Kaokoland Cascade Tufa Survey – 2023 Research

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Abstract :- The ongoing Kaokoland Cascade Tufa Survey aims to identify and document all the tufa occurrences in the Kunene Region of Northern Namibia. Documentation of the tufas represents a preliminary stage in the long term study of the deposits from palaeontological, archaeological, palaeoclimatic, geomorphological, taphonomic and biogeochemical perspectives. Twenty tufa occurrences have already been described in Kaokoland (and seven in the Naukluft Mountains) and this report adds a further 9 examples in Kaokoland. It is clear from examination of satellite imagery that, in the Kunene region, many more tufa deposits remain to be explored.

Key words :- Tufa, Pleistocene, Kunene Region, Palaeoclimate

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Introduction

Cascade tufa deposits and related superficial calcareous sediments comprise an important research base concerning Pleistocene and Recent palaeoclimatic conditions. The Kaokoland area in the Kunene Region of northwestern Namibia (Fig. 1) is today an arid steppic to desert region, but the presence of abundant tufa deposits scattered over a wide area indicates that at times in the past the local climatic conditions were probably more humid and cooler than they are at present.

Currently available evidence indicates that, during the Pliocene to Recent, there were at least three phases of active tufa deposition in Kaokoland interspersed with periods of non-deposition or of erosion. Fossils and stone tools cemented into the tufas provide a source of information concerning the ages of the tufas. The oldest occurrence of fossils so far encountered in the Kaokoland tufas is estimated to be of Middle Pliocene age, the microfauna from Okongwe correlating with that from the Makapansgat cave breccias of South Africa which are dated ca 3 Ma (3.0-2.7 Ma, Pickford, 2006; or 3.03-2.58 Ma, Herries *et al*. 2013). However, the majority of the Kaokoland tufa deposits are younger, several of them containing Middle Stone Age and Late Stone Age lithic implements (Pickford *et al*. 2016; Pickford, 2019, 2020).

Examination of satellite imagery suggests that many tufa deposits remain to be discovered in the Kunene Region, but the digital signatures of the potential occurrences need to be verified by ground control. A ten day survey was undertaken in October, 2023, in order to examine some of the potential tufa occurrences identified via satellite imagery in the country west and north of Opuwo, and southwards between Opuwo and Sesfontein.

The aim of this paper is to list the positively identified tufas and related deposits and thus to add to the inventory of known tufa occurrences in Namibia (Mocke, 2014; Mocke *et al*. 2022; Pickford, 2019, 2020; Pickford & Senut, 2010; Pickford *et al*. 1993, 1994, 2009, 2016). The fact that several of the tufas contain stone tools is of interest to the archaeological community, because few if any of these sites were previously known to yield items of archaeological interest.

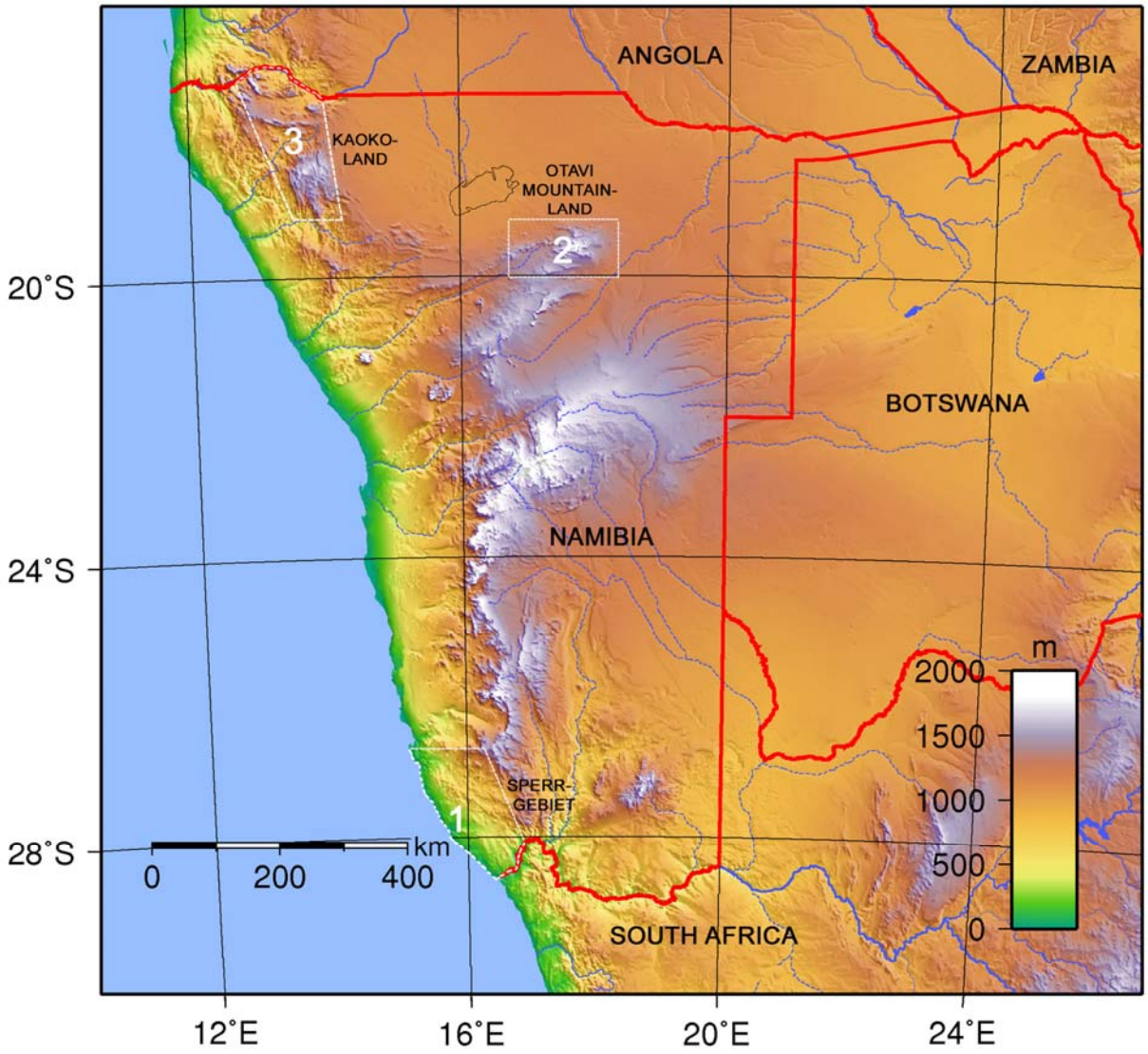

Figure 1. The three main areas in which the Namibia Palaeontology Expedition has permits to survey. 1) Sperrgebiet, 2) Otavi Mountainland, 3) Kaokoland (in Kunene Region). Other fossiliferous zones in the country are the Naukluft Mountains and the Namib-Naukluft Park.

Results

The October, 2023 Cascade Tufa Survey resulted in the verification of nine previously unmapped Plio-Pleistocene to Recent fossiliferous tufas and related karstic and epikarstic deposits in Kaokoland, both north and south of Opuwo (Table 1). Searches in incised tufa complexes at Okombeiza and Otjitaime Downstream failed to yield any vertebrate fossils, but it is stressed that, due to time constraints, much of the outcrop area was not surveyed in detail. At most of these sites there were at least two phases of tufa deposition, with complex interfingering relationships with fluviatile conglomerates and groundwater calcretes. However, at Khowarib, there is evidence of at least three episodes of tufa deposition, with tufa lobes interfingering with fluviatile sediments that have been overprinted by incipient pedogenic calcrete (hardpan) processes and cemented slope debris.

Location maps (Figs, 2, 4, 7 etc.) are modified from Google Earth, north to the top of the page.

Table 1. Tufa complexes of Kaokoland surveyed in October, 2023 (in alphabetical order).

