Morphology and Formation of Incised Meanders in Wadi "BIR EL AIN" East of Sohag(Egypt)

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Abstract:

The study aims at investigating the response of the incised meander through meander development. It emphasizes field measurements of incised meander morphology and their links with meander morphology like Fundamental Category of Wadies system. Comparisons in different regions and types with Quantitative Parameters on incised meanders morphology have helped in distinguishing different characteristics and approach formations and evolutions. Based on the (TM) and Field investigations, and the measures that other studies had proposed, the study has reached the morphology and the formation of incised meander. The finding suggests that incised meanders in Geological Structures, Strata and Lithology, Knick points (by backwater) effect of landform are the key factors to shape incised meander and meander itself in Wadi Bir El-Ein. The Evaluation of incised meander in the study area obeys the variation of formations, discharge amounts, Gradient, sea level fall and morphology and demonstrates the channel incisions and Crustily Uplifts. So, the incised meander needs more geomorphological investigation especially in our country.

Keywords :meander, incised meander, Wadies, channel incision, Wadi Bir El-Ein, knick point.

Introduction:

This Paper presents the geomorphological analysis of morphology and Formation of incised meander in an approximately 463 Km 2 drainage Basin located at the eastern Sohag. In the study area , the Fluctuations of base level to lower by approximately 2-9 m , the Fluvial system adapted to the lower base level by headword erosion. This is indicated by Knickpoints in the longitudinal stream profiles

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and by continuous upstream narrowing of the width of the valley floor towards these knickpoints .

Incised valleys are ubiquitous features of disturbed landscapes as incision had resulted mainly from sea level fluctuation and has been formed through the geological history starting from the Precambrian to the present (Zaitlin, et al, 1994; smith and read, 2000). The study of incised meander valleys will be of significance not only in stratigraphic division and understanding the sea level fluctuation but also in effective hydrocarbon exploration (chumming , L., et al , 2004) .

Stream incision and development of Stream Profiles are Fundamental aspects of landscape evolution that can be examined over wide range of spatial and temporal scales.

On a watershed scale, long - term stream incision commonly occurs in response to the downstream lowering of base level, and is often influenced by regional or local tectonic processes.

On a local or reach scale, incision occurs in response to interaction between individual floods and the channel bed which are in turn influenced by flood hydrology, sediment transport, channel gradient, and substrate resistance, lithologic variation within a watershed. Variable resistance to erosion can affect incision and development of the stream profile on temporal scales ranging from individual floods to millions of years during the pluvial periods.

Incised valleys are key-area for the sedimentary record of sea level fall on continental margins. They also display two major kinds of sediment fill (zaitlin , et al , 1994) :simple fills corresponding to a single depositional sequence (Li ,et al, 2002 , Gutierrez ,et al , 2003 , Weber et al , 2004 a,) and compound fill corresponding to multiple , superimposed, cycles of incision and deposition (Tesson,et al , 2005) .

In this paper, the researcher presents data on the characteristics of stream (long profile , Knick point , cross section , bed rock formation, 'Geological setting' and climatic conditions), the later provide insights into the elevation of stream channel in study area .

Development of some features is associated with incision providing an excellent constraints on some conditions. For example, development is influenced by base level fall at Wadis mouth which in turn results in incision of the Wadi supported by the faulting and folding to the meandering belt. Also, the presence of many high knick-points on long profile results from climatically triggered and tectonically exacerbated pulse of incision within the watershed.

Definitions:-

1- **Incised meanders:**

Are asymmetrical in cross-section, albeit to various degrees plate (1- a,b). They are autogenic forms which develop their asymmetry as a result of lateral migration of the river during incision, as witness the development of slip-off slopes and undercut bluffs (King, 1942, p. 152; Birkenhauer, 1991, p. 297). Incised meanders evolve to such an extent that 'goose necks' (of which there are well-known examples in the canyons of the Colorado River in southwestern USA), and eventually, abandoned meander cut-offs, congeners of oxbow lakes, are also formed (Twidale, 1955; in greater measure than their plains counterparts incised meanders display structural control. East of Adelaide, where the River Torrens flows through the western margin of the Mt. Lofty Ranges, it pursues a winding course in its gorge section. The river channel and gorge trend parallel to strike (in phyllite) and cleavage (in gneiss) for a substantial proportion of their length in this sector (Twidale, 1972).

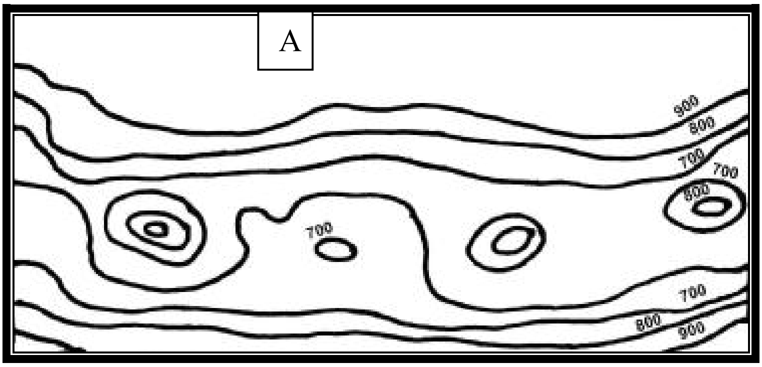


Fig. (1 a) Incised Meander by contour lines

Plate (1) incised meander in Wadi Bir El Ain

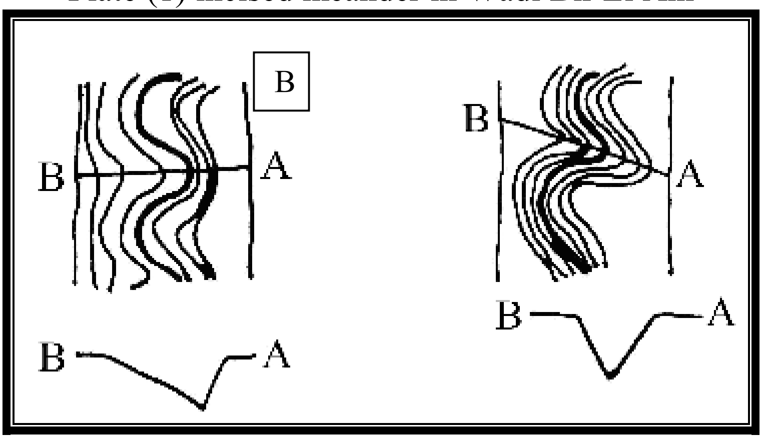


Fig. (1b) incised meander by contour lines (i) ingrown meander (ii) entrenched meander.

Objective:

The aim of this investigation lies in 8 aspects:

1) To understand the role of geomorphological, geological and climatological settings in formating the incised meanders.
2) To illustrate the relationship between knick zone and incised meander in wadi Bir El-Ein .
3) To identify typicality and complexity of meanders in the study area basin based on parameters compared with other meanders in other regions.
4) To explore diverse formation conditions in contrast with other incised meanders of different condition in different types of localities, and to connect morphology with evolution of the incised meanders.
5) To show the numerous factors responsible for initiating incised meander or channel incision.
6) To Study the lateral sediments (Terraces) in order to identify the relation between incision and base- level fall.
7) To Study the morphology of incised meanders and their links with meander (bend) morphology.
8) To study the morphologic characteristics of Wadi bir el Ain Basin and their reflection on incision and incised meanders.

Study area:

The study area in this investigation is Wadi Bir El-Ain. This Wadi is named as such due to the presence of a water spring. Wadi Bir El-Ain is a main channel which receives run off water from several ravines. It is subject to frequent, but unperiodic, floods from rain falling on the Red sea Mountains (ridges). Furthermore, there are subsurface springs running among rock fractures and pouring in several places as well as surface water reservoirs formed in depressions (El- Sharkawi, H., and Fayed, A., 1975). The main stream has 36 Km Long, and the Basin cover an area exceed on 463 Km^2 (Fig. 2). It is covering an area between

26˚ 36` to 26˚ 55″ Latitude. And 31˚ 46` to 32˚ Longitude, North eastern sohag city .

