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Babylon university- Collage of Science
Department of Applied Geology

Project of Research

Structural and engineering analysis of the rock structures of the Nafael Formation, Bahr al-Najaf depression

By Student

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1445 **2024**

بسم الله الرحمن الرحيم

{يَرۡفَعِ ٱللَّهُ ٱلَّذِينَ ءَامَنُواْ مِنكُمۡ وَٱلَّذِينَ أُوتُواْ ٱلۡعِلۡمَ دَرَجَٰتٖۚ وَٱللَّهُ بِمَا تَعۡمَلُونَ خَبِيرٞ}

سورة المجادلة ايه (١١)

SUPERVISORS CERTIFICATION

I acknowledge that this research **(Structural and engineering analysis of the rock structures of the Nafael Formation, Bahr al-Najaf depression)** was prepared under my supervision in the Department of Applied Geology, College of Science - University of Babylon in partial fulfillment of the requirements for the Bachelor's degree in Geology.

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Date: / /2024

Dedication

قال تعالى: (قل اعملوا فسيرى الله عملكم ورسوله والمؤمنون)

إلهي لا يطيب الليل إلا بشكرك ولا يطيب النهار إلا بطاعتك. ولا تطيب اللحظات إلا بذكرك.. ولا تطيب الآخرة إلا بعفوك. ولا تطيب الجنة إلا برؤيتك

الله جل جلاله

إلى من بلغ الرسالة وأدى الأمانة.. ونصح الأمة.. إلى نبي الرحمة ونور العالمين

سيدنا محمد صلى الله عليه وسلم

إلى من كلله الله بالهيبة والوقار.. إلى من علمني العطاء بدون انتظار.. إلى من أحمل أسمه بكل افتخار.. أرجو من الله يرحمه وستبقى كلماتك نجوم أهتدي بها اليوم وفي الغد وإلى الأبد

والدي العزيز ـ رحمه الله

إلى ملاكي في الحياة.. إلى معنى الحب وإلى معنى الحنان والتفاني.. إلى بسمة الحياة وسر الوجود إلى من كان دعائها سر نجاحي وحنانها بلسم جراحي إلى أغلى الحبايب

أمي الحبيبة

إلى منارة العلم والعلماء إلى الصرح الشامخ ..... الجامعة الإسلامية إلى الذين حملوا أقدس رسالة في الحياة إلى الذين مهدوا لنا

كما أهدي ثمرة جهدي لأستاذي الكريم **الدكتور: جعفر حسين علي الزبيدي** الذي كلما تظلمت الطريق أمامي لجأت إليه فأناره لي وكلما دب اليأس في نفسي زرع فيا الأمل لأسير قدما وكلما سألت عن معرفة زودوني بها وكلما طلبت كمية من وقته الثمين وفروه لي بالرغم من مسؤولياته المتعددة

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Abstract

The main goal of studying the faults in the study area is a greater understanding of the tectonic history of the Arabian Plate and to determine the direction of the main efforts of the region. This research dealt with the structural analysis of the joint systems found in the Bahr al-Najaf region.

One of the most effective geological structures on the rock slope stability is the orientation of the joints concerning the attitude of the bedding plane and the slope (inclination angle and direction), thus a geometrical analysis for joints has been performed for rock slopes to assess their instability; Four stations have been studied for both Tertiary rocks and Alluvial fan sediments which exist in three stations only. The main failure types in the study area are rock fall in all stations, toppling in two stations, and (potentially wedge sliding) in one station along the intersection line of the joint sets concerning the lateral slope of station No.2. While the suggested ways to improve the slope stability and protection versus rock failures are re-slope, trimming and ditches.

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CHAPTER ONE

1.1 Introduction

Many Miocene formations are exposed in the Western Desert region, including Najaf Governorate, where their discoveries appear in the Najaf Sea, 30 km to the south. The Nafael formation was chosen for the purpose of the study. This formation extends in many areas south of the Euphrates River, which extends from Al-Qaim to Samawah. Deposition dates back to the middle Miocene era in the study area, occupying many of the wide hills in the study area. This formation was recently added to the stratigraphic column in Iraq, where it includes parts of the Euphrates, Nafael, and the lower part of Injana, as explained and announced by Sissakian et al (1997). Geologically, the study area is located within the secondary Salman range, which belongs to the stable pavement range. Which is characterized by shallow basement rocks (Goff and Jassim 2006). The exposed formations in the Bahr al-Najaf area, in ascending sequence, are: Dammam, Euphrates, An-Nafail, Injana, Al-Zahra, and Dabdaba, in addition to Quaternary sediments. Geological map showing formations exposed in the geology (after Sisakian 2000)

1.2 Aim of the study

Analyzing the joint systems in the studied area and shedding light on their origin and the mechanics of their development. The research included several field, laboratory, and office aspects by collecting information about the region and modeling to conduct laboratory tests to study the characteristics.

