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

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SUTGM PROGRAMME:

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

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

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Preface:

This manuscript explores the concept of server-based thematic mapping and its integration with Cloud Computing, AI, and Object-Based Image Analysis (OBIA) for geological mapping applications. The study highlights the advantages of utilizing AI and machine learning for tasks that traditionally require human intelligence, such as data analysis and classification. Precise identification and mapping of geological formations are essential for geological research, natural resource exploration, and environmental conservation. The traditional method of mapping rock formations via remote sensing has limitations in terms of precision and efficiency, especially for expansive regions. The adoption of server-based cloud computing and OBIA has revolutionized geological mapping by offering a cost-effective and efficient solution for handling complex geological features over vast areas. The integration of different geological datasets from various sources enables the creation of comprehensive and accurate geological maps, thereby facilitating enhanced data analysis and decision-making processes in geological surveys. Cloud-based servers enable real-time collaboration among geologists, streamline data processing, and provide access to advanced analytical tools for identifying relationships between geological features. The shift towards liberalization and public access to spatiotemporal data, including multisensory satellite data, has opened up new possibilities for

geological research and exploration. The benefits of server-based unified thematic geological mapping in cloud computing lie in its ability to integrate diverse geological datasets, identify new patterns in geological data, enable real-time data analysis, and utilize advanced analytical tools for creating detailed geological maps for various applications. The manuscript emphasizes the importance of input data quality, field observations, laboratory results, and continuous verification processes to enhance the accuracy of geological maps. The new protocol presented in this study offers high precision, rapid project implementation, and significant cost reductions compared to traditional mapping methods, making it a valuable approach for geological surveys in challenging terrains with geopolitical limitations and risks.

Introduction: Geological mapping, an essential practice for geological research, environmental conservation, and natural resource exploration, traditionally involved manual methods using remote sensing, which could be limited in precision for expansive areas. However, the advent of server-based thematic mapping and cloud computing has transformed this process, offering cost-effective, efficient solutions for handling complex geological features on a larger scale. Cloud computing, delivering various computing services over the internet, AI, and machine learning play vital roles in enhancing geological mapping processes. These technologies enable tasks such as data analysis, image recognition, and decision-making, thereby improving data collection, modeling, and communication in geology and hazard assessment. The shift towards server-based unified thematic geological mapping in cloud computing has revolutionized geological surveys by allowing the integration of diverse geological datasets, real-time collaboration, and access to advanced analytical tools. This approach enables quick and efficient studies, integration of geological units, and a reduction in information analysis/update processes on a global scale. Field observations, laboratory results, and continuous verification processes are crucial in ensuring the accuracy of geological maps. The advanced protocol discussed in this context offers high precision, rapid project implementation, and significant cost reductions compared to traditional methods, making it highly beneficial for geological surveys in challenging terrains with geopolitical limitations and risks. Moreover, advancements in technology have facilitated liberalization and public access to spatiotemporal data, including multisensory satellite information, enhancing geological research possibilities. The integration of various data sources and advanced analytical tools in cloud computing allows geologists to create detailed and accurate geological maps for diverse applications, improving mineral exploration, environmental management, and land-use planning efficiency. By combining clustering, field checking, and Random Forest machine learning algorithms, we have effectively extracted relevant features from remote sensing datasets to create unified thematic geological maps of significant areas in Iran, specifically the Lut Desert and the Makran area in Southeast Iran. The incorporation of clustering techniques helps in grouping similar geological features based on their attributes, while field validation ensures the accuracy and reliability of the data collected. Additionally, the utilization of Random Forest machine learning algorithms enhances the classification of geological units by training the model on the collected data to make predictions about new samples. In other hands, a combination of remote sensing technologies, field data collection, and advanced algorithms on the Google Earth Engine platform, the study aims to enhance the accuracy and efficiency of mapping rock units in the targeted area, showcasing the integration of cutting-edge technologies for geological analyses and mapping applications. This integrated approach not only streamlines the mapping process but also enables a more holistic understanding of the geological landscape, facilitating more informed decision-making in areas such as mineral exploration, environmental planning, and hazard assessment. Furthermore, by focusing on these specific regions with unique geological characteristics, the study contributes valuable insights that can benefit various research, government, and commercial initiatives in Iran. Overall, our study showcases the power of merging advanced technologies with traditional geological mapping approaches to produce comprehensive and accurate geological maps, opening up new possibilities for leveraging remote sensing data in geospatial analysis and resource management.

Geological Setting: Central Iran, situated between the active Alborz Mountains in the north and the Sanandaj-Sirjan zone in the south, is a region of geological importance characterized by active strike-slip faults and low GPS deformation rates. The Central Iran Block (CIB) within the Iranian Plateau plays a crucial role in accommodating the dextral shear resulting from the interaction between the Arabian and Eurasian tectonic plates, driven by the Zagros collision domain to the west and the Makran subduction zone to the east. In Western Central Iran and the Lut borders, a network of dextral faults, including the Dehshir, Anar, Nayband, Gowk, West Neh, Kahurak, East Neh, Assaghi, Nosratabad, and Zahedan faults, is present. The Nayband fault acts as the north-south boundary between the Lut and Tabas blocks. The Tabas block in Central Iran features higher elevations (up to 3000 m above sea level), while the Lut block in eastern Iran has lower, flatter terrain (<500 m above sea level). The Lut Desert, influenced by the Nayband and Neh faults, displays a diverse geological evolution with sedimentary, igneous, and metamorphic rocks spanning from the Precambrian to the Holocene era. This geological history has been shaped by tectonic activities, erosion, redeposition, and climatic changes, leading to the development of extensive dunes and desert landforms that define the unique landscape of the Lut Desert. In the southeastern part of Iran and southwestern Pakistan lies the storied Makran region, boasting a historical legacy spanning over 3000 years. Bounded by the Minab-Sabzevaran fault system to the west and the Chaman-Ornach-Nal fault system to the east, with the Oman Sea to the south, the nearly 1000-kilometer-long Makran wedge is witnessing escalating urbanization along its sparsely inhabited and pastoral coastline. The Makran Subduction Zone (MSZ) running along the coasts of Pakistan and Iran holds significant importance for tectonic activities, particularly earthquakes and tsunamis, ranking as the second most seismically active area in the Indian Ocean, following Indonesia. The catastrophic Makran earthquake of 1945 triggered a tsunami that resulted in casualties spanning Oman, Northern India, and the Seychelles, underscoring the seismic hazards inherent to this region. The continuous subduction of the Arabian plate beneath Central Iran and Afghanistan, initiated during the Cretaceous epoch, remains pivotal in shaping the tectonic landscape of the area. Geodetic measurements via GPS indicate a convergence rate of approximately 2 cm/year between the Arabian and Eurasian plates within the Gulf of Oman, emphasizing the dynamic tectonic processes unfolding in this locale.

Disscusion: SUTGM Programme based on Server-based thematic mapping, cloud computing, and artificial intelligence (AI) as a revolutionizing geological mapping technique. Integration of Object-Based Image Analysis (OBIA) in a cloud computing environment has shown remarkable cost-effectiveness and efficiency, particularly in handling complex geological features over extensive areas. This approach enables precise identification and mapping of geological formations, crucial for geological research and natural resource exploration. Traditional mapping methods, relying on manual digitization of aerial photos or spectral pixel classification, have limitations in precision and scalability. The shift towards server-based cloud computing and OBIA has accelerated the production of second-generation geological thematic maps, offering faster, more comprehensive insights with improved accuracy to a global standard. The introduction of unified thematic geological mapping using cloud-based servers has further streamlined data access and analysis, promoting efficient geological surveying at reduced costs. By allowing real-time collaboration among geologists and advanced analytical tools for relationship identification among geological features, this modern approach enhances decision-making during geological surveys. The innovative methodology presented in this research leverages OBIA techniques in a cloud computing setting, integrating clustering, field checking, and Random Forest (RF) machine learning algorithms to map geological rock units with high accuracy. Achieving an overall mapping accuracy of ~85% in the Lut Desert and the Makran area underscores the effectiveness of this methodology in geological mapping. The research emphasizes the importance of utilizing diverse remote sensing datasets like Sentinel-2, Sentinel-1, Landsat-8, ASTER, and Digital Elevation Model (DEM) for detailed geological analyses. Integration of these datasets in the Google Earth Engine (GEE) platform enables comprehensive and accurate geological mapping in remote terrains. Segmentation processes using higher-resolution Sentinel-2 images have been crucial in identifying and classifying geological features, paving the way for clustering and classification analyses. By optimizing segmentation parameters and conducting field observations for accuracy assessment, the study ensures robust validation of remote sensing analyses for geological mapping. The deployment of the Random Forest algorithm for classification tasks based on spectral and spatial characteristics has proven effective in delineating rock unit boundaries and creating detailed geological maps. This approach offers valuable insights for future geological research, resource management, and environmental conservation. The strategic implications of this research, aligning with sustainable development goals and economic resilience, highlight the potential for integrated thematic geological mapping to support national wealth production, hazard assessment, and natural resource exploration. The utilization of advanced technologies like AI in geological mapping signifies a shift towards more efficient, cost-effective, and accurate mapping methodologies with broad applications in the field of earth sciences.

Pilot project: Our study introduces an innovative approach for rock unit mapping by employing Object-

Based Image Analysis (OBIA) techniques within a cloud computing environment. Through the integration of clustering, field validation, and Random Forest (RF) machine learning algorithms, we have successfully extracted pertinent features from diverse remote sensing datasets. This investigation has led to the development of a novel protocol for geological mapping, which has been tested in the vast expanse of Iran's Lut Desert (~30000km2) and later in the approximately 5000km2 southeastern region of Iran in the Makran area. The primary objectives of these pilot projects were to formulate and implement new methodologies for the creation of geological thematic maps using pre-existing data such as satellite imagery and processing in cloud computing environments, such as the Google Earth Engine (GEE), combined with comprehensive field and laboratory validation. By implementing our RF methodology within a cloud computing framework, we were able to effectively handle extensive datasets and enhance computational efficiency. This approach offers a precise and efficient alternative to traditional geological mapping, thus supporting natural resource exploration and environmental management. Our research provides valuable insights into geological evolution while enhancing the scalability and efficiency of thematic mapping procedures.

Methodology and Dataset: In this study, various remote sensing (RS) datasets were utilized to map rock units in the Lut Desert and Makran zone of

Iran. The datasets used include Sentinel-2, Sentinel-1, Landsat-8, ASTER, and Digital Elevation Model (DEM) .These datasets, particularly the detailed spectral information from ASTER and the reliable insights from Sentinel-1's radar data, along with topographic data from DEM, are crucial in generating geological maps of a part of the Lut and the Makran in Iran. The object-based rock unit mapping conducted in the Google Earth Engine (GEE) environment showcases the significance of integrating multiple RS datasets for comprehensive and accurate geological analyses in remote and challenging terrains like the Lut Desert and the Makran.

Segmentation: In the context of segmentation, higher-resolution images are often preferred as they offer more detailed information about objects and features in an image, aiding in accurate identification and classification based on specific criteria (Chen et al., 2018). For this study, Sentinel-2 images were chosen for segmentation due to their higher spatial resolution compared to other available images. The Sentinel-2 (MSI) images have a spatial resolution of 10-20 meters, enabling a more detailed analysis of geological features in the Lut Desert study area. Shape and scale are crucial parameters in image segmentation as they help control the size and shape of extracted objects from the image. These parameters play a significant role in object-based image analysis, where images are segmented into meaningful objects based on criteria such as texture, color, or shape. Following optimization of shape and scale parameters, the segmentation process was applied to the Sentinel-2 image dataset of the Lut Desert. The segmentation results, depicted in Figure 5, laid the groundwork for subsequent analysis, including clustering and classification of geological features in the region . By utilizing high-resolution Sentinel-2 images and optimizing segmentation parameters, the study aimed to enhance the accuracy of geological feature identification and classification in the Lut Desert, highlighting the importance of detailed image analysis for meaningful object-based image processing and analysis.

Random Forest: Random Forest is a popular ensemble learning algorithm used for classification and regression tasks due to its high accuracy and robustness in handling complex datasets. In remote sensing and geospatial analyses, Random Forest can classify image objects into different land cover or rock types based on their spectral and spatial characteristics. This study utilized Random Forest to classify image segments generated from clustering and field-checking outcomes. The algorithm used a variety of features from remote sensing data, segmentation, and field measurements to classify image objects into rock unit classes. The model's accuracy was evaluated using metrics such as overall accuracy and kappa coefficient, with varying results between training and testing data, indicating potential overfitting on the training data. An analysis of input features' importance showed that morphological features and Sentinel-1 radar products were crucial in distinguishing rock units. The application of Random Forest offered a flexible and powerful approach for creating detailed geological maps from remote sensing and field data. By delineating rock unit boundaries, a comprehensive geological map of the Lut Desert as well as Makran zone in the Coastal and the Outer zone were developed, providing valuable insights for future research and resource management. The study's findings were visually presented through maps showcasing the geological features of the area.

