Journal of Kirkuk University –Scientific Studies , vol.2, No.3,2007

The Relationship between Geological Structure and Failure Type in the Rock Slopes of Parts of Anah Monocline, West of Iraq

Saad Numan Al-Saadi Basim Rushdi Hijab* jaafer Hamza Ajjotheri***
** College of Science -University of Baghdad*
***College of Arts -University of Al-Qadsiya*

Abstract

Field observations and assessment of rock slope stability in selected sites in Anah monocline, West of Iraq, revealed the presence of different types of slope failure. The distribution and abundance of failure types are related to different discontinuity patterns in various structural positions within the asymmetrical Anah monocline. This is the first study that relates failure types to the structural position in a major fold. This relationship was observed all over the monocline area and confirmed by studying four stations along a traverse normal to the fold axis. The study revealed that wedge sliding is relatively common in the northern limb of Anah monocline whose dip angle is(35)$^{\circ}$ with conjugate shear joints (S2) whose intersection lines plunge downdip.The plane sliding is prevailing in the hinge area with conjugate shear joints (S1) whose intersection lines are parallel to the hinge of the fold. Toppling failure is relatively dominant in the southern limb whose dip angle is less than (5)$^{\circ}$with two pairs of vertical orthogonal joints (F1, F2, and F3, F4) which are normal to the bedding planes. Rockfall was almost equally abundant in all structural positions which indicates no structural position influence on it. The concluded relationships are attributed to the dependence of most failure types on the discontinuity pattern, which is in turn, largely influenced by the structural position, in addition to the relationship between the discontinuities and the slope face.

Introduction

Location of the Study Area:

The study area lies West of Iraq, about 20 kms West of Anah city. It lies between longitudes (41° 41$'$ 40″ and 41° 43$'$ 30″) East, and latitudes (34° 19' 38" and 34° 20' 33") North. Its area is about 9 km^2 (Fig.1).

Aims of the Study:

The main aims of this study are to investigate slope instability in the area to determine failure types and their relationship with

a-The discontinuity patterns.

b-The structural position of the asymmetrical monoclinal fold.

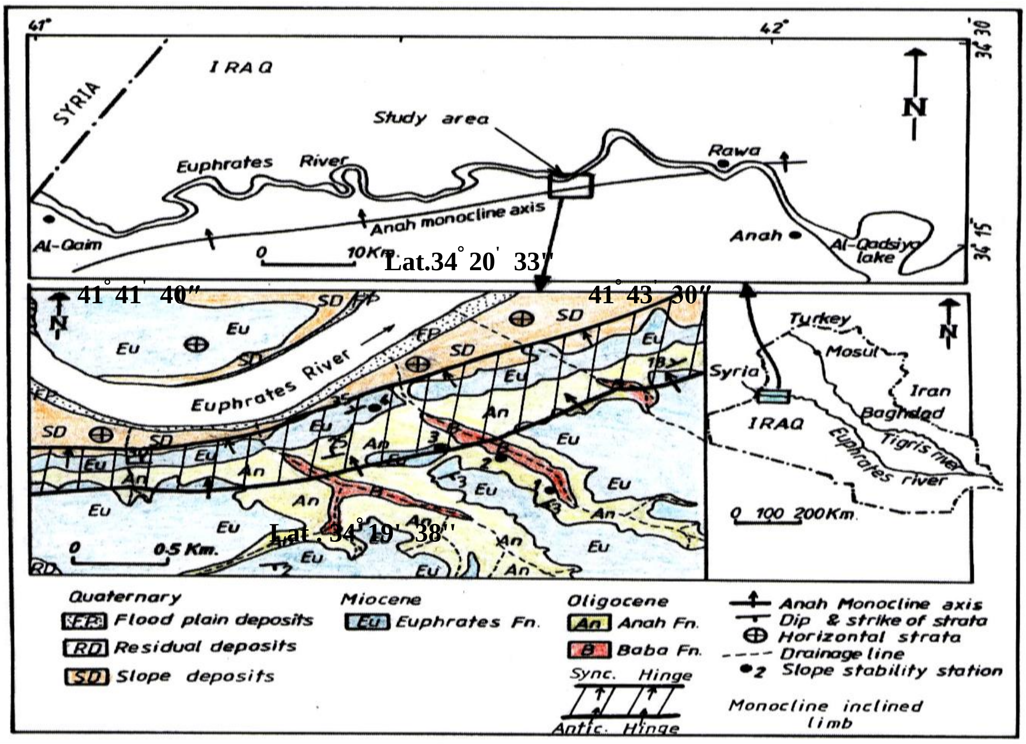


Figure 1: Location and geological maps of the study area.

