Revision of the timing of accumulation of the raised beach deposits of the central Sperrgebiet, Namibia

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Abstract :- The presence of Cainozoic marine sediments in the Sperrgebiet, Namibia, was noted as early as 1908 when diamonds were found at Kolmanskop. Because of the economic interest of these deposits, geological investigations were undertaken, which led to detailed mapping of their distribution, initially by Beetz (1926). In the Central Sperrgebiet early investigators correlated the 'highest' beach deposits (ca 160 metres above present-day mean sea-level) to the Eocene, referred to in the old literature as 'Höchster Stand der Eocänsee' or the 'Eocäne Marine Inundation' (Kaiser, 1926). Liddle (1971) extended this « ancient » strandline a few kilometres northwards to Elfert's Tafelberg. Dingle *et al.* (1983) dated it to the late Palaeocene – early Eocene. In contrast, along the Namaqualand coastal plain in South Africa, marine deposits attributed by Pether (1986, 1994) to the 90 metre package, the 50 metre package, and the 30 metre package were correlated to the Miocene.

Re-examination of the conglomerates at Eisenkieselklippenbake and Buntfeldschuh which crop out at ca 150-160 metres above sea level, reveals that some of the deposits are considerably younger than the Eocene, being instead of early Miocene (Aquitanian-Burdigalian) age. The beach conglomerates at both of these localities contain well-rounded and polished cobbles of densely ferruginised gravel and sand associated with cobbles of a great variety of other rock types (quartzite, silcrete, silicified freshwater limestone, vein quartz, agates, pebbles of banded ironstone formation (BIF), jasper etc.).

The conclusion about the Miocene age of the beaches follows from the observation that the ferruginisation of near-surface deposits in the sector of the Sperrgebiet between Kerbehuk in the south and Elisabethfeld-Grillental in the north occurred during the Oligocene (more precisely, the Chattian) the process petering out during the Early Miocene (Aquitanian-Burdigalian), and ceasing altogether with the establishment of hyper-aridity in the region (onset of fully desert conditions in the Namib) ca 17 Ma.

This means that cobbles derived from the break-up of the ferruginised deposits must be younger than the Chattian. Many of the cobbles of ferruginised sediment contain clasts of agate, BIF and jasper, vein quartz, silicified limestone etc. which were already present in the superficial deposits of the region prior to the Chattian, supporting the old conclusions concerning the presence of Eocene marine deposits in the Sperrgebiet. The revised age of the Eisenkieselklippenbake and Buntfeldschuh beach conglomerates means that the timing of the geomorphological development of the region, such as the back-cutting of the Buntfeldschuh Escarpment, requires revision, as do the correlations of near-surface deposits such as the fluvial Blaubok and Gemsboktal formations (Pickford, 2015) which are of Eo-Oligocene and Miocene age respectively.

Key words :- Raised beach, Miocene, Oligocene, Eocene, Ferruginisation

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Introduction

Ferruginised superficial deposits in the Sperrgebiet were originally correlated to the Late Cretaceous (Beetz, 1926; Kaiser, 1926; Liddle 1971) or younger periods (Kakaoberg – Pleistocene : Du Toit, 1954, cited by Hallam, 1964; Goethite Ring : Ward & Swart, 2018).

Pickford (2015) showed that the supposedly Cretaceous occurrences of 'ferricrete' near Pomona were considerably younger (Late Oligocene : Chattian) as were the outcrops in the Buntfeldschuh area. Further study has revealed that in the Sperrgebiet the processes of ferruginisation faded out during the Early Miocene, and did not extend into the Middle Miocene as postulated by Pickford (2015) nor was there any ferruginistion during the

Pleistocene as postulated by Ward & Swart (2018) the ferruginisation of the Goethite Ring outcrop having probably taken place during the same phase as the ferruginised deposits at Buntfeldschuh (Pickford, 2016). The youngest evidence of ferruginisation in the region occurs at Elisabethfeld and Grillental where patches of fossiliferous Early Miocene (Aquitanian-Burdigalian) sediments have been ferruginised (Pickford, 2016).

As now understood, ferruginisation of superficial deposits in the Sperrgebiet began when sea-levels dropped from the Rupelian high level to the extremely low sea stand that characterised the Chattian (Miller, 2009), and the process weakened and ceased altogether when sea-level rose again during the Aquitanian and Burdigalian. The process was driven by iron-rich groundwaters (Fe_2) flowing from the interior of the continent towards the Atlantic Ocean, that precipitated the iron as Fe_30_4, when encountering oxygen-rich near-surface deposits.