1.3 Geology of the study area

At the end of the Middle Eocene, the stable shelf, except for the north-south trending strip in the Rutba Ridge, was covered by a shallow coastal basin (Jassim and Goff, 2006), where sediments of the Dammam Formation were deposited (Buday and Jassim, 1987). This was followed by an increase in uplift and folding processes during the Oligocene era associated with a broad marine retreat, causing the emergence of some confined and restricted basins in the northwestern to southeastern parts of Iraq (Buday, 1980). The Oligocene basin is located in the Mesopotamian range. The Salman range and the secondary ranges of the Euphrates and Zubair in Mesopotamia underwent uplift in Oligocene time (Jassim and Goff 2006). As a result, there are no deposits in the study area in the Oligocene to early Miocene period. A new marine advance then occurred in the Miocene. During the early Miocene, the sedimentary basin in the region was very shallow and relatively coastal at first, which led to the deposition of clastic and limestone rocks such as the Euphrates Formation. In the middle Miocene, the development of the basin was similar to what it was during the early Miocene. At first, limestone deposits were deposited in the waters. The shallows represented by limestone (Nafael Formation) (Jassim and Goff, 2006). In the late Miocene to Pliocene, a re-uplifting process occurred again over the entire area of the stable shelf. The paleogeographical development was directly affected by this movement, and is characterized by the deposition of continental clastic coinciding with molasses with continued sedimentation, which The still faint and mobile Injana Formation later characterized the Quaternary with the development of river systems (Buday, 1987).

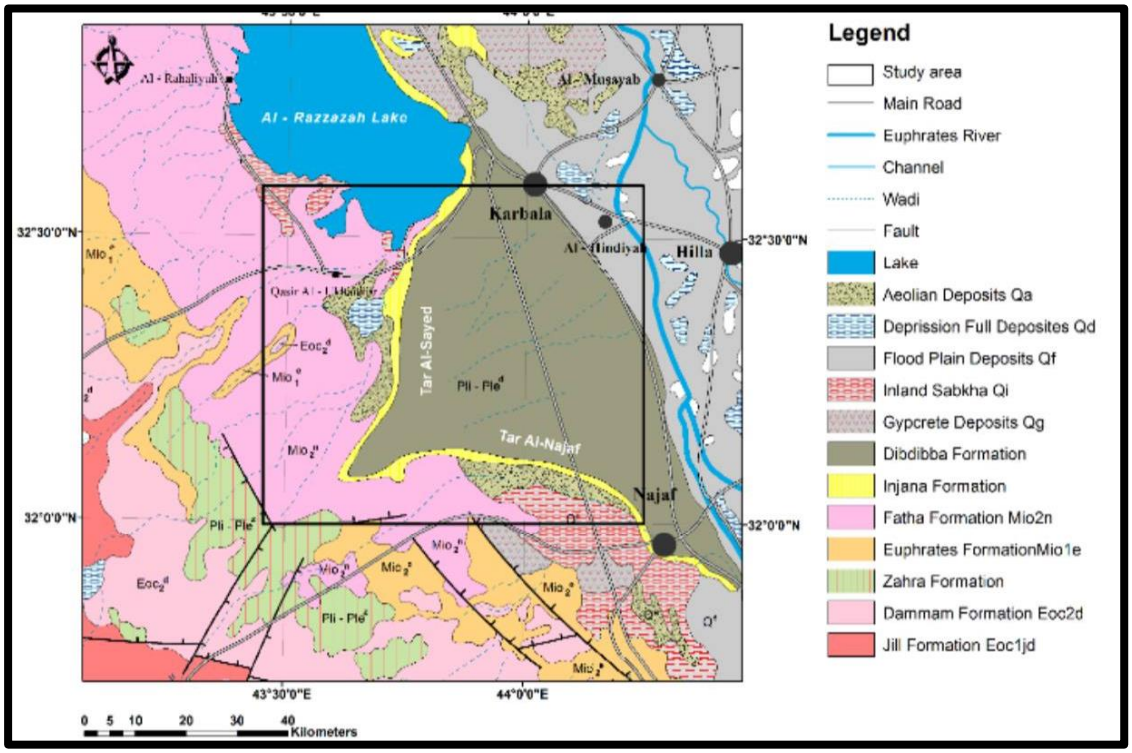


Figure (1.1) Shows a geological map of the study area (Barwary and Slewa 2013)

CHAPTER TWO

2.1 Structural Geology

is one of the branches of earth science. It is concerned with studying the secondary earth structures resulting from the exposure of earth crust rocks to the process of deformation due to tectonic and non-tectonic forces. Structural geology is divided into two main branches: (Fig 2.1)

- **Structural analysis** is one of the branches of structural geology, which is concerned with studying the earth's structures geometrically and structurally. Therefore, it is divided into engineering analysis and structural analysis.