Figure (2) the study area
By: Google earth

Background:

Incised meander formation are well documented, one of the original description of an incised valley system was established by Fisk (1944). Fisk and Mc Farlan (1955) were also among the first to describe the relationship between the incision and filling of Mississippi valley with the falling and rising of sea level. Incised–valley system have been interpreted throughout geological history from Precambrian to the Quaternary (Fisk , 1944; Li et al ,1985 ; Li et al ,1988; Allen and Posamentier ,1993;Dalrymple et al , 1994 ; Zang and Li , 1996 ; Gupt , 1999) . Incised valley may be developed in both loose sediment and bedrock (Fisk,1944; Roy,1994;Nichol et al 1996 , 1997) . It has been realized during the development of sequence stratigraphy that recognition of incised valley system provides an important criterion for the identification of sequence boundaries (Van Wagoner ,et al ,1988,1990) . It is generally comprehended that paleo-valley incision is controlled by sea –level fall , while sea – level rise and abundant sediment supply lead to the fill of incised valley (Fisk and Mc Farlan,1955; Zaitlin et al ,1994;Li ,et al , 2000) .

Channel incision can increase bank height and steepen bank strength is equal to the down slope gravitational forces that drive bank failure (Casman and Thorne , 1988) .

Morphologic characteristics , classification and formation of meanders have been much reported in literatures , Mathhas(1941) defined meanders as some letter – S channel patterns fashioned in alluvial materials, and made ashap distinction between normal and abnormal stream-meanders; the latter are great loops that normally leas to knockoffs and isolation of ox-bow lakes . Valley slope, bed load, discharge, bed resistance , and transverse oscillation are regarded as basic factors of river meandering .

Brice (1974) made quantitative definition of meander loop but the criterion of meander loop but the criterion was problematic; a scheme for the evolution and four main categories of loops were proposed : simple symmetry, simple asymmetry , compound symmetry and compound asymmetry . Meander is also categorized into regular or irregular, simple or compound, and cute or flat patterns.

Shen et al (1993) classified meanders into plain meanders and mountain incised meander on the basis of landform. The former can be divided into general (sinuosity is 1.5 – 5); the later covers normal and deformed incised meanders, and rock resistibility is vital to its shape. In the light of their shape and evolution, plain meanders can be categorized as free and limited meanders .the later which is shape and unnatural go through rocky banks that are not eroded easily.

Leopold and Wolman (1960) have established relational expressions for meander characteristics among meander wavelength, bank-full channel width, amplitude and radius of curvature.

Finally, I can say, so differentiation among researchers on meander which they put emphasis on Wadies dynamics, which is used to describe the evolution and distribution of components and shapes are important contents and shapes formed by running water . Plane shapes are important contents in meander studies, which inevitably interact with lateral and longitudinal changes.

Many achievements of researches into meander morphology and parameters are mainly based on free meanders; those based on incised meanders are comparatively less, that is, the disequilibrium between the two emerges.

Researches on meanders have been done mainly on a single river or Wadies, and the researches on meanders of other rivers (Wadies) in the world are absent.

Materials and Methods:

The present study is entirely based on field investigation and has depended also on map analysis carried out on Morphmetric parameters on topographical map of sohag scale 1:250.000 published by Egyptian survey authority; in addition the study is based on TM.

The choice of Morphmetric variables that were examined in this study was based on the result obtained from previous studies ,in some previous studies these morphometric variables have been used to analyze the morphometric settings of other wadi basins in other areas (Morisawa , 1962 , Gregory and Willing , 1973 , Nebegu,2005, Mosleh , K., 2003) .

Geological and climatic setting:

1- Geological and structure Setting :

The study area is apart of the Nile valley and Eastern Desert that has been geologically investigated by many authors such as Sandford and Arkel (1939) ; Shukri (1950) ;Butzer and Hansen (1968) ; Said (1962 , 1975,1981,1983,1990) ; Wendofond Schild (1980); Issawi (1983); Issawi et al (1978) ; Issawi and Mc Cauley (1992); Mahran (1992); Omer (1996); Ahmed (2006); Omara et al (1973) . Ramadan (1992) and Senosy ,H., 1994

The stratigraphic section in Map area belongs to the Recent, Pleistocene , Plio – Pleistocene and Lower Eocene , whilst in Wadi Bir El-Ain is represented in Lower Eocene , which are founded the incision processes and incised meander . Fig (3).

The Eocene formation are considered the widest dominated in study area, which is cutting by group of Wadies and tributaries so, it is cutting and spotted by some steep scarps which are represented the water shed divide among these tributaries. This scarps represented by the dolomite limestone mixed by sandstone with thick 225 m (Omara, s., et al., 1973, p. 160; Barron and Hume, 1902, p.19). Field observation explain dominate some solution and disintegration by Wadies and rills, this formation is called Essawia Member (Said,R.,1981,p.17) .

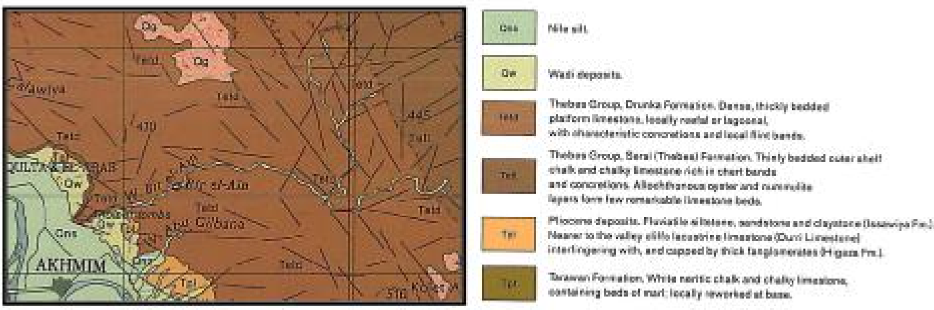


Fig. (3) Simplified geological map for the study area (after Conoco, 1987).

The lower Eocene rocks "Qassab formation" , Omara ,1973) are represented in succession of the Lower Eocene rocks exposed in Wadi Bir El –Ain has been established by measuring and describing four the surface sections at different localities within the geological map area .

Although most of the succession of the lower Eocene rocks exposed is built up of calcareous rocks , yet variations in the Lithology and faunal content made it possible and possible to divide it into three rocks units of member status . These unites are designated from top to bottom as Salamony , Sheikh and Qassab members.

(I) Salamony Member: The upper most beds exposed in the study area , which are composed of whitish, sugary , chalky limestone furnish the Salamony member (96 m) , whereas the basal grayish to greenish massive , poorly fossilifereous limestone (56 m) ,rich in flint concretion , constitute the Qassab member .

(ii) Sheikh Member: The middle lower Eocene is the middle portion measures some (137.5) meters and can be easily traced in the field. It is composed of yellowish to reddish, highly fossilifereous limestone inter bedded with conspicuous chart band.

(iii) The lower low Eocene (Qassab Member): The lower portion measures some (56) meters and also can be easily traced in the field . it is composed of basal grayish to greenish massive , poorly fossilifereous limestone , (56) meters rich in flint concretion , constitutes the Qassab member (lower low Eocene) . The intercalating shale beds yield of several smaller foraminifera indicating a lower lower Eocene age. in addition to the Qassab formation is represent the strata which the incised meanders are formed and incision are happened . generally, the three members are connected together with a marked lithological contact, its contact with the underlying Qassab member is, on the other hand, is marked by the preponderance of nummulites and assilina spp. and the limestone beds are of the microfacies association of limestone's belonging to the Qassab and Sheikh members are indicative of an environment of intermittent disturbance of an otherwise relatively calm shallow sea, possibly by strong currents and waves.

Structurally:

The Eocene strata have a gentle north – northwest regional dip. The morphological surface features dominating the area are true reflection of structural elements exhibited the drainage pattern is, as well, guided by fault and joints trends. The most distinctive structural features is the predominance of faults which dissect the limestone in the four common direction prevailing in the stable shelf of Egypt

(Said, R., 1962, pp: 30-35). They are mostly shallow high – angle normal faults. Few of them are traced for along distance, whereas the majority is of local importantance (Fig., 4) (Senosy, M., 1994, p. 110).

