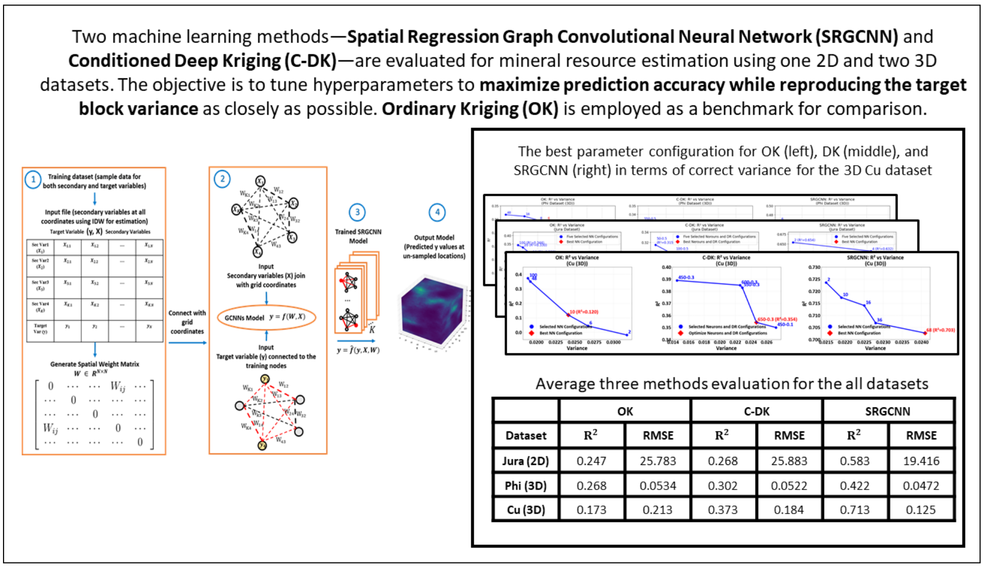
Room: D205 2025-10-11 14:30

Machine-learning (ML) algorithms are increasingly employed in mineral resource estimation (MRE) because they offer a flexible representation of the non-linear spatial continuity of ore bodies. However, most applications neglect the change-of-support problem, whereby grade variance reduces when data are aggregated from sample to block support, thus potentially biasing block models that do not consider this. In this study, block-scale variance—calculated with Krige's volume–variance relation—is explicitly incorporated as a constraint during hyperparameter tuning of two networks: Conditioned Deep Kriging (C-DK) and the newly proposed Spatial Regression Graph Convolutional Neural Network (SRGCNN). SRGCNN, introduced here in the context of geostatistical modeling, captures spatial structure and feature similarity through graph-based learning. Hyperparameters are tuned to maximize the coefficient of determination (R^2) and to ensure that predicted block grades reproduce the target variance. The workflow is evaluated on the public 2D Jura dataset and on two 3D datasets for copper grade and porosity estimation, with Ordinary Kriging (OK) serving as the benchmark. Relative to OK, C-DK increases R^2 from 0.247 to 0.268 on Jura, from 0.268 to 0.302 on porosity, and from 0.173 to 0.184 on copper; SRGCNN attains higher R^2 values of 0.583, 0.422, and 0.713, respectively, by jointly modeling spatial autocorrelation and attribute similarity within an irregular graph of composites. Both networks honor the prescribed block variance, mitigate smoothing bias, and yield statistically coherent block models—establishing a rigorous and computationally efficient pathway to integrate geostatistical theory with modern ML for data-driven MRE.



	OK		C-DK		SRGCNN	
Dataset	R^2	RMSE	R^2	RMSE	R^2	RMSE
Jura (2D)	0.247	25.783	0.268	25.883	0.583	19.416
Phi (3D)	0.268	0.0534	0.302	0.0522	0.422	0.0472
Cu (3D)	0.173	0.213	0.373	0.184	0.713	0.125

S1211. Detecting rich layer structures of Rare Earth Elements in deep sea muds by geostatistical and unsupervised learning methods

Vitor Ribeiro de Sá (Kyoto University),
Katsuaki Koike (Graduate School of Engineering, Kyoto University)
Room: D205 2025-10-11 14:50

Rare earth elements and yttrium (REY) are vital for advancing modern industries and transitioning towards sustainable technologies. As REY gains increasing importance in raw material policies, deep-sea mining emerges as a promising alternative to land-based mining, potentially reducing environmental impacts. REY are primarily hosted in bioapatite, a mineral phase crucial for understanding their distribution in marine environments. This study focuses on modeling REY-rich layers in a seafloor deposit within the Japanese exclusive economic zone using a multivariate dataset comprising major elements (e.g., P2O5 and MnO), minor elements, and REY. A key challenge in geostatistical modeling of their contents is addressing the effect of closure, which expresses the data as proportions, potentially distorting linear patterns. To overcome this problem, the dataset is log-ratio transformed. We apply geostatistical methods: Turning Bands Simulation (TBSIM) and Truncated Gaussian Simulation (TGSIM), alongside machine learning techniques: Principal Component Analysis (PCA) and Hierarchical Clustering Analysis (HCA), to optimize data and build 3D spatial models of REY-rich layers. PCA helps reduce the dimensionality of the multivariate dataset, facilitating the identification of key patterns, and HCA allows for the classification of pelagic layers based on REY-grade features. The spatial modeling result through TBSIM and TGSIM reveals the distribution and formation processes of high REY content layers. In addition, the HCA result indicates distinct groups of REY concentrations, which are further elucidated through the application of TGSIM. Our methodology enhances the understanding of REY deposit formation in the deep seafloor and provides a robust framework for mineral resource modeling in frontier regions.

S1212. Block Co-simulation of Multi-element Mine Tailings: Enhancing Resource Estimation through Sequential Gaussian and Turning Bands Approaches

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Room: D205 2025-10-11 15:10

Block co-simulation plays a critical role in modern resource estimation by capturing spatial uncertainty at the volumetric scale relevant to mining operational decisions. In multi-element mine tailings, accurately capturing the joint spatial distribution of correlated metals is essential for reliable grade-tonnage forecasting and effective environmental management. This study evaluates the performance of block-support Sequential Gaussian Co-simulation (SGCOSIM) and block-support Turning Bands Co-simulation (TBCOSIM) at the Haveri copper mine tailings site in Finland, focusing on modeling of four cross-correlated variables: copper (Cu), silver (Ag), sulfur (S), and iron (Fe).

A notable challenge was the non-additive nature of Fe, which required density correction across all variables to ensure consistency in block-support simulations. Thus, simulations were conducted on metal mass rather than grade values. Additionally, the heterotopic nature of the dataset – featuring only 192 sulfur samples compared to 1,114 for Cu, Ag, and Fe – necessitated robust co-simulation strategies to accurately reproduce spatial cross-correlations.

Both methods generated 100 realizations using a 5 × 5 × 1 m block size with a 5:5:1 discretization scheme, under the assumption of simple kriging. Validation based on variogram reproduction and statistical parameters indicated that SGCOSIM and TBCOSIM achieved comparable quality in block simulations. While both methods yielded realizations with comparable statistical reproducibility under equivalent neighborhood parameters, SGCOSIM required significantly more computational time than TBCOSIM. Consequently, TBCOSIM is preferred for its superior computational efficiency, particularly when larger neighborhoods are required.

Keywords: Block Co-simulation; Resource Estimation; Sequential Gaussian Co-simulation; Turning Bands Co-simulation; Non-additivity; Density Correction; Mine Tailings; Multivariate Geostatistics

S1213. Tools and statistical tests to assess spatial decorrelation

Raimon Tolosana Delgado (Helmholtz Institute Freiberg for Resource Technology HIF-HZDR),
Ute A. Mueller (Edith Cowan University, Perth, Western Australia)
Room: D205 2025-10-11 16:30

In geostatistical simulation the modelling of multivariate spatial data is usually preceded by the application of a spatial decorrelation procedure, such as PCA, MAF or UWEDGE, in addition to a transformation to multivariate normality (PPMT, RBIG, FlowAnamorphosis etc). If the quality of the spatial decorrelation is appraised at all, this is done by rule of thumb. The common measures used for this appraisal are square and relative deviation from diagonality along with spatial diagonalisation efficiency. These can be evaluated numerically and graphically and there are guidelines under which decorrelation is deemed adequate. For none of these is there a statistical distribution that would allow performance of a test for statistical significance and so this question has been ignored. The main reason is the presence of autocorrelation in the variables, which makes tests in the spatial domain infeasible. We propose an approach that makes use of the fast Fourier transform to construct a test statistic in frequency space based on estimates of the auto-and cross covariance functions. The distribution of the test statistic is obtained from permutations of the data so that the test can be considered non-parametric. We show that this distribution approximates the exact distribution for the most common stationary variogram functions. In this contribution we illustrate the various appraisal tools and tests applied to both simulated as well as real case studies from mining.

S1215. A case study on top-cut model for reserve estimation of a fracture-related gold deposit

XIAONING LIU (China University of Geosciences (Beijing)),
Sara Kasmaeeyazdi (University of Bologna),
Francesco Tinti (University of Bologna),
Gongwen Wang (China University of Geosciences (Beijing))
Room: D205 2025-10-11 16:50

Accurate gold reserve estimation and 3D resource modelling using blasthole data remains a significant challenge due to the presence of highly skewed, long-tailed grade distributions dominated by extreme high-grade values. This issue frequently arises in gold deposit grade estimation, particularly in fault-controlled gold deposits with high grade variability. With applying kriging estimation, there are challenges due to a tiny minority of extreme values with a significant proportion of the metal content and part of the data variability, potentially introducing estimation bias. Traditional approaches such as capping, have been employed to address this challenge, which can yield acceptable results in some mining operations, but exists underestimation risk. To improve the practices of handling long-tailed grade data, top-cut model (2013) was proposed. This method decomposes the grade data into three components: a truncated grade representing the mid-to-low grade population, a weighted indicator term representing the mid-to-high grade population, and a residual term capturing the extremely high-grade population. The estimation is based on the cokriging of the truncated grade and the indicator and a separate kriging for residuals. Using a fault-controlled gold deposit, Xincheng gold deposit in China as a case study, this paper evaluates the estimation performance of the top-cut model compared to ordinary kriging and capping through cross-validation and block model validation via trench data. The result shows that top-cut model provides the best estimates for the gold orebody with high spatial variety compared to other methods. Furthermore, it is revealed that the estimation of top-cut model effectively limits the spatial influence of outliers while preserving more variability of the grade distribution—crucial for realistic reserve estimation and informed mine planning.

S13 Intelligent Reservoir Characterization and Modeling

Qiyu Chen (China University of Geosciences),
Guillaume Pirot (The University of Western Australia),
Zhesi Cui (School of Computer Science, China University of Geosciences (Wuhan)),
Shaoqun Dong (China University of Petroleum (Beijing)),
Gang Liu (China University of Geosciences),
Shu Jiang (China University of Geosciences)

Reservoir characterization and modeling are crucial for informed decision-making in resource exploration, development, and management. These processes are widely applied in the exploration and production of subsurface reservoirs for hydrocarbons, geothermal energy, groundwater, and other resources. Recent advancements in computational techniques, machine learning, and integrated geological modeling have significantly enhanced the ability to characterize the complex spatial patterns and processes of subsurface reservoirs. This session will focus on the latest innovations in intelligent reservoir characterization and modeling, combining traditional geological expertise with emerging AI-based technologies. Presentations will cover a variety of topics, from data-driven modeling, AI-based pattern reconstruction, and digital twins, to the integration of multiple-disciplinary datasets such as seismic, well logs, and production data. The session will showcase how these intelligent approaches help improve reservoir characterization, simulation, and management, enabling more efficient and sustainable resource extraction.

S1301. Developing training images for multiple-point statistics modelling of the Lower Burdekin Delta aquifer

Guillaume Pirot (The University of Western Australia),
Dylan Irvine (Charles Darwin University),
Cristina Solorzano-Rivas (Flinders University),
Adrian D Werner (Flinders University)
Room: B228 2025-10-10 10:30

The spatial heterogeneity of hydrogeological properties has a strong influence on the transport of groundwater and contaminants. Thus, proper characterisation and modelling of subsurface heterogeneity is key to support groundwater resource management decisions. When conceptual models are available as training images, multiple-point statistics (MPS) algorithms are adequate tools to generate models characterised by complex spatial heterogeneity, while honouring local observations.

This work presents a methodology to generate heterogeneous deltaic sediment deposits of the Lower Burdekin Delta aquifer (Australia) that can be used as training images. Then, using the DeeSse implementation of a MPS algorithm (Direct Sampling), the model realizations conditionally match local sediment observations derived from legacy borehole logs.

The training image required by the MPS algorithm describes the spatial heterogeneity of the sediments. Here it is generated with an object-based algorithm where the main sediments of the aquifer (clay lenses and sand lenses) are represented by truncated ellipsoids. The resulting training image is consistent with a previous conceptual geological model of the aquifer and reproduces both global sediment proportions and distributions of sediment thicknesses.

Preliminary results show that the generated 3D models can honour the conceptual spatial heterogeneity of the sediments, the global summary statistics of these sediments within 4% of error and local observations from the borehole logs.

This work is supported by Lower Burdekin Water and an Australian Research Council Linkage Project (project number LP210100430), the ARC-funded Loop: Three-dimensional Bayesian Modelling of Geological and Geophysical data (LP210301239), and by the Mineral Exploration Cooperative Research Centre through the Australian Government Cooperative Research Centre Program (CRC Document 2025/30).

S1302. The Intelligent Characterization Method of Non-stationary Reservoir Structures Guided by Pattern Categories

Dajie Chen (China University of Geosciences (Wuhan)),
Qiyu Chen (China University of Geosciences)
Room: B228 2025-10-10 10:50

Reservoir structure characterization plays a crucial role in visualizing subsurface architectures and provides essential technical support for oil and gas exploration and development. Due to the inherently non-stationary of reservoir structures, traditional geostatistical methods are often inadequate for their accurate representation. With the rapid development of deep learning, deep learning-based reservoir characterization has emerged as a prominent research focus in geological modeling. Compared to conventional methods, deep learning approaches offer the capability to construct high-resolution, high-heterogeneous 3D reservoir models under conditioning data constraints. However, current deep learning-based geological modeling techniques still face challenges in capturing the spatial variability of non-stationary reservoir structures.

To address the limitation, this study proposes an intelligent characterization method for non-stationary reservoir structures guided by pattern categories. First, a multi-pattern reservoir structure encoder is developed based on an autoencoder framework, which efficient encoding and decoding of diverse reservoir structure patterns. Second, a novel diffusion model-based framework is introduced for intelligent characterization of non-stationary reservoir structures. To overcome the challenge of learning multiple structural patterns in a single training process—this method leverages a latent-space diffusion model to design a non-stationary reservoir structure characterization network. The network can learn encoded representations of different reservoir patterns under the guidance of categorical information, and further supports conditional generation of reservoir structures, ensuring consistency with prior geological knowledge.

The proposed method first encodes the original reservoir structures into latent space using the multi-pattern encoder. The non-stationary characterization network then learns and generates reservoir characterizations within this latent space, which are subsequently decoded back into spatial structures. The method is validated using both two-dimensional and three-dimensional multi-pattern datasets. A suite of statistical analyses—including variogram analysis, connectivity evaluation—is conducted to assess model performance. The results demonstrate that the proposed method effectively and accurately characterizes non-stationary geological structures.

S1303. Interpretable deep learning-based characterization of subsurface structures with self-representation learning

Zhesi Cui (School of Sustainable Energy, China University of Geosciences),
Qiyu Chen (China University of Geosciences),
Gang Liu (China University of Geosciences),
Shu Jiang (China University of Geosciences)
Room: B228 2025-10-10 11:10

Accurate characterization of subsurface structures serves as the foundation for robust subsurface process modeling and advances Earth's scientific understanding. The deep learning technique offers novel opportunities to enhance the conventional workflows of subsurface structure characterization. However, the black-box deep neural networks make it difficult to understand and constrain the characterization process. Several approaches, such as attention-based models and saliency maps, have been proposed to improve interpretability. These methods often focus on post-hoc explanations or local feature importance, which may not fully capture the complex spatial heterogeneity inherent in subsurface structures. In this work, we propose a novel approach for improving the understanding of deep learning-based characterization, termed MCSR-Net, leveraging a self-representation learning strategy to precisely estimate spatial heterogeneity. The self-representation learning strategy is presented to improve the interpretation of deep learning-based characterization approaches and reduce the artifacts in generated realizations. The self-representation learning strategy includes a self-representation network for providing latent representations of subsurface structures and a loss function for optimizing the consistency of implicit features. Additionally, to achieve integration of multiple observations, a conditioning data encoder is embedded in MCSR-Net to enhance the efficiency of extracting spatial features. A joint loss function is employed to optimize the training process and improve the performance of conditional simulations. This study systematically evaluates the performance of MCSR-Net using three synthetic data sets of subsurface fluvial deposits. A comparative experiment is conducted to demonstrate the advantages of MCSR-Net in characterizing subsurface structures with spatial heterogeneity. Results show performance with an average RMSE, SSIM, PSNR, and F1 of 0.013, 0.975, 23.556, and 0.924 overall datasets for our best model. These results underscore the reliability and superiority of MCSR-Net in applications of spatial information analysis, surface structure modeling, hydrogeological modeling, and inversion.

S1304. GAN-Variogram Fusion: Deep Generative Reservoir Modeling with Multi-Prior Geological Constraints

Xu Yang (College of Science, China University of Petroleum (Beijing)),
Shaoqun Dong (China University of Petroleum (Beijing)),
Guohao Xiong (China University of Petroleum (Beijing)),
Huangshuai Kong (China University of Petroleum (Beijing)),
Xu Bai (China University of Petroleum, Beijing)
Room: B228 2025-10-10 11:30

Fine-scale reservoir modeling is of great significance for enhancing hydrocarbon recovery. To quantify the spatial variability and correlation of the reservoir and accurately characterize its heterogeneity, this study proposes a conditional generative reservoir modeling method that integrates variogram knowledge and sand thickness priors. This methodology employs well log and sand thickness as constraints to ensure that the generated model accurately captures the geometry and spatial distribution of the reservoir sedimentary. A dual-deep pyramid spatial attention-based generative adversarial network is further proposed, integrating dilated convolution techniques for fine extraction of sedimentary facies features. Furthermore, a variogram-based regularization term is integrated into the loss function to penalize abrupt transitions in spatial variability and attribute anomaly clustering, thereby ensuring that the model generates reservoir structures in accordance with geostatistical theories. At the inference phase, the latent vector is optimized by integrating well log, sand thickness, and variogram-based loss functions, yielding geologically reliable reservoir models accurately capture geostatistical features. Experimental results indicate that the model effectively captures spatial geological structures, facilitating more finer extraction of reservoir sedimentary facies features, with a reconstruction accuracy of 87%. Regarding spatial variability, the experimental variogram curve of the generative model exhibits an 85.1% fit with the target variogram.

S1306. GGBondSAGE: A framework for three-dimensional characterization of subsurface stratigraphic structures using GraphSAGE

Jiale Guo (China University of Geosciences (Wuhan)),
Qiyu Chen (China University of Geosciences)
Room: B228 2025-10-10 11:50

Three-dimensional (3D) geological modeling technology has been widely and deeply applied in the fields of mineral, oil and gas exploration, underground space development and utilization and geological disaster forecasting. The intelligent 3D quantitative characterization of complex subsurface structures has become a hotspot in the field of geoinformatics in the new era. In this study, we propose a framework to establish a bond between geological objects and graph structures by using an improved GraphSAGE neural network (namely GGBondSAGE). The improved GraphSAGE network is designed by graphically characterizing 3D geometric and topological relationships of stratigraphic structures. The Bi-mean aggregation mechanism and the dual-channel hybrid splicing strategy proposed in this work not only effectively captures the spatial morphological features of the geological interfaces of strata, but also significantly improves the robustness of the network model . Various experiments were performed on three typical datasets. The realizations of GGBondSAGE and the comparison analysis show that the proposed GGBondSAGE is able to characterize the heterogeneous stratigraphic structures well.

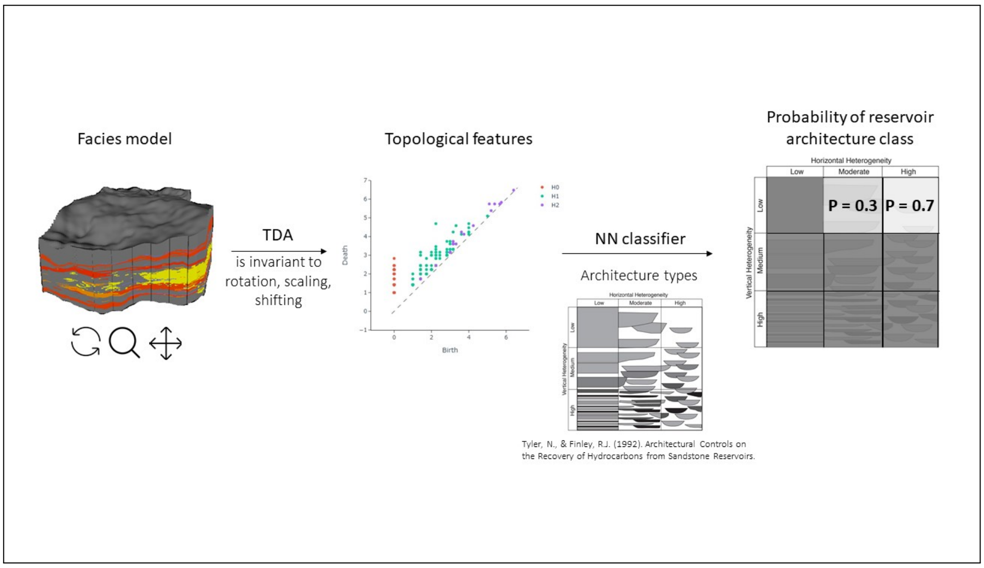
S1307. Topological Representation of Geological Models as a Universal Architecture Descriptor

Anna Vetkina,
Gleb Shishaev (Tomsk Polytechnic University),
Timofey Kalyakin (Tomsk Polytechnic University)
Room: B228 2025-10-10 12:10

When moving to AI-centric systems in a petroleum engineering task, it is essential to have characteristics of a reservoir model that can be used for any reservoir architecture.

In this study, we propose Persistent Homology (PH) tool to compute topological features that describe the reservoir model. PH is a technique used in Topological Data Analysis to study qualitative features of data that persist across multiple scales. PH is independent of input dimensions and coordinates, and generally describes the shape of the data. Therefore, the proposed topological features can serve as universal representative characteristics for reservoir models of any size and any architecture, which can be used in Machine Learning applications.

Our experiments have shown that topological representations of geological models for five depositional environments (tidal dominated delta, wave-dominated shoreface, barried islands, meandering and braided rivers) perform well in the classification task with an accuracy of 0.98. This means that the proposed topological metric can be further used as a regularization in generative AI to control the depositional environment of the generated geological models.



S1308. Enhancing Subsurface Model Flexibility through Telescopic Integration and Physics-Informed Machine Learning

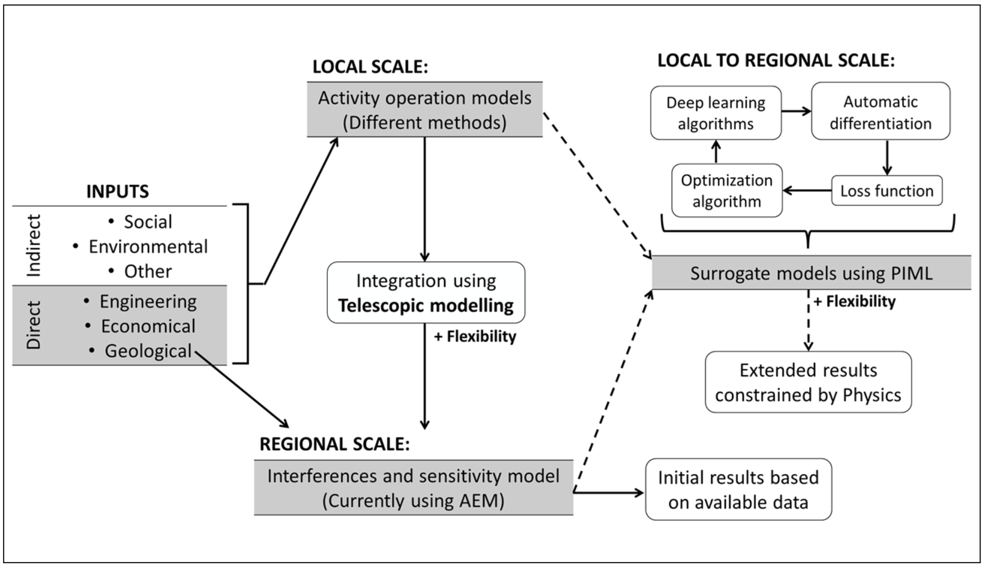
Jose Rodriguez (Geological Survey of Belgium),
Kris Piessens (Geological survey of Belgium),
Kris Welkenhuysen (Geological survey of Belgium)
Room: B228 2025-10-11 10:30

Effective planning and management of deep subsurface energy systems, including geothermal extraction and natural gas storage, require modelling approaches that incorporate site-specific details, capture interactions across scales, and handle uncertainty in the presence of limited data. This study presents two complementary strategies aimed at increasing the flexibility and utility of regional models: Telescopic Modelling and Physics-Informed Machine Learning (PIML).

Telescopic Modelling has already been applied by performing detailed local simulations that integrate both direct and indirect inputs, including hydrogeological, operational, and external constraints. These locally informed outputs, rather than being purely hydrogeological, reflect broader contextual influences. They are then incorporated into a regional model developed using the Analytic Element Method (AEM) by applying boundary conditions that embed this rich local information. This approach enables the regional model to account for interactions among co-located activities while maintaining computational efficiency.

In parallel, surrogate modelling using PIML is being planned to further enhance model flexibility. The initial goal is to emulate groundwater flow, with potential extensions to more complex simulations involving processes such as heat transfer and multiphase flow. Both local and regional surrogates will be tested, and depending on performance, one or both may be adopted. The first phase will focus on Physics-Informed Neural Networks (PINNs) due to their ability to incorporate governing equations, making them suitable for training on datasets derived from diverse modelling approaches. This diversity could allow the surrogates to generalize beyond the limitations of any single simulation tool and help address the scarcity of deep subsurface data. Operator-based methods such as PINO and FNO may also be explored depending on feasibility.

These two methodologies, Telescopic Modelling and PIML-based surrogate modelling, are being advanced as complementary tools to improve model adaptability, scalability, and integration capacity in subsurface systems.


LOCAL SCALE:
Activity operation models (Different methods)
LOCAL TO REGIONAL SCALE:
Deep learning algorithms
Automatic differentiation
Optimization algorithm
Loss function
INPUTS
Indirect
• Social
• Environmental
• Other
Direct
• Engineering
• Economical
• Geological
Integration using Telescopic modelling
+ Flexibility
Surrogate models using PIML
+ Flexibility
Extended results constrained by Physics
REGIONAL SCALE:
Interferences and sensitivity model (Currently using AEM)
Initial results based on available data

S1310. WE-ME: A Comprehensive System for Automated Standardization and Extraction of Well Data for Seismic Interpretation Workflows

Maria Eduarda Candida Francklim Francisco (Federal University of Rio de Janeiro), Francisco Manoel Wohnrath Tognoli

Room: B228 2025-10-11 10:50

Brazil hosts one of the largest well data repositories in the world, managed by the National Agency of Petroleum, Natural Gas, and Biofuels (ANP). The revitalization programs for exploration and production in onshore (REATE) and offshore areas (PROMAR) have made these data more accessible, opening new possibilities for exploration and research. However, the vast volume and diverse file formats present significant challenges for data preparation, especially if linked with advanced analyses in seismic interpretation software. The absence of standardization within historical records and between them and contemporary ones makes manual processing difficult, making it slow and prone to errors. To address these issues, a Python-based system, named WE-ME (Well data Extraction - Made Easy), was developed to automate the organization and processing of ANP data. It filters and structures essential information, including UTM coordinates, datum, directional data (measured depth, true vertical depth, inclination, azimuth), lithological information, lithostratigraphy, chronostratigraphy, checkshots, evidence of hydrocarbons and the year the wells were drilled. The outputs are summarized spreadsheets and files ready for integration with seismic interpretation software. Processes to extract, transform and load (ETL) data, which used to take weeks, can now be performed in minutes. The validation step used data from the Santos, Campos and Acre Basins (Brazil), demonstrating successful integration with a seismic interpretation software. By leveraging Python's flexibility, WE-ME enables the creation of customizable scripts that streamline repetitive tasks, improve data accessibility and facilitate reproducibility. This work highlights how automation can simplify the handling of big data, stimulating the use of the large Brazilian well database in exploratory studies and contributing to the optimization in geosciences and the energy industry. Furthermore, the success of this approach in the Brazilian context highlights its potential applicability to other regions rich in resources - both natural and data-related - that face similar challenges.

S1311. Kolmogorov-Arnold Networks: Advancing Lithofacies Interpretation from Well Logs through Interpretable Deep Learning

Leting Wang (College of Science, China University of Petroleum (Beijing)),
Shaoqun Dong (China University of Petroleum (Beijing)),
Junkun Quan (China University of Petroleum (Beijing)),
Fuyu Zhang (China University of Petroleum Beijing),
Ruixiang Bi (College of Science, China University of Petroleum (Beijing), Beijing, China. 102),
Shaopeng Song (College of Science, China University of Petroleum (Beijing), Beijing, China. 102)
Room: B228 2025-10-11 11:10

Accurate well log facies identification is crucial for efficient oil and gas exploration and development. However, the complex nonlinear relationship between conventional well log data and intricate lithofacies poses challenges for traditional machine learning methods, particularly regarding deep feature extraction and model interpretability. To address these limitations, this study investigates the application of Kolmogorov–Arnold Networks (KAN) for well log lithofacies identification. Based on the Kolmogorov-Arnold representation theorem, KAN employs learnable univariate functions as activation functions. This architecture theoretically allows KAN to approximate arbitrary multivariate continuous functions with potentially simpler structures, thereby better capturing the complex nonlinearities inherent in well log data. Our approach involves necessary preprocessing of well log data followed by the construction of a KAN-based lithofacies classification model. We evaluate the KAN model's performance on a real-world dataset containing diverse lithofacies. The identification performance of the KAN model is compared against other deep learning models to validate its effectiveness and demonstrate its potential advantages. We also provide recommendations for constructing suitable KAN models for this specific task. Experimental results indicate that the KAN model achieves comparable or superior identification accuracy compared to existing methods, often with fewer parameters. This highlights its significant potential for addressing nonlinear classification problems in well log analysis. This research represents a preliminary exploration of KAN's utility in lithofacies identification, offering a novel perspective and potential avenues for future research and practical applications.

