EXPLORING THE WORLD OF GEOLOGICAL MAPPING

Khasanova Nigora Daniyarovna
1st-year master's student at Tashkent University of Information Technologies named after Muhammad al-Khwarizmi
khasanovanigora555@gmail.com

ABSTRACT

Geographical Information Systems (GIS) have revolutionized the field of geological mapping and data analysis, providing a dynamic platform for understanding the Earth's complex features. This article embarks on a comprehensive journey through the evolution of GIS, tracing its historical roots in cartography to its present-day digital marvels.

Delving into the heart of GIS applications in geological mapping, the article offers a detailed overview of the systems in use globally. It highlights the diverse methodologies employed in creating geological maps.

The insights gained from this research lay the foundation for future advancements in the field. Notably, as a direct outcome of this study, a national geoinformation system of geological data is being developed, marking a significant stride toward efficient and comprehensive geospatial data management.

Keywords*: Geological GIS Applications,Evolution of GIS, Comparative Analysis, USA, Europe, Asia, Geospatial Technology, Decision-Making, Geoinformation Infrastructure, National GIS System, Resource Management.*

INTRODUCTION

Geospatial technologies have become indispensable tools in contemporary geological studies, offering unparalleled capabilities for data visualization, analysis, and decision-making. This journey into the world of geological mapping and data analysis is framed against the backdrop of GIS history, revealing its transformative evolution from manual cartography to sophisticated digital mapping tools. While developed countries like the USA and various European nations have embraced advanced geological GIS applications, regions such as Asia showcase unique approaches to harnessing these technologies. Notably, Uzbekistan, situated at the crossroads of Central Asia, faces a distinct challenge – the absence of a national GIS system tailored to its geological context.

The purpose of this research embark on a twofold mission. Firstly, it delves into the historical roots of GIS, tracing its progression as a crucial tool in understanding Earth's complex features. As we explore the evolution of GIS, we uncover how it has shaped the contemporary landscape of geological mapping, paving the way for innovative methodologies employed in different regions across the globe.

The second facet of this study involves a comparative analysis of existing geological GIS systems in the USA, Europe, and Asia. Through this comparative lens, we identify best practices and innovative methodologies that have been instrumental in advancing geological mapping and data analysis. As we traverse the geospatial terrain, we highlight how GIS has been harnessed to unravel the complexities of unique geological terrains in different corners of the world.

Recognizing the absence of a national GIS system in Uzbekistan, the research sets the stage for the next phase – proposing developing a national geoinformation model and geodatabase for digital geological maps. Through this exploration, we not only contribute to the global understanding of geological GIS applications but also strive to fill a crucial void in the geospatial infrastructure of Uzbekistan.

METHODS

The story of Topographic Mapping and GIS Evolution. Embarking on a journey through the annals of cartography, we unveil the remarkable story of topographic mapping and Geographic Information Systems (GIS), a narrative woven with centuries of innovation, strategic vision, and technological leaps. The evolution of these geospatial disciplines mirrors not only the advancement of mapmaking techniques but also the changing landscapes of societies and their intricate relationships with the environment.

18th Century: Early Mapping and Military Applications

The 18th century marked the beginning of systematic topographic mapping, driven largely by military and strategic needs.

Military cartographers in European nations, such as France and England, started creating detailed maps for military planning and navigation.Techniques like triangulation were employed for accurate mapping over large areas.

19th Century: Ordnance Survey and the Rise of Topographic Mapping

The 19th century saw a significant leap in topographic mapping, especially with the establishment of organizations dedicated to mapping entire regions.

The Ordnance Survey, founded in 1791 in the United Kingdom, became a pioneer in systematic topographic mapping, producing detailed maps for civilian and military use.

Early 20th Century: Aerial Photography and Contour Lines

The early 20th century witnessed technological advancements that revolutionized mapping techniques.

Aerial photography became a game-changer, allowing for more detailed and efficient mapping. This innovation had significant implications for topographic mapping.

