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Development and Application of Geological Survey Information Technology in CGS

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Abstract

Geological informatization has undergone three development periods, namely digitization period, networking period, and intelligence (big data) period. The paper reviewed the role China Geological Survey (CGS) has played in the course and summarized major contributions over the past two decades. For fully utilizing the massive geodata for better supporting social and economic development, CGS conducted research and development of geo-information technologies, such as various software tools by adopting the current popular GIS, database and computer technologies, the upgraded Digital Geological Survey System (DGSS) based on cloud computing, big data and AI application, the national geodatabase system, the model and standard system, and the national geological database --GeoCloud 3.0. CGS also participated in several international cooperative programs, e.g. the Deep-time Digital Earth (DDE) and International Geoscience Program (IGCP), which promoted the progress of geoinformation technology in the world at large. In the new era, CGS has to conquer a series of obstacles to ensure secured data management, high level of data integration, guaranteed data quality and intelligent services.

Keywords: Achievements, Application, Big Data, GeoCloud, Geological Informatization

1. Introduction

The rapid development of information technology has given birth to the contemporary technological revolution, transforming and overturning our existing work and life patterns. Geological survey is fundamental and pioneering for social and economic development, which lays solid foundation for energy and resources management and development, natural disaster prevention, environmental protection, infrastructure construction, etc. The integration of geological survey with information technology made by China Geological Survey has undergone some important periods. It gained great momentum since beginning of the 21st century, with fruitful and remarkable achievements (Yongjie, 2007). The article, based on the authors' understanding of and practical experience in geological information construction research, systematically overviews and summarizes the major achievements, and proposes the development direction in the future.

2. Three development periods of geological informatization

The geological informatization process is generally in line with the national informatization process. After the digitization and networking periods, it's entering into the big data era (Hequan, 2013).

2.1 Digitization period. The period, started from the 1960s and ended in 2002 with the invention of field digital collector, features with digital recording and single machine computing. The geological survey applying IT technology in terms of computerization at the early stage, i.e., replacing human with calculator or computer, followed by the set up of various retrospective databases, as well as computer facilitated calculation and statistical analysis. At the late stage it came computer aided drafting (CAD), which gradually developed into compilation of vector maps by using GIS technology, and compilation of geological reports by using computer. In 2002, China Geological Survey successfully developed the field digital collector (Chaoling, 2016), a cornerstone marking the realization of digitization in geological survey. As a result, the related working methods of geological survey have basically achieved the transformation from analog to digital mode.

2.2 Networking period. The period, started from 2002 and ended in 2016 with the implementation of China's geological big data project (Yongjie, 2016; Yongjie, 2018), features with interconnection and sharing based on digitization. It covers data file sharing, email transmission, network office work, network computing and information services. The China Geological Survey, built up in 1999, launched the Digital Land Programme in this period, and proposed the overall framework of geological survey informatization in 2002 based upon advanced computer, network, wireless communication and database technologies.