S1312. Deep Neural Network Loss Function Development for Extreme Event Forecasting in Time Serie

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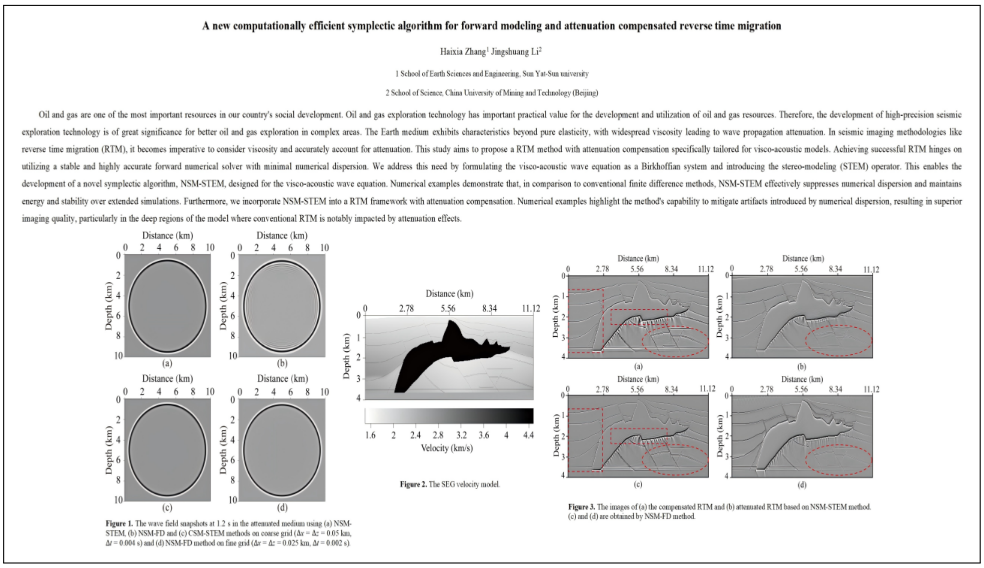
Julien Straubhaar (Center for Hydrogeology and Geothermics, Université de Neuchâtel, Neuchâtel, Sw),
Erwan Gloaguen (Water, Earth, Environment Center, Institut national de la recherche scientifique),
Maxime Claprood (Department of Applied Science, Université du Québec à Chicoutimi, Chicoutimi, C),
Philippe Renard (University of Neuchâtel),
Dany Lauzon (Department of Civil, Geological and Mining Engineering, Polytechnique Montréal),
Reed Maxwell (Princeton University)
Room: B228 2025-10-11 11:30

Groundwater is a vital resource for human consumption and economic development, making accurate forecasting tools essential for sustainable management. With the rise of data-driven deep learning (DL) methods, hydrologists have increasingly turned to these approaches for predictive groundwater resource modeling. In this study, we introduce the Extreme Loss Function (ELF). This is a novel, model-agnostic loss function designed to enhance the forecasting of extreme groundwater events, such as high and low flow periods, in regression-based DL models. To evaluate the performance and generalizability of ELF, we tested it on two contrasting datasets: (1) a karst spring discharge dataset from the Milandre Karst system in Switzerland and (2) a monitoring well dataset from Quebec, Canada. These diverse datasets were chosen to assess ELF's data independence. Furthermore, we assessed the model-independence of ELF by applying it to two fundamentally different DL architectures: a Gated Recurrent Unit (GRU) autoencoder and a Graph WaveNet (GWN) model. Missing data in both time series were imputed using a direct sampling Multiple Point Statistics (MPS) method, which generates statistically realistic realizations by integrating complementary inputs such as precipitation, temperature, and seasonal trends. Both DL models were trained on the MPS-completed datasets using ELF and compared against the conventional Mean Absolute Error (MAE) loss function. Results show that ELF significantly improves the GWN model's ability to forecast extreme events, while providing modest improvements for the GRU autoencoder. These findings demonstrate that ELF effectively constrains DL models during training to better capture extreme behaviors, offering a valuable tool for enhancing groundwater level forecasting.

S1313. High-precision Seismology: Research on Full Waveform Inversion in Symplectic Stereo-modeling Format

haixia zhang (Sun Yat-sen University),
qiuming Cheng,
Jiandong Huang (School of Earth Sciences and Engineering, Sun Yat-Sun university)
Room: B228 2025-10-11 11:50

Oil and gas are one of the most important resources in our country's social development. Oil and gas exploration technology has important practical value for the development and utilization of oil and gas resources. Therefore, the development of high-precision seismic exploration technology is of great significance for better oil and gas exploration in complex areas. The Earth medium exhibits characteristics beyond pure elasticity, with widespread viscosity leading to wave propagation attenuation. In seismic imaging methodologies like reverse time migration (RTM), it becomes imperative to consider viscosity and accurately account for attenuation. This study aims to propose a RTM method with attenuation compensation specifically tailored for visco-acoustic models. Achieving successful RTM hinges on utilizing a stable and highly accurate forward numerical solver with minimal numerical dispersion. We address this need by formulating the visco-acoustic wave equation as a Birkhoffian system and introducing the stereo-modeling (STEM) operator. This enables the development of a novel symplectic algorithm, NSM-STEM, designed for the visco-acoustic wave equation. Numerical examples demonstrate that, in comparison to conventional finite difference methods, NSM-STEM effectively suppresses numerical dispersion and maintains energy and stability over extended simulations. Furthermore, we incorporate NSM-STEM into a RTM framework with attenuation compensation. Numerical examples highlight the method's capability to mitigate artifacts introduced by numerical dispersion, resulting in superior imaging quality, particularly in the deep regions of the model where conventional RTM is notably impacted by attenuation effects.



S1314. Dynamic Characterization of CO Flooding Fronts: Collaborative Modeling Integrating Physics-Constrained Deep Learning with Data Assimilation

Haochen Liu (China University of Petroleum (Beijing)),
Yuming Liu (College of Geoscience, China University of Petroleum (Beijing)),
Qi Chen (China University of Petroleum (Beijing)),
Fan Zhang (College of Geoscience, China University of Petroleum (Beijing))
Room: B228 2025-10-11 12:10

To address critical challenges in CO flooding processes within low-permeability reservoirs - including strong reservoir heterogeneity, pronounced nonlinear characteristics of multiphase seepage, and ambiguous seismic front responses - this study proposes a collaborative modeling methodology integrating physics-constrained deep learning with multimodal dynamic data assimilation. By developing a physics-informed U-Net++ network incorporating Darcy's law and pore interface stability mechanisms, we integrate slip suppression effects at CO -rock interfaces revealed through molecular dynamics simulations with nonlinear parameters obtained from core flooding experiments into network training, achieving high-resolution identification of CO fronts in 4D seismic data. Through an improved ensemble Kalman filter algorithm, we establish a multi-source data assimilation framework encompassing seismic inversion, inter-well monitoring, and petrophysical parameters to construct a dynamically updated digital twin reservoir model. Application in a Shengli Oilfield block demonstrates: The root mean square error of CO front prediction is reduced to 0.13, while the correlation coefficient between permeability field inversion and core measurements reaches 0.83, significantly outperforming conventional methods. This approach supports injection-production parameter optimization that enhances recovery factor by 12%, providing an innovative technical pathway for carbon sequestration efficiency evaluation and intelligent reservoir control.

S1315. Data-driven prediction of geo-engineering sweet spots in tight sandstone reservoirs

Minghao Zhao (China University of Petroleum (Beijing)),
Yuming Liu (College of Geoscience, China University of Petroleum (Beijing)),
Qi Chen (College of Geoscience, China University of Petroleum (Beijing)),
Zhuang Liang (College of Geoscience, China University of Petroleum (Beijing))
Room: B228 2025-10-11 12:12

Tight sandstone reservoirs are a key focus in current oil and gas exploration and development. Their complex geological conditions and differences in reservoir physical properties pose significant challenges for "sweet spot" prediction. Traditional prediction methods that rely heavily on the experience of geologists and engineers face limitations such as strong subjectivity and great uncertainty. With the advancement of data-driven technologies, new pathways for predicting "sweet spots" in tight sandstone reservoirs have emerged. This study focuses on the X gas field in the northern Ordos Basin and proposes an intelligent prediction model that integrates a Triangular Topology Aggregation Optimization algorithm (TTAO), Random Forest (RF), and Multi-Head Self-Attention (MSA), based on a geological-engineering integration concept.

The research finds that the sweet spots in the reservoir are influenced by the synergistic effects of geological factors, rock mechanics, and fracturing engineering parameters. In term

S1316. Interlayer Modeling in Braided River Reservoirs Using Multi-Condition Constrained Generative Adversarial Networks

Qi Chen (China University of Petroleum (Beijing)),
Yuming Liu (College of Geoscience, China University of Petroleum (Beijing)),
Minghao Zhao (China University of Petroleum (Beijing)),
Haochen Liu (College of Geoscience, China University of Petroleum (Beijing))
Room: B228 2025-10-11 12:14

The interlayers within braided river reservoirs exhibit characteristics of diverse types, significant scale variations, and complex spatial distributions due to frequent channel migration and swing. Their accurate characterization constitutes a key geological challenge in reservoir heterogeneity studies and remaining oil potential exploitation. Addressing technical bottlenecks such as insufficient effectiveness of seismic data constraints and incomplete abstraction of multi-point geostatistical patterns, this study proposes an interlayer modeling method based on multi-conditional constrained generative adversarial networks (GANs). By establishing a deep learning framework capable of simultaneously learning interlayer development pattern features and spatial correlations of conditional data, we achieved three-dimensional interlayer modeling driven by geological patterns and coordinated with conditional data. Taking the braided river reservoirs of Guantao Formation in Shengli Oilfield as research subject, test results demonstrate that compared with traditional modeling methods, the 3D interlayer models constructed by this algorithm show over 85% consistency with typical braided river depositional patterns in Bohai Bay Basin and conditional data. Furthermore, quantitative metrics including morphological fidelity, structural characterization accuracy, and geological pattern restoration degree significantly outperform other interlayer modeling methods. This approach provides a novel technical pathway for 3D geological modeling of highly heterogeneous reservoirs.

S1317. Application of Copula Method in Petroleum Resources Assessment

Shiyun Mi (Research Institute of Petroleum Exploration & Development, PetroChina), Qian Zhang (Research Institute of Petroleum Exploration & Development, PetroChina)
Room: B228 2025-10-11 12:16

Petroleum resources assessment may provide biased result if the correlation between geological variables involved in the assessment is ignored. This paper proposes a key implementation technology to estimate the petroleum resources of each of three source sequences in a geological sag, after modeling the correlation between geological parameters by using the Copula method. This technology can be applied to the entire-sag oil resource estimation and other petroleum resource assessment purposes. Based on the actual stratigraphic data, the proposed technology is simulated. The result shows that the predicted oil resources may be deviant if the correlation between geological variables is not considered. The greater the correlation coefficient is, the greater the deviation between the predicted resources with and without considering the correlation is.

S1318. CNN-Deep Forest-Isolation Forest Ensemble for Thin-Layer Sand Body Prediction in Sparse Well Regions

Fan Zhang (China University of Petroleum (Beijing)),
Yuming Liu (College of Geoscience, China University of Petroleum (Beijing)),
Qi Chen (China University of Petroleum (Beijing)),
Haochen Liu (College of Geoscience, China University of Petroleum (Beijing))
Room: B228 2025-10-11 12:18

In offshore oilfields, traditional seismic attribute analysis faces dual challenges of geological complexity and sparse well constraints, leading to inadequate feature characterization and significant ambiguity in predicting thin-interbedded sandbody distributions. To address these limitations, this study innovatively establishes an intelligent OBN seismic attribute fusion framework based on multiscale frequency-domain interpretation. First, six characteristic frequency-band attribute sets (8-15 Hz, 16-25 Hz, 26-35 Hz, 36-45 Hz, 46-55 Hz, 56-65 Hz) are extracted through time-frequency wavelet decomposition, establishing mapping relationships between geological features and frequency responses. A cascaded hybrid deep learning model is designed, where convolutional neural networks (CNN) extract high-frequency detailed features, while Deep Forest's adaptive feature selection mechanism enables nonlinear fusion of multiscale seismic attributes. An enhanced Isolation Forest algorithm constructs a 3D seismic anomaly factor field, achieving unsupervised detection of subtle sandstone reservoirs with amplitude variation rates below 15%, showing 32% sensitivity improvement over conventional methods. Finally, deep abstract features extracted by stacked autoencoders (Stacked AE) are concatenated with 12 screened geology-sensitive attributes, forming an integrated reservoir identification mechanism in multidimensional feature space. Validated with OBN seismic data from a Chinese offshore oilfield, the method successfully delineates key subunit sandbody distributions, demonstrating 0.85 correlation with well-derived sandbody thickness. Results indicate the proposed frequency-division intelligent attribute fusion and anomaly detection method exhibits strong potential under sparse-well and complex geological conditions, providing novel technical solutions for reservoir characterization in hydrocarbon exploration and development.

S14 Compositional and density data analysis in geosciences

Karel Hron (Palacky University Olomouc),
Alessandra Menafoglio (Politecnico di Milano),
Jennifer McKinley (Queen's University Belfast),
Caterina Gozzi (University of Florence)

Compositional and density data analysis in geosciences

This session will focus on the statistical/machine and deep learning treatment, modelling and interpretation of compositional and density data in geochemical applications, particularly for geochemical exploration and mapping. It will address the challenges of geochemical mapping with relative data, either with compositional data (typically geochemical data) and density data (typically particle size distributions). Geological survey data typically have both relative and spatial elements, both of which must be considered for meaningful analysis. The performance of empirical geochemical approaches also deteriorates when the geochemical datasets are too large, typically consisting of tens of thousands of observations and tens of variables. Conversely, such large datasets are advantageous for the distributional (functional) data approach that will be discussed in this session. The session will explore popular unsupervised multivariate/functional data analysis methods, such as dimension reduction (PCA) and clustering, to uncover inherent relationships and patterns in the relative data. It will also discuss process discovery and validation using techniques such as discriminant analysis, machine learning and deep learning methods for pattern identification and classification. All contributions on the application of (1) multivariate geoscience data processing within a compositional framework in a geoscience context (2) functional data analysis processing with distributional data by considering their relative character are welcome.

S1401. Application of Knowledge-Driven Compositional Data Analysis (CoDA) in metallogeny and exploration indicators: A case study of gold deposits in northwestern Argentina

xiufa chen (Development and Research Center, China Geological Survey),
Jennifer M. McKinley (Queen's University Belfast),
Yongzhi Wang (College of GeoExploration Science and Technology, Jilin University),
Dongjie Zhao (Development Research Center, China Geological Survey)
Room: D205 2025-10-10 10:30

The Central Andean Orogenic Gold Belt, which spans the entire Andean orogenic belt, is one of the most significant gold belts in the world. There have been numerous large-scale gold deposits discovered in both the northern and southern regions of the belt in recent years. In contrast, the central region, specifically in the northwestern part of Argentina, has not seen any significant progress in gold exploration. In order to provide better support for future gold prospecting and exploration efforts in this area, it is necessary to conduct research on how to extract more information from the existing geological mineral resource and geochemical data. A compositional data analysis (CoDA) approach is employed to effectively account for the closure effect of the geochemical data. Principal component analysis method is employed to explore the characteristics of elemental assemblages in geochemical data. The research on typical gold deposits is used to determine geological backgrounds and mineralization characteristics, providing valuable information for the Knowledge-driven CoDA method. The approach was employed to explore the combinations of indicator elements associated with gold deposits. As a result, four groups of compositional balances related to gold mineralization are revealed and verified. The first group of compositional balance represents the regional collision orogeny and is associated with extensively developed peraluminous rocks, specifically S-type granites. The second group represents the Ordovician Akoite Formation sedimentary strata, which serve as the primary ore-bearing strata for orogenic gold deposits in the region. The third group represents the primary mineralizing elements, including gold (Au), antimony (Sb), lead (Pb), and others. The fourth group primarily reflects the alteration characteristics of gold deposits, such as chloritization alteration. The combination of four groups can be utilized to effectively determine gold mineralization and exploration area.

Keywords: compositional data analysis, principal component analysis, gold deposits, Andean orogenic gold belt

S1402. Exploring soil evidence as a proxy for the availability of toxins for human intake from air and traffic pollution: a compositional data analysis approach.

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Room: D205 2025-10-10 10:50

Air pollution is a known environmental health hazard with particulate matter with diameter less than 2.5 µm (PM2.5) of particular concern. Soils may provide evidence of past and modern-day anthropogenic pollution. As such, soils can present a proxy for the availability of toxins for human intake from environmental pollution. In this study we test the assumption that soils can be used to determine anthropogenic contamination, most specifically air and traffic pollution. We use road buffers (testing buffers of different sizes: 300m, 500m, 1000m and 2000m) for an elemental sub composition (comprising As, Al, Co, Cr, Mn, Cd, Cu, Fe, Zn, Mo, Pb, Sn and Sb) of a combined rural and urban soil geochemistry database of total elemental concentrations (XRF).

A compositional balance approach combined with regression analysis is used to assess the relationship between air pollution data (PM2.5) and environmental toxins found in soils associated with proximity to major road networks. Initial findings indicate statistically significant associations between PM2.5 with principal ilr balances for As, Zn, Pb, Sb and Sn (relative to control elements Al, Co, Cr, Mn, Cd, Cu and Fe) for the smallest road buffers.

As part of the UKRI ESRC funded SPACE (Supporting Environments for Physical and Social Activity Healthy Ageing and Cognitive Health) project, source fraction data for PM2.5 have been determined for nine emission sources comprising agriculture, road traffic, non-road traffic, energy-coal, energy-other, industry-coal, industry-other, wildfires and windblown dust. In this study, source-specific PM2.5 fractions were derived by multiplying the total PM2.5 concentration tagged to each soil sample by local fractions of the nine emission sources. As PM2.5 source fraction data are also compositional, a compositional balance and multivariate analysis approach is used to assess the relationship between the environmental toxins associated with proximity to road networks and the source-specific PM2.5 fractions.

S1403. Decomposition of functional PCA in density data analysis of large-scale geochemical data

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Sonja Greven (Humboldt University of Berlin),
Tomas Matys Grygar (Czech Academy of Sciences)
Room: D205 2025-10-10 11:10

Increasingly, geochemical mapping is producing large amounts of data, and with it the need for appropriate statistical processing persistently grows. For interpretation purposes, instead of simply feeding data into a deep neural network, it is useful to post-stratify the entire data distribution into smaller and homogeneous sub-areas. This produces a sample of distributions, commonly represented as (potentially multivariate) probability density functions (PDFs). Specific properties of PDFs are well captured by Bayes spaces with a Hilbert space structure. Moreover, embedding multivariate PDFs in Bayes spaces allows their orthogonal decomposition into independent and interactive parts, where the former can be further decomposed into orthogonal geometric marginals and the latter into orthogonal PDFs capturing interactions of all orders. After performing the centered logratio (clr) transformation, the PDFs can be analysed as functional data in a subspace of the standard L2 space. In this paper, we focus on functional principal component analysis (FPCA) and its application to bivariate densities, which can still be nicely visualised, as well as to the vector of orthogonal densities from their decomposition. We show that performing FPCA on the original bivariate densities is equivalent to performing bivariate FPCA on the decomposed densities (the vector of the interactive part and the geometric marginals). Furthermore, the eigenfunctions and scores are decomposed accordingly, and this allows to identify which parts of the decomposition contribute most to the variation of the densities. The theoretical results are complemented by an illustration on an empirical data set from a large-scale geochemical mapping, whose post-stratification results in bivariate densities of (log-transformed) risk elements Cu and Zn in 77 districts of the Czech Republic.

S1404. Trace element partitioning between apatite and alkaline-carbonate melt

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Bernard Charlier (Université de Liège)
Room: D205 2025-10-10 11:30

Apatite [Ca10(PO4)6(F, Cl, OH)] is a ubiquitous mineral in igneous, metamorphic, and sedimentary rocks. Its crystal structure can accommodate a variety of trace elements. As a common accessory phase, apatite is weakly affected by later alteration, preserving information about the parent magma and making it of significant importance in petrology. When tracing magma evolution based on the composition of apatite, it is necessary to elucidate the partitioning behavior and controlling factors (P, T, fO2, and crystal-melt composition) of various elements between apatite and melt.

To better constrain the trace elements partitioning between apatite and silicate ± carbonatite melts, we conducted 12 experiments at pressures of 5 kbar and temperatures of 1000-1150 °C in a piston cylinder apparatus, and run products were analyzed for trace elements by laser ablation inductively coupled plasma-mass spectrometry (LA-ICP-MS). We report new experimental apatite/melt partition coefficients for a wide range of trace elements (REEs, Rb, Ba, Y, Sr, Zr, Hf, etc.).

Using these measured trace element partition coefficients, we established a lattice strain model formalism for apatite and silicate melts, allowing us the estimate the physical properties of the crystallographic sites hosting the trace elements. Combining our results with previously published data (158 experiments with 1744 experimental trivalent element partitioning data), we propose a general model to predict partition coefficients between apatite and silicate ± carbonatite melts under a wide range of P-T conditions.

S1406. Study on crystallisation dynamics of basaltic lava from Huoshaoshan volcano, in Wudalianchi area NE China

Runxin Zhang (College of Resource Environment and Tourism, Capital Normal University)

Room: D205 2025-10-10 11:50

Abstract: This work simulates the dynamic crystallisation process of basaltic lava from Huoshaosahn volcano,Wudalianchi Mountains under natural conditions of lava flow surface cooling, and investigates the relationship between crystal crystallisation characteristics and the cooling rate in terms of the mineral micro-morphology and structure, quantity, size, and morphological boundaries. The results show that: (1) with the cooling rate slows down from 0.5℃/min to 0.03℃/min, the morphology of newborn olivine evolves from needle-like and rail-like to hexagonal hollow and elongated bars, and the arrangement changes from haphazardly interlaced to parallel and ordered; newborn monoclinic pyroxene develops from needle-like aggregates to feathery and nearly autogenous hearth strips; and tremolite begins to develop at 0.0468℃/min and matured into feathery and clustered at 0.03°C/min. (2) The change of crystal quantity with cooling rate can be divided into three stages, namely crystal development stage, crystal coarsen stage and crystal stable equilibrium stage. (3) The relationship between the size and the number density of olivine crystals under the eight groups of cooling rates showed a good power law relationship, and the power law index ranges from 2.50 to 2.83, which indicates that the crystal size distribution is less sensitive to the cooling rate; however, the crystal size increases abruptly at 0.1℃/min, and the mechanism needs to be further investigated. (4) The boundary of the newborn olivine show fractal characteristics, and the fractal dimension ranges from 1.27 to 1.45, with the smallest D-value (1.27) at 0.075℃/min, indicating that the crystal morphology is regularised; the boundary complexity tends to be stabilised after the rate is slowed down further. This study provides an important experimental basis for revealing the kinematic mechanism of the lava flows from Wudalianchi volcano as well as the kinetic crystallisation process.

Keywords: Huoshaoshan, Basaltic lava, Melting-cooling-crystallization, Cooling rate, Crystal morphology, Fractals

S1407. Rare Earth Element Composition as an Indicator of Sediment Provenance in Plio-Quaternary Deposits of the Northern Croatian Basin

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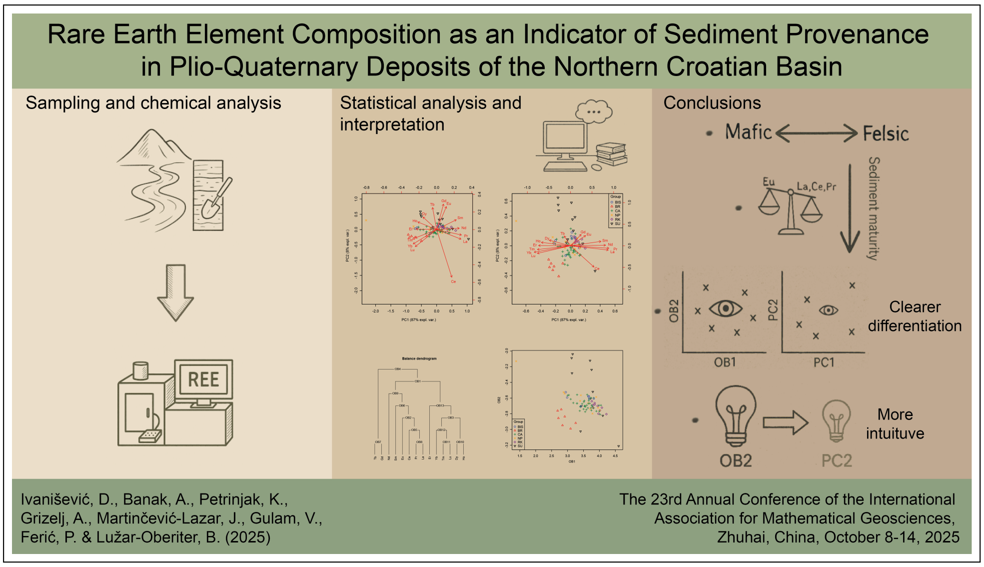
Adriano Banak (Croatian Geological Survey),
Krešimir Petrinjak (Croatian Geological Survey),
Anita Grizelj (Croatian Geological Survey),
Jasmina Martinčević-Lazar (Croatian Geological Survey),
Vlatko Gulam (Croatian Geological Survey),
Pavle Ferić (Croatian Geological Survey),
Borna Lužar-Oberiter (Faculty of Science, Department of Geology)
Room: D205 2025-10-10 12:10

Within this study, the rare earth element (REE) composition was analysed in 85 samples from six clastic sediment profiles of Plio-Quaternary age in the continental region of Croatia. REE are valuable markers due to their chemical stability and resistance to fractionation during sedimentary processes. The aim of this study was to identify individual REEs or groups of REEs that could aid in the differentiation and provenance interpretation of the sediment profiles.

Associations between parts were examined by calculating the proportionality index of parts. A stronger association was observed among neighboring lanthanides as their atomic number increased, reflecting the lanthanide contraction effect. However, cerium and europium deviated from this trend, likely due to their variable oxidation states. Next, robust principal component analysis (PCA) was performed and compositional form and covariance biplots were constructed. The form biplot revealed two distinct groups of samples, while the third group spreads across the biplot. According to the covariance biplot, samples with negative PC1 scores are relatively enriched in light REE, while those with positive scores are relatively enriched in heavy REE. The differences between the three groups appear to result from their geographical locations and, consequently, the varying provenance of sediment. Finally, principal balances were constructed using the optimal algorithm. The first optimal balance (OB1) contrasts light REEs against heavy REEs. The second optimal balance (OB2) contrasts europium against lanthanum, cerium, and praseodymium. OB1, like PC1, likely differentiates samples with more felsic from those with more mafic compositions. Downward trend in OB2 values possibly indicate increasing sediment maturity. The sample groups were better differentiated in the plane defined by OB1 and OB2 than in the plane defined by PC1 and PC2 in the form biplot. Moreover, while the interpretations of PC1 and OB1 were similar, OB2 was more intuitive to interpret than PC2.


Rare Earth Element Composition as an Indicator of Sediment Provenance in Plio-Quaternary Deposits of the Northern Croatian Basin
Sampling and chemical analysis
REE
Statistical analysis and interpretation
Conclusions
Mafic
Felsic
Eu
La,Ce,Pr
Sediment maturity
OB2
OB1
PC2
PC1
Clearer differentiation
OB2
PC2
More intuituve
Ivanišević, D., Banak, A., Petrinjak, K., Grizelj, A., Martinčević-Lazar, J., Gulam, V., Ferić, P. & Lužar-Oberiter, B. (2025)
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S1408. Noise Reduction Strategies in Experimental Sorption Data for CO Coal Seams

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Cristina F. Alves Rodrigues (Universidade Fernando Pessoa),
Irma D. García Calvillo (Universidad Autónoma de Coahuila),
Luis Fernando Camacho Ortegón (Universidad Autónoma de Coahuila),
Arturo Bueno Tokunaga (Universidad Autónoma de Coahuila),
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Room: D205 2025-10-10 12:12

Accurate interpretation of sorption data is essential for understanding gas behavior in coal seams, particularly in the context of carbon capture, utilization, and storage (CCUS). However, pressure–time data obtained from volumetric adsorption–desorption experiments often contain noise and variability, which can hinder subsequent modeling and analysis.

This study focuses on the preprocessing of real experimental data to reduce such errors and improve the reliability of derived concentration profiles. The raw data, originally expressed as pressure over time, are transformed into concentration using the Langmuir volume relationship. To address the inherent noise in the experimental measurements, several smoothing techniques are applied and evaluated, including moving mean, locally weighted scatterplot, Gaussian, local Regression, and Savitzky–Golay filters.

Each method is assessed based on its ability to preserve the physical trends of the data while minimizing distortions. The comparative analysis reveals that local Regression and Savitzky–Golay filters perform best, offering an optimal balance between smoothness and fidelity to the original signal. These techniques enable clearer trend identification and support more accurate downstream calculations, such as the estimation of diffusion coefficients.

The results aim to compare the advantages and limitations of each method, demonstrating that appropriate mathematical filtering significantly enhances data quality. This, in turn, allows for more robust interpretations and reduces uncertainty in subsequent modeling steps, such as the estimation of diffusion coefficients. The study highlights the importance of preprocessing in experimental sorption studies and provides a reproducible approach for researchers working with similar datasets in CCUS-related investigations.

S15 Marginal Seas - Modeling of interfaces between continents and oceans for sustainable development

Jan Harff (University of Szczecin, Institute of Marine and Environmental Sciences, Szczecin, Poland),
Junjie Deng (School of Marine Sciences, Sun Yat-Sen University),
Joanna Dudzinska-Nowak (Institute of Marine and Environmental Sciences University of Szczecin),
Jingpeng Zhang

Large parts of the world's population live near coasts and estuaries, so that the interactions between land and ocean play a fundamental role in the living conditions of these people. Disturbances of natural balances in the land-ocean mass and energy transfer caused by human activities and climate change require new holistic management concepts for the protection and sustainable use of the resources in marginal seas. These concepts base on the transdisciplinary interpretation of scientific data and the simulation of the development of marginal sea processes on integrated time scales. Numerical methods and models addressing climate and environmental change in the geological past but also for future projections are available, but more recently there are promising methods of big data analysis, Artificial Intelligence (AI) and Machine Learning (ML) debated and applied. The qualified use of these methods requires transdisciplinary co-operation chains between the natural sciences, socioeconomics and the humanities. In the proposed session, we invite representatives of these disciplines, together with data scientists and modelers to contribute through lectures and discussions to the development of advanced methods supporting sustainable planning and management of marginal seas.

S1501. Development of mouth bars and bifurcation along the West Pearl River main course, China

Haixian Xiong (Sun Yat-sen University),
Bangliang Lu,
Qian Wang,
Jianxue Wu
Room: B222 2025-10-12 10:30

River mouth bars' formation is a key process of the delta development and river bifurcation, but details of the long-term developmental history of mouth bars and their role in the delta evolution are substantially less well documented. To characterize deltaic mouth bars' development, this study investigated the Sixianjiao, Jun'an, Da'aosha and Denglongsha mouth bars formed successively along the main course of the West Pearl River. The detailed lithological analyses of sediment cores indicate that the mouth bar sediment is characterized by its sandy nature with mud laminations or lenses and poorly preserved foraminifera. The onset of mouth bar sedimentation is affected by water depth. The Sixianjiao and Jun'an mouth bars initiated at shallower water depth (8.0m and 11.0m, respectively) due to the restrictions of higher basement landforms. In an area where water is deeper, the mouth bar development would begin only with the site being elevated up to about 16.0m water depth, such as a case in Da'aosha. The duration between their onset and end of vertical growth varies between 2000 and 2800 years, which is inversely related to their sedimentation rates between 2.7 and 5.7 mm/a, indicating the importance of sediment supply. In addition, the locations of the four mouth bars were to some extent determined by the antecedent landscapes. Finally, the ages of these four mouth bars show a chronological order from land to sea, reflecting seaward delta progradation, contrary to previous morpho-dynamical numerical model's predictions. Our reconstruction of the West Pearl River mouth bars' developmental history provides a new insight into the geomorphological evolution of the Pearl River delta, a special delta developed within a complex estuarine bay.

