Exploration of Gold, Copper, Magnetite, Hematite, Manganese, Magnesium, Chromite, Antimony, Bauxite, Industrial soils, Nickel, Cobalt, Lead, Lithium minerals using Landsat8 satellite

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KEYWORDS:

Gold, Nickel, Lithium, Minerals exploration, mine analysis, Landsat8

ABSTRACT

In this study, we provided an accurate and complete method for exploration and analysis of Gold, Copper, Magnetite, Hematite, Manganese, Magnesium, Chromite, Antimony, Bauxite, Industrial soils, Nickel, Cobalt, Lead and Lithium minerals in the desired area. Mineral exploration can be done using the seven bands from Landsat8 satellite images, through combination of different maps, a specific color spectrum and number obtained from map. Also we used four important formulas of band compounds as follows:

(((b7+b6+b5)/b6), ((b5+b4+b3)/b6), ((b3+b2+b1)/b6)) as RGB, ((b3+b1)/b2), ((b3+b5)/b4), ((b5+b7)/b6)) as RGB, ((b3/b1), (b5/b7), b6) as RGB, (pca((b7+b6+b5)/b6), pca((b5+b4+b3)/b6), pca((b3+b2+b1)/b6)) as RGB.

In our method, we used (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps in all mentioned minerals exploration which is obtained from the above four formulas respectively and by dividing the Landsat8 satellite images into two parts, enhancing the effectiveness of identifying and exploring geological data. Using the band compounds (((b7+b6+b5)/b6), ((b5+b4+b3)/b6), ((b3+b2+b1)/b6)) as RGB and (pca((b7+b6+b5)/b6), pca((b5+b4+b3)/b6), pca((b3+b2+b1)/b6)) as RGB, the speed and accuracy of exploration and analysis of the desired area increase greatly. And the correct analysis can be identified, and each mineral is placed in its correct color spectrum and numerical range. If the potential, reserve and the average grade of the minerals in the desired area decrease or increase, you can see them with a specific number and color spectrum. You can also analyze any mine everywhere around the world to decide which one is better, what kind of minerals you have in that mine, and also to find the best points of that mineral. In addition, it significantly enhances the acceleration of discoveries while also lowering mining costs and optimizing mine exploitation. We used mineral data of some parts of Iran in all examples in this study.

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Date of submission (**preprint**): **31 July 2025**

Author's note: Formula **(1)** and Formula **(4)** constitute the core contributions of this study. Formula (1) was originally derived and documented by the author on July 6, 2025 (corresponding to 15 Tir 1404 in the Persian calendar). Although Formula (4) was not explicitly recorded in the original notes dated July 6, 2025, it is directly derived from Formula (1), which was documented on that date. The formula is included here for clarity and completeness. Formula (3) was revised and finalized by the author on March 18, 2025, and documented via email and Word file for record. The author notes that earlier unpublished drafts of Formula (3) also exist.

Note: Version **1** of this manuscript has been submitted to ***Environmental Earth Sciences*** for peer review.

*This is version **2** of the manuscript, submitted to **EarthArXiv** for preprint.

1. Introduction

For the discovery of minerals, humans have made numerous efforts to locate and utilize them more efficiently. For this reason, many satellites have been launched for mining exploration. The Landsat8 satellite captures high-quality images of the Earth's surface, significantly accelerating mineral discovery. Through data processing software and the proper use of wavelength information from these satellite images, mineral exploration can be conducted more easily.

We used four important band compounds formulas as follows:

- (((b7+b6+b5)/b6), ((b5+b4+b3)/b6), ((b3+b2+b1)/b6)) as RGB
- ((b3+b1)/b2), ((b3+b5)/b4), ((b5+b7)/b6)) as RGB [1]
- ((b3/b1), (b5/b7), b6) as RGB [2]
- (pca((b7+b6+b5)/b6), pca((b5+b4+b3)/b6), pca((b3+b2+b1)/b6)) as RGB

We used a new method for exploration and analysis of most minerals in the desired area. In our method, we used (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33), (MAP4, MAP44) maps in all minerals exploration to evaluate the presence of Gold, Copper, Magnetite, Hematite, Manganese, Magnesium, Chromite, Antimony, Bauxite, Industrial soils, Nickel, Cobalt, Lead and Lithium minerals and the changes in potential, average grade and reserves of these minerals in the desired mine.

(MAP1, MAP11) map was generated using the band compound (((b7+b6+b5)/b6), ((b5+b4+b3)/b6), ((b3+b2+b1)/b6)) as RGB. The simple band composition (b3, b2, b1) as RGB is by default and it is made of b3 (red), b1 (blue), b2 (green) bands, and it is not optimal for the exploration of most minerals, and we must use all seven bands and maintain the ratio (3, 2, 1). For this reason, we take help from the formula below, which is part of the series, and first select three bands out of the seven bands.

$$(n, k)= ((n-1)*(n-2)*(n-k+1))/(k!)$$

In this band compound, we have no shadow and the green space is visible exactly in green, water sources (rivers and etc) are also visible in dark blue. but in (b3, b2, b1) as RGB, the green space and water sources are visible in black, while the points with high potential are also in black, which creates a contradiction and causes mistakes in the analysis of the desired area. In this band compound, we see a more accurate color spectrum for different mineral materials. The best point of the mineral can be observed in black or white or sky blue colors. In these points, the potential and reserves of minerals reach their highest levels. It is best to use this optimal band compound for mineral exploration and analysis of the desired area.

(MAP2, MAP22) map was generated using the band compound ((b3+b1)/b2), ((b3+b5)/b4), ((b5+b7)/b6)) as RGB [1] . Using this map, we can identify what types of minerals may exist in the desired area. Also, the average grade of some minerals can be estimated in desired square (any pixel of map). In this map, dark blue represents vegetation, while sky blue may indicate the presence of silica or soil minerals.

(MAP3, MAP33) map was generated using the band compound ((b3/b1), (b5/b7), b6) as RGB [2], and we corrected the bands for exploration of all minerals mentioned in this study. It plays a crucial role in all minerals exploration. This map enables confirmation of most minerals. Moreover, it facilitates the determination of whether a given mineral deposit is of sedimentary (blue) or igneous origin (light pink or green). In addition, yellow indicates the presence of vegetation cover or other interfering elements that exist alongside the mineral deposits.

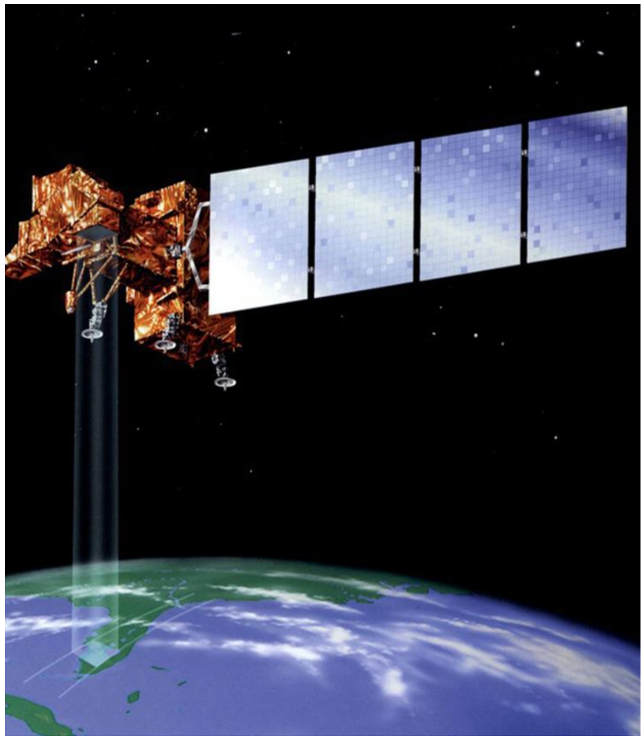
(MAP4, MAP44) map was generated using the band compound (pca((b7+b6+b5)/b6), pca((b5+b4+b3)/b6), pca((b3+b2+b1)/b6)) as RGB. And the ratio (3, 2, 1) must also be maintained. It has a decisive role in the exploration and analysis of minerals in any desired area. There is usually another map with a different color spectrum and the same band combination. If the potential, reserve and the average grade of the minerals in the desired area decrease or increase, you can see them with a specific number. We used this band compound in the exploration minerals mentioned in this study. The speed and accuracy of exploration and analysis of the desired area increase greatly. The correct analysis eliminates the duality of analysis or multiple analyses.

It is best to use this optimal band combination for mineral exploration and analysis of the desired area. In addition to the potential strength of minerals, different minerals can also be separated from each other.

In most discoveries of minerals, three formulas are complementary and we should use all the three. We have tried to cover the most commonly used minerals on earth. Furthermore, we recognized the correct analysis in any desired area. It is possible to distinguish between certain sulfide and oxide minerals. This study aims to identify the most important minerals in mines and also to be able to identify strong and weak places of those minerals in the desired mine and to also reduce the mining costs a lot. In addition, the discovery of minerals should be done in the most optimal way, and we can use these methods in other planets as well.

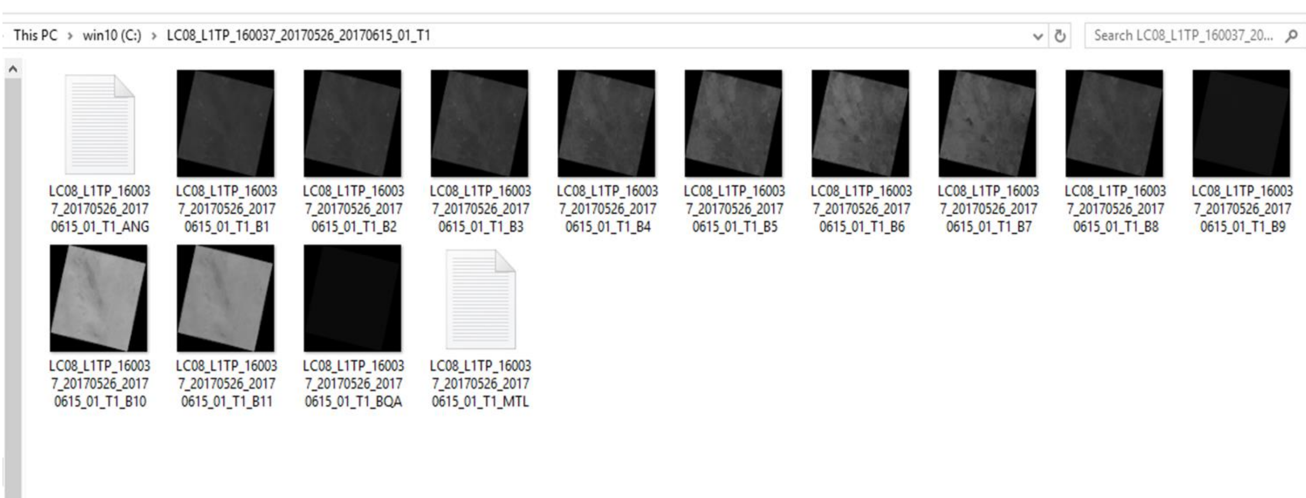
Therefore we were able to identify the best point of that mineral and the best mineral in the desired area. We used the specific color spectrum of the maps and the number given in some maps to identify the mentioned minerals. We determined whether the mine was economically viable or not. Also, the strength and weakness of the mineral in the desired area can be transferred to the marked points from a map to "KMZ" type file and these points can be used in GPS for exploration. This applies to all continents of the planet. We succeeded in the optimal use of minerals exploration in the desired area. In addition to the presented examples, numerous instances of mineral discovery and analysis using this method exist. However, due to the scope of this study, it is not feasible to include all of them.

Landsat8 satellite was launched on February 11, 2013. This satellite provides high quality images from all over the earth with different wavelengths. The best images of this satellite are from 2017. Therefore we used Landsat8 satellite images from 2017 in our minerals exploration. Due to the impact of meteorites on this satellite, the quality of the photos decreased in the following years. This satellite has two sensors, the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). In all maps in this study, we used the images of Landsat8 satellite bands (Blue(2), Green(3), Red(4), Near Infrared(5), SWIR 1(6), SWIR 2(7), Thermal Infrared 2 (11)). These bands are of the TIFF file type. Fig 1.1 shows a part of the earth that is photographed by Landsat satellite with different wavelengths [3].



(Fig 1.1) A picture of the Landsat satellite

When Landsat8 satellite images are decompressed, these images are as follows (Fig 1.2). Landsat8 data is available to the general public and can be downloaded at http://earthexplorer.usgs.gov.



(Fig 1.2) Images of part of the earth, all bands of Landsat8 satellites

The Advanced Land Imager (ALI) sensor was launched on November 21, 2000. (ETM+) sensor on Landsat7 has a swathe width of 185 km and also Landsat8 sensor has a Ground resolution of 30m. The performance characteristics of ALI, ETM+ and Landsat8 are listed in (Table 1.1) [4].

(Table 1.1) Performance characteristics of the ALI, ETM+ and Landsat8 OLI/TIRS sensors

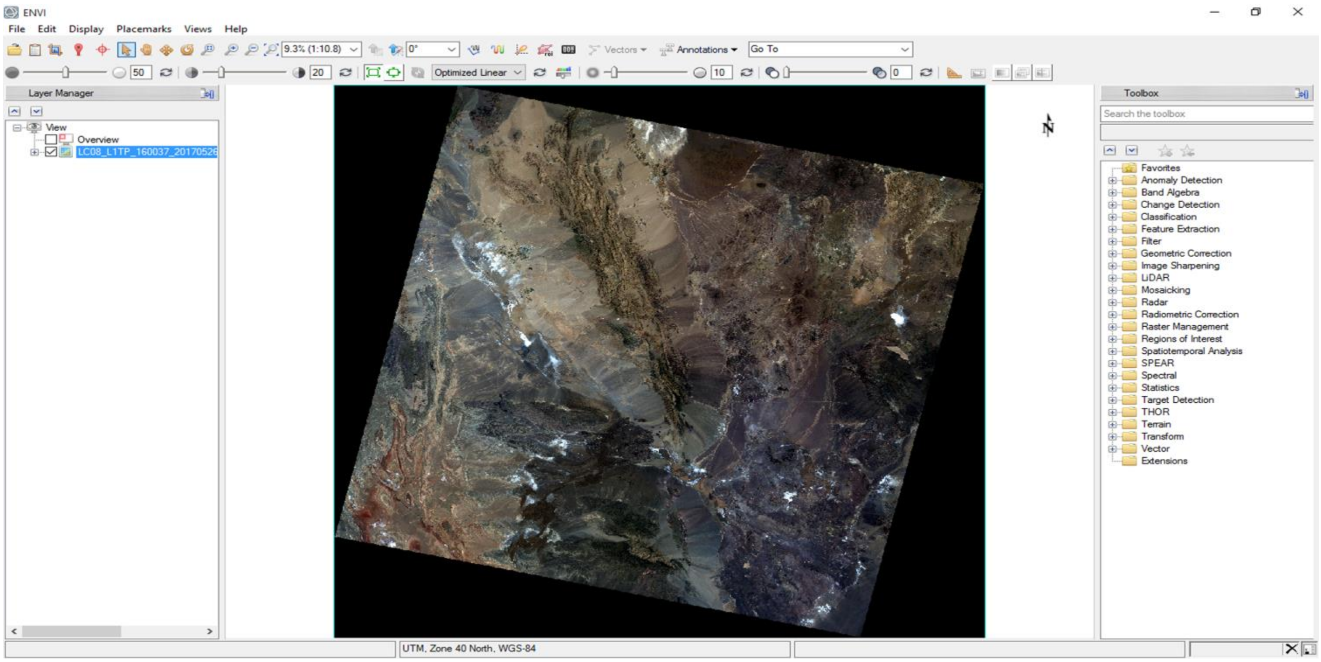
Sensors	Subsystem	Band number	Spectral range (μm)	Ground resolution (m)	Swath width (km)
ALI	VNIR	Pan	0.480–0.690	10	37
		1	0.433–0.453	30	
		2	0.450–0.515		
		3	0.525–0.605		
		4	0.633–0.690		
		5	0.775–0.805		
		6	0.845–0.890		
	SWIR	7	1.200–1.300		
		8	1.550–1.750		
		9	2.080–2.350		
ETM+	VNIR	Pan	0.520–0.900	14.25	185
		1	0.450–0.515	28.50	
		2	0.525–0.605		
		3	0.633–0.690		
		4	0.780–0.900		
	SWIR	5	1.550–1.750		
		7	2.090–2.350		
	TIR	6	10.45–12.50		
Landsat 8	VNIR	1	0.433–0.453	30	185
		2	0.450–0.515		
		3	0.525–0.600		
		4	0.630–0.680		
		5	0.845–0.885		
	SWIR	6	1.560–1.660		
		7	2.100–2.300		
	Pan	0.500–0.680	15		
		9	1.360–1.390		
	TIR	10	10.30–11.30		
		11	11.50–12.50		

The visible near-infrared (VNIR), the short-wave infrared (SWIR) and the thermal-infrared (TIR) are abbreviated.

The images and data of OLI have helped us a lot in all matters of land fields, mining maps and climate changes that occur on earth [5]. It consists of nine bands. Landsat8 satellite has two TIRS (Landsat Thermal Infra-Red Sensor) sensors: Thermal Infrared 1(b10) and Thermal Infrared 2(b11). Both of them have high resolution and great impact in minerals exploration. Also they provide us with more detailed data. These sensors are QWIP (Quantum well infrared photo detectors) and use quantum well structures. This thermal imager operates in Pushbroom mode with two Infra-Red channels: 10.9 μm and 12 μm [6] and uses the split-window technique [7].

2. Steps of data process of Landsat8 satellite images using Envi software

Envi software version 5.3 was utilized for data processing. To open the Landsat 8 images, the "File" menu was navigated to, "Open As" was selected, and the Landsat option was chosen. Then, "GeoTIFF with Metadata" was clicked, the corresponding metadata text file ("LC08_L1TP_160037_20170526_20170615_01_T1_MTL") was selected, and "Open" was clicked. Upon loading the dataset, the default RGB band compound (Band 4, Band 3, Band 2) was displayed in Envi software (Fig 2.1).To ensure proper processing of Landsat8 satellite images, a structured four-step workflow was followed, with each step applied sequentially to maintain consistency and accuracy in the analysis.



(Fig 2.1) default band compound (b4,b3,b2) as RGB in Envi software

2.1. Using "Radiometric Calibration" technique in Envi software

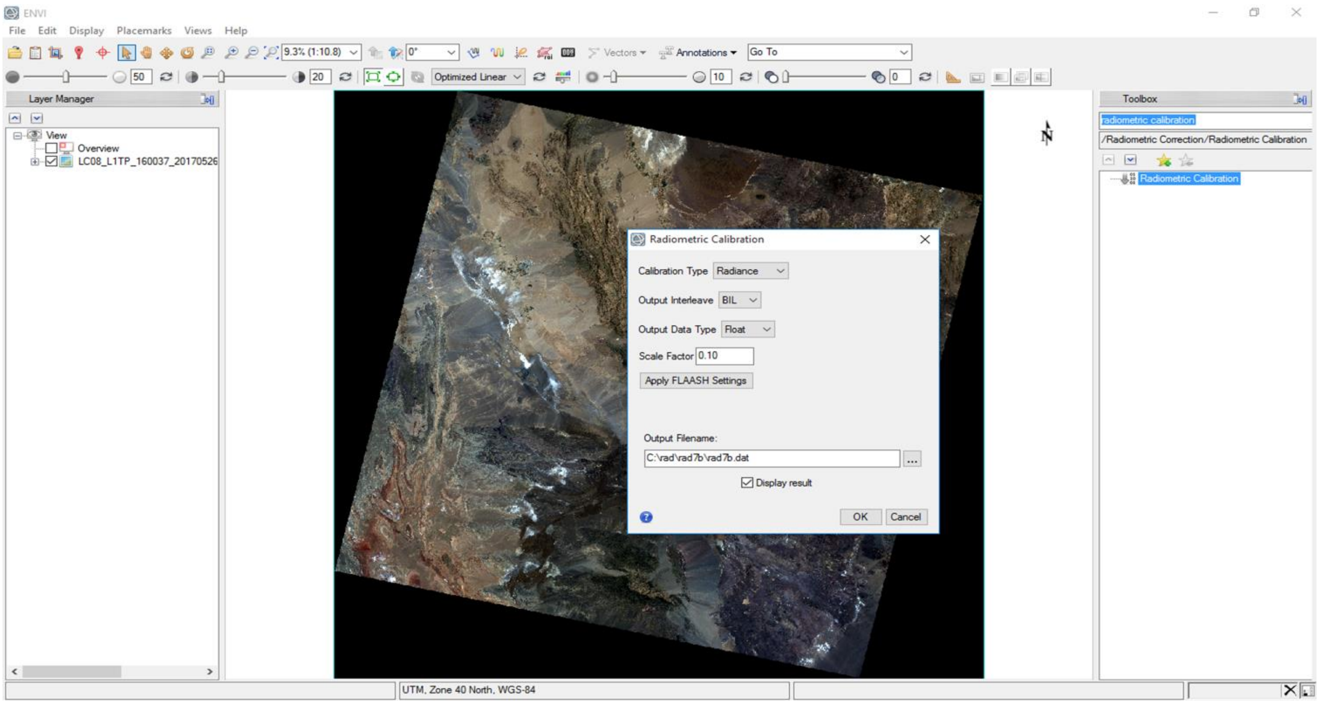
Radiometric calibration technique was applied, and calibrated radiance data were processed. The OLI seven bands (Multispectral bands) and TIRS bands were used as input.

The steps of setting the "Radiometric Calibration" technique in the software are as follows [8]:

"Radiometric Calibration" was typed in the "toolbox" section of the ENVI software and then was clicked. In the "file selection" section, LC08_L1TP_160037_20170526_20170615_01_T1_MTL_MultiSpectral was selected. The "Spectral Subset" option was clicked, the OLI seven bands were selected, and OK was clicked. The "Apply Flash Settings" option was clicked, and the following items were placed.

Calibration Type: Radiance, Output Interleave: BIL, Output Data Type: Float, Scale Factor: 0.10

The path of the desired file was entered and the file was saved as "rad7b.dat" (Fig 2.1.1).

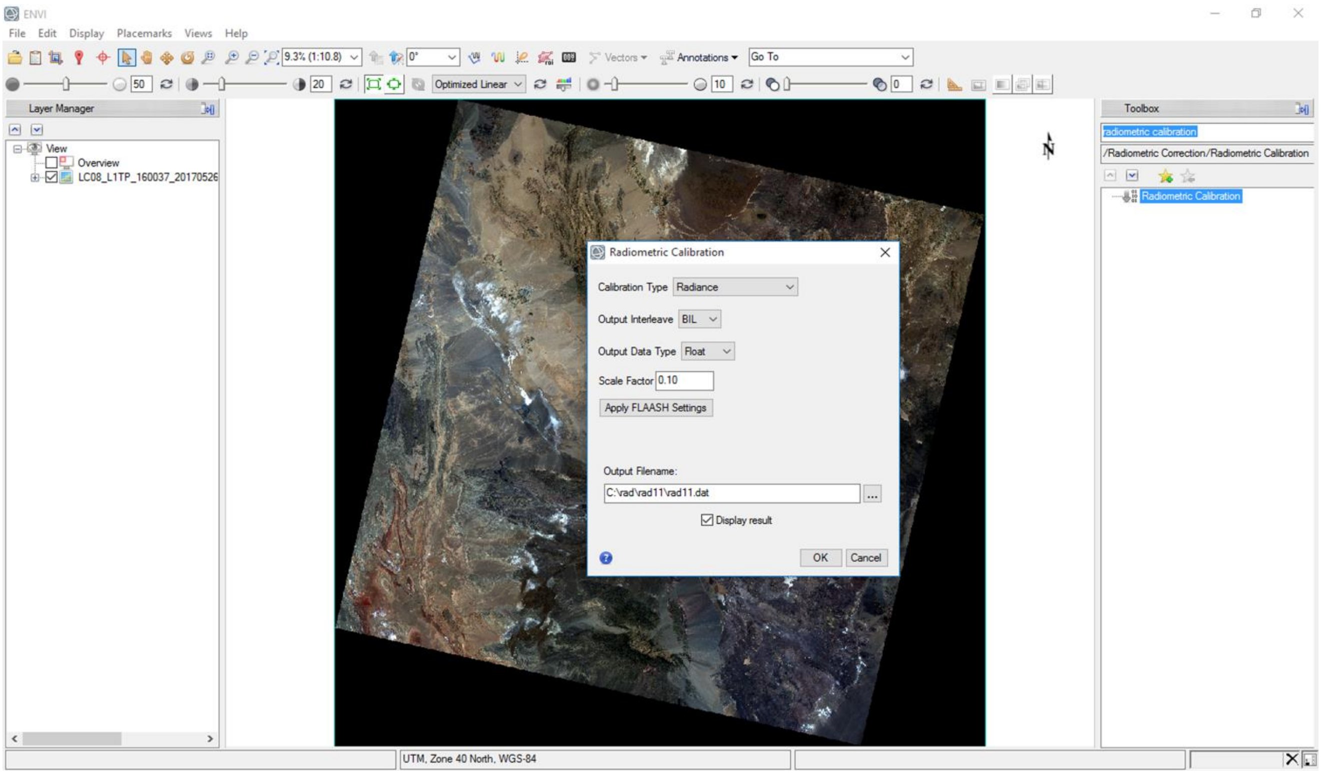


(Fig 2.1.1) Radiometric Calibration setting and saving seven OLI bands as "rad7b.dat"

"Radiometric Calibration" was entered in the "Toolbox" section of the ENVI software and was clicked. In the "File Selection" section, a file named "LC08_L1TP_160037_20170526_20170615_01_T1_MTL_Thermal" was selected. The "Spectral Subset" option was clicked, two Thermal bands were selected, and OK was clicked. Additionally, the "Apply Flash Settings" option was selected, and the following parameters were set.

Calibration Type: Radiance
Output Interleave: BIL
Output Data Type: Float
Scale Factor: 0.10

Finally, the target file path was defined, and the output was stored under the name "rad11.dat" (Fig 2.1.2).



(Fig 2.1.2) Radiometric Calibration setting and saving two Thermal bands as "rad11.dat"

2.2. Using Flaash method in Envi software

After configuring Radiometric Calibration technique on OLI seven bands (Multi Spectral bands), the output file "rad7b.dat", which was created recently, is used as Radiance input using the Fast Line of Sight Atmospheric Analysis of Hypercubes (Flaash) method [9].The steps of setting the Flaash method in the software are as follows [9] :

"Flaash" was written in the "Toolbox" section of the ENVI software, and "Flaash Atmospheric Correction" was clicked. In the "Input Radiance Image" section, the file prepared in Section 2.1 of this study, named "rad7b.dat", was provided as input, and OK was clicked.In the "Radiance Scale Factors" section, the "Use Single Scale Factor for All Bands" option was selected and OK was clicked. Next, in the "Output Reflectance File" section, the output file was saved as "Flaash.img", in a specified path. In the "Output Directory for Flaash Files" section, the previously used folder was selected. Additionally, in the "Rootname for Flaash Files" section, a name such as "flash" was entered.

In the "Sensor Type" section, the "Multispectral" option was located and "Landsat8 OLI" was clicked. Finally, the remaining fields were completed according to the "metadata" file accompanying the Landsat8 satellite images (Fig 2.2.1).

Full Display of LC08_L1TP_160037_20170526_20170615_01_T1

Data Set Attribute	Attribute Value
Landsat Product Identifier	LC08_L1TP_160037_20170526_20170615_01_T1
Landsat Scene Identifier	LC81600372017146LGN00
Acquisition Date	2017/05/26
Collection Category	T1
Collection Number	1
WRS Path	160
WRS Row	037
Target WRS Path	160
Target WRS Row	037
Nadir/Off Nadir	NADIR
Roll Angle	-0.001
Date L-1 Generated	2017/06/15
Start Time	2017:146:06:43:28.0500040
Stop Time	2017:146:06:43:59.8200010
Station Identifier	LGN

(Fig 2.2.1) The "metadata" file related to the images of Landsat8 satellite

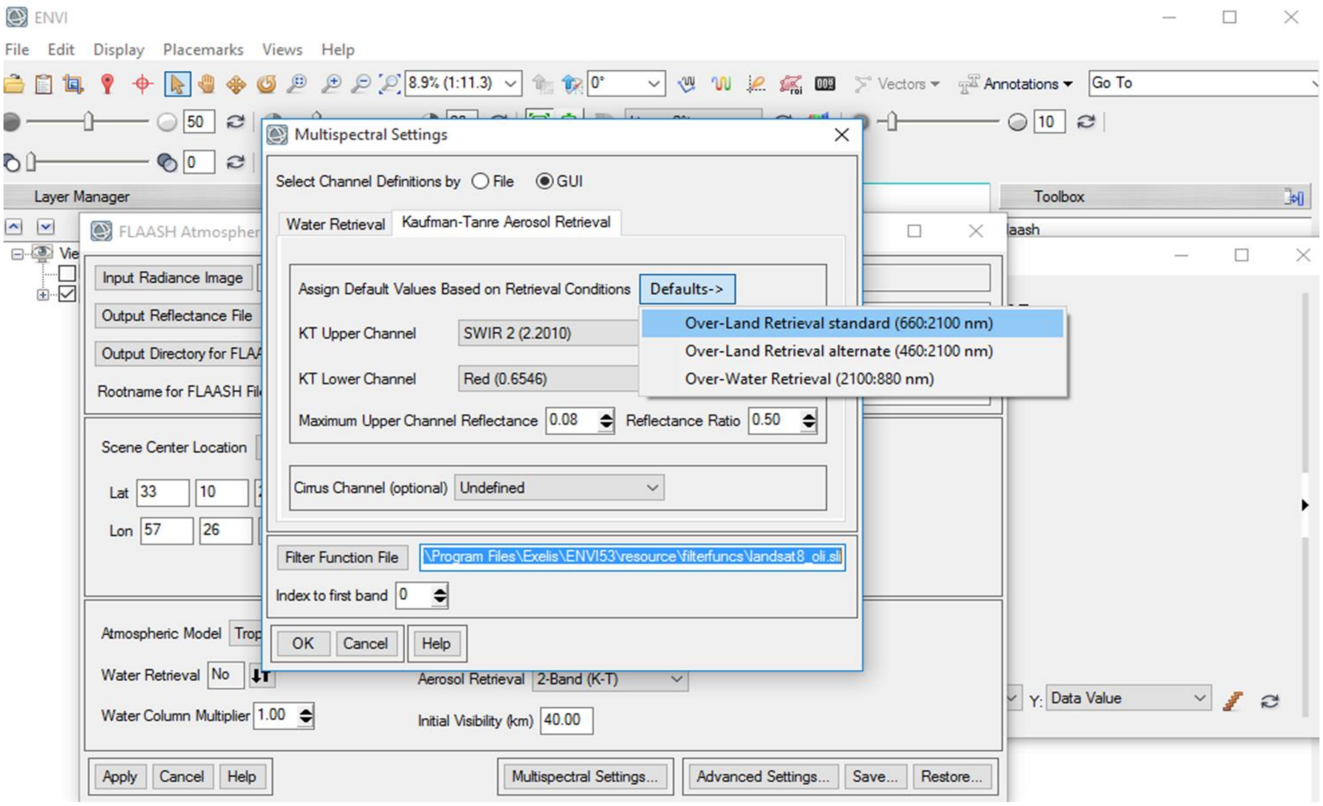
The value was set to 0.5 in the "Ground Elevation (km)" section. Then, from the "Acquisition Date" section, the value 05/26/2021 was set in the "Flight Date" section (Fig 2.2.1). Similarly, from the "Start Time" section, the value (06:43:29) was set in the "Flight Time GMT (HH:MM:SS)" section.

In the "Aerosol Model" section, the "Tropospheric" option was set. Next, the "Multispectral Settings" option was clicked, then the "Kaufman-Tanre Aerosol Retrieval" menu was clicked, the "Defaults" option was selected, and "Over-Land Retrieval Standard (660:2100nm)" was chosen.

Additionally, the "Filter Function File" option was clicked, and "Open" was clicked, followed by "New File". The following path was provided:

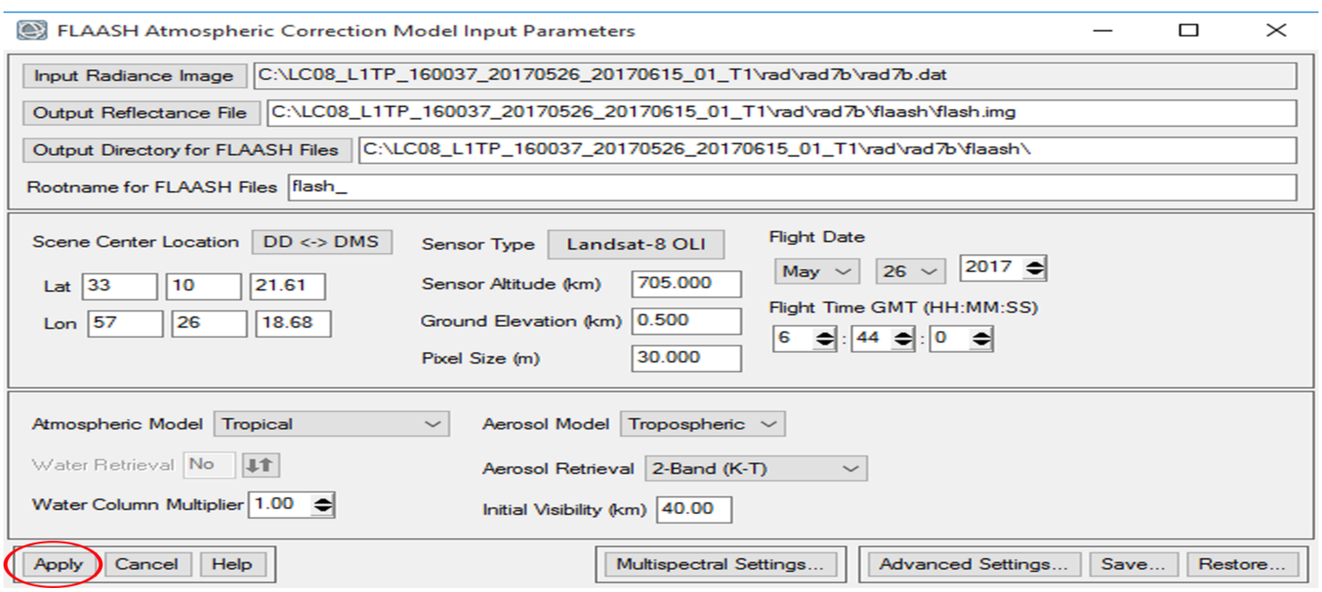
C:\Program Files\Exelis\ENVI53\resource\filterfuncs\Landsat8_OLI.sli

Finally, the "Landsat8_OLI.sli" file was selected and "ok" was clicked (Fig 2.2.2).



(Fig 2.2.2) selecting "Landsat8_OLI.sli" and "Over-Land Retrival standard (660:2100nm)" option in "Multispectral Settings" window

"Apply" was clicked and the process was waited until 100% (Fig 2.2.3).



