SUTGM PROGRAMME

Server based Unified Thematic Geological Mapping

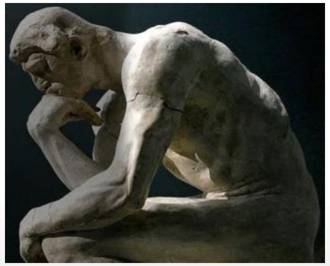
The SUTGM PROGRAMME

The Server-based Unified Thematic Geological Mapping Programme (SUTGM) represents a bilateral and international multidisciplinary initiative focused on advanced geological mapping utilizing cloud computing, machine learning, and artificial intelligence. Sponsored by the ………, this innovative programme aims to produce high-precision, server-based thematic geological maps in scale 1:100,000 and 1:50,000 over a two-year period.

The SUTGM brings together a diverse team of specialists with expertise spanning geology, remote sensing, programming, machine learning, and artificial intelligence. A key feature of the programme is its emphasis on knowledge and technology transfer, fostering close collaboration under the umbrella of the UNESCO Chair on Coastal Geo-Hazard Analysis (UCCGHA). This collaboration is further strengthened through joint fieldwork and a series of workshops organized throughout the programme, ensuring the exchange of cutting-edge methodologies and the development of long-term professional relationships.

By integrating advanced technologies and fostering international cooperation, the SUTGM aims to deliver state-of-the-art geological mapping solutions while promoting capacity building and sustainable development in the field of geosciences.

OBJECTIVES



The **SUTGM** program is ultimately designed to (1) provide new and modern information on server-based integrated thematic geological maps through collaboration with regional specialists, and (2) to develop and evaluate a comprehensive and implement machine learning and AI in geological mapping in different aspects of geology.

BASIC IDEA OF THE SUTGMO PROGRAMME

The basic idea is, drawing inspiration from the abundant geological documents, (1) to establish a synthesis of the complex polyphase tectonic and stratigraphic evolution of the main sedimentary and orogenic basins which developed in the domain of……., and (2) provide an appropriate algorithm, compatible with the field of machine learning and cloud computing for segmentation and clustering of object bases, and (3) generate an integrated set of thematic maps in geology, environmental geology, mineral exploration, and (4) data sharing and knowledge and technology transfer.

ZONE OF INTEREST

The SUTGM Programme aims to cover all lands without dense vegetation within two years, spanning up to 90,000 square kilometers across Central Asia, West Asia, the Middle East, and parts of Africa. The SUTGM Programme aims to cover all lands without dense vegetation within two years, spanning up to 90,000 square kilometers across Central Asia, West Asia, the Middle East, and parts of Africa. This ambitious initiative will utilize advanced technologies, including high-resolution satellite imaging and machine learning algorithms, to identify and map areas of potential mineral resources. The programme's findings will be made available to local governments, research institutions, and other stakeholders, enabling data-driven decision-making and collaborative efforts to address the region's pressing economic challenges. With its focus on empowering communities and promoting environmental stewardship, the SUTGM Programme is poised to make a lasting impact on the region's ecological and socioeconomic trajectory.

WORKING METHODE

Server-Based Thematic Mapping and Its Role in Modern Geological Applications:

Server-based thematic mapping is an advanced process that involves creating and displaying maps to illustrate the spatial distribution of specific themes or topics, such as population density, climate patterns, or land use. This process relies on servers that host both the data and the mapping software, enabling efficient and scalable map generation. When combined with **cloud computing**—the delivery of computing services like servers, storage, databases, networking, software, analytics, and intelligence over the internet—thematic mapping becomes a powerful tool for handling large datasets and complex analyses. Cloud computing provides the infrastructure necessary to support high-performance computing, ensuring seamless integration and accessibility of geological data.

Artificial Intelligence (AI) and Machine Learning (ML) further enhance this process by enabling computer systems to perform tasks that traditionally require human intelligence, such as data analysis, image recognition, natural language processing, and decision-making. In geology and hazard assessment, AI and ML offer transformative applications, including improved data collection and handling, enhanced modelling and prediction capabilities, and more effective communication of results. These technologies are particularly valuable for precise identification and mapping of geological formations, which are critical for geological research, environmental conservation, and natural resource exploration.

Traditional geological mapping techniques often rely on manual digitization of aerial photographs or digital images, or pixel-based classification using spectral characteristics. While these methods are faster and simpler than advanced techniques, they can result in misclassified pixels, especially in regions with similar spectral properties. This limitation often leads to less accurate mapping, particularly when dealing with expansive areas.

In recent years, the integration of server-based cloud computing and Object-Based Image Analysis (OBIA) has revolutionized geological mapping. OBIA, in particular, has emerged as a cost-effective and efficient solution, especially within cloud computing environments. This approach excels at integrating data from diverse sources and managing complex geological features across large regions. By considering the spatial context of objects, OBIA can accurately distinguish between different geological formations, enabling precise identification and mapping.

Geological thematic maps, often referred to as the second generation of geological maps, represent a significant advancement in the field. These maps facilitate rapid and efficient studies, integrate legends and geological units seamlessly, and significantly reduce the time required for data analysis and updates to meet global standards. In essence, they provide a faster, more comprehensive understanding of geological data, making it easier to analyze and update information on a global scale.

Server-based unified thematic geological mapping in cloud computing represents the cutting edge of modern geological mapping. By leveraging cloud-based servers to store and process geological data, this approach ensures scalability, efficiency, and precision. It combines the strengths of cloud computing, AI, and OBIA to deliver accurate, high-resolution geological maps that are essential for research, resource exploration, and environmental management. This innovative methodology not only enhances the accuracy of geological mapping but also supports the development of sustainable solutions for geological and environmental challenges.

Key Advantages of Server-Based Unified Thematic Geological Mapping

1. Integration of Diverse Datasets: This approach combines geological data from multiple sources, creating comprehensive and highly accurate maps. It enables geologists to uncover new patterns and trends, enhancing the depth and quality of geological analysis.
2. Real-Time Data Access and Analysis: Cloud-based servers allow real-time access and analysis of geological data, accelerating decision-making during surveys, especially in time-sensitive or emergency scenarios.
3. Advanced Analytical Tools: Advanced tools in cloud environments help identify relationships between geological features, such as rock formations and fault lines, and pinpoint areas with potential mineral deposits or resources. This supports detailed mapping for exploration, environmental management, and land-use planning.
4. Cost and Time Efficiency: Compared to traditional methods, server-based mapping offers high precision, rapid implementation, and cost reductions of up to 10 times, making it ideal for large-scale surveys and resource exploration.

Process and Quality of Server-Based Thematic Mapping

The quality of thematic maps depends on input data, including pre-existing and newly generated datasets. Key factors include:

- Data Selection: Choosing the right platform, spectral data, radar, and aerial photographs ensures accurate initial maps.
- Field Observations and Laboratory Analysis: Field sampling and lab results refine maps by integrating age, lithological, and geochemical data.
- Field Verification: Targeted observations of rock units, based on processed data and satellite imagery, ensure reliability, even beyond the study area.
- Layered and Iterative Processing: Iterative spatial data processing and integration with pre-existing data reduce uncertainty and quantify errors for each unit.

Second-Generation Geological-Thematic Maps

These maps are characterized by rapid production, integrated legends and units, and reduced reliance on instrumental analysis. They adhere to global standards and are particularly useful in geopolitically sensitive or inaccessible areas.

Conclusion

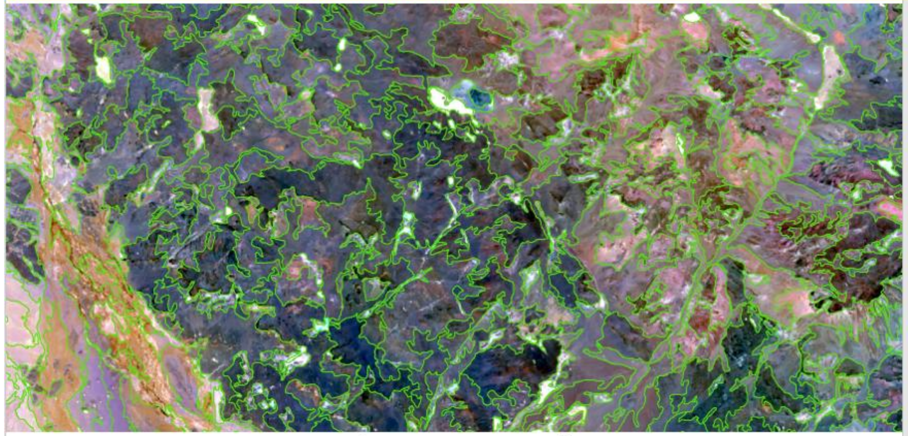
Server-based unified thematic geological mapping in cloud computing represents a paradigm shift, combining advanced technologies like AI and machine learning with traditional methods. It delivers high precision, rapid implementation, and cost efficiency, enhancing data accuracy and accessibility while supporting sustainable resource management and environmental conservation. This innovative approach addresses modern geological challenges, offering a powerful solution for research and exploration.

PILOT PROJECT

Our research introduces an innovative method for rock unit mapping, utilizing OBIA techniques in a cloud computing environment. By integrating clustering, field checking, and Random Forest (RF) machine learning algorithms, we extracted relevant features from various Remote Sensing datasets. Our study achieved a % overall accuracy of 82.1% in mapping geological rock units in Iran's Lut Desert (~30000km2), and also recently in ~ 6000km2 SE Iran in Makran area. The aim of both of the pilot projects was to formulate and use the new methodologies to prepare geological thematic maps based on pre-existing data such as satellite imagery and cloud computing process on public servers such as Google Earth Engine (GEE) combined with field and laboratory controls. Implementing our RF methodology in a cloud computing environment allowed us to handle vast datasets and enhance computational efficiency. This approach provides a precise and efficient alternative to traditional geological mapping, supporting natural resource exploration and environmental management. Our research yields valuable insights into geological evolution, while also improving the scalability and efficiency of the thematic mapping procedure. The project's achievements in the preparation of an integrated and homogeneous geological map in the western Lut and also in Makran area in the Coastal and Outer Makran zones include innovation in methods and procedures, fast and accurate data production, an integrated method for online geological studies, cost and time savings in engineering, exploration, and geology projects, optimization of geological-exploratory study costs with unlimited capability for simultaneous loading and processing of large data, and hardware/ software platforms for three-dimensional geological maps. The research was conducted using international standards and the latest scientific achievements in the field of Machine Learning. In addition, it offers unlimited capabilities for simultaneous loading and processing of large data, preparing a suitable platform for the encyclopaedia of earth sciences, and providing hardware and software platforms for the preparation of three-dimensional geological maps.

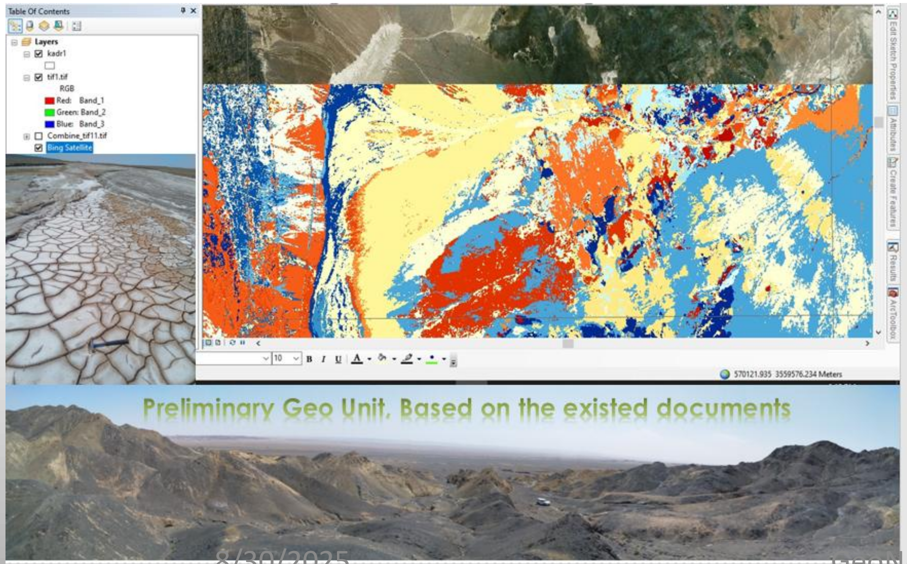
This research satisfied four counters of artificial intelligence in the field of machine learning: transfer learning, few-shot learning, reinforcement learning, and meta-learning.

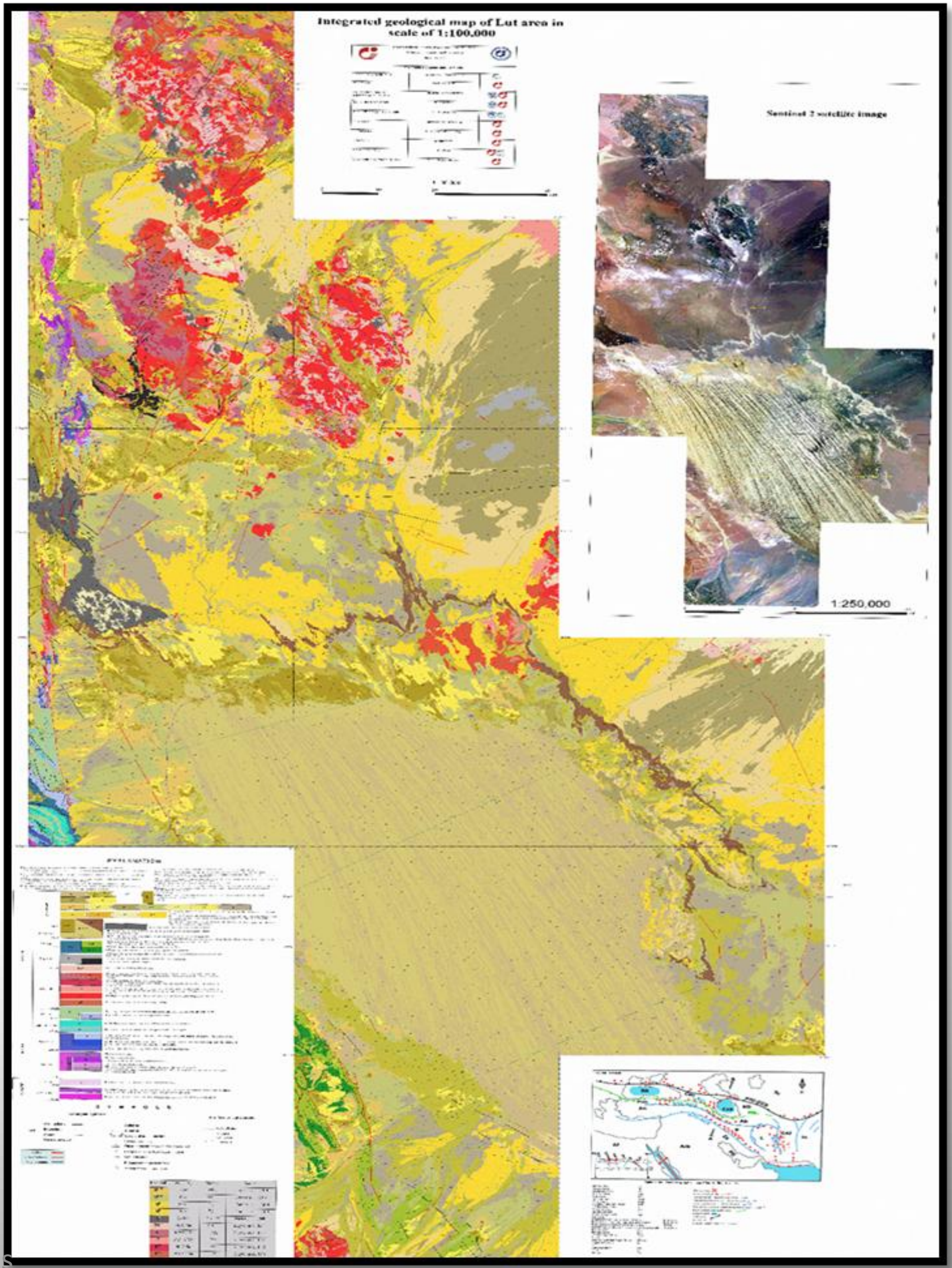
Formal editing of outcrops based on quantitative error computational simulation by segmentation method



Segmentation factor 600 to 200, ~scale 1:250000 to 1:50000

Based on field observation by using 64 physical and chemical indices





RELEVANT PUBLICATIONS

- **Hamid Nazari**, (2025). Next-Gen Onshore Geological Mapping: The Power of AI for Faster, More Precise Results; 11th conference Minerals of the Ocean, June 3-5th, ST. Petersburg, Russia.