Previous Works:

The most interesting works in the study area are the following: Fouad, et al., (1986) studied the geology and structure of Anah region between Haditha city and 15 km West of Anah city. Al-Asade (1996) studied some geotechnical properties of surface rocks of a suggested site for Rawa hydroelectric power station (Which is the southern part of the study area). She also assessed slope stability in various locations and found toppling and rockfall in these slopes and prepared failure hazard map. Fouad (1997) studied the tectonic and structural evolutions of Anah region, using seismic, boreholes, and surface geological data. The Consulting Scientific Bureau (2002) studied the proposed Ejbail dam site with detailed geological and geophysical investigation works. Rock slope stability studies in Iraq and in the world focused on the role of discontinuities during the failure without relating failure modes to the major structure (Evans, 1981;Hoek & Bray, 1981; Al-Saadi, 1981, 1988, 1991;Hamasur,1991;Al-Saadi & Al-Jassar, 1993;Al-Momani & Al-Saadi, 1998;Al-Saadi & Al-Momani, 1998; Al-Saadi, et al., 1998;Al-Saadi & Tokmachy, 1998; Tokmachy & Al-Saadi, 1998 ;Al-Saadi & Al-Hamdani, 2005). Therefore, the previous works in the study area and in the world did not investigate the relationship between failure types and the structural positions in a major fold like Anah monocline, which is the aim of this study.

Methodology:

The present study involved three stages of field, laboratory, and office works. In the field stage a geological map was prepared(Fig.1)discontinuity survey was carried out in relation with slope stability assessment at four stations along a traverse normal to the monocline axis. Laboratory test included point load test to determine indirectly the compressive strength of the rocks in the stations. Office work involved the representation and analysis of field data using stereographic projection and writing the paper.

Geology of the study area

Stratigraphy:

Depending on field work of this study in addition to the studies of Buday(1980),and Fouad(1997) there are three formations exposed in the study area (ranging in age from Middle Oligocene to Lower Miocene) and covered by Quaternary deposits in some places. These formations (from oldest to youngest) are Baba (Middle Oligocene), Anah (Upper Oligocene), and Euphrates (Lower Miocene) (Buday, 1980) (Figs.1&2).

Thick. (m)	Age	Fn	Unit	Lith.	Lithological Description
1.5-2	Lower Miocene	Euphrates	Recrystallized Limestone		Thinly bedded recrystallized limestone
13-15			Upper Massive Chalky Limestone		Chalky dolomitic limestone, massive
4-5			Bedded Chalky Limestone		Chalky dolomitic limestone, bedded
			Lower Massive Chalky Limestone		Chalky dolomitic limestone, massive
13-15			Shelly Limestone		Shelly dolomitic limestone, well bedded and hard
11-13			Basal Conglomerate		Conglomerate pebbles are very hard limestone
4-5	Upper Oligocene	Anah	Bedded Limestone		Limestone hard and well bedded
25-35			Massive Limestone		Limestone hard and massive coralline limestone
8-16	Middle Oligocene	Baba			Limestone soft and massive coralline limestone

Figure 2: Geological column of the study area.

Tectonics and Structure:

Depending on the tectonic divisions of Iraq after Buday&Jassim (1987), the study area is located within the stable shelf of Iraq, in the northern part of Rutba–Jezira Zone. It lies in the southern part of the Jezira Subzone. Field study revealed that structurally, Anah monocline is the major structure in the study area, its average trend is 072°, its average width is locally about 0.5 km, and its northern limb dips 18- 35°N, while the southern limb dips 2-5°S. It consists of two segments different in the direction of axis and the dip of strata. The western segment is trending N 85°E. and it northern limb dips about 30°N, whereas the eastern segment trends N 60-75°E, and its northern limb average dip is about 18°NW but reaches 35° in some places. The studied stations traverse lies in the eastern segment of the monocline (Fig.1). In addition, each one of these segments consists of a number of small segments separated by areas of local clockwise swing of the hinge trend to E-W, occupying deep valleys that drain from the right (south) bank of the Euphrates River. These local deviations or differences in the trend of Anah monocline axis may be controlled by subsurface faults (Al-Mashriqi, 2003). Detailed field study of the discontinuities in the area proved the presence of four common sets of orthogonal discontinuities designated F1, F2, F3 and F4, and three less common discontinuity systems designated S1, S2, and S3 in the study area (Fig.3). The discontinuities sets are persistently developed and characterized by being normal to the bedding planes,while the discontinuity systems are less common, locally developed, and are inclined at various degrees to the bedding planes. This grouping of discontinuities also was noticed by Fouad, et al., (1986), Fouad (1997) and the Consulting Scientific Bureau (2002).The orthogonal discontinuity sets F1 and F2 are normal to the bedding and their mean trends are N 25°E and N 65°W respectively (Fig.3 A&B). The orthogonal discontinuity sets F3 and F4 are normal to the bedding and their mean trends are N 75°E and N 15°W respectively (Fig.3 C&D). The S1 discontinuity system consists of two intersecting sets trending N 75° E (they are parallel to the monocline axis) and dipping at high angle (55°) to the bedding planes. One set $S1_{(S)}$ dips southward and the other $S1_{(N)}$ dips northward. The acute angle between the two intersecting sets is bisected by the normal to the bedding planes while the obtuse angle bisector is in the dip direction (Fig.3 E&F). The S2 discontinuity system consists of two sets whose intersection lines are trending N 15°W with the acute angle bisected by the normal to the bedding plane, while the obtuse angle bisector is parallel to the strike. These discontinuity sets whose intersection lines trend N 15° W (perpendicular to the monocline axis) are dipping at high angle (55°) to the bedding planes (Fig.3 G&H), and plunging northward parallel to the inclined north limb (Fig.3 G&H).The S3 discontinuity system consists of two intersecting sets trending N 75° E, one dips to the north, and the other dips to the south, enclosing an acute angle bisected by the line parallel to the dip of bedding planes. The sets of this discontinuity system which trend N 75°E (Parallel to the monoclinal axis) are dipping at low angle (35°) to the bedding planes (Fig.3 G&H). These sets and systems of discontinuities were found restricted to certain structural positions as was noted by Fouad (1997) too (Fig.3). The discontinuity sets F1, F2, F3, and F4 are found in all parts of the monoclinal fold but they are better developed in the southern limb of the monocline. The S1 system was found in the anticlinal bend of the monocline (Fig.3F), while the S2 system was found in the northern limb of the monocline, and S3 system was found in the synclinal bend of the monocline (Fig.3 H).

