Re-evaluation of the Geology of the Elandsfontein (Hopefield) Site, South-western Cape, South Africa

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The author reviews the significance of geological evidence at an important fossil site.

Re-examination of the Elandsfontein site complex by geomorphologic, sedimentologic, and pedologic criteria shows that: (i) external stratigraphic relationships are poorly established; (ii) the site has a complicated history with episodes of eolian activity, with or without dune formation, interrupted by several periods of soil development or fluvial activity; and (iii) the geomorphologic evolution indicated can only be interpreted with recourse to environmental changes. The Acheulian occupation floor excavated by Wymer can be confirmed as a contemporaneous association related to a former land surface; similarly, at least the bulk of the fossil horizon(s), including the Saldanha Skull, is not the result of a long accumulation by deflation, but was quickly buried in sediment on a gently-undulating, non-dunal surface. The Middle Pleistocene age indicated by the faunal association is compatible with the geomorphologic sequence proposed, and both the fauna and pollen suggest Acheulian occupance in a more mesic, 'savanna' environment rather than the heath-scrub of the modern dune fields.

Considerable interest has focused on the Elandsfontein (or Hopefield) site complex ever since the discovery of the 'Saldanha Skull' here in 1953 (refs 1 and 2) and the excavation of an assemblage of fossil bones and associated Acheulian artifacts in essentially primary context[3]. Elandsfontein is situated 97 km NNW of Cape Town, some 16 km inland at 33°05'S, 18°15'E, in the Sandveld region[4]. Rainfall averages near 300 mm, coming preeminently in the winter months between May and September[5]. The climate is semiarid mesothermal according to the Thornthwaite classification (DB_2^1d), cool-semiarid with winter moisture, by the Koeppen system (*BSks*). The vegetation is acidophile Cape heath and sclerophyllous scrub[6].

A meticulous geological study was soon published by Mabbutt[4], with a variety of minor revisions or complementary data provided by Oakley[7], Needham[8], Deacon[9] and Singer and Wymer[3]. The present commentary is based on a brief visit in September, 1971, at which time a number of sediment samples were collected and subsequently studied in detail in the Paleo-Ecology Laboratory of the University of Chicago. The field examination was facilitated by guidance to the key exposures by David Parish, who had participated in all stages of the 1965–66 excavations, and whose unique knowledge of the site is greatly appreciated.

The points to be made by this commentary are that: (i) no convincing *external* stratigraphy has yet been established for Elandsfontein on geological grounds, (ii) the local micro-stratigraphy of Elandsfontein is more complex and informative than previously believed but remains to be fully clarified, and (iii) the sedimentologic and above all, the pedogenetic evidence does indeed suggest climatic changes. These criticisms are not raised by way of quibbling, and it deserves to be emphasized that Mabutt's study[4] stands up remarkably well after 15 years, particularly in view of the initial difficulties of working at this site. However, Elandsfontein is too important for the African Pleistocene record[10,11] not to deserve yet another scrutiny of its stratigraphy and paleoecological context. The present observations suggest that additional field and laboratory work needs and deserves to be done.

The Sandveld Plateau and its Cover Sands

The stratigraphic base of the Elandsfontein site is provided by a broad marine planation surface, the Sandveld Plateau, cut across Paleozoic shales and slates of the Malmesbury Series at about 75-100 m elevation[4,8]. This erosional surface appears to be part of a wider marine feature in the southwestern Cape[12,25], possibly related to the late Tertiary Coastal Platform of the southern Cape Province[13]. Mabbutt[4,25] suggests a 'Kageran', presumably early Pleistocene age, but allows that development may have begun during Tertiary times.