Tufa Complex	Latitude	Longitude	Altitude (GPS)
Ekoto Bastion Tufa	17°56'06.8''S	13°13'20.7''E	1110 m
Kaoko Otavi groundwater calcrete dome and tufa	18°17'51.3''S	13°39'48.3''E	1449 m
Khowarib calc tufa	19°16'29.4''S	13°53'39.1''E	723 m
Okombako Bastion Tufa	18°52'15.0''S	14°02'43.0''E	1308 m
Okombeiza Barrage Tufa	18°48'06.9''S	13°33'59.9''E	1146 m
Okongwe tufa lobes	18°53'50.0''S	14°04'15.0''E	1228 m
Okapiku Cascade Tufas	18°53'21.0''S	14°03'22.0''E	1306 m
Okovanatje Cascade Tufa	18°51'38.0''S	14°02'25.0''E	1347 m
Omokutu, barrage tufa *in situ* in river bed	19°16'29.1''S	13°53'58.6''E	795 m
Omungunda show cave (= Rocky 3)	17°47'56.8''S	13°41'21.0''E	1345 m
Omungunda stone tool site	17°47'55.3''S	18°41'20.2''E	1359 m
Ongongo Spring Tufa	19°08'23.0''S	13°49'10.0''E	731 m
Opuwo Cascade Tufa	18°07'14.6''S	13°53'19.1''E	1280 m
Otjisakumuka Cascade Tufa	19°05'40.5''S	13°57'01.1''E	1065 m
Otjitaime Downstream cascade tufas	18°51'59.7''S	13°44'36.3''E	1202 m
Otjitieue groundwater calcrete dome and tufa	18°43'07.2''S	13°32'19.4''E	1140 m

Opuwo (= Enough in Himba)

A cascade tufa lobe crops out 8 km southeast of Opuwo, visible from the main road between Opuwo and Etosha (Figs 2-3). The complex is just north of the road and is ca 70 metres broad by 60 metres long and ca 20-30 metres thick in the middle. There are layers of moss-tufa interfingering with more massive tufa containing moulds of plant remains, mainly sedge stems and occasional larger plants. A few land snails (*Xerocerastus*, *Sculptaria*) were observed in the tufa as were some stone tools and lithic flakes, suggesting a late Pleistocene to Recent age for deposition of the tufa. The superficial deposits surrounding the tufa lobe consist of cemented river gravels in the valley interfingering with calcrete on the flatter ground. Stone tools and waste flakes, mainly made of quartz, are scattered in many places on the surface.

Figure 2. Location of the Opuwo Cascade Tufa, Kaokoland.

Figure 3. The Opuwo Cascade Tufa, Kaokoland.

Omungunda

At Omungunda Camp, 33 km north-west of Opuwo, half a km north of the road to Epupa Falls, there is a tufa complex close to a Show « Cave » (in fact, a rock shelter) (Figs 4-7). The site was previously published as Rocky 3 by Pickford *et al*. (1993). In the Himba dialect, the name means 'Place of the Cave'.

The floor of the rock shelter has an infilling of loose, silty deposits containing waste flakes and occasional stone tools. A few hundred metres upstream of the camp there is a cascade tufa complex blocking the valley on which is growing a large Baobab Tree. The tufas at this site comprise classic moss-tufas as well as more massive varieties rich in impressions of plant remains. On the south-western flank of the valley between the tufa lobe and the rock shelter, there is a large exposure of red breccia rich in stone tools, waste flakes and fossils, as well as slope-wash cobbles. The breccia represents cemented floor debris that accumulated on the sloping floor of a cave or rock shelter, but that is now exposed to the sky. Close examination of the breccia reveals that it has scarce, poorly preserved remains of rodents, bovids and possibly equids, and well-preserved land snail shells (mainly *Xerocerastus*).

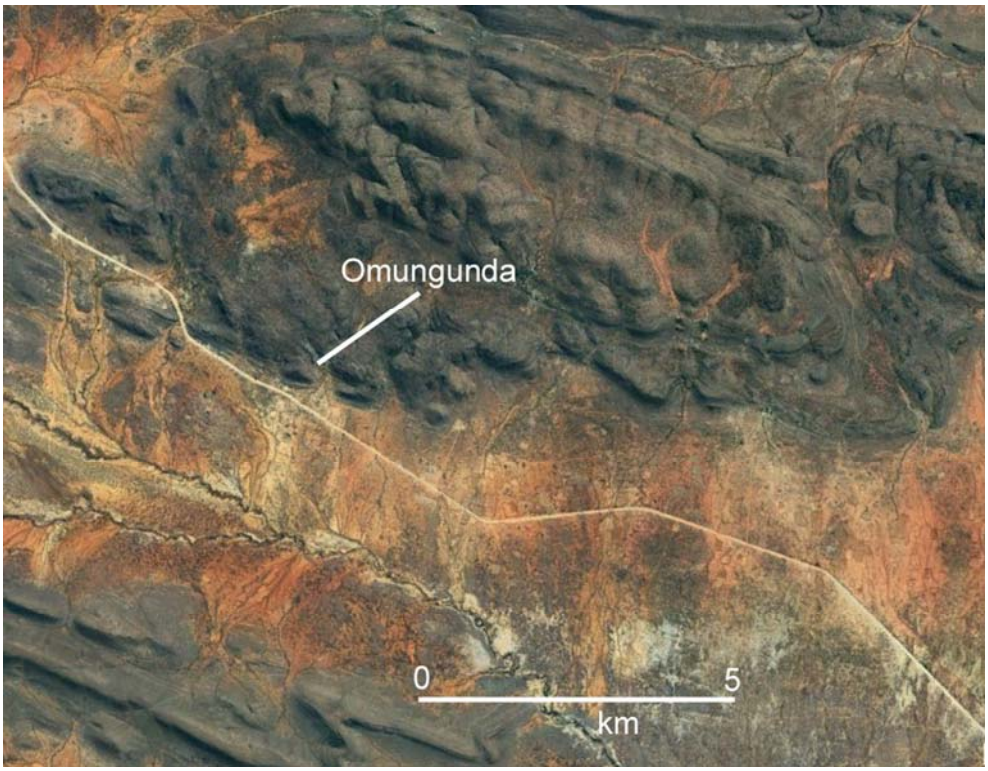

Figure 4. Location of the Omungunda area with the show cave, cave breccia and cascade tufa, Kaokoland.

Figure 5. Omungunda Cascade Tufa with its Baobab Tree, Kaokoland.

On the eastern flank of the same valley, there is an additional series of small tufa lobes, with similar overall structures to the one on which the Baobab tree is growing.

As is usual in Kaokoland, there are large areas of calcrete and cemented fluvial valley-bottom conglomerates upon which the tufa lobes grew. The age of all these superficial deposits is late Pleistocene to Recent.

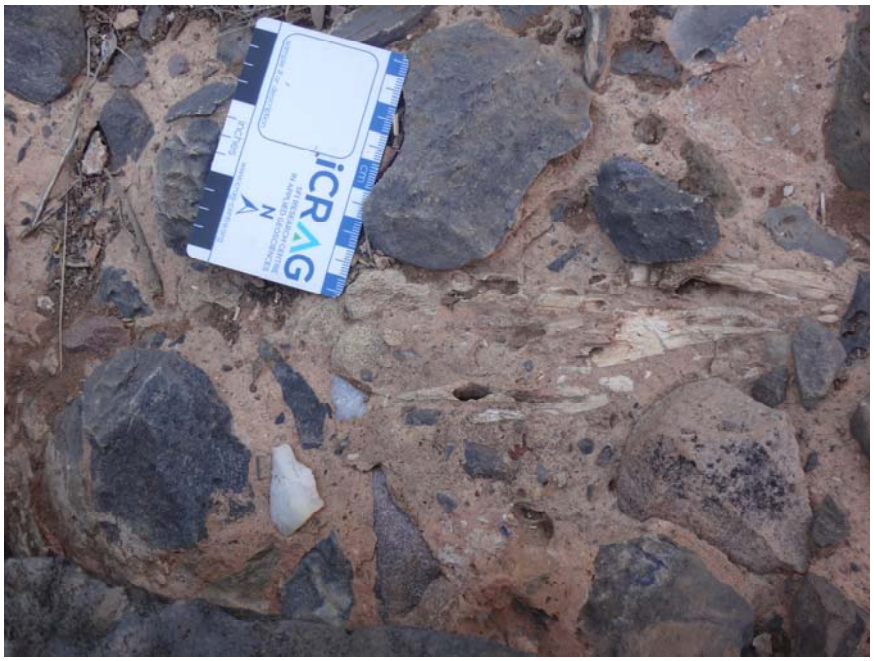

Figure 6. Omungunda cave breccia containing worked lithic flakes of quartz and quartzite plus a large bone (possibly equid).

Figure 7. Concentration of worked quartz flakes and other stones cemented into cave floor sediments at Omungunda, Kaokoland.

Ekoto

Some 67 km west of Opuwo, south of the road to Etanga, there is an impressive tufa complex known as Ekoto (= Hornbill in the Himba dialect) (Figs 8-11). This deposit is not to be confused with an immense Barrage Tufa with the same name that occurs 150 km to the southeast (Pickford, 2019).

