

# Engineering and Tectonic Study of Rocks Discontinuities in the Proposed Abo-Hederya Quarry Site, Missan SE Iraq

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## Abstract

A detailed field survey of discontinuity (fractures) was carried out in the proposed Abo-Hederya Quarry Site, 70 km east Missan city, south-east of Iraq, where Al-Mukdadiya Formation (Upper Miocene-Pliocene) is exposed. The discontinuity survey was carried out in 10 stations covering the study area. At each station notes were collected about beds (lithology, thickness and orientation) and discontinuities (orientation, density, spacing, persistence and aperture). The slope stability analysis suggests that there is no real hazard area that could affect the quarry in future. Tectonic analysis demonstrates that tension fractures are common in the study area, while shear fractures (okl, hko, hol and hkl) are the less. The maximum principal stress direction in the study area is N (15 - 40) E, which is compatible with the regional tectonic stress in the area.

## Keywords

Discontinuity, Fatha Formation, Missan, Iraq

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## 1. Introduction

The stability of rock slopes is significantly influenced by the structural setting of the rock in which the slope is excavated which refers to naturally occurring breaks in the rock such as bedding planes, joints and faults which are naturally called discontinuities. The properties of discontinuities relative to stability include orientation, persistence, roughness and infilling [1].

The main aims of the present study are identifying the regional stresses led to these discontinuities, assess-

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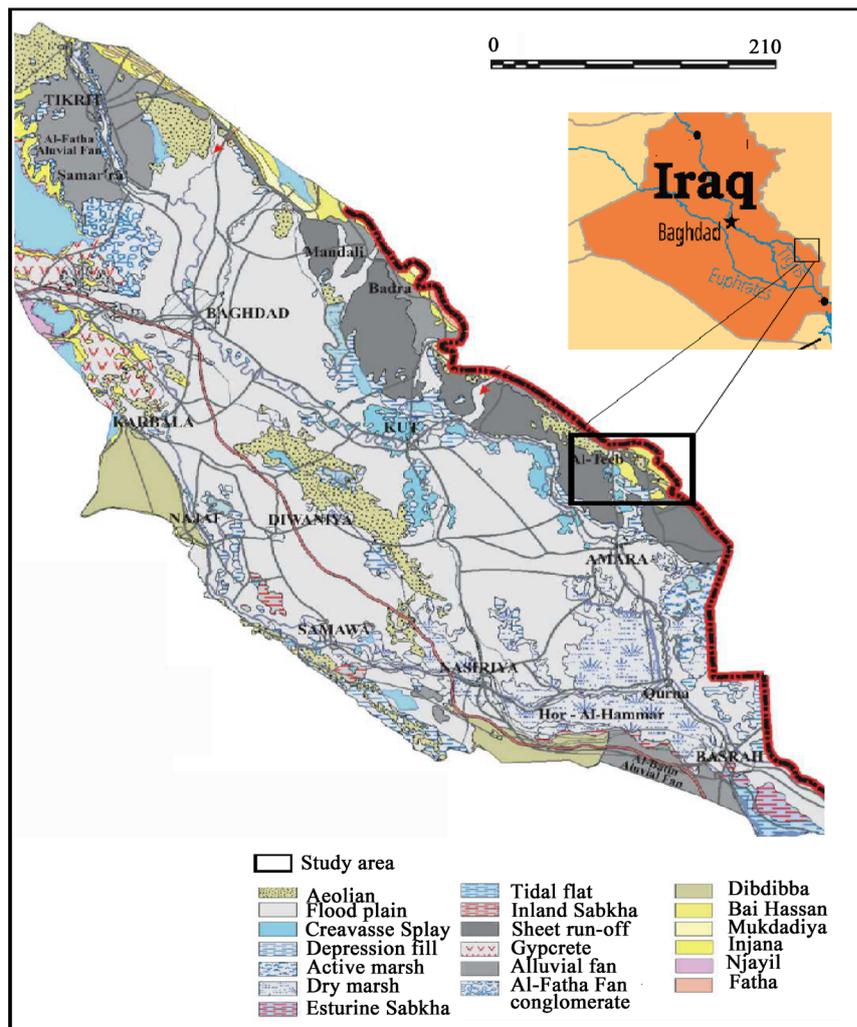
ment of the effect of rock discontinuities (orientation, density, spacing, persistence, and aperture) on rock slope stability and the influence of rock slope stability on the proposed Abo-Hederya quarry that affects the safety of the quarry.