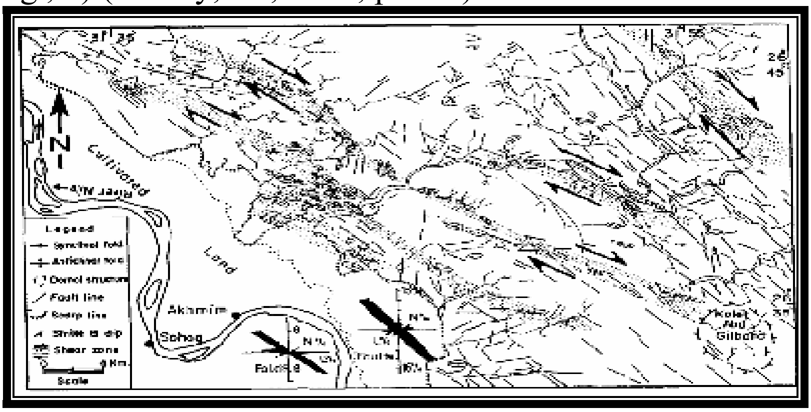


Fig (4) **structure in study area**
<u>after</u>: Youssef , M., et al . 1998

2- Climatic conditions :

The Meteorological data in the study area are obtained from Sohag meteorological station. The study area is located in eastern sohag. The study area is considered a part of the Eastern Desert . it lies within the barren desert that is distinguished by hot summer and cold winter with an obvious change in the temperature range. It is distinguished by the scarcity of rain and relatively high moisture content. The area is affected by northern winds especially in summer and the mean wind direction is north to northwest directions. The average seasonal wind velocity ranges between 2.3 and 6.3 km/h. In November 1994, the area received about 25 mm/day where floods struck the Red Sea and the Nile Valley provinces and caused serious damage (EMA, 2000) and in January 2010, floods struck the eastern side of sohag governate which involved the study valley (Elbeih, s., et al, 2011, pp: 16-17); it belongs to the arid belt of Egypt where it is characterized by long and hot summer and warm winter with almost no rainfall.

Table (1) Climatic Data from 1942 up to 1975 at the study area (Egyptian Meteorological Authority – sohag station database)

Data	Temperature				Evaporation Range	Rain Fall		Relative Humidity %
	Annual Average	Max Temp °C	Min Tem °C	Month Average		Annual Average Mm/m2	Max In one Day Mm/m 2	
Sohag Station	23.2	47.3 30/1970	0.4 22 / 1966	13.8- 30.8	7.4 mm	4.1	14.6 mm 15 / 1969	41%

The Table (1) illustrates The average maximum recorded temperature is 47.3 ˚C in June (1970) while the minimum is 0.4 ˚ C recorded in January (1966) Furthermore it is characterized by extreme Temperature with annual range about 23.4 ˚c and 30.8 ˚c (Mosleh .K., 2001 , pp : 540-541) ; The relative humidity ranges around 41% ,The rainfall over the study area is very limited and variable (Diab et al., 2002; Abu El Ella and Abdel Mogeeth, 1993).

I can say, the climatologically normal indicate that amount of rainfalls which fall in one day 15/ 1969) is recorded in sohag station about (14.6) mm , so the waterfall in arid regions characterized by sporadic and irregular unfortunately , the result is flood sheet, The later is responsible to incision processes in Wadies .

Result and Discussion :

(A) **Morphometric analysis of Wadi Bir el Ain drainage Basin :**

The dimensions of stream (channel) in my study area included in this study are based on previous work (Mosleh, K., 2003); and these data from which measurements are derived, are presented in table (2),which illustrates the following:-

(i) Wadi Bir el Ain represents one of the biggest Wadies in the east of sohag; it extends from south east – North West with 36 km and expands in area circa 463 km 2. it has a longitudinal shape , as a result to the structure of the study area Fig., (5) , Hence this Wadi can catch more of underground water

(Ashour , M., 1990 , P.45) , It extends over sandstone and limestone with high porosity. Thus water flows as a springs in some spots along the Wadi (300 m above S.L.), The elongation shape associated with Bifurcation ratio exceed on 3.8 , This causes the occurrence of flood sheets which result in avalanches in wadi and the destruction of the buildings in the mouth of wadi Bir el Ain (kawther city).

Table (2) Morphmetric and Relief setting for Wadi Bir El- Ain basin

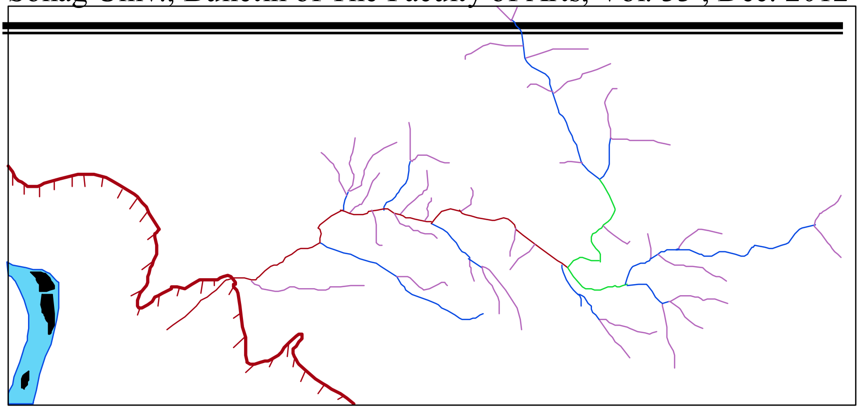
Basin	Area Km2	Form Factor	Gradient	SUM Stream Numbers	Drainage Density	Bifurcation on Ratio	Relief ratio	Lon. Ratio	Order
Bir El El- Ain	463	0.35	.011	2538	3.7	3.8	1.6	0.67	7

After: Mosleh, K., 2001, P. 547.

(ii) The number of streams (orders) exceed on 2538 streams; this means that the biggest area and the variable formation and its fractures, this factor indicates the reflection of dissected and denudate the area surface (incision processes) . this factor is one of the responsible factors in incised formation .

(iii) Drainage Density is decreased compared with wetted area (Schumm , 1956, P.602) ; and also is low compared with some Egyptian areas in eastern Desert . This is due to the local variability in Lithology , Fractions, hydrologic settings , Gradient and the stage of age for the Wadi .

(ix) The morphmetric characteristics refers to the steep gradient , so it is reflected in the distribution of Knick- points on the Long – Profile .



After : TM landsate scale 1:50000 (1999) .

Fig. (5) Wadi Bir El-Ain Basin Network

(B) - **INCISED CHANNEL MORPHOLOGY**:

The dimensions of stream (channel) in my study area, are included in this study are based on previous work (Mosleh, K., 2003); and these data, from which measurements are derived, are presented in table (2).

(B -1) The Correlations among geometric parameter meanders:

To study (define) the correlation among the parameters , the study used low, s Leopold and Wolman (1960) , which involved meander length , channel width and meander half – wave length , in addition to the relation between half –wave length and width of stream (El Husseni , E., 1975 , pp: 129 – 152) .

Table (3) Fig (6) illustrate that mean average between length and width is (1.8), while the average between length and radius is (3.8) ,this refers to decrease values comrable with the standard numbers which are suggested by Leopold and Wolman (1960) are 10 , This refers to the old stage which cross meanders in study area .

Leopold et al (1964, pp: 309 -310) revered to the positive relationship between meander length, width of stream or channel, There is a well established relationship between channel width and meander wavelength, which is usually approximately ten to fourteen times the bank full width (Chorley et al., 1984). Meander wavelength is more strongly related to channel width than to bank full discharge. This is because secondary circulation within the whether are flow in alluvial or bedrock streams channel, which is significant in meander development and is controlled by channel size (Charlton, R., 2007 , p.139). Dury (1970) revered also that meander length is between 7-10 time Wadi width in incised meander (Graf , 1988 , p. 199) . In addition , drainage basin size should play a significant role in determining incision depth .