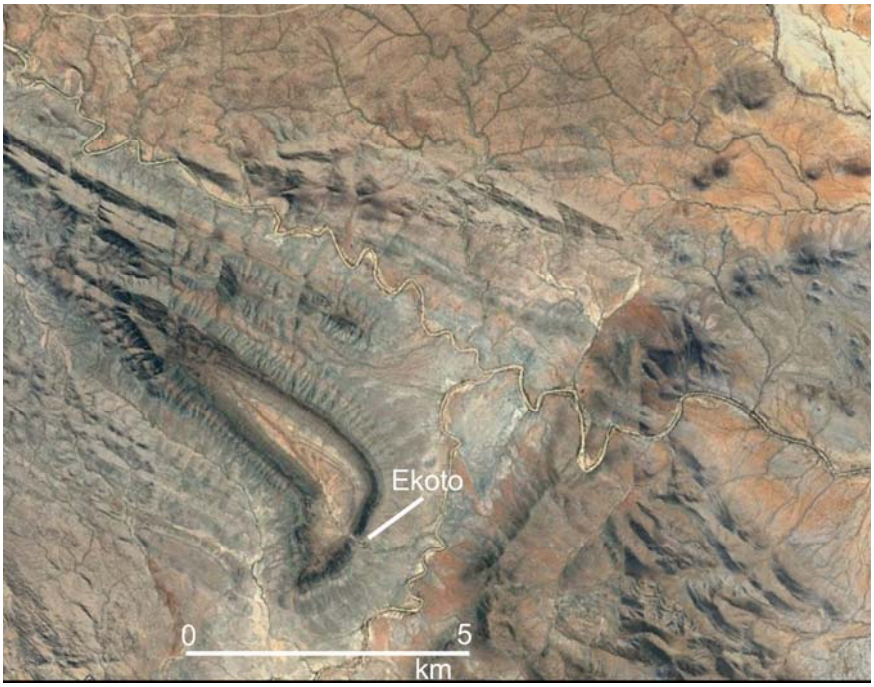

Figure 8. Location of Ekoto Bastion Tufa, Kaokoland.

This Ekoto Tufa Complex is some 50 metres tall, and comprises a Barrage Tufa that dammed the valley and then grew outwards to form a Bastion Tufa. It is ca 70 metres broad at its widest, and ca 90 metres long from the upstream margin to the downstream cliff edge. Upstream of the lobe edge, there is a relatively flat area representing sediments that infilled the ancient valley in which the tufa grew. A variety of large trees including figs grow on this flat area. Water is present in shallow depressions in this infilling, where hundreds of sheep and goats gather to feed and drink. There is also a resident population of baboons at the site, but they tend to spend the daytime hours on the steep mountains that flank the valley to its north and south.

Figure 9. Ekoto Bastion Tufa, Kaokoland, with impressive examples of bryophyte curtains along its margins.

Figure 10. Concentric layers of moss tufa exposed in the cliff at Ekoto, Kaokoland.

There are at least two generations of tufa deposition at Ekoto, and the tufas interfinger with cemented valley-bottom conglomerates and valley-flank calcretes and cemented slope debris. The only fossils observed comprised mosses and other plant remains (sedge stalks, tree roots and stems), and a single fragment of bone. There are however, stone tools and waste flakes incorporated in the tufas and the calcretes, suggesting a Late Pleistocene to Recent age for some of the deposits.

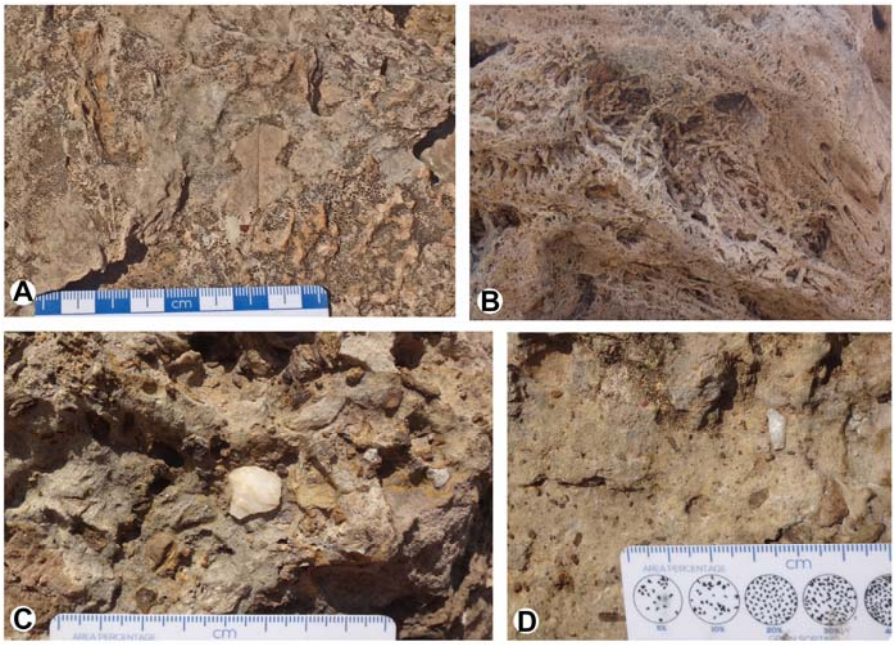

Figure 11. Fossils and stone tools embedded in tufa and groundwater calcrete at Ekoto, Kaokoland. A) dicotyledon leaf imprint in tufa, B) a mass of plant stems coated in tufa, C-D) worked flakes of quartz cemented into groundwater calcreted conglomerate.

Okombeiza

6.8 km south of Otjikondovirongo, there is a deeply incised tufa complex known as Okombeiza (= Kitchen in Himba) (Figs 12-15). The tufa fills an ancient valley which was floored by heavily cemented valley-bottom conglomerates and flanked by hill-slope debris cemented by groundwater calcrete. The barrage tufa infilled the valley for a distance of ca 800 metres and at its broadest it is some 200 metres across. The thickest sections are about 30 metres deep, thinning rapidly laterally towards the flanks of the valley. A dolomite promontary within the valley is the site of a small cave which gives the area its name. This cave has a large opening on its southern end, and a small vertical aven-like opening above. There are abundant stone tools, as well as ostrich eggshell beads in the loose soils beneath the cave entrance.

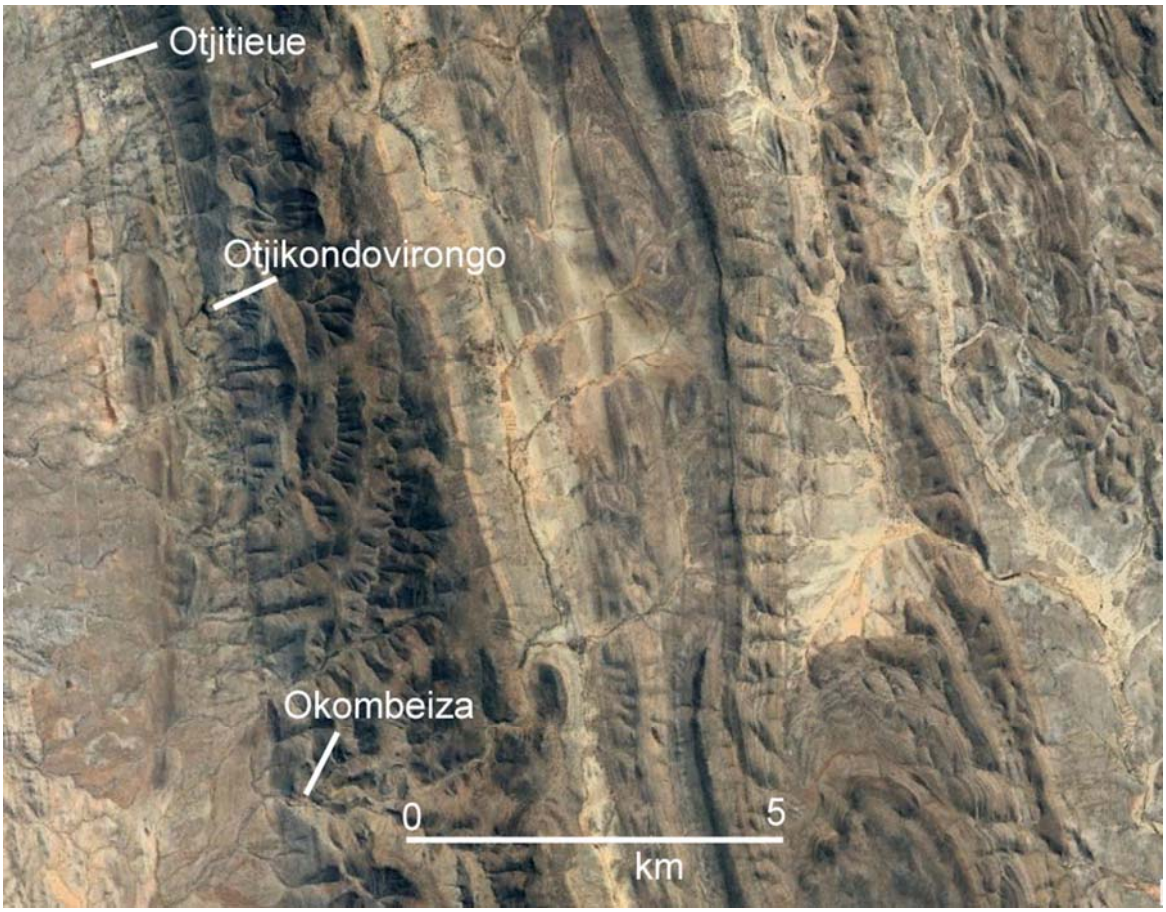

Figure 12. Location of Okombeiza Barrage Tufa, Otjikondovirongo Bastion Tufa and Otjitieue spring dome, Kaokoland.