## 2. The Study Area

The study area is located in Abo-Hederya (longitude 47°19'42.9"E, and latitude 23°26'28.2"N) proposed quarry in Missan Governorate 95 km east of Amara city within Mukdadiya Formation (**Figure 1**).

The exposed formation in the study area is Mukdadiya formation. The name Mukdadiya formation was used by [2] to replace the Lower Bakhtiari formation [3]. Mukdadiya (Lower Bakhtiari) Formation comprises up to 2000 meters of fining upwards cycles of gravely sandstone, sandstone and red mudstone. The Formation was deposited in fluvial environment in a rapidly subsiding foredeep basin. The age based on the vertebrate fauna is Late Miocene [4]. The lower contact is recognized lithologically by the first occurrence of the pebbly sands. It is distributed mostly in the Foothill Zone. The upper contact of the formation that overlain Mukdadiya Formation is diachronous [5]; it is recognized lithologically by the appearance of the first thick (more than 1 meter) conglomerate horizon [6]. In the study area the upper contact of Al-Mukdadiya formation is an erosional surface (angular unconformity surface), with the overlain quaternary deposits.

The study area is located within Himreen subzone, foothill zone, which is a part of unstable shelf according to tectonic map of Iraq (1996) (**Figure 2**) [5] [7]. It is in an extension of asymmetrical Himreen anticlines, with



**Figure 1.** Location and geological map of study area [8].

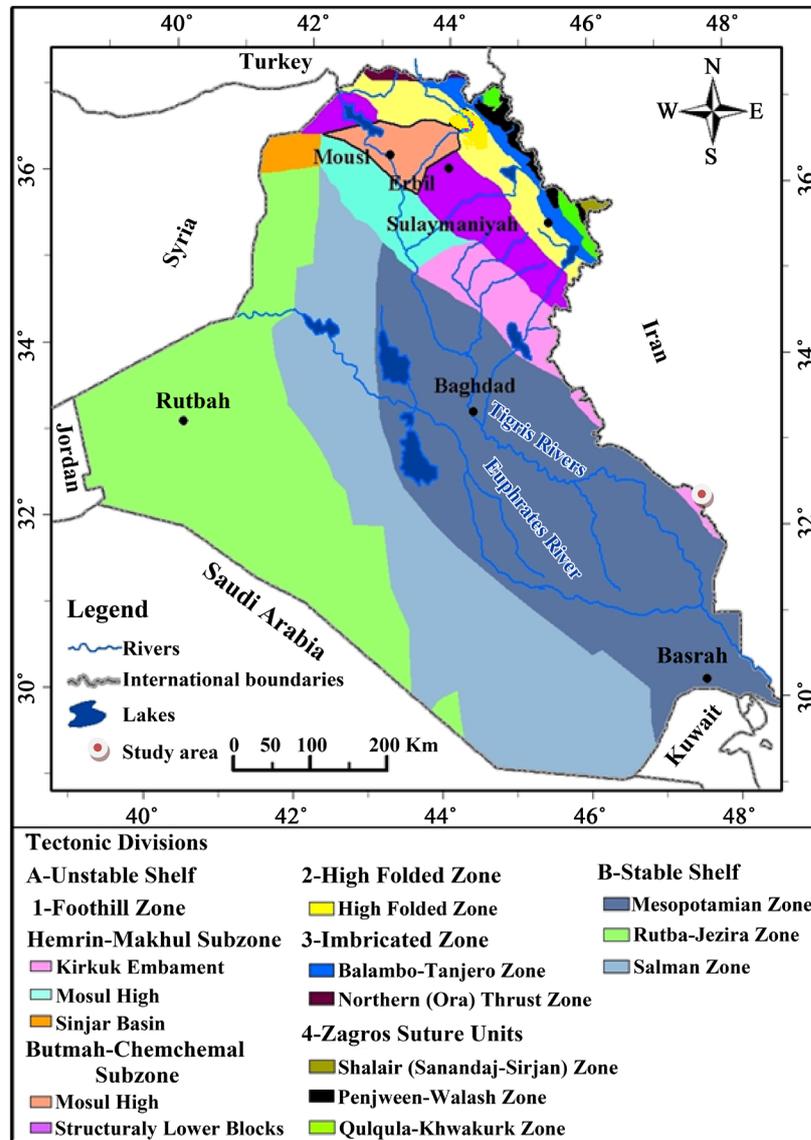


Figure 2. Tectonic map of Iraq (modified after [3]).

fold axis trending NW-SE, and bounded between two thrust faults with NW-SE direction (Figure 1), as a result of the collision between the Arabian and Iranian plates. The dip of the beds has an average value ranging from 20 to 8° because of their location near the hinge area of the fold as in Figure 1.