(1) Geometric Analysis includes direct measurements of the physical characteristics of the rock body, thus determining the type of structure and its geometric dimensions.

It can be said that engineering analysis is concerned with answering questions that begin with (what and where).

(2) Genetic Analysis includes two types of analysis: nematic analysis and dynamic analysis. It can be said that structural analysis is concerned with answering questions that begin with (why, how and when). **It is of two types:**

- Kinematics Analysis, which is an explanation of how the deformation process occurs in the rock body, that is, it is concerned with the study of ductility.

-Dynamic Analysis: The goal of this analysis is to reconstruct the force that caused the deformation of the rock body, that is, it is concerned with studying stress

- **Geotectonic** is one of the branches of structural geology, which is concerned with studying how the forces that make up Earth's structures arise.

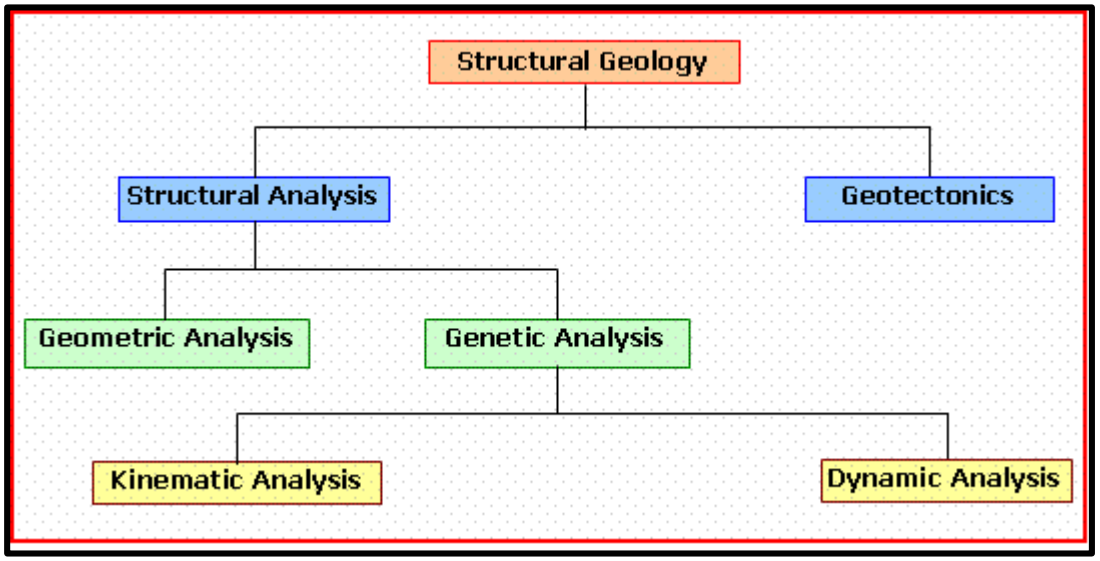


Fig 2.1 Flow chart showing the branches of structural geology

2.2 Geological structures

They are geometric patterns of rocks whose dimensions, shapes, and distribution can be determined. Depending on the reasons for their formation, they are divided into two basic types: (Figure 2. 2)

(1) Primary geological structures

These are the geological structures that are formed during the sedimentation process, that is, they are formed as a result of non-tectonic causes. Examples include: stratigraphic structures, cross-stratification, mud cracks, and neem marks.

(2) Secondary geological structures

These are the geological structures that are formed after the completion of the sedimentation process, that is, they are formed as a result of tectonic causes, examples of which include: folds, fractures, which include joints, fissures, veins, and faults, salt structures, and igneous structures, and these secondary structures are what the science of structural geology is interested in studying, with its branch represented by compositional analysis.

