5 Hills and Ridges in Southwestern Nigeria

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Abstract

The Basement Complex rocks of southwestern Nigeria host a variety of residual hills. A distinction can be made among hills based on their parent materials and mode of formation. The hills include mesas, inselbergs, tors, regolith hills (i.e., erosional residuals in regolith), and regolith/forest-covered hills developed in amphibolite and diorite. Most common are inselbergs, which based on size have been classified into whalebacks, turtlebacks, bornhardts, and castle kopjes. They are either symmetrical or perfectly domical—bornhardts, elongated and symmetrical, or elongated and asymmetrical. They occur in clusters and with higher density in granitic plutons, but are scattered in various gneisses. These physical features have become a veritable touristic resource in the area. Good examples include the Idanre hills and the location of Abeokuta around the famous Olumo rock (which is actually a tor) in 1830.

Keywords

Basement complex • Granitic hills • Inselberg • Idanre hills • Olumo rock • Ado-awaye • Residuals

5.1 Introduction

Hills are elevations or groups of elevations rising above the level of the surrounding country culminating in well-marked summits. Local relief is generally less than 300 m. Steep-sided types are characterized by slopes above 12°, while gently sloping types are characterized by slopes less than 12°. Ridges are elevations whose length much exceeds the width. Hills and ridges occur all over the Basement Complex rocks of Nigeria, whereas outliers of sedimentary rocks form hills over the Basement Complex rocks in Sokoto, Lokoja, and Abeokuta areas. However, given the extent of the country, attention in this chapter will be focused on the Basement Complex rocks of southwestern Nigeria.

The Basement Complex rocks of southwestern Nigeria are bounded to the south by the Abeokuta sedimentary formation and to the east by the Niger River. The border with the Republic of Benin marks the boundary to the west, while the appearance of the Nupe Sandstone formation constitutes the northern boundary. The area is thus bounded approximately by latitudes 6°50′N and 9°00′N and longitudes 2° 40′E and 6° 40′E (Fig. 5.1).

The whole area lies between 90 m a.s.l at the contact with the sedimentary formation and 550 m a.s.l at the primary watershed between the rivers draining into the Atlantic Ocean and the Niger River, with several hills and ridges rising higher than these levels. The area which slopes from the north to the south is dissected by rivers Ogun, Ona, Osun, Owena, Osse, and Siluko and their tributaries (Fig. 5.1). The emphasis here is on the area draining into the Atlantic Ocean.

5.2 Inselberg Description and Classification

Inselbergs can be classified according to their size, form, and appearance. Large and elongated inselbergs have been designated as whalebacks (Jeje 1973; Olusola 2019), while smaller elongated types have been described as turtlebacks by Oyawoye (1965). Where they are relatively high, rounded, and topped by domes, they are known as bornhardts. Castle kopjes are sub-rounded in ground plan but conical and castellated in appearance. Twidale (1982, 1998) recognized three principal types of inselbergs, viz. castle kopjes, bornhardts, and nubbins, with the first and the last derived

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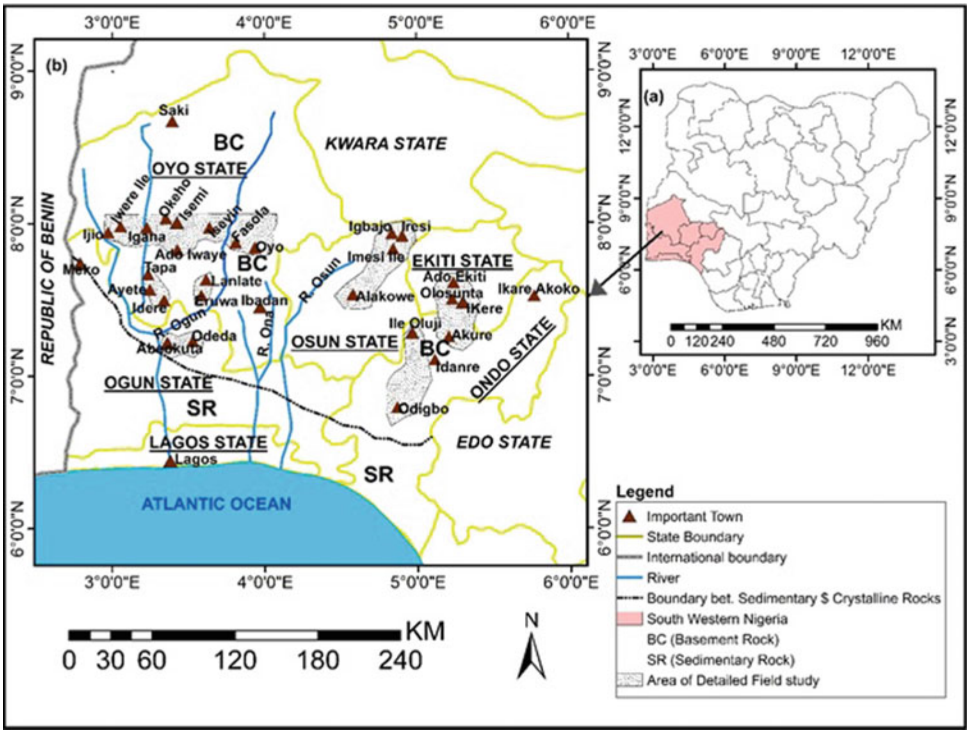

Fig. 5.1 Map of Southwestern Nigeria showing major lithology, waterbodies, major rivers, and rock outcrops

from the second. Migon (2006) classified bornhardts into domed inselbergs and shield inselbergs. Some of the characteristics of bornhardts outlined by Migon (2006) include steep, bare and upward-convex slopes, a sharp piedmont angle, and a mantle of talus derived from sheet structure at the foot slopes. Shield inselbergs on the other hand are characterized by slope angles as low as 10‾15°, flat summit surfaces and in most cases, a less abrupt piedmont junction. However, the major distinguishing factor between these various categories of inselbergs appears to be the ratio between the long and short axes which simplifies the issue of whether an inselberg is a bornhardt or shield/turtle back. This is illustrated in Table 5.1.

The Elongation Index, which is the ratio between the short and the long axes of inselbergs, measured for landforms present on the different rock types in the Basement Complex rocks in the extreme southwestern part of SW Nigeria, covering about 5000 km^2, is shown in Table 5.1, while Table 5.2 illustrates the occurrence of inselberg as related to the parent rocks.

About 83% of inselbergs developed in the migmatized gneisses in the study area are less than 32 ha in area. This situation is slightly different regarding inselbergs developed in granites. Seventy-five percent of those developed in the coarse porphyritic biotite and biotite-muscovite granite are less than 32 ha. However, the largest inselberg covering more than 121 ha occurs in this rock. In the undifferentiated older granite, 86% are less than 32 ha, which is quite different from the situation of those developed in coarse porphyritic hornblende granite-syenite, with 67% less than 32 ha. This is illustrated in Table 5.3, while Table 5.4 illustrates inselberg heights in different rocks.

5.3 Types of Hills

Distinctions can be made among hills based on their parent materials and mode of formation. The hills in the study area include mesas, inselbergs, tors, regolith hills (i.e., erosional residuals in regolith) developed in amphibolite and diorite. There are also convex summits with soil cover all over. The emphasis here will be on inselbergs and related forms.

