

Quantitative Revolution in Geomorphology and Challenges and Effect of Cycle of Erosion

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Abstract

This paper focuses on the factors that led to the kick-starting of the cycle of erosion and its many stages. It also observes the factors responsible for its relevance and effects today, which also led to the decline of Davisian Model that described it earlier. The methodology adopted for the study was mainly primary data observed in some areas around the buffer zones of Sahel/Sudan Savannah. Few recommendations were offered on why should the study of Aeolian and fluvial geomorphology must persist.

Keywords: Revolution, Geomorphology, Davis Model,
(Effects of Cycle of) Erosion.

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Background to the Study

Geomorphology is a scientific study of the structure, behavior, nature, classification, nomenclature, processes, distribution and interaction of landforms and landscapes, and surface of the Earth, and enquiry into the origin of these features. Although it is the study of the origin and dynamism of the morphology (structure and forms) of the earth's land surface, but the morphology of seafloor and the analysis of extra-terrestrial terrains can still be put into consideration. Geomorphology and Physical Geography are interwoven. It can be the geological aspect of the visible landscape (Kankara, 2017).

Series of stages through which landforms were believed to pass from their initiation, following an uplift to their plantation by erosion is the erosion cycle, as formulated by William Morris Davis in the year 1884. It remained a dominant scene in Geomorphological studies in the last century (Kankara, 2014b). Cyclic or historical geomorphology is another approach to geomorphology as schemed by William Morris Davis (1848-1934), the celebrated American Geographer, geologist, meteorologist, who founded the science of geomorphology.

The main stages were: Youthful stage, where hills are steep, river profiles are irregular (see plates ii and iii); Maturity stage when river profiles are smoothly concave-up and incision had markedly slowed, and old age, when the landscape is reduced to a gently undulating surface or peneplain (last stage of the transformations of landforms, rolling in to a nearly flat-land) (Kankara, 2014a; Kankara, 2014b) (see plates i and iv). This framework of landforms has now largely been dropped out of use because quantitative revolution in Geomorphology that followed with its emphasis on measurements of forms and processes aided by rapidly improving technologies brought about the death of Davisian Model. There are great and infinite varieties of landforms distributions on Earth. They are formed from variety of rock types and multiple of processes and over variable length of time.

Endogenic processes gave rise to tectonic landforms, while exogenic made denudational landforms. The processes identified and described are geological (structural), weathering and removal by gravity, water, ice, wind and man (Ibrahim, 1990; Kankara, 2009).



Plate i: Peniplanation/mesas at Anguwan Danbausha in south Katsina, Katsina State, 2009

During the later stages a progressively wider area becomes subject to the influence of a single base-level erosion, and at the same time the original mountain masses are related to isolated residual hills (plate i). With the continued decrease of relief and of slope rainfall and action of running water becomes progressively less important (plate v). Depletion removes much of the previous accumulated alluvial infill and abrasion attack an increasing area of bare rock on the desert peneplain, forming a low-level erosion surface.



Plate ii: Inselbergs with prominence Dutse, northern Nigeria, 2017



Plate iii: Rugged Landscape at Birnin Kudu, northern Nigeria, 2018



Plate iv: End point of Davisian Cycle, Bungudu side, Zamfara State-Nigeria, 2015



Plate v: Aerial view of Dutse city, Jigawa State Nigeria. This signifies an evidence of rugged terrain and continuous decrease of relief, 2018.

The Gondwana peneplain which occurs at a height of 1,200m or more Above Sea Level (ASL) is believed to date from Cretaceous times, so called because it is thought to have been formed before the break-up of Gondwana land through Continental Drift. The African Pedeplain at 600 meters (approximately 2000 ft) and above is assigned to early Cenozoic (plate ii).

Pedeplain may be multicycle in origin that is the effect of more than one cycle of erosion may be superimposed on the desert landscape (plate v). The reconstruction of the palaeo environment of deposition for the younger meta sedimentary rocks is difficult from direct field evidence, as there is no actual reality of the precise bedrock structure directly under the meta sediments within the older meta sediments of the palaeo basins.

Materials and Method

The Study Areas/Data/Collection and Analysis

Areas considered for the study are the entire zones of Hausa Planes. This, therefore, requires no map or scale of the areas because it will be monumental, unbearable unscaled and cumbersome. But secondary data from lecture notes (Kankara, 2009) provided more

on such. Moreover, students of 100 level of Department of Geography were taken out for excursion around the State, from 2012 to 2014, and Distant Field Trip with 300 Level students between 2017 and 2018 as accompanied by lecturers in the Physical Geography unit. Geomorphology, Soil Science, Climate variability, water resources and distributions and mineral deposits and their studies were studied. Maps were also produced. Reports were submitted. It was from the excursions that data for the study was expunged.

