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Geomorphology of Jeddah Governate, with Emphasis on Drainage Systems

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*Abstract***.** Jeddah Governate comprises three distinct geomorphological zones; the Red Sea and shore features, the coastal plain, and coastal hills and pediments. The last zone lies east of the municipal Jeddah city and consists of low lying hills, and an elongated N-S oriented depression, forming a basin that lies within the coastal hills.

The Red Sea displays landforms that characterize prograde shorelines; implying that the Red Sea is recently in regression. Such features include flat lying sandy beaches, lagoons, sabkhas, sea islands, bars and spits, as well as the raised dead coral terraces and marine limestones exposed inland.

The drainage in the area consists of a large number of systems; twelve of which were considered to be major systems that were delineated, described and analyzed morphometrically. These systems are, from north to south: Wadi Al-Kura', Wadi Muraygh and Wadi Ghuraiyah, Wadi Um Hablayn, Wadi Burayman, Wadi Hutayl, Wadi Bani Malik, Wadi Mirayyikh, Wadi Quwayzah, Wadi Ushayr, Wadi Ghulayl, Wadi Al-Khumrah and Wadi Fatimah. All of these systems drain westwards towards the Red Sea, except Wadi Fatima that abruptly diverts direction to the north at its lower course along the coastal plain and this could be attributed to active faulting.

A large number of wadi channels, both major and minor, terminate within the coastal plain at a distance from the Red Sea shore. This phenomenon could be attributed to one or more factors, such as active neotectonics, human activities and shore drift.

Almost all of the drainage systems in the area exhibit parallel patterns along the coastal plain, whereas they display dendritic to

subdendritic and radial pattern upstream. The drainage density of the wadi systems varies in the previously mentioned geomorphologic zones of Jeddah Governate, being the highest along the coastal hills zone.

Keywords: geomorphology, drainage systems, aerial photographs, Jeddah, Saudi Arabia.

Introduction

Jeddah Governate lies at approximately the middle part of the Red Sea shore of Saudi Arabia (Fig. 1). The mapped area occupies a stretch of land along the shore, 60 km long and 40 km wide. It is bounded by latitudes 21˚15'00" and 21˚55' 00" N, and longitudes 39˚ 00'00" and 39˚30' 00" E. The great majority of the drainage systems in this area are directed towards the west, whereas at the extreme eastern part of the area, few systems are directed towards the east which have been ignored in this study.

Field investigations in conjunction with RADARSAT satellite imagery, aerial photographs and topographic maps of Jeddah city and environs are utilized to delineate, and morphometrically analyze the drainage systems in the concerned area. The basic sources of data used to perform this work are the 1956 aerial photographs that predate the recent expansion of residential areas of Jeddah city. However, these areas constitute the lower courses of the main drainage systems and could be considered minimal compared to the whole area.

The main purpose of this study is to delineate the drainage systems at Jeddah Governate to provide the first detailed drainage map available (based on aerial photography interpretation under stereoscope) and perform analyses of these systems so as to assess their impact on the city. The second purpose is to study the geomorphologic features specially the coastal features so as to infer the direction of the shoreline migration and its possible effect on the city.

A number of workers investigated various aspects of geomorphology, hydrology and drainage morphometry within and around Jeddah Governate (Abdulrazzak *et al.*, 1988; Basmaci and Al-

Kabir, 1988; Basmaci and Hussein, 1988; Abu-Rizaiza *et al.*, 1989; Sorman and Abdulrazzak, 1993; Abu-Rizaiza and Sarikaya, 1994; Gutub and Awadalla, 1994; Onder, 1994; Shehata *et al.*, 2001).

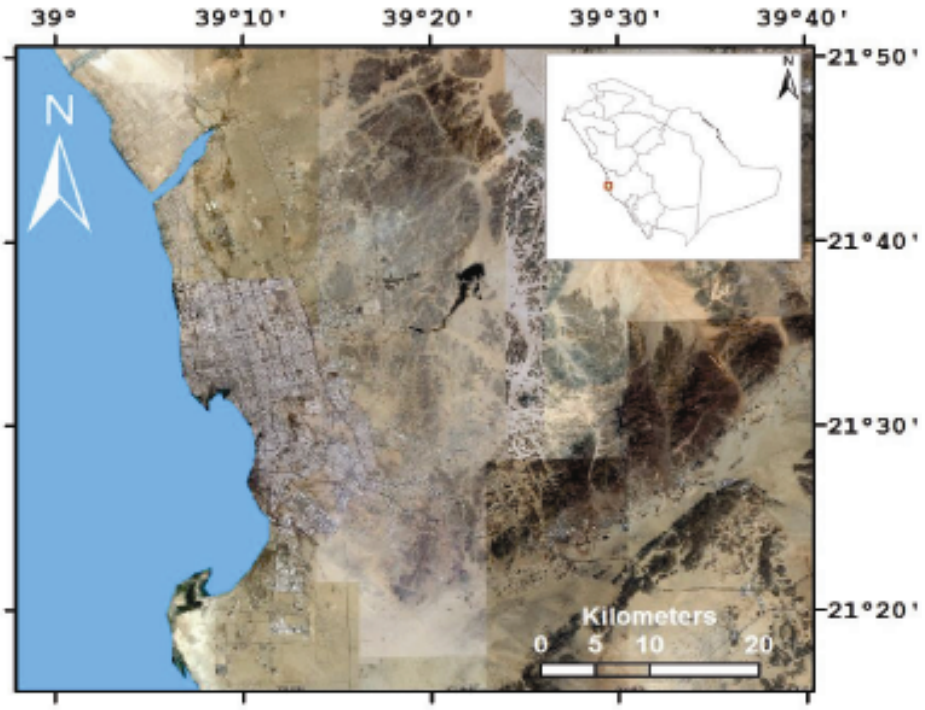

Fig. 1. Location map.

