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Editorial: Methods and advances in marine geology and hydrodynamics environment

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Editorial on the Research Topic
Methods and advances in marine geology and hydrodynamics environment

Over the years, there has been a growing focus from both the academic and industrial communities on the development of subsea mineral resources (such as oil, gas, hydrates, polymetallic nodules, and rare earth elements), the exploitation of renewable marine energy sources (including wind power, tidal energy, and wave energy), coping with extreme weather conditions (such as storm surges, high temperatures, and extreme drought), and the protection of the marine environment (covering aspects like geology and ecology). These developments present substantial opportunities and challenges to the field of marine geology and the hydrodynamics environment. In light of these considerations, we have proposed the Research Topic, *Methods and Advances in Marine Geology and Hydrodynamics Environment*, to compile the latest advancements in the aforementioned critical areas.

This Research Topic comprises 18 original research papers contributed by 93 authors. The research within encompasses a spectrum of methodologies, including *in-situ* observations, geological surveys, laboratory experiments, numerical simulations, big data analysis, artificial intelligence, and theoretical analyses. These approaches collectively offer valuable insights into the realms of marine geology and the hydrodynamics environment. In this summary, we highlight key findings derived from the 18 research papers featured in this Research Topic.

Marine geological survey

Chen et al. investigated the paradox of submerged carbonate platforms on passive margins with growth potential exceeding typical subsidence rates. Manned submersible observations, sampling, and high-resolution acoustic data were employed in the northern

South China Sea to categorize Early Miocene platform strata into three units formed on fault-created topography. Rapid subsidence and eustatic rises during the Early Miocene drove platform deposition. A transition from aggrading to prograding margins occurred in the Middle Miocene with the cessation of faulting. Subsequently, during the late Middle Miocene, the platform submerged due to asymmetric backstepping influenced by summer monsoon-induced upwelling. High subsidence rates in the Late Miocene halted platform growth. This study provides insights into the past drowning mechanism of a Miocene carbonate platform, serving as a seismic analog for ancient, isolated platforms globally.

Fan et al. investigated the seismic response of seabed sites in the Qiongzhou Strait, with a particular focus on the influences of seawater, soft sediments, and bedrock earthquake motion. Employing a fluid-solid weak coupling model incorporating a non-Masing constitutive model for dynamic seabed soil behavior, the study disclosed that seawater acts as a suppressor of seismic motion, especially in shallow seabed layers, impacting both vertical and horizontal responses. The research identified bidirectional coupled seismic effects, challenging conventional one-dimensional site analysis methods. Seawater exhibited a depth-dependent influence, with more pronounced effects in shallow sediment layers. The study underscores the significance of accounting for seawater effects in marine engineering seismic analyses, highlighting their detrimental impact on seismic resistance.

Gao et al. investigated the resistivity structure beneath an extinct mid-ocean ridge in the South China Sea using marine magnetotelluric (MT) instruments. Through the imaging of the electrical properties of the mantle, the study revealed a positive correlation between the thickness of the lithospheric lid (>100Ωm) and its age, ranging from 20 to 90 km. The presence of a closed melt ascent channel beneath the stalled ridge resulted in a small melt trap. Low-resistivity anomalies (<1Ωm) persisted at depths of 80-160 km, indicating the sustained presence of partial melt after the cessation of spreading. The research further highlighted the magmatic transformation of the lithosphere-asthenosphere boundary during cooling, estimating a melt content of 1-12%. Gao et al.'s study provides valuable insights into the electrical structure beneath ceased mid-ocean ridges, contributing to our understanding of their post-spreading evolution.

Li et al. employed seismic tomography to analyze the velocity structure of the upper mantle in the Southernmost Mariana subduction zone, with a focus on data obtained during a six-month experiment utilizing 11 ocean bottom seismometers. The subducting slab exhibited elevated P- and S-wave velocities, approximately 2-6% higher than those of the normal mantle, along with a lower Vp/Vs ratio and an average dip of 45° at depths ranging from 50 to 100 km. The velocity images provided novel insights into anomalies within the mantle wedge above the subducting slab, revealing areas with slower velocities and suggesting the potential presence of mantle serpentinization and water in the outer forearc. Notably, a melt production region beneath the central forearc block at depths of 40–60 km indicated possible melting processes occurring in this specific area. Li et al.'s study contributes valuable information to our understanding of the complex dynamics in the Southernmost Mariana subduction zone.

Liu et al. investigated a large-scale Quaternary submarine fan in the northern South China Sea, employing recently acquired comprehensive 3D seismic and well data. The study revealed that this sand-rich fan displays a distinctive tongue-shaped configuration with a SW-NE flow direction. Notably, the fan's maximum dimensions were observed to be 140 km in length and 35 km in width. The research findings suggest that the formation and development of the submarine fan are predominantly influenced by sea-level fluctuations, constrained geomorphology, and sediment supply dynamics. This study contributes valuable insights into the processes governing deep-water sedimentation and carries implications for the exploration of shallow gas reservoirs in the South China Sea. The unique characteristics of the fan, as identified by Liu et al., provide a deeper understanding of the complex interplay between geological factors shaping submarine landscapes in this region.