Table 5.1 Elongation index of the Inselbergs

Rock types	Whalebacks	Turtlebacks	Bornhardts	Castle kopjes
Granites	2.6	1.6	1.1	1.3
Migmatised Gneiss	3.5	2.1	1.2	–

Source Jeje (1973)

Table 5.2 Percent occurrence of inselberg forms as related to parent rocks

Rock type	No. all forms	Whaleback	Turtleback	Bornhardt	Castle kopje	Complex
Total number		82	188	67	11	37
Coarse porphyritic, biotite, biotite, muscovite granite	157	31.8	42.4	13.2	5.10	7.6
Migmatite gneiss	153	13.7	62.8	13.7	–	9.8
Undifferentiated older granite	25	12.0	60.0	16.0	–	12.0
Coarse, porphyritic, hornblende, granite-syenite	15	26.7	13.3	6.7	13.3	40.0
Porphyroblastic gneiss	10	30.0	60.0	–	–	10.0
Granite-gneiss	3	–	66.7	–	33.3	–
Augen-gneiss	1	100.0	–	–	–	–
Muscovite, tourmaline, granite-gneiss	1	–	100.0	–	–	–

Source Jeje (1973)

Table 5.3 Inselbergs' sizes in different rock types

Size hectares	Coarse, porphyritic biotite, biotite muscovite granite		Migmatised gneiss		Undifferentiated older granite		Coarse porphyritic hornblende granite syenite	
	Number	%	Number	%	Number	%	Number	%
0–8	29	18.6	54	35.5	5	20	2	13.3
8–16	41	26.1	53	34.9	7	28	3	20
16–24	26	16.7	19	12.5	6	24		
24–32	22	14	10	6.6	3	12	4	26.7
32–40	7	4.6	2	1.3	–		1	6.7
40–49	5	3.3	4	2.6	1	4	2	13.3
49–57	5	3.3	–	–	1	4	–	–
57–65	4	2.7			–	–		
65–73	3	2			1	4	1	6.7
73–81	1	0.7	2	1.3	–	–	2	13.3
81–89	1	0.7	2	1.3	–	–	–	
89–97	–	–	2	1.3	–	–		
97–105	1	0.7	2	1.3	1	4		
105–113	–		–	–	–	–		
113–121	3	2	1	0.7	–	–		
121		4.6	–	–	–	–		
			–	–				
			1	0.7				

Source Jeje (1973)

5.3.1 Inselbergs

The word "inselberg" is German and stands for "Island Mountain". It was coined by William Bornhardt (1864–1946) in 1900. The inselberg is an isolated rock hill, knob, ridge, or a small mountain that rises abruptly from a gently sloping or virtually level surrounding plain. The term inselberg was initially applied to arid landscape features; however, it has since been used to describe a range of rock features in various geographical contexts, leading to

Table 5.4 Inselbergs' heights in different rocks (in m)

Class interval (15.2 m)	Coarse porphyritic biotite, biotite muscovite granite %	Migmatised gneiss %	Undifferentiated older granite %	Coarse, porphyritic, hornblende, granite-gneiss %
15.2–30.4	16.7	30.2	16	7.7
30.4–45.6	21.8	24.3	24	15.4
45.6–60.8	13.5	19	28	7.7
60.8–76.0	14.8	11.8	8	23
76.0–91.2	9.6	4	4	–
91.2–106.4	9	4.6	4	7.7
106.4–121.6	3.2	2.6	–	15.4
121.6–136.8	3.2	0.7	–	7.7
136.8–152.0	2.5	0.7	12	15.4
152.0–167.2	1.3	0.7	–	–
167.2–182.4	0.6	0.7	–	–
Above 182.4	3.8	0.7	4	–

Source Jeje (1973)

Fig. 5.2 An Inselberg—Olosunta Inselberg near Ikere in Ekiti State

Fig. 5.3 A Tor

confusion about the precise definition. According to Wilson (1900), "inselberg" has been defined as "steep-sided isolated hill rising relatively abruptly above gently sloping ground". This definition includes features such as mesas, buttes, conical hills with rectilinear sides typically found in arid regions, regolith covered, concave-convex hills, rock crests over regolith slopes, rock domes with near-vertical sides, and tors formed of large boulders but with solid rock cores. However, the word inselberg is now exclusively applied to solid rock island hill or mountain protruding abruptly from a plain cut across regolith (Fig. 5.2). Inselbergs are ubiquitous all over the Earth.

5.3.2 Tors

Tors are closely related to inselbergs and are also known as boulder inselbergs. These are piles of spheroidally weathered rock blocks rooted in bedrock and exposed as a basal rock surface following the removal of the overlying saprolite. When still concealed by the weathering mantle, the blocks are called corestones. Individual blocks may be less than 0.8 m in diameter, while the most common are sizes ranging between 1 and 3 m in diameter (Fig. 5.3). Most are less than 30 m in height and their cross-profiles may be highly irregular. They frequently occur in association with domed inselbergs, particularly in granites, either as clusters of boulders surrounding bornhardts or on the summits of emerging inselbergs. They may, however, also occur separately as described by Linton (1955) from southeastern England. Thomas (1993) attributed the relationship between domes and tors to the spatial variations in the jointing frequencies and the development of different types of hierarchies of jointing in granite. Tors also occur in gneissic rocks as small boulders and tend to disintegrate along the mineral bands (Faniran et al. 2021).

5.4 Inselberg Occurrence

Inselbergs are commonly associated with granitic rocks and various types of gneisses, and occasionally schists. They are partially covered by vegetation in the humid areas, but are virtually bare in the savannas and semi-arid areas.

Migmatite and the various gneisses underlie about 75% of the Basement Complex areas, supporting gently undulating and rolling plains. However, where rock structure and lithology are suitable, the plains are dotted with impressive hills/inselbergs all over southwestern Nigeria (Fig. 5.4). Notable ones include the famous Ado-Awaye Hill; many inselbergs are found are around Shaki and between Iseyin and Oyo (see Fig. 5.5). Several such hills dot the plains in Ekiti, Ondo, and Kogi States as evident myriads of inselbergs in Ikare, Akoko, and Kabba area, and specifically in Ife-Ijumu area along Omuo-Kabba-Lokoja road and around Okene. Those in the latter area are often referred to as Kukuruku Hills. Oyinloye (2011) observed that both the pink granite and gneiss give rise to hills in Ile-Ife-Ilesa, Ibadan and Eruwa areas. Granite-gneiss gives rise to series of inselbergs, often less than 100 m high, especially within the campus of Obafemi Awolowo University and along Ife-Ilesa road. The massive amphibolite and hornblende gneiss occurring widely in Ile-Ife-Ilesa area give rise to series of low hills. These forested low hills, less than 100 m high, encircle the southern part of Ilesa.

Inselbergs occur mainly in the various types of granites such as the coarse porphyritic, biotite-muscovite granite; coarse porphyritic, hornblende, syenogranite; undifferentiated older granite; medium to coarse grained granite and charnockite among others. These occur as discrete plutonic bodies ranging from about 90 km^2 at Eruwa-Lanlate and 310 km^2 in Idanre to about 410 km^2 in Akure-Ikere-Ado-Ekiti area. Apart from these three areas, these rocks are also found all over the southwestern Basement Complex area, specifically near Odigbo and Ile-Oluji in the Ondo State; in

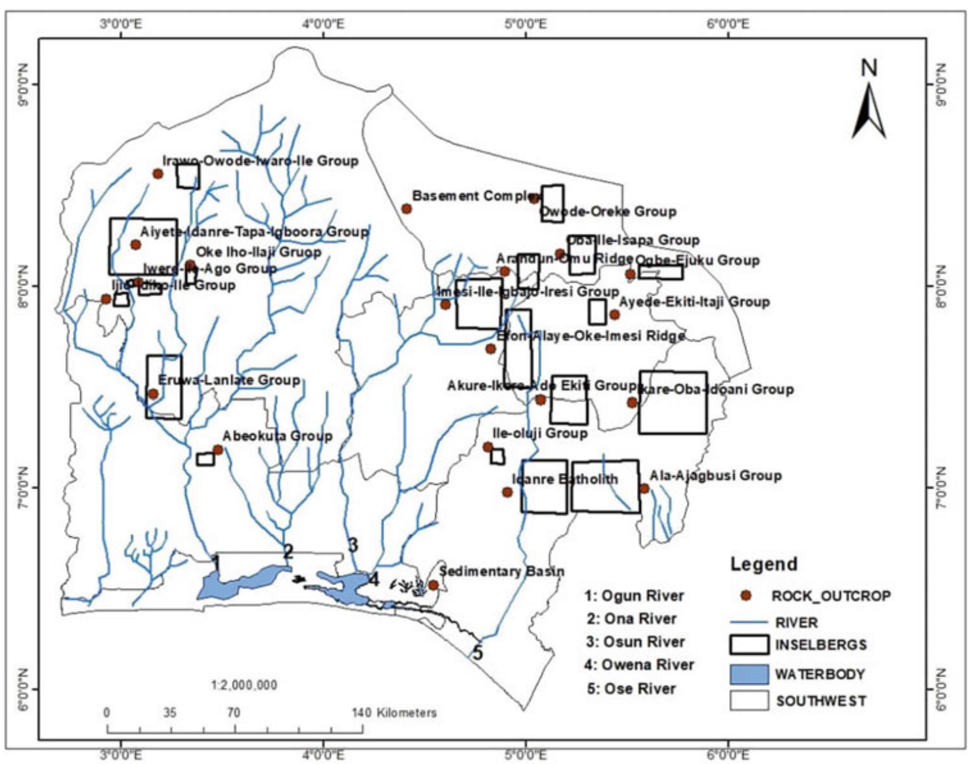

Fig. 5.4 Map of Southwestern Nigeria showing groups of inselbergs within the basement complex area