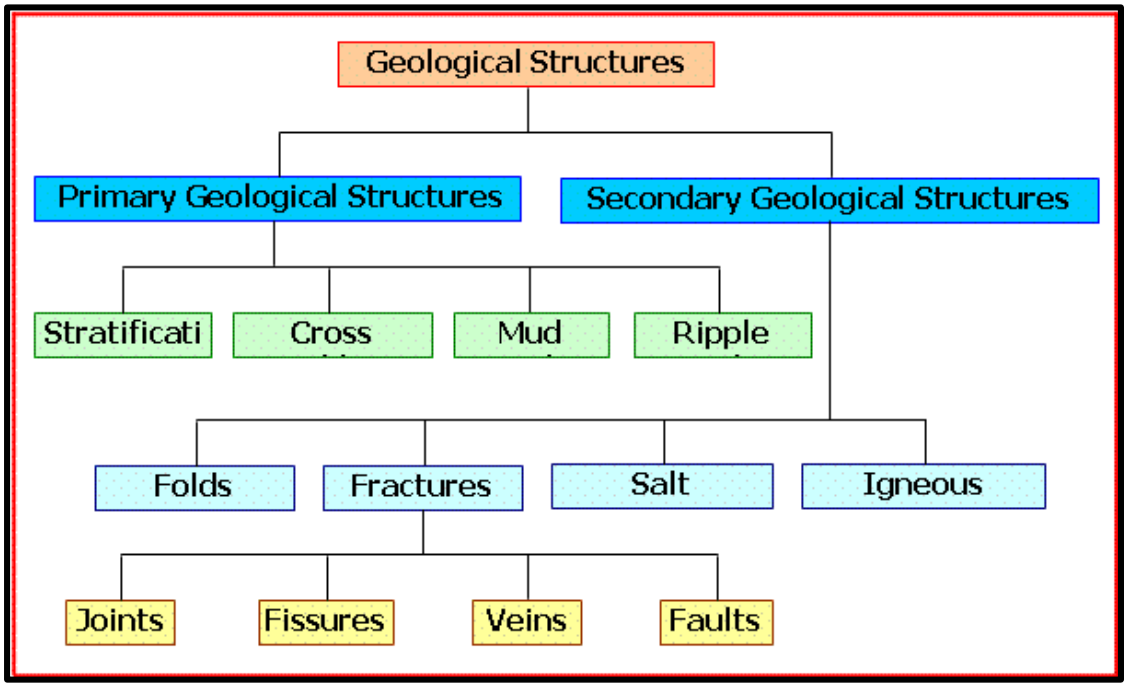


Fig 2.2 A diagram showing the divisions of primary and secondary geological structures

2.3 Geomorphology

The geomorphological phenomena in the study area are:

1-Units of Structural–Denotational Origin: Structural Ridges Escarpments. This feature is attributed to the tectonic activity due to the thrusting of the northeastern limb of Hemrin South anticline above the northeastern limb (Al-Musawi, 2020).

2-Units of Fluvial Origin:

A- Alluvial fan: The alluvial fan is recognized by its flat surface and gentle slope with an irregular width that can exceed 12km, it is composed of poorly sorted clastic sediments often gravels, cobbles, and boulders with less amount of sand, silt, and clays (Al-Musawi et al., 2020).

B- In-fill valley: It is characterized generally by well-rounded gravels composed of gypsum, limestone and sandstone, their size ranges from 2-5cm, and the total thickness of these sediments does not exceed few meters (Al-Musawi, 2020).

2.4 Materials and Methods

Joints are brittle structures and they are found often everywhere at the crust (Fossen, 2016). The stability of rock slopes is usually influenced by the structural pattern of

the rock in a slope, the important structures affecting the stability of rock slopes are the discontinuities including (bedding plane, joints …etc. (Hoek and Bray, 1981; Hostani and Hamasur, 2022). The joints are the most common defect planes in the rock masses, the estimation of slope stability within the same slope may vary according to the orientation of the slope concerning the orientation of discontinuities (Kliche, 1999). The discontinuities measured in this study (joints and bedding planes) have been obtained from Four stations along Nafael formation. The attitude of the bedding plane as well as of the joints has been measured, and the slope parameters (attitude, height, and length) were measured also. The joints have been classified concerning the three orthogonal tectonic axes according to (Hancock and Atiya, 1979; Hancock, 1985). Rock slope stability assessment was performed according to the poles of planes plotted by stereographic projection (using stereonet10 software) according to (Wyllie and Mah, 2004).

CHAPTER THREE

3.1 Analysis Rock Slope Stability

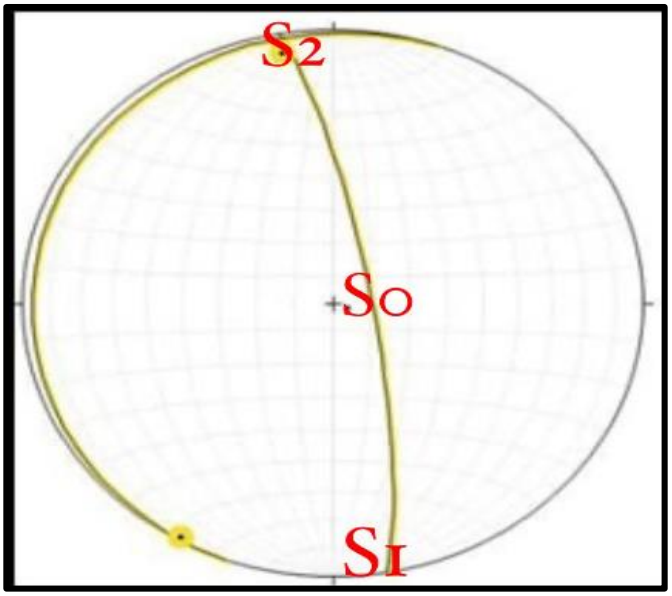
Four stations have been measured and five types of joint sets are recorded (Table 3.1).

