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The Influence of the Lineament Geological Features on the Hydrologic Flow Direction of Wadi Al Kuf Catchment Area, Cyrenaica, Northeastern Libya

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Abstract: Wadi Al Kuf Catchment Area WKCA is one of the largest watershed basins on Al Jabal al Akhdar Cyrenaica anticlinorium, the area is more than 960Km2, and considers as a semi-wet basin. This basin highly affected with lineaments geological features just like morphometric and tectonics types including fissures, fault systems and joints set systems in the highly karst lime stones of Al Jabal al Akhdar group lithological formations. These lineaments phenomena were measured and extracted from the radar images of digital terrain model of 30 meters space grid, and the hyper spectral Landsat 8 of 15 meters pixel resolution, they were processed and interpreted by several geospatial geomatics and geological software. The direction orientation and the rock density of these fissures, fractures, joints set systems, faults and the morphometric dendritic drainage pattern had been measured and illustrated from the rose diagram analysis and the geological map. The main stream of this catchment area WKCA is the 6th order and mainly parallel to the main trend direction with the first escarpment circular fault at the major orogeny tectonic fault of Al Jabal al Akhdar uplift, and these lineaments features is averaged 58.3o with the azimuth degree along the main stream. The drainage density, lineaments density analysis and distribution of the WKCA have been classified as low lineaments rock fractures in the eastern boundary of the basin, moderate lineaments rock fissures in the middle of the basin and high density of rock fracture in the western and northern boundary of the basin, these had reflected the deep percolations and infiltrations to the ground water bearing aquifer in the WKCA through the secondary and the tertiary porosity of the hydrological karst system.

Keywords: Morphometric, Tectonic, Lineaments, Lineaments Density, Geospatial, DTM, Rose Diagram, Hydrology, Escarpments, Deep Percolation.

INTRODUCTION

WadiAl Kuf Catchment area (WKCA) is located in Cyrenaica north east of Libya, at the middle of the northern flank of Al Jabal al Akhdar between longitude 22^0 00’ 24” E, latitude 32^0 46’ 25” N, and longitude 21^0 24’ 03” E and 32^0 47’ 09”N with elevation 870 m to 0 m above main sea level, with total area about 959.26 Km^2 and perimeter 222.26 km after (Ammar,2018) Figure. (1), WKCA is mainly covered and partially covered with the most of 90% of Libyan flora, this vegetation cover is like the following *maquis shrubland, Juniperus phoenicea, Cedrus atlantica (cultivated), Pistacia lentiscus, Arbutus pavarii, Olea europaea, Myrtus communis, Quercus coccifera and some groves of Cupressus sempervirens*,(Meith, 1989). but unfortunately, in the last two decade this vegetation cover had deteriorated and became vulnerable and fragile by the human impacts’ degradation and the misused activates.

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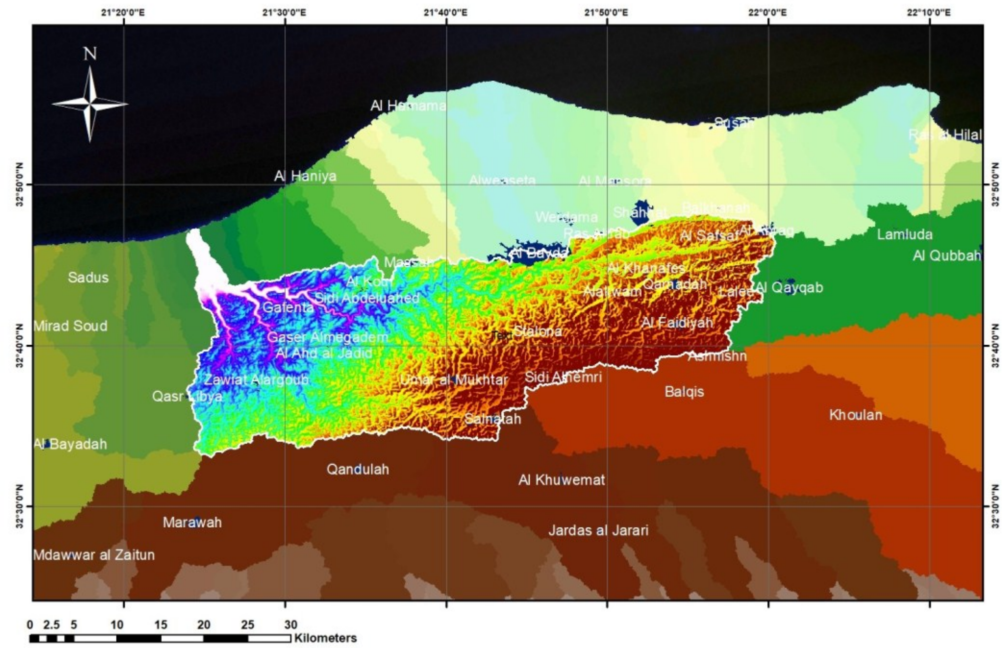

