# Lineament Assessment of Aynak Copper mine using Remote Sensing approach

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**Abstract**. This research developed a new approach to extract the lineaments using Landsat, QuickBird and ALOS PALSAR satellite remotely sensed data in Aynak copper mine which is located in Kabul tectonic block and the Tethyan Copper Belt of Afghanistan. Lineaments and trench directions are not relatively studied in the study area which will bring obstacles in exploration and extraction of the mine. This research aims to extract the lineaments for studying the better trench direction in the study area. Lineaments such as faults and joints are extremely important structures that not only show the surface structure but also give us important knowledge about the subsurface of the earth. Afghanistan is a part of the Alpine-Himalayan orogenic belt which suffers from high tectonic movements in some areas, especially north-eastern and central parts which leads to the occurrence of different lineaments and unconformities. Lineaments can be surveyed and mapped using field geological survey or using satellite remotely sensed data. Satellite remote sensing data costs less and takes less time compare to field geological survey for lineament extraction. This research used Landsat 8 natural color with 2, 3, 4 band composition, QuickBird 1m resolution, and ALOS PALSAR 12.5 m satellite imagery to detect and map the lineaments in the Aynak copper mine area in Afghanistan. Geomatica software was used for lineament extraction using the Manual technique. Then the rose diagrams of the lineaments were plotted using Polar Plots extension of ArcGIS. Next, the rose diagrams derived from the two mentioned lineament extraction techniques were compared and evaluated. Global Mapper software was used for the extraction of lineaments using Visual technique and to map the rivers and ridges in the Aynak area of interest for validation of the results. Finally, the best orientation for trenches in Aynak copper mine was derived. This study found that faults and joints in the study area have a NE-SW trend and directions. This study will contribute to a better understanding of the trench direction and mineral exploration in Aynak copper mine.

## 1. Introduction
Geospatial data has been utilized in various aspects of geoscience, geology, mining, archaeology, and environmental sciences. Lineament extraction is an important part of a geological survey and a crucial aspect of a tectonic survey. Extracting lineaments and faults from satellite imagery and analyzing these structural elements have always been of great help in such studies. Lineaments deduced from

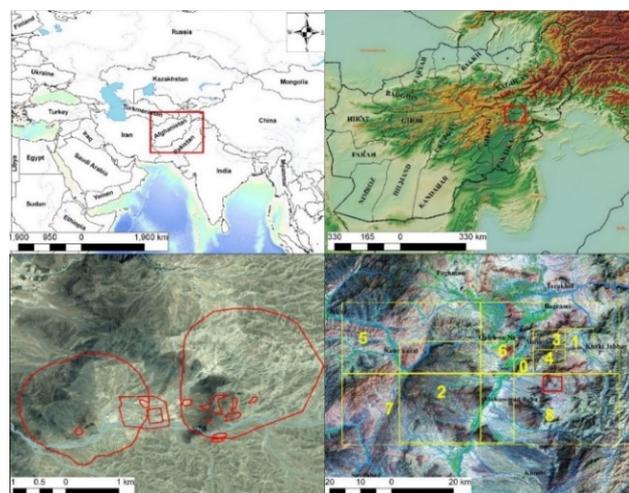satellite imagery have the benefit of obtaining lineaments that are not detectible by the human eyes [1].

The Aynak copper mine area is a particularly important tectonic region in the Kabul tectonic zone and an essential area of mineral interest in the presence of metallic mineral deposits such as copper, cobalt, and chromium. Many studies using remote sensing methods have been done in this area since the last decades [2]. Lineaments in Aynak copper Area of Interest (AOI) was analyzed using geospatial digital data to detect regions where the fracture in rocks are denser than the other areas [3]. The mere source used to categorize morphostructural lineaments were aerial photographs for a long period. Satellite images facilitated this task because: remotely sensed data are cost-effective, more practical data management, more wide-ranging evaluation of lineament continuity, and the extensive vision offered by satellite image that eliminates many details that might eradicate important features not discovered in the scale of aerial photos [4].