As a result, if derived or reworked blocks of ferruginised sediment are found in a deposit in this sector of the Sperrgebiet, then that deposit is likely to be younger than Chattian, which was the period during which ferruginisation occurred.

In 2023, detailed surveys of Buntfeldschuh and Eisenkieselklippenbake were undertaken in order to refine the age of accumulation of the agate- and BIF-bearing beach gravels exposed there at an altitude of ca 150 metres asl.

Buntfeldschuh

Ferruginised superficial rocks crop out widely but intermittently at Buntfeldschuh. Kakaoberg is an impressive mass of ferruginised aeolianite overlying altered bedrock and shallow marine sediments, and overlain by Namib I Calc-crust (Fig. 1). Elsewhere in the Buntfeldschuh area, ferruginised rocks comprise coarse angular gravel lag, marine sands, and ancient beach gravels (Fig. 4, 5). Ferruginisation post-dates shallow marine sediments that have yielded fossil teeth of the sand shark (*Isurus* sp.) and button-like teeth of 'parrot-fish' (Figs 2, 3). The fossils suggest that the deposits are younger than the Lutetian, not as old as the Palaeocene, the estimate published by Dingle *et al*. (1983).

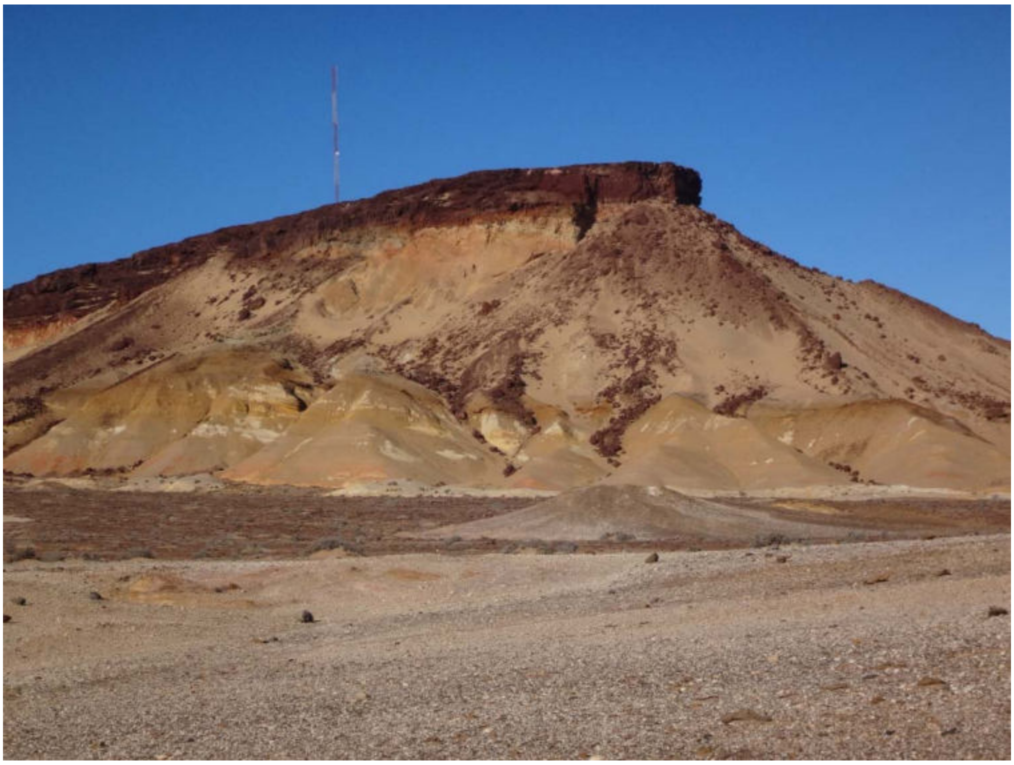

Figure 1. Stratigraphic succession at the northern nose of the Kakaoberg, alterite at the base, ferruginised aeolian sands at the top, with Eocene marine sand, gravels and conglomerates in between.