It is possible that cutting of the Sandveld Plateau may potentially be linked with the fossiliferous occurrences of Langebaanweg, where the oldest, late Pliocene faunas[14] are related to a series of littoral and marine deposits[26]. Be that as it may, the oldest, sandy deposits resting on the Sandveld Plateau to a maximum elevation of 200 m are believed to be penecontemporaneous with planation, representing littoral or mixed littoral-eolian facies[4,8,15]. These are identified by Mabbutt[4] with the 'basal silver-grey sands' underlying the fossiliferous horizon at Elandsfontein, although his criteria-grading and surface texture of sand grains – are inadequate and are, furthermore, not borne out by more detailed textural

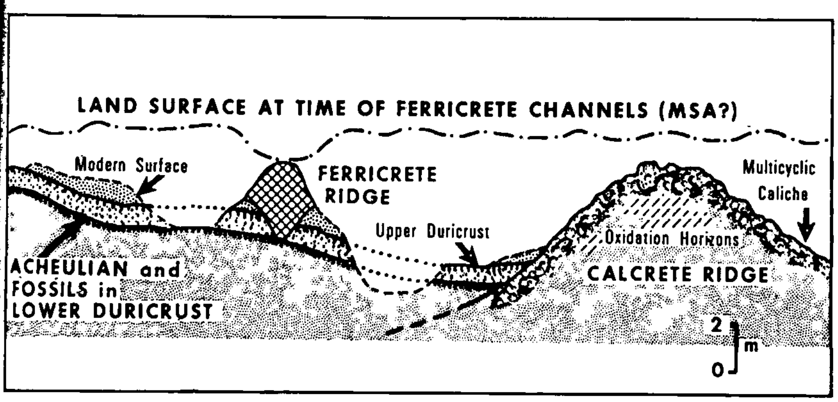

Fig. 1 Composite, generalised stratigraphy at Elandsfontein.

analyses (ref. 8, Appendices A and C).

For all practical purposes there is no information as to whether or not the surface sands are considerably younger than the Sandveld Plateau, or whether or not several generations of surface sands – without dunal topography – are represented. In particular, simplistic interpretation of the Sandveld Plateau and its cover sands would be grossly misleading in any extension to the southern Cape, where the true complexity of erosional and depositional history has begun to be realized[13]. What is more, the various sediments at Elandsfontein and elsewhere in the Sandveld are remarkably similar in terms of both texture and sand micro-morphology, except for the case of active dune sands[8].

Mabbutt (ref. 4, Fig. 6) has published simple textural histograms of a total of 14 samples from Elandsfontein and which were graded by only 4 sieves (approximately 775, 390, 250 and 190 microns). Needham[8] carried out 33 textural analyses using 8 sieves between 885 and 108 microns, and 10 using 24 sieves between 3.35 mm and 60 microns. About a half of Needham's samples came from Elandsfontein proper, with 20 from the Sandveld and selected modern dunes and river sands. Only 6 (of an original collection of 12) samples were analyzed by the present writer, as a control check. These were graded not by an excessive number of coarse sieves, but both by hydrometer and wet-sieving (after decalcification), so as to determine comprehensive size classes of 2, 6, 20, 37, 63, 210, 595 and 2000 microns. These analyses showed that arbitrary lower limits of 190 or 108 microns rendered textural data of limited applicability since 52-60% and 25-29%, respectively, by weight of each of our samples was finer than these cut-off grades. Thus the textural classes obtained by both Mabbutt and Needham are too coarse, while Needham's sorting indices are far too 'good'. In addition, we found that all of the ferruginous samples were bimodal, with some clay fraction present but no silts whatever in the 2-40 micron grade. Thus cumulative quartiles could be determined for all fractions above 37 microns to allow computation of meaningful indices of sorting. We calculated the simple but useful Trask coefficient of sorting, $S_0 = \sqrt{Q_1/Q_3}$, where Q_1 is the first, Q_3 the third quartile, and $Q_1 > Q_3$. Limited variation is the most notable characteristic with Q_1 ranging 275-335 microns, Md (Q_2) 155-185 microns, Q_3 102-108 microns, and S_0 1.64-1.80; that is, all sands are fine and moderately well sorted.

In these circumstances textural analyses are meaningful only when applied to continuous vertical profiles. Minor vertical or horizontal changes of facies equal or exceed differences between stratigraphic units, so that textures simply cannot be used for identification purposes as suggested by Mabbutt[4]. The same applies to rounding indices of quartz sands. We found a general improvement of rounding with increasing size but the sands are generally well rounded, reflecting on considerable, undoubtedly multicyclic transport. Variation in rounding was ±5% among the 6 samples, again inadequate for simple differentiation.