- **Hamid Nazari,** Jalal Karami, Saied Arefipour, Aram Fathian, Mohammad Fonodi, (2025). GeoNexus: Leveraging Cloud and AI for Server-Based Unified Thematic Geological Mapping, FIRST ARTIFICIAL INTELLIGENCE IN MARITIME INDUSTRIES CONFERENCE, May 6-7th, Tehran-Iran.

- **Hamid Nazari**, Jalal Karami, Saied Arefipour, Aram Fathian, (2025). Geological Mapping in the Era of AI: Leveraging Innovation for Precision and Speed! UNESCO Chair on Coastal Geo-Hazard Analysis, UCCGHA 033, ISBN:978-622-8423-35-7.

- **Hamid Nazari**, Jalal Karami, Saied Arefipour, (2024). SUTGM PROGRAMME: A New Protocol for Server-Based Unified Thematic Geological Mapping (GeoNexus), UNESCO Chair on Coastal Geo-Hazard Analysis, UCCGHA 027, ISBN: 978-622-8423-21-0.

- **Hamid Nazari,** Jalal Karami, Saied Arefipour, (2024). Geological Mapping in the Era of AI: Leveraging Innovation for Precision and Speed, Barcelona, Catalonia, Spain.

- **Hamid Nazari**, Jalal Karami, Saied Arefipour, Mohammad Fonoudi, Afshin Akbarpour, (2024), Server Based Unified Thematic Geological Mapping, GEOKURDISTAN VI The 6th International Geological Conference of Kurdistan, November 5th -7th, Iraq.

- <u>**Nazari H.**</u>, Karami J., Arefipour S., (2023). The Server based unified thematic Geological mapping in cloud computing, approach: Deep Machin Learning, Regional symposium on Geospatial Information Exchange and Research (GIER), March 07-08, Muscat-Oman.

- **Nazari H.**, Karami J., Arefipour S., Aghaali E., (2023). Using artificial intelligence and Machine learning in the mapping of quaternary units, Quaternary of Iran, Vol. 8, No. 3-4, pp. 379-403 (in Persian).

- **Nazari H.**, Karami J., Arefipour S., (2022). The Server based unified thematic Geological mapping in cloud computing, AAPG Europe Regional Conference: [Revitalizing Old Fields and Energy Transition in Mature Basins](), 3 – 4 May 2022, Budapest, Hungary.

UNESCO Chair on Coastal Geo-Hazard Analysis
Research Institute for Earth Sciences Geological Survey of Iran
unesco Chair

Abstract

The Server-based Unified Thematic Geological Mapping (SUTGM) program is an interdisciplinary global geological research initiative that unites experts in geology, remote sensing, programming, machine learning, and artificial intelligence (AI) to capitalize on cloud computing and machine learning advancements. Its core goals are to deliver current information via integrated geological maps and to enhance the utilization of machine learning and AI in geological mapping. The program emphasizes server-based thematic mapping and cloud computing for efficient management of extensive geological datasets, employing object-based image analysis (OBIA) to precisely identify geological formations. Within the SUTGM program, AI and machine learning are pivotal in boosting the efficiency and accuracy of geological mapping. These technologies assist in processing vast geological datasets, integrating data from diverse sources, and uncovering patterns and trends that may otherwise go unnoticed. The outcomes of SUTGM comprise integrated thematic geological maps that expedite surveys, incorporate time unit legends, and notably lessen reliance on instrumental analyses. This methodology enables nationwide coverage with heightened precision and speed at reduced costs compared to traditional methods. The program's objectives include the precise rectification of satellite images, assessing the effectiveness of multispectral and hyperspectral images, and establishing a unified geoscience database. Thematic geological maps, recognized as the second generation of geological maps, provide swift and effective analyses, integrate legends and geological units, and dramatically decrease the time needed for analyzing and updating information to adhere to global standards. These maps strive to offer a quicker and more comprehensive insight into geological data, streamlining the analysis and updating of information on a global scale. Conversely, SUTGM epitomizes a contemporary approach to geological mapping that harnesses cloud-based servers for storing and processing geological data. A pilot project carried out in Iran's Lut and Makran regions successfully implemented this approach across areas spanning 30,000 km2 and 5,000 km2, achieving an accuracy rate ≥90% in mapping rock units, underscoring the effectiveness of incorporating AI and machine learning in geological mapping. These studies progressed through three primary phases involving documentary and unlocking trapped data on paper, satellite imagery analysis, image processing and machine learning, and field observations adhering to a new protocol.

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2024

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SUTGM PROGRAMME: A New Protocol for Server-Based Unified Thematic Geological Mapping (GeoNexus)

UCCGHA 027

2024

UNESCO Chair on Coastal Geo-Hazard Analysis
Research Institute for Earth Sciences
Geological Survey of Iran
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Abstract

The Server-Based Unified Thematic Geological Mapping of Makran (SUTGMM) is a comprehensive geospatial study conducted at a scale of 1:50,000, focusing on the Makran region, located in southeastern Iran along the northern margin of the Oman Sea. This region is characterized by diverse geological formations resulting from the collision of the Arabian and Eurasian plates, including volcanic and sedimentary sequences, turbidite basins, and Quaternary deposits. Makran's rich geological heritage, coupled with its historical importance, makes it a prime subject for advanced geoscientific research and mapping.

Utilizing a novel approach combining cloud computing, machine learning, and object-based image analysis, the project leverages the power of Google Earth Engine for the processing and analysis of large datasets. The random forest algorithm, used for geological classification, has enabled the creation of a unified geological map with an accuracy of 85%, highlighting the effectiveness of this integrated approach.

This project has provided valuable insights into the complex geological context of the Makran region. The geological units mapped in SUTGMM represent a time range from the Oligocene to the Quaternary period. This includes older formations from the Oligocene and Miocene, as well as more recent Pleistocene and Quaternary deposits. The units highlight the region's complex geodynamic evolution, influenced by both tectonic activity and sedimentary processes.

The GeoNexus geodatabase, as the final product of the SUTGMM project, represents a major advancement in geological mapping by using cloud computing, machine learning, field surveys, and multi-source data integration to enhance the accuracy, efficiency, and comprehensiveness of geological outputs. Ultimately, the findings from this study are expected to support sustainable development efforts and foster a deeper understanding of the Makran region's geodynamic processes.

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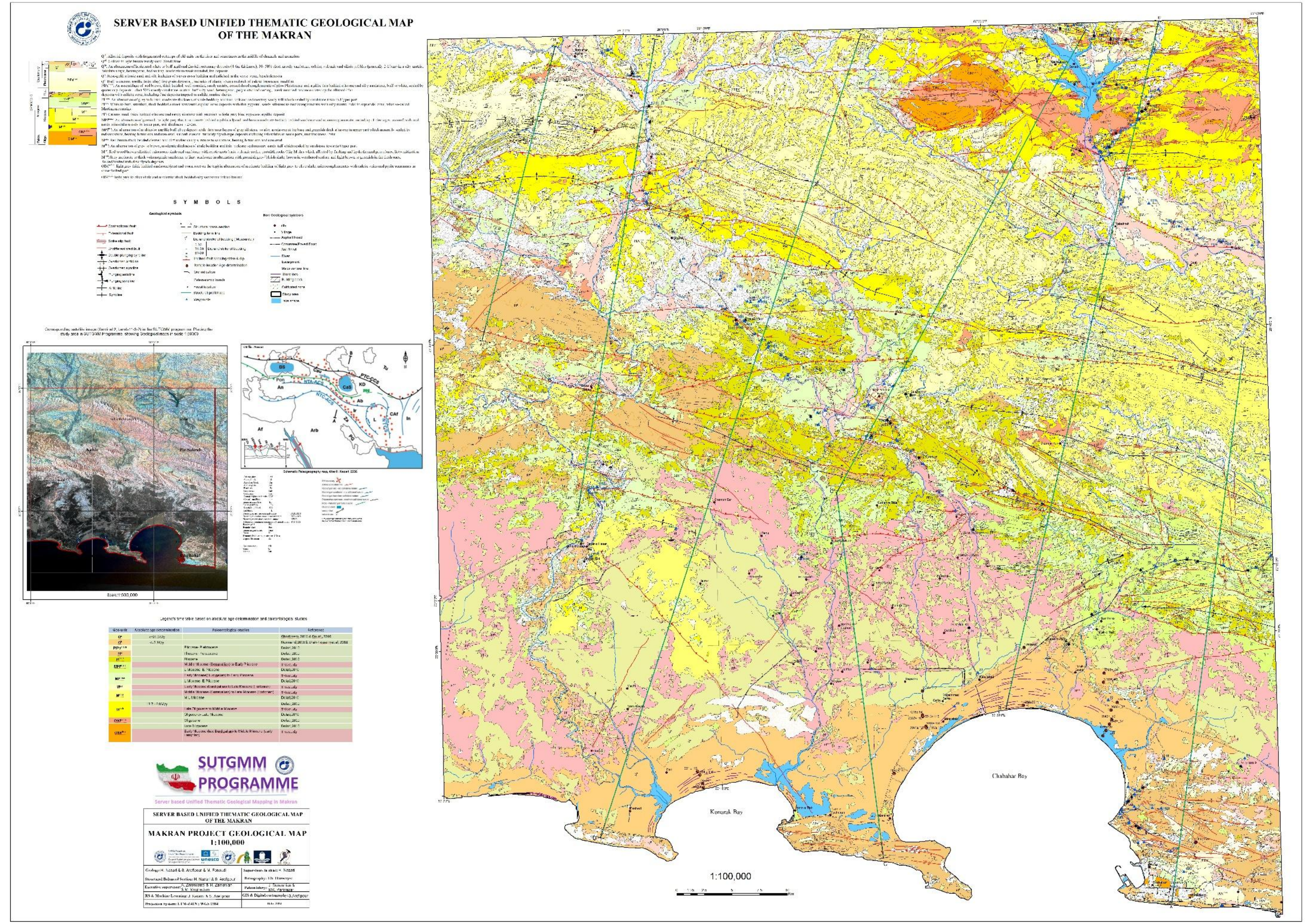
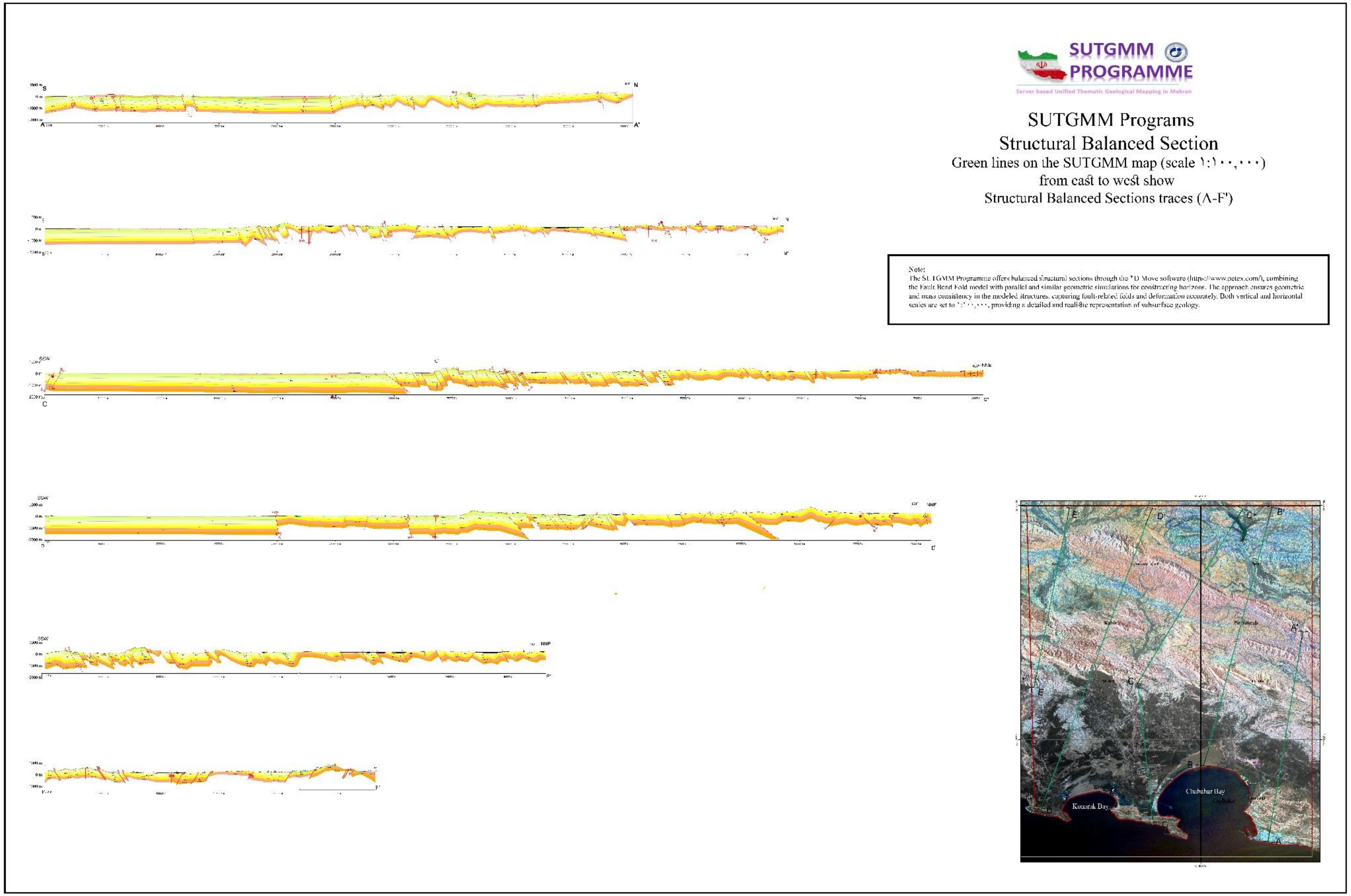
Geological Mapping in the Era of AI: Leveraging Innovation for Precision and Speed

SUTGMM PROGRAMME
Server based Unified Thematic Geological Mapping in Makran

UCCGHA 033

2024


SERVER BASED UNIFIED THEMATIC GEOLOGICAL MAP
OF THE MAKRAN
S Y M B O L S
Chabahar Bay
Konarak Bay
1:100,000
SUTGMM
PROGRAMME
Server based Unified Thematic Geological Mapping in Makran
SERVER BASED UNIFIED THEMATIC GEOLOGICAL MAP
OF THE MAKRAN
MAKRAN PROJECT GEOLOGICAL MAP
1:100,000


SUTGMM PROGRAMME
Server based Unified Thematic Geological Mapping in Makran
SUTGMM Programs
Structural Balanced Section
Green lines on the SUTGMM map (scale ۱:۱۰۰,۰۰۰)
from east to west show
Structural Balanced Sections traces (A-F')
Note:
The SUTGMM Programme offers balanced structural sections through the ۳D Move software (https://www.petex.com/), combining the Fault Bend Fold model with parallel and similar geometric simulations for constructing horizons. The approach ensures geometric and mass consistency in the modeled structures, capturing fault-related folds and deformation accurately. Both vertical and horizontal scales are set to ۱:۱۰۰,۰۰۰, providing a detailed and realistic representation of subsurface geology.
Chabahar Bay
Konarak Bay

SUTGMM PROGRAMME

Server based Unified Thematic Geological Mapping in Makran

Geological Map of ZIRDAN

Abstract:

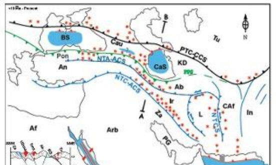
The Server-Based Unified Thematic Geological Mapping of Makran (SUTGMM) is a comprehensive geospatial study conducted at a scale of 1:50,000, focusing on the Makran region, located in southeastern Iran along the northern margin of the Oman Sea. The Makran region is characterized by diverse geological formations resulting from the collision of the Arabian and Eurasian plates, including volcanic and sedimentary sequences, turbidite basins, and Quaternary sediments. Makran's rich geological heritage, coupled with its historical importance, make it a prime subject for advanced geoscientific research and mapping.