The lineaments attained from Sentinel 1 agree very well with the sudden variations extents of shading and slope while those obtained from ASTER data and Landsat-8 follow mostly the borders between the lithological units [5]. Multispectral satellite imagery and QuickBird panchromatic with 2.4 m and 61 cm ground resolution, respectively deliver different perceptions into the surface rupturing process associated with this earthquake. The results signpost that this earthquake generated a 2–5 km-wide surface rupture zone with a compound geometric pattern. A 10-km-long surface rupture zone established alongside the pre-existing Bam fault trace [6]. Morphological analysis of topographic characteristics, especially lineaments, has long been utilized in tectonic and structural studies and has become an important instrument in tectonic examines [7].

The study area is located in an active tectonic zone, but there isn't enough knowledge about the tectonic and the lineaments of Aynak copper mine. Furthermore, some other researchers who studied the lineaments of the study area used less precise methods for lineament extraction. For example, Lineaments of Aynak AOI have delineated visually and also automated techniques, but the satellite image used was DEM with 30 m resolution and Landsat natural-color image [8]. This research aims to extract the lineaments and identify a better trench trend in the study area. To achieve the aim of this research, there are three objectives as follows:

- To assess the automatic and visual lineament extraction method
- To validate the results derived from lineament extraction techniques
- To determine the best direction for trenches relative to lineament orientatio

The main focus of this research is finding the most efficient lineament extraction method and assessing the orientation of the trench associated with lineaments in the study area. Aynak Copper Mine is located 30 km Southeast of Kabul City [9] as shown in Figure 1.



**Figure 1.** Schematic map showing the location of the study area.

The red square in bellow right side of the map, numbered as 8 in Figure1, shows the study area and numbers from 0 to 7 shows other copper occurrences and minerals in the region.

## 2. Geology of Aynak Copper Mine

The Aynak copper, cobalt, and chromium area of interest (AOI) are situated in eastern Afghanistan in southern Kabul. The area of the main Aynak AOI is 3,439.37 square kilometers (km²), which includes five subareas shown in Figure 2.



**Figure 2.** Geological map of the study area.

Four of the subareas, Kelaghey-Kakhay (27 km²), Bakhel Charwaz (40 km²), Yagh-Darra Ghul-Darra (57 km²), and Kharuti Dawrankhel (66 km²) are prospective for copper-cobalt deposits. A fifth subarea, Logar valley (1,013 km²), is prospective for chromite and possibly Platinum Group Element (PGE) deposits [10]. Conglomerate and sandstone are dominant in the exploration area which belongs to the Quaternary system/period of geological time scale refer to Figure 2. In general, the age of rocks in the Aynak copper deposit area is from Proterozoic to Cenozoic eras.

## 3. Research Methodology

The main intention of the research is to investigate the utilization of Landsat and QuickBird remote sensing data for detecting the main structures and lineament features such as faults, fractures, and joints and their orientation relative to the orientation of trenches in Aynak copper deposit. ALOS PALSAR satellite image is used for producing a Digital Elevation Model. Analyzing and processing the Landsat image is done in Geomatica software. In this software, for analyzing the lineament features and for better visualization of the images, some algorithms and filters are used. In the Automatic technique, the lineaments were extracted using Geomatica software in the Landsat image. In Visual technique, the lineaments were extracted using Global Mapper software in a QuickBird image. The ridge and river map for results validation of Landsat images was also produced by Global Mapper. Finally, the trench map was produced using the QuickBird image. The rose diagrams were provided using Polar Plots.

### 3.1 Methodology

In this study, lineaments were extracted using a remote sensing method. Based on this method, first, satellite images with high resolution such as Landsat, Digital Elevation Model, and QuickBird are provided. Automatic lineament extraction is done by Geomatica 2018 software in Landsat 8 image. Visual lineament extraction is done by Global Mapper 20 software in Landsat 8 and QuickBird