Review of Related Literature

The geological history of peniplanation zones is also synonymous to geological History of the Nigerian Basement rock, generally lying in the vast region east of West African craton that was affected by the Pan African Orogenic event about 650 Ma ago (plate ii) (Kogbe, 1976; Arthaud et al., 2008). Evidence from the cratonic margin in Hoggar and Pharussian, Ghana and Togo indicates that the West African region that was affected by Pan-African, east of the craton has evolved through plate tectonics involving continents to continent collision and subduction, an incomplete anatexis or melting of the oceanic crust and formation of acidic magma, leading to the emplacement of older granites at the late Precambrian to early Paleozoic period (Woakes et al., 1987). The older granites have yielded almost uniformly Pan African. The field occurrences of these granites, however, show that they are not of the same age (Kogbe, 1976; Ajibade, 1986).

Since the dawn of the geologic times about nine (9), Orogenic movements took place, such as fracturing of the earth. Intensive folding occurred in the Pre-Cambrian. The three more recent Orogenic cycles are Caledonian, Hercinian and Alphine. The Alphine is the last of the major Orogenic movements, almost 30 my ago. Mountain ranges were squeezed up and over thrust on a very great scale. The Geological History of the entire Hausa plains is similar to the Geological History of the Nigerian Basement. It generally lies in the vast area of east of West African Craton that was affected by the Pan African Orogeny about 650+150 Ma ago. Evidence from the cratonic margin in Hoggar and Pharussian, Ghana and Togo indicates that the Pan African belt in western part of Africa, east of the craton has evolved through plate tectonics involving continents to continent collision and subduction, incomplete melting of crust and formation of magma, leading to the emplacement of the older granites during the late Precambrian to early Paleozoic period. The most extensive outcrop of Tertiary-Recent activity is on the Biu and Longuda Plateaux of Northeastern Nigeria and of Jos Plateau. Scattered occurrences exist within the Benue Through the dominant rock type is basalt with alkaline affinities. Grant (1969) showed that the geochronological dating of basaltic rocks spans from 22 Ma-0.7 Ma. More activities that are of recent are expectedly related to the event along areas around the volcanic zones in Cameroun.

The sedimentary areas in the areas under peniplanations almost occupy half of the land area of Nigeria, in which sedimentary basins form part (plates i and v). The Basins include: The Benue Basin, which is categorized into three (3) the Upper and Lower Benue, Adamawa (or Gongola) Basin, the Yola Basin, in the East there is the Anambra Basin, The Bida Basin, in the north-west there is the Sokoto Basin and the Niger Delta Basin. The

Sokoto basin in the north-west and the far Chad Basin in the northeast are part of the Iulemeden and Taodeni Basins, which are outside Nigeria with histories dating back to the Paleozoic (Whiteman, 1982). The oldest sedimentary rocks dated at the surface in Nigeria (excluding the basement complexes) are early Cretaceous (Albian) in age and the youngest sediments are the present day Niger-Delta complex deposits which are being laid down at the present by the Benue and Niger distributaries in the coastal areas of south Nigeria (Okonkwo, 1995) Sedimentary rocks and sediments are found in six major basins which occupy about 462,000 square kilometers (or approximately 191,000 miles), which is almost 50% of the area occupied or covered by basement rocks.

Quantitative Revolution and Challenges of Davisian Model

It was discovered in recent years, resurrection of the concepts of isostasy (defined by Dutton and later ignored by Davis) led to the formulation of a more realistic but more complex model (Bennett & Ike, 1984; The Web, 2009), briefly conducted here in which landforms may be viewed as responses to more or less continuous interaction between tectonic activity, sub-aerial denudation and isostatic adjustment.

a. Reasons for the challenges

Davisian model of erosion must be faced with a lot of criticisms and challenges due to the following reasons:

- i. Any such simple model such as W. M. Davis's Model of cycle of erosion can be complicated by the complexity of underlying materials, resulting in differential rates of denudation and the instability, marking the geological History of Earth in the last fifty (50) years.
- ii. There is also a slope declining idea, faced as they are with much-conflicting evidence of expensive pediments cut both in hard and weathered rocks; forms attributed to certain ages cannot be substantiated. An example here is the so-called old age landscape rarely encountered over large areas. Examples are: Mississippi Basins in the US and Jos Plateau, Nigeria are depositional, not erosional. While peneplain can readily be explained otherwise (Plate i)
- iii. Moreover, the Principle of Denudation chronology in the cyclic theory of landforms evolution is complex and so is not readily applicable in a work such as the present one, dealing with examples of landforms which should be easily recognized and described in the field.
- iv. There must be a weakness, uncertainty and complexity in preparing a simple model for landforms structure, process of their development and stages, especially those evolved many millions of years. More so, the processes are not directly observable at the present time so that a lot rely on intelligent guesswork and extrapolation.
- v. Mainly because of plateaus and mountains coastal lowlands or plains are not extensive, and so this can make a cycle of erosion so difficult. Although the rivers

of Asia and North America have alluvial plains built up in their lower courses than in Africa. The longest Deltas in Africa are Rivers Niger (41,600sq km) and River Nile (26,000sq km) (Kankara, 2009)