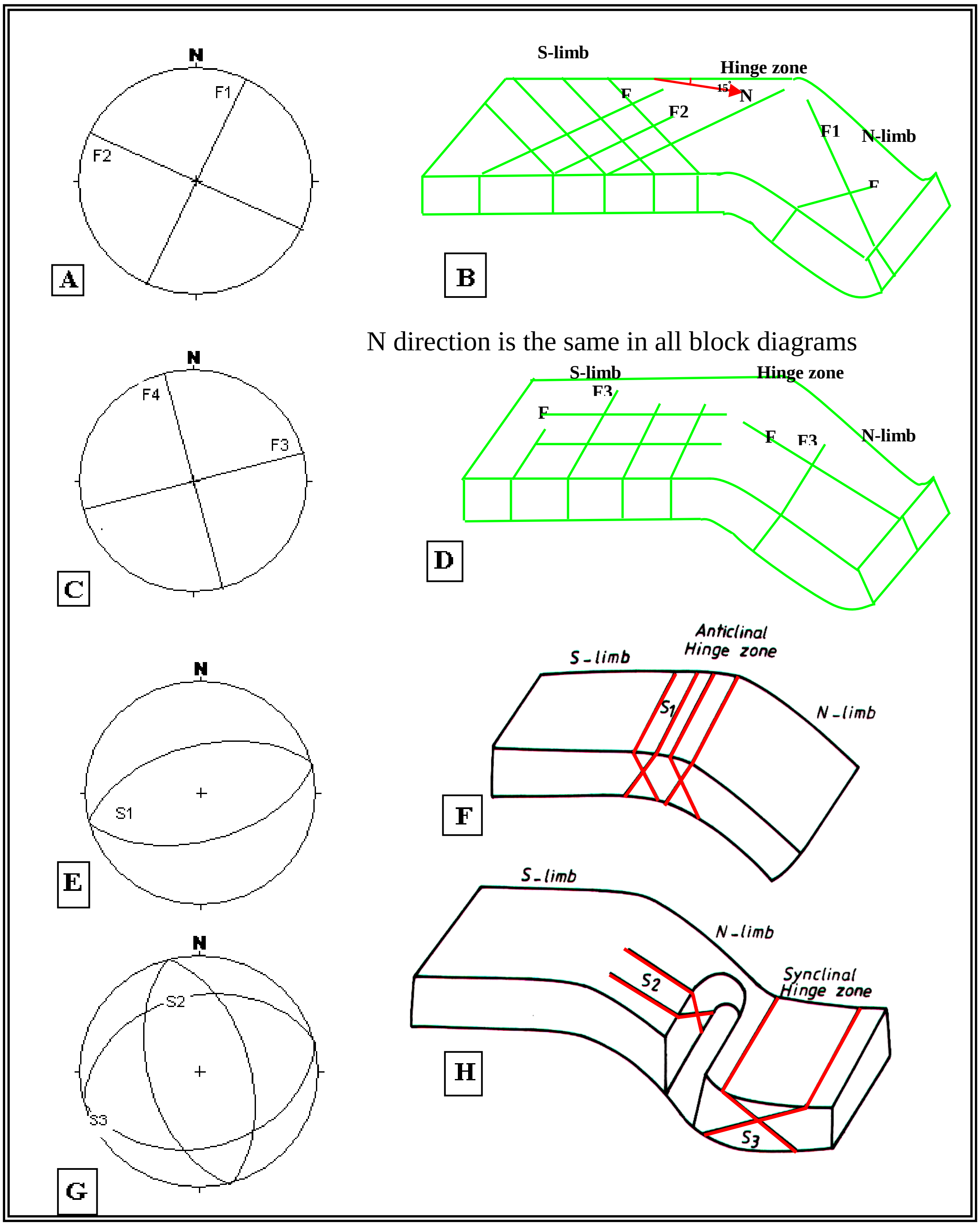


Figure 3: Orientations of discontinuity groups of the study area.
Stereogram (A) and block diagram (B) of F1 & F2 discontinuity sets.
Stereogram(C) and block diagram (D) of F3 & F4discontinuity sets.
Stereogram (E) and block diagram (F) of S1 discontinuity system.
Stereogram (G) in horizontal layer orientation and block diagram (H) of S2 &S3 discontinuity systems.