satellite images. Ridge and river map is produced by Global Mapper 20 using the ALOS PALSAR satellite image. Moreover, a trench map is produced by Global Mapper software using QuickBird satellite imagery. The entire satellite images used in this study are preprocessed. All the processes that are used to achieve the aim and objectives of the study are shown in the simplified flowchart of methodology (Figure 3). Then the rose diagrams for the extracted lineaments are then plotted using the Polar Plots ArcGIS 10.5 extension. There are three methods of lineament extraction; Automatic (Digital), Visual (Manual), and Mixed (Automatic and Visual) techniques. In this study, both Automatic and Visual lineament extraction techniques are used to compare both results and choose the best method to get the most accurate results from lineament extraction. All the maps are prepared by ArcGIS 10.5 software.
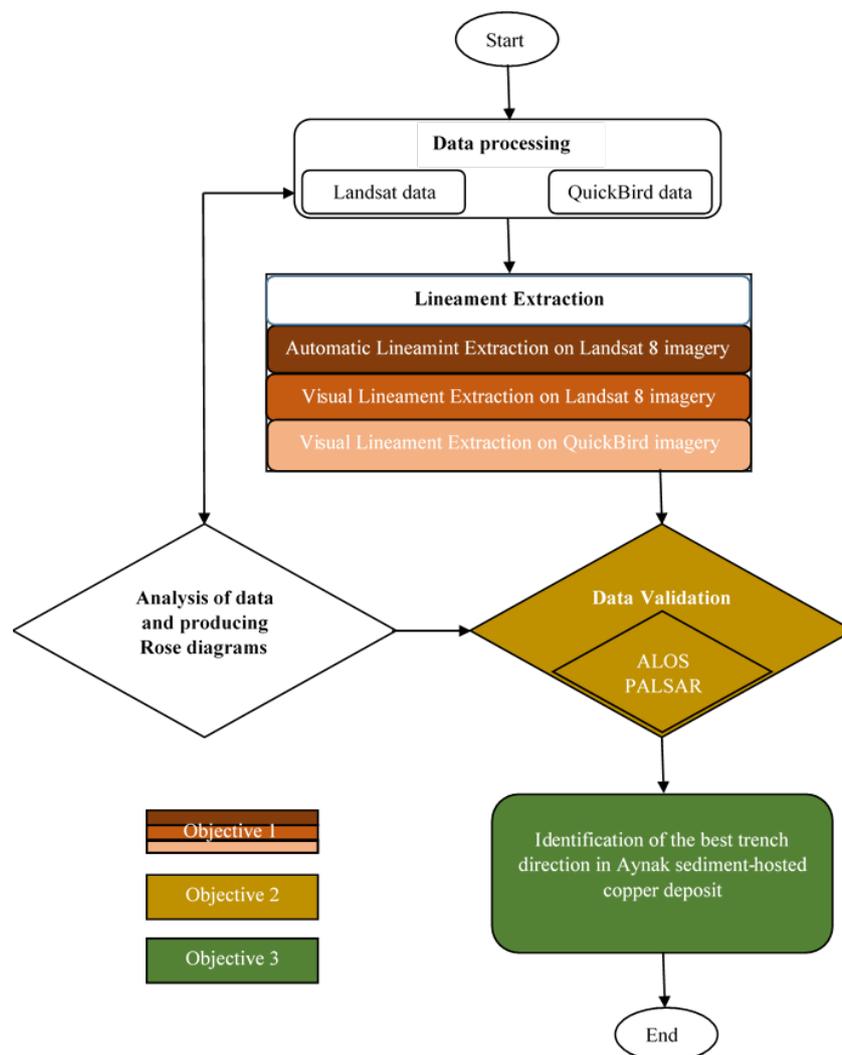


**Figure 3.** Simplified flowchart of the methodology used in this research.

The flowchart shows the steps followed to achieve the aim and objectives of this research. The first step according to the flowchart is processing the two main data types and then three methods of lineament extraction from the mentioned data. Next, data validation and analysis are integrated and intractive which then the analysis can be connected to data processing. Finally, the final product which is the best trench direction in Aynak copper mine is obtained.

