THE GEOLOGIC CONTRIBUTION TO MOUNTAIN SLOPE INSTABILITY AND ITS EFFECT ON LANDSLIDES. A CASE STUDY TO THE GHARIAN AREA, NW LIBYA

Emhemed Ali Alfandi[1*] and Mahmoud Alghadban Meeloud[2]

[1] Department of Geology, Faculty of Science, University of Sabratha
[2] Higher Institute of Engineering Sciences - Technology, Gharian Department of Oil and Gas
[*] emhemed.alfandi@sabu.edu.ly

Abstract

This research investigates the causes of Landsides at Gharian Tripoli highway. Geomorphology, geology, and climate play the most important role in preparatory process of landslide initiation in any region.

The area has specific geological features, where the clastic rocks formations and carbonates formations exhibit good exposures that give a clear knowledge for causes of the landside. Data presented here are based on a detailed fieldwork mapping and analysis of rainfall statistical data, which were monitored from 2011 until 2019.

The results of this study confirm that the weakness in the rock blocks will lead to the movements of the most important rock fall (Landsides) because the angle of stability of blocks ranging from (60 - 89) with NNW faults -dipping steeply NE and down throwing to the NE.

The excavation works used to make the Gharian Tripoli highway on the slopes had significant impact in determining the angle of stability of the blocks and making the rock (road cut) more susceptible to erosion factors.

Keywords: Landsides; Field work; Faults; slope; Rainfall; Rocks; Gharian Tripoli highway; Libya.

Introduction

Natural hazard is defined as the probability of occurrence of potentially phenomena with specified period of time and within a given area. Landsides constitute one of the major hazards that cause losses in lives and property and costs worth billions of euros (Varnes, 1984 and Gar, 2009).

Landsides studies involve complex analyses with multitude of factors and used to be studied systematically in order to evaluate the hazard. Increasingly computer based tools are found to be useful in landsides mapping.

Geomorphology, geology, and climate play the most important role in preparatory process of landslide initiation in any region. Geological factors like faults, rocks, and fractures are of the factors that may influence the movement of slope. The factors, which are usually related to landsides, are geology, soil type, land surface temperature, land cover, slope aspect, slope inclination, land elevation, and underground water level due to the usual large extension of the rainfall events (Dubey et al., 2005; Dikishit and Satyan, 2018). Normally the cause of landslide is determined by carrying out some soil sample, rock, slope, inclination, and geology, (Abdul Rahman and Mapjabil, 2017). Gharian area has many types of rocks and different degrees of slope. It is important for this research to be done, as it will help engineers in decision making about landsides, and planning of roads and other constructions.

Location of the Study Area

The study area is a part of Gabel Nafusah escarpment, which is located in northwest Libya about 60 km south of the Mediterranean coast with Wadi Ghan to the east and 56 km from Kiklah to the west Figure (1).

This area is bounded by the Ghadamis Basin in the south and the Jafarah Basin to the north. Mesozoic strata outcrop in northern Libya and south-eastern Tunisia where an almost complete sequence from Triassic to Cretaceous; it is known as one of the few areas in the whole African continent (Bishop,1975).