The Okombeiza deposits comprise a complex interfingering of barrage tufas, calcretes and valley-bottom conglomerates, implying a series of depositional phases interrupted by periods of erosion, cut-and-fill and stasis. Caves that formed in the tufas were the sites of speleothem formation with classic examples of stalactites, stalagmites and flowstone. There are examples of moss tufa and denser tufa enclosing plant remains (sedges, reeds, trees, leaves). No vertebrate or invertebrate fossils were observed, but only a few hours were spent examining what is a vast area of exposure.

Figure 13. View of Okombeiza Cave, with groundwater calcrete and barrage tufa deposits close to its entrance.

Figure 14. The Okombeiza Barrage Tufa blocking the valley downstream from Okombeiza Cave.

Figure 15. Alternating layers of conglomerates and laminated tufa deposits in the Okombeiza valley, Kaokoland.

Otjitieue

3 km north of Otjikondovirongo, there is a large tufa dam, well removed from the dolomite cliffs to the east (ca 0.5 km) (Figs 12, 16). There appears to have been a resurgence at the place which built up a semi-circular dam-like wall to the west, some 5 metres tall at its greatest height. The depression uphill from the tufa wall acted as a dam in which silts and sands accumulated, completely infilling the depression, but without becoming heavily cemented.

There are many stone tools and waste flakes exposed on the surface, but none were observed *in situ* in the tufas, although lack of time meant that not all the tufa outcrop could be examined. However, the silts and calcrete that crop out widely in the area contain many shells of the land snail, *Achatina*, most easily observed in the incised parts close to the present-day drainage lines in the area.

Figure 16. Otjitieue tufa terrace, Kaokoland. A) the tufa terrace viewed from the north, B) the clay and silt infilling the 'dam-like' depression bordered by the terrace, C) the southern margins of the tufa terrace, D) stone implements scattered on the surface of the deposits.

Otjitaime Downstream

Otjitaime is known for the immensely rich and diverse microfauna that it yielded (Pickford, 2019) (Figs 17-18). The main cliff at the site is 1.1 km broad and almost 100 metres tall, making it one of the largest barrage tufas known in the world. Fittingly, in the Himba dialect, Otjitaime signifies a 'Holy Place', or a 'Place that must be revered or respected'.

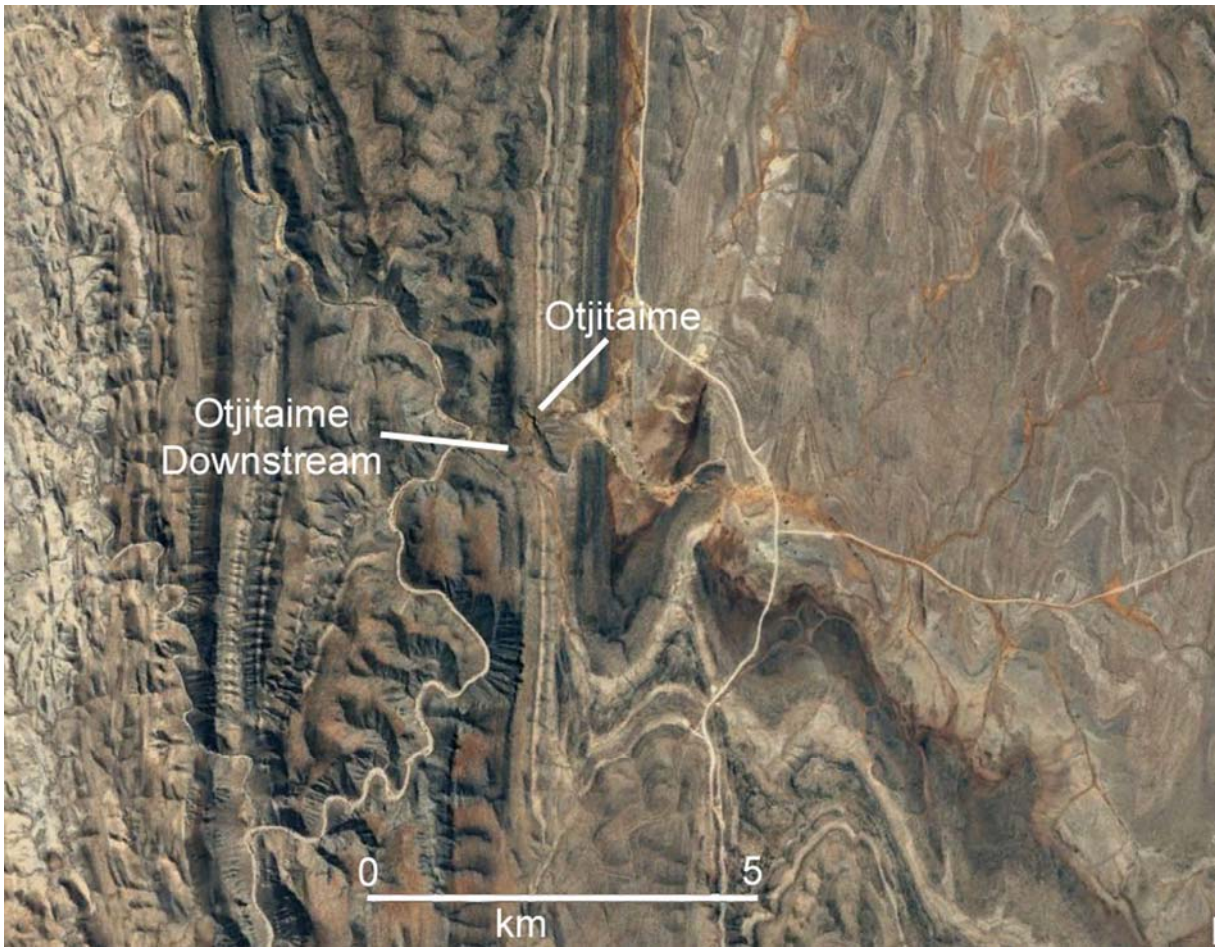

Figure 17. The Otjitaime Barrage Tufa and the downstream sector of the same complex, Kaokoland.

Downstream of the Otjitaime cliff, there are other superficial tufa and fluviatile deposits that crop out for some 800 metres along the valley, comprising a complex of cut-and-fill tufa and fluvial conglomerate accumulations, similar in many ways to those at Okombeiza, but on a larger scale. Examination of these tufas for three hours failed to yield any vertebrate or invertebrate fossils, although plant fossils occur in abundance. Despite the apparent lack of vertebrate fossils, further surveys are warranted, because at Otjitaime cliff, the fossil sites are areally minute, being less than 1 metre in diameter, but immensely rich in concentrations of micromammals (Pickford, 2019). The greatest thickness of the tufas in this downstream sector of the complex is ca 30 metres, with rapid changes in thickness observed both laterally and along the axis of the valley.

It is likely that the Otjitaime fossil concentrations accumulated in small hollows developed in the tufas which were inhabited by owls and other birds of prey, which regurgitated their pellets inside the caves. Speleothems such as stalactites and stalagmites occur near the fossil concentrations.

Figure 18. Otjitaime barrage tufa, downstream sector, some 5-6 metres thick in places.

Kaoko Otavi

Kaoko Otavi is an important spring complex named after a local chief (Kaoko) (Figs 19-20). There are two large springs north of the main road, and in the hills beyond there are signs of small barrage tufas, but time constraints prevented examination of the latter. Both of the tufa mounds have been modified by human activities, with the installation of walls, pump stations, drainage channels and pipes, but some of the original deposits can be made out, which reveal that overall, they resemble the water hole tufa domes that occur along the southern margin of Etosha Pan (Pickford *et al*. 2014).