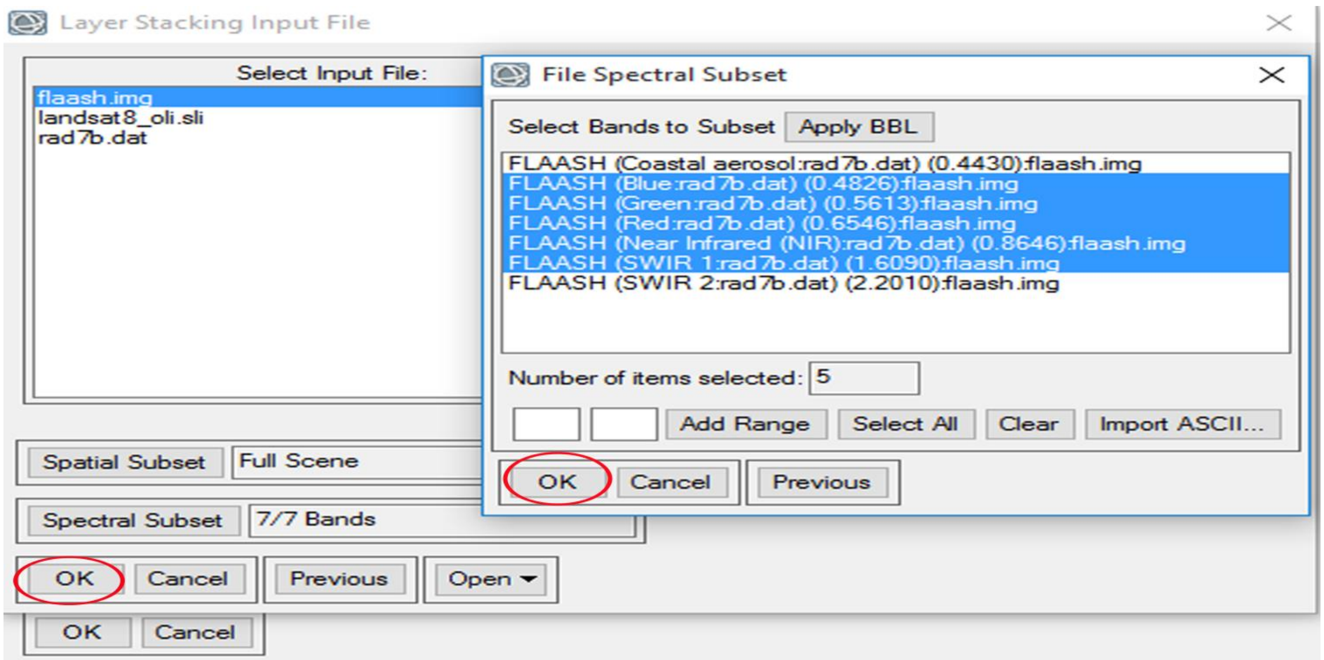
(Fig 2.2.3) configuring “Flaash" settings in Envi software

2.3. Stacking Landsat8 satellite bands

In this step, all the bands needed to create maps of different minerals were merged in order.

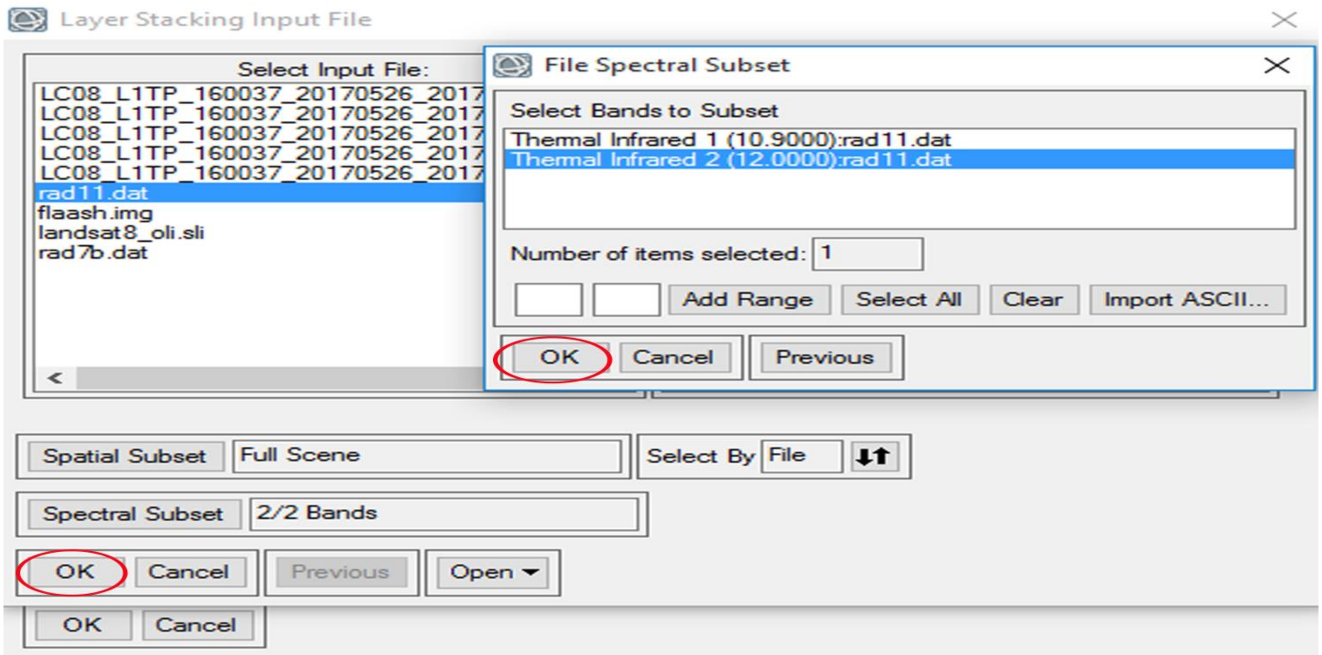
The steps of stacking bands in the software are as follows:

"Layer Stacking" was written in the "toolbox" section of the Envi software and then clicked. In the "Layer Stacking parameters" section, "import file" was clicked. The "Flaash.img" file, created in part 2.2 of this study, was selected as input and then the “Spectral Subset” option was clicked. Bands BLUE, GREEN, RED, Near Infrared, SWIR1 (2, 3, 4, 5, 6) were selected, and then "ok" was clicked (Fig 2.3.1).



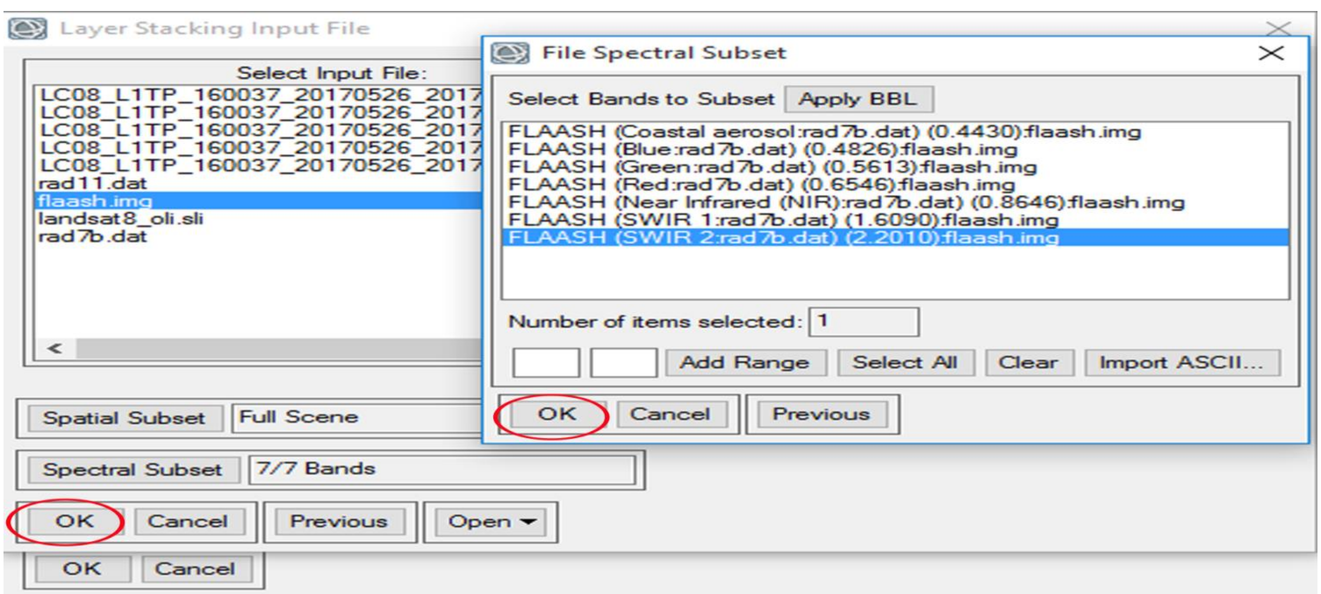
(Fig 2.3.1) selecting bands BLUE, GREEN, RED, Near Infrared, SWIR1 (2,3,4,5,6) from “Flaash.img”

"Import file" option was clicked in the "Layer Stacking parameters" window, then "rad11.dat" was selected in the "Layer Stacking Input File" section, which was created in part 2.1 of this study. The "Spectral Subset" option was clicked, "Thermal Infrared2" band was selected, and then "ok" was clicked (Fig 2.3.2).



(Fig 2.3.2) selecting "Thermal Infrared2" band from "rad11.dat"

"Import file" option was clicked in the "Layer Stacking parameters" window, then "Flaash.img" was selected in the "Layer Stacking Input File" section in the software. The "Spectral Subset" option was clicked, the "SWIR 2" band was selected, and then "ok" was clicked (Fig 2.3.3).



(Fig 2.3.3) selecting “SWIR 2” band from “Flaash.img”

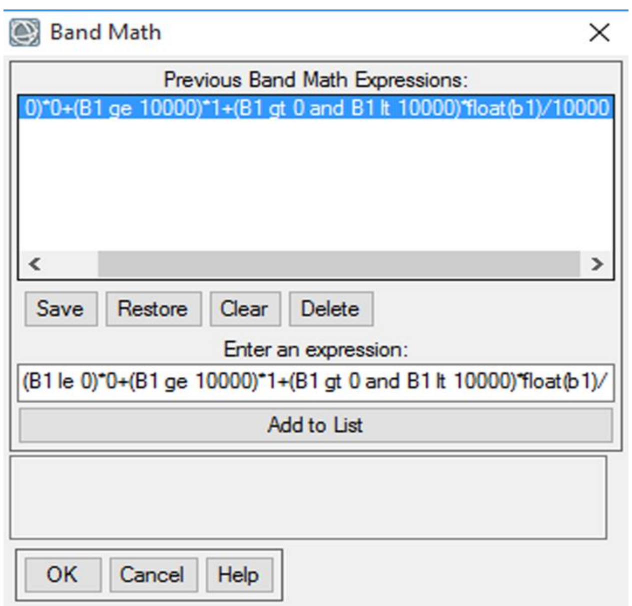
"Choose" option was clicked in the "Layer Stacking parameters" window. Then, the file was saved as "stack7b.img" in the desired path.

2.4. Using math in Envi software

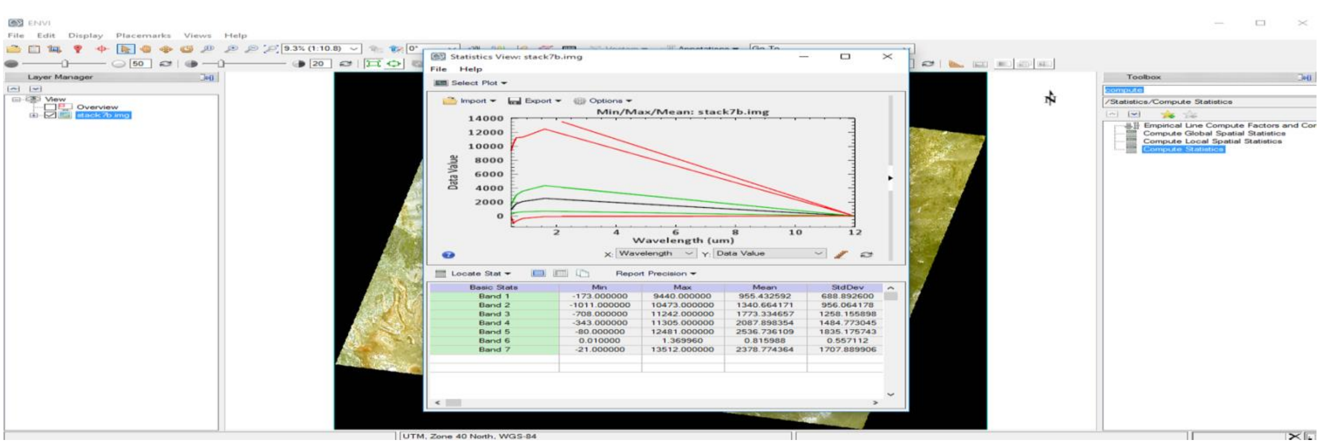
In this step, the algorithm of the calculated statistics was used with the following equations.

Rescaling of the Flaash output to a 0-1 reflectance scale for each band of the stack was performed using Band Math. This formula was written in Band Math: (Fig 2.4.1).

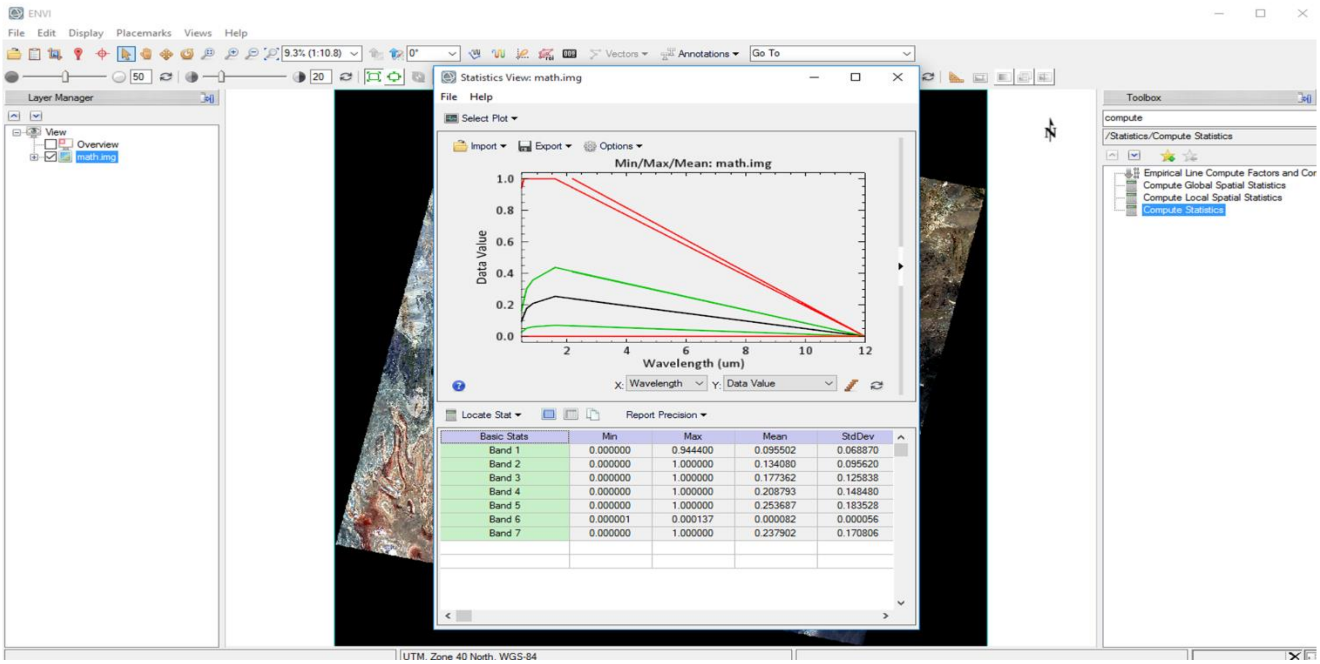
P= (b1 le 0)*0+(b1 ge 10000)*1+(b1 gt 0 and b1 lt 10000)*float(b1)/10000 [10]
Where P is image reflectance, and b1 is the band to be corrected. b1 was set equal to the "stack7b.img" file that was created in part 2.3 of this study. [10] Histogram of the reflectance values is shown in (Fig 2.4.2) and (Fig 2.4.3).



(Fig 2.4.1) Entering the formula in "Band math" section in Envi software

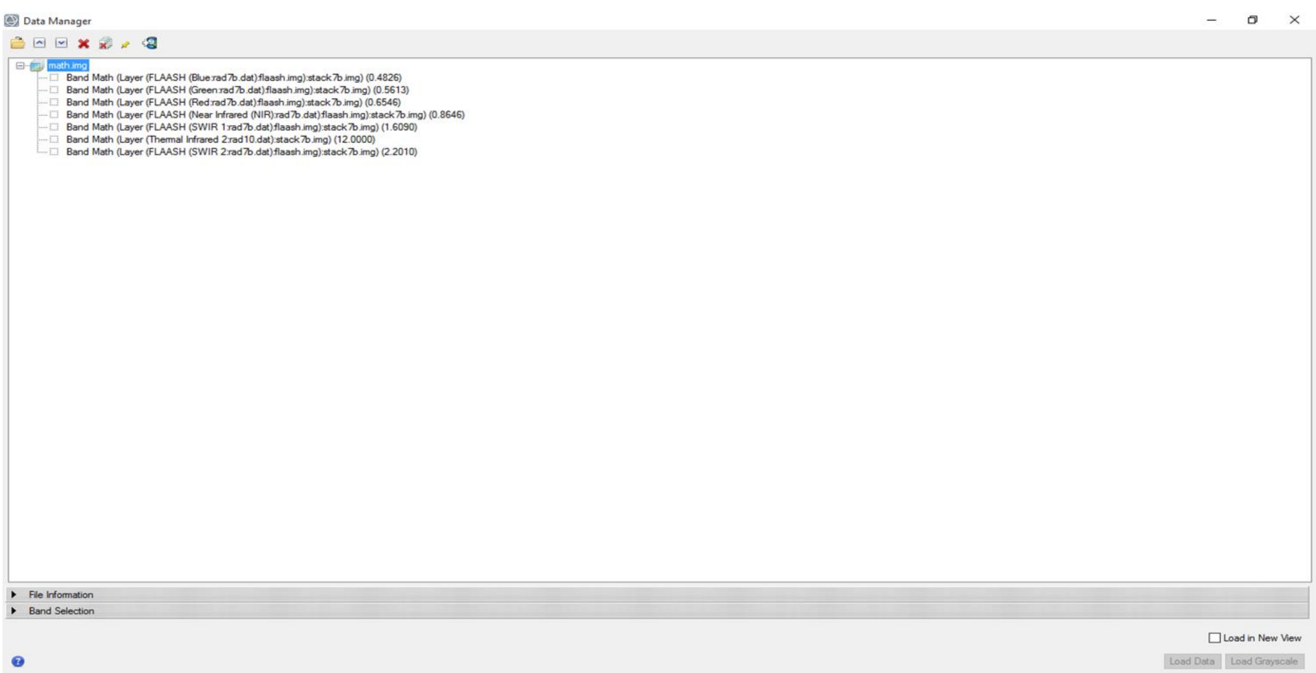


(Fig 2.4.2) Histogram reflectance value before correction



(Fig 2.4.3) Histogram reflectance value after correction

The file was saved in a path as "math.img".The order of the bands is band2, band3, band4, band5, band6, band11, band7 of Landsat8 satellite which is shown in Fig 2.4.4.



(Fig 2.4.4) The order of the bands in "math.img"

3. **Dividing "math.img" file (which we created in part 2.4 of this study) into two files and using "mnf" and "stretch" methods on both files and naming output of these two maps as "stretchleft.img" and "stretchright"**

In this step, "math.img" was opened in the Envi software, which was created in Section 2.4 of this study. In the "Data Manager" section of Envi, Band 6 was selected and the "Load Grayscale" option was clicked to load Band 6.
Next, a large rectangle was considered covering almost half of "math.img". The latitude and longitude points in both corners of the rectangle had to be completely inside Band 6. The latitude and longitude coordinates of the upper left and lower right corners of the rectangle were noted.

Then, the word "Resize Data" was typed in the "Toolbox" section of Envi and it was clicked. In the "Resize Data" window, "math.img" was selected and the "Spatial Subset" option was clicked. Next, the "Map" option in the "Select Spatial Subset" section was clicked. In the "Spatial Subset by Map Coordinates" window, the geographical coordinates of the upper left corner of the rectangle were entered. Finally, in the "Value Cursor" section of Envi, the geographical coordinates of any point on the map were obtained.

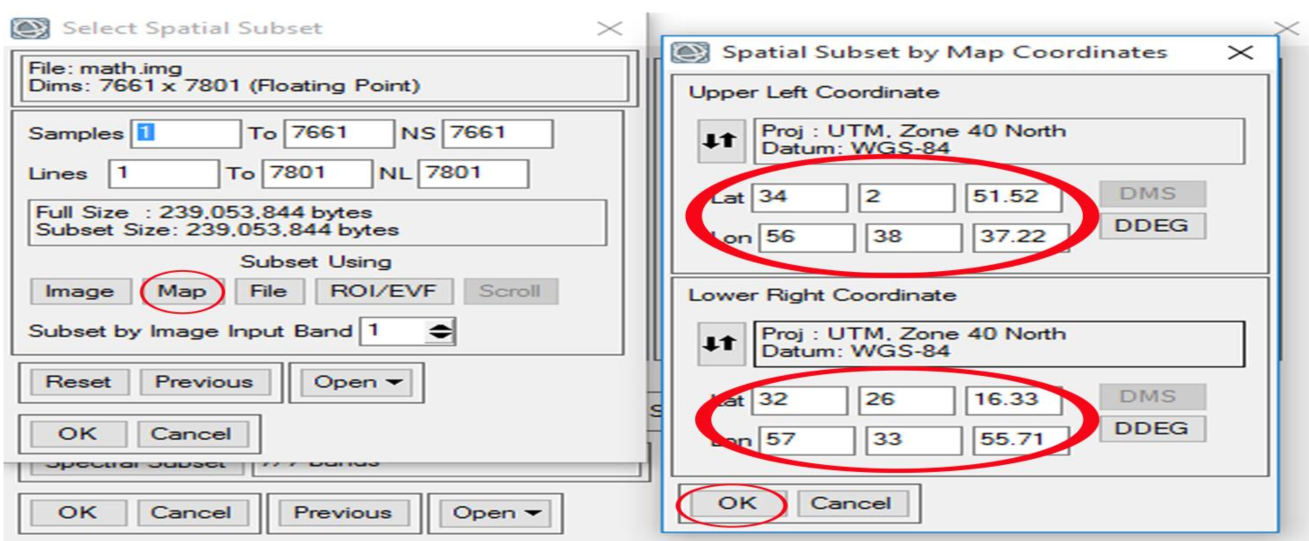
For example, the upper left coordinate:

34 2 51.52
56 38 37.22

And the lower right coordinate:

32 26 16.33
57 33 55.71

Ok was clicked and the file was saved as "r2.img" (Fig 3.1).

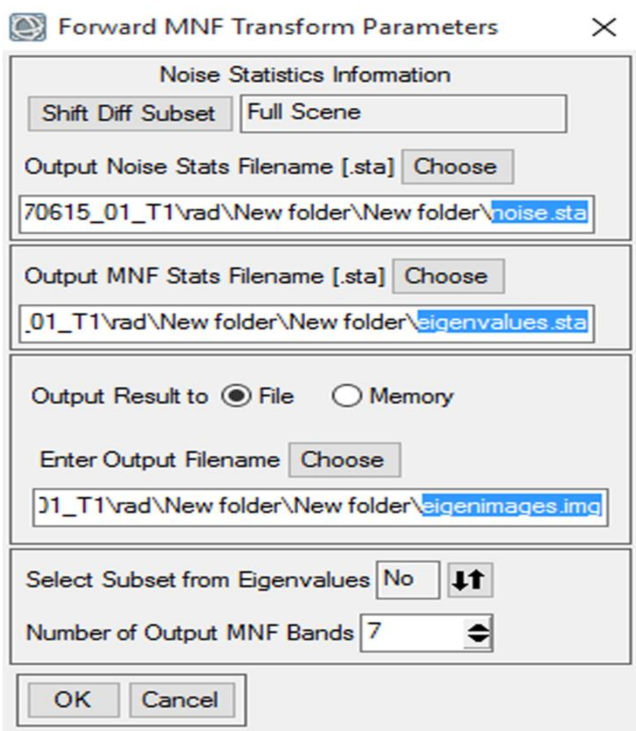


(Fig 3.1) placing the latitude and longitude on "math.img"

The Minimum Noise Fraction (MNF) is an enhanced linear algorithm designed to distinguish data from noise while reducing data dimensionality. It helps reducing the spectral and noise dependence of image bands and the amount of error existing in detection of the target features. MNF method detects the amount of noise in all bands and can remove the noise from useful information [11]. The steps of MNF method in the software are as follows:

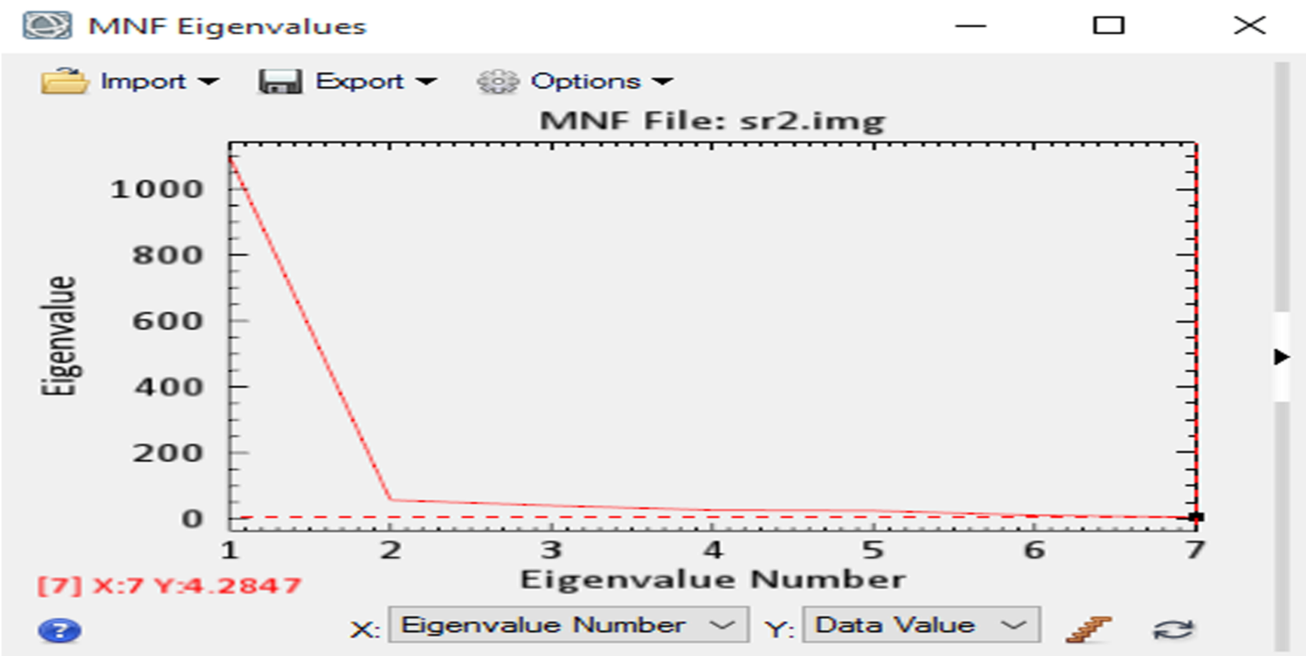
In the "Toolbox" section of the Envi software, "MNF" was typed and the "Forward MNF Estimate Noise Statistics" option was selected. In the "MNF Transfer Input File" section, the recently created file "r2.img" was chosen and confirmed by clicking OK.Next, the "Forward MNF Transfer Parameters" window was opened. In the "Output Noise Stats Filename" section, the "Choose" option was clicked, and the file was saved in a specific path as "noise.sta". Similarly, in the "Output MNF Stats Filename" section, "Choose" was clicked, and the file was saved in a designated location as "eigenvalues.sta".

Then, in the "Enter Output Filename" section, the "Choose" option was selected. saved the file in a specific path as "eigenimages.img", and finally clicked ok (Fig 3.2).



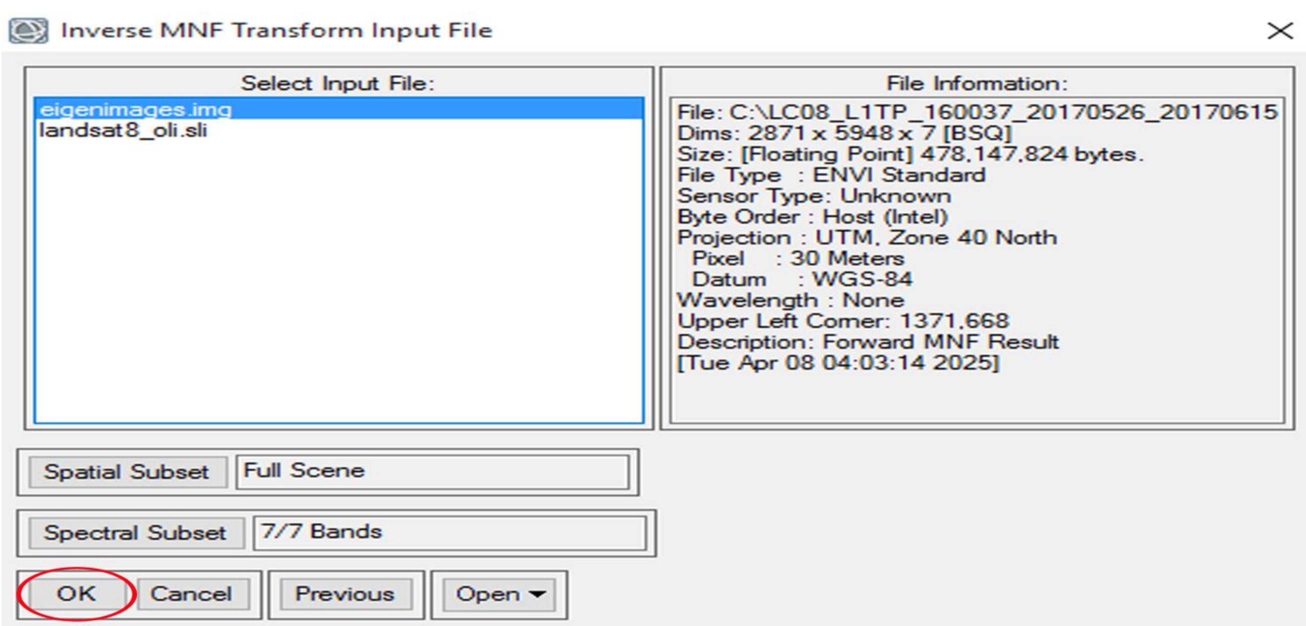
(Fig 3.2) saving "MNF" files

The "MNF Eigenvalues" diagram is shown in (Fig 3.3). For better quality of maps and more accurate output, "Eigenvalue" value of all bands should be greater than two, otherwise in the "toolbox" section of the Envi software "MNF" is typed, "Inverse MNF Rotation" option is selected, the "Eigenimages.img" file is selected and "Spectral Subset" option is clicked on. "Eigenvalue" value of every band should not be chosen smaller than two [11]. However, we suggest select all bands in any condition because the desired area may have better quality than other places on the map."Eigenvalue" value of all bands is greater than 4.2847 in this example that is ideal (Fig 3.3).



(Fig 3.3) MNF (Minimum Noise Fraction) diagram

In the "Toolbox" section of the Envi software, "MNF" was typed and the "Inverse MNF Rotation" option was selected. The "Eigenimages.img" file was chosen, the "Spectral Subset" option was clicked, all seven bands were selected, and the selection was confirmed. The output was saved as "r3.img" (Fig 3.4).



(Fig 3.4) selecting "Eigenimages.img" and confirming all seven bands

Stretch Data was used to perform file-to-file contrast stretching.Data stretching function is a method for changing the data range of a given input file. Also it can show the input and output histograms. Stretched enhanced data and maps have a great impact on detection and exploration of minerals [12].

The stretching method was used as follows [12]:

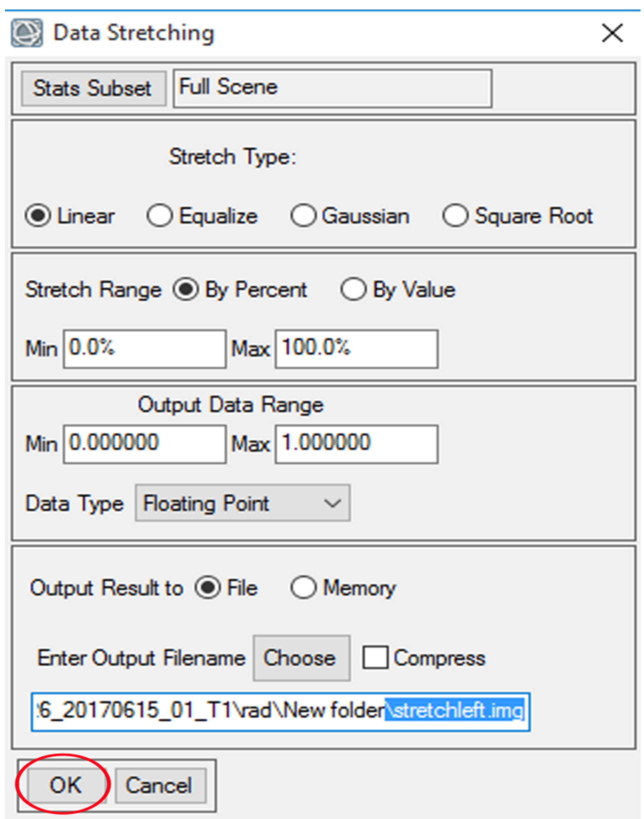
In the "toolbox" section of the Envi software, "Stretch Data" was written, and "r3.img" created recently was selected. The 'Data Stretching' section was filled as follows:"

Strech type:linear, Strech range: By percent, MIN:0%, MAX:100%

Filling "Output Data Range" section is as follows:

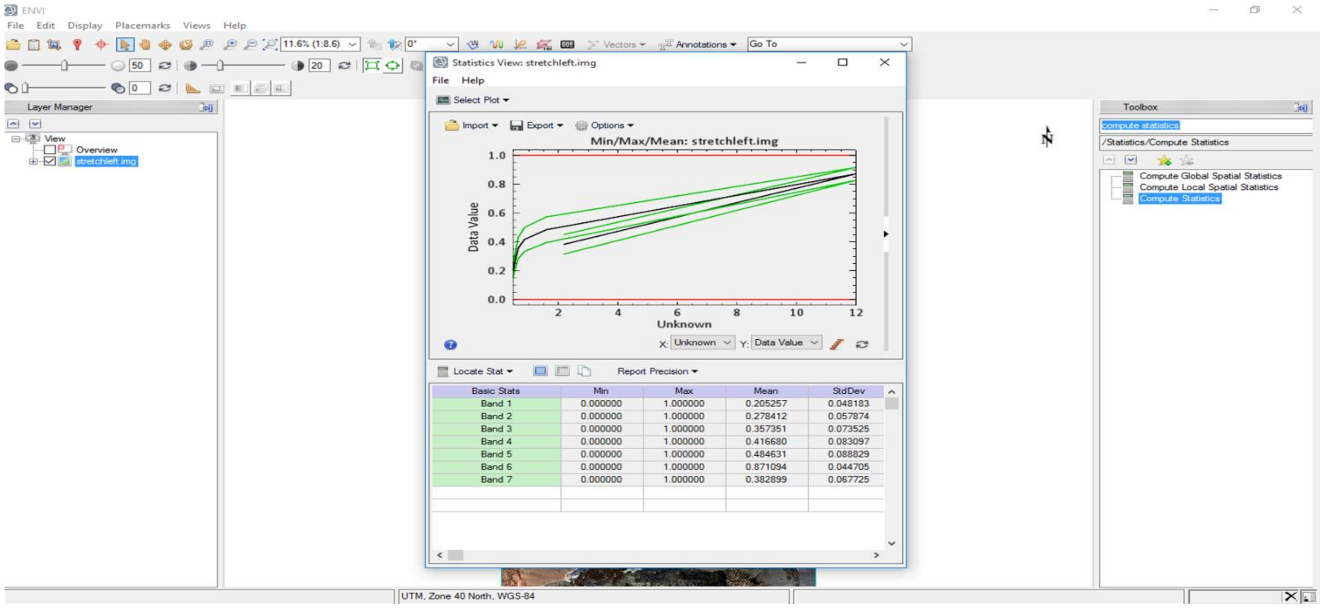
"MIN:0.000000 and MAX:1.000000 and Data Type: Floating Point" Entered.