Table (3) The correlation among meander parameters in study area

Meanders Points	L / W	L / R	R / W
A	2.8	2.7	1.30
B	1.7	5	0.33
C	1.6	3.7	0.43
D	2.4	2.8	0.85
E	1.2	3.7	0.33
F	1.2	5.5	0.16
G	2.2	4.5	0.33
H	1.3	2.7	0.16
Mean	1.8	3.8	0.48

L= length R = Radius w = weight

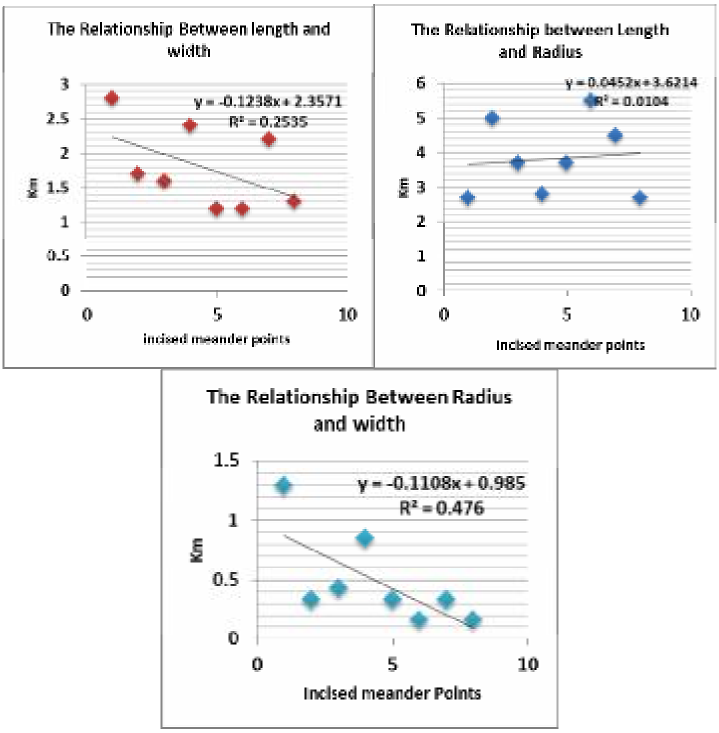


Fig (6) The Relationship Between the incised meander Parameters

2- Morphmetric Analysis to slope angle

(2-1) Frequency Distribution of slope angles Categories

Table (4) show the Frequency Distribution of Slope Angles Categories

Slope Angles	Gradient	Length (m)	%
0-10˚	Gentle	180	19.4
11-30˚	Moderate	119	13
31-45˚	Steep	289	31.2
More than 45 ˚	Cliffs	337	36.4
Sum	-	925	100 %

From: Field Study

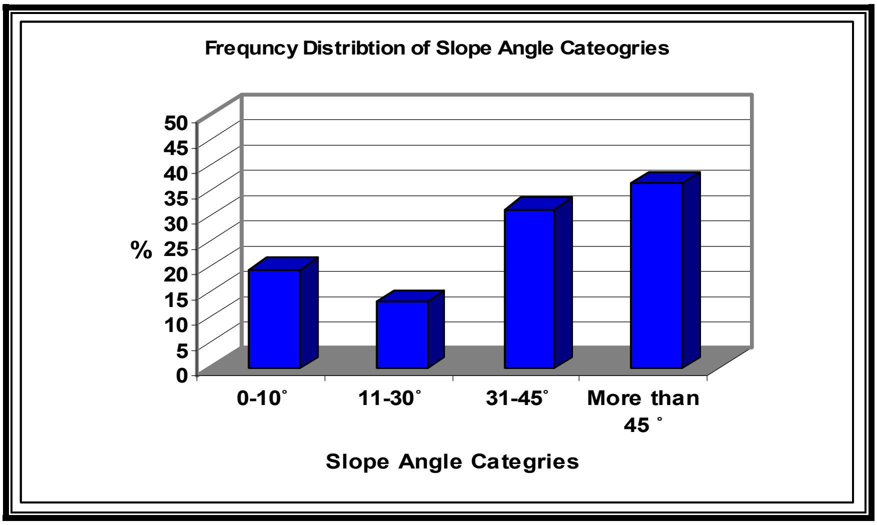


Fig (7) Frequency Distribution of Slope Angles (Categories)

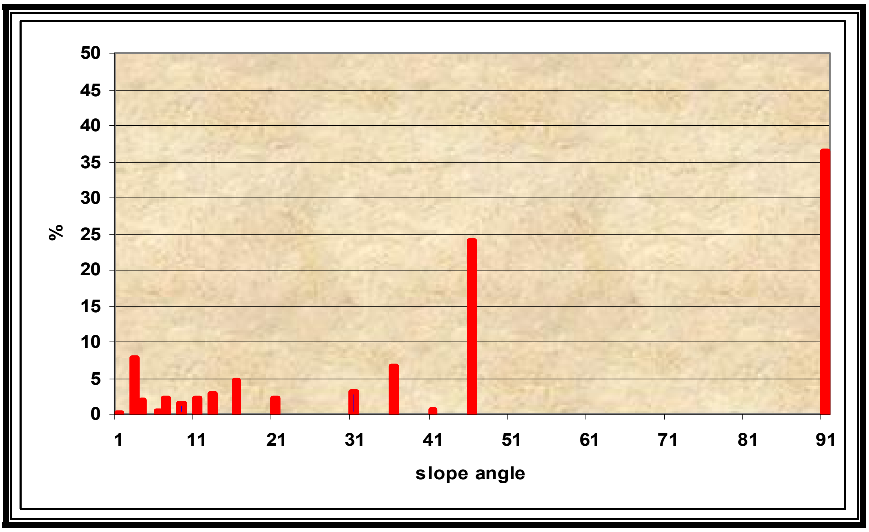


Fig. (8) The Frequency Distribution of Slope Angles

Table (4), Fig., (7) and (8) illustrate that:-

1- The steep gradient and cliffs have the first class with 67.6 %,This indicates the tectonic active and denudate rates on sides of incised meanders.

2- The Frequency Distribution is regular except from angle 15 ˚ until angle 35 ˚ , this is due to the effect of geomorphological processes (i.e. , mass wasting , running water , weathering , human activities) .

3- The Frequency Distribution characterized by Bio-modal, which characterizes the Arid and Semi Arid Region (Young, A., 1972, pp: 167 -168).

(B -2) CONTROLS ON INCISED CHANNEL MORPHOLOGY

Incised channels are the product of long-term valley, Incision coupled with the effects of large-scale sub- aerial exposure and weathering (Schumm, 1993) These factors make it difficult to identify the dominant controls on valley or channel morphology, which include base-level fall, gradient profiles, climate, Lithology and tectonics. Vertical incision commonly initiates when base-level fall exposes a surface with a steeper gradient than the fluvial equilibrium profile, and the shelf break Schumm & Ethridge, 1994; Wood et al., 1994; Posamentier & Allen, 1999).

Wadi systems aim to equilibrate their gradient profiles to the imposed lowering of base level by the process of landward knickpoint migration (Schumm et al., 1984; Schumm & Ethridge, 1994; Hassan & Klein, 2002; Ethridge et al., 2005).

Knickpoint- migration rates, which determine the degree of long-profile equilibration, are shown to correlate with drainage areas, which serve as proxies for discharge (Loget & Van Den Driessche, 2009)., the degree of vertical incision is attributed to the magnitude of base-level fall (Schumm, 1993; van Heijst & Postma, 2001) and the angle of the exposed break in slope (Woodet al., 1994).

Knickpoints generally only move several kilometers upstream for small, high- gradient systems, whereas large, low-gradient rivers adjust their profiles hundreds of kilometers upstream (Blum & To ¨ rnqvist, 2000). Valley width is linked primarily to the rate of base-level fall and climate. At slow rates of sea- level fall, channel migration and associated slope- adjustment processes operate over longer time spans, which results in wider valleys (Schumm & Ethridge, 1994).

The role of climate in incised- channel development is complex because river and slope processes are affected by variations in temperature, precipitation and flood frequency and/or magnitude, and their effects on vegetation and surface runoff characteristics change over varying time scales (Blum et al., 1994;; Leigh et al., 2004).

These parameters are difficult to constrain throughout the long time period of incised-channel evolution, but all contribute to valley incision/excavation and accretionary processes. For example, dry climates are characterized by variable discharge and low amounts of channel-margin vegetation, which decreases bank stability and promotes valley widening (Schumm & Brackenridge, 1987).

Valley dimension also varies along dip in bends, at tributary junctions, and as a result of changes in substrate and/or tectonic influence (Schumm & Ethridge, 1994; Ardies et al., 2002; Plint & Wadsworth, 2003).

The researcher argued that the incised meander and channel present the most complete record of fluvial response to sea-level flactuations and many of the variables responsible for their evolution can be constrained, such as sea-level, climate, drainage- basin size, gradients, substrate Lithology and tectonics. Although the agreement among geomorphologies that incised meander are channel insight of sea level fall, but Dalrple et al , 1994 and Posamentier , 2001 , assumed that incised meander channels or meanders are commonly used to mark sequence boundaries associated with the low stand system tracts , while valley incision has been attributed primarily to base level lowering , the possibility that it may be unrelated to base level has also been raised , also special cases in which base level lowering does not result in valley incision have been described by Pasamentier (2001) . A few examples relating valley incision to non – base level parameters exist. (Khadkikar, A., and Rajshekhar, C., 2005, P. 295).

