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Research Article

El Kalaeet - El Foula Area Cracks in the West Kordofan State, Sudan: Environmental Impacts and Geological Hazards

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I N F O

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A B S T R A C T

Nemours surface cracks appeared suddenly in the West Kordofan State in the southwestern part of Sudan. These cracks demonstrated from El Foula town to El Kalaeet area about 10 km north Babanosa city. The occurrence of these cracks resulted from a heavy rainfall gives preliminary indications of the relationship of these phenomenon with the (surface or subsurface) water. Their actual depth reach to six meters, the three-fold shapes attributed to the precise cracks that originally existed in the affected layers. Cracking zones reflect areas in which water is easier to penetrate into deeper zones, indicating their connection with the subsurface water.

The cracks had different sizes ranging from few centimeters to several meters and orientations generally from north to south, and some where they characterized by triangular forms. These phenomena were resulted due to the internal leakage and horizontal groundwater movement from the runoff of the rainfall in the surface towards the main basin in the area.

The detailed investigations indicated that there is no problem for this event, but there are some precautions people must have to take into consider. In addition, people should avoid the distribution of the opening cracks and fissures for any reason as far as they could to avoid any geological hazards and environmental impact in the area that resulted due to these cracks.

Keywords: Cracks, Geological Hazarad, El Foula, Sudan, West Kordofan

Introduction

West Kordofan State which is located in the south western part of Sudan between longitude 28°10´ and 29°00´ E and latitudes 12°30´ and 13°10´ N. containing numerous basins areas in Sudan and famous of ground water and even petroleum and gas, beside the agricultural and animals hurts activities. The geological characteristics of the area let it to be affected by variable surface structures such as cracks within the rock units structures. In June 2018 arround El Kalaeet area about 10 km north Babanosa city many cracks and fissures appeared after a heavy rain falls in the area, which make the people worried about the Environmental impacts and the hazards due the this

phenomena. Local media reported that some of these crack and fissures are as much as 50 meters deep and up to few kilometers wide. Few days later the same cracks and fissures appeared again in another places far away from the first appearance, this time in El Foula city the capital of the West Kordofan State. These phenomena become a general issue for the governments of Sudan and this State; therefore, these events must be study in detail to reveal what was hide for the whole. In this article, we conducted a detailed study for the El Kalaeet area and El Foula area in order to reveal the initial beginning of these cracks. Moreover, the reasons, types, orientation, sizes, continuation, field relationships, describing orientations are measurements, the internal textures are particularly striking of these cracks and its environmental impacts with the involve geological hazards, also to find solutions for any related effects in the area and how they can avoid them.

Literature Review

Earth cracks can be defined as large fissures in the ground formed as a result of soil surface tension due to lowering of the ground surface elevation, which is mainly caused from groundwater pumping or any other geological processes. The cracks or fissure zones normally occur parallel where softer soils abut bedrock (Zhong and Tappo, 1989; Wells and Coppersmith, 1994; En Nahud Metrological Authority, 2013; Tang et al., 2015). The differences in subsurface characteristics cause the soil to experience differential settling as water is pumped out of the aquifer. This causes tension at the soil's surface, which results in the formation of a crack. These surface fractures initially open up slowly as the land surface lowers with time (Cai et al., 2001; Chang et al., 2014). However, during large rainfall events, the cracks and fissures tend to open up much more quickly, because the water erodes the soil in and around the opening areas. An earth fissure can potentially be hundreds of meters deep and several miles long; it is a geologic hazard that poses a significant risk to humans, animals, and our infrastructure.

These cracks and fissures happened due to natural and human factors, the natural factors such as earthquakes, volcanoes and subsurface soil quality. While the human activities are groundwater utility, that affected the compaction of the above sediments after water pumping (Jones and Warren, 1976; Fellows, 1999; El Mansour et al., 2019).

Appearance of earth cracks and fissures in the sedimentary basins generally refers to many reasons. They can appeared as results of the continuation of the water pumping from the aquifer, which let the small size cracks to start due to differential subsidence of the soil in the area in the result of the continuous pumping formed vertically and horizontally shrink and compacted soil. The basic aspects of studying cracks information are their geometry, orientation, and fill mineralogy and textures.

