Geology, Geomorphology and Evolution of the Landscapes of Cross River Region, South-Eastern Nigeria

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Abstract

The Cross River State in the south-eastern part of Nigeria hosts some remarkable landforms and resultant landscapes that have been created by a series of processes dating from the Precambrian to recent times. The Precambrian basement and associated landforms are well expressed within the Obudu Plateau and the Oban Massif, built primarily of granites and metamorphic rocks, as well as other numerous rock units. These Precambrian geologic domains bear relics of ancient geodynamics and evolutionary land-forming processes with its scenic mountain ranges, deeply incised valleys and cascading waterfalls. Also within the Cross River State are landforms associated with sedimentary rocks, typically exemplified by the karst geomorphology of the Mfamosing Formation with weathering and dissolution structures such as caves, stalactites and stalagmites, pinnacle structures, sinkholes and burrow trails.

Keywords

Obudu Plateau • Oban Massif • Mfamosing Formation • Granite landforms • Karst • Waterfalls

15.1 Introduction

The Cross River State lies in the south-eastern end of Nigeria, covering a total land mass of about 20,156 km^2. The state is of heterogeneous geological composition, with associated features of variable geomorphological expressions. These features range from the lowlands of the southern deltaic sedimentary basin (Calabar Flank and host to a well-developed karst topography) through the sediment fill of the Mamfe embayment to the rugged highlands of the mountain ranges of the Oban Massif and the Obudu Plateau.

The geologic setting of the Cross River area and its associated landforms has been reported to be resultant of a series of geological and geomorphological events from the Precambrian through to the Cretaceous–Cenozoic periods. The landscape and landforms exhibit characteristic features that indicate they are extensions of adjoining geologic suites to the west (Southern Benue Trough) and east (Cameroon volcanic line). The entire area has a complex geology and is built of varying rock types, representing different geologic events over time and space. This chapter aims to present the geology, geomorphology, origin and evolution of the basement complex and the karst terrain within the study area.

15.2 Setting and Location

The Cross River State lies on the south-eastern fringe of Nigeria between latitudes 4–7° N and longitudes 8–9° E. The state has a prominent place in the history of Nigeria as its capital city, Calabar, was the first capital city of the country. The state also has a rich cultural history embedded in well-documented artefacts. The Cross River State is characterized by a tropical climate marked by two distinct seasons: wet and dry. The wet season spans a period of about six months (May–October), and the dry season lasts from November to April. Temperatures are high with negligible diurnal and annual variations. The average monthly temperature in the area ranges from 29 to 34° C. The state experiences an annual rainfall of about 2300 mm with annual mean daily relative humidity and evaporation of 76–86% and 3.85 mm/day, respectively (Petters et al. 1989). The peaks of precipitation are usually between June and August and vary annually. The state exhibits a vast array of vegetation, guinea savannah type in the northernmost part, with veldt and forest types in other parts of the north. The central and southern parts are dominated by luxuriant,

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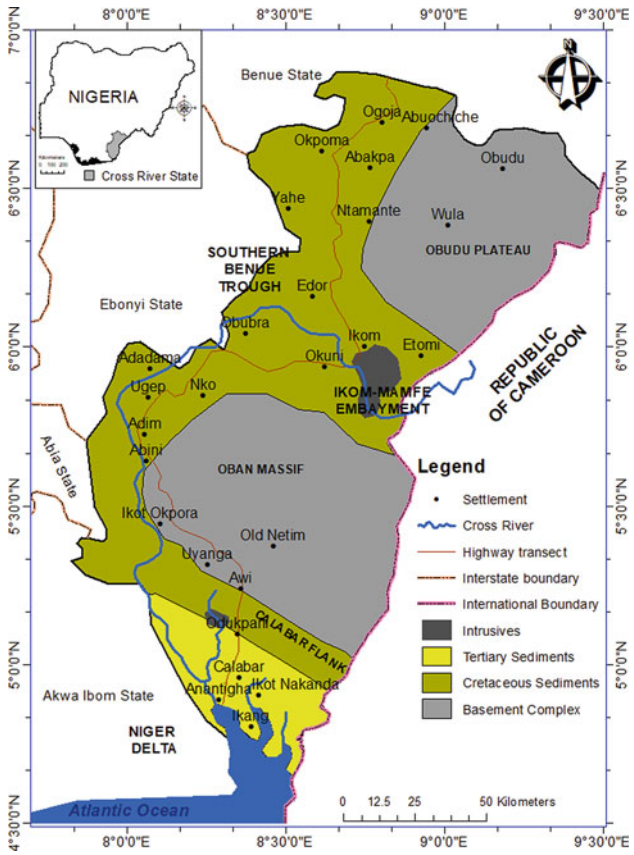

