



UNESCO Chair on
Coastal Geo-Hazard Analysis

Research Institute for Earth Sciences
Geological Survey of Iran



SUTGMO PROGRAMME

Server based Unified Thematic Geological Mapping in Oman

2024-2027

The SUTGMO PROGRAMME

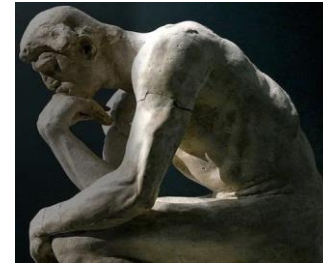
The Server based Unified Thematic Geological Mapping in Oman Programme (**SUTGMO**) is an Bilateral/ International multi-disciplinary geological mapping in cloud computing approached Machine learning and AI sponsored by Omani Government.

This 3-Years programme aims at preparing a The Server based Thematic Geological Maps in territory of the Sultanate of Oman in scale of 1:50,000.

SUTGMO drive together a group of specialists whose expertise includes several domains of Geology, Remote sensing, Programming and Machine learning and Artificial Intelligence. One of the main feature of SUTGMO is transferring of the knowledge and technology as well as close relationships that develop between Iranian and Omani specialists under umbrella of the UNESCO Chair on Coastal Geo-Hazard Analysis (UCCGHA), through common field works and workshops organized during the programme.



OBJECTIVES



The **SUTGMO** program is ultimately designed to (1) provide new and modern information on server-based integrated thematic geological maps of the Omani domain 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 literature dealing with Omani geology, (1) to establish a synthesis of the complex polyphase tectonic and stratigraphic evolution of the main sedimentary and orogenic basins which developed in the Omani domain, 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 generated geology, and (4) data sharing and knowledge and technology transfer.



ZONE OF INTEREST

The entire territory (~309,000 km²) of the Sultanate of Oman is limited to the Strait of Hormuz and the Gulf of Oman in the north and the Arabian Sea in the east.

WORKING METHODE

Preface:

Server-based thematic mapping is the process of creating and displaying maps that show the spatial distribution of a theme or topic, such as population density, climate, or land use, using a server that hosts the data and the mapping software. Cloud computing is the delivery of computing services, such as servers, storage, databases, networking, software, analytics, and intelligence, over the internet.

AI or artificial intelligence is the use of computer systems to perform tasks that normally require human intelligence, such as data analysis, image recognition, natural language processing, and decision-making. AI has many potential applications in geology and hazard assessment, such as improving data collection and handling, enhancing modeling and prediction, and providing effective communication. AI and machine learning are techniques that enable computers to perform tasks that normally require human intelligence, such as data analysis, image recognition, natural language processing, and decision-making.

Precise identification and mapping of geological formations is crucial for geological research, environmental conservation, and natural resource exploration. The typical technique for mapping rock formations via remote sensing entails manually digitizing aerial photos or digital images or classifying individual pixels based on spectral characteristics using traditional classification methods on desktop systems. While this method is quicker and simpler than more advanced mapping techniques, it can occasionally possess misclassified pixels with similar spectral properties. This can lead to less precise mapping and also limitations for expansive regions.

Over the last few years, there has been a notable increase in the adoption of server-based cloud computing and Object-Based Image Analysis (OBIA) for geological mapping. This approach has proven to be cost-effective and efficient, particularly in a cloud computing environment, due to its ability to seamlessly integrate data from various sources and solutions while effectively managing complex geological features across vast areas. With its unique ability to consider the spatial context of objects, OBIA can distinguish between different geological features, aiding in precise identification.

The geological thematic maps, known as the second generation of geological maps, offer quick and efficient studies, integration of legends and geological units, and a significant reduction in the analysis and update of information to a global standard. In simpler terms, these maps are designed to provide a faster and more comprehensive understanding of geological data, making it easier to analyze and update information on a global scale. On the other hands, server-based unified thematic geological mapping in cloud computing is a modern approach to geological mapping that utilizes cloud-based servers to store and process geological data.