Mid-20th Century: Digital Cartography and GIS Precursors

The latter half of the 20th century brought about the transition from manual to digital methods in cartography, laying the groundwork for GIS.

Introduction of computers for map production and storage, marking the shift toward digital cartography.

Roger Tomlinson, a Canadian geographer, is often credited with creating one of the earliest GIS in the 1960s for managing land resources.

Late 20th Century: GIS Development and Accessibility

The late 20th century witnessed the formalization and widespread adoption of GIS as a distinct field.

Esri, founded by Jack Dangermond in 1969, played a pivotal role in the development and popularization of GIS software.

The development of spatial databases allowed for the storage and retrieval of geospatial data in a structured manner.

21st Century: Web GIS and Open Data

The 21st century has seen a democratization of GIS and a shift toward web-based mapping platforms.

The emergence of web GIS platforms, such as Google Maps, made geospatial information more accessible to the general public.

Open-source GIS software, like QGIS, gained popularity, fostering collaboration and innovation in the GIS community.

Present and Future: Integration and Smart Mapping

The present era is characterized by the integration of GIS into various sectors and the emergence of smart mapping technologies.

Current Developments:

Integration of GIS with remote sensing technologies, IoT devices, and big data analytics for real-time spatial analysis.

Advances in 3D mapping and visualization technologies are enhancing the representation of topographic features.

In summary, the historical context of topographic mapping and GIS is marked by a progression from manual cartography to the digital age, with key milestones including the establishment of mapping agencies, technological innovations, the advent of GIS software, and the current trend toward integrated and smart mapping solutions.

RESULTS AND DISCUSSION

Geological geoinformation systems (GIS) are technical tools and software used to store and manage data for the study, location, imaging, analysis, and construction of geographic information. GIS includes databases, maps, and fundamental structural information.

Geological information is a cornerstone of sustainable resource management, environmental protection, and land use planning. The effective management of geological data is crucial for harnessing the economic potential of mineral resources, mitigating environmental risks, and facilitating informed decision-making.

The advent of GIS technology has enabled the digitization of geological data and the creation of digital geological maps. This has revolutionized data access and analysis in geological studies [10].

Geological geoinformation systems find wide applications in geological research, agriculture, the economy, ecology, construction, and various other fields. They play a crucial role in managing geographic information and studying structural data.

Geological GIS analysis encompasses the following primary areas:

- Geodesy and Cartography: Used for topographic map preparation, geodetic data monitoring, thematic map creation, navigation maps, relief analysis, and land resource management.

- Ecology and Scientific Research: In ecological research, ecological monitoring, hydrological research, and other scientific disciplines, GIS is employed for the study and analysis of geographic data.

- Economic Sectors: GIS is employed for data analysis in economic research, economic sector studies, consumption analysis, and export management.

- Social Fields: Applied to the study and analysis of social sciences, GIS aids in examining living standards and analyzing information related to occupations and activities.

- Agriculture: GIS assists in optimizing planting, irrigation, fertilization, and harvesting by considering factors like soil quality, topography, and yield performance. It is a valuable tool in agriculture due to its data integration, visualization, and analytical capabilities, leading to more efficient and sustainable farming practices.

- Public Administration and Defense: GIS is used in the public administration, defense, and security sectors for information analysis and security enhancements.

Geological GIS applications have seen widespread use globally, contributing significantly to the understanding of geological phenomena. In the United States, the United States Geological Survey (USGS) has been a pioneer in developing and implementing robust GIS applications for geological mapping and hazard assessment [1]. Similarly, Europe has made substantial progress in this domain through initiatives such as the European Geological Data Infrastructure (EGDI), fostering collaboration and data sharing among member countries [2].

Geological GIS analysis in the United States may include the following:

1. United States Geological Survey (USGS): The USGS is the primary organization in the United States responsible for the creation, research, and dissemination of geological information and maps. The USGS, or "United States Geological Survey," compiles, analyzes, and manages geological information, prepares geological maps, enhances and manages geological inquiry data, and maintains a significant information database. They also engage in acquiring geological maps and analyzing geophysical, mineralogical, and other geological information.