The "choose" option was clicked, and it was saved as "stretchleft.img" with the default band compound (b3, b2, b1) as RGB (Fig 3.5).



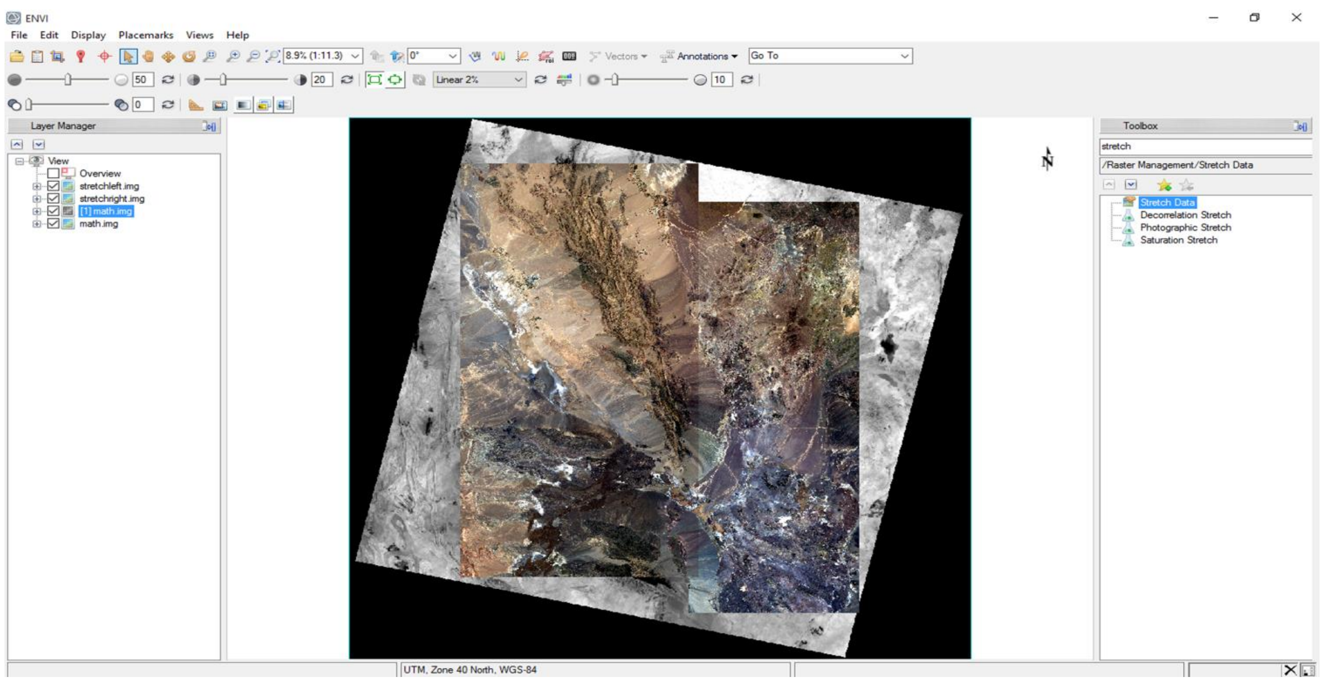
(Fig 3.5) "stretch" setting on "r3.img"

In the "toolbox" section of the Envi software, "compute Statistics" was written, the "compute Statistics" option was clicked, the "stretchleft.img" file was selected, and 'ok' was clicked. Histogram stretched values is shown in Fig 3.6.



(Fig 3.6) Histogram steretched on "stretchleft.img"

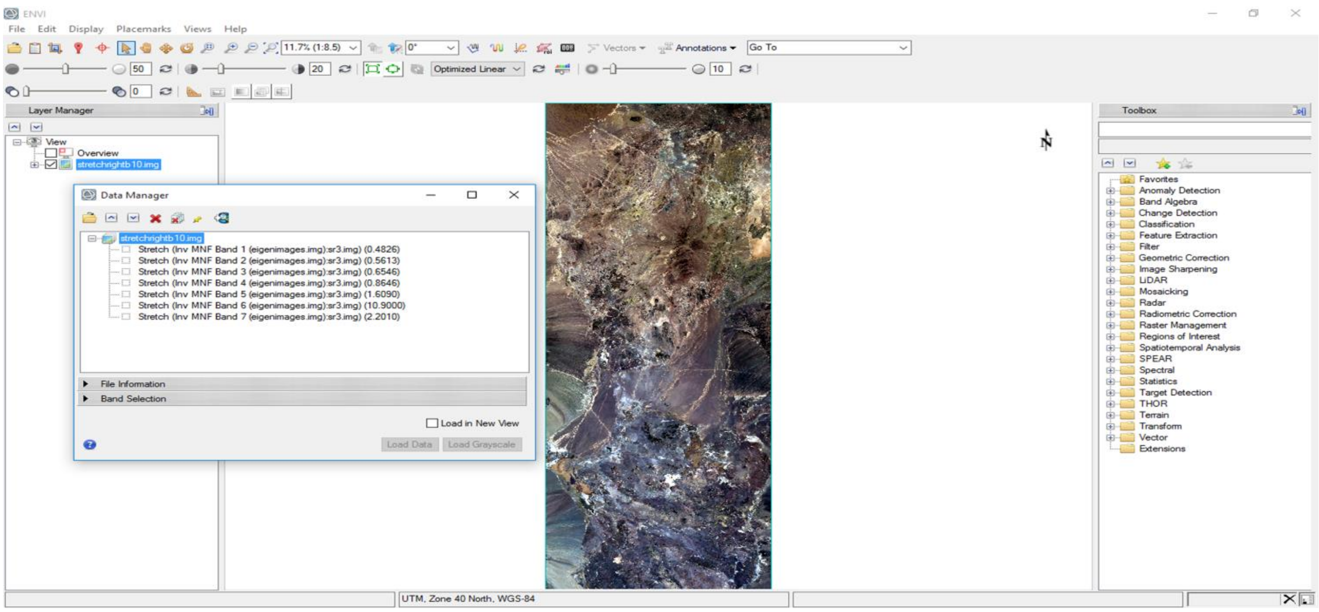
In this study we did all the items of part 3 for right rectangle in "math.img" then named the file as "stretchright.img" with default band compound (b3, b2, b1) as RGB (Fig 3.7). Dividing the Landsat 8 satellite images into two parts and using the maps enhanced the effectiveness of identifying and exploring geological data.



(Fig 3.7) Creating two files including "stretchleft.img" and "stretchright.img" with default band compound (b3, b2, b1) as RGB

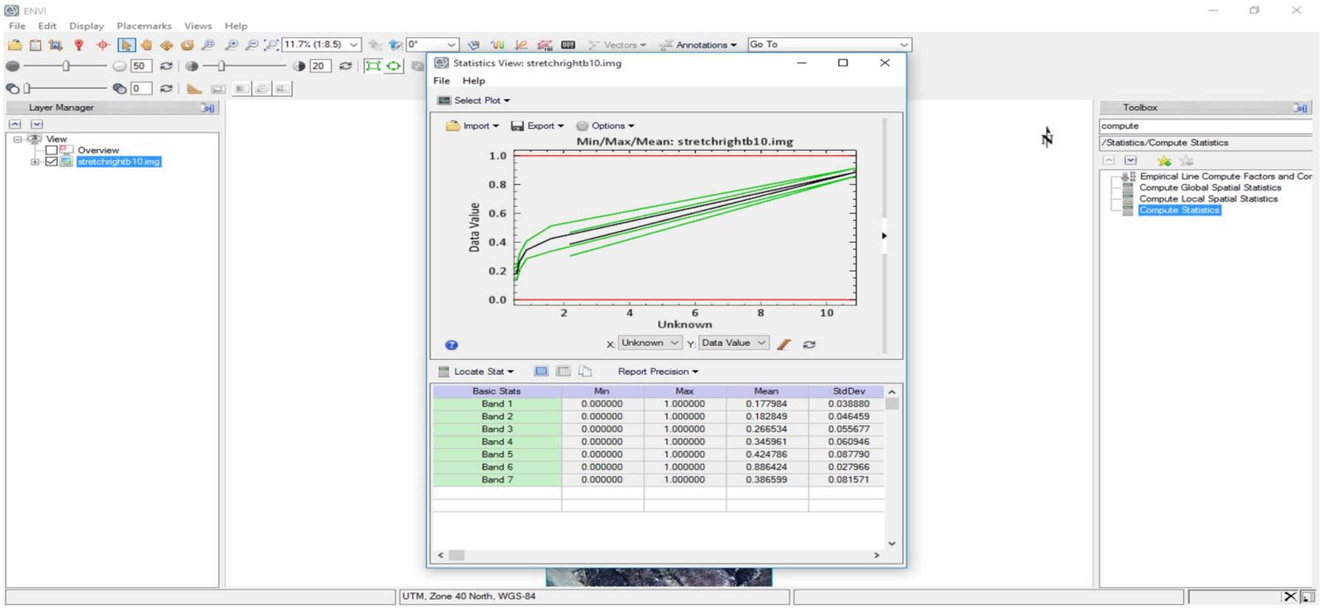
3.1. Comparing thermal bands 10 and 11 from Landsat8 satellite

Bands 10 and 11 are Thermal Infrared 1 and Thermal Infrared 2, respectively, in Landsat8 satellite. We compared these two bands according to the part 2.3 of this study and we set the band 6 as band 10. Again we set the band 6 as band 11. We repeated all the steps of part 2.4 and part 3 of this study for band 10. Finally, the order of the bands in the "stretchrightb10.img" file is as follows: (Fig 3.1.1).



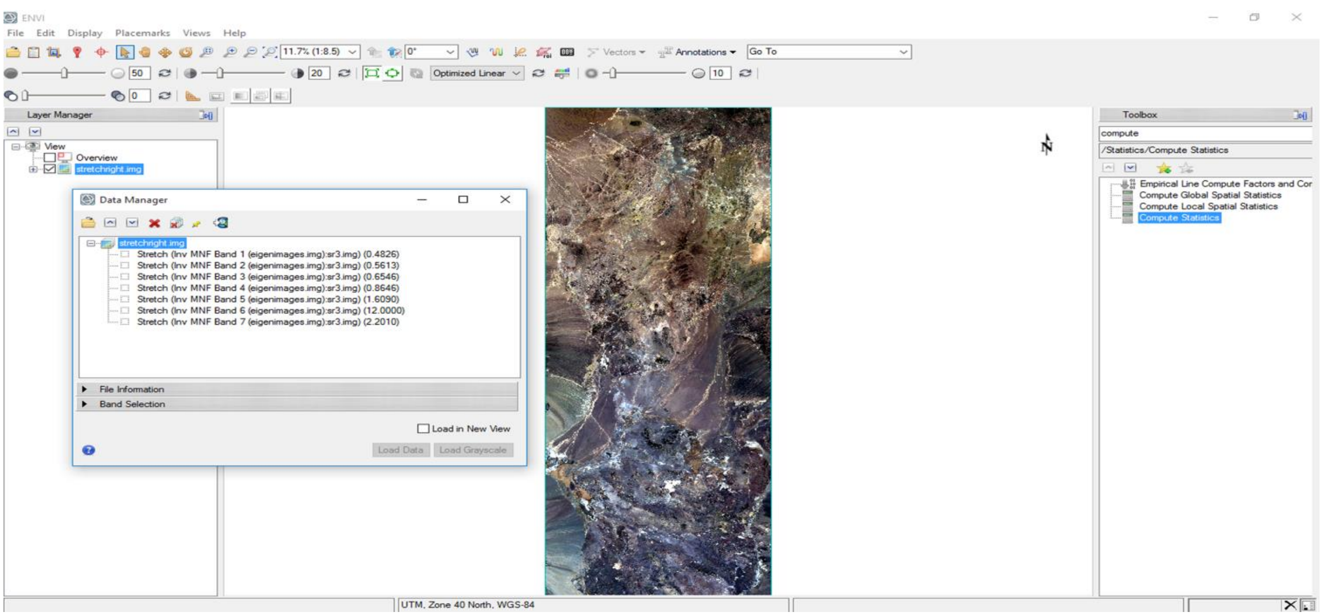
(Fig 3.1.1) order of the bands in "stretchrightb10.img" while using thermal band10

In the "toolbox" section of the ENVI software, "Compute Statistics" was typed, the "Compute Statistics" option was clicked, the "stretchrightb10.img" file was selected, and OK was clicked. Histogram stretched values is shown in Fig 3.1.2.



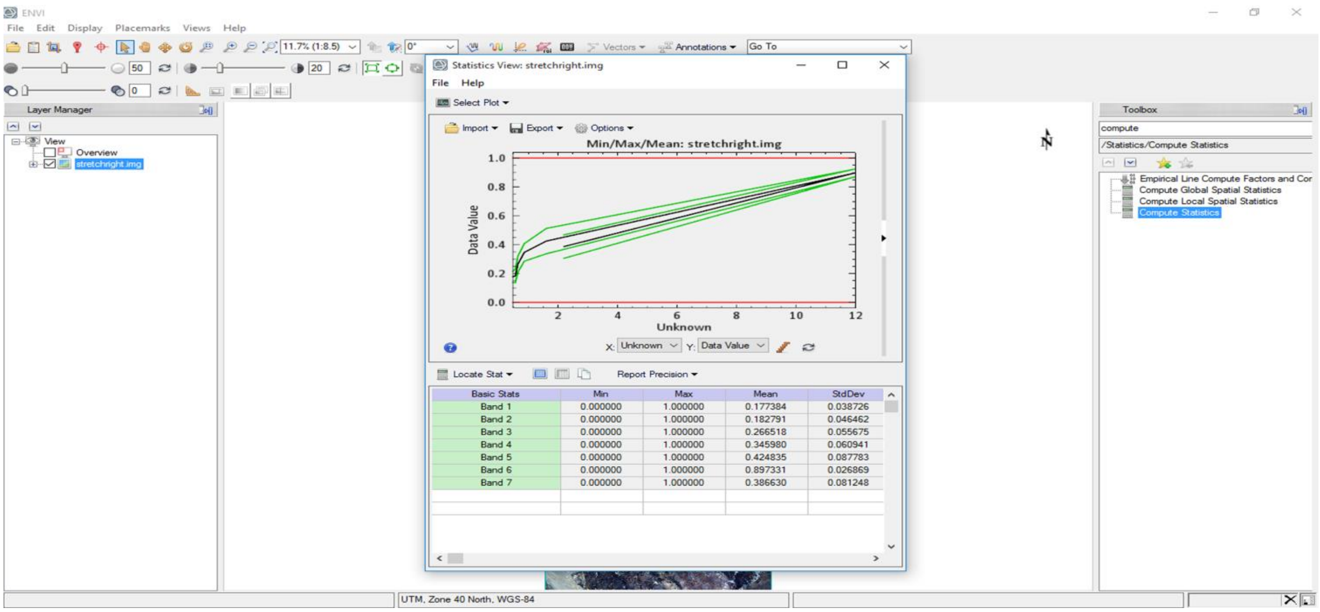
(Fig 3.1.2) Histogram stretched in "stretchrightb10.img" while using thermal band10

According to Part 2.3 of this study, band 6 was set as band 11. Finally, the order of the bands in "stretchright.img" was defined as follows (Fig 3.1.3).



(Fig 3.1.3) order of the bands in "stretchright.img" while using thermal band11

In the "toolbox" section of the Envi software, "compute Statistics" was written, the "Compute Statistics" option was selected, "stretchright.img" was chosen, and OK was clicked. Histogram stretched values is shown in Fig 3.1.4.



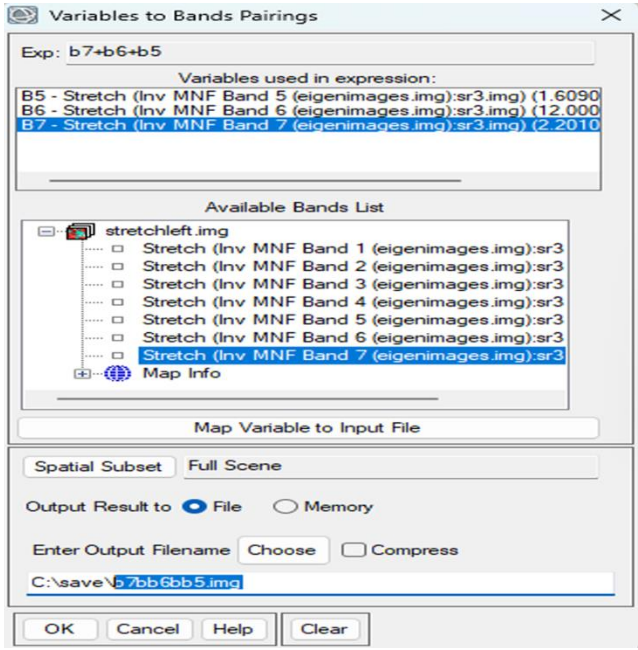
(Fig 3.1.4) Histogram stretched in "stretchright.img" while using thermal band11

As you can see in the Fig 3.1.2, the value 0.886424 in the "Mean" column is for the band 6. Also in the Fig 3.1.4 the value 0.897331 in the "Mean" column is for the band 6 and it is more than the previous state. The band 11 provides us with more data and details on the map. For this reason, we used the band 11 for all the maps in this study.

3.2. Using band compound (((b7+b6+b5)/b6), ((b5+b4+b3)/b6), ((b3+b2+b1)/b6)) as RGB on (stretchleft.img, stretchright.img) and naming output of these two maps as "MAP1.img" and "MAP11.img"

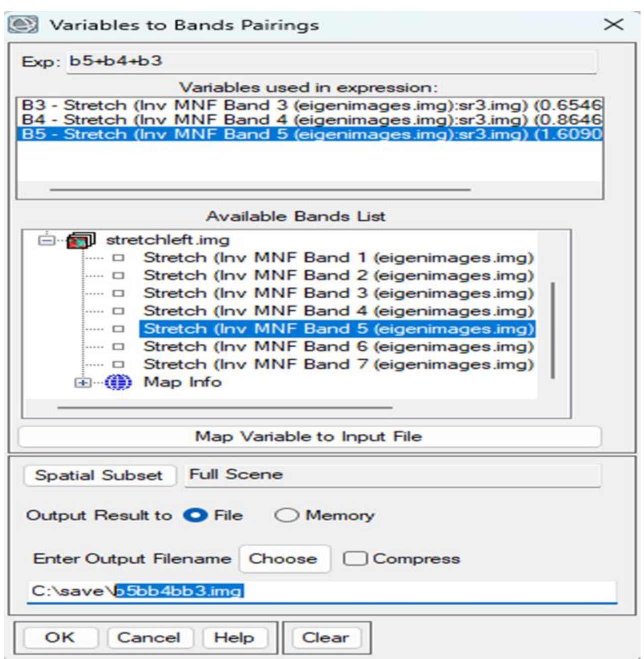
First, "strechleft.img" and "stretchright.img" were opened in the ENVI software. In the

"toolbox" section of the ENVI software, "math" was written and "Band Math" was selected. The value "b7+b6+b5" was entered in the "Enter an expression" section and OK was clicked. Then, the "Variables to Bands Pairings" window was accessed. In the "Variables used in expression" section, "b7" was selected as the seventh band from "stretchleft.img", and "b6" was selected as the sixth band from "stretchleft.img", and also "b5" was selected as the fifth band from "stretchleft.img". The "Choose" option was clicked, and the output was saved as "b7bb6bb5.img" (Fig 3.2.1).



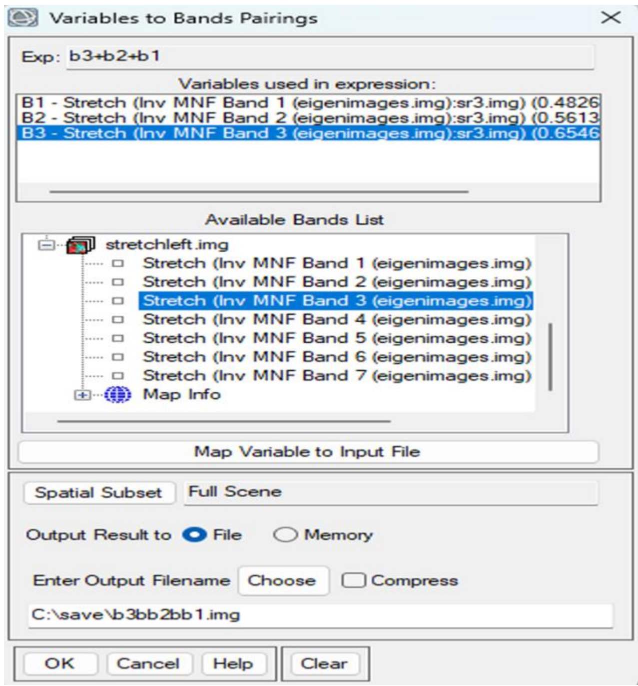
(Fig 3.2.1) applying formula "b7+b6+b5" on "stretchleft.img" and saving it as "b7bb6bb5.img"

In the "toolbox" section of the Envi software, "math" was typed and "Band Math" was selected. The value "b5+b4+b3" was entered in the "Enter an expression" section, and OK was clicked. The "Variables to Bands Pairings" window was then accessed. In the "Variables used in expression" section, "b3" was selected as the third band from "stretchleft.img", and "b4" was selected as the fourth band from "stretchleft.img", and also"b5" was selected as the fifth band from "stretchleft.img". The "Choose" option was clicked, and the output was saved as "b5bb4bb3.img" (Fig 3.2.2).



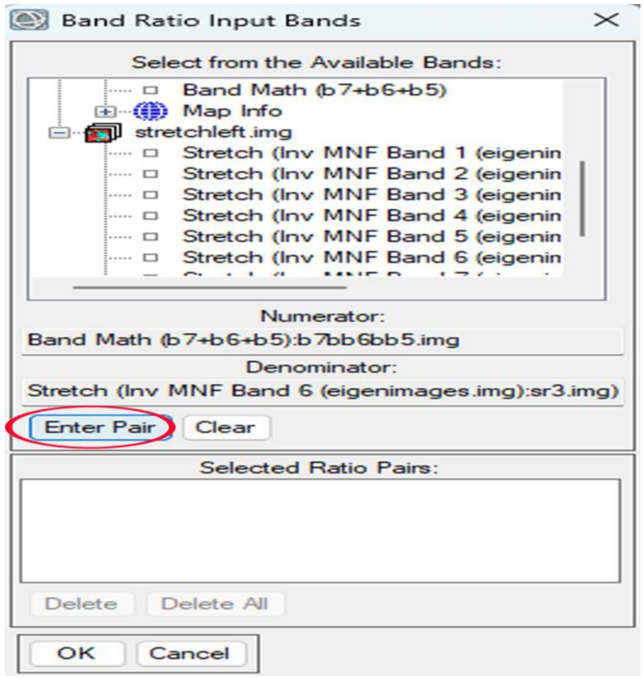
(Fig 3.2.2) applying formula "b5+b4+b3" on "stretchleft.img" and saving it as "b5bb4bb3.img"

In the "toolbox" section of the Envi software, the word "math" was written, and "Band Math" was selected. The value "b3+b2+b1" was set in the "Enter an expression" section, and OK was clicked. The "Variables to Bands Pairings" window was entered. In the "Variables used in expression" section, "b3" was selected as the third band from the "stretchleft.img" file, and "b2" was selected as the second band from "stretchleft.img", and also"b1" was selected as the first band from "stretchleft.img" The "Choose" option was clicked, and the result was saved as "b3bb2bb1.img" (Fig 3.2.3).



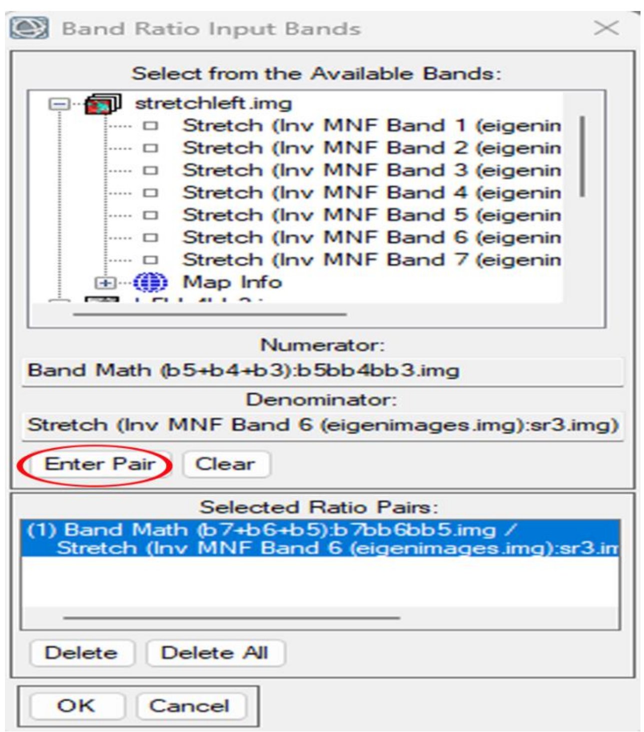
(Fig 3.2.3) applying formula "b3+b2+b1" on "stretchleft.img" and saving it as "b3bb2bb1.img"

In the "toolbox" section of the Envi software, "Band Ratios" was written and selected, and the "Band Ratio Input Bands" window was opened. In the "Numerator" section, "b7bb6bb5.img", which was created recently, was selected. In the "Denominator" section, the sixth band from "stretchleft.img" was selected, and the "Enter Pair" option was clicked (Fig 3.2.4)



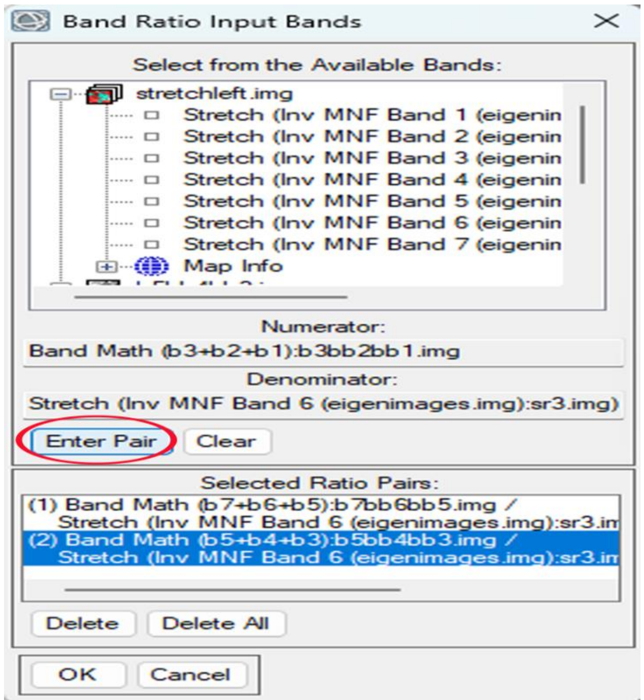
(Fig 3.2.4) using formula "((b7+b6+b5)/b6)"

In the "Numerator:" section, "b5bb4bb3.img", which had been created recently, was selected. In the "Denominator:" section, the sixth band from "stretchleft.img" was selected, and the "Enter Pair" option was then clicked (Fig 3.2.5).



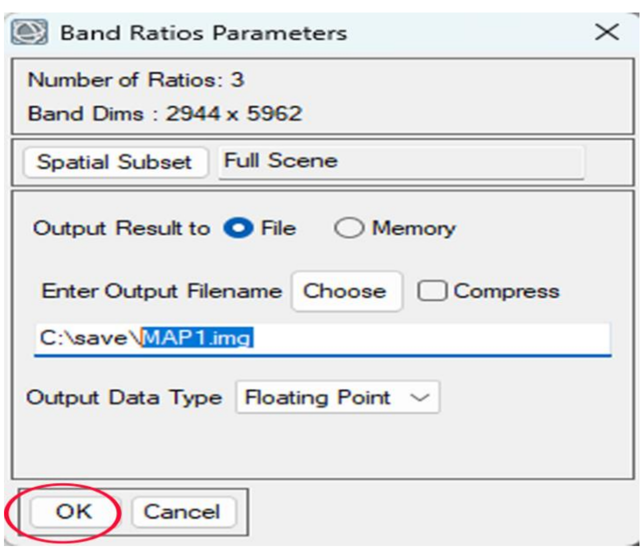
(Fig 3.2.5) using formula "((b5+b4+b3)/b6)"

In the "Numerator:" section, the file "b3bb2bb1.img", which had been created recently, was selected. In the "Denominator:" section, the sixth band from the "stretchleft.img" file was selected, and the "Enter Pair" option was then clicked (Fig 3.2.6).



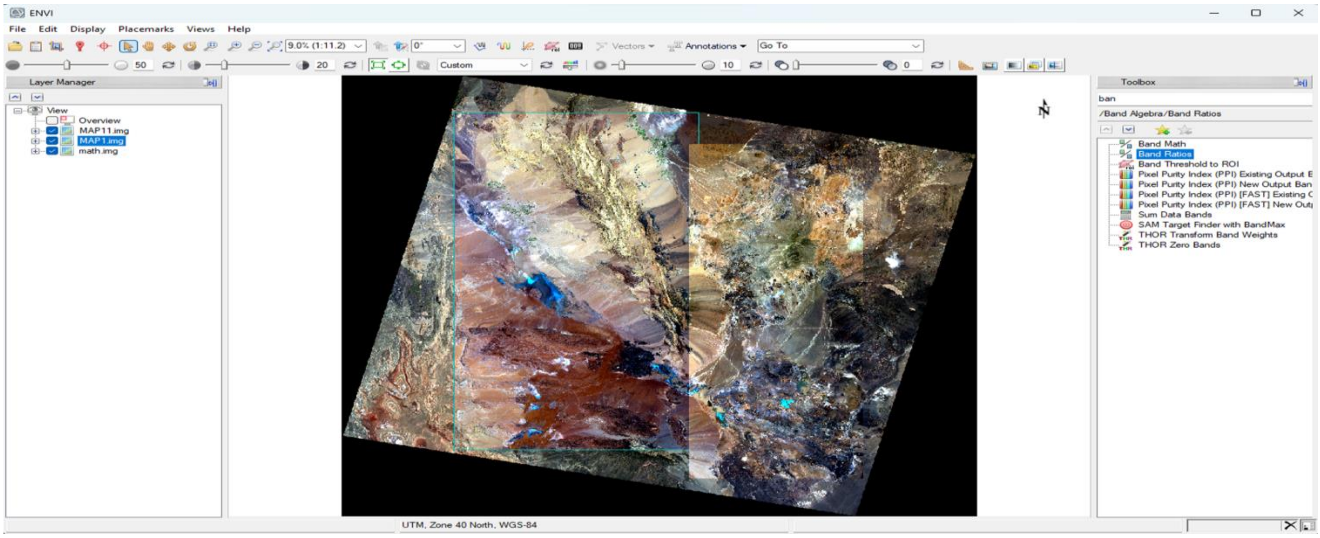
(Fig 3.2.6) using formula "((b3+b2+b1)/b6)"

Then we clicked on "choose" option in the "Band Ratios Parameters" section and saved it as "MAP1.img" in a certain path and then clicked on ok (Fig 3.2.7).



(Fig 3.2.7) saving "MAP1.img"

We performed all the steps in part 3.2 of this study for "stretchright.img" and saved it as "MAP11.img" in a certain path. "MAP1.img" and "MAP11.img" are shown in the Fig below (Fig 3.2.8).

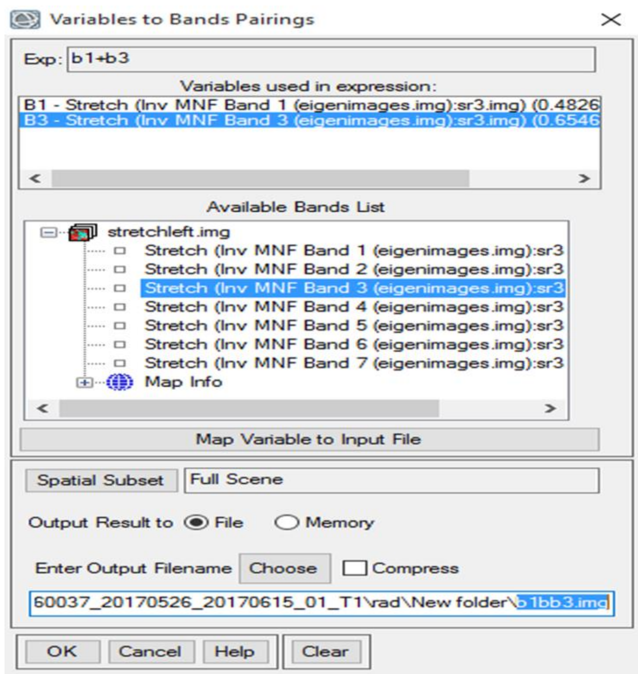


(Fig 3.2.8) "MAP1.img" and "MAP11.img"

3.3. Using band compound ((b3+b1)/b2), ((b3+b5)/b4), ((b5+b7)/b6)) as RGB on (stretchleft.img, stretchright.img) and naming the output of these two maps as "MAP2.img" and "MAP22.img"

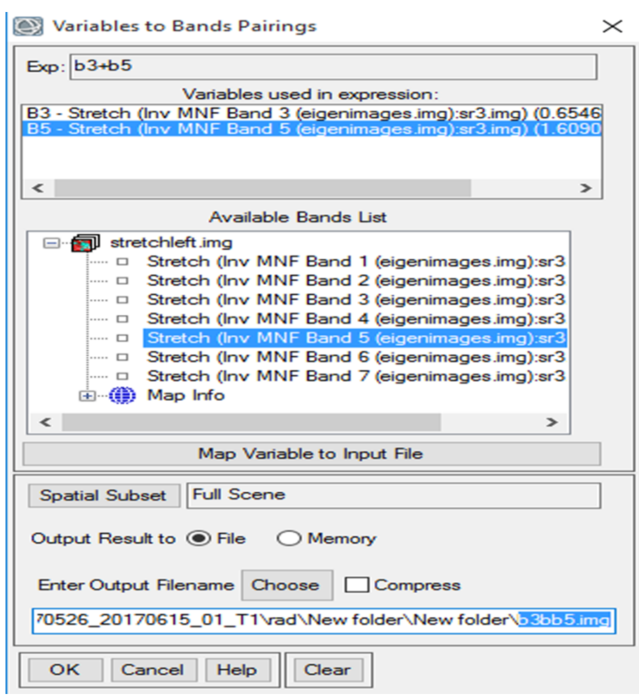
First, "strechleft.img" and "stretchright.img" were opened in the ENVI software. In the

"toolbox" section of the ENVI software, "math" was written and "Band Math" was selected. The value "b1+b3" was entered in the "Enter an expression" section and OK was clicked. Then, the "Variables to Bands Pairings" window was accessed. In the "Variables used in expression" section, "b1" was selected as the first band from "stretchleft.img", and "b3" was selected as the third band from "stretchleft.img". The "Choose" option was clicked, and the output was saved as "b1bb3.img" (Fig 3.3.1).