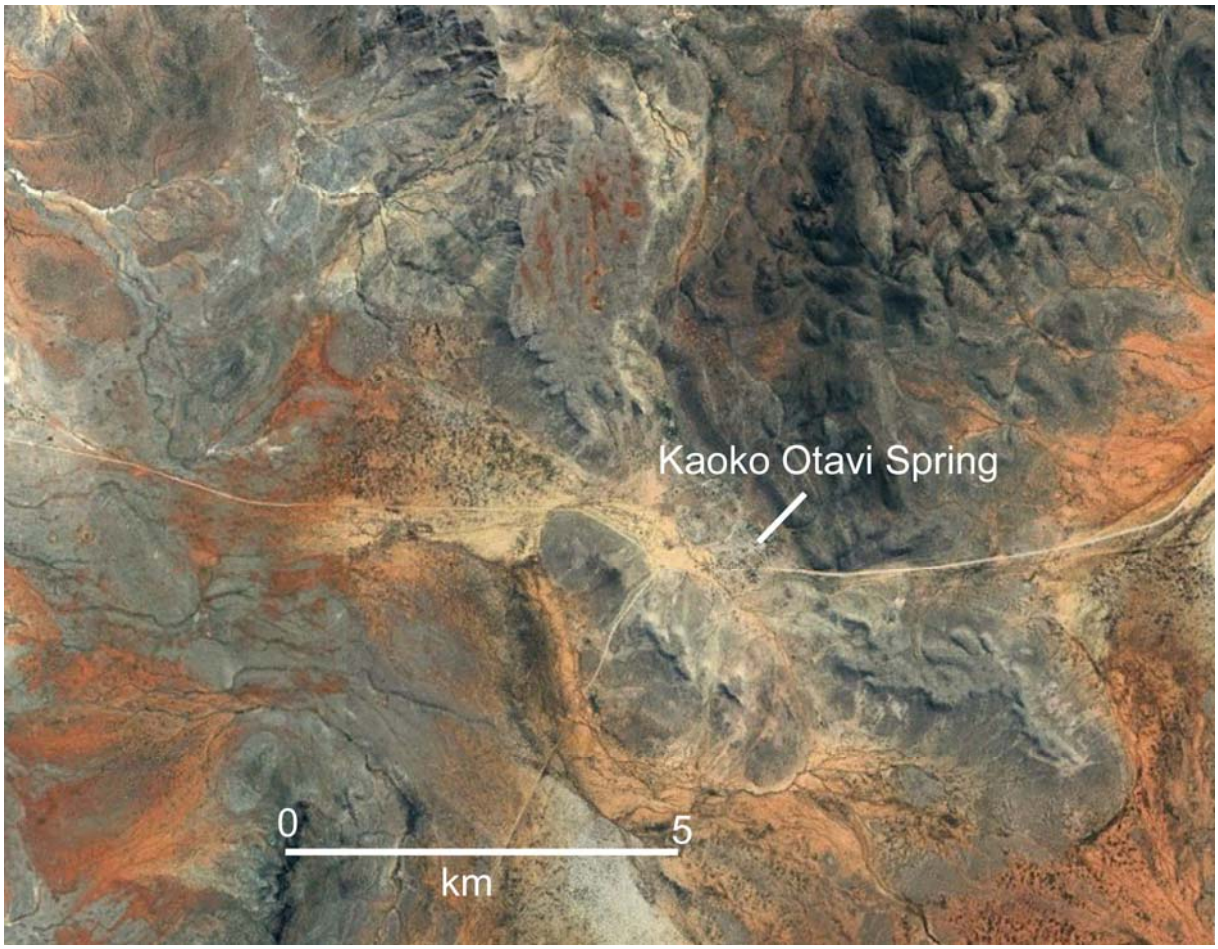

Figure 19. Location of Kaoko Otavi Spring, Kaokoland.

The calcareous deposits at Kaoko Otavi are predominantly of sedimentary origin cemented by calcium carbonate (groundwater calcrete) although there is evidence of a large diameter tufa dome and small tufa terraces as well. In many ways, the main occurrence recalls the calc tufa terrace at Otjitieue, but on a larger scale, and it is similar to some of the water hole tufa domes that occur along the southern margin of Etosha Pan (Pickford *et al*. 2014). The groundwater calcretes at Kaoko Otavi yield a few freshwater snail taxa, such as *Bulinus* and planorbids but no vertebrates were observed. As usual, there are plenty of stone tools littering the surface, and a few are cemented into the calcrete and tufa.

Figure 20. Kaoko Otavi tufa and groundwater calcrete dome, showing part of the southern slopes of the dome that have not been too altered by human developments.

Okombako

A re-examination of the tufas at Okombako (= Funnel in the Himba dialect) near Okozonduno (Figs 21-22), failed to yield any vertebrate remains. However, some plant fossils were found. The other tufa deposits in the same valley (Okongwe, Okapiku, Okovanatje) were not surveyed, but were photographed from a distance. These tufas featured in a publication by Pickford (2019).

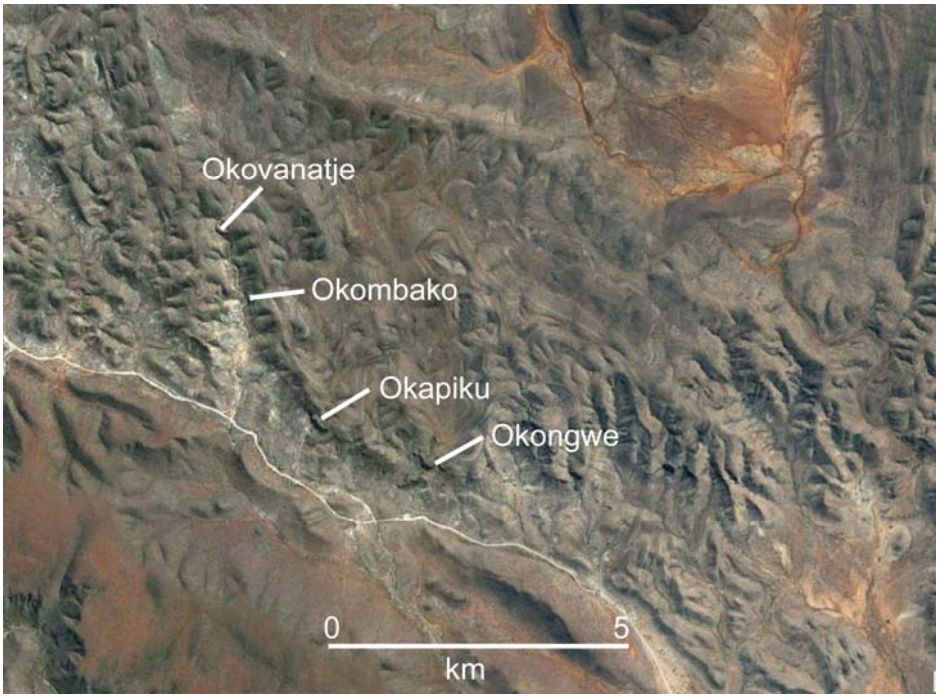

Figure 21. Map showing the distribution of four of the barrage and bastion tufas in the Okozonduno region, Kaokoland.

Figure 22. Bryophyte curtain tufas and caves in the Bastion Tufa at Okombako, Kaokoland.

Otjisakumuka

The Otjisakumuka tufas comprise a plaquage covering a tall linear cliff of Proterozoic conglomerates, oriented almost North-South (Figs 23-26). Huge pieces of the tufa plaquage have broken off the cliff, and have come to rest on the slopes and valley floor beneath. There is also a sloping apron of tufa at one point that cements and overlies slope debris. Close to the lodge, there is an extinct spring complex that forms a ridge standing out from the cliff. This ridge is composed predominantly of cemented conglomerate but has some tufa facies, as well as groundwater calcrete formation. No fossil vertebrates were observed, but there are many stone tools and waste flakes in the area, some of them cemented into the tufa and calcrete.