2. The National Geospatial Program (NGP): NGP emerged as a new and dedicated force committed to advancing the National Spatial Data Infrastructure (NSDI). In a demonstration of its dedication, the U.S. Geological Survey (USGS) affirmed its commitment to refocusing and revitalizing its efforts to meet the nation's critical geospatial information needs. The NGP brings together essential components for building the NSDI, including The National Map (integrated base data), The National Atlas (interactive thematic mapping), the Federal Geographic Data Committee (FGDC, responsible for coordination, policy, and standards), and Geospatial One-Stop (information discovery and access).

3. Bureau of Land Management (BLM): The Bureau of Land Management plays a critical role in the United States, specifically managing public lands, mineral resources, mineral exploration, and other geological data. The BLM utilizes geological GIS systems to support geological mapping, mineral exploration, geological hazard assessments, and other geological research.

4. U.S. Geological Survey National Minerals Information Center (USGS NMIC): The USGS National Minerals Information Center focuses on the assessment of mineral resources, compilation of analytical data, and the preparation of statistics. The center maintains a comprehensive database of mineral resources, their composition, export, and other statistical information for the United States.

5. State Geological Surveys: Each U.S. state has its own State Geological Survey, which utilizes its individual geological GIS systems. They are responsible for researching state-specific geological information, managing surface and mineral

resources, and conducting geological research. They play a significant role in providing geological data and managing resources at the state level.

6. Industry Organizations: Geological analysis and information are supported by industry organizations that prepare geological GIS systems for information, mapping, and analysis of geological information for the management and coordination of information between geological industries, armed services, and companies. These organizations may be internal or external to the geological industry.

The USGS offers various applications and platforms that leverage GIS and geospatial technologies. Here are some notable ones:

The National Map (TNM): TNM is a suite of applications that provide access to a wide range of geospatial data layers, including topographic maps, imagery, elevation data, land cover, and more. Users can explore and download geospatial data through web-based applications.

Earth Explorer: Earth Explorer is an online search, discovery, and ordering tool developed by the USGS. It allows users to search, preview, and download a vast array of satellite and aerial imagery datasets.

USGS Earthquake Hazards Program: The USGS provides real-time earthquake data through various tools, including interactive maps and applications that display seismic activity worldwide. The "ShakeMap" application, for example, provides real-time maps of ground shaking and impact.

USGS Science Data Catalog (SDC): SDC is an online catalog that provides access to a wide range of USGS datasets. Users can search for and download geospatial datasets related to various earth science disciplines.

LandsatLook Viewer: The USGS offers the LandsatLook Viewer, an online tool that allows users to view and download full-resolution satellite imagery from the Landsat program.

USGS Streamer: This is a web-based tool that allows users to trace the paths of rivers and streams in the United States. It provides a visual representation of the upstream and downstream areas for a given location.

Geological Geographic Information Systems (GIS) data in European countries are typically managed by national geological survey organizations or government agencies responsible for geology and natural resources. The use of national geological geoinformation systems (GIS) in European countries varies, and many nations have well-established systems to manage geological data for various purposes. These agencies collect, maintain, and provide access to geological data through various GIS platforms and tools. Here is a list of some European countries with varying levels of use of national geological geoinformation systems:

1. United Kingdom: The British Geological Survey (BGS) manages a comprehensive geological GIS system. It provides extensive geological data, maps, and online tools for users. The UK has a high level of utilization for land planning, environmental assessment, and resource exploration.

2. Germany: Germany, through the Federal Institute for Geosciences and Natural Resources (BGR), has a sophisticated geological GIS system. It is widely used for environmental protection, groundwater management, and natural hazard assessment.

3. Norway: Norway's Geological Survey of Norway (NGU) operates a robust geological GIS system. It supports mineral resource management, environmental monitoring, and geological hazard assessment. The system is known for its high-quality data and accessibility.

4. France: France has a well-established geological GIS managed by institutions such as BRGM (the French Geological Survey). It is extensively used for environmental management, mineral exploration, and research.

