Exploring Key Areas in Research and Development of Geological Survey Technology in the Modern Era

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Abstract. The research and development of geological survey technology in the modern era encompasses crucial domains, including unmanned aerial vehicles (UAVs) and remote sensing technology, geophysical exploration techniques, remote sensing geochemical technology, digital geological survey methods, high-performance computing, data processing technology, and geological survey instruments and equipment. These areas of focus provide significant tools and support for geological surveys, aiding in the identification of geological features, mineral resources, and environmental changes. Moreover, they contribute to enhancing the efficiency, accuracy, and capabilities of geological surveys, providing scientific support for resource exploration and environmental management.

Keywords: Geological survey; Technological advancement; Development strategy; Comprehensive research.

1 Introduction

The research and development of geological survey technology encompass several key areas, including unmanned aerial vehicles (UAVs) and remote sensing technology, geophysical exploration techniques, remote sensing geochemical technology, digital geological survey technology, high-performance computing and data processing technology, as well as geological survey instruments and equipment. These areas of research and application provide crucial means and support for geological surveys [1-2]. UAVs and remote sensing technology enable the acquisition of high-resolution surface imagery and terrain data, aiding in the identification of geological features and mineral resources. Geophysical exploration techniques, utilizing gravity, magnetic, and electromagnetic methods, offer valuable insights into underground geological information, thereby supporting mineral exploration and resource assessment. Remote sensing geochemical technology combines remote sensing and geochemical methods to remotely gather information on the distribution of surface chemical elements, facilitating the inference of potential mineral resource deposits [3-6]. Digital geological survey technology utilizes computer and information technology to process, analyze, and simulate geological data, thereby enhancing survey efficiency and accuracy. High-performance computing and data processing technology expedite data processing speed and improve

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the precision of simulation computations [7-12]. The research and development of geological survey instruments and equipment enhance survey capabilities and standards [13-15]. Advancements in these key areas drive the progress and development of geological survey technology, providing scientific support for resource exploration and environmental management [13-17].

2 Unmanned Aerial Vehicles (UAVs) and Remote Sensing Technology

UAVs and remote sensing technology play a crucial role in geological surveys. Firstly, UAVs equipped with high-resolution cameras or sensors capture detailed surface imagery. These images provide rich information for identifying and analyzing geological features, such as terrain characteristics, fault lines, and changes in landforms. Moreover, UAVs' flexibility and maneuverability enable access to complex or inaccessible areas, ensuring comprehensive and detailed data acquisition for geological investigations.

Secondly, remote sensing technology allows for the retrieval of both surface and subsurface terrain data. Satellite and airborne remote sensing techniques provide high-resolution data on terrain, including Digital Elevation Models (DEMs) and topographic maps. These datasets are valuable for generating accurate topographic maps, geological profiles, and three-dimensional geological models, facilitating a better understanding of geological structures and tectonic characteristics. Additionally, remote sensing technology enables the detection of important geological information, such as groundwater hydrology, rock distribution, and underground resources.

In addition to surface imagery and terrain data, UAVs and remote sensing technology assist in identifying mineral resources and monitoring environmental changes. Multispectral and hyperspectral remote sensing techniques extract spectral information from the surface and vegetation, enabling the inference of geological element and mineral distributions. This aids in identifying potential mineral resources and mineralized zones. Furthermore, remote sensing technology supports the monitoring of environmental changes, including land use alterations, water pollution, and vegetation coverage, contributing to environmental protection and ecological monitoring efforts.

3 Geophysical Exploration Techniques

First and foremost, gravity measurement is a technique used to study the distribution of subsurface materials by measuring changes in the Earth's gravity field. By employing gravity instruments to measure gravity values at various locations, it becomes possible to infer variations in subsurface density, thereby providing insights into geological features such as rock types, structural characteristics, and sedimentary basins. Gravity measurement techniques find widespread applications in mineral exploration, including the exploration of oil, gas, and geothermal resources.

Moreover, magnetic measurement is a method employed to investigate the distribution of subsurface materials by analyzing fluctuations in the Earth's magnetic field. By measuring the intensity and direction of the magnetic field at the surface using magnetic instruments, it becomes possible to identify magnetic substances beneath the Earth's surface, such as magnetite, magnetic rocks, and mineral deposits. Magnetic measurement techniques hold significant importance in mineral exploration, petrology research, and environmental surveys.

Furthermore, electromagnetic (EM) exploration is a technology utilized to study subsurface structures and mineral resources by measuring the electromagnetic response of the Earth. This technique capitalizes on the variances in electrical conductivity and magnetic permeability of subsurface rocks and minerals. By generating and detecting electromagnetic signals, EM exploration enables the identification of subsurface electromagnetic responses. EM exploration techniques find extensive applications in mineral exploration, hydrogeological surveys, and environmental monitoring endeavors.

4 Remote Sensing Geochemical Techniques

Remote sensing geochemical techniques utilize remote sensing technology to acquire surface reflection and radiation information, combined with geochemical methods to analyze the chemical content and composition of the Earth's surface. Remote sensing data can be obtained through aerial or satellite remote sensing, covering vast surface areas and providing multispectral data with high spatial resolution. By interpreting and analyzing remote sensing data, information on surface chemical elements, such as metallic elements and organic substances, can be obtained.