### 3. Methodology

Field work was carried out for 8 days, from 7th to 14th Feb., 2015. It covered the discontinuity, lithology, and geomorphologic features survey. It was carried out in 10 stations. The area of each station was not less than 2.5 × 2.5 m, while the location and distribution of these stations were mainly based on the availability of exposures and the importance of engineering and structural position. At each station notes were collected for beds (lithology, thickness and attitude) and discontinuities (orientation, density, spacing, persistence, and aperture). The office work of the present study included calculating, representing and analyzing of the field data.

### 4. Geomorphologic Features of Study Area

The most common geomorphologic features found in the studied area were as follows:

**Strike Ridges:** Strike Ridges are Common within Mukdadiya as in **Figure 3(a)**.

**Rill Erosion:** This feature is more effective and influential on the soft rocks that cover large areas (**Figure 3(b)**).

**Gully Erosion:** This feature is effective on solid rocks like Sandstone (**Figure 3(c)**).

**Badland Erosion:** This type of sculpture is common in Mukdadiya Formation composed of complex valleys and irregular lands (**Figure 3(d)**).

**Mesa:** Mesa formed when the beds are horizontal or near to horizontal (or sub horizontal) as in **Figure 3(e)**.

**Sand Sheets:** They are scattered among different part of the studied area as in **Figure 3(f)**.

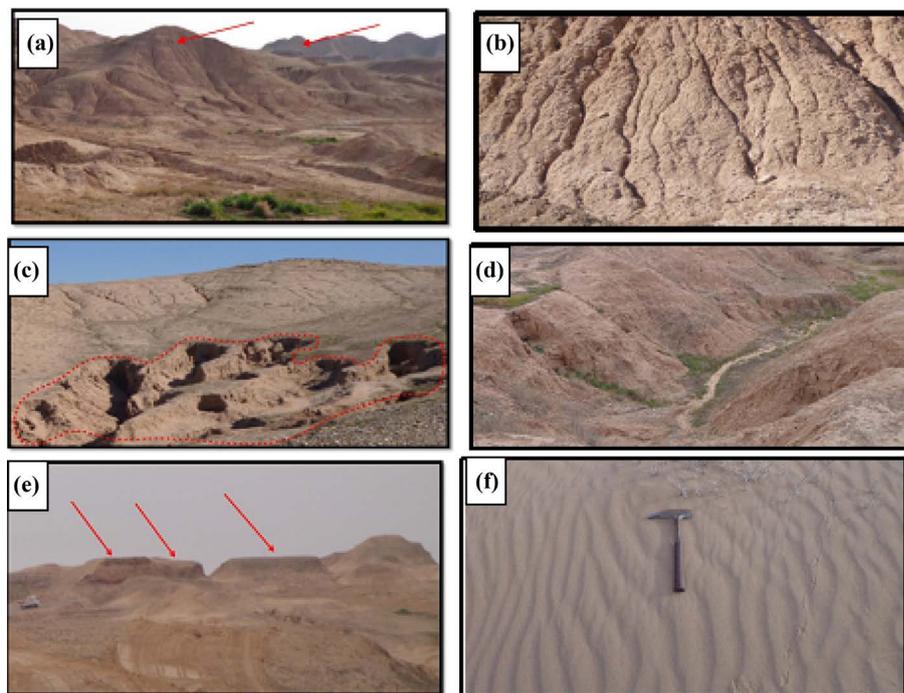