- vi. Great interior Basins sink in between these plateaus (Ajibade, 1983) mostly of structural origin. Nearly all the Basins have very restricted outlets to the seas.
- vii. Cuttings and embankments, huge quarries and large mining slag-heaps are familiar and are man-made activities, leading to the formation of scenery and or lesser landforms (Preece & Wood, 1980)
- viii. By means of Dams large lakes have been formed, sometimes as much as 100 miles long; vast areas have been reclaimed from seas, as in the Netherlands, rivers have been deviated and canals built.
- ix. Elsewhere, the reckless cutting down of forests and the ploughing up of grasslands in semi-arid areas has in some places greatly accelerated the erosive action of some of the natural agents.
- x. Soil erosion is indeed, whether it is by wind or by gullying due to running water is perhaps the World's biggest agricultural problem. The US has already lost one-eighth of its topsoil, and many other countries are seriously affected.

b. What to consider

- i. A later regional folding phase probably in late Eburnean resulted in a local anticlinal dome which affected both the migmatites and the metasedimentary sequences. In the late Pan African, a deep weathering process resulted in the vast excessive wearing of upper portions of the anticlinal structure exposing the eastern and western limbs within which the carbonate and schist occur as truncated alternated bands with the basement migmatites. The region is underlined by igneous inselbergs and low-lying migmatite rocks of the basement, which also bear the prominent relief, which appear as massive ridges and isolated dome-shaped structures. The average elevation is between 305-630m above sea level. The extended and dissected peneplained landscape in which the higher part form the drainage divides of streams flowing towards north and south into Atlantic ocean form major features in northern Nigeria. It is also believed that the denudational History of peniplanations or episodes began with marine transgression from the Tethys sea which extended southwards from North Africa in the late Maastrichtian times resulting in the deposition of marine sediments (Kankara, 2009).
- ii. This region comprises of different rocks which were formed during different periods of geological History. The higher plains comprise a dissected plateau of complex crystalline rocks which are characterized by ranges of hills. The high

plains are part of an extensive upland which stretches across northern Nigeria from eastern Sokoto as far as Bauchi and Abuja. They represent a stage in the geomorphic history of the area known as the African planation surface which is formed by erosion process. This region of Pre-Cambrian rocks is dissected by numerous shallow valleys which form the drainage channels or streams.

- iii. Since the Miocene period, continental conditions have prevailed and some uplift of the crust has occurred. Depositions of sediments have been restricted to superficial deposits of less and cover sands during arid phases of the Pleistocene and Holocene, together with alluvial deposits by river sedimentations during the wetter phase, were Davisian Model of erosion works well.

Flooding in Semi-Arid Regions as added Catalysts

Flood is among the natural disasters associated with the body of waters: lakes, streams, Dams, Oceans, and Seas that exceed their bank full capacity to the neighboring land surfaces. Geological hazards, on the other hand, are the extremes of the hydrological records with events of large magnitudes, hence concerned to the Environmental Agencies, water supply and waste disposal bodies, the emergency service agencies, insurance agencies and many more.

This section of the paper examines the flood determinants in the Dam collapse, with particular attention to some earth dams in Katsina State; the Sabke Dam, Bunsuru Dam and Jibia Dam. Data for the study were collected through fieldwork of students of the Department of Geography, Federal University Dutsinma, Katsina State that involves physical on-sight assessment of building structures, use of sub-surface thermometer for finding sub-surface, infiltration and underground water depletion conditions, microclimate consideration and geomorphology of the area, and also the quality of soil/land of the place (Kankara, 2012). This primary source of data involves field visits to the areas.

The frequency of instability of building structures is on the increase, lowering of the groundwater table and contaminations are also identified within the study area which further triggers challenges of the cycle of erosion.

Conclusion

William Morris Davis's Cycle idea was derived from the ideas of Orogenic cycle favored by Dana and Le Conte, and prolonged sub-aerial denudation towards base level. Alternative cyclic denudation models challenged Davis's Model.

Recommendations

1. More studies on fluvial and Aeolian geomorphology in Tertiary Institutions are desirable in order to keep abreast knowledge of earth science without gap.
2. Knowledge and studies on how Landforms are today being modified by man's activities are also needed.

3. Prompt rejuvenation of abandoned earth dams by involving geologists and geomorphologists.

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