The Zirdan sheet (Sheet No. 8141-4) is a 1:50,000 geological map produced as part of the SUTGMM project, which aims to provide a detailed geological map of the Makran region. This sheet encompasses 686.39 square kilometers and covers a diverse range of geological features, including alluvial deposits, volcanic and sedimentary sequences, as well as tectonic structures that are integral to understanding the region's geodynamic evolution. The mapped area lies within coordinates ranging from 60.50°E, 25.75°N to 60.75°E, 26.00°N.

This project integrates data from multiple remote sensing sources such as Sentinel-1, Sentinel-2, Landsat 8, and ASTER, as well as digital elevation models (DEMs) to capture spectral, geological, and topographical information at various resolutions. By leveraging a novel approach that combines cloud computing, machine learning, and object-based image analysis, the SUTGMM project utilizes Google Earth Engine for processing and analyzing large datasets. The random forest algorithm employed for geological classification has enabled the creation of a unified geological map with an accuracy of 85%, emphasizing the efficiency and reliability of this integrated methodology.

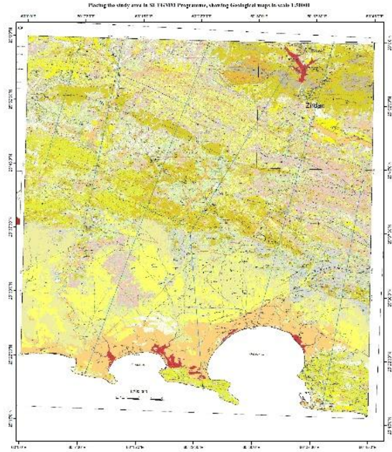
The geological units mapped in the Zirdan sheet represent a time range from the Oligocene to the Quaternary period. The includes older formations from the Oligocene and Miocene, as well as more recent Pleistocene and Quaternary deposits. These units are crucial for understanding the tectonic activity and sedimentary processes that have shaped the Makran region over millions of years.

The GeoNexus geodatabase, as the final product of the SUTGMM project, represents a major advancement in geological mapping by incorporating cloud computing, machine learning, field surveys, and multi-source data integration to enhance the accuracy, efficiency, and comprehensiveness of geological outputs. Ultimately, the findings from this study are expected to support sustainable development efforts and foster a deeper understanding of the region's geodynamic processes.



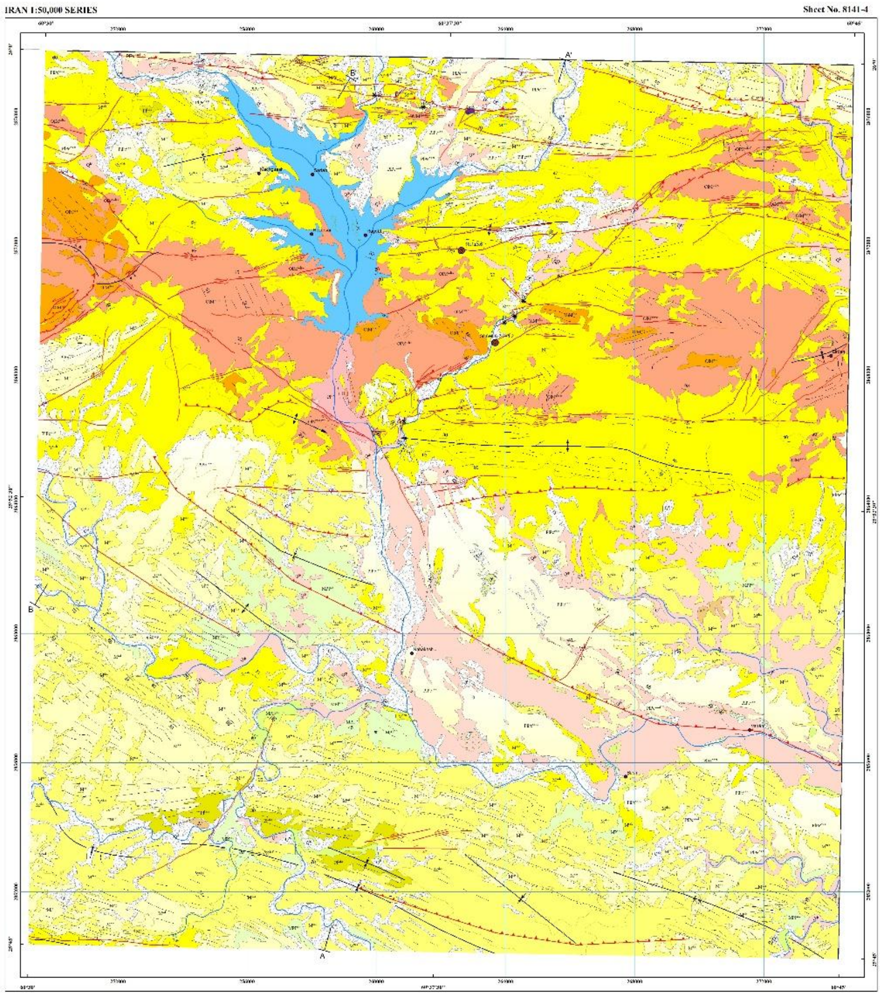
Schematic Paleogeography map, After H. Nazari, 2020

Placing the study area in SUTGMM Programme, showing Geological maps in scale 1:50000



IRAN 1:50,000 SERIES

Sheet No. 8141-4



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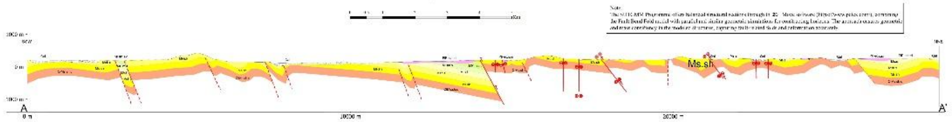
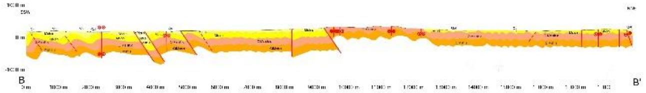
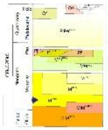




EXPLANATION



SYMBOLS

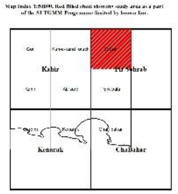
Legend's time table based on absolute age determination and paleontological studies

Geo-unit	Absolute age determination	Paleontological studies	Reference
Qt	<~21.3K/y		Ghafibraz, 2016 & Dolati, 2010
Qf	<~7.0K/y		Normand, 2019 & Shah hosseini et al. 2018
PlPc		Pliocene- Pleistocene	Dolati, 2010
Pl		Pliocene- Pleistocene	Dolati, 2010
Pl		Pliocene	Dolati, 2010
MPl		Middle Miocene (Serravallian) to Early Pliocene	This study
		L Miocene- E Pliocene	Dolati 2010
MPl		Early Miocene (Burdigalian) to Early Pliocene	This study
		L Miocene- E Pliocene	Dolati 2010
M		Early Miocene (Burdigalian) to Late Miocene (Tortonian)	This study
M		Middle Miocene (Serravallian) to Late Miocene (Tortonian)	This study
		M-L Miocene	Dolati 2010
M	13.7 - 12.0 K/y		Dolati, 2010
		Late Oligocene to Middle Miocene	This study
		Oligocene- Late Miocene	Dolati 2010
OlM		Oligocene	Dolati, 2010
OlM		Late Oligocene	Dolati, 2010
		Early Miocene (late Burdigalian) to Middle Miocene (early Langhian)	This study

SERVER BASED UNIFIED THEMATIC GEOLOGICAL MAP OF THE MAKRAN

ZIRDAN GEOLOGICAL MAP 1:50,000

Geology: H. Nazari & S. Arefipour & M. Fohoudi	Supervisor in chief: H. Nazari
Structural Balanced Section: H. Nazari & S. Arefipour	Petrography: Gh. Hoseinyar
Executive supervisor: A. Zarasvandi & F. Zamanian & M. Moghadam	Paleontology: J. Daneshian & MR. Pedramfar
RS & Machine Learning: J. Karami & S. Arefipour	GIS & Digital cartography: S. Arefipour
Projection System: UTM Z41N ; WGS 1984	Sheet No. : 8141-4 / Date: 2024



SUTGMM PROGRAMME

Server based Unified Thematic Geological Mapping in Makran

Geological Map of
PARK BALA

Abstract:

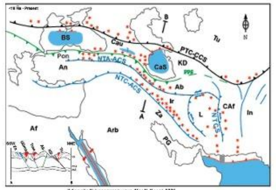
The Server-Based Unified Thematic Geological Mapping of Makran (SUTGMM) is a comprehensive geospatial study conducted at a scale of 1:50,000, focusing on the Makran region, located in southeastern Iran along the northern margin of the Oman Sea. The Makran region is characterized by diverse geological formations resulting from the collision of the Arabian and Eurasian plates, including volcanic and sedimentary sequences, turbidite basins, and Quaternary sediments. Makran's rich geological heritage, coupled with its historical importance, make it a prime subject for advanced geoscientific research and mapping.

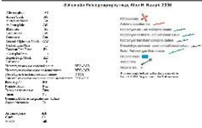
The Park Bala sheet (Sheet No. 8141-3) is a 1:50,000 geological map produced as part of the SUTGMM project, which aims to provide a detailed geological map of the Makran region. This sheet encompasses 697.87 square kilometers and covers a diverse range of geological features, including alluvial and beach deposits, volcanic and sedimentary sequences, as well as tectonic structures that are integral to understanding the region's geodynamic evolution. The mapped area lies within coordinates ranging from 60.50°E, 25.50°N to 60.75°E, 25.75°N.

This project integrates data from multiple remote sensing sources such as Sentinel-1, Sentinel-2, Landsat 8, and ASTER, as well as digital elevation models (DEMs) to capture spectral, geological, and topographical information at various resolutions. By leveraging a novel approach that combines cloud computing, machine learning, and object-based image analysis, the SUTGMM project utilizes Google Earth Engine for processing and analyzing large datasets. The random forest algorithm employed for geological classification has enabled the creation of a unified geological map with an accuracy of 85%, emphasizing the efficiency and reliability of this integrated methodology.

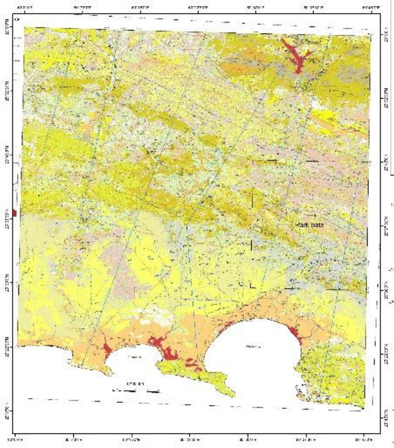
The geological units mapped in the Park Bala sheet represent a time range from the Oligocene to the Quaternary period. This includes older formations from the Oligocene and Miocene, as well as more recent Pleistocene and Quaternary deposits. These units are crucial for understanding the tectonic activity and sedimentary processes that have shaped the Makran region over millions of years.

The GeoNexus geodatabase, as the final product of the SUTGMM project, represents a major advancement in geological mapping by incorporating cloud computing, machine learning, field surveys, and multi-source data integration to enhance the accuracy, efficiency, and comprehensiveness of geological outputs. Ultimately, the findings from this study are expected to support sustainable development efforts and foster a deeper understanding of the region's geodynamic processes.



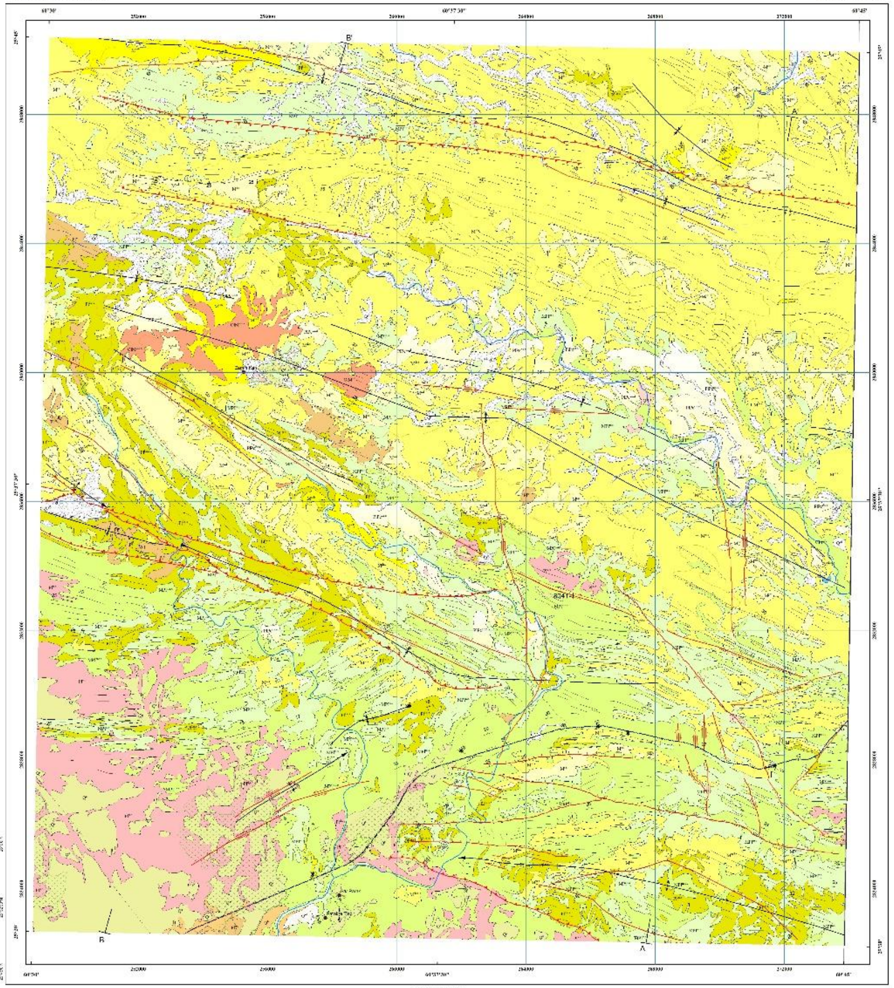


Placing the study area in SUTGMM Programme, showing Geological maps in scale 1:50000