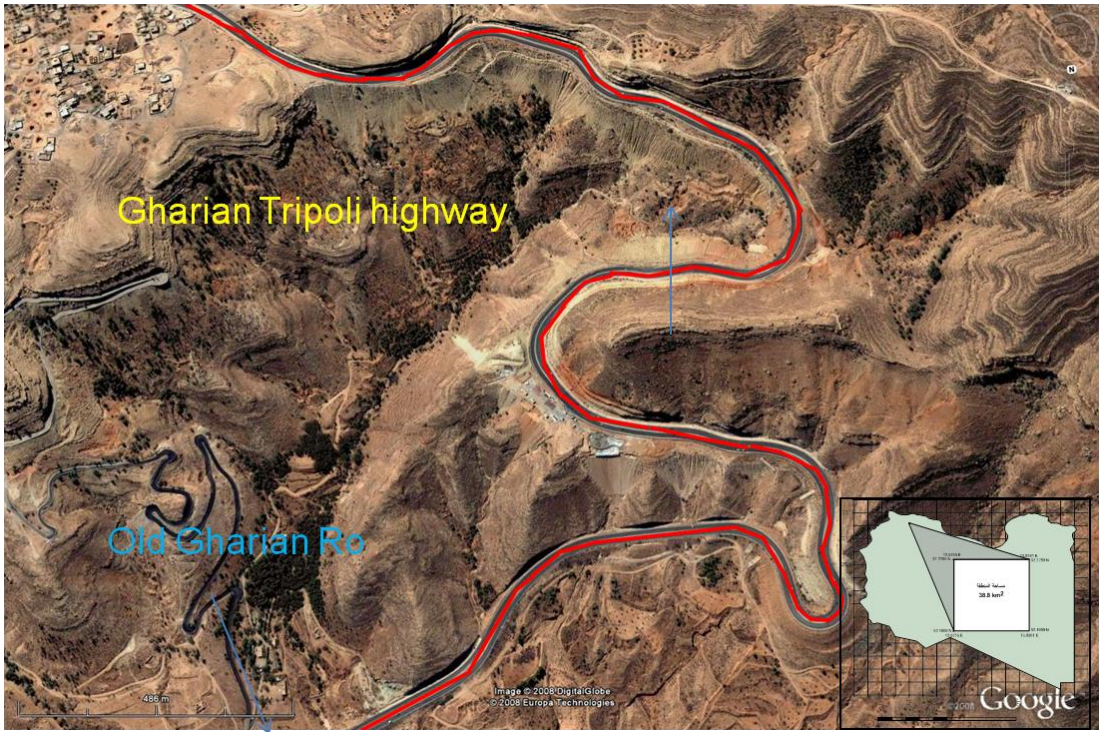

Figure (1): Map Showing Location of Studied Area (Gharian-Tripoli Highway).

Methodology

The main source data used in this study consists of

- A Google earth satellite image, a geologic map and a 1:50,000 scale topographic map sheet numbers 3/1989, which was obtained from the Libyan Industrial Research Centre, were used for detecting the topography and sequence stratigraphic of the Gharian area.
- The cumulative monthly and annual rainfall data monitored from 2011 to 2019.

The research was carried out systematically in three phases: (i) Site investigations carried out in the field (Gharian Tripoli high way) (ii) Analysis of rainfall Statistical data gathered from agencies, and also from previous literatures.

(iii) Software used to produce the landslide inventory, the factor maps (Slope gradient, slope aspect, elevation etc.

Results and Discussion

1. Geology of the Landsides Area

Gharian Tripoli high way has not been thoroughly studied; this study highlights the factors that contribute to the landsides such as rocks and rain. The study area is located within the Jabel Nafusah Uplift NW Libya and its main rocks are Mesozoic rocks (Desio, 1971; Desio et al, 1963; and Alfandi, 2012) which are divided into seven information's Figure (2). The Triassic-Early Cretaceous succession in Gharian area consists of the Middle Triassic Ras Hamia (Kurrush) Formation, and Late Triassic Aziza, Abu Shyabah, Abu Ghayian and Kikiah Formations, followed by the Late Cretaceous Sid. Sid consists of two members namely, the lower unit which is Ain Tobi member and the upper unit which is Yifran member.

Gharian Formation which overlies Yifran Member and is composed of hard crystalline dolomitic limestone contains bands of chart (El-Hinnawy and Cheshitev, 1975). This sequence was exposed because of Aziza Fault zone (Miocene age) and later by the up doming of these sediments which resulted from the up rise of the phonolitic and trachytic mush type magma during Tertiary. The highest elevation in this area is 750 meters above sea level.