Climate

The climate of Jeddah Governate is a hot arid desert type, with scarce rainfalls in spring season. Based on ten years records by the Ministry of Defense and Aviation (1999) that cover the period between 1990 and 1999, the temperature reaches a maximum of 49^{o} C within the period between March and August, and a minimum of 17.3^{o} C in the period between January and February. The relative humidity ranges between a maximum of 100% in the period between August to November, and a minimum of 5% in the period between January and March. The precipitation rate is about 55 mm/year.

General Geology and Structure

The area of study constitutes a part of the western Arabian Shield, which is covered by Neoproterozoic rocks consisting of various types of volcanics and volcaniclastics, together with several varieties of intrusives (diorites, granodiorites and granites). These rocks are covered by Tertiary and Quaternary lavas and sediments, and in places by recent sediments and sabkhas. Three distinct geologic units could be distinguished in the concerned area, these are from oldest to youngest, the Neoproterozoic basement, the Tertiary sediments and lavas, and the Holocene sediments and sabkhas. The Neoproterozoic rocks lie in the eastern part of the area, i.e. the area that is occupied by the Red Sea hills and pediments. They consist of volcanic rocks, comprising andesite and dacite, intruded by plutonic rocks including diorite and granite. Shumaysi, Usfan and Hadat Ash-Sham Formations that are covered by basaltic lavas represent the Tertiary rocks recorded in the area east of Jeddah city. The Holocene unit includes the recently emerged marine deposits and corals, the recent basaltic lava flows, the wadi alluvium, sabkha deposits and the aeolian sands along the coastal plain and pediments (Moore and Al-Rehaili, 1989).

The distribution of the geomorphologic units across the area, as well as the previously mentioned lithologic units is strongly controlled by the structures. As the area constitutes a portion of the Red Sea coast, it is implicit that it shared the history with the Red Sea rift that evolved during the Tertiary time through a series of tectonic events that resulted in the Red Sea rift. Therefore, the tectonic events that brought about the Red Sea rift had their impact on the evolution and development of the lithostratigraphy and geomorphology of the area.

The borders of the geomorphologic zones are aligned concordant to the Red Sea shore and is generally aligned in NNW direction. This alignment is as well concordant with that of the faults that formed the Red Sea Rift as a spreading ocean (Schmidt *et al.*, 1982). In addition, Sharm Ubhur is interpreted by same authors (*e.g.* Schmidt *et al.*, 1982; Coleman, 1984; Moore and Al-Rehaili, 1989) to be an inland extension of the transform faults that compensate the differential movement between the different parts of the spreading ocean crust beneath the Red Sea.

Drainage Systems

The drainage systems were stereoscopically delineated from the aerial photographs, bearing in mind the water-divide lines between various sub-basins, as well as basin perimeters that were visualized with the aid of topographic maps while preparing Fig. 2 and 3.

The natural drainage at Jeddah Governate consists of a large number of wadis, almost 80 drainage systems. These systems are classified, based on their size, into major and minor systems. Minor systems are those in which the main stream is less than 10 km in length. Twelve major systems are distinguished; these are Wadi Al-Kura', Wadi Muraygh and Wadi Ghuraiyah, Wadi Um Hablayn, Wadi Burayman, Wadi Hutayl, Wadi Bani Malik, Wadi Mirayyikh, Wadi Quwayzah, Wadi Ushayr, Wadi Ghulayl, Wadi Al-Khumrah and Wadi Fatimah. The description and classification of drainage systems is carried out systematically from north to south; *i.e.*, from Wadi Al-Kura' to Wadi Fatimah.

The classification and analysis of these systems involved descriptive and geometrical aspects. The description of the systems included their distribution; *i.e.*, location, extent or size, shape of catchment area, orientation, stage of development, genetic classification and the drainage patterns.

Wadi Al-Kura'

This system is located at the northernmost part of Jeddah Governate. It initializes at the coastal hills and ends up at the northeastern tip of Sharm Ubhur. The system consists of numerous channels or subsystems that are disconnected or separated from the main course of the wadi. The upper courses of this system are formed of short branches, which display subdendritic pattern, while the lower courses are formed of long straight courses displaying parallel pattern. Owing to its extension through more than one geomorphologic zone, the system shows more than one genetic characteristic; such as it is subsequent upstream in coastal hills and resequent along the coastal plain.

