Sedimentological interpretation of the Florisbad spring deposits, South Africa

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INTRODUCTION

The fossil and archaeological site of Florisbad is a 7 m mound of spring beds, consisting of quartz sands, interbedded with organic horizons or local spring vent intrusions, and partly mantled by aeolian materials. The highly complex suite of spring sediments (Rubidge & Brink 1985) is located above an inclined dyke of Karroo dolerite, intruded within the local Ecca shales (Grobler & Loock 1988). The water emerges at a constant temperature of 28.8°C, some 12° warmer than the mean air temperature. Possible deep-seated aquifers include Precambrian Basement rocks and Ecca shales. However, the sodium chloride content (778 mg Na, 1 321 mg Cl per liter) and a steady release of methane gas (Fourie 1970) suggest saline and also carbonaceous facies of the Ecca shales, and Grobler & Loock (1988) indicate an artesian source via Ecca sediments from a higher source area 40 km to the north, modified by a geothermal convection system reaching to 400 m below the site surface.

The site was studied and sediments sampled in 1970, 1973 and 1982. This spring record was substantially amplified in 1974 by study of the sediments and soils in the drainage line that links the site with the Hagenstad Pan, as well as of the adjacent Modder River valley and a tributary that issued from the parallel spring site of Vlakkraal. The results of this research have already been presented as a concise summary elsewhere (Butzer 1984a, b), and it shows a close concordance of hydrologic and geomorphic behaviour in all the local subsystems. This suggests that the Florisbad spring history is primarily related to regional environmental trends. However, the sedimentological profile has not been published and is the subject of this paper. Its detailed analysis here allows some refinement on the earlier syntheses.

Firstly, the profile will be described according to the microstratigraphic levels that I identified in the extensive exposures of the 1982 excavations (Fig. 1); facies development here sometimes differs from that in the 1938 and