Fig1. Location Map of Wadi Alkuf Catchment Area With Other Basins

The weather distinguished as the Mediterranean climate according to Köppen climate classification (Lohmann et al., 1993), the average precipitation between 450 and700 mm per year (Cheblak& Ammar,2014).WKCA is one of the importantprovincesin Al Jabal al Akhdar anticlinorium it passed through 17 ruler settlements area, villages and cities like southern part of Albida, southern part of Shahat city, Figure.1.Tectonically the WKCA laid between shoreline, the first escarpment and end of the second escarpment of Al Jabal al Akhdar. This part of Al Jabal al Akhdar anticlinorium economically unique for the precipitation rain fall, runoff ground water recharges, by these kinds of studies it could help for sustainable development of this part of Al Jabal al Akhdar. This study used the geospatial information sciences techniques to calculate both the type of the lineaments features morphometric like Wadi segmented and stream orders and the tectonic lineaments like fissures, faults, joints systems and analyze to find the relationship between these lineaments' components and the water movement transport directions.

Geology and Tectonic Activities: WKCA is the main important part of Cyrenaica anticlinorium sitting between first and second escarpment of the Mediterranean costal promontory . The Cyrenaica promontory was formed tectonically and evolved as inversed anticlinorium represents a dextral constructional duplex faluts. These areas are bounded by the northern flank of Cyrenaica and the southern flank of Cyrenaica dextral wrench Fault Systems figure. 2, (Anketell, 1996) The eastern part of the Cyrenaica Fault System, at the boundary between the Al Jabal al Akhdar inversion anticlinorium and the Cyrenaica Platform, shows one of the few places which exhibit evidence of an en echelon shearing attributed to a right lateral wrenching along the fault. This shear system, however, inactive to westward against the main body of the Al Jabal al Akhdar inversion structure. It was noted that the "present-day Wadies" in this area run in a general W-E direction parallel to the Cyrenaica Fault System, (Anketell, 1996). The other types of fault system had other trend orientations This fact found during the interpretation of the satellite image and the morphometric phenomenon of the WKCA. Where is the main trend of the Al Kuf

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basin is mainly west –East direction parallel to the main circular fault the of the first escarpment Figure.2. and the joints systems mainly 45^0 to 60^0 -degree azimuth direction to the main

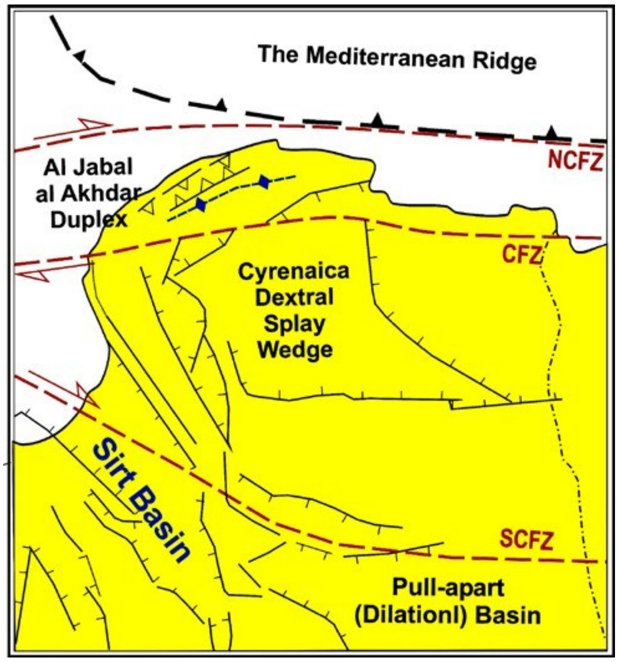

Fig (2). Main fault zones of the Cyrenaica (ANKETELL 1996) HUGUEN & MASCLE 2001).

fault and other fault systems of the WadiAl Kuf and its tributaries evolved genesis. According to the geological map of Albyda sheet NI34-15 (Röhlich, 1974), the WKCA isfully covered with tertiary rocks formation of Al Jabal al Akhdar group the lithology description with main four rock formations started from northern part of the WKCA to the southern part of the basin,

Darnah Formation: (Röhlich, 1974) Eocene epoch serious, Lutetian-Priabonian stage age, the formation consists of a basal bed of hard, massive, fine-grained, creamy grey limestone, which contains Nummulites gizhensis, followed upward by light grey, medium-grained, nummulitic limestones with intercalations of dolomitic limestones. The upper part contains reefal facies (coralgal and coralline limestones) with Nummulites sp., which alternates with grey, nummulitic limestones. After (El Hawat & Abdulsamad, 2004). This formation appears and fully cover of the study area up to the first escarpment and can find it also in the wadi's sides, figure. 3.