*3.1.1.  Lineament Extraction on Landsat 8 image.*

a)   Automatic Lineament Extraction on Landsat 8 using Geomatica software

Geomatica software is a comprehensive and integrated desktop software that features tools for remote sensing, digital photogrammetry, geospatial analysis, map production, mosaicking, and more developed by PCI Geomatics [11]. In this technique, first, Landsat 8 image was used to extract the lineaments in the study area (Figure 4). Next, for lineament extraction using this method, the Landsat 8 satellite imagery was imported in Geomatica 2018 software. In this software, from Algorithm Library in Tools menu, the Line algorithm was selected to automatically extract the lineaments in the study area.
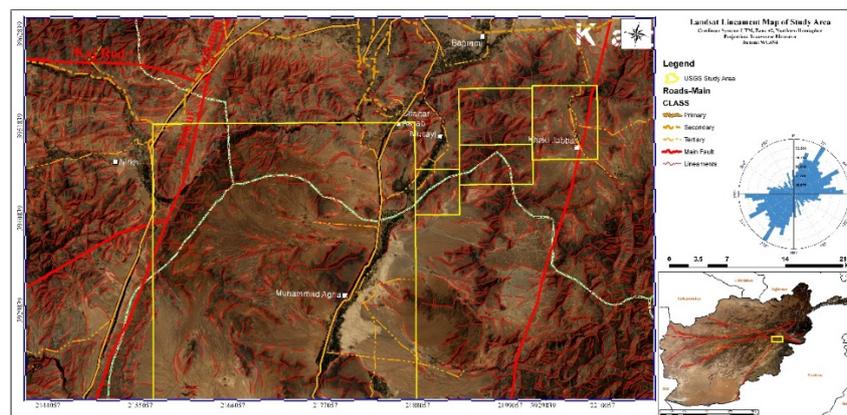


**Figure 4.** Lineament extraction of Aynak copper, cobalt, and chromium AOI using Landsat 8 image.

b)   Visual Lineament Extraction on Landsat 8 using Global Mapper software

In Visual technique, first, Landsat 8 satellite image was processed in Global Mapper software to extract the lineaments in the study area (Figure 5). In this technique, the lineaments are drawn by our expertise. There are two major trends for lineaments in this method and also there are some minor trends showing N140E (Figure 5). It can be seen that the lineaments which are drawn by the Manual technique are more accurate than the Automatic technique. However, still there are some errors because of the inadequate resolution of Landsat 8 satellite imagery.
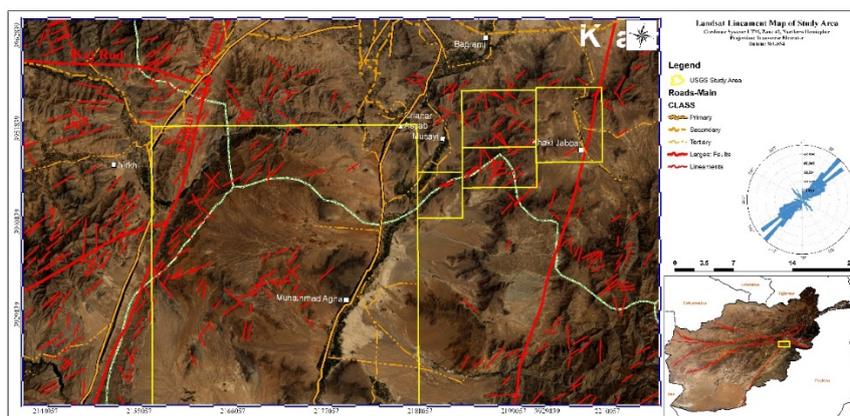


**Figure 5.** Lineament extraction of Aynak copper AOI using Landsat 8 image by Visual technique.

*3.1.2.  Validation of results using Global Mapper software.* To verify the results of previous sections, the ridge and river map of the study area was produced by Global Mapper and ArcGIS software using the ALOS PALSAR satellite image, and the rose diagrams of each one were plotted using Polar Plots.

To distinguish between linear features and non-linear features the ridge and river map significantly contribute to the validation of the results. As it can be seen that the northwest-southeast is the major trend (Figure 6) for the ridges and rivers in the study area and it shows a noticeable similarity with Landsat 8 results. This fact confirms the existence of errors in the Automatic lineament extraction method of study. It also approves errors in the Visual lineament extraction technique on Landsat 8 imagery because of the inadequate resolution of this satellite image. Therefore, the results of the automatic extraction of lineaments cannot be relied upon and cannot use it to analyze the tectonic structure status of the study area. In this regard, other parts of this study are devoted to the visual lineament extraction method. For producing, ridges and rivers map the ALOS PALSAR DEM was opened in Global Mapper software and then from Toolbox, Analysis was selected. In the Analysis, the watershed was selected to produce ridges as shown in Figure 6.
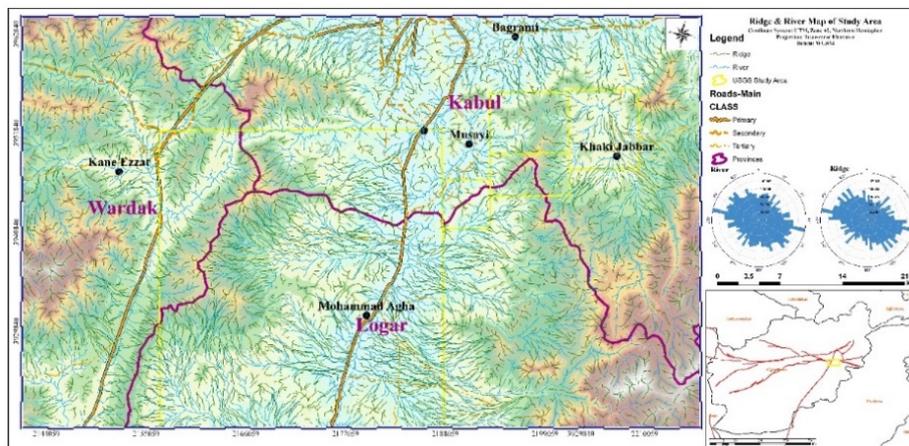