S1502. Storm Surge Impacts under Estuarine Morphodynamic Transitions: A Case Study of the Shizimen Estuary in Macao Informed by Typhoon Track Analysis along the Chinese Coast

Yi Zhang (School of Marine Sciences, Sun Yat-sen University, China),
Junjie Deng (School of Marine Sciences, Sun Yat-Sen University)
Room: B222 2025-10-12 10:50

As a strong tropical cyclone in the Northwest Pacific, typhoons pose significant threats to China's coastal regions, particularly the Guangdong-Hong Kong-Macao Greater Bay Area. This study focused on Macao, one of the regions with the highest proportion of land reclamation in the world and systematically investigated the characteristics of typhoon tracks over the years and the dynamic state transformation process of Macao Estuary geomorphology. It also explored the region's resilience in response to storm surge disasters.

Based on the best track dataset (1949–2023) from the China Meteorological Administration (CMA) and historical nautical chart data (1929–2023) of the Shizimen Estuary in Macao, we applied K-means and Tslearn-based clustering techniques for typhoon classification, and conducted multi-period erosion-deposition analyses through GIS tools. Preliminary findings include: (1) In the past 75 years, approximately 25% of typhoons making landfall in China have affected Guangdong Province, with westward-moving typhoons being particularly impactful. (2) Human activities have driven a transition in the distributary pattern of the Shizimen Estuary, from a natural island-blocked morphology to an artificially structured cross-shaped bifurcation pattern. We will use the 2018 Super Typhoon Mangkhut as a prototype to construct a synthetic wind field based on the Holland model and ECMWF reanalysis data. The TELEMAC-2D hydrodynamic model will then be employed for scenario-based simulations of storm surge inundation. This will further elucidate how the geomorphic and dynamic transformation of the Shizimen bifurcation system influences Macao's resilience against storm-induced disasters.

S1503. Spatial pattern of land-sea interactions of the southern Baltic Sea coasts derived from high resolution remote sensing data.

Joanna Dudzinska-Nowak (Institute of Marine and Environmental Sciences University of Szczecin)

Room: B222 2025-10-12 11:10

In terms of presently occurring climate changes, observed sea level rise an increased number and intensity of storm events, which pose a real threat to broadly defined coastal safety, it is crucial to precisely monitor changes in the coast and to determine scenarios for the development of the coastline. However, the shallow coastal area is very difficult to study due to the need to use separate measurement methods for terrestrial and sea parts, as well as their technical limitations.

The traditional method of coastal zone monitoring includes topographic-bathymetric measurements carried out in profiles perpendicular to the shore, spaced every 0.5 km. In the terrestrial part of the profile and in the shallow water up to 1.5 m depth, geodetic methods, while the deeper part hydrographic methods a single-beam echosounder were used, because due to the small depth, the use of a multi-beam echosounder was not effective. Comparison of the measurements obtained in subsequent years allowed to determine the size of changes along the profile lines, but without any reliable information between, which is necessary to understand coastal morphodynamics. Precise results of spatial analyses based on historical aerial photographs have contributed to better understanding coastal processes and the permanent introduction of photogrammetric methods, included high resolution orthophotomaps and airborne laser scanning data, to coastal monitoring conducted by Maritime Offices in Poland.

The presented research show the results of using airborne laser scanning technology in monitoring the southern coast of the Baltic Sea. From the first attempts undertaken in 2007 to regular monitoring carried out in 2023 and 2024. From technical description, trough validation of the method accuracy, to the first results presenting spatial pattern of the coastal zone morphology changes, which is a big step forward to better understand coastal morphodynamics.

S1504. Evolving Sediment Supply to the Coast of the Gulf of Mexico Marginal Sea since 3000 y BP

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Bailey Wycoff (Department of Geology and Geophysics, Louisiana State University),
Andrew Carter (Dept. of Earth and Planetary Sciences, Birkbeck),
Jerzy Blusztajn (Department of Geology and Geophysics, Woods Hole Oceanographic Institution)
Room: B222 2025-10-12 11:30

Models of large alluviated rivers suggest that communication of erosional signals from the headwaters to the coast should be impractical over most timescales because of sediment buffering and recycling in flood plains. A new Late Holocene sedimentary record of the Mississippi River was used to reconstruct a 3000-year record of sediment compositions in the lower reaches and delta of this catchment. Sr and Nd isotope compositions combined with major and trace elements and detrital zircon U-Pb ages reveal a stable weathering process but show that weathering proxies are controlled by grain size, with little evidence for a long-term trend in chemical weathering since 3000 years BP. The impact of weathering and mineral sorting during transport on 87Sr/86Sr extends to silt-sandy sediment in which coarser material is generally lower in this ratio compared to fine sediment. There is a long-term trend towards more erosion of from the Superior Province via the Upper Mississippi increasing after 2000 y BP, as constrained by Monte Carlo modelling of zircon population. This was a time when the climate dried, and humans adopted a more settled rather than hunter-gatherer lifestyle. Another change is noted after 500 years BP, close to the start of the Little Ice Age, a time of colder dried climate. There has been a gradual decrease in flux from the Rocky Mountain foreland basin delivered by the Missouri River, although this has still remained the dominant source of sediment. While there has been significant stability in the provenance of the Mississippi River, there have been short-term changes in zircon populations, indicating short-lived pulses of erosion that survive intact at the coast. There has also been more gradual centennial scale changes, with maximum sediment supply from the Missouri River at the Last Glacial Maximum and a steady increase in flux from the Red and Arkansas rivers after around 400 y BP. The Mississippi River is not fully buffered on centennial scales prior to the installation of man-made levees, although shredding of erosional signals between source and the coast occurred on decadal to centennial scales.

S1505. Granularity End-member analysis application on paleoclimatic change in Beibu Gulf, NW South China Sea

Jingpeng Zhang (School of Marine Sciences, Sun Yat-Sen University),
Ping Li (Guangzhou Marine Geological Survey, China Geological Survey, China),
Kai Liang (Guangzhou Marine Geological Survey, China Geological Survey, China),
Yulong Xue (Marine Geological Survey of Hainan Province, China)
Room: B222 2025-10-12 11:50

In order to enhance the understanding of suborbital scale climate change and its influence on the development of ancient human cultures in low latitude zone, a sedimentary core with 717 cm length from a marginal sea of Beibu Gulf, NW South China Sea, was analyzed to produce a higher resolution proxy through grainsize analysis, supported by more dense and precise age dating work.

The Bayesian function was employed to calculate and construct age-depth model for this sedimentary core using R programming, based on carbon age dating data from 16 sediment samples. The result shown this core covered time span since ca. 13 cal. kyr. BP to present, in term of crossing the late stage of Last Deglacial to Holocene.

Grainsize data from 359 samples was processed using End-member modeling analysis via the AnalySize program on the Matlab platform. The End-Member unmixing method decomposed the grain-size data into three predominant End-member components: 4-6 μm, 8-11 μm and 43-58 μm, respectively, which collectively account for ca. 99% of the total variance.

By calculating the standard deviation for each grainsize data in each sediment sample, a dataset conducive to sensitive grainsize analysis was established. The standard deviation exhibited peaks at the 8-11 μm and 48-63 μm components, which were defined as sensitive granularity within this sediment core, corresponding to End-member component 2 and 3.

The End-member 2 demonstrated a similar trend to 18O curve from Dongge Cave, which is widely recognized as indicative of changes in the Eastern Asian Monsoon. The End-member 3 revealed a notable anomalous event occurring around 4500-4000 cal. yr. BP, which had not been previously recognized by conventional grainsize components analysis. This sedimentary anomaly, occurring during the transition from Middle to Late Holocene, coincides with collapse of the Neolithic Culture of China (NCC) amidst rapid climatic changes.

S1507. Balancing Physical and Human-Driven Morphodynamic Changes: Insights from the Pearl River Estuary

Junjie Deng (School of Marine Sciences, Sun Yat-Sen University),
Hongze Yu (School of Marine Sciences, Sun Yat-sen University, China),
Yi Zhang (School of Marine Sciences, Sun Yat-sen University, China),
Jingyu Hu (School of Marine Sciences, Sun Yat-sen University, China),
Giovanni Coco (School of Marine Sciences, Sun Yat-sen University, China),
Jiaxue Wu (School of Marine Sciences, Sun Yat-sen University, China)
Room: B222 2025-10-12 12:10

The Pearl River Estuary, home to one of the world's densest human populations, exemplifies the delicate balance between natural dynamics and anthropogenic pressures. Our study explores how human activities and environmental changes interact to reshape this vital system, potentially driving it toward a tipping point. By integrating historical data, a Bayesian Network model, and a process-based morphodynamic model, we quantify the relative contributions of sediment supply, land reclamation, dredging, sand mining, and sea-level rise to estuarine evolution. Sediment supply remains the dominant driver, but human interventions and rising sea levels significantly disrupt the system's dynamics potentially leading to a tipping point in the estuarine morphodynamics of the Pearl River Estaury. We identify three distinct phases of estuarine evolution, revealing how cumulative pressures driven by anthropogenic pressure could force the estuary into different states with ecological, economic and societal consequences.

S1508. Training Strategies Matter: Improving Intelligent Sea Level Forecast in the North Pacific

Jiangnan He (Sun Yat-Sen University),
Wenfang Lu (Sun Yat-Sen University),
Young-Heon Jo (Pusan National University)
Room: B222 2025-10-12 14:30

Sea level anomaly is a vital ocean variable that reflects multi-scale ocean dynamics. A accurate forecast of sea level is essential for effective environmental stewardship and disaster prevention. Machine learning, with its ability to detect complex patterns, has become an essential tool in ocean forecasting systems. However, much of the focus has been on enhancing model accuracy by refining model structures and expanding training datasets, while the importance of training strategies is often overlooked. We use sea level data with a resolution of $0.25° \times 0.25°$ as the ground truth to achieve daily sea level forecast in the North Pacific. This study advances existing methodologies by integrating tailored training strategies for sea level forecasting. First, the model predicts daily changes in sea level relative to the previous day rather than absolute sea level, improving its ability to capture gradual sea level variations. Additionally, inspired by operational forecasting methods, we introduce two novel strategies called iterative training and rolling training, designed to better 30-day sea level forecasts.

We compared performance before and after the improvements, showing that the new training strategies significantly elevate the average performance on the test set and enhance the model's long-term predictive capabilities. Iterative training and rolling training results in a 15%-20% reduction in spatiotemporal RMSE for 10 to 30 days ahead of prediction. Moreover, iterative training outperforms rolling training by offering lower training costs and superior results. The final sea level forecast model demonstrates improved performance across spatial fields, time series, and spatiotemporal statistical indicators, surpassing both persistence and PSY, a data product of state-of-the-art numerical ocean forecasts. The spatiotemporal RMSE of the final model is only 18%-71% and 85%-97% of PSY and persistence.

S1509. Comparison of pristine and anthropogenically impacted river mouth systems exemplified by two case studies of the South China Sea's northern shelf

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Junjie Deng (School of Marine Sciences, Sun Yat-Sen University),
Joanna Dudzinska-Nowak (Institute of Marine and Environmental Sciences University of Szczecin),
Jakub Miluch (Polish Geological Institute - National Research Institute, Marine Geology Branch),
Jingpeng Zhang (School of Marine Sciences, Sun Yat-Sen University)
Room: B222 2025-10-12 14:50

River mouths systems serve as the gateways from the continents to the oceans, connecting drainage areas and depositional marine basins. These gateway areas host human populations over long periods of settlement history. The natural environment of densely populated hot spots along the global coasts are increasingly threatened by climate change induced rising sea-level, floods, storms, tsunamis, coastal erosion and the degradation of the natural environment due to anthropogenic impacts. To mitigate the threats management strategies for sustainable development of the continent-ocean gateways are to be elaborated and applied in particular in the densely populated areas. Modeling procedures help remarkably to understand the functioning of the river mouth systems considering in particular the effect of natural and anthropogenic system drivers. Contributing to answer corresponding questions we have compared a pristine paleo-river mouth system in the Beibu Gulf and the highly anthropogenically impacted Pearl River Estuary (PRE). For the analysis, natural factors such as global and local sea-level variation, vertical isostatic coastal movements, climate development, and sedimentary balances on the coastal structure were considered for both study areas using a conceptual model incorporating sequence stratigraphic approaches. For the PRE, anthropogenic activities, such as coastal construction in particular, were additionally considered. For future projections, which are crucial for management strategies, the question of the sediment balance must be in particular answered, whereby the periodicity analysis of empirical data plays a critical role. To answer these complex questions, the cooperation of interdisciplinary teams involving natural scientists, engineers, and socio-economists is indispensable.

S1510. Study on Groundwater Pollution Risk Assessment in Leizhou Peninsula Based on Machine Learning: A Case of Inorganic Nitrogen, Iron, and Manganese

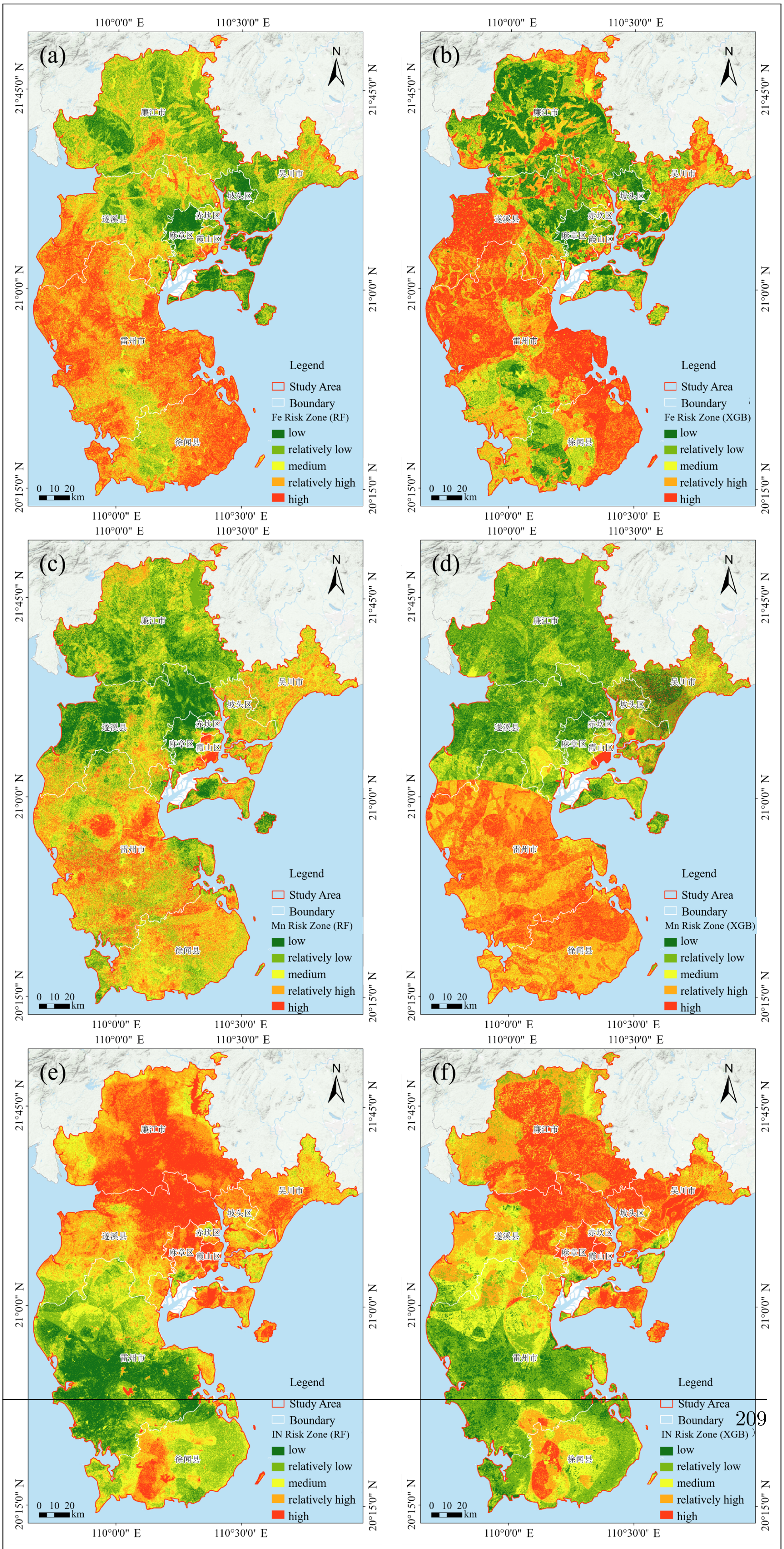
Zhenxiong Li (SUN YAT-SEN UNIVERSITY),
Ya Wang (School of Earth Science and Engineering, Sun Yat-sen University, Guangzhou, Chin)
Room: B222 2025-10-12 15:10

The groundwater in the Leizhou Peninsula faces severe combined contamination from inorganic nitrogen, iron, and manganese, significantly impacting the local ecosystem and threatening residents' drinking water safety. Using an improved DRASTIC index system, this study integrated multi-source data (topography, meteorology, hydrogeology, and socio-economics) to construct Random Forest (RF) and XGBoost models, systematically evaluating groundwater contamination risks of iron, manganese, and inorganic nitrogen. Key conclusions are as follows:

(1) Twenty multidimensional features from four aspects (hydrogeology, topography, meteorology, socio-economics) were integrated. Recursive Feature Elimination (RFE) screened core factors, Synthetic Minority Over-sampling Technique (SMOTE) addressed class imbalance, and Bayesian hyperparameter optimization enhanced model performance. RF outperformed XGBoost in predicting all three contaminants, with AUC values of 0.764 (iron), 0.7929 (manganese), 0.7524 (inorganic nitrogen), and Spearman coefficients of 0.63, 0.58, 0.55, showing stronger robustness in capturing positive samples and handling high-dimensional heterogeneous data.

(2) Feature importance and SHAP interpretability analysis revealed spatial concentration differentiation driven by multiple factors. Iron risk was dominated by aquifer thickness, annual rainfall, and permeability; manganese by industrial density, land use, and rainfall; inorganic nitrogen by groundwater depth, aquifer thickness, land use, and rainfall. High-risk iron zones clustered in Leizhou's Quaternary sedimentary belt; manganese in Xiashan's coastal areas; inorganic nitrogen in northern agricultural regions linked to fertilizer leaching and shallow groundwater.

(3) The machine learning-based method reduces reliance on high-density sampling. RF, more robust with high-dimensional data, provides scientific risk mapping for groundwater pollution control in the Leizhou Peninsula.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21°0'0" N
20°15'0" N
N
廉江市
吴川市
坡头区
赤坎区
遂溪县
麻章区
霞山区
雷州市
徐闻县
0 10 20 km
Legend
Study Area
Boundary
Fe Risk Zone (RF)
low
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(b)
Legend
Study Area
Boundary
Fe Risk Zone (XGB)
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(c)
Legend
Study Area
Boundary
Mn Risk Zone (RF)
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(d)
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Study Area
Boundary
Mn Risk Zone (XGB)
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(e)
Legend
Study Area
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IN Risk Zone (RF)
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S16 Towards Large AI Models for Geosciences

Suihong Song (Department of Energy Science and Engineering, Stanford University),
Xiaocai Shan (Institute of Geology and Geophysics, Chinese Academy of Sciences),
Keyu Liu (School of Geosciences, China University of Petroleum (East China)),
Xin Li (Research Institute of Petroleum Exploration and Development, CNPC),
Mingliang Liu (Department of Energy Science and Engineering, Stanford University)

As geosciences face increasingly complex challenges, large AI models—whether versatile fundamental models for multiple tasks or task-specific models with fewer parameters—may offer transformative opportunities. By leveraging cutting-edge algorithms, established geoscientific knowledge, and vast quantities of observable data, these AI models could reshape the landscape of geoscientific research and applications. This session focuses on (1) AI methodologies possibly used for large AI models, (2) construction of large-scale and high-quality training datasets, and (3) practices of already trained large AI models. Submissions are invited on AI techniques applicable to geosciences, including but not limited to Generative Adversarial Networks (GANs) and diffusion models conditioned on observable geoscientific data, discriminative and segmentation methods tailored for domain-specific applications, as well as large language model (LLM) related technologies. A major challenge in geosciences is the development of robust training datasets. We welcome contributions exploring workflows, methodologies, software solutions, best practices, and semi-technical narratives related to data collection and labeling. Some training data, such as conceptual geomodels, are especially scarce and could be constructed using simulation-based approaches, such as process-mimicking methods and efficient physics-based simulations. Long-term satellite imagery, spanning decades, also offers immense potential for dataset creation. Abstracts detailing methods, tools, or case studies for constructing such datasets and introducing new data libraries are particularly encouraged. Some large AI models may have already been trained for specific tasks. We encourage submissions that delve into the datasets, methodologies, performance benchmarks, and insights derived from these models. Lastly, the session seeks visionary contributions that explore the challenges and future prospects of large (or multi-task fundamental) AI models in geosciences. These grand perspectives can inspire novel approaches and set the stage for future advancements.

S1601. LAMGeo Initiative: Large Generative AI Model for Geomodelling

Suihong Song (Department of Energy Science and Engineering, Stanford University),
Tapan Mukerji (Stanford University)
Room: B210 2025-10-10 12:10

Recent advances in generative AI have opened new frontiers in geological modeling. The LAMGeo initiative aims to develop a foundational AI model for geomodelling across a wide range of reservoir types and geological hierarchies. The core components of LAMGeo include the collection of geological knowledge, construction of conceptual geomodels, development of specialized AI algorithms for geomodelling and porous media flow simulation, training of AI models conditioned on both static and dynamic data, deployment of the trained foundational AI model, and eventual field application for reservoir modeling and production forecasting.

Central to the initiative are three pillars: conceptual geomodel construction that captures geological knowledge, generative AI algorithms for geomodelling, and AI algorithms for flow simulation. A general workflow for conceptual geomodel construction has been proposed, and a benchmark dataset of turbidite lobe models has been developed based on real-world measurements.

Several generative AI approaches have been explored, including GANSim and DiffSim, but significant technical challenges remain. These include: how to incorporate the hierarchical nature of geological bodies during training; how to represent multiscale geological structures at the same hierarchical level; and how to address the stationarity versus non-stationarity of geological features. For flow simulation, both physics-informed and data-driven AI methods have shown promise, though challenges persist.

We propose a roadmap for the LAMGeo initiative that emphasizes interdisciplinary collaboration among geoscientists, AI researchers, and industry partners. This initiative seeks to build a robust bridge between geological knowledge and the practical needs for geology-aware subsurface models.

S1602. MigratoryGPT: A Multimodal LLM-Driven Framework for Next-Generation Migratory Bird Habitat Monitoring

Linshu Hu (Zhejiang University),
( )
Room: B210 2025-10-10 12:12

The complexity of migratory habitat dynamics and heterogeneous ecological data demand transformative monitoring frameworks beyond traditional species distribution models. We introduce MigratoryGPT, an end-to-end framework powered by GeoGPT for intelligent habitat monitoring. It automates key ecological indicator generation, real-time habitat evolution and anomaly detection, and delivers tailored interpretable decision-support reports for conservation managers. The framework comprises three core components: firstly, domain experts construct a comprehensive knowledge architecture encompassing key ecological concepts, relationships, and indicator schemas. GeoGPT leverages this to generate a formal ontology ensuring semantic precision and interoperability, while an automated pipeline extracts entities and relations from extensive ecological literature to form a dynamic knowledge graph. Secondly, multimodal monitoring agents, integrating machine vision, audio perception, and remote sensing monitoring, establish an integrated intelligent monitoring system to quantify health indicators, habitat quality, and anthropogenic disturbances. Thirdly, an automated RAG workflow enables analysis-to-report generation with closed-loop visualization. Validated on Poyang Lake datasets, the framework demonstrates significant improvements in quantitative accuracy and qualitative interpretability for habitat evolution tracking. This scalable, cost-effective solution establishes a paradigm shift in ecological monitoring, extensible to broader biodiversity conservation challenges.

S1603. GeoGPT.RAG: open-sourced retrieval models and RAG system for Geoscientist

Fei Huang (Zhejiang Lab),
Fan Wu (Zhejiang Lab),
Zeqing Zhang (Zhejiang Lab),
Qihao Wang (Zhejiang Lab),
Hongyang Chen (Zhejiang Lab),
Jieping Ye (Zhejiang Lab)
Room: D209 2025-10-13 10:30

GeoGPT is an open large language model system built to advance research in the geosciences. To enhance its domain-specific capabilities, we integrated Retrieval-Augmented Generation (RAG), which augments model outputs with relevant information retrieved from an external knowledge source. GeoGPT uses RAG to draw from the GeoGPT Library, a specialized corpus curated for geoscientific content, enabling it to generate accurate, context-specific answers. Users can also create personalized knowledge bases by uploading their own publication lists, allowing GeoGPT to retrieve and respond using user-provided materials. To further improve retrieval quality and domain alignment, we fine-tuned both the embedding model and a ranking model that scores retrieved passages by relevance to the query. These enhancements optimize RAG for geoscience applications and significantly improve the system's ability to deliver precise and trustworthy outputs.

GeoGPT reflects a strong commitment to open science through its emphasis on collaboration, transparency, and community-driven development. As part of this commitment, we have open-sourced two core RAG components—GeoEmbedding and GeoReranker.

In this report, we introduce our open-sourced models and our RAG systems' recent progress, including synergizing RAG and reasoning ability for Large Reasoning Model(LRM), to support geoscientists, researchers, and professionals worldwide with powerful, accessible AI tools.

S1604. A Big Data-Driven Spatiotemporal Intelligence Platform for Lushan UNESCO Global Geopark

Linshu Hu (Zhejiang University),
( ),
Jin Luo
Room: D209 2025-10-13 10:50

This study proposes a knowledge-driven Mountain-River-Lake Large Model (Shan-Jiang-Hu Model), a novel multimodal geospatial intelligence framework for integrated watershed management. By synergizing multi-source heterogeneous data (including literature repositories, authoritative databases, remote sensing imagery, IoT sensor networks, and in-situ monitoring systems) through hierarchical knowledge distillation, the model establishes a cognitive computing paradigm for cross-scale, cross-domain ecological analysis. The framework innovatively combines three core components: (1) A domain-specific knowledge architecture characterizing watershed element interactions (water-soil-atmosphere-biology-human activities) with spatiotemporal-explicit graph embeddings; (2) A hybrid reasoning engine integrating GeoGPT-based linguistic models with physics-informed neural operators for conservation-development tradeoff analysis; (3) An adaptive modeling cascade employing attention-guided transfer learning to derive task-specific submodels for extreme event detection and trend forecasting. Empirical validation in Poyang Lake Basin demonstrates the model's capability in real-time anomaly detection, early warning , and scenario-based decision optimization . This geospatial AI advancement provides a replicable paradigm for balancing ecological integrity with socioeconomic development in complex watershed systems.

S1605. A Novel Intelligent Prediction Approach for Porphyry Copper Resources Using MM-LLMs and Multi-Agents

Yongzhi Wang (Jilin University),
Shibo Wen (Jilin University),
Yuhao Dong (Jilin University),
Xingyu Chen (Macau University of Science and Technology),
Bowen Li (Jilin University)
Room: D209 2025-10-13 11:10

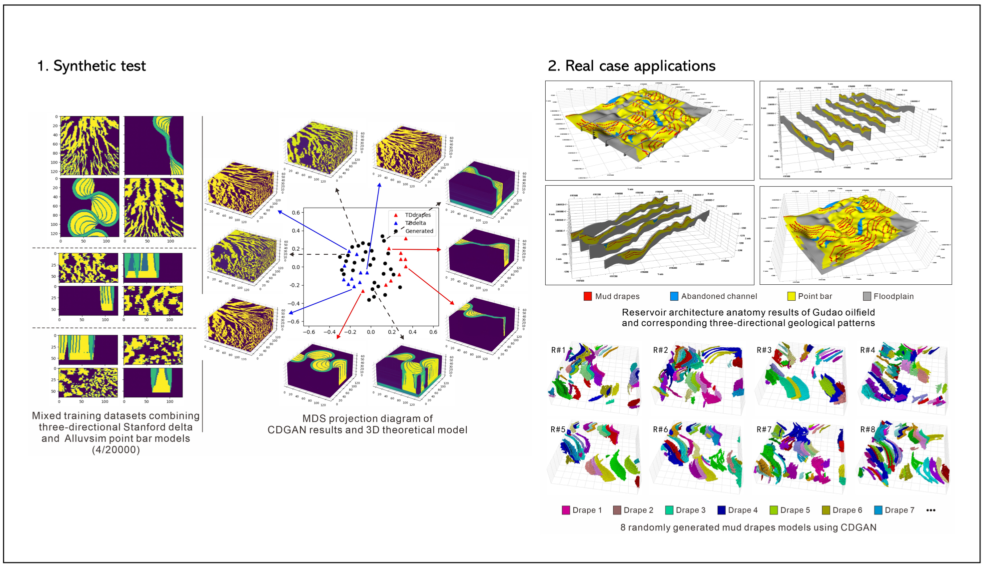
Large language models (LLMs) are changing the world rapidly including geosciences, and so does the agents. LLMs play the role of brains of geoscientists and agents interact with the real physical world by cooperating with LLMs. This paper proposes a novel approach to simulate the thinking methods and reasoning styles of geoscientists in the field of mineral resources prediction based on multimodal large language models (MM-LLMs) and multi-agents (MA), which contributes to MCP (Model Context Protocol) that serves as a flexible intelligent prediction architecture (IPA) builder to organize all kinds of remote tools, resources and prompts supported by MM-LLMs and MA accessed by specific MCP servers. The services include simple geochemical data processing agents and super multi-agents working for complex contexts. Each of the super ones can organize several agents to complete specific tasks such as generating geophysical interpolation maps or other analysis tasks and mining works in sequence. LPA integrates geological agents, geophysical agents, geochemical agents, and remote sensing agents under a unified MCP environment. It performs all tasks of porphyry copper resources prediction automatically when the client sends a prompt, The prediction agent accesses the GNN (Graph Neural Network) prediction tool and outputs the mineral prospectivity map. This paper suggests an innovative approach with an one click All-in-One pattern to carry mineral resources prediction intelligently and tries to explore a new paradigm in the agent AI era for future.