Geomorphology:

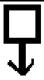
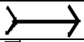
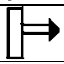
The geomorphology of the study area is controlled by structure, lithology, and fluvial processes. Structural control on the land relief is very clear and exhibited by the elevated areas adjacent to the southern bank of Euphrates River where the anticlinal hinge of the monocline extends roughly parallel to the river course. The height of the plateau south of the river exceeds 270m (a.m.s.l), which is about 120m above the river bank level (150m);while the areas of the synclinal northern side of the monocline north of the river rise gently and gradually northward to170-180m (a.m.s.l), i.e, about 20-30m above the river bank level. The lithological variations of stratigraphic units help to increase the differential weathering and erosion. Euphrates River plays an important geomorphic role in the area by forming river terraces and flood plains. The distribution and orientations of the valleys are controlled structurally; there is a close correlation with the direction and occurrence of the major tectonic lineaments. These valleys are commonly bounded by long sharp cliffs. The drainage pattern is almost dendritic and controlled by subhorizontal strata in the southern limb of the monocline, while along the slopes of the northern inclined limb of the monocline (near the river southern bank) the drainage pattern becomes parallel following the ground slope and dip of strata toward the river.

Slope stability assessment of the study area:

Field observations revealed a consistent picture of failure types related to certain discontinuity pattern and varying with the structural position from the southern limb to the anticlinal hinge area, to the northern (steeper) limb of the monocline. Therefore, four stations were chosen to assess the relationship between failure types and structural position in the monocline. These are stations 1 & 2 in the southern subhorizontal limb, station 3 in the anticlinal hinge area, and station 4 in the northern (steeper) limb of the monocline along a traverse normal to the monocline hinge (Fig.1).

Engineering geological description of rocks at all stations was carried out according to Anon (1972) and σc is the compressive strength of the rock material. The ground slope and dip of beds discontinuities are indicated by two numbers, the first to the left indicates (the inclination or dip) direction (as azimuth from North), and the second to the right indicates the angle, like $350/35^{\circ}$. Overhanging slope is indicated by the letters (OH). The dot in the stereograms represents the pole of the average dip of a discontinuity set, and the triangle is the pole of the average dip of bedding planes (table 1).

Table (1): Symbols used in this paper

Symbol	Description	Symbol	Description
σ_c	Compressive strength of rock material		Rock fall
ν	Vertical slope		Wedge sliding
OH	Overhanging slope		Toppling
•	Pole of average dip of a discontinuity set		Rock rolling
▲	Pole of average dip of bedding planes	F1,F2,F3, &F4	Joint sets in the study area
Rock Mass 	Trend 0f vertical or overhanging slope, rock mass lies behind the slope	I S2a,S2b	Intersection line between S2a&S2b joint sets
	Plane sliding	S1(N),S1 (s),S2(a),& S2(b)	Joint sets within S1&S2 joint systems
S1,S2 ,&S3	Joint systems in the study area		

Station No. 1 (The Effect of F3 and F4 Sets of Discontinuities):

This station lies in the southern limb of Anah monocline at about 500m south of the monocline axis (Fig.1). The slope is 16m high, 15m long parallel to its trend, and its inclination is 075/60-OH (Fig.4). The average dip of strata is 165/3°. In the upper part of the slope, a 4m thick rock layer is exposed belonging to Anah Formation and cut by F3 and F4 discontinuities. These rocks are gray, coarse grained, very thickly bedded, very widely jointed, moderately weathered, LIMESTONE, strong (σ_c=50 MPa). The bedding plane is highly weathered and eroded so that active undercutting left some parts of the slope overhanging. This has resulted in secondary toppling of limestone blocks, and rockfall. The F4 discontinuities acted as back release surfaces while F3 discontinuities acted as lateral release surfaces during toppling failure. More blocks are liable to toppling in the future. Some blocks have rolled down the lower slope after detachment has occurred.