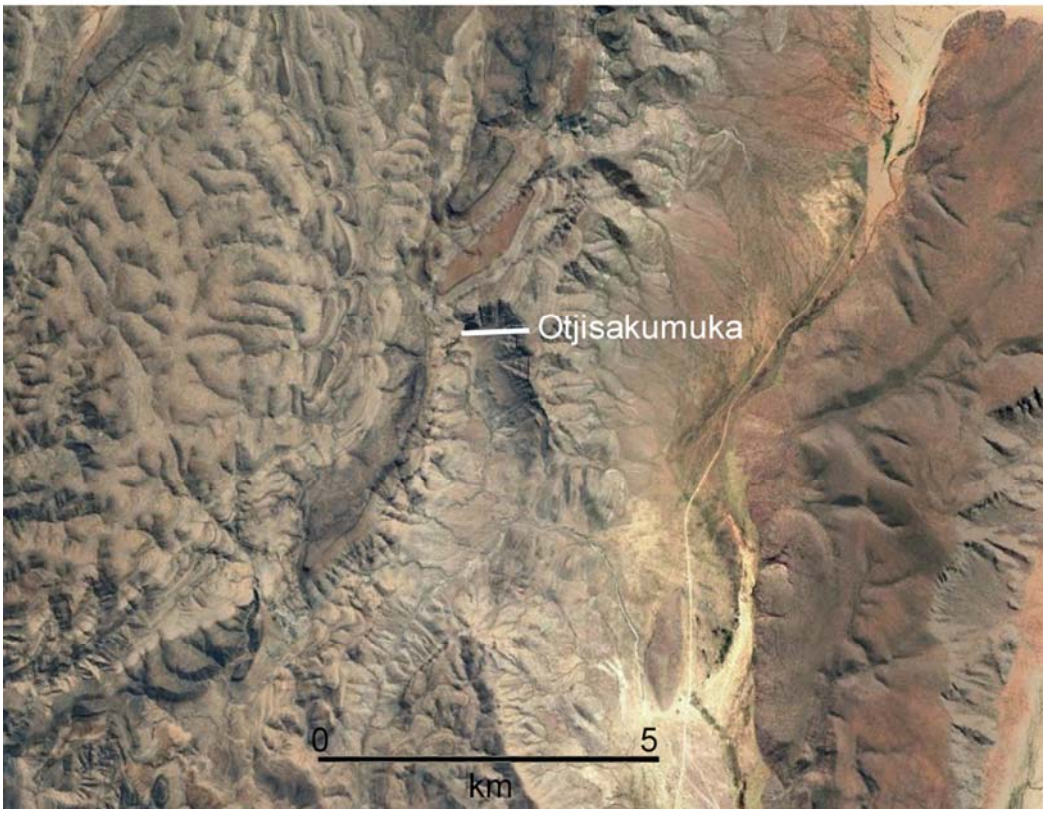

Figure 23. Location of the Otjisakumuka tufa complex, Kaokoland.

Figure 24. The tall, almost vertical barrage tufa and a sloping tufa apron overlying Proterozoic conglomerates at Otjisakumuka, Kaokoland.

Figure 25. Close-up view of the barrage tufa at Otjisakumuka, from which large blocks of bryophyte curtains have broken off.

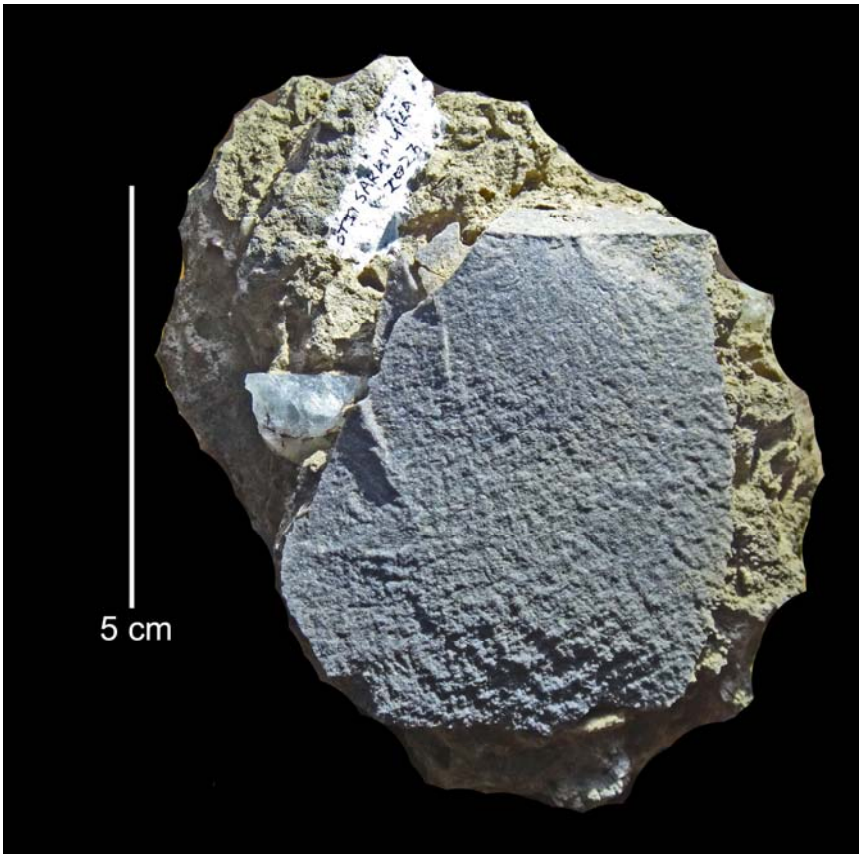

Figure 26. Worked stone embedded in tufa from Otjisakumuka (note the bulb of percussion at the top of the flake and the worked flake of quartz next to it).

Ongongo

A brief survey of Ongongo (= Amazing in Himba) (Fig. 27) confirmed the presence of at least two generations of tufa deposition, a well-cemented one immediately overlying densely indurated fluvial conglomerates which overlie bedrock, the other, more porous, overlying the former. There are also outcrops of groundwater calcrete interfingering with the tufa.

There are abundant well preserved leaves in some of the Ongongo tufas, as described by Mocke (2014) and some outcrops contain gastropods (*Achatina*, planorbids) (Fig. 28).

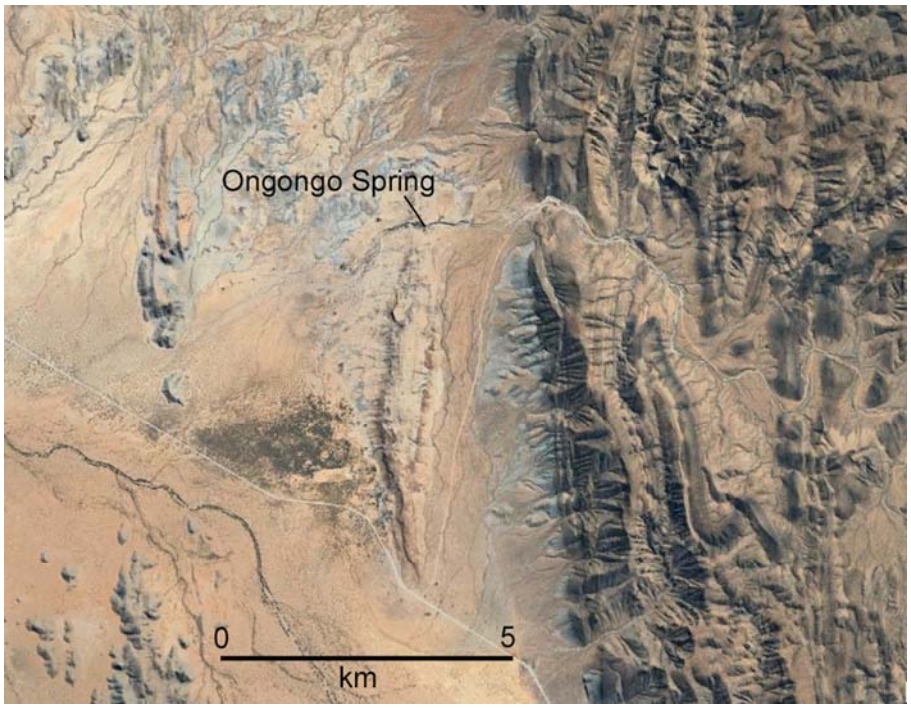

Figure 27. Location of the Ongongo Spring tufa complex, Kaokoland.

Figure 28. Fossilised leaves and land snails in barrage tufa at Ongongo Spring, Kaokoland. A-C) fossil leaves, D) shells of *Achatina* sp.

Khowarib-Omokutu

12 km south of Warmquelle is the Khowarib Valley (Figs 29-34) that has been partly infilled with stratified conglomerates, hardpan soils and tufa deposits, which have been incised by recent erosive processes, thereby exposing an impressive series of strata over a distance of about 7 km along the valley and up to 500 metres across it. A thickness of 10 metres of sediments is observed in several outcrops, comprising laterally continuous layers of semi-indurated hardpan soils, barrage tufas, tufa domes and conglomerates.