Fig. 15.1 Geological map of the Cross River State showing the geomorphological areas of interest

rainforests with tall trees as canopies and thick undergrowth, forming a stratified forest appearance.

The state is underlain by the only Precambrian basement outcrop of south-eastern Nigeria (the Oban Massif and the Obudu Plateau) (Fig. 15.1).

These basement complexes have been defined as giant spurs which represent the western prolongation of the Cameroon Mountains into the Cross River plains (Ekwueme 2003). These basement spurs form horst structures which are separated by sediment-filled grabens. The two basement spurs are flanked on the southeast by the Cameroon volcanic line and in the northwest by the Benue Trough, which is believed to be a structural feature made up of Cretaceous–Cenozoic sediments and igneous rocks (Fitton 1987). The Cameroon volcanic line, according to Geze (1943), is a prominent, 1600-km-long lineament that comprises oceanic and continental volcanoes (Fitton 1987).

The Oban Massif and Obudu Plateau are believed to have been uplifted to a height of between 1200 and 2000 m by the magmatism on the Cameroon line (Fitton 1987; Ekwueme 1991).

The Oban Massif has been defined to be a dissected plateau with elevations of up to 1125–1200 m above sea level in some places (Ayi 1987; Ekwueme 2003).

The Obudu Plateau is more of a rugged mountain range, which is an extension of the Bamenda Massif that stretches from the Cameroon Republic into eastern Nigeria. Spot heights above 1500 m above sea level have been reported from the Obudu ranch resort.

The karst country topography within the Calabar Flank is represented by the Mfamosing Formation, which is an accumulation of carbonate platforms that rimmed the Oban Massif. Sequel to its burial at depth, the Mfamosing Formation was exhumed by Neogene tectonics along the Cameroon volcanic line and subsequently karstified (Reijers 1998). Tectonism involving vertical movement of the underlying basement resulted in faulting and jointing within the karst formation, further enhancing karstification (Reijers 1998).

Therefore, the morphology of the Cross River State is a complex of landforms and geomorphic features resulting from both endogenous and exogenous processes acting over an extensive geologic time frame.

15.3 Geology

15.3.1 Basement Igneous and Metamorphic Rocks

The basement complex as exposed in the Oban Massif and Obudu Plateau exhibits a heterogeneous array of rock suites that are igneous and metamorphic in origin, and their occurrences are controlled by different episodes of formation and tectonism. However, the dominant rocks across the basement spurs are granites, gneisses, migmatites and older meta-sediments. The rocks in the Oban Massif and Obudu Plateau are dated as pre-Pan African (evidenced from relics of Kibarean Orogeny) and Pan African (Ekwueme 1990).

The Obudu basement complex is characterized by granitic gneisses, migmatite gneisses and schistose rocks which have undergone regional metamorphism and plutonism evidenced in shearing, folding and faulting structures that are dominantly in the N–S direction (Edet et al. 1994; Ekwueme 1994). The gneisses are banded and migmatic. Surface features include deeply weathered landscapes.

The major rock types within the Oban Massif are younger intrusives (syenites and associated rocks), granodiorites, pegmatites, porphyritic biotite gneissose granite and gneisses (biotite gneiss, hornblende gneiss associated with schist). These rocks are mostly medium to coarse grained with extensive banding structures on the eastern flank of the

massif (Ekwere 2010). These rocks are cross-cut by quartzofeldspathic dykes and veins giving them migmatic aspects (Ekwueme 2003). The massif exhibits a variation of lithological units with characteristic textures (Raeburn 1927; Rahman et al. 1981; Ekwueme 2003; Ekwere 2010; Ekwere et al. 2012).

