CHAPTER- 4
GEOMORPHOLOGICAL PROCESSES AND CLASSIFICATION UNITS OF RVB

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4.1. Introduction

The study of topographic forms / geomorphic units/landforms is the science of geomorphology (Strahler, 1957). The geomorphic character of a region has a strong control on the water harvesting system. Geomorphological process is the imprint of geology and structural settings of the region. The geomorphology includes the study of the drainage pattern, topographical aspects and geomorphic landforms, etc. (Miller, 1953).

The geomorphology, scientific study of landforms and landscapes, the term usually applies to the origins and dynamic morphology (changing structure and landform) of the earth surfaces. But it can also include the morphology of the seafloor and the analysis of extraterrestrial terrains. Sometime it is includes the field of physical geography. Geomorphology is really the geological aspects of the visible landscape (Getis et al, 2004., William, 2005). Geomorphologists study the shape of the earth’s surface and the various processes that change the landscape. For example when large pieces of the earth’s crust move laterally (Kale, and Gupta, 2001., Singh, 2006), they create huge compressional forces that can bend or even break rocks.

4.2. Background about geomorphology

4.2.1. Earlier concept in geomorphology

A Practical knowledge of geomorphology is acquired naturally when people have to find dependable water supply for irrigation, learn to navigate rivers and build settlements on slopes. All long- standing civilisations have such practical knowledge. The floods of the Nile, for example, had been recorded and studied for thousands of years. 5000 years ago, during the reign of King Menss of Egypt, clay bunds were used to hold back the floodwater of the Nile for irrigation when the annual flood receded. The same knowledge about the behaviour of a large river is required in order to do so; the ancient Egyptians measured the flow of the Nile year after year, although that was not really to study the geomorphology of the river, but to assess irrigation taxes.

The Chinese and Indian civilisations also controlled water as a resource, but we do not have as much knowledge of this aspect of history as we should have. For example, the tank irrigation of South India is an ancient practice, a practice which was
carried to Southeast Asia. The irrigation system of Angkor in Cambodia is perhaps the best known example of geomorphological knowledge and practice among the ancient Greeks, Romans and later towards the end of the first millennium among the Arabs (Kale, and Gupta, 2001., Singh, 2006).

One approach to the science of landforms is by means of historical, cyclic geomorphology. The concepts involved were worked out at the turn of the 20th century by the American geologist Davis, who stated that every landform could be analyzed in terms of structure, process, and stage. The first two are also treated by process geomorphology, discussed below. But the third, by introducing the element of time, is subject to a far greater degree of interpretation. Davis argued that every landform underwent development through a predictable, cyclic sequence youth, maturity, and old age. (Getis et al 2004)

Historical geomorphology relies on various chronological analyses, notably those provided by stratigraphic studies of the last 2 million years, known as the Quaternary period. The relative chronology usually may be worked out by observation of stratigraphic relationships, and the time intervals involved may then be established more precisely by dating methods such as historical records, radiocarbon analysis, tree-ring counting (dendrochronology), and paleomagnetic studies. By applying such methods to stratigraphic data, a quantitative chronology of event is constructed, that furnishes a basis for calculating long-term rates of change.

4.2.2. Modern geomorphology
4.2.2.1. Pre Huttonian period

The beginning of the modern geomorphological thought and practice is attributed to several scholars towards the end of the eighteenth and the beginning of the nineteenth century. Earlier there were several advances in geomorphological knowledge. Such as Florentian Leonardo da Vinci’s (1452 – 1519) understanding of the flow of water and its role in carrying sediments. The Swiss, De Saussure’s (1740 – 1799) account of the Alps and glaciers, and the theorising of hydrologic cycle.

Modern geomorphology, however, is traditionally believed to have started with book, Theory of the Earth, which was first published in 1788 and the find
version in 1795. Hutton's theory of the earth is written in 1802 by his friend John Playfair (1748 -1819).

4.2.2. 2. Hutton period

Hutton is known for his recognition of granite as an igneous rock and his friend's work in geology. But he is best known for his two summary statements in earth science. These were- (1) "the present is the key to the past" and (2) no vestige of a beginning – no prospect of an end. Another dramatic change came into geomorphologic thinking in the early nineteenth century that also originated in Europe. For years the Swiss mountain farmer has noticed evidences of glaciers in the Alps being bigger and stretching further down the valleys in the pass (Thornbury, 1945).