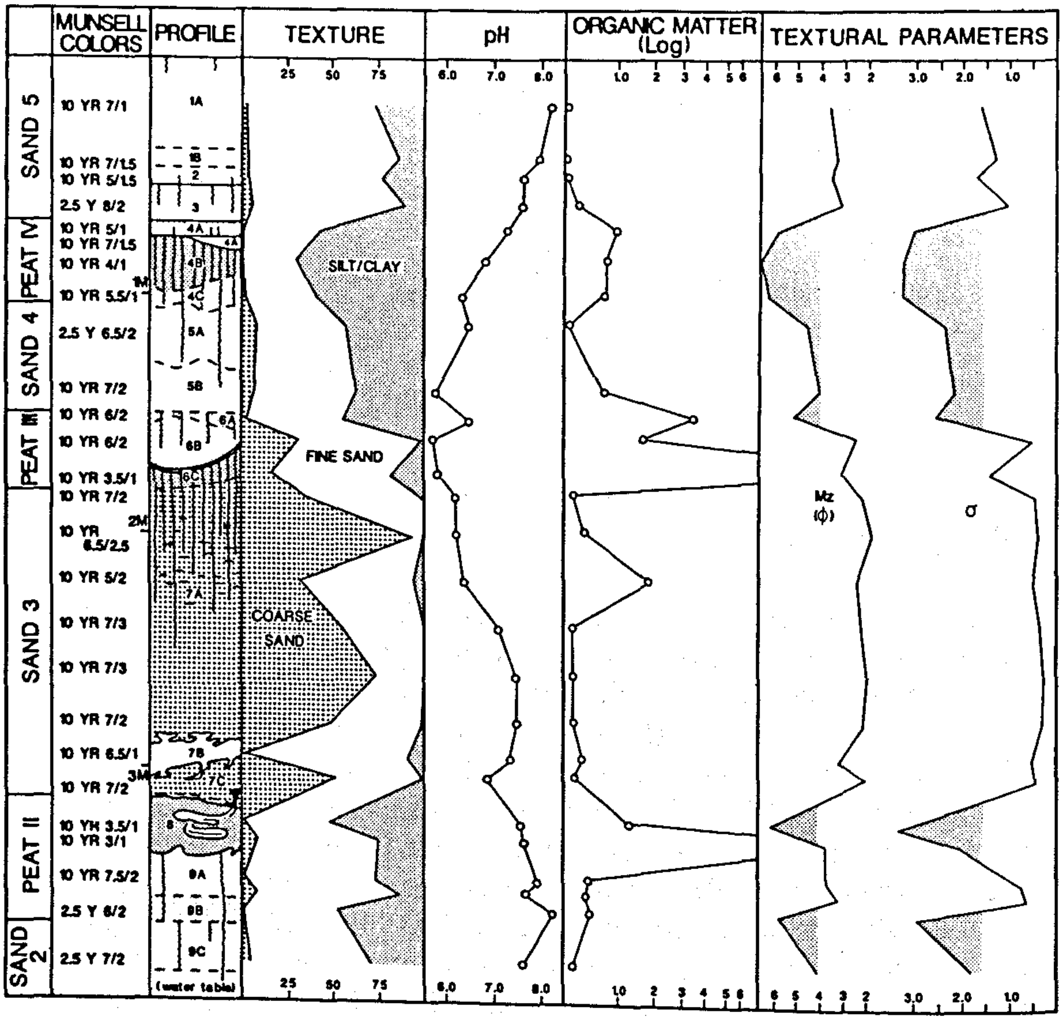

Figure 1. Florisbad spring; exposure of the 1982 excavation

1952 excavations (see Meiring 1956: Fig. 1, Kuman & Clarke 1986: Fig. 2). In as far as possible, I have adhered to the traditional, informal nomenclature for the successive units. Secondly, the analytical data and their change through time are discussed in terms of salient features and any intrinsic problems. Finally, the basic trends of sedimentation and organic enrichment are synthesized, and interpretations offered. It may be noted that many of the published ^{14}C dates come from the older excavation faces, where the 'peat' units lack defintion in terms of interwoven vegetation structures, where the base of Peat IV is within a meter of the surface, and where the roots of modern eucalyptus trees penetrate down into Peat III. This helps explain the inherent problems of the ^{14}C dates, as assembled by Kuman & Clarke (1986) – with a cautionary note that the older dates are not always assigned to the correct units.

PROFILE DESCRIPTION

Sand 5

Unit 1A (25-35 cm). Light gray sandy loam; laminated, wavy and non-parallel; under a cap of disturbed soil and thinning to south; minimal soil development, but weak and diffuse oxidation mottling.

Unit 1B (5-10 cm). Light gray loamy sand; laminated.

Unit 2 (15-25 cm). Gray sandy loam; laminated; filled root voids (3-4 mm) in lower half indicate buried A-horizon; lower contact abrupt; locally converges with unit 4, in which case organic content is higher (10 YR 3.5/1) and dolerite grit is present.

Unit 3 (10-20 cm). White sand, laminated, in root zone of unit 2; lower contact abrupt, dipping up to 2.5% south.

Peat IV

Unit 4A (5-8 cm). Organic, gray loam; moderate soil structure and filled root voids (5 mm) indicate buried A-horizon; locally separated from unit 4B by a lens of light gray loam (5-8 cm); lower contacts abrupt.

Unit 4B (10-25 cm). Organic, dark gray, clay loam; strong, prismatic soil structure and abundant root casts (3-5 mm) indicate A-horizon of major palaeosol; surface dips 2% to south. ^{14}C date 5 530 BP (Pta-1123) on black, organic muck of semi-aquatic facies in the old section, of 3 550 and 3 580 BP (Pta-3617, 3631) in the new excavation.

Unit 4C (7-15 cm). Organic, mixed gray and light gray, clay loam; wavy, non-parallel laminations; weak soil structure, organic intrusions penetrating from unit 4B along decomposing roots.

Sand 4

Unit 5A (25-30 cm). Light gray sandy loam; moderate soil structure; abundant organic mottles related to root zone from unit 4B.

Unit 5B (20 cm). Organic, light gray, sandy loam; columnar structure and weak organic and oxidation mottling; basal 5 cm laminated fine sand; lower contact abrupt.

Peat III

Unit 6A (0-8 cm). Organic, light brownish gray, sandy loam; columnar structure and abundant carbonized root fragments (1-4 mm) in lower part; weak A-horizon of palaeosol; ^{14}C date 4 370 BP (Pta-1127) on 'reed stems or roots' (J.C. Vogel, pers. comm.) is obviously inverted with Pta-1128, and probably applies to roots from unit 4B.