S1606. Cross-dimensional reservoir facies modeling method based on generative adversarial networks

Xun Hu (Yangtze University),
Yanshu Yin (Yangtze University),
Suihong Song (Department of Energy Science and Engineering, Stanford University),
pengfei xie (Yangtze University),
Lixin Wang (Yangtze University)
Room: D209 2025-10-13 11:30

Generative adversarial networks (GAN) have proven effective for simulating complex reservoir environments such as meandering channels and deltas. In classic GAN, the dimensionality of the training data determines the dimensionality of the generated data; that is, a 2D (or 3D) reservoir facies simulator (generator) requires training from a corresponding 2D (or 3D) dataset. However, most available 3D geological datasets (e.g., seismic or object-based models) suffer from low resolution or oversimplification, limiting their practical application. In contrast, 2D geological data like outcrop profiles and satellite images offer greater detail and wider coverage, providing a rich foundation for 3D model reconstruction.

We propose CDGAN, a cross-dimensional GAN-based framework for generating 3D geological models form 2D data. Its architecture combines a 3D discriminator, a slicer, and a 2D discriminator to resolve the dimensional incompatibility. A multi-discriminator strategy mitigates directional pattern interference, and progressive growing technology improves training stability and multi-scale feature representation. For well data conditioning, two approaches are introduced: (1) latent space optimization, which uses pretrained GANs with search algorithms (e.g., CMA-ES) to match well data; and (2) conditional retraining, where constructs 3D training dataset from pretrained GAN is used to train an extra conditional GAN (e.g., GANSim). CDGAN was validated on synthetic and real area cases. In theoretical tests, 2D-to-3D results closely resemble those from direct 3D training. In real applications, experts-interpreted facies plane and profile maps enable pretrained GANs to generate 3D models that aligned well with known geological interpretations. Moreover, the same pretrained generator is capable of producing diverse 3D models when trained on different types of 2D datasets. This approach effectively bridges the gap between traditional 2D reservoir architecture anatomy and 3D modeling. It provides a robust, data-driven solution for technical support for practical deep learning-based geological modeling and the development of large (language) geological models.



1. Synthetic test
2. Real case applications
Mixed training datasets combining three-directional Stanford delta and Alluvsim point bar models (4/20000)
MDS projection diagram of CDGAN results and 3D theoretical model
TDdrapes
TSdelta
Generated
Mud drapes
Abandoned channel
Point bar
Floodplain
Reservoir architecture anatomy results of Gudao oilfield and corresponding three-directional geological patterns
R#1
R#2
R#3
R#4
R#5
R#6
R#7
R#8
Drape 1
Drape 2
Drape 3
Drape 4
Drape 5
Drape 6
Drape 7
8 randomly generated mud drapes models using CDGAN

S1607. Efficient Time Series Forecasting Model Based on Hierarchical Frequency Decomposition and Dynamic Fusion

Xin He (China University of Geosceicnes(Wuhan)),
Guo Chen (China University of Geosciences (Wuhan))
Room: D209 2025-10-13 11:50

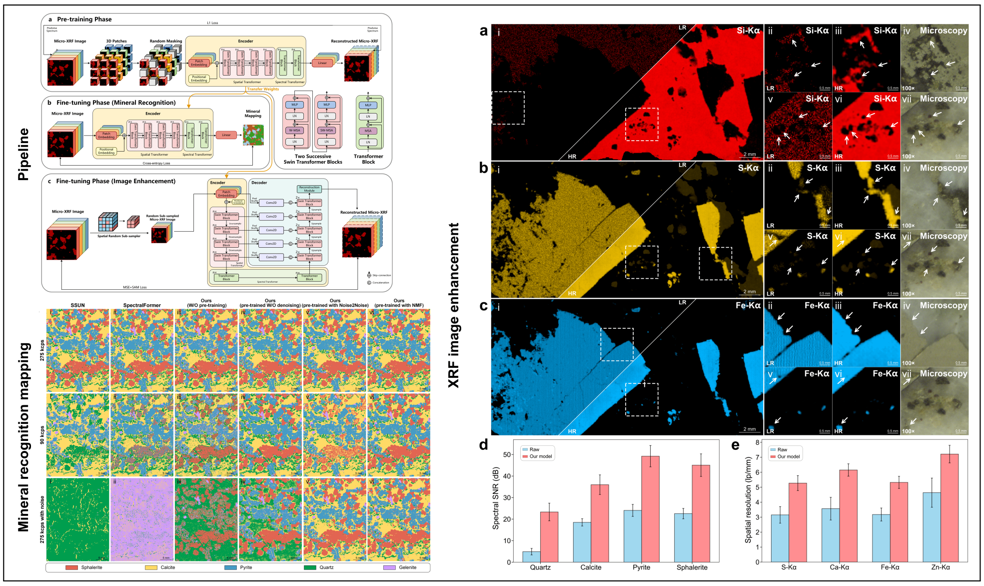
Due to the widespread existence of time series data in various fields, accurate time series prediction is of great significance and has been widely applied in practical fields such as energy, meteorology, finance, and geological disasters. Although many predictors using different network architectures have been proposed, Transformer-based models have demonstrated state-of-the-art performance in time series prediction. However, Transformer-based predictors still face the problems of vulnerability to high-frequency signals, low computational efficiency, and bottlenecks in the utilization of the full spectrum. These issues are essentially the key cornerstones for accurately predicting time series with thousands of points. In this paper, we explore a new perspective to inspire signal processing in deep time series prediction. This paper proposes a deep learning model based on hierarchical frequency analysis (Hierarchical Frequency Model, HFM). The model divides the original signal into low-frequency and high-frequency components through frequency domain decomposition, and designs targeted processing modules respectively: for the low-frequency part, a bidirectional LSTM and a one-dimensional convolutional neural network (CNN) are used to capture long-term dependencies and local patterns. For the high-frequency part, a linear denoising layer is used to extract detailed features, and learnable dynamic fusion weights are introduced to achieve adaptive fusion of multi-band information. Finally, we conduct extensive experiments on five time series prediction benchmarks, and the experimental results show that our method improves both in terms of effectiveness and efficiency.

S1608. Robustness and image enhancement in micro-X-ray fluorescence images using self-supervised learning

Weiming JIANG (School of Earth Sciences and Resources, China University of Geosciences, Beijing),
Jie YANG (China University of Geosciences, Beijing)
Room: D209 2025-10-13 12:10

X-ray fluorescence (XRF) is a convenient and non-destructive approach for elemental analysis. While advantageous, XRF spectrum quality further susceptible to variations in measurement conditions and comparatively limited spatial resolution relative to other elemental mapping methodologies. This study introduces the self-supervised deep learning frameworks designed to enhance XRF image quality and model robustness to address spectral complexity across diverse measurement conditions. A transformer-based model was pretrained via mask image modeling on a large-scale XRF dataset. To overcome the absence of noise-free reference data, a self-supervised training framework incorporating a random neighbor sub-sampler was developed to generate paired input-output datasets for image enhancement fine-tuning. Subsequently, the model was fine-tuned to mineral recognition in rock samples, which is demonstrated that the model maintains robust performance across variations in peak-to-background ratios, noise distributions, and spectral artifacts. The results of image enhancement show that the proposed model achieves a 70.86% improvement in spatial resolution and a 94.7% enhancement in overall signal-to-noise ratio (SNR) for XRF images. Notably, the model successfully reconstructed fine veins and grain that were undetectable in the original images. Furthermore, it exhibited a 378.44% increase in the SNR of XRF spectra corresponding to light elements, such as silicon. In mineral recognition tasks, the model attained state-of-the-art classification accuracy (97.55%) while maintaining an average sensitivity of 8.65% across various measurement conditions. By integrating image enhancement with mineral identification, the framework enables high-resolution mineral distribution mapping that transcends conventional instrumental limitations. Crucially, this methodology eliminates dependence on curated supervised datasets by leveraging naturally accrued XRF data from routine laboratory operations, thereby reducing experimental overhead. The proposed methodology represents a data-driven paradigm that maximizes the utilization of existing laboratory data archives, which is broadly applicable to spectroscopic instruments capable of generating three-dimensional hyperspectral data cubes.

Keywords: X-ray Fluorescence Spectroscopy, Deep Learning, Image Enhancement, Mineral Recognition.



Pipeline
a Pre-training Phase
b Fine-tuning Phase (Mineral Recognition)
c Fine-tuning Phase (Image Enhancement)
Mineral recognition mapping
SSUN
SpectralFormer
275 kcps
90 kcps
275 kcps with noise
Sphalerite
Calcite
Pyrite
Quartz
Galenite
XRF image enhancement
Si-Kα
S-Kα
Fe-Kα
Microscopy
LR
HR
Raw
Our model
Spectral SNR (dB)
Spatial resolution (lp/mm)
Quartz
Calcite
Pyrite
Sphalerite
S-Kα
Ca-Kα
Fe-Kα
Zn-Kα

S17 Geochemical Mapping for Anomaly Identification and Mineral Exploration

Yue Liu (China University of Geosciences, Wuhan),
Shuyun Xie (China University of Geosciences, Wuhan),
Emmanuel John Carranza (Univ. of the Free State),
Pingping Zhu (Kunming University of Science and Technology)

Geochemical mapping plays a crucial role in the identification of geochemical anomalies and the subsequent exploration of mineral resources, serving as a key tool for efficient and sustainable mineral discovery. This section aims to discuss and advance the latest methodologies, technologies, and applications in geochemical mapping. Geochemical mapping facilitates the detection and characterization of ore-forming anomalies—variations in the concentrations of geochemical elements in soils, rocks, and stream sediments—that could indicate the presence of economically valuable mineral deposits. The section will showcase successful mineral discoveries and innovative approaches across various geological settings. Central to the discussions will be advanced techniques such as multi-element analysis, compositional data analysis, isotopic fingerprinting, tectono-geochemical analysis, and integration of other geological data, to enhance the accuracy of anomaly mapping. Additionally, the role of artificial intelligence (AI), machine learning, and big data analytics in processing and interpreting high-dimensional geochemical data will be highlighted, demonstrating their impact on modern exploration strategies. The section will discuss the future trends, including AI and uncertainty analysis in geochemical mapping, and integration of geochemical data with other geoscientific data to create comprehensive mineral exploration framework.

S1701. Integrating Geochemical Mapping and Machine Learning for Precision Agriculture: Predicting Selenium-Rich and Low-Heavy-Metal Cropping Zones

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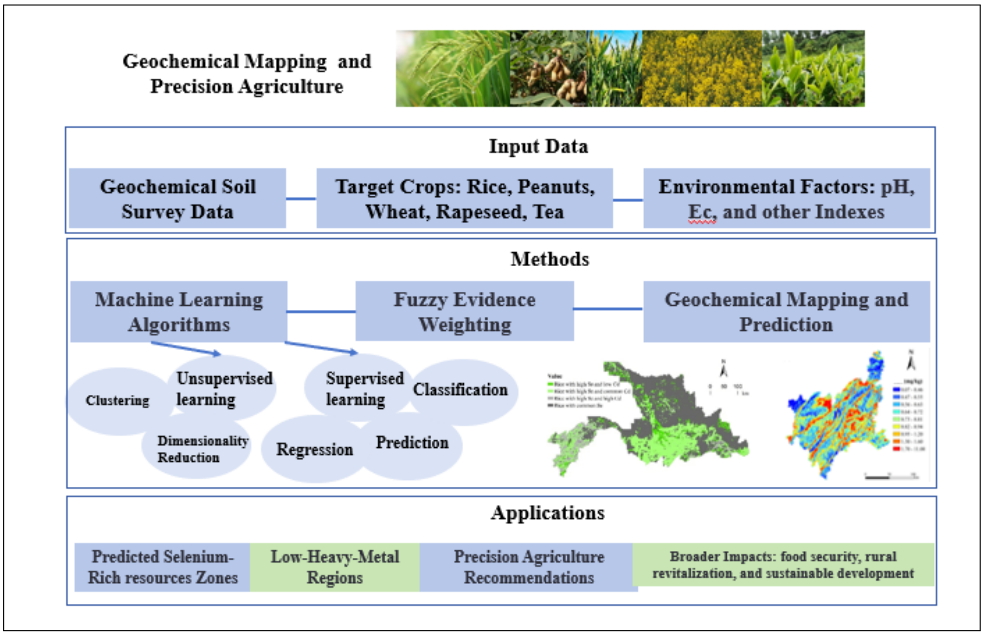
Weiji Wen (China University of Geosciences, Wuhan),
Hongtao Shi (State Key Laboratory of Geological Processes and Mineral Resources (GPMR), Facul),
Frank Zhang (School of Computing, University of the Fraser Valley, Canada)
Room: D205 2025-10-10 16:00

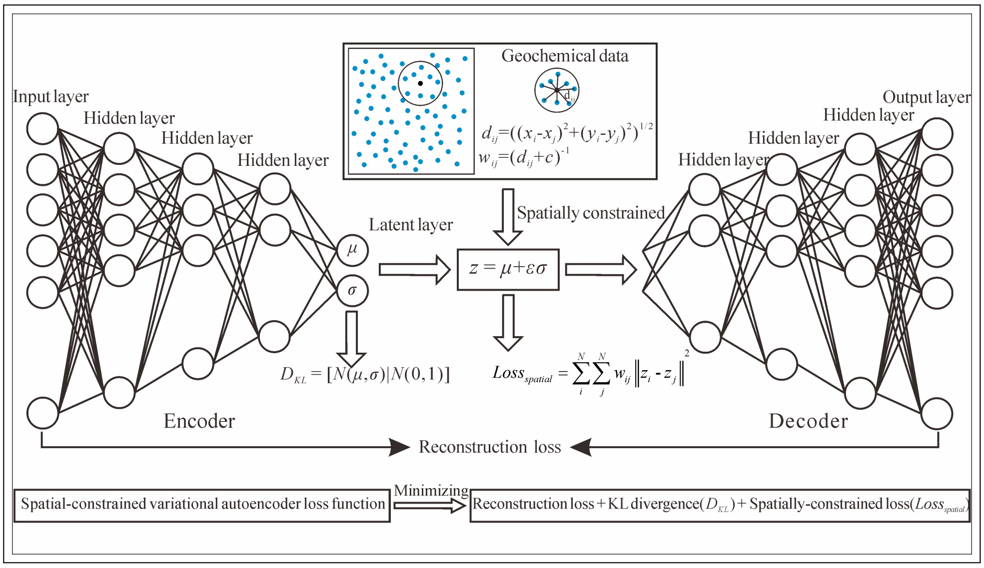
Selenium (Se), an essential micronutrient for human health, plays a critical role in dietary nutrition. Despite the importance of Se-rich crops such as rice and peanuts as primary dietary sources, the relationship between soil selenium content and crop selenium enrichment remains complex and site-specific. This study introduces an innovative framework that combines fuzzy evidence weighting, BP Neural Network, and random forest algorithms to predict regions in Hubei Province suitable for cultivating selenium-rich and low-heavy-metal crops. The predictions from both methods indicated that selenium-rich, high-quality rice is distributed in northern Hubei, central Hubei, and the Enshi region of southwestern Hubei. Moreover, the proportion of ordinary rice-growing areas exceeded 57.6% in both models. In the planting plan based on the BP neural network, the proportion of Grade I high-quality rice planting areas was higher than that obtained using the fuzzy evidence weight method. However, the total proportion of high-quality rice was slightly lower. Research on typical regions revealed that, overall, acidic yellow-brown soils rich in Se and Mo are conducive to crop absorption of soil selenium, while P and S hinder selenium uptake. For different crops: soils rich in As and Pb favor the cultivation of selenium-rich wheat. By integrating geochemical mapping with multi-target geochemical survey data, this approach identifies areas with optimal geochemical conditions for precision agriculture while assessing the spatial distribution of other essential nutrients. The findings not only support the sustainable utilization of selenium resources but also provide tailored fertilization and planting strategies for regions affected by heavy metal contamination or nutrient imbalances.


Geochemical Mapping and Precision Agriculture
Input Data
Geochemical Soil Survey Data
Target Crops: Rice, Peanuts, Wheat, Rapeseed, Tea
Environmental Factors: pH, Ec, and other Indexes
Methods
Machine Learning Algorithms
Fuzzy Evidence Weighting
Geochemical Mapping and Prediction
Clustering
Unsupervised learning
Dimensionality Reduction
Supervised learning
Classification
Regression
Prediction
Applications
Predicted Selenium-Rich resources Zones
Low-Heavy-Metal Regions
Precision Agriculture Recommendations
Broader Impacts: food security, rural revitalization, and sustainable development

S1703. Spatially Constrained Variational Autoencoders for Geochemical Data Denoising and Uncertainty Analysis

Dazheng Huang (China University of Geosciences),
Renguang Zuo (China University of Geosciences, Wuhan),
Jian Wang (Research Institute of Petroleum Exploration and Development),
Raimon Tolosana Delgado (Helmholtz Institute Freiberg for Resource Technology HIF-HZDR)
Room: D205 2025-10-10 16:20

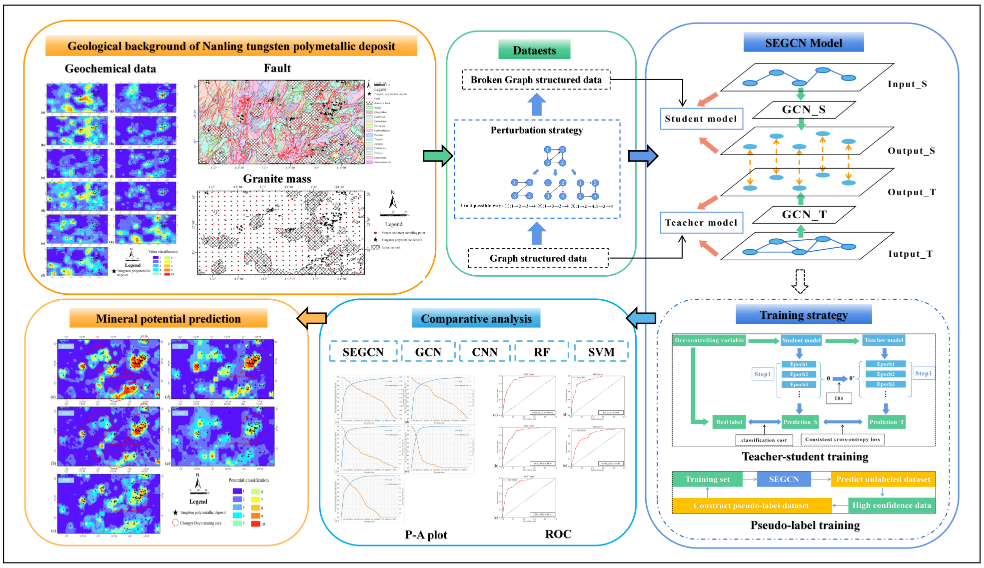
Geochemical surveys are fundamental in mineral exploration by revealing element distributions that may indicate promising deposits. However, uncertainties arising from sampling, laboratory analyses, and data preprocessing frequently affect high-dimensional geochemical datasets, manifesting as both random noise and systematic bias. Traditional denoising methods, such as filters, tend to oversmooth the data, thereby obscuring the localized anomalies that are crucial for identifying mineralized zones. To address these challenges, a novel framework is introduced for denoising multi-element geochemical datasets with robust uncertainty quantification: the Spatially Constrained Variational Autoencoder (SC-VAE). SC-VAE integrates a variational autoencoder with an innovative spatial regularization mechanism. By incorporating an adjacency matrix that reflects the geographic proximity of sampling points, the framework enforces spatial continuity in the latent space. This constraint effectively suppresses noise while preserving fine-scale, localized anomalies that indicate true geological signals. Moreover, the probabilistic structure of the variational autoencoder enables rigorous uncertainty quantification of the denoised outputs, an essential aspect for informed decision-making in exploration. To enhance the model's performance, a two-stage Bayesian optimization process is employed. The first stage fine-tunes the network architecture parameters to maximize reconstruction accuracy, while the second stage adjusts the strength of the spatial regularization to achieve an optimal balance between noise suppression and the preservation of localized geochemical anomalies. The proposed methodology was applied to the northwestern part of Sichuan Province, China, a region known for gold mineralization. Experimental results indicate that SC-VAE effectively reduces noise, as evidenced by a decreased nugget effect in variograms, while maintaining the integrity of key geochemical features. These improvements enhance the reliability of subsequent analyses, such as anomaly detection, mineral potential mapping, and resource assessment.


Geochemical data
$d_{ij}=((x_i-x_j)^2+(y_i-y_j)^2)^{1/2}$
$w_{ij}=(d_{ij}+c)^{-1}$
Input layer
Hidden layer
Hidden layer
Hidden layer
Latent layer
Spatially constrained
$z=\mu+\varepsilon\sigma$
Hidden layer
Hidden layer
Hidden layer
Output layer
$D_{KL}=[N(\mu,\sigma)|N(0,1)]$
$Loss_{spatial}=\sum_i^N\sum_j^N w_{ij}\|z_i-z_j\|^2$
Encoder
Decoder
Reconstruction loss
Spatial-constrained variational autoencoder loss function
Minimizing
Reconstruction loss + KL divergence(D_{KL}) + Spatially-constrained loss($Loss_{spatial}$)

S1704. Prospective Mineralization Areas Delineation for Tungsten Polymetallic Deposits in Nanling, China Based on a Novel Self-Ensembling Graph Convolutional Network

Yonghang Lou (China University of Geosciences (Wuhan))
Room: D205 2025-10-10 16:40

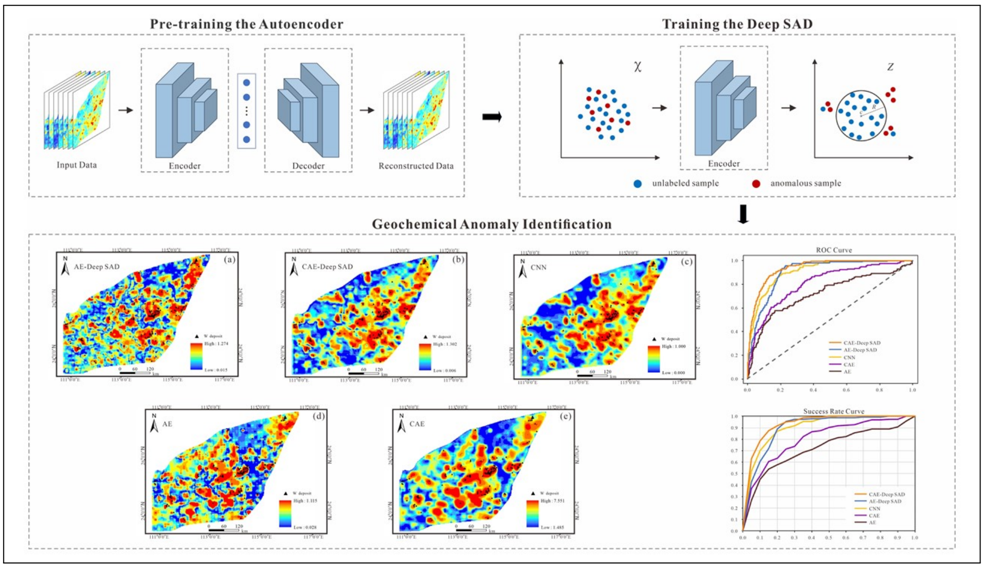
The graph convolutional network (GCN) has proven to be a powerful tool for exploration criterion identification and mineral prospectivity analysis because of its excellent ability to integrate and capture complex spatial geo-anomalies associated with mineralization. However, the graph convolution of the GCN is essentially a special form of Laplacian smoothing that can result in the over-smoothing of output features. This over-smoothing can undermine the reliability of prospective mineralization areas delineation, which aims to identify mineralization-related geo-anomalies typically characterized by a series of anomalous values in the GCN model. To solve this problem, we introduce a novel deep learning model, the Self-Ensembling Graph Convolutional Network (SEGCN), which integrates the mean teacher model with the GCN model by fully learning unlabelled geological features. To illustrate the superiority of the SEGCN model, a case study for tungsten polymetallic prospectivity analysis was carried out in the Nanling belt, China. The SEGCN model was used to build a classification model based on the fusion of multiple geospatial datasets, including geochemical data and data on faults and rock masses. The SEGCN model was compared with conventional GCN, convolutional neural network (CNN), random forest (RF), and support vector machine (SVM) in terms of their classification performance and predictive accuracy and was evaluated via receiver operating characteristic (ROC) curves and predictionarea (PA) plots. The results demonstrated that the SEGCN model significantly outperformed the other four models in mapping tungsten polymetallic prospectivity in the Nanling region (China). We concluded that the SEGCN model can establish an efficient, robust and high-performance classification model to effectively recognize favourable mineralizing targets from multi-source geo-anomalies, thereby suppressing the over-smoothing effect in the GCN.



S1705. Identification of Geochemical Anomalies Using a Deep Semi-Supervised Anomaly Detection Model

Rui Bi (China University of Geosciences (Wuhan)),
Qinglin Xia (School of Earth Resources, China University of Geosciences)
Room: D205 2025-10-11 10:30

Geochemical anomaly identification is a crucial step in mineral resource exploration, aiming to detect potential mineralized areas within complex geochemical datasets. In recent years, machine learning techniques, particularly deep learning algorithms, have been proven to be highly efficient tools for identification geochemical anomalies related to mineralization. Machine learning techniques can be broadly categorized into supervised and unsupervised learning, each with its limitations. Supervised learning relies heavily on large amounts of labeled data, typically using known mineral deposits as positive samples, while selecting appropriate negative samples poses a challenge. On the other hand, unsupervised learning does not require labeled data but fails to fully utilize the limited available positive samples, leading to lower anomaly detection accuracy. To address these limitations, this study introduces the deep semi-supervised anomaly detection (Deep SAD) model for geochemical anomaly identification. This approach trains the model using only known positive samples and unlabeled data, avoiding negative sample selection while effectively leveraging the limited available positive samples. To evaluate the effectiveness of the Deep SAD method in mineralization-related geochemical anomaly identification, the Nanling area in China was selected as the case study region. Two models, AE-Deep SAD and CAE-Deep SAD, were developed based on the Deep SAD framework and compared with deep autoencoders (AE), convolutional autoencoders (CAE), and convolutional neural networks (CNN). Comparative results indicate that CAE-Deep SAD performs best in terms of the ROC curve and success-rate curve, outperforming AE-Deep SAD, AE, CAE, and CNN. This demonstrates that the CAE-Deep SAD model exhibits superior anomaly detection capability and provides an effective solution for geochemical anomaly identification.



S1706. Probabilistic Neural Networks for mineral prospectivity evaluation based on multisource geospatial data

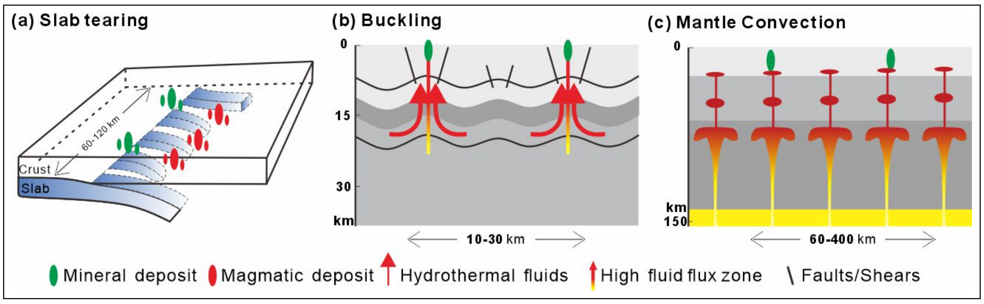
Yue Liu (China University of Geosciences, Wuhan)
Room: D205 2025-10-11 10:50

Mineral Prospectivity assessment has emerged as a pivotal tool in supporting decision-making in mineral exploration, enabling the identification of regions with high potential for mineral deposits by primary integrating geological and geochemical data. Deep learning technology has proven to be an effective tool to solve numerous intricate problems in the field of geochemical mapping and mineral exploration. Nonetheless, most deep learning models fail to adequately capture the uncertainty in predictions. Furthermore, conventional deep learning models often exhibit overconfidence in mineral predictions, which hinders their effectiveness in practical scenarios. To address these shortcomings, a Bayesian deep learning (BDL) framework was developed for mineral prospectivity assessment and uncertainty estimation based on geological and geochemical data. The BDL framework predicts a more confident exploration strategy while maintaining flexibility to address uncertainties in predictions. Two popular posterior approximation approaches, sampling-based Metropolis-Hastings (MH) Monte Carlo and variational inference (VI), were considered to estimate model parameters and associated uncertainties in the BDL framework. The effectiveness and generality of the BDL were demonstrated through a case study for W-Sn prospectivity mapping of the Nanling region. The results show that both MH-based BDL and VI-based BDL can yield high prediction accuracy, while uncertainty estimates depend on specific approximation approach. By comparisons between the two BDL models, the MH-based BDL provides more robust uncertainty estimates, while VI-based BDL model tends to underestimate uncertainty and couple the two types of uncertainty strongly.

S1707. Spatial distribution pattern of concealed copper deposits in the Southeastern Coastal Belt and implications for ore deposits localization, South China

Pingping Zhu (Kunming University of Science and Technology),
Qiuming Cheng (Sun Yat-sen University)
Room: D205 2025-10-11 11:10

Southeastern Coastal Belt of China has been identified as a Jurassic concealed porphyry copper belt, yet the spatial distribution patterns of porphyry copper deposits remain unclear. To address this scientific issue, this study approaches the problem from the perspectives of singularity and periodicity. First, machine learning methods were employed to predict the spatial distribution probabilities of concealed porphyry copper deposits. Subsequently, wavelet analysis was applied to investigate the periodic distribution patterns of these deposits. The results reveal that the spatial distribution periods of ore-forming elements (Cu, Au, and Re) associated with porphyry copper deposits in the southeastern coastal region are approximately 88 km, 95 km, and 95 km, respectively, exhibiting periodic distribution characteristics typical of porphyry copper deposits in a subduction zone setting. Additionally, zircon Hf isotope mapping and the spatial probability distribution of porphyry copper deposits also demonstrate periodic patterns similar to those of the ore-forming elements. Integrating regional geological evolution and metallogenic processes, this study concludes that the concealed porphyry copper deposits along the southeastern coast exhibit a periodic distribution pattern of approximately 90 km and possess significant mineralization potential comparable to the South American Andean metallogenic belt. These findings hold substantial implications for understanding the periodic distribution mechanisms of porphyry copper deposits and guiding exploration efforts in the southeastern coastal region of China.



S1709. A Dual-Constrained Interpolation Framework Integrating Medium Heterogeneity and Spatial Anisotropy for Geochemical Modeling

Na Ren (China University of Geosciences (Wuhan))
Room: D205 2025-10-11 11:30

Abstract:

This study addresses the challenge of predicting the spatial distribution of geochemical elements in complex geological environments by proposing a two-dimensional interpolation method that integrates medium attributes and spatial anisotropy. Traditional methods often suffer from insufficient accuracy due to their neglect of stratigraphic medium heterogeneity and directional diffusion variability. Based on geochemical point data, the research focuses on four core components:

(1) Medium-Specific Attenuation Parameter Modeling: Statistical analysis of element migration patterns in distinct strata (e.g., sedimentary rocks, igneous bodies) is conducted to establish a medium-dependent kernel function attenuation parameter library.