Al Bayda Formation: (Röhlich, 1974) Epoch serious Oligocene, Lower Oligocene, Rupelian stage time. The Algal Limestone member of Al Bayda formation (Kleinsmiede & Van Den Berg, 1968), It is composed of thick-bedded or massive, white and yellowish, fossiliferous, medium-grained to microcrystalline, algal calcarenites and calcirudites, which get harder near the top of the sequence due to the presence of corals. Coralline red algae, which are frequent throughout the member, form crusts as well as algal rhodoliths, the formation is rich in microfossils (e.g. Nummulites intermedium, N. vascus, N. cf. fichteli, N. ex. gr. hantkeni, N. incrassatus, N. bouillei, Operculinadiscoidea, Lepi-docyclina (Eulepidina) ephippioides, miliolids, Gypsinasp., Rotalia sp. and various species of ostracods). Additional to these, a high percentage of re-deposited Priabonian microfauna is observed. These fossils were possibly only transported over a small distance. Coralline red algae such as Lithothamnionsp. and Archaeolithothamnion maughiniare common throughout. Common macrofossils include echinoids (e.g. Hemiaster scillae, Echinolampus cherichirensis), gastropods, pelecypods (e.g. Pectensp., Glycymerissp., Ostreasp.), and corals. The fauna indicate deposition in shallow neritic condition during the Lower Oligocene. This formation and the lithological member covered the full part of the second escarpment in the study area.

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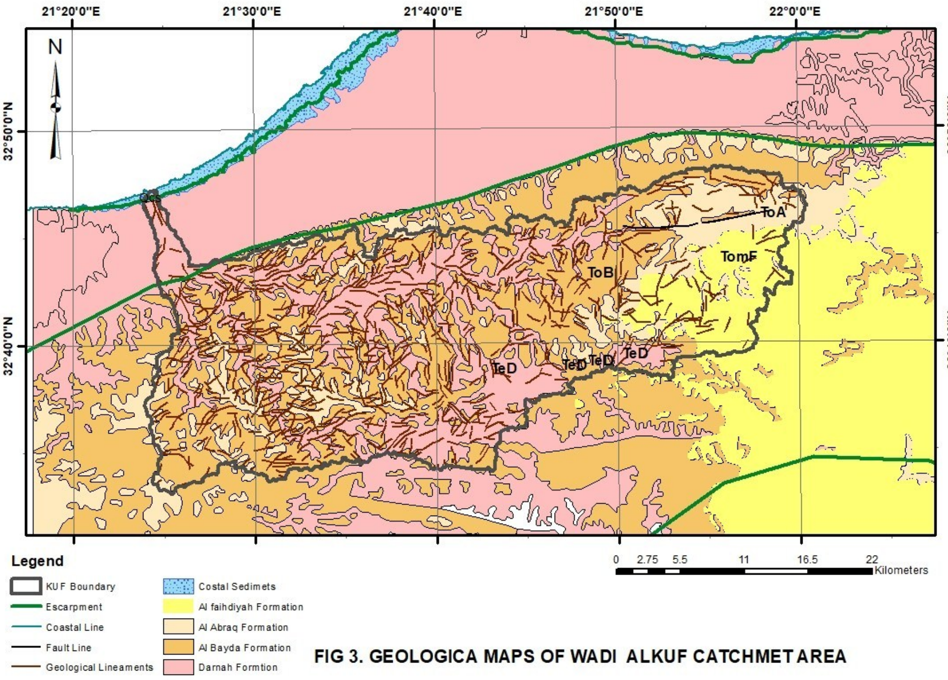

FIG 3. GEOLOGICA MAPS OF WADI ALKUF CATCHMET AREA

Al Abraq Formation: The term was introduced by (Röhlich, 1974): (Middle to Upper Oligocene, Chatian. It consists of partly calcarenitic to calcilutitic, partly dolomitic limestones, dolomites, and marls. In the type section it starts with basal greenish marls followed upward by yellowish, thick-bedded to massive calcarenites with Operculinasp. and Heterosteginasp. in the upper part. These are interbedded with nummulitic limestones and marls, which form several coarsening upward cycles. The lithology is also highly variable due to the epeirogenic movements during the Oligocene-Miocene times, attested by major slump structures and contorted bedding developed W of the Wadi Al Kuf bridge. In the Darnah area, the uppermost part is characterized by massive, cream yellow to rusty cream calcilutites or fine-grained calcarenites, which contain abundant echinoids. The basal part consists of nummulitic marly or clayey siltstones, which have dark spots of glauconitic and is intercalated with algal limestones. The environment of deposition is deep neritic to shallow marine with brackish influence. Shore environments are developed in the S and deeper marine environments