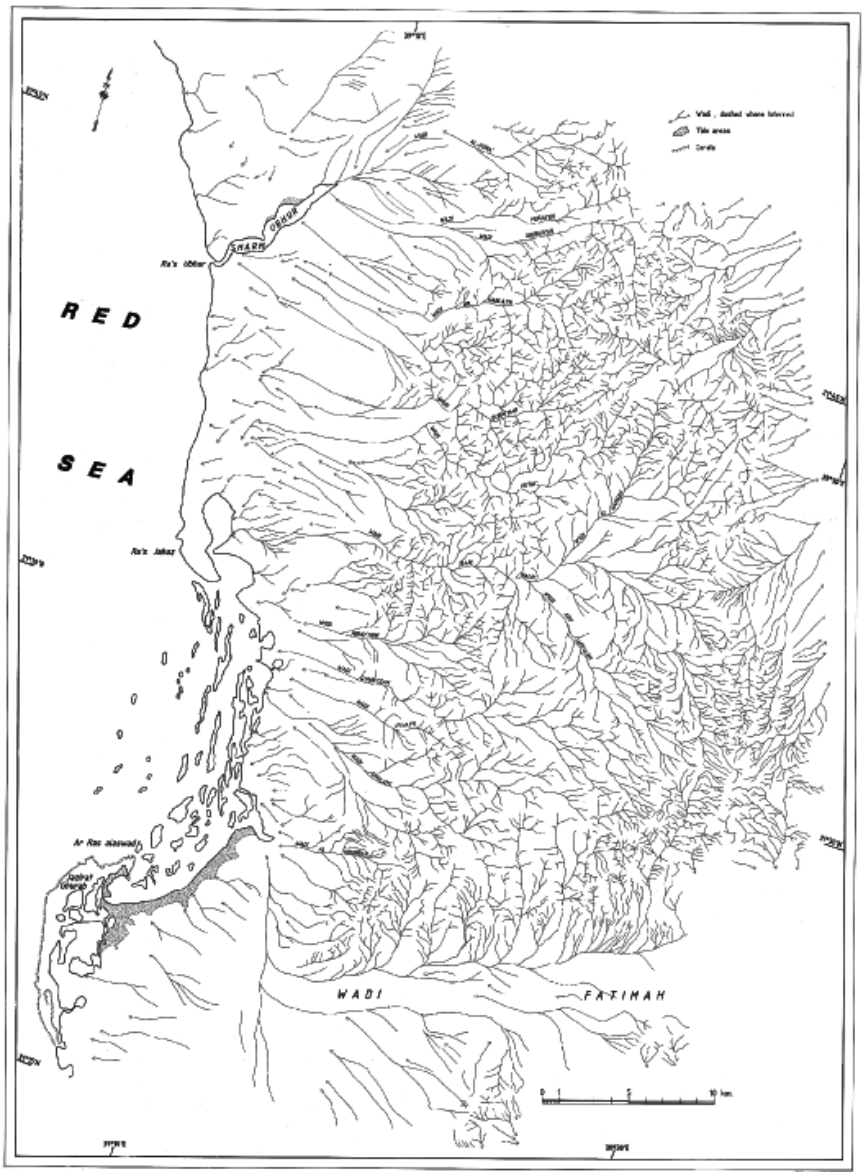

Fig. 2. Drainage map of Jeddah Governate based on aerial photography stereopairs (aerial photographs of 1953 and 1956).

Wadi Muraygh and Wadi Ghuraiyah

These two wadis lie south of, and adjacent to, Wadi Al-Kura' system. They are aligned in parallelism along a significant part of their

courses. Their upper courses exhibit a sudden and sharp shift in a N-S direction, while the lower courses are directed approximately toward the west, possibly due to some tectonic factors.

The major wadi courses are about 24 km long. Their uppermost parts are directed from south to north, while their middle and lower courses are directed approximately westwards. Long major channels and short branches or tributaries, mostly meet at lower channels that are straight to slightly curved. At their upper courses, they together display trellis pattern in some places and angular patterns locally. The lower courses of the wadi show parallel pattern, where the catchment area describes an elongate shape oriented in E-W direction.

Wadi Um Hablayn

This system is located to the north of King Abdulaziz Airport. It is formed of major channels, with some minor lower courses formed of long straight channels. The upper courses are formed of curved high density branched channels which display subdendritic pattern and probably in sequent, while the lower courses show parallel consequent pattern. The lower courses exhibit less intensity branching. The main wadi channel terminates within the coastal plain at about 1.5km from the seashore.

Wadi Burayman

This wadi is located in the north of Jeddah city and consists of numerous curved short upper channels and double channels, with a possibility of stream congestion at its middle course. The lower courses terminate at about 2 km from the Red Sea shore together with a few short separate channels within close proximity to its basin. The drainage density is high as it is heavily branched at the upper courses than at the lower parts of the drainage basin and is moderate to high at the upper part within the coastal hills.

Wadi Hutayl

This system is at the northern part of Jeddah city. It comprises a long narrow system up to 25 km long. Numerous minor channels show parallel pattern and a consequent system at the lower part of its catchment area. These are straight to slightly curved channels that display sub-parallel patterns. The upper courses are formed of straight long major stream channels, with curved short tributaries. These together exhibit

subdendritic drainage pattern. Some of the main wadis are subsequent streams because they are adjusted to faults and fractures. The drainage basin area is elongate, banana-shaped within which the main wadi is directed toward the west.

Wadi Bani Malik

This is perhaps the most important system in the area in terms of length and basin area. The wadi pours into the northern tip of Jeddah bay at Al-Hamra district. The lower course consists almost of a single channel with a number of branches near its outlet. The middle course includes some branches that join the main wadi approximately at right angles. From the middle course and upstream, the branches meet the main wadi at acute angles. The catchment area is mushroom-shaped, with the southern branches formed of straight channels, while the northern ones are formed of curved channels.