Accuracy assessment: The accuracy assessment section of the scientific manuscript examines the vital role of field observations and ground-truth data in validating remote sensing and geospatial analyses, particularly in the context of geological mapping and mineral exploration. Field checking procedures were employed to evaluate the alignment of clustering outcomes and verify rock unit assignments. By collecting geological data and rock type information, the study team compared these findings with clustering IDs generated from the analysis, leading to the refinement of clustering results from 40 to 37 clusters. The subsequent application of the Fuzzy C-Means (FCM) clustering algorithm based on field observations allowed the segmentation of images into the revised clusters, with each cluster manually labeled according to rock unit names. This thorough validation process demonstrated a strong correlation between the assigned rock units and observed geological features in the field, enhancing the accuracy and reliability of the geological mapping process. Furthermore, the refined cluster labels derived from field checking served as inputs to train the Random Forest algorithm for additional analysis, ensuring that adjustments based on ground-truth data were integrated to maintain accuracy and reliability throughout the study. To provide a quantitative evaluation of the classification model's performance, a confusion matrix was employed as a visual tool in machine learning. This matrix depicted the accuracy of the model in predicting various classes by comparing true class labels with predicted class outcomes. By visually representing the model's predictive performance, the confusion matrix offered valuable insights into classification accuracy, misclassifications, and areas for potential improvement within the model. The comprehensive analysis presented in the confusion matrix allowed for a detailed examination of the model's performance across different classes, highlighting both its strengths and weaknesses. By identifying misclassifications and areas for enhancement, the confusion matrix aided in optimizing the model's accuracy and refining its predictive capabilities for future applications in geological mapping and mineral exploration. The study showcased the successful integration of multi-source and multi-resolution remote sensing data with machine learning algorithms within a Cloud Computing environment for rock unit mapping in the Lut and Makran regions. Through an object-based methodology, the researchers achieved precise and detailed thematic maps suitable for a range of geological and environmental applications. This innovative protocol offers distinct advantages, including high accuracy, expedited project execution, and substantial cost savings compared to conventional mapping techniques. The research underscores the importance of quality and diverse remote sensing data, highlighting the efficiency gains facilitated by Cloud Computing in managing and processing extensive datasets effectively. By adhering to international standards and leveraging cutting-edge advancements in Machine Learning, this study establishes a benchmark for future endeavors in geological surveys and remote sensing applications. The programme's accomplishments in generating integrated and coherent geological maps in the western Lut Desert and the Makran area, covering the Coastal and Outer Makran zones, involve methodological innovations, rapid and precise data acquisition, an integrated platform for online geological research, cost and time efficiencies in engineering and exploration projects, optimization of geological survey costs with unrestricted capabilities for concurrent data loading and processing, and the provision of hardware and software infrastructure for three-dimensional geological mapping. The study adhered to global standards and incorporated the latest Machine Learning developments, enabling seamless data processing and establishing a robust platform for compiling earth science resources and creating three-dimensional geological maps. The concept of second-generation geological-thematic maps embodies the expediency of studies, integration of legends and geological units, significant reduction in instrumental analysis reliance, and simultaneous information production updates with precision and global standards. Given the escalating geopolitical constraints and risks associated with geological surveys and mineral exploration in border or restricted access regions, the adoption of innovative methodologies such as this protocol proves highly beneficial and informative. Noteworthy features of the new protocol include high precision, rapid project execution, and cost reductions of up to tenfold compared to traditional mapping methods, marking significant advancements in the field. This research successfully demonstrated the application of four artificial intelligence forms in machine learning: transfer learning, few-shot learning, reinforcement learning, and meta-learning. From a strategic standpoint, the development of integrated thematic geological maps leveraging cloud computing infrastructure aligns with sustainable development and economic resilience, not only enhancing national wealth through future mineral resource provisions but also safeguarding national assets by evaluating hazards like climate change, floods, and earthquakes and their economic implications over brief periods. This underscores the economic and strategic importance of the SUTGM Programme.

Summary: This report presents the findings of the first phase of the SUTGM Programme, which investigated the Lut area of the Central Iranian Plateau, with an updated protocol incorporating work done in

both the Lut area and the Makran zone from 2020 to 2024. Over four years, our team collected and analyzed extensive data on the regions' structural evolution, crust-thinning processes, and crustal stress orientation. Key findings include the identification of primary sedimentary facies indicative of extensive tectonic sedimentary basins. Our study focused on large tectonic movements and resulting accommodation pathways in numerous sedimentary sequences in the Lut basin. Analysis of fault, fold, and seismic line datasets confirmed the sedimentary architectures of four distinct sequences, supporting indications of regional crustal-stress anomalies linked to plate boundaries. In the Makran area, re-evaluation of structural geology data showed that Late Miocene deformation significantly influenced the formation of extension tectonic structures during Early Pliocene exhumation. Preliminary research also suggests an increase in sedimentation rates along major synclines as tectonic displacement increases. With phase one field research and primary analysis complete, phase two planning began in 2024.

This report outlines the first draft of the experimental framework, integrating geodynamic simulation resources that utilize AI to efficiently process high-resolution, time-dependent geological event information.

CHAPTER 1: Generalities

1-1- Introduction

Today, scientists are trying to take advantage of human knowledge in order to know more about the environment and its resources. Geological information and maps are one of the sources that can economically play an effective role in the development of industries and production, energy supply, and financial support of any country. Keeping in mind that the development of the mining sector is one of the main topics of the development programs, the purpose of which is the optimal use of the country's land resources, self-sufficiency, and employment. It is obvious that studies based on the world standard by applying the new technologies, will accelerate the projects.

1-2- The process of geological mapping with the help of remote sensing data in cloud space

Preparing thematic maps and especially geological maps, considering the geological-structural complexities of the crust, and the process of preparing the map from a scientific, and technical point of view, depends strongly to hardware and software with the multivariable complexities of the crust, according to the purpose of the subject. More than two decades of trial-and-error efforts of experts in benefiting from new technologies in various fields led to a better understanding of the mathematical logic of the connection of surface variables of the earth such as the type of vegetation, materials, type and color of rock deposits, erosion and redeposition of sediments together with the function of structural elements and controllers of the basin.

In this respect, always in addition to specialized limitations, the very high volume of data to be processed has been considered as one of the most important limitations of using remote sensing data in geological studies and preparation of geological-thematic maps. Although with the advancement of knowledge and information technology, unlimited access to all pre-existing spatial data, the possibility of very fast programming and processing in the cloud environment of the server, together with user access to pre-prepared samples and the possibility of uploading data in addition to what is available in the server environment, it has provided.

The high speed of the studies, the integration of the legend and geological units in the areas with the same climatic conditions, the comparative-nature and source separation of unconsolidated sediments and a significant reduction in the use of instrumental analysis, the simultaneous economy of the information production process with maintaining the accuracy and the up-to-date standard is one of the remarkable characteristics of such studies. Briefly, the roadmap and breaking down of the project in preparing the second-generation geological maps can be presented as follows (Table 1, Figure 1 & Figure 2).

Table 1: Brief description of the conceptual model and project requirement assessment

Service description	group	Row
-Reviewing previous literatures and studies related to the topic of the project -Designing the structure of the project implementation process including the required data and images (optical and radar satellite images, and elevation and geomorphological data). -Geological maps	requirement assessment and literature review	1
- Determining the right time of the images for project. - Removing noise from optical and radar images and elevation data	Preprocessing of data and images	2
-Spectral processing of Landsat8, Sentinel2 data (PCA methods and band ratios) in order to extract a variety of indicators. -Processing ASTER thermal images in order to extract emissivity and other indicators -Processing VV and VH radar images related to Sentinel 1 in order to highlight geomorphological and tectonic features (mathematical operations) -Processing digital elevation data (DEM) in order to extract geomorphological indicators including slope, aspect, hillshade	Data processing and extraction of desired indicators	3

- Clustering algorithms on desired indices in order to reach to optimal clustering	Clustering processes on data processed images	4
Implementation of clustering algorithm on defined parts and based on features extracted from multiple sources	Performing the clustering process on segments	5
Designing the route to sections and sampling and at the same time interacting with the image processing experts to modify the maps and possible changes in the number of clusters or the indicators used	First stage field visit and sampling .	6
At this stage, with the help of the results from the analysis of the samples and the experiences of the experts, a comprehensive review is done on the initial maps and a supervised classification is carried out in order to determine and extract the number and type of rock units from the satellite images	Examining the results of sample analysis and revising the initial maps in order to implement the supervised classification	7
At this stage, by controlling and integrating all the pre-existing data the results, it is presented in the form of an integrated map and legend	Preparation of map and final report .	8

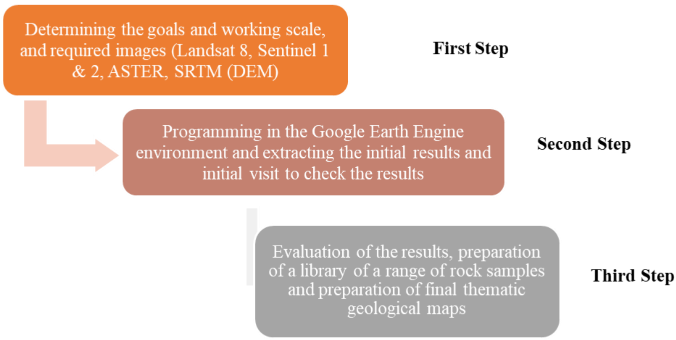

Figure 1: Phasing of the proposed framework

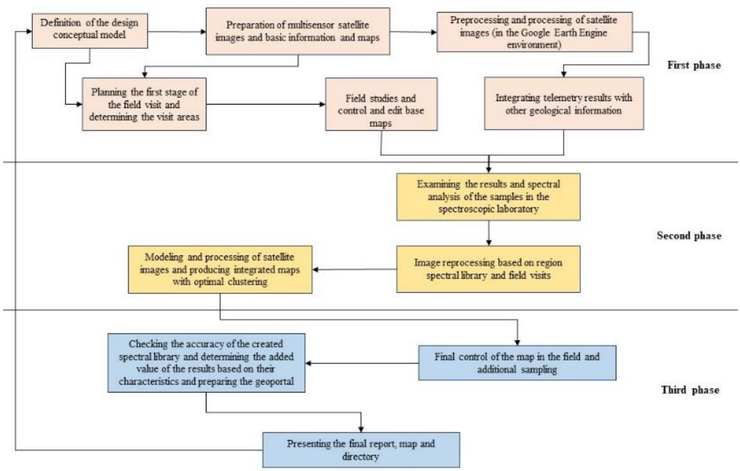

Figure 2: Additional preliminary flowchart of the project process

CHAPTER 2: DATA, WORKING ENVIROMENT AND USED ALGORITHMS

2-1- Introduction

In ground resources studies, there are two general methods for collecting information, which include: a) ground base method b) remote sensing (RS) method. One of the new and effective tools in the field of environmental studies, earth sciences, and mineral explorations is the use of remote sensing technology and the use of satellite data and computer systems with high processing resolution. "Remote sensing is defined as the science and of obtaining physical and chemical information from terrestrial and atmospheric features through the characteristics of electromagnetic waves reflected or emitted such features, without direct contact. The history of remote sensing began with aerial photographs and entered a new phase with the launch of satellites and the use of multispectral scanners. Some of the remote sensing images advantages, are as follows:

- Imaging in different areas of the electromagnetic spectrum, including visible, infrared reflective and thermal areas, and microwave parts.

- Having a broad vision to study large-scale phenomena, with the explanation that the spatial structure of some of the phenomena, such as geological trends, are so large that they cannot be analyzed in aerial photographs and large-scale maps. Therefore, due to their wide view, satellite images provide the possibility of analyzing such phenomena.

- Time repetition and the ground resolution make it suitable for the desired study topics.

- Satellite imagery of inaccessible areas.

Among the first applications of remote sensing in geology are the use of geological interpretation techniques of aerial photos (photogeology), MSS satellite images of Landsat1 to study morphological features and anomalies of iron oxide in the visible wavelength. After that, the French SPOT satellite products were used by geologists because of their unique resolution and the high visibility provided by spatially overlapping images. The application of remote sensing in geology accelerated with the advent of the TM sensor of the Landsat satellite.

The images of this sensor were used for many years in the field of petrology preparation and description of lineaments, especially in the field of mineral alteration map. In 1999, the Landsat 7 satellite settled into orbit a more advanced model of the TM sensor called ETM+, which provided much higher quality images than the previous series. Unfortunately, in 2003, this sensor with a technical defect, lost its efficiency. Due to the high importance of the images of this sensor for experts in various sciences, especially natural sciences, finally in 2013 the Landsat 8 was launched into space with the OLI/TIRS sensor. This sensor is similar to the ETM+ sensor, although it has differences with it in terms of spectral resolution. This sensor contains 9 bands in the region of reflective wavelengths (subsensor OLI), 7 of which are similar to TM and ETM+ series of previous Landsats. Two other bands named coastal/aerosol band which is in the wavelength range of 433 to 453 nm and cirrus band which is in the wavelength range of 1360 to 1390 nm have been added to the previous set of 7 bands which allow scientists to identify clouds more accurately and allows to measure the atmospheric water content and the thickness of the clouds. Also, the OLI/TIRS sensor collects information from the surface of the earth as a push broom, while the ETM+ sensor collects as a whisk broom. In this way, the quality of information collected through the array of sensors in Landsat 8 is much better than the information collected using the oscillating mirror in Landsat 7. Also, because the sensors of Landsat 8 satellite have a radiometric resolution of up to 16 bits, small differences in the energy reached by the sensor, which is important for distinguishing effects in very dark areas of the earth's surface, are easily recorded and stored. The specifications of Landsat 7 and 8 are given for comparison in Table 3 1. Also, Table 3-1 shows the differences of these two sensors in the bandwidth and the position of each band relative to the position of the atmospheric aperture.