It is our considered opinion that the basic cover sands of the Sandveld have provided a remarkably homogeneous sediment medium, that has been repeatedly reworked by eolian and fluvial processes. At this point the minor textural differences are of less stratigraphic value than macroscopic features such as pedogenetic modifications.

The Calcrete Ridge

One of the few older features with obvious topographic expression at Elandsfontein is the 'Calcrete Ridge' of Singer and Wymer[3]. This has a relief of up to 10 m, a width of at least 60 m, and a length of 1 km; dune foreset bedding is evident, and the land snail *Trigonephrus globulus* is present[4]. Trending north-south, this fossilized linear dune has been compared with rather more massive dunes that interrupt the westward drainage of the site[3 4]. On the basis of the dunal topography, the calcrete condition, and the presence of *Trigonephrus* and phosphatic sand grains, Mabbutt[4] correlates this Calcrete Ridge with the coastal 'Dorcasia Limestone', which includes the cover sands of Langebaanweg. Finally, because a similar calcrete sand covers a number of 6-8 m beach terraces ('Minor Emergence'), Mabbutt[4] implicitely concludes that all calcreted dunes, including that at Elandsfontein, are of Upper Pleistocene ('Gamblian') age.

The complexity of eolianite generations along the southern Cape coast[13] again cautions against a simplistic interpretation in the Sandveld. Our own incidental observations at Langebaanweg and among the deeply-weathered dune fields north of Malmesbury gave ample grounds to believe that several generations of dune-forms, sediments, and paleosols will ultimately be identified in these areas. Consequently we must regard the Calcrete Ridge as of undetermined age.

The calcrete horizons of the Calcrete Ridge may attain a thickness of 1.5-2.0 m, but they are complex indeed. Calcification may occur in discrete layers, in part reduced to a cryptocrystalline calcite, in part laminated, and the carbonate content ranges from less than 2 to greater than 70%. Cutting 1, in particular, shows evidence of repeated 'disturbance.' So, for example, Mabbutt[4] already noted multiple solution pipes. We further believe that some discrete calcrete masses suggest former sand-blasted pedestals or detached surface blocks that have since been re-buried in younger sediment. In fact, the contemporary linear surface is misleading in view of the evidence of multiple deflation, selective corrosion, refilling, and recalcification. Thus the Calcrete Ridge may be as much an erosional yardang as a dune, and the contemporary crest may not follow the original crest line. This would help explain the traces of fauna and artifacts recovered from the immediate subsurface of the Calcrete Ridge.

Apart from these multiple phases of calcretion, other pedogenetic alteration of the Calcrete Ridge has also been complex. Below the crust there are several limonitic horizons disposed according to primary sand bedding. These may contain 13% clay fraction, with medium, subangular blocky structure, and reddish yellow (7.5 YR 7/8) colour. The 'clay' consists primarily of ferruginous compounds, with some clay minerals and amorphous silica. Dispositions of the lower of these horizons suggests (Cg) groundwater horizons, probably due to lateral seepage of moisture rich in mobilized ferric hydroxides; the uppermost zone of discoloration could, however, represent an illuvial B-horizon[9]. These ferruginous levels appear to postdate the last major phase of calcretion.

The Fossiliferous Horizon (Lower Duricrust)

The fossiliferous horizon(s) and the key Acheulian occurrence coincide with a discrete, subhorizontal zone of low-grade calcareous concretions (2-5% $CaCO_3$), clearly younger than the Calcrete Ridge. These concretions normally coincide with a diffuse zone of ferruginization, so that colours range from very pale brown (10 YR 8/4) and pink (7.5 YR 7-8/4) to dark brown (5-7.5 YR 3/2), and 'clay' content – mainly goethite ($HFeO_2$) – ranges from 2.0-3.5%.