Numerous patterns are displayed by various orders at different locations within the catchment area. At the extreme east of the basin, the system shows a sub-parallel pattern, a semi rectangular pattern at the area lying 7 km east of the beach and subdendritic pattern at the rest of the basin.

The drainage branching ranges between very low at the western zone to moderate at the central zone to low, where the wadi branches into Wadi Abu Jaffalah and Wadi Al-Hafnah, and to very heavily at the top part of the mushroom at the extreme east.

Wadi Mirayyikh

A relatively short system than the others in the area that lies south of Wadi Bani Malik and terminates at the central zone of Jeddah City. A few vague channels; now separated from the main wadi might have once been either a continuation of the wadi or another branch lying north of Wadi Mirayyikh to the Red Sea.

The drainage system and the adjacent or neighboring channels are almost similar in that they are formed of approximately straight long channels aligned in sub-parallel orientation. The northern part of the system differs from the southern part in that it is formed of short and curved tributaries that are directed towards north or south. The system thus displays sub-parallel as well as angular patterns. The drainage basin is relatively wider compared to its length. It differs also in this regard

from the rest of the wadi systems in the area. The drainage density is very low in the western part and is moderate to high at the eastern part of the basin.

Wadi Quwayzah

A long narrow system that lies south of Wadi Mirayyikh. It is formed of a single major channel at its outlet near the seashore and a few branches that extend in E-W direction and displays a sub-parallel pattern. The drainage density is very low at the lower part in the west and is moderate at its eastern zone.

Wadi Ushayr

This is a short wadi that is about 12 km long and is directed from approximately the southeast of Jeddah down to the center of the city. The course of the main wadi downstream is straight and lacks branches, while the upper eastern parts are curved and intensely branched displaying angular pattern.

Wadi Ghulayl

This wadi terminates south of Jeddah city at about 3 km from the Red Sea shore. It is formed of curved channels that exhibit subdendritic pattern. The drainage density is low at the western part of the basin and is moderate at the eastern part.

Wadi Al-Khumrah

It constitutes a system that is located south of Jeddah city. It is a major wadi; however, it is well-branched showing a high density and subdendritic pattern.

Wadi Fatimah

This system occupies a large area of the southern part of Jeddah Governate. The drainage channels of this system show a remarkable diversity in terms of morphology, orientation, patterns and textures. It is worth mentioning that the present study covered only a small part of Wadi Fatimah system which occupies a much larger area to the east of Jeddah Governate.

The main wadi extends from ENE to WSW along most of its course; however, south of Jeddah city it abruptly diverts its orientation towards the north, possibly due to active faulting (Azzedine *et al.*, 1998). The main wadi describes a linear E-W course at its eastern part and a linear N–S course near the industrial city south of Jeddah harbor indicating a subsequent stream.

The main tributaries are slightly curved and they join the main wadi at an acute angle, except at the uppermost northeastern course, where the tributaries that are short join the main wadi at approximately right angels.

The drainage patterns displayed by the system include angular, radial, sub-parallel and yazoo patterns. The drainage density varies from very low at its lower course to very high at the uppermost course of the system.

Geomorphology

Three major geomorphologic zones are clearly distinguished (Fig. 3). These zones are aligned in sub-parallel orientation in N-S direction. They are, from west to east, as follows:

1) The Red Sea and its shoreline features.

2) The coastal plain.

3) The coastal hills and pediments.

The Red Sea Shore Zone

The Red Sea shoreline at Jeddah Governate, with upper limit of 0.5 m of elevation is very irregular as it extends inland at some areas to a distance of more than 100 m, especially at Al-Hamra district. It can be divided into two distinct sub-zones or parts; the northern part and the southern part; the later starts exactly halfway from the top down the shoreline at Ra's Jahaz (Fig. 3). The northern shoreline is almost straight, the monotony of which is abruptly broken at the extreme north by Sharm Ubhur, a narrow linear protrusion of the sea inland. This part of the shore is characterized by gently sloping to flat mostly sandy beaches with some beach ridges, lagoons, sabkhas and salt flats.