Liu et al. examined the influence of the early Miocene transgression on the evolutionary dynamics of sedimentary systems in the South China Sea. Their investigation revealed that the regional sea level experienced a sustained rise of at least 100 m during the early Miocene. As a consequence of this marine transgression, there was a noteworthy transformation in the nature of depositional systems, transitioning sequentially from tidal flats to meandering river deltas and eventually to shallow marine shelf systems. The study delineates the intricate transitional processes inherent in depositional systems during prolonged marine transgression events. The insights gained from this research hold significance not only for understanding the local sedimentary evolution in the South China Sea but also for contributing to the broader knowledge of how marginal sea basins globally undergo complex transformations during extended transgressive phases.

Ren et al. investigated the influence of gas migration pathways on gas hydrate accumulation in the Shenhu Area, a crucial region in global gas hydrate research. Employing contemporary core-log-seismic data and gas geochemical analyses, the study identified diverse gas migration mechanisms and their roles in hydrate formation. This involved the integration of geological models incorporating faults and gas chimneys. The research underscored the prevalence of thermogenic gas and identified deep faults as the primary conduits for this particular gas type. Based on these findings, Ren et al. proposed a three-gas combined production model, targeting both deep and shallow gas reservoirs alongside gas hydrates. The study contributes valuable insights into the understanding of gas hydrate accumulation dynamics in a key global research area.

Wang et al. conducted a study on the geoacoustic properties of seafloor sediments in the East China Sea using an *in-situ* acoustic measurement technique. The research revealed a robust curvilinear correlation between *in situ* sound speed and attenuation with physical properties, including wet bulk density, porosity, and mean grain size. Leveraging these correlations, the authors derived empirical regression relationships that link *in situ* acoustic properties to the physical properties of the sediments. This study not only supplements *in situ* measurement data but also extends the predictive methods for understanding the acoustic properties of seafloor sediments. These findings contribute to advancing our knowledge of the intricate relationships between physical and acoustic properties in seafloor sediments, offering a valuable resource for future research in this field.

Laboratory test

Guo et al. explored inversion methods using data collected from three-dimensional sediment traps. Through the integration of corrected capture efficiency, sample inversion, and transport flux analysis, they developed analytical techniques capable of accurately inverting sediment transport processes. Validation of this method was achieved through an annular flume test, measuring turbidity, pressure, and particle size of the water stream. Additionally, the successful application of the analytical method was demonstrated in a slice experiment, establishing a relationship between particle size and the concentration of captured samples. This study offers a valuable approach to streamline the high-resolution 3D time series of sediment transport processes. Such refined methods hold promise for investigating the evolution of the sea, ecological cycles, and marine engineering applications.

Wu et al. focused on the offshore wind farm industry's growth, using the Shaba wind farm in southern China as a case study. The investigation employed *in-situ* cone penetrometer (CPTu) tests and borehole sampling to analyze the cyclic resistance of marine clay for offshore foundation design. Despite complex soil conditions with multiple layers, the study compared classification and mechanical properties through CPTu interpretation and laboratory tests, revealing that a single physical indicator is insufficient for determining cyclic resistance in marine clay. The conventional method in existing literature was found unsuitable, leading to the development of a new evaluation method based on a linear relationship between cyclic resistance and depth-corrected CPTu index. The research could potentially provide reliable guidance for the rapid expansion of offshore wind farms.

Xiao et al. investigated the cyclic threshold shear strain properties (γ_{tp} and γ_{td}) of saturated marine clay in the Yangtze estuary through strain-controlled multistage undrained cyclic triaxial tests, varying the plasticity index (I_p). They found that both γ_{tp} and γ_{td} increase with higher I_p, where γ_{tp} consistently exceeds γ_{td}. Notably, they drew conclusions that stiffness degradation in marine clay may not necessarily coincide with pore water pressure generation, but the two phenomena can mutually influence each other. Moreover, they compared terrestrial soils and marine clays from other regions and suggested that the unique sedimentary conditions in the Yangtze estuary result in smaller γ_{tp} and γ_{td} values, attributed to the combined effects of the marine sedimentary environment and the flow-tidal wave system.

You et al. focused on the variation in sediment sources in the South China Sea, examining it through the analysis of Rare Earth Elements (REEs), Sr isotopes (87Sr/86Sr), and Nd isotopes (ƐNd) in detritus fractions of MD05-2901 sediments in the northwestern South China Sea. The primary contribution of the study lies in the conclusion that MD05-2901 sediments sensitively record changes in weathering intensity on land and transport pathways in the coastal regions during the Holocene. The authors clarified the effects of different rivers on the northwestern South China Sea based on the values of 87Sr/86Sr and ƐNd in the Fe-Mn oxy-hydroxides, which is crucial for a better understanding of the primary sources of terrigenous material and their temporal variations in the region.