5. Sweden: Sweden's Geological Survey of Sweden (SGU) maintains a comprehensive geological GIS system. It supports mineral exploration, land use planning, and environmental assessments.

6. Finland: Geological Survey of Finland (GTK) manages Finland's geological GIS system, which is utilized for mineral exploration, land use planning, and environmental monitoring.

7. Spain: Spain has a geological GIS system managed by the Geological and Mining Institute of Spain (IGME). It is used for mineral resource management, environmental monitoring, and geological hazard assessment.

8. Italy: Italy's Institute for Environmental Protection and Research (ISPRA) is involved in managing the country's geological GIS system. It is utilized for various purposes, including environmental protection, land use planning, and hazard assessment.

9. Netherlands: The Geological Survey of the Netherlands (TNO) manages a geological GIS system used for land subsidence studies, environmental monitoring, and subsurface mapping.

10. Poland:Poland's National Geological Institute (PGI-NRI) operates a geological GIS system used for mineral exploration, environmental monitoring, and research.

11. Greece: Greece's Institute of Geology and Mineral Exploration (IGME) manages a geological GIS system supporting mineral exploration, environmental management, and hazard assessment.

12. Iceland: The National Energy Authority of Iceland (NEA) manages geological GIS data used for energy resource assessments, environmental monitoring, and geological hazard studies.

These examples showcase the diversity in the use and development of national geological geoinformation systems across European countries, reflecting their individual geological characteristics, economic priorities, and environmental concerns.

These national geological survey organizations often have dedicated websites and online platforms where you can access geological maps, datasets, and other geological information. Additionally, the European Geological Data Infrastructure (EGDI) project aims to provide a harmonized European geological GIS infrastructure for sharing geological data across European countries.

Geological Geographic Information Systems (GIS) data in Asian countries are typically managed by national geological survey organizations, government agencies, or research institutions responsible for geology, natural resources, and environmental management.

Across Asia, diverse approaches to geological GIS applications are evident. Countries like China and Japan have developed advanced systems, showcasing the dynamic nature of GIS implementation in the region. A noteworthy example is the study on solar energy potential utilizing GIS-based urban residential environmental data, as exemplified by a case study in Shenzhen, China [4]. This study underscores the diverse applications of GIS in assessing renewable energy potential, demonstrating the utility of geospatial tools beyond traditional mapping functions.

Examining global perspectives, institutions like the Geological Survey of Japan (GSJ) have played a crucial role in advancing geological GIS applications. GSJ, under the aegis of the AIST (National Institute of Advanced Industrial Science and Technology), has been instrumental in mapping Japan’s geological features with a focus on seismic hazards and natural resources [5]. The experiences and methodologies adopted by GSJ contribute valuable insights to the broader understanding of geological GIS applications.

Another facet of GIS application lies in flood prediction studies, exemplified by a scrutiny of the performance of GIS-based Analytical Hierarchical Process (AHP) approach and the Frequency Ratio model in flood prediction. A case study of Kakegawa, Japan, highlights the significance of geospatial techniques in understanding and predicting natural disasters, showcasing the international relevance of GIS in addressing environmental challenges [6].

This table provides a comparative overview of the level of Geological Geographic Information System (GIS) utilization in various countries, highlighting key aspects of their respective infrastructures. The "Level of Use" categorizes the extent to which GIS is integrated into geological studies, while the "Overview" briefly outlines the key functionalities and emphases in each country's geological GIS landscape.