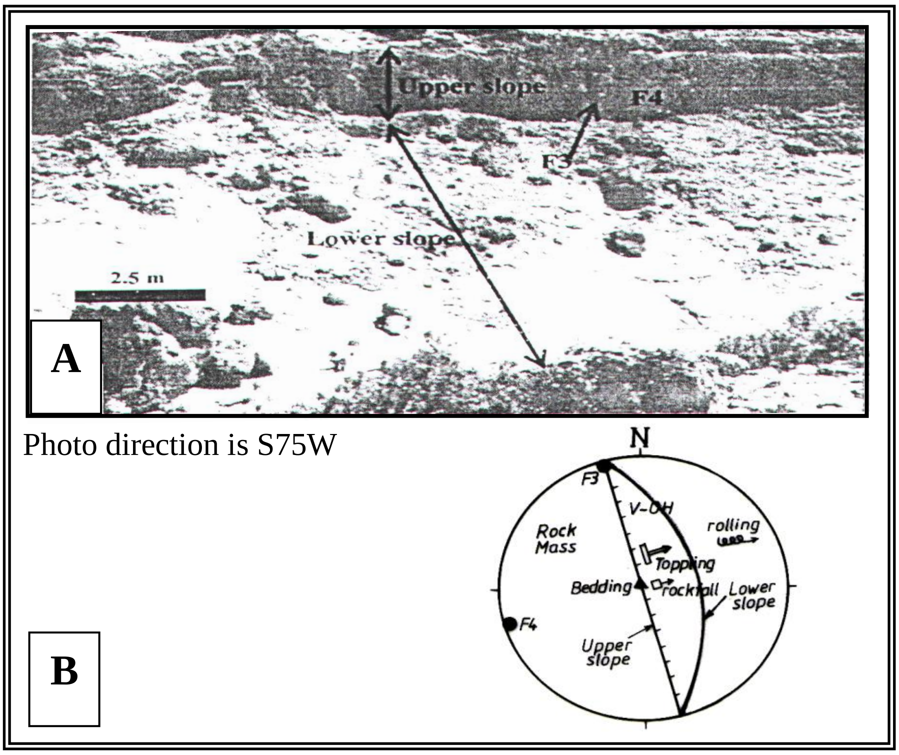


Figure 4: Station No. 1 (A) Front view, (B) Stereogram of discontinuities, slope and failure type relationship.

Station No. 2 (The Effect of F1 and F2 Sets of Discontinuities):

This stations lies in the southern limb of Anah monocline at about 150m south of the monocline axis (Fig. 1). The slope is 12m high and 30m long along its trend (Fig. 5). The average dip of strata is $165/3^{\circ}$. It consists of upper slope (4m high) and lower slope (8m high).The upper slope inclination is (055/80-OH) and its layers (of Anah Massive Unit) are gray, coarse grained, very thickly bedded, very widely jointed, moderately, weathered, LIMESTONE, strong (σ_c = 62 MPa). The lower slope inclination is $055/60^{\circ}$ and its layers (of Baba Formation) are yellowish white, coarse grained, very thickly bedded, very widely jointed, moderately weathered, LIMESTONE, moderately strong (σ_c = 42 MPa). The limestone layers in the upper slope are cut by two sets of discontinuities (F1 and F2) which acted as lateral and back release surfaces respectively during the secondary toppling failure of rock block bounded by these sets. The undercutting along the bedding planes at the upper slope's toe promoted toppling failure and rockfall. All these conditions make the slope active, unstable and liable to more toppling and rockfall in the future. Toppled and fallen blocks have rolled down the lower slope.

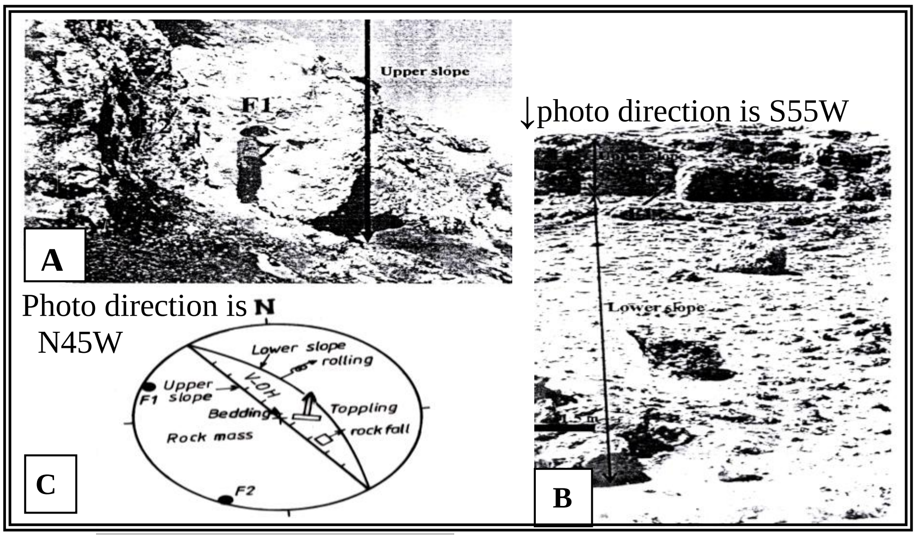


Figure 5: Station No.2 (A) Side view, (B) Front view and (C) Stereogram of discontinuities slope, and failure type relationships.

Station No. 3 (The Effect of S1 System of Discontinuities):

This station lies in the hinge area of Anah monocline (Fig. 1). The slope is 4m high, 6m long along its trend, and its inclination is 350/75°-OH (Fig.6). The average dip of strata is 350/3°. Euphrates Formation rocks are exposed in the slope face. Its rocks are brownish white, medium grained, thickly bedded, very widely jointed, moderately weathered, LIMESTONE, moderately strong (σ_c= 35 MPa). These layers are cut by two intersecting sets of discontinuities belonging to S1 system. Discontinuities of $S1_{(N)}$ set that dip northward (down slope) acted as sliding surfaces, while those dipping southward $S1_{(S)}$ acted as back release surfaces during the plane sliding process. Some vertical discontinuities of F4 set acted as lateral release surfaces.