Remote sensing geochemical techniques have broad applications in geological surveys. Firstly, by analyzing the distribution characteristics of surface chemical elements, it is possible to infer the potential distribution of mineral resources. The relationship between different types of mineral deposits and surface chemical elements has been extensively studied, thus remote sensing geochemical techniques can be employed to identify potential mineral resource areas. Secondly, remote sensing geochemical techniques can be utilized for environmental monitoring, such as detecting the pollution levels and chemical composition of surface water and soil, providing references for environmental protection and resource management. Additionally, this technique can be applied in land-use planning, agricultural production, and ecosystem monitoring, among other fields.

5 Digital Geological Survey Techniques

Digital geological survey techniques encompass various key domains, including Geographic Information Systems (GIS), geological modeling, and data mining. GIS serves as a foundational component, integrating and managing large volumes of geological data for storage, querying, visualization, and analysis. It facilitates efficient data organization, retrieval, and collaborative work, forming a reliable basis for geological surveys.

Geological modeling techniques are vital in digital geological surveys. Through mathematical modeling and simulation of geological objects, these techniques enable the prediction and simulation of geological processes and phenomena. They aid in understanding the formation mechanisms of geological phenomena, inferring geological structures and evolution, and providing theoretical foundations and predictive modeling tools for geological surveys.

Data mining techniques play a pivotal role in digital geological surveys, uncovering valuable insights by analyzing patterns, correlations, and trends within extensive geological datasets. They assist in identifying regularities and anomalies, providing data-driven decision support and optimizing survey methodologies and strategies.

The development and application of digital geological survey techniques contribute to enhanced efficiency and accuracy. By reducing manual operations and data processing time, these techniques yield more comprehensive, accurate, and intuitive results. Furthermore, they introduce new research methods and tools, driving the advancement and innovation of geological science.

6 High-Performance Computing and Data Processing:

High-performance computing technology utilizes large-scale computational resources and parallel computing methods to accelerate the processing speed of geological data and enhance the efficiency of simulation computations. By leveraging high-performance computing platforms, efficient storage, access, and processing of massive geological datasets can be achieved, enabling effective management and analysis of voluminous data. Additionally, high-performance computing technology supports complex geological simulations and numerical modeling, yielding more precise geological predictions and simulation results.

Data processing techniques play a pivotal role in geological investigations. Geological data encompass diverse types and formats, including geophysical data, geological geochemical data, and remote sensing data. Through the application of data processing algorithms and methodologies, these data can be cleansed, integrated, interpreted, and analyzed to extract valuable information and insights. Data processing techniques encompass various approaches such as data visualization, data mining, and machine learning, which aid in uncovering hidden patterns and correlations within geological data, thereby assisting in addressing challenges and resolving issues encountered in geological investigations.

The integration of high-performance computing and data processing techniques in the research and development of geological surveys contributes to improved efficiency, accuracy, and reliability of geological investigations. By optimizing computational algorithms and harnessing parallel computing resources, the processing speed of geological data and the execution efficiency of simulation computations can be accelerated. Furthermore, the application of data processing techniques enables in-depth analysis and comprehensive understanding of geological data, offering robust information support for geological surveys.

7 Geological Survey Instruments and Equipment

Geological exploration drilling rigs are crucial equipment for conducting underground surveys and obtaining samples. They are used to drill through the Earth's crust, rocks, and soil layers, allowing access to underground structures and collecting rock samples. The development of advanced, efficient, and precise geological exploration drilling rigs can significantly enhance drilling efficiency and accuracy, enabling the acquisition of more comprehensive and reliable geological information.

Geophysical instruments serve as indispensable tools in geological surveys, allowing for the measurement of various physical field parameters underground, including gravity, magnetic fields, and electromagnetic fields. The ongoing development of geophysical instruments aims to improve measurement accuracy and resolution, facilitating the acquisition of more precise information about underground geological structures and mineral resources.

Chemical analysis instruments are utilized in geological surveys to analyze the chemical composition and elemental content of geological samples. The advancement of sophisticated, highly sensitive, and accurate chemical analysis instruments can greatly enhance analysis efficiency and accuracy, thereby providing more detailed and dependable chemical information to support geological surveys.

8 Conclusion

The research and development of geological survey technologies have made significant progress in key areas such as unmanned aerial vehicles and remote sensing, geophysical exploration, remote sensing geochemistry, digital geological surveys, high-performance computing and data processing, and geological survey instruments and equipment. These advancements have provided new opportunities and challenges for geological surveys. Unmanned aerial vehicles and remote sensing technology play a pivotal role by providing high-resolution surface imagery and terrain data, facilitating the identification of geological features, mineral resources, and environmental changes. Geophysical exploration techniques offer non-invasive methods for studying underground geological structures and mineral resources, furnishing essential information for mineral exploration, resource assessment, and environmental monitoring. Remote sensing geochemical techniques enable non-invasive remote observation and estimation of potential mineral resource distributions. However, digital geological survey techniques face challenges related to data quality and model accuracy, necessitating further research and development. High-performance computing and data processing technologies encounter challenges concerning data security and quality control, requiring intensified research efforts to enhance their application capabilities. The continuous innovation of geological survey instruments and equipment is crucial for improving performance and reliability. These advancements in key areas have introduced new methods and tools for geological surveys, elevating their efficiency, accuracy, and providing scientific support for resource exploration, environmental management, and sustainable development. Future research should continue to explore innovative applications and technological breakthroughs in these areas to propel the continual development and progress of geological survey technology.

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