**Figure 6.** Ridge and river map of the study area by Global Mapper software using ALOS PALSAR.

*3.1.3. Visual Lineament Extraction on QuickBird image.* In previous sections, it was explained that lineament extraction using Automatic technique had some relative error due to a lack of suitable filtering and inadequate resolution of the satellite images used.
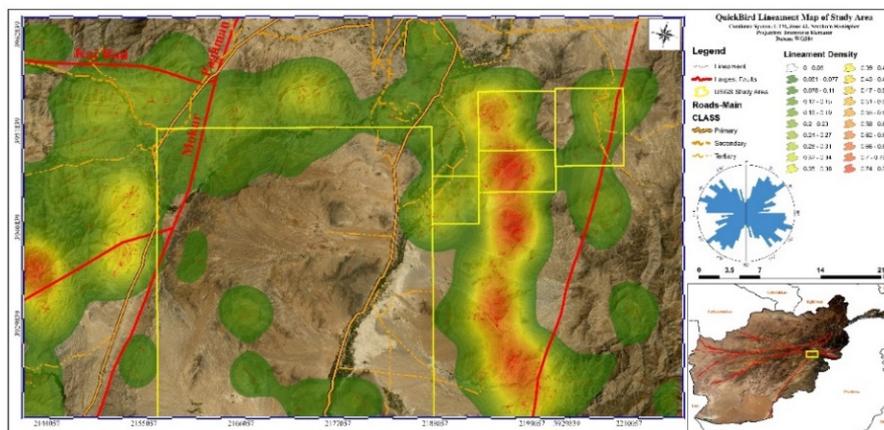


**Figure 7.** Line density map of Aynak copper mine processed by Global Mapper software ArcGIS.

Therefore, to obtain better results the highest resolution satellite image here QuickBird was used and Visual technique was used to extract the linear features, Figure 7. *The lineament density* is the total length of all the documented lineaments divided by the total area of study.

## 4. Results and Discussion

*4.1. Extracting Lineaments using Landsat 8 and the Associated Rose Diagrams by Polar Plots*