Among the widely used sensors in the field of geology and exploration of mineral resources is the ASTER (Advanced Thermal Emission and Reflection Radiometer) sensor, which was installed on the Terra satellite, and with its relatively suitable spatial and spectral resolution, it has made a significant impact on geological and exploration studies is sensor has a relatively suitable spectral separation power in the reflective infrared range where most of the minerals have a spectral absorption diagram, and has made it possible to separate all kinds of alterations. In addition, with five spectral bands in the thermal infrared range is considered the only Multi thermal sensor, and through it, it is possible to separate rock units. The ASTER sensor takes images with the following characteristics:

- Visible and near-infrared (VNIR) images with a ground resolution of fifteen meters (three bands)

- Short wave infrared (SWIR) images with ground resolution of 30 meters (six bands).

- Thermal infrared (TIR) images with a ground resolution of 90 meters (five bands).

- The characteristics of ASTER sensor images are given in Table 2.

Table 2: Characteristics of ASTER sensor images

Characteristic	VNIR	SWIR	TIR
Spectral Range	Band 1: 0.52 - 0.60 µm Nadir looking	Band 4: 1.600 - 1.700 µm	Band 10: 8.125 - 8.475 µm
	Band 2: 0.63 - 0.69 µm Nadir looking	Band 5: 2.145 - 2.185 µm	Band 11: 8.475 - 8.825 µm
	Band 3: 0.76 - 0.86 µm Nadir looking	Band 6: 2.185 - 2.225 µm	Band 12: 8.925 - 9.275 µm
	Band 3: 0.76 - 0.86 µm Backward looking	Band 7: 2.235 - 2.285 µm	Band 13: 10.25 - 10.95 µm
		Band 8: 2.295 - 2.365 µm	Band 14: 10.95 - 11.65 µm
		Band 9: 2.360 - 2.430 µm	
Ground Resolution	15 m	30m	90m
Data Rate (Mbits/sec)	62	23	4.2
Cross-track Pointing (deg.)	±24	±8.55	±8.55
Cross-track Pointing (km)	±318	±116	±116
Swath Width (km)	60	60	60
Detector Type	Si	PtSi-Si	HgCdTe
Quantization (bits)	8	8	12
System Response Function	VNIR Chart	SWIR Chart	TIR Chart
	VNIR Data	SWIR Data	TIR Data
ASTER bands superimposed on model atmosphere			

One of the advantages of ASTER images compared to ETM is its high spectral separation power, especially in the near infrared wavelength ranges, which plays a significant role in the separation of alterations. In order to measure the spectral separation of the two aforementioned sensors, see Figure 3. As can be seen from figure 3, the most differences can be seen in the infrared range, where the ASTER sensor, in addition to increasing the number of spectral bands, has also decreased the width of the bands, which helps to distinguish the alterations more accurately.

The European Space Agency has organized the Copernicus program as a ground observation mission. The main purpose of this program is to monitor the earth using data and images with high accuracy and continuously. The European Space Agency has planned seven missions for the Sentinel program (Sentinel 1, 2, 3, 4, 5p, 5, 6). The Sentinel mission includes radar and optical imaging of the oceans, atmosphere, and land. Each Sentinel mission is based on two satellites in order to shorten the ground coverage period. The Sentinel 1 satellite is designed based on taking radar images at night and day. The first Sentinel-1A satellite was launched in April 2014 and the Sentinel-1B satellite was launched in April 2016. These satellites capture images in the C-band range. Sentinel-2 satellites capture optical images with high optical precision. Sentinel-2A was launched in June 2015 and Sentinel-2B in March 2017. Below are the technical specifications of the Sentinel-2 satellites (Table 3, Figure 3).

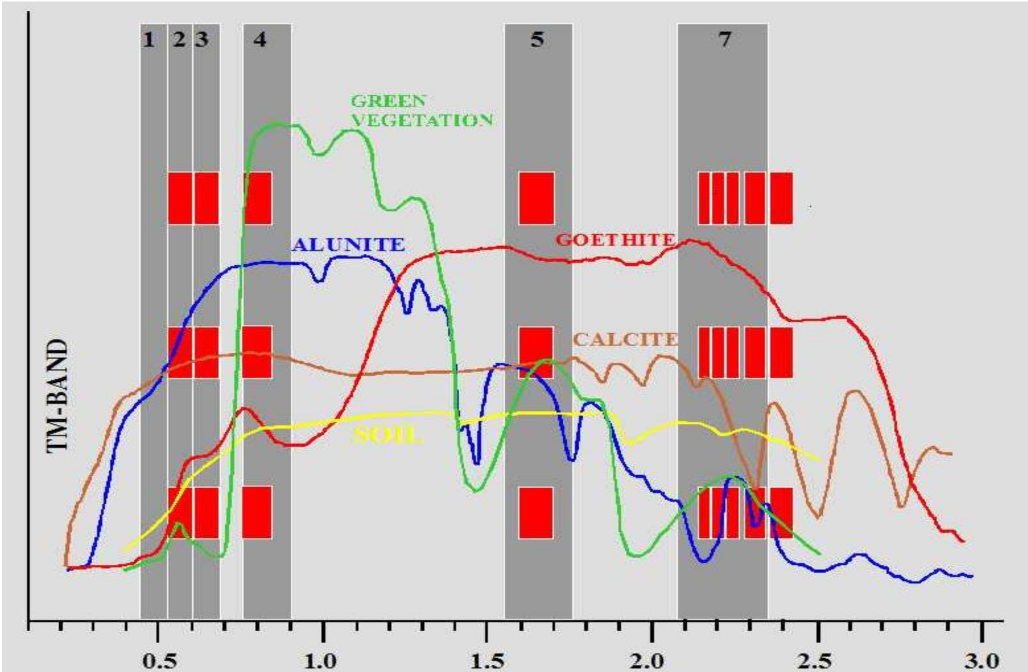

Figure 3: Comparison of spectral resolution of ETM and ASTER

Table 3: Spectral and spatial characteristics of Sentinel2

Sentinel-2 bands	Central wavelength (μm)	Resolution (m)
Band 1 – Coastal aerosol	0.443	60
Band 2 – Blue	0.490	10
Band 3 – Green	0.560	10
Band 4 – Red	0.665	10
Band 5 – Vegetation red edge	0.705	20
Band 6 – Vegetation red edge	0.740	20
Band 7 – Vegetation red edge	0.783	20
Band 8 – NIR	0.842	10
Band 8A – Vegetation red edge	0.865	20
Band 9 – Water vapour	0.945	60
Band 10 – SWIR – Cirrius	1.375	60
Band 11 – SWIR	1.610	20
Band 12 – SWIR	2.190	20

2-2- Cloud Computing

2-2-1- Introduction

Cloud computing can be defined as on demand-availability system based on computer capabilities, especially in the storage of huge amounts of information and its processing capabilities, which are not directly managed by users. Large cloud spaces usually have distributed functions in different places other than the main center. The cloud systems can be limited to an organization, in which case they are called enterprise cloud systems. In the second case, they belong to several organizations, which in this case are considered as public cloud systems. The main philosophy of such systems is to share information resources in order to achieve economic scale and integration. In other words, such systems provide the possibility of minimizing the amazing costs of information technology infrastructure in companies. Below is the figure of the main components of a cloud computing system (Figure 4).

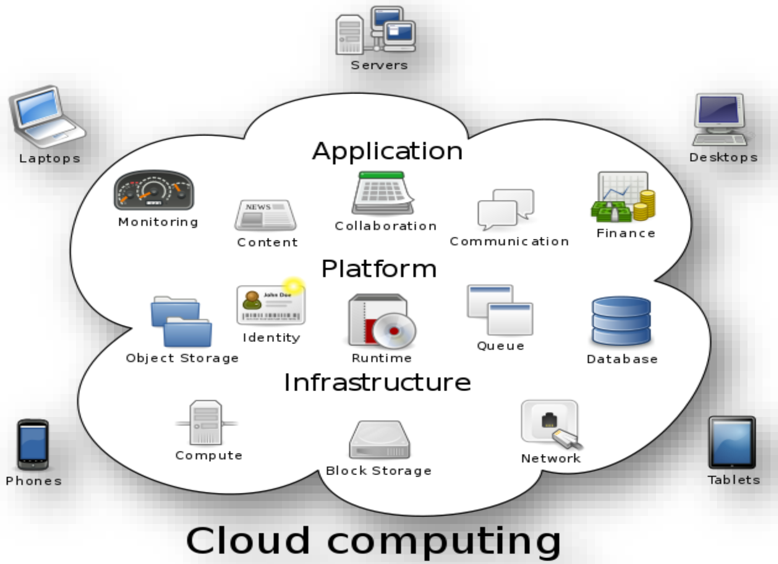

Figure 4: The main components of a cloud computing system

As seen in the image above, the three main and basic parts of such systems include infrastructure, platforms and applications. In the infrastructure sector, the two components of storage blocks and master cloud processors play a key role in cloud systems.

2-2-2- Google Earth Engine (GEE)

As a cloud computing system, the GEE system, for the first time in, enabled the rapid processing of a large amount of satellite images. For example, without this system, it would not be possible to monitor changes in vegetation, water and land resources on a large scale. This system has created a multi-byte database (1015 or 250) of satellite images and other terrestrial information along with functions and processing operators at scale on the planet. These two unique capabilities have made it possible for scientists, researchers and computer programmers to study changes and trends in environmental events. The three components of this powerful system include satellite images, processing algorithms and environmental applications (Figure 5).

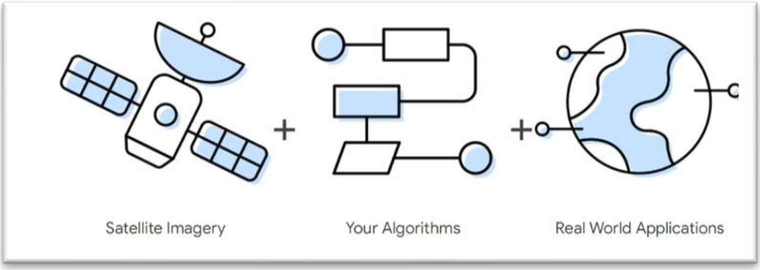

Figure 5: Three important components of GEE system as a cloud computing system

In the GEE database, there is a complete archive of all satellite images, geophysical data and information, elevation, terrestrial information, and indicators such as NDVI, LST, Emissivity and radar data for different years and in various time intervals. Examples of these images and information, are given in Figure 6,Figure *7*,Figure *8*Figure 9).