(B-3) Incised-channel width and cross-sectional area

Incised-channel width can be over two orders of magnitude greater than depth; this shows that the factors controlling valley or channel width are more important for modulating the rate of creation of sediment accommodation during the subsequent sea-level rise than the factors controlling channel depth. As valleys flood and fill with sediment during sea-level rise, variations in the morphology of the channel banks strongly control the rate of creation of sediment accommodation.

Researchers have shown that incised-channel width is controlled primarily by the rate of base- level fall, the angle of the newly exposed shelf, climate and the duration of subaerial exposure (Schumm, 1993; Schumm & Ethridge, 1994; Ardies et al., 2002; Ethridge et al., 2005).

The rate of base-level fall should determine the degree of lateral fluvial adjustment prior to entrenchment. Once the active river channel incises to a level where it is unable to overtop its banks, the morphology of the valley banks are principally modified by processes related to subaerial weathering and mass wasting. These processes are linked closely to vegetation and its controls on channel-side stability, which are ultimately related to climate (Schumm, 1993; Schumm & Ethridge, 1994; Ardies et al., 2002). The duration of subaerial exposure determines the degree to which slope-adjustment processes can operate and modify the morphology of interfluve areas and valley banks. Flume studies also suggest that fluvial activity (meandering, etc.) associated with the transgressive stage of incised channel infilling modifies valley flanks substantially, which results in valley sides being highly diachronous along strike (Strong & Paola, 2006, 2008).Fig (11).

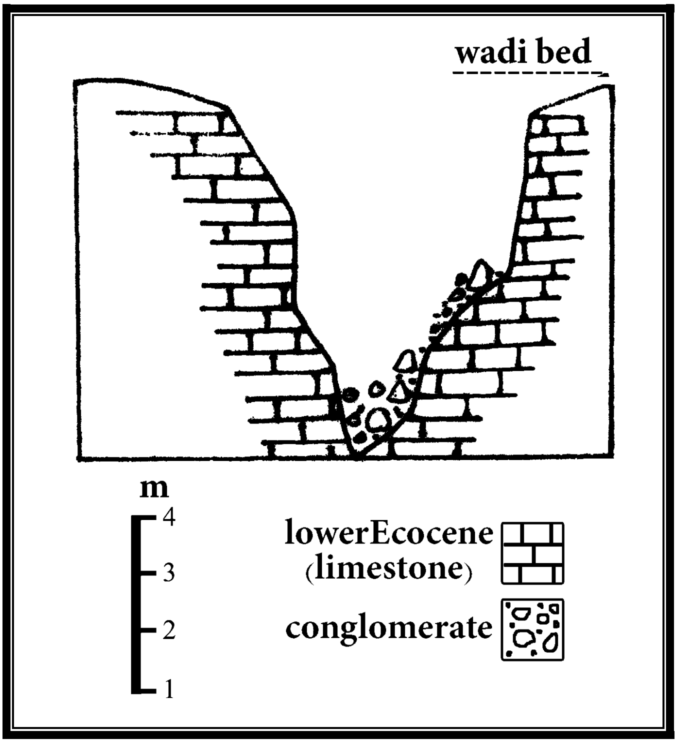


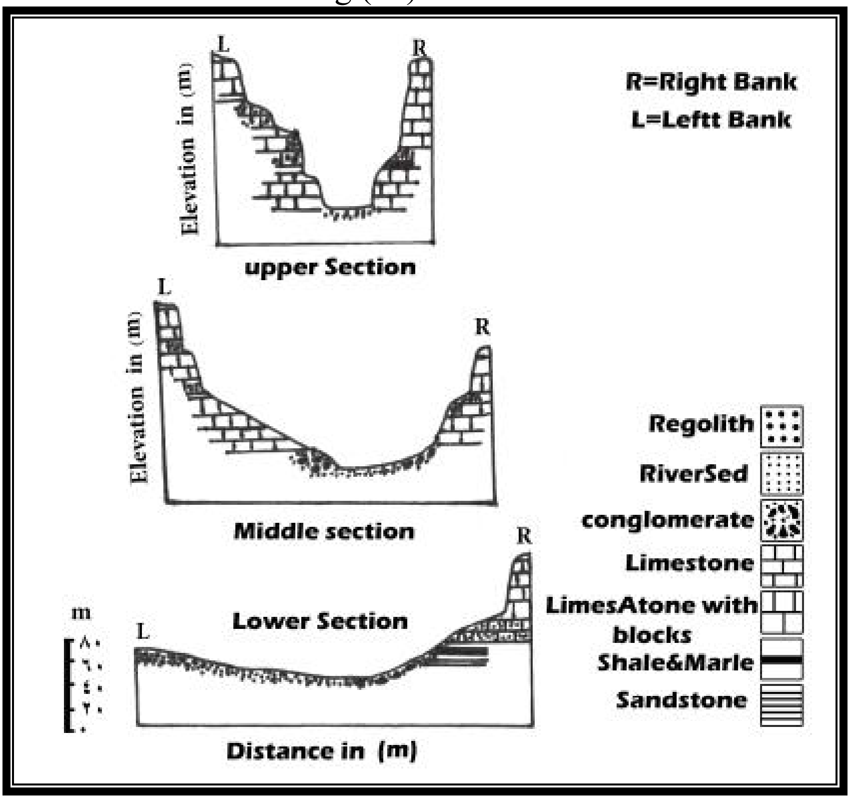
Fig . (9) Cross – section in incised meander in lower section of Wadi Bir El- Ain

It is Obvious from Field Observation and analyzes to Cross section that:

(i) The cross section from Fig.(9) of a valley is assumed to have the shape (V) in incised meanders with irregular , due to most real valley cross sections are not smooth , but irregular , it also describe to include local variability , the later introduced is generally insignificant for variation in formation characteristics, or variation in responded to erosion factors ,which eroded one side and deposited in the other .

(ii) The points of meander have a special characteristics ,which the water flow in rapid and velocity of erosion is high , so increase in erode rates especially in concave side , hence become steep , and the cross section seems un- sequence or irregular Fig., (10) .

(iii) According to Lithology of channel perimeter and channel morphology two main types of channel categories ; The first ;predominantly rock reach , and the second reach of gravel deposition , could be identified in the field .
(iv) Approximately few kilometers middle stream and upper stream of Wadi Bir el-Ain(knickpoints) the wadi runs through a narrow bedrock (bends) with steep to near – vertical walls ,the channel width generally varies between 5-10 meters (incised meanders) . The representative cross-sections are shown in Fig (10) .



Reprinted from: Mosleh , K., (2001)

Fig. (10) Show The Cross –Sections of Wadi Bir El-Ain

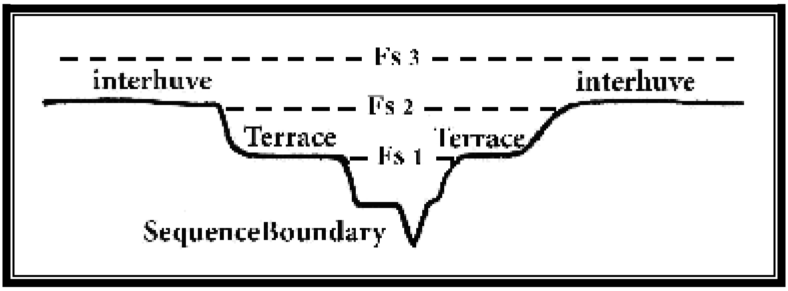
(B-3-1) Sedimentation in meander (Bend) area (sequence boundaries)

Field study observation show that sedimentation in a meander Bend obeys the fining up wards cycles is deposited with this sedimentary sequence identified as the most probable by transition probability analysis.

Although, Jackson (1976) suggests that the classic fining – upwards sequence requires fully developed flow with equilibrium between flow velocity, bed material sizes and bed forms. In addition, stratigraphical details reflect both the prevailing balance between gravel and sand supply and the more local downstream sorting within the bend from bar head to tail. Other complexities in meander sedimentation include chute comprised of gravel, sand and stone boulders during the falling stage. (Al- Abyan, A., and Chalov,R., 1998 , p. 211) .