Mabbutt[4] already noted that these concretions were created by calcification, followed by some solution and ferruginization, and subsequently recemented with carbonates. He also noticed major differences in the thickness and degree of calcification of this horizon with variable proximity to the calcareous 'source' provided by the Calcrete Ridge. These points may well explain the considerable variability of the concretionary level from one locale to the next. It is not necessarily true, however, that there is only one, unique fossil horizon. Systematic determination by microprobe of key cementing products from bone, adhering bone matrix, and concretions needs to be carried out on the basis of a controlled grid, such as was set up by Wymer (pers. comm.) in 1966. This could serve to show once and for all whether there are one or more horizons represented among the discontinuous outcrops and deflated surfaces (the 'calcareous plains' of Singer and Wymer[3]) in different segments of the site area, for example, west and east of the Calcrete Ridge.

Mabbutt[4] fortunately mapped the basic topography of the fossil horizon. This eliminates a great deal of speculation, and corroborates the field impression of a smoothly undulating surface expression for this level, east of the Calcrete Ridge. It also clearly shows the westward surface dip of about 0.5° from 95 to 88 m above sea level. The question is whether the concretions and ferruginization mark: (i) a former pedogenetic horizon, running subparallel to its coeval land surface, (ii) a calcareous sand deposited in a series of shallow depressions or swales, (iii) a calcareous horizon originally deposited just above a groundwater table with little direct relationship to the then-existing surface topography, or (iv) deposition of reworked concretions and bone into sheetwash. The last of these possibilities, (iv), is precluded by a lack of adequate surface relief, and by the demonstration of a gently undulating paleo-topography for this horizon. Primary deposits (ii) or groundwater calcretes (iii) are also unlikely in view of the discrete occurrence and irregular shape of the concretions, which are typical of a pedogenetic Ca-horizon. We are therefore inclined to accept the fossiliferous horizons as the subsoil manifestation of a former land surface. Significantly, there is no evidence for dunes on this surface, and we agree with Mabbutt's picture[4] of a "fairly smooth sand slope traversed by braiding channels connecting shallow pans which might dry out seasonally."

The Ferruginous Sand Horizon (Upper Duricrust)

About 60-100 cm of clean sand, locally ferruginized to a brown (10 YR 4/3) colour and with as much as 5.5% clay and goethite, rest on top of the fossiliferous horizon. Then follows a second, subparallel crust of ferricrete nature. Typically 10-15 cm thick, this semi-continuous zone of ferruginization is compact and semi-cemented where exposed. Colour is dark reddish brown (2.5-5 YR 2/2-3) or brown (7.5 YR 5.5/4), and there are 8% ferruginous compounds and clays. Where deflated, the resulting lag surface forms the 'ferruginous plains' of Singer and Wymer[3]. It appears to predate the local Middle Stone Age.

The exact genesis of this ferruginous sand is uncertain. It could be the Bh-horizon of a podsolic soil, or a Cg-horizon resulting from lateral water seepage, from groundwater fluctuations, or from impregnation of depression 'soils' by iron-rich surface waters. In any case, the planar, gently dipping nature of the preserved out-crops indicates another smoothly undulating land surface. It also shows that the local topography had remained similar since the time of the fossil horizon. The intervening phase of sand accretion may have either been the result of sheetwash or diffuse eolian accumulation.

Ferricrete Ridges

Following further sand deposition, the last and most curious of the fossil features at Elandsfontein were created. These are sinuous ridges (sinuosity index 1.2), the two major examples of which run subparallel, in a south-southwesterly direction obliquely across the existing slope, with crest elevations dropping from 94 to 88 m and 97 to 91 m, respectively[4]. Overall relief today is 1.5-5 m, and the longest of these ridges can be traced subcontinuously for over 1 km. The tops of these narrow ridges are fully indurated with ferruginous cement and have 'rinds' of dark grey to dark reddish brown (5 YR 4/1, 2/2) colour, with cores of brown to reddish yellow (10 YR 5/3, 7.5 YR 6-7/6). Ferricretion decreases rapidly with depth, but remains vertical in its orientation. In profile, these ridges simulate asymmetry due to undercutting of the western faces by deflation and sand blast, with accumulation on the eastern flanks. Finally, these Ferricrete Ridges show repeated minor 'tributary' convergences, trending 'downstream.'