Having the best results require to use several methods and various satellite images to be able to compare results obtained from different methods and validate the results. Using Automatic lineament extraction of Landsat image, Figure 8, indicates that the major trends for joints in the study area are N30, N60, and N90. There are also minor trends N160. These rose diagram doesn't have a clear orientation and based on Automatic lineament extraction of Landsat data the joints are dispersed. The accuracy of this method is low because the spatial resolution of the Landsat 8 image in its best situation is (15-30) m. To get a clear comprehension, Visual technique for lineament extraction on the same Landsat image was applied, Figure 9.  The major trends showed the direction of N40 which is near to the correct result of the tension direction ($\sigma$1) or N45 of the study area. The other major trend is N50. Also, there are two sub-trends N140E and N150E.
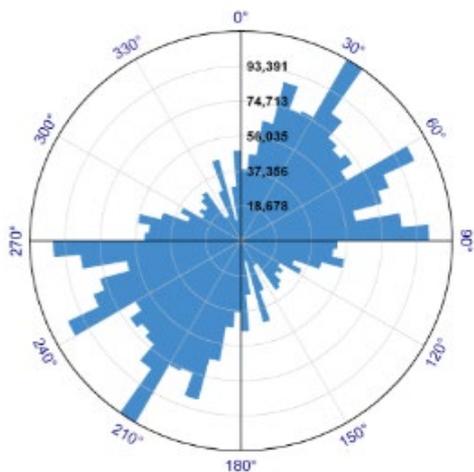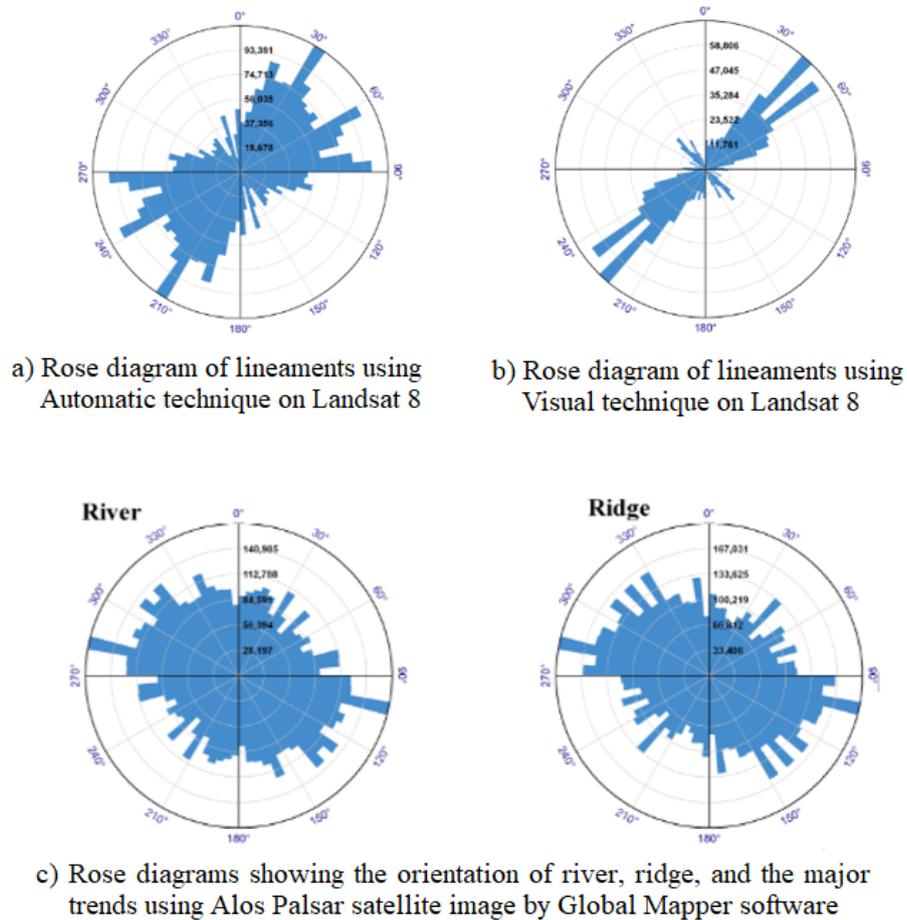


**Figure 8.** Rose diagram showing the orientation of lineaments using Automatic lineament extraction technique on Landsat image
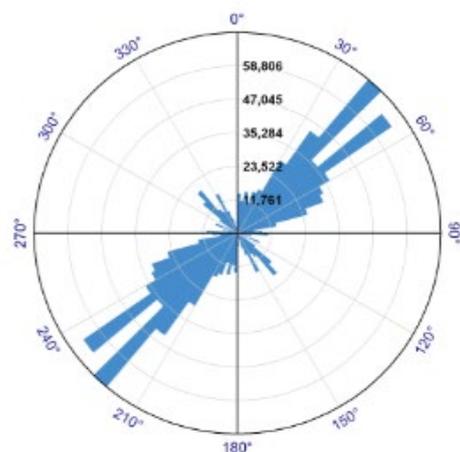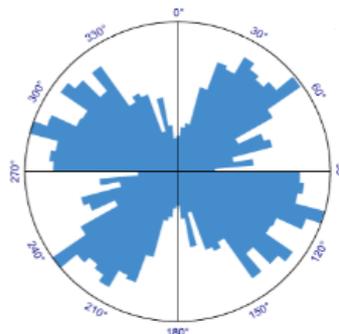
**Figure 9.** Rose diagram showing the orientation of lineaments and the major trends using Visual lineament extraction technique on Landsat image