Al Faidiyah Formation: (Pietersz, 1968) lower Miocene epoch serious, Burdigalian-Aquitanian stage time, it consists a basal clay and an upper limestone basal conglomerate, which consists of reworked lithoclasts and shells of gastropods, echinoids, large foraminifers, and oysters, as well as debris, and shark teeth, some of which derived from older formations. The conglomerate is followed by soft, yellow-brown, glauconitic, argillaceous, skeletal limestones, marls, and green clays. This formation is wide spreading in the south east of the WKCA, figure. 3. Regarding to the faults & joints sets system and the tectonic activates for the main region and to the karst lithological formations which reflected of the intensive and dominated karst phenomenon activities in the region specially in the study area of the WKCA that was extremely response formed of the drainage patterns tributaries and the Wadi's shape. All of these could be found in this study by analyzed of the orientations of liniments features, density and the stream flow direction.(Ford & Williams, 2007).

Methodology and Techniques: This study used geospatial information sciences in different way such as remote sensing techniques including image processing of DTM digital terrain modeling of highest-resolution topograph-

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ic data generated from NASA's Shuttle Radar Topography Mission (SRTM) in 2000 was to be released globally by late 2015 with 30-meter grid space, also used Landsat 8 hyper spectral bands 15-meter resolution, vector topographic maps scale 1:50,000 for Survey Department of Libya SDL digitized by Geoplan Company, Vector Geological map of Libya for central industrial research IRC Albyda Sheet (Röhlich, 1974) digitized by Geoplan Co., In this study used several software for evaluation, interpretation and calculation Hydro Arctool 10.6.1, ArcGis 10.6.1 for hydrological calculations and mapping, Envi 5.3 image processing by the above methods and techniques can interpretations, Geomatica 2017 for distinguished and determined the lineaments types, Rock works 16 for geological interpretations and to can draw Rose diagram analysis.

Stream Order: The Wadi`s mouth defines as valley place in the stream network, which suites general cartographic purposes. The nature of stream order is the first step to understand the drainage basin analysis. It is defined as a measure of the position of a stream in the hierarchy of tributaries. (Ammar, 2018) In the area under consideration, there are 11616 stream segments linked with 6 orders of the streams orders. consideration, there are 11616 stream segments linked with 6 orders of the streams orders.

Table (l). Stream Segments, Orders and Length of WadiAl Kuf Catchment Area.

Stream Order	Stream Segment	Stream Length Km	Bifurcation Ratio	Main Bifurcation	Main Stream Length (L	Cumulative Mean stream length (CL	Stream length Ratio
1	6078	1040.39	0.00	1.50	0.17	0.17	0
2	2529	555.45	2.40		0.22	0.39	1.29
3	1377	310.91	1.84		0.23	0.62	1.04
4	820	154.06	1.68		0.19	0.80	0.83
5	455	95.01	1.80		0.21	1.01	1.11
6	357	74.63	1.27		0.21	1.22	1.00

Stream length: is 2230.44 km covering. The catchment area is about 959.26 km^2. First order tributaries con stitute more than 52 % of all segments at a stream length of about 1040 km figure. 4.