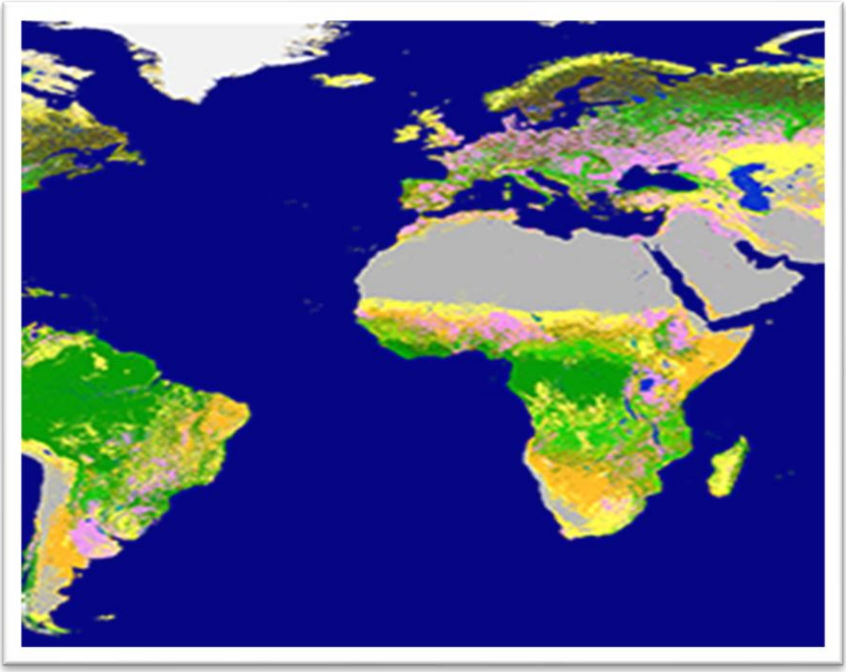

Figure 6: Copernicus Global Land Cover Layers: CGLSLC100 collection 2

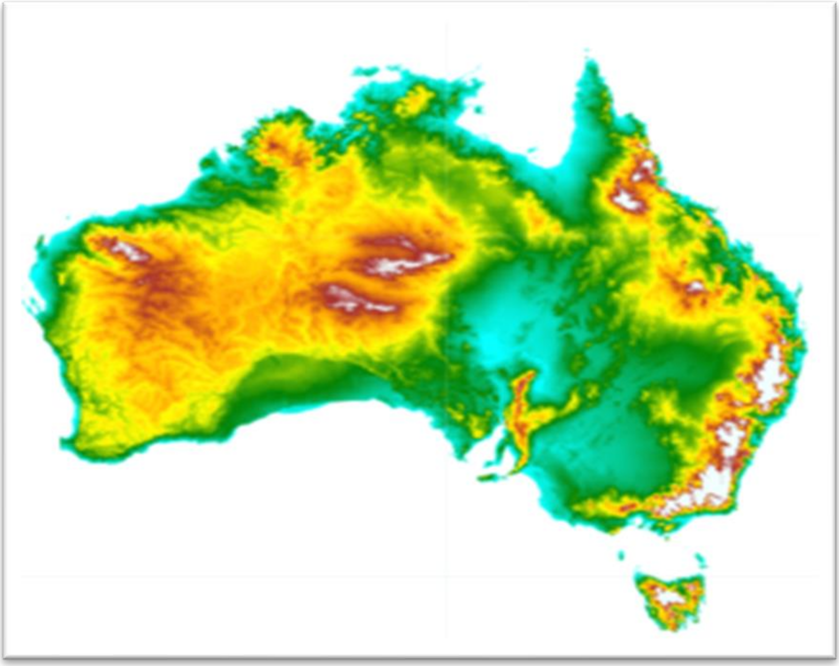

Figure 7: Copernicus Global Land Cover Layers: CGLS-LC100 collection 2

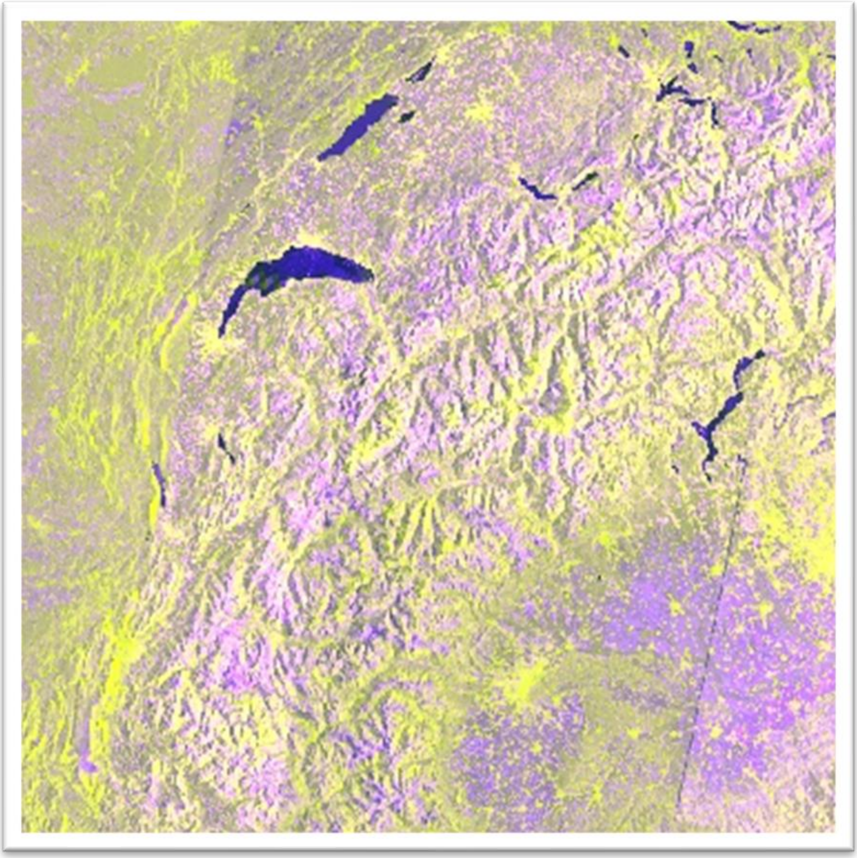

Figure 8: Sentinel-1 SAR GRD: C-band Synthetic Aperture Radar Ground Range Detected, log

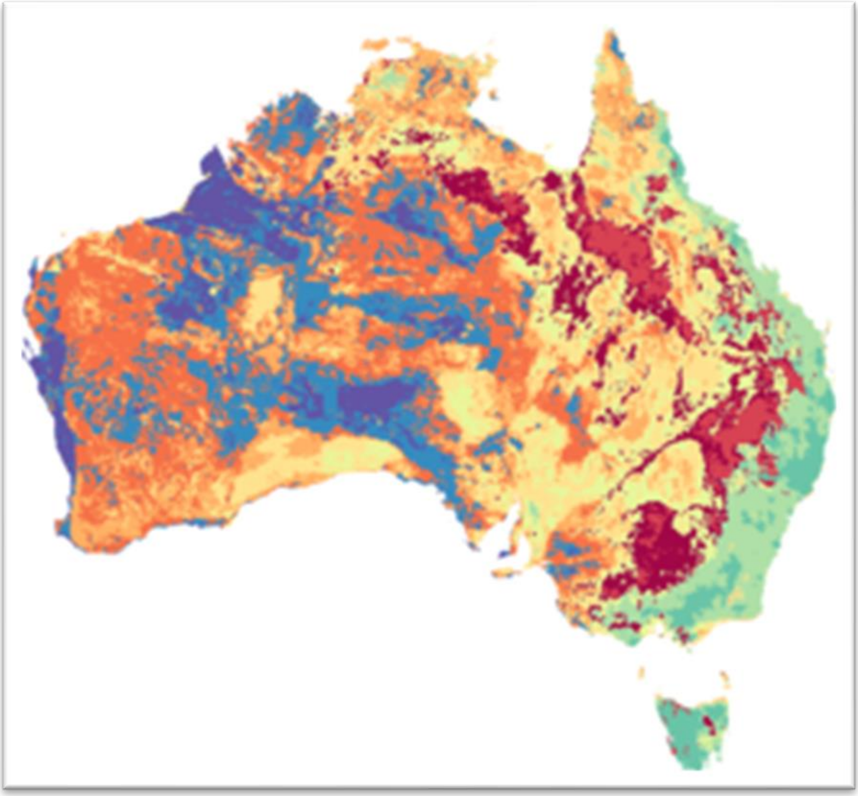

Figure 9: SLGA: Soil and Landscape Grid of Australia (Soil Attributes)

2-2-3- Preparation and processing of Sentinel-1 images (dual-polarization C-band Synthetic Aperture Radar (SAR)

Radar images cover a wide range of geological studies. These studies include the topics of engineering geology (subsidence, earthquake) to the preparation of geological structures and economic geology. Sentinel-1 radar images, due to the characteristics of capturing two modes VV and VH (vertical transmission-vertical reception, and vertical transmission-horizontal reception) in the C-band range (wavelength 3 to 6 cm), have a very high mapping capability.) are played by geological units and faults. examples of comparison of two radar images (VH) and Sentinel-2 for the two regions of Deh Saif and Lut Desert clearly shows the capability of this radar image in displaying geological structures (Figure 10Figure 11Figure 12Figure 13).

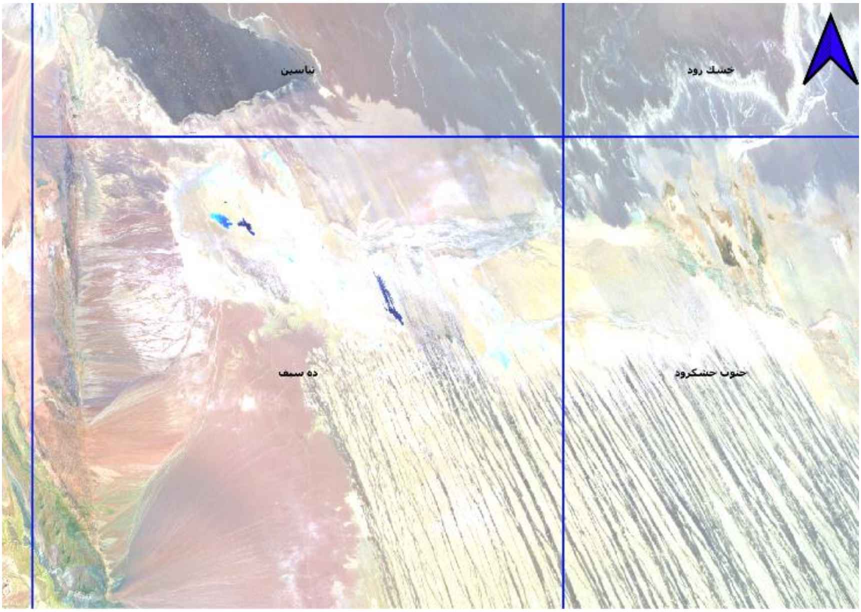

Figure 10: Image of Sentinel-2 MSI sensor from Deh Saif sheet (combination of 2-4-9 bands)

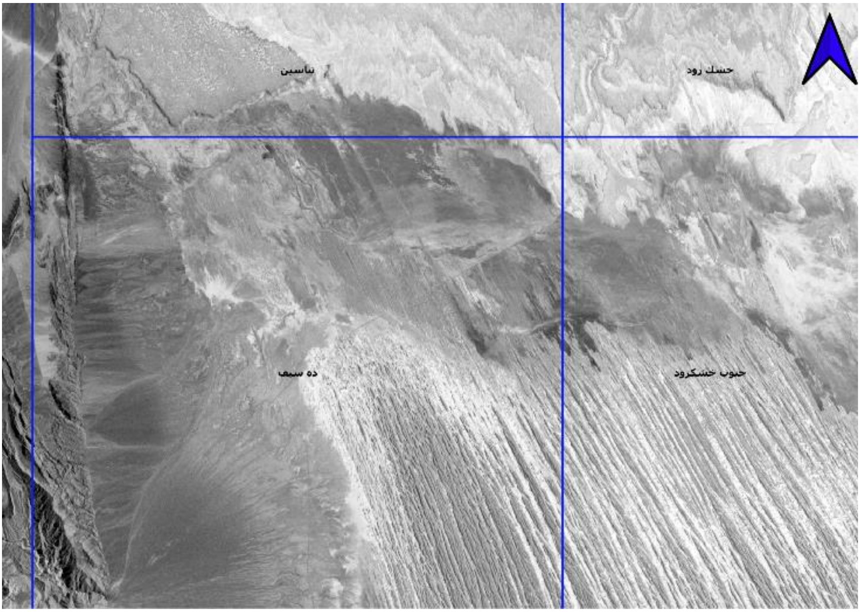

Figure 11: Image of Sentinel-1 with the VH band from the Deh Saif sheet

Figure 12: Image of Sentinel-2 MSI sensor from Lut sheet (combination of 2-4-9 bands)

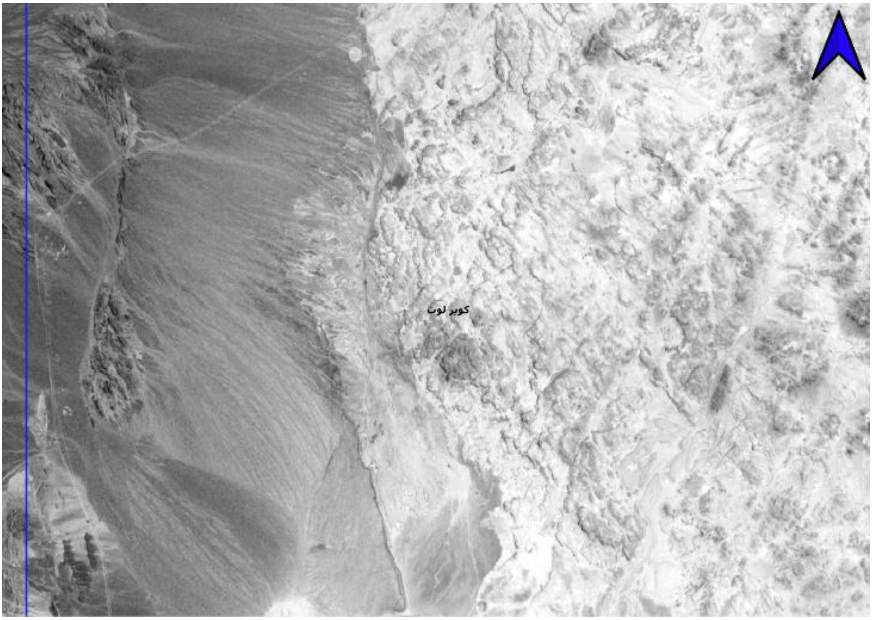

Figure 13: Image of Sentinel-1 with the VH band from the Lut sheet

In the GEE environment, by using mathematical calculations on two VV and VH images, the distinction of geological units and structures was highlighted, and resulted images were used as input for map preparation algorithms in the next step and had a significant impact on the separation of units.

2-2-4- Preparation and processing of digital elevation model images (SRTM)

Among the data that play an important role in the diagnosis and separation of geological units, especially when other spectral information is not responsive (due to the spectral similarity between the units), information such as the digital elevation model is very useful. In this study, elevation data were not used directly, but processing was done on them, Slope, Aspect, Hillshade and Profie and Plan Convexity information were extracted from this image, and finally the five mentioned information were used along with DEM.

