

Inquiry into the Organizational Logic and Thinking Cultivation Mode of Geophysical Practice Teaching in Liujiang Basin

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Abstract: Field practice is a crucial component in the talent cultivation of geophysics and exploration technology and engineering, serving the dual purposes of bridging theory with practice and fostering engineering thinking and geological intuition. Using the Liujiang Basin in Qinhuangdao as a practical platform, this paper explores and implements a structured, progressive teaching approach for gravity and magnetic exploration. The six-week internship is organized into two stages: three weeks of field perception and data acquisition, followed by three weeks of indoor digital processing and model reconstruction. This approach shifts the teaching focus from simple instrument operation training to the analysis of physical fields, 3D inversion interpretation, and geological modeling. By introducing professional software platforms such as Oasis montaj, and UBC-GIF, students have deepened their understanding of gravity and magnetic anomaly characteristics and significantly improved their ability to analyze complex subsurface geological structures using geophysical information. Data from recent internships indicate that students have shown marked improvement in both the initiative for data processing and the completeness of geological interpretation, demonstrating the effectiveness of this progressive approach in practical teaching.

Keywords: Gravity and Magnetic Exploration; Practical Teaching; Teaching reform

1. Organizational Logic of Internship

Geophysical practical teaching is highly systematic and continuous; relying solely on short-term field operations is insufficient to form a comprehensive professional understanding. Integrating the geological conditions of the Liujiang Basin teaching base with professional training objectives, this internship program is divided into two closely linked stages, enabling students to achieve a progressive enhancement of capabilities—from field perception to theoretical analysis, and finally to model interpretation^[1].

1.1. Hierarchical Design and Goal Setting of the Internship

(1) Field Perception and Multi-dimensional Data Acquisition Phase (Weeks 1–3)

The primary objective of this phase is to establish students' initial understanding of the relationship between geological spatial structures and physical field distributions^[2-4]. In the complex mountainous terrain of the Liujiang Basin, students utilize high-precision gravimeters and magnetometers to conduct standardized observations, acquiring raw data that reflects differences in subsurface density (ρ) and magnetic susceptibility (κ).

Through hands-on operation, students gain an intuitive grasp of the non-uniform spatial distribution of geophysical fields and understand the fundamental correspondence between geological bodies and gravity/magnetic anomalies. Simultaneously, completing tasks such as survey line layout, instrument operation, data recording, and quality control in the field helps foster field adaptability, teamwork awareness, and a consciousness for raw data quality control.

(2) Digital Reconstruction and Physical Mechanism Enhancement Phase (Weeks 4–6)

Indoor teaching focuses on using platforms such as Oasis montaj and UBC-GIF to perform pre-

processing, potential field correction, inversion calculation, and comprehensive interpretation of the data collected earlier. Through a complete data processing workflow, students gradually transition from perceiving "observed data" to constructing "geological models."

In practice, students often tend to view data processing as merely "clicking buttons following a checklist." Therefore, we emphasize the physical principles behind each correction step, guiding students to establish a systematic geological-geophysical integrated analytical mindset and achieve a transition from perceptual knowledge to rational judgment^[5].

1.2. Construction Mechanism of Collaborative Learning Communities

The internship employs a "project team" management model. Each group consists of 5–6 students, implementing a rotation system for roles such as observation, verification, navigation, recording, and quality control. This role rotation allows students to fully comprehend the complete workflow of gravity and magnetic exploration, preventing a limited understanding confined to a single post.

After daily field work, each group conducts a centralized review centered on issues such as closure errors, repeat observation errors, and anomaly identification, analyzing the sources of error and discussing improvement measures. This continuous feedback mechanism helps students gradually form rigorous data quality awareness and scientific attitudes while enhancing their collaborative and problem-solving abilities in complex engineering environments.

2. Field Guidance and Practice Planning Driven by Physical Mechanisms

The core of the field teaching stage is not merely completing data acquisition tasks, but helping students connect classroom potential field theory with real-world geological phenomena, transforming abstract physical formulas into spatial understandings of stratigraphic structures and regional tectonic frameworks.