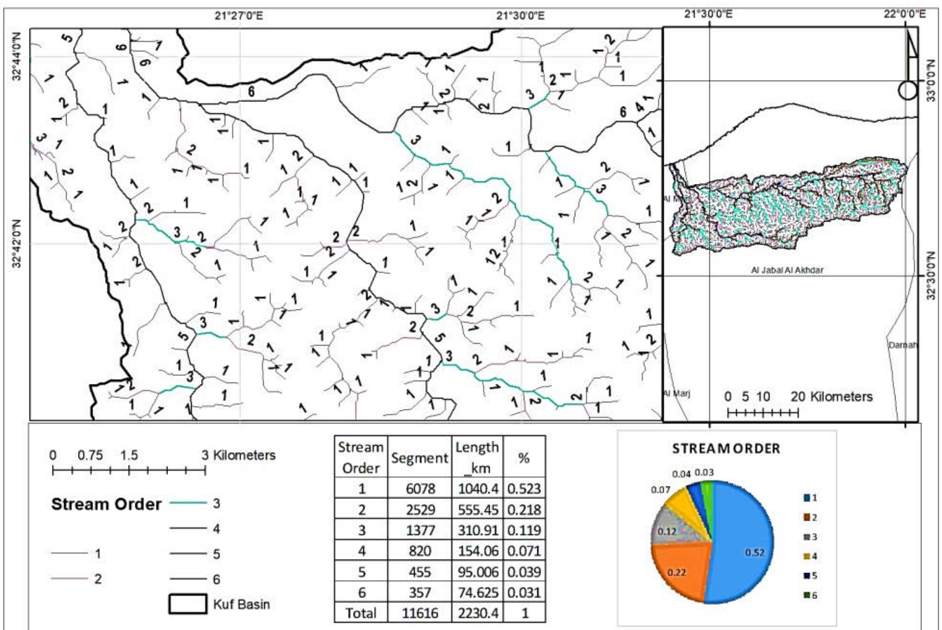

Figure 4 Stream Order and Stream Segments Percent of Wadi Alkuf Basin

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Morphometric lineaments parameters of WKCA drainage network after (Ammar, 2018) From the table 1.and figure.4. had noticed that the stream 6th order crossed the WKCA by more than 75 Km long trendingorientation is mainly WNW to ESE direction as approximate direction of the main circular fault of the first escapement.

Basin Shape: is mainly elongated and this elongation ration calculated and defined as the ratio of a diameter of a circle of the same area as the basin to the maximum basin length (Schumm, 1956). It is a very significant index in the analysis of basin shape that helps to shed light on the hydrological character of a drainage basin. Re= √A /π / Lb, where A= Area of the Basin (Km^2), Lb=Maximum Basin length in km's. If values are near 1.0, the region is typical of low relief (Strahler, 1964). The elongation ratio in the study area was found to be 0.15 indicating relatively moderate countered to high relief of the terrain and rectangular elongated shape of the drainage basin, Figure.1. (Ammar, 2018).

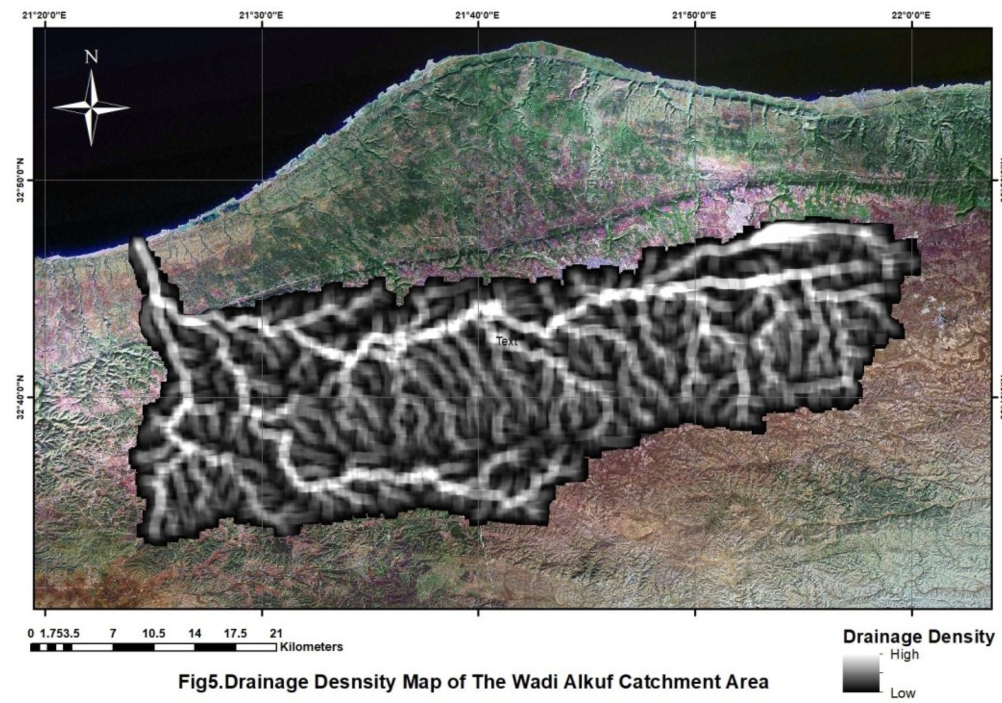

Fig5.Drainage Desnsity Map of The Wadi Alkuf Catchment Area

Dendritic Drainage Pattern: A common drainage pattern in which the tributaries join the gently curving mainstream at acute angles, resembling in plain view the branching habit of an oak or chestnut tree; it is produced where a consequent stream receives several tributaries which in turn are fed by smaller tributaries. It indicates streams flowing across horizontal rock strata and homogenous soil typified by the landforms of soft and carbonate sedimentary rocks, (Ford & Williams, 2007), This pattern effected and formed from the joint set systems of the soluble karstified lithology, figure.,4.