From the field study; the present study demonstrated the influence of active meandering by flood (flood sheet) is classic interpretation of the complex sedimentology of valley fill .

Bank morphology records the balance of erosional and depositional processes induced by the alignment and energy of flow at differing flow stages. Bank morphology is also a function of bank composition (texture). Banks comprising sands and gravels are more susceptible to erosion than those with a high silt–clay content. However, the former are also more likely to have bank-attached depositional forms along their margins. But this isn't general in all incised meanders points , but from field investigations study founded more deferential on incised meander's banks . (fig.11) .



After: Mac Donald, A., et al , 1998 , P.1158

Fig (11) Sequence boundaries are composed of incised meander region
(valleys) and flatter regions (Terraces and interfluves)

The erosion surface generated by Base – level fall within fluvial formation typically is composed of two types of geomorphological elements ; incised meander area formed by down cutting river (valley) and streams , and relatively flat area where stream down cutting is insignificant , the incised area are the valley system , and the relatively flat areas include both the interfluves adjacent to the valley and terraces within larger valley systems (Mac- Donald , A., 1998 , pp: 1157-1158).

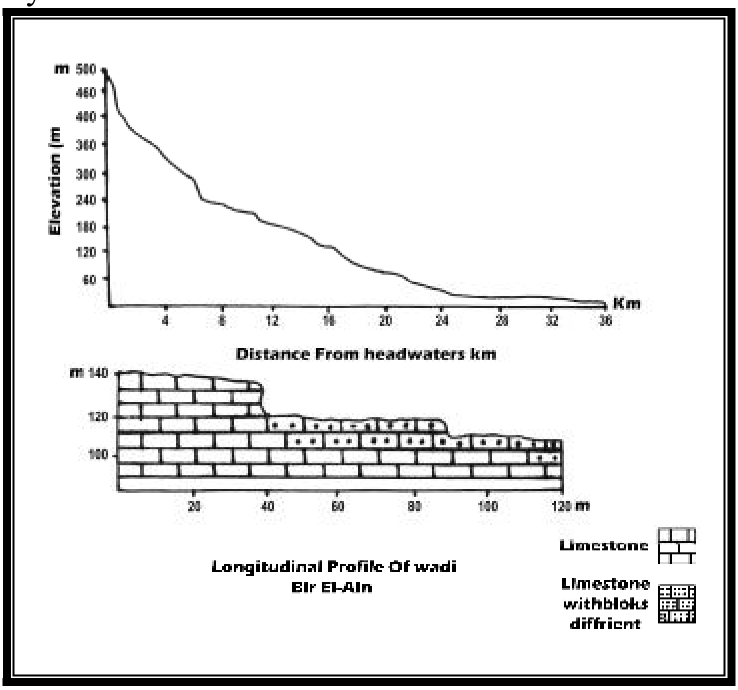
The cross section from Fig. (10) of a valley is assumed to have the shape irregular especially in incised meander, it is also desirable to include (i): local variability; this local variability introduce is generally insignificant for lithological variation (limestone, merle, shale), this variation is resulted a different responds to erosion processes which denudate in side and sediment in other.
(ii): There are remains to Karest solution which refers to the Pluvial periods (Said , R., 1981 , pp: 93-97) and climatic changes through the geological periods furthermore the recent rainfall which effect in solute limestone rocks .

(B-4) Long – profile characteristics:-

(B-4- I) Channel gradient and the long profile

Fig (12) illustrate that , (i) The long profile is represented concave shape ,but the degrees of concavity is more differential which the long profile has some convex parts , due to lithological variation , durable in rainfall , and gradient ,the latter is between 0 ˚ – 5 ˚ . (ii) The long profile seems some steep gradient points, due to different formation and tectonic fractions. (iii)These steep points is represented the knickpoints, or rejuvenation points.

(iv) the channel longitudinal profile of Wadi Bir El-Ain displays disturbances where landslides affect areas .



Reprinted from: Mosleh, K.,(2001)

Fig . (12) Longitudinal Profile of Wadi Bir El-Ain

(B-4-2)Geomorphological Features along the long- profile

There are many features or bed forms such as riffle – pool sequence and large scale dunes course local, within reach gradient variation. For example, the valley fill gradient inherited from paleo- channel deposition controls the present power expenditure rate and therefore the channel pattern, sinuosity and gradients. (Richards, K., 2009, p. 222). In normal valleys which widen downstream, equilibrium channel gradients are less than or equal to valley gradient. Meander development and incised sinuosity on a steep valley surface lengthens the long profile and alters the overall long – profile shape , which therefore both an independent control in that records the history of fluvial processes , and a dependent variable in that it incorporates contemporary steady- state adjustments .

The long – profile is the least transient expression of fluvial processes reflecting as it does geological influences such as the effect on available relief of tectonic history and base – level change , of erosion and deposition and of the distribution of outcrops of different lithology . When discharge increases rapidly downstream with increasing contributing area, profile concavity is greater. In consequence, the profile form reflects the inverse discharge – slope relation by being convex upward as a result of aggradations by the individual rare flood events. (Schumm, 1961), the features can summarize in the following:-

(i) Potholes

These deep, circular scour features are formed in bedrock channel reaches by abrasion Plate., (2-3) .(Charlton, R,. 2008 , p.133) , abrasion is the process by which the channel boundary is scratched, ground and polished by particles carried in the flow.

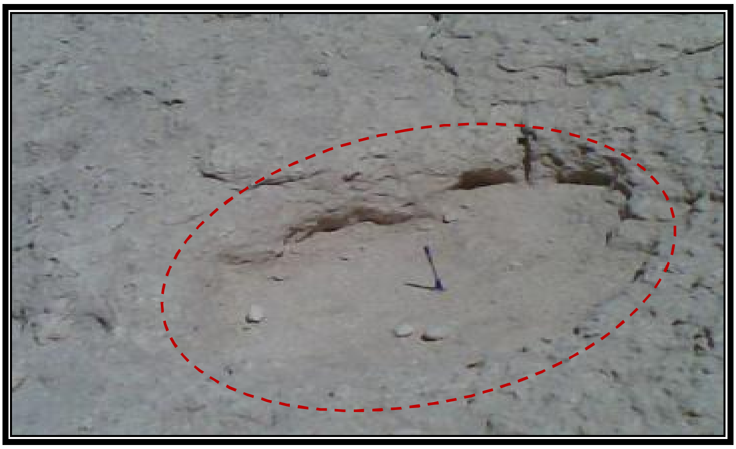


Plate (2) Deep, circular, scour feature formed at the base of a bedrock step.

Erosion is often concentrated where there are weaknesses and irregularities in the rock bed, which allow abrasion to take place at an accelerated rate. This can lead to the development of potholes, deep circular scour features that often form in bedrock reaches. Once a pothole starts to develop, the flow is affected, focusing further erosion. Any coarse material that collects in the pothole is swirled around by the flow, deepening and enlarging it, and literally drills down into the channel bed. Over time potholes may coalesce, leading to a lowering of the bed elevation.(Charlton, R,. 2008 , P.96) .

B

Plate (3A,B) shows how potholes have contributed to bed lowering near the site of a waterfall.

<u>Note:</u> **The Scouring by finer material carried by the flow, such as sand, leads to the development of sculpted forms.**

B) Bedrock Bars

(ii) Bedrock bars

In incised bedrock channels, the flow sometimes moves around bedrock bars (Plate 4). These form when multiple sub-channels are incised into the bedrock substrate, leaving 'islands' or bedrock bars between them. Bedrock bars may form the core of a bedrock-alluvial bar, which becomes covered by a layer of sediment on which vegetation becomes established.(Charlton, R,. 2008 , p.133) .

Plate (4) show the bed rock bars which In incised bedrock channels,
the flow sometimes moves around bedrock bars.

(iii) Knick points and incision:

Knick points—locally steep sections of the longitudinal profile of a stream are key features in the interpretation of fluvial channels and the evolution of fluvially dissected landscapes. This study investigates the origin of knick points in Wadi Bir el- Ain and their implications with incision along the valley.