## 5. Discontinuities

Discontinuity is a general term for any mechanical break that has zero or relatively low tensile strength, it is a collective term that includes feature such as joint (a barren closed discontinuity on which no measurable slip is observed), vein (a discontinuity in which visible mineral infill took place), fissure (a discontinuity with a void space), fault (a discontinuity along which a detectable slip has occurred), and bedding plane (a discontinuity that separates the adjacent rock beds) [9]-[11]. The discontinuities strongly effect the mechanical and hydrological properties of a rock mass, in term of its strength, deformability, stability, porosity, and permeability [8], accordingly, the discontinuities play a major role in the design and safety of civil works [10] and the occurrence and movement of ground water and hydrocarbons [12] (H. There are many field and laboratory parameters which can be used to evaluate any site under study. The type of these parameters depends on the purpose of the study [9]. In the present study only five field parameters were used. These are: orientation, density, spacing, persistence, and aperture. The parameters have direct relations to the geotechnical aspects of the study area.

### 5.1. Discontinuity Orientation

Discontinuity orientation is the attitude of discontinuity in space. It could show grouping into sets (group of parallel discontinuities that maintain their orientation over considerable area) and system (applied to two intersecting discontinuity sets with relatively fixed angle of intersection) [9].

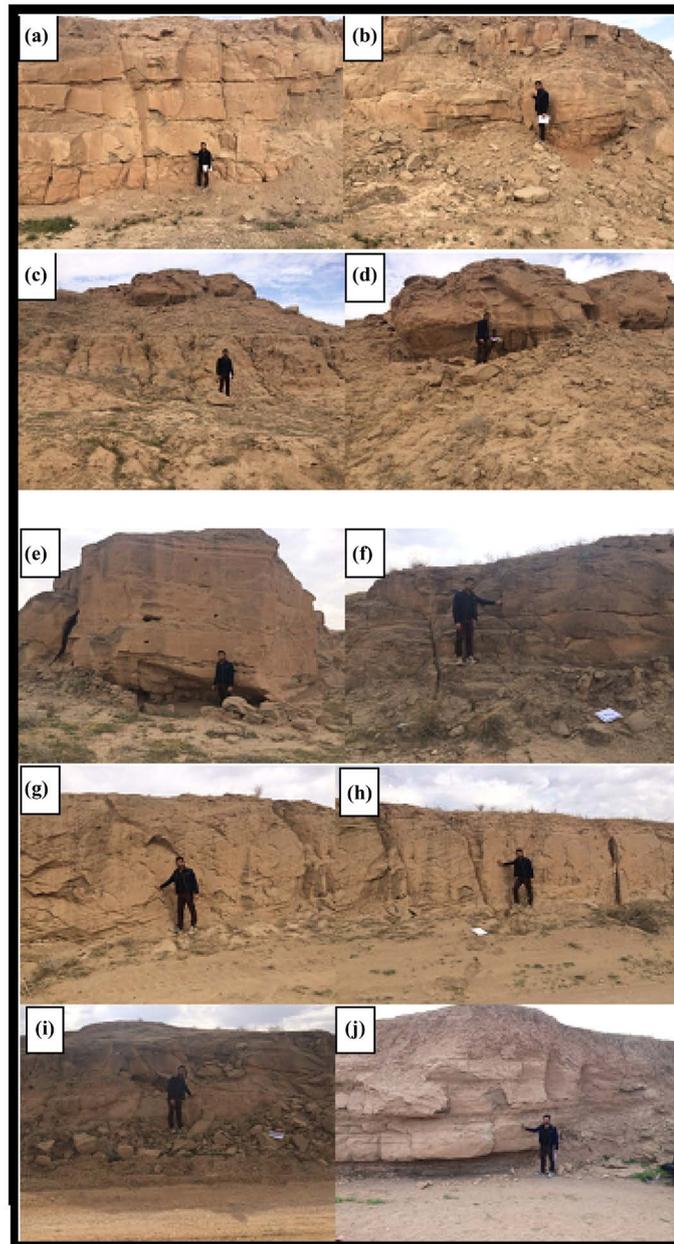
The discontinuity orientation can be described by the dip of the line of steepest inclination measured [13] [14],



**Figure 3.** Geomorphologic Features of study area ((a) Strike Ridges; (b) Rill Erosion; (c) Gully Erosion; (d) Badland Erosion; (e) Mesa; (f) Sand sheet).