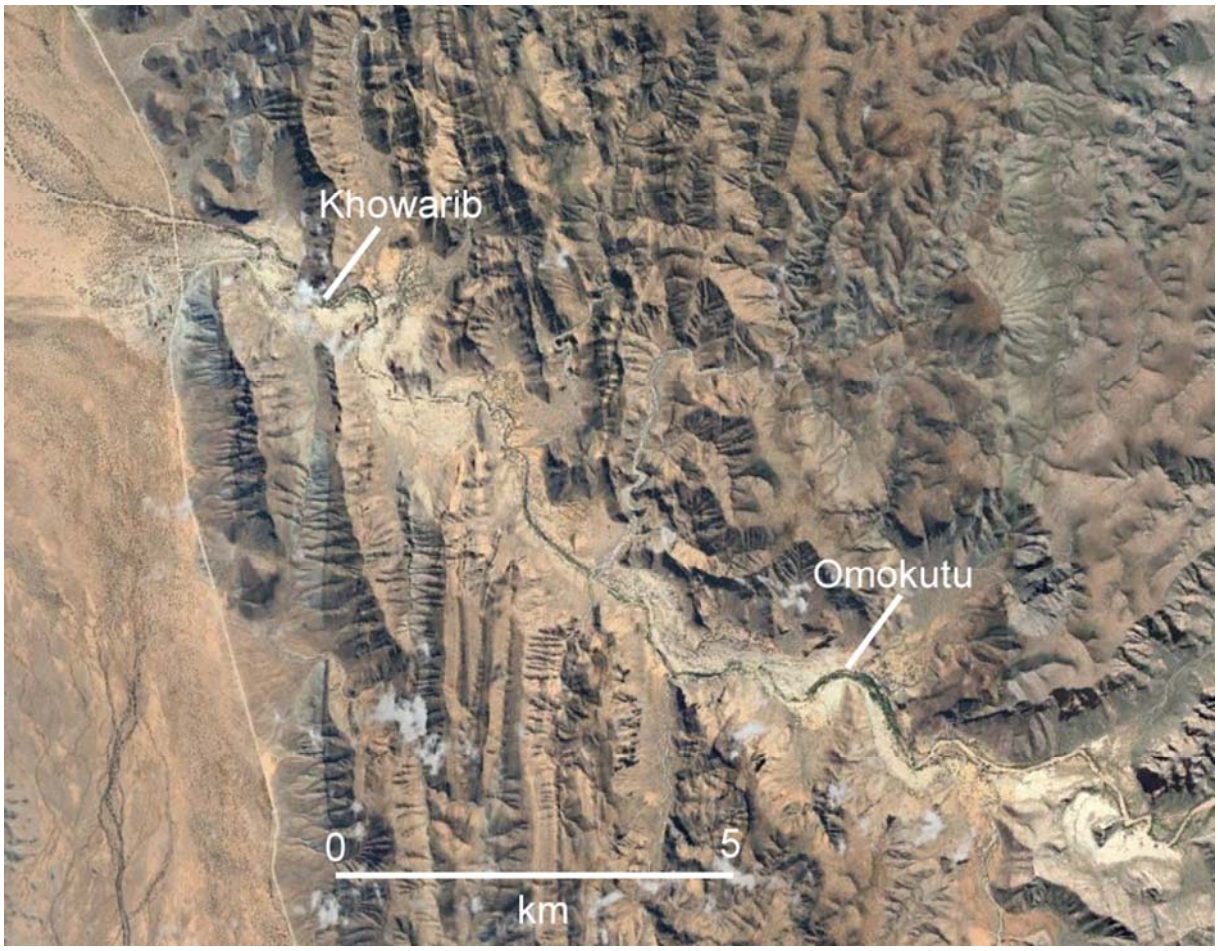

Figure 29. Location of Khowarib and Omokutu, Kaokoland.

At Omokutu (= Canyon in Himba) a barrage tufa is exposed in the bed of the present-day river, overlying a densely indurated conglomerate that itself overlies Proterozoic dolomite. The tufa is overlain by hardpan soil layers to a depth of several metres.

The Khowarib cascade tufas are extemely well endowed with plant remains, and in places freshwater and terrestrial gastropods were observed (planorbids, *Xeroceratus*). No vertebrates were encountered though. Lithic implements and waste flakes are scattered over the surface of many outcrops.

The silty sediments in the uppermost layer of the terraces close to Khowarib Camp Site yield hundreds of centimetric tufa rinds that precipitated onto plant remains that lay scattered on or close to the ancient land surface. The occurrence suggests that the valley was flooded for long enough for several layers of tufa to precipitate onto the plants, suggesting a swamp-like environment. Similar deposits occur at the Sesfontein Camel Camp (Pickford *et al*. 2016).

Figure 30. River-bed exposures, between Khowarib and Omokutu, of steeply dipping Basement dolomite, overlain by horizontally bedded basal conglomerates and interstratified layers of barrage tufas, silts, incipient hardpan soils and cascade tufas. Loose dark red sands of aeolian origin occur in many places (see Fig. 31).

Figure 31. Tufa coating the roof, walls and floor of a small cave that was eroded into hardpan soils of the Khowarib Valley, Kaokoland (see Fig. 30, cliff in the background).

Figure 32. Concentric layers of tufa forming large rounded masses exposed in the flanks of the Khowarib Valley, Kaokoland.

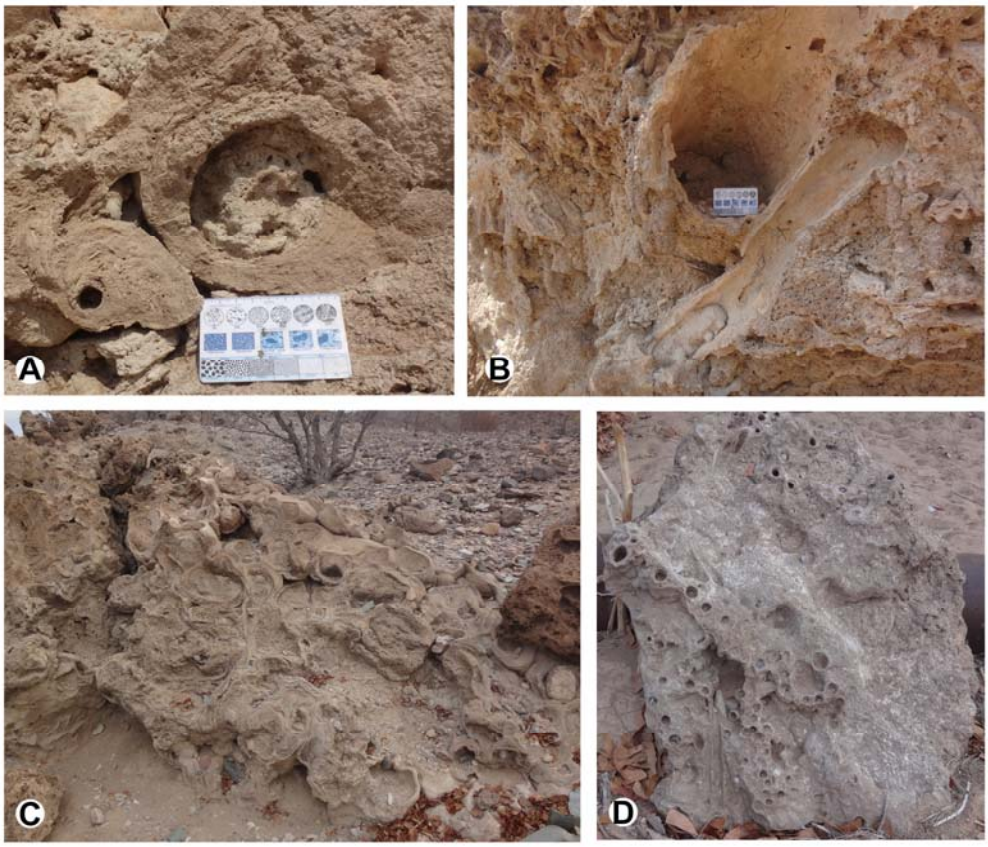

Figure 33. Plant impressions and tufa coatings in the Khowarib Valley, Kaokoland. A-B) imprints in tufa of stems of trees and reeds, C) concentric layers of tufa forming irregular conjoined masses, D) sections of plant stems coated in tufa.