(2) Spatial Variogram Range Ellipse Modeling: Using geostatistical variogram models, the directional heterogeneity of element diffusion is quantified, and dynamic elliptical search windows are constructed to characterize spatial asymmetry in element migration.

(3) Dual-Constrained Interpolation Algorithm: At each interpolation grid node, kernel function parameters are automatically selected based on local medium types, while anisotropic neighborhood ranges are defined by variogram-derived ellipses, enabling an adaptive interpolation framework.

(4) Interpolation Accuracy Validation: The proposed method is compared with traditional Kriging and inverse distance weighting (IDW) approaches through cross-validation and field sampling data, demonstrating superior performance in prediction accuracy and spatial consistency.

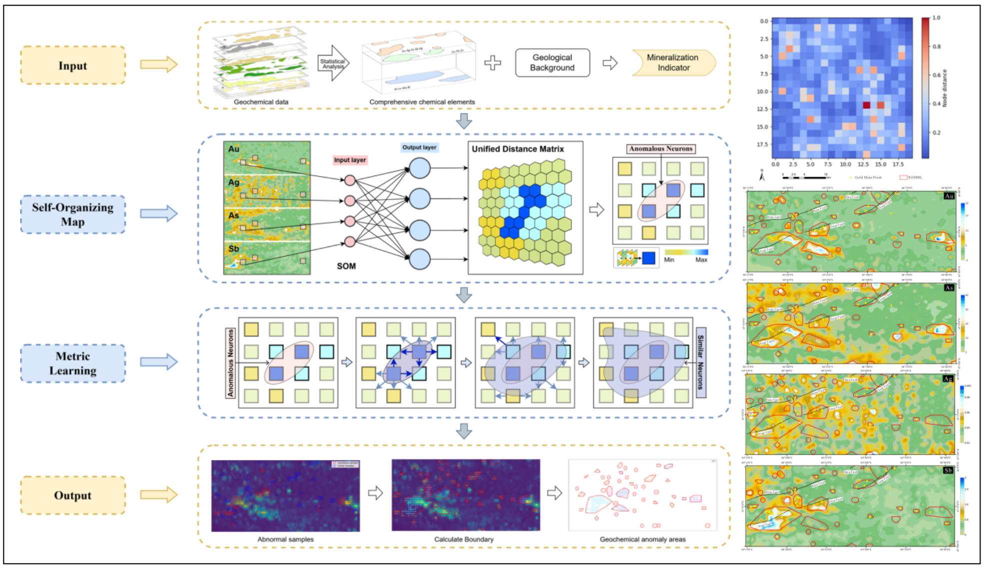
Keywords:

Geochemical interpolation; Medium heterogeneity; Variogram; Anisotropy; Geological modeling

S1710. Extraction of Geochemical Anomalies in Hatu Area based on SOMML Method

Yajie Feng (Jilin University),
Yongzhi Wang (Jilin University)
Room: D205 2025-10-11 11:50

Geochemical anomalies are critical indicators for mineral prospectivity mapping. Traditional anomaly detection methods often assume specific statistical distributions, limiting their applicability in complex geological settings. In contrast, machine learning techniques can capture nonlinear relationships between elements without requiring such assumptions, effectively distinguishing between background and anomalous patterns. However, these models typically rely on extensive labeled datasets and lack the integration of geological domain knowledge, resulting in reduced interpretability and generalization. In this study, we introduce a Self-Organizing Map and Metric Learning (SOMML) approach for geochemical anomaly mapping in the Hatu region of Xinjiang, China. Considering the region's metallogenic framework, four key ore-related elements (Au, Ag, As, and Sb) were selected based on their critical role as indicators of mineralization processes. The SOM model adaptively learned the spatial distribution patterns of these elements, identifying neurons associated with significant composite anomalies. Subsequently, metric learning quantified the similarity between anomalous neurons and their neighbors, allowing for refined anomaly delineation. Experimental results demonstrate that SOMML successfully identified anomalies encompassing nearly all known mineral occurrences in the study area. The extracted anomalies closely align with established geological knowledge and metallogenic models. Compared with conventional machine learning methods, SOMML achieved comparable recognition of known deposits while reducing the anomalous area, primarily due to its ability to incorporate geological feature relationships rather than relying solely on statistical similarity. This research highlights the effectiveness of the SOMML approach in enhancing the accuracy and interpretability of geochemical anomaly detection. The resulting anomaly maps provide a valuable decision-support tool for guiding future mineral exploration efforts in the Hatu region.



S1711. Recognition of Multiple-Depth Deposit-Relevant Enrichment Footprints By Blind-Source Separation of Spectrally-Filtered Geochemical Signals

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Seyed Hassan Tabatabaei (Department of Mining Engineering, Isfahan University of Technology, Isfahan, Ira),
Shahram Hosseini (Institut de Recherche en Astrophysique et Planétologie (IRAP), Université de Tou),
Yannick Deville (Institut de Recherche en Astrophysique et Planétologie (IRAP), Université de Tou),
Emmanuel John Carranza (Univ. of the Free State)
Room: D205 2025-10-11 12:10

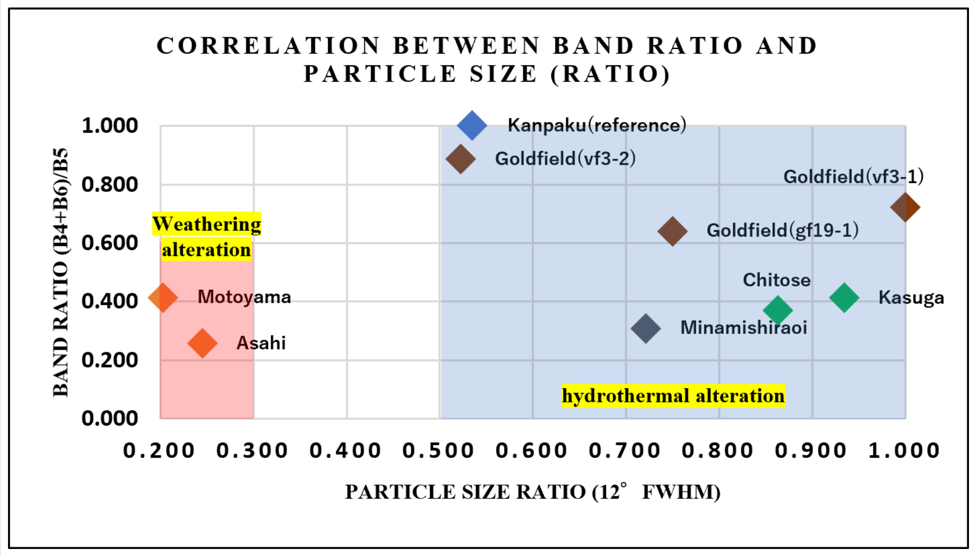
A model for blind-source separation is presented to retrieve geochemical signal sources for the recognition of multiple-depth deposit-relevant enrichment footprints in intricate metallogenic systems. This model comprises of two sequential modules. Module 2 caters to the spectral decomposition of an admixture of elements to derive various frequency-linked signal components induced by a variety of geological sources. Module 2 caters to the retrieval of the sources of spectrally-decomposed geochemical signals in accordance with the statistical assumptions regarding the transmittal of these signals from their sources. The model was used in a real case trial to process surficial geochemical signals of deposit-forming elements in a multiple-phase mineral system to appraise the bearing of source-linked signals in representing subsurface deposit-relevant enrichment footprints. Multifractal filtering, in accordance with the posited scale invariance features of a power spectral density plane, was implemented to obtain enhanced elemental images from a variety of spectral bands. With the assumption of linear instantaneous transmittal, the FastICA method was used to encode spectrally-decomposed models of elemental admixtures and retrieve source-linked geochemical signals related to a variety of geological processes. Support vector machines were utilized to train classifiers to form statistical linkages between surficial geochemical signals and near-surface/subsurface deposit-relevant enrichment footprints in the study area. The accuracies of the classification results show that it is possible to recognize and distinguish more effectively near-surface/subsurface deposit-relevant enrichment footprints by making use of retrieveed source-linked signals than by making use of a combination of elements or spectrally-decomposed geochemical signals. The results signify the ability of proposed BSS model to retrieve source-linked geochemical signals efficiently in order to recognize robust deposit-relevant enrichment footprints with combined grade–depth resolution for guiding further exploration of metals.

S1713. Remote Sensing-based Discrimination of Kaolinite Origin for a New Indicator of Metal Deposit Exploration

Shoya Ikeuchi (Kyoto),
Masahide Kishimoto,
Taiki Kubo (Department of Urban Management, Graduate School of Engineering, Kyoto University),
Koki Kashiwaya,
Katsuaki Koike (Graduate School of Engineering, Kyoto University),
Tetsuro Yoneda
Room: D205 2025-10-11 12:30

In resource exploration using remote sensing, the main method for identifying hydrothermal alteration minerals is to use reflection spectra and emission spectra, and kaolinite is one of the representative minerals. Kaolinite is extracted as an alteration mineral using remote sensing image analysis, mainly for the exploration of porphyry copper deposits, gold deposits, and VMS deposits. In recent years, the distribution of kaolinite on the surface of Mars has also been estimated, suggesting the possibility of metal ore formation.

Kaolinite forms through two primary geological processes: surface-level chemical weathering in warm and humid climates, and hydrothermal alteration under acidic and high-temperature conditions at various crustal depths. Kaolinite formed under the latter conditions can be used as an indicator for metal ore exploration. Remote sensing may be the most effective exploration method for wide areas by identifying this type of kaolinite. Based on those backgrounds, this study aimed to develop remote sensing technology for metal ore exploration using kaolinite as an indicator. For this, we investigated the correlation between the differences in mineral composition and chemical properties of kaolinite derived from weathering and hydrothermal alteration and the reflectance spectrum in the visible to short-wave infrared region. The analysis used kaolinite samples collected from hydrothermal deposits in Japan and the United States, as well as from kaolinite mines in Japan. In addition, the reflectance spectra of kaolinite from weathered regions and hydrothermal regions were compared using images from the Earth Observation Satellite (EO-1) Hyperion. The results showed that there were differences in particle size between samples derived from hydrothermal alteration and those derived from weathering alteration, and that the reflectance index at wavelengths of 2.16 to 2.22 μm, which is the absorption band of Al-OH, may be effective for discriminating between weathered and hydrothermally altered kaolinites.


CORRELATION BETWEEN BAND RATIO AND PARTICLE SIZE (RATIO)
BAND RATIO (B4+B6)/B5
1.000
0.800
0.600
0.400
0.200
0.000
0.200
0.300
0.400
0.500
0.600
0.700
0.800
0.900
1.000
PARTICLE SIZE RATIO (12° FWHM)
Kanpaku(reference)
Goldfield(vf3-2)
Goldfield(vf3-1)
Goldfield(gf19-1)
Weathering alteration
Motoyama
Asahi
Chitose
Kasuga
Minamishiraoi
hydrothermal alteration

S18 Integrating AI and Geological Modeling for Enhanced Geo-Steering to Improve Drilling Efficiency

Yupeng Li,
Taizhong Duan (Sinopec Petroleum Exploration and Production Research Institute)

The oil and gas industry stands on the brink of a technological revolution where artificial intelligence (AI) and geological modeling are merging to revolutionize geo-steering practices. Geological modeling plays a critical role in geo-steering, enhancing both the precision and safety of drilling while providing more efficient and cost-effective solutions for resource development. This session is designed to explore the latest advancements, challenges, and solutions in geo-steering technologies, with a particular focus on the essential roles of geological modeling and AI in enhancing drilling efficiency and precision. We invite contributions that address the following aspects, but are not limited to them:

(1) Data Integration and Predictive Analytic: Geological modeling, when combined with various data sets, significantly enhances predictive capabilities regarding resource location and environmental impacts. This leads to increased drilling success rates and reduced costs associated with drilling failures. (2) Real-Time Decision Support: The synergy between geological modeling and real-time data streams, such as Logging While Drilling (LWD) and Seismic While Drilling (SWD), offers robust support for geo-steering, enabling swift and informed decisions. (3) Risk Management and Safety: Geological modeling provides crucial insights for predicting and managing drilling risks, which is vital for planning appropriate drilling mud weights and casing programs to prevent blowouts and well control incidents. (4) Drilling Efficiency Improvement: Geological modeling facilitates the optimization of well trajectories, reducing the likelihood of encountering complex formations, improving the rate of penetration, and increasing the probability of successfully hitting the target reservoir.

S1801. Deep Learning-Based Rapid While-Drilling Update Technology for 3D Geological Models and Its Application

Yanfeng Liu (Sinopec),
Taizhong Duan (Sinopec Petroleum Exploration and Production Research Institute),
Wenbiao Zhang (Sinopec Research Institute of Petroleum Exploration and Development),
Meng Li (Sinopec Research Institute of Petroleum Exploration and Development),
Yuan Huang (Sinopec Research Institute of Petroleum Exploration and Development)
Room: D205 2025-10-12 14:30

Accurately drilling deep complex reservoirs, such as thin clastic sandstone bodies or fractured-vuggy carbonate reservoirs, poses significant challenges for geosteering. Pre-drill geological models often suffer from inaccuracies in predicting target reservoir spatial location and internal structure due to limitations in seismic resolution, interpretation uncertainties, and time-to-depth conversion errors, leading to low drilling success rates. To address this, this paper proposes a rapid update technology for deep reservoir geosteering geological models based on deep learning. This technology utilizes deep learning algorithms as its core. Initially, a large training dataset is built, enabling an intelligent network to learn the complex seismic-to-geology mapping. Before drilling, the target area's seismic and offset well data are input into the pre-trained network to quickly generate an initial geosteering model. During drilling, while-drilling logging data, including sonic, gamma-ray, and resistivity measurements, are acquired in real-time. The while-drilling sonic data are used to update the velocity field around the wellbore and ahead-of-the-bit, facilitating rapid seismic re-imaging and migration to correct the structural model. Concurrently, while-drilling logging suites, combined with AI-based interpretation, rapidly identify lithology, reservoir boundaries, and internal barriers/interlayers, updating the lithofacies model. This updated model provides real-time guidance for adjusting the drilling trajectory. The technology was tested on well TH12581 targeting a deep fractured-vuggy reservoir in the Tahe Area Block 10, Tarim Basin. Results demonstrate that the while-drilling update process significantly improved the accuracy of the target fractured-vuggy body's depth prediction (T74 interface corrected from -5648m progressively towards the actual depth near -5520m) and shape characterization as drilling approached the target. This validates the technology's reliability and practicality for enhancing geosteering success rates when drilling small-scale targets in complex deep reservoirs.

S1802. Utilizing Deep Learning for Carbonate Depositional Facies Modeling and Model Updating

Meng Li (Sinopec Research Institute of Petroleum Exploration and Development),
Taizhong Duan (Sinopec Petroleum Exploration and Production Research Institute),
Yanfeng Liu (SINOPEC),
Yuan Huang (SINOPEC)
Room: D205 2025-10-12 14:50

Sedimentary facies description is crucial in oil and gas development and geology. Facies modeling, a quantitative tool, often relies on geological statistical methods. However, traditional two-point statistics struggle with complex, non-homogeneous facies, while multi-point statistics are limited by the quality of training images. Carbonate rocks, being biogenic, exhibit complex facies controlled by factors such as tectonic background, depositional environment, and biological types, making accurate 3D modeling challenging. Existing geological statistical methods often fail to capture the intricate spatial variations of carbonate facies due to data limitations.

Deep learning, with its ability to handle complex tasks, has shown promise in fields like image recognition. Its effectiveness depends on sample quantity and quality, as well as network structure and training. In oil and gas, simulation techniques have been used to generate large datasets, leading to breakthroughs in tasks like intelligent fault prediction and fluvial facies prediction. However, successful applications in carbonate 3D geological modeling remain limited, particularly in aligning predictions from seismic data with well data.

In this study, we address these challenges by using integrated simulation techniques, including sedimentary, structural, rock physics, and seismic forward modeling. By perturbing simulation parameters, we generate large-scale, high-quality datasets that bridge the gap between well and seismic data, providing a robust foundation for end-to-end training of deep learning networks. This approach not only overcomes sample limitations but also enhances the accuracy of facies predictions. Additionally, we introduce a novel deep learning architecture inspired by the CLIP concept, which effectively integrates multi-modal data for well conditioning. During drilling, as well information is updated, this method can rapidly update the model through fine-tuning, supporting the completion of Geo-Steering tasks. The approach has been initially applied to the Yuanba gas reservoir in China, showing potential for improving carbonate facies modeling and reducing uncertainties in reservoir characterization.

S19 Big Data and AI-Driven Innovations in geoscience from Chinese scholars organized by the IAMG Topical Section for Chinese

Yongzhang Zhou (Sun Yat-sen University),
Gang LIU (China University of Geosciences (Wuhan)),
Hui Yang (China University of Mining and Technology),
Xiaohui JI (China University of Geosciences, Beijing),
Weisheng Hou (Sun Yat-sen University),
Zhijun Chen (China University of Geosciences (Wuhan))

This session welcomes all big data and AI-driven ideas and research in geoscience to address the development, especially current and future challenges in big data mining and machine learning in geoscience from Chinese scholars, and is organized by the IAMG Topical Section for Chinese Members. The rising demand for critical minerals and environment offers economic opportunities but also poses environmental and geopolitical challenges in China. Recent progress in data science and machine learning has shown great potential to accelerate the discoveries of mineral deposits, improve resource efficiency, and sample/survey optimization. Such big data and AI-driven approaches can more effectively deepen insights into geochemical, geological, geophysical, remote sensing, environmental data, and beyond, thereby proving better-informed mineral exploration. This session will cover the latest data science and machine learning advancements in combining such multi-disciplinary data to enhance sustainable and efficient decision-making in mineral exploration. Studies using new data-driven approaches for geochemical data analysis, geological modeling, geophysical inversion, mineral prospectivlity mapping, decision-making under geological uncertainty, are encouraged.

S1901. Research on AI mineral prospecting methodology based on the Qinzhou - Hangzhou Bays metallogenic belt, South China

Yongzhang ZHOU (Sun Yat-sen University),
Wenjia Li (School of Earth Sciences and Engineering, Sun Yat-sen University),
Biaobiao Zhu (Center for Earth Environment & Resources, Sun Yat-sen University)
Room: B222 2025-10-11 16:30

The Qinzhou - Hangzhou Bays metallogenic belt is a national level key metallogenic zone with huge mineral potential in China. Based on the belt's huge geological and deposit data, this project will build a large language model and knowledge graph in regional geology and mineral exploration domain, and evaluate important mineral-exploration scenarios and big data mining & AI algorithm operators. Mineral exploration intelligent inference mechanism integrating with large general language models and knowledge graphs, also with an external geological knowledge base, will be developed. Relying on the Tianhe-2 Supercomputing platform, it will do data analysis and application verification associated with mineral exploration intelligent inference, and create a self-consistent, high-performance-computing-oriented, and replicable intelligent mineral exploration method system. The project will also generate intelligent mineral prediction method result reports for two specific scenarios: 1:50,000 mineral prediction and lead-zinc mineral prediction in the Qinzhou - Hangzhou Bays metallogenic belt. The project will boost the development of a new-generation intelligent mineral exploration system suited to China's geological conditions, propelling the advancement of intelligent mineral exploration to new heights.

Key words: Mineral prospecting and exploration; prospecting area; AI prospecting; Big data mining; Qinzhou - Hangzhou Bays metallogenic belt

S1902. Machine Learning-Based Mineral Exploration via White Mica Spectral Footprints

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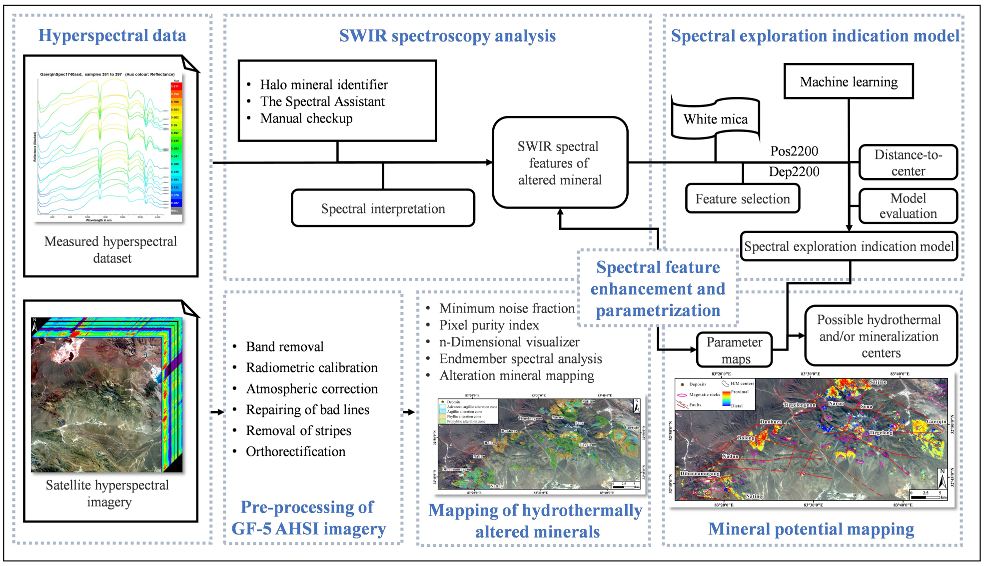
Wenlei Wang (Institute of Geomechanics, Chinese Academy of Geological Sciences),
Jie Zhao (China University of Geosciences (Beijing)),
Zhibo Liu (Chinese Academy of Geological Sciences)
Room: B222 2025-10-11 16:50

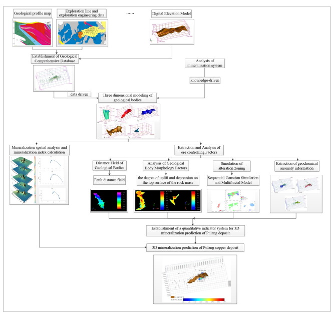
Short-wave infrared (SWIR) spectroscopy is essential for mineral identification, alteration mapping, and mineral exploration in deposits like porphyry and epithermal deposits. However, it relies on hyperspectral data from surface or drill hole samples, and its potential application in satellite remote sensing remains to be explored. This study constructed a machine learning-based spectral exploration indication model of white mica. By integrating measured spectra from Analytical Spectral Devices (ASD) and hyperspectral images from the GaoFen-5 (GF-5) satellite, this study focused on the Duolong mineral district in Tibet to conduct alteration mapping, SWIR spectroscopy analysis, and mineral exploration. The results showed that the hydrothermally altered minerals in the Duolong mineral district are mainly composed of white mica, kaolinite, and chlorite, with minor amounts of sulphate and carbonate, forming a typical alteration zoning pattern in the porphyry Cu system surrounding the mineralized zone. Additionally, SWIR analysis of the Gaerqin deposit revealed the spatial variation of both the position (Pos2200) and depth (Dep2200) of the Al-OH absorption feature in white mica surrounding the granodiorite porphyry. A spectral exploration indication model of white mica was constructed using machine learning algorithms, enabling the further prediction of potential hydrothermal and/or mineralization centers based on its spatial distribution. Consequently, the spectral exploration indication model of altered minerals, employing machine learning, not only expands the application fields of spectral footprints but also enhances the accuracy and convenience of remote sensing mineral exploration prospecting, thereby providing novel insights for future mineral exploration.



S1903. 3D Prediction of Pulang Copper Deposit in Yunnan Based on Geospatial Weighting

Xiaochen Wang (Shanxi Institute of Technology),
Qinglin Xia (School of Earth Resources, China University of Geosciences),
Mengyu Zhao (Henan Polytechnic University),
Shuai Leng (Hubei Geological Survey),
Xiaochen Wang (Shanxi Institute of Technology)
Room: B222 2025-10-11 17:10

Three-dimensional (3D) metallogenic prospectivity modeling has become increasingly important in deep mineralization prospecting. This study uses geological data for the Pulang porphyry copper deposit in southwest China, to create a 3D prospectivity model that defines prospective areas for future exploration for copper mineralization in the study area. The 3D spatial analysis method was used to characterize the distribution of ore-controlling geological bodies such as faults, strata, intrusions, and alteration zones in Pulang deposit. By applying the distance field and morphological feature analysis method, the spatial distance and morphological correlation between orebodies and ore-controlling factors were quantitatively revealed, and a quantitative indicator system was established. The alteration intensity was quantitatively simulated using the sequential Gaussian simulation algorithm, while the fractal and multifractal models were adopted to characterize the 3D spatial distribution patterns of copper, enhancing understanding of mineralization alteration zoning and enrichment mechanism of copper. A 3D prospecting model integrated multisource data via geographically weighted regression model, enabling high-precision mineral prediction. The results provide a novel approach for targeting concealed orebodies and improve prospecting reliability in porphyry copper systems.



S1904. Three-Dimensional Mineral Prospectivity Mapping by a Gradient Boosting Integrated Learning Method with Strong Data Type Adaptability:Acase study of the Haopinggou Gold Polymetallic Deposit,China

Mingjing Fan (Tianjin Center,China Geological Survey(North China of Geoscience Innovation)),
Keyan Xiao (SinoProbe Laboratory, Institute of Mineral Resources, Chinese Academy of Geologi),
Li Sun (SinoProbe Laboratory, Institute of Mineral Resources, Chinese Academy of Geologi),
Yang Xu (China University of Geosciences (Beijing))
Room: B222 2025-10-11 17:30

In recent years, three-dimensional mineral prospectivity mapping (3DMPM) has become an important methodological framework for predicting concealed mineral deposits. The application of machine learning algorithms to 3D mineralization prediction has gained increasing attention, particularly due to their capacity to integrate and analyze complex, multi-source geological data. However, the incorporation of heterogeneous data types often introduces variability and uncertainty into predictive outcomes, which remains a key challenge.This study investigates a gradient boosting ensemble learning approach, selected for its high adaptability to diverse data structures, and systematically evaluates the influence of different data types on prediction performance. The Haopinggou gold-polymetallic deposit, situated in the Xiong'ershan region of the western Henan metallogenic belt, is used as a case study. A comprehensive three-dimensional geological model of the deposit was constructed based on detailed geological, geochemical, and geophysical data. Subsequently, a 3D mineral prospectivity model was developed within the mineral systems framework.To quantify the contribution of individual data types to the predictive results, the SHapley Additive exPlanations (SHAP) method was employed. The results demonstrate that the gradient boosting model trained on binary (presence/absence) features yields higher AUC values and improved classification accuracy compared to models using continuous data types. Furthermore, the model effectively delineates deep-seated exploration targets, providing a robust scientific basis for subsequent drilling and deep exploration in the Haopinggou area.

S1905. Multidimensional Geochemical Anomaly Detection and Mineralization Mechanism Analysis Based on Interpretable Machine Learning

Han Feng (Guangxi University for Nationalities),
Lina Ge (AI School, Guangxi Minzu University),
Yongzhang Zhou (Sun Yat-Sen University)
Room: B222 2025-10-11 17:32

The exploration of gold mineralization in complex geological settings demands innovative approaches to anomaly detection and mineralization prediction. This study proposes a novel framework leveraging interpretable machine learning to enhance gold prospecting in the Pangxidong area, utilizing multi-element geochemical data (AU, AS, SB, etc.). We employ XGBoost with SHAP (SHapley Additive exPlanations) to detect anomalies and quantify the contribution of 19 geochemical elements and spatial coordinatesto gold mineralization. SHAP analysis reveals key mineralization indicators (e.g., AU-AS-SB associations) and their interactions, while spatial autocorrelation analysis elucidates anomaly distributions linked to geological structures. Interpretable visualizations, including SHAP force plots and spatial heatmaps, provide transparent insights into mineralization mechanisms, bridging machine learning with geological understanding. Our model identifies high-potential gold targets, validated against known anomalies. By integrating interpretable AI with geochemical and spatial data, this study offers a robust, transparent tool for mineral exploration, improving target delineation and supporting efficient resource assessment in the Pangxidong region.

S1906. Geochemistry Open Source Software: Machine Learning for Geochemists Who Don't Want to Code

J ZhangZhou (Zhejiang University),
J. ZhangZhou (Zhejiang University)
Room: B210 2025-10-12 10:30

Geochemistry is an open-source automated machine learning Python framework. Geochemists need only provide tabulated data (e.g. excel spreadsheet) and select the desired options to clean data and run machine learning algorithms. The process operates in a question-and-answering format, and thus does not require that users have coding experience. Version 0.7.0 includes machine learning algorithms for regression, classification, clustering, dimension reduction and anomaly detection. After either automatic or manual parameter tuning, the automated Python framework provides users with performance and prediction results for the trained machine learning model. Based on the scikit-learn library, Geochemistry has established a customized automated process for implementing machine learning. The Python framework enables extensibility and portability by constructing a hierarchical pipeline architecture that separates data transmission from algorithm application. The AutoML module is constructed using the Cost-Frugal Optimization and Blended Search Strategy hyperparameter search methods from the A Fast and Lightweight AutoML Library, and the model parameter optimization process is accelerated by the Ray distributed computing framework. The MLflow library is integrated into machine learning lifecycle management, which allows users to compare multiple trained models at different scales and manage the data and diagrams generated. In addition, the front-end and back-end frameworks are separated to build the web portal, which demonstrates the machine learning model and data science workflow through a user-friendly web interface. In summary, Geochemistry provides a Python framework for users and developers to accelerate their data mining efficiency with both online and offline operation options. All source code is available on GitHub (https://github.com/ZJUEarthData/geochemistrypi), with a detailed operational manual catering to both users and developers (https://geochemistrypi.readthedocs.io/en/latest/).

Geochemistry π
A PYTHON FRAMEWORK FOR GEOCHEMISTRY

S1907. Research on Large Model-Based Knowledge Graph Construction and Smart Risk Detection for Mineral Resource Supply Chains

Kun Wang (Institute of Mineral Resources, Chinese Academy of Geological Sciences),
Qishen Chen (Institute of Mineral Resources, Chinese Academy of Geological Sciences),
Yanfei Zhang (Institute of Mineral Resources, Chinese Academy of Geological Sciences),
Guodong Zheng (Institute of Mineral Resources, Chinese Academy of Geological Sciences),
Qiang Li (Institute of Mineral Resources, Chinese Academy of Geological Sciences),
Jiayun Xing (Institute of Mineral Resources, Chinese Academy of Geological Sciences),
Tao Long (Institute of Mineral Resources, Chinese Academy of Geological Sciences),
Zhenqing Li (Institute of Mineral Resources, Chinese Academy of Geological Sciences),
Xin Ren (Institute of Mineral Resources, Chinese Academy of Geological Sciences),
Chenghong Shang (Institute of Mineral Resources, Chinese Academy of Geological Sciences),
Qi Yu (Institute of Mineral Resources, Chinese Academy of Geological Sciences),
Yu Zhao (Institute of Mineral Resources, Chinese Academy of Geological Sciences)
Room: B210 2025-10-12 10:50

The latest wave of technological revolution has spurred surging demand for mineral resources. With intensifying geopolitical complexities worldwide, supply risk analysis of critical minerals has emerged as a key research priority internationally. Mineral resource supply is subject to multifaceted drivers such as geological availability, market fluctuations, geopolitical tensions, and environmental hazards. However, constructing an intelligent risk identification model to rapidly detect high-impact risk events affecting mineral supply chains from online news sources remains a significant challenge. This study proposes a large model-driven approach for constructing knowledge graphs and intelligent identification of mineral resource supply risks. Leveraging LightRAG technology combined with large language models' contextual understanding and reasoning capabilities, the method automatically extracts entity relationships from massive heterogeneous data to achieve dynamic knowledge graph construction and updating. Utilizing a risk propagation algorithm based on complex network and attention mechanisms, this study analyzes the impact of disruptive events on different mineral commodities and their dynamic evolutionary trends, ultimately establishing an intelligent risk identification and early warning framework. Initial experimental results demonstrate that the proposed method achieves higher sensitivity and accuracy in mineral resource risk identification, offering promising potential as an intelligent decision-support tool for strategic mineral resource management.