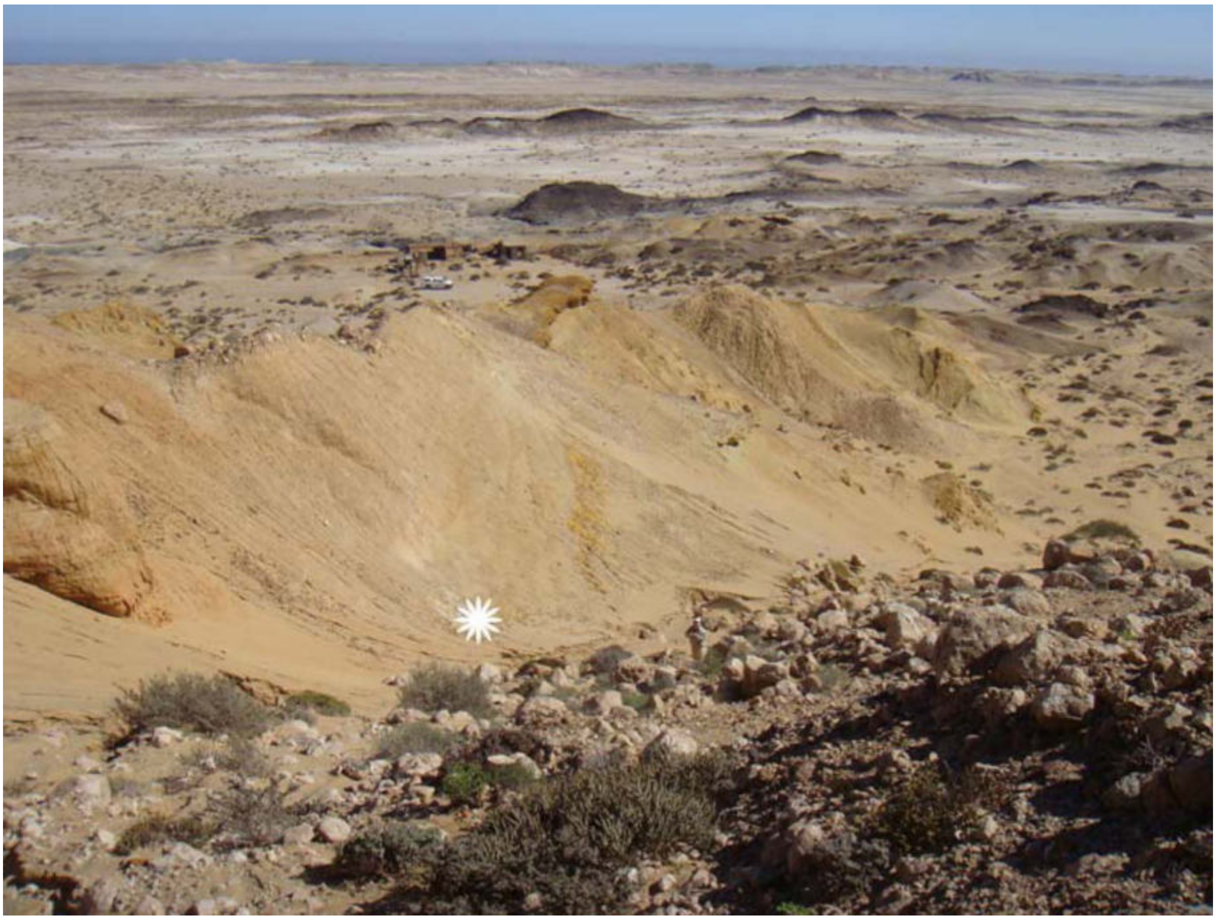

Figure 2. Shallow-water marine sands and gravels that crop out close to the Camel Camp at Buntfeldschuh, Namibia, yield fossilised teeth of sharks and fish (white star) (see Fig. 3). Note the vehicle parked close to the Camel Camp.

Figure 3. Fossil teeth of the sand shark (*Isurus* sp.) and 'parrot-fish' from marine sandy gravels east of the Camel Camp at Buntfeldschuh (see Fig. 2) (scale : 10 mm). These fossils suggest a post-Lutetian age for the sediments from which they were collected.

Figure 4. Outcrop in the northern sector of the Buntfeldschuh exposures preserving a 25 cm thick layer of densely ferruginised coarse conglomerate and sand overlying altered basement rocks (visible beneath the overhang in shadow), and itself unconformably overlain by 2-3 metres of younger, unconsolidated, poorly sorted coarse-to-fine conglomerate and sand.