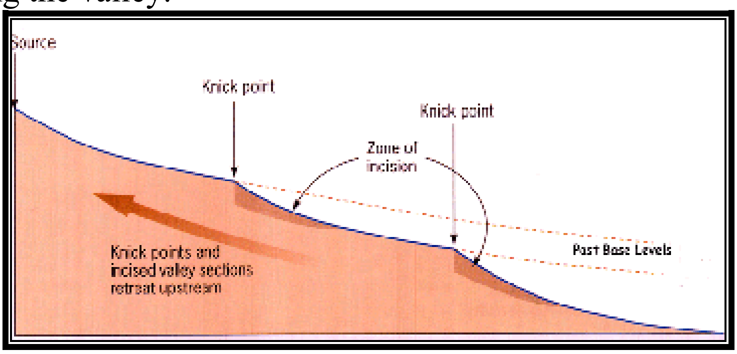


Fig (13). Schematic illustration of a typical knick point on a long profile of a channel.
The knickpoint defines the mobile boundary between the adjusting and relict portion of the channel.

The interpretation of knick points is largely independent of notions of grade or steady-state. That is, locally steeper sections of stream profiles may provide evidence of underlying controls or processes without making any assumptions about normative profile shapes. Fig (13) .

Knick points and convexities are attributable to several factors, which are not independent or mutually exclusive (Knighton, 1998; Burbank and Anderson, 2001; Schumm, 2005). Variations in resistance, typically associated with Lithology, are a common cause, particularly of waterfall-type knickpoints. As the resistant materials are eroded more slowly they stand out in relief as higher slopes within the channel. Structural features such as faults, fractures, or other joints may result in steps or cascades due to selective removal of rock slabs along vertical or sub- horizontal weathered joints. Knickpoints in the bedrock streams of Wadi Bir El Ain studied by Mosleh , K., (2003), for example, He found to be entirely sea level fall and structurally controlled or influenced Tectonic deformation of channels can also result in profile convexities, independently of any associated rock structures. knickpoints may also result from sediment inputs from tributaries or hillslopes. Where these inputs exceed fluvial transport capacity or competence, a knickpoint or zone may be associated with the debris. Localized erosion within a channel may also result in local steepening. This may be associated with critical thresholds of stream power, influencing a stream's ability to incise its bed, or with non - fluvial channel erosion such as debris flows, or dissolution in fluvio-karst systems. Removal of sandy debris or other flow obstructions may also result in localized incision. Variable effects of bed load as protective cover or abrasive tool may be associated with knickpoints formation, and may also be important with respect to the type of knickpoints (see, e.g.,Gasparini et al., 2007; Pasternack et al., 2007). Locally steeper slopes can sometimes be associated with lateral channel changes. Meander cutoffs locally reduce channel distance, thus increasing slope. Successful avulsions result in occupation of steeper slopes than the abandoned channel (see, e.g., Slingerland and Smith, 2004). Human modifications such as channelization, artificial cutoffs, and impoundments may also create knickpoints. many knickpoints are, or are at least interpreted as being, due to down cutting or incision associated with base level lowering. In this case the knickpoint represents a locus of incision, which may migrate upstream, thus translating the effects of the lower base level. Such migrating knickpoints may become stalled because of lithological and structural controls. Whatever the initial cause of a knickpoints, an additional factor in its persistence may be insufficient time for stream profiles to adjust to disturbances or changes. Independently of any notions of normative grade or steady-state profiles, adjustments to e.g., sediment inputs, cutoffs, avulsions, and migrating incision local may reduce or eliminate profile convexities over time. (Phillips , et al , 2010)

Plate (5) Knick point in A) upper section and B) in middle section of Wadi Bir el Ain.

Studies of knickpoints and knick zones have tended to emphasize particular causes, such as Lithology (Miller, 1991), base level change (Bowman et al., 2007), tectonic deformation (Schumm ,et al., 2000), or upstream migration of an incision signal (Anthony and Granger, 2007a). This emphasis is generally attributable to an explicit interest in the relationship between a particular forcing and the profile response. However, more broadly focused studies of knickpoints have often found multiple causality within the same river system. For instance, Bishop et al. (2005) and Crosby and Whipple (2006) found knick point locations and recession rates to be a function of both transmission of an incision signal upstream and stream power (related to drainage area). Larue (2008) found profile convexities to be due to a combination of tectonic, structural, and lithological controls. In Wadi Bir El- Ain, incision apparently drives the formation of knickpoints, but local structural features determine their location, size and morphology (Phillips and Lutz, 2008).

The presence of several similar (knickpoints) , but buried and inactive , knickpoints along the upper and middle course reach indicates that the locus of most active channel incision has shifted with time (Wohl,E., et al , 1994 , pp:1-13) , probably in response to base level changes associated with tectonic activity along the Wadi Bir El Ain ,thus the rate and manner of channel incision along the wadi are controlled by lithologic variability and tectonic uplift as they influence channel morphology and gradient , which in turn influence hydraulics and sediment transport .

Morphology of knickpoints

In the area of the knickpoints where the channel gradient increases, the Wadi runes to a large extent a bedrock. From field measurements the channel is approximately 2-5 m wide, 3-9 m deep and it displays a V-shaped cross- sectional geometry. And the gradient is very steep to cliff its slope angles a ca 35°- more 45 degrees. The lower Eocene conglomerates exposed in the channel are polished and display streamline forms. Locally, it is mantled by a ca.50 – 200 cm thick cover of gravel and conglomerate blokes of several m3 that are derived from Eocene blocks .

a- Geomorphological process below the knick point

In the lower portion below the knickpoints, the braided nature of the valley belt and the clast supported fabric of the deposits suggest that sediment transport occurs episodically as bedloads during high discharge events. The bordering hillslopes reveal a variety of geomorphic features that suggest of occurrence of episodic and continuous mass movement processes . The angular lower contacts of these slopes indicate that the down-slope flux of sediment is balanced by sediment transport in channels. The dip angles measured on the lower portion of the two sides hillslopes display magnitudes that are characteristic for an at – yield mechanical state , and the associated bulges that border the scars in the down slope direction (landslide deposits) .The smoothness of the uppermost portions of these slopes indicates that the predominant nature of sediment transport is soilfluction .(Schlunegger , F., and Schneider , H., 2005 , pp :111- 112) .

In contrast, the nearly vertical slopes of the hillslopes on left side of the valley indicate that erosion and sediment mobilization occurs by rock falls. The slopes are likely to be beyond the critical angle of failure .it appears that the left and right hillslopes reflect the dip of bed rock rocks forming the incised channel or meanders.

b- Some features is associated with Geomorphological process below the knick point

1- **Rapids:**

are stair-like arrangements of boulders on steep slopes. Individual particles are numerous enough or large enough to break the water surface at mean annual discharge (Graf, 1979). Rapids form by transverse movement of boulders at high flow stage (recurring perhaps once every few years). A series of ridges of coarse clasts spaced proportionally to the size of the largest clast is produced. Grant et al. (1990) distinguish rapids from riffles by their increased steepness, their greater areal proportion of supercritical flow, and the arrangement of boulders into transverse ribs that span the channel. Rapids in bedrock channels may be analogous with riffles in alluvial systems. plate (6) .

2- **Plunge Pools**

Are formed under the force of natural source, such as a waterfall or rapids , the swirling water , sometimes caring rocks within it , erodes the wadi or stream bed into a basin , often featuring irregular and rough sides . plunge pools are erosional features which occur in the youth stage of Wadies or rivers , when soft rock has been eroded back to a knickpoint ,water constantly bombards its base . Because this rock is often less dense than surrounding strata, the water from the higher grate continues eroding downward. from field study can measured the dimensions to some pools which around 50 cm depth and 1 m width , because sometimes they was filled by sediments , some pools are joined together and forming channel in the main stream .

Plate: (6) Rapids in upper section of Wadi Bir Al Ain

Bisson ,P., et al (1981) classified the pools into two major groups **;** ***the first*** , backwater pools occur wher major obstructions occur in the channel , these include in study area boulders, bars and large stones which are felled from wadi hillslopes ,which fall into these pools with declining velocity and energy gradient .consequently , sediments are deposited into these locations and format separation zones on the lee side of boulders and blocks of stones . ***The Scand*** group, Dammed pools occur upstream of boulder lines in rapids and, on a larger scale , upstream of channel spanning debris jams or gravel accumulation .
In addition to the later , from field study the researcher found some pools are joined or connected ,this are called scour pools which occur where a construction which the water run around it , these represent the deepest places in the incised channel in Wadi Bir el Ain .Plate (6) .