Drainage density (Dd): The density of stream network in a basin has long been recognized as a topographic characteristic of fundamental significance. It is an expression of the closeness or spacing of channels (Horton, 1932). The significance of drainage density is recognized as a factor determining the time travel by water (Schumm, 1956). The measurement of Dd is a useful numerical measure of landscape dissection and runoff potential (Chorley, 1969). On the one hand, the Dd is a result of interacting factors controlling the surface runoff; on the other, it is itself influencing the output of water and sediment from the drainage basin (Ozdemir & Bird, 2009). Dd is known to vary

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with climate and vegetation, soil, rock properties, relief, and landscape evolution processes (Oguchi, 1997). The Dd of the Wadi Al Kuf-watershed basin is 2.33 km/km2. Figure.5shows that the drainage density in the study area, which is relatively low, clearly indicates that the region has permeable subsoil, highly liniments tectonic feature relatively moderate vegetation cover, and gentle to medium relief (Ammar, 2018) Drainage density in the study area varies between low and high as shown in figure.5. Furthermore, the illustration shows aggregation around and in the main trunk of first and second order streams.

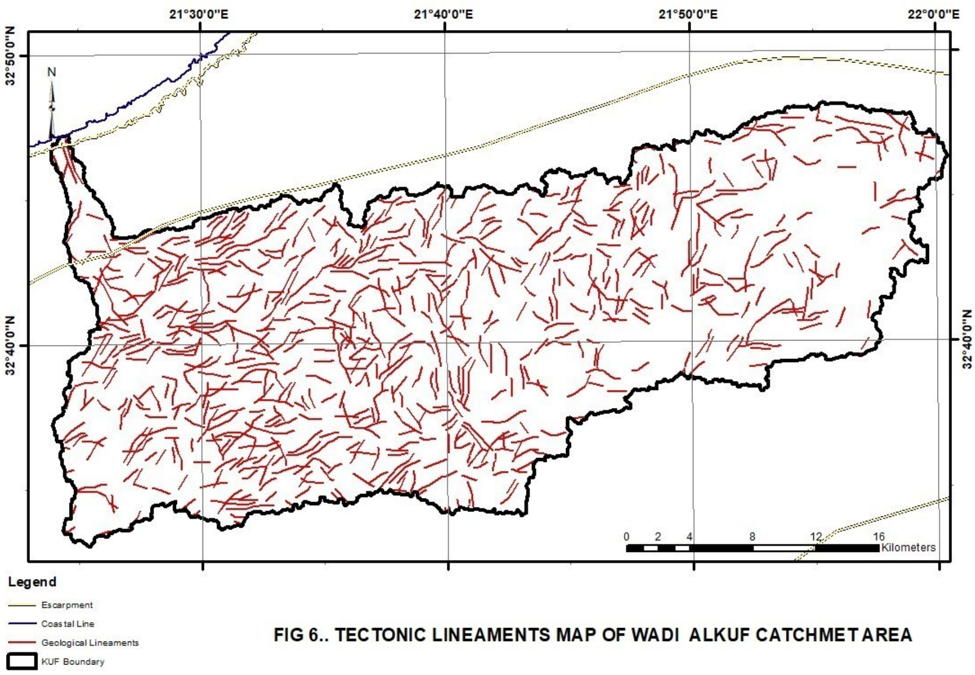

FIG 6.. TECTONIC LINEAMENTS MAP OF WADI ALKUF CATCHMET AREA

Lineaments: A lineament is an interpreted line "one dimensional" drawn in a relation from linear to semi-linear terrain forms of any linear features in the ground that can be extract out as lines or scratches appeared as an evident because of contrasts in the terrain or the ground cover on either side in space and radar image visualizations and interpretations, (Wise, 1982). It has two types of lineaments morphometric and tectonic, (Gay Jr, 2012).

Morphometric Lineaments: is the line features exposed from physical and chemical weathering of the karstic limestone lithology and from the alluvial erosion activities in the study area, it can be summarized in the stream orders and the drainage pattern shape of the catchment area.

Tectonic Lineaments: In the characterization of WKCA site that may have potential for hosting a secondary porosity and fissure fractures for karstic bedrock, it is essential to understand the existent framework of brittle deformation zones in the bedrock occurred by several tectonic orogenic

activities, (Soden et al., 2014) These zones have affected on deep percolation of groundwater recharge movement in the region. The image resolution for the source data is a limited in structural interpretation of the land forms. This limitation is related to the remote-sensing techniques used, and the auxiliary information (e.g. geological data, maps and field observations) that can support the interpretation of the main types of faults systems and joint set systems (Tiren, 2010) From the image interpretation of the DTM of the SRTM 30 meters grid space and the Land sat 8 satellite images hy-