Figure 5. Wave-worn cobbles from ca 140-150 masl at Buntfeldschuh, Sperrgebiet, Namibia. The goethite that cemented the Eocene sandy-pebbly deposits was precipitated during the Chattian, a period of low sea-level. The ferruginised layers that resulted were broken up by wave action during the Aquitanian-Burdigalian, periods of high sea-level, leaving behind well-rounded and polished cobbles.

Eisenkieselklippenbake

Both of the outcrops of ancient beach deposits at Eisenkieselklippenbake (Fig. 6) yielded rounded and abraded pebbles of densely ferruginised sand in which there are diverse pebbles of quartz, BIF and agates (Fig. 7). The fact that the exotic clasts of agate and BIF are cemented by ferruginised sand (goethite) indicates that the accumulation of these clasts in the area was pre-Oligocene, because ferruginisation processes in this region of the Sperrgebiet occurred during the Oligocene (Chattian) and basalmost Miocene. The same beach gravels contain blocks of fossiliferous silicified freshwater limestones derived from local outcrops on both sides of the valley in which the beach deposits occur. There are also well rounded cobbles of silicified Plaquette Limestone. The fossils in the freshwater limestones are of Middle to Late Eocene age, as is the Plaquette Limestone which crops out sporadically but widely in the vicinity of the Klinghardt Mountains as well as at Chalcedon Tafelberg, Steffenkop and Black Crow. These agate-bearing gravels therefore accumulated after silicification of the freshwater limestones, but prior to ferruginisation, from which it is concluded that they must have been deposited at the very end of the Eocene or lowermost Oligocene, prior to the onset of the Oligocene (Chattian) low sea-stand.

The ferruginised cobbles in the Eisenkieselklippenbake beach gravels (Fig. 7) are well rounded with the pebbles embedded in them abraded level with the densely ferruginised matrix, indicating break-up of the ferruginised deposit into cobbles which were then rounded by wave action and water-borne sand abrasion.

On this basis this it is concluded that the Eisenkieselklippenbake beach gravels comprise a composite unit, with some clasts originally deposited during the terminal Eocene, followed by reworking at the onset of the Miocene, possibly with the input of additional agates and associated clasts. In between these two marine episodes there occurred the ferruginisation of parts of the marine gravels, as well as of the surrounding superficial outcrops on the flanks of the valley.

Overall therefore, it is concluded that the Eisenkieselklippenbake beach deposits have a rather similar history to those of the Buntfeldschuh area where initial deposition of agates occurred during the Eocene (teeth of the sand shark *Isurus* in the marine layers indicate a Lutetian or later age), followed by ferruginisation (Kakaoberg) then by cutting back of the Buntfeldschuh cliff during the first high sea-level of the Miocene (Aquitanian), during which similar beach gravels with ferruginised, agate-bearing cobbles accumulated about 10 metres above the foot of the escarpment at an altitude of ca 150 metres asl.

Figure 6. Miocene beach deposits at Eisenkieselklippenbake (the eastern outcrop) in a shallow valley incised into Priabonian-Bartonian silicified freshwater limestone deposits (brown ridges either side of the beach deposits).

Figure 7. Ferruginised sandy-pebbly cobbles containing agates and BIF collected from the two ancient beach remnants at Eisenkieselklippenbake, ca 150 masl. Top row, the two sides of a cobble from the westernmost outcrop; Bottom row, two views of a cobble from the easternmost outcrop.

Blaubok

A situation somewhat similar to that at Eisenkieselklippenbake, but on a smaller scale, occurs at the summit of the hill west of Blaubok Beacon, where ferrruginised masses of conglomerate have been broken up into cobbles up to 15 cm in diameter that have been abraded and rounded by wave action in an ancient beach or energetic shallow water marine setting (Fig. 8) (Pickford, 2016).

Figure 8. Wave-rounded cobbles of ferruginised Blaubok conglomerate cropping out near the summit of the hill west of Blaubok Beacon, at an altitude (GPS) of 141 masl.

Discussion and Conclusions

The new interpretation of the Buntfeldschuh, Eisenkieselklippenbake and Blaubok outcrops provides support for the stratigraphic relationships published by Pickford (2015) but the timing and duration of events requires minor revision. Silicification of fossiliferous freshwater limestones and the Plaquette Limestone occurred prior to or during the late Bartonian (ca 39-38 Ma), the first input of marine fossils (sharks) and gravels (agate, BIF, jasper etc.) occurred during the late Bartonian to Rupelian (some time between 33.9 and 28.1 Ma) and the ferruginisation of superficial deposits occurred during the Chattian to basal Miocene (ca 28.1-21.0 Ma), while the Aquitanian beach episode (ca 23-21 Ma) reworked the pre-existing marine deposits (some of which had been ferruginised) by breaking up the ferruginised gravels that had been cemented during the Late Oligocene.