15.3.2 Cretaceous Sedimentary Rocks

The Cretaceous sediments of southern Nigeria have been termed the Calabar Flank. The Mfamosing karst country is composed of rocks believed to be the oldest marine unit on the Calabar Flank, dated to Middle Albian (Lower Cretaceous) based on ammonite fossils (Forster and Scholz 1979). According to Reijers and Petters (1997), the karst bearing formation is made up of four recognizable facies; (1) bioclastic pelletoidal packstones and grainstones, (2) psuedosparitic mudstones, wackestones and packstones, (3) algal packstones and stromatolitic boundstones and (4) admixtures of any of the above facies with siliciclastic materials. These facies indicate a shallow marine, a nearshore depositional system with high-energy grainstone bars and lagoons (Reijers 1998). The development of these carbonate structures was periodically interrupted by influxes of siliciclastic materials and occasional exposure of the seafloor carbonates. These reacted with meteoric water resulting in destabilization, localized leaching, formation of secondary porosities and pseudo-chalky texture (Reijers 1998).

15.4 Major Relief Features

15.4.1 The Obudu Plateau

The Obudu Plateau can be described as a range of rolling mountains with gently sloping escarpments of less than 10° inclinations. The plateau is not perfectly planar across a greater part. In detail, it is composed of an alternating sequence of swells and troughs which vary in width, with relief amplitude in the order of 100–250 m. These undulating features mostly trend in the dominant structural orientation of N–S across the plateau.

The most elevated parts of the plateau include Becheve (> 1200 m), Bassang (1150 m) and Amette (1200 m), which are located on the north-eastern flank of the plateau. Other adjoining areas fall to heights of about 500–850 m above sea level and include Old Tikette, Ogbakoko and Utanga.

Lying amidst the mountain ranges are flat-floored extensive basins such as Keyi, Bellinge and Amama. These peneplain basins have extended and well-developed regolith profiles, incised by valleys that lay paths for numerous stream channels. The streams are sinuous with low flow velocities.

The most impressive geomorphic feature of the plateau is the Becheve mountain range (Fig. 15.2) which constitutes a set of the highest peaks in the area. It is expressed as an overlapping array of hills and is visible from across a distance. The hills host a mountain cattle ranch with characteristic veldt-type grasslands. Sections of the hills are thickly forested. Dissections are common on parts of the slopes, and these host cascading waterfalls at varying altitudes (Fig. 15.3), with headwaters below the mountain peaks. The escarpments along which the falls are located show no lithological variations and thus are not related to rock resistance or differential weathering features.

15.4.2 The Oban Massif

The Oban Massif is a constellation of flat lands, subdued hills and rugged mountainous country, with isolated peaks of up to heights of 1200 m above sea level. The average elevation of the massif is only 150 m above sea level, rising gradually from the south northwards and falling again towards the Cross River in the north. The human settlement of the massif is more on the subdued and lowland areas margined by topographic highs (Fig. 15.4).

The western flank of the massif is more subdued relative to the eastern sector. Deep weathering profiles characterize most of the western sector which is dominantly built of granites, granodiorites and gneisses with pegmatite intrusions, which have undergone intensive weathering and prolonged rock quarrying operations. The hills in the western sector have gentle slopes with inclinations generally less than 10°. These are well exposed in the landscape over localities such as Uyanga, Igbofia, Ifunkpa, Old Netim and Okom-Ita.

The eastern sector of the massif is more rugged with isolated hills that rise steeply and abruptly with slope inclinations of more than 30° as exposed in areas such as Akor, New Ndebiji and Iko-Essai. These hills are often dissected by V-shaped valleys and are thickly forested to the summits of even the highest peaks in some locations. The dissected and indented escarpments propagate rock weathering with the formation of talus as evidenced in the boulders and screes seen within the valleys (Fig. 15.5).