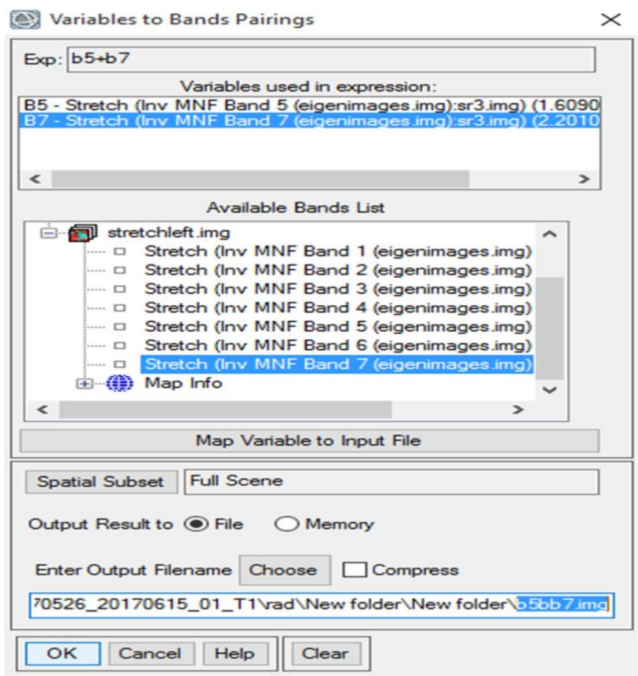
(Fig 3.3.1) applying formula "b1+b3" on "stretchleft.img" and saving it as "b1bb3.img"

In the "toolbox" section of the Envi software, "math" was typed and "Band Math" was selected. The value "b3+b5" was entered in the "Enter an expression" section, and OK was clicked. The "Variables to Bands Pairings" window was then accessed. In the "Variables used in expression" section, "b3" was selected as the third band from "stretchleft.img", and "b5" was selected as the fifth band from "stretchleft.img". The "Choose" option was clicked, and the output was saved as "b3bb5.img" (Fig 3.3.2).



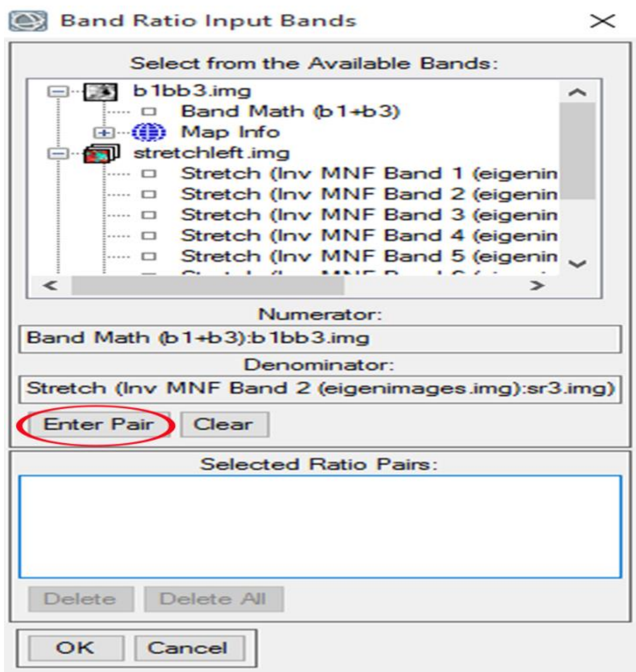
(Fig 3.3.2) applying formula "b3+b5" on "stretchleft.img" and saving it as "b3bb5.img"

In the "toolbox" section of the Envi software, the word "math" was written, and "Band Math" was selected. The value "b5+b7" was set in the "Enter an expression" section, and OK was clicked. The "Variables to Bands Pairings" window was entered. In the "Variables used in expression" section, "b5" was selected as the fifth band from the "stretchleft.img" file, and "b7" was selected as the seventh band from "stretchleft.img". The "Choose" option was clicked, and the result was saved as "b5bb7.img" (Fig 3.3.3).



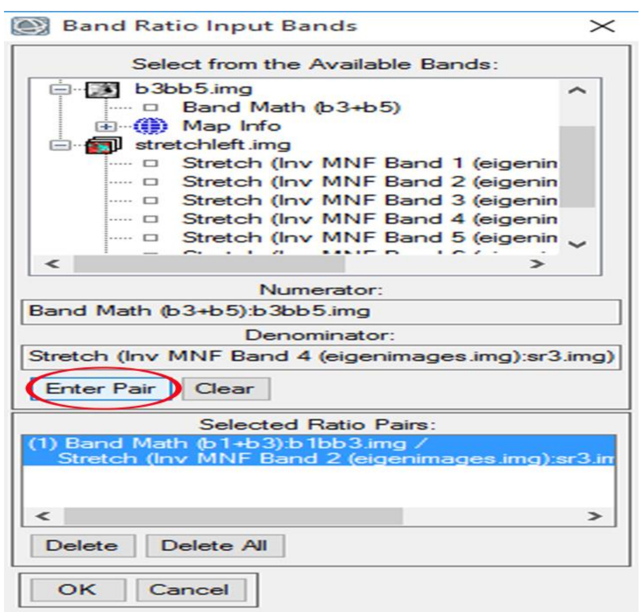
(Fig 3.3.3) applying formula “b5+b7” on "stretchleft.img" and saving it as " b5bb7.img "

In the "toolbox" section of the Envi software, "Band Ratios" was written and selected, and the "Band Ratio Input Bands" window was opened. In the "Numerator" section, "b1bb3.img", which was created recently, was selected. In the "Denominator" section, the second band from "stretchleft.img" was selected, and the "Enter Pair" option was clicked (Fig 3.3.4).



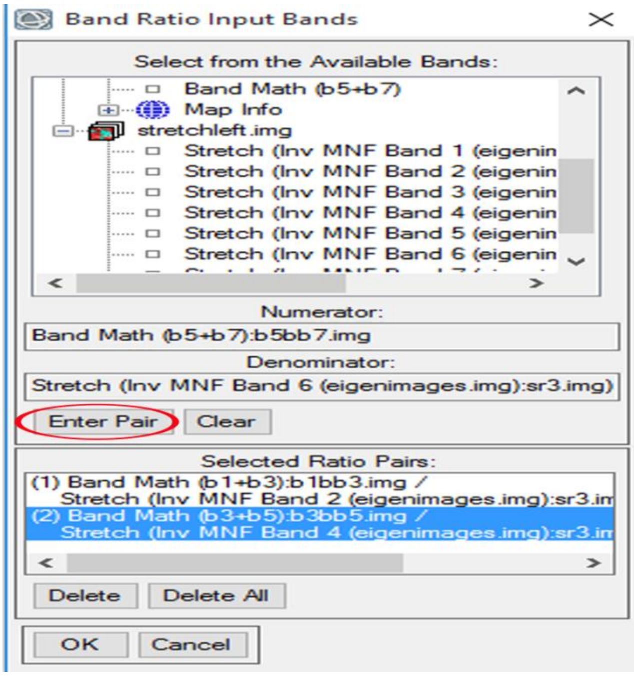
(Fig 3.3.4) using formula "((b3+b1)/b2)"

In the "Numerator:" section, "b3bb5.img", which had been created recently, was selected. In the "Denominator:" section, the fourth band from "stretchleft.img" was selected, and the "Enter Pair" option was then clicked (Fig 3.3.5).



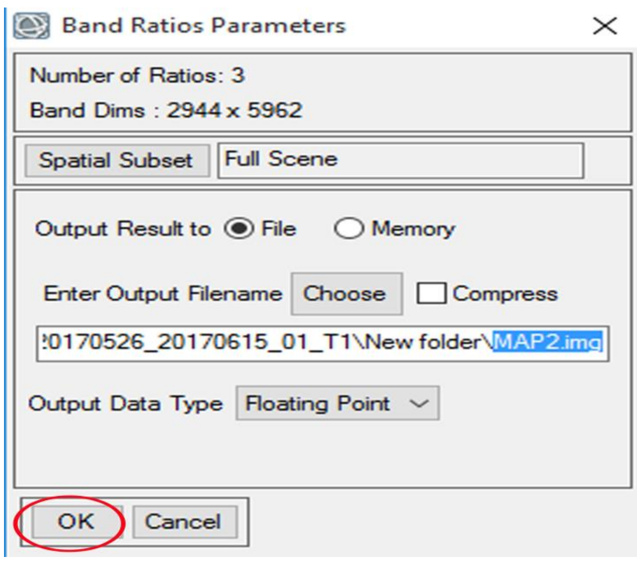
(Fig 3.3.5) using formula "((b3+b5)/b4)"

In the "Numerator:" section, the file "b5bb7.img", which had been created recently, was selected. In the "Denominator:" section, the sixth band from the "stretchleft.img" file was selected, and the "Enter Pair" option was then clicked (Fig 3.3.6).



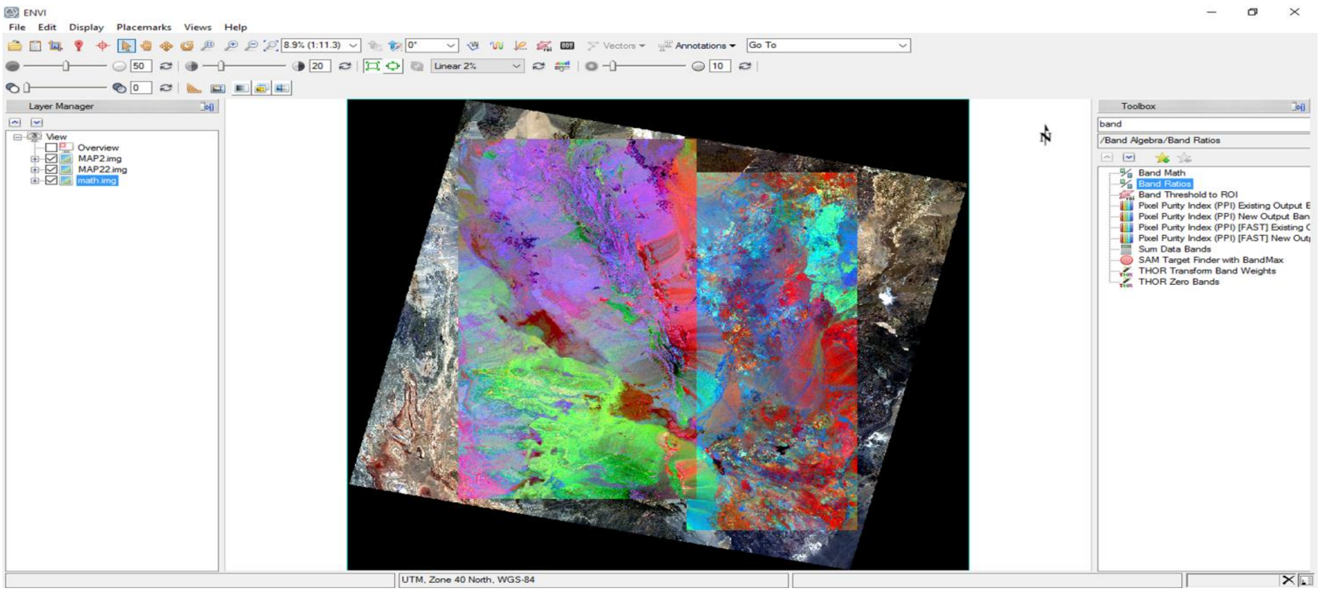
(Fig 3.3.6) using formula "((b5+b7)/b6)"

Then we clicked on "choose" option in the "Band Ratios Parameters" section and saved it as "MAP2.img" in a certain path and then clicked on ok (Fig 3.3.7).



(Fig 3.3.7) saving "MAP2.img"

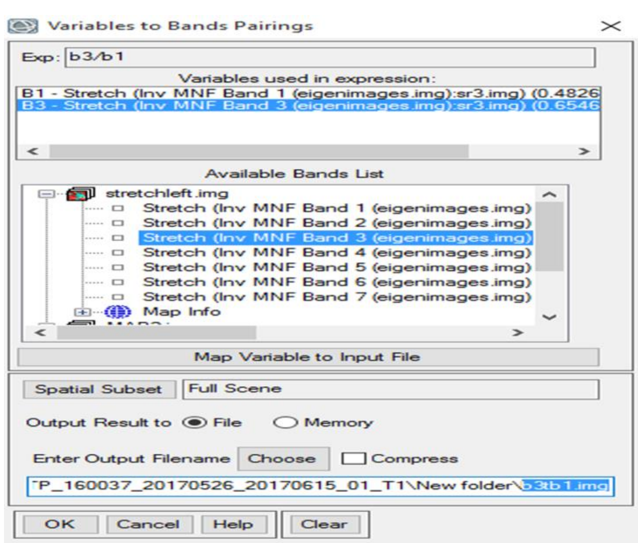
We performed all the steps in part 3.3 of this study for "stretchright.img" and saved it as "MAP22.img" in a certain path. "MAP2.img" and "MAP22.img" are shown in the Fig below (Fig 3.3.8).



(Fig 3.3.8) "MAP2.img" and "MAP22.img"

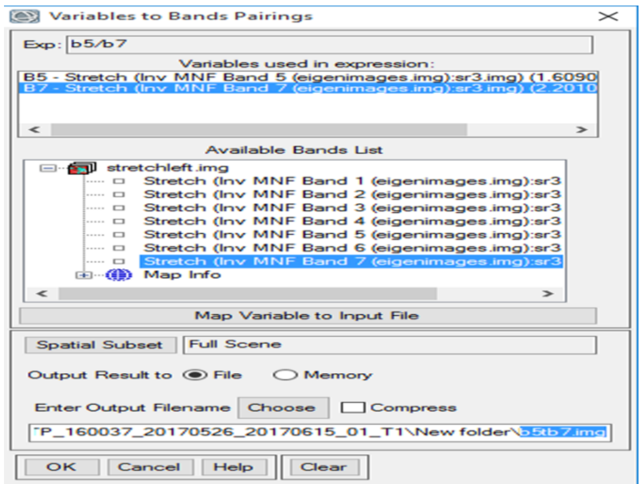
3.4. Using band compound ((b3/b1), (b5/b7), b6) as RGB on stretchleft.img or stretchright.img and naming output of these two maps as "MAP3.img" and "MAP33.img"

First, the files "strechleft.img" and "stretchright.img" were opened in the Envi software. Then, in the "toolbox" section of the Envi software, "math" was written, the "Band Math" option was clicked, the value "b3/b1" was set in the "Enter an expression" section, and OK was clicked. The "Variables to Bands Pairings" window was entered. In the "Variables used in expression" section, "b1" was selected as the first band from the "stretchleft.img" file, "b3" was selected as third band from the "stretchleft.img" file, the "choose" option was clicked, and the result was saved as "b3tb1.img" (Fig 3.4.1).



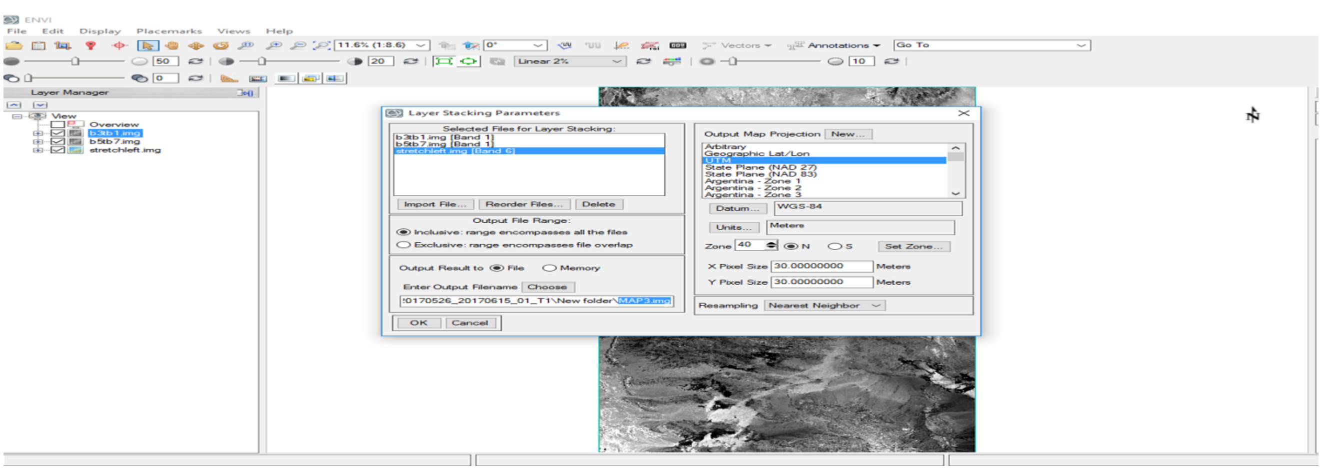
(Fig 3.4.1) using formula "(b3/b1)" and saving it as "b3tb1.img"

In the "toolbox" section of the Envi software, the word "math" was written and the "Band Math" option was clicked. The value "b5/b7" was set in the "Enter an expression" section and confirmed by clicking OK. The "Variables to Bands Pairings" window was entered. In the "Variables used in expression" section, "b5" was selected as the fifth band from the "stretchleft.img" file, and "b7" was also selected as the seventh band from the same file. The "choose" option was clicked, and the result was saved as "b5tb7.img" (Fig 3.4.2).



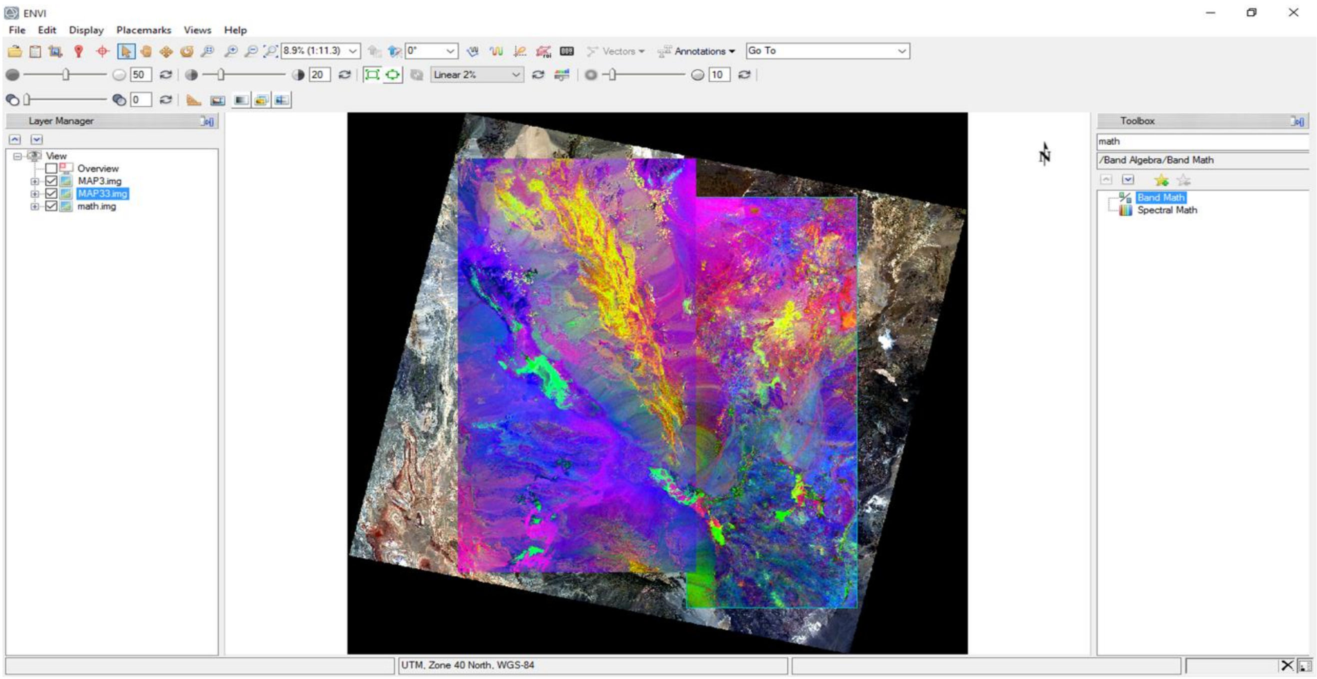
(Fig 3.4.2) using formula "(b5/b7)" and saving it as "b5tb7.img"

In the "toolbox" section of the Envi software, "Layer Stacking" was written and the "Layer Stacking" option was clicked. In the "Layer Stacking parameters" window, the "import file" option was clicked, leading to the "Layer Stacking Input File" window. The file "b3tb1.img", created recently, was selected, and confirmed by clicking OK. The "import file" option was clicked again, and the file "b5tb7.img", also created recently, was selected and confirmed. Then, the "import file" option was clicked once more, and the file "stretchleft.img" was selected. The "Spectral Subset" option was chosen, only band 6 was selected, and confirmed by clicking OK. Finally, the result was saved as "MAP3.img" (Fig 3.4.3).



(Fig 3.4.3) stacking band compound ((b3/b1),(b5/b7),b6) as RGB and saving it as "MAP3.img"

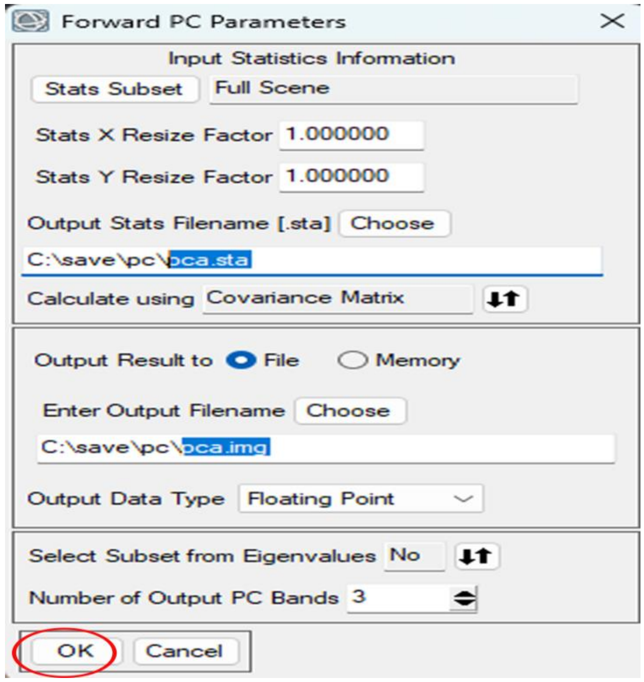
We performed all the steps in part 3.4 of this study for the file "setretchright.img" and saved it as "MAP33.img" in a certain path.
"MAP3.img" and "MAP33.img" are shown in the Fig 3.4.4.



(Fig 3.4.4) "MAP3.img" and "MAP33.img"

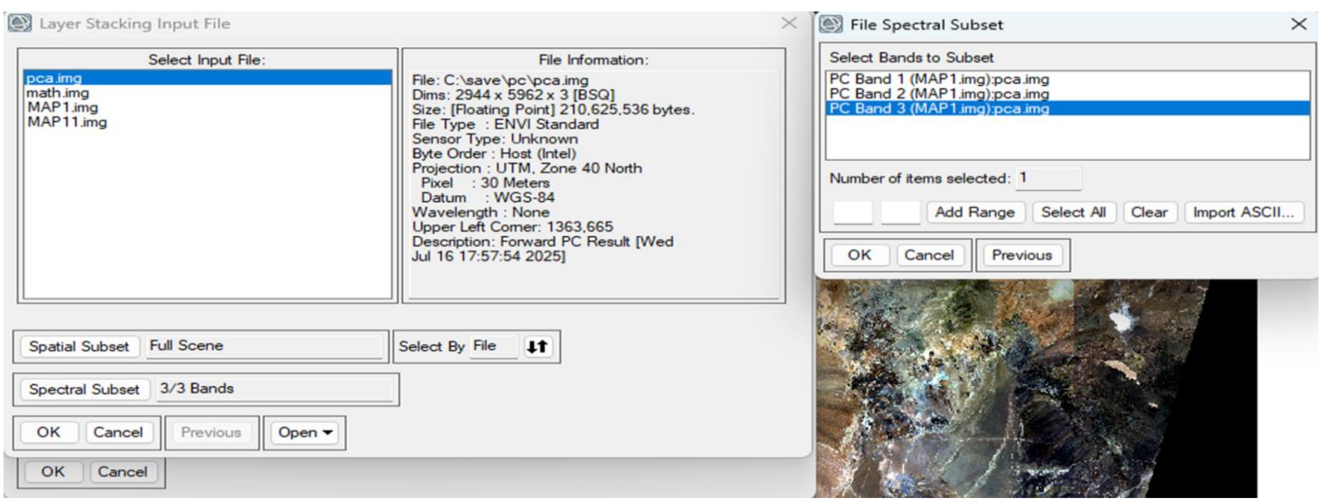
3.5. Using band compound (pca((b7+b6+b5)/b6),pca((b5+b4+b3)/b6),pca((b3+b2+b1)/b6)) as RGB on MAP1.img or MAP11.img and naming output of the two maps as "MAP4.img" and "MAP44.img"

First, the files "MAP1.img" and "MAP11.img" were opened in the Envi software. In the "toolbox" section of the Envi software, "pca" was written, and the "Forward PCA Rotation New Statistics and Rotate" option was clicked. In the "Principal Components Input File" window, the file "MAP1.img" was selected and confirmed by clicking OK. The "Forward Pc Parameters" window was entered. In the "Output Stats Filename [.sta]" section, the "choose" option was clicked and the file was saved as "pca.sta". In the "Enter Output Filename" section, the "choose" option was clicked again, the file was saved as "pca.img", and the process was confirmed by clicking OK (Fig 3.5.1).



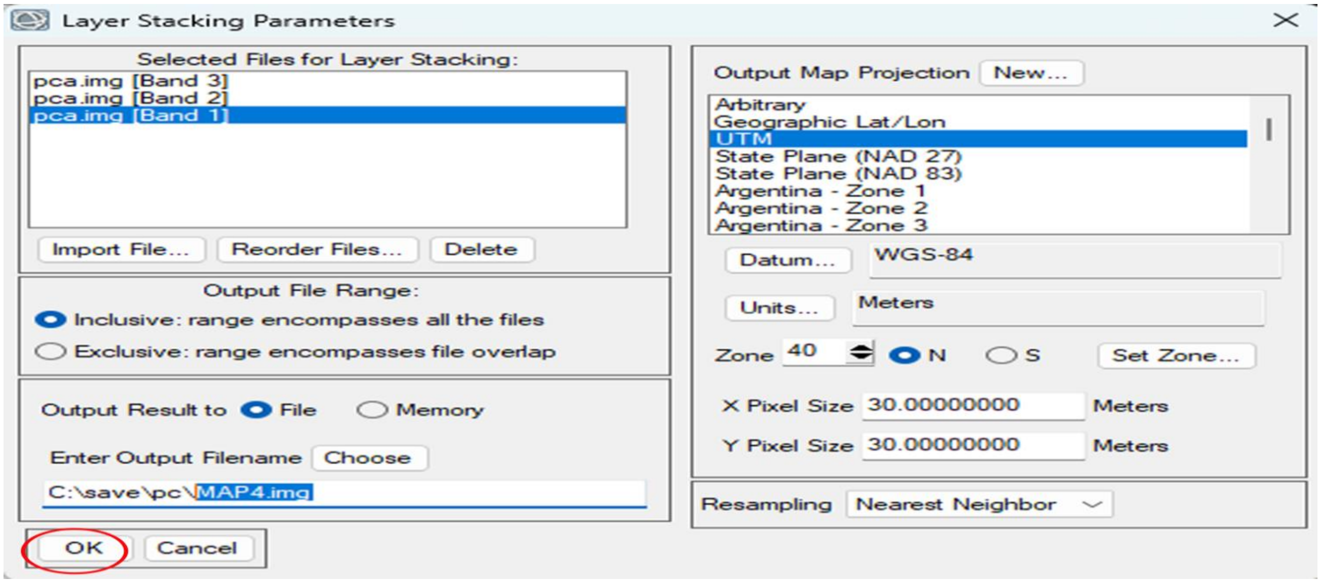
(Fig 3.5.1) saving "pca.img"

In the "toolbox" section of the Envi software, "Layer Stacking" was written and the "Layer Stacking" option was clicked. The "Layer Stacking parameters" window was entered and the "import file" option was selected. In the "Layer Stacking Input File" window, the file "pca.img", which had been created recently, was selected. Then, the "Spectral Subset" option was clicked, only band three was selected, and the selection was confirmed by clicking OK (Fig 3.5.2).



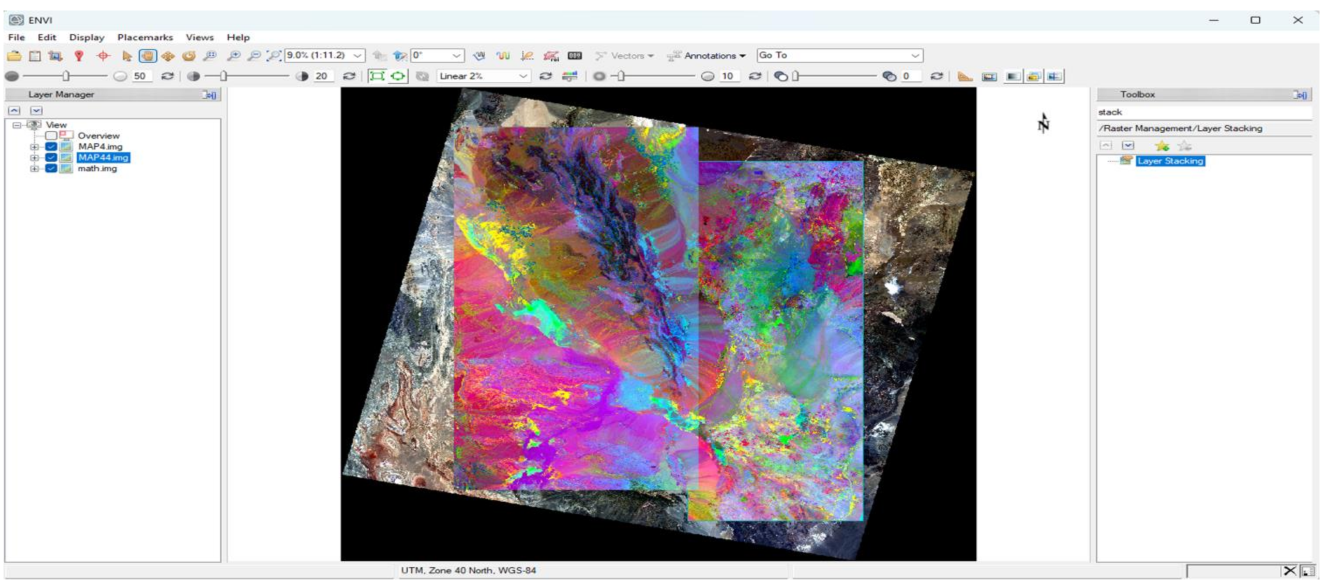
(Fig 3.5.2) selecting band 3 from "pca.img"

The "import file" option was clicked, and the file "pca.img" created recently was selected. The "Spectral Subset" option was then clicked, and only band two was selected before clicking on ok. Again, the "import file" option was clicked, "pca.img" was selected, and the "Spectral Subset" option was clicked. Only band one was selected, and ok was clicked. Finally, the "choose" option was clicked, the file was saved as "MAP4.img", and ok was clicked (Fig 3.5.3).



(Fig 3.5.3) stacking band compound (pca3, pca2, pca1) as RGB and saving it as "MAP4.img"

We performed all the steps in part 3.5 of this study for "MAP11.img" and saved it as "MAP44.img" in a certain path. "MAP4.img" and "MAP44.img" are shown in the Fig 3.5.4.



(Fig 3.5.4) "MAP4.img" and "MAP44.img"

4. Results and discussion

After processing the data on the landsat8 satellite images and creating maps related to different band compounds from these data observed in the (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps, we discuss the exploration of the minerals mentioned in this study.

(MAP1, MAP11) map was generated using the band compound (((b7+b6+b5)/b6), ((b5+b4+b3)/b6), ((b3+b2+b1)/b6)) as RGB. The simple band composition (b3, b2, b1) as RGB is by default and it is made of b3 (red), b1 (blue), b2 (green) bands, and it is not optimal for the exploration of most minerals, and we must use all seven bands and maintain the ratio (3, 2, 1). For this reason, we take help from the formula below, which is part of the series, and first select three bands out of the seven bands.

(n, k)= ((n-1)*(n-2)*(n-k+1))/(k!)

(7, 3)= (7*6*5)/6

(5, 3)= (5*4*3)/6

(3, 3)= (3*2*1)/6

We add the numbers in the form of the fraction and divide it by the denominator of the fraction. And the ratio (3, 2, 1) must also be maintained.

Red= (7+6+5)/6=3(red)

Green= (5+4+3)/6=2(green)

Blue= (3+2+1)/6=1(blue)

This formula is also used in (MAP4, MAP44).The final band composition is as follows.

(((b7+b6+b5)/b6), ((b5+b4+b3)/b6), ((b3+b2+b1)/b6)) as RGB

In this band compound, we have no shadow and the green space is visible exactly in green, water sources (rivers and etc.) are also visible in dark blue. but in (b3, b2, b1) as RGB, the green space and water sources are visible in black, while the points with high potential are also in black, which creates a contradiction and causes mistakes in the analysis of the desired area. In this band compound, we see a more accurate color spectrum for different mineral materials. The best point of the mineral can be observed in black or white or sky blue colors. In these points, the potential and reserves of minerals reach their highest levels. It is best to use this optimal band compound for mineral exploration and analysis of the desired area.

(MAP2, MAP22) map was generated using the band compound ((b3+b1)/b2), ((b3+b5)/b4), ((b5+b7)/b6)) as RGB [1] . Using this map, we can identify what types of minerals may exist in the desired area. also, the average grade of some minerals can be estimated in desired square (any pixel of map). In this map, dark blue represents vegetation, while sky blue may indicate the presence of silica or soil minerals.

(MAP3, MAP33) map was generated using the band compound ((b3/b1), (b5/b7), b6) as RGB [2]. We corrected the bands for exploration of all minerals mentioned in this study: the b5/b7 ratio was used instead of the b6/b7 ratio, and Thermal Infrared 2 (band 11) was used instead of Thermal Infrared 1(band 10). The reason for using band 6, which is the same as band 11 in the Landsat8 satellite images, is that in addition to giving us a more accurate map of different minerals, it also shows more data and details in maps. Therefore, we applied these changes to all maps and we compared Thermal Infrared bands. The (MAP3, MAP33) map plays a crucial role in minerals exploration. This map enables confirmation of most minerals. Moreover, it facilitates the determination of whether a given mineral deposit is of sedimentary (blue) or igneous origin (light pink or green). In addition, yellow indicates the presence of vegetation cover or other interfering elements that exist alongside the mineral deposits.