Table 3.1. Joint sets of the study area

Station No.	S0	S1	S2
St.1	hol	hkl	-
St.2	hko 1>a	hko2>a	-
St.3	ac	hko	-
St.4	hkl	ac	-

3.1.1 Station No.1

The beds of the Nafael Formation (the exposed thickness is 5.0m) are exposed in this station and covered by approximately 4m of Alluvial fan sediments forming angular unconformity, the total height of the slope is about 9m. The dip of the bedding plane is 251/46, and the beds are segmented by two sets of joints (ac): 351/80 and (hko): 082/47. The main slope inclination is 016/78. S1 acts as the back release surface and S2 acts as the lateral release surface, segmenting the beds into blocks (Fig.3.1). The alluvial fan sediments have cracks that develop into tension cracks near the end of the slope face.



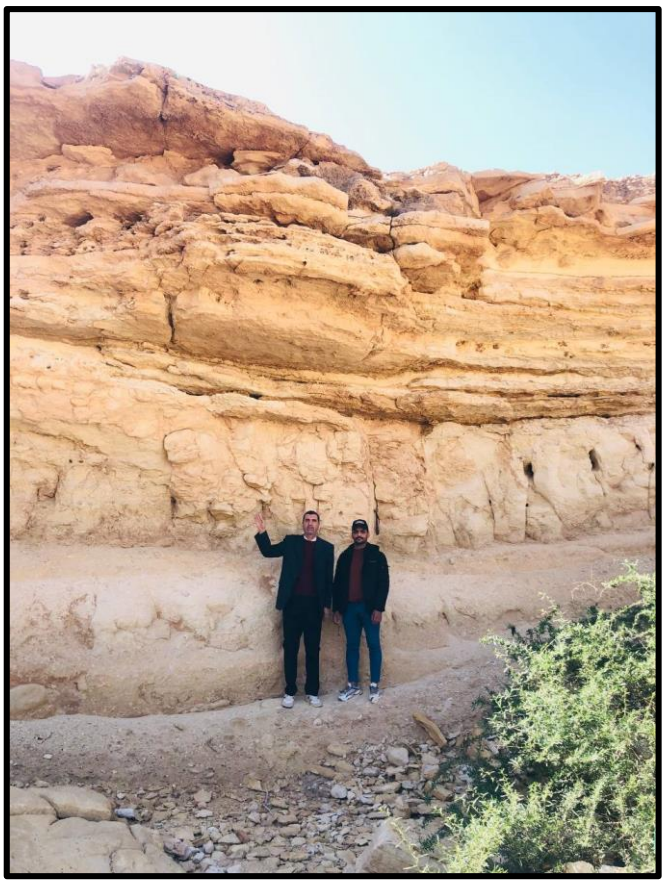


Fig (3.1) Station No.1: a) stereographic projection; detached block and general view

3.1.2 Station No. 2

The beds of the Nafael Formation rocks (the exposed thickness is 6.5m) are exposed in this station, covered by 0.4m of gypcreat. The attitude of the bedding plane is 011/28, segmented by two sets of joints, (hkl): 227/87 and (ac): 340/89. The slope face is step: 068/80. The spacing of S1 in the gypsum bed is 220cm and of S2 is 115cm; in the underlain marl bed is 10cm for each one, while the spacing in the claystone bed at the bottom of the exposure is 75cm and 60cm respectively. S1 set acts as a lateral release surface and the S2 set acts as a back release surface

The failure mode: the failure that has occurred is rock fall, detached blocks were fall-down with various sizes ranging from 8.0cm up to 2.4m. The potential failure mode is rock fall. Fig (3.2) illustrates station No.2