S1910. Progress and Reflections on the Construction of Geological Data Management and Sharing System

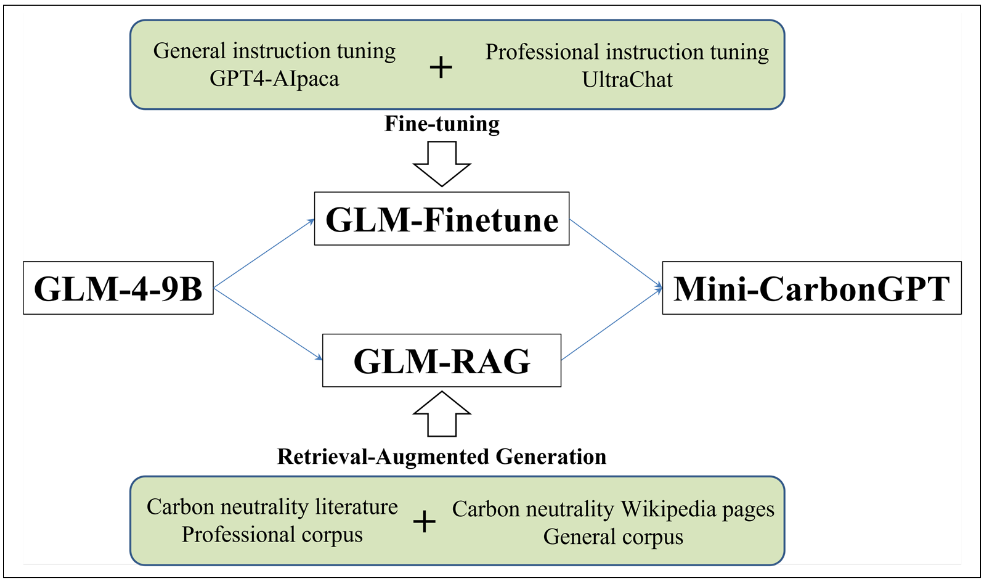
shoutao jiao (CHINA GEOLOGICAL SURVEY),
rongmei liu (Survey Center of Comprehensive Natural Resources, CHINA GEOLOGICAL SURVEY),
wei ren (Survey Center of Comprehensive Natural Resources, CHINA GEOLOGICAL SURVEY),
mingming zhao (Survey Center of Comprehensive Natural Resources, CHINA GEOLOGICAL SURVEY),
yan yang (Survey Center of Comprehensive Natural Resources, CHINA GEOLOGICAL SURVEY),
hanrui sun (Survey Center of Comprehensive Natural Resources, CHINA GEOLOGICAL SURVEY),
hailong yu (Survey Center of Comprehensive Natural Resources, CHINA GEOLOGICAL SURVEY),
jing lu (Survey Center of Comprehensive Natural Resources, CHINA GEOLOGICAL SURVEY),
min wen (Survey Center of Comprehensive Natural Resources, CHINA GEOLOGICAL SURVEY),
yi yue (Survey Center of Comprehensive Natural Resources, CHINA GEOLOGICAL SURVEY),
ning cui
Room: B210 2025-10-12 11:10

The geological data management and sharing system adopts a hybrid architecture of PostgreSQL+MongoDB+distributed file system, establishing a next-generation big data infrastructure foundation. Its storage management supports common distributed file systems such as S3, HDFS, OBS, OSS, and MinIO. The system utilizes the Spring Cloud 2.0 microservices architecture overall, with the high-performance Nacos framework serving as the service registry center. The system has completed development of functional modules including data ingestion, integrated display, system management, and data lake, achieving end-to-end integrated organizational management for uploading, reviewing, aggregating, distributing, and sharing services of geological survey project data. The system supports application scenarios such as large-scale parallel computing, integrated analysis, and visualization.

S1911. Mini-CarbonGPT: A Domain-Specific Large Language Model for Carbon Neutrality

Jianhua Ma (SUN YAT-SEN UNIVERSITY),
Yongzhang Zhou (Sun Yat-sen University)
Room: B210 2025-10-12 11:30

Carbon neutrality represents a critical pathway for mitigating global climate change, encompassing interdisciplinary domains such as geology, energy, economics, and environmental science. While general-purpose large language models (LLMs) hold significant promise in this field, their performance often falls short in addressing the demands of specialized interdisciplinary applications, necessitating the development of domain-specific LLMs. This study introduces Mini-CarbonGPT, a large language model specifically tailored to the carbon neutrality domain. The model is built via a meticulously curated dataset, including supervised fine-tuning data (50,000 general instructions and 5,382 professional instructions), a retrieval corpus (6,096 documents and 60,000 Wikipedia pages), and evaluation datasets (700 objective and 249 subjective questions). Mini-CarbonGPT leverages the open-source GLM-4-9B model for supervised fine-tuning and integrates retrieval-augmented generation (RAG) to enhance its knowledge retrieval and generation capabilities. The study also details the methods used to construct the training datasets, including pretraining resources, and provides a comprehensive analysis of their effectiveness. Evaluation metrics, covering both objective and subjective assessments, demonstrate that Mini-CarbonGPT achieves an 80.57% accuracy rate on objective questions, surpassing the performance of the original GLM-4-9B model and four commercial LLMs. Furthermore, it achieves marked improvements in automated metrics, GPT-o1 scores, and keyword coverage for subjective questions. Despite requiring further refinement in semantic expression, Mini-CarbonGPT provides actionable strategies and specialized knowledge that can guide decision-making in carbon neutrality research. The dataset and methodologies presented in this study offer valuable resources for advancing LLMs research in interdisciplinary carbon neutrality and fostering the development of integrated decision-making solutions.



S1912. Geochemical provinces mapping of Mars using compositional data analysis of GRS data

Chao Li (Institute of Geological Survey, China University of Geosciences (Wuhan)),
Kefa Zhou (Technology and Engineering Center for Space Utilization, Chinese Academy of Scie),
Jinlin Wang (Technology and Engineering Center for Space Utilization, Chinese Academy of Scie),
Qing Zhang (Technology and Engineering Center for Space Utilization, Chinese Academy of Scie),
Jiantao Bi (Technology and Engineering Center for Space Utilization, Chinese Academy of Scie),
Wei Wang (Technology and Engineering Center for Space Utilization, Chinese Academy of Scie),
Heshun Qiu (Technology and Engineering Center for Space Utilization, Chinese Academy of Scie)
Room: B210 2025-10-12 11:50

Although the Martian elemental geochemical provinces have been mapped by multivariate statistics based on Euclidean space through the S, Cl, H2O, Si, Fe, K, Ca, and Al elemental abundance data acquired by the Mars Gamma Ray Spectrometer (GRS). However, GRS elemental geochemical data are similar to compositional data with closure effects. Therefore, the results obtained by directly processing GRS data using conventional multivariate statistics may still have uncertainties. In this study, the isometric log-ratio (ilr) transformation was used to eliminate the closure effect of GRS elemental abundance data. Exploratory data analysis, principal component analysis, and robust principal component analysis (RPCA) were performed on the raw data, log-transformed, and ilr-transformed data of the elements, respectively. Afterwards, hierarchical cluster analysis (HCA) was applied to map the geochemical provinces of Martian elements. The following results were achieved: (1) the box plots and cumulative density curves show that the ilr dataset is more homogeneous and closer to a normal distribution after eliminating the closure effect compared to the raw data and log-transformed data of the GRS elements; (2) only RPC1 of ilr-transformed data was able to reveal effective elemental assemblages, namely, mobile S-Cl-H2O assemblage related to hydrothermal activity and Si-Fe-K-Ca-Al assemblage related to basalt composition, and the spatial distribution characteristics of the RPC1 scores were consistent with the distribution characteristics of the global thermal inertia and albedo; (3) the HCA analysis of the first three robust principal components based on the ilr transform produced five different clustering results (e.g., clusters number=2, 3, 4, 5, 6), and when the number of clusters was five, the five elemental geochemical provinces were more reflective of the material distribution patterns on the Mars surface.

S1913. A Deep-learning Based Sub-pixel Mineral Detection Method on Martian Surface

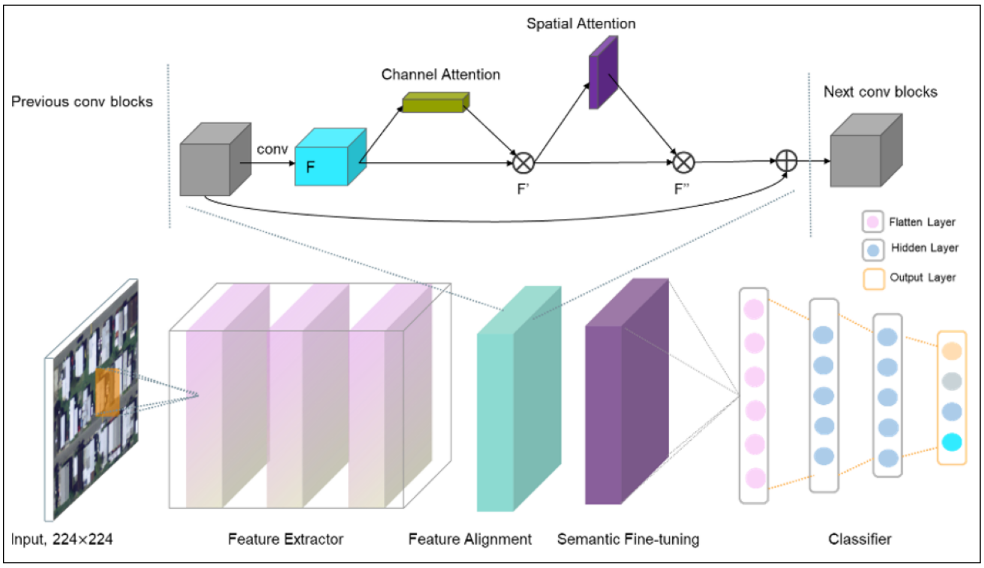
Heshun Qiu (Technology and Engineering Center for Space Utilization, Chinese Academy of Scie),
Kefa Zhou (Technology and Engineering Center for Space Utilization, Chinese Academy of Scie),
Jinlin Wang (Technology and Engineering Center for Space Utilization, Chinese Academy of Scie),
Jiantao Bi (Technology and Engineering Center for Space Utilization, Chinese Academy of Scie),
Qing Zhang (Technology and Engineering Center for Space Utilization, Chinese Academy of Scie),
Wei Wang (Technology and Engineering Center for Space Utilization, Chinese Academy of Scie),
Chao Li (Institute of Geological Survey, China University of Geosciences (Wuhan))
Room: B210 2025-10-12 12:10

Considering the intimate mixing of minerals on Martian surface and the limitation of spatial resolution of hyperspectral images, mixed pixels are prevalent, so sub-pixel detection is important for obtaining information on the distribution and abundance of minerals. Currently, researchers have carried out massive mineral exploration work applying CRISM hyperspectral data, Tianwen-1 Mars Mineral Analyzer data and other Martian spectral data. However, existing sub-pixel mineral detection techniques still have the following issues: (1) Estimating the number of Martian mineral endmembers is a challenging task, and existing methods for Martian mineral endmember extraction and abundance estimation often require that the number of endmembers be known. (2) Existing Mars mineral subpixel detections are often based on a priori knowledge and statistical methods, while the application of deep learning, especially unsupervised neural network models, to this problem has yet to be fully explored. (3)Although existing methods have worked well for sub-pixel detection in some specific regions of Mars, they have not worked well on some other regions. Considering the above problems, the study proposes a deep-learning based sub-pixel mineral detection method on Martian surface. The method performs endmember extraction and abundance estimation of Martian minerals by constructing an unsupervised learning model, thus realizing a more fine-grained identification and mapping of Martian minerals. Meanwhile, this study provides an accurate autonomous estimation to determine the number of endmembers, which improves the accuracy of subsequent missions. The results of mineral exploration experiments conducted in different regions of Mars show that the proposed method generalizes well, which has potential for mineral detection on global scale of Mars.

S1916. C-Noisystudent: Curriculum Learning with Nosiy Student Improves Remote Sensing Scene Classification

Sheng Chang (Beijing Normal University),
Zhihao Chen (Beijing Normal University),
Zongyao Yin (Beijing Normal University),
Xianchuan Yu (Beijing Normal University)
Room: B222 2025-10-11 17:34

To address the scarcity of labeled samples in remote sensing scene classification, this paper proposes C-NoisyStudent, a semi-supervised framework integrating curriculum learning with the noisy student paradigm. The method introduces a progressive four-stage training strategy. Initially, a teacher network is pre-trained on limited labeled data to establish baseline predictions. Subsequently, high-confidence pseudo-labels generated by the teacher are iteratively incorporated into the training set, while unlabeled samples undergo TendarAffine—a semantic-preserving affine transformation that constrains geometric deformations by randomly shifting three image corner points within controlled radii. During this phase, a hierarchical augmentation strategy (HRandAug) is applied, combining TendarAffine with color enhancement, elastic distortion, and random erasing, to progressively escalate data perturbations from weak to strong levels. Finally, the student network, trained under these noise-injected conditions, updates the teacher model parameters cyclically to refine pseudo-label quality. Evaluated on a ResNet50-D baseline enhanced with CBAM attention modules, experiments using only 10% labeled data achieve overall accuracies of 96.9%, 95.4%, and 93.2% on the UC Merced Land, AID, and RESISC45 datasets, respectively, outperforming the baseline by 2.5–7% and surpassing the SS-RCSN method on AID and RESISC45. The framework's innovations lie in its curriculum-aligned noise scheduling mechanism, which balances stability and robustness through controlled perturbation escalation, and the TendarAffine operator that preserves semantic integrity during geometric transformations. Results demonstrate the effectiveness of leveraging unlabeled data to mitigate small-sample challenges in remote sensing scene classification.



S1917. Multi-scale and Progressive Intelligent Prospecting Prediction Using Geological Big Data Part 2

Chunfang KONG (School of Computer, China University of Geosciences),
Qian Tian,
Chonglong WU (School of Computer, China University of Geosciences),
Kai Xu (School of Computer Science, China University of Geosciences, Wuhan 430074, China)
Room: B210 2025-10-12 14:30

Nowadays exploration for hidden orebodies is important and requires new methods for prospecting and exploration. Data-driven metallogenic prediction models using ensemble learning are becoming a powerful tool for deep hidden mineral exploration. However, prospecting prediction models based on ensemble learning face some general problems, especially parameter tuning of the model, which is a time-consuming and labor-intensive process requiring tedious computation and sufficient expert experience. To this end, this paper proposes ensemble learning models based on multi-source geological knowledge and Bayesian optimization algorithm to solve these problems. Specifically, the manganese (Mn) Mn ore deposits mineralization prediction database is first constructed based on the multi-source geological knowledge; Then, the metallogenic prediction models of Mn are established in northeastern Guizhou based on AdaBoost and random forest (RF) models; Finally, Bayesian optimization algorithm (BOA) is used to find the most suitable hyperparameters for BOA-AdaBoost and BOA-RF models through 5-fold cross-validation. The performance of the proposed models is verified by using comparative tests and such as accuracy, recall, precision, F1-score, kappa, and AUC values. The experimental results show that AUC values of both BOA-AdaBoost and BOA-RF models are all significantly improved, indicating that BOA is a powerful optimization tool and the optimization results provide a reference for the hyperparameter setting of the ensemble learning model. Moreover, the results also show that the BOA-AdaBoost model has higher prediction accuracy (92.8%) and geological generalization ability than the BOA-RF model, and has great potential in metallogenic prediction. The mineral prediction map based on the BOA-AdaBoost model provides important clues for the prospecting of deep hidden Mn ore deposits in northeastern Guizhou and can guide future mineral exploration and development.

Metallogenic prediction of manganese ore based on ensemble learning model and Bayesian optimization algorithm in northeastern Guizhou

KONG Chunfang[1,2,3,4], Tian Qian[1], WU Chonglong[1,2,3,4], XU Kai [1,2,3,4]

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2. *Engineering Technology Innovation Center of Mineral Resources Explorations in Bedrock Zones, Ministry of Natural Resources, Guiyang* 550081*, China*
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Abstract: Nowadays exploration for hidden orebodies is important and requires new methods for prospecting and exploration. Data-driven metallogenic prediction models using ensemble learning are becoming a powerful tool for deep hidden mineral exploration. However, prospecting prediction models based on ensemble learning face some general problems, especially parameter tuning of the model, which is a time-consuming and labor-intensive process requiring tedious computation and sufficient expert experience. To this end, this paper proposes ensemble learning models based on multi-source geological knowledge and Bayesian optimization algorithm to solve these problems. Specifically, the manganese (Mn) Mn ore deposits mineralization prediction database is first constructed based on the multi-source geological knowledge; Then, the metallogenic prediction models of Mn are established in northeastern Guizhou based on AdaBoost and random forest (RF) models; Finally, Bayesian optimization algorithm (BOA) is used to find the most suitable hyperparameters for BOA-AdaBoost and BOA-RF models through 5-fold cross-validation. The performance of the proposed models is verified by using comparative tests and such as accuracy, recall, precision, F1-score, kappa, and AUC values. The experimental results show that AUC values of both BOA-AdaBoost and BOA-RF models are all significantly improved, indicating that BOA is a powerful optimization tool and the optimization results provide a reference for the hyperparameter setting of the ensemble learning model. Moreover, the results also show that the BOA-AdaBoost model has higher prediction accuracy (92.8%) and geological generalization ability than the BOA-RF model, and has great potential in metallogenic prediction. The mineral prediction map based on the BOA-AdaBoost model provides important clues for the prospecting of deep hidden Mn ore deposits in northeastern Guizhou and can guide future mineral exploration and development.
Keywords: Metallogenic prediction, Ensemble learning, Manganese, Guizhou

S1919. Completion of mineral knowledge graph based on large language model

Xiaohui JI (China University of Geosciences, Beijing)
Room: B210 2025-10-12 14:50

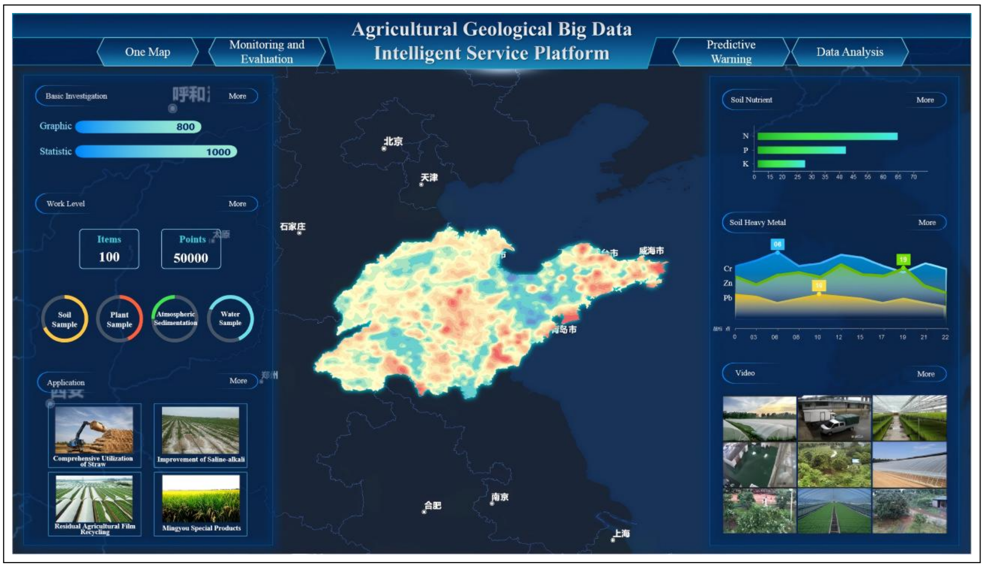
To enhance the completeness and accuracy of existing mineral knowledge graphs, a method for completing mineral knowledge graphs based on large language models is proposed. First, relevant corpora are obtained and the most relevant texts from the corpus are selected using the BM25 algorithm to form the knowledge graph completion database. For each relationship in the original knowledge graph, corresponding sub-corpora are constructed through regular matching and support information retrieval. Each sub-corpus undergoes word segmentation and frequent pattern mining and filtering to obtain frequent pattern triples for each relationship. After adding head and tail entities, corresponding prompt templates are generated. The obtained prompt templates and the newly added triplet data set, which are embedded, are used as training data to fine-tune the large language model. For each mineral entity, the matching relationships are selected, and the prompt templates for these matching relationships are obtained. The candidate entities for the matching relationships are retrieved through knowledge graph embedding, and the entity with the highest score after concatenating the prompt templates and using the fine-tuned large language model is selected as the completion entity. This process adds new triples to the mineral knowledge graph.

S1920. Innovative Practices of Big Data in Agricultural Geology

Xiuwen Zhang (Shandong Institute of physical and chemical exploration),
Chuang Zhao (Shandong Institute of physical and chemical exploration),
Jianbiao Dong (Shandong Institute of physical and chemical exploration)
Room: B210 2025-10-12 15:10

In recent years, agricultural geological data in Shandong Province has become increasingly abundant, but the amount of data is huge, and there is relatively little comparison, analysis, and application between data.To achieve the evaluation, analysis, and application of diverse agricultural geological data, build a smart application and service system for the whole province, and provide rich data and thematic achievement information for society.Based on soil elements and relevant data from the comprehensive agricultural geological survey in Shandong Province, a basic data framework is established to achieve functions such as data visualization analysis and intelligent prediction.Conduct overlay and aggregation analysis of vector data of agricultural geological achievements at different scales; Carry out application demonstrations in the fields of recommending famous and special target areas, recommending soil environmental risk areas, and classifying farmland quality categories; Explore the application of agricultural geochemical monitoring for soil geochemical evaluation.By establishing a data network, independent and unclearly correlated data can be transformed into visualized and integrated conclusions, providing data decision-making for society, government departments, and research institutes.

Keywords: agricultural geological big data; 8 application subsystems; ”Geology+Agriculture+Big Data ”; rural revitalization



S1921. Three Generations of Chinese Mathematical Geoscientists and Their Active Involvement and Contributions to the International Association for Mathematical Geosciences

Yongzhang ZHOU (Sun Yat-sen University),
Xiaogang Ma (University of Idaho)
Room: B210 2025-10-12 15:30

Three generations of Chinese geomathematical scholars can be recognized based on their significant involvement, international cooperation and influence in IAMG. The first generation are represented by Professors Pengda Zhao and Di Zhou. Prof. Zhao is an Academician of CAS and a Foreign Academician of the Russian Academy of Natural Sciences. He received IAMG Krumbein Medal in 1992. Prof. Zhou served as a council member of IAMG (1992-1996).

The second generation are represented by Professors Qiuming Cheng and Yongzhang Zhou. Prof. Cheng is an Academician of the CAS and a Foreign Academician of the European Academy of Sciences. He served IAMG as president (2012-2016), and received the Krumbein Medal in 2008. Prof. Zhou teaches at Sun Yat-sen University and is a Foreign Academician of both the Russian Academy of Engineering and the Russian Academy of Natural Sciences. He served IAMG as the National Representative (1997-2001) and received Chayes Prize in 2015. Professors Yongqing Chen (IAMG Council, 2012-2016), Gang Liu (IAMG Council, 2012-2016), Guangsheng Yan (IAMG Council, 2016-2020), Shuyun Xie (IAMG Awards Committee, 2011-2020) and Deyi Xu (IAMG Nomination Committee, 2016-2020) are also active participants of 2nd generation.

The third generation are represented by Prof. Renguang Zuo and Dr. Xiaogang Ma. Prof. Zuo teaches at China University of Geosciences, and served as a councilor of IAMG from 2020 to 2024. Dr. Ma is an associate professor at University of Idaho. He received the IAMG Vistelius Award in 2015, served as IAMG councilor (2016-2020) and chair of IAMG Awards Committee (2019-2025). Included in the third generation are Wenlei Wang (Vistelius Award, 2019), Professors Jie Zhao (Council, 2020-2024), Guoxiong Chen (Vistelius Award, 2025), Lijing Wang (Vistelius Award, 2025).

The contributions of three generations of Chinese mathematical geoscientists reflect not only individual excellence but also the rapid advancement and global integration of the field.

Three Generations of Chinese Mathematical Geoscientists and Their Active Involvement and Contributions to the International Association for Mathematical Geosciences

Yongzhang Zhou, Sun Yat-sen University, China
Xiaogang Ma, University of Idaho, USA

With the involvement of affairs related to the IAMG who was found in 1968, Chinese scholars have gone through a process of change, shifting from being closed to becoming open, and from learning from others to running alongside them and even taking the lead.

Three generations of Chinese geomathematical scholars can be recognized based on their significant involvement, international cooperation and influence in IAMG. The first generation were born before 1949 and had their undergraduate education before the Cultural Revolution of China, with a solid knowledge in geology. The second generation were born in 1960s and attended universities in the first decade after the Cultural Revolution. Most of them have overseas experience of studying and working. The third generation were born around 1980s, and entered university around or after 2000, and are the active generation at present.

The first generation are represented by Professors Pengda Zhao and Di Zhou. Among them, Prof. Zhao, former president of China University of Geosciences, is an Academician of the Chinese Academy of Sciences and a Foreign Academician of the Russian Academy of Natural Sciences. He received the IAMG Krumbein Medal In 1992. Prof. Di Zhou, former deputy director of the South China Sea Institute of Oceanology, CAS, served as a council member of IAMG (1992-1996).

The second generation are represented by Professors Qiuming Cheng and Yongzhang Zhou. Prof. Qiuming Cheng is an Academician of the Chinese Academy of Sciences and a Foreign Academician of the European Academy of Sciences. Prof. Cheng was the IAMG councilor (2004-2008), the vice president (2008-2012), and then the president (2012-2016). He received the Krumbein Medal in 2008, and was appointed as the IAMG Distinguished Lecturer in 2022. Prof. Yongzhang Zhou, the former dean of the Department of Earth Sciences of Sun Yat-sen University, China, is a Foreign Academician of both the Russian Academy of Engineering and the Russian Academy of Natural Sciences. He served as the National Representative of IAMG (1997-2001), Member of the IAMG Awards Committee (2007-2011), Member of the IAMG Nomination Committee (two terms: 2008-2012 and 2012-2016), and the recipient of IAMG Felix Chayes Prize in 2015. Professors Yongqing Chen (IAMG Council, 2012-2016), Gang Liu (IAMG Council, 2012-2016), Guangsheng Yan (IAMG Council, 2016-2020), Yong Ge (Associate Editor of C&G), Shuyun Xie (IAMG Awards Committee, 2011-2020) and Deyi Xu (IAMG Nomination Committee, 2016-2020) are also active participants of the second generation.

The third generation are represented by Prof. Renguang Zuo and Dr. Xiaogang (Marshall) Ma. Prof. Renguang Zuo is a professor of China University of Geosciences (Wuhan). He served as a councilor of IAMG from 2020 to 2024, and was awarded IAMG Distinguished Lecturer. Dr. Xiaogang (Marshall) Ma is an associate professor at the Department of Computer Science, University of Idaho, USA and a visiting scientist at Carnegie Institution for Science. He received the IAMG Vistelius Award in 2015, served as IAMG councilor (2016-2020) and chair of IAMG Awards Committee (2019-2025). Included in the third generation are Wenlei Wang (Vistelius Award, 2019), Professors Jie Zhao (Council, 2020-2024), Dr. Zhijun Chen (Student Committee, 2011-2015; Outreach Committee, 2013-2020), Guoxiong Chen (Vistelius Award, 2025), Lijing Wang (Vistelius Award, 2025).

The contributions of three generations of Chinese mathematical geoscientists reflect not only individual excellence but also the rapid advancement and global integration of the field. With continued innovation in spatial analysis, big data, data science, and AI, mathematical geosciences in China are thriving. The active engagement of young scholars, growing international

S1922. Offset-Attention Mechanism Based Deep Learning Approach for 3D Geological Modeling

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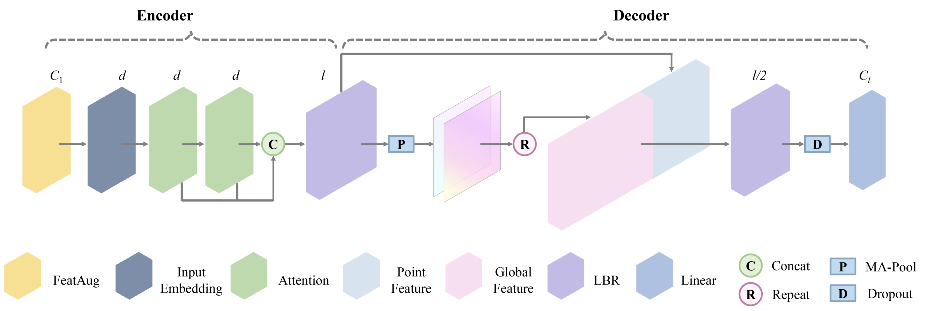
Liang Wu (School of Computer Science, China University of Geosciences, Wuhan 430078, China),
Yanjie Xing (School of Geography and Information Engineering, China University of Geosciences)
Room: B210 2025-10-12 15:32

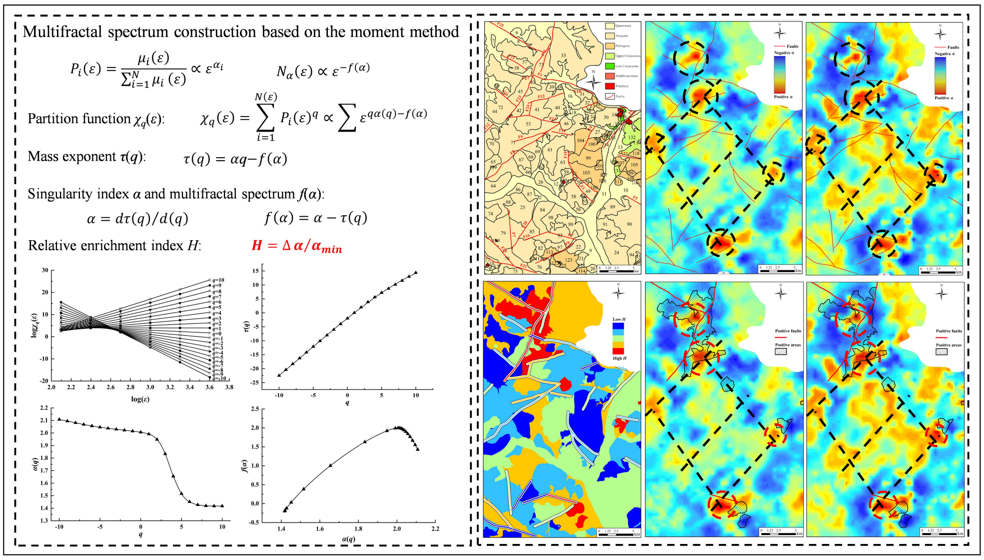
Deep learning approaches for 3D geological modeling enable automated identification of critical geological features, advancing intelligent modeling. This study proposes an offset-attention driven geological modeling method using (OADGM), a deep learning model to predict lithology categories of 3D points. Experiments were conducted in Chengdu's Tianfu New Area, China, utilizing data from 719 boreholes preprocessed through resampling and standardization. The dataset was divided into training and test sets (4:1 ratio). A comparative analysis with a standard stacking model demonstrated OADGM's superior performance, achieving an accuracy of 97.33%. Results indicate that OADGM effectively reduces model complexity while capturing geological regularities, including the topology of geological bodies, stratigraphic geometry, and spatial lithology distribution. This approach enhances simulation accuracy of subsurface geology, offering a robust framework for interpreting actual subsurface geological conditions.