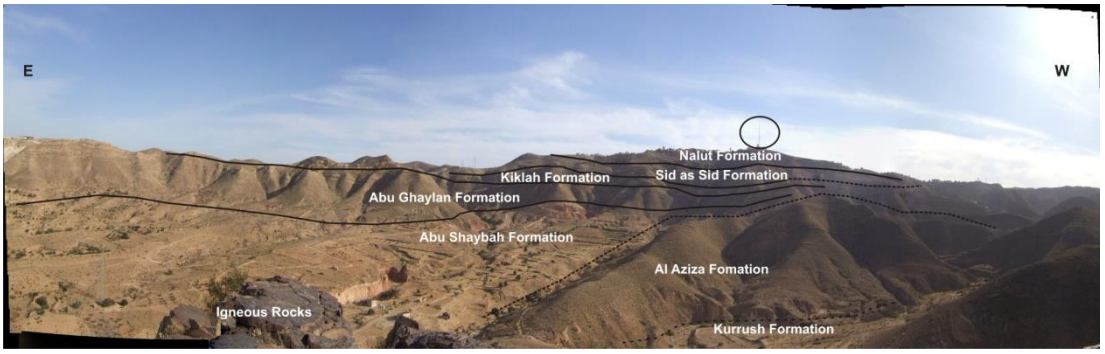

Figure (2): Photographic Image Showing the Main Formations at the Gharian Area.

Results from Site Investigation

The results from the site investigation retrieved from Google earth Satellite images of the landslide, the morphology of the landslide, and the sample location points are presented below.

1. Fault Plains and Joints

Faults and joints in the field area were undertaken by a series of traverses at two principle locations, primarily along Old Gharian Tripoli road and Gharian Tripoli highway, which provided the best-exposed sections.

Mapping results show that there are three faults trends in the study area Figures (3) and (4). These (NW-SE) faults modify when they steepen up strata or when the faults actually appear to cut the NE-SW structures. The NE-SW orientated across the road reveals a slightly simple overall structure in those strata Figures (5) and (6) that have a component of dip similar to those essentially dip gently south. The NW-SE trend is related to Ghadamis Basin during the Early Palaeozoic time when deposition was effected by the NNW-SSE uplifts of the Tamboka in the west and the Tripoli- Tibisit Arches (Antketell and Ghellali, 1991).

The NE-SW fault trend is related to the movement which led to the uplift of several ENE-WSE arches and erosion of the lower Palaeozoic rocks, particularly along the Dahar –Nafusah uplift in NW Libya and central Tunisia (Antketell, 1991; Gabtni, 2009).

The E-W fault trend is related to the third major fault system that runs from west to east near Al Aziza town, where it joins the SE trending Wadi Ghan Fault Zone (Boote et al, 1998; Swire and Gashgesh, 2000).

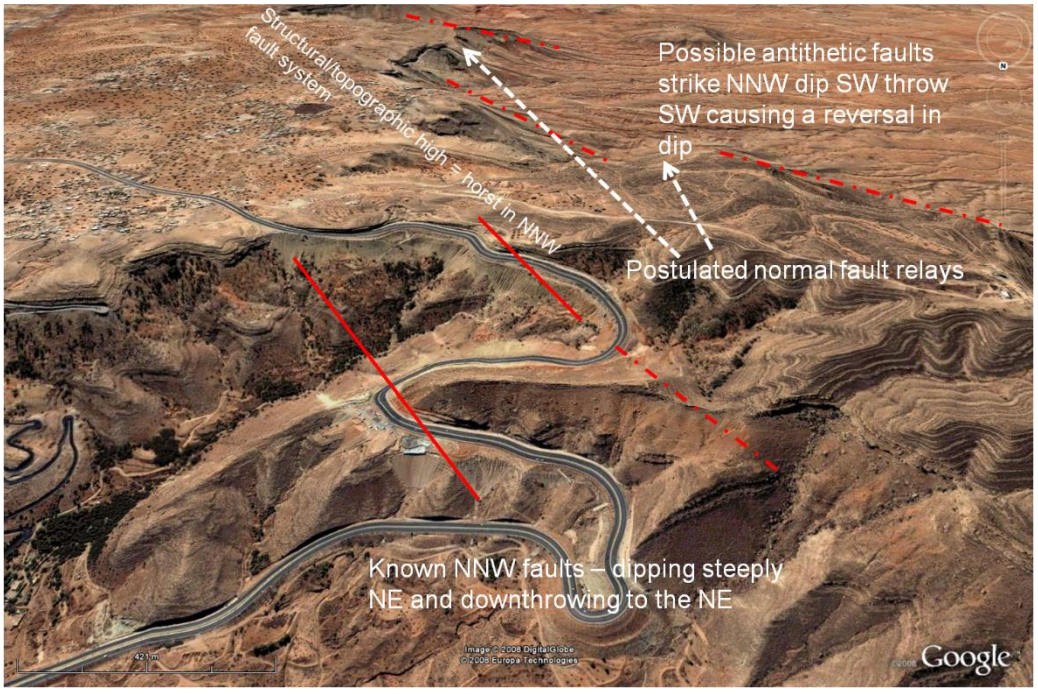

Figure (3): Front View of The Google Earth Satellite Image of The Landslide and Displacement in the Kiklah Formation Due to an NNW Fault Parallel to the Image.