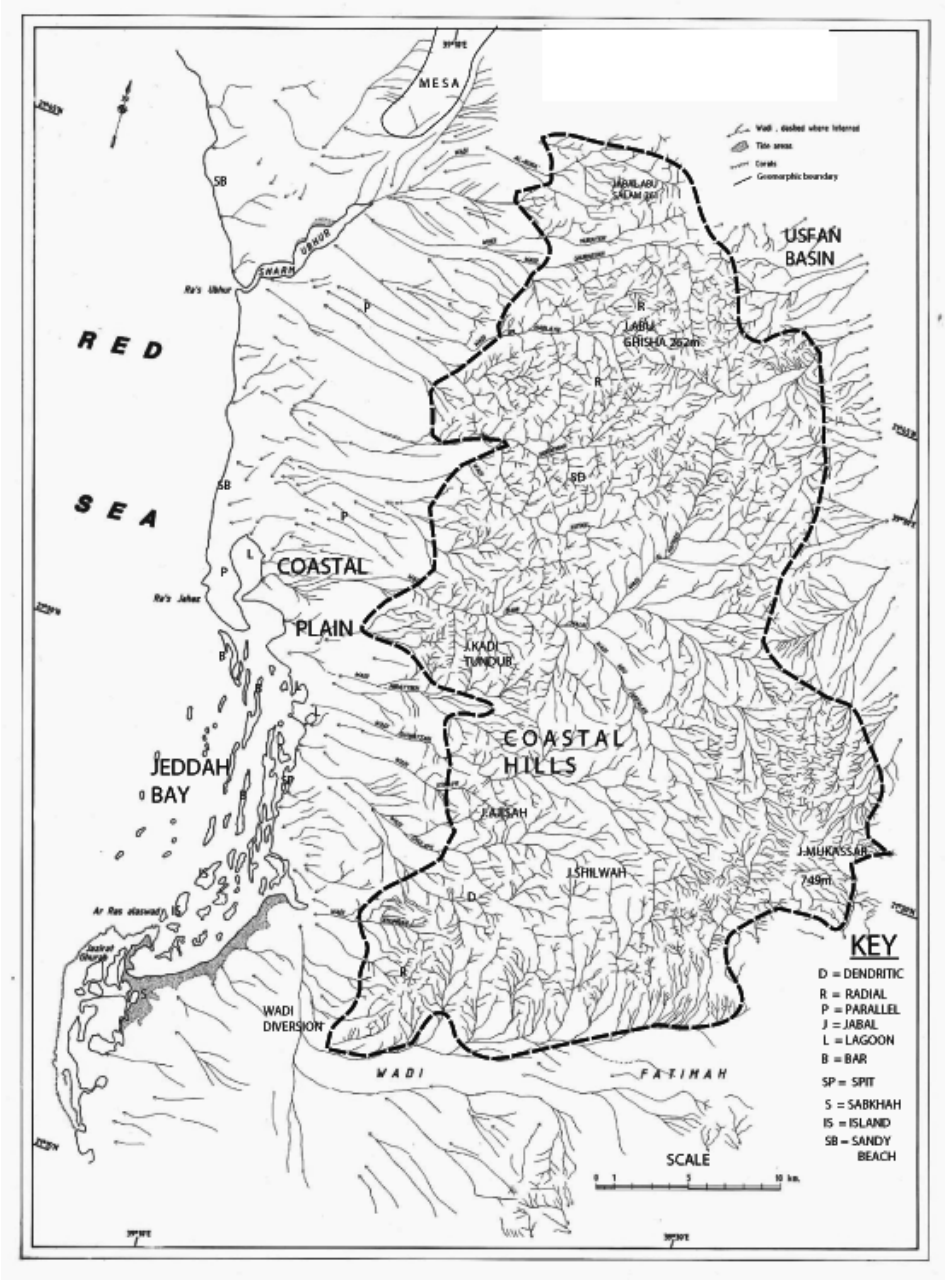

Fig. 3. Geomorphologic map.

The southern shoreline roughly describes a huge complex concave bay, named herein “Jeddah Bay”. The shoreline at this part is remarkably

irregular forming numerous irregular closed and open lagoons, such as Al-Arbaeen Lagoon. More than fifty islands are also present within and south of Jeddah Bay. These islands are generally elongate or bar-like aligned in N-S orientation. Some of these islands display a variety of forms such as linear, curved complex, spits, and coral atolls or irregularly shaped or forms. Two small peninsulas form the northern and the southern ends of Jeddah Bay; these are Ra's Jahaz in the north and Ar Ras Alaswad in the south.

Coral reefs exhibit numerous forms almost along the entire shoreline. They include fringing and barrier reefs along the southern part of the Red Sea shore. In addition, a great number of the Red Sea islands, in fact, represent raised dead coral terraces.

The coastal landforms observed along Jeddah shoreline are indicative of an emergent shoreline (prograde shoreline). Supportive criteria indicating the emergence include the gently sloping to almost flat sandy beaches, the presence of bars, spits, lagoons and sabkhas. In addition, the raised coral terraces and the presence of marine limestone along the Red Sea shore are diagnostic of emergence.

The Coastal Plain Zone

This zone, which is approximately 10 km wide, lies east of the Red Sea shore and extends in a N-NW direction. It is straight at its northern part and is curved towards the southwest at the southern part along Wadi Al-Khumrah (Fig. 3). The coastal plain has an almost flat relief, with gradient ranging between 0.002 at the northern part and 0.005 south of Makkah road, except for a few depressions along the beach fringes that probably represent dried-up lagoons and depressions. On the other hand, numerous irregularities in elevation crop out, such as one lying south of Al Arbaeen lagoon, where the elevation attains 13 m above mean sea level (msl). In some other areas, numerous, however, small the elevation reaches up to 8 m and 10 m (Laurent *et al.*, 1973).

A large number of wadis that are directed westwards toward the Red Sea cut the coastal plain. This plain is wider in the north around Sharm Ubhur and in the south than in the middle part. Many sabkhas are clearly manifested in the 1956 aerial photographs along the coastal plain, most of which have now been masked by the residential areas of the rapidly

growing Jeddah city. However, coralline limestone, alluvial terraces, fluvial deposits, sabkhas and aeolian sands cover most of the coastal plain.

The human activities possibly played a significant role in obliterating most of the natural geomorphologic features, especially the wadi courses, salt flats and the sabkhas along most parts of the coastal plain.