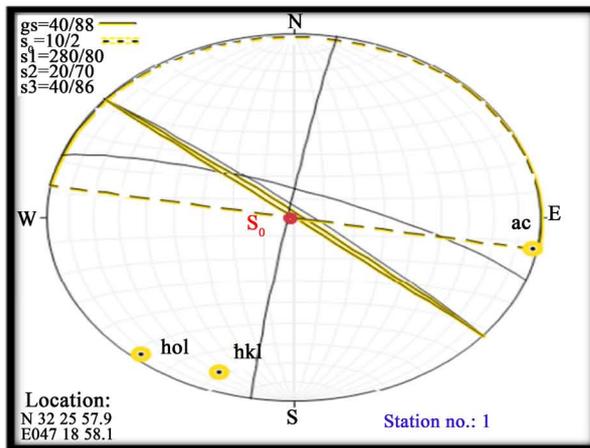
from horizontal, and by the dip direction measured clock wise from true north. Example: dip direction/dip angle ( $025^{\circ}/45^{\circ}$ ). The average readings of the discontinuity orientations in the stations of the study area were designated in **Table 1** as 1; 2; 3; 4; 5; 6; 7; 8; 9; 10. Discontinuity (fracture) analysis according to the principal tectonic axes was done to detect the geometrical and genetic relationship with the stresses in the region. Fractures were representative in the form of shear fracture sets (okl, hko, hol and hkl) and extension fracture set (ac).

The common discontinuity sets are persistently developed and are characterized by being normal to the bedding, while the less common discontinuity sets are characterized by being inclined at various degrees to the bedding (**Figures 4(a)-(i)**). Stereograms (stereographic projection) of orientations of discontinuities groups using stereonet ver. 8.9 software were done as shown in (**Figures 5(a)-(j)**). From stereographic projection, indicates

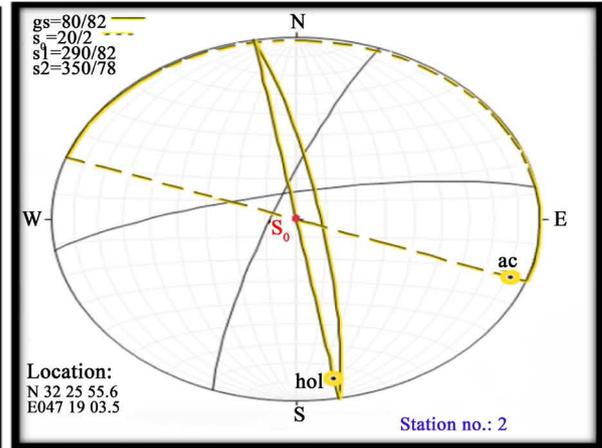


**Figure 4.** (a) The dominant fractures in station; (b) The dominate fractures in station; (c) The dominant fractures in station; (d) The dominant fractures in station; (e) The dominant fractures in station; (f) The dominant fractures in station; (g) The dominant fractures in station; (h) The dominant fractures in station; (i) The dominant fractures in station; (j) The dominant fractures in station.

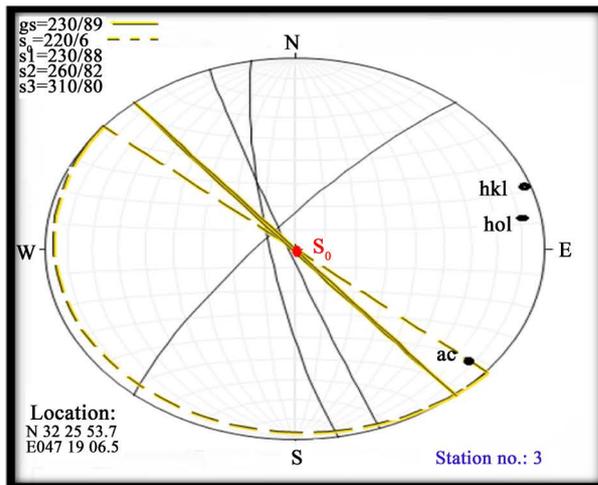
that there are no conjugate systems of fractures in the same station to make use of it in finding the maximum principal stress. Therefore, tension set fractures (ac) were considered, which always accompanist to conjugate system and resulting from the same maximum stress, to find the maximum principal stress in the study area which represent the regional stress in the area. It was found that the maximum principal stress direction in the study area was between N15E to N40E.