S1926. Multifractal analysis of geo-exploratory data to facilitate new discoveries in mineral exploration

Wenlei Wang (Institute of Geomechanics, Chinese Academy of Geological Sciences)
Room: D205 2025-10-13 10:30

This study proposes an integrated nonlinear framework for geo-exploratory data analysis in underexplored regions, focusing on Cu mineralization targeting in the Zhule-Mangla district of Northern Tibet, China. Combining 1:50,000-scale geological map and geochemical data, we employ local singularity analysis (LSA) and multifractal spectrum techniques to decode structural controls and element distribution patterns associated with porphyry-epithermal systems. LSA delineates a mesh-like structural framework characterized by NE- and NW-trending Cu anomalies, highlighting zones of geochemical singularity linked to mineralization potential. A novel multifractal parameter, the relative enrichment index H, is introduced to quantify spatial heterogeneity in element distribution across scales. Global multifractal spectra guide localized analyses of Cu concentrations, revealing material accumulation zones critical for mineralization. The synergistic application of these methods identifies four high-priority exploration targets marked by superimposed structural anomalies and scale-invariant enrichment signatures. This approach bridges structural geology with advanced geochemical pattern recognition, offering a refined workflow for mineral exploration in data-scarce regions. The results demonstrate the efficacy of integrating nonlinear techniques to prioritize exploration efforts, advancing methodologies for geo-data interpretation while providing actionable insights for resource targeting in underexplored areas.



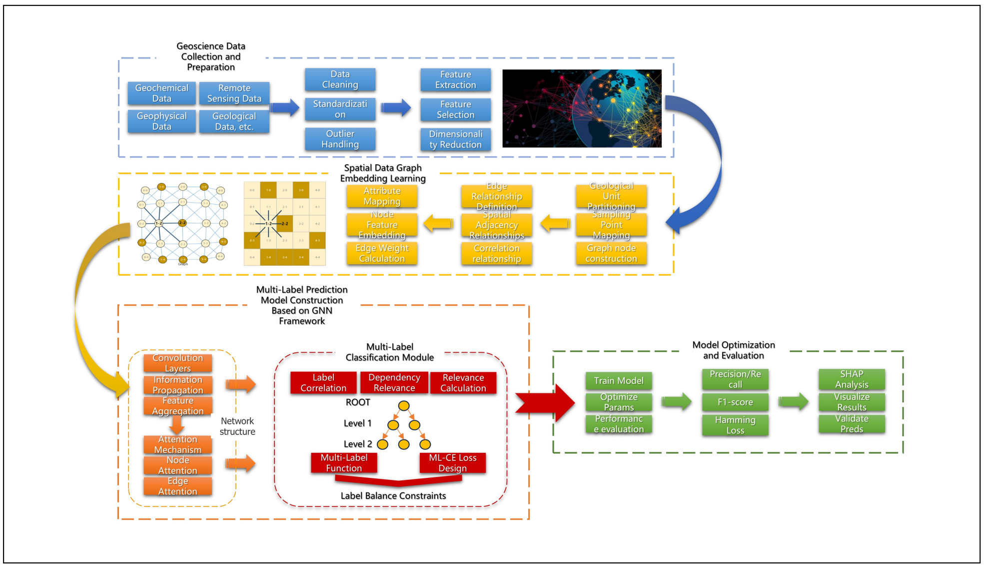
S1928. Multi-label mineral resource prediction method based on graph neural network with application

Tianbao Guo (China University of Geosciences (Beijing)),
Tianbao Guo (China University of Geosciences (Beijing))
Room: D205 2025-10-13 10:50

The rapid advancement of big data and artificial intelligence has revolutionized mineral prospectivity mapping, yet traditional methods struggle with high-dimensional, heterogeneous geological data and deep mineralization feature extraction. This study proposes a novel Graph Neural Network (GNN)-based multi-label classification algorithm to address these limitations, focusing on improving prediction accuracy and efficiency in complex metallogenic regions like the Qinling Orogenic Belt. We first analyze the challenges of integrating multi-dimensional geological data and the potential of multi-label classification techniques, inspired by breakthroughs in computer vision.

Given the nonlinearity, high dimensionality, and class imbalance inherent in mineral datasets, conventional single-label or multi-class approaches often fail to capture the multi-attribute characteristics of deposits. Our methodology integrates GNNs with multi-label classification to model intricate geological relationships, emphasizing: 1) a tailored GNN architecture for mining spatial and attribute correlations in graph-structured geological data; 2) fusion strategies for multi-source heterogeneous data to resolve interoperability issues; and 3) empirical validation using field-collected data from the Qinling region, demonstrating superior predictive performance compared to traditional methods.

This research provides a framework for leveraging deep learning in mineral exploration, offering enhanced accuracy and novel insights for targeting polymetallic deposits in geologically complex terrains. The results underscore the transformative potential of GNN-driven multi-label classification in advancing data-driven mineral resource prediction.



S1930. Evaluating Deep Forest as an Efficient Alternative to Deep Neural Networks in Data-Driven Mineral Prospectivity Mapping

Abdallah M. Mohamed Taha (China University of Geosciences (Wuhan)),
Gang Liu (China University of Geosciences),
Qiyu Chen (China University of Geosciences),
Kai Xu (School of Computer Science, China University of Geosciences, Wuhan 430074, China)
Room: D205 2025-10-13 11:10

Mineral prospectivity mapping (MPM) has increasingly relied on deep learning (DL) algorithms to uncover complex spatial patterns in geoscientific data. However, the effectiveness of these models, particularly deep neural networks (DNNs), is often hindered by their high complexity and reliance on large, well-labeled datasets, which are frequently limited in real-world exploration scenarios. To address these challenges, this study investigates the potential of Deep Forest (DF), a non-neural deep learning model that replaces backpropagation and neural structures with a cascade ensemble architecture. While DF offers a more computationally efficient and data-resilient alternative for mineral exploration, its application in this domain remains largely underexplored.

To evaluate its performance, DF was benchmarked against four well-established DNN models, namely Convolutional Neural Network (CNN), Long Short-Term Memory (LSTM), Gated Recurrent Unit (GRU), and Self-Attention Neural Network (SANN), by using 12 feature variables derived from geochemical, geological, and remote sensing data in the gold-rich Abidiya region of north-central Sudan. The results show that DF achieved the highest classification accuracy (OA = 0.979), matching GRU, and demonstrated a strong predictive performance with an AUC value of 0.984—only lower than GRU and CNN, and LSTM (by 0.002). DF required only 13 seconds to complete training using optimized hyperparameters, which was 67 seconds faster than CNN and nearly 10 times faster than GRU.

Furthermore, DF maintained stable performance with augmented data and outperformed all DNN models when training data was reduced by 90%. It consistently exhibited low exploration risk as indicated by high p-AUC (area under the prediction-rate curve) values, outperforming DNN models, which tended to show higher risk under sparse data conditions. These findings position DF as a viable, efficient, and reliable model for practical mineral prospectivity applications, offering a compelling alternative to more complex neural architectures in both resource-rich and data-limited settings

S1931. Multi-scale and Progressive Intelligent Prospecting Prediction Using Geological Big Data Part 1

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Yiping Tian,
Yan Li
Room: D205 2025-10-13 11:30

In response to the problems of adaptability of metallogenic models, complexity of metallogenic conditions and incomplete prospecting information, this paper, based on the metallogenic geological background of the study area and previous prospecting experience, combined with the theory of dissimilarity and metallogenic system theory, and integrated geological thinking with computational thinking, focuses on exploring the multi-scale multi-objective progressive prospecting prediction method. Firstly, the data assimilation and fusion method of geophysical, geochemical and remote sensing data from large to small scales is studied. Through model-free mining, the background conditions for mineral formation and possible controlling factors are revealed. Secondly, a knowledge graph is established through multiple case reviews, and the knowledge association, inference and assimilation of geological big data mining results are studied to achieve the combination of model-free and model-based methods. Finally, a geological model based on the integration of three-dimensional structure and attributes is constructed, and machine learning methods are studied to conduct data-model joint-driven metallogenic prediction, providing support for the delineation of target areas.

By applying this multi-scale multi-objective progressive intelligent prospecting prediction method, combined with the geological data from the deep parts of two ore concentration areas in the western part of Guizhou Province, China, a geological model based on the integration of three-dimensional structure and attributes was constructed. Various bottleneck technologies in data aggregation, assimilation and fusion were explored and broken through. Then, based on machine learning methods, data-model joint-driven prospecting prediction and exploration target area delineation were carried out. Through multiple verification drilling holes, two concealed rich ore bodies with a thickness of 2-4 meters were successfully drilled in the deep parts of the two prediction areas, which is promising to obtain two large-scale lead-zinc ore deposits. The prediction effect is proved to be relatively good.

Multi-scale and Progressive Intelligent Prospecting Prediction Using Geological Big Data

Xu Kai[1,2,3,4,5], Kong Chunfang[1,2,3,4,5], Wu Chonglong[1,2,3,4,5 *], Tian Yiping[1,2,3,4,5], Li Yan[3,4]

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Abstract: In response to the problems of adaptability of metallogenic models, complexity of metallogenic conditions and incomplete prospecting information, this paper, based on the metallogenic geological background of the study area and previous prospecting experience, combined with the theory of dissimilarity and metallogenic system theory, and integrated geological thinking with computational thinking, focuses on exploring the multi-scale multi-objective progressive prospecting prediction method. Firstly, the data assimilation and fusion method of geophysical, geochemical and remote sensing data from large to small scales is studied. Through model-free mining, the background conditions for mineral formation and possible controlling factors are revealed. Secondly, a knowledge graph is established through multiple case reviews, and the knowledge association, inference and assimilation of geological big data mining results are studied to achieve the combination of model-free and model-based methods. Finally, a geological model based on the integration of three-dimensional structure and attributes is constructed, and machine learning methods are studied to conduct data-model joint-driven metallogenic prediction, providing support for the delineation of target areas.

By applying a multi-scale, multi-objective progressive intelligent prospecting prediction method, integrated with geological data from the deep sections of two ore concentration areas in western Guizhou Province, China, a geological model based on the integration of three-dimensional structure and attributes was constructed. Various bottleneck technologies in data aggregation, assimilation and fusion were explored and broken through. Then, based on machine learning methods, data-model joint-driven prospecting prediction and exploration target area delineation were carried out. Through a number of boreholes used for verification, 2-4 m thick concealed rich ore bodies have been drilled in the deep part of the two prediction areas. It is hoped that two large-scale lead-zinc deposits will be obtained, which proves that the prediction method is effective.

Keywords: Multi-scale, Geological big data, Progressive, Data fusion, Prospecting prediction

S1932. A Preliminary Exploration of Vertical Model Construction in the Landslide Domain Based on the DeepSeek Large Language Model and Retrieval-Augmented Generation (RAG) Technology

He Luhao,
YongZHang ZHOU (Sun Yat-sen University),
Jianhua MA (Research Center for Earth Environment and Resources, Sun Yat-sen University, Zhu)
Room: D205 2025-10-13 11:50

With the rapid advancement of large language models (LLMs) in the field of natural language processing, their application value in geological disaster monitoring, early warning, and decision support has become increasingly prominent. However, general-purpose LLMs often face challenges such as insufficient domain-specific knowledge coverage and inaccurate understanding of technical terminology when applied to highly specialized fields like landslide studies. To address these limitations, this study conducts a preliminary exploration of vertical model construction for the landslide domain based on the DeepSeek LLM, in combination with retrieval-augmented generation (RAG) technology. First, relevant literature, case studies, and geo-environmental data pertaining to landslides were systematically compiled and rigorously filtered to build a high-quality multimodal knowledge base using vectorized encoding. Subsequently, during the inference phase of the DeepSeek model, the RAG technique was employed to dynamically retrieve and integrate key information related to landslide risk assessment, causative analysis, and monitoring and early warning. Preliminary experimental results demonstrate that this vertical modeling approach exhibits better adaptability to the specialized requirements of landslide-related text analysis and knowledge reasoning. It not only provides new perspectives for landslide disaster prediction and management but also offers a viable technical reference for constructing vertical LLMs in other specialized domains.

S1933. Multi-modal 3D Geological Model Similarity Measurement and Indexing Method

He Zhenwen (China University of Geosciences)
Room: D205 2025-10-13 12:10

Indexing and similarity computation of multi-modal 3D geological models are fundamental to efficient access and intelligent analysis of large-scale 3D model-related data in the field of geoscience information technology. However, several challenges persist, such as difficulties in embedding and expressing multi-modal geological features, the complexity of measuring and computing multi-modal similarity, and the high cost of concurrent control in indexing. Additionally, there is a lack of a unified indexing mechanism and similarity measurement method for multi-modal 3D geological models. We uses a multi-valued voxel model (MVVM) to represent 3D geological models, which embeds geological features in the form of a four-dimensional tensor, capable of expressing information from different modalities such as grids, point clouds, images, texts, and videos. By applying multi-variate sequence operators (MVSO), the multi-valued voxels are transformed into multi-variate sequence datasets, thereby converting the complex problem of multi-modal 3D geological model similarity measurement into multiple simpler and parallelizable single sequence similarity computation problems. Furthermore, a sequence data index is constructed based on the Hexadecimal Aggregation Approximation method (HAX), which overcomes the limitations of hierarchical structures on parallel indexing implementation. This approach refines the granularity of parallel indexing while reducing the overhead of concurrent control, aiming to achieve efficient similarity indexing and computation for multi-modal 3D geological models. Our research provides a feasible, general, and efficient distributed parallel solution for large-scale multi-modal 3D geological model data in a distributed computing environment, enabling rapid data access and similarity computation.

S20 ADVANTAGES OF VISUALIZATION, PHYSICS-INFORMED MACHINE LEARNING, DIGITAL TWINS, MULTIFRACTAL AND P-ADIC FORECASTING FOR G

KLAUDIA OLESCHKO (INSTITUTO DE GEOCIENCIAS, UNAM),
ALEXANDER BALANKIN (ESIME-Zacatenco del Instituto Politécnico Nacional, MEXICO),
ANDREY KHRENNIKOV (LINNAEUS UNIVERSITY, VÄXJÖ, SWEDEN)

Big Data is envisaged as the New Science of Complexity. This benchmark requires a new approach to visualization, physics-informed and statistics-informed machine learning, and fusion of multimessenger and multiscale Information gathered inside the trillions-sensors and images world. The metadata comes in several formats and dimensions, objects of non-controlled changes of number systems during collection, transmission, storage, encoding, sharing, and exchange through different devices and across digital networks from the metacomplex world. The disappearance, transformation, or emergence of numbers and digits doesn't always worry the users. Far less attention is put to answering Visser's (2022) seminal question: "Which number system is "best" for describing empirical reality."The emerging numbers commonly have no or at least different physical meanings, changing the analysis and model results. The precise interpretation, machine- and deep-learning, data-driven modeling, algorithm, and physical laws extraction directly from the data require strong fidelity to raw Big Data spatial-temporal Turing-like pattering. These patterns are embedded into the original 1D, 2D, or 3D numerical matrix and should be extracted from the raw messages, signals, and images. Based on the physics-informed approach, we focus on numbers pattering, fusing, and unifying Big Geo Data inside the probability-embedded medium. We introduce the new concept of the universal, Turning' morphogen-type patterning quantifier of System multiscale structure complexity extracted from physics-informed and statistics-informed raw data and images with moving space-temporal boundaries. We documented the precision/exactness of our approach on the raw seismic and X-ray computer tomography 3D data, showing their suitability for coding/decoding multimessenger, multidimensional, and multiphysics Information, controlling each data alteration by supervised forecasting of the amplitude histogram roughness. The latter is selected as a solid visual analytics attribute for statistical/geostatistical forecasting. Our Group designed the computed techniques for quantitative pattern extraction, measuring, and modeling under the maximum fidelity of transmission criteria as the Standard Methods of Measurement (SMM) of metacomplexity, coupling the physics-informed matrices with statistics-informed networks. Muuk'il Kaab (MIK) agile, natural-language (bees-type) software was designed and calibrated for data fusion, adimensional measures extraction (multifractal singularity spectrum), forecasting, and mapping of each attribute of Big Data patterning. We want to share our theoretical and field results of more than ten years of testing and application of these new Metacomplexity Universal Quantitative Attributes (MCUQA) for complex fracture (corridors) pattern recognition, measurement, multiscale visualization, and skeletonization. The concept of Metacomplexity Cyber Laboratory (MC-CybLab) is introduced and put into action in oil fields to restore fractures' geometrical and topological attributes and forecast their corridors by thermodynamic, multifractal, and p-adic adimensional measures. Our session aims to optimize the fusion of multidimensional multiphysical raw data sets by the same nature-inspired beetype software through data visualization, image analytics, virtualization, and the unification and forecasting of physics-informed measures with number theory.

S2001. ANÁLISIS DE LA CONECTIVIDAD DE FRACTURAS Y LA DINÁMICA DE LAS AGUAS SUBTERRÁNEAS A TRAVÉS DE ALGORITMOS INSPIRADOS EN LA NATURALEZA Y GEMELOS DIGITALES

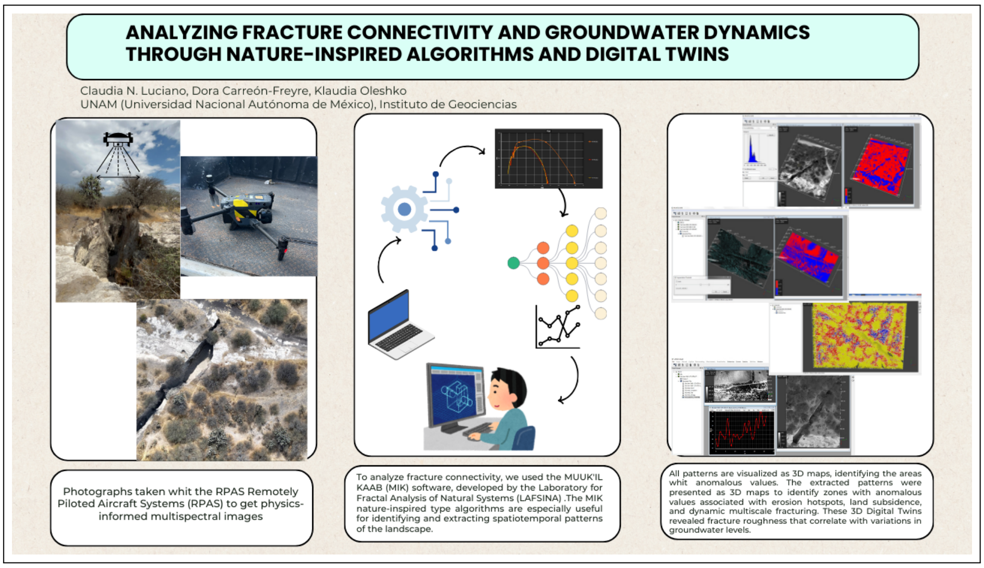
Claudia Noemí Luciano Soria (Instituto de Geociencias, UNAM),
Dora Carreón-Freyre,
Klaudia Oleshko (INSTITUTO DE GEOCIENCIAS, UNAM)
Room: B228 2025-10-10 14:30

This study explores the relationship between fracture systems' geometric and topological characteristics and groundwater flow patterns within an aquifer. Faults and fractures may be preferential pathways or barriers to subsurface water movement. Since groundwater constitutes the primary water source for the local population and economic activities, understanding its interaction with subsurface geological architecture is essential. Groundwater extraction conditions vary with depth, well distribution, and the structural geology of the sub-basin.

To analyze fracture connectivity, we used the MUUK'IL KAAB (MIK) software, developed by the Laboratory for Fractal Analysis of Natural Systems (LAFSINA) under Oleshko's Group (SENER168638, 2011–2015). MIK applies nature-inspired algorithms to extract and visualize the 3D spatiotemporal patterns from physical environments and numerical data matrices obtained through multiscale sensors. These datasets contribute to developing Digital Twins representing groundwater piezometric levels and isosurfaces in the study area.

Digital Twins integrate Big Data with physics-informed models inside the interactive computational environment, enabling enhanced monitoring and prediction of environmental time-space dynamics. This study captured multispectral images using Remotely Piloted Aircraft Systems (RPAS) in two zones of San Miguel de Allende, Guanajuato (Mexico). One zone contains an open fracture, while the other features are related to the hidden sediment-filled fracture patterns. We analyzed the structural dynamics of both families of attributes.

The extracted patterns were presented as 3D maps to identify zones with anomalous values associated with erosion hotspots, land subsidence, and dynamic multiscale fracturing. These 3D Digital Twins revealed fracture roughness that correlate with variations in groundwater levels, offering insights into the subsurface hydrogeological behavior. The integration of machine learning and geospatial modeling provides a novel framework for assessing fracture connectivity and its broader environmental implications useful for the future sustainable water use.



S2002. Apple iPhone LiDAR for Advanced Machine Learning of Soil Surface Roughness

César Alberto Cortés Prado (Institute of Geosciences, UNAM.),
Mariano Cerca (Institute of Geosciences, UNAM.),
Klaudia Oleshko (INSTITUTO DE GEOCIENCIAS, UNAM),
Mario Martínez-Méndez† (Graduate School , México),
Michel Esteves (Institute of Research for Development, France),
Cesar Alberto Cortés Prado
Room: B228 2025-10-10 14:50

We present the first Library for Surface Roughness Multiscale Measuring and Modeling (SRMMM) using Advanced Machine Learning techniques and Digital Twin frameworks. The dataset was obtained from long-term experimental plots established in Molic Andosols of Central Mexico, severely affected by hydric erosion. Surface roughness surrogate models were captured in situ using epoxy resin casts before and after controlled rainfall simulations. These physical models were preserved unaltered at the Laboratory for Fractal Analysis of Natural Systems (LAFSINA), Institute of Geosciences, UNAM.

Eight terrain surrogates were analyzed, each representing contrasting conditions of roughness, wettability, erodibility, tillage, and land management. In this study, we used the built-in LiDAR sensor of an Apple iPhone to capture high-resolution 3D measurements of these physical soil surfaces. The smartphone-based LiDAR provided detailed digital elevation models (DEMs) with rich textural data, offering a novel and cost-effective method for quantifying soil surface roughness. The LiDAR measurements were calibrated with big data from multiscale, multisensory analyses: from field rain simulations to laboratory roughness studies with laser.

The LiDAR-derived .las files were processed using MUUK'IL KAAB (MIK)—a nature-inspired software developed by the multidisciplinary team at LAFSINA. This tool enables 3D data visualization and statistical analysis of Turing-like spatiotemporal roughness patterns through geometric and topological descriptors such as entropy, root mean square (RMS), and multifractal spectra.

Correlation analysis with laboratory-grade laser profilometry and erosion data from rainfall simulations validated the accuracy of the smartphone LiDAR, leading to the development of a new Fusion Model of scale-invariant hydric erosion.

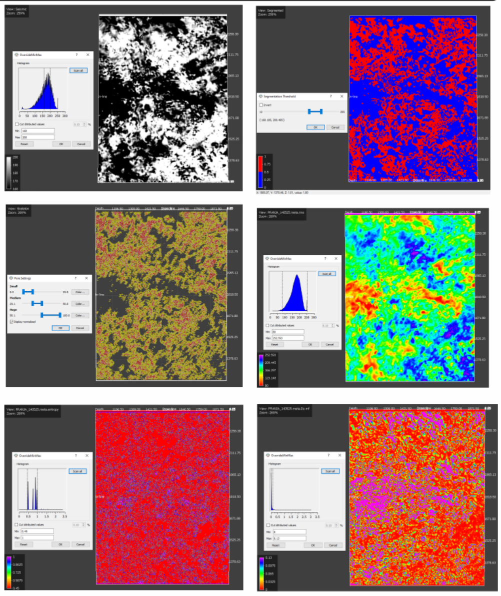
This study demonstrates that smartphone-integrated LiDAR technology offers a powerful, accessible, and innovative tool for soil surface analysis, with far-reaching applications in geomorphology, sustainable agriculture, and ecohydrological research.

Apple iPhone LiDAR for Advanced Machine Learning of Soil Surface Roughness

High resolution surface terrain models were obtained in agricultural fields in Mexico, at different wettability conditions and anthropogenic disturbance.The models were placed at unaltered conditions in LAFSINA Institute of Geosciences, UNAM.

iPhone LiDAR was used to obtain digital elevation models of each model.

The raw iPhone data was loaded in the software MUUK'IL KAAB developed by UNAM- LAFSINA.

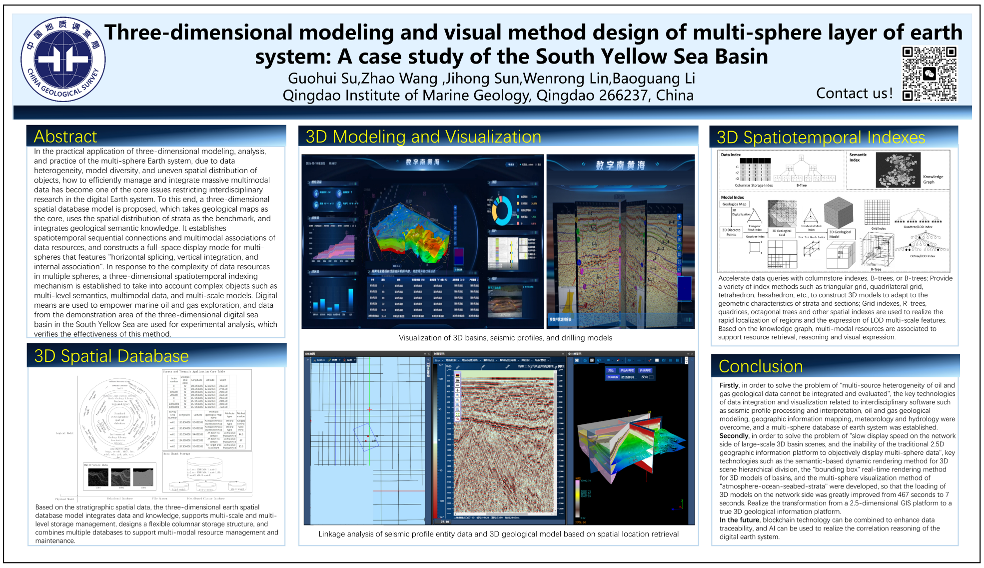


There were obtained geometrical and statistical properties with the software MUUK'IL KAAB ; this tool enables 3D data visualization and statistical analysis of Turing -like spatiotemporal roughness patterns through geometric and topological descriptions such as entropy, root mean square(RMS), and multifractal spectra.This study demonstrates that smartphone - integrated LiDAR technology offers a powerful, accesible , and innovative tool for soil surface analysis , with far-reaching applications in geomorphology, sustainable agriculture and ecohydrological research.

S2003. Three-dimensional modeling and visual method design of multi-sphere layer of earth system: A case study of the South Yellow Sea Basin

zhao wang (Qingdao Institute of Marine Geology),
zhao wang (Qingdao Institute of Marine Geology),
Guohui Su (Qingdao Institute of Marine Geology),
Jihong Sun (Qingdao Institute of Marine Geology),
Wenrong lin (Qingdao Institute of Marine Geology),
Baoguang Li (Qingdao Institute of Marine Geology)
Room: B228 2025-10-10 15:10

In the practical application of three-dimensional modeling, analysis, and practice of the multi-sphere Earth system, due to data heterogeneity, model diversity, and uneven spatial distribution of objects, how to efficiently manage and integrate massive multimodal data has become one of the core issues restricting interdisciplinary research in the digital Earth system. To this end, a three-dimensional spatial database model is proposed, which takes geological maps as the core, uses the spatial distribution of strata as the benchmark, and integrates geological semantic knowledge. It establishes spatiotemporal sequential connections and multimodal associations of data resources, and constructs a full-space display mode for multi-spheres that features "horizontal splicing, vertical integration, and internal association". In response to the complexity of data resources in multiple spheres, a three-dimensional spatiotemporal indexing mechanism is established to take into account complex objects such as multi-level semantics, multimodal data, and multi-scale models. Digital means are used to empower marine oil and gas exploration, and data from the demonstration area of the three-dimensional digital sea basin in the South Yellow Sea are used for



S21 Computational Geoscience

Chunan Tang

As the advancement of Earth system science, Computational Geoscience has emerged as a new discipline that leverages computational science to drive exploration and discovery within the realm of geosciences. Characterized by its inherent multidisciplinary nature, Computational Geoscience facilitates the investigation of interactions between various internal and external factors within the Earth system through computer simulations, thereby becoming an essential methodology for Earth system research.

In recent years, the development of digital earth technologies has significantly propelled the integration of numerical simulation, supercomputing, big data with geosciences, leading to substantial progress in simulating global-scale issues such as climate modeling, tsunamis, and earthquakes. However, research in Computational Geoscience is still in its infancy concerning fundamental scientific questions about major earth evolution processes like plate tectonics, supercontinent cycles, ice ages, and mass extinctions, as well as in the study of natural disasters such as mountain landslides and in the geomechanical research on reservoirs for deep/ultra-deep, deepwater, and unconventional oil and gas exploration and development.

This session aims to explore the application of advanced numerical computation methods in geosciences and welcomes submissions on all topics related to the following themes: (1) Computational Solid Earth; (2) Computational Engineering Geology; (3) Reservoir Geomechanics.