(MAP4, MAP44) map was generated using the band compound (pca((b7+b6+b5)/b6), pca((b5+b4+b3)/b6), pca((b3+b2+b1)/b6)) as RGB. And the ratio (3, 2, 1) must also be maintained. It has a decisive role in the exploration and analysis of minerals in any desired area. There is usually another map with a different color spectrum and the same band combination. If the potential, reserve and the average grade of the minerals in the desired area decrease or increase, you can see them with a specific number. We used this band compound in the exploration minerals mentioned in this study. The speed and accuracy of exploration and analysis of the desired area increase greatly. The correct analysis eliminates the duality of analysis or multiple analyses. It is best to use this optimal band combination for mineral exploration and analysis of the desired area. In addition to the potential strength of minerals, different minerals can also be separated from each other.

4.1. Exploration of Gold mineral with Landsat8 satellite

The (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were used in all explorations of the Gold mineral. For example, the Iran Zarmehr Gold mine was used. First, the (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were opened in the Envi software. The geographical coordinates of any point in the desired area on the map could be obtained from the "Value Cursor" section in the Envi software. In the "toolbox" section of the Envi software, the term "Resize Data" was entered and selected. Then, "MAP1.img" or "MAP11.img" was selected, and the "Spatial Subset" option was clicked. In the "Select Spatial Subset" window, the "Map" option was selected and the following coordinates were entered.

Upper left coordinate:
35 21 10.19
58 53 31.68

And the lower right coordinate:
35 20 27.46
58 54 35.83

Then, "OK" was clicked and the file was saved as "AU1.img" in a specified path (Fig 4.1.1). All the steps in part 4.1 of this study were performed for the file "MAP2.img" or "MAP22.img", and it was saved as "AU11.img" in a specified path (Fig 4.1.2). Similarly, all the steps in part 4.1 were performed for the file "MAP3.img" or "MAP33.img", and it was saved as "AU111.img" in a specified path (Fig 4.1.3). Also, all the steps in part 4.1 were performed for the file "MAP4.img" or "MAP44.img", and it was saved as "AU1111.img" in a certain path (Fig 4.1.4). Color spectrum in these four maps should be as follows:

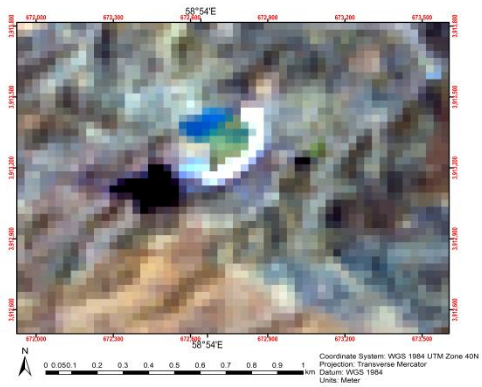
Map1, MAP11: **black** or dark purple or purple

MAP2, MAP22: **yellow** and or **light orange** and **number>2**

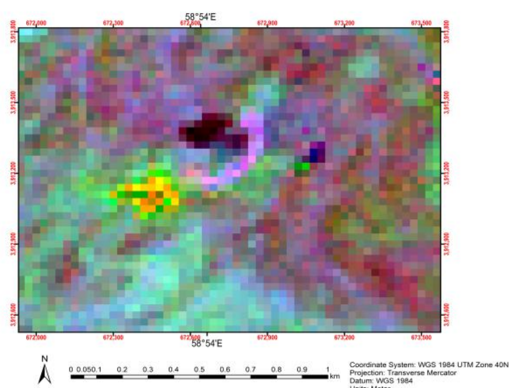
MAP3, MAP33: **light pink (**igneous origin**)** or pink or purple or dark purple or blue (sedimentary)

MAP4, MAP44: **sky blue** or blue and **number** < = **-0.01**

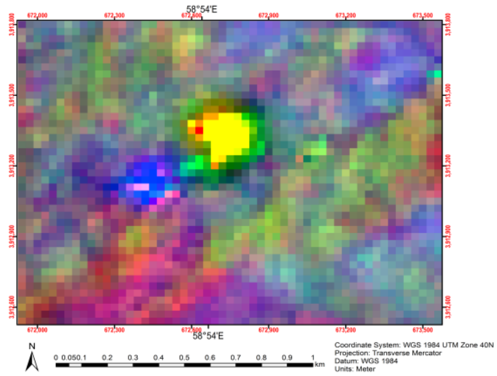
The mode was set to "Optimized Linear" when the "AU1.img", "AU11.img", "AU111.img", and "AU1111.img" maps were checked in the Envi software. The Arcgis software (V10.5) was used for the final output of the Gold maps.



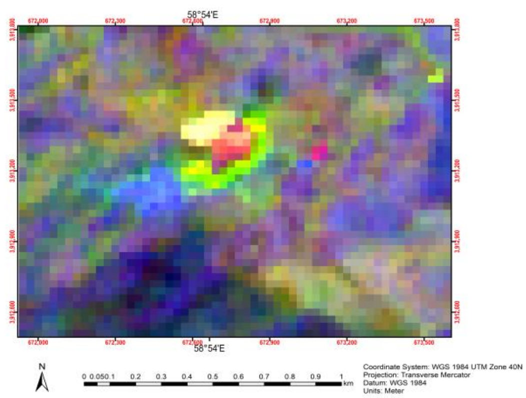
(Fig 4.1.1) The image "AU1.img" constructed from (MAP1, MAP11) by the Author with the name of Iran Zarmehr mine. ESM_4.1 original data available in Online Resource



(Fig 4.1.2) The image "AU11.img" constructed from (MAP2, MAP22) by the Author with the name Iran Zarmehr mine. ESM_4.1 original data available in Online Resource



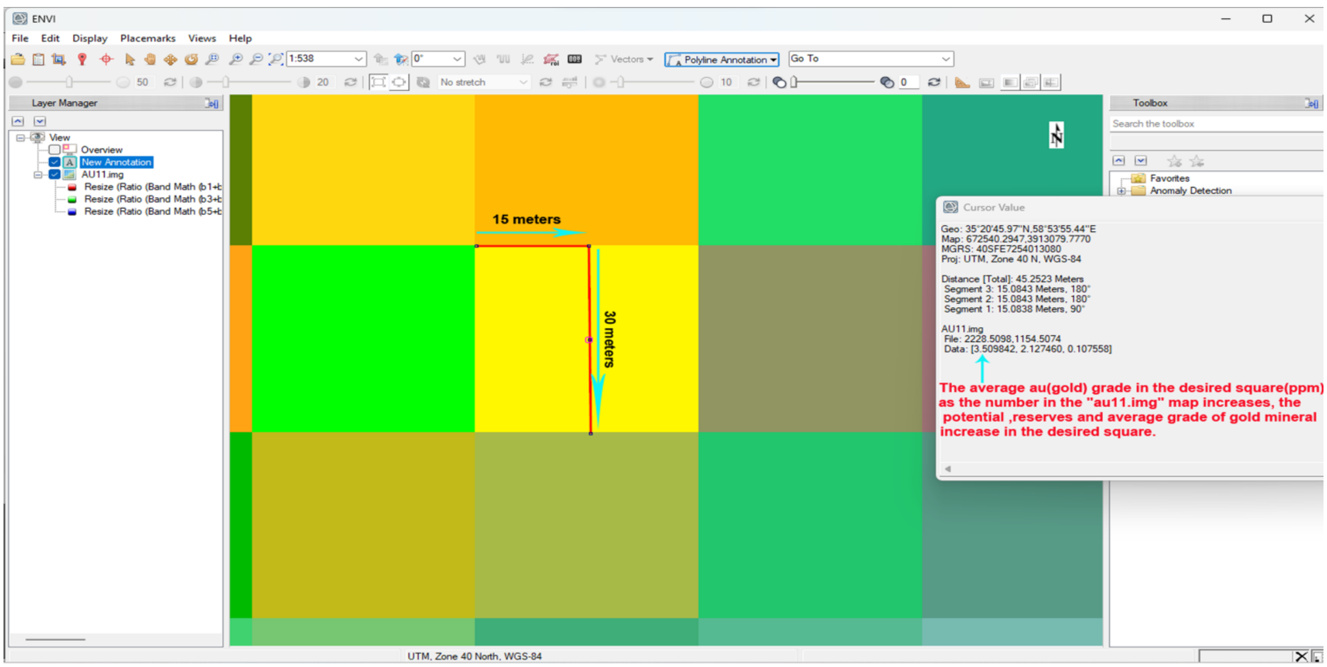
(Fig 4.1.3) The image "AU111.img" constructed from (MAP3, MAP33) by the Author with the name Iran zarmehr mine. ESM_4.1 original data available in Online Resource



(Fig 4.1.4) The image "AU1111.img" constructed from (MAP4, MAP44) by the Author with the name Iran zarmehr mine. ESM_4.1 original data available in Online Resource

Analysis of the desired area:

As you can see in the "AU11.img" map, yellow or bright orange colors show the presence of Gold mineral in the desired area provided that light pink (igneous origin) or purple or dark purple or blue (sedimentary) colors are in "AU111.img" map and black or dark purple or Purple are in "AU1.img" map and sky blue or blue are in "AU1111.img" map and for sure, a number larger than 2 can be seen in the "AU11.img" map (from the "Value Cursor" section in the Envi software) and also for sure, a number smaller than -0.01 can be seen in "AU1111.img" which is the confirmation of Gold mineral in the desired square (any pixel of map). As it tends to yellow in the "AU11.img" map, and as it tends to black in the "AU1.img" map, and as the number in the "AU11.img" map increases, the potential, reserves and average grade of Gold mineral increase in the desired square. According to the map data in "AU11.img" in the "Cursor value" section of the Envi software, you can see up to the number 5 which shows the average grade of this mineral in the desired square, which is the ppm unit for this mineral. We considered a point on the map which is usually a square with a side of thirty meters (any pixel of map). Yellow or bright orange colors are the most important color spectrum for the exploration of Gold mineral in the most optimal and best condition in the map "AU11.img" and the black in the map "AU1.img" and the light pink in "AU111.img" map and the sky blue in "AU1111.img" map. All four colors must be seen for the desired point (desired square). A number larger than 2 can be seen in the " AU11.img" and also for sure a number smaller than -0.01 can be seen in "AU1111.img". If vegetation (In "AU11.img" map, the dark blue) is present all around the mineral deposit, it is sulfide gold otherwise it is oxide gold. Therefore in the desired area it is oxide gold. If we divide the desired square into two equal parts, from the center of the square, fifteen meters to the left, fifteen meters to the right, fifteen meters to the top, fifteen meters to the bottom, and thirty meters to the depth of that square, we can have that mineral in high potential points (Fig 4.1.5). Points on the map containing minerals can be transferred from the map to the "KMZ" type file, and these points can be conFigd in GPS and then used for exploration. In " AU111.img" map, yellow indicates the presence of vegetation cover or other interfering elements that exist alongside the mineral deposits. Also In "AU11.img" map, the dark blue is Vegetation and the sky blue can be silica (it should be seen on the map around the Gold mineral to confirm this mineral) or soil minerals.



(Fig 4.1.5) The average of Gold (AU) grade (ppm) in the desired square (from the center of the square to a distance of fifteen meters around) shown by arrows in "AU11.img" map

4.2. Exploration of Copper mineral with Landsat8 satellite

The (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were used in all explorations of the Copper mineral. For example, the Copper mine in Bardskan city, Razavi Khorasan Province, Iran, was used. First, the (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were opened in the Envi software. The geographical coordinates of any point in the desired area on the map could be obtained from the "Value Cursor" section in the Envi software. In the "toolbox" section of the Envi software the term "Resize Data" was entered and selected. The "MAP1.img" or "MAP11.img" file was then selected, the "Spatial Subset" option was clicked, the "Select Spatial Subset" window was entered, and the "Map" option was clicked to enter the following coordinates.

Upper left coordinate:
35 7 9.66
58 20 30.55

And the lower right coordinate:
35 4 45.64
58 25 4.25

"Ok" was clicked and the file was saved as "cu1.img" in a certain path (Fig 4.2.1). All the steps in part 4.2 of this study were performed for the file "MAP2.img" or "MAP22.img", and it was saved as "cu11.img" in a certain path (Fig 4.2.2). Similarly, all the steps in part 4.2 were performed for the file "MAP3.img" or "MAP33.img", and it was saved as "cu111.img" in a certain path (Fig 4.2.3). Also, all the steps in part 4.2 were performed for the file "MAP4.img" or "MAP44.img", and it was saved as "cu1111.img" in a certain path (Fig 4.2.4). Color spectrum in these four maps should be as follows:

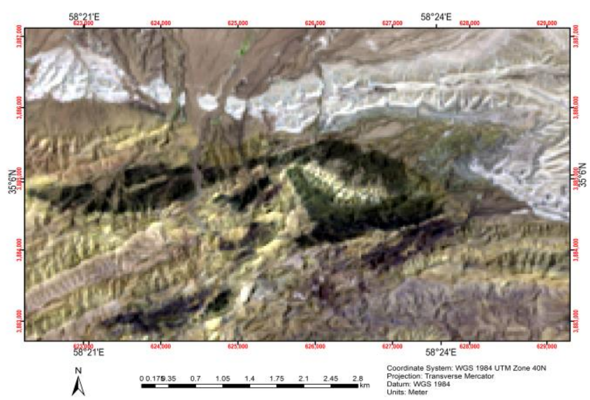
MAP1, MAP11: **black** or dark purple or purple or dark brown or brown

MAP2, MAP22: **red-orange** (**orangish red**) and **number**>**2**

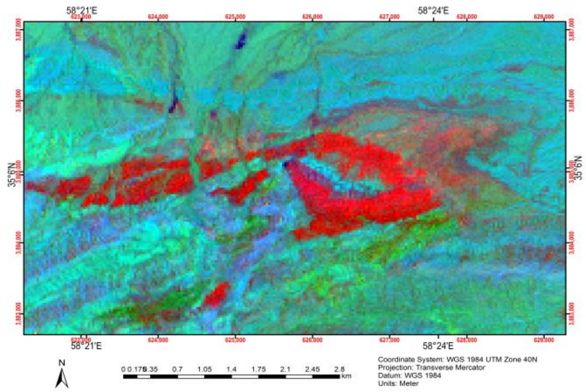
MAP3, MAP33: **light pink** (igneous origin) or purple or dark purple or blue (sedimentary)

MAP4, MAP44: **white** or **light pink** or sky blue and **0.01** < =**number** < = **0.2**

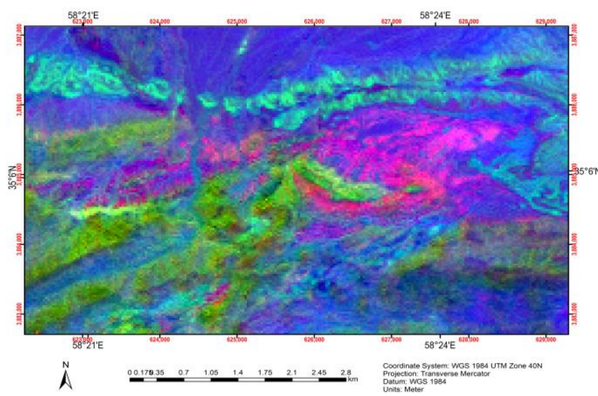
The mode was set to "Optimized Linear" when the "cu1.img", "cu11.img", "cu111.img" and "cu1111.img" maps were checked in the Envi software. The Arcgis software (V10.5) was used for the final output of the Copper maps.



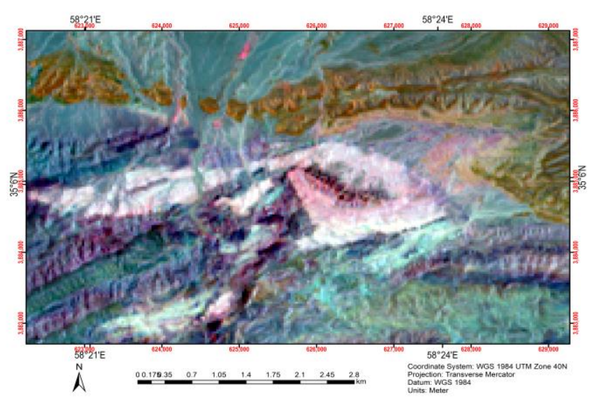
(Fig 4.2.1) The image "cu1.img" constructed from (MAP1, MAP11) by the Author with the name of Copper mine in Bardskan city, Razavi Khorasan Province, Iran. ESM_4.2 original data available in Online Resource



(Fig 4.2.2) The image "cu11.img" constructed from (MAP2, MAP22) by the Author with the name Copper mine in Bardskan city, Razavi Khorasan Province, Iran. ESM_4.2 original data available in Online Resource



(Fig 4.2.3) The image "cu111.img" constructed from (MAP3, MAP33) by the Author with the name Copper mine in Bardskan city, Razavi Khorasan Province, Iran. ESM_4.2 original data available in Online Resource



(Fig 4.2.4) The image "cu1111.img" constructed from (MAP4, MAP44) by the Author with the name Copper mine in Bardskan city, Razavi Khorasan Province, Iran. ESM_4.2 original data available in Online Resource

Analysis of the desired area:

As you can see in the "cu11.img" map, Red-orange (orangish red) color shows the presence of Copper mineral in the desired area provided that light pink (igneous origin) or purple or dark purple or blue (sedimentary) colors are in "cu111.img" map and black or dark Purple or Purple or dark brown or brown colors are in "cu1.img" map and for sure, a number larger than 2 can be seen in the "cu11.img" map (from the "Value Cursor" section in the Envi software) and also white or light pink or sky blue colors are in "cu1111.img" map and for sure, a number smaller than 0.2 and larger than 0.01 can be seen in cu1111.img "map (from the "Value Cursor" section in the Envi software) which is the confirmation of Copper mineral in the desired square (any pixel of map). As it tends to Black in the "cu1.img" map, and as it tends to light pink in the "cu111.img" map and as the number increases in the "cu11.img" map and "cu1111.img" map, the potential, reserves and average grade of Copper mineral increase in the desired square. Here we refer to an article that uses Band ratios of 4/2, 6/7, 10 in RGB showing the presence of Copper in Purple [2]. We corrected the bands for exploration of all minerals mentioned in this study. We generalized and used band 11 instead of band 10 and used other band compounds and other maps to further confirm this mineral. Also we provided an accurate and complete method for exploration and analysis of most minerals. We used optimal band compounds ((b3/b1), (b5/b7), b6)as RGB and (((b7+b6+b5)/6), ((b5+b4+b3)/6), ((b3+b2+b1)/6))as RGB and (pca((b7+b6+b5)/6), pca((b5+b4+b3)/6), pca((b3+b2+b1)/6)) as RGB in the exploration of the Copper and other minerals mentioned in this study. According to the map data of "cu11.img", the average grade of this mineral in the "Cursor value" section of the Envi software can be the percentage of copper in the desired square. Also according to the map data of "cu1111.img" in the "Cursor value" section of the Envi software as the number increases, the potential of Copper (Numeric range (0.01, 0.2)), average grade and reserves increase in the desired square. We considered a point on the map which is usually a square with a side of thirty meters (any pixel of map). The most important color spectrum for the exploration of Copper mineral in the most optimal and best condition is orangish-red color in "cu11.img" map, the black in "cu1.img" map, and the light pink in "cu111.img" map and white or light pink in "cu1111.img" map. All four colors must be seen for the desired point and for sure, a number larger than 2 can be seen in the "cu11.img" map and also for sure, a number smaller than 0.2 and larger than 0.01 can be seen in "cu1111.img" map. If vegetation (In "cu11.img" map, the dark blue) is present all around the mineral deposit, it is sulfide Copper otherwise it is oxide Copper. Therefore in the desired area it is oxide Copper. If we divide the desired square into two parts, from the center of the square, fifteen meters to the left, fifteen meters to the right, fifteen meters to the top, fifteen meters to the bottom, and thirty meters to the depth of that square, we can have that mineral in high potential points. Points on the map containing minerals can be transferred from the map to the "KMZ" type file, and these points can be conFigd in GPS and then used for exploration. In "cu11.img" map, the dark blue is Vegetation and the sky blue can be silica (it should be seen on the map around the Copper mineral to confirm this mineral) or soil minerals.

4.3. Exploration of Fe (magnetite(fe3o4), hematite(fe2o3)) minerals with Landsat8 satellite

The (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were used in all explorations of the Fe (Magnetite, Hematite) mineral. For example, the Fe mine in the north of bam city, Kerman province, Iran, was used. First, the (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were opened in the Envi software. The geographical coordinates of any point in the desired area on the map could be obtained from the "Value Cursor" section in the Envi software. In the "toolbox" section of the Envi software the term "Resize Data" was entered and selected. The "MAP1.img" or "MAP11.img" file was then selected, the "Spatial Subset" option was clicked, the "Select Spatial Subset" window was entered, and the "Map" option was clicked to enter the following coordinates.

Upper left coordinate:
30 3 9.37
58 55 41.91

And the lower right coordinate:
30 1 21.21
58 57 19.07

OK was clicked and the file was saved as "fe1.img" in a certain path (Fig 4.3.1). All the steps in part 4.3 of this study were performed for the file "MAP2.img" or "MAP22.img", and it was saved as "fe11.img" in a certain path (Fig 4.3.2). Similarly, all the steps in part 4.3 were performed for the file "MAP3.img" or "MAP33.img", and it was saved as "fe111.img" in a certain path (Fig 4.3.3). Also, all the steps in part 4.3 were performed for the file "MAP4.img" or "MAP44.img", and it was saved as "fe1111.img" in a certain path (Fig 4.3.4).Color spectrum in these four maps should be as follows and There are two modes:

First Mode:

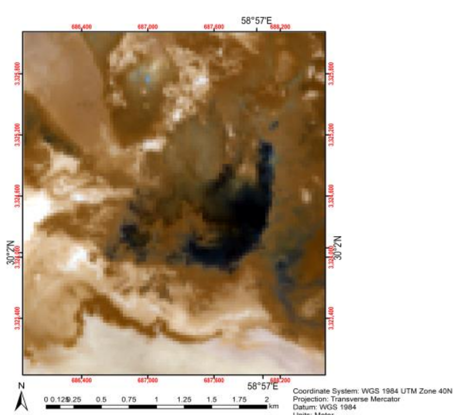
MAP1, MAP11: **black** and or dark purple or dark brown or brown

MAP2, MAP22: **dark purple** or purple or dark red or **dark brown** or brown

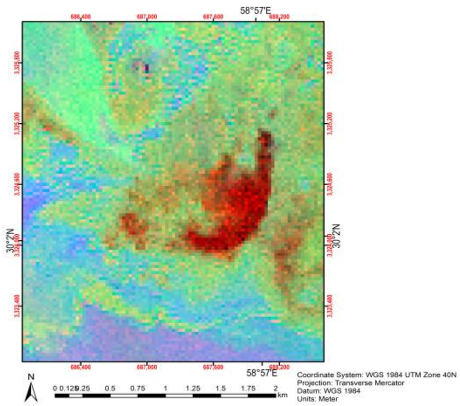
MAP3, MAP33: **green** or yellow

MAP4, MAP44: **sky blue** or blue or green and **-0.2** < =**number** < = **-0.01**

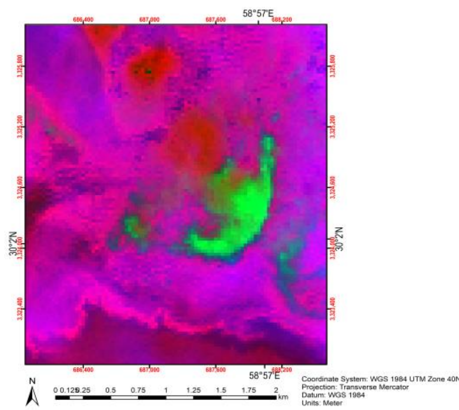
"Optimized Linear" mode was set when checking the "fe1.img", "fe11.img", "fe111.img", and "fe1111.img" maps in the ENVI software. ArcGIS software (V10.5) was used for the final output of the Fe maps.



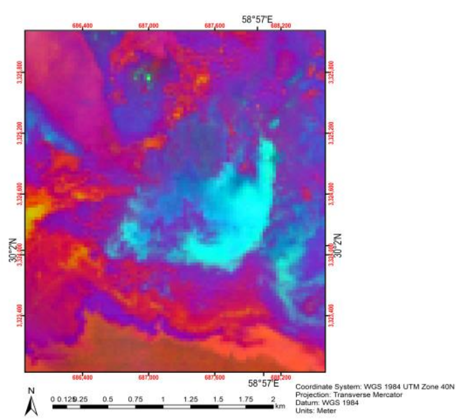
(Fig 4.3.1) The image "fe1.img" constructed from (MAP1, MAP11) by the Author with the name Fe mine in the north of bam city, Kerman province, Iran. ESM_4.3.1 original data available in Online Resource



(Fig 4.3.2) The image "fe11.img" constructed from (MAP2, MAP22) by the Author with the name Fe mine in south of Bakharz city, Razavi Khorasan Province, Iran. ESM_4.3.1 original data available in Online Resource



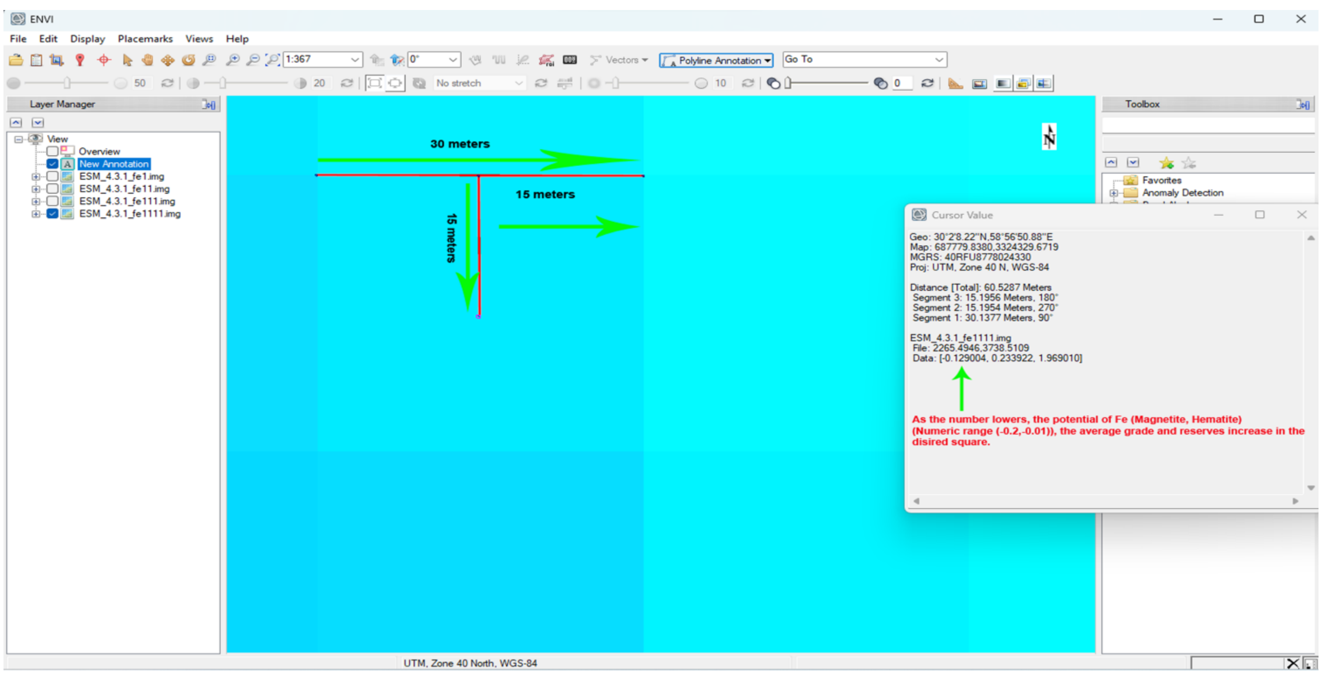
(Fig 4.3.3) The image "fe111.img" constructed from (MAP3, MAP33) by the Author with the name Fe mine in the north of bam city, Kerman province, Iran. ESM_4.3.1 original data available in Online Resource



(Fig 4.3.4) The image "fe1111.img" constructed from (MAP4, MAP44) by the Author with the name Fe mine in the north of bam city, Kerman province, Iran. ESM_4.3.1 original data available in Online Resource

Analysis of the desired area:

As you can see in the "fe11.img" map, dark purple or dark red or dark brown or brown or purple colors show the presence of Fe mineral in the desired area provided that green or yellow colors are in "fe111.img" map and black and or dark purple or dark brown or brown colors are in "fe1.img" map and sky blue or blue or green are in "fe1111.img" map and for sure, a number smaller than -0.01 and larger than -0.2 can be seen in fe1111.img "map(from the "Value Cursor" section in the Envi software) which is the confirmation of Fe mineral in the desired square (any pixel of map). As it tends to Black in the "fe1.img" map, and as it tends to sky blue in the "fe1111.img" map, and as it tends to dark purple or dark brown colors in the "fe11.img" map, the potential and reserves of Fe mineral increase. According to the map data of "fe1111.img" in the "Cursor value" section of the Envi software, as the number lowers, the potential of Fe (Magnetite, Hematite) (Numeric range (-0.2, -0.01)), the average grade and reserves increase in the desired square. We considered a point on the map which is usually a square with a side of thirty meters (any pixel of map). The most important color spectrum for the exploration of Fe (Magnetite, Hematite) mineral in the most optimal and best condition is dark purple or dark brown in "fe11.img" map, the black in "fe1.img" map, the green in "fe111.img" map and also the sky blue in "fe1111.img" map. All four colors must be seen for the desired point and for sure, a number smaller than -0.01 and larger than -0.2 can be seen in "fe1111.img" map. If we divide the desired square into two parts, from the center of the square, fifteen meters to the left, fifteen meters to the right, fifteen meters to the top, fifteen meters to the bottom, and thirty meters to the depth of that square, we can have that mineral in high potential points (Fig 4.3.5). Points on the map containing minerals can be transferred from the map to the "KMZ" type file, and these points can be conFigd in GPS and then used for exploration. In "fe111.img" map, yellow indicates the presence of vegetation cover or other interfering elements that exist alongside the mineral deposits. Also In "fe11.img" map, the dark blue is Vegetation and the sky blue can be silica or soil minerals.



(Fig 4.3.5) As the number lowers, the potential of Fe (Numeric range (-0.2,-0.01)), the average grade and reserves increase in the desired square (from the center of the square to a distance of fifteen meters around) shown by arrows in " fe1111.img" map

In the **second mode**, For example, the Fe mine in the North West of Neyshabur city, Razavi Khorasan Province, Iran, was used. It is enough to obtain the desired area coordinates. In the "toolbox" section of the Envi software the term "Resize Data" was entered and selected. The "MAP1.img" or "MAP11.img" file was then selected, the "Spatial Subset" option was clicked, the "Select Spatial Subset" window was entered, and the "Map" option was clicked to enter the following coordinates.

Upper left coordinate:

36 26 20.08
58 34 1.85

And the lower right coordinate:

36 23 45.86
58 37 1.88

OK was clicked and the file was saved as "fe2.img" in a certain path (Fig 4.3.6). All the steps in part 4.3 (second mode) of this study were performed for the file "MAP2.img" or "MAP22.img", and it was saved as "fe22.img" in a certain path (Fig 4.3.7). Similarly, all the steps in part 4.3 (second mode) were performed for the file "MAP3.img" or "MAP33.img", and it was saved as "fe222.img" in a certain path (Fig 4.3.8). Also, all the steps in part 4.3 (second mode) were performed for the file "MAP4.img" or "MAP44.img", and it was saved as "fe2222.img" in a certain path (Fig 4.3.9). Color spectrum in these four maps should be as follows:

The **second mode**:

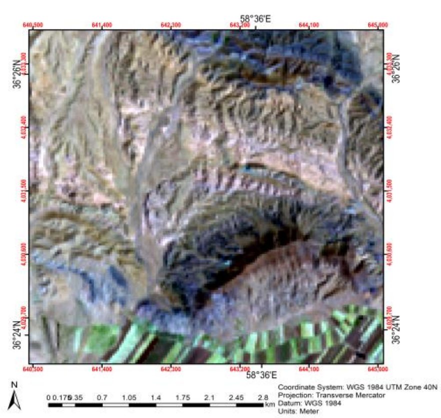
Map1, MAP11: **black** or dark purple or purple or dark brown or brown

MAP2, MAP22: **light blue**

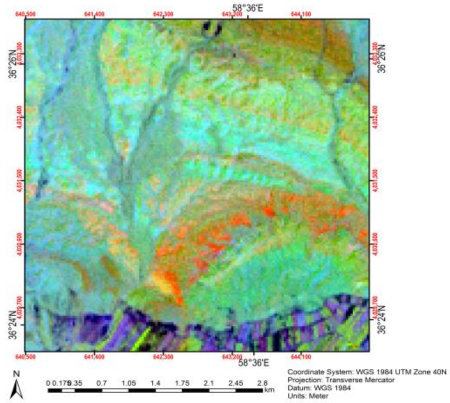
MAP3, MAP33: **dark green** or green

MAP4, MAP44: **light pink** or **pink** or red or purple and **0.01**<= **number** <= **0.2**

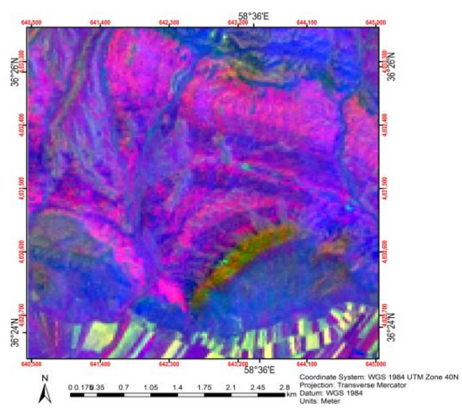
"Optimized Linear" mode was set when checking the "fe2.img", "fe22.img", "fe222.img", "fe222.img" and "fe1111.img" maps in the ENVI software. ArcGIS software (V10.5) was used for the final output of the Fe maps.



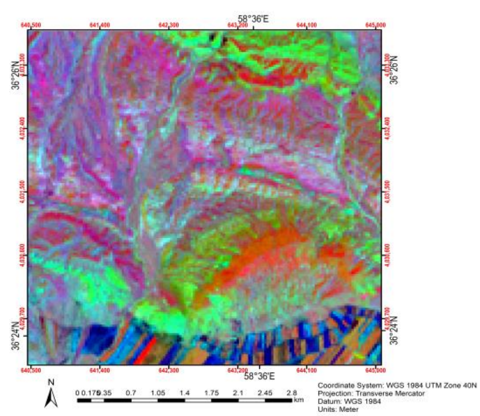
(Fig 4.3.6) The image "fe2.img" constructed from (MAP1, MAP11) by the Author with the name Fe mine in North West of Neyshabur city, Razavi Khorasan Province, Iran. ESM_4.3.2 original data available in Online Resource



(Fig 4.3.7) The image "fe22.img" constructed from (MAP2, MAP22) by the Author with the name of Fe mine in North West of Neyshabur city, Razavi Khorasan Province, Iran. ESM_4.3.2 original data is available in Online Resource



(Fig 4.3.8) The image "fe222.img" constructed from (MAP3, MAP33) by the Author with name Fe mine in North West of Neyshabur city, Razavi Khorasan Province, Iran. ESM_4.3.2 original data available in Online Resource



(Fig 4.3.9) The image "fe2222.img" constructed from (MAP4, MAP44) by the Author with name Fe mine in North West of Neyshabur city, Razavi Khorasan Province, Iran. ESM_4.3.2 original data available in Online Resource

Analysis of the desired area:

As you can see in the "fe22.img" map, light blue color shows the presence of Fe (Magnetite, Hematite) mineral in the desired area provided that black or dark purple or purple or dark brown or brown is are in "fe2.img" map, dark green or green are in "fe222.img" map, and light pink or pink or red or purple colors are in "fe2222.img" map and for sure, a number smaller than 0.2 and larger than 0.01 can be seen in "fe2222.img" map (from the "Value Cursor" section in the Envi software) which is the confirmation of Fe mineral in the desired square(any pixel of map). As it tends to light pink in the "fe2222.img" map, and as it tends to dark green in the "fe222.img" map, the potential and reserves of Fe (Magnetite, Hematite) mineral increase. According to the map data of "fe2222.img" in the "Cursor value" section of the Envi software as the number increases, the potential of Fe (Magnetite, Hematite) (Numeric range (0.01, 0.2)), average grade and reserves increase in the desired square .We considered a point on the map which is usually a square with a side of thirty meters (any pixel of map). The most important color spectrum for the exploration of Fe (Magnetite, Hematite) mineral in the most optimal and best condition is dark green in "fe222.img" map, light pink or pink in "fe2222.img" map, the light blue in "fe22.img" map and the black in "fe2.img" map. All four colors must be seen for the desired point and for sure, a number smaller than 0.2 and larger than 0.01 can be seen in "fe2222.img" map. If we divide the desired square into two parts, from the center of the square, fifteen meters to the left, fifteen meters to the right, fifteen meters to the top, fifteen meters to the bottom, and thirty meters to the depth of that square, we can have that mineral in high potential points. Points on the map containing minerals can be transferred from the map to the "KMZ" type file, and these points can be conFigd in GPS and then used for exploration. In "fe22.img" map, the dark blue is Vegetation.