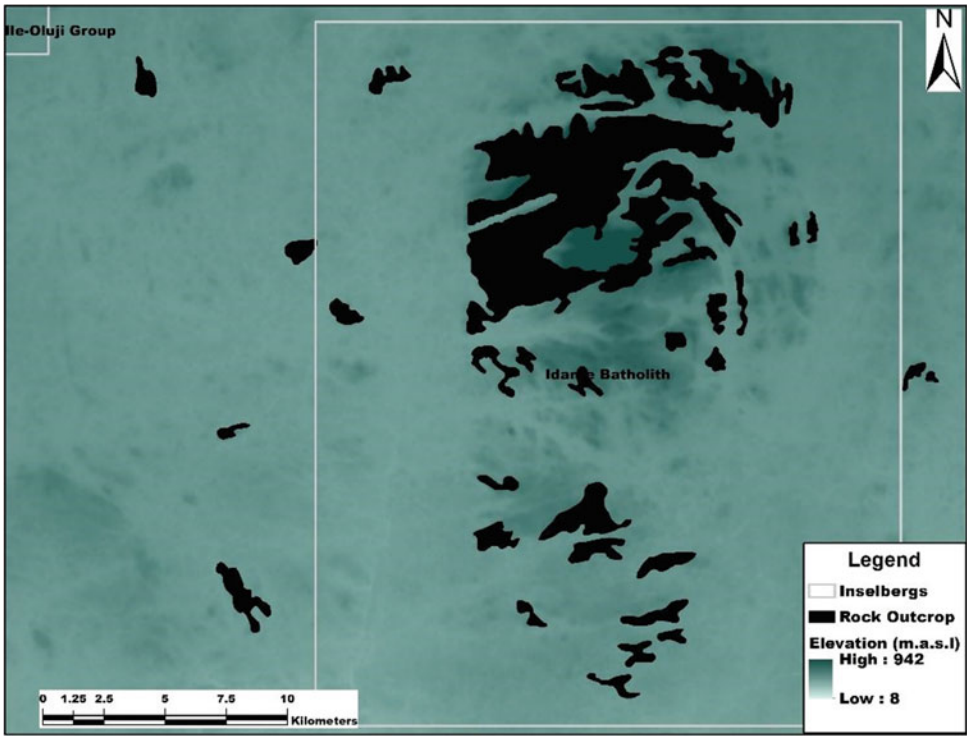

Fig. 5.5 Inselberg pattern NE of Idanre Town

Aiyete-Idere-Tapa-Igboora, Iwere-Ile, Ijio, Oke-Iho-Isemi in the Oyo State; Abeokuta-Odeda in the Ogun State; Imesi-Ile-Igbajo-Iressi and Alakowe (near Ife) in the Osun State among many occurrences. These rocks altogether underlie just about 15% of the Basement Complex area of southwestern Nigeria. Inselbergs in these granites occur in clusters, especially where the parent granite pluton is traversed by several vertical joints as at NE of Idanre town (Fig. 5.5). This section of the Idanre hills is traversed by series of NW–SE and NNE-SSW joints. About forty individual inselbergs occur in a cluster in an area of about 50 km^2.

Clusters may be circular, with massive inselbergs occurring in a circular form as in Ijio in the Afijio Local Government Area of the Oyo State (Fig. 5.5). However, the occurrence may be also in the form of a massive tableland surrounded/fringed by several inselbergs or half-exposed domes. Good examples are observable in Eruwa, Oke-Iho-Isemi, and Imessi-Ile-Igbajo-Iressi areas (Fig. 5.6). Old Eruwa town is located on a tableland surrounded by about 10 inselbergs of various sizes. The town, about 1.0 km^2 in area, is underlain by thick regolith exhibiting few rock outcrops. Afolabi (2017) quoting Thomas (1994) about the granitic terrain in Igbajo area observed that “the Igbajo plateau retains a deeply weathered upper surface, with domes currently emerging at the surface”. Oke-Iho and Isemi are towns located on such a plateau, 16 km^2 in the area, standing at about 100 m above the local surfaces. The plateau is surrounded by massive inselbergs, some of which are bornhardts, while several others are whalebacks, all surrounding an area covered by regolith containing massive corestones, and occasional lateritic ironstone on which the towns of Oke-Iho and Isemi are located. However, granitic inselbergs can also be located in a ribbon pattern of few kilometers apart, such as along the Akure-Iju-Ikere-Ado-Ekiti road. Among these are the massive bornhardts such as Olosunta, Orole, and several others. Both Olosunta and Orole are now locally deified with annual festivals associated with them.

Generally, inselbergs occur as singular features and far apart in all the varieties of gneisses and schist as exemplified by the Oyo Plains. In a study carried out in an area of 5000 km^2 on the Basement Complex in a part of southwestern Nigeria, Jeje (1973) commented on the frequency of occurrence of inselbergs in different rocks as follows: “in the granitic terrain at Eruwa-Lanlate and Idere-Tapa, inselbergs occur at a rate of 1 per 2.5 km^2 (40 per 100 km^2), in the gneissic area around Ado-Awaye, they occur at a rate of 1 per 6.5 km^2 (15 per 100 km^2), but in the same rock type around Oyo, inselbergs occur at a rate of 1 per 15.5 km^2 (7 per 100 km^2). In the granite-syenite and the Undifferentiated Older Granite terrain at Oke-Iho and Iwere-Ile areas, they occur at a rate of 1 per 0.8 km^2 (125 per 100 km^2)”.

5.5 Some Aspects of Inselberg Morphometry

In the ground plan, inselbergs are mainly elliptical, rounded or complex. In profile, they are either domical or symmetrical—bornhardts, with little or no basal scree slope

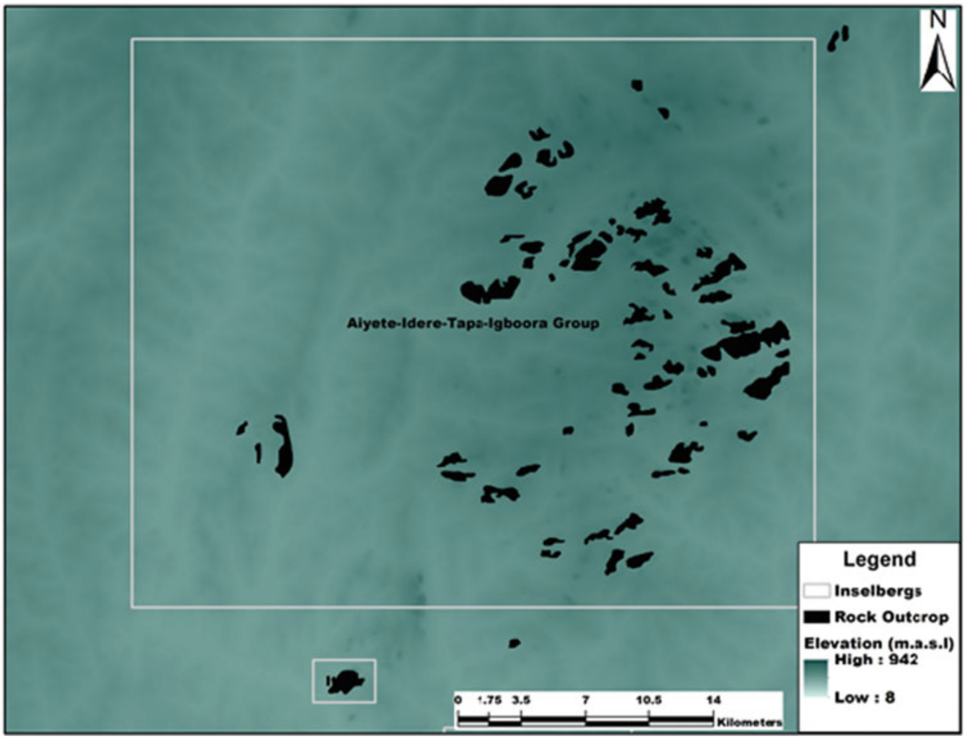

Fig. 5.6 Cluster of inselbergs in Ijio-Igbo-Ora area, Oyo State

Fig. 5.7 A Bornhardt in Ado-Ekiti

(Fig. 5.7), or elongated and symmetrical, or elongated and asymmetrical, with lower-inclination slopes carrying regolith/soil and partially vegetated or complex (Fig. 5.7). In several cases, they are devoid of scree slopes. These various forms are related mainly to rock structure and lithology, especially with regard to:

- Rock foliation
- Direction of foliation and angle of dip
- The presence of bounding joints.