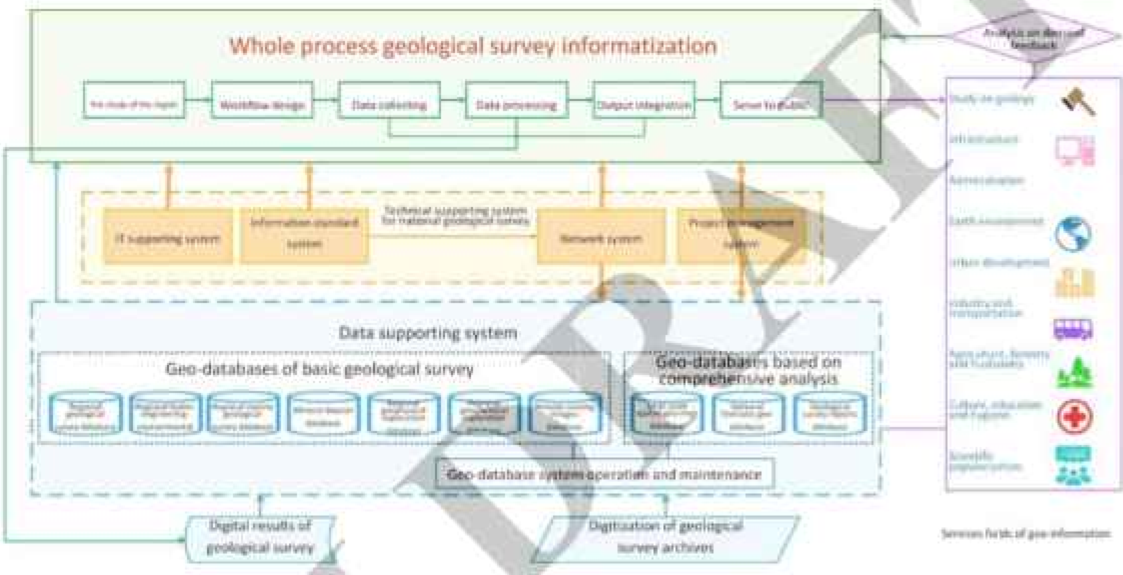

Fig. 1: Architecture of geological survey informatization construction (Jiahuan, 2005)

2.3 Intelligence (big data) period. The period started from 2016, featuring with rapid data clustering, virtual management of information infrastructure, data mining and fusion analysis. With the fast advancing of big data, cloud computing and intelligence, the projects "Geological Big Data Technology Development and Pilot Application" and "Geological Big Data and Information Services" were implemented, resulting in the put forward of systematic geological big data infrastructure (Fig.2) as well as construction ideas, such as to improve the geodata collecting and processing system in a more normative way, to set up the geodata clustering system to be a real time updating system, to form and enrich the geodata and information service system, to promote collaborative services, to build up the "GeoCloud" big data supporting platform, etc.

3. Major achievements

Over the past two decades, CGS has accumulated huge amount of information and geological data. In order to fully utilize these data for better supporting social economic development, CGS conducted around 1,500 projects for informatization with considerable outputs.

3.1 Research and development of various software tools

Geo-database management software: used for management of multi-source heterogeneous data of different scales, in terms of geology, mineral, energy, geophysics, geochemistry, remote sensing, marine, etc. Geological survey data collecting software: used for field data collection in geological mapping, mineral

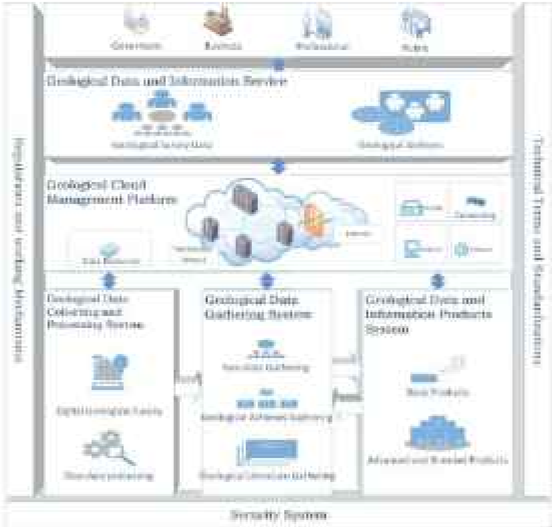

Fig. 2: Architecture of the construction of geological big data system (Yongjie, 2023)

resources exploration, energy resource investigation, ground water inspection and environmental geological survey, etc. Geological 3D modeling software: used for 3D modelling and simulation in geological structure study, mineral exploration, oil and gas basin analysis, marine geology, etc. with gravity, magnetic, electricity and seismic data of geophysical survey (Minghua, 2011), and deep-Earth exploration data and drone data. Simulation and prediction software: used for data processing, data analysis, data mining, data simulation and prediction in the studies related with geophysics, geochemistry, petroleum, natural gas, geological disaster, remote sensing, geothermal, ground stress, etc.