Massive swell structures are commonly found in most areas of the eastern flank of the massif, typically in Oban town (Fig. 15.6). These swell structures show intensive folding, deep plunge and foliations with lineations in the NE–SW directions.

Drainage within the massif is controlled by fractured and jointed zones. The massif is well drained by a network of

Fig. 15.2 Undulating surface topography of the Obudu Plateau

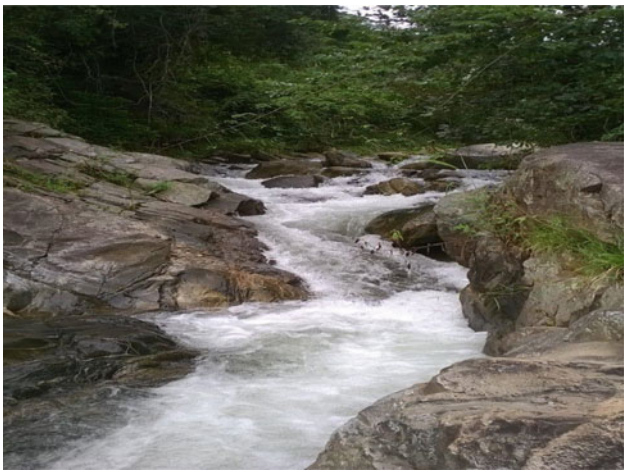

Fig. 15.3 Cascading waterfall stream within the Obudu Plateau

rivers, which include waterfalls and actively eroding channels.

Two major rivers drain the massif: the Great Kwa and Calabar. These rivers and their intersections with the escarpments provide some of the most interesting features within the Oban Massif: numerous waterfalls and their associated turbulent streams at the hill bottoms.

Prominent among the waterfalls is the Kwa Falls. The river runs from the Precambrian basement through the Cretaceous sediments of the Calabar Flank and falls between Mfamosing and Oban at Aningeje on the eastern sector of the massif (Fig. 15.7).

The geology within Aningeje is dominated by banded schists with pegmatites, which are highly deformed and segregated into light and dark portions. These are best exposed within the Kwa Falls area (Fig. 15.8). The rocks show steep dip inclinations of 80–90° towards a NE–SW direction.