Granitic inselbergs are often elongated and symmetrical as most of those in Idanre or domical as those between

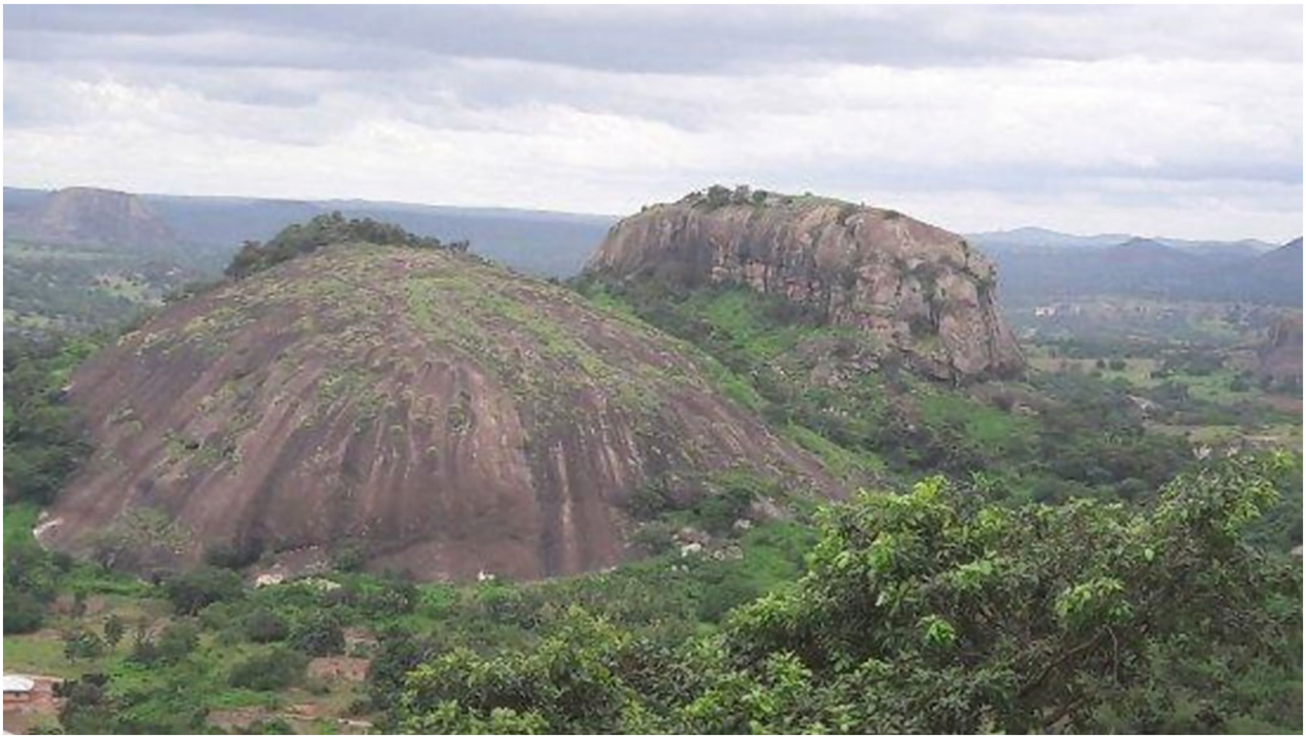

Fig. 5.8 Ado-Awaye rocks (Inselberg)

Akure and Ikere-Ekiti (Fig. 5.4). Some have pronounced asymmetry as the case of Ilele hill at Ijio (Fig. 5.4). Inselbergs built of migmatized gneisses are elongated but are largely asymmetrical. These characteristics are determined by foliation, direction of strike, and the angles of dip of foliation. Where the dip and strike of foliation coincide, the inselbergs are mainly elongated and symmetrical as the case of Ado Rock in Ado-Awaye (Fig. 5.8), where the strike of foliation is 340° NNW and the dip is vertical. Locally, the long axes of the inselbergs built of coarse porphyritic granite trend in NNE-SSW direction as the parent rocks.

Where vertical joints cut across the dip of foliation, asymmetry is pronounced as observed on an inselberg north of Fasola near Oyo. In most cases, inselbergs formed in gneisses have extremely steep bounding slopes on one side and gentle slopes on the other one, e.g., Aseke hill near the old water work in Oyo. Only occasionally are the slopes uniformly steep, as in granites. The steep bounding slopes are often emphasized by subsurface rotting and erosion at the base of the inselbergs, and this leads to the formation of convex slopes or overhangs (Fig. 5.9).

Morphometric features of inselbergs developed in the coarse porphyritic granite areas of Igbajo, Otan, Aiyegbaju, and Iresi as determined on 10 sampled inselbergs by Afolabi (2017) are presented in Table 5.5. As the author did not know the names of individual inselbergs, he substituted numerical values for their identification. The table is meant to illustrate some characteristics of inselbergs concerning their perimeter, areas, maximum and minimum slope length, relative relief, absolute elevation above the sea level, and maximum slope angles.

The high values for the coefficient of variation for perimeter, area, maximum slope length, and relative relief indicate a considerable variance in the sizes of the sampled inselbergs, which may apply to inselbergs on different rock types all over the Basement Complex rocks, but the relatively low values of the coefficient of variations for parameters such as elevation above sea level, minimum slope length, and maximum slope angles indicate that inselbergs developed on the same rock may share some common characteristics as also shown in the Idanre hills.

5.6 Ridges

Ridges are developed in quartzites, quartz-schists, and other types of schists. These rocks are found in parts of the Oyo, Osun, Ekiti, and Kwara States. Their occurrence in Ilesa area of the Osun State was mapped by de Swardt (1953) on a scale of 1:125 000 for the Geological Survey of Nigeria as Sheet 31. It was also mapped by the same agency in Ibadan area on the scale of 1:250 000. The most recently published geological map of Nigeria (2004) shows the rocks to extend from Oke-Igbo (Ondo State) through Ilesa area (Osun State)

Fig. 5.9 An Inselberg with an overhanging slope

Table 5.5 Morphometric properties of sampled inselbergs developed in coarse porphyritic granite

S/n	Inselberg	Perimeter (km)	Area (km^2)	Maximum slope length (m)	Minimum slope length (m)	Relative relief (m)	Elevation above sea level (m)	Maximum slope angle (°)
1	Hill 01	1.476	0.163	352.982	262.843	47.78	410.89	30.00
2	Hill 02	1.131	0.094	652.200	269.765	38.57	430.72	31.00
3	Hill 03	2.143	0.258	270.927	221.195	46.72	408.68	40.00
4	Hill 04	2.537	0.429	777.895	512.968	109.74	410.68	33.00
5	Hill 05	5.075	1.177	733.126	424.682	80.09	530.97	40.00
6	Hill 06	3.996	0.981	1057.558	611.456	138.02	517.81	39.00
7	Hill 07	4.239	0.977	1168.926	752.078	96.59	484.62	28.00
8	Hill 08	4.115	0.895	1067.277	646.796	123.33	471.71	36.00
9	Hill 09	4.181	1.159	990.196	541.365	76.96	517.82	28.00
10	Hill 10	3.128	0.458	478.832	226.252	31.70	593.14	23.00
11	Mean	3.202	0.659	755.00	447.934	78.95	477.69	33.80
12	Std. (δ)	1.327	0.421	316.14	51.6	37.41	62.72	5.77
13	Co.V	41.44%	63.88%	41.87%	11.52%	47.38%	13.13%	10.07

Source Afolabi (2017)

to the Kwara State, thus traceable for a distance of about 180 km. The occurrence in the Ilesa area, which Rahaman (1988) referred to as Effon Psammite Formation, is in the form of elongated bodies trending N-S and NNE-SSW (Fig. 5.10). In Ibadan area, the rocks appear contorted in ground plan, trending NNW-SSE, and reminiscent of old folds. Three types of quartzite have been recognized: massive, fissile, and mica schist/quartz-schist.