With this approach, geological data can be easily accessed and analyzed by different users from various locations. It allows geological surveys to be conducted more efficiently and at a lower cost. Cloud computing provides a cost-effective solution for storing and processing large amounts of data. It also allows geologists to collaborate with one another in real-time and share their findings instantly. With the advent of advanced technology and knowledge, there has been a shift towards liberalization and public access to medium and large-scale spatiotemporal data. This includes over three decades of continuous monitoring of the earth's crust using multisensory satellites in different orbits, which are now available on a public platform for research, government and commercial use. Access to pre-existing location-based data, fast processing in a server's cloud environment with pre-prepared samples, and the ability to load additional data have opened up new perspectives for the use of multisensory and server satellite data.

The main advantages of server-based unified thematic geological mapping in cloud computing are that it allows for the integration of different geological datasets from various sources. This helps to create a complete and more accurate geological map. The integration of different datasets also enables geologists to identify new patterns and trends in geological data that may not have been visible before. Furthermore, cloud-based servers allow geologists to access and analyze geological data in real-time, which can help to speed up the decision-making process during a geological survey. Another advantage of server-based unified thematic geological mapping is that it enables geologists to use advanced analytical tools to analyze geological data. These tools can help to identify relationships between different geological features, such as rock formations and fault lines. They can also help to identify areas that are likely to have mineral deposits or other geological resources. By using these tools, geologists can create more accurate and detailed geological maps that can be used for a variety of purposes, including mineral exploration, environmental management, and land-use planning.

The process and quality of producing server-based thematic maps depend largely on the input data, both pre-existing and generated data, during the geological study process. Choosing the right platform for processing information, spectral data and radar for satellite images, and even using aerial photographs suitable for the desired scale plays a crucial role in preparing and increasing the accuracy of the initial map. Field observations and sampling combined with laboratory results can help achieve maximum and possible final accuracy in the verification process. Rehabilitation and optimization of age, lithological, and geochemical data of each separated rock unit, in addition to using significant information published from the integration of laboratory data obtained from multiple stages of field control, are also important. Field verification based on the initial map, the possibility of access and targeted observation one or more times separated from each rock unit resulting from the process of data processing and satellite images, not only in the quadrilateral area of the map, but even beyond the study area cover. The nature of layered and multiple processing of spatial information and its online integration with pre-existing data, both in the area and in the surrounding areas, are among the factors that determine the final uncertainty coefficient in proportion to the amount and accuracy of processed information and data set.

Doing this process not only improves the accuracy and uncertainty of server-based second-generation geological maps from qualitative coefficient (speculation) to numerical coefficient, but also determines the error coefficient of each unit relative to the surrounding unit. However, at the end of this stage, not only is it possible to edit and correct (manually) point-by-point map correlations with satellite and aerial imagery with higher accuracy, which is necessary.

Second generation geological-thematic maps mean: rapidity of studies, integration of legends and geological units, significant reduction in the use of instrumental analysis, simultaneous saving of the process of updating information production with precision and global standards. So, due to the increasing geopolitical limitations and risks of geological surveys and mineral exploration in border or limited access areas, the use of a new method such as this protocol seems very useful and informative.

High precision, rapid project implementation and cost reduction up to 10 times compared to traditional mapping methods could be mentioned as important markers of the new protocol.

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). The aim of the pilot project 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.