S2101. Bayesian Nonlinear Seismic Inversion Using ADA-MCMC and Zoeppritz-Based Forward Model

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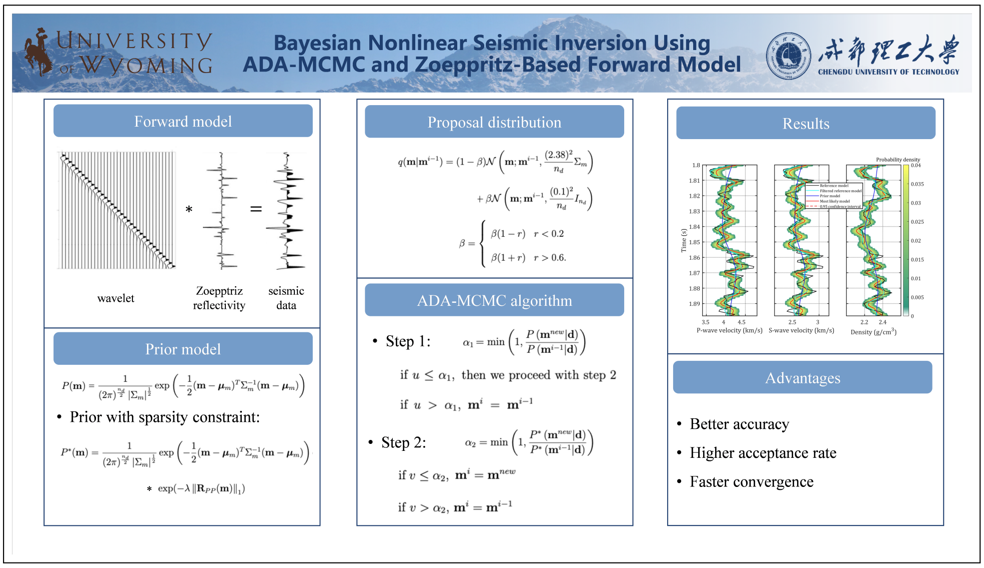
Dario Grana (Department of Geology and Geophysics, University of Wyoming),
Xiaotao Wen (Key Laboratory of Earth Exploration and Information Technology of Ministry of Ed),
Bo Li (Key Laboratory of Earth Exploration and Information Technology of Ministry of Ed),
Leandro Passos de Figueiredo (LTrace Geosciences)
Room: B222 2025-10-11 14:30

Seismic inversion seeks to estimate the elastic properties of subsurface rocks from seismic reflection data. This study presents a nonlinear Bayesian inversion approach based on the Zoeppritz equations, aiming to improve accuracy and computational efficiency. We employ an Adaptive Delayed Acceptance Markov Chain Monte Carlo

(ADA-MCMC) algorithm to sample the posterior distribution and quantify solution uncertainty. The adaptive component enhances acceptance rates, while the delayed acceptance strategy accelerates sampling by reducing computational cost. A sparse-constrained prior and a mixture model proposal distribution are incorporated to further refine the inversion. The output is a full posterior probability density function (PDF) of elastic properties at each location, allowing for robust uncertainty quantification beyond mean and standard deviation. Validation on 1D synthetic models shows improved accuracy compared to conventional Bayesian methods that rely on Gaussian assumptions and linearized physics. Application to a 2D dataset confirms the method's practical utility and scalability.



S2102. Lacustrine Basin Sedimentation Simulation Using a Particle-in-Cell Framework: Methodology and Efficacy

Yuangui Zhang (Bureau of Geophysical Prospecting Inc., China National Petroleum Corporation),
Maoshan Chen (Bureau of Geophysical Prospecting Inc., China National Petroleum Corporation),
Lei Li (Bureau of Geophysical Prospecting Inc., China National Petroleum Corporation),
Haisheng Yu (Bureau of Geophysical Prospecting Inc., China National Petroleum Corporation)
Room: B222 2025-10-11 14:50

Stratigraphic forward modeling (SFM) quantitatively simulates clastic sediment erosion, transport, and deposition through deterministic physical principles, serving as a critical predictive tool for basin analysis and hydrocarbon exploration.

We develop here a novel hydrodynamic-based simulation method for clastic stratigraphy forward modelling by innovatively refining the Particle-in-Cell (PIC) simulation framework. In this method, fluid flow is represented by discrete particles that propagate through the simulation domain following hydrodynamic principles. The interaction between these particles and the underlying geological formations results in continuous erosion and deposition processes, enabling the modeling of sediment transport and landscape evolution. Navier-Stokes equation is utilized to describe fluid particle motion. To overcome the high computational cost of traditional solvers of Navier-Stokes equation, we propose a computationally efficient numerical method, facilitating the establishment of a high-performance fluid flow simulation framework.

A meandering fluvial-lacustrine system was established to validate the proposed method. The simulation framework tracks sediment-laden fluid particles from their entry at the source points through the meandering river until they discharge into the lake basin. The test results demonstrate rapid flow deceleration at the river-lake transition zone induces sediment deposition, forming a prograding deltaic system. Initial deposition is dominated by coarse-to-fine sands in proximal zones, with only trace clay fractions extending toward the basin center. As sedimentation progressed, the accommodation space in shallow regions diminished, causing sediments to gradually advance toward the basin center, resulting in the development of a continuous clay depositional system from delta front to basin center. The simulated depositional patterns exhibit strong consistency with established sedimentological principles governing fluvial-lacustrine transitions, confirming the method's geological fidelity.

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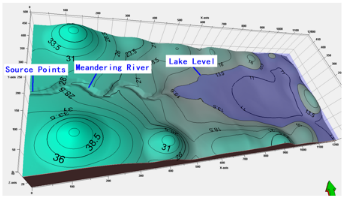
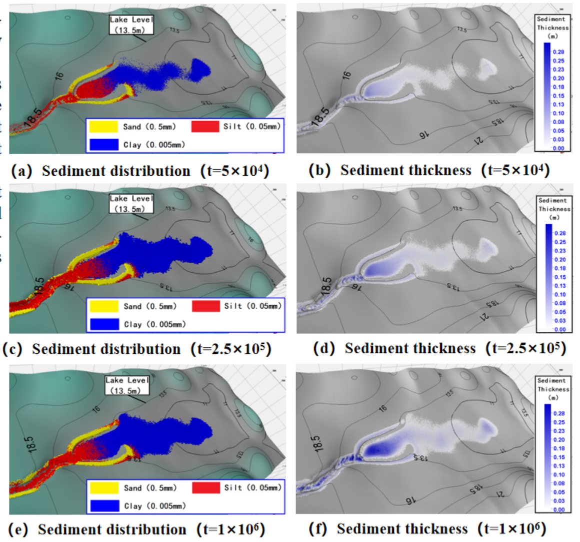


Initial topography



(a) Sediment distribution ($t=5\times10^4$)

(b) Sediment thickness ($t=5\times10^4$)

(c) Sediment distribution ($t=2.5\times10^5$)

(d) Sediment thickness ($t=2.5\times10^5$)

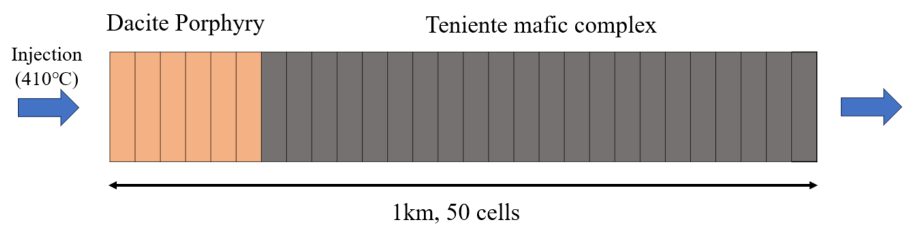
(e) Sediment distribution ($t=1\times10^6$)

(f) Sediment thickness ($t=1\times10^6$)

S2103. Numerical simulation for identifying control factors on porphyry copper mineralization with application to the El Teniente deposit in Chile

Michiharu Enatsu (Kyoto University),
Katsuaki Koike (Graduate School of Engineering, Kyoto University)
Room: B222 2025-10-11 15:10

Porphyry copper deposits are one of the most significant sources of global copper production, and their importance is projected to increase due to the growing demand for copper. To meet this demand, discovering new deposits is becoming increasingly critical. A deeper understanding of the genesis of porphyry copper systems can provide insights into the conditions necessary for ore formation and contribute to the development of more effective exploration strategies. However, the porphyry copper system involves complicated interactions among geological, geochemical, and hydrological processes that occur over large spatial and temporal scales. These processes are inherently impossible to reproduce experimentally. Accordingly, numerical simulation techniques have become a powerful tool for reconstructing metallogenic processes under realistic geological conditions. Based on that background, this study aims to identify key factors controlling copper mineralization, such as fluid temperature, pH, redox conditions, and fluid-rock interactions through a numerical simulation using TOUGHREACT, a reactive transport simulator. The El Teniente porphyry copper deposit, one of the largest deposits in Chile, is selected for a case study. As a result, the thermal, hydrological, and chemical conditions necessary for copper precipitation from hydrothermal fluids were estimated. Our results contribute to a more comprehensive understanding of ore-forming environments and offer a framework for guiding effective exploration.



One-dimensional horizontal simulation of hydrothermal fluid flow in El Teniente deposit

S2104. Improved Geostatistical Simulation for Coastal Salinity Mapping through the Integration of Markov-Type Categorical Prediction and Geophysical Data

Liming Guo (Ghent University),
Thomas Hermans (Ghent Univeristy, Ghent, Belgium),
Wouter Deleersnyder (Ghent Univeristy, Ghent, Belgium)
Room: B222 2025-10-11 15:30

Accurate characterization of subsurface salinity distribution is critical for managing groundwater resources, especially in coastal and deltaic environments threatened by saltwater intrusion, and airborne electromagnetic data contain crucial information for mapping salinity. Geostatistical simulations play a key role in quantifying spatial uncertainty and enabling multiple realizations of lithological and hydrogeological models (Isunza Manrique et al., 2023). In this study, we propose an integrated modeling framework that combines Markov-type Categorical Prediction (MCP), a geostatistical technique based on a training image (Benoit et al., 2018), geophysical inversion, and petrophysical constraints to improve the realism and accuracy of salinity distribution. Bulk electrical conductivity (ECb), a key geophysical indicator, is linked to water conductivity (ECw), related itself to salinity, and lithology via a petrophysical relationship. We derive joint conditional probabilities P(Lithology, ECw ECb) using discretized ECb and ECw classes, and combine them with lithological categorical probabilities from the MCP framework using a stochastic model (Hermans et al., 2015). The final conditional distribution from geostatistical simulations constrained by geophysical data, P(Lithology, ECw ECb, MCP, petrophysics), allows the generation of consistent lithological and water conductivity maps. This approach significantly reduces the uncertainty in lithological realizations and provides a physically-grounded alternative to salinity mapping, accounting for lithological uncertainty, providing an efficient path forward for large-scale groundwater salinity assessment from geophysical data sets.

References

Benoit, N., Marcotte, D., Boucher, A., D'Or, D., Bajc, A. and Rezaee, H., 2018. Directional hydrostratigraphic units simulation using MCP algorithm. Stochastic environmental research and risk assessment, 32, pp.1435-1455.

Hermans, T., Nguyen, F. and Caers, J., 2015. Uncertainty in training image-based inversion of hydraulic head data constrained to ERT data: Workflow and case study. Water Resources Research, 51(7), pp.5332-5352.

Isunza Manrique, I., Caterina, D., Nguyen, F., & Hermans, T. (2023). Quantitative interpretation of geoelectric inverted data with a robust probabilistic approach. Geophysics, 88(3), B73-B88.

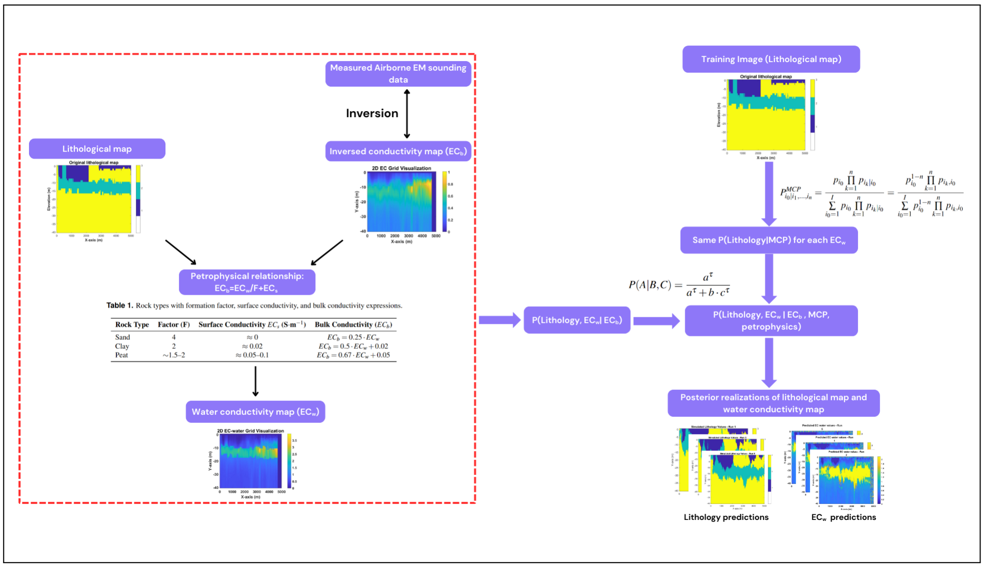


Table 1. Rock types with formation factor, surface conductivity, and bulk conductivity expressions.

Rock Type	Factor (F)	Surface Conductivity EC_s ($S\cdot m^{-1}$)	Bulk Conductivity (EC_b)
Sand	4	≈ 0	$EC_b = 0.25\cdot EC_w$
Clay	2	≈ 0.02	$EC_b = 0.5\cdot EC_w + 0.02$
Peat	$\sim$1.5–2	$\approx$ 0.05–0.1	$EC_b = 0.67\cdot EC_w + 0.05$

S22 Deep-time Digital Earth (DDE) big science program: tools, services and scientific progress

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Junxuan Fan (Nanjing University),
Yong Ge (Jiangxi Normal University),
Jieping Ye (Zhejiang Lab),
James G Ogg (Purdue University),
Enjiang Yue (Zhejiang University)

The Deep-time Digital Earth (DDE) Program is an international big science initiative designed to create an integrated platform for geoscience data, aligned with the FAIR principles (Findable, Accessible, Interoperable, and Reusable). Over its ten-year plan, this ambitious program seeks to harmonize global deep-time Earth data across multiple domains—including the biosphere, lithosphere, and hydrosphere—to advance data-driven discoveries in Earth's evolutionary history. To achieve its vision of open science, DDE will develop cutting-edge tools and services for data mining, knowledge discovery, and AI-driven analysis. By fostering global collaboration and innovation, DDE aims to improve our understanding of Earth's deep-time processes and ultimately transform our research paradigm.

S2201. Significant role of geoscience standards supporting IUGS-DDE program Open and FAIR

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Harvey Thorleifson (CGI/University of Minnesota),
Simon Hodson (CODATA),
Francois Robida (CGI/France),
Mark Rettenbury (CGI/GNS, New Zealand)
Room: B228 2025-10-12 10:30

FAIR data are the fuel of Artificial Intelligence. Standards are critical for data FAIR. Great efforts were taken by the international science program Deep-time Digital Earth program (DDE) of IUGS for the standardization of cross-domain data, knowledge and service resources Open and FAIR. Big progress has been made with the leading of DDE Standards Group thru the RD project Geosciences Data Standards for DDE. The Formal Geoscience Knowledge System Review Procedure was issued and provided in Aug.2020 which guided the fast development of the

DDE knowledge system based on the Geoscience Terminology of the Commission for Geoscience Information (CGI) of IUGS. The Geoscience Information Metadata Standard (DS01-2023) with FAIR principle implies and machine readable issued and released in November 2023 at the International Forum of Geoscience Standards at Suzhou, which guided the DDE multiple disciplinary resources metadatabase development and DDE platform cataloguing for resources finable and accessible. The CGI/OGC GeoSciML for geosciences data exchange has been implemented in Chinese 1:1&0.5 million geological map databases release thru DDE-China node as a demonstration. And demonstrations of EarthResoirceML and GroundWaterML were also done. Thematic standards for geological time scale, 3D-outcrop, regional minerals assessment, igneous rock database, etc. were also developed by DDE working groups. These standards meet preliminarily the demand of DDE to a large extent for simplicity, efficiency, domain coverage, geological time scale, long tail data, machine readability, and consistency with existing international standards. Further, the 2025-2027 RD project FAIR Principles implementation for DDE with the utilization of expertise from CODATA (the Committee on Data of the International Science Council) through WorldFAIR+ initiative and from global communities' practices will ensure DDE data resources FAIR in practice towards the goal of data driven discovery and research, with continuously close cooperation and overcome challenges from the fast-changing world.

S2202. DDE Geomorphology Community: Progress and Applications

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Yang Chen (School of geography, Nanjing Normal University),
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Guoan Tang (School of geography, Nanjing Normal University)
Room: B228 2025-10-12 10:50

In response to the rapid advancements in big data and information technology, the field of geomorphology is shifting towards a data-driven research paradigm. At the forefront of this transition is the Geomorphology Working Group, which is actively developing a community platform under the framework of the Deep Digital Earth (DDE). This platform aims to integrate geomorphological data, models, case studies, and maps, providing a comprehensive resource to meet the evolving needs of geomorphological research.

Recognizing the complexity and diversity of geomorphological research, we have coordinated and harmonized large-scale data resources such as global topographic data and basic landform units. These data resources encompass multi-scale information, ranging from microscopic to macroscopic levels, and from regional to global scopes, thereby supporting a wide array of geomorphological investigations. In addition to data integration, we have incorporated research models such as geomorphology classification and mapping, as well as geomorphological process simulations. These models serve as versatile tools, enabling researchers to delve into various aspects of landform evolution, topographic change, and the interactions between landscape and environment.

Furthermore, the Geomorphology Working Group reproduced of classic geomorphological case studies. By doing so, we provide researchers with clear examples of research workflows, helping them to better understand and apply existing theories and methodologies. Through these concerted efforts, the DDE Geomorphology Community aspires to provide a robust, integrated platform that not only augments the research and application potential of geomorphology but also catalyzes innovation within the discipline. Our overarching objective is to advance geomorphological science and to amplify its influence in both academy and practical application.

S2203. Mapping Crustal Vp/Vs in North America With a Machine Learning Approach

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Yunfeng Chen (Zhejiang University),
Wenyu Zhao (Zhejiang University),
J. ZhangZhou (Zhejiang University),
Shang Ma
Room: B228 2025-10-12 11:10

Vp/Vs (Poisson's ratio) provides critical information for constraining the bulk crustal

composition, stress state, and tectonic evolution of the Earth. The receiver function technique has been extensively utilized to constrain the crustal Vp/Vs, yet the reliability of measurements can be affected by complex structures and uneven distribution of seismic stations. Consequently, the interpolated Vp/Vs maps can often be biased by unreliable observations, especially in data-sparse regions. We tackle these issues by proposing a machine learning model that integrates multiple geophysical data sets to estimate Vp/Vs, leveraging the physical and structural properties of the crust. We train the model by compiling an extensive data set of

global Vp/Vs measurements at 13,314 seismic stations and employ XGBoost to map Vp/Vs with other key crustal properties. Experiments using data from the (a) United States and (b) United States and Canada demonstrate superior prediction accuracy, achieving an overall R2 value of 0.84 in both cases. Feature importance analysis indicates that crustal tectonic type, geographic coordinates, mid-crust shear-wave velocity, and crustal thickness primarily capture Vp/Vs variations, together explaining over 70% of reduction in the normalized root-mean-square error. The inclusion of other features further refines small-scale Vp/Vs variation. Compared to cubic and Kriging interpolations, the predicted Vp/Vs map from machine learning exhibits less local extremes and a better alignment with the first-order crustal structure across the continent. This study highlights the capability of machine learning to uncover complex geophysical relationships for reliable Vp/Vs estimates and its potential to constrain crustal composition at a continental scale.

Abstract Vp/Vs (Poisson's ratio) provides critical information for constraining the bulk crustal composition, stress state, and tectonic evolution of the Earth. The receiver function technique has been extensively utilized to constrain the crustal Vp/Vs, yet the reliability of measurements can be affected by complex structures and uneven distribution of seismic stations. Consequently, the interpolated Vp/Vs maps can often be biased by unreliable observations, especially in data-sparse regions. We tackle these issues by proposing a machine learning model that integrates multiple geophysical data sets to estimate Vp/Vs, leveraging the physical and structural properties of the crust. We train the model by compiling an extensive data set of global Vp/Vs measurements at 13,314 seismic stations and employ XGBoost to map Vp/Vs with other key crustal properties. Experiments using data from the (a) United States and (b) United States and Canada demonstrate superior prediction accuracy, achieving an overall R^2 value of 0.84 in both cases. Feature importance analysis indicates that crustal tectonic type, geographic coordinates, mid-crust shear-wave velocity, and crustal thickness primarily capture Vp/Vs variations, together explaining over 70% of reduction in the normalized root-mean-square error. The inclusion of other features further refines small-scale Vp/Vs variation. Compared to cubic and Kriging interpolations, the predicted Vp/Vs map from machine learning exhibits less local extremes and a better alignment with the first-order crustal structure across the continent. This study highlights the capability of machine learning to uncover complex geophysical relationships for reliable Vp/Vs estimates and its potential to constrain crustal composition at a continental scale.

S2204. Progress of DDE Country Node (China) Construction

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Room: B228 2025-10-12 11:30

Based on the geological data platform of China Geological Survey, DDE Country Node (China) organizes and integrates geological data in the field of geological survey according to the relevant needs of DDE big science plan and DDE knowledge graph and knowledge system, and builds a DDE national demonstration node, providing geological science data services for global users and providing an open data application and scientific research platform for global science.

(1) Release DDE-China Geologic-cloud-platform (v1.0), and released database with DDE-data lake and protected by certification technology.

The global alliance cooperation of geoscience among the national geological surveys is an important mode of supporting the digital geological survey and geoscientific research. DDE-China is an open, interactive, and cooperative platform. It implements a novel digital solution for geodata production, display, and products application with the creative distributional cloud architecture.

To make DDE-China as a model of DDE international national nodes, it builds a DDE national node system and network with national geological survey institutions as the core implementation.

(2) Based on DDE standards, publish the data sets with interdisciplinary and cross-national nodes. Besides, it should make the rules for the data collecting and sharing following the native laws and rules. Finally, it should try on data utilization and cross-development.

(3) It releases a series of Deep-Time related databases indicating the evolutionary characteristics of geology, geotectonic, and mineral, etc. All databases adopt the DDE metadata standard and the data interface can be applied for free. Besides, the geoinformation of these databases can be viewed on the web.

(4) Release digital survey system with EN vision , Apps, desktop software integrated by desktop-cloud & web applications.

S2205. Mineral potential Explorer: A cloud-native Platform For Mineral Resource Prediction

Jie YANG (China University of Geosciences, Beijing)
Room: B228 2025-10-12 11:50

We have developed the Mineral Potential Explorer (MPE) platform, a cloud-native platform integrating ”storage, computation, and application,” designed to provide one-stop support for data, algorithms, and computing power for mineral resource prediction. The platform employs a guided interface and an easy-to-use interactive model, significantly lowering the barrier to accessing mineral resource data, enhancing the computational efficiency of prediction algorithms, and simplifying the learning and application of mineral potential prediction.

MPE utilizes a workflow-based approach as the core computational model for mineral potential prediction. Users construct nodes by dragging and dropping data and algorithm modules, connecting them by configuring parameters, thereby forming a visualized computational process that clearly displays the entire prediction procedure. The platform’s built-in algorithms cover key stages such as data conversion and processing, feature extraction, machine learning, and result evaluation. Concurrently, MPE offers diverse data and chart visualization functions to assist users in evaluating computational results. Furthermore, the platform supports the saving, loading, and sharing of workflows, promoting scientific collaboration and knowledge dissemination.

To further enhance the platform’s level of intelligence and user experience, we have introduced Large Model Agent functionality. This Agent is capable of: 1) Intelligent Guidance: Based on user input and data characteristics, it intelligently recommends suitable workflow templates and algorithm combinations; 2) Parameter Optimization: It assists users in the automatic optimization and configuration of model parameters; 3) Natural Language Interaction: It allows users to query data, control processes, and interpret results using natural language. By integrating the Large Model Agent, MPE aims to construct a more intelligent, efficient, and user-friendly mineral potential prediction environment, empowering geoscientists to make more precise resource assessments and exploration decisions.

S2206. DEEP: DDE Enabling and Empowering Platform

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Yuanyuan Wang (Zhejiang University),
Enjiang Yue (Zhejiang University)
Room: B228 2025-10-12 12:10

Big Data and AI have transformed Earth sciences, enabling data-driven discovery. While digital infrastructures have simplified access for most, deep-time geoscience faces challenges with scattered heterogeneous data and traditional theoretical methods. To overcome this, we propose the DEEP (DDE Enabling and Empowering Platform)—a one-stop online research platform for geoscientists.

Utilizing cloud computing and advanced tech, it offers open access to deep-time geoscientific data, knowledge, models, and computing power under the coordination of the Deep-time Engine . DEEP is aimed at enabling and empowering global geoscientists' collaborative innovation and discoveries via the global accessible entrance (https://deep-time.org). The platform is a significant advancement in geoscientific exploration, fostering global collaboration and promoting a data-driven research paradigm within the framework of open science.

S2207. Digital Twins in Geosciences and Engineering

Jin Qi (Zhejiang University),
Jin Qi (Zhejiang University)
Room: B228 2025-10-12 14:30

The Digital Twins of the Ocean (DTO) is a new generation of virtual systems with marine science at its core and computer technology as its support. As a frontier of international scientific and technological innovation, the DTO aims to use information systems and artificial intelligence technology to serve real scenarios in the marine field. Over the past 10 years, our team has carried out interdisciplinary development and application in the field of digital twins, and has made some progress in application scenarios such as marine engineering, marine environment, and Earth's evolution:

1 A marine environment DTO for the protection of Hong Kong-Zhuhai-Macao Bridge (HZMB) Island Tunnel project. By organizing, managing, and visualizing real-time monitoring data of the marine physical environment we have achieved real-time analysis and information decision-making of wind, wave, and current data, providing precise marine environmental forecast information for the construction of the HZMB.

2 A DTO platform for the marine ecological environment of the coastal waters, achieving the governance of multi-source data such as buoys, ship measurements, and remote sensing data. The DTO is capable of conducting automated or customized water quality assessments, red tide warnings, and oil spill risk alerts which provides real-time and online computational assessments for coastal tourism areas, marine protected areas, and major marine engineering areas, providing digital demonstration applications for the safety of marine ecological environment and the sustainable development of the marine economy.

3 A geological digital twin platform, which is currently being developed within the Deep-time Digital Earth (DDE) Big Science Program. This system has initially achieved visualization and analysis of multidimensional geospatial-temporal data such as dynamic simulation of paleo tectonic plates and custom drawing of geological profiles, with the expectation of aiding geoscientists worldwide by coupling data, knowledge, models, and computing power, providing scientific inspiration for geoscientists, and promoting data-driven Earth science research.

S2208. Enhancing High Temperature Geochemistry Data Quality Through Expert Efforts

J. ZhangZhou (Zhejiang University),
J. ZhangZhou (Zhejiang University)
Room: B228 2025-10-12 14:50

The rapid advancement of statistical methods and machine learning algorithms applied to data from cyberinfrastructures offers significant opportunities to uncover the secular evolution and chemistry of the solid Earth. However, these cyberinfrastructures, in their current state, contain raw data with missing categories, errors (including in age information), and misplaced chemical compositions that may conflict with published data. These inaccuracies primarily arise from the absence of standardized practices for publishing rock geochemistry data and limitations in optical character recognition techniques used to convert tablet data into readable formats. As a result, the data quality issues in cyberinfrastructures are not inherent to the infrastructure itself, but rather to the data publishing format.

Before the data input process to cyberinfrastructures can be fully standardized to ensure high-quality data, an alternative approach involves experts working on cleaning and refining the data to ensure it aligns with original publications, then providing feedback to improve the infrastructure. However, this process of data cleaning and manual input is both tedious and time-consuming. In this study, we present expert datasets resulting from systematic data cleaning and input efforts involving 20 geochemists. The high degree of reliability and comprehensiveness achieved in this work provides direct benefits to the research community. To ensure accessibility, the standardized database will be freely available and published as supplements in geochemistry research papers. Additionally, we will continue uploading the standardized data to GEOROC and EarthChem to further improve the data quality of cyberinfrastructures. Last but not least, the datasets will be available as the high temperature geochemistry database on DDE platform.

S2209. Similarity metrics for three-dimensional geologic body property models

Guo Chen (China University of Geosciences (Wuhan)),
Xin He (China University of Geosciences (Wuhan))
Room: B228 2025-10-12 15:30

This paper is based on a self-constructed 3D geoid attribute modeling dataset (GeologicalNet), a similarity measure based on the joint analysis of Hilbert curve voxelization and multi-attribute sequence is proposed. Firstly, the 3D model is discretized into a voxel grid, and the attribute values of each voxel are mapped into multiple one-dimensional sequences (single-attribute sequences) according to their spatial proximity by using the spatial filling property of 3D Hilbert curves, so as to preserve the distribution pattern of geological attributes in 3D space; subsequently, the local deformation difference and global trend similarity of single-attribute sequences are measured by combining the dynamic temporal regularization (DTW) and the Pearson correlation coefficient respectively. The local deformation difference and global trend similarity of single-attribute sequences are measured by combining dynamic time regularization (DTW) and Pearson's correlation coefficient, and the multi-attribute similarity scores are fused by the geologic a priori knowledge-driven adaptive weight assignment. Experiments based on the self-constructed dataset show that the method improves more than the traditional voxel comparison method in the cross-region reservoir comparison task, and reduces the retrieval time-consuming to linear complexity by the sequence segmented hashing technique, which provides a scalable technological path for the intelligent analysis of large-scale multi-attribute geological models.

S2210. Integrating geological maps:Advances in Standardized Mapping and AI-driven comprehension of geological maps

Yang Song (Chinese Academy of Geological Sciences),
Zhenhan Wu,
Yangyu Huang
Room: B228 2025-10-12 15:10

The Deep-time Digital Earth (DDE) Program is a big science initiative that integrates and standardizes global geological data to advance geoscience research. A key achievement is the development of the 1:5M scale Geological Map of the World, which harmonizes diverse continental and oceanic geological maps with historically inconsistent legends, stratigraphic classifications, and databases. This project integrates the international geological maps of continents and oceans at a scale 1:5M which have been produced under the supervision of the CGMW, establish the legend system and adequate metadata database for the map, and construct the uniform, homogenous and digital Geological Map of the World at the scale 1:5M. Led by the Commission for the Geological Map of the World the Chinese Academy of Geological Sciences ,and DDE this effort establishes a unified digital framework that serves as a central portal for accessing and analyzing geological data within DDE. The digital map could be used as a portal or an entry point to access other geological data of the CGMW-DDE mapping initiative through the GMG.

To enhance data usability, Team has developed the Global Layer platform, an interactive visualization tool that transforms complex geological datasets into accessible maps for researchers and the public. Additionally, in collaboration with Microsoft Research Asia, the program explores AI-driven geologic map interpretation using the PEACE (Empowering Geologic Map Holistic Understanding with MLLMs project aims to improve machine comprehension of geological maps, bridging the gap between raw data, visual representations, and scientific insights.

These innovations support critical applications in the resource exploration and civil engineering, demonstrating role in advancing Geo-science through data integration, AI-enhanced analysis, and open-access tools. By combining big data, visualization technologies, and machine learning, the program not only facilitates global geological research but also sets a foundation for future discoveries in Earth system science.

Contributions by topic

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M130 Spherical Mathematics, Probablity and Statistics

S0802

M140 Multivariate Statistics

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M150 Bayesian Statistics

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