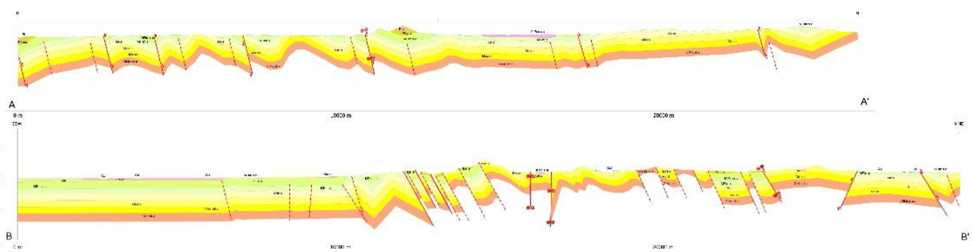


IRAN 1:50,000 SERIES

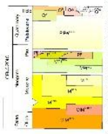
Sheet No. 8141-3



Scale: 1:50,000



EXPLANATION



SYMBOLS

Geological symbols

Non-Geological symbols

Legend's time table based on absolute age determination and paleontological studies

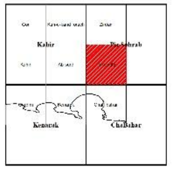
Geo-unit	Absolute age determination	Paleontological studies	Reference
Q^{t}	<=21.3K/y		Ghorbani, 2016 & [illegible], 2010
Q^{f}	<=7.3K/y		Normand, 2016 & Shah-hosseini et al. 2016
[illegible]		Pliocene- Pleistocene	Dolati, 2010
[illegible]		Pliocene- Pleistocene	Dolati, 2010
[illegible]		Pliocene	Dolati, 2010
[illegible]		Middle Miocene (Serravallian) to Early Pliocene	This study
		L Miocene- E Pliocene	Dolati 2010
[illegible]		Early Miocene (Burdigalian) to Early Pliocene	This study
		L Miocene- E Pliocene	Dolati 2010
[illegible]		Early Miocene (Burdigalian) to Late Miocene (Tortonian)	This study
[illegible]		Middle Miocene (Serravallian) to Late Miocene (Tortonian)	This study
		M-L Miocene	Dolati 2010
[illegible]	13.7 - 6.0M/y		Dolati, 2010
		Late Oligocene to Middle Miocene	This study
		Oligocene- Late Miocene	Dolati 2010
[illegible]		Oligocene	Dolati, 2010
[illegible]		Late Oligocene	Dolati, 2010
		Early Miocene (late Burdigalian) to Middle Miocene (early Langhian)	This study

SERVER BASED UNIFIED THEMATIC GEOLOGICAL MAP OF THE MAKRAN

PARK BALA GEOLOGICAL MAP
1:50,000

Geologist: H. Nazari & S. Arefipour & M. [illegible]	Supervisors in chief: H. Nazari
Structural Balanced Section: H. Nazari & S. Arefipour	Petrography: Sh. Hosseinpor
Executive supervisor: A. Zarasvandi & F. Zamanian & M. Morshedian	Paleontology: J. Daneshian & MR. [illegible]
RS & Machine Learning: J. Karami & S. Arefipour	GIS & Digital cartography: S. Arefipour
Projection System: UTM Z41N : WGS 1984	Sheet No.: 8141-3 — Date: 2024

Map Index 1:50000, Red filled sheet showing study area as a part of the SUTGMM Programme limited by brown line.



SUTGMM PROGRAMME

Server based Unified Thematic Geological Mapping in Makran

Geological Map of CHABAHAR

Abstract:

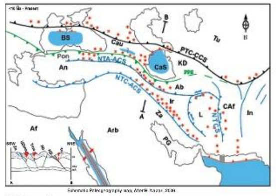
The Server-Based Unified Thematic Geological Mapping of Makran (SUTGMM) is a comprehensive geospatial study conducted at a scale of 1:50,000, focusing on the Makran region, located in southeastern Iran along the northern margin of the Oman Sea. The Makran region is characterized by diverse geological formations resulting from the collision of the Arabian and Eurasian plates, including volcanic and sedimentary sequences, turbidite basins, and Quaternary sediments. Makran's rich geological heritage, coupled with its historical importance, make it a prime subject for advanced geoscientific research and mapping.

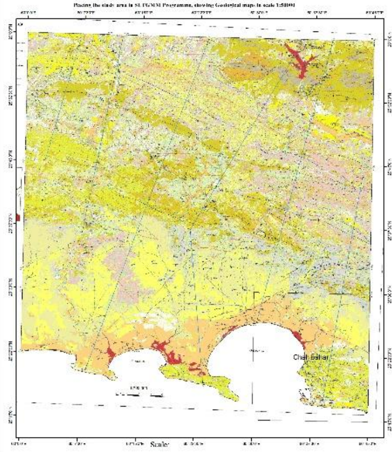
The Chabahar sheet (Sheet No. 8140-4) is a 1:50,000 geological map produced as part of the SUTGMM project, which aims to provide a detailed geological map of the Makran region. This sheet encompasses 699.33 square kilometers and covers a diverse range of geological features, including alluvial and beach deposits, volcanic and sedimentary sequences, as well as tectonic structures that are integral to understanding the region's geodynamic evolution. The mapped area lies within coordinates ranging from 60.50°E, 25.25°N to 60.75°E, 25.50°N.

This project integrates data from multiple remote sensing sources such as Sentinel-1, Sentinel-2, Landsat 8, and ASTER, as well as digital elevation models (DEMs) to capture spectral, geological, and topographical information at various resolutions. By leveraging a novel approach that combines cloud computing, machine learning, and object-based image analysis, the SUTGMM project utilizes Google Earth Engine for processing and analyzing large datasets. The random forest algorithm employed for geological classification has enabled the creation of a unified geological map with an accuracy of 85%, emphasizing the efficiency and reliability of this integrated methodology.

The geological units mapped in the Chabahar sheet represent a time range from the Oligocene to the Quaternary period. This includes older formations from the Oligocene and Miocene, as well as more recent Pleistocene and Quaternary deposits. These units are crucial for understanding the tectonic activity and sedimentary processes that have shaped the Makran region over millions of years.

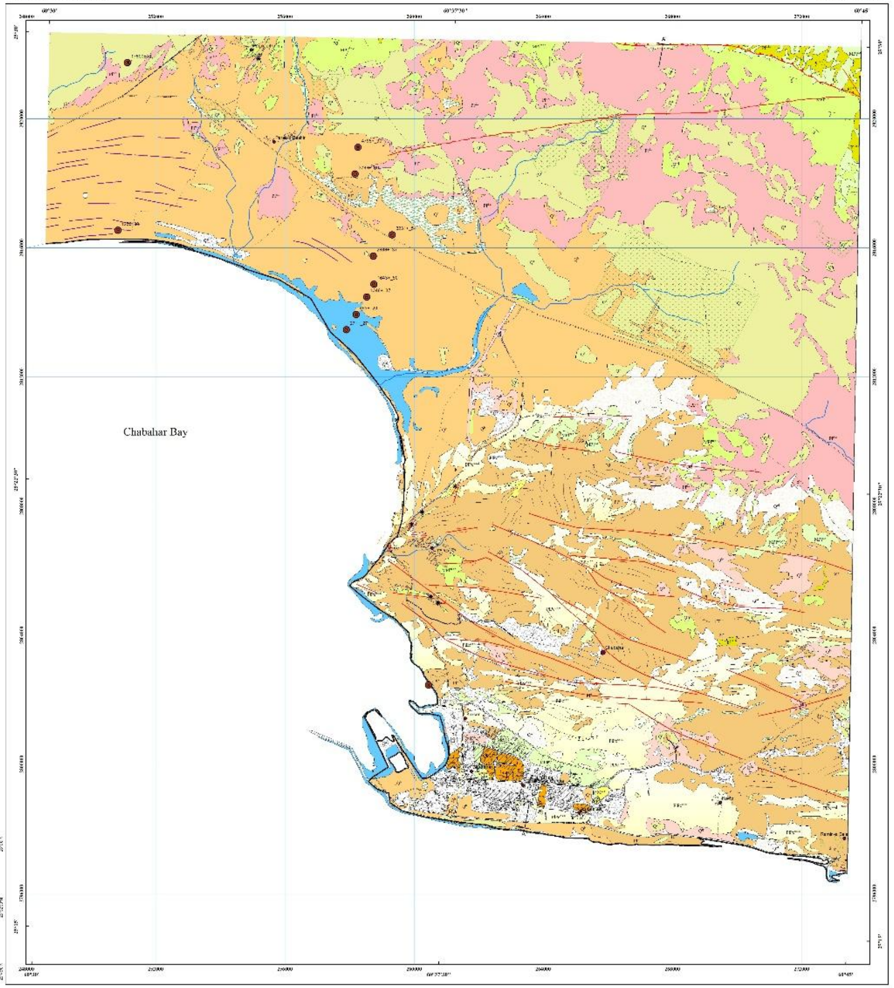
The GeoNexus geodatabase, as the final product of the SUTGMM project, represents a major advancement in geological mapping by incorporating cloud computing, machine learning, field surveys, and multi-source data integration to enhance the accuracy, efficiency, and comprehensiveness of geological outputs. Ultimately, the findings from this study are expected to support sustainable development efforts and foster a deeper understanding of the region's geodynamic processes.



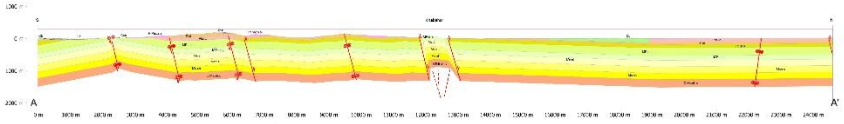


IRAN 1:50,000 SERIES

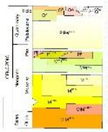
Sheet No. 8140-4



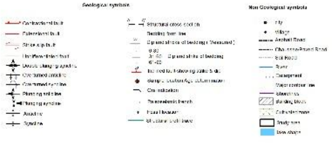
Scale: 1:50,000



EXPLANATION



SYMBOLS



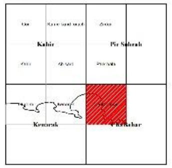
Geo unit	Absolute age determination	Paleontological studies	Reference
Q[illegible]	<~21.5K/y		Gharibreza, 2016 & Do et al., 2010
Q[illegible]	<=7.3K/y		Normand, 2018 & Shah hosseini et al., 2018
PlPe[illegible]		Pliocene- Pleistocene	Dolati, 2010
Pl[illegible]		Pliocene- Pleistocene	Dolati, 2010
Pl[illegible]		Pliocene	Dolati, 2010
MPl[illegible]		Middle Miocene (Serravallian) to Early Pliocene	This study
		L Miocene- E Pliocene	Dolati 2010
MPl[illegible]		Early Miocene(Burdigalian) to Early Pliocene	This study
		L Miocene- E Pliocene	Dolati 2010
M[illegible]		Early Miocene (Burdigalian) to Late Miocene (Tortonian)	This study
M[illegible]		Middle Miocene (Serravallian) to Late Miocene (Tortonian)	This study
		M-L Miocene	Dolati 2010
M[illegible]	[illegible]M/y		Dolati, 2010
		Late Oligocene to Middle Miocene	This study
		Oligocene- Late Miocene	Dolati 2010
OlM[illegible]		Oligocene	Dolati, 2010
OlM[illegible]		Late Oligocene	Dolati, 2010
		Early Miocene (late Burdigalian) to Middle Miocene (early Langhian)	This study

SERVER BASED UNIFIED THEMATIC GEOLOGICAL MAP OF THE MAKRAN

CHABAHAR GEOLOGICAL MAP 1:50,000

Geology: H. Nazari & S. Arefipour & M. Fonoudi	Supervisors in chief: H. Nazari
Structural Balanced Section: H. Nazari & S. Arefipour	Petrography: Gh. Hoseinyar
Executive supervision: A. Zarasvandi & H. Zamanian & S.M. Moghadam	Paleontology: J. Daneshian & MR. Parvizpour
RS & Machine Learning: J. Karami & S. Arefipour	GIS & Digital cartography: S. Arefipour
Projection System: UTM-Z41N ; WGS 1984	Sheet No.: 8140-4

Map Index 1:50000, Red filled sheet showing study area as a part of the SUTGMM Programme



SUTGMM PROGRAMME

Server based Unified Thematic Geological Mapping in Makran

Geological Map of KUH-E-KAND KORUCH

Abstract:

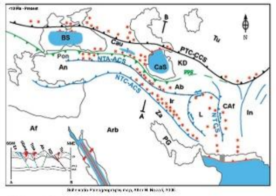
The Server-Based Unified Thematic Geological Mapping of Makran (SUTGMM) is a comprehensive geospatial study conducted at a scale of 1:50,000, focusing on the Makran region, located in southeastern Iran along the northern margin of the Oman Sea. The Makran region is characterized by diverse geological formations resulting from the collision of the Arabian and Eurasian plates, including volcanic and sedimentary sequences, turbidite basins, and Quaternary sediments. Makran's rich geological heritage, coupled with its historical importance, make it a prime subject for advanced geoscientific research and mapping.

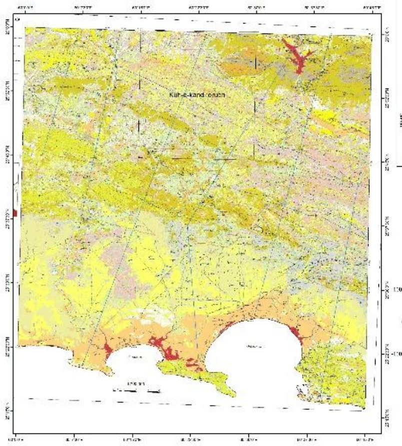
The Kuh-e-kand Koruch sheet (Sheet No. 8041-1) is a 1:50,000 geological map produced as part of the SUTGMM project, which aims to provide a detailed geological map of the Makran region. This sheet encompasses 696.39 square kilometers and covers a diverse range of geological features, including alluvial deposits, volcanic and sedimentary sequences, as well as tectonic structures that are integral to understanding the region's geodynamic evolution. The mapped area lies within coordinates ranging from 60.25°E, 25.75°N to 60.50°E, 26.00°N.

This project integrates data from multiple remote sensing sources such as Sentinel-1, Sentinel-2, Landsat 8, and ASTER, as well as digital elevation models (DEMs) to capture spectral, geological, and topographical information at various resolutions. By leveraging a novel approach that combines cloud computing, machine learning, and object-based image analysis, the SUTGMM project utilizes Google Earth Engine for processing and analyzing large datasets. The random forest algorithm employed for geological classification has enabled the creation of a unified geological map with an accuracy of 85%, emphasizing the efficiency and reliability of this integrated methodology.

The geological units mapped in the Kuh-e-kand Koruch sheet represent a time range from the Oligocene to the Quaternary period. This includes older formations from the Oligocene and Miocene, as well as more recent Pleistocene and Quaternary deposits. These units are crucial for understanding the tectonic activity and sedimentary processes that have shaped the Makran region over millions of years.