Country	LevelofUse	Overview
China	High	Well-developed geological GIS infrastructure managed by China Geological Survey (CGS). Extensively used for mineral exploration, environmental management, and geological hazard assessment. Significantemphasison geoinformation systemsingeologicalstudies.
India	ModeratetoHigh	Geological Survey of India (GSI) utilizes geological GIS for mineral exploration, environmental monitoring, and groundwater resource management. Level of use varies across states, with more developed regions employing GIS technology more extensively.
Japan	High	Geological Survey of Japan (GSJ) has a sophisticated geological GIS system used extensively for geological research, resource assessment, and disaster management. Strongfocusontechnologyandinnovation.
Indonesia	Moderate	Indonesian Geospatial Information Agency (BIG) enhancing geological GIS capabilities. Used for mineral resource management and environmental monitoring; room for further development.
Australia	High	Geoscience Australia manages advanced geological GIS systems used for mineral exploration, environmental studies, and natural resource management. Extensive geological surveys contribute to a high level of GIS use.
South Korea	High	Korea Institute of Geoscience and Mineral Resources (KIGAM) manages a comprehensive geological GIS system extensively used for mineral exploration, environmental research, and hazard assessment.
Russia	ModeratetoHigh	Federal Agency for Mineral Resources (Rosnedra) manages geological GIS systems for mineral resource exploration and management. Level of use varies across regions due to the vastness of the country.
Iran	Moderate	Geological Survey of Iran (GSI) employs geological GIS for mineral exploration, environmental management, and hazard assessment. Levelofuseinfluencedbyeconomicfactors.
Saudi Arabia	Moderate	Saudi Geological Survey (SGS) utilizes geological GIS for mineral exploration, groundwater management, and environmental monitoring. Levelofusegraduallyincreasing.
Malaysia	Moderate	Mineral and Geoscience Department Malaysia (JMG) manages geological GIS systems for mineral exploration, land use planning, and environmental studies. Levelofusereflectsthecountry'seconomicactivities.

Table 1. Comparative Overview of Geological GIS Usage in Selected Countries

This comparative analysis offers insights into the diverse approaches and emphases of geological GIS applications across selected countries, contributing to a broader understanding of global geospatial infrastructures [7, 8, 9].

The impact of geological GIS applications in these countries extends across various domains:

Resource Management: High levels of GIS use in countries like China, Japan, and Australia contribute significantly to efficient resource management, particularly in mineral exploration and environmental studies.

Innovation and Technology: Japan's GSJ and South Korea's KIGAM stand out for their strong focus on technology and innovation, showcasing the transformative role of GIS in geological research.

Economic Influence: The use of GIS in economic sectors, as seen in China and India, demonstrates its influence on economic research, sector studies, and consumption analysis.

International Relevance: The moderate to high use in Russia highlights the GIS systems' adaptability to vast and diverse geographical regions, showcasing international relevance.

This overview sets the stage for a detailed analysis of geological GIS applications globally, with a specific focus on Uzbekistan's potential for GIS development and its impact on geological studies.

While the Geological Survey of Japan (GSJ) and the Geological Survey of the United States (USGS) exhibit high levels of GIS usage, this study reveals distinct patterns in the European context. Countries such as Germany and the United Kingdom share similarities with Japan in their emphasis on technology and innovation. However, variations in the level of GIS adoption across European nations underscore the importance of considering regional factors and specific geological contexts in the implementation of GIS technologies.

While this study provides valuable insights into the current state of geological GIS usage in Europe, limitations exist, including the focus on selected countries and the potential influence of regional variations. Future research could delve deeper into specific regional influences and consider the impact of geopolitical factors on GIS adoption. Additionally, exploring the integration of emerging technologies, such as artificial intelligence, in geological GIS applications presents an exciting avenue for future investigation.

CONCLUSION

In conclusion, this study has undertaken a comprehensive journey through the historical evolution of GIS, revealing its transformative role in geological studies.

From humble beginnings in manual cartography to the sophisticated digital mapping tools of today, GIS has not only reshaped the global landscape of geological mapping but has become an indispensable asset in understanding the intricacies of our planet.

Furthermore, it is envisaged that the outcomes of this research will play a pivotal role in the development of a national geoinformation model and geodatabase of digital geological maps. By understanding the diverse approaches and influences on GIS adoption, this research provides a blueprint for the creation of tailored strategies that can inform the establishment of a robust national geoinformation infrastructure in Uzbekistan.

In the ever-evolving landscape of GIS, our exploration serves as a testament to the endless possibilities that lie ahead, promising a future where geological studies continue to be enriched by the transformative capabilities of geospatial technologies.

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