These ridges are interpreted by Mabbutt[4] as deflated, ferruginized dune cores or spines, by Needham[8] as a product of iron precipitation along an acidic/alkaline interface within existing sand bodies, while Deacon[9] relates them to development of a podsolic B-horizon on a dipping slope. In point of fact, these forms have close analogues in features already described from Bushmanland, in the western Cape by Knetsch[16] and from Nubia, by Knetsch and by Butzer and Hansen[17].

In local disposition, these clinker-like heaps recall the deposits of ferruginous volcanic springs. However, the lineation, sinuosity, and 'tributary' converge in relation to a persistent slope can only be related to a linear source of mobile iron sols. Furthermore the iron concentration decreases rapidly with depth, so that impregnation came from above, diffusing downward and, to some extent, laterally. We therefore feel confident in interpreting these ridges as iron-impregnated channel beds or subchannel sands, beneath former stream channels. The surrounding, unimpregnated sands have since been deflated several metres – down at least 3 m to the Upper Duricrust. Thus the topography has been inverted, with at least 2 palaeo-drainage systems now preserved by these ferricrete 'pseudo-eskers'. Streams in the humic, acidic environment of the wetter Cape 'macchia' today carry large concentrations of hydrated iron and, over a sandy substrate that rapidly becomes alkaline with depth (pH today 6.0-7.4; see also ref. 8, Table IV), precipitation would indeed by favoured. Ultimately, as the streams disappeared, in the course of time the iron would be increasingly converted to irreversible forms.

Careful examination of these ferricrete ridges at Elandsfontein showed that they are distinctly younger than the Upper and Lower Duricrusts as well as the Calcrete Ridge (contrary to Mabbutt[4], but in agreement with Deacon[9]). Mabbutt *et. al*[18] reported similar ridges from the coast at Bok Baai, where they are developed above 6-8 m beach platforms, but project to below modern sea level and so suggest a correlation with the initial glacial-eustatic regression of the Upper Pleistocene. Since these features are relatively unusual, and since they would not be preserved indefinitely, the two occurences *may* indeed be contemporaneous – although the argument is not a strong one.

Stratigraphic Synthesis

The events discussed above are summarized by Table I. It can be seen that correlations with external events are minimal and that, since Pleistocene paleoclimatic trends in South Africa are far from predictable, the faunas will necessarily be paramount in dating the Lower Duricrust.

Successive additions to and revisions of the Elandsfontein mammalian assemblage have been reported by Singer[1,2], Cooke[19,20], Bone and Singer[21], Singer and Wymer[22], and Hendey[23] with unpublished revisions included in Klein[24]. Of a minimum number of 50 species/genera represented at Elandsfontein, at the very least 20% are extinct, and a broad concensus of opinion indicates strong affinities with the Vaal-Cornelia 'faunal span,' as well as similarities to the fauna of Olduvai Bed IV. On the other hand, the Elandsfontin fauna is far more archaic than assemblages of the Florisbad-Vlakkraal 'faunal span,' and Klein[11] notes the striking contrast with Klasie's River Mouth, where strata resting immediately on a 'Last Interglacial' beach (and all dating greater than 35 000 B.P. by ^{14}C) include 43 large mammalian species, of which only 2 were extinct in historical times. As a composite, therefore, the Elandsfontein fauna must be accepted as Middle Pleistocene rather than early Upper Pleistocene.

Radiometric dating has been of limited help, since ^{14}C assays are useless on materials of such paleontological age. Potential for uranium series dating does exist, however.