The first type comprising fused, highly metamorphosed quartz is the veritable ridge maker. It occurs as bands several meters thick on the ridges east of Ilesa. A road-cut northeast of Itawure (near Effon Alaye) shows the fissile type which displays folds, faults, and fractures of the original sandstone. It is highly permeable and thus permits no runoff or stream development across the formation. The angle of dip is quite steep grading into

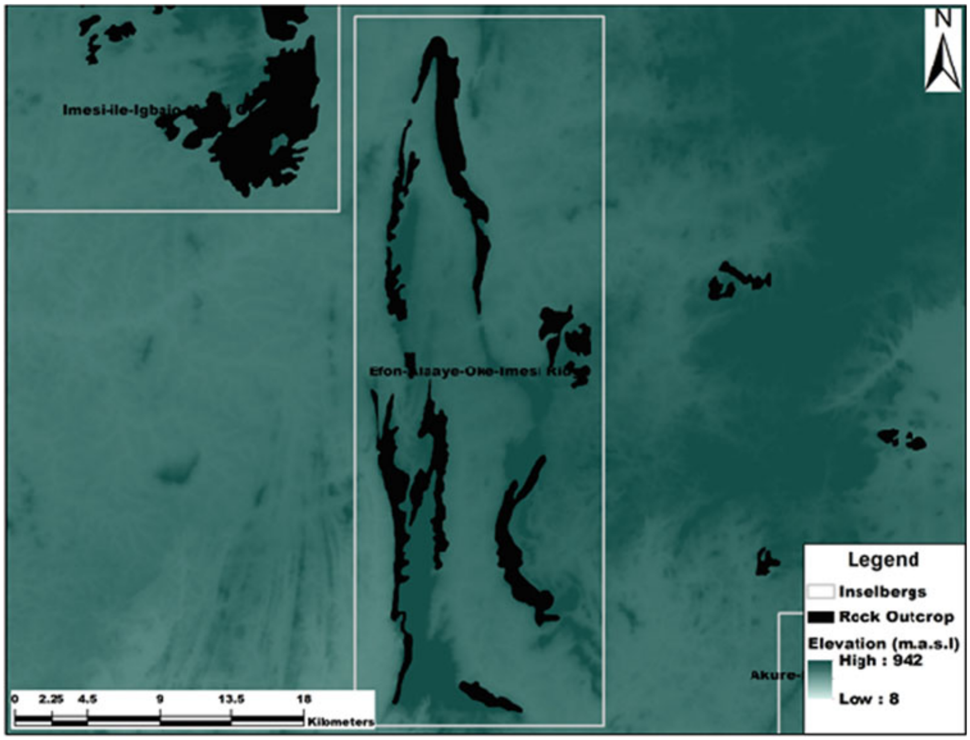

Fig. 5.10 A map showing Efon ridge and southern part of Imesi-Ile-Igbajo-Iresi group of inselbergs

vertical, while most of the joints follow the NE-SW foliation.

5.6.1 Ridges Around Ibadan

Ridges formed in quartzite-quartz-schist are common around the city of Ibadan. The ridges occur mostly as elongated hill chains and only a few are continuous over a few kilometers. The one within Ibadan, the Aremo ridge, is in form of seven hills, each of which accommodates important landmarks in the town such as Mapo Hall, the old Roman Catholic Church Seminary, Bower Tower, and Premier Hotel. The ridge at Olokemeji near Eruwa is in form of a tight loop through which the Ogun River cuts a deep canyon. Table 5.6 shows some morphometric properties of the most prominent ridges.

5.6.2 Ridges East of Ilesa

The ridges to the southeast of Ilesa are more impressive than those around Ibadan (see Fig. 5.10). Between the rivers Oni in the south and Epolu, a tributary of the Osun, in the north are about seven narrow broken chains of forested ridges. The first four immediately SE of Ilesa, each generally less than 0.5 km basal width, trend N–S for distances of 15–20 km, attaining an elevation of 380 m a.s.l. on the northern bank of River Oni, rising to 485 m a.s.l. to the NE of Iwaraja. Local relief hardly exceeds 100 m along all the ridges. Immediately east of these are three higher ridges rising from about 350 m a.s.l. east of Iperindo at 70 m above the local surface to 540 m a.s.l. in the extreme north, trending for about 15 km. These merge into a single ridge (in fact as a chain of hills) north of Erinmo, continuing further north for a distance of about 12 km before fading out. Maximum slope angles on

Table 5.6 Some aspects of the morphometric properties of ridges around Ibadan

Ridge	Mean slope (°)	Standard deviation (°)	Local relief (m)	Length (km)
Olokemeji	23	4.1	96	5.5
Arowosegbe	19.6	3.8	45	2
Ijaiye	22.9	4.3	106	10.5
Aremo	12.2	2.3	71	4.5
Ayantola	14.9	4.2	103	10

Source Faniran and Jeje (2002)

these ridges, which are covered by flaggy weathered debris, exceed 35°. In between the ridges, gneisses and biotite-schist crop out (de Swardt 1953).

East of the low ridges is the most impressive ridges all-over southwestern Nigeria. These two ridges are separated by an undulating low surface less than 300 m a.s.l. in the south, rising to about 400 m a.s.l. in the north and bounded by the upper Owena river in the south and Osun river in the north. These ridges stand above 645 m a.s.l., about 290 m above the local surface east of Esa-Oke-Oke Imessi Road. The western branch originates north of Ikeji, where it merges with a severely dissected granite pluton with peaks above 750 m a.s.l. The ridge trends NNW-SSE. Its basal width exceeds 2 km for a considerable distance before narrowing down to about 1.5 km, becoming wider again around Effon Alaye, after which it bifurcates into a Y shape. It attains elevations above 700 m a.s.l. for over about 25 km distance. The eastern branch originating south of Ikogosi also trends NNW-SSE, both converging north of Oke Imessi after about 54 km from Ikeji. The summit of the eastern branch is at about 690 m a.s.l. for a long distance. So consistently flat is the summit that de Swardt (1953) pronounced it as the third and uppermost erosion surface in Ilesa area. He traced the middle surface to the summits of the lower narrower series of quartz-schist ridges to the west (already described) and the lowest surface to the upper Owena and Osun basins. The wide summits sustain many rivers as evident near Effon Alaye, Ipole, Erin-Odo, and Oke-Ila. On descending the steep, near-vertical slopes of the ridges, these rivers gave rise to falls and rapids among which are Olumirin (Erin-Odo) and Ayinkunnuigba (Oke-Ila).

The slopes bounding the ridges are very steep, displaying the classic four standard hillslope elements of King (1967). The flat summit is followed downslope by cliffs of quartzite outcrops, usually less than 15 m high but higher where the scree slope below has been eroded. Below the cliffs are the rectilinear scree slopes composed of a matrix of scree material ranging from cobbles to massive rock blocks, all immersed in soil aggregates varying from coarse to fine sand, silt, and clay. The scree slope is regularly cultivated to various crops, especially upland rice. The footslope below comprises the flat valleys of the adjoining rivers, Owena and Osun together with their tributaries. Veritable canyons have been eroded into the scree slopes by the rivers originating from the upper summit of the ridges. The ridges survived several cycles of weathering and erosion around them because of the relative resistance of massive quartzite, while the quartz-schists are highly permeable and hardly produce any runoff after the rains, but the water seeps out at the ridge base to sustain perennial rivers, especially in Ekiti area (Ogunkoya and Jeje 1987).