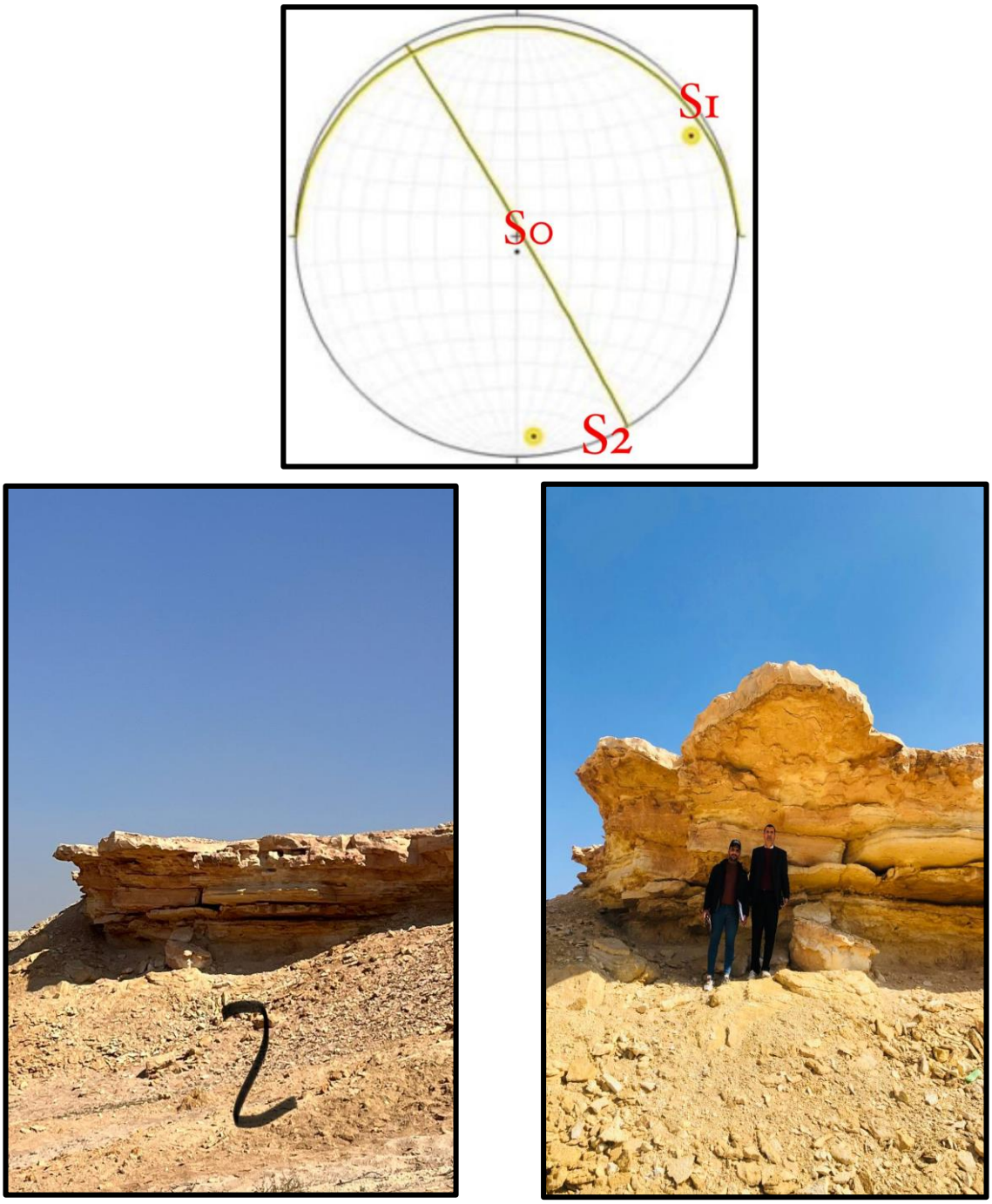


Fig (3.2) Station No.2: a) stereographic projection; detached block and general view

3.1.3 Station No.3

Nafael Formation rock beds (7.5m) are exposed in this station and covered by approximately 1.5m of Alluvial fan sediments forming angular unconformity, the total height is 9m. The dip of the bedding plane is 064/25, and the beds are segmented by two sets of joints (293/72 and 181/74) making a system of hko>a. This area has two slopes, the main slope inclining 171/90 and there is a lateral slope inclining 084/36. The lateral slope composed of remnant gravels from the weathered alluvial fan with rock fragments of sandstone of the Injana Formation, both are ranging in size from 2.0-30.0cm.

The failure mode: the main failure modes along the general slope are rock fall and toppling; the fall-down blocks ranging in size from 25.0cm reach up to 3.0m, and the potential failure type is rock fall and toppling too. The failure type that occurred along the lateral slope is (rolling) rock fall, the potential failure that may occur in the future is rock fall, and wedge sliding when the toe of the lateral slope will be eroded or cut by erosion processes or by human activity in order to daylight the bedding plane on the slope face. Fig (3.3) illustrates station No.3