Palaeoclimatic Interpretations

The details of eolian accummulation, calcification and stabilization, and, ultimately, deflation and sand-blast (phases 3-6 of Table I) are basically compatible with a semiarid climate, much as that of today. Since accumulation of the Calcrete Ridge and analogous features in this sector of the Sandveld, basic drainage divides have remained similar, precluding lateral shifts of rivers in the area. Furthermore, since deposition of the 'Dorcasia limestone', coastal proximity has played an increasingly minor geomorphologic role at Elandsfontein. Consequently, the various events since phase 3 are best interpreted by climatic oscillations to the drier and wetter side, leading to alternate opening and regeneration of the vegetation mantle.

Several subsequent events (7 or 8-12) are best understood in a more mesic environment, with fluvial processes dominant, little or no eolian activity, and a mobilization of iron comparable to that of wetter regions in the southwestern Cape. It would be misleading to give quantitative analogues in view of the lack of systematic soil data from this area, but we are unquestionably dealing with climatic oscillations to the wetter side of the modern spectrum.

These inferences are borne out by the faunal assemblage (phase 8). If broadly coeval, the large number of diverse herbivorous forms, including a great variety of antelopes, argue for grassveld or a grassveld-bushveld mosaic, instead of arid grassland or the present heath and sclerophyllous scrub with its relatively low carrying capacity and low species diversity[3,24]. Furthermore, hippopotamus implies a permanent water body nearby, while the elephant and giraffids suggest some arboreal vegetation[3].

Both the geomorphological interpretation and the faunal assemblage find corroboration in the substantial pollen data of E. M. van Zinderen Bakker and J. A. Coetzee[3,22]. These include a total of 991 pollen grains alone from 14 coprolite samples from the archaeological and fossil horizon (8). The sands (7) suggest a dry, succulent Karroo vegetation, the fossiliferous Lower Duricrust (8) an open vegetation of bushveld aspect, with very little macchia but including aquatic plants. The overlying sands include little but Compositae, while the higher ferruginous horizons show an increase in Protaceae, Ericaceae, Cyperaceae, as well as inferring the possible presence of *Podocarpus* and

Table I Geomorphologic evolution at Elandsfontein

(15) Localized deflation (beginning somewhat prior to 1906), with formation of a field of merging barkhan dunes.

(14) Land surface during Later Stone Age and Dutch contact times probably formed by a thin mantle of humified cover sands, locally exposing Upper Duricrust.

(13) Deflation of surface sands to level of Upper Duricrust, inverting former stream topography (phase 12) to create Ferricrete Ridges.

(12) Ferruginous impregnation of the substrate below sinuous streams, draining southwestward across the site. Early 'Last Glacial' age regression? Middle Stone Age occupance?

(11) Sand accumulation (3-5 m).

(10) Ferruginization of surface or subsurface sands, in relation to land surface parallel to that of Lower Duricrust; processes uncertain. Upper Duricrust ('Ferruginous Plains')

(9) Sand accumulation (0.6-1.0 m), without dunal topography.

(8) Accumulation of the fossil horizon(s), including the Saldanha Skull, as well as the key Acheulian occupation floor, with respect to a gently undulating, planar and non-dunal surface, in a calcareous subsurface medium subsequently enriched in iron. Lower Duricrust ('Calcareous Plains'). Late Middle Pleistocene fauna(s).

(7) Sand accumulation or reworking, thickness uncertain, processes unknown. Some Acheulian occupance?

(6) Infilling of a yardang/pedestal topography (micro-relief of 1.5 m) on the Calcrete Ridge, with renewed calcification. Earliest Acheulian occupance?

(5) Deflation, sand-blast, and corrosion of Calcrete Ridge.

(4) One or more phases of calcification.

(3) One or more periods of dune modeling, including formation of the dune core to the Calcrete Ridge.

(2) Accumulation of a complex body of multicyclic sands ultimately derived from marine-littoral or littoral-eolian processes, on top of the Sandveld Plateau. Cumulative thickness unknown; age indeterminate.

(1) Bevelling of the 75-100 m Sandveld Plateau by marine and littoral processes. Late Tertiary?

Archaeological associations based on Singer and Wymer (ref. 3); also Wymer, personal communication.

Widdringtonia on the nearby mountains.

The deflation phase (13) saw a return to semiarid conditions that have persisted with little modification into recent times.

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