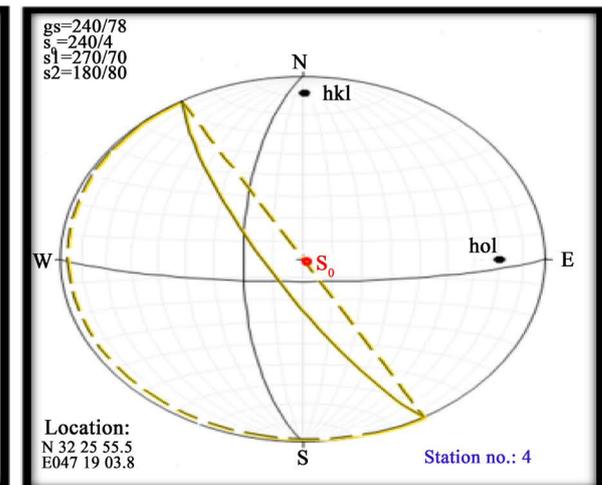
(a)



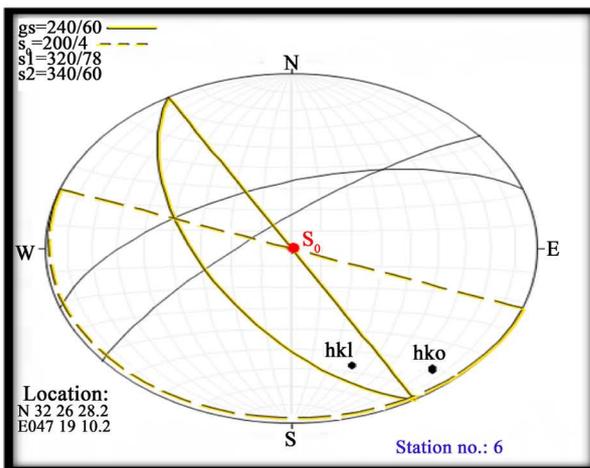
(b)



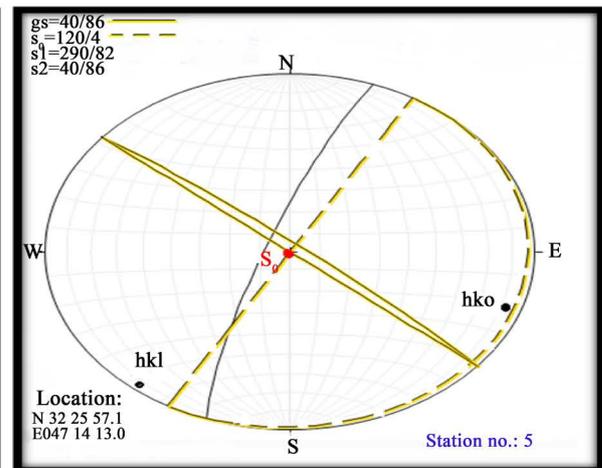
(c)



(d)



(e)



(f)