3.2 Development and upgrading of Digital Geological Survey System (DGSS)

The research and pilot test of field data collector can be dated back to late 1990s, and was completed in 2002 with the establishment of point-routing-boundary (PRB) geological mapping data description model. The technology, widely deployed to regional geological survey projects in field data collection, data sorting, data processing, and presentation of result information, basically realized the informatization of geological survey (Chaoling, 2016).

With the improvement of information technology, CGS integrated the existing regional geological survey data collection system, mineral resources investigation and assessment system, digital compass, mineral exploration data collection and reserve calculation functions to develop the Digital Geological Survey System (DGSS).

Nowadays, the big data, cloud computing and wireless communication technologies need to be combined. Through efforts, a push service system for location based geological data and archive was proposed, as well as remote virtual computing, mineral and rock identification system, etc. All these has upgraded the DGSS to be a more intelligent system.

In terms of intelligent geological mapping (Yangchun, 2021), the purpose is to improve the ability of geological object identification, such as tectonics, lithology, lithological combinations, to improve the efficiency and accuracy of field survey, to deepen the level of pre-study and comprehensive study, to enhance the ability to solve key geological issues, and to diversify result presentation to provide optimized services, through combination of vast data, massive knowledge and AI algorithm. As a result, the technical framework driven by "data+knowledge+intelligent algorithm" was set up, which greatly improved the ability of intelligent data collection and the accuracy of geological object recognition.