Study Area

The area where these cracks and fissures appeared is located in West Kordofan State with area approximately 1040 km^2 between longitudes 28°10′ and 29°00′ E and latitudes 12°30′ and 13°10′ N mainly or geographically can be divided into two areas El Kalaeet and El Foula area (Figure 1). El Foula town, which is the capital of this State, is one of the studied areas and it is about 780 km southwest of Khartoum capital of Sudan. Connected with Khartoum by railway through kosti, El Dibaibat and asphalt road approximately 780 km from Khartoum the through El Obeid, El Dibaibat and then non-asphaltic road to Babanosa town and El Kalaeet area.

Kalaeet Area

Location

The El Kalaeet area is located 12 km north of Babanosa (Figure 2). From the geological viewpoint, the area was generally consider a sedimentary region, where the sediment thickness extends to about several meters on the country rocks. These sediments include the formation of the Nubian sandstone (below), the Umm Rawaba, and the superficial deposits at the top of the sequence (Eismaeil, 2016). The area is located within the basin of the aquifers as well as the oil basins that are extended to the south and southeast. Topographically, its slope towards the south characterizes the area; therefore, the water system in general is heading to the south part of the region (En Nahud Metrological Authority, 2013).

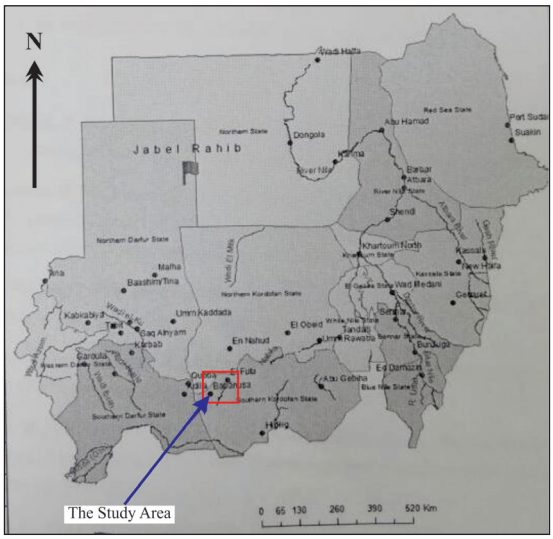

Figure 1.Location Map of the Study Area in West Kordofan State

Accessibility

Climate

West Kordofan State lies within the semi savanna type of climate. Winter which extends from December to February

is dry and cool and characterized by temperature ranges from15 C˚ to 28 C˚, in the summer season which starts from March and ends in June it is very hot, the temperature ranges from 35C˚ to 50C˚ (En Nahud Metrological Authority, 2013). The duration of the rainfall is between four to five months, usually from May to October with a highest peak in August; the average of the annual rainfall in El Foula and Babanosa stations is about 354.25mm/ Year (En Nahud Metrological Authority, 2013). The prevailing winds in winter are generally from northeast, while during summer and the rainy seasons are from southwest.

Topography

Topographically the area is largely a fast plain of low relief, with some mobile and stabilized sand dunes (Qoz), and elsewhere broken occasionally by small outcrops of numerous isolated hills in the northern part of the area. The area is famous by seasonal wades such as Abu Gamria, Abu Snone, Wad Bokhary and Umm Dafso represents the main drainage system in the area. This plain has altitude ranges between 500 to 700 m (a.m.s.l) dipping towards southeast and south (Eismaeil, 2016).

Soil and Vegetation

The soil cover in the area closely corresponds to the distribution of the superficial deposits and consists of several different soil types. These soils are products of weathering of the bedrocks as well as some active sand dunes. Qoz sand is locally veneer by silt or clay and clayey sand. This area dominantly is covered sand dunes (Qoz sand) in the north part, while the eastern part the laterite soil is the main soil and in the southern part enclosed by sandy clay soil mixed with carbonate soil. In the depression and khors areas, sheets of silt and clays generally cover the sand. The south western part of the West Kordofan State is dominantly covered by many type of trees that made heavy forest in some places such as in El Mujlad area. The main trees type is acacia including (Acacia Senegal), Hashab and (Acacia tortillas), Sayal. There are other types of trees that dominated in the north part of the State are (Leptadenia Pyrotechica) Marikh, (Calotropis Procera), Oshar and (Chrozophora Plitca) Argosy beside different types of grasses, which seasonally grow during the rainfall (Eismaeil, 2016). In general, the vegetation density increases towards the south part of the State depending into the climatic conditions and soil type.