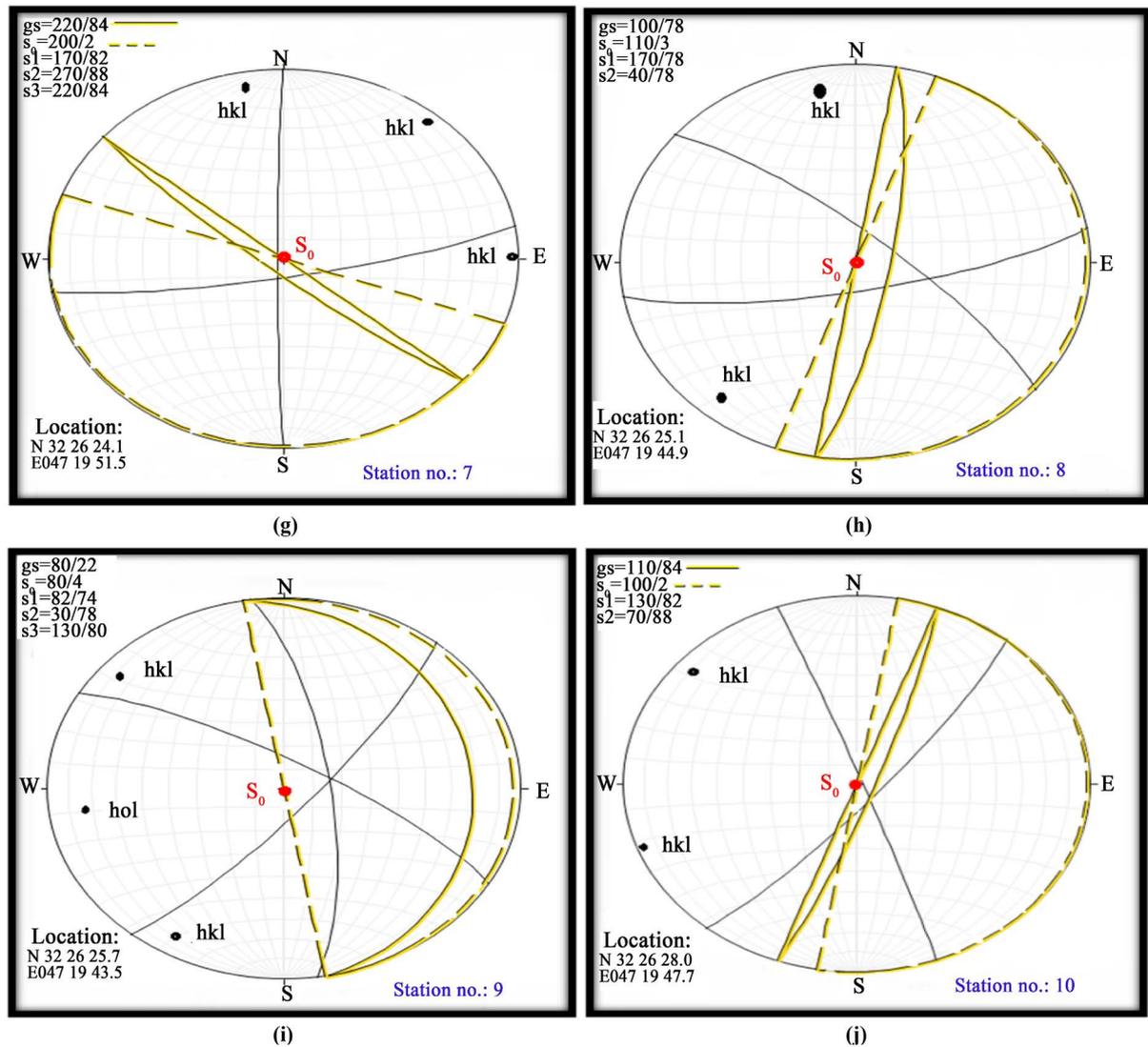


Figure 5. Stereogram of orientations of discontinuities (fractures) groups in stations (1, 2, 3, 4, 5, 6, 7, 8, 9, and 10).

### 5.2. Discontinuity Density (d)

It is the cumulative trace length of discontinuities in a given area regardless of their orientation [15] [16] (Figure 6).

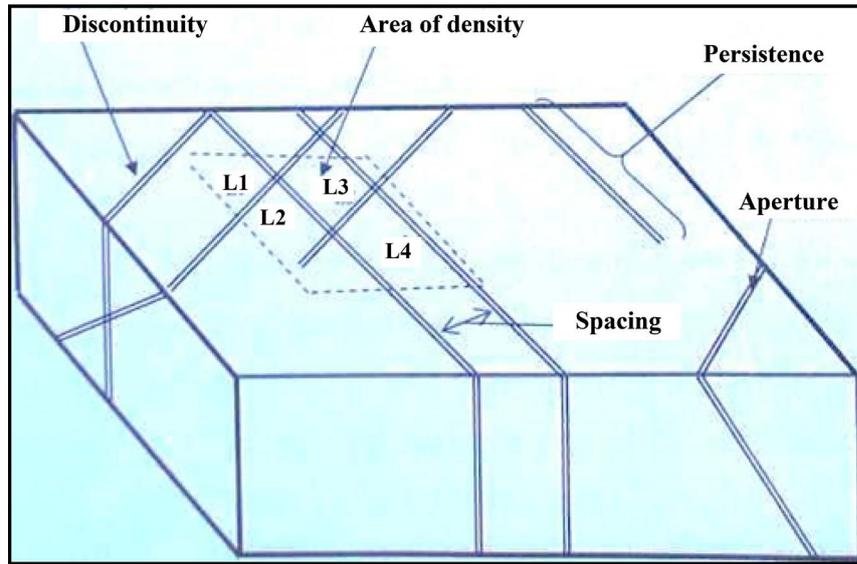
In the present study, it was measured within an area about  $2.5 \times 2.5$  m of each field station using the following equation:

$$d = \frac{1}{A} \times \sum_{i=1}^N Li$$

where:

- $d$  = discontinuity density
- $A$  = area of discontinuity density measurement ( $m^2$ )
- $i$  = discontinuity number
- $N$  = whole number of discontinuities within  $A$
- $L$  = discontinuity length (m).