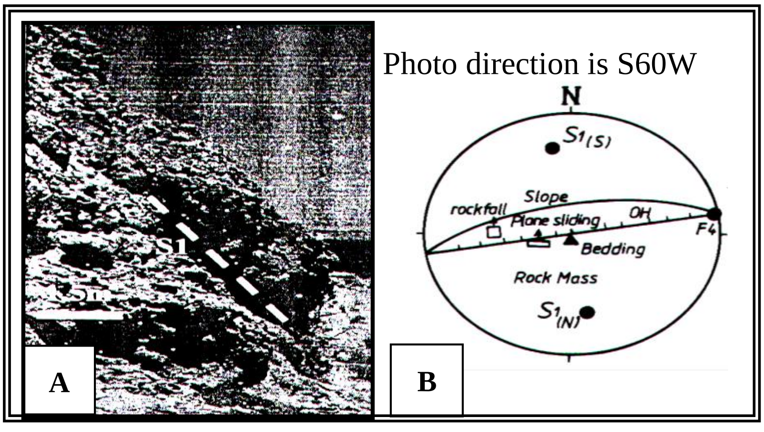


Figure 6: Station No. 3 (A) Side view, (B) Stereogram of discontinuities - slope relationship and failure type.

Station No. 4 (The Effect of S2 System of Discontinuities):

This station lies in the northern (inclined) limb of Anah monocline(Fig.1). The slope is 5m high, 5m long parallel to its trend (Fig.7).Its inclination is 350/90°, and the average dip of strata is 350/35°. The Shelly Limestone Unit of Euphrates Formation is exposed in this station. The rocks are yellowish brown, medium grained, very thickly bedded, very widely jointed, moderately weathered, shelly LIMESTONE, moderately strong(σ_c=42MPa). The rock mass is cut by two intersecting sets $S2_{(a)}$and $S2_{(b)}$of S2 discontinuity system which acted as sliding surfaces during wedge sliding that occurred at this station (Fig.7).Rock fall has also occurred here.

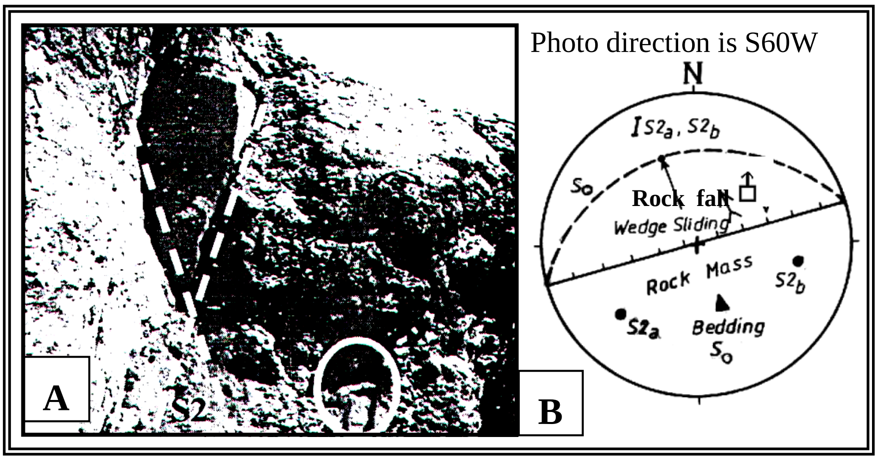


Figure 7: Station No. 4 (A) Side view, (B) Stereogram of discontinuities slope and failure type relationship.

The relationship between failure type and structural positions in the monoclinal fold

It appears from stability assessment in the four studied stations that good relationships exist between failure type, discontinuity pattern, and the structural position in the Anah monoclinal fold (Fig. 8) and table (2) as follows:

(1) In the southern (Subhorizontal) limb, toppling failure has occurred where two pairs of orthogonal subvertical discontinuities normal to the bedding planes exist. In each pair, one set acted as lateral release surface, while the other acted as back release surface.

(2) In the anticlintal hinge area of the monocline, plane sliding has occurred where two intersecting discontinuities of S1 system are striking parallel to the hinge so that one set is dipping northward $S1_{(N)}$ (downslope) and acted as sliding surface, while the other set $S1_{(S)}$ dips southward and acted as back release surface.

(3) In the northern (Inclined) limb of the monocline, wedge sliding has occurred along the line of two intersecting discontinuities of S2 system. The discontinuities of the two sets acted as sliding surfaces.