5.6.3 The Low Ridges South of Ipetu-Ijesa

Two low ridges developed in quartz-schists south of Ipetu-Jesa are separated from the high quartzite ridges to the north by the Ipetu-Ikeji road. The two ridges are divided by the tributary of River Oni. The northern ridge, trending NW–SE, is about 15 km long and about 1 km wide in the NW, declining in basal width to about 400 m in the extreme east. Elevation varies from 380 m a.s.l. in the south to 425 m a.s.l. to the north. It rises for 50 m above the local surface in the south to 110 m in the northwest. The asymmetrical ridge is more or less an escarpment with very steep slopes up to 60° to the west and south and very gentle long slopes facing east. The gentle slope is heavily dissected to depths in excess of 50 m by the upper tributaries of the River Akunri, a tributary of River Oni.

The southern ridge, trending approximately E-W and about 12 km long, is higher than its northern neighbor. It rises from 450 m a.s.l. in the extreme west to 500 m a.s.l. at the eastern end, standing about 150 m above the local surface. The symmetrical ridge, about 400 m to 1.2 km of basal width, is bounded by steep slopes about 45° for most of its length, except at the extreme eastern side where the slopes are flatter. It is also dissected by the tributaries of the River Oni into three individual but continuous ridges. South of these ridges are several N-S, NW–SE, and NE-SW trending minor ridges developed in quartz-schists. They vary in length from 2 to 3 km and in elevation from 380 to 390 m a.s.l. These are close to Onipanu, Oja Bamikemo, and Mofere villages in the Ondo State.

5.7 The Development of the Hills and Ridges

The development of landscape on the Basement Complex rocks of southwestern Nigeria including the hills and ridges and indeed elsewhere in the humid tropics has been explained by the concept of etch-planation by Thomas (1966, 1974, 1994), Jeje (1970, 1973, 1986), Twidale (1981, 1990, 2007a, b), Summerfield and Thomas (1986), Ollier (1992, 2010) and Modenesi et al. (2011) among several others. The theoretical underpinning of the concept involves deep chemical weathering, the survival of structurally sound parts of the various rocks, and the subsequent removal of the regolith under several weathering and erosion cycles. Thus, as defined by Thomas (1968), an etchplain is "a form of planation surface associated with crystalline shields and ancient massif which do not display tectonic relief and developed under tropical conditions promoting rapid chemical decomposition of susceptible rocks". Thus, according to Thomas (1974, 1994), the landscape of the clustered hills (inselbergs) in the various granitic terrains such as in Igbajo-Imesi-Ile (Fig. 5.11) represent "dominantly stripped and incised etchsurfaces", while

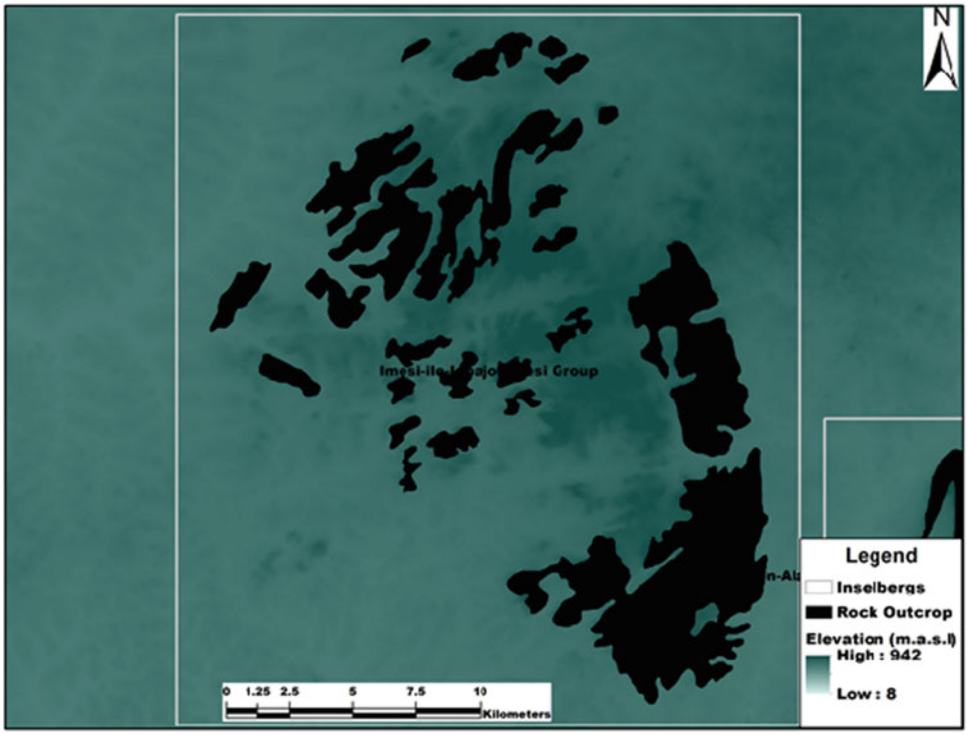

Fig. 5.11 Igbajo-Imesi group of Inselbergs in Osun State

Jeje (1986) assigned the landscape around Ibadan dominated by ridges developed in quartz-schist as "partially stripped etchplain". The ridge landscape to the southeast of Ilesa may also fall into this category.

However, one of the problems of etch-planation vis-a-vis the occurrence of massive inselbergs and ridges standing up to 700 m above their local surfaces is to establish the number of weathering/erosion cycles that occurred before these features evolved, especially where there are no clear-cut erosion surfaces as those established for the Guyana Massif by Schubert et al. (1986) and Clapperton (1993). The germane question is: Were these massive inselbergs and ridges formed by repeated cycles of weathering and erosion around them as suggested by Thomas (1974) or within a single cycle of weathering and erosion over a very long time? Rabassa (2010) appeared to have shed some light on this problem by the application of Gondwana-paleo-landscape development. His idea is summarized in what follows:

The paleo-landscapes were generated when the former Gondwana supercontinent was still in place and experienced similar tectonic conditions all over its surface. Gondwana planation surfaces are characteristic of cratonic regions which have survived in the landscape without being covered by marine sediments over extremely long periods having been exposed to long-term subaerial weathering and denudation. The genesis of the present-day paleo-landscapes relates to extremely humid and warm paleo-climates of "hyper tropical" nature with permanent water-saturated soils, or perhaps extremely paleo-monsoonal climates with seasonal long-term cyclic fluctuations from extremely wet to extremely dry.

Deep chemical weathering profiles with well-defined weathering front perhaps down to many hundreds (up to 1 000) of meters deep developed. The weathering products included clays, kaolinite, pure quartz, other silica form sands, silcretes (silica), calcretes (calcium carbonate), and ferricretes, all formed under different environmental conditions. Annual precipitation was up to 10,000 mm, with extremely high temperatures 25–35 °C. Extremely stable tectonic and climatic conditions prevailed from the Jurassic to mid-Cretaceous.

Rifting and continental drift started about 130–115 million years ago and environmental conditions started to differ in the adjacent areas of the rifted continents (South America and Africa). By the Late Cretaceous, some 90 million years ago, the gap between the two continents was considerable and landscape evolution changed. However, it was still warm and wet; weathering proceeded to hundreds of meters. Weathered debris remained stable and in place, with denudation being very slow due to tectonic stability. Denudation commenced vigorously from the middle Eocene due to tectonic instability associated with the Alpine-Andean orogeny which involved epeirogenic uplifts of the continents.

Rabassa at this stage introduced the concept of Passive Margin Geomorphology. This states that once Gondwana broke up, new margins were formed on which consequent rivers originated as in West Africa. With tectonic activities involving uplift of the new continents, these consequent rivers cut down and created scarps that retreated inland.

Also, these rivers descending to the coast through steep continental margins were highly erosive and able to cut down through the thick regolith to expose the basal weathering surface to different degrees. Thus at the passive margins, etchplains were developed during periods of tropical climate and long-term intervening tectonic stability, which he estimated to have occurred about six specific times since the mid-Tertiary based on the erosion surfaces in the Guyana Massif. Thus, the massive hills and ridges associated with the etchplains started to emerge from the mid-Tertiary. This possibly induced Thornbury (1969) to assert that no current area of the earth surface is older than the Tertiary period.