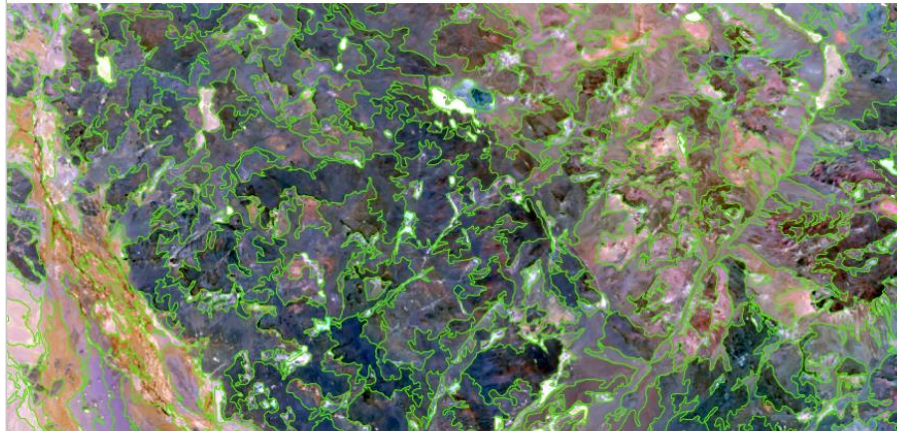
The project's achievements in the preparation of an integrated and homogeneous geological map in the western Lut area include innovation in methods and procedures, fast and accurate data production, an integrated method for online geological studies, cost and time savings in engineering, exploration, 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 