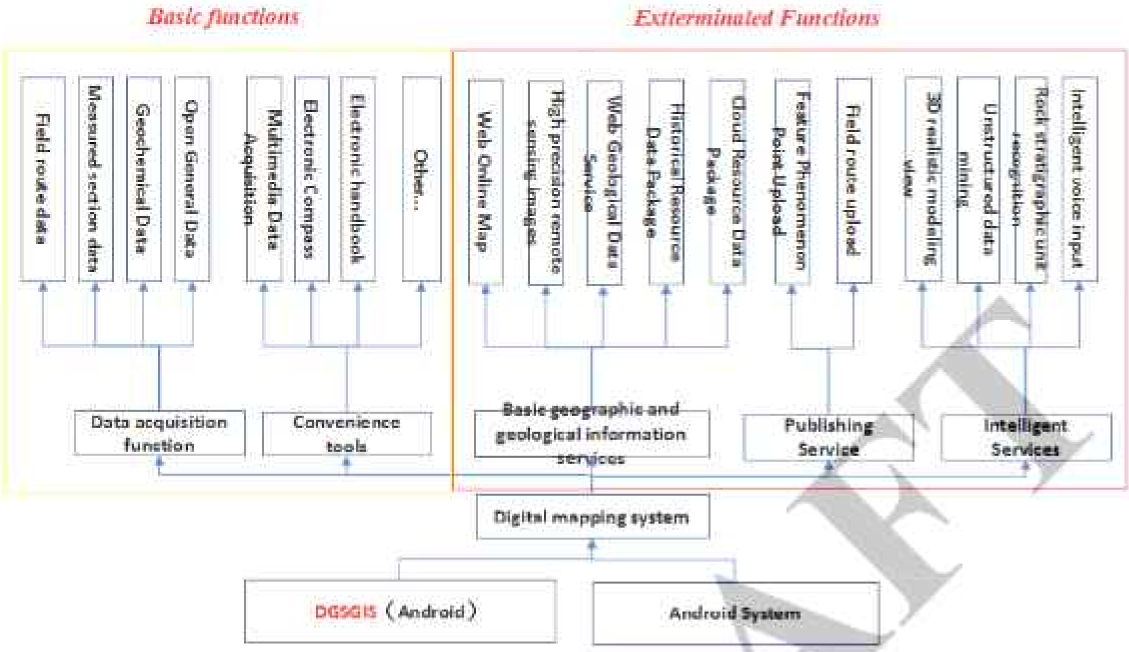

Fig. 3: Digital Geological Survey System for Android

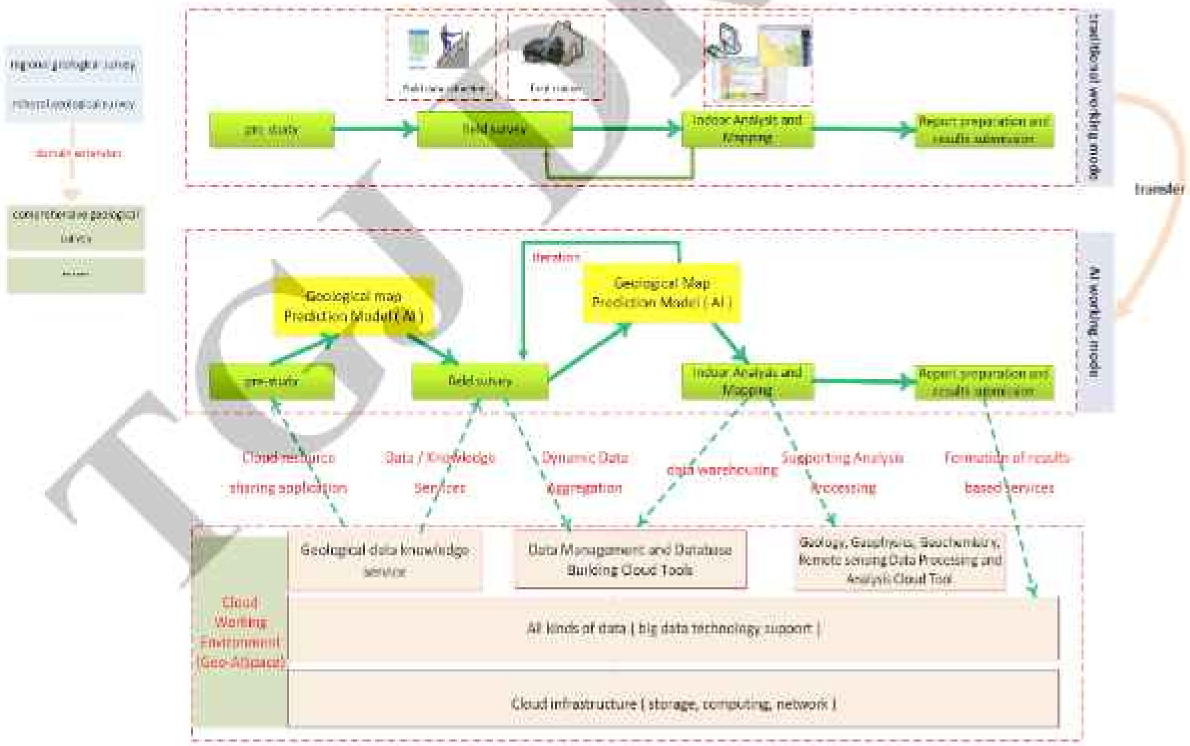

Fig. 4: Technical Framework Driven by Data+Knowledge+Intelligent Algorithm

3.3 Establishment of the national geological database system

CGS has successfully established a system of national geological databases covering various regions at different scales with varied themes, which have been playing fundamental roles in China's geological survey planning, deployment, and mineral resources exploration and utilization, as listed below