4.2.2. 3. Post Huttonian period

For the next major advance in geomorphological knowledge happened in the United States towards the end of the nineteenth century after the end of civil war which led to break of thinking in geomorphological knowledge. The three geologists associated with this break of thought are Powell (1834- 1912) Gilbert (1843- 1918) and Dutton (1841- 1912). They worked in different parts of the United States (Bloom, 2003., Sen, and Prasad, 2002., Singh, 2006, Phillips, 2005).

The period Davis (1850- 1934), who was the professor of geology at Harvard University, made some advances in geomorphology. He said the landforms are function of three variables which he called structure, process and time. His other theory called "geomorphological cycle" or "the cycle of erosion" did not pass the test of time and is known as an intellectual curiosity.

4.3. Geomorphological processes

4.3.1. Weathering

Weathering initiates the erosion of rock, causing alterations in the surface layers. In dry climates, the top layer of a rock may expand from the heat of the sun and crack off from the lower layers. If the rock consists of several minerals, the minerals may expand at different rates and break up the rock. In cold climates, frost
breaks up rocks because rainwater, which seeps into cracks and pores in the rock, expands when it freezes (Grohmann, 2005), rain in damp climates acts chemically as well as mechanically in the weathering of rocks. As the rain passes through the atmosphere it absorbs carbon dioxide, forming carbonic acid, which dissolves some minerals and decomposes others. Feldspar, a common family of minerals in granite, is changed into clays, and certain minerals in basalt combine with oxygen and water to form iron oxides, such as limonite. Plants play a role in weathering as roots can split rocks and extract soluble nutrients.

4.3.2. Water erosion

Water plays an important role in erosion by carrying away material that has been weathered and broken down. When an area receives more water than the ground can absorb, the excess water flows to the lowest level, carrying loose material with it. Gentle slopes are subject to sheet and soil erosion, in which the runoff removes a thin layer of topsoil without leaving visible traces on the eroded surface (Giles, and Franklin, 1998., Gani, and Abdelsalam, 2006., Marren et al 2006., Sthiannopkao et al 2007). This erosion may be balanced by the formation of new soil. However, especially in arid areas having little vegetation, the runoff leaves a pattern of gullies formed by rivulets. Water can even erode solid rock (Figs. 4.1and 4.2), especially along streambeds where the fragments that are carried with the current, scour and abrade. Every year rivers deposit about 3.5 million tons of eroded material into the oceans.

4.3.3. Coastal erosion

Coastal erosion of rocky cliffs and sandy beaches results from the action of ocean waves and currents (Maksud, and Midorikawa, 2004). This is especially severe during storms. In many parts of the world the loss of land due to coastal erosion represents a serious problem. The action of waves, however, does not extend to a great depth, and the sea tends to cut a flat platform (Fig.4.3), characteristic of marine erosion, into coastal rocks.
4.3.4. Wind erosion

Wind is another active agent of erosion, especially in arid climates with little vegetation. Wind blowing across bare land lifts particles of sand and silt but leaves behind larger pebbles and cobbles. Eventually, a surface layer of closely packed stones (Fig. 4.4), called a desert pavement, is formed as the sand and silt is removed (Rai., 1980., Buschiazzo et al., 2007., Liu et al., 2007). The removal of large quantities of loose material is called deflation. Deflation lowers the landscape slowly, usually less than a meter in a thousand years.

4.3.5. Human impact on erosion

Without human activity, losses of soil through erosion would in most areas probably be balanced by the formation of new soil. On virgin land, a mantle of vegetation protects the soil. When rain falls on a surface of grass or on the leaves of trees, some of the moisture evaporates before it can reach the ground (Feoli et al 2002., Baroni et al, 2007., Vanacker et al, 2007).