The GeoNexus geodatabase, as the final product of the SUTGMM project, represents a major advancement in geological mapping by incorporating cloud computing, machine learning, field surveys, and multi-source data integration to enhance the accuracy, efficiency, and comprehensiveness of geological outputs. Ultimately, the findings from this study are expected to support sustainable development efforts and foster a deeper understanding of the region's geodynamic processes.

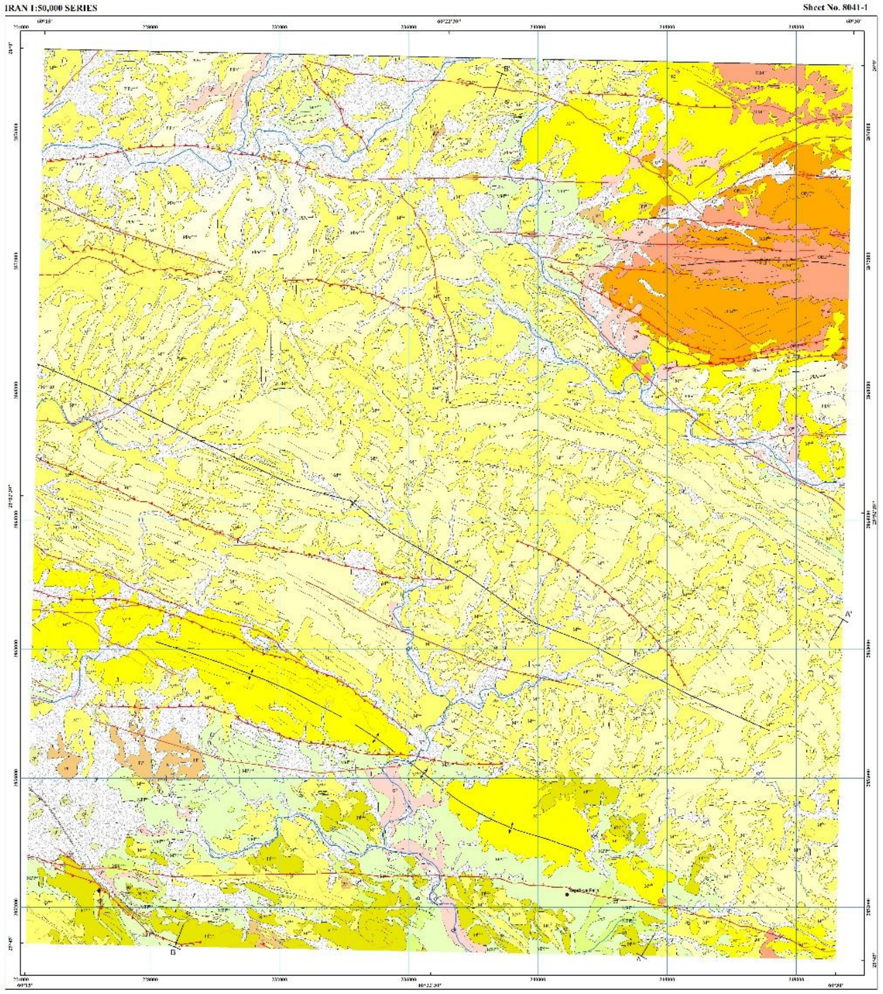




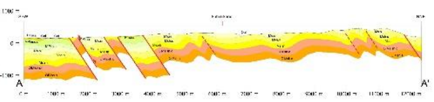
Placing the study area in SUTGMM Programme, showing Geological maps in scale 1:50000

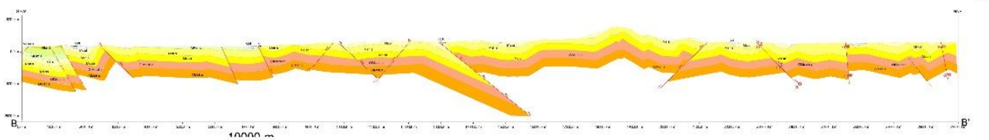
IRAN 1:50,000 SERIES

Sheet No. 8041-1

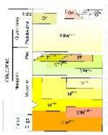


Scale: 1:50,000





EXPLANATION



SYMBOLS

Geological symbols

Non Geological symbols

Legend's time table based on absolute age determination and paleontological studies

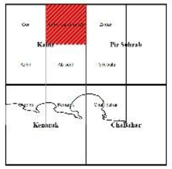
Geo-unit	Absolute age determination	Paleontological studies	Reference
Q	<=21.3K/y		Ghorbani, 2016 & Dolati, 2010
Q	<=7.3K/y		Normand, 2018 & Shah-hosseini et al. 2018
PlPs		Pliocene- Pleistocene	Dolati, 2010
Pl		Pliocene- Pleistocene	Dolati, 2010
Pl		Pliocene	Dolati, 2010
MPl		Middle Miocene (Serravallian) to Early Pliocene	This study
		L.Miocene-E. Pliocene	Dolati 2010
MPl		Early Miocene(Burdigalian) to Early Pliocene	This study
		L.Miocene- E.Pliocene	Dolati 2010
M		Early Miocene (Burdigalian) to Late Miocene (Tortonian)	This study
M		Middle Miocene (Serravallian) to Late Miocene (Tortonian)	This study
		M-L Miocene	Dolati 2010
M	13.7 - 6.0M/y		Dolati, 2010
		Late Oligocene to Middle Miocene	This study
		Oligocene - Late Miocene	Dolati 2010
OlM		Oligocene	Dolati, 2010
OlM		Late Oligocene	Dolati, 2010
		Early Miocene (late Burdigalian) to Middle Miocene (early Langhian)	This study

SERVER BASED UNIFIED THEMATIC GEOLOGICAL MAP OF THE MAKRAN

KUH-E-KAND KORUCH GEOLOGICAL MAP1:50,000

Geology: H. Nazari & S. Arefipour & M. Honarvar	Supervisors in chief: H. Nazari
Structural Balanced Section: H. Nazari & S. Arefipour	Petrography: Gh. Hoseinyar
Executive supervisor: A. Zarasvandi & H. Zamanian & M. Moghadam	Paleontology: J. Daneshian & MR. Daraei
RS & Machine Learning: J. Karami & S. Arefipour	GIS & Digital cartography: S. Arefipour
Projection System: UTM Z41N : WGS 1984	Sheet No.: 8041-1 / Date: 2024

Map Index 1:50000. Red filled sheet showing study area as a part of the SUTGMM Programme limited by known line.



SUTGMM PROGRAMME

Server based Unified Thematic Geological Mapping in Makran

Geological Map of

AB SARD

Abstract:

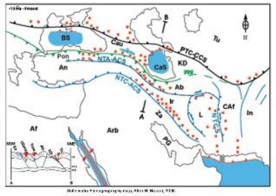
The Server-Based Unified Thematic Geological Mapping of Makran (SUTGMM) is a comprehensive geospatial study conducted at a scale of 1:50,000, focusing on the Makran region, located in southeastern Iran along the northern margin of the Oman Sea. The Makran region is characterized by diverse geological formations resulting from the collision of the Arabian and Eurasian plates, including volcanic and sedimentary sequences, turbidite basins, and Quaternary sediments. Makran's rich geological heritage, coupled with its historical importance, make it a prime subject for advanced geoscientific research and mapping.

The Ab Sard sheet (Sheet No. 8041-2) is a 1:50,000 geological map produced as part of the SUTGMM project, which aims to provide a detailed geological map of the Makran region. This sheet encompasses 697.87 square kilometers and covers a diverse range of geological features, including alluvial and beach deposits, volcanic and sedimentary sequences, as well as tectonic structures that are integral to understanding the region's geodynamic evolution. The mapped area lies within the coordinates ranging from 60.25°E, 25.50°N to 60.50°E, 25.75°N.

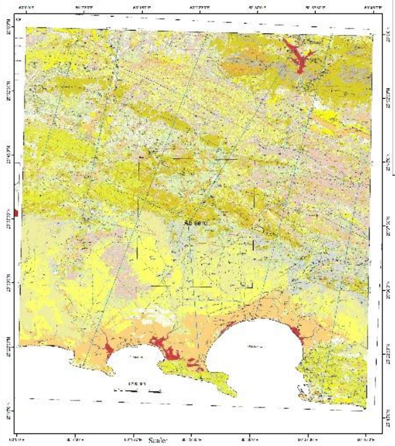
This project integrates data from multiple remote sensing sources such as Sentinel-1, Sentinel-2, Landsat 8, and ASTER, as well as digital elevation models (DEMs) to capture spectral, geological, and topographical information at various resolutions. By leveraging a novel approach that combines cloud computing, machine learning, and object-based image analysis, the SUTGMM project utilizes Google Earth Engine for processing and analyzing large datasets. The random forest algorithm employed for geological classification has enabled the creation of a unified geological map with an accuracy of 85%, emphasizing the efficiency and reliability of this integrated methodology.

The geological units mapped in the Ab Sard sheet represent a time range from the Oligocene to the Quaternary period. This includes older formations from the Oligocene and Miocene, as well as more recent Pleistocene and Quaternary deposits. These units are crucial for understanding the tectonic activity and sedimentary processes that have shaped the Makran region over millions of years.

The GeoNexus geodatabase, as the final product of the SUTGMM project, represents a major advancement in geological mapping by incorporating cloud computing, machine learning, field surveys, and multi-source data integration to enhance the accuracy, efficiency, and comprehensiveness of geological outputs. Ultimately, the findings from this study are expected to support sustainable development efforts and foster a deeper understanding of the region's geodynamic processes.

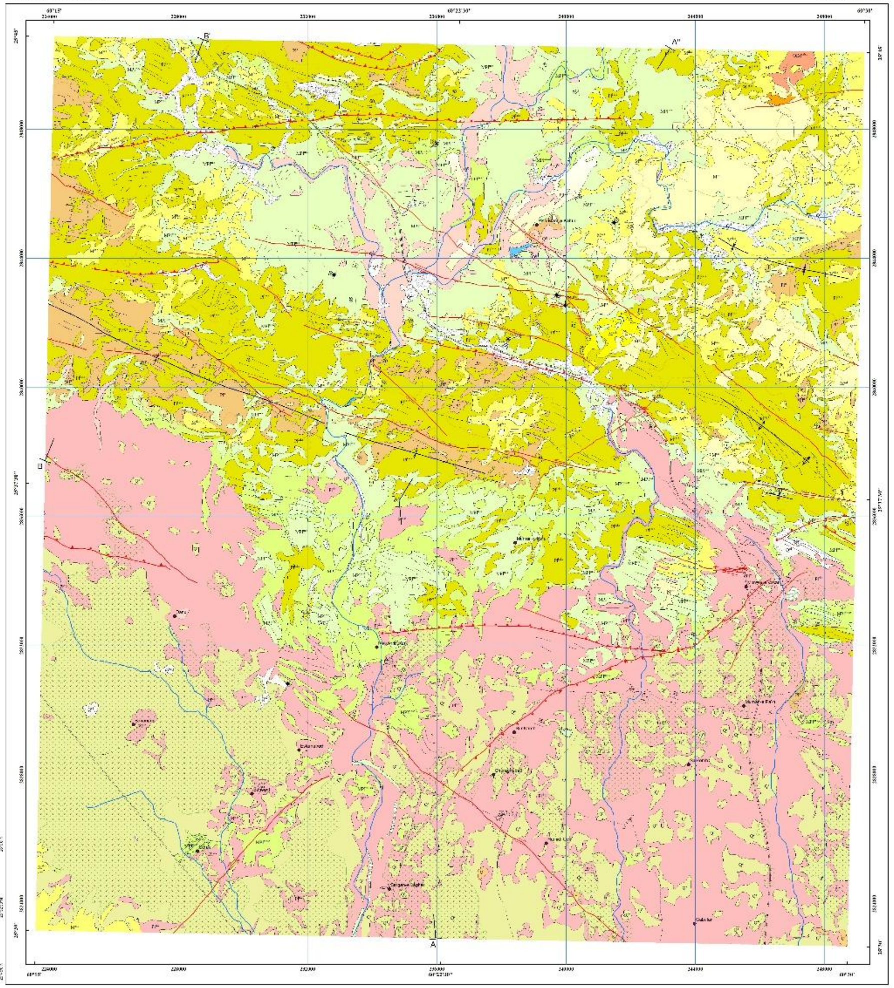


Placing the study area in SUTGMM Programme, showing Geological maps at scale 1:50000

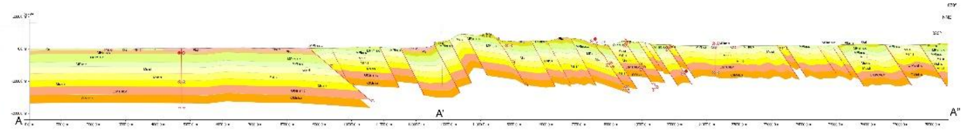


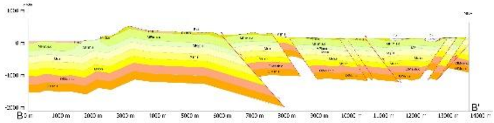
IRAN 1:50,000 SERIES

Sheet No. 8041-2

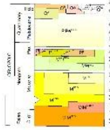


Scale: 1:50,000





EXPLANATION

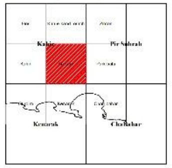


SYMBOLS

Legend's time table based on absolute age determination and paleontological studies

Geo-unit	Absolute age determination	Paleontological studies	Reference
Q	<~21.3K/y		Gharibreza, 2016 & Dolati, 2010
Q	<~7.0K/y		Normand, 2018 & Shah-hosseini et al. 2018
PlPc		Pliocene-Pleistocene	Dolati, 2010
Pl		Pliocene-Pleistocene	Dolati, 2010
pl		Pliocene	Dolati, 2010
MPl		Middle Miocene (Serravallian) to Early Pliocene	This study
		L Miocene- E Pliocene	Dolati, 2010
MPl		Early Miocene (Burdigalian) to Early Pliocene	This study
		L Miocene- E Pliocene	Dolati, 2010
M		Early Miocene (Burdigalian) to Late Miocene (Tortonian)	This study
M		Middle Miocene (Serravallian) to Late Miocene (Tortonian)	This study
		M-L Miocene	Dolati, 2010
M	1.07 - 6.0M/y		Dolati, 2010
		Late Oligocene to Middle Miocene	This study
		Oligocene- Late Miocene	Dolati, 2010
OlM		Oligocene	Dolati, 2010
OlM		Late Oligocene	Dolati, 2010
		Early Miocene (late Burdigalian) to Middle Miocene (early Langhian)	This study

Map Index 1:50000, Red filled sheet showing study area as a part of the SUTGMM Programme limited by brown line.