*4.1.1 Validation of Lineaments Extracted from Landsat 8 image.* The major trend for the ridges and rivers is northwest-southeast (Figure 10) and it shows a noticeable similarity with the trends of Landsat 8 lineament rose diagrams. This displays errors in the Automatic lineament extraction technique. It also approves errors in the Visual lineament extraction technique on Landsat 8 imagery because of *the inadequate resolution of this satellite image*. Therefore, the results of the automatic extraction of lineaments cannot be relied upon and cannot  be used to analyse the tectonic structure status of the study area.

a) Rose diagram of lineaments using
Automatic technique on Landsat 8

b) Rose diagram of lineaments using
Visual technique on Landsat 8

c) Rose diagrams showing the orientation of river, ridge, and the major
trends using Alos Palsar satellite image by Global Mapper software

**Figure 10.** Comparing the rose diagrams of Landsat 8 image and ridge and river.

*4.2. Extracting Lineaments using QuickBird satellite image and the Associated Rose Diagrams by Polar Plots.* Next, visual lineament extraction on Quick bird high resolution about 1 m was applied and the lineaments were extracted using Global Mapper software. In this method, QuickBird satellite imagery was used and about 1500-1600 lines were drawn manually. In the rose diagram (Figure 11) which shows the trend of faults and joints using the lineament density in the study area, exactly it can be seen that the major trends are N45 or tension direction ($\sigma$1) of the Aynak copper mine fractures and N130 which is the extension direction ($\sigma$3) of the study area. It also shows that the major trends of lineaments in the study area are northeast-southwest and northwest-southeast (N45E-N130E).
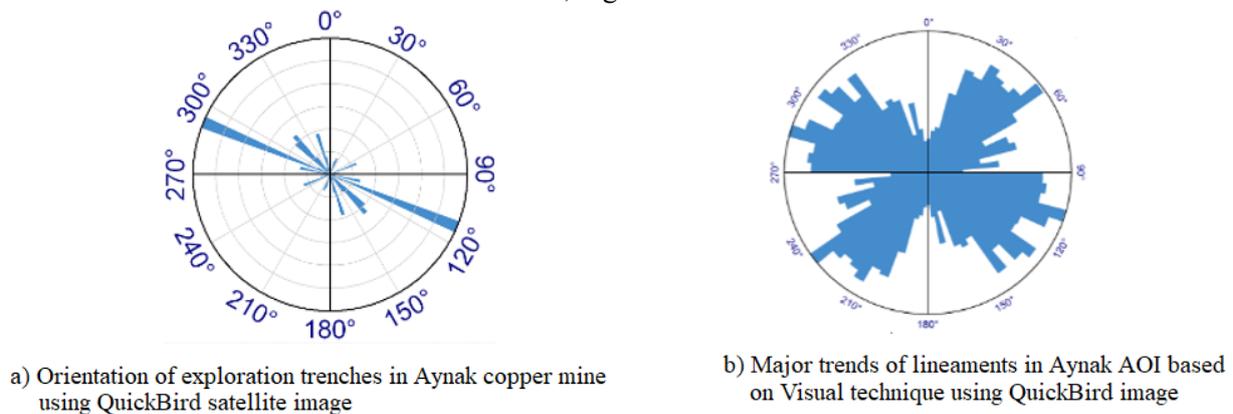


**Figure 11.** Rose diagram showing the orientation of lineaments and the major trends using Visual lineament extraction technique on QuickBird satellite image