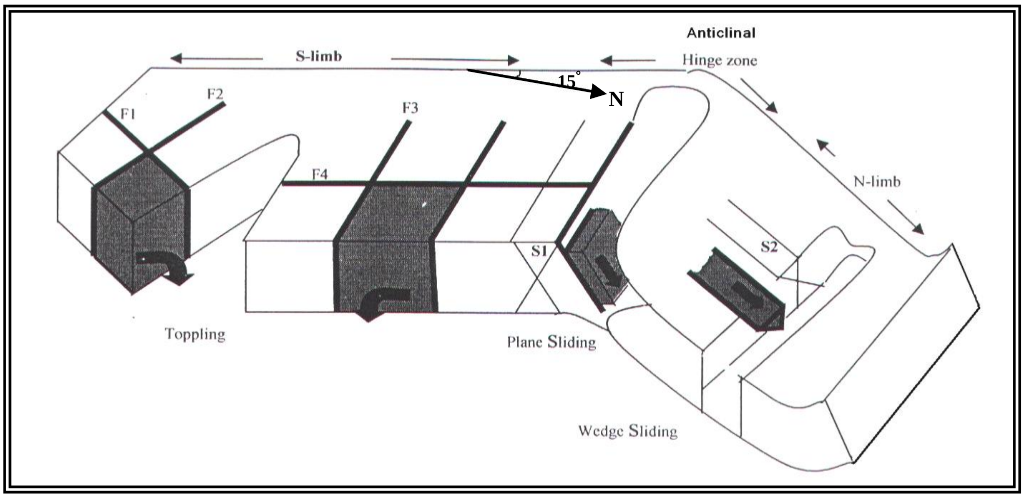


Figure 8: Schematic block diagram of the monocline and the discontinuities that control the rock block failure.

Table 2: The relationship between failure types, discontinuities and the structural position in the monoclinal fold

Station No.	Structural position	Discontinuity	Failure type
1	S.limb	F3&F4 sets	Toppling &rock fall
2	S.limb	F1&F2 sets	Toppling &rock fall
3	Hinge zone	S1 system	Plane sliding &rock fall
4	N.limb	S2 system	Wedge sliding &rock fall

Conclusions:

From the distribution and abundance of failure types and discontinuity patterns in the different structural positions of Anah monocline, the following points are concluded:

1- The discontinuity pattern varies in Anah monocline with the structural position so that certain discontinuity pattern is dominant locally in one structural position and changes to other pattern in other structural position. Thus, two pairs of orthogonal subvertical discontinuities (F1, F2, and F3, F4) are dominant in the southern (subhorizontal) limb; two sets of intersecting discontinuities in S1 system are dominant in the anticlinal hinge area, they are intersecting along lines parallel to the monocline hinge; and two sets of S2 system in the northern (inclined) limb are intersecting along lines plunging parallel to the dip direction of the northern inclined limb.

2- Failure type varies with the discontinuity pattern and their relationship with the slope so that toppling failure is associated with subvertical orthogonal sets F1, F2, F3, and F4, while plane sliding is associated with inclined discontinuities of S1 system, and wedge sliding is related to inclined discontinuities of S2 system.

3- From the above relationships in (1) and (2), it appears that failure type changes with the structural position (depending on the dominant local discontinuity pattern), so that toppling failure is common in the southern subhorizontal limb, plane sliding is common in the anticlinal hinge area, while wedge sliding is dominant in the northern inclined limb of the monocline.

4- Rockfall is common in all stations (In all structural positions) because this mode of failure is more controlled by slope steepness than structural factor like discontinuity pattern that normally governs other failure types.

References

- Al-Asade, A.A., (1996): Engineering Geological Study of Basement Rocks of Suggested Location of Rawa Hydro-Electric Power Station, M.Sc. thesis, University of Baghdad, 141p.
- Al-Mashreqi, A.H., (2003): The Study of Northern Anah Graben Boundaries Using Magnetic and Resistivity (Wenner Array) Method. Unpub. M.Sc. thesis, University of Baghdad, 205p.
- Al-Momani, M.Q., and Al-Saadi, S.N., (1998): Assessment of carbonate rock slope stability in selected sites north of Jordan, Proc. 8th. Int. Cong. of IAEG, Vancouver, Canada, A.A.Balkema, Rotterdam: Vol.5, pp. 3095-3100.
- Al-Saadi, S.N.,(1981): A Method for Mapping Unstable Slopes with Reference to the Coastline of S.W. Dyfed, Wales, Unpublished Ph.D. thesis, University of Bristol, 252p.
- Al-Saadi, S.N., (1988): Modes of failure in the rock slopes of injana area, Central Iraq, Proceedings of the Int. Symp. On the Geology of Deserts and Desert Environment, Baghdad, Vol.1, pp. 227-245.
- Al-Saadi, S.N., (1991): Composite-base toppling of rock slopes South of Degala Area, NE Iraq. J.Sc: & Nat., Vol.1, pp. 35-45.
- Al-Saadi, S.N., and Al-Hamdani, (2005): The environmental significance of rock slope instability in parts of Al-Qadsiya Lake Slopes, West of Iraq, Dirasat, Pure Sciences, Vol. 32, pp.19-31.
- Al-Saadi, S.N., and Al-Jassar, S.H.,(1993): Rock slides along Haibat-Sultan road, N. Iraq, Proc. 3rd Int Conf. on Case Histories in Geotechnical Engineering, St. Louis, Missouri, June 1-4, pp. 443-450.
- Al-Saadi, S.N., and Al-Momani, M.Q.,(1998): The stability of clastic rock slopes West of Hamrin dam area, East of Iraq, Proc. 8th .Int. Cong. of IAEG, Vancouver, Canada, A.A. Balkema,Rotterdam,Vol.2 pp.1299-1304.
- Al-Saadi, S.N., Al-Zubaydi, J.H., and Nash'at, I.H.,(1998): Toppling mechanisms in sub-horizontal-layer slopes of Tar Al-Najaf area, Middle Iraq. Proc. 8th. Int. Cong. of IAEG, Vancouver, Canada, A.A. Balkema, Rotterdam, Vol. 3, pp. 1457-1461.