Drainage System

The area is very lack with hills and mountains, which is controlled the rainfall runoff, the water sources, which are Wadis and Khors (Mijaigga, khor Bnia, wadi alglaa, Jagmny and Umm Dafwad smoaa are the famous khors in the area), are ephemeral and carry runoff only during the rainy season. Therefore, the drainage in the area affected by several facts such as relief elevation, rocks type, geological structures, and climate conditions. Most of surface water in the study area flow to depression areas like fuolat monem and fuolat tama in the central part. In the eastern part, most of surface water joins the major seasonal water course in the area khor El rwiana, (Ghinaya, 2001; Eismaeil, 2016)), while in the southern part the run off is turn to the area of Bahar El Arab. Locally and more commonly in some parts of the area some runoff is stored in Hafirs or dams to be used in dry season.

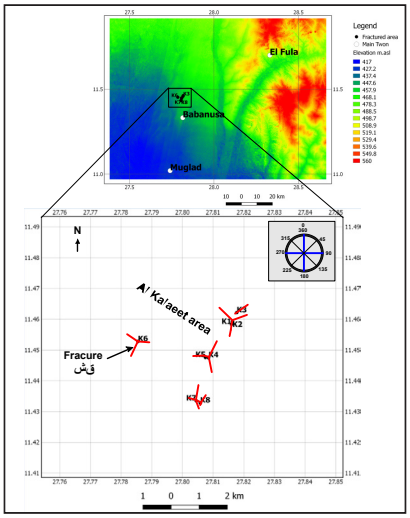

Figure 2.Location Map of Cracks in the Study Area

Population

The population in West Kordofan State approximately estimated to be about 227608, (Central Bureau of statistics, 2013). Many tribes were occurred in this state, but Hammar tribe is the main inhabitant in the area together with other minor tribes groups such as Bagara, kababeesh, Nuba, Dainkka, Noweer, Fur and others. Most of these tribes are either permanently settled in towns or neighboring villages, or rest as nomads who migrate seasonally in searching for water and pasture for their herds. The area is famous for dry-farming (farming during rainy season) and the main agricultural products are Durra, Groundnuts, sesame and Arabic Gum, which is collected chiefly for export and also animal breeding and mobile trade.

Kalaeet Cracks

As it is known, the area has seen cracks and fissures on the ground in three cycles during the 70th as the first cycle and 80th which is the second one and 2018 the most recent cycle which has the biggest effect and make a big view for the area. It is worth mentioning that these cracks occurred in response to a heavy rain continued for many hours continuously, which indicates the link this event with the water (sub surface or surface). It should be noted that similar cracks and fissures occurred in El Foula city in the same time and in the aftermath of the rainfall, but its

cracks and fissures were less intense than its counterparts in the El Kalaeet area. According to some previous reports and people speech, this phenomenon occurred in the two regions for the first time about ten years ago, but it was not as severe and did not raise concerns such as those recent ones.

Interpretation and Analysis of The Phenomenon

The Department of Geology from the University of Kordofan organized a field trip to the areas of El-Foula and El-Kalaeet on 17/7/2018 for collecting field information for scientific analysis and thus finding the actual causes of this phenomenon.

Field Observations

The field observations could be discussed through main points; the apparent depth of these cracks and fissures reached up to 6 meters and no (vertical or horizontal) movements were observed in the field affected by the cracking processes. Most of the cracks in many parts are very extensive (similar to digging processes) due to the collapse of these cracks and their descent down through the crack zone (Figure 3). Majority of the investigated cracks were characterized by triangular forms (Figure 2 and 4), with different angles directions, and with a proximately north to south orientation (Figure 2). Cracks and fissures located in the southernmost part of the affected area were having water up to depth of 1.5 m from the surface of the earth (Figure 5). It is worth mentioning that this water is the rainfall water before the trip day, and this fall is the first fall came after the precipitation that resulted in the aftermath of those cracks. The exposed layers across the virtual depth are two layers; A top layer with a thickness of up to three meters, consisting of weak red sand, which is considered to be the wind sediment of the origin (sedimentation). An undersea layer of fish, who's open, reached to three meters thickness. This layer consists mostly of soft sand, with some nodes consisting of oxides (iron oxide), incoherent, mostly gray with the presence of colors after the green, yellow, red and other in the form of sporadic spots caused by climatic and natural changes following its deposition period in what was known as Mottling's geology.