Numerical simulation

Fan et al. discussed the feasibility of the submerged floating tunnel with polygonal cross-sections from a point of submarine slide hazards, using the computational fluid dynamics method. It was found that the impact load of submarine slide mass was affected by the thickness and velocity of slide mass movement. Compared with the submerged floating tunnels with circle cross-sections, the polygonal form with fewer edges shows a greater impact load. On this basis, a simplified evaluation approach for the tunnel with polygonal cross-sections was proposed to determine the impact load, which provides a useful reference for the future design of submerged floating tunnels.

Lu et al. proposed a fully coupled Computational Fluid Dynamics (CFD) and Discrete Element Method (DEM) model, which enabled them to quantitatively investigate the particle-scale dynamics of turbidity current propagation over different bedforms. They found that the obstacle placed on the flatbed is capable of clearly diminishing the inter-particle collisions and the particle kinetic energy, weakening the particle-fluid interactions, and further making more sediment particles settle in front of the obstacle. The increase in obstacle height caused diverse flow morphologies, and intensified the impacts of obstacle on the particle dynamics of turbidity currents. Their study has the potential to provide valuable insights into understanding turbidite-related geological phenomena from the point of view of particulate flow.

In-situ observation

Wu et al. conducted in-situ tripod observations of the sediment ridge within a contourite drift in the northern South China Sea, aiming to comprehend the primary dynamic processes influencing sedimentation on such drifts. The researchers documented two recurring events of heightened suspended sediment concentration (SSC): one involving near-bottom high SSC events occurring solely within 15 meters above the seafloor, and the other encompassing full-depth high SSC events that span the entire water column. The mechanisms driving these identical SSC events were examined through tidal current measurements. The study revealed that full-depth high SSC events occur when local shear variance is low, supporting the conclusion that sediment transport via northwestward diurnal tidal currents predominates in locally resuspending sediment at the ridge. Additionally, by comparing SSC, instantaneous velocities, bed shear stresses, and turbulent kinetic energy, the researchers identified tidal currents and internal waves as critical factors influencing sediment resuspension. This *in-situ* measurement provides high-resolution, deep-ocean, reliable velocity, and sediment datasets, which can aid in investigating sedimentation processes in contourite drifts. Furthermore, it underscores the significance of diurnal tidal currents as the primary dynamic force regulating the sedimentary processes of contourite drifts.

Artificial intelligence

Du et al. advanced the field of geohazard prediction by applying recurrent neural network (RNN) models to forecast wave-induced pore pressure in submarine sediments, a key factor in assessing seabed stability. Their study compares three RNN models—standard RNN, LSTM, and GRU—and demonstrates that each model accurately predicts pore pressure under varying oceanic conditions. The GRU model, in particular, shows exceptional accuracy with an absolute error of less than 2 kPa. This research not only enhances our understanding of seabed dynamics but also lays the groundwork for developing more effective early warning systems against wave-induced liquefaction. Their integration of RNN models with *in-situ* monitoring data marks a significant step forward in geological time series analysis, offering a new tool for disaster prevention in marine environments.

Integrated approach

Wang et al. presented a detailed assessment of risk zones related to submarine geological hazards in the Chengdao area of the Yellow River subaqueous delta based on the analytical hierarchy process (AHP). The system of assessment index for risk zonation was established with four aspects of the hydrodynamic condition, engineering geological environment, disaster geological conditions and human engineering activities. Eight geological hazard evaluation factors were selected and the distribution characteristics of each evaluation factor were discussed in detail by combining qualitative analysis and quantitative calculation. The results show that the areas with a high geological hazard risk in this region are mainly distributed in the areas with water depths of 9–12 m, where the hydrodynamic effect is strong, with many human engineering activities, and seriously suffered from geologic hazards. The study results can provide a scientific basis for engineering construction and hazard prevention in the Chengdao area.

Zhou et al. investigated sediment transport trends and influencing factors in typical coastal bedrock island sea areas, utilizing high-precision bathymetric surveys, high-density sediment sampling, grain-size trend analysis, and hydrodynamic numerical modeling. The study identified near-bottom flow velocity as the primary factor controlling the general patterns of sediment transport trends. Additionally, submarine topography was observed to transport sediments down its slope and influence sediment transport direction by constraining near-bottom flow. The presence of aquaculture-related organic matter, scallop fragments, and artificial facilities was found to increase sedimentation rates, induce sediment coarsening, and impede sediment transport. These findings provide valuable insights into the modern sediment dynamics in small-scale coastal bedrock island sea areas, shedding light on the intricate interplay between hydrodynamics, topography, and anthropogenic influences on sediment transport in these environments.

Author contributions

XG: Writing – review & editing. FH: Writing – review & editing. YL: Writing – review & editing. NW: Writing – review & editing. CZ: Writing – review & editing. NZ: Writing – review & editing.

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Conflict of interest

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