2-2-5- Preparation and processing of Emissivity images of ASTER sensor

One of the most important data and information about geological units, which plays an incomparable role in their separation, is the temperature of the units and, accordingly, the temperature emission in infrared wavelengths, which is called Emissivity in remote sensing. can be The ASTER sensor is the only sensor that captures 5 bands in the thermal infrared range and is called a multi-Thermal sensor. Later, through these images, the information of the emission coefficient or Emissivity is extracted. In this project, 5 Emissivity data were used in the map preparation process. In the image below, it can be seen that the thermal information shows the clear contrast of the geological units.

2-3- The basic object process of preparing geological maps

2-3-1- Formation of primary units with segmentation process

In the preparation of ground maps, there are generally two approaches, pixel-based and object-based. In the basic pixel type, the processing unit is the pixel and the spectral information of the pixels is used. Among the limitations and disadvantages of this method is that it is not compatible with the ground conditions. The second limitation is in the type and number of features used. In basic pixel methods, the features must be the same and from the same source (for example, all inputs are spectral bands), and these two limitations to bound the use of basic pixel methods. One of the most challenging areas of preparing land cover maps is the field of geology. These challenges are caused by two components: 1- very high spectral similarity of geological units and 2- some units do not exist in visual reality and should be conceptually defined based on the opinion of geological experts. These two components have caused that until now pixel-based methods have not been very successful in the field of preparing geological maps.

In the basic object process of preparing terrestrial maps, the first step is segmentations on the images. Usually, in the segmentation stage, an image with high spatial accuracy is used. For this reason, Sentinel 2 images with ground accuracy of 10 and 20 meters were used in this project.

One of the important and fundamental issues in image segmentation is determining the scale and shape in this process. The scale parameter is determined based on the variance within the fragments, with the explanation that when the scale number is low, it means that units with more homogeneity are located in one part and smaller parts are automatically created. On the contrary, when we take the scale number high, it means that the aim is to prepare parts that have a higher variance, and the result is that larger parts are created. Determining the scale number is different based on the studied area and the used image and is determined based on different conditions. In other words, it is not possible to determine a constant number for all regions. In this project, segmentation was done based on trial and error and experience, based on three scales of 200, 400, and 600. Based on field studies and basic knowledge, the number 400 was determined. Another important point is determining the shape parameter. Setting these two parameters at the same time can have different results. In Figure 14 & Figure 15 below, the overview of the software and the window for setting parameters are given.

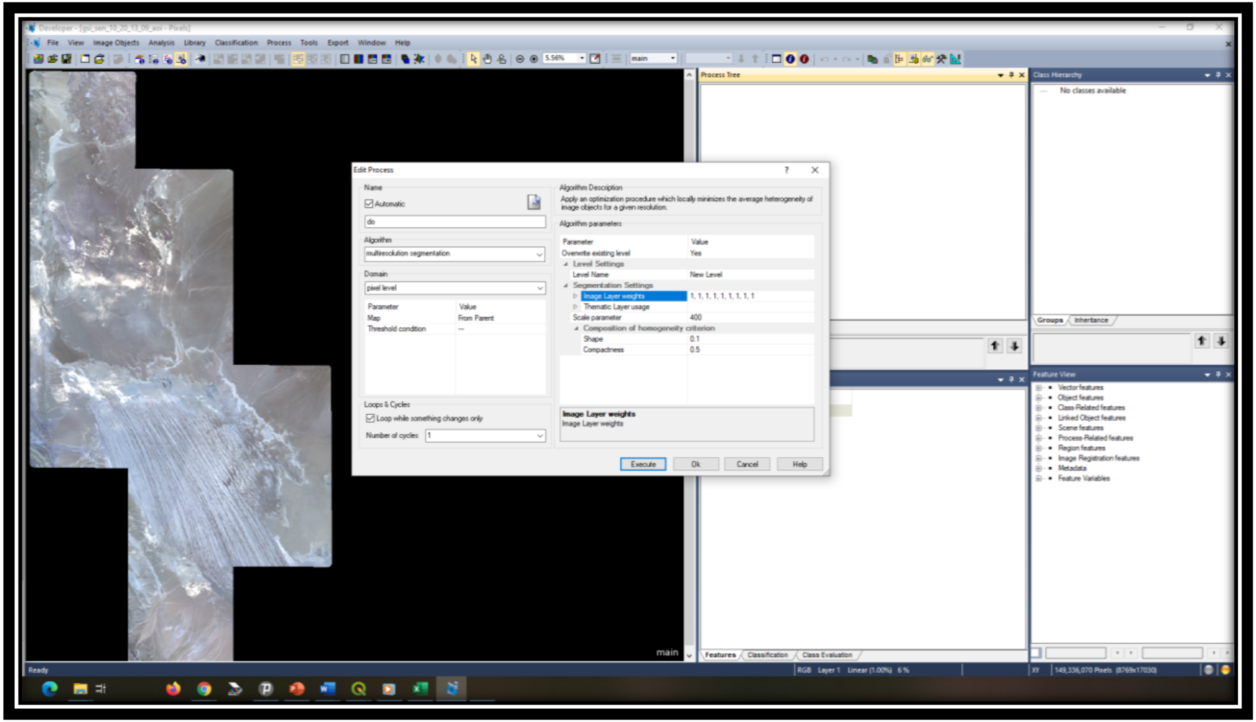

Figure 14: General view of Ecognition software using for segmentation

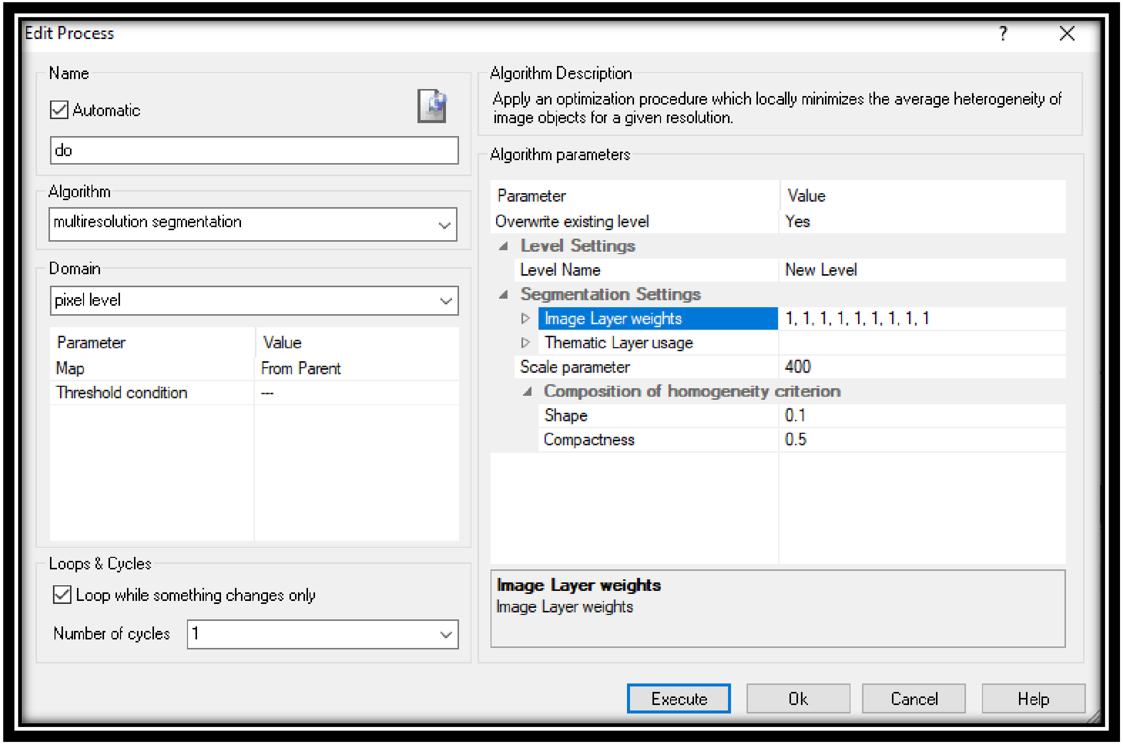

Figure 15: The special window for setting segmentation parameters of Ecognition software

One of the problems and limitations of the traditional methods of preparing geological maps is the lack of integration and inconsistency at the edge of adjacent maps. The biggest advantage of preparing maps in this way is the integration of maps in the entire region and the elimination of inconsistencies in the margins of the map. Another point about the old maps is their high non-compliance with land units and the omission of many details, an issue that has been completely resolved in segmentation.

2-4- Clustering of the studied area and extraction of primary geological units

The second step after segmentation is segment clustering. The purpose of clustering is to reach the primary classes of the region and to determine the degree of differentiation of the primary units. In fact, this process is inevitable as a part of the map preparation process. To implement the clustering process, a number of sources of features with different scales and sources were used. The table 4 lists these features. Determining the number of clusters plays a significant role in determining the primary geological units and should be based on the knowledge of experts and field studies.

The output of this step is used as a guide for experts for the first visit. In other words, this initial map helps to clarify and present the initial view of experts, and with the help of experts, some classes are reduced or increased. At this stage, a close relationship is established between field and office studies, and in most cases, the number of clusters is optimized with the coordination of the parties. At this stage, even many clusters have a geological identity and a geological label is prepared for them. During the initial field visit process, the expert information is transferred to the image processing operator and based on this information, the number of clusters and the quantity and quality of the used features are optimized. At the end of this stage, to a large extent, the number and type of geological units are stabilized and preparations are made for the process of classification and extraction of final classes.

As seen in Figure 16, by using clustering, a basic classification and recognition of geological units is obtained.

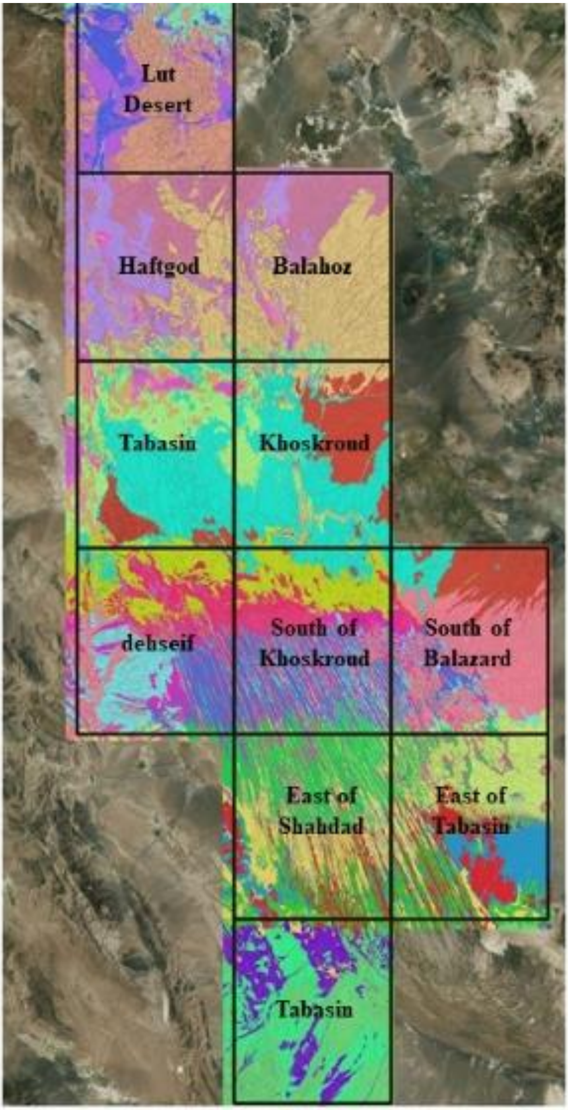

Figure 16: Results of initial clustering (40 clusters) of parts based on 51 characteristics

As mentioned in the chapter on satellite image processing, one of the most important stages of satellite image processing is the clustering algorithm. There are various statistical, mathematical and intelligent methods of clustering, which are all considered as data processing methods. In this study, all the indices of Landsat8 and Sentinel-2 images (PCA images), the processed information of Sentinel-1 radar images, and the Hillshade image of the SRTM sensor used as input to the clustering system. The WEKA algorithm, which is one of the machine learning methods, was used to cluster the input images. The number of classes was optimized based on the opinion of the experts. To continue 25 clusters were selected first, and after initial checks, 35 classes and finally 40 classes were finalized. The type of input images was also optimized based on sensitivity analysis and adding and removing variables. The maps 3-40 and 3-41 have been finalized after clustering and cartographic corrections (Figure 17 & Figure 18).