The Coastal Hills and Pediments Zone

This geomorphologic zone, which extends roughly in a N-NW orientation, lies east of the Red Sea coastal plain. It constitutes a large number of low-lying hills that are surrounded by flat alluvium covered pediments. The hills range in elevation between a few tens of meters in the west to a few hundred meters in the east above mean sea level (msl). The pediments that lie between these hills are almost less than one hundred meters above msl. The alluvial cover of the pediments outcrops consist of wind-blown sands, fluvial fan deposits, as well as collovial or talus deposits at the fringes of the coastal hills zone.

Some characteristic features are present in this zone, such as the spectacular 200 m high mesa located northeast of Sharm Ubhur which is formed of basaltic lava flow (Harrat Al-Kura') possibly of Tertiary age. The slopes of the mesa are very steep and are covered by talus cones and aprons. Sabkha, fluvial deposits and wind blown sands cover the low-lying flat lands below the mesa.

Numerous peaks and hogbacks are present and they litter this zone at various locations; the most important of these hills are Jabal Al Mukassar (750 m msl), Jabal Shilwah (~500 m msl), Jabal Abu Safa (361 m msl) and Jabal Abu Ghisha (262 m msl).

The coastal hill zone is abruptly broken at its eastern side by a NNW aligned depression that hosts Tertiary and Recent sediments, comprising Usfan and Hadat Ash Sham formations.

The most extensive pediments are those areas that form the fringes of Usfan and Hadat Ash-Sham basins and the area around Al-Jamoom Township (northeast and east of Jeddah City).

Drainage Texture

The drainage textural parameters are shown in Table 1, and are used to denote the frequency of changes of drainage characteristics within an area, taking into account the drainage channels as a unit aggregate. Texture has been used in relation to the frequency and the density of the drainage network.

Horton (1945) defined drainage density (D) in quantitative terms, as:

$$D = L/A \quad (1)$$

Where:

L is the total length of drainage channels within a drainage basin.

A is its surface area.

Additionally, the drainage frequency is defined as:

$$F = N/A \quad (2)$$

Where:

N is the total number of channels in a drainage basin. Furthermore, this can be also continued with the previous expression which yields this:

$$D = (L*F)/N \quad (3)$$

It is however, that infiltration (I) is directly proportional to DF, *i.e.*

$$I = D*F \quad (4)$$

The dissection of the ground surface by channels bears logarithmic function to the drainage density (Smith, 1950).

In bedrock areas, these patterns depend mostly on the lithological characters of the underlying rocks, the attitudes of these rock bodies and the arrangement and spacing of the lithological and structural weakness encountered by the runoff (Taylor and Schwarz, 1952).

In some areas, the texture reflects differences in surficial materials (Belcher, 1948; Frost, 1940; Frost and Woods, 1948; Hittle, 1949; Parvis, 1950).

Table 1. Textural parameters of Jeddah drainage systems.

Al-Kura'

Wadi Al-Kura' (Basin Area = 86.22 sq.km) (Relief H = 105 meters)

Order	No. of Channels (N)	Length, km (L)	Draiange Density (D)	Drainage Frequency (F)	Infiltration, cm/h (I)
1st I	103	48			
2nd II	22	35.28			
3rd III	5	13.68			
4th IV	2	19.08			
5th V	1	1.62			
Total	133	117.66	1.36	1.54	2.11

Muraygh & Ghuraiyah

Wadi Muraygh and Ghuraiyah (Basin Area = 93.6 sq.km) (Relief H = 402 meters)

Order	No. of Channels (N)	Length, km (L)	Draiange Density (D)	Drainage Frequency (F)	Infiltration, cm/h (I)
1st I	155	108			
2nd II	89	55.2			
3rd III	9	26.44			
4th IV	2	7.56			
5th V	1	16.26			
Total	256	213.46	2.28	2.74	6.24

Um Hablayn

Wadi Um Hablayn (Basin Area = 56.34 sq.km) (Relief H = 465 meters)

Order	No. of Channels (N)	Length, km (L)	Draiange Density (D)	Drainage Frequency (F)	Infiltration, cm/h (I)
1st I	138	101.4			
2nd II	38	35.28			
3rd III	8	22.26			
4th IV	2	27.66			
Total	186	186.6	3.31	3.30	10.93

Table 1. Contd.

Burayman

Wadi Burayman (Basin Area = 73.44 sq.km) (Relief H = 205 meters)

Order	No. of Channels (N)	Length, km (L)	Draiange Density (D)	Drainage Frequency (F)	Infiltration, cm/h (I)
1st I	69	91.98			
2nd II	38	33			
3rd III	8	20.64			
4th IV	2	6.06			
5th V	1	13.02			
Total	118	164.7	2.24	1.61	3.60

Hutayl

Wadi Hutayl (Basin Area = 101.88 sq.km) (Relief H = 361 meters)

Order	No. of Channels (N)	Length, km (L)	Draiange Density (D)	Drainage Frequency (F)	Infiltration, cm/h (I)
1st I	166	113.6			
2nd II	40	29.94			
3rd III	7	18.9			
4th IV	1	27.9			
Total	214	190.34	1.87	2.10	3.92

Bani Malik

Wadi Bani Malik (Basin Area = 250.02 sq.km) (Relief H = 750 meters)

Order	No. of Channels (N)	Length, km (L)	Draiange Density (D)	Drainage Frequency (F)	Infiltration, cm/h (I)
1st I	384	316.5			
2nd II	113	146.28			
3rd III	32	65.82			
4th IV	7	27.9			
5th V	2	15.6			
6th VI	1	21			
Total	539	593.1	2.37	2.16	5.11

Table 1. Contd.