Table 1: Major National Thematic Geological Databases

No.	Name of DB	Description of DB	Function
1	Basic Geology Database	lithology and mineral, structure, paleontology and fossils, isotopic dating data, etc.	support CGS deployment of geological survey and scientific research
2	Marine Ecological Database	marine geological data, structural data, landform data, marine mineral resources data and marine geological hazard data	provide basic data for marine geology and ocean environment studies
3	Geophysical Exploration Database	geophysical surveying data of gravity, aeromagnetic, geomagnetic, electricity and seismic	support to regional geological structure studies, mineral assessment and exploration, and energy resources exploration of petroleum and mining industries
4	Geochemical Survey Database	stream sediment samples' analytical data, heavy minerals data and soil, irrigation water and atmospheric deposition samples data	provide data resource and evidences for mineral exploration, ecological environment assessment, soil quality evaluation and endemic disease studies
5	Remote Sensing Database	satellite images and aerial photographs in the past 10 years	provide efficient use in geohazards mitigation, mining environment monitoring, urban geological survey, etc.
6	Drilling Database	important geological drilled holes data, key physical core images and specimens catalogue data	provide solid support to geological exploration and deep earth studies in China
7	Mineral Resources Database	data of ore distribution, resources and reserves, mineral exploitation and utilization, mining activities and geological settings	support exploration and utilization of mineral resources in China
8	Energy Resources Database	spatial distribution data and reserves of major petroliferous basins, oil fields and natural gas fields	provide support to energy resources exploration in China
9	Geological Disaster Survey Database	data of landslide, collapse, debris flow, land collapse, land subsidence, and surface sinks, along with dynamic monitoring data in major geohazard locations	provide strong support for potential hazard identification and post-disaster reconstruction in China

Table 1: Major National Thematic Geological Databases (continued)

No.	Name of DB	Description of DB	Function
10	Hydrogeological Survey and Water Resources Survey Database	data of groundwater and surface water around China, along with spatial data of over 1,000 national 1:200,000 hydrogeological maps	provide support for efficient utilization of water resources in China
11	Ecological Environmental Survey Database	survey data and real-time monitoring data of urban geology, mining environment, ecological rehabilitation, geological heritage, geoparks, etc.	provide data services for decision making in ecological environment protection and geo-tourism
12	Natural Resources Comprehensive Survey Database	survey data of national and provincial forests, grasslands and wetlands	serve for natural resources management and ecological environment assessment in China

These national thematic databases have been put into application, which well meet the demands of relevant national Ministries and local governments, as well as contributing a great deal to lifting people's living standard in the country (Yongjie, 2011). E.g., the National Geological Disaster Database clearly shows the location, potential affection areas, major causes of the development of geohazards in China's 2,020 counties linked with an technologically unified country-province-city-county 4-level monitoring network. By applying AI technology for geohazards identification and prediction, CGS has acquired 9,675 suspecting hazard locations in China, and thus effectively avoided 4,296 risks by early warning and that saved lives of some 146,000 people and avoid direct economic loss about 5 billion RMB, and the value of the database is obviously reflected in serving the livelihood of the residents.

Another example is the Hangzhou Intelligent Urban Database, which provides basic data to Hangzhou's intelligent management in terms of urban planning, transportation, public security, environment protection, and instant information released to the public for prevision and alleviation of natural disasters. It highly improves the capability of instant response to emergencies and hazards. The database helps the local government on efficient management of modern metropolis to benefit the residents for a better live.

Fig.5: Hangzhou Intelligent Urban Management Data

3.4 Establishment of geological data model and standard system

By referring to international standard systems such as ISO, OGC, W3C, etc., and taking into account both basic standards and thematic standards, CGS has built up a full life cycle standard system, which adopts the four-layer architecture of geological information modeling, enables cross-platform interoperability of data models, and guarantees a strong support of standards to the whole--processdata management of geological survey. These include basic standards, data collection standards, basic geological data model standards, data storage standards, data service standards, data management standards, and software R&D standards, etc. The core basic geological data model standards, consisting of basic geographic, geological, mineral, geophysical and geochemical models provide fundamental support to the formation and management of various geological databases.