Trees and grass serve as windbreaks, and a network of roots helps to hold the soil in place against the action of both rain and wind. Agriculture and lumbering, as well as housing, industrial development, and highway construction (Fig. 4.5), however, partially or wholly destroy the protective canopy of vegetation and greatly speed up erosion of certain kinds of soils. Erosion is less severe with crops such as wheat, which cover the ground evenly, than with crops such as corn and tobacco, grown in rows.
Fig. 4.1: Water erosion in Albarh area of RVB

Fig. 4.2: Water erosion in sandstone of RVB

Fig. 4.3: Coastal line of Red Sea in west area of RVB

Fig. 4.4: Wind erosion in tehamah plain of RVB

Fig. 4.5: Human impacts on erosion in RVB
4.4. Geomorphological classification

The studies of the geomorphological classification of units of the Rasyan Valley Basin depend on the satellite imagery and different maps (geology, topographical sheets, soil, and vegetation). Field studies, and topological digital elevation model (DEM) (Fig.4.6 to 4.17) can be divided into:

4.4.1. Mountain ranges

Mountain ranges in Rasyan Valley Basin have been formed as a result of tripartite process of volcanic activities which resulted in lava outbreaking though cracks and crater, along with the interior rise of the openness of the Red Sea and Aden Gulf. These ranges differ, among themselves, in length, extension, shape, height and also slope aspect, according to the genetic aspects and features of climate – which consequently affected the topography (Asselen, and Seijmonsbergen, 2006). The areas can be said, have the shape of two main grand curves;

4.4.1.1. Northern mountain range

The first one represents the northern range, which is extended to the north-west; northern parts, east west and the range consist of a set of peaks and mounts (Nama, Dager, Alhorim and Shamir). The main features of the range are their high slopes and extreme descents in most of their parts which are widely cut by the rivers, so that it looks quite rugged (Fig. 4.6).

4.4.1.2. Southern mountain range

These ranges have their length which is extended from the east to the west, with little deviation in the basin. The range consists of tripartite granitic batholiths in the eastern part including Jabal Saber and Jabal Habashi. They also consist of volcanic formation in the south-eastern part. The western part of this unit, however, is covered by the sedimentary, sandstone and limestone formations, such as Hajdah and Albarh. This unit represents the southern and eastern borders of the study area, accompanied with a set of mountain peaks and river. The unit also has the feature of its rocky homogeneity, represented by granite (in the east of the range), and the volcanic formation (in the middle part) and the sandstone and limestone formation (in the west).
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Fig. 4.6: DEM of Rasyan Valley Basin

Fig. 4.7: DEM and DTM of sub-basin, Wadi Alhaymah of RVB

Fig. 4.8: DEM and DTM of sub-basin, Wadi Ahajep of RVB
Fig. 4.9: DEM and DTM of sub-basin, Wadi Alshajarah of RVB

Fig. 4.10: DEM of sub-basin, Wadi Alrahahabah of RVB

Fig. 4.12: DEM of sub-basin Wadi Ad Duwayna of RVB

Fig. 4.13: DEM, DTM and grid of sub-basin, Wadi Alhaimah of RVB
Fig. 4.14: DEM and DTM of sub-basin, Wadi Alrahaba of RVB

Fig. 4.15: DEM of sub-basin, Wadi Aldabab of RVB

Fig. 4.16: DEM of sub-basin, Wadi Ad Duwayna of RVB
Fig. 4. 17: Digital elevation model map of Rasyan Valley Basin
The unit is also characterized by its few valleys in comparison to volcanic rocks. We also notice based on GIS and remote sensing data that these volcanic formations are overlapped and interplayed with the old sedimentary ones on the one hand, and with the increasingly formation of the archaeological importance on the other (Figs. 4.17 and 4.18).

4.4.2. Plateaus

There are two main types of plateaus in Rasyan Valley Basin which can be described in terms of their formation, shape, area, and the converge of the surface. They are as follows:

4.4.2.1. Eastern plateau:

The eastern plateau is considered as the largest plateau in Rasyan Valley Basin. It has the following borders: city of Taiz (in the south), Jabal Saber (in the south-east) Sharab Alsalam and Alranah (in the north-west). The eastern plateau is also extended and lengthened in the east, till the water boundary located between RVB and Tuban Valley Basin. Its surface is covered with silty clay, and sand. The surface is connected physically to some of the small hills, especially in the western and southern parts (Fig. 4.19). Its surface is used in forming activities, which mainly depend upon rainfall. There is also another kind of formation based on groundwater in winter the can be said that the eastern plateau is characterized by elevated surface with little amount of sloping.

4.4.2.2. Internal plateaus:

Internal plateaus differ from the eastern ones in length and extension and also in the area and shape. The internal plateaus have a small area but with different direction (Fig. 4.20 and 4.21). It is cut by erosion which resulted in an increase in texture of the surface material.