Mirayyikh

Wadi Mirayyikh (Basin Area = 59.76 sq.km) (Relief H = 200 meters)

Order	No. of Channels (N)	Length, km (L)	Draiange Density (D)	Drainage Frequency (F)	Infiltration, cm/h (I)
1st I	102	69			
2nd II	22	33.6			
3rd III	6	15			
4th IV	1	9.06			
Total	131	126.66	2.12	2.19	4.65

Quwayzah

Wadi Quwayzah (Basin Area = 68.4 sq.km) (Relief H = 180 meters)

Order	No. of Channels (N)	Length, km (L)	Draiange Density (D)	Drainage Frequency (F)	Infiltration, cm/h (I)
1st I	91	65.16			
2nd II	23	32.34			
3rd III	5	10.98			
4th IV	1	20.52			
Total	120	129	1.89	1.75	3.31

Ushayr

Wadi Ushayr (Basin Area = 14.4 sq.km) (Relief H = 150 meters)

Order	No. of Channels (N)	Length, km (L)	Draiange Density (D)	Drainage Frequency (F)	Infiltration, cm/h (I)
1st I	17	14.46			
2nd II	2	5.1			
3rd III	1	6.36			
Total	20	25.92	1.80	1.39	2.50

Table 1. Contd.

Ghulayl

Wadi Ghulayl (Basin Area = 80.3 sq.km) (Relief H = 216 meters)

Order	No. of Channels (N)	Length, km (L)	Draiange Density (D)	Drainage Frequency (F)	Infiltration, cm/h (I)
1st I	119	95.6			
2nd II	28	40.2			
3rd III	6	18.7			
4th IV	2	15.4			
5th V	1	20.1			
Total	156	190	2.37	1.94	4.60

Al-Khumrah

Wadi Al-Khumrah (Basin Area = 24.5 sq.km) (Relief H = 56 meters)

Order	No. of Channels (N)	Length, km (L)	Draiange Density (D)	Drainage Frequency (F)	Infiltration, cm/h (I)
1st I	45	29.94			
2nd II	12	11.7			
3rd III	3	10.08			
4th IV	1	3.12			
Total	61	54.84	2.24	2.49	5.57

Fatimah

Wadi Fatimah (Basin Area = 356.7 sq.km) (Relief H = 750 meters)

Order	No. of Channels (N)	Length, km (L)	Draiange Density (D)	Drainage Frequency (F)	Infiltration, cm/h (I)
1st I	410	288.6			
2nd II	113	144.8			
3rd III	34	81.9			
4th IV	5	42			
5th V	1	24			
Total	563	581.3	1.63	1.58	2.57

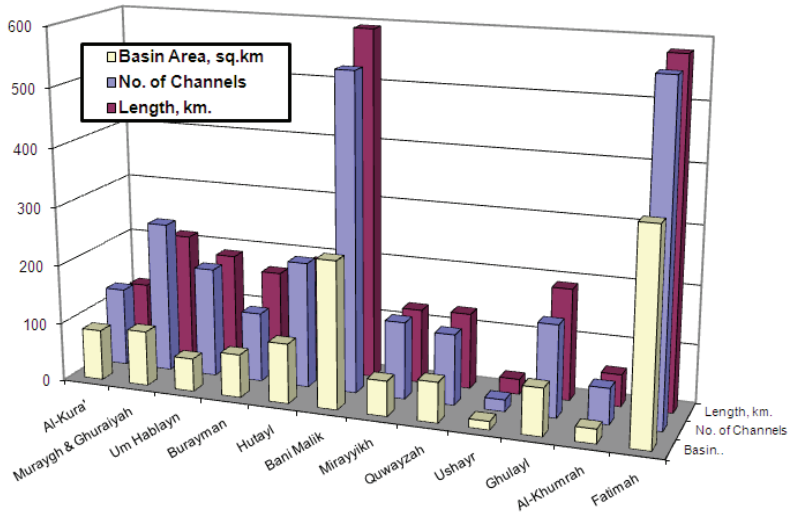

Fig. 4. Drainage systems characteristics in Jeddah Governate.

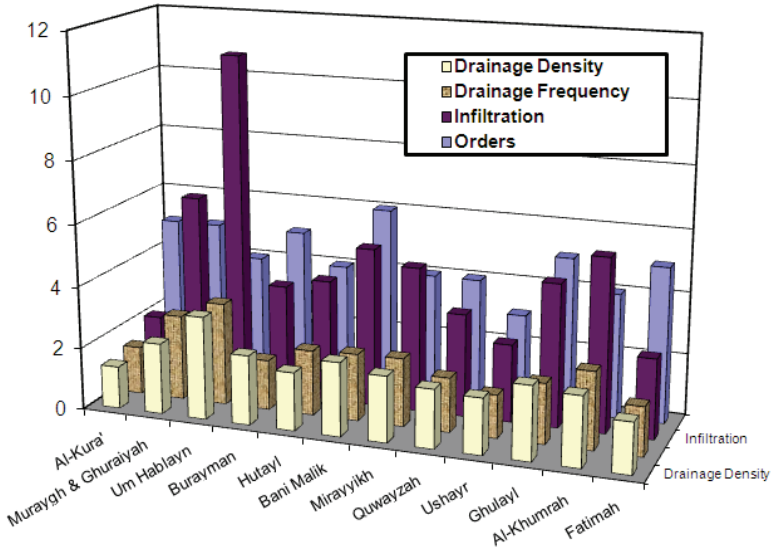

Fig. 5. Textural parameters of drainage systems in Jeddah Governate.