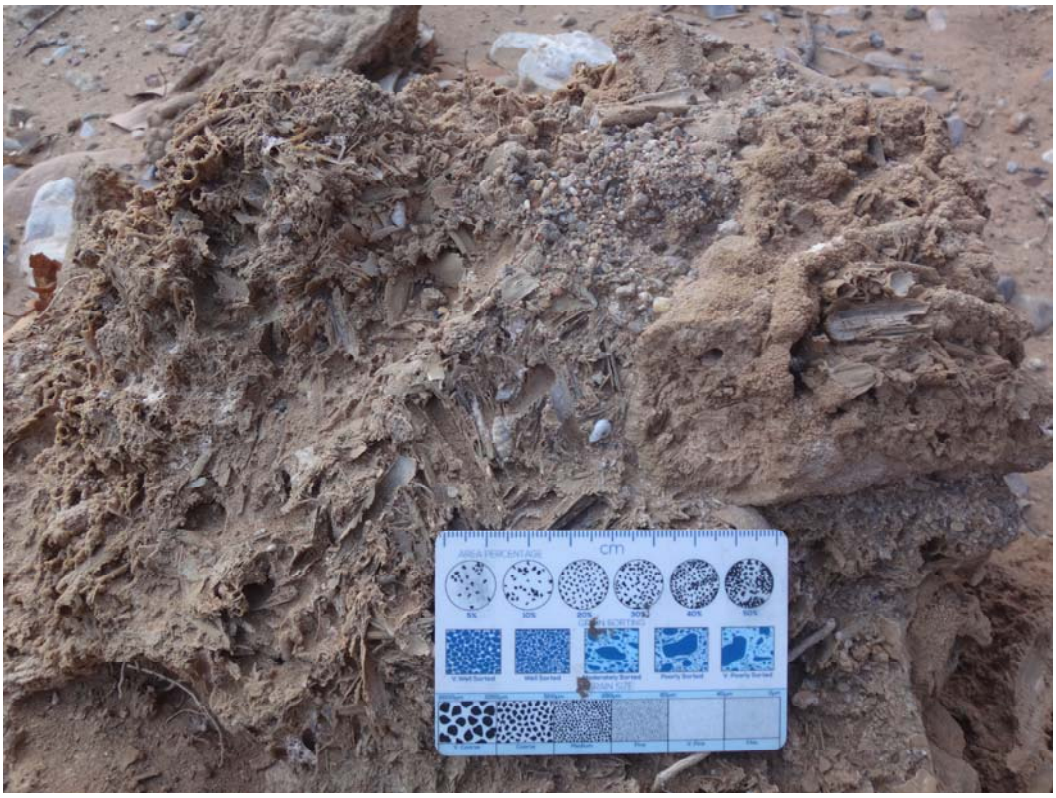

Figure 34. Fossilised shells of *Xerocerastus* and a planorbid intermingled with comminuted plant remains (fossilised elephant dung?) in a barrage tufa at Khowarib, Kaokoland.

An interesting aspect of the Khowarib Valley sequence is that there appear to have been at least three episodes of tufa formation, interstratified with accumulations of silt and clay which show evidence of moderate to clear hardpan soil development. Detailed mapping and stratigraphy of the deposits would be well worth undertaking, in order to understand better the palaeoclimatic signatures that are undoubtedly preserved in the succession.

A preliminary hypothesis is that hardpan soils accumulated and formed during warmer periods, whereas tufas tended to develop during cooler somewhat more humid periods. The Khowarib succession likely holds the key to supporting or to refuting such a suggestion.

Taphonomy

Soils and superficial sediments in areas of Miombo and Mopane woodlands are generally poorly endowed with phosphates due to low concentrations of this element in the bedrock from which the soils and sediments were derived. Kaokoland, with its dominant Mopane vegetation is no exception to this general rule. A consequence of this poverty in phosphorus, is that any bones and teeth that accumulate on or in the soils will be attacked by a variety of organisms in search of this element which is essential for life functions. Among these organisms, fungi, bacteria, small insects and even plant roots will exploit the bones and teeth for their content of phosphorus. The exploitation can occur extremely rapidly, with bones of large mammals such as zebras disappearing within a few years. An added factor in the destruction of bones and teeth in Kaokoland is the climate, with hot, arid conditions promoting the cracking and spalling of bones, eventually leading to their destruction (Fig. 35).

Figure 35. Long bones of a large mammal undergoing longitudinal cracking and flaking under hot, arid climatic conditions at Otjisakumuka, Kaokoland. The bones are also undergoing attack by fungi, bacteria and other organisms in search of phosphorus. The humerus in the middle has also been squashed by trampling.

As a result, fossil vertebrates tend to be rare in deposits that accumulated in Miombo and Mopane woodland settings. The paucity of vertebrate fossils in most of the Kaokoland tufas and sediments is probably due to low concentrations of phosphorus in the soils and sediments. However, there are exceptions such as the fossil-rich but volumetrically restricted concentrations at Otjitaime, Okongwe, Omatapati and Ozombindi (Pickford *et al*. 2019; Mocke *et al*. 2022), and these exceptions demand an explanation. In all four cases, it is likely that the bones and teeth accumulated in damp, waterlogged or flooded depths of cavities in the tufas, the water protecting them from being exploited by fungi and other organisms long enough for them to become fossilised. Furthermore, being inside dark, relatively cool cavities, the bones were protected and teeth from the hot, arid conditions that prevail at the land surface in Kaokoland, which explains why many of the fossils at these localities are well preserved and complete.

Discussion and Conclusions

The October, 2023, field survey confirmed the presence of nine previously unrecorded tufa sites in Kaokoland (Table 2). Fossil mammals were found in cave breccia at Omungunda associated with land snails and stone tools (Late Stone Age facies). The palaeocave itself has been unroofed by erosion, but the red breccia has resisted and large patches remain along the valley flank between the Show Cave and the Baobab Tufa. Fossil mammals are not abundant, but dental remains of bovids, possibly equid and rodents were observed. The quantity of worked stone cemented into the breccia is impressive, with some fine examples of flakes showing conchoidal fracture cones, bulbs of percussion and retouched edges. Most of the worked lithics are in quartz, but some are in dolomite and dark grey quartzite.

Ekoto and Otjisakumuka comprise impressive tufa complexes, the latter developed into a tourist lodge. Kaoko Otavi and Otjitieue are examples of groundwater calcretes surrounding resurgences some distance from the neighbouring hills. Most of the deposits in these occurrences comprise sediments (silts, clays, hardpan soils) with only minor development of moss tufas.

Table 2. Palaeontological and Archaeological content of Tufa complexes of Kaokoland surveyed in October, 2023 (alphabetical order : + - present, ° - not observed). In bold are previously unreported tufas.

Tufa Complex	Plants	Gastropods	Vertebrates	Lithics in tufa
Ekoto Bastion Tufa	+	°	+	+
Kaoko Otavi groundwater calcrete dome and tufa	°	+	°	°
Khowarib calc tufa	+	+	°	°
Okombako Bastion Tufa	+	°	°	°
Okombeiza Barrage Tufa	+	°	°	°
Okongwe tufa lobes	+	+	+	+
Okapiku Cascade Tufas	+	°	°	°
Okovanatje Cascade Tufa	+	°	°	°
Omokutu, barrage tufa *in situ* in river bed	+	°	°	°
Omungunda show cave (previously Rocky 3)	°	°	°	°
Omungunda stone tool site	+	+	+	+
Ongongo Springs Tufa	+	+	°	°
Opuwo Cascade Tufa	+	+	°	+
Otjisakumuka Cascade Tufa	+	°	°	+
Otjitaime Downstream cascade tufas	+	°	°	°
Otjitieue groundwater calcrete dome and tufa	+	+	°	°

Okombeiza is a deeply dissected barrage tufa complex, with impressive quantities of plant fossils, but no vertebrates were observed. However, not all the outcrops could be examined on account of shortage of time.

The Khowarib Valley is a most intriguing place, because there were at least three phases of tufa deposition interstratified with clastic deposits (clays and silts forming incipient to mature hardpan soils and conglomerates). This is one of the few places seen so far in Kaokoland that show such a complete succession of intercalated tufas and clastic deposits, so it would be well worth further detailed study in order to throw light on Pleistocene to Recent palaeoclimatic conditions in the region.

It is stressed that there are many more occurrences of tufa to be identified and mapped in Kaokoland, the results of the recent survey underlining this fact, during which nine previously unmapped occurences were confirmed. The identification of the Khowarib deposits was fortuitous as they are not clearly expressed on satellite imagery, unlike many of the tufas described thus far (Pickford, 2019). Overall, Kaokoland appears to be well endowed with a large variety of calcareous superficial deposits, ranging from tufa deposits of various sorts (barrage, cascade, terrace, bastion tufas) to groundwater calcretes, hardpan domes, cemented conglomerates, and cave deposits that accumulated within tufa complexes (Otjitaime, Okombeiza etc.).

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