*4.3. Trench Map and its Rose diagram relative to Lineaments Orientation.* Based on the third objective of this research it is necessary to evaluate the trench alignment relative to the major trends of lineaments in Aynak copper, cobalt, and chromium area of interest.
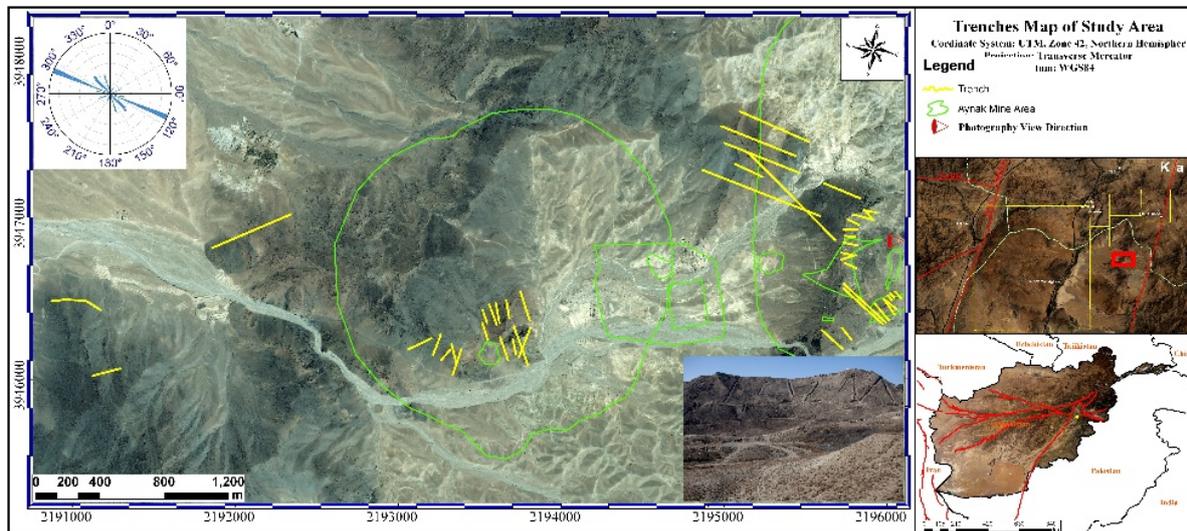


**Figure 12.** Trench map of Aynak copper, cobalt and chromium area of interest processed by Geomatica 2018 software and ArcGIS 10.5.

Therefore, the rose diagram of trenches in the area is obtained from QuickBird satellite imagery and compared to the major trend of lineaments in the study area. The majority of trenches are excavated in the mining exploration area (Figure 12). Therefore, in this study, the direction of these trenches was studied based on lineaments trend, Figure 13.



a) Orientation of exploration trenches in Aynak copper mine using QuickBird satellite image

b) Major trends of lineaments in Aynak AOI based on Visual technique using QuickBird image

**Figure 13.** Comparison of trends of trenches and lineaments

## 5. Conclusion

Based on this research it can be concluded that Visual lineament extraction technique (Figure 7) have better results because in this method the trends of lineaments exactly follow the N45E or tension direction ($\sigma$1) of the Aynak copper mine and N130E which is the extension direction ($\sigma$3) of the study area.

In the Automatic method of lineament extraction (Figure 8) the major trends for joints in the study area are N30, N60, and N90. There are also minor trends N160. These rose diagrams do not have a clear orientation and based on Automatic lineament extraction of Landsat data the lineaments are

dispersed. This lineament extraction technique cannot distinguish between tectonic and non-tectonic features.

The rose diagram retrieved from ridges and rivers (Figure 10) shows the N10 trend for both rivers and ridges and it can be seen that it has a direction opposite to the direction of major joint trends. However, the rose diagrams derived from Automatic techniques count River, ridges, joints, roadsides, and other manmade structures as lineaments. The rose diagrams of the river and ridges which come from DEM, validate our results.

Finally, according to the trench rose diagram the orientation of trenches excavated on Aynak copper mine shows a trend of N120 which is parallel to the extension direction forces in the rock layers of Aynak copper AOI and prone to destruction. The best direction for trenches is perpendicular to major trends of lineaments (Figure 13).

The tectonic and tectonic structure of Aynak copper, cobalt, chromium are of interest reveals that this area is located in an active tectonic zone and most of the tectonic structures of this area haven't been studied adequately, so it is recommended to implement the detailed tectonic survey in this area.

Lineament extraction in Aynak copper mine is an almost new aspect of tectonic and seismotectonic studies and the limited researches, for example, the USGS research for Geohydrology research of Aynak copper, cobalt and chromium AOI mostly used Automatic lineament extraction technique which cannot discriminate between tectonic and non-tectonic structures so it is recommended that Visual lineament extraction technique should be used in future studies.

According to trends of faults in the Ayank copper area, most of the trench directions in Aynak copper mine are in the wrong direction. Therefore, it is recommended that in future studies, tender, search, exploration, and excavation the trench direction should be perpendicular to the joints and faults orientation.

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