SERVER BASED UNIFIED THEMATIC GEOLOGICAL MAP OF THE MAKRAN

AB SARD GEOLOGICAL MAP 1:50,000

Geology: H. Nazari & S. Arefipour & M. Foroudi	Supervisors in chief: H. Nazari
Structural and Balanced Section: H. Nazari & S. Arefipour	Petrography: Gh. Hoseinyar
Executive supervisor: A. Zaraswandi & H. Zamanian & N. Moghadam	Paleontology: J. Daneshian & MR. Parizadar
RS & Machine Learning: J. Bazarn & S. Arefipour	GIS & Digital cartography: S. Arefipour
Projection System: UTM Z41N ; WGS 1984	Sheet No.: 8041-2

SUTGMM PROGRAMME

Server based Unified Thematic Geological Mapping in Makran

Geological Map of

KONARAK

Abstract:

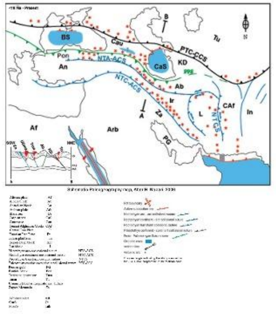
The Server-Based Unified Thematic Geological Mapping of Makran (SUTGMM) is a comprehensive geospatial study conducted at a scale of 1:50,000, focusing on the Makran region, located in southeastern Iran along the northern margin of the Oman Sea. The Makran region is characterized by diverse geological formations resulting from the collision of the Arabian and Eurasian plates, including volcanic and sedimentary sequences, turbidite basins, and Quaternary sediments. Makran's rich geological heritage, coupled with its historical importance, make it a prime subject for advanced geoscientific research and mapping.

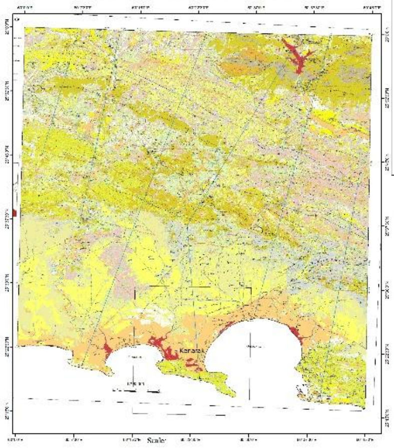
The Konarak sheet (Sheet No. 8040-1) is a 1:50,000 geological map produced as part of the SUTGMM project, which aims to provide a detailed geological map of the Makran region. This sheet encompasses 699.33 square kilometers and covers a diverse range of geological features, including alluvial and beach deposits, volcanic and sedimentary sequences, as well as tectonic structures that are integral to understanding the region's geodynamic evolution. The mapped area lies within coordinates ranging from 60.25°E, 25.25°N to 60.50°E, 25.50°N.

This project integrates data from multiple remote sensing sources such as Sentinel-1, Sentinel-2, Landsat 8, and ASTER, as well as digital elevation models (DEMs) to capture spectral, geological, and topographical information at various resolutions. By leveraging a novel approach that combines cloud computing, machine learning, and object-based image analysis, the SUTGMM project utilizes Google Earth Engine for processing and analyzing large datasets. The random forest algorithm employed for geological classification has enabled the creation of a unified geological map with an accuracy of 85%, emphasizing the efficiency and reliability of this integrated methodology.

The geological units mapped in the Konarak sheet represent a time range from the upper Miocene to the Quaternary period. This includes older formations from the upper Miocene and Pliocene, as well as more recent Pleistocene and Quaternary deposits. These units are crucial for understanding the tectonic activity and sedimentary processes that have shaped the Makran region over millions of years.

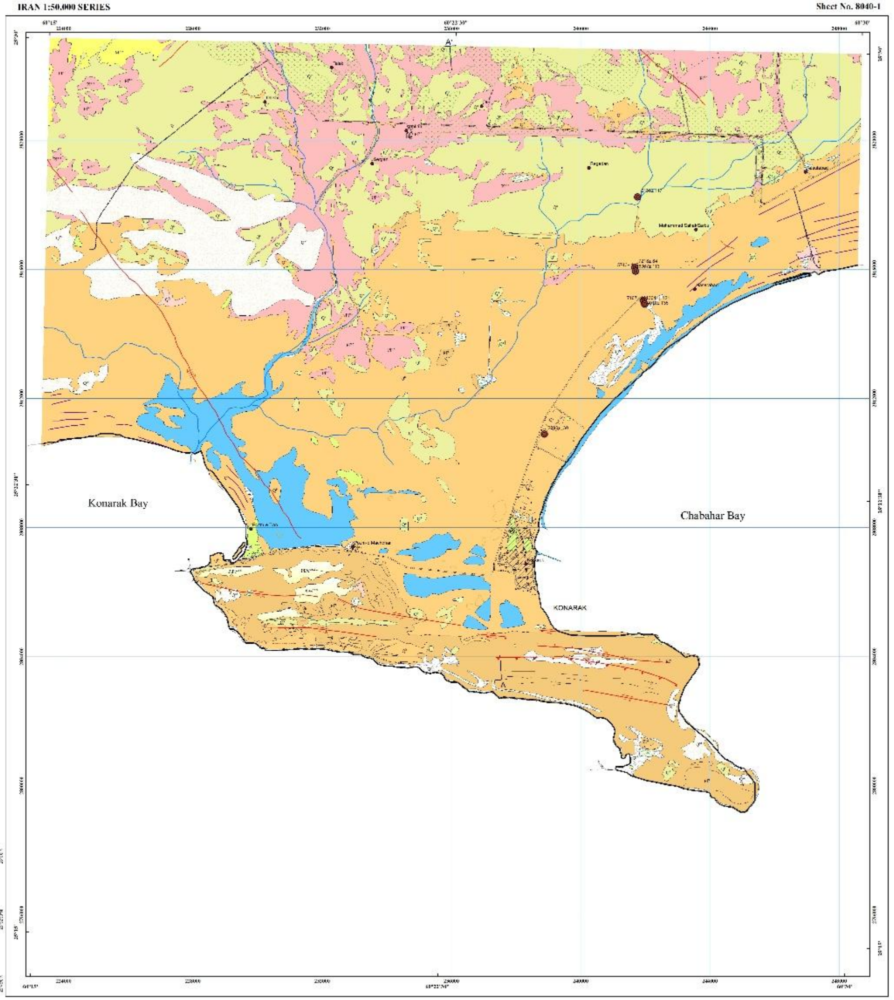
The GeoNexus geodatabase, as the final product of the SUTGMM project, represents a major advancement in geological mapping by incorporating cloud computing, machine learning, field surveys, and multi-source data integration to enhance the accuracy, efficiency, and comprehensiveness of geological outputs. Ultimately, the findings from this study are expected to support sustainable development efforts and foster a deeper understanding of the region's geodynamic processes.





IRAN 1:50,000 SERIES

Sheet No. 8040-1



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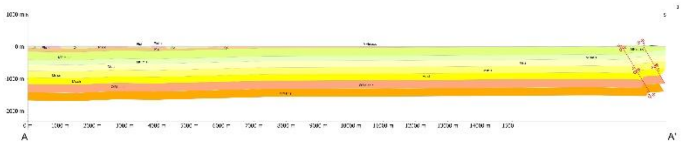
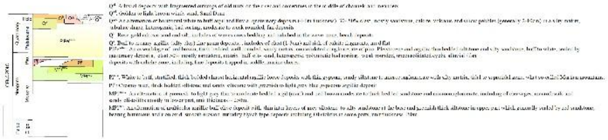
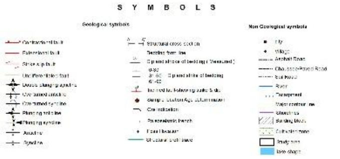


EXPLANATION





Geo unit	Absolute age determination	Paleontological studies	Reference
Q	<=21.3K/y		Gharibreza, 2016 & Dolati, 2010
Q	<=7.3K/y		Normand, 2018 & Shah-Hosseini et al, 2018
PlPe		Pliocene- Pleistocene	Dolati,2010
Pl		Pliocene- Pleistocene	Dolati,2010
Pl		Pliocene	Dolati,2010
MPl		Middle Miocene (Serravallian) to Early Pliocene	This study
		L Miocene- E Pliocene	Dolati,2010
MPl		Early Miocene(Burdigalian) to Early Pliocene	This study
		L Miocene- L Pliocene	Dolati,2010
M		Early Miocene (Burdigalian) to Late Miocene (Tortonian)	This study
M		Middle Miocene (Serravallian) to Late Miocene (Tortonian)	This study
		M-L Miocene	Dolati,2010
M	13.7 - 6.0M/y		Dolati,2010
		Late Oligocene to Middle Miocene	This study
		Oligocene- Late Miocene	Dolati,2010
OlM		Oligocene	Dolati,2010
OlM		Late Oligocene	Dolati,2010
		Early Miocene (late Burdigalian) to Middle Miocene (early Langhian)	This study

SERVER BASED UNIFIED THEMATIC GEOLOGICAL MAP OF THE MAKRAN

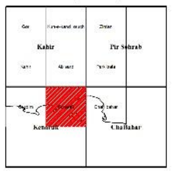
KONARAK GEOLOGICAL MAP

1:50,000

Supervisors in chief: H. Nazari

Petrography: Gh. Hoseinyar

Projection System: UTM Z41N, WGS 1984



SUTGMM PROGRAMME

Server based Unified Thematic Geological Mapping in Makran

Geological Map of

GOR

Abstract:

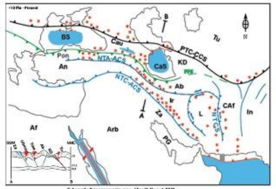
The Server-Based Unified Thematic Geological Mapping of Makran (SUTGMM) is a comprehensive geospatial study conducted at a scale of 1:50,000, focusing on the Makran region, located in southeastern Iran along the northern margin of the Oman Sea. The Makran region is characterized by diverse geological formations resulting from the collision of the Arabian and Eurasian plates, including volcanic and sedimentary sequences, turbidite basins, and Quaternary sediments. Makran's rich geological heritage, coupled with its historical importance, make it a prime subject for advanced geoscientific research and mapping.

The Gor sheet (Sheet No. 8041-4) is a 1:50,000 geological map produced as part of the SUTGMM project, which aims to provide a detailed geological map of the Makran region. This sheet encompasses 896.39 square kilometers and covers a diverse range of geological features, including alluvial deposits, volcanic and sedimentary sequences, as well as tectonic structures that are integral to understanding the region's geodynamic evolution. The mapped area lies within coordinates ranging from 60.00°E, 25.75°N to 60.25°E, 26.00°N.

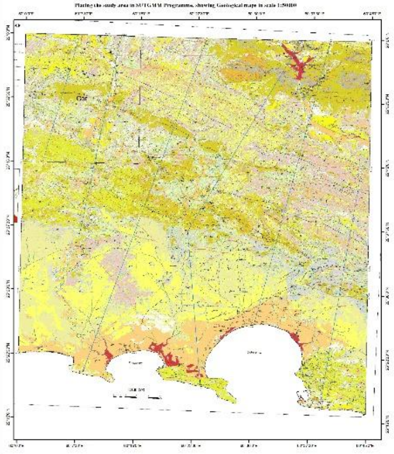
This project integrates data from multiple remote sensing sources such as Sentinel-1, Sentinel-2, Landsat 8, and ASTER, as well as digital elevation models (DEMs) to capture spectral, geological, and topographical information at various resolutions. By leveraging a novel approach that combines cloud computing, machine learning, and object-based image analysis, the SUTGMM project utilizes Google Earth Engine for processing and analyzing large datasets. The random forest algorithm employed for geological classification has enabled the creation of a unified geological map with an accuracy of 85%, emphasizing the efficiency and reliability of this integrated methodology.

The geological units mapped in the Gor sheet represent a time range from the Oligocene to the Quaternary period. This includes older formations from the Oligocene and Miocene, as well as more recent Pleistocene and Quaternary deposits. These units are crucial for understanding the tectonic activity and sedimentary processes that have shaped the Makran region over millions of years.

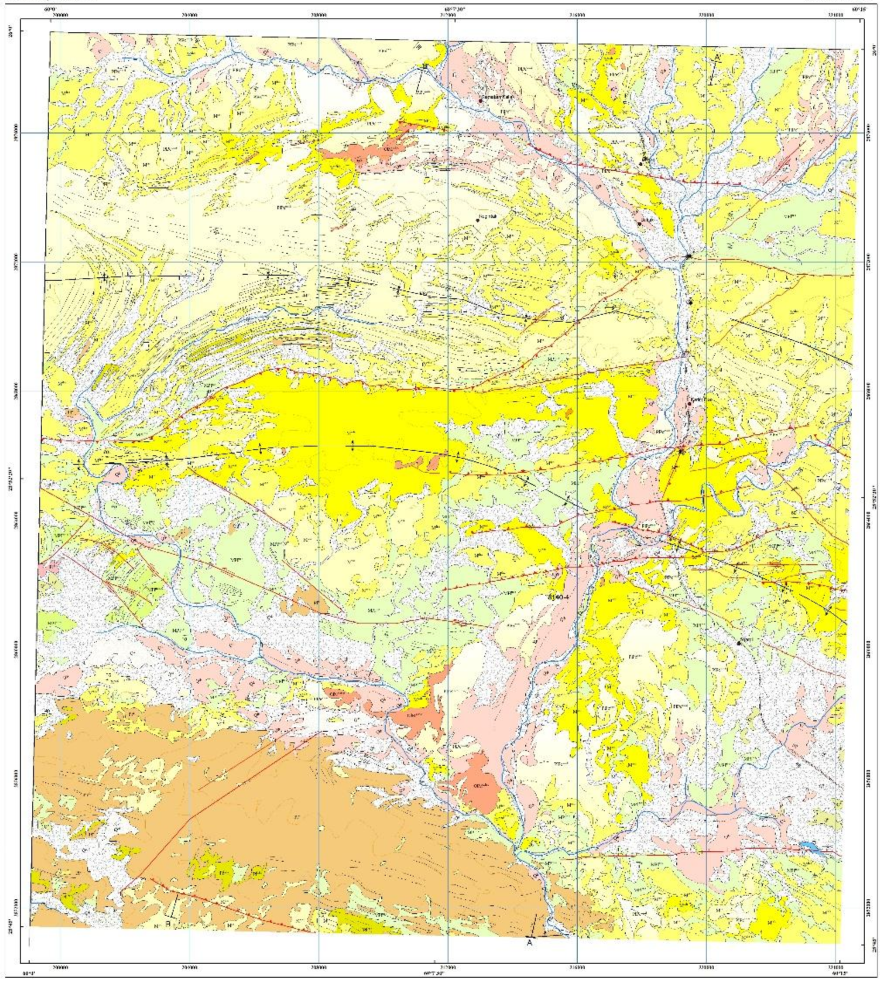
The GeoNexus geodatabase, as the final product of the SUTGMM project, represents a major advancement in geological mapping by incorporating cloud computing, machine learning, field surveys, and multi-source data integration to enhance the accuracy, efficiency, and comprehensiveness of geological outputs. Ultimately, the findings from this study are expected to support sustainable development efforts and foster a deeper understanding of the region's geodynamic processes.