encyclopedia of earth sciences, and providing hardware and software platforms for the preparation of three-dimensional geological maps.

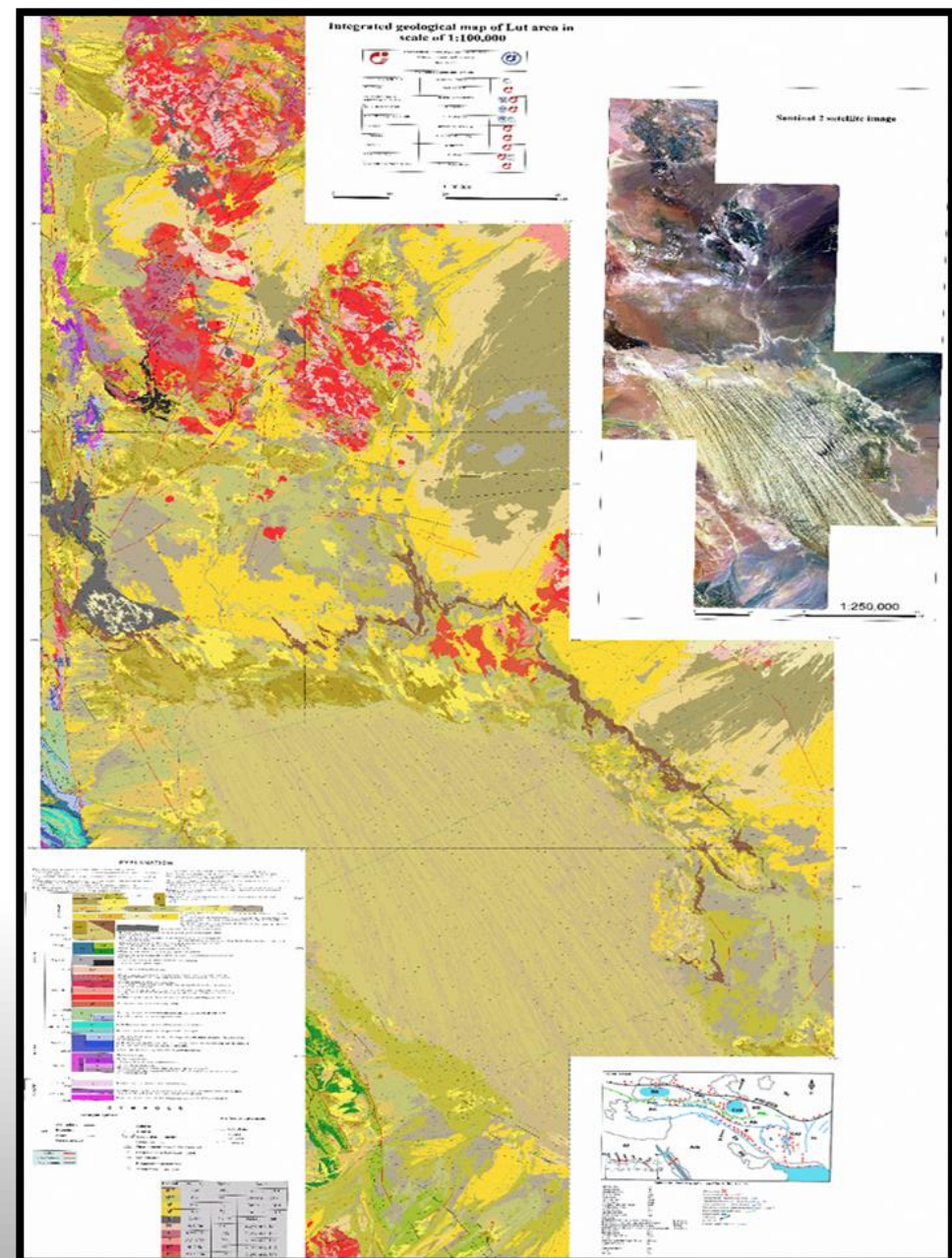
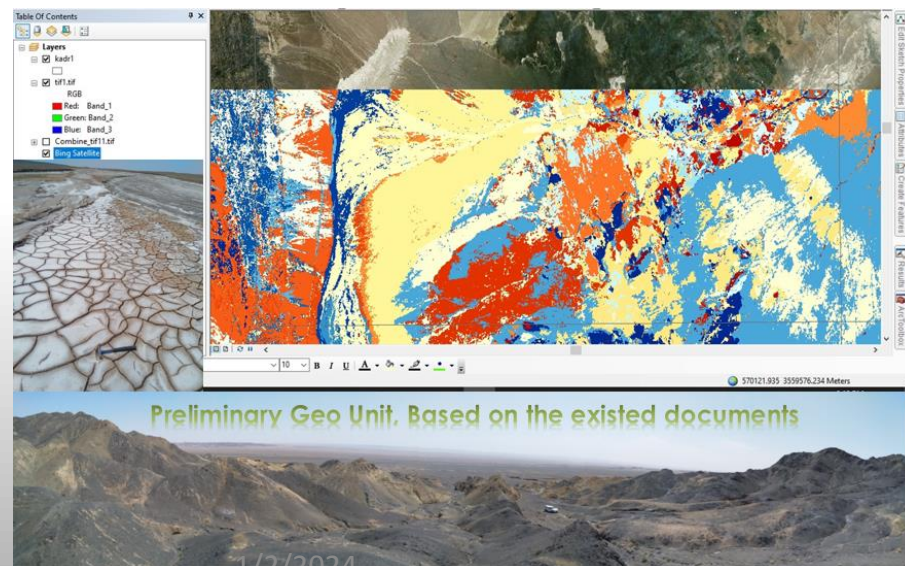
This research satisfied four counters of artificial intelligence in the field of machine learning: transfer learning, few-shot learning, reinforcement learning, and meta-learning.