4.4.3. Hills:

Hills are different from mountains from the fact that they are lower than mountains, with little slope and limited height. They are formed in RVB with tripartite time, with overprints of quadripartite time. The hills were also exposed to
the various factors of erosion, and this led to the elimination of many of their primordial milestones, so that they have become less in height.

The hills slope in different directions and have circular, conical and triangular shapes. The hills are formed in the west of Taiz city, north of Hajdah, and also in the north-east and north-west of Albarh and Shamir area. They can also be found in the area, called Riabt Maqnanah. There are also found in the western plain; the north-west of Mafraq Al Maka (Figs. 4.22 and 4.23).

4.4.4. Valleys (Rivers)

Valleys represent from the view of length and broadness – a characterized geomorphological phenomenon in Rasyan Valley Basin, observation reveals that the north-western north and southern part looks very short. The distance between the first, second and third level stream orders and shows limited length, especially at the bottom of the river (Ng, 2006).

On the contrary, one can notice that the middle part of the RVB look more extended and broadened. Furthermore, the levels look quite longer. Some sediment (fragments and sand) on either side of the area can also be noticed.

4.4.5. Plains

This geomorphological unit, "plains" can be found in the western part of the basin (from Albarh area into the coastal line on the Red Sea). The widens in the Al-Barh and narrows in the area of Al-Mafraq. It widens again in the western part of study area (Fig. 4.17). The height of the plain is between zero up to 500 meters. The plain's surface is covered with various old sediments (sand, clay, silt, gravel and angular fragment) and also with same quadrilateral hills which can be formed in the northern of Al-Mafraq and in the south of Albarh and south-east of Harthah Valley Basin.

Some of the old rivers and river terraces are also identified and observed in the western parts of the plains with the soft sediments on moving beach sand, Salinas, in the study area.
Fig. 4.18: Jabal Saber in the west of RVB

Fig. 4.19: Alhoban Plateau in east of RVB

Fig. 4.20: Mountain range and plateau in southern part of RVB

Fig. 4.21: Internal plateau of RVB

Fig. 4.22: Maqbanah hills in north-west of RVB

Fig. 4.23: Hills in west of RVB
4.4.6. Coastal line

The coastal line is extended into the west of Wahija on the Red Sea coast, with a distance of about 4.012 km which represents the borders of the western basins. The morphological shape of the coastal line is straight with little sloping. It takes the shape of a curve in the middle part (Fig. 4.3.) and is characterized in its medium depth of pavements.

4.4.7. River banks

River banks are limited in spread because of the fact that the basin is still in its youth age of the geomorphological development (Taylor, and Steven, 2006). Some of the river banks are formed in the northern coast of Taiz city and also in east of the Wadi Albadab and in the middle parts of the study area.

Fluvial systems consist of a set of various rivers with structural manifestations and carvel river terraces which are different in their formation (gravel, deposit, sand, clay stone and silt) as a product of vertical erosion which attempts to reach the base level in some condition of climate change which leads to and deepening of river paths which in turns leads to farming of a new set of river terraces which differ in their thickness of vertical layers. This is mainly according to erosional factors and the capacity of waters in carrying various sediments and its process of sedimentation in the lower levels (Figs. 4.24 and 4.25).

4.4.8. Waterfalls

Waterfalls are found-north and south-west-north of the study area. The geomorphological phenomena consist of various rock formations differ in terms of compaction and resistance. The solid geological formations actually the one in resisting the erosion processes, in the upper part of the study area, whereas the brittle ones are found only below. Waterfalls, however, may also be found in the strong rocky edges which powerfully resist the erosion process. The waterfalls are formed mainly because of water erosion and possibly by shaping of leads down stream.
4.4.9. Agricultural terraces

Agricultural terraces are considered mainly as a geomorphological feature generated by human activity in Rasyan Valley Basin especially on the mountain and slopes of hills and internal plateaus (Fig. 4.26). The agricultural terraces are built from various rock types. They have the shape of lengthened belts to coincide with contour lines. Soil can be found in these terraces used in farming activities. Soil, however, is exposed to the constant process of erosion and scouring, especially in the weak and waste land.