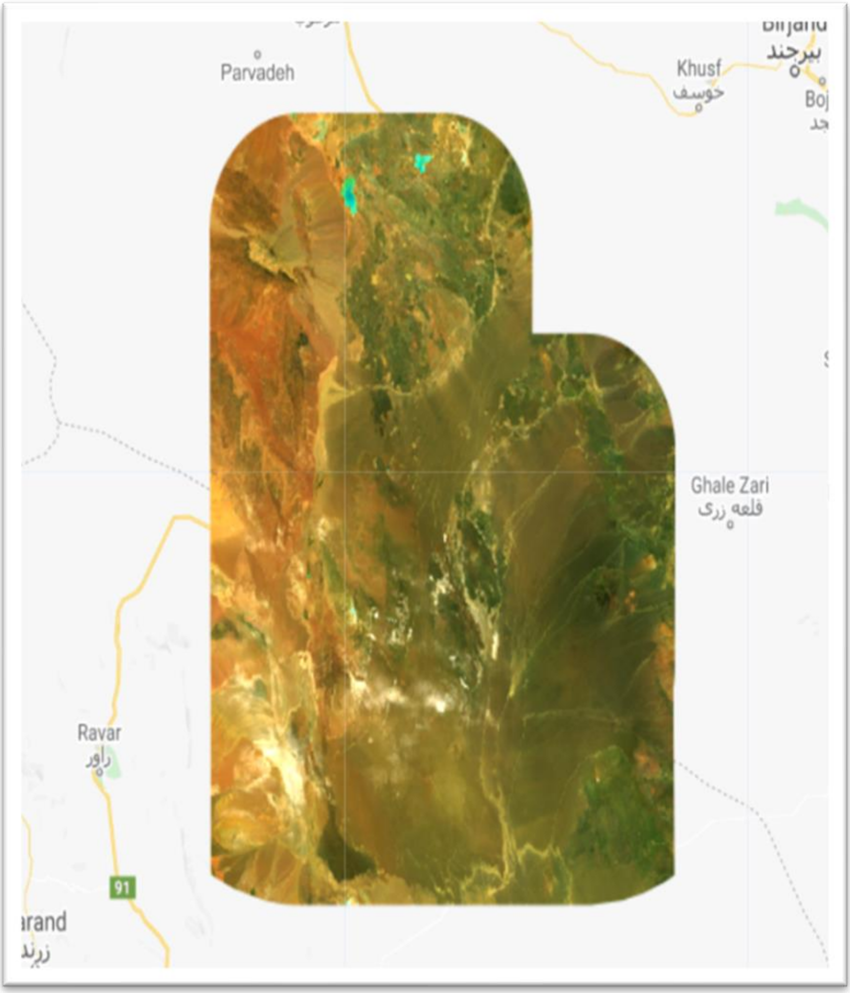

Figure 17: Integrated image of MSI sensor related to Sentinel-2 of the studied area (2-4-9 band composition)

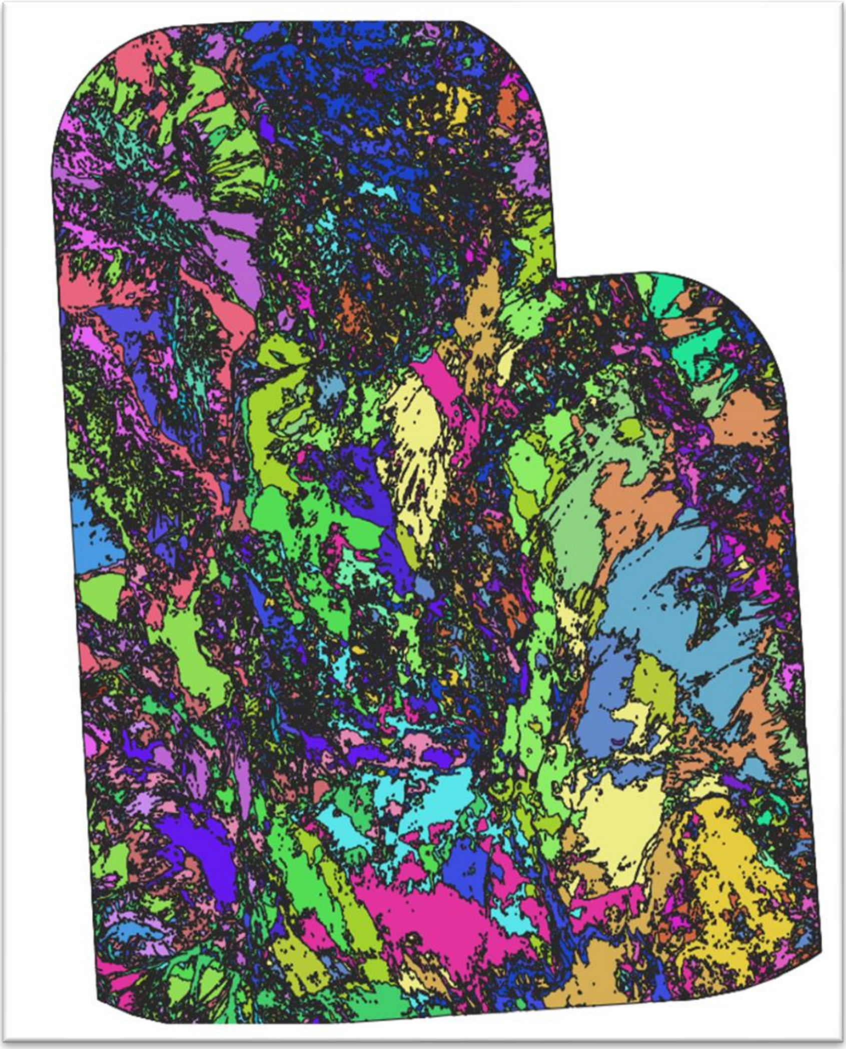

Figure 18: Clustering map without radar data from the studied area

After the field investigations and consultation with the working team, the results of radar data were also examined, which had a better resolution in the rock units (Figure 19 & Figure 20).

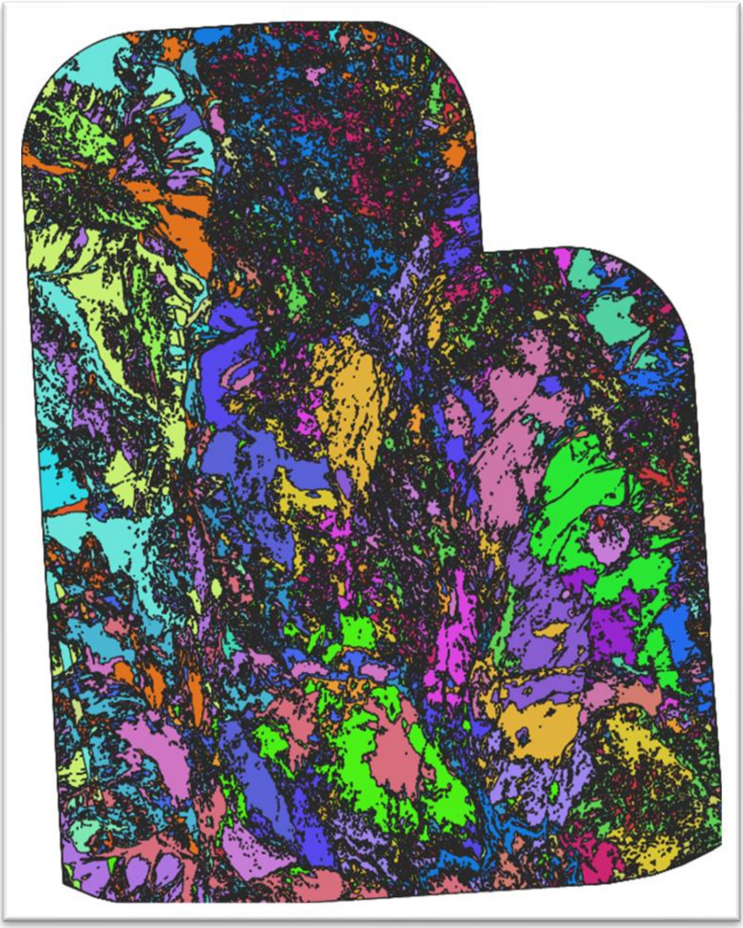

Figure 19: Clustering map with radar data from the studied area

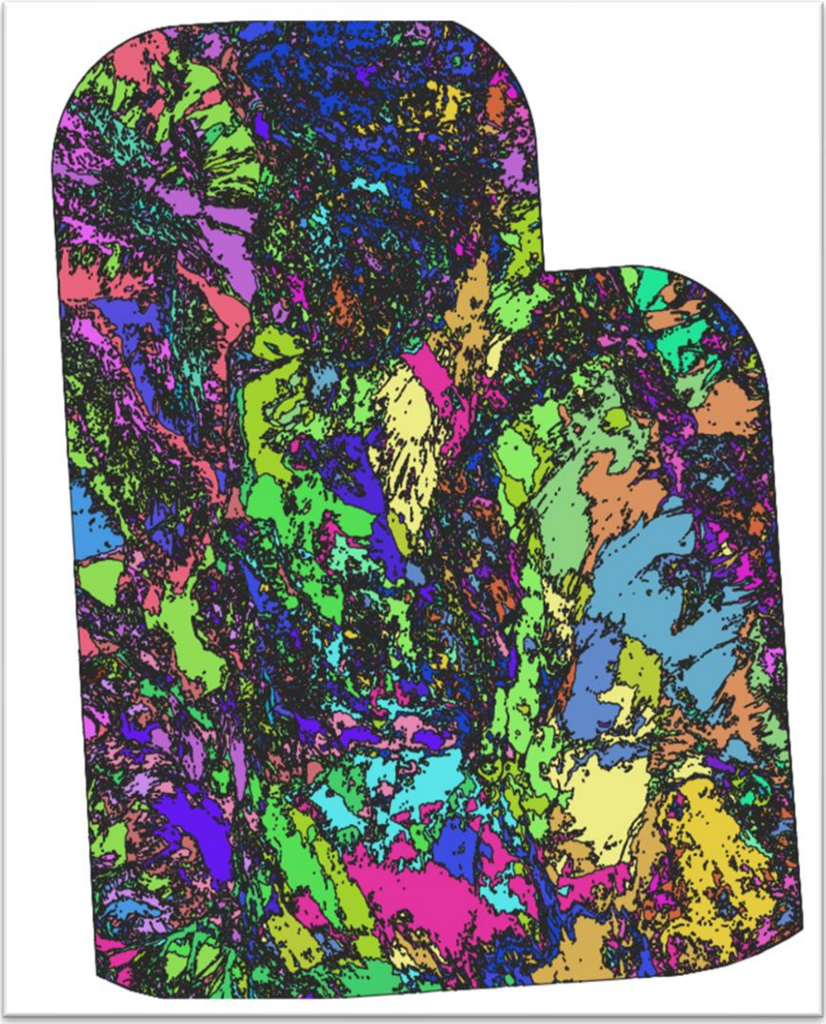

Figure 20: Clustering map without radar data from the studied area

2-5- Comparison of clustering with different methods

In order to compare the different clustering files compiled in the project. See Table 4.

Table 4: Comparison table

No	point N.	X	Y	Z	Sample N.	Lab.	Type of rocks	Clus_PCA_Hill_40cz40_repair_discripted_21_04_final	clustering_pca_hill_vh_40c_may6__Z40_repair	Clus_PCA_sen_OLI_Hill__VHVV_40cz40__25_04	E-A	E-B	E-c	prefer cluster
								A	B	C				
	001	57	32	644			Plain deposits	23	12	17	16-18	18-24	9-10	C
	002	57	32	658			Plain deposits	23	16	17	16-18	18-19	9-10	C
	003	57	32	674			Sed. Rockes	23	24	25	E	3-10-18-30-31-34-35	25-31-35	C
	004	57	32	655			Sed. Rockes	11	12	0	15	E	E	A
							Sed. Rockes							
	006	57	32	686			Sed. Rockes	15	16	17	E	E	E	E
	007	57	32	676				23	12	17	18	24		
	008	57	32	667				11		0				
	009	58	32	595			plain deposits	11	12	0	E	24	24-25-18	B
	010	58	32	611			plain deposits	18	16	5	19-18-25-30	24-18	19-25-24-34-30	C
	011	58	32	607			plain deposits	18	16	5	19-18-25-30	24-18	19-25-24-34-30	C
	012	58	32	642			plain deposits	18	16	5	19-18-25-30	24-18	19-25-24-34-30	C
	013	58	32	593				6	7	17	32		34	C
	014	58	32	579				6	16	17		25-19	34	C
	015	58	32	578			plain deposits	6	36	10	24-18		18-24-15	B
	016	58	32	716	99-NY-001-f	f	sed. Rocks	11	6	5	31-25-35-34-36-18-15	35-19	25-24-30-34	B

	017	58	32	719			sed. Rocks	23	24		24-25-18-19-15-16-10-9-	24-19-30-31-34-35	25-24-30-34	C
	018	58	32	686			sed. Rocks	11	24	0	25-36-15-28-25-2	24-19-30-31-34-35	E	B
	019	58	32	650	99-NY-002-f	f	sed. Rocks	11	16	5	25-36-15-28-25-2	E	24-25-19-30-31-34	
	020	57	32	621	99-NY-003-f	f	sed. Rocks	6	7	10		18	16-18-	C
	021	57	32	615			sed. Rocks	37	7	13	04-أكتبر	19-16-15-18	E	A
	022	57	32	610			sed. Rocks	6	7	13	16	19-16-15-18	18	
	023	57	32	584	99-NY-004-f	f	sed. Rocks	15	16	17	E	E	E	
	024	57	32	556			sed. Rocks	23	9	13	18-24-30-35-	19-20-31-32-33	18	C
	025	58	32	555			sed. Rocks	18	16	5	24-25	18-24	19-24-30-19-25	B
	026	58	32	548			sed. Rocks	15	16	5	Ok	18-24	19-24-30-19-25	A
	027	58	32	571			sed. Rocks	15	16	5	Ok	18-24	19-24-30-19-25	A
	028	58	32	558			sed. Rocks	22	23	2	24	30-24	30	C
	029	57	32	612			sed. Rocks	6	7	17	19-18	Ok	Ok	C
	030	57	32	610			sed. Rocks	6	7	17	E	E	E	
	031	58	32	614			sed. Rocks	15	16	5	OK	24-18-30	30-24-18	A
	032	58	32	660			sed. Rocks	11	16	5	E	E	E	
	033	58	32	715			sed. Rocks	11	6	0	24-25-30-34	34-30-24	Ok	C
	034	58	32	733	99-NY-006-p	p	sed. Rocks	11	12		24-25-30-35	E	E	
	035	58	32	740			sed. Rocks	5	6	16	Ok	Ok	Ok	C
	036	58	32	710			sed. Rocks							
	037	58	32	698	99-NY-007-f	f	sed. Rocks	15						