Schematic Paleogeography map, After N Nazari, 2006

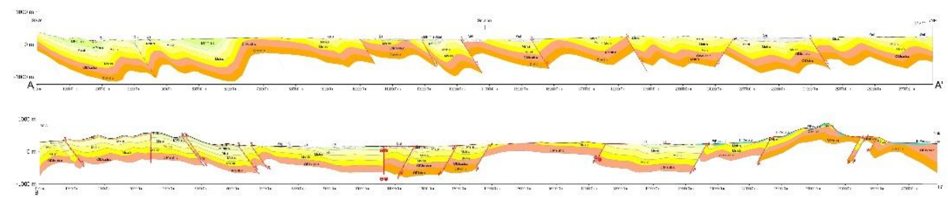


Placing the study area in SUTGMM Programme, showing Geological maps in scale 1:50000



IRAN 1:50,000 SERIES

Sheet No. 8041-4



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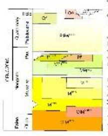
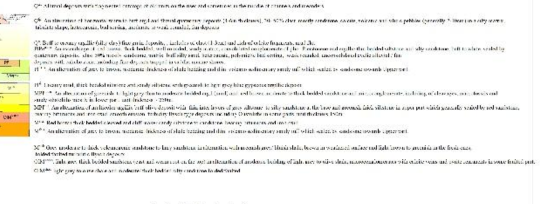
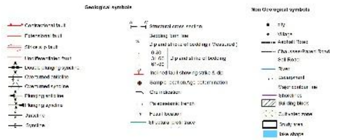


EXPLANATION



S Y M B O L S



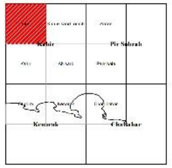
Legend's time table based on absolute age determination and paleontological studies

Geo-unit	Absolute age determination	Paleontological studies	Reference
Q	<~21.3K/y		Ghafibreza, 2016 & Dolati, 2010
Q	<~7.3K/y		Normand, 2018 & Shah hosseini et al. 2018
PlPc		Pliocene- Pleistocene	Dolati, 2010
Pl		Pliocene- Pleistocene	Dolati, 2010
Pl		Pliocene	Dolati, 2010
MPF		Middle Miocene (Serravallian) to Early Pliocene	This study
		L.Miocene- E.Pliocene	Dolati 2010
MPF		Early Miocene(Burdigalian) to Early Pliocene	This study
		L.Miocene- E.Pliocene	Dolati 2010
M		Early Miocene (Burdigalian) to Late Miocene (Tortonian)	This study
M		Middle Miocene (Serravallian) to Late Miocene (Tortonian)	This study
		M-L. Miocene	Dolati 2010
M	13.7 - 12.4M/y		Dolati, 2010
		Late Oligocene to Middle Miocene	This study
		Oligocene- Late Miocene	Dolati 2010
OlM		Oligocene	Dolati, 2010
OlM		Late Oligocene	Dolati, 2010
		Early Miocene (late Burdigalian) to Middle Miocene (early Langhian)	This study

SERVER BASED UNIFIED THEMATIC GEOLOGICAL MAP OF THE MAKRAN

GOR GEOLOGICAL MAP
1:50,000

Geology: H. Nazari & S. Arefipour & M. Fenoudi	Supervisors in chief: H. Nazari
Structural Balanced Section: H. Nazari & S. Arefipour	Petrography: Gh. Hoseinpour
Executive supervisor: A. Zamanian & F. Zamanian & M. Moghadam	Paleontology: J. Daneshian & MR. Parvizian
RS & Machine Learning: J. Karami & S. Arefipour	GIS & Digital cartography: S. Arefipour
Projection System: UTM-Z41N ; WGS 1984	Sheet No. : 8041-4 — Date: 2024



Map index 1:50000. Red filled sheet showing study area as a part of the SUTGMM Programme limited by brown line.

SUTGMM PROGRAMME

Server based Unified Thematic Geological Mapping in Makran

Geological Map of

KAHIR

Abstract:

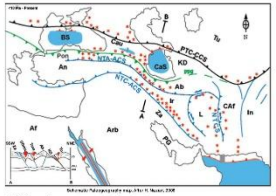
The Server-Based Unified Thematic Geological Mapping of Makran (SUTGMM) is a comprehensive geospatial study conducted at a scale of 1:50,000, focusing on the Makran region, located in southeastern Iran along the northern margin of the Oman Sea. The Makran region is characterized by diverse geological formations resulting from the collision of the Arabian and Eurasian plates, including volcanic and sedimentary sequences, turbidite basins, and Quaternary sediments. Makran's rich geological heritage, coupled with its historical importance, make it a prime subject for advanced geoscientific research and mapping.

The Kahir sheet (Sheet No. 8041-3) is a 1:50,000 geological map produced as part of the SUTGMM project, which aims to provide a detailed geological map of the Makran region. This sheet encompasses 697.87 square kilometers and covers a diverse range of geological features, including alluvial deposits, volcanic and sedimentary sequences, as well as tectonic structures that are integral to understanding the region's geodynamic evolution. The mapped area lies within coordinates ranging from 60.00°E, 25.50°N to 60.25°E, 25.75°N.

This project integrates data from multiple remote sensing sources such as Sentinel-1, Sentinel-2, Landsat 8, and ASTER, as well as digital elevation models (DEMs) to capture spectral, geological, and topographical information at various resolutions. By leveraging a novel approach that combines cloud computing, machine learning, and object-based image analysis, the SUTGMM project utilizes Google Earth Engine for processing and analyzing large datasets. The random forest algorithm employed for geological classification has enabled the creation of a unified geological map with an accuracy of 85%, emphasizing the efficiency and reliability of this integrated methodology.

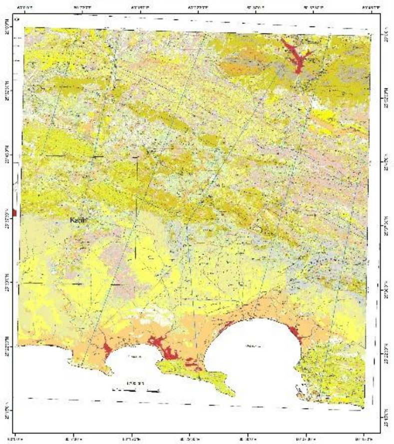
The geological units mapped in the Kahir sheet represent a time range from the Oligocene to the Quaternary period. This includes older formations from the Oligocene and Miocene, as well as more recent Pleistocene and Quaternary deposits. These units are crucial for understanding the tectonic activity and sedimentary processes that have shaped the Makran region over millions of years.

The GeoNexus geodatabase, as the final product of the SUTGMM project, represents a major advancement in geological mapping by incorporating cloud computing, machine learning, field surveys, and multi-source data integration to enhance the accuracy, efficiency, and comprehensiveness of geological outputs. Ultimately, the findings from this study are expected to support sustainable development efforts and foster a deeper understanding of the region's geodynamic processes.



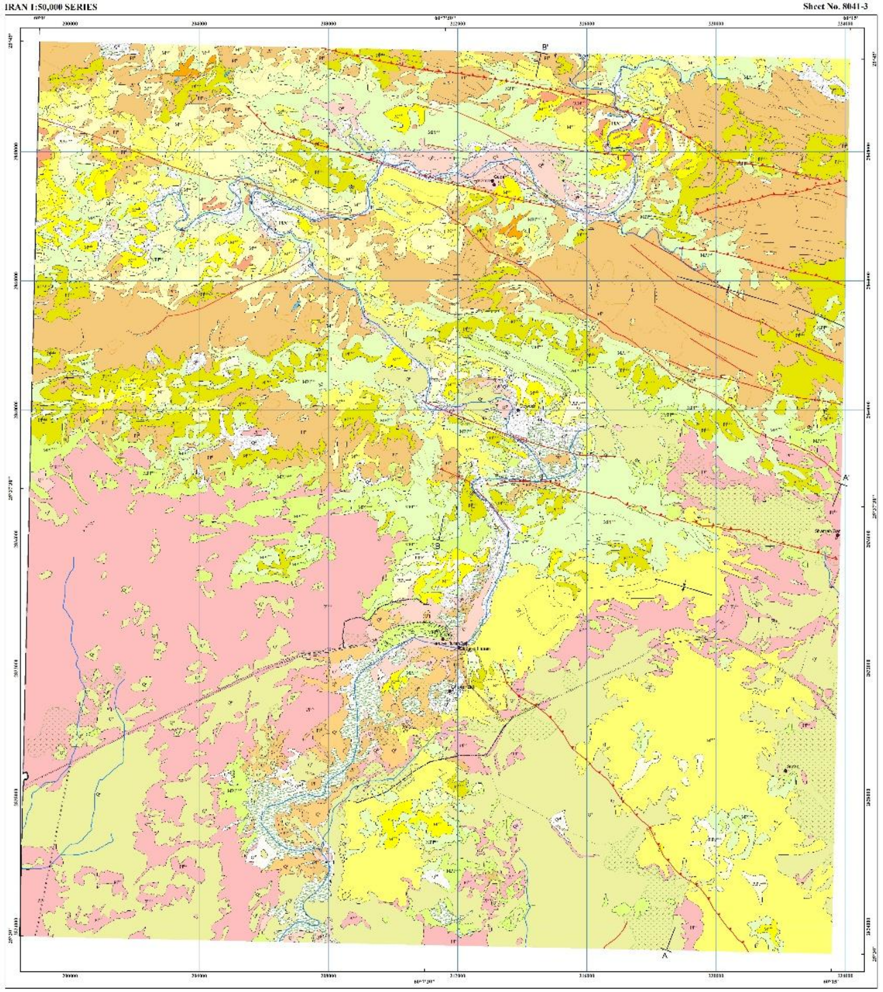
Schematic Paleogeography map (After H. Nazari, 2008)

Placing the study area in SUTGMM Programme, showing Geological maps in scale 1:50000

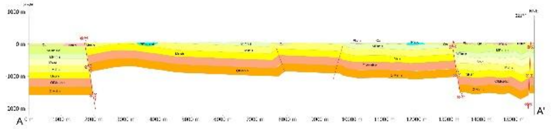


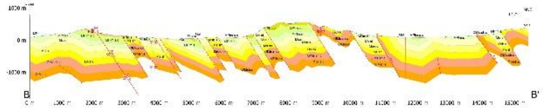
IRAN 1:50,000 SERIES

Sheet No. 8041-3

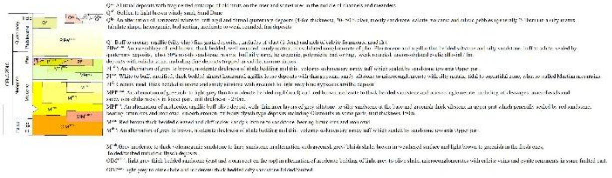


Scale: 1:50,000

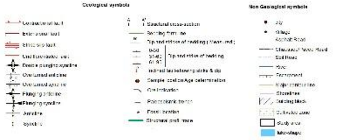




EXPLANATION



S Y M B O L S



Legend's time table based on absolute age determination and paleontological studies

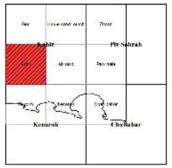
Geo unit	Absolute age determination	Paleontological studies	Reference
Q	<~21.3K/y		Gharibreza, 2016 & Dolati, 2010
Q	<=7.3K/y		Normand, 2018 & Shah-hosseini et al. 2018
PlPe		Pliocene- Pleistocene	Dolati, 2010
Pl		Pliocene- Pleistocene	Dolati, 2010
Pl		Pliocene	Dolati, 2010
MPl		Middle Miocene (Serravallian) to Early Pliocene	This study
		L Miocene- E Pliocene	Dolati, 2010
MPl		Early Miocene (Burdigalian) to Early Pliocene	This study
		L Miocene- E Pliocene	Dolati, 2010
M		Early Miocene (Burdigalian) to Late Miocene (Tortonian)	This study
M		Middle Miocene (Serravallian) to Late Miocene (Tortonian)	This study
		M- L Miocene	Dolati, 2010
M	1.07 - 6.26M/y		Dolati, 2010
		Late Oligocene to Middle Miocene	This study
		Oligocene- Late Miocene	Dolati, 2010
OlM		Oligocene	Dolati, 2010
OlM		Late Oligocene	Dolati, 2010
		Early Miocene (late Burdigalian) to Middle Miocene (early Langhian)	This study

SERVER BASED UNIFIED THEMATIC GEOLOGICAL MAP OF THE MAKRAN

KAHIR GEOLOGICAL MAP 1:50,000

Geology: H. Nazari & S. Arefipour & M. Fazmali	Supervisors in chief: H. Nazari
Structural Balanced Section: H. Nazari & S. Arefipour	Petrography: Sh. Hoseinyar
Executive supervisor: A. Zarasvandi & H. Zamanian & M. Moghadam	Paleontology: Hamedani & MS. Farbodzar
RS & Machine Learning: J. Karami & S. Arefipour	GIS & Digital cartography: S.Arefipour
Projection System: UTM-Z41N ; WGS 1984	Sheet No.: 8041-3

Map Index 1:50000, Red filled sheet showing study area as a part of the SUTGMM Programme limited by brown line



SUTGMM PROGRAMME

Server based Unified Thematic Geological Mapping in Makran

Geological Map of

GURDIM

Abstract:

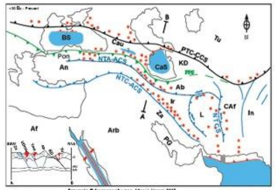
The Server-Based Unified Thematic Geological Mapping of Makran (SUTGMM) is a comprehensive geospatial study conducted at a scale of 1:50,000, focusing on the Makran region, located in southeastern Iran along the northern margin of the Oman Sea. The Makran region is characterized by diverse geological formations resulting from the collision of the Arabian and Eurasian plates, including volcanic and sedimentary sequences, turbidite basins, and Quaternary sediments. Makran's rich geological heritage, coupled with its historical importance, make it a prime subject for advanced geoscientific research and mapping.

The Gurdim sheet (Sheet No. 8040-4) is a 1:50,000 geological map produced as part of the SUTGMM project, which aims to provide a detailed geological map of the Makran region. This sheet encompasses 699.33 square kilometers and covers a diverse range of geological features, including alluvial and beach deposits, volcanic and sedimentary sequences, as well as tectonic structures that are integral to understanding the region's geodynamic evolution. The mapped area lies within the coordinates ranging from 60.00°E, 25.25°N to 60.25°E, 25.50°N.

This project integrates data from multiple remote sensing sources such as Sentinel 1, Sentinel 2, Landsat 8, and ASTER, as well as digital elevation models (DEMs) to capture spectral, geological, and topographical information at various resolutions. By leveraging a novel approach that combines cloud computing, machine learning, and object-based image analysis, the SUTGMM project utilizes Google Earth Engine for processing and analyzing large datasets. The random forest algorithm employed for geological classification has enabled the creation of a unified geological map with an accuracy of 85%, emphasizing the efficiency and reliability of this integrated methodology.

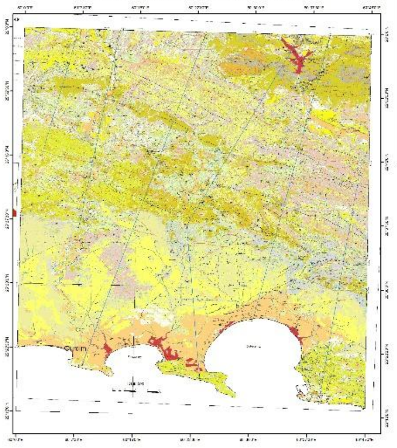
The geological units mapped in the Gurdim sheet represent a time range from the upper Miocene to the Quaternary period. This includes older formations from the upper Miocene and Pliocene, as well as more recent Pleistocene and Quaternary deposits. These units are crucial for understanding the tectonic activity and sedimentary processes that have shaped the Makran region over millions of years.

The GeoNexus geodatabase, as the final product of the SUTGMM project, represents a major advancement in geological mapping by incorporating cloud computing, machine learning, field surveys, and multi-source data integration to enhance the accuracy, efficiency and comprehensiveness of geological outputs. Ultimately, the findings from this study are expected to support sustainable development efforts and foster a deeper understanding of the region's geodynamic processes.