Fig. 15.4 Landscape and settlement in parts of the Oban Massif

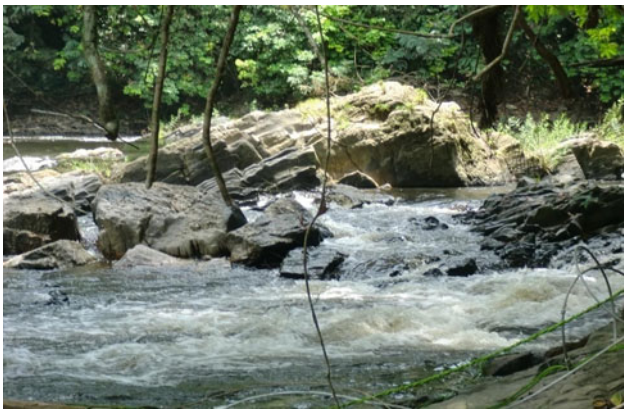

Fig. 15.5 Weathered boulders and screes along valleys within the Oban Massif

Fig. 15.6 Folded and foliated gneiss outcrop in Oban town

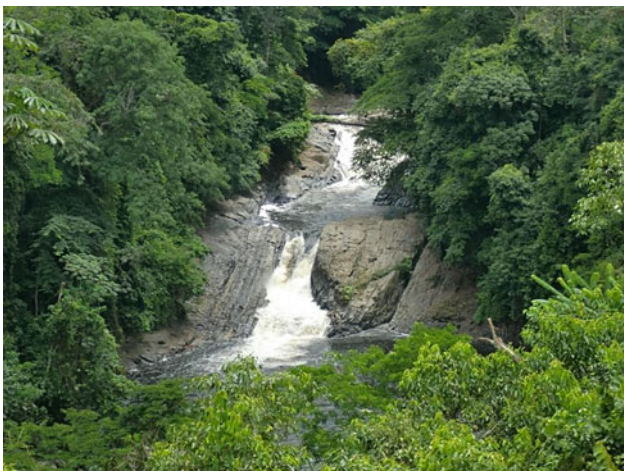

Fig. 15.7 Kwa Falls in Aningeje, eastern Oban Massif

Fig. 15.8 Banding structures on the schists within the Kwa Falls

15.4.3 Mfamosing Karst Formation

The Mfamosing karst formation belongs to the Calabar Flank which is a sedimentary basin in south-eastern Nigeria bordered to the west by the crystalline basement of Oban Massif. The Calabar Flank sedimentary basin is founded on the continental margin dominated by a system of NW–SE trending step faults. This fault system resulted in the formation of horst and graben structures within the area. The flank is composed of a vast array of Cretaceous and younger sedimentary rocks. The stratigraphic profile of the flank was controlled by vertical tectonics of the fault blocks and by eustatic sea-level change within the adjacent South Atlantic Ocean.

The Mfamosing Formation has massive exposures situated at Mfamosing, Mbuebu and Agbung villages. The thickest exposure of the limestone is at the Mfamosing quarry type section, about 50 m high. The Mfamosing Limestone is also believed to have accumulated on carbonate platforms that rimmed the Oban Massif and was also constructed on an offshore basement high. The Mfamosing Formation is impregnated with calcareous intercalations of marls and shales at some sites.

The karst country, typified in Mfamosing village and its environs, spans more than 120 km^2. It exhibits undulating topography with elevations of up to 80 m asl with variations of $\pm$ 10 m, with the development of associated karst features such as caves and dissolution structures (Fig. 15.9). The caves are found in villages such as Etakpini, Mbuebu and New Netim, of which that in Etakpini is most remarkable, extending 10–40 m with passages, chambers and multiple entrances. The karst caves host relics of dissolution structures such as stalactites and weathered stalagmites on the cave floors (Fig. 15.10). The calcareous units within the karst formation are densely burrowed with dissolution features and variable assemblages of fossil forms (Fig. 15.11).

Fig. 15.9 Karst pinnacle structure exposed at Mfamosing village

Fig. 15.10 Typical cave within the karst formation

Fig. 15.11 Burrows and dissolution structures on the karst landform

15.5 Human Impacts on the Cross River State Landscape

The influence of human activities has greatly altered the geomorphology and landscape of the Cross River State. The impacts have been mostly due to rock quarrying for construction purposes. The western sector of the Oban Massif has been most affected by granite rock quarrying dating back to the last fifty years. The area hosts many abandoned and working quarries. The quarrying has led to deep excavation pits and caldera-like features, and most of these are flooded to form lakes and ponds.

The excavations have also provided favourable conditions for weathering and regolith development. This is occasioned by structural discontinuities initiated by the use of explosives during rock blasting, thereby creating pathways for water percolation and increased dissolution paths within the country rocks.

The eastern sector of the massif and the Obudu Plateau has only experienced minimal rock quarrying activities. The karst country's topography has also suffered alterations due to the quarrying of limestone for cement production and other industrial applications. Most of the abandoned limestone quarries have become flooded to form ponds.

However, the modified landforms and the features within each of these geologic and geomorphic suites remain and are still potential tourist sites. Most important of these are the Obudu ranch resort and the Kwa Falls.

15.6 Conclusion

The landscape of the Cross River State is built on multiple geologic dynamics giving rise to geodiversity with varied geomorphological expressions. The Precambrian basement complex with granitic rocks has been greatly influenced by jointing and faulting, and this is visible in the Obudu Plateau and Oban Massif. These two geologic suites are made up of features of different configurations and elevations. Prominent among these are hills of varying heights with steep and gentle slopes, boulder fields, bedrock stream channels and waterfalls.

In the southern part of the state is a karst terrain of the Mfamosing Formation. This carbonate terrain hosts solution features such as caves and associated stalactites and stalagmites, pinnacle structures, burrows and sinkholes.

All these geomorphic features across the state remain of interest for visitors and adventurers. Some tourist facilities and accommodations are currently on the ground for most of the sites and have been catering for visitors over the years.

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