4.4.10. Rocky collapses

Rocky collapses were found in Rasyan Valley Basin as a product of various forming processes resulted in some heights over the river valleys with a face of sloping shape turns, in some areas, 90 degrees. These rocky forms are found in the northern, western north, and also the southern of planting and volcanic rocks, lacking any kinds of human activities. They can be also found in the-west of, and also the south-east with some limited rocky faces located in the middle parts of Rasyan Valley Basin (Fig. 4.27).

4.4.11. Sandhills

Sandhills are formed as a product of water shortage and the highest average of temperature, as well as the various mechanical and chemical processes of erosion (Al-Farraj, and Harvey, 2000., and Ion Livingstone et al, 2007). Sandhills are found in the study area in the near area of coastal line, such as Wahijah. The color of sand varies between silvery white in the connected area to the coast, and the yellowish white in the internal area, near Wahjah village (Fig. 4.29).

4.4.12. Coastal Marshes

Marshes can be defined as a low land of about few centimeters away from the coastal line. Marshes which are found near the coastal line in Wahjah village are a product of breaking waves on the cheek of the coast filled with Sea water. The surface of these phenomena is covered with dactylifera.
Fig. 4.24: River bank in the middle of RVB

Fig. 4.25: River bank in the western part of RVB

Fig. 4.26: Agricultural terraces in the highlands of RVB

Fig. 4.27: Rocky collapses in the Saber mountain of RVB
4.4.13. Al-Khazajah (Spongeonea)

It is the form of elevated areas of limited length, formed in summer season as a product of water which is saved in this area. Soil keeps water in its pores and then it changes with sponge features. It is, in fact, a phenomenon that can never be used for farming in the study area.

4.4.14. Land Collapses

Land collapses forms a geomorphological phenomena in mountain parts (Jabal Habashi, Taiz, Shara'ab, Alramadah and Shamir). Land collapses are formed as a result of formation process, loss of support, fracture systems in addition to the erosion process. The active factors of erosion played a big part in forming this phenomenon. The breaking of the solid layers causes their fall into various directions of various slopes which lack trees and plantation.

Two main factors the causative factors for land collapses:

On one hand, the shape of the angle and the length of slope, furthermore, and clashes between layers (solid and brittle) serve to increase the activity of collapse. On the other hand, heavy rainfalls cause a large erosion of soil, subsequent collapses of the land in the south-eastern parts.

The process of extracting, their querying, undercutting by erosion of fissile materials, especially in the mountain area is also considered as one of the big factors behind this collapse, as in area of Shara'ab Alsalam, Sabir and Shamir.

4.4.15. Valley Deposits

Valley deposits are also geomorphological phenomena, formed usually in the Valleys outlet, between mountains (Longhitano, and Colella, 2007). Sediments of various shapes, size, reflect the water erosion strength and its capacity of sedimentation and transformation (Figs. 4.29 and 4.30).

Two big factors are behind valleys formation. They are the high rate of rainfall and sloping degree. The phenomena can be clearly found in the south, north and middle parts of the Rasyan Valley Basin.
4.4.16. Valley bottom sedimentation

Valley bottom's sedimentation is phenomena that tell a place indicates flow of water. It can be also defined as the specific area between the two banks of the valley. The valley's bottom is made up of soft sediments pebbles, fragments and sand which are found in the western parts of the study area. It is noticed that sediments in the middle parts of the RVB are, softer than those in the other parts (Fig. 4.31 and Fig. 4.32). This phenomena is in constant change from season to season, according to water erosion and its activities.

4.4.17. Salinas

Salinas are geomorphological and by human activity formed phenomena existing in the far west-south of the study area. It is nearer the coastal line. It takes the square and rectangular shapes and is characterized by clay soil of poor draining to prevent leaking of water to the underground water table (Fig. 4.33), (Boggs et al 2006). Water is stored in the salinas during the tide process or by prepared channels for this purpose. It is the form of elevated area of limited length. It will left for about 15 days to one month for complete evaporation and finally salt remains on the Salinas area in the RVB.
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Fig. 4.28: Sandhill in Tehamah plain of RVB

Fig. 4.29: Valley filled deposits in highlands of RVB

Fig. 4.30: Valley deposits in the middle part of RVB

Fig. 4.31: Valley bottom's sedimentary rocks in highlands of RVB

Fig. 4.32: Valley bottom's sediments in lowland of RVB

Fig. 4.33: Salinas in RVB