It showed wide variation (Table 1) and it was used to evaluate the porosity and permeability of the exposed rocks of the study area.



**Figure 6.** Schematic block diagram shows the discontinuity spacing, persistence and aperture modified after [9] [16].

**Table 1.** The average readings of the discontinuities in the study area.

Station No.	Location	Elevation (m)	Discon. Density (m)	Discon. Spacing (m)	Discon. Persistence (m)	Discon. Aperture (cm)	Discon. Orientation (S1, S2, S3)
1	N32 25 57.9 E047 18 58.1	29	2.2	1.2	5	1	114/84
2	N32 25 55.6 E047 19 03.5	32	1.1	1	2	1.5	320/80
3	N32 25 53.7 E047 19 06.5	31	1.4	0.7	4	0.9	266/84
4	N32 25 55.5 E047 19 09.8	36	0.8	0.6	2.5	1	225/75
5	N32 25 57.1 E047 19 13.0	28	1.2	1.3	3	2.1	165/84
6	N32 26 28.2 E047 19 10.2	30	0.6	1.1	1	0.8	330/69
7	N32 26 24.1 E047 19 51.5	33	0.9	0.4	5	1.2	220/85
8	N32 26 25.1 E047 19 44.9	30	1.1	1.2	2	0.9	105/78
9	N32 26 25.2 E047 19 43.5	29	1.3	0.5	2	1.3	81/78
10	N32 26 28.0 E047 19 47.7	29	1.1	2.2	2	2.0	100/85

### 5.3. Discontinuity Spacing

Discontinuity spacing is the perpendicular distance between adjacent discontinuities [9]. Discontinuity spacing is one of the most important parameters because of its direct influence on rock slope stability and intact rock block size [9] [17]. In the present study, the average spacing of each discontinuity set was measured at each station, and then the average spacing of discontinuities was computed for each station (**Table 1**).

### 5.4. Discontinuities Persistence

Discontinuities persistence is the trace length of discontinuities as observed on the surface of exposures and it is

one of the most important rock mass parameters, because of its direct influence on rock slope stability and quarry. In the present study, the average persistence of discontinuity was measured for each station (**Table 1**).

### 5.5. Discontinuities Aperture

Discontinuities Aperture is the perpendicular distance between adjacent rock walls discontinuities [9] [18] [19]. The discontinuities aperture was measured for each discontinuities set. Next, the averages of apertures were found for all the observed discontinuities at each station (**Table 1**). The values of discontinuities aperture were increasing toward the center and decreasing on the top of the hills between the valleys.

## 6. Conclusions

Abo-Hederya is an arid area where wind is considered as principal geomorphological factor influencing rock slope geomorphology. Aeolian differential erosion acting on weak strata is forming overhanging unstable slopes.

The most common fractures have high dip angle (sub vertical) therefore they act as back release surfaces (BRS), lateral release surfaces (LRS) or composite back release surfaces (CBRS) but not as sliding surfaces. Their spacing and orientation also determine the size and shape of the failed rock blocks.

The high or low values of the discontinuities parameters have direct relationship with the structural position of the study area.

The slope stability analysis suggests that the different discontinuities sets have direct influence on slope failure in the study area. Nevertheless slope failure is limited in size distribution and has no much hazard on the quarry itself.

Fracture analysis reveals the geometrical and genetic relationship with the principal tectonic stresses, and it indicates that the maximum principal stress causing these fractures is directed N15 - 40E which is compatible with the regional stress resulting from Arabian plate motion towards NE. It has been found that tension fractures are common in the study area, while shear fractures are relatively less. This might be related to the structural position where the area is on the extension of the fold axis area.

The main stress in study area is compression and there might be some local stresses which have been represented in the form of tension fractures set (ac) and shear fractures sets (hko, hol and hkl).

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