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



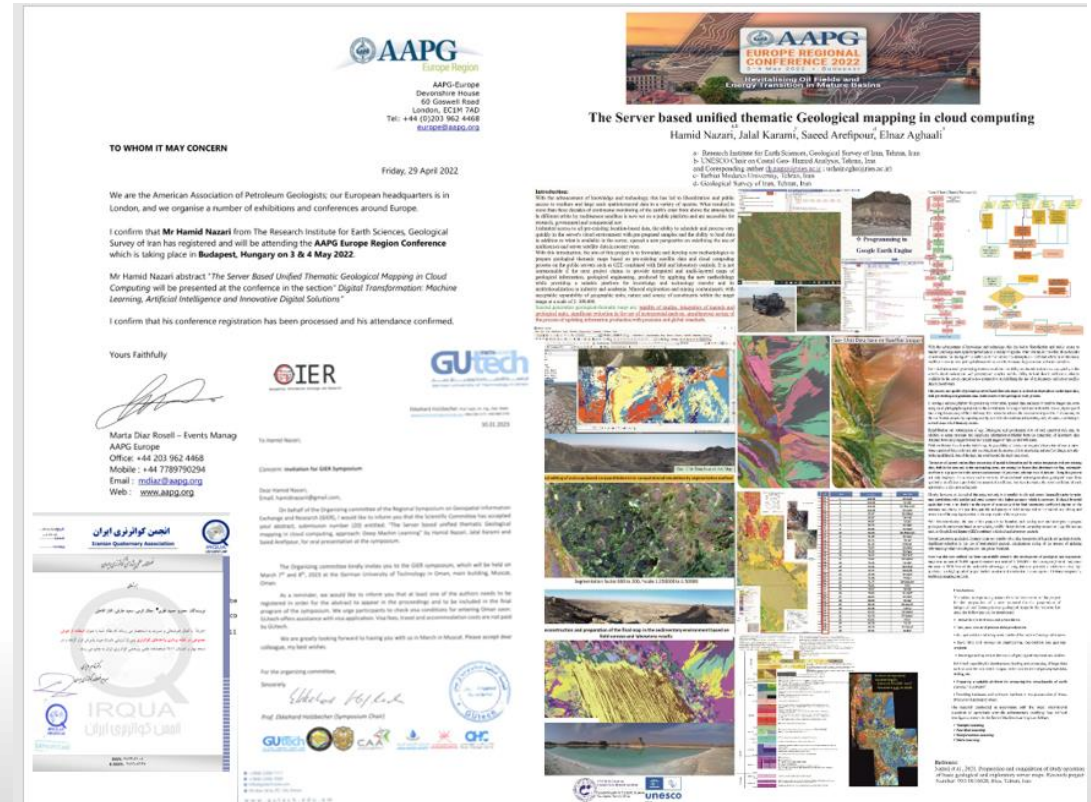
RELEVANT PUBLICATIONS

Karami J., **Nazari H.**, Arefipour S., Mousivand AJ., (2024). Cloud Computing-Aided Unified Object-Based Geological Mapping Using Data Mining and Machine Learning on multi-resolution data, Lut Desert, Iran, (Under Revision in the Remote Sensing of Environment).

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., (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., (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.



SUTGMO PRODUCTS

The Sultanate of Oman, with an area of approximately 309,000 Km² has become a major destination for geotourism and an increasing number of visitors are attracted by the spectacular outcrops that the country has to offer, which is covered by 129 sheets of geological maps at a scale of 1: 100,000 or 515 sheets of maps at a scale of 1: 50,000.

Due to time constraints, in addition to the very high international cost of preparing geological thematic maps with traditional methods, with all the problems caused by the inconsistency and heterogeneity of borders and legends in information layers such as: Geology, Exploration of mineral resources, Environmental geology and Engineering Geology at a scale of 1: 50,000. Nationwide coverage of a geologically diverse country in the Oman region requires either more than 150 operational teams for 3 years or 15 teams for more than 10 years. Meanwhile, the use of new instructions in the preparation of integrated base server maps, similar to what was mentioned above, allows for nationwide mapping in a three-year period with much higher accuracy and speed and much lower cost.

So, from a strategic point of view, the development of integrated thematic geological maps based on the Server in the path of sustainable development and economic resilience, both in the production of national wealth by providing the necessary mineral resources to the country for future, that in preserving national assets by assessing hazards such as climate change, floods and earthquakes and their rates in relation to national GDP over a short period seems not only very economical but also very important.

In this way, the UNESCO chair on Coastal Geo-Hazard Analysis and its wide network of partners and colleagues and world-renowned scientists and experts, including the country of Oman, within the framework of the scientific council, will be a suitable platform to ensure the training and implementation of such a pioneering project.