Figure 3.Cracks in many Parts displaying Collapses and their descent Down through the Crack Zone

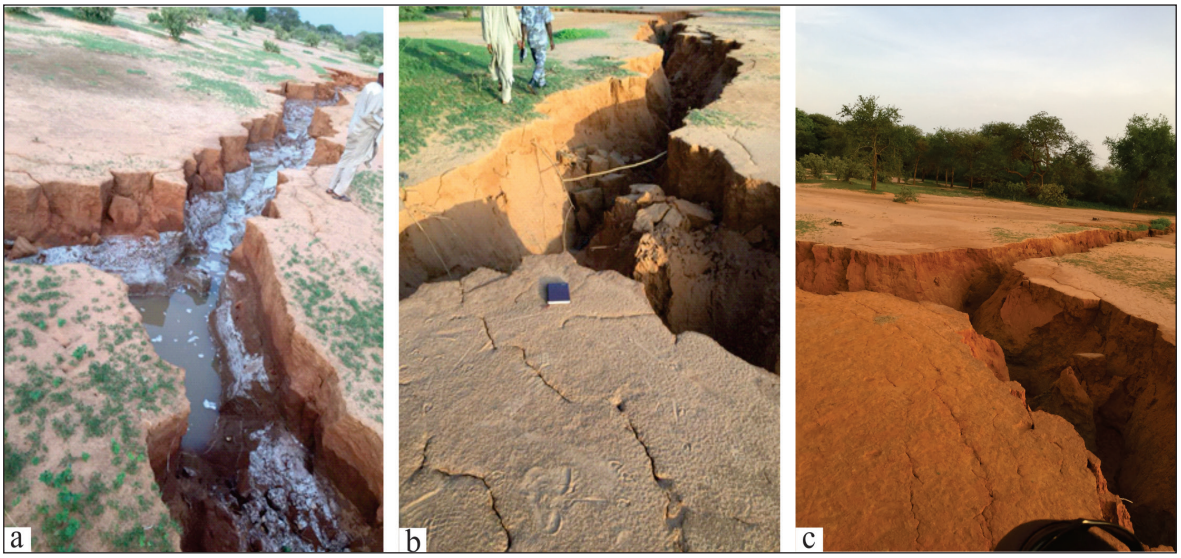

Figure 4.The Investigated Cracks Showing Triangular Forms

Figure 5.Cracks and Fissures Containing Water

Interpretation of Observations

According to the field observations and the all data available during our investigations, we can assume that these cracks had the following probability; The occurrence of these cracks is resulted from a heavy rain fall gives preliminary indications of the relationship of the phenomenon with the water (surface or subsurface), because of the absence of any observed movements reduces the probability of linking the phenomenon to any earth quick. The actual depth of the stratified areas is much more than six meters, which confirms that most of the cracks became more like drilling by the flow of a large volume of the sediments of the layers across the cracks zones to depths greater than those observed depths. Sedimentary rocks are characterized by the fact that they have orthogonal cracks at the levels of stratification and are often radial forms (Holmes, 1944). Thus, the three-fold shapes observed on these cracks may be attributed to the precise cracks that originally existed in the affected layers but were not observed. Cracking zones in their current position reflect areas in which water is easier to penetrate into deeper zones with full-day waterfalls. This indicates that the level of sub-surface water is very close to the surface of the earth, so the observed water in some of these cracks is connected to the sub ground or subsurface water, since it is reported around the area southern and to the east direction to El Foula. The water is located near the surface of the earth, only a few centimeters from the surface of the Khiran, where it is locally called Mashish water. Through the above observations and investigations, these cracks, which occurred in the areas of El Kalaeet and El Foula, are related to both surface water and underground water. (Figure 6) represents what happened to the area, and can be explained in six points; firstly, the water level before the occurrence of consistency was under the two layers affected by cracking. Secondly the heavy precipitation of rainfall before of the appearance of these cracks, there was a sudden rise in the level of subsurface water that covered the bottom layer (gray) and partly the upper red layer. Thirdly, as the subsurface water will experience a drawdown leakage to recharge the groundwater, it will also experience sub-surface runoff in the direction of the general slope of the area (towards the south). The bottom leakage and horizontal flow will be concentrated in the initial cracks. These bands are able to appear on the surface of the earth during the formation of these cracks. As the two layers are in a waterlogged or saturated state and their

materials are originally disassembled, the lattice ranges widen with the vertical and horizontal water movement. Fourthly As a result of the internal leakage and horizontal movement of the water, there will be soon drop in the water level below the diameter so that the two layers again will above the water level of the under groundwater. Fifthly Because of the tow affected layers are in general unconsolidated materials, especially the red top layer; cracking processes will occur on the sides of the cracks zones to trap the rundown materials down through these zones. The cracking zones will therefore widen to give a grafted pattern (bases to the down). Lastly these conical holes are very similar to the so-called sinkhole drills, which are formed in limestone places where melting of calcareous materials occurs if they are saturated or flooded (Kaufmann, 2007; Alrowaimi, 2016; Alrowaimi, et al., 2016).