Rabassa concluded by observing as follows: "The deep chemical weathering was the main agent in the formation of these Mesozoic paleo-landscapes, with weathering fronts reaching to depths perhaps up to 1000 m. When the climate changed in the latest Cretaceous and then again later in the Paleogene, the huge thickness of weathered debris was removed by continuous denudation. The weathered materials mostly montmorillonite-beidellite-hydromicas and kaolinite were transported by superficial runoff toward the ocean basins, most of which were opened by the rifting process in the Cretaceous where they were deposited during most of the Tertiary. When the denudation was complete or almost complete, the ancient weathering front became exposed and typical landforms and deposits related to its roots are found in the most significant paleo-landscapes. Corestones, duricrusts of many different types (ferricretes, silcretes, calcretes), inselbergs, bornhardts, tors, domes are the most relevant landforms present in these paleo-landscapes. These landforms are found as landscape elements forming part of planation surfaces of which the most important are the etchplains generated by deep chemical weathering and later by prolonged denudation. Other planation surfaces such as pediplains are found."

Thus, with the explanation by Rabassa et al. (2010), the development of massive inselbergs and ridges can be explained as follows: The landscape got weathered to depths more than 1000 m ever before the supercontinent Gondwana broke up, and with both tectonic and climatic instability since the middle Eocene, the thick regolith got eroded gradually to expose the hills and ridges. These features rose higher and higher as the regolith around them got eroded under several tectonic and climatic instability regimes. Thus, almost all the inselbergs are not older than mid-Tertiary as argued by Thomas (1965).

5.8 Tourism Potentials of the Hills and Ridges

This issue is examined in the chapter on geoheritage, with particular emphasis on the Idanre Hills. However, individual hills are of high potential tourist interest. Most of the hills on the Basement Complex rocks, even where very isolated, attract the attention of various religious groups whose members visit the hills regularly for purposes of praying and in some instances these people do live on these hills. Good examples include Oke-Olorunkole on the outskirt of Ibadan on old Oyo road and King Solomon Hill on Ilesa-Ife road in Osun State.

Apart from the above, the clustered granitic hills in Igbajo-Imessi Ile served as the war theater for the Ibadan and Ekiti Parapo-Ijesa warriors during the Yoruba Civil War of 1886–1893. The area has become a veritable tourist attraction, more so when a war museum has been established in Igbajo. In fact, most of the hills served as places of refuge or as defensible locations during the internecine wars in Yorubaland during the nineteenth century. Good examples include the Idanre Hills and the location of Abeokuta around the famous Olumo Rock (which is actually a tor). One of the most famous hills in this regard is Ado rock, also known as Oke-Ado Mountain in Ado-Awaye, 20 km southwest of Iseyin. The hill served as home to Awori dwellers who chose the hilltop as refuge from Dahomey armies in the nineteenth century.

The hill exhibits several features of tourism interest among which are the staircase leading to the hill top (Fig. 5.12), the hanging lake (Fig. 5.13), the "elephant" tree (Fig. 5.14), the so-called mysterious cluster of foot prints known as *foot prints of the elders* (Plate 10). There are also features such as Ishage rock (Fig. 5.15) and smaller lakes—Iya Alaro, Iya Oniru, and Agbomofunyake. There is also a system of rills on the western face, especially on the upper dome as the hill is a good example of dome-on-dome inselberg. In addition, eight large and deep gullies are eroded along joints in the rock on its eastern face (Fig. 5.16).

A staircase with 369 steps leads to the top of the hill and as one climbs it, the beautiful vista of extremely flat Oyo

Fig. 5.12 Staircase on Ado-Awaye Inselberg

Fig. 5.13 Hanging Lake on Ado-Awaye

Fig. 5.14 Elephant tree

Fig. 5.15 Grinding pits on Ado-Awaye Inselberg

Plains dotted with several inselbergs unfold. The major problem with the staircase is that unlike the one on Idanre hills, it has no resting stations along its entire length and there are no railings. The suspended lake is one of the two in the world, the other being located in Colorado, USA—the Hanging Lake in Colorado is located 11 km east of Glenward Springs (Akande 2012—https: even trends wordpress. com/2012/03/16/ado-awaye-hill). The Ado-Awaye hanging lake is about 4 m in diameter but elongated along joints at one end to about 6 m. The water is green in color at sight (not algae induced) but crystal clear when fetched into containers. It is reported to maintain the same level at all seasons and also reputed to be bottomless. As it is credited with therapeutic powers, religious groups throng the venue for prayers. The lake appears to have developed at the intersection of vertical joints. The intersection was subject to deep chemical weathering and gradual removal of the decayed material. The question is: Was it formed by weathering when the rock was still buried by superjacent regolith and exposed by the gradual removal of the regolith? Smaller lakes on the hill include Iya alaro ("the dying mother"), Iya oniru ("the mother of locust beans"), and Agbomofunyake ("the one who drops the baby for the mother to care for").

Several pits in form of footsteps up to 15 cm deep with the length of the long axes more than double the short axes, referred to as "footprints of the elders", are found on the

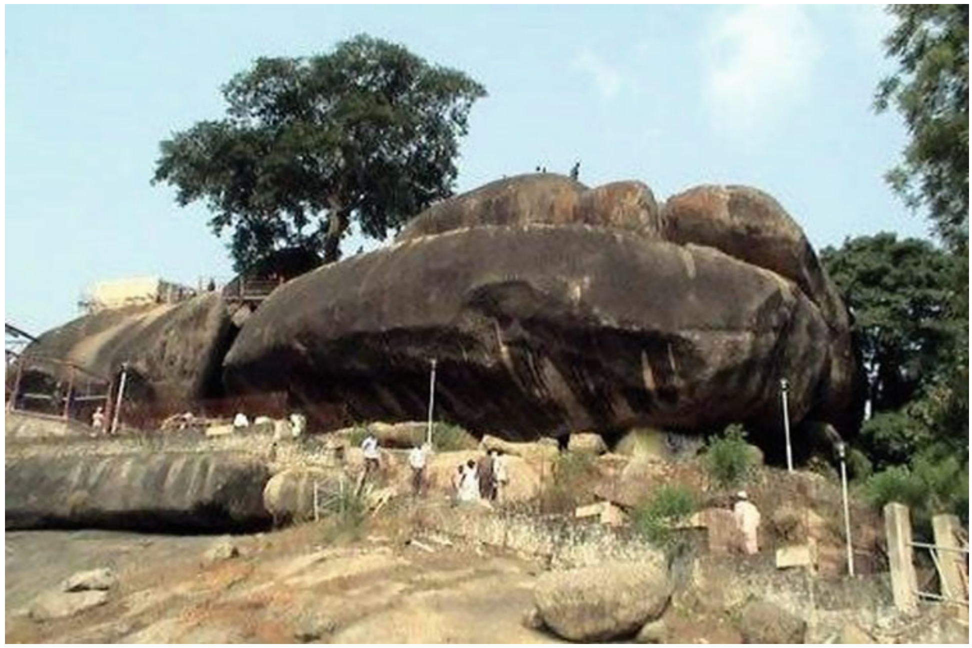

Fig. 5.16 Isagha rock, a delicately balanced rock on the Inselberg

hilltop surface. What has been referred to as mysterious clusters of indentation are grinding pits of which Akande (2012) claimed to have recognized about 100 on the hill uppermost flat slope. However, this author recognized about 14 some distance from the hanging lake. Some of these are larger than the others, indicating communal usage. Akande (2012) also observed that grinding pits of various sizes are still currently in use by women to grind pepper, while bigger ones are used as water reservoirs during the rainy season.

The "elephant" tree could be found at some distance from the lake. It is a tree that fell but somehow its trunk got mangled in such a way that it resembles an elephant trunk at first glance (https://titiwonderlust.wordpress.com/2014/09/21/. Another interesting feature is the Ishage rock, a huge boulder balanced precariously and delicately and standing upright on one of its smaller edges.