2.1. Understanding Geological Background and Designing Exploration Schemes

First, students are organized to inspect typical geological sections, such as the Ordovician limestone section in Liangjiashan. Through field observation of the lithological characteristics of different strata, students analyze density and magnetic susceptibility differences. Teachers employ heuristic teaching to guide students in thinking about the gravity and magnetic anomaly characteristics that different strata might produce, establishing the correspondence between physical property parameters and geological bodies.

On this basis, students are guided to lay out survey lines according to the principle of "prioritizing the direction perpendicular to the tectonic strike." Students are required to independently complete an "Outdoor Data Acquisition Plan," including gravity base station tie-in path design, magnetic diurnal variation station layout, and observation point density selection, thereby cultivating preliminary engineering design and plan argumentation capabilities.

2.2. Standardized Observation and Spatial Field Perception

Gravity and magnetic measurements are conducted across the entire area, with a focus on training students to master instrument usage standards, observation workflows, and precision control methods. Repeated observations, base station checks, and field recording ensure that data quality meets the requirements for subsequent processing.

When survey lines cross intrusive dikes, fault zones, or stratigraphic contact zones, teachers combine real-time observation data to guide students in analyzing the causes of anomaly variations. For example, obvious fluctuations in magnetometer readings often reflect the presence of subsurface magnetic bodies, enabling students to form preliminary anomaly recognition capabilities in the field.

2.3. Quality Evaluation and Dynamic Correction

Students must independently perform base station checks, error analysis, and data quality evaluation. For gravity, the focus is on zero-drift correction, tidal correction, and instrument stability checks; for magnetic surveys, the emphasis is on the continuity of diurnal variation curves and anomaly disturbance

analysis. For discovered anomalous points or "jump" points, students are encouraged to conduct on-site re-measurement and cause investigation, which helps them deeply realize that the authenticity of raw data is the cornerstone of all subsequent interpretation work, thus cultivating a rigorous scientific attitude and the awareness of problem-tracking.

In the field, we often observed that students tend to fall into the mechanical operation trap of "collecting data for the sake of collection." To address this, we linked internship tasks closely with real geological structure identification, mandating that students analyze the geological background before laying out survey lines. This significantly corrected the tendency to "emphasize data while neglecting geology" and has become one of the most significant pedagogical findings of this teaching reform.

3. Digital Reconstruction Based on Oasis montaj and UBC-GIF

The indoor data processing phase is a vital link for integrating field results and theoretical enhancement, and it is also the phase where students' practical capabilities improve most significantly. The core goal is to cultivate students' abilities in judgment, analysis, and comprehensive interpretation within complex data streams.

3.1. Physical Understanding of Data Pre-processing and Potential Field Correction

The teaching focus is not on mechanically completing software workflows, but on helping students understand the physical meaning behind each correction parameter.

(1) Gravity Data Correction and Anomaly Extraction

Using the Gravity module of Oasis montaj, students perform drift correction, tide correction, latitude correction, Bouguer correction, and terrain correction on gravity observation data. The focus is on comparing the applicability of different terrain correction methods (such as flat-plate approximation vs. 3D terrain correction) in complex terrain areas and analyzing their impact on the accuracy of Bouguer gravity anomaly maps.

Especially in the areas of the Liujiang Basin with significant terrain relief, the focus is on discussing the important role of terrain correction in identifying weak structural anomalies and the control effects of selecting different density parameters on the features of anomaly maps.

(2) Magnetic Field Component Separation and Multi-scale Analysis

Regarding regional magnetic field characteristics, the MagMap module is utilized to perform Reduction to Pole (RTP) processing to weaken the impact of oblique magnetization on anomaly position judgment. Power Spectrum analysis is combined to estimate the depth of main field sources, and methods such as upward continuation and band-pass filtering are used to separate shallow high-frequency anomalies from deep background fields. Through multi-scale field separation, students understand the control relationship of geological bodies at different depths on magnetic anomalies, enhancing their understanding of regional tectonic patterns.

3.2. 3D Physical Property Inversion and Parameter Optimization Based on UBC-GIF

The UBC-GIF 3D inversion module is a key enhancement component of this teaching mode, aiming to help students understand the non-uniqueness of geophysical inversion problems and the importance of constraints.

(1) Grid Discretization and Spatial Model Construction

Based on the survey area scope, sampling interval, and burial depth of target geological bodies, the core inversion area and peripheral buffer zones are set reasonably. By analyzing the impact of grid size on computational efficiency and model resolution, students understand that inversion results are not necessarily better with finer grids, but require a balance between accuracy and stability.