4.4. Exploration of Manganese mineral with Landsat8 satellite

The (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were used in all explorations of the Manganese mineral. For example, the Manganese mine in the Southwest of Qom city, Iran, was used. First, the (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were opened in the Envi software. The geographical coordinates of any point in the desired area on the map could be obtained from the "Value Cursor" section in the Envi software. In the "toolbox" section of the Envi software the term "Resize Data" was entered and selected. The "MAP1.img" or "MAP11.img" file was then selected, the "Spatial Subset" option was clicked, the "Select Spatial Subset" window was entered, and the "Map" option was clicked to enter the following coordinates.

Upper left coordinate:

34 26 35.31
50 42 18.17

And the lower right coordinate:

34 24 4.55
50 45 38.44

OK was clicked and the file was saved as "mn1.img" in a certain path (Fig 4.4.1). All the steps in part 4.4 of this study were performed for the file "MAP2.img" or "MAP22.img", and it was saved as "mn11.img" in a certain path (Fig 4.4.2). Similarly, all the steps in part 4.4 were performed for the file "MAP3.img" or "MAP33.img", and it was saved as "mn111.img" in a certain path (Fig 4.4.3). Also, all the steps in part 4.4 were performed for the file "MAP4.img" or "MAP44.img", and it was saved as "mn1111.img" in a certain path (Fig 4.4.4). Color spectrum in these four maps should be as follows:

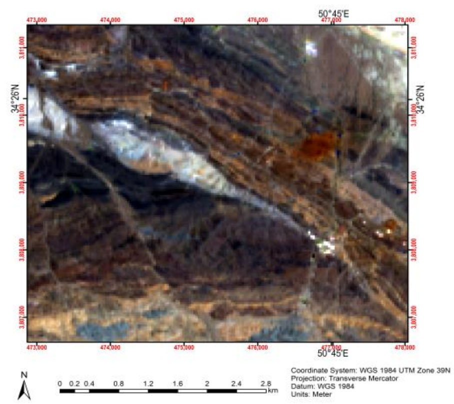
Map1, MAP11: **black** or dark purple or purple or dark brown or brown

MAP2, MAP22: **yellow** or **green**

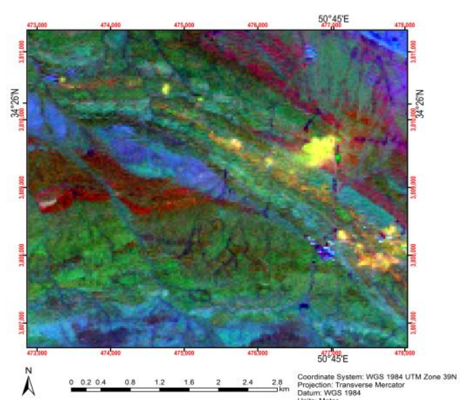
MAP3, MAP33: **light pink (igneous origin)** or dark purple or purple or blue **(**sedimentary**)**

MAP4, MAP44: **dark blue** and **-0.2** < =**number** < = **-0.01**

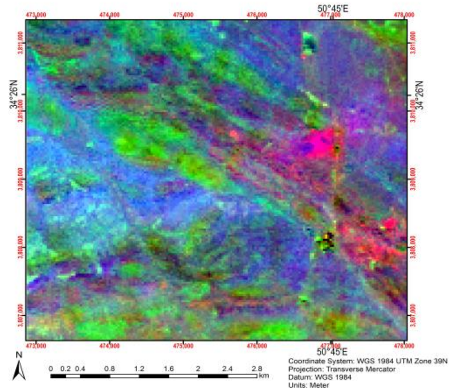
"Optimized Linear" mode was set when checking the "mn1.img", "mn11.img", "mn111.img", and "mn1111.img" maps in the ENVI software. ArcGIS software (V10.5) was used for the final output of the Manganese maps.



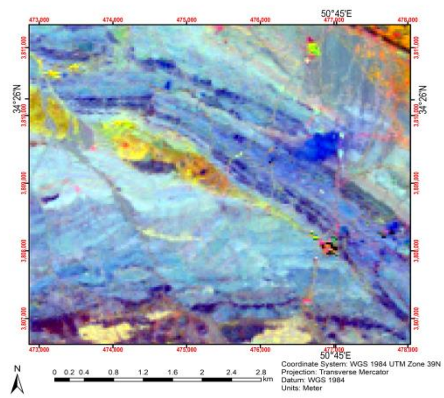
(Fig 4.4.1) The image "mn1.img" constructed from (MAP1, MAP11) by the Author with the name Manganese mine in Southwest of Qom city, Iran. ESM_4.4 original data available in Online Resource



(Fig 4.4.2) The image "mn11.img" constructed from (MAP2, MAP22) by the Author with the name Manganese mine in Southwest of Qom city, Iran. ESM_4.4 original data available in Online Resource



(Fig 4.4.3) The image "mn111.img" constructed from (MAP3, MAP33) by the Author with the name Manganese mine in Southwest of Qom city, Iran. ESM_4.4 original data available in Online Resource



(Fig 4.4.4) The image "mn1111.img" constructed from (MAP4, MAP44) by the Author with the name Manganese mine in Southwest of Qom city, Iran. ESM_4.4 original data available in Online Resource

Analysis of the desired area:

As you can see in the "mn1111.img" map, the dark blue show the presence of Manganese mineral in the desired area provided that light pink (igneous origin) or purple or dark purple or blue **(**sedimentary**)** colors are in "mn111.img" map, black or dark purple or purple or dark brown or brown colors are in "mn1.img" map and yellow or green colors are in "mn11.img" map and for sure, a number smaller than -0.01 and larger than -0.2 can be seen in "mn1111.img" map (from the "Value Cursor" section in the Envi software) which is the confirmation of Manganese mineral in the desired square (any pixel of map). As it tends to black in the "mn1.img" map, As it tends to yellow in the "mn11.img" map, as it tends to light pink in the "mn1111.img", the potential and reserves of Manganese mineral increase in the desired square. Here we refer to an article that uses combining ratio bands ((b3+b1)/b2), ((b3+b5)/b4), ((b5+b7)/b6)) as RGB, and (pca3, pca2, pca1) as RGB. It shows the presence of Manganese in dark blue in "mn1111.img" map (Fig 4.4.4) [1]. We generalized and used other band compounds and other maps to further confirm this mineral. We provided an accurate and complete method for most minerals. Also We used optimal band compounds ((b3/b1), (b5/b7), b6)as RGB and (((b7+b6+b5)/6), ((b5+b4+b3)/6), ((b3+b2+b1)/6))as RGB and (pca((b7+b6+b5)/6), pca((b5+b4+b3)/6), pca((b3+b2+b1)/6)) as RGB in the exploration of the Manganese and other minerals mentioned in this study. According to the map data of "mn1111.img" in the "Cursor value" section of the Envi software, as the number lowers, the potential of Manganese (Numeric range (-0.2,-0.01)), average grade and reserves increase in the desired square. We considered a point on the map which is usually a square with a side of thirty meters (any pixel of map). The most important color spectrum for the exploration of Manganese mineral in the most optimal and best condition is yellow or green colors in "mn11.img" map, the black in "mn1.img" map, the dark blue in "mn1111.img" map and the light pink in "mn111.img" map. All four colors must be seen for the desired point and for sure, a number smaller than -0.01 and larger than -0.2 can be seen in "mn1111.img" map. If vegetation (In "mn11.img" map, the dark blue) is present all around the mineral deposit, it is sulfide Manganese otherwise it is oxide Manganese. Therefore in the desired area it is oxide Manganese. If we divide the desired square into two parts, from the center of the square, fifteen meters to the left, fifteen meters to the right, fifteen meters to the top, fifteen meters to the bottom, and thirty meters to the depth of that square, we can have that mineral in high potential points. Points on the map containing minerals can be transferred from the map to the "KMZ" type file, and these points can be conFigd in GPS and then used for exploration. In "mn11.img" map, dark blue is Vegetation and the sky blue can be silica (it should be seen on the map around the Manganese mineral to confirm this mineral) or soil minerals.

4.5. Exploration of Magnesium mineral with Landsat8 satellite

The (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were used in all explorations of the Magnesium mineral. For example, the Magnesium mine in the Southeast of Sarbisheh city, South Khorasan province, Iran, was used. First, the (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were opened in the Envi software. The geographical coordinates of any point in the desired area on the map could be obtained from the "Value Cursor" section in the Envi software. In the "toolbox" section of the Envi software the term "Resize Data" was entered and selected. The "MAP1.img" or "MAP11.img" file was then selected, the "Spatial Subset" option was clicked, the "Select Spatial Subset" window was entered, and the "Map" option was clicked to enter the following coordinates.

Upper left coordinate:

31 51 41.39
60 9 41.13

And the lower right coordinate:

31 48 19.89
60 13 48.84

OK was clicked and the file was saved as "mg1.img" in a certain path (Fig 4.5.1). All the steps in part 4.5 of this study were performed for the file "MAP2.img" or "MAP22.img", and it was saved as "mg11.img" in a certain path (Fig 4.5.2). Similarly, all the steps in part 4.5 were performed for the file "MAP3.img" or "MAP33.img", and it was saved as "mg111.img" in a certain path (Fig 4.5.3). Also, all the steps in part 4.5

were performed for the file "MAP4.img" or "MAP44.img", and it was saved as "mg1111.img" in a certain path (Fig 4.5.4). Color spectrum in these four maps should be as follows:

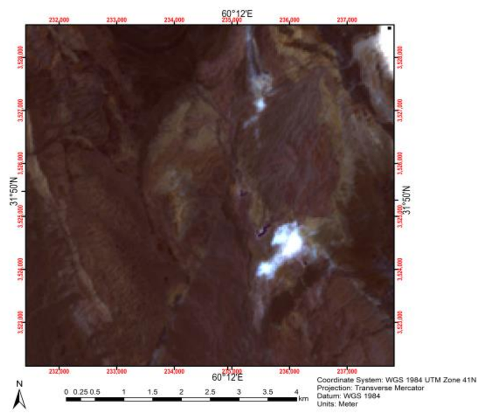
MAP1, MAP11: **white**

MAP2, MAP22: purple or dark purple or pink or blue

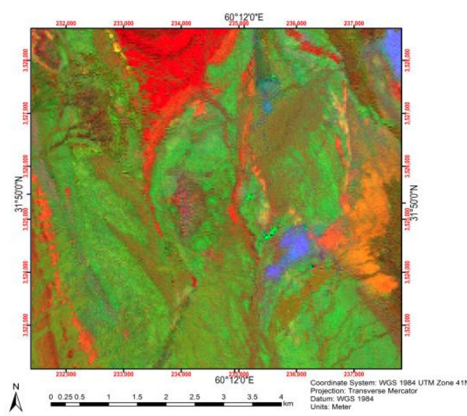
MAP3, MAP33: **green**

MAP4, MAP44: **yellow** and **0.1**< = **number** < = **1**

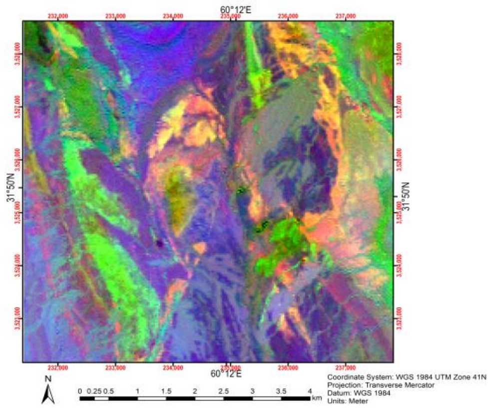
"Optimized Linear" mode was set when checking the "mg1.img", "mg11.img", "mg111.img", and "mg1111.img" maps in the ENVI software. ArcGIS software (V10.5) was used for the final output of the Magnesium maps.



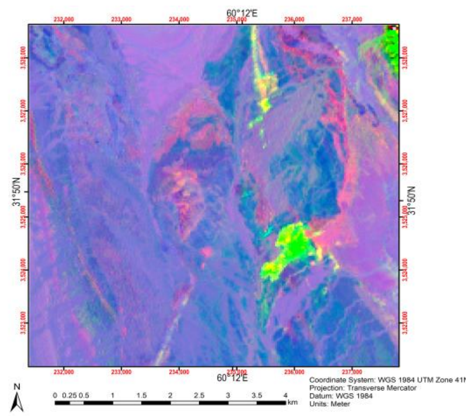
(Fig 4.5.1) The image "mg1.img" constructed from (MAP1, MAP11) by the Author with the name Magnesium mine in Southeast of Sarbisheh city, South Khorasan province, Iran. ESM_4.5 original data available in Online Resource



(Fig 4.5.2) The image "mg11.img" constructed from (MAP2, MAP22) by the Author with the name Magnesium mine in Southeast of Sarbisheh city, South Khorasan province, Iran. ESM_4.5 original data available in Online Resource



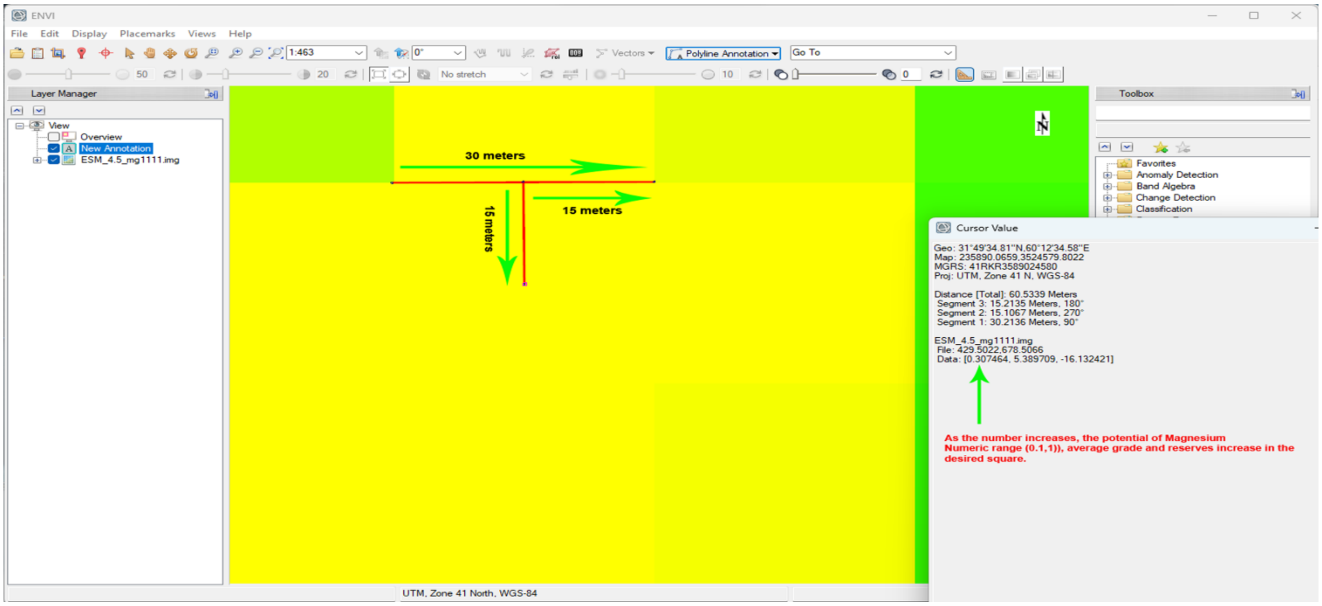
(Fig 4.5.3) The image "mg111.img" constructed from (MAP3, MAP33) by the Author with the name Magnesium mine in Southeast of Sarbisheh city, South Khorasan province, Iran. ESM_4.5 original data available in Online Resource



(Fig 4.5.4) The image "mg1111.img" constructed from (MAP4, MAP44) by the Author with the name Magnesium mine in Southeast of Sarbisheh city, South Khorasan province, Iran. ESM_4.5 original data available in Online Resource

Analysis of the desired area:

As you can see in the "mg1111.img" map, the yellow shows the presence of Magnesium mineral in the desired area provided that dark purple or purple or pink or blue colors are in "mg11.img" map, white in "mg1.img" map, green in "mg111.img" map and for sure, a number smaller than 1 and larger than 0.1 can be seen in "mg1111.img" (from the "Value Cursor" section in the Envi software) which is the confirmation of Magnesium mineral in the desired square (any pixel of map). As it tends to yellow in the "mg1111.img" map, and as it tends to white in the "mg1.img" map, the potential and reserves of Magnesium mineral increase in the desired square. According to the map data of "mg1111.img" in the "Cursor value" section of the Envi software, as the number increases, the potential of Magnesium (Numeric range (0.1,1)), average grade and reserves increase in the desired square. We considered a point on the map which is usually a square with a side of thirty meters (any pixel of map). The most important color spectrum for the exploration of Magnesium mineral in the most optimal and best condition is the green in "mg111.img" map, the yellow in "mg1111.img" map, and the white in "mg1.img" map. All three colors must be seen for the desired point and for sure, a number smaller than 1 and larger than 0.1 can be seen in mg1111.img "map. If we divide the desired square into two parts, from the center of the square, fifteen meters to the left, fifteen meters to the right, fifteen meters to the top, fifteen meters to the bottom, and thirty meters to the depth of that square, we can have that mineral in high potential points (Fig 4.5.5). Points on the map containing minerals can be transferred from the map to the "KMZ" type file, and these points can be conFigd in GPS and then used for exploration. In "mg11.img" map, dark blue is Vegetation and the sky blue can be silica or soil minerals.



(Fig 4.5.5) As the number increases, the potential of Magnesium (Numeric range (0.1, 1)), average grade and reserves increase in the desired square (from the center of the square to a distance of fifteen meters around) shown by arrows in "mg1111.img" map

4.6. Exploration of Chromite mineral with Landsat8 satellite

The (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were used in all explorations of the Chromite mineral. For example, the Chromite mine in the west of Sabzevar city, Razavi Khorasan province, Iran, was used. First, the (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were opened in the Envi software. The geographical coordinates of any point in the desired area on the map could be obtained from the "Value Cursor" section in the Envi software. In the "toolbox" section of the Envi software the term "Resize Data" was entered and selected. The "MAP1.img" or "MAP11.img" file was then selected, the "Spatial Subset" option was clicked, the "Select Spatial Subset" window was entered, and the "Map" option was clicked to enter the following coordinates.

Upper left coordinate:

36 26 19.79
56 40 39.28

And the lower right coordinate:

36 22 0.98

56 50 1.36

OK was clicked and the file was saved as "cr1.img" in a certain path (Fig 4.6.1). All the steps in part 4.6 of this study were performed for the file "MAP2.img" or "MAP22.img", and it was saved as "cr11.img" in a certain path (Fig 4.6.2). Similarly, all the steps in part 4.6 were performed for the file "MAP3.img" or "MAP33.img", and it was saved as "cr111.img" in a certain path (Fig 4.6.3). Also, all the steps in part 4.6 were performed for the file "MAP4.img" or "MAP44.img", and it was saved as "cr1111.img" in a certain path (Fig 4.6.4). Color spectrum in these four maps should be as follows:

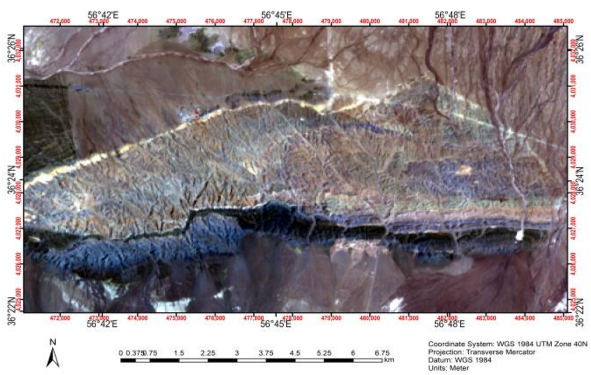
MAP1, MAP11: gray

MAP2, MAP22: **sky blue**

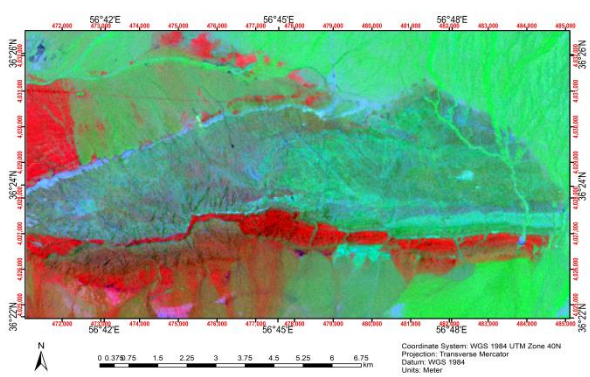
MAP3, MAP33: **light pink** or pink or **green**

MAP4, MAP44: **dark blue** or dark purple or green and **-0.2** < =**number** <= **-0.01**

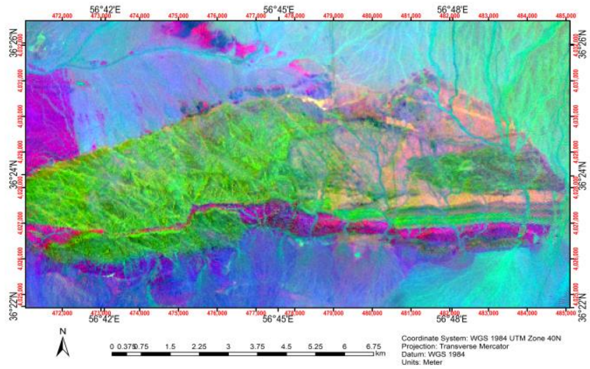
"Optimized Linear" mode was set when checking the "cr1.img", "cr11.img", "cr111.img", and "cr1111.img" maps in the ENVI software. ArcGIS software (V10.5) was used for the final output of the Chromite maps.



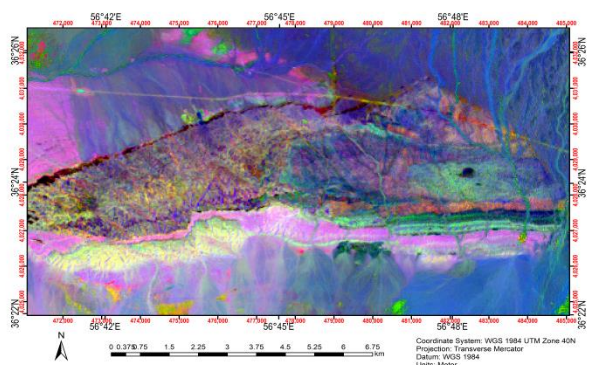
(Fig 4.6.1) The image "cr1.img" constructed from (MAP1, MAP11) by the Author with the name Chromite mine in west of Sabzevar city, Razavi Khorasan province, Iran. ESM_4.6 original data available in Online Resource



(Fig 4.6.2) The image "cr11.img" constructed from (MAP2, MAP22) by the Author with the name Chromite mine in west of Sabzevar city, Razavi Khorasan province, Iran. ESM_4.6 original data available in Online Resource



(Fig 4.6.3) The image "cr111.img" constructed from (MAP3, MAP33) by the Author with the name Chromite mine in west of Sabzevar city, Razavi Khorasan province, Iran. ESM_4.6 original data available in Online Resource



(Fig 4.6.4) The image "cr1111.img" constructed from (MAP4, MAP44) by the Author with the name Chromite mine in west of Sabzevar city, Razavi Khorasan province, Iran. ESM_4.6 original data available in Online Resource

Analysis of the desired area:

As you can see in the " cr11.img " map, sky blue color shows the presence of Chromite mineral in the desired area provided that light pink or pink or green colors are in "cr111.img "map, dark blue or dark purple or green are in "cr1111.img "map, gray is in "cr1.img "map and for sure, a number smaller than -0.01 and larger than -0.2 can be seen in cr1111.img "map (from the " Value Cursor " section in the Envi software) which is the confirmation of Chromite mineral in the desired square (any pixel of map). As it tends to green in the "cr111.img" map, and as it tends to dark blue in the "cr1111.img" map, potential and reserves of Chromite mineral increase in the desired square. According to the map data of "cr1111.img" in the "Cursor value" section of the Envi software, as the number lowers, the potential of Chromite (Numeric range(-0.2,-0.01)), average grade and reserves increase in the desired square. We considered a point on the map which is usually a square with a side of thirty meters (any pixel of map). The most important color spectrum for the exploration of Chromite mineral in the most optimal and best condition is sky blue in "cr11.img" map, light pink or green colors in "cr111.img" map, and dark blue or green in "cr1111.img" map, and gray in "cr1.img" map. All four colors must be seen for the desired point and for sure, a number smaller than -0.01 and larger than -0.2 can be seen in cr1111.img "map. If we divide the desired square into two parts, from the center of the square, fifteen meters to the left, fifteen meters to the right, fifteen meters to the top, fifteen meters to the bottom, and thirty meters to the depth of that square, we can have that mineral in high potential points. Points on the map containing minerals can be transferred from the map to the "KMZ" type file, and these points can be conFigd in GPS and then used for exploration. In "cr11.img" map, dark blue is Vegetation and the sky blue can be silica or soil minerals.

4.7. Exploration of Antimony mineral with Landsat8 satellite

The (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were used in all explorations of the Antimony mineral. For example, the Antimony mine in the Southwest of Sefidabeh city, Sistan and Baluchestan province, Iran, was used. First, the (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were opened in the Envi software. The geographical coordinates of any point in the desired area on the map could be obtained from the "Value Cursor" section in the Envi software. In the "toolbox" section of the Envi software the term "Resize Data" was entered and selected. The "MAP1.img" or "MAP11.img" file was then selected, the "Spatial Subset" option was clicked, the "Select Spatial Subset" window was entered, and the "Map" option was clicked to enter the following coordinates.

Upper left coordinate:

30 50 59.63
60 2 12.81

And the lower right coordinate:

30 43 41.98
60 8 34.77

OK was clicked and the file was saved as "sb1.img" in a certain path (Fig 4.7.1). All the steps in part 4.7 of this study were performed for the file "MAP2.img" or "MAP22.img", and it was saved as "sb11.img" in a certain path (Fig 4.7.2). Similarly, all the steps in part 4.7 were performed for the file "MAP3.img" or "MAP33.img", and it was saved as "sb111.img" in a certain path (Fig 4.7.3). Also, all the steps in part 4.7 were performed for the file "MAP4.img" or "MAP44.img", and it was saved as "sb1111.img" in a certain path (Fig 4.7.4). Color spectrum in these four maps should be as follows:

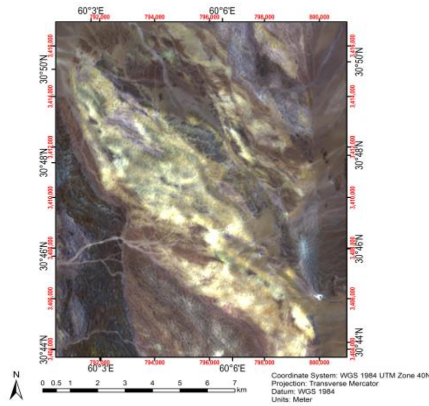
MAP1, MAP11: **yellow** or **white** or brownish yellow or yellowish white

MAP2, MAP22: **white**

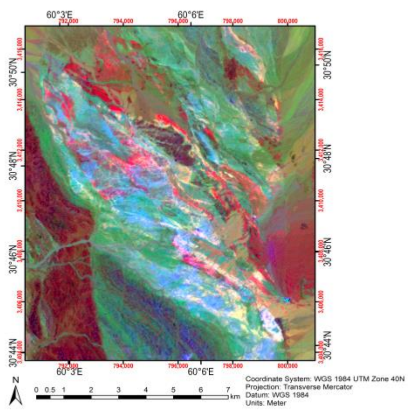
MAP3, MAP33: **green** or yellow

MAP4, MAP44: **black** or **dark purple** or purple or dark red and **-0.4** < = **number** < = **-0.01**

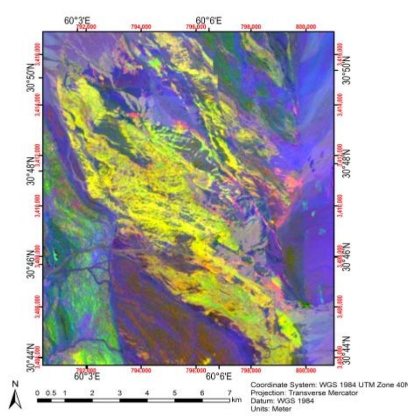
"Optimized Linear" mode was set when checking the "sb1.img", "sb11.img", "sb111.img", and "sb1111.img" maps in the ENVI software. ArcGIS software (V10.5) was used for the final output of the Antimony maps.



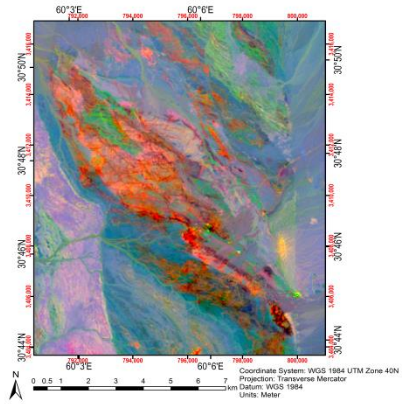
(Fig 4.7.1) The image "sb1.img" constructed from (MAP1, MAP11) by the Author with the name Antimony mine in Southwest of Sefidabeh city, Sistan and Baluchestan province, Iran. ESM_4.7 original data available in Online Resource



(Fig 4.7.2) The image "sb11.img" constructed from (MAP2, MAP22) by the Author with the name Antimony mine in Southwest of Sefidabeh city, Sistan and Baluchestan province, Iran. ESM_4.7 original data available in Online Resource



(Fig 4.7.3) The image "sb111.img" constructed from (MAP3, MAP33) by the Author with the name Antimony mine in Southwest of Sefidabeh city, Sistan and Baluchestan province, Iran. ESM_4.7 original data available in Online Resource



(Fig 4.7.4) The image "sb1111.img" constructed from (MAP4, MAP44) by the Author with the name Antimony mine in Southwest of Sefidabeh city, Sistan and Baluchestan province, Iran. ESM_4.7 original data available in Online Resource

Analysis of the desired area:

As you can see in the " sb11.img " map, white color shows the presence of Antimony mineral in the desired area provided that green or yellow colors are in " sb111.img "map, dark purple or black or purple or dark red colors are in "sb1111.img "map, yellow or white or brownish yellow or yellowish white in " sb1.img "map and for sure, a number smaller than -0.01 and larger than -0.4 can be seen in sb1111.img "map (from the " Value Cursor " section in the Envi software) which is the confirmation of Antimony mineral in the desired square (any pixel of map). As it tends to green in the "sb111.img" map, and as it tends to white in the "sb11.img" map and as it tends to dark purple in the "sb1111.img" map, the potential and reserves of Antimony mineral increase in the desired square. According to the map data of "sb1111.img" in the "Cursor value" section of the Envi software, as the number lowers, the potential of Antimony (Numeric range (-0.4,-0.01)), average grade and reserves increase in the desired square. We considered a point on the map which is usually a square with a side of thirty meters (any pixel of map). The most important color spectrum for the exploration of Antimony mineral in the most optimal and best condition is the white in "sb11.img" map and yellow or white or yellowish white in "sb1.img" map, the green in "sb111.img" map, and the dark purple or black in "sb1111.img" map. All four colors must be seen for the desired point and for sure, a number smaller than -0.01 and larger than -0.4 can be seen in sb1111.img "map. If we divide the desired square into two parts, from the center of the square, fifteen meters to the left, fifteen meters to the right, fifteen meters to the top, fifteen meters to the bottom, and thirty meters to the depth of that square, we can have that mineral in high potential points. Points on the map containing minerals can be transferred from the map to the "KMZ" type file, and these points can be conFigd in GPS and then used for exploration. In "sb111.img" map, yellow indicates the presence of vegetation cover or other interfering elements that exist alongside the mineral deposits. Also In "sb11.img" map, dark blue is Vegetation and the sky blue can be silica or soil minerals.

4.8. Exploration of Bauxite mineral with Landsat8 satellite

The (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were used in all explorations of the Bauxite mineral. For example, the Bauxite mine in the Northeast of Shahrud city, Semnan province, Iran, was used. First, the (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were opened in the Envi software. The geographical coordinates of any point in the desired area on the map could be obtained from the "Value Cursor" section in the Envi software.

In the "toolbox" section of the Envi software the term "Resize Data" was entered and selected. The "MAP1.img" or "MAP11.img" file was then selected, the "Spatial Subset" option was clicked, the "Select Spatial Subset" window was entered, and the "Map" option was clicked to enter the following coordinates.