Apart from Ado rock, several other inselbergs are noted for their tourism potentials. Good examples include the massive bornhardts near Ikere-Ekiti (Olosunta and Orole) collectively known as Ikere Hills; Agunrege inselberg in Oke Ogun; the Iwere Hill in Iwere-Ile; and Ijio Hill both in the Oyo State near the boundary with Benin Republic.

The quartzite-quartz-schist ridges are notable mainly for the waterfalls developed across them in many places. The waterfall near Oke-Ila is actually a series of short falls more or less in form of cataracts, but the one close to Erin-Ijesa is more spectacular. Before the advent of Christianity, this waterfall was deified by the local people who designated it *Olumirin,* i.e., another god or deity and were worshiping it. The upper part comprises four distinct falls, while the lower part is in the form of rapids which cut deeply into the scree slope at the lower part of the ridge. Of the upper four falls, the upper three are short, with none exceeding 5 m as perpendicular falls, but the lowest one is the most impressive. At the peak of the raining season, it drops about 100 cumecs of water through a free fall of about 10 m below which there is a shallow pool about 15 m in diameter, accommodating swimmers especially in the raining season (Fig. 5.17). The importance of the waterfall has long been appreciated by the state government who provided accommodation near the waterfall in form of fenced self-contained bungalows and built a staircase and walkway to link the area of accommodation with the area of the waterfall. The waterfall in Ipole and Effon Alaye in form of rapids interspersed with short free falls is yet to attract any developmental attention as much as the one near Erin-Ijesa.

Overall, the inselbergs and ridges though endowed with high potential tourism attraction are yet to be comparably developed with the way the Idanre Hills have been developed by successive governments in the Ondo State.

5.9 Conclusion

A variety of hills have developed on the Basement Complex rocks of southwestern Nigeria, but the most common are inselbergs, which based on sizes have been classified into whalebacks, turtlebacks, bornhardts, and castle kopjes. They are either symmetrical or perfectly domical—bornhardts; elongated and symmetrical; or elongated and asymmetrical. They occur in clusters and with higher density on granitic plutons, but are scattered on various gneisses. Those on

Fig. 5.17 A pool at the base of Olumirin Falls near Erin-Odo

granites appear to be higher and larger than those on gneisses, but their slope angles are equally steep. Quartzite and quartz-schist are the ridge makers. Ridges on the latter are by far lower and narrower than those developed on quartzite as observed around Ibadan, and to the southeast and east of Ilesa. Ridges on quartzite are massive, with elevation generally above 650 m. Variably dissected two major ridges extend for more than 50 km east of Ilesa to the Kwara State and sustain several waterfalls developed by rivers originating from the summits.

The concept of etch-planation applied to account for the development of the hills and ridges has been further highlighted by the paleo-landscape model developed by Rabassa (2010), who postulated that these hills and ridges developed on paleo-landscapes from the ancient Gondwana continent, which experienced deep weathering over 1000 m, with a highly irregular weathering front. With the fragmentation of the supercontinent from the middle Cretaceous, the regolith was removed following several cycles of uplift/climate change. Though in need of further refinement, this theory appears to satisfactorily explain the origin of the inselbergs and ridges more than 500 m above their footslopes on the Basement Complex rocks of southwestern Nigeria and indeed in most of the tropical areas.

References

Afolabi RA (2017) Morphology and spatial distribution of residual landforms in Igbajo-Imess Ile Osun Drainage Basin, South Western Nigeria. M.Sc. Thesis, Obafemi Awolowo, University, Ife

Clapperton CM (1993) Quartenary geology and geomorphology of South America. Elsivier, Amsterdam, p 774

De Swardt RMJ (1953) The geology of the area around Ilesa. Geological Survey of Nigeria, Bull 23

Faniran A, Jeje LK, Ebisemiju SF, Olusola AO (2021) Essentials of geomorphology, 2nd edn. Penthouse Publishers, Ibadan, p 455p

Faniran A, Jeje LK (2002) Humid tropical geomorphology. Heinemanns, Ibadan, 414 p

Faniran A, Jeje LK, Ebisemiju FS (2006) Essentials of geomorphology

Jeje LK (1970) some aspects of the geomorphology of South Western Nigeria, Ph.d. Thesis, Edinburgh

Jeje LK (1973) Inselbergs evolution in a humid tropical environment: the example of south western Nigeria. Zeits Fur Geomorph N.F. 17 (2):194–225

Jeje LK (1986) Landscape evolution in the humid tropics and implications for land resources evaluation. In: Inaugural Lecture, vol 81, Obafemi Awolowo University, Ife

King LC (1967) Morphology of The Earth; a study and synthesis of world scenery

Linton DL (1955) The problem of tors. Geogr J 121(4): 470–487

Migon P (2006) Geomorphological landscapes of the world. Oxford University Press

Modenessi-Gautheri MC, Moltade MC, Toledo SK, Hiruma F, Taioli F, Shimada H (2011) Deep weathering and landscape evolution in a tropical plateau. CATENA 85:221–230

Ogunkoya OO, Jeje LK (1987) Sediment yields from some third order basins on the basement complex in South Western Nigeria. CATENA 14:387–397

Olusola AO (2019). Process-forn dynamics of Upper Ogun River Basin, Southwestern Nigeria. PhD Thesis submitted to the Department of Geography, University of Ibadan, Ibadan, Nigeria

Ollier CD (1992) Age of soils and landforms in Uganda. Israel J Earth Sci 41:227–231

Ollier CD (2010) Very deep weathering and related landslides. In Calceterra D, Parise M (eds) Weathering as a predisposing factor to slope movements. Geological Social Engineering Geological Special Publication No 22

Oyawoye M (1965) Review of Nigeria pre-cretaceous. In: Rayment A (ed) Aspects of the geology of Nigeria. University Press, Ibadan

Oyinloye AO (2011) Geology and geotectonic setting of the basement complex rocks in southwestern Nigeria: implications on provenance and evolution. vol 5 chapter
Rabassa JO (2010) Gondwana paleolandscapes: long-term landscape evolution, genesis, distribution and age
Rabassa J, Carignano C, Cioccale M (2010) Gondwana paleosurfaces in Argentina: an introduction. Geociências 29(4):439–466
Rahaman MA (1988) Recent advances in the study of the basement complex of Nigeria. In: Symposium on the geology of Nigeria. Obafemi Awolowo Univversity
Schubert C, Brieno H, Fritz D (1986) Palaeo-environment aspects of the Caroni-Paraguay river basin (south-eastern Venezuela). Interciencia, V 11:278–289
Summerfield MA, Thomas MF (1986) Long-term landform development, editorial introduction. In: Gardiner V (ed) International geomrphology, 1986, Part II, Wiley, pp 927–933
Thomas MF (1965) Some aspects of the geomorphology of domes and tors in Nigeria *Zeit*. Fur Geomorph 9:63–81
Thomas MF (1974) 'Tropical Geomorphology: a study in weathering and landform development in warm climates. Macmillian, London
Thomas MF (1993) Geomorphology of the humid tropics: a study of weathering and denudation in low latitudes. John Wiley, London
Thornbury WD (1969) Principles of geomorphology, 2nd edn. Wiley, New York
Twidale CR (1981) Granitic Inselbergs, domed, block strewn castellated. Geog J 147(1)
Twidale CR (1982) Granitic landforms. Elsevier Scientific Publishing
Twidale CR (1990) The origin and implications of some erosional landforms. J Geol 98:343–364
Twidale CR (1998) Granitic bornhardts: their morphology, characteristics and origins
Twidale CR (2007a) Ancient Australian Landscapes, New South Wales. Rosenberg Publishing Coy, 144 p
Twidale CR (2007b) Bornhardts and associated fracture patterns. Revista Assoc Geologica Argentina 62(1):139–153
Thomas MF (1994) Geomorphology in the Tropics. Wiley, Chichester
Thomas MF (1966) Some geomorphological implications of deep weathering patterns in crystalline rocks in Nigeria. Trans Inst Br Geogr 173–193
Thomas MF (1968) Some outstanding problems in the interpretation of the geomorphology of tropical shields. British Geomorph Res Group, Publ 5, p 4
Wilson HW (1900) XX. On the velocity of solidification and viscosity of super-cooled liquids. Lond Edinb Dublin Philos Mag J Sci 50 (303): 238–250