The meandering parameter (morphology):
Some geomorphologies (Leopold and Wolman, 1957 , Schumm and Khan , 1972 , Carson , 1984 , Bridge , 1985) postulated that river forms reflect three main independent factors, namely (1) the discharge regime which depends on climatic and soil conditions; (2) the slope or gradient conditioned by the relief of the area crossed by the river; (3) the erodibility of the bed depending on the sediment properties. These three controls determine features of the river pattern and hydraulic conditions of the flow. Lokhtin offered a channel development criterion, defined as the ratio between the stream power (indexed by the gradient) and the erodibility of the bed (indexed by grain size). Lower values of this criterion correspond with stable sinuous 'meandering' rivers; higher ones conform to unstable divided or 'braided' streams.

Original classifications of river channel pattern (Leopold and Wolman 1957) discerned three essential types: straight, meandering and braided. Anatomizing, split, wandering, 'meandertal' (meandering Talweg) and some other patterns were distinguished later, and were interpreted either as transitional forms or as subtypes. As new types were discerned, new classification schemes were developed. Nowadays the classification of Kellerhals et al. (1976) is most detailed, but it appears to be rather complicated.

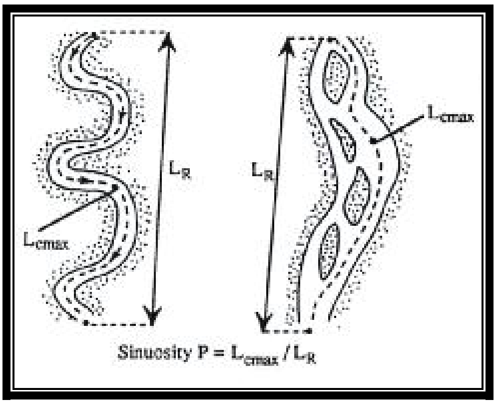
This classification was criticized by Chalov (1979, 1983), who argued that it fails to distinguish the structural levels of fluvial relief: side bars and meanders, mid-channel bars and floodplain islands are all treated as comparable forms in terms of their role in the classification. Chalov recommended three classes of relief to be defined: floodplain, channel form and bar. Another shortcoming occurs in that limiting conditions of channel migration were given little consideration, and are only relative to the meandering process. Accordingly, Chalov (1983, 1996) proposed distinguishing Incised rivers and rivers with wide floodplains (wide-floodplain rivers), transitional types of rivers with confined channels as well. Each of these could be subdivided as straight, meandering or branched. Vertical deformation plays a general role in the development of incised channel patterns. Morphological features of incised rivers are determined mainly by the geological structure and history of the valley. Channels formed along folds and faults in hard rocks are rather straight. Incised meanders usually develop as a result of the intensive incision of originally sinuous rivers in relatively soft rocks. Multiple channels in this case are connected either with hard rock exposure in the river bed (structural branches) or with accumulation areas where flow capacity decreases both in valley expansions and when slope diminishes as a result of downstream changes in Lithology. Although ,variable of factors are responsible to channel sinuosity ,I can interpret the development of bed rock channel sinuosity to indicate high lateral erosion relative to bed incision , and that increasing sinuosity is a key mechanism by w hich Wadies widen their valleys either downstream or over time (Jansen , et al , 2006 ; Ahmed ,A., and Fawzi , A., 2009) .

1- Meandering pattern:

Two minor modifications have been adapted to the procedures previously used in defining the sinuosity of channel (e.g. Leopold and Wolman, 1957); firstly, the channel length has been measured along a line that runs mid-way between the channel banks. this has allowed measurement readily form topographical maps, areal photographs and satellite images, and also has the advantage that the channel length is unlikely to change in a major way with changes or river water level (Friend, P and Bristow , C., 1993, p. 115) .

Secondly , the meandering (sinuosity) parameter has been extended to multi – channel situation where it is based on the mid – channel length of the channel that is widest in each reach of the channel belt Fig . (14) the modified sinuosity parameter P, is defined as :-

$$\mathbf{P} = \mathbf{L}\ \mathrm{CMAX}\ /\ \mathrm{L\ R}$$



After : (Friend, P and Bristow , C., 1993, p. 115) .

Fig . (14) Diagram representing the calculation of the Sinuosity of Single-channel and multi-channel Wadies

Where LR is the overall length of the channel belt reach measured along a straight line , and L cmax is the mid-channel length for the same reach , or the mid-channel length of the widest channel , where there is more than one channel Fig. (14) .

Various methods are used to quantify the geometric characteristics of meandering channels. These are based on measurements that can be made in the field, from maps, aerial photographs and, increasingly, satellite images. The spacing of meander bends, or meander wave length(L), can be determined by measuring the straight – line distance from one bend to the next , Cook and Doornkamp (1977) , which there is a well established relationship between channel width and a meander wave length , which is approximately 10 to 14 times the bankfull width .Radius of curvature (rc) , can be determined by fitting a circle to the centre line of a meander bend , this allow to comparison between channels of different sizes, the tightness of bend is usually expressed as the ratio between the radius of curvature and channel width at the bend :-

Tightness of Bend = rc/w

This ratio is relatively small for tight bends and increases for bends that curve more gradually. Observations have shown that many bends develop an rc/w ratio of 2 to 3. For bends that are tighter than this, flow separation leads to increased energy losses (Bagnold, 1960).

Incised meander formation and development

Incised channels are ubiquitous features of disturbed landscape, whether incision results from natural causes or as the result of human activities, incised channels are found wherever and whenever there is as access of flow energy (sediment transporting capacity) relative to the amount of sediment supplied to the stream (Simon , A., and Darby , S., 2002 , pp: 229 – 230) .

The precise causes of sediment supply- transport imbalances that lead to incision have been intensively researched (Schumm , et al , 1984) ;(Schumm , 1999) is noticed that river (valley) tendency to meander in where increase in sediments especially the silt and mud in banks and beds of channels and the meander channel is steep gradient and deep , ,while the straight channel is shallow . so, there are correlate between sinuosity and bedloads ,which increase in meandering while the loads on bed as abed load .

Durey (1970, pp: 266–270) reveres that incised meander is induced by streams, work within the Pleistocene, which amount of sediments are derived with flood waters so, it can say that incised meander are induced by the variation in river regime.

But we can accept this opinion absolutely because two reasons: The first; we can't estimate the rates of erosion and sediments which are formed this meanders, to difficulties imagined completely invasion for the rains and runoff through the Pleistocene. The Scand; The effect of structure and biological factors in Wadi pattern.

Finally ,and based on the result of some geomorphological studies and field investigation , recent study can summarized the main factors which the channel shape associated with them including changes in climate , land cover (sediments) , tectonics , the role of plants , relief and gradients, and it has been realized that sea level fluctuation .

Conclusion :

1- The Data is collected give a detailed picture of the incised meander characteristics' and formation in Wadi Bir El- Ain .

2- A Variety of Knickpoints exists in Wadi Bir El –Ain, while some of these are likely related to base level change and incision in Wadi Bir El-Ain drainage Basin.

3- Field study indicated that the Knickpoints not attribute to single factor is dominated ,such as changes in base level, but there are local factors such include rock fall rapids are collected by mass wasting from adjacent valley hillslopes ,structurally controlled headwater cliffs , and discharge influence in created some knickpoints and incised channel associated with them.

4- The geological Lithology, structure and gradient can interpret the development of the bedrock incised meanders in Wadi Bir El – Ain .

5- The morphology of Wadi and the factors of discharge (drainage basin size, gradient and climate) play the most significant role in determining to what degree Wadi systems are able to adjust vertically in response to sea-level fall.

6- The sedimentation in a meander bend and incised meander obey the fining – up wards cycles is deposited, with this sedimentary sequence identified as the most probable by transition probability analysis.

7- According sinuosity index, channel in Wadi Bir El-Ain is described by meandering, this interpret the development of bedrock channel sinuosity to indicate high lateral erosion relative to bed incision.

8- The study has found that a smoothly concave longitudinal profile is not necessarily a normative state for present-day Wadies. On the other hand, strongly concave profiles can arise in areas of active faulting, in the absence of the presumed steady-state relationship between discharge, slope and sediment supply associated with the formation of graded profiles.

9- One of the most important conclusions of my work refers to the relation between the incised channel or meander and the presence of knickpoints , the discharge factors and wade's morphology .

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