The textural parameters are listed in Table 1 deduced by the use of the abovementioned equations, while Fig. 4 and 5 display these parameters as histograms for the ease of comparison.

Figure 4 shows basin areas, number of channels and length of channels for each system, while Fig. 5 shows textural parameters. Wadi Um Hablayn exhibits the highest infiltration followed by Wadis Muraygh & Ghuraiyah. Wadi Al-Khumrah which comes third in terms of infiltration shows also a high frequency.

Discussion and Conclusions

The drainage systems exhibit a great diversity in terms of patterns, genetic types and textures. These differences in the drainage network delineate three distinct zones; all are directed from north to south. The coastal plain zone with long straight wadi channels that are directed towards the west, except for the lower course of Wadi Fatimah that is directed towards the north possibly due to tectonic factor. The drainage pattern is mostly parallel at this zone and the density is low. The second drainage zone is represented by the coastal hills with mostly curved heavily branched wadi courses that display a number of patterns, such as radial, dendritic, subdendritic patterns and angular. The third drainage zone is the Usfan basin; a depression resulting from block faulting and exhibits long, widely spaced channels that display subdendritic pattern.

Comparing various parameters of the individual drainage basins comprising the drainage systems of Jeddah Governate shows that Wadi Bani Malik and Wadi Fatimah are the largest systems. Drainage diversions and possible drainage piracies are also attributable to active tectonics or faulting**.**

Jeddah Governate constitutes three geomorphologic zones, namely, the Red Sea and its shore features, the coastal plain and the coastal hills and pediments. Each of these zones is characterized by its typical landforms. The coastal and marine features exposed along Jeddah seashore indicate that the Red Sea is in regression at the present time.

The drainage network at Jeddah Governate consists of numerous wadi systems, twelve of which are considered main systems, delineated and analyzed. These major wadis are, from north to south Wadi Al-Kura', Wadi Muraygh and Wadi Ghuraiyah, Wadi Um Hablayn, Wadi Burayman, Wadi Hutayl, Wadi Bani Malik, Wadi Mirayyikh, Wadi Quwayzah, Wadi Ushayr, Wadi Ghulayl, Wadi Al-Khumrah and Wadi Fatimah.

Many of these drainage systems terminate within the coastal plain at a distance from the Red Sea shore; a phenomenon that is attributable to

one or more of the following factors: active faulting, human activities or shore drift.

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جيومورفولوجية محافظة جـــدة مع التركيز على أنظمة تصريف الأوديـــة

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المستخلص. تتكون محافظة جدة من ثلاث نطاقات جيومورفولوجية متميزة: هي نطاق الشاطئ والبحر الأحمر، نطاق السهل الساحلي، نطاق التلال الساحلية والمصاطب، ويقع النطاق الأخير شرق مدينة جده ويتضمن تلالاً منخفضة، ومنخفضاً باتجاه شمال–جنوب، يُشكل حوضاً ضمن التلال الساحلية.

نطاق البحر الأحمر يتكون من أشكال تميز السواحل المتقدمة (المكتسبة)، والتي تشير ضمناً إلى أن البحر الأحمر في تراجـــع، وتتضمن مظاهرًا مثل شواطئ رملية مستوية، وبحيرات، وسبخات وجزر، وألسنة بحرية بالإضافة إلى شـــرفات مرجانيـــة مرتفعـــة، وصخور داخلية بحرية من الحجر الجيري.

يتضمن التصريف في المنطقة عـــدداً كبيـــراً مـــن الأنظمـــة (الأودية). اثنا عشر نظام أودية كبرى، تـــم تحديـــدها ووصـــفها وتحليلها مورفومترياً. هذه الأنظمة هي من الشمال إلى الجنـــوب: وادي الكُراع، وادي مريغ ووادي غُريـــة، وادي أم حبلـــين، وادي بريمان، وادي هُطيل، وادي بني مالك، وادي مريخ، وادي قويزة، وادي عُشير، وادي غُليل، وادي الخُمرة، ووادي فاطمة. تصب كل

هذه الأنظمة غرباً نحو البحر الأحمر، ماعدا وادي فاطمة الذي يحول اتجاهه شمالاً في نهاياته على طول السهل الساحلي، وهذا يمكن أن ينسب إلى التصدع النشط.

ينتهي عدد كبير من قنوات الأودية العظمى والصغرى ضمن السهل الساحلي على مسافة من شاطئ البحر الأحمر، وهذه الظاهرة يمكن أن تنسب إلى واحدة أو أكثر من العوامل، مثل البنائيات الحديثة النشطة أو النشاطات البشرية أو انجراف الشواطئ.

مُعظم أنظمة التصريف في المنطقة من النمط المتوازي على طول السهل الساحلي، بينما يكون النمط "شُجيري – شُجيري متفرع"، أو شعاعي في أعالي الأودية، وتتفاوت كثافة أنظمة التصريف في النطاقات الجيومورفولوجية المذكورة سابقاً في محافظة جدة، ولكنها تُظهر كثافة أعلى على طول نطاق التلال الساحلية.