	038	58	32	689			sed. Rocks	24		33				
	039	58	32	685			sed. Rocks			17				
	040	58	32	694			sed. Rocks			0				
	041	58	32	731			sed. Rocks	11						
	042	58	32	739			sed. Rocks	5						
	043	58	32	735			dyke in shale							
	044	58	32	719			sed. Rocks							
	045	58	32	721			sed. Rocks		12					
	046	58	32	715			sed. Rocks			17				
	047	58	32	673			sed. Rocks							
	048	58	32	683	99-NY-008-f , 99-NY-009-w	f,w	sed. Rocks		12					
	049	58	32	694			sed. Rocks							
	050	58	32	691			sed. Rocks							
	051	58	32	710			sed. Rocks							
	052	58	32	706			sed. Rocks							
	053	58	32	739	99-NY-010-w , 99-NY-011-p	W,P	sed. Rocks			25				
	054	58	32	711	99-NY-012-f	f	sed. Rocks	15	12	5	31-25-35-34-36-18-15	35-19	25-24-30-34	B
	055	58	32	734	99-NY-013-p , 99-NY-014-p , 99-NY-015-p	p	igneus	0	1	2	24-25-18-19-15-16-10-9-	24-19-30-31-34-35	25-24-30-34	C
	056	58	32	713			igneus	30	24		25-36-15-28-25-2	24-19-30-31-34-35	E	B
	057	58	32	0			plain deposits	23		25	OK	24-18-30	30-24-18	A

	058	58	32	687			plain deposits	13	40	30				
	059	58	32	772	99-NY-016-f	f	sed. Rocks	38		16				
	060	58	32	778	99-NY-017-p , 99-NY-018-p	p	sed. Rocks							
	061	58	32	757	99-NY-019-p , 99-NY-020-XRD	P;XRD	igneus							
	062	58	32	768	99-NY-021-p	P	igneus							
	063	58	32	742	99-NY-022-f	f	sed. Rocks	23	25	2	E	E	E	
	064	58	32	738			garden	31	17					
	065	58	32	760			sed. Rocks	11	12	25	15-18-16-30-25	E	E	A
	066	58	32	760	99-NY-023-w	w	igneus							
	067	58	32	770			sed. Rocks							
	068	57	32	786			sed. Rocks		12					
	069	57	32	786			sed. Rocks		16					
	070	58	32	913	99-NY-024-f	f	sed. Rocks	27	6	25	25-26-21-0-31	19	35-31-25-30-34-9-3	B
	071	58	32	921	99-NY-025-f	f	sed. Rocks	22	23	2	33-27-32-	32-16-24-18	32-30-24-18	C
	072	58	32	926			plain deposits							
	073	58	32	932			plain deposits							
	074	58	32	977	99-NY-026-w	w	sed. Rocks	11		0				
	075	58	32	741	99-NY-027-p	p	pyroclastic	10	15	34	10-11-12-4-5-6-	12-5-6-	12-5-6-19-25-33	B

	076	58	32	727			plain deposits			36				
	077	58	32	729	99-NY-028-XRD, 99-NY-029-p	XRD ; P	igneus	35	15		3-4-5-11-15-19-25-35	35-6-7-12	35-25-6-7-12	C
	078	58	32	728	99-NY-030-p, 99-NY-031-p	p;p	pyroclastic			31			35-19	
	079	58	32	737			pyroclastic	8	9	31	10-4-3-24-30-18-19	35-15-10-4-19	35-19	C
	080	58	32	733			pyroclastic	15	36	31	E	35-25-18-15-9	35-19	C
	081	58	32	718			scree	6		31			35-19	
	082	58	32	715						31			35-19	
	083	58	32	716			pyroclastic			31			35-19	
	084	58	32	717			pyroclastic	18	9	31	E	35-15-10-4-19	35-19	C
	085	58	32	727					15	31			35-19	
	086	58	32	721			igneus		36	31			35-19	
	087	58	32	713	99-NY-032-p	p	pyroclastic			31			35-19	
	088	58	32	712	99-NY-033-p	p	pyroclastic	35	11	31	34-35-25-15-9-10-11-12-3-4-5	34-35-25-15-9-10-11-12-3-4-5	35-19	C
	089	58	32	706	99-NY-034-p	p	pyroclastic	22		2				
	090	58	32	703			pyroclastic							
	091	58	32	696			pyroclastic		7	10				
	092	58	32	697			pyroclastic	6	29	35				
	093	58	32	689	99-NY-035-p	p	igneus	17	26	34	3-4-5-11-15-19-25-35	35-6-7-12	35-25-6-7-12	C
	094	58	32	687				37	38	33				

	095	58	32	685			igneus			10				
	096	58	32	684			pyroclastic	6	7	10				
	097	58	32	685			plain							
	098	58	32	698			pyroclastic	37	23	1				
	099	58	32	707				22	23	33				
	100	58	32	721			plain deposits	37	26	33				
	101	58	32	922			igneus							
	102	58	32	945			pyroclastic	14	24	25				
	103	58	32	962			plain deposits			1				
	104	58	32	795	99-NY-036-p	p	pyroclastic	18	12					
	105	58	32	796			pyroclastic	35	2	29				
	106	58	32	789			pyroclastic	14						
	107	58	32	787	99-NY-037-p	p	pyroclastic		11	29				
	108	58	32	787	99-NY-038-p	p	pyroclastic	35	36	36				
	109	58	32	804			pyroclastic	14	2	20				
	110	58	32	843	99-NY-039-p, 99-NY-040-p, 99-NY-041-p	p	pyroclastic	19	11	33				
	111	58	32	837			plain deposits		20	34				
	112	58	32	856	99-NY-042-p , 99-NY-043-p	p	igneus	32	2	19	25-26-21-0-31	19	35-31-25-30-34-9-3	B
	113	58	32	843			pyroclastic	19	29	32	33-27-32-	32-16-24-18	32-30-24-18	C
	114	58	32	809			pyroclastic	10		19				
	115	58	33	835	99-NY-044-p	p	pyroclastic	35	25					

	116	58	33	856	99-NY-045-p, 99-NY-046-p	p	pyroclastic	19	20	32				
	117	58	33	869			pyroclastic		11	33				
	118	58	33	822				10	15	31			35-19	
	119	58	32	1000			sedimentary	27	6	16				
	120	57	32	1031			sedimentary	22	23					
	121	58	32	611			fan deposits	24	36	39			19	
	122	58	32	597			playa	0	1				19	
	123	58	32	617			fan deposits	17	20	34				
	124	58	32	628			flood zone	24	25	32				
	125	58	32	631			flood zone	27	18	20				
	126	58	32	633	99-NY-047-p&XRF	p&XRF	igneous		28					
							slope wash							
	127	58	32	661	99-NY-048-p, 99-NY-049-p, 99-NY-050-p	p	igneous	38	40	7	1-22-23	30-24		C
	128	58	32	646			sand blow							
	129	58	32	640			plain deposits	17	34					
	130	58	32	637			plain deposits		18					
	131	58	32	636			igneous	1	34	28				
	132	58	32	634			fan deposits	33	34					
	133	58	32	657			mud flat	1	18	28	31-25-35-34-36-18-15	35-19	25-24-30-34	B
	134	58	32	640			pyroclastic	29	5	28	24-25-18-19-	24-19-30-31-34-35	25-24-30-34	C

											15-16-10-9-			
	135	58	32	641			igneus	38	39	18	25-36-15-28-25-2	24-19-30-31-34-35	E	B
	136	58	32	669	99-NY-051-p , 99-NY-052-p	p	igneus							
	137	58	32	707	99-NY-053-p , 99-NY-054-XRD , 99-NY-055-XRF , 99-NY-056-p	p;XRD;XRF;P	pyroclastic	2	2	38				
	138	58	32	684			slope wash	1	3					
	139	58	32	683	99-NY-057-p , 99-NY-058-XRD	p;XRD	pyroclastic	1	33					
	140	58	32	670			fan deposits	14	33					
	141	58	32	676			fan deposits	19	15	19				
	142	58	32	677										
	143	58	32	669			plain deposits	33	34					
	144	58	32	678			pyroclastic							
	145	58	32	658	99-NY-059-p	p	igneus		34					
	146	58	32	771	99-NY-060-p	p	igneus	22	23	2				
	147	58	32	735	99-NY-061-f	f	sedimentary rocks	27	24					

	148	58	32	697	99-NY-062-p , 99-NY-063-XRD	p;XRD	igneus	2						
	149	58	32	699	99-NY-064-p	p	pyroclastic	14	2	19	3-4-5-11-15-19-25-35	35-6-7-12	35-25-6-7-12	C
	150	58	32	725	99-NY-065-p	p	pyroclastic	8	9	22				
	151	58	32	697	99-NY-066-p	p	pyroclastic			31			35-19	
	152	58	32	704			pyroclastic			22				
	153	58	32	682			plain deposits							
	154	58	32	755	99-NY-067-p	p	pyroclastic		2	29				
	155	58	32	699			young deposit	10	15	6	25-26-21-0-31	19	35-31-25-30-34-9-3	B
	156	58	32	694	99-NY-068-p	p	igneus	10						
	157	58	32	695	99-NY-069-p	p	pyroclastic	35						
	158	58	32	675			igneus	35		36				
	159	58	32	666	99-NY-070-p	p	sedimentary rocksNg	24	7	10				
	160	58	32	661			Sedimentary deposits		36	39			E	
	161	58	32	639			fan deposits			33				
	162	58	32	631			Playa			31			35-19	
	163	58	32	606			sedimentary	24	7	10				
	164	58	32	580			young deposit	7	8	27				
	165	58	32	561			playa			3				
	166	58	32	0			playa	6	38	33	33-27-32-	32-16-24-18	32-30-24-18	C

							qt deposits							
	168	58	32	675			pyroclastic	17	2	34				
	169	58	32	664			playa	10	11	10				
	170	58	32	666	99-NY-071-p	p	igneus	33	40	29				
	171	58	32	668	99-NY-072-p	p	igneus	38						
	172	58	32	660			plain deposits	13		7				
	173	58	32	658			altered zone	4						
	174	58	32	658	99-NY-073-XRD	xrd	dyke							
	175	58	32	652			altered zone	10	11	29	32-21 زون آلتره نیست		زون التره نیست	
	176	58	32	721	99-NY-074-f	f	sedimentary rocks	15	16	5	E	E	30-31-34-25-24-16	
	177	58	32	715			sedimentary rocks	15	16	5	E	E	30-31-34-25-24-16	
	178	58	32	718			sedimentary rock	15	16	0	E	E	E	
	179	58	32	721			stream deposits	15	16	0	18		31-30-	

Table 4, prepared based on the needs of the project to achieve the best clustering of units. In table 4, according to the field collection points, the class related to each cluster file, it was examined and based on the errors in each point, the clusters were compared. Each of the clusters were created on the base of a specific method and are the result of a combination of various factors. Of course, the number of clusters in each file is considered 40 clusters. The result of this comparison gives the best surface lithology clustering method of the studied area.

2-6- Conclusion

The process and quality of the production of unified server-based thematic geological maps is absolutely dependent on the input data, both pre-existing and gathering data in the process of geological studies.

Selecting the right platform for information processing, spectral and radar data, satellite images and even aerial photos according to the desired scale in preparing and to increase accuracy of the initial map has a significant and undeniable role. It is obvious to achieve the maximum desired accuracy in the verification process will be achieved by repeating field observations, sampling and of course combining it with laboratory results. Reconstruction and optimization of the available dates, lithological and geochemical data of different rock units, in addition to the reliable published data will come from the integration of laboratory data obtained from sampling conducted in multiple stages of field control.

Field checking based on the preliminary base map allows to control each separated rock unit several times as a result of the data processing process and the satellite-based geospatial image, not only in the area of understudy, but beyond that in the coverage area.

The nature of layered and repeated processing of spatial information and its online integration with pre-existing data, whether in the target area or in the surrounding regions, is one of the factors that determine the final uncertainty coefficient based on the amount and accuracy of the data used. This process improves the accuracy and uncertainty of the second-generation seversl-base geological maps not only from a qualitative coefficient (speculation) to a quantitative one, which determines the error coefficient of each unit in relation to the surrounding unit.

It is clear that at the end of this stage, it is possible to edit the map (manually) point by point in comparison with satellite and aerial images with higher accuracy.