Upper left coordinate:
36 50 57.58
56 8 6.99

And the lower right coordinate:
36 50 4.82
56 10 1.48

OK was clicked and the file was saved as "Bauxite1.img" in a certain path (Fig 4.8.1). All the steps in part 4.8 of this study were performed for the file "MAP2.img" or "MAP22.img", and it was saved as "Bauxite11.img" in a certain path (Fig 4.8.2). Similarly, all the steps in part 4.8 were performed for the file "MAP3.img" or "MAP33.img", and it was saved as "Bauxite111.img" in a certain path (Fig 4.8.3). Also, all the steps in part 4.8 were performed for the file "MAP4.img" or "MAP44.img", and it was saved as "Bauxite1111.img" in a certain path (Fig 4.8.4). Color spectrum in these four maps should be as follows:

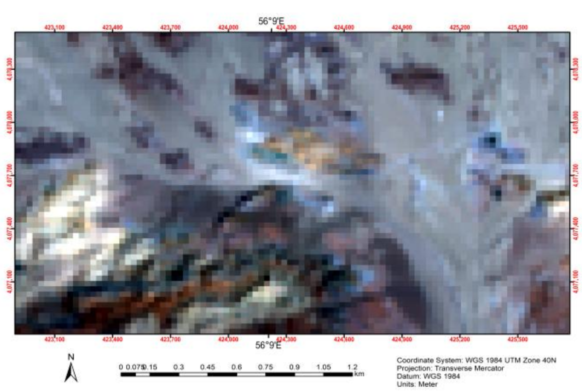
Map1, MAP11: **black** or dark purple or purple or dark brown or brown

MAP2, MAP22: **green** or **yellow**

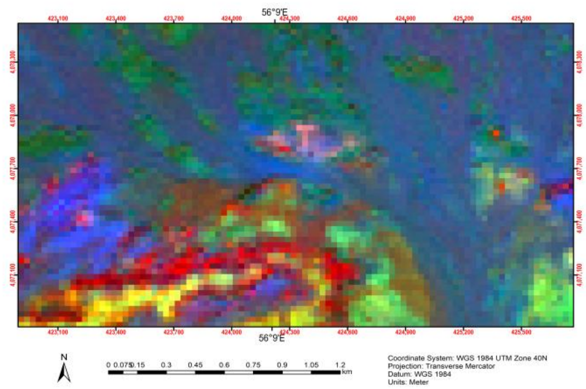
MAP3, MAP33: **green (igneous origin)** or blue **(**sedimentary**)**

MAP4, MAP44: **dark blue** or dark purple or purple and **-0.3** < = **number** < = **-0.01**

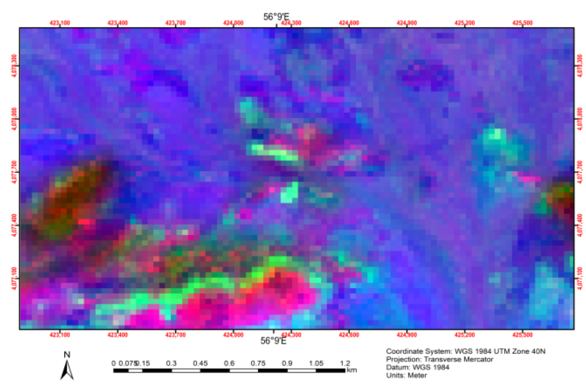
"Optimized Linear" mode was set when checking the "Bauxite1.img", "Bauxite11.img", "Bauxite111.img", and "Bauxite1111.img" maps in the ENVI software. ArcGIS software (V10.5) was used for the final output of the Bauxite maps.



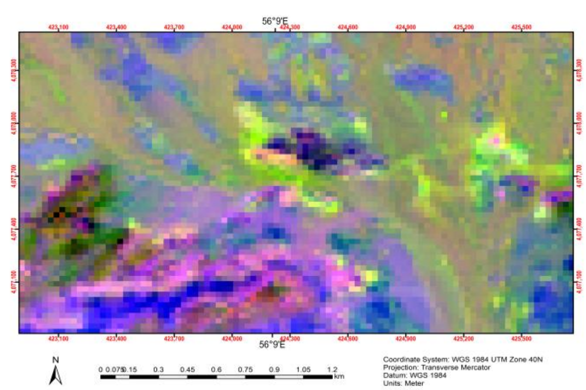
(Fig 4.8.1) The image "Bauxite1.img" constructed from (MAP1, MAP11) by the Author with the name Bauxite mine in Northeast of Shahrud city, Semnan province, Iran. ESM_4.8 original data available in Online Resource



(Fig 4.8.2) The image "Bauxite11.img" constructed from (MAP2, MAP22) by the Author with the name the Bauxite mine in Northeast of Shahrud city, Semnan province, Iran. ESM_4.8 original data available in Online Resource



(Fig 4.8.3) The image "Bauxite111.img" constructed from (MAP3, MAP33) by the Author with the name Bauxite mine in Northeast of Shahrud city, Semnan province, Iran. ESM_4.8 original data available in Online Resource



(Fig 4.8.4) The image "Bauxite1111.img" constructed from (MAP4, MAP44) by the Author with the name the Bauxite mine in Northeast of Shahrud city, Semnan province, Iran. ESM_4.8 original data available in Online Resource

Analysis of the desired area:

As you can see in the " Bauxite 11.img " map, green or yellow colors show the presence of Bauxite mineral in the desired area provided that green (igneous origin) or blue **(**sedimentary**)** are in "Bauxite111.img" map, dark blue or dark purple or purple are in "Bauxite1111.img "map, black or dark purple or purple or dark brown or brown are in "Bauxite1.img" map and for sure, a number smaller than -0.01 and larger than -0.3 can be seen in Bauxite 1111.img "map (from the "Value Cursor" section in the Envi software) which is the confirmation of Bauxite mineral in the desired square (any pixel of map). As it tends to yellow in the "Bauxite11.img" map, and as it tends to black in the "Bauxite1.img" map, also as it tends to green in the "Bauxite111.img" map potential and reserves of Bauxite mineral increase in the desired square. According to the map data of "Bauxite1111.img in the "Cursor value" section of the Envi software, as the number increases, the potential of Bauxite (Numeric range (-0.3, -0.01)), average grade and reserves increase in the desired square. We considered a point on the map which is usually a square with a side of thirty meters (any pixel of map). The most important color spectrum for the exploration of Bauxite mineral in the most optimal and best condition, is yellow or green colors in " Bauxite11.img" map, the black in "Bauxite1.img" map, the green in Bauxite111.img" map and the dark blue in " Bauxite1111.img" map. All four colors must be seen for the desired point and for sure, a number smaller than -0.01 and larger than -0.3 can be seen in Bauxite 1111.img "map. If we divide the desired square into two parts, from the center of the square, fifteen meters to the left, fifteen meters to the right, fifteen meters to the top, fifteen meters to the bottom, and thirty meters to the depth of that square, we can have that mineral in high potential points. Points on the map containing minerals can be transferred from the map to the "KMZ" type file. These points can be conFigd in GPS and then used for exploration. In "Bauxite11.img" map, dark blue is vegetation and sky blue can be silica or soil minerals.

4.9. Exploration of industrial soils mineral with Landsat8 satellite

The (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps

were used in all explorations of the industrial soil mineral. For example, the industrial soil mine in the north of Tabas city, South Khorasan province, Iran, was used. First, the (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were opened in the Envi software. The geographical coordinates of any point in the desired area on the map could be obtained from the "Value Cursor" section in the Envi software. In the "toolbox" section of the Envi software the term "Resize Data" was entered and selected. The "MAP1.img" or "MAP11.img" file was then selected, the "Spatial Subset" option was clicked, the "Select Spatial Subset" window was entered, and the "Map" option was clicked to enter the following coordinates.

Upper left coordinate:

33 27 3.41
57 51 39.69

And the lower right coordinate:

33   20   45.56
58   0   22.72

OK was clicked and the file was saved as "Industrial soil1.img" in a certain path (Fig 4.9.1). All the steps in part 4.9 of this study were performed for the file "MAP2.img" or "MAP22.img", and it was saved as "Industrial soil11.img" in a certain path (Fig 4.9.2). Similarly, all the steps in part 4.9 were performed for the file "MAP3.img" or "MAP33.img", and it was saved as "Industrial soil111.img" in a certain path (Fig 4.9.3). Also, all the steps in part 4.9 were performed for the file "MAP4.img" or "MAP44.img", and it was saved as "Industrial soil1111.img" in a certain path (Fig 4.9.4).

Color spectrum in these four maps should be as follows:

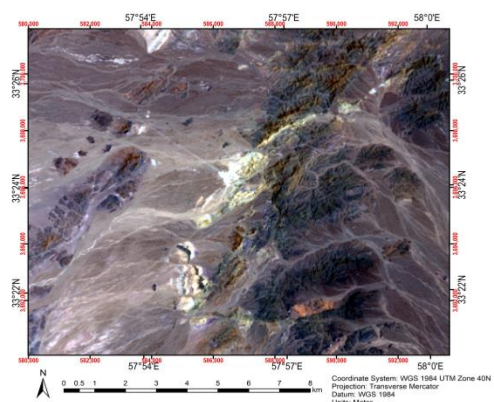
MAP1, MAP11: **white**

MAP2, MAP22: light blue or pink or purple

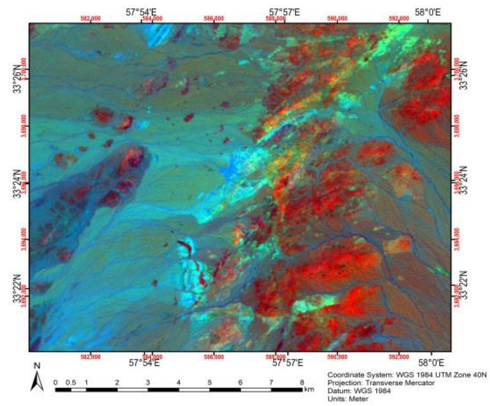
MAP3, MAP33: **green**

MAP4, MAP44: **yellow** or light green and **0.01** < = **number** < = **0.3**

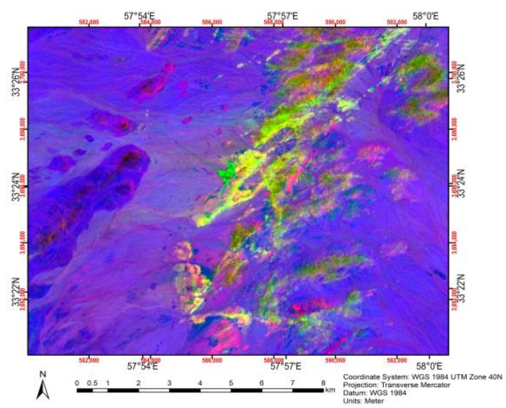
"Optimized Linear" mode was set when checking the "Industrial soil1.img", "Industrial soil11.img", "Industrial soil111.img", and "Industrial soil1111.img" maps in the ENVI software. ArcGIS software (V10.5) was used for the final output of the Industrial soil maps.



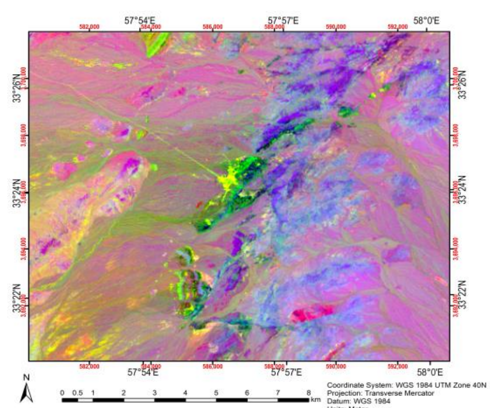
(Fig 4.9.1) The image "Industrial soil1.img" constructed from (MAP1, MAP11) by the Author with the name Industrial soil mine in Southeast of Boshruyeh city, South Khorasan province, Iran. ESM_4.9 original data available in Online Resource



(Fig 4.9.2) The image "Industrial soil11.img" constructed from (MAP2, MAP22) by the Author with the name Industrial soil mine in Southeast of Boshruyeh city, South Khorasan province, Iran. ESM_4.9 original data available in Online Resource



(Fig 4.9.3) The image "Industrial soil111.img" constructed from (MAP3, MAP33) by the Author with the name Industrial soil mine in Southeast of Boshruyeh city, South Khorasan province, Iran. ESM_4.9 original data available in Online Resource



(Fig 4.9.4) The image "Industrial soil1111.img" constructed from (MAP4, MAP44) by the Author with the name Industrial soil mine in Southeast of Boshruyeh city, South Khorasan province, Iran. ESM_4.9 original data available in Online Resource

Analysis of the desired area:

As you can see in the "Industrial soil111.img" map, green shows the presence of Industrial soil mineral in the desired area provided that white is in "Industrial soil1.img" map, light blue or pink or purple colors in "Industrial soil11.img " map, light green or yellow colors are in "Industrial soil1111.img" map and for sure, a number smaller than 0.3 and larger than 0.01 can be seen in "Industrial soil1111.img" map (from the " Value Cursor " section in the Envi software) which is the confirmation of industrial soil mineral in the desired square (any pixel of map). As it tends to yellow in the "Industrial soil1111.img" map, and as it tends to white in "Industrial soil1.img" map, the potential and reserves of industrial soil mineral increase in the desired square. According to the map data of "Industrial soil1111.img" in the "Cursor value" section of the Envi software, as the number increases, the potential of industrial soil (Numeric range (0.01,0.3)), average grade and reserves increase in the desired square. We considered a point on the map which is usually a square with a side of thirty meters (any pixel of map). The most important color spectrum for the exploration of Industrial soil mineral in the most optimal and best condition is green in "Industrial soil111.img", yellow in "Industrial soil1111.img" map, and white in "Industrial soil1.img" map. All three colors must be seen for the desired point and for sure, a number smaller than 0.3 and larger than 0.01 can be seen in "Industrial soil1111.img" map. If we divide the desired square into two parts, from the center of the square, fifteen meters to the left, fifteen meters to the right, fifteen meters to the top, fifteen meters to the bottom, and thirty meters to the depth of that square, we can have that mineral in high potential points. Points on the map containing minerals can be transferred from the map to the "KMZ" type file, and these points can be conFigd in GPS and then used for exploration. In "Industrial soil11.img" map, dark blue is vegetation.

4.10. Exploration of Nickel mineral with Landsat8 satellite

The (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were used in all explorations of the Nickel mineral. For example, the Nickel mine in the North East of Arsenjan, Fars province, Iran, was used. First, the (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were opened in the Envi software. The geographical coordinates of any point in the desired area on the map could be obtained from the "Value Cursor" section in the Envi software. In the "toolbox" section of the Envi software the term "Resize Data" was entered and selected. The "MAP1.img" or "MAP11.img" file was then selected, the "Spatial Subset" option was clicked, the "Select Spatial Subset" window was entered, and the "Map" option was clicked to enter the following coordinates.

Upper left coordinate:
30 1 29.16
53 33 32.26

And the lower right coordinate:
29 56 49.11
53 38 52.96

OK was clicked and the file was saved as "ni1.img" in a certain path (Fig 4.10.1). All the steps in part 4.10 of this study were performed for the file "MAP2.img" or "MAP22.img", and it was saved as "ni11.img" in a certain path (Fig 4.10.2). Similarly, all the steps in part 4.10 were performed for the file "MAP3.img" or

"MAP33.img", and it was saved as "ni111.img" in a certain path (Fig 4.10.3). Also, all the steps in part 4.10 were performed for the file "MAP4.img" or "MAP44.img", and it was saved as "ni1111.img" in a certain path (Fig 4.10.4).Color spectrum in these four maps should be as follows:

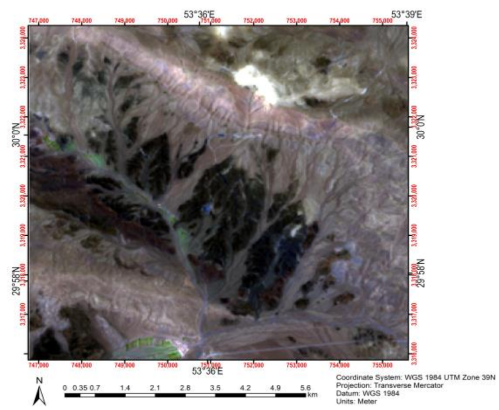
MAP1, MAP11: **black** or dark purple or purple or dark brown

MAP2, MAP22: **green**

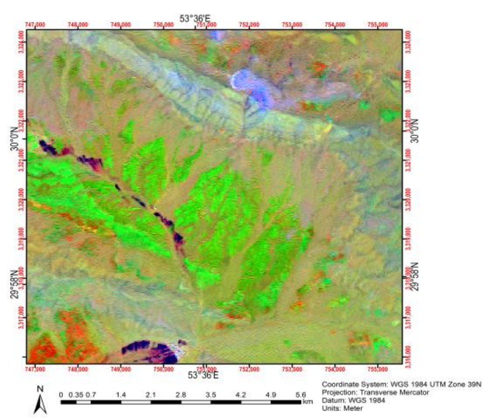
MAP3, MAP33: **sky blue** or white

MAP4, MAP44: **sky blue or light pink or** purple **0.01** < = **number** < = **0.2**

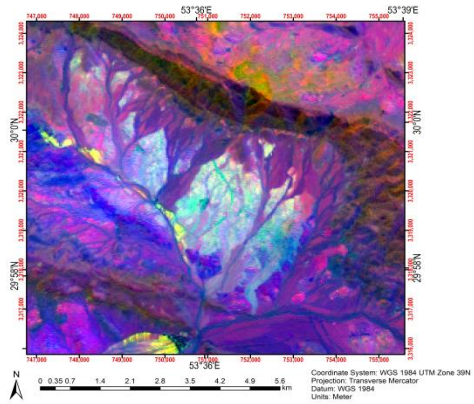
"Optimized Linear" mode was set when checking the "ni1.img", "ni11.img", "ni111.img", and "ni1111.img" maps in the ENVI software. ArcGIS software (V10.5) was used for the final output of the Nickel maps.



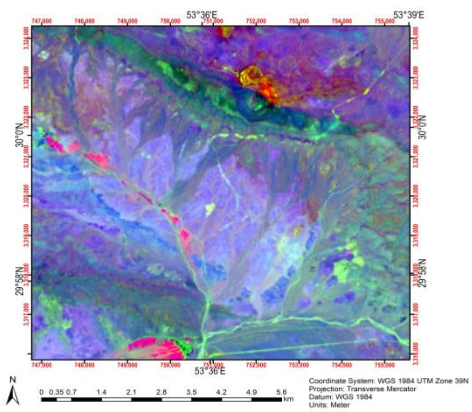
(Fig 4.10.1) The image "ni1.img" constructed from (MAP1, MAP11) by the Author with the name Nickel mine in North East of Arsenjan, Fars province, Iran. ESM_4.10 original data available in Online Resource



(Fig 4.10.2) The image "ni11.img" constructed from (MAP2, MAP22) by the Author with the name Nickel mine in North East of Arsenjan, Fars province, Iran. ESM_4.10 original data available in Online Resource



(Fig 4.10.3) The image "ni111.img" constructed from (MAP3, MAP33) by the Author with the name Nickel mine in North East of Arsenjan, Fars province, Iran. ESM_4.10 original data available in Online Resource



(Fig 4.10.4) The image "ni1111.img" constructed from (MAP4, MAP44) by the Author with the name Nickel mine in North East of Arsenjan, Fars province, Iran. ESM_4.10 original data available in Online Resource

Analysis of the desired area:

As you can see in the "ni11.img" map, green shows the presence of Nickel mineral in the desired area provided that black or dark purple or purple or dark brown or colors are in "ni1.img" map, white or sky blue colors are in " ni111.img "map, sky blue or light pink or purple are in "ni1111.img" map and for sure, a number smaller than 0.2 and larger than 0.01 can be seen in "ni1111.img" map (from the " Value Cursor " section in the Envi software) which is the confirmation of Nickel mineral in the desired square (any pixel of map). As it tends to sky blue in "ni111.img" map, and it tends to black in "ni1.img" map, the potential and reserves of Nickel mineral increase in the desired square in the desired square. According to the map data of "ni1111.img" in the "Cursor value" section of the Envi software, as the number increases, the potential of Nickel (Numeric range (0.01,0.2)), average grade and reserves increase in the desired square. We considered a point on the map which is usually a square with a side of thirty meters (any pixel of map). The most important color spectrum for the exploration of Nickel mineral in the most optimal and best condition is green in "ni11.img" map, sky blue in "ni111.img"map, black in "ni1.img" map and sky blue or light pink in "ni1111.img" map. All four colors must be seen for the desired point and for sure, a number smaller than 0.2

and larger than 0.01 can be seen in "ni1111.img" map. If we divide the desired square into two parts, from the center of the square, fifteen meters to the left, fifteen meters to the right, fifteen meters to the top, fifteen meters to the bottom, and thirty meters to the depth of that square, we can have that mineral in high potential points. Points on the map containing minerals can be transferred from the map to the "KMZ" type file, and these points can be conFigd in GPS and then used for exploration. In "ni11.img" map, dark blue is Vegetation and sky blue can be silica or soil minerals.

4.11. Exploration of Cobalt mineral with Landsat8 satellite

The (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps

were used in all explorations of the Cobalt mineral. For example, the Cobalt mine in the Southwest of Sarbisheh city, South Khorasan province, Iran, was used. First, the (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were opened in the Envi software. The geographical coordinates of any point in the desired area on the map could be obtained from the "Value Cursor" section in the Envi software. In the "toolbox" section of the Envi software the term "Resize Data" was entered and selected. The "MAP1.img" or "MAP11.img" file was then selected, the "Spatial Subset" option was clicked, the "Select Spatial Subset" window was entered, and the "Map" option was clicked to enter the following coordinates.

Upper left coordinate:
32 23 52.83
59 40 11.42

And the lower right coordinate:
32 21 49.66
59 43 0.74

OK was clicked and the file was saved as "co1.img" in a certain path (Fig 4.11.1). All the steps in part 4.11 of this study were performed for the file "MAP2.img" or "MAP22.img", and it was saved as "co11.img" in a certain path (Fig 4.11.2). Similarly, all the steps in part 4.11 were performed for the file "MAP3.img" or "MAP33.img", and it was saved as "co111.img" in a certain path (Fig 4.11.3). Also, all the steps in part 4.11 were performed for the file "MAP4.img" or "MAP44.img", and it was saved as "co1111.img" in a certain path (Fig 4.11.4). Color spectrum in these four maps should be as follows:

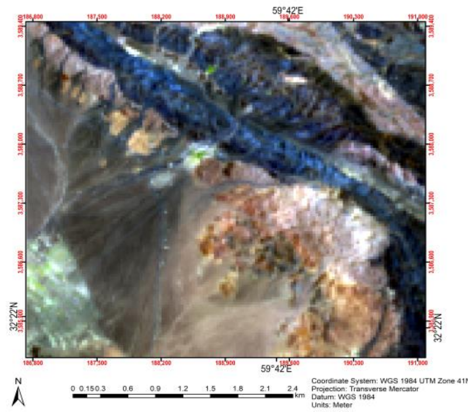
MAP1, MAP11: **black** or dark purple or purple or dark brown or brown

MAP2, MAP22: **Red-orange** (**orangish red**) and **number** > **2**

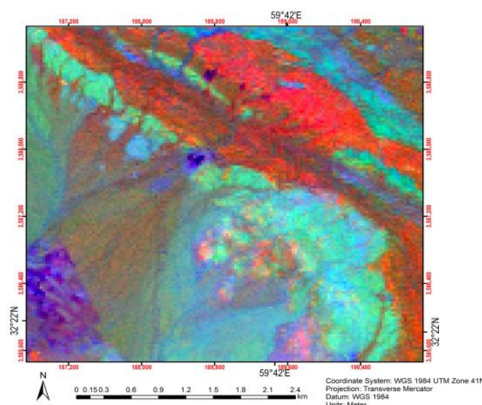
MAP3, MAP33: **green**

MAP4, MAP44: **blue** or sky blue or purple and **-0.2 <number <-0.01**

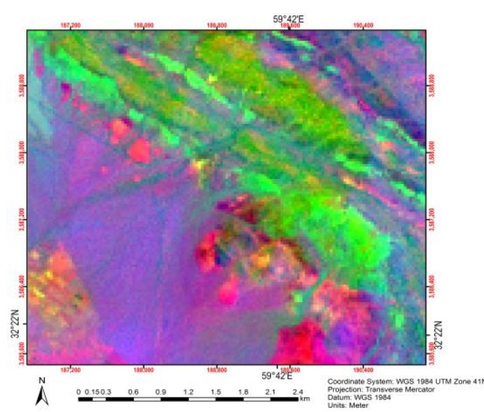
"Optimized Linear" mode was set when checking the "co1.img", "co11.img", "co111.img" and "co1111.img" maps in the ENVI software. ArcGIS software (V10.5) was used for the final output of the Cobalt maps.



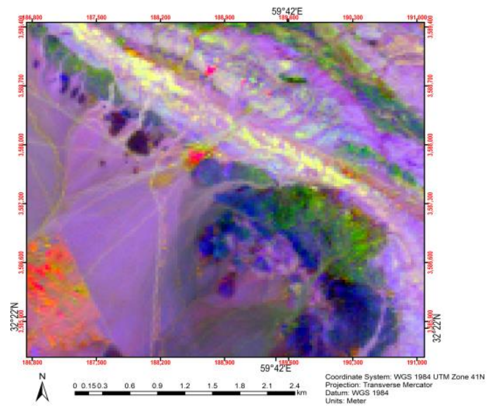
(Fig 4.11.1) The image "co1.img" constructed from (MAP1, MAP11) by the Author with the name Cobalt mine in Southwest of Sarbisheh city, South Khorasan province, Iran. ESM_4.11 original data available in Online Resource



(Fig 4.11.2) The image "co11.img" constructed from (MAP2, MAP22) by the Author with the name Cobalt mine in Southwest of Sarbisheh city, South Khorasan province, Iran. ESM_4.11 original data available in Online Resource



(Fig 4.11.3) The image "co111.img" constructed from (MAP3, MAP33) by the Author with the name Cobalt mine in Southwest of Sarbisheh city, South Khorasan province, Iran. ESM_4.11 original data available in Online Resource



(Fig 4.11.4) The image "co1111.img" constructed from (MAP4, MAP44) by the Author with the name Cobalt mine in Southwest of Sarbisheh city, South Khorasan province, Iran. ESM_4.11 original data available in Online Resource

Analysis of the desired area:

As you can see in "co11.img" map, Red-orange (orangish red) shows the presence of Cobalt mineral in the desired area provided that black or dark purple or purple or dark brown or brown colors are in "co1.img" map, green is in "co111.img" map and also blue or sky blue or purple colors are in "co1111.img" map and for sure, a number larger than 2 can be seen in "co11.img" map (from the "Value Cursor" section in the Envi software) and for sure, a number smaller than -0.01 and larger than -0.2 can be seen in co1111.img "map which is the confirmation of Cobalt mineral in the desired square (any pixel of map). As it tends to black in "co1.img" map, and it tends to blue in "co1111.img" map potential and reserves of Cobalt mineral increase in the desired square. According to the map data of "co11.img" in the "Cursor value" section of the Envi software, as the number increases, the potential, reserves and average grade of Cobalt mineral increase in the desired square. Also cccording to the map data of "co1111.img" in the "Cursor value" section of the Envi software, as the number lowers, the potential of Cobalt (Numeric range (-0.2, -0.01)), average grade and reserves increase in the desired square. We considered a point on the map which is usually a square with a side of thirty meters (any pixel of map). The most important color spectrum for the exploration of Cobalt mineral in the most optimal and best condition is orangish red in "co11.img" map, the black in "co1.img" map, the green in "co111.img" map and the blue in "co1111.img" map. All four colors must be seen for the desired point and for sure, a number smaller than -0.01 and larger than -0.2 can be seen in "co1111.img" map. If we divide the desired square into two parts, from the center of the square, fifteen meters to the left, fifteen meters to the right, fifteen meters to the top, fifteen meters to the bottom, and thirty meters to the depth of that square, we can have that mineral in high potential points. Points on the map containing minerals can be transferred from the map to the "KMZ" type file, and these points can be conFigd in GPS and then used for exploration. In "co11.img" map, dark blue is Vegetation and sky blue can be silica or soil minerals.

4.12. Exploration of lead mineral with Landsat8 satellite

The (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were used in all explorations of the lead mineral. For example, the lead mine in the North of Torbat-e Jam, Razavi Khorasan Province, Iran, was used. First, the (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were opened in the Envi software. The geographical coordinates of any point in the desired area on the map could be obtained from the "Value Cursor" section in the Envi software. In the "toolbox" section of the Envi software the term "Resize Data" was entered and selected. The "MAP1.img" or "MAP11.img" file was then selected, the "Spatial Subset" option was clicked, the "Select Spatial Subset" window was entered, and the "Map" option was clicked to enter the following coordinates.

Upper left coordinate:
35 30 48.62
60 43 27.16
And the lower right coordinate:
35 27 54.25
60 45 59.77

OK was clicked and the file was saved as "pb1.img" in a certain path (Fig 4.12.1). All the steps in part 4.12 of this study were performed for the file "MAP2.img" or "MAP22.img", and it was saved as "pb11.img" in a certain path (Fig 4.12.2). Similarly, all the steps in part 4.12 were performed for the file "MAP3.img" or "MAP33.img", and it was saved as "pb111.img" in a certain path (Fig 4.12.3). Also, all the steps in part 4.12 were performed for the file "MAP4.img" or "MAP44.img", and it was saved as "pb1111.img" in a certain path (Fig 4.12.4). Color spectrum in these four maps should be as follows:

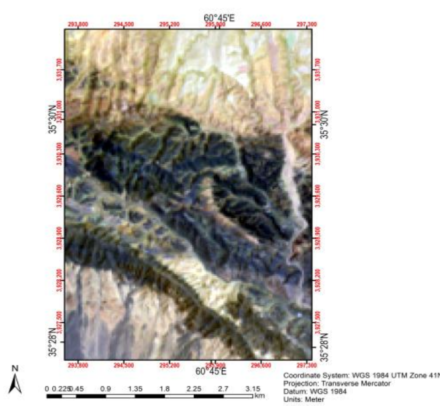
Map1, MAP11: **black** or dark Purple or Purple or dark brown or brown

MAP2, MAP22: **dark Purple** or Purple or **dark brown** or brown

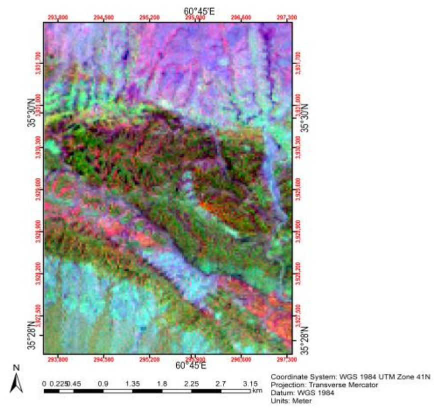
MAP3, MAP33: **green**

MAP4, MAP44: **light pink** or pink or sky blue and **0.01**< =**number** < = **0.2**

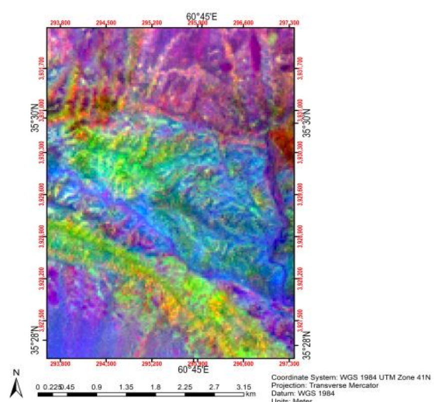
"Optimized Linear" mode was set when checking the "pb1.img", "pb11.img", "pb111.img", and "pb1111.img" maps in the ENVI software. ArcGIS software (V10.5) was used for the final output of the lead maps.



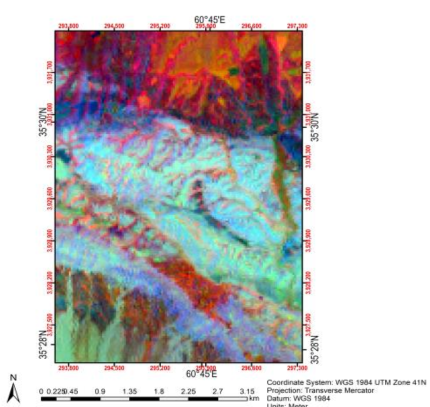
(Fig 4.12.1) The image "pb1.img" constructed from (MAP1, MAP11) by the Author with the name lead mine in North of Torbat-e Jam, Razavi Khorasan Province, Iran. ESM_4.12 original data available in Online Resource



(Fig 4.12.2) The image "pb11.img" constructed from (MAP2, MAP22) by the Author with the name lead mine in North of Torbat-e Jam, Razavi Khorasan Province, Iran. ESM_4.12 original data available in Online Resource



(Fig 4.12.3) The image "pb111.img" constructed from (MAP3, MAP33) by the Author with the name lead mine in North of Torbat-e Jam, Razavi Khorasan Province, Iran. ESM_4.12 original data available in Online Resource



(Fig 4.12.4) The image "pb1111.img" constructed from (MAP4, MAP44) by the Author with the name lead mine in North of Torbat-e Jam, Razavi Khorasan Province, Iran. ESM_4.12 original data available in Online Resource

Analysis of the desired area:

As you can see in the "pb11.img" map, dark Purple or Purple or dark brown or brown colors show the presence of lead mineral in the desired area provided that green is in "pb111.img" map, black or dark Purple or Purple or dark brown or brown colors are in "pb1.img" map, light pink or pink or sky blue colors are in "pb1111.img" map and for sure, a number smaller than 0.2 and larger than 0.01 can be seen in "pb1111.img" map (from the "Value Cursor" section in the Envi software) which is the confirmation of lead mineral in the desired square (any pixel of map). As it tends to light pink in "pb1111.img" map, and as it tends to black in "pb1.img" map, and also as it tends to dark Purple or dark brown colors in "pb11.img" map, potential and reserves of lead mineral increase in the desired square. According to the map data of "pb1111.img" in "Cursor value" section of Envi software, as the number increases, the potential of lead(Numeric range(0.01, 0.2)), average grade and reserves increase in the desired square. We considered a point on the map which is usually a square with a side of thirty meters (any pixel of map). The most important color spectrum for the exploration of lead mineral in the most optimal and best condition is the green in "pb111.img" map, dark Purple or dark brown colors in "pb11.img" map, the black in "pb1.img" map, and the light pink in "pb1111.img" map. All four colors must be seen for the desired point and for sure, a number smaller than 0.2 and larger than 0.01 can be seen in "pb1111.img" map. If we divide the desired square into two parts, from the center of the square, fifteen meters to the left, fifteen meters to the right, fifteen meters to the top, fifteen meters to the bottom, and thirty meters to the depth of that square, we can have that mineral in high potential points. Points on the map containing minerals can be transferred from the map to the "KMZ" type file, and these points can be conFigd in GPS and then used for exploration. In “pb11.img” map, dark blue is Vegetation and sky blue can be silica or soil minerals.

4.13. Exploration of Lithium mineral with Landsat8 satellite

The (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were used in all explorations of the Lithium mineral. For example, the Lithium mine in the Lut Desert, Kerman province, Iran, was used. First, the (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were opened in the Envi software. The geographical coordinates of any point in the desired area on the map could be obtained from the "Value Cursor" section in the Envi software. In the "toolbox" section of the Envi software the term "Resize Data" was entered and selected. The "MAP1.img" or "MAP11.img" file was then selected, the "Spatial Subset" option was clicked, the "Select Spatial Subset" window was entered, and the "Map" option was clicked to enter the following coordinates.