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perspectral bands of the WKCA study area, can inventoried and collected the number of geological lineaments features and their directions orientation trends as a set of systemsfigure.6.It could map them from the data illustrated, by using certain geological software as an earth work 16 to can draw the rose diagram orientation trends and to interpreted the statistical analysis data. From the statistical estimated data, the total 1928-line geological joints and several faults feature the bidirectional type used in this rose diagram with class interval 10 degree, the main orientation of these joints is 58.2^{o} azimuth and the minor orientation of the joint set is 238.18^{0} azimuth, the confidence interval is 7.2^{0}, 95% confidence accuracy and the stander deviation of the main data is 36.69 as showing in the figure.8Geospatial information sciences used in this study in different ways such as remote sensing techniques including image processing of DTM digital terrain modeling of highest-resolution topographic data generated from NASA's Shuttle Radar Topography Mission (SRTM) and Ladsat8 with 15-meter pixel size resolution hyperspectral bands.

From the table (1) and the figure.4 and figure.8 of the rose diagram analysis could findthe dominant stream segments from the order 1 up to 5 order are mainly the same angle of the major trend angle of the tectonic lineaments trend of 58.2^{0} azimuth degree to the 6^{th} order of the main stream and with the same geometry angel with the first escapement fault.

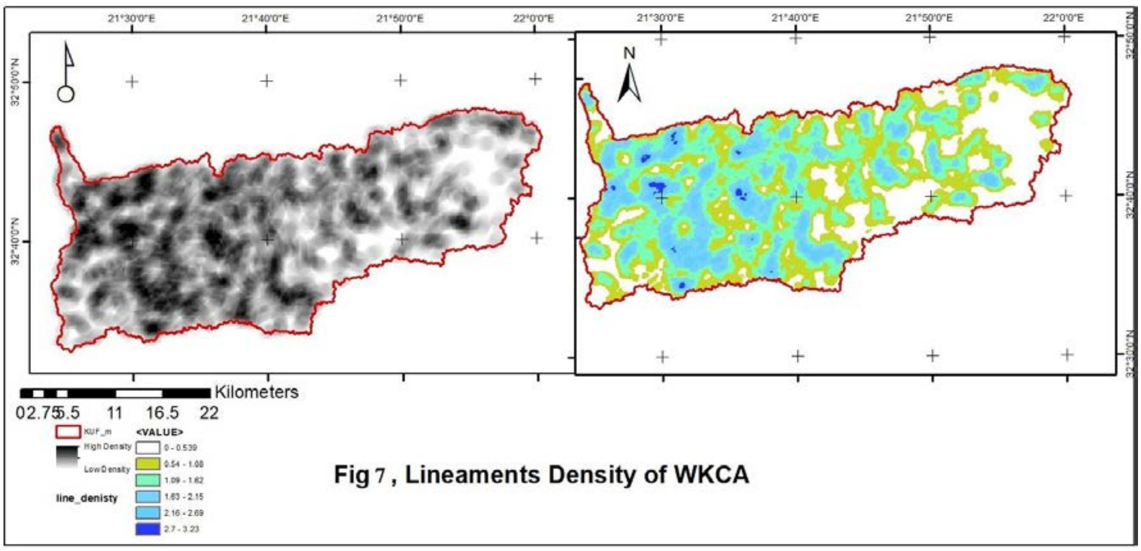

Fig 7 , Lineaments Density of WKCA

Lineaments Density: Lineaments are structurally controlled linear or curvilinearfeatures, which are identified from the satellite imagery and Digital Terrain Model DTM by their relatively linear alignments. These features express the surface topography of the underlying structural features. Lineaments represent the zones of Faults, fissures, and joint set system resulting in increased secondary and tertiary porosity and permeability. These factors are geohydrologically very important as they arethe path ways for groundwater percolation movement (Cheblak M& Ammar A, 1998). Lineament density ofan area can indirectly reveal the groundwater potential, since the presence of lineaments usually denotes a permeable zone. Areas with high lineament density are good for groundwater potential zones, (Haridas, Aravindan, & Girish, 1998; Ni, Zhang, Liu, Yan, & Li, 2016). The lineament density map of the study area as shown in Figure.ure 8. Can find the highest lineaments density in the western boundary of the watershed basin and moderated lineaments density in the middle of the

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study area but the lowest fracture density in the eastern part of the WKCA's boundary.