It is necessary to remind again that there is no doubt that the level of accuracy and final uncertainty factor depends on the accuracy and resolution of the input data, the quantity and quality of field observations, and finally the editing of the map according to the output scale of the target map (Figure 21).

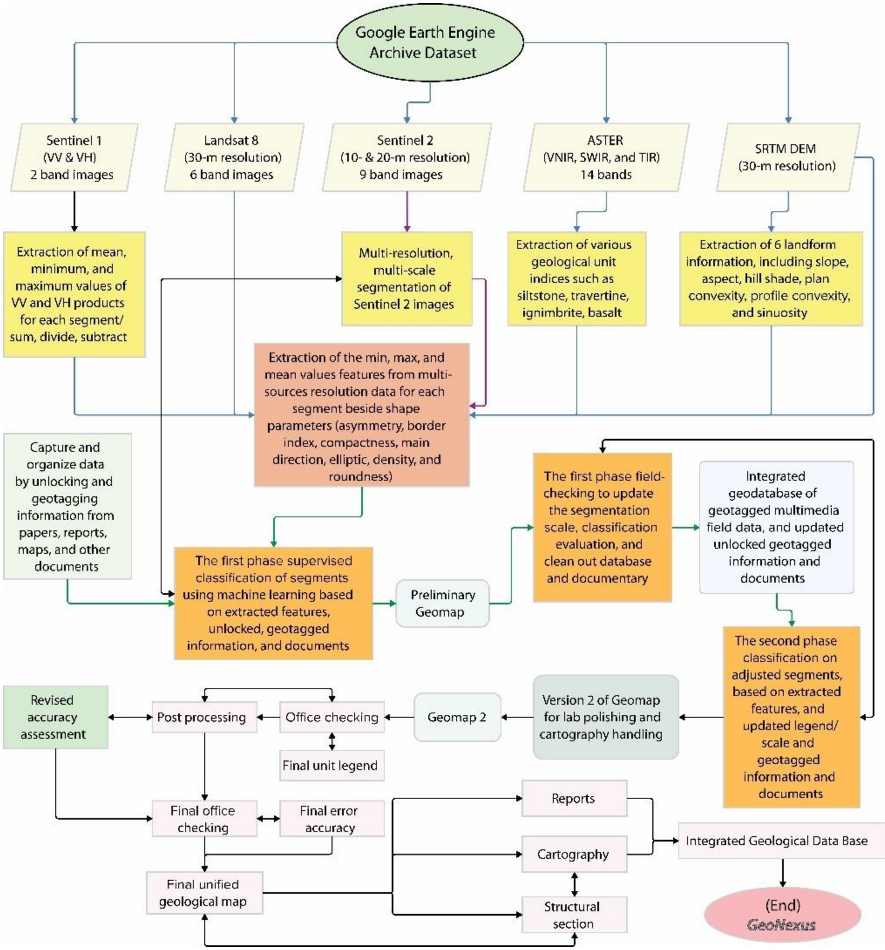

Figure 21: Flowchart of the upgraded logical tree for the preparation of base server thematic maps based on the use of the processing platform

GEE (Google Earth Engine), the letters A-B-C-D-E & F is a window to the flowchart with higher resolution and detail than the image data processing steps in the map production process. In this model the selection of the type of satellite images indicated in the flowchart is appropriate for the accuracy required for preparing geological maps has been done on scale 1:100,000. Obviously, in the preparation of server-based thematic maps (second generation maps) according to the strategic importance of production information and the sensitivity factor or confidentiality! They provide the possibility of using dedicated (native) platforms and satellite images with higher resolution and spatial accuracy in the same flowchart with the same arrangement.

The application of the above guidelines in the preparation of unified server-based thematic mapping made it possible of creating an integrated and homogeneous map of nearly 30,000 square kilometers (an area equal to the area of two rectangles 1:250,000) of the Western Lut region, only with Less than one hundred expert-day field study days in 2019, (Nazari et al., 2022).

The second-generation dynamic Geological maps benefit from integration in the legend based on maximum sharing of physical characteristics, texture, construction and age of each unit (Figure 22 & Figure 23). Therefore, they are very dynamic and practical in reproducing separative maps based on accepted standards.

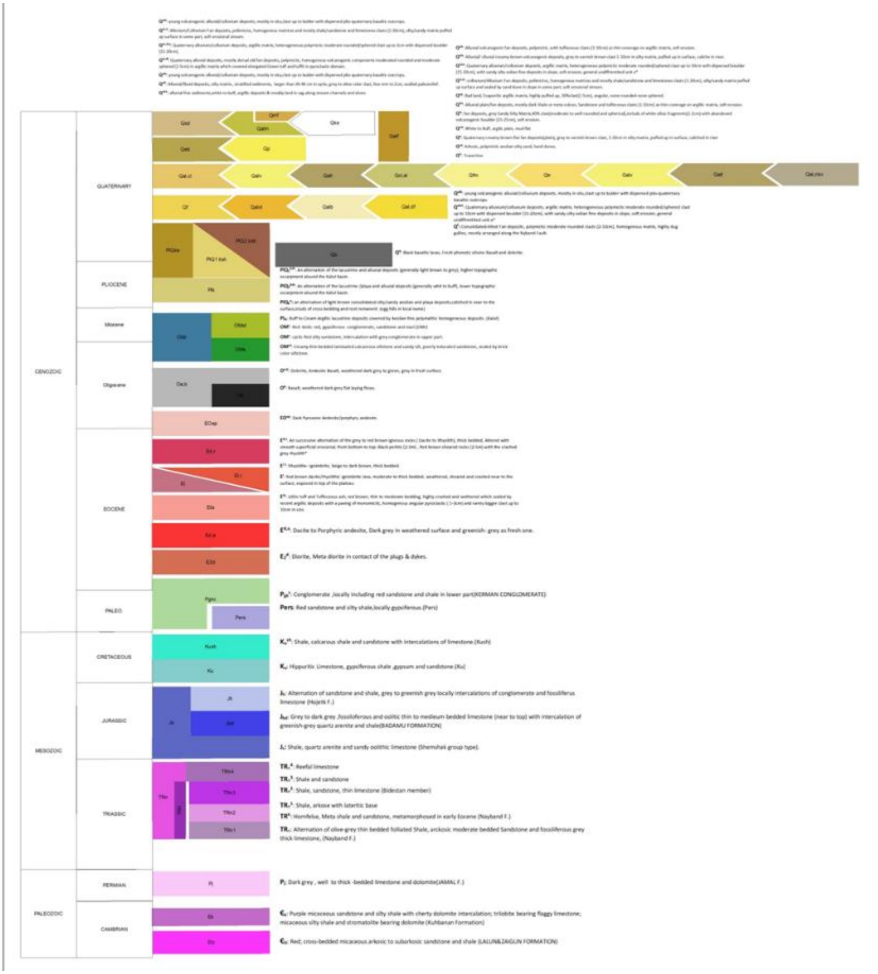

Figure 22: A view of the integrated legend and the dynamics of the second-generation geological map in the Western Lot area, benefiting from the features of this legend, applying and presenting the results of previously published scattered absolute dating in the stratigraphy of Quaternary deposits and volcanic and metamorphic facies rocks are relative to the results of paleontological and stratigraphic studies

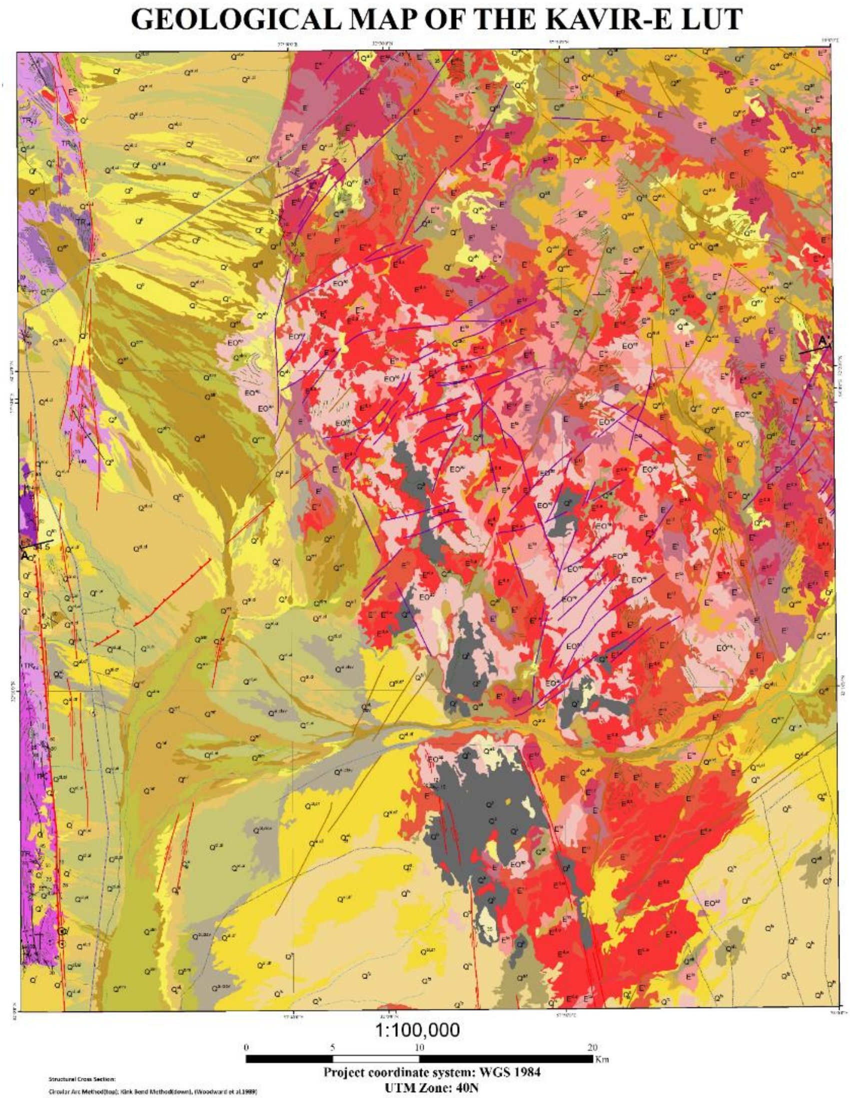

Figure 23: Close view of integrated and homogeneous geological map of Lut desert

In order to prepare geological time units, it is necessary to compile and scrutinizing the up-to-date geological time scale, which is provided by international commissions global scale. No one person or expert committee proposed the geological time scale used today. Time scale tables have been developed through the efforts and experimentation of many independent geologists. Today, the recognition of official subdivisions of geologic time scale is determined by international committees.

In geological maps, the geological time scale is used to describe map surface information in the format of the legend with stratigraphic division and arrangement, with the oldest at the bottom and the youngest at the top. Stratigraphic columns are a graphical representation of the vertical succession of sedimentary and volcanic rocks at the time of their deposition. The outline of stratigraphic relationships conceptually expresses the relative position of each unit with respect to other units and also with regard to geological structures. They give an idea of the succession of geological events and the relationship between them and supplement the information given in the legend of the mapped units.

The main aim of the present protocole is preparing a guideline for unified server-based thematic geological maps (Second generation geological maps). It is worth mentioning that these maps prepare the geological information in combining the stratigraphic data with absolute dating data and regional time-rock equivalence. The arrangement of differentiated geological units in Kavir-e-Lut region are present in stratigraphic-time form (Nazari et al., 2023) with regards to equivalence and calibration processes of absolute datings, the structure of the legend in Kavir-e- Lut project presented in the form of time-unit.

Therefore, in expressing some of the achievements of the project of preparing a new protocole for the preparation of unified and homogeneous geological maps in the Western Lut area, the following can be mentioned:

- Innovation in methods and guidelines
- Fast, accurate and precise data generation
- An up-to-date and integrated method for online studies and dynamics of geology, exploration and engineering
- Saving time and cost of engineering, exploratory and geological projects

- Redesigning and optimizing the costs of geological-exploratory studies
- Proposed plan to set up and use the first parallel processing system in the country's geosciences
- Unlimited ability to simultaneously download and process large data such as satellite and aerial images, aerial and terrestrial geophysical data, drilling, etc.
- Preparing a suitable platform for preparing the encyclopedia of earth sciences, "Geopedia."
- Providing a hardware and software platform in the preparation of 3D geological maps

Therefore, it is not wrong, if we consider the design and implementation of multi-purpose geological studies of the Western Lut as a key point of cooperation and structural improvement of various specialized departments of the Geological and Survey of Iran. The present research carried out in companion with the latest international standards of up-to-date scientific achievements and resulted of the four sensors of artificial intelligence in the field of **Machine Learning** is as follows:

Transfer Learning

Short-Term Trainings

Reinforcement Learning

Meta Learning

Artificial intelligence, machine learning, deep neural networks, are among the phrases and terms that can activate your imagination about the future in which robots think and organisms are repairing.

Relevant publications:

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.

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., 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., (2024). Geological Mapping in the Era of AI: Leveraging Innovation for Preci-sion and Speed, Barcelona, Catalonia, Spain.

Nazari H., (2024). Server Based Unified Thematic Geological Mapping, GEOKURDISTAN VI The 6th International Geological Conference of Kurdistan, Iraq.