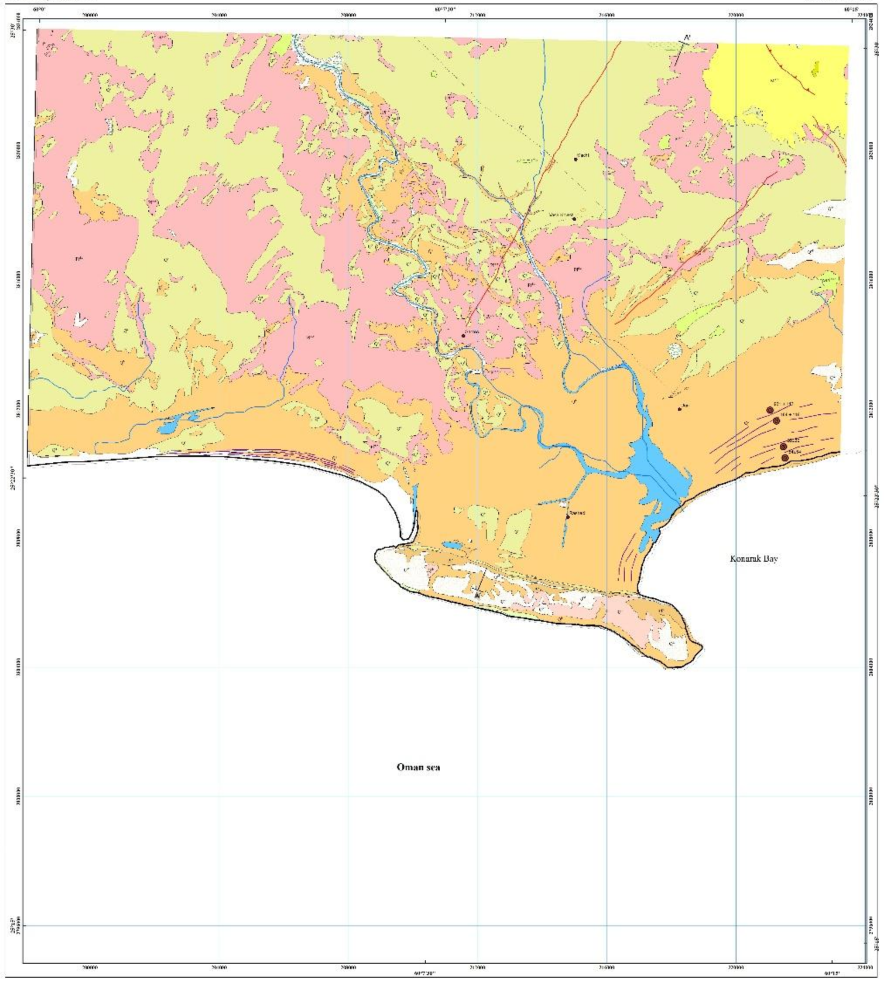
Schematic Paleogeography map (after Hessami, 2002)

Placing the study area in SUTGMM Programme, showing Geological maps in scale 1:50,000

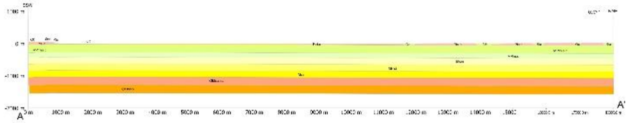


IRAN 1:50,000 SERIES

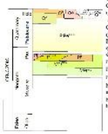
Sheet No. 8040-4

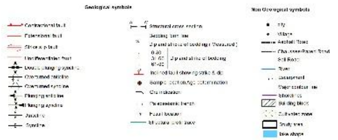


Scale: 1:50,000



EXPLANATION





Legend's time table based on absolute age determination and paleontological studies

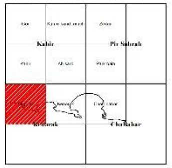
Geo-unit	Absolute age determination	Paleontological studies	Reference
Qt	<=21.3Ky		Gharibreza, 2016 & Dolati, 2010
Qt	<=7.85Ky		Normand 2018 & Shah-hosseini et al. 2018
PlPe		Pliocene- Pleistocene	Dolati,2010
Pl		Pliocene- Pleistocene	Dolati,2010
Pl		Pliocene	Dolati,2010
MPl		Middle Miocene (Serravallian) to Early Pliocene	This study
		L Miocene- E Pliocene	Dolati,2010
MPl		Early Miocene(Burdigalian) to Early Pliocene	This study
		L Miocene- E Pliocene	Dolati,2010
M		Early Miocene (Burdigalian) to Late Miocene (Tortonian)	This study
M		Middle Miocene (Serravallian) to Late Miocene (Tortonian)	This study
		M L Miocene	Dolati,2010
M	13.7 - 6.0M/y		Dolati,2010
		Late Oligocene to Middle Miocene	This study
		Oligocene Late Miocene	Dolati,2010
OlM		Oligocene	Dolati,2010
OlM		Late Oligocene	Dolati,2010
		Early Miocene (late Burdigalian) to Middle Miocene (early Langhian)	This study

SERVER BASED UNIFIED THEMATIC GEOLOGICAL MAP OF THE MAKRAN

GURDIM GEOLOGICAL MAP 1:50,000

Geology: H. Nazari & S. Arefipour & M. [illegible]	Supervisors in chief: H. Nazari
Structural Balanced Section: H. Nazari & S. Arefipour	Petrography: [illegible]
Executive supervisors: A. Zarasvandi & H. Zamanian & K. Moghadam	Paleontology: J. Daneshian & [illegible]
RS & Machine Learning: J. Karami & S. Arefipour	GIS & Digital cartography: S. Arefipour
Projection System: UTM-Z41N : WGS 1984	Sheet No.: 8040-4 / Date: 2024

Map index 1:50000, Red filled sheet showing study area as a part of the SUTGMM Programme limited by brown line.



DESIRED AND NEEDS

Desired goals and achievements:

- Accurate correction of satellite images through modeling in the Google Earth Engine environment and the simultaneous launch of the national parallel processor system.
- High atmospheric modeling of images and with the help of spectral samples.
- Determining the added value of satellite images (multispectral and hyperspectral) based on spectral samples and determining the efficiency of different images.
- Creating ground scale results based on different images.
- Validation of the results of different radar and optical image sources in the preparation of integrated geological and engineering maps.
- Comprehensive geological information, mineralogical analysis, soil mechanics and rock mechanics of the samples in the form of a geoportal (GIS system).
- Presenting a new and up-to-date method in preparing thematic geological maps.
- Preparation of an integrated map of geology, Environment Geology, Mineral resources as well as Engineering geology and Seismotectonics at a scale of 1: 50,000.
- Creating an integrated database of geology, engineering and earthquake-construction
- Equipping and setting up a parallel processing system.
- Equipping and setting up the drone system for high precision coastal mapping.
- Earthquake hazard assessment and tsunami modeling.
- Conducting educational workshops.

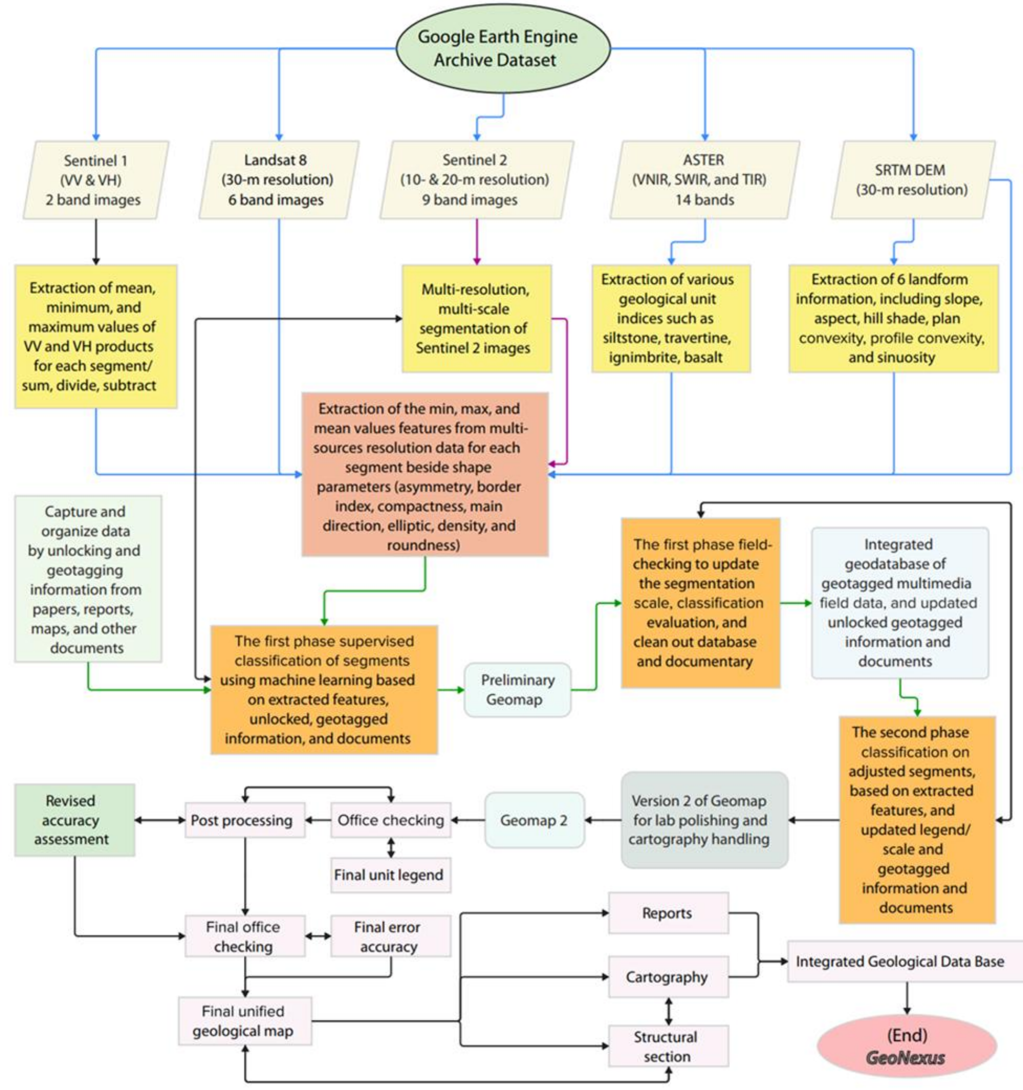
The need for work and the economic approach of the plan:

- The possibility of better detection and more accurate determination of outcrops using accurate ground and satellite information.
- Reducing the high costs of ground sampling.
- Significant reduction of errors in map preparation.
- Detailed analysis of minerals in a superficial and broad way, instead of point analyses.
- Lack of proper development in infrastructure.
- Determining a precise scientific framework in geological studies with satellite data.
- Absence of a local spectral library based on the geological conditions of the country.
- Examining the capabilities and added value of existing satellite images.
- Determining the exact ground scale for spectral measurements.
- Creating a geoportal for geoscience researchers and professionals.
- Knowledge and technology transfer.

TASK FORCES ACTIVITIES

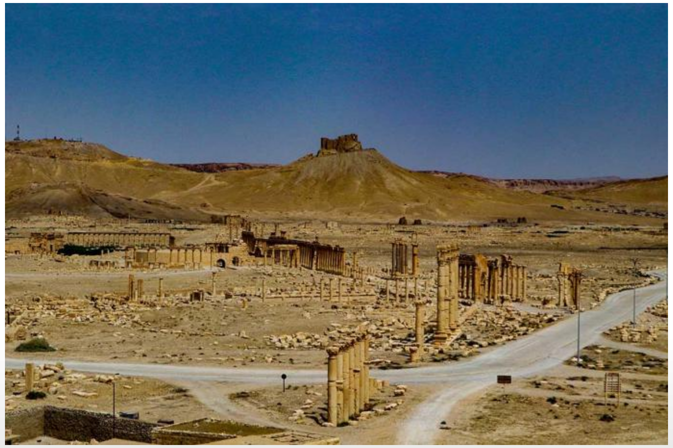
Procedure:

- Unlocking Trapped data on Paper: Collecting information and reviewing past studies
- Checking the collected information and preparing basic geological maps and GEE platform
- Segmentation
- Field opening training workshop of the project
- Presentation of the initial report
- Conducting online field operations and controlling and editing basic maps
- Necessary surveys and sampling
- Preparation of integrated legend during field studies
- Preparation and laboratory studies on samples
- Presentation of the second report
- Modeling and processing of satellite images and reproduction of integrated maps with optimal clustering Preparation of integrated maps at a scale of 1:100,000 with legends and signs
- Transverse Structural Section in the MOVE
- Final control of the map on the ground and additional sampling
- Modification of integrated maps on a scale of 1:50,000 with a legend
- Compilation of the report of thematic geological maps
- Cartography, GIS and final digitization
- Preparation of database
- Designing and setting up a parallel processing system
- Using and operationalizing the drone system for accurate coastal mapping
- Presentation of final reports and maps
- Making referee corrections
- Seminar at the end of the project
- The final training workshop of the project
- WebGIS backup



PARTICIPANTS

UNESCO Chair on
Coastal Geo-Hazard Analysis
Research Institute for Earth Sciences
Geological Survey of Iran
unesco
Chair



COST

- Personnel expenses
- The cost of necessary trips, including the cost of tickets, accommodation, food and transportation
- Laboratory costs
- The cost of devices, equipment, and materials needed to be purchased from the project credit facility
- Parallel processing system cost
- The cost of the drone system
- Short Well drilling costs
- Meeting and workshops
- Other expenses
- Total costs
- Tax and other Statutory deductions

Estimated Cost per kilometer square 25 US $

DESIGNER AND SCIENTIFIC PERFORMER

Hamid Nazari
UNESCO Chairholder
Research Institute for Earth sciences
Geological Survey of Iran,
Azadi SQ., Meradj Blv.,
P.O. Box :13185-1494,
Tehran-Iran
Code Postal : 1387835841
Tel:(+98) 021- 66070518
Fax:(+98) 021- 66070511
h.nazari@ries.ac.ir
hamidnazarii@gmail.com
uccgha.ries@gmail.com
https://unescoiran.com/

Biography

Born on February 18, 1968, in Tehran, Iran, the candidate is a highly accomplished geologist with proficiency in Persian, French, and English. Since 2021, he has held the prestigious position of UNESCO Chairholder in Coastal Geo-Hazard Analysis, reflecting his expertise and leadership in the field. His academic and professional journey includes serving as Vice-Director and Deputy of Research (2009–2021) at the Research Institute for Earth Sciences (RIES), where he currently heads the Innovation Department.

He holds a Bachelor’s and Master’s degree in Geology from Iranian universities, followed by a PhD in Paleoseismology from Université Montpellier II, France (2002–2006). His academic pursuits continued with a Post-Doctorate in Active Tectonics at the University of Cambridge, UK (2007–2011), and culminated in the attainment of the Habilitation à Diriger des Recherches (HDR) in Science of the Universe from Université de Montpellier, France, in 2015.

With over three decades of professional experience at the Geological Survey of Iran (GSI) and RIES, he has established himself as a leading expert in geohazards, geo-archaeology, paleoclimatology, and, more recently, the application of machine learning and artificial intelligence in geological mapping. His extensive international scientific collaborations and close engagement with the United Nations Educational, Scientific and Cultural Organization (UNESCO) underscore his global impact in the field. He has authored numerous publications indexed in the Web of Science (WOS), further solidifying his contributions to the scientific community.

In addition to his scientific endeavors, he is a recognized social activist and critical socio-political analyst in Iranian media. Since 2025, he has been the founder and CEO of Intelligent Geo-Mine Co., a pioneering enterprise leveraging advanced technologies in geological and mining applications.