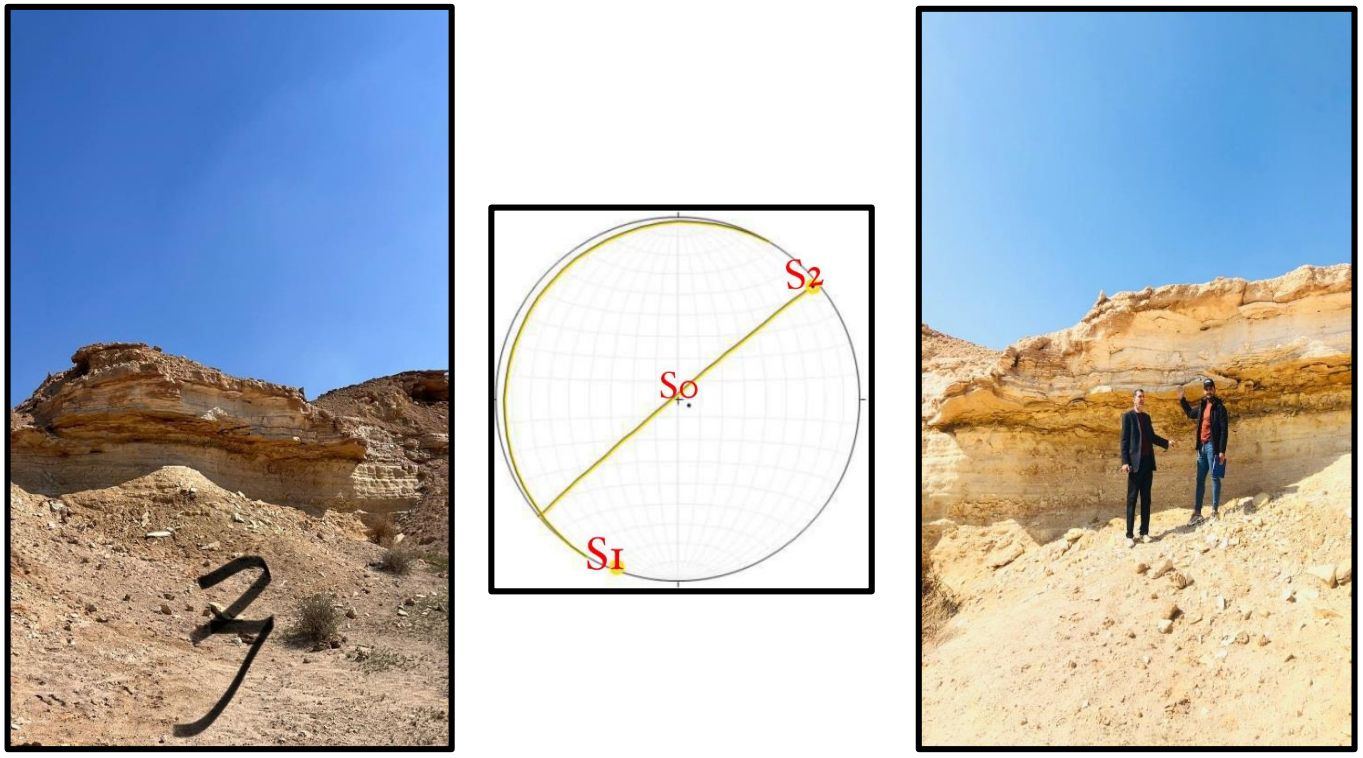


Fig (3.3) Station No.3: a) stereographic projection; detached block and general view

3.1.4 Station No. 4

The rocks of Nafael Formation are exposed in this site, the attitude of the bedding plane is 014/40, the beds are segmented by three sets of joints, (hkl): 179/71, (hkl): 226/73 and (okl): 340/39. The main slope attitude is 157/35. S1 set acts as a back release surface, S1 set acts as a lateral release surface and S2 set acts as a base surface, effecting together to segment the bed into blocks.

The failure type: The failure type that has occurred in this station is rock fall, the fall down blocks ranging in size from 0.3m to 3.0m, the reason for the variation in size is the variation in the persistence of the S2 joint set. The potential failure is rack fall.