3.5 Establishment of national geological database - GeoCloud 3.0

China Geological Survey issued and conducted standards for constructing the national geological database - GeoCloud in 2016. The tasks include integration of information infrastructure, web resource, geodata resource, data processing system, management system, application analysis system, service system, etc., and development of database, platform architecture, portal, etc., with advanced cloud computing, big data and AI technology. The project significantly promoted efficient management of national geoscience data and information. With fast development, today's GeoCloud 3.0 is a clustering service system with 75 large nodes linking national and provincial geological surveys and geoscience research institutions. It provides functions as data resource pool management and coordination, data retrieval and downloading, online data processing and analysis, analysis and application

Fig. 6: China National Geological Database - GeoCloud 3.0

of thematic data, project management and quality monitoring, automatic data and knowledge pushing, etc

GeoCloud has been used widely to support the planning and deployment of national geological work (Yongjie, 2019). In particular, GeoCloud 3.0 has been supporting the assessment, exploration and utilization of mineral resources. Based on comprehensive integrated analysis of the geological, geophysical, geochemical, remote sensing, heavy minerals and drill holes data form the National Geological Database, different mineralization and exploration models for the optimization of exploration blocks and targeting areas were developed, which guided the delineations and discoveries of more than 30 strategic minerals, such as copper, gold, and polymetallic metallogenic zones, lithium beryllium, niobium and tantalum prospect zones. It also contributed greatly to the decision-making in natural resources management for minerals utilization and mining industry, along with the distribution data of mining rights and current mines and their productions.

3.6 International cooperation in geo--information

Over the past decade, CGS has actively participated in the database construction and data sharing in international big science programs, such as International Geoscience Program (IGCP), Deep-time Digital Earth (DDE), Resource and Environment Effects of Global Karst Dynamic Systems, Mapping the Chemical Earth, etc. Geoinformation cooperation with more than 60 countries including the US, Germany and UK has been conducted and compilation of global digital geological maps and construction of global magmatic rock database, and CGS data and technology sharing to IGCP, DDE, OneGeology, etc. are being actively carried out.

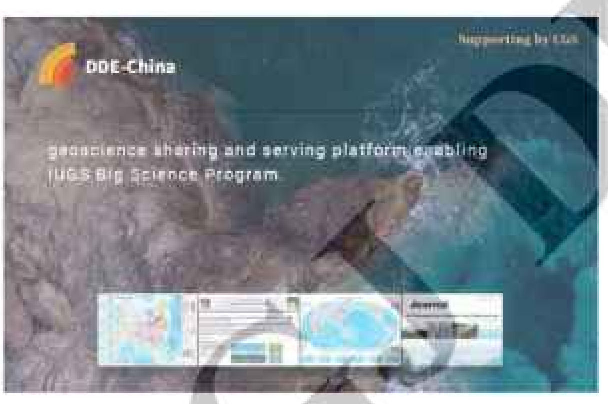

Fig. 7: DDE-China Node

Fig. 8: DDE Standard Task Group Led by CGS

4. Enlightenment for future development

At present, CGS is confronted with lack of data policy for the security management and updating the national geodatabases, lower level of data integration, distributed data center architecture of diverse data formats, etc. Focusing on the new demands of the country's economic and social development, CGS has to further improve the application effect and efficiency with AI and latest technologies to better serve the national geological survey, natural resource management and economic development.

Stresses should be made to deepen the research on improving internationalization, digitization and intelligence of geoscience data models and standards, and on data management software technology for dynamic aggregation and updating of multi-source heterogeneous 2D and 3D spatiotemporal data. Moreover, comprehensive data analysis and simulation should be strengthened to improve the understanding of the earth system. Besides, CGS also needs to push forward the metallogenic belt resource data assessment, the application of cloud computing, big data and AI in intelligent geological survey and mapping, mineral resources prospecting, geohazards identification and early warning, etc.

5. Conclusions

(1) The development of geological informatization led by CGS can be divided into three periods as digitization period, networking period and intelligence (big data) period, each with their own prominent features.

(2) Through consistent efforts for more than two decades, CGS has launched national programs and projects in terms of geological informatization and accumulated rich experience in combining strength from all parts to fulfill her commitment as a non-profit institution.

(3) At present, facing new challenges and opportunities, CGS will attach more importance to advancing the intelligent geological survey course for more extensive application in the national major projects and everyday needs of residents.

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