Figure (4): Picture of Fault, Showing the Threat Posed this Fault Instability on Road Users.

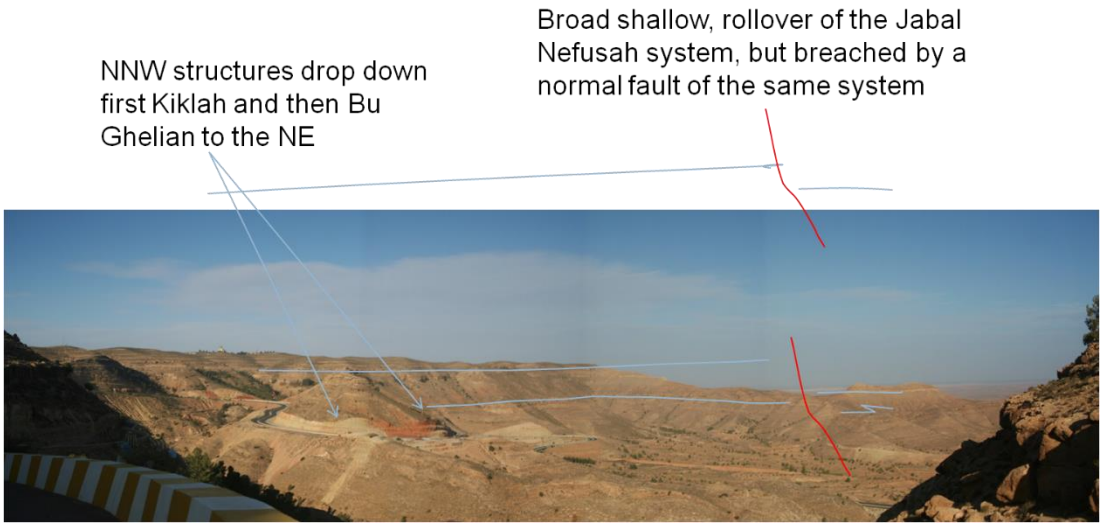

Figure (5): Nafusah Escarpment North of the Village of Abu Ghaylan. Kiklah Formation Displaced by Two Major Normal Faults of the Jabel Nafusah System and Forming a Broad, Low Amplitude Anticline Between Them.