Re-examination of the marine gravels in the Central Sperrgebiet which are currently ca 150 metres above sea-level, reveal that several outcrops (Buntfeldschuh, Eisenkieselklippenbake, Blaubok) contain wave-rounded cobbles of densely ferruginised sediment. The style of rounding of the cobbles indicate that ferruginisation occurred prior to the action of waves, which broke up layers of ferruginised sediments and then rounded and abraded the cobbles that resulted from this action.

Ferruginisation of superficial deposits in the Central Sperrgebiet was widespread but sporadic in distribution, with geothitic cement indurating a wide variety of deposits, ranging from angular reg to fine sand and silt. Such rocks occur from Elisabethfeld and Grillental in the north to Kerbehuk in the south, and from close to the present-day coastline in the west (possibly offshore as well) to as far inland as the edge of the Klinghardt Mountains (Pickford, 2016).

The superficial deposits of the Sperrgebiet where iron precipitation occurred were indurated by goethitic cement which in many places is extremely dense : to the extent that some of the deposits were originally mapped as silicified sediments (Kaiser, 1926).

Where information about the timing of the ferruginisation can be observed or inferred, it is concluded that there was but a single phase of this geochemical process that occurred over a period of several million years during the Chattian and basalmost Miocene.

The distribution and type of ferruginisation indicates that these deposits comprise groundwater 'ferricretes'. Reduced iron (Fe_2) was transported in solution by groundwaters flowing from the interior of the continent towards the coast, and upon encountering oxygen-rich environments close to the ancient land surface, the iron was precipitated as Fe_3O_4.

The existence of this long-lived groundwater process during the Chattian suggests that the palaeoclimate in the interior of the continent during this phase may well have been relatively humid, and that the arid to hyper-arid conditions that later prevailed in the Namib Desert didn't get established until the end of the Early Miocene, some 17 Ma.

It is likely that the drop in sea-level during the Chattian to ca 150 metres below present-day levels, resulted in an increase in the flow of groundwater westwards through the Sperrgebiet when compared to the periods of high sea-level prior to and after the Chattian when the coastal parts of what is now the Sperrgebiet were transgressed to an altitude of ca 150 metres above present-day sea-levels.

Ward & Swart (2018) considered that the iron in the Sperrgebiet 'ferricretes' resulted from hydrothermal processes related to the Klinghardt volcanic cluster, but the timing of the deposition renders this unlikely.

Silicification of the superficial deposits in the Sperrgebiet, in contrast, predated the phase of ferruginisation (Pickford, 2016) and the siliceous rocks could well be the result of hydrothermal processes related to the Klinghardt magma chamber.

Furthermore, the phase of travertine deposition in the Sperrgebiet (Pliocene to Pleistocene, Pickford, 2018; Senut *et al*. 2019) that was also linked to the long term flow of groundwater towards the Atlantic Ocean, was more related to the circulation of groundwaters enriched in Calcium ions than to hydrothermal activity at hot-springs.

The implications of this reinterpretation of the Sperrgebiet diamond-bearing raised beach deposits that contain cobbles of ferruginised sediment are far-reaching in that there are both economic and scientific issues to be resolved.

The Eisenkieselklippenbake and Buntfeldschuh beach gravels occur at an altitude of ca 150 metres above modern mean sea-level. South of the Orange River in Namaqualand, South Africa, the highest marine package is reported to be about 90 metres above sea-level (the so-called 90 metre package of Pether, 1986, 1994). Has there been down-warping or down-faulting of the region south of the Orange River relative to the Sperrgebiet, or uplift of the Sperrgebiet relative to Namaqualand, or both? (Pickford, 1998). Are the Namaqualand data reliable? Why are there no mapped equivalents of the 90 metre, 50 metre and 30 metre marine packages in the Central Sperrgebiet (Ward & Swart, 2018). Were such deposits present but then destroyed by erosion, leaving only a few remnants of their presence in sheltered locales such as Eisenkieselklippenbake and Buntfeldschuh? Further research is required.

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