- Al-Saadi, S.N., and Tokmachy, A.A.M.,(1998): Rock slope instability including new modes of failure from Sidoor Area, East of Iraq. Proc. 8th. Int. Cong. of IAEG, Vancouver, Canada, A.A.Balkema, Rotterdam, Vol. 2, pp. 1305-1309.
- Anon,(1972): The preparation of maps and plans in terms of engineering geology, Q.J. Enging. Geol, Vol.5, pp. 293-382.
- Buday, T.,(1980): The Regional Geology of Iraq. V.I: Stratigraphy and Paleogeography, Dar Al-Kutib Publ. House, Mousl, Iraq, 445p.
- Buday, T., and Jassim, S.Z., (1987): The Regional Geology of Iraq. V.II, Tectonism, Magmatism, and Metamorphism, D.G. Geological Survey and Mineral Investigation, Baghdad, Iraq, 352p.
- Consulting Scientific Bureau,(2002): Ejbail Dam Project, Internal Report, University of Baghdad.
- Evans, R.S.,(1981): An analysis of secondary toppling rock failures- the stress redistribution method, Q.J. Enging. Geol. Vol.4, pp. 77-86.
- Fouad, S.F.,(1997): Tectonic and Structural Evaluation of Anah Region, West of Iraq, Unpub. Ph.D. Dissertation, University of Baghdad, 105p.
- Fouad, S.F., Al-Marsoumi, A., Saleh, F., Hassan, F., & Nanno, H., (1986): Detailed Geological Survey of Anah area, Geosurve, Library, Baghdad.
- Hamasur, G.A.,(1991): Engineering Geological Study of Rock Slope Stability in Haibat Sultan Area , Northeast Iraq ,unpublished M.Sc.thesis ,College of Science ,University of Slahaddin ,Arbil ,Iraq .153 P.
- Hoek, E., and Bray, J.W.,(1981): Rock Slope Engineering, 3rd ed., Institution of Mining and Metallurgy, London, 358p.
- Tokmachy, A.A.M., and Al-Saadi, S.N.,(1998): Failures in structurally stable slopes in Southern Hamrin Mountain, East of Iraq, 8th Int. cong. of IAEG, Vancouver, Canada, A.A. Balkema, Rotterdam: Vol. 2, pp. 1311-1314.

Journal of Kirkuk University –Scientific Studies , vol.2, No.3,2007

العلاقة بين التركيب الجيولوجي و نوع الانهيارات في المنحدرات الصخرية في أجزاء من طية عنة أحادية الميل غرب العراق

سعد نعمان السعدي*　　باسم رشدي حجاب*　　جعفر حمزة الجوذرى **

***كلية العلوم ــ جامعة بغداد**

****كلية الآداب ــ جامعة القادسية**

الخلاصة

أظهرت الملاحظات و التقييم الحقلي لاستقرارية المنحدرات الصخرية في مواقع مختارة من طية عنة أحادية الميل(Anah Monocline) غرب العراق وجود أنواع مختلفة من انهيارات المنحدر. إن توزيع ووفرة أنواع الانهيارات تتعلق بأنماط الانقطاعات المختلفة في مواقع تركيبية متنوعة ضمن طية عنة أحادية الميل غير المتناظرة. هذه أول دراسة تربط بين أنواع الانهيارات و بين الموقع التركيبي في طية رئيسية. لوحظت هذه العلاقة في كل منطقة الطية أحادية الميل، وتم التأكد منها بدراسة أربعة محطات على طول مسار عمودي على محور الطية. أظهرت الدراسة إن الانزلاق الاسفينى (Wedge Sliding) شائع نسبيا فى الجانب الشمالي من طية عنة أحادية الميل و الذي يميل بزاوية (35 °) وفيه نظام فواصل قصية مقترنة (S_2) تغطس خطوط تقاطعها باتجاه ميل الطبقات. الانزلاق المستوى (Plane Sliding) يسود فى منطقة مفصل الطية الذي فيه فواصل قصيه مقترنة (S_1) والتي توازى خطوط تقاطعها مفصل الطية. الانهيار الانقلابي (Toppling) يسود نسبيا فى الجانب الجنوبي للطية والذي يميل بزاوية اقل من(5°) وفيه زوجان متعامدان من الفواصل العمودية (F4,F3,F2,F1) والمتعامدة مع سطوح التطبق. السقوط الصخري (Rock fall) كان فى الغالب متوفر بشكل متساوي فى كل المواقع التركيبية مما يدل على عدم تأثير الموقع التركيبي عليه. تعزى العلاقات المستنتجة إلى اعتماد معظم أنواع الانهيارات على نمط الانقطاعات والذي بدوره يعتمد بشكل كبير على الموقع التركيبي، بالاضافه إلى العلاقة بين الانقطاعات ووجه المنحدر.