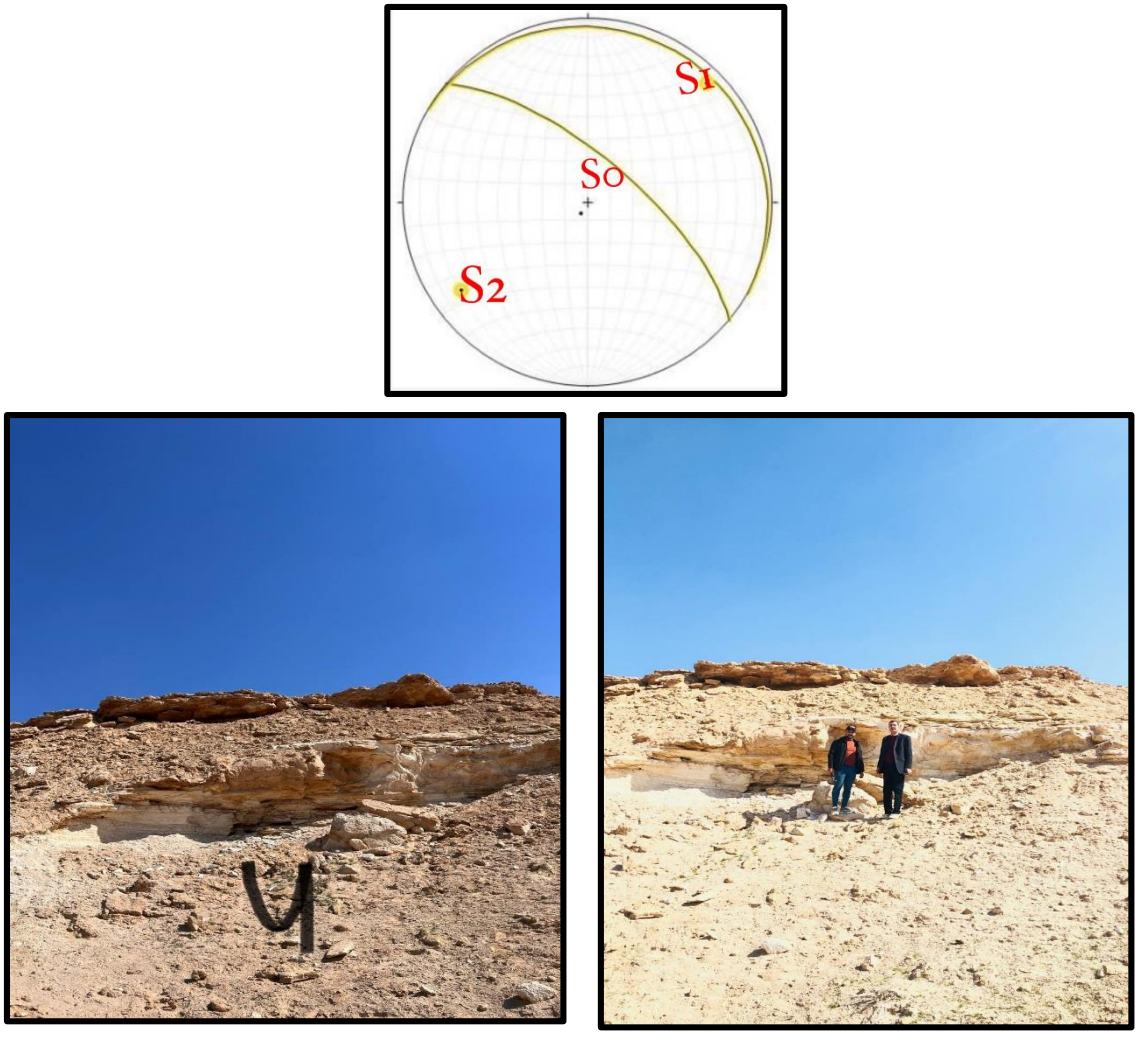


Fig (3.4) Station No.4: a) stereographic projection; detached block and general view

CHAPTER FOUR

4.1 Conclusions

The exposed rock beds in the study area belong to the Nafael Formation and Injana Formation, The Quaternary sediments belong to the alluvial Fan and infill Valley. The joints in the studied area are (hkl, hko, hol, okl and ac), the dominant type is hkl. All five studied slopes are unstable, the main types of failures had occurred are rock fall in all the studied stations, and toppling in stations 1 and 2. The potential failures in the rock slopes are rock fall in all stations, toppling in stations 1 and 2, and wedge sliding may occur in station No.2 at a lateral slope. The improvement of rock slope stability and protection versus failures were suggested; these ways are re-slope, trimming, ditches and wire mesh.

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الملخص

ان الهدف الرئيسي من دراسة الصدوع في منطقة الدراسة هو فهم أكبر للتاريخ التكتوني للصفيحة العربية وتحديد اتجاه الجهود الرئيسية للمنطقة. تناول هذا البحث التحليل البنيوي للأنظمة المشتركة الموجودة في منطقة بحر النجف.

من أكثر التراكيب الجيولوجية فعالية على ثبات المنحدرات الصخرية هو اتجاه الفواصل فيما يتعلق بوضع مستوى الفرشة والانحدار (زاوية الميل واتجاهه)، وبالتالي تم إجراء تحليل هندسي للفواصل للمنحدرات الصخرية لتقييم مدى تماسكها. عدم الاستقرار؛ تمت دراسة أربع محطات لكل من الصخور الثلاثية ورواسب المروحة الغرينية والتي توجد في ثلاث محطات فقط. أهم أنواع الأعطال في منطقة الدراسة هي سقوط الصخور في جميع المحطات وانهيارها في محطتين و(احتمال الانزلاق الإسفيني) في محطة واحدة على طول خط تقاطع المجموعات المشتركة بالنسبة للمنحدر الجانبي للمحطة رقم ٢. بينما الطرق المقترحة لتحسين ثبات المنحدر وحمايته من انهيارات الصخور هي إعادة الانحدار والتشذيب والخنادق.

وزارة التعليم العالي والبحث العلمي

جامعة بابل-كلية العلوم

قسم علم الأرض التطبيقي

مشروع بحث التخرج

التحليل التركيبي والهندسي لتراكيب صخور تكوين النفايل منخفض بحر النجف

للطالب

حسين حمودي يوسف محمد حسن

بكالوريوس علوم /علم الأرض التطبيقي

العام الدراسي ٢٠٢٣-٢٠٢٤

بأشراف

أ.د. جعفر حسين علي

٢٠٢٤م ١٤٤٤ هـ