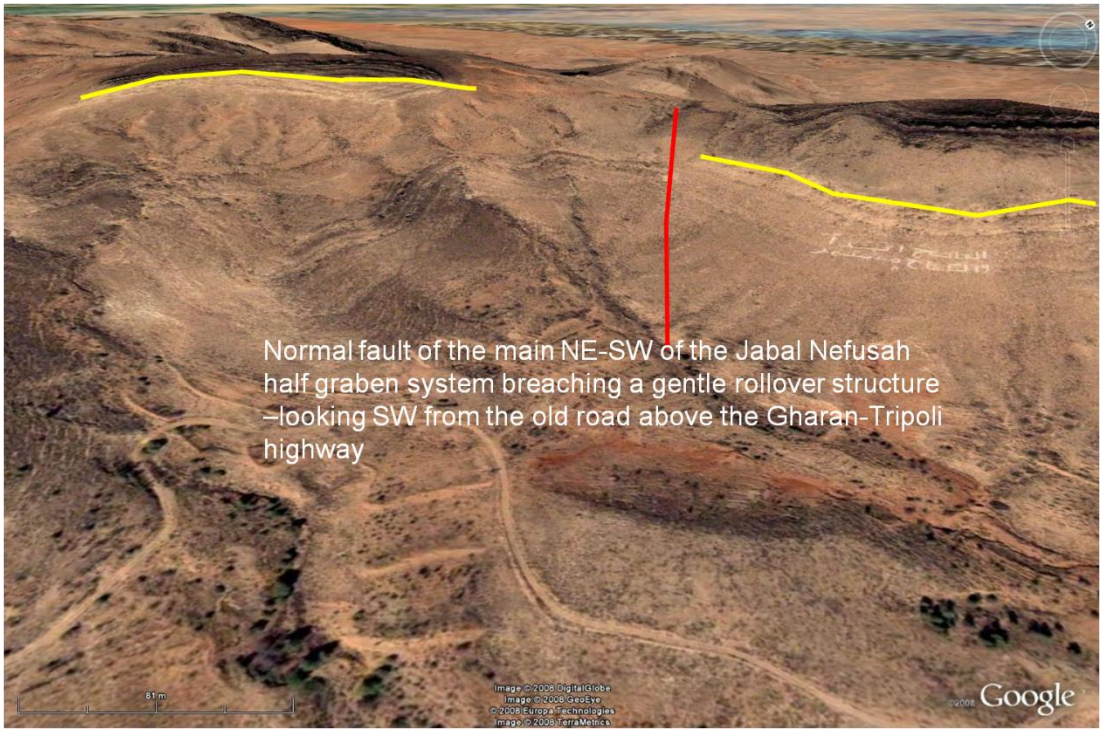

Figure (6): Normal Faults Showing a Significant Offset of the Abu Ghylan and Kikalah - Looking SW From the Old Road above the Gharan-Tripoil Highway.

Results From Rainfall Statistical Data

Gharian area has plateau climate: high rainfall and humidity, and low winter temperatures. Records of the rainfall in the area from 2011 till 2019, the monthly rainfall data in 2011, and the cumulative monthly rainfall data in year 2011 until 2019 were analysed. Figure (7) shows the amount rainfall from 2011 to 2013, the monthly rainfall values in 2014-2016, and the cumulative monthly rainfall values of 2017-2019.

Analysis shows that monthly rainfall in 2011- 2019 increased gradually and got a peak value of rainfall during the winter but great variability can be observed among the different locations. The intensity in winter was high enough to trigger the landside occurred in Gharian Tripoli highway; the accumulation of water in the Kikalah sandstones and Abu Ghyalan Formation increased the pore pressure and reduced the shear strength of the sandstone.