Upper left coordinate:
30 48 16.03
58 21 51.30

And the lower right coordinate:
30 46 23.63
58 25 11.64

OK was clicked and the file was saved as "Li1.img" in a certain path (Fig 4.13.1). All the steps in part 4.13 of this study were performed for the file "MAP2.img" or "MAP22.img", and it was saved as "Li11.img" in a certain path (Fig 4.13.2). Similarly, all the steps in part 4.13 were performed for the file "MAP3.img" or "MAP33.img", and it was saved as "Li111.img" in a certain path (Fig 4.13.3). Also, all the steps in part 4.13 were performed for the file "MAP4.img" or "MAP44.img", and it was saved as "Li1111.img" in a certain path (Fig 4.13.4).Color spectrum in these four maps should be as follows:

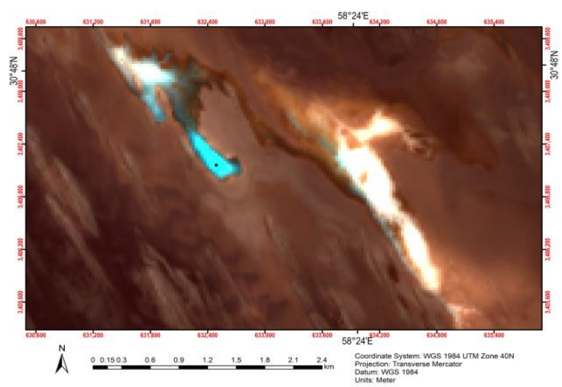
MAP1, MAP11: **sky blue**

MAP2, MAP22: **dark Purple** or dark brown

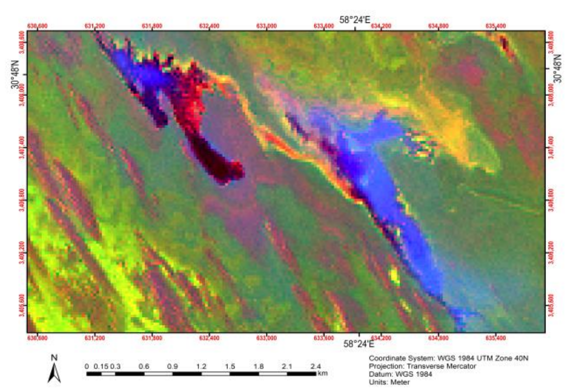
MAP3, MAP33: **green**

MAP4, MAP44: **green** and **-3**< =**number** < = **-0.1**

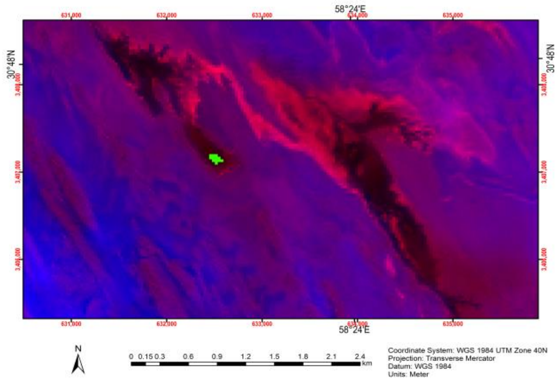
"Optimized Linear" mode was set when checking the "Li1.img", "Li11.img", "Li111.img", and "Li1111.img" maps in the ENVI software. ArcGIS software (V10.5) was used for the final output of the Lithium maps.



(Fig 4.13.1) The image "Li1.img" constructed from (MAP1, MAP11) by the Author with the name Lithium mine in Lut Desert, Kerman province, Iran. ESM_4.13 original data available in Online Resource



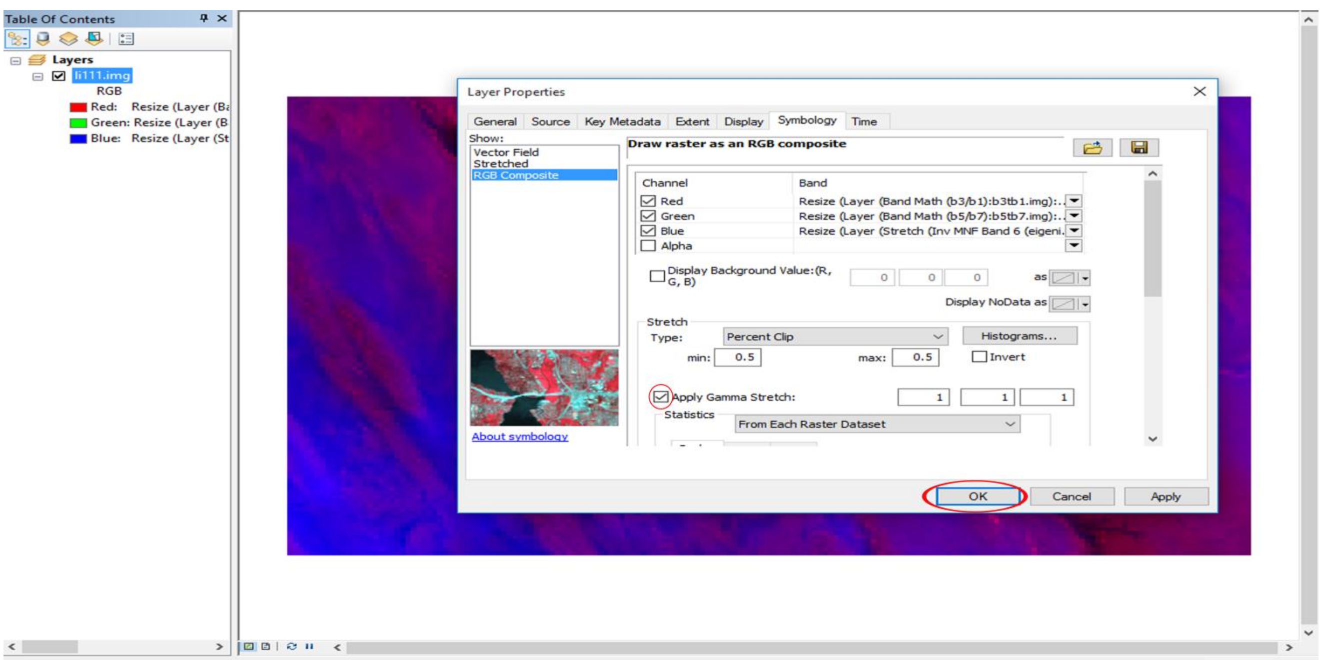
(Fig 4.13.2) The image "Li11.img" constructed from (MAP2, MAP22) by the Author with the name Lithium mine in Lut Desert, Kerman province, Iran. ESM_4.13 original data available in Online Resource



(Fig 4.13.3) The image "Li111.img" constructed from (MAP3, MAP33) by the Author with the name Lithium mine in Lut Desert, Kerman province, Iran. ESM_4.13 original data available in Online Resource

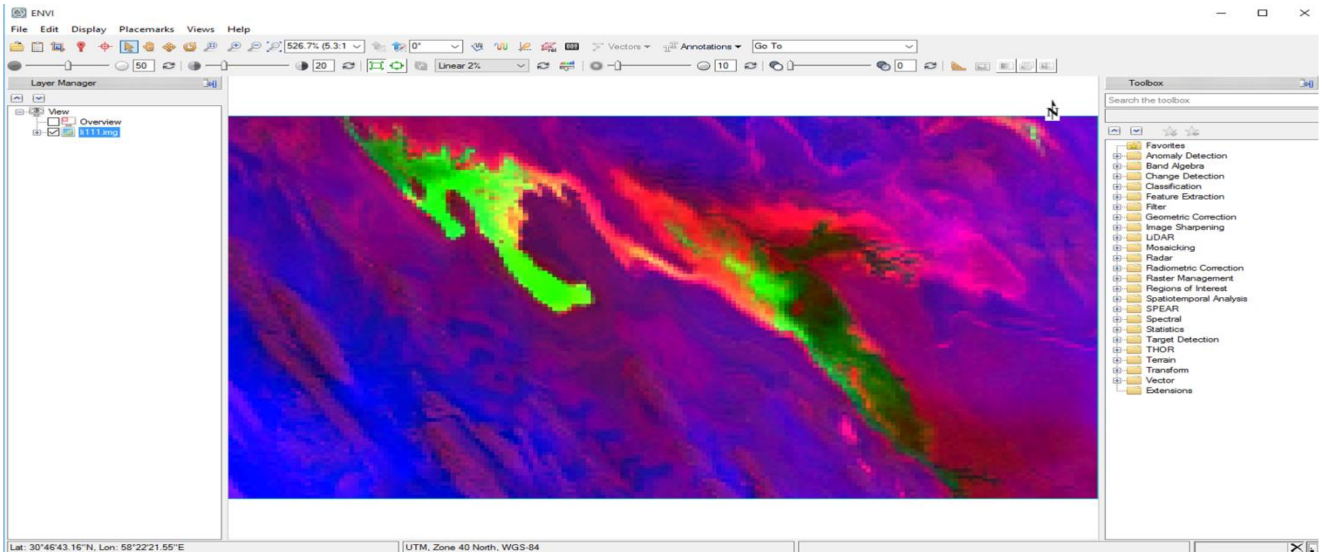
Due to the high quality and large amount of data that exists in this area of the "Li111.img" map, this map is not fully displayed in Arcgis Software.

We opened "Li111.img" map in the Arcgis software and selected "Li111.img" map on the left side of the software in the "Table of Contents" section of the Arcgis software. We entered the "Layer Properties" window and confirmed the "Apply Gamma Stretch Statistics" item and clicked on ok (Fig 4.13.5)

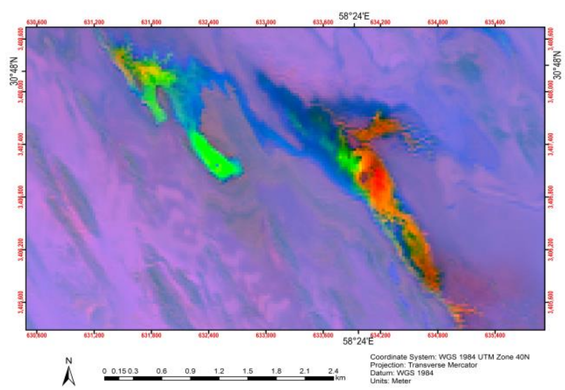


(Fig 4.13.5) Confirming the "Apply Gamma Stretch Statistics" item on "Li111.img" map in Arcgis software

The original quality of the "Li111.img" map in the Envi software is displayed in Fig 4.13.6.



(Fig 4.13.6) original quality of the "Li111.img" map in Envi software



(Fig 4.13.4) The image "Li1111.img" constructed from (MAP4, MAP44) by the Author with the name Lithium mine in Lut Desert, Kerman province, Iran. ESM_4.13 original data available in Online Resource

Analysis of the desired area:

As you can see in "Li11.img" map, dark purple or dark brown show the presence of Lithium mineral in the desired area provided that green is in "Li111.img" map, green in "Li1111.img" map, sky blue in "Li1.img" map and for sure, a number smaller than -0.1 and larger than -3 can be seen in "Li1111.img" map (from the "Value Cursor" section in the Envi software) which is the confirmation of Lithium mineral in the desired square (any pixel of map). As it tends to dark Purple in "Li11.img" map, and as it tends to green in "Li1111.img" map, and as it tends to sky blue in "Li1.img" map, the potential and reserves of Lithium mineral increase in the desired square. In addition to Lithium, we can also have the bromine (Br) mineral with high reserves and purity in the desired area. The reason behind the presence of bromine mineral is that we can see up to number -2.60 in "Li1111.img" map and it shows a very low number. We have a lot of points like this in this area which is unique in comparison with other places of Iran. According to the map data of "Li1111.img" in the "Cursor value" section of the Envi software, as the number lowers, the potential of Lithium(Numeric range(-3, -0.1)), average grade and reserves increase in the desired square. We considered a point on the map which is usually a square with a side of thirty meters (any pixel of map). The most important color spectrum for the exploration of Lithium mineral in the most optimal and best condition is the dark purple in "li11.img" map, the sky blue in "li1.img" map, the green in "li111.img" map, and the green in "li1111.img" map. All four colors must be seen for the desired point and for sure, a number smaller than -0.1 and larger -3 than can be seen in "Li1111.img" map. If we divide the desired square into two parts, from the center of the square, fifteen meters to the left, fifteen meters to the right, fifteen meters to the top, fifteen meters to the bottom, and thirty meters to the depth of that square, we can have that mineral in high potential points. Points on the map containing minerals can be transferred from the map to the "KMZ" type file, and these points can be conFigd in GPS and then used for exploration. In "Li11.img" map, dark blue is Vegetation and sky blue can be silica or soil minerals or Magnesium.

4.14. Identifying the correct analysis in any desired area

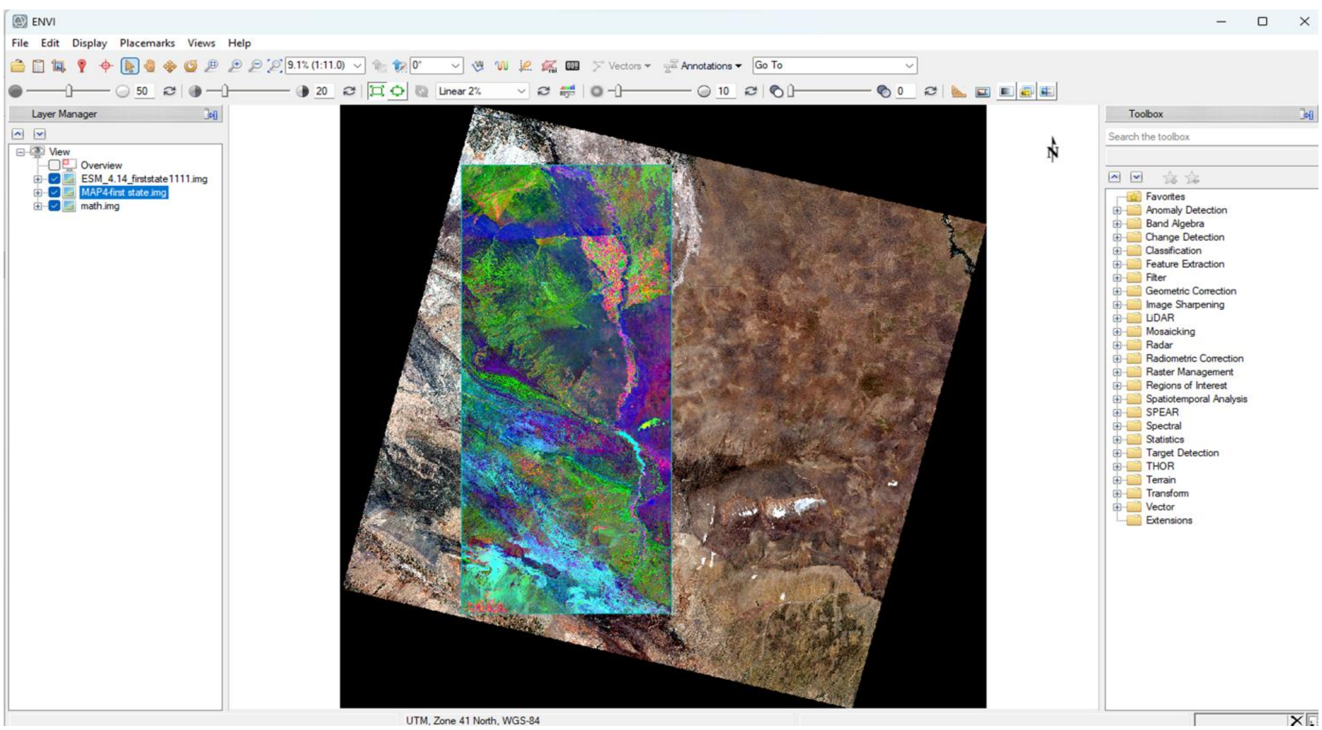
There is a very important point to identify the correct analysis in any desired area**.** (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) maps give a constant color spectrum by resizing maps. However, (MAP4, MAP44), map generally gives you a different color spectrum by resizing map on "math.img". Finally, it gives you a different Analysis. (MAP4, MAP44) map has a decisive role in the correct analysis of minerals. First, the (MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33) and (MAP4, MAP44) maps were opened in the Envi software.

For example, the following area was considered:

upper left coordinate:
35 33 43.88
60 34 26.59

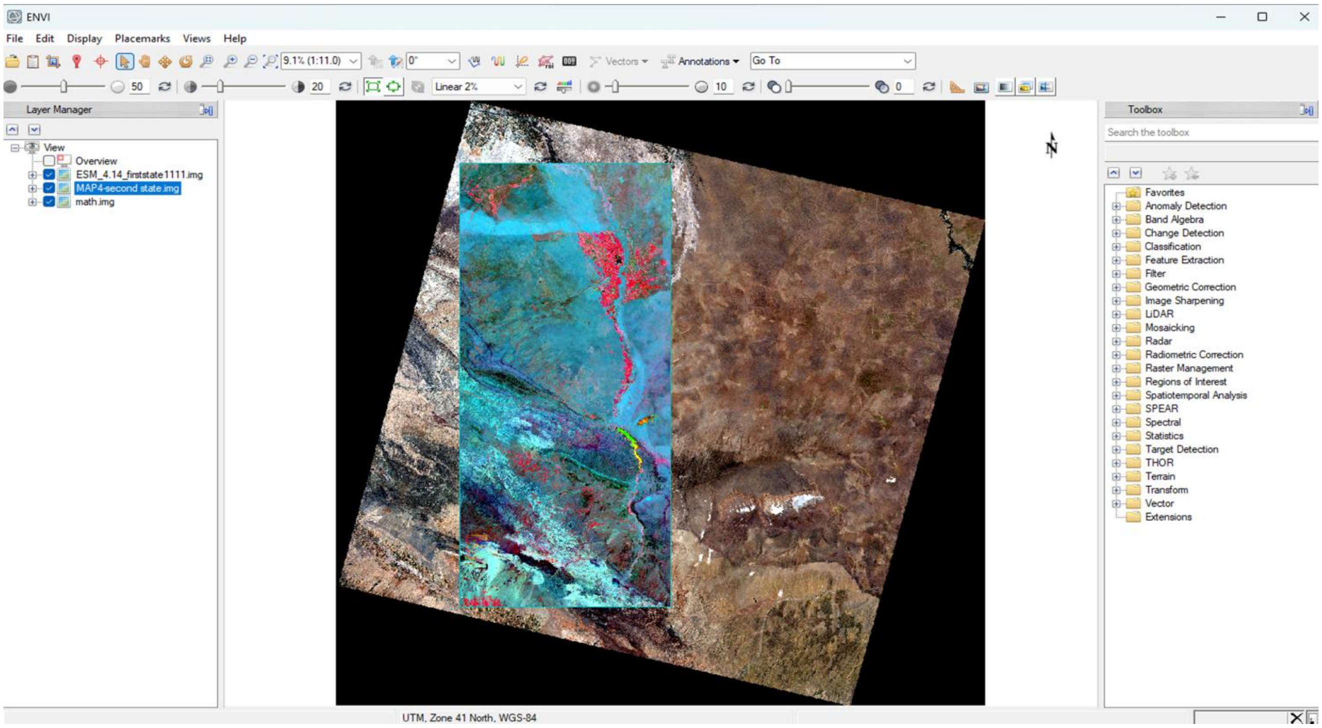
And the lower right coordinate:
35 28 3.84
60 39 58.56

(MAP4, MAP44) map in the first state is shown in Fig 4.14.1



(Fig 4.14.1) different color spectrum by resizing (MAP4, MAP44) on "math.img" in the first state (generated by the Author)

(MAP4, MAP44) map in the second state is shown in Fig 4.14.2.

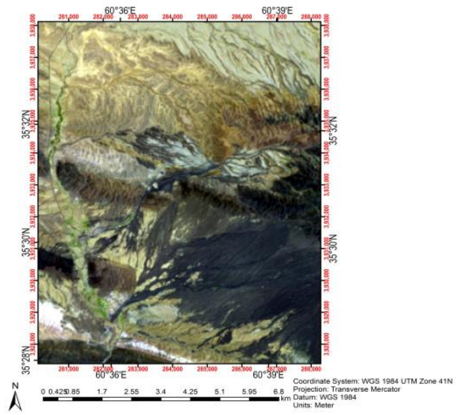


(Fig 4.14.2) different color spectrum by resizing (MAP4, MAP44) on "math.img" in the second state (generated by the Author)

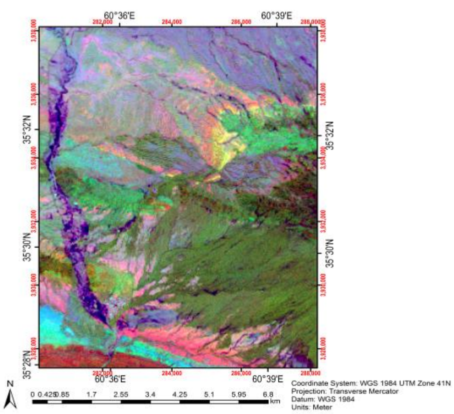
In the "toolbox" section of the Envi software the term "Resize Data" was entered and selected. The "MAP1.img" or "MAP11.img" file was then selected, the "Spatial Subset" option was clicked, the "Select Spatial Subset" window was entered, and the "Map" option was clicked to enter the following coordinates.

Upper left coordinate:
35 33 43.88
60 34 26.59
And the lower right coordinate:
35 28 3.84
60 39 58.56

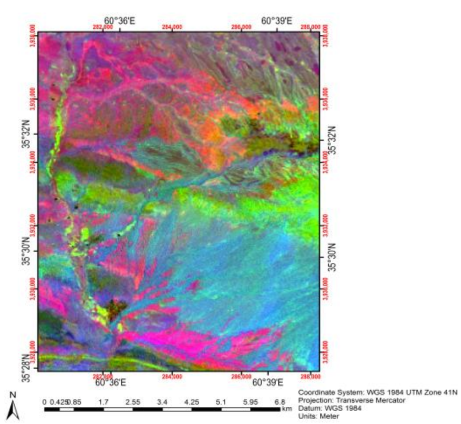
OK was clicked and the file was saved as "constant1.img" in a certain path (Fig 4.14.3). All the steps in part 4.14 of this study were performed for the file "MAP2.img" or "MAP22.img", and it was saved as "constant11.img" in a certain path (Fig 4.14.4). Similarly, all the steps in part 4.14 were performed for the file "MAP3.img" or "MAP33.img", and it was saved as "constant111.img" in a certain path (Fig 4.14.5). Also, all the steps in part 4.14 were performed for the file "MAP4.img" or "MAP44.img" (in the first state) and it was saved as "firststate1111.img" in a certain path (Fig 4.14.6). Similarly, all the steps in part 4.14 were performed for the file "MAP4.img" or "MAP44.img" (in the second state) and it was saved as "secondstate1111.img" in a certain path (Fig 4.14.7).



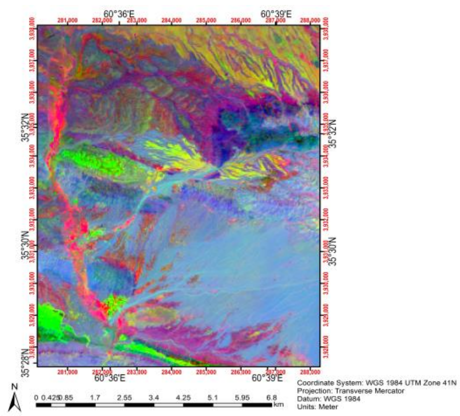
(Fig 4.14.3) The image "constant1.img" constructed from (MAP1, MAP11) by the Author with constant color spectrum. ESM_4.14 original data available in Online Resource



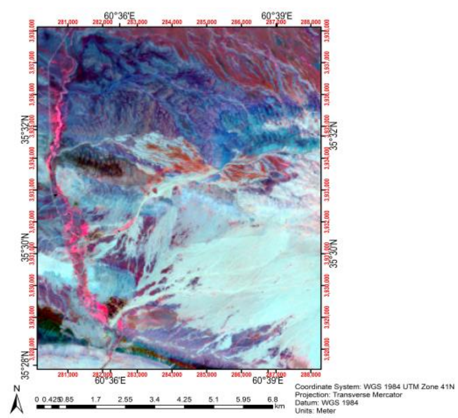
(Fig 4.14.4) The image "constant11.img" constructed from (MAP2, MAP22) by the Author with constant color spectrum. ESM_4.14 original data available in Online Resource



(Fig 4.14.5) The image "constant111.img" constructed from (MAP3, MAP33) by the Author with constant color spectrum. ESM_4.14 original data available in Online Resource



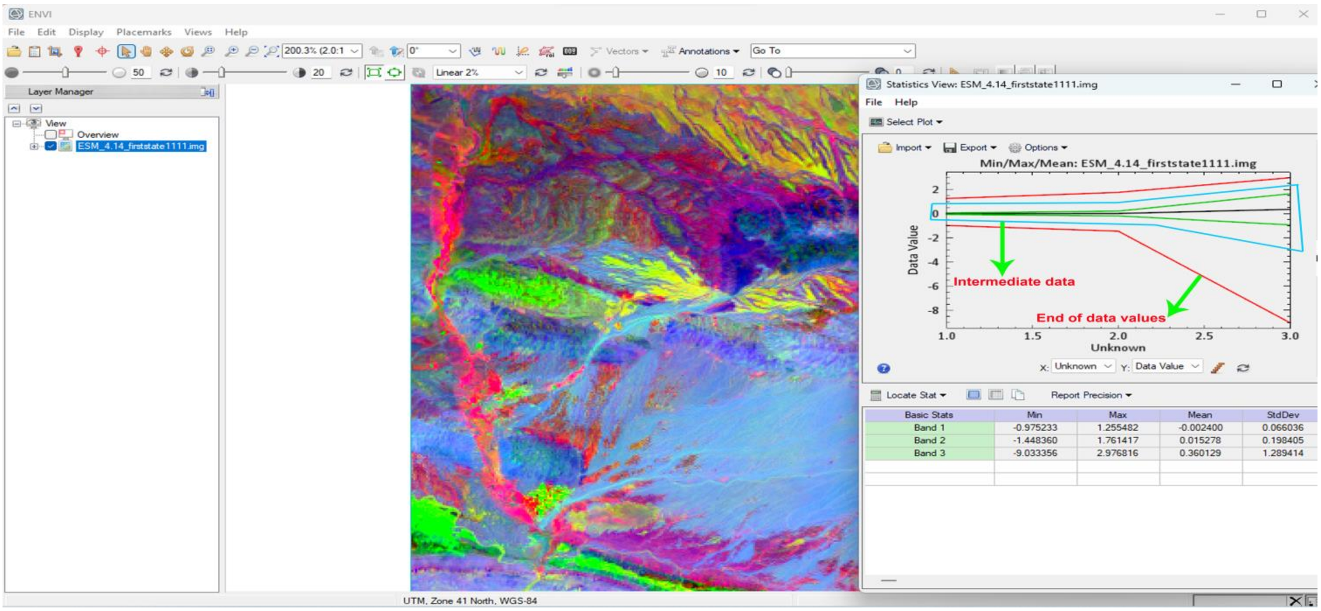
(Fig 4.14.6) The image "firststate1111.img" constructed from (MAP4, MAP44) by the Author with Variable color spectrum in the first state. ESM_4.14 original data available in Online Resource



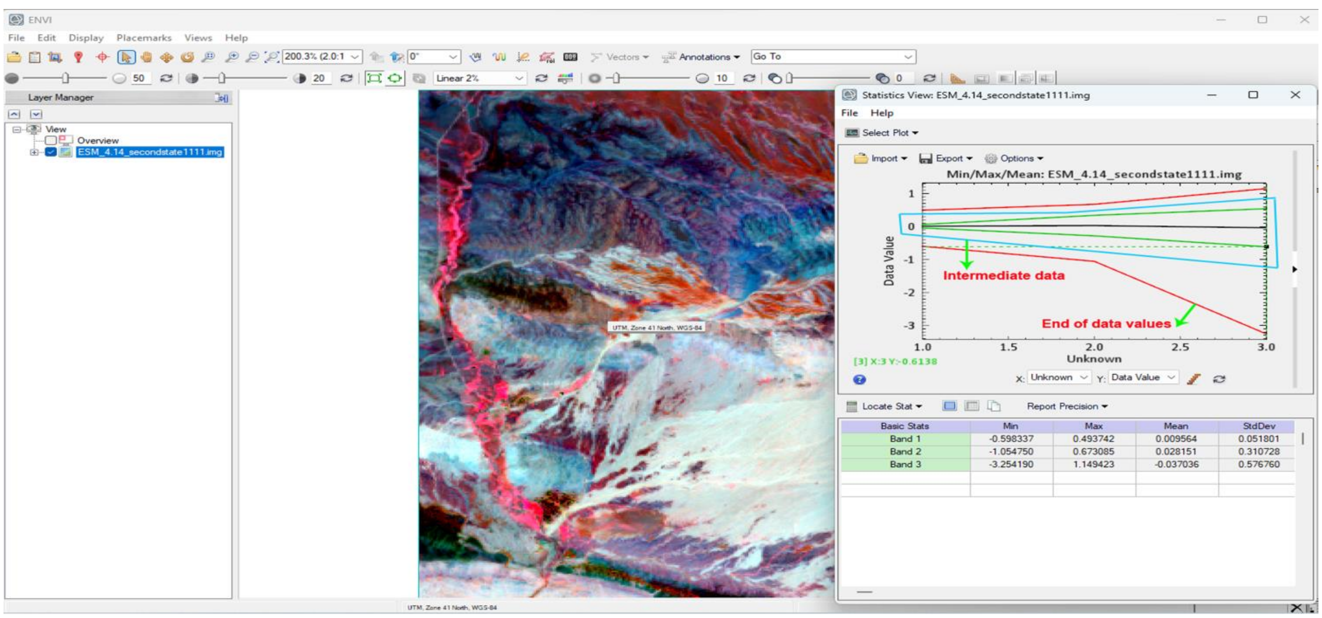
(Fig 4.14.7) The image "secondstate1111.img" constructed from (MAP4, MAP44) by the Author with Variable color spectrum in the second state. ESM_4.14 original data available in Online Resource

Analysis of the desired area in the first and second state:

You should see Lead, copper, and gold minerals in the first state in the maps. However, in the second state, you should see Manganese, Chromite, and Lead. To identify the correct analysis in the desired area, "compute Statistics" in the "toolbox" section of the Envi software was used and clicked. Then, in the "file selection" section, "firststate1111.img was selected. Histogram correct Analysis in the first state is shown in Fig 4.14.8. And also Histogram wrong Analysis in the second state is shown in Fig 4.14.9.



(Fig 4.14.8) Histogram correct Analysis. intermediate data and end of data values specified by arrows in " firststate1111.img" map



(Fig 4.14.9) Histogram wrong Analysis. intermediate data and end of data values specified by arrows in "secondstate1111.img" map

As you can see in histograms, to identify the correct analysis in the desired area, at least, any three intermediate data must be in an upward direction and confirm itself (concave upward). And in the best case, almost all three intermediate data coincide on a line (zero concavity) (Fig 4.14.8). Otherwise, the analysis is wrong. In addition to identifying the correct analysis using histograms, the color spectrum and numerical range can also be used to identify vegetation and other minerals (using other maps) in map (MAP4, MAP44). If the data match, the analysis is correct; otherwise, the analysis is incorrect. For example, the color spectrum for vegetation in map (MAP4, MAP44) is usually pink or red and the number is greater than zero. Similarly, the color spectrum for copper in map (MAP4, MAP44) is light pink and the number is greater than 0.01 and less than 0.2. If it matches other maps((MAP1, MAP11), (MAP2, MAP22), (MAP3, MAP33)), the analysis is correct; otherwise, we must create another map by changing the size on map "math.img". Then you should see Lead, Copper and Gold minerals in the desired area and the first state is correct (Fig 4.14.8). We can achieve accurate analysis without physical presence.

Conclusion

We were able to discover minerals such as Gold, Copper, Fe (magnetite, Hematite), Manganese, Magnesium, Chromite, Antimony, Bauxite, Industrial soils, Nickel, Cobalt, lead, Lithium with combination of different maps of Landsat8 satellite images. We found important and accurate data on the explorations of each mineral. Also found the best point of the mountain in the "Cursor value" section using Envi software, which is the highest number for some minerals or the lowest number for some minerals. We considered each pixel of these maps to be almost a square with a side of 30 meters and if we divide the desired square into two parts, from the center of the square, fifteen meters to the left, fifteen meters to the right, fifteen meters to the top, fifteen meters to the bottom, and thirty meters to the depth of that desired square, we can have that mineral in high potential points. Also, we recognized the correct Analysis in any desired area and mineral deposit of sedimentary or igneous origin. It is possible to distinguish between certain sulfide and oxide minerals

In this study, we used four important formulas of band compounds as follows:

- (((b7+b6+b5)/b6), ((b5+b4+b3)/b6), ((b3+b2+b1)/b6)) as RGB
- ((b3+b1)/b2), ((b3+b5)/b4), ((b5+b7)/b6)) as RGB [1]
- ((b3/b1), (b5/b7), b6) as RGB [2]
- (pca((b7+b6+b5)/b6), pca((b5+b4+b3)/b6), pca((b3+b2+b1)/b6)) as RGB

In band compound ((b3/b1), (b5/b7), b6) as RGB we corrected the bands for exploration of all minerals mentioned in this study.

We used band compounds (((b7+b6+b5)/6), ((b5+b4+b3)/6), ((b3+b2+b1)/6))as RGB and (pca((b7+b6+b5)/6), pca((b5+b4+b3)/6), pca((b3+b2+b1)/6)) as RGB so that the speed and accuracy of exploration and analysis of the desired area increase greatly. And the correct analysis can be identified, and each mineral is placed in its correct color spectrum and numerical range. Also we can see the overall view of space and other planets in more details using a telescope. The color spectrum is optimal in this case. And we can achieve correct analysis faster. It is best to use this optimal bands combination for mineral exploration and analysis of the desired area.

In our method, we showed a complete combination of maps and color spectrum and analysis for exploration each mineral and obtained a more accurate state of the minerals which makes this study unique. We showed the average grade of some mineral in the desired square. Finally, you can compare any mine with others around the world, to decide which one is better and what kind of minerals you have in that mine and also to identify the strength and weakness of the mine in terms of potential and average grade and reserve in the desired area. It significantly enhances the acceleration of discoveries while also lowering mining costs and optimizing resource extraction. With this method, the discovery and analysis of other minerals can be achieved.

This idea has the ability to be commercialized on the planet. In addition to preparing maps of different minerals for the customer, it is possible to analyze the desired mineral range in PDF format. It also shows potential points of different minerals with different colors in a file with "KMZ" format to be presented to the customer.

In 2023, we made significant discoveries in the world, and this continued in 2024 and beyond. The Landsat satellite has been a great aid in various fields, including meteorology, agriculture, Environmental pollution, space sciences, and geology. It has reduced the costs and time required to obtain many exploratory data and has accelerated the discovery of natural resources and water sources.

Similarly, as we use the Landsat satellite to explore mineral resources—reducing costs and significantly increasing efficiency—we can apply the same approach to Earth-like planets. By sending satellites to such planets, we can obtain both general and detailed data about them. This would allow us to understand all the conditions of a planet without physically traveling there, ensuring that humans can step onto these planets with greater confidence, security, and peace of mind.

Version Statement:

This is version 2 of the manuscript, submitted to EarthArXiv for preprint. Version 1 of this manuscript has been submitted to Environmental Earth Sciences for peer review.

Data Availability Statement

The data supporting the findings of this study will be made available on Supplementary File and youtube (ExplorationMetalMinerals) at [https://www.youtube.com/@ExplorationMetalMinerals] upon publication.

Appendix A: Formula Metadata and Derivation Dates

Formula (1) and Formula (4) constitute the core contributions of this study. Formula (1) was originally derived and documented by the author on July 6, 2025 (corresponding to 15 Tir 1404 in the Persian calendar). Although Formula (4) was not explicitly recorded in the original notes dated July 6, 2025, it is directly derived from Formula (1), which was documented on that date. The formula is included here for clarity and completeness. Formula (3) was revised and finalized by the author on March 18, 2025, and documented via email and Word file for record. The author notes that earlier unpublished drafts of Formula (3) also exist.

These derivation records are briefly noted in the manuscript footnotes and have also been compiled into the supplementary file titled:

" **Patent_Formula_Exploration2_2025.zip**" for archival and verification purposes.

Acknowledgements

The author is thankful to NASA Land Processes Distributed Active Archive Center User Services, USGS Earth Resources Observation and Science (EROS) Center https://earthexplorer.usgs.gov/)for providing Landsat8 satellite images.

Funding

. No funding was received to assist with the preparation of this manuscript.

Author Contributions

The author solely contributed to the conception, design, the data analysis, execution, and writing of the manuscript.

Statements and Declarations

The author has no competing interests to declare that are relevant to the content of this study.
All figures are original and created by the author.

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