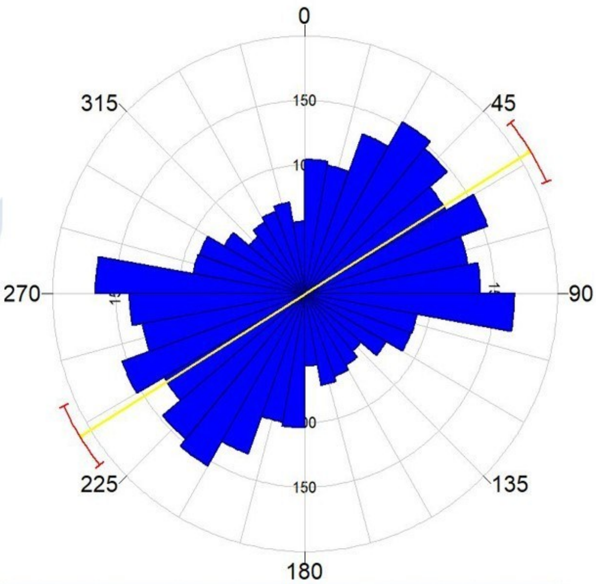

Fig8. Rose Diagram of Lineaments Geological Features of Wadi AlKuf Catchment Area.

CONCLUSION

The main stream of WKCA is the 6th stream order and is mainly parallel to the first escarpment direction ENE- WSW in the main trend direction also in the other hand the morphometric lineaments of the other stream orders segments with the tectonic lineaments features the angle is 58.2^{0}NE degree along the main stream(the 6th order). The annual total average precipitation of the WKCA is approximately 650 mm, that means about 624 million cubic meters, these lineaments feature of faults, fissures and joint set systems helped the deep percolation and infiltration in the WKCA to recharge the ground water aquifers and the water bearing formations of the region during the water movement of runoff transports to the sea shoreline .From the lineaments density map figure.7, found the joint systems and fractures lineaments density highly distributed in the western part of the study area and the low lineaments density in the eastern boundary to the WKCA which reflected the increasing of the lineaments joint set systems and fractures at the west more than the east pattern part of the study area, that leads to more water percolation through the joints fractures ad joints of the karst rocks to recharge the groundwater aquifers and water bearing rocks in the west of the catchment area more than the eastern side. And more flooding flash or runoff to the east rather than the western side of the basin.

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تأثير الظواهر الخطية الجيولوجية على اتجاه الجريان في حوض وادي الكوف برقة شمال شرق ليبيا.

عمار عبد المطلب عمار*

الرئيس التنفيذي لشركة جيوبلان لأعمال الهندسة المكانية، شحات –ليبيا

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المستخلص: حوض وادي الكوف أحد أكبر الأحواض المائية بالجبل الأخضر، إقليم برقة بمساحة تقدر بحوالي 960 كيلومتر مربع، هذه الحوض متأثر تأثيراً مباشراً بالظواهر الخطية الجيولوجية مثل الظاهرة المرفومترية المكونة لنمط التصريف النهري الشجيري ورتبته النهرية، والظاهرة الخطية التكتونية مثل مجموعة الفواصل الخطية والصدوع والانكسارات المؤثرة بقوة على الطبيعة الكارستية لتكوينات الجبل الأخضر الصخرية. قد يمكن قياس واستخلاص وتجميع بيانات هذه الظاهرة الخطية بواسطة الصورة الردارية من نموذج التضاريس الرقمي بفراغ شبكي 30 متراً SRTM وصورة الأقمار الاصطناعية Landsat 8 بدقة مكانية 15 متراً. السمات الخطية هذه عولجت وفسرت بعدة برمجيات مكانية وجيولوجية لتحديد اتجاه وكثافة هذه الانكسارات والفواصل في الصخور الرئيسة المكونة للحوض. نجد أن الرتبة السادسة للنهر الرئيسي للحوض موازي للصدع الدائري المكون الرئيسي لصدع المصطبة الثانية للحافة الشمالية للجبل الأخضر، ونجد ان فواصل وانكسارات وصدوع هذا الحوض والنمط الشجيري تتموضع وتتجه بحوالي 58.3 باتجاه زاوية السمت مع المجرى الرئيسي لحوض الكوف. وكما نجد أيضاً كثافة هذه الانكسارات ضعيفة في شرق حدود الحوض ومتوسطة الكثافة في منتصف الحوض وعالية الكثافة غرب الحوض وهذا يعكس عليها كلما اتجهنا غربا ازداد معدل الرشح العميق لمياه الهطول المطري لشحن المياه الجوفية، وكلما اتجهنا شرق الحوض نجد أن معدل الجريان السطحي واحتمالات الغمر والفيضان في شرق الحوض أكثر من غرب الحوض.

الكلمات المفتاحية: السمات الخطية المرفومترية، السمات الخطية التكتونية، كثافة السمات الخطية، الجيوماكني، وردة الرسم البياني، نموذج التضاريس الرقمي، الهيرولوجي، المصاطب الصدعية، الرشح العميق.

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