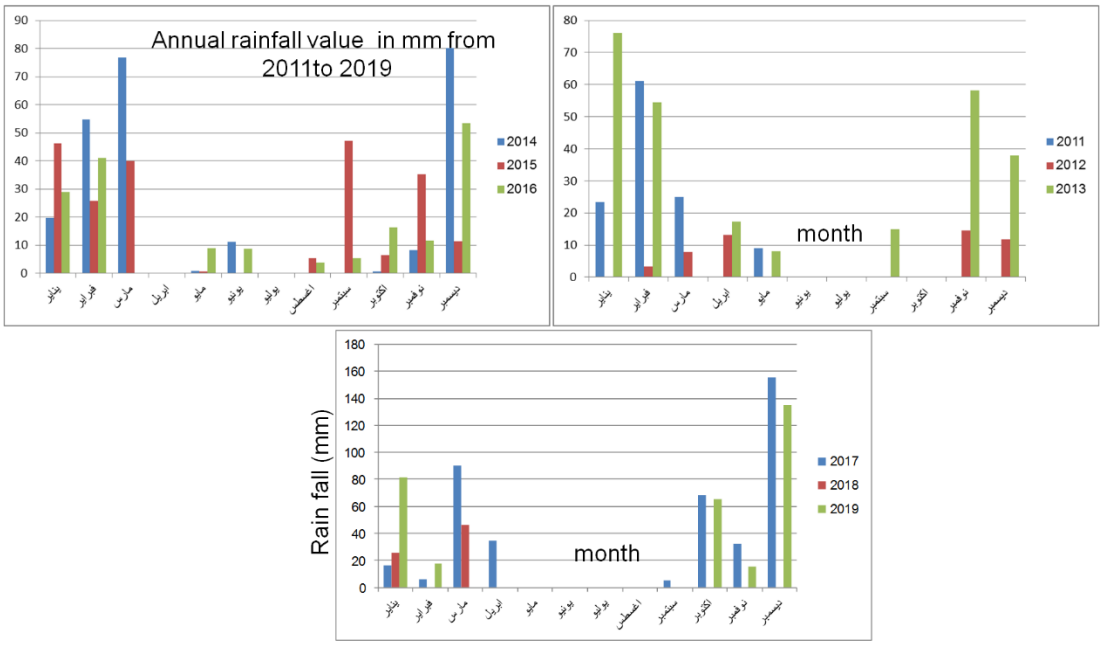

Figure (7): Rainfall Statistical Data.

Geomorphological Features

Geomorphology, geology, and climate play the most important role in the preparatory process of landslide initiation. The rock type is mainly formed of Limestone due to the formation of Sidi as Ain Tob member and soft rocks that are highly affected by chemical and physical weathering. Therefore, when the erosion surface cuts into carbonates (such as Sidi as Side Formation), it is topographically normal as dissolution is very slow. On the other hand when the erosion surface reaches the intervening

clastics (Such as Kiklah Formation), it becomes readily inverted as they are rapidly eroded by the highly seasonal natural of the run-off in flash events (Simms, 2004).

The carbonate rock reduced the chemical weathering effect and increased the mechanical weathering effect caused by the thermal effect. The highest ridges are capped by Ain Tobi carbonates and Abu Ghylan Formation with a clear intervening step between them that reflects erosion of clastics rocks (Kiklah Formation). These clastics rocks are exposed in escarpment between the two carbonates Figure (8) and are considered the most important from a geomorphological point and a catalyst factor for the movement of the blocks into Gharian Tripoli High way Figure (8). This is because the angle of stability of blocks ranges from 60 to 90 degree.

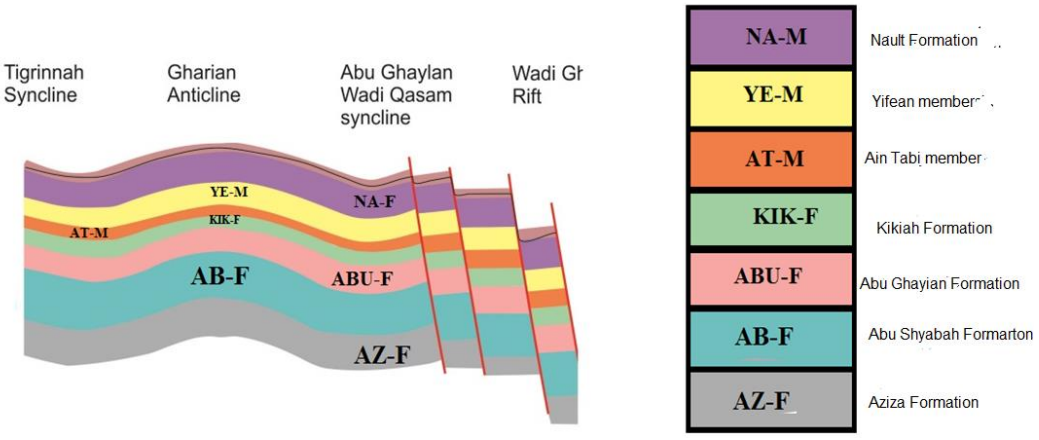

Figure (8): Differential Erosion and its Interplay with the Main Structures over Time.

Conclusions

The study has shown that the use of a combination of investigations such as, rainfall statistical data, geology (faults, lithology, geomorphology) is successful in landslide investigation. A number of important conclusions are listed below.

1. Landsides occurrences are widespread in some part of Gharain Tripoli highway.
2. Rock slope is very important before and after cutting rocks (road cut). Rock affects the main road construction in Gharian Tripoli highway and consequently has a profound effect on slope stability
3. The slope of land is major contributing factor to the occurrence of landside and is closely related to many other factors that include climate, lithology, structure, and geomorphic history.
4. The occurrence of landslides associated with higher cumulative rainfall is because of the increase of pore water pressures within the slope material.

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