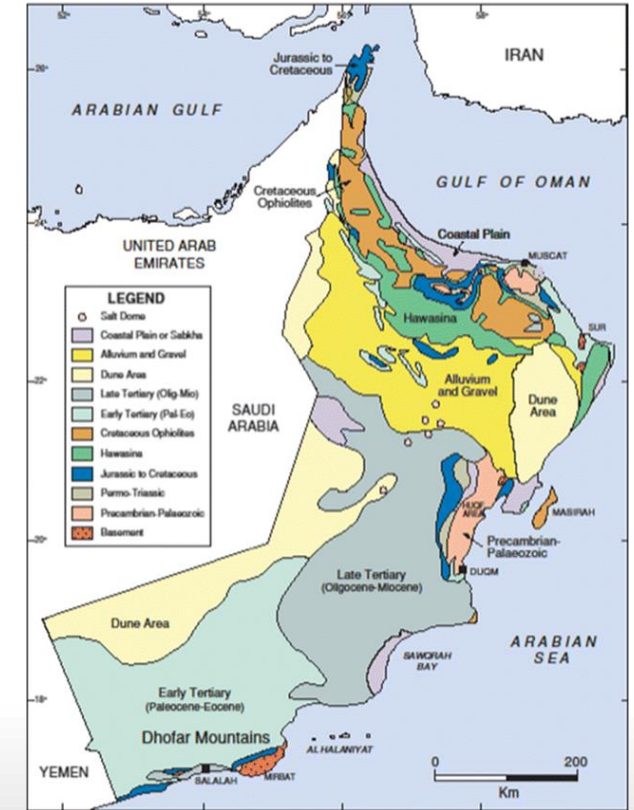


SCIENTIFIC PROGRAMME

The Server Based Thematic Geological Mapping in the Sultanate of Oman: scale: 1:50,000

Oman's geology includes diverse landscapes that are a blend of its geological history and climate over the past millions of years. The rock outcrops of Mount Hajar, Huqf and Dhofar are a point of interest for international geologists. The rock record spans about 825 million years and includes at least three periods when the country was covered in ice. Oman, located at the southeastern corner of the Arabian Plate, is slowly being pushed northward as the Red Sea widens. The high mountains of Hajar and the drowned valleys of Musandam are dramatic witnesses to this. Generally speaking, Oman is tectonically quite calm. Musandam experiences occasional tremors when the Arabian plate collides with the Eurasian plate. During the Cretaceous, Oman was adjacent to a subduction zone and part of the upper mantle and overlying seafloor volcanics were pushed onto the continental crust. This obductive sequence of ultramafic to mafic rocks is the Semail Ophiolite Complex. The ophiolite is locally rich in copper and chromite deposits.

The interior plains of Oman consist of young sedimentary rocks, wadi gravels, dune sands and salt flats. Beneath is a miles-thick stack of older sedimentary rocks that host the country's hydrocarbon resources. Ancient salt, which comes to the surface in many salt domes like Qarat Kibrit, plays an important role in the formation of many of these oil and gas accumulations. Recently, by overweighing the possible underground hydrogen methods and based on Oman's geology, deep aquifers were not suitable for hydrogen storage. Although, Salt basins are good candidate for underground storage; due to the large salt basin in Oman, salt caverns are known to successfully contain hydrogen and the guaranteed safety of the storage.



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:

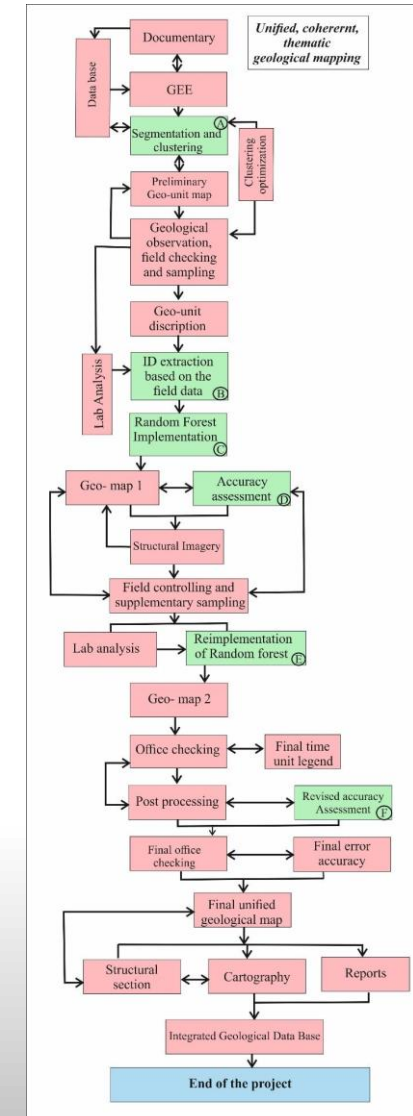
- The possibility of better detection and more accurate determination of outcrops using accurate ground and satellite information.
- Reducing the high costs of ground sampling.
- Significant reduction of errors in map preparation.
- Detailed analysis of minerals in a superficial and broad way, instead 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:

- 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 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



PROJECT SCHEDULE

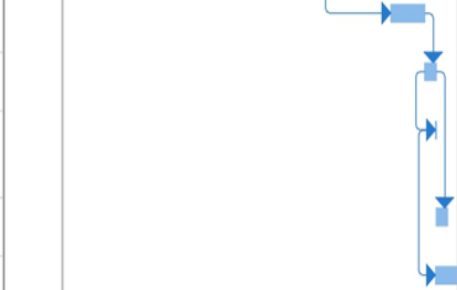
Row		Weight percent	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	Gathering information and buying equipment	4%	30 days																							
2	Checking the collected information and preparing geological base maps and GEE platform	10%		90 days																						
3	Field opening training workshop of the project	1%				20 days																				
4	Presenting a preliminary report					20 days																				
5	Parallel processing system	3%					60 days																			
6	Field study, controlling and editing basic maps (10 field teams)	10%																								
7	Necessary scrolling and sampling	5%																								
8	Preparation of integrated legend during field studies	4%																								
9	Preparation and laboratory studies on samples	7/5%																								

DETAILED SCHEDULE

(MS PROJECT)





ID		Task Mode	Task Name	Duration	Start	Finish	Predecessors	2024 H1	H2	2025 H1	H2	2026 H1	H2	2027 H1	H2	2028 H1
25			Presenting final reports and maps	90 days	Mon 12/04/27	Sun 25/07/27	22SS+150 days									
26			Do referee corrections	30 days	Mon 26/07/27	Sun 29/08/27	25									
27			Conference at the end of the project in Tehran	2 days	Sat 28/08/27	Sun 29/08/27	26SS+28 days									
28			practical training workshop	30 days	Mon 30/08/27	Sun 03/10/27	26									
29			Pay 100% of the contract amount	60 days	Sat 28/08/27	Thu 04/11/27	27SS									
Project: - Date: Mon 01/01/24			Task		Inactive Summary		External Tasks									
			Split		Manual Task		External Milestone									
			Milestone		Duration-only		Deadline									
			Summary		Manual Summary Rollup		Progress									
			Project Summary		Manual Summary		Manual Progress									
			Inactive Task		Start-only											
			Inactive Milestone		Finish-only											
Page 3																

PARTICIPANTS



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 US \$



DESIGNER AND SCIENTIFIC PERFORMER

Biography

Birthday on February 18th 1968 in Tehran-Iran; Languages: Persian, French and English; UNESCO Chairholder of Coastal Geo-Hazard Analysis since 2021, former Vice-Director and Deputy in Research (2009- 2021) in Research Institute for earth Sciences (RIES), and current Head of the Innovation department in RIES; Bachelors and Masters in Iranian universities in Geology and then 2002-2006 educated as PhD student in Paleoseismology from Université Montpellier II in Montpellier- France; Post Doctorate in Active Tectonics from Cambridge University, Cambridge-UK between 2007-2011 and the HDR (Habilitation à Diriger des Recherches) in Science of Universe from Université de Montpellier in Montpellier- France at 2015.

A Geologist with more than three decades of professional experience at the Geological Survey of Iran (GSI) and the Research Institute of Earth Sciences (RIES) as well as a social activist and a critical socio-political analyst in the Iranian media, who has extensive formal experience in many international scientific collaborations in the field of geohazards, geo-archaeology, paleoclimatology and recently machine learning and AI in geological mapping and working closely with the Organization of the United Nations for Education, Science and Culture as UNESCO Chairholder, with numerous WOS publications.

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/>