(2) Objective Function Constraints and Prior Information Introduction

In inversion parameter settings, noise levels and error tolerances are set reasonably based on field data quality evaluation results. Drill hole data, surface outcrop information, and rock physical property parameters are introduced as a Reference Model to improve the geological rationality of the inversion results. By comparing changes in model residuals (RMS) and stability with and without geological

constraints, students understand the critical role of prior information in geophysical interpretation.

(3) Iterative Convergence Monitoring and Parameter Tuning

During the inversion process, students are guided to observe the fitting error curve and the model variation process in real-time, understanding the balance between data fitting terms and model smoothing terms. There is often no single answer to parameter adjustment; students need to judge which result is more consistent with actual geological conditions through continuous trial and error, which is the core part of inversion training.

It is worth mentioning that, regarding common issues like result divergence and high errors in UBC-GIF inversion, we do not directly provide optimal parameters. Instead, we guide students to construct a Reference Model. This training mode, which "forces" students to backtrack to borehole and outcrop information, greatly promotes the establishment of students' geological-geophysical coupling thinking^[6].

3.3. 3D Comprehensive Interpretation and Model Validation

(1) 3D Physical Property Slice Analysis

Using 3D visualization tools, students conduct comprehensive analyses of the density and magnetic susceptibility models obtained from inversion, including horizontal slices, vertical profiles, and arbitrary direction profiles. By observing the spatial morphology of anomalous bodies as they change with depth, students establish a three-dimensional understanding of subsurface geological bodies.

(2) Multi-source Information Comprehensive Validation

The 3D inversion results are spatially superimposed with field geological boundaries, rock bedding attitudes, and known geological data, with a focus on verifying whether high gravity anomaly areas correspond to the extension of high-density strata, and whether magnetic anomaly areas reflect deep hidden magmatic activity.

Through the closed-loop process of "field observation—model inversion—geological validation," students gradually form a complete geophysical thinking mode, transitioning from perceptual knowledge to quantitative interpretation.

4. Teaching Effectiveness Evaluation and Core Quality Cultivation

Through the introduction of professional software platforms such as Geosoft and UBC-GIF, teaching evaluation is no longer based solely on the completion of achievement maps, but pays more attention to students' improvement in analytical ability, practical skills, and comprehensive literacy.

4.1. Enhancement of Geological Interpretation Ability

In past teaching, some students were often more concerned with whether the maps were complete, ignoring the geological significance behind the anomalies. After training in 3D inversion and comprehensive interpretation, students can proactively combine physical property distributions to analyze subsurface structural characteristics. They are no longer limited to plotting planar contour maps but have gradually acquired the ability to interpret complex geological problems using geophysical anomalies.

4.2. Formation of Engineering Thinking and Scientific Norms

During parameter setting and model optimization, students need to continuously adjust grid sizes, constraints, and noise levels. This process is often accompanied by repeated trial and error, making them gradually realize the importance of data quality and processing norms. Compared to simply completing software operations, many students only truly realized after their first inversion failure that the most important thing in engineering practice is often not "calculating it," but "why it is calculated this way."

4.3. Effective Integration of Theoretical Knowledge and Practical Capability

Many students found potential field theory abstract in classroom learning. However, during the digital reconstruction process, by participating in parameter setting and model interpretation, they can more intuitively understand the specific applications of theoretical formulas in engineering. Such training helps

complete the cognitive process from theoretical formulas to numerical models, and then to geological interpretation, narrowing the gap between classroom teaching and engineering practice.

5. Conclusion and Outlook

The progressive teaching approach for gravity and magnetic exploration in the Liujiang Basin demonstrates that reasonable teaching organization and support from professional software platforms have significant practical significance for improving the quality of geophysical practice teaching at the undergraduate level. By combining field data acquisition with indoor 3D inversion analysis, it not only enriches the content of practical teaching but also enables students to complete systematic training in a relatively realistic scientific research environment.

In the future, the teaching system can further introduce multi-parameter joint constraint inversion methods for gravity, magnetic, and electrical data, gradually perfecting the comprehensive interpretation system for subsurface multi-physical fields, and continuously improving students' comprehensive analytical ability and practical innovation capability in complex geological conditions^[7].

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