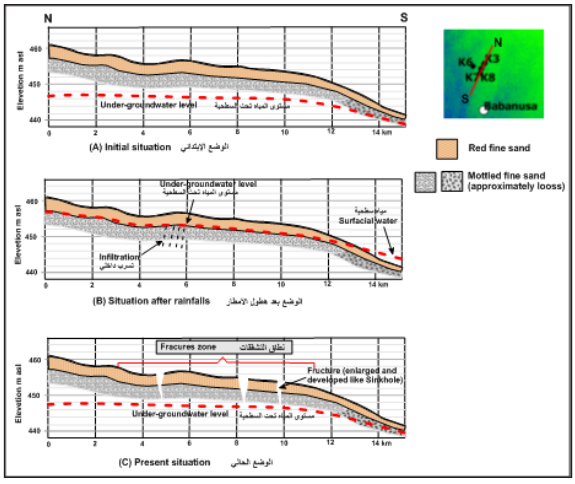

Figure 6.Explains what Happened in the Area During These Phenomena

Environmental Impacts and Hazards

Earth cracks and fissures which, occurred in West Kordofan State are a result of groundwater pumping or discharge from the runoff of the rainfall in the surface. They aren't completely safe from the geologic hazard (Zhong and Tappo, 1989; Coppersmith and Youngs, 2000). The hazardous of these cracks have caused a number of problems for humans and animals and so environmental impacts in the area and over the several decades. These cracks destroyed pipelines, roads, canals, and even homes and all infrastructures of the state. Moreover, they can by the reasons of animals killing if they fell into a crack or fissure, which can be opened up, during the previous and coming up raining seasons. These earth cracks and fissures can also be another general view issue that they create an easy place for groundwater contamination. The continuation of these cracks can be a bridge for pollution, pesticides, and other chemicals processes that simply make their way deep into the earth and enter an aquifer by flowing these cracks, and the infiltration process normally would purified the water essentially skipped where these cracks and fissure exists. The problem of earth cracks and fissures didn't exist many decades ago, but nowadays we are using up our groundwater reserves as results of the industrial revolutions and population increasing. These new utilities are more than 100 times faster than nature can replenish it. This imbalance has resulted in a net drop of the groundwater table and thus a drop the ground surface elevation. Unless we can solve our water problem, we won't be able to solve the fissure problem. Generally we can assume that the effects of these cracks and fissures as following:

1. If these cracks continued they may threat and destruction of a number of vital installations in the State, including gas and petroleum traps in the area.
2. Escaping of the surface and groundwater in the area through dents of these cracks.
3. Bending and deformation of the wells in the area.
4. Damage of the roads that will come through the cracks area.
5. Residential buildings collapse that may occur in the cracks area.

Conclusion

The earth cracks and fissures that appeared with different sizes and orientations in El Kalaeet and El Foula area in the West Kordofan State were located in the zone of sedimentary basins that include the most economical and commercial target for Sudan Republic. These cracks were resulted from the groundwater movement from the runoff of the rainfall in the surface towards the south part of the area.

Generally no essential geological hazard and environmental impacts will affect the humans and animals directly, although it may kill animals and destroyed pipelines, roads, canals, and even homes if they continued. Moreover, they were places for groundwater contamination through their continuation.

Recommendations

Finally through all investigations of all available events and its geological hazards, we can reach to the up coming recommendations:

1. Advertise and broadcasting the geological information in social media and provide the cracks and fissures maps and aerial photographs to the public for avoiding any impact geological hazards the land.
2. Avoid building or constructions that is on or near the areas of these phenomena even don't be fooled by the smallest of cracks it only takes one good rain to open them up and there is no way to predict when that will happen.
3. For preventing migration of these cracks and fissures in the future to avoid fissures entirely even it is covered

up with new soil or concrete, which is a potential problem, we must study all ways of the mitigate of these cracks.

4. The most important and big question the people worried about is living with an existing cracks or nearby is possible?, all investigations and detailed study we made, indicated that there is no problem about this issue, only there are some precautions people will need to take into their consideration. Also people should avoid the distribution of the opening cracks for any reason as far as they could.
5. The government of the State should made many efforts to prevent water from getting into these cracks, because keeping them dry will help ensure that they doesn't turn into a huge crevice.
6. The plants, trees, or lawns near these cracks shouldn't be watering them or irrigated because this also could exacerbate the problem.

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