Unit 6B (7-25 cm). Organic, light brownish gray, laminated sand; ferruginous concretions up to 1.5 cm diameter; abundant roots from unit 6A above; basal contact undulating and abrupt.

Unit 6C (5-12 cm). Organic, very dark gray, laminated loamy sand, as matrix for web of carbonized vegetation mat and 5 mm roots, that extend 25-60 cm into underlying unit 7A; thickens to 25 cm towards south, where upper contact less sharp and overlying units thin to 130 cm; old solid carbon date of 19 530 BP (L-1271 D) presumably too young, while the discordant ^{14}C of 10 000 BP (Pta-1125) on 'reed stems' (J.C. Vogel, pers. comm.) in the old section very probably applies to roots from unit 6A, as do the newer dates of 8 790 and 11 700 BP (Pta-3609, 3643). Surface dips 2-4% to south.

Sand 3

Unit 7A (110-115 cm). Very pale brown coarse sand; with multiple, light gray to grayish brown, organic laminae of finer sands, arranged in 5-20 cm sets with wavy, parallel or subparallel bedding, inclined up to 7% to southeast; occasionally particles of Ecca shale (> 0.5 mm). Includes a Middle Stone Age assemblage (Kuman & Clarke 1986) and has a ^{14}C date of 'greater than 43 700' (Pta-3465).

Unit 7B (0-15 cm). Light gray fine sand, laminated, with small-scale organic 'flame' structures above and below; possibly injected between units 7A and 7C during a vent eruption. Also with infinite ^{14}C dates (greater than 47 200 and 44 600 years, Pta-3623, 3611).

Unit 7C (7-20 cm). Light gray coarse sand, laminated, with 'flame' structures above and below.

Peat II

Unit 8 (20-25 cm). Organic, very dark gray sandy loam, interbedded with dark gray loam and pockets of light gray loam; with vegetation structures, root impressions; laminated but disposed in convoluted 'sweeps'; both upper and lower 'flame' contacts, suggesting intense compression and reworking during a vent eruption; A-horizon of a semi-aquatic soil, but exhibiting intact vegetation structures and less disturbance on slightly higher ground; ^{14}C date of 'greater than 42 600 years' (Pta-1108) on 'rootlets'.

Unit 9A (15-20 cm). Weakly organic, light gray, laminated sandy loam; fine (1 mm), carbonized roots.

Unit 9B (10-15 cm). Weakly organic, light brownish gray, laminated loam; vegetation structures and fine vertical roots; incipient A-horizon.

Sand 2

Unit 9C (20 cm to watertable, February 1982). Light gray, laminated sandy loam; prominent vertical root impressions (1-4 mm) intruding from unit 9B. According to Fourie (1970: Fig. 1), this unit (which provided the Middle Stone Age collections of 1938-52) appears to have a total thickness of 120 cm over Peat I (80 cm thick), Sand 1 (60 cm), and the Basal Peat (2 cm), resting on decomposing, dolerite cobbles or bedrock.

ANALYTICAL DISCUSSION

The bigger picture of changing energy conditions over time is illustrated by a selection of the textural data from the twenty-six samples spanning 3.5 m of the profile down to the watertable (Fig. 1). As has long been known, this sedimentary sequence represents a series of spring deposits, accumulating around the periphery of one or more spring vents ('eyes').

During periods of subdued flow, low-energy conditions allowed silt and clay to remain in this micro-depositional environment, a pattern particularly characteristic of units 4A to 6A (40-70% finer than 63 µm). During periods of rapid ('flush') flow, relatively coarse sands (mainly in the 210-355 µm size category) dominate the retained sediments, with almost all silts and clays washed away in suspension; this is the case in units 7A and 7C (30-95% coarser than 210 µm). At other times, intermediate conditions prevailed, so in units 1A to 3 and 8 to 9C.

At longer intervals, a spring vent erupted with great force, tearing out older sediment, while injecting fresh sands mixed with reworked older material. A minor such event is historically recorded after an earthquake in 1912 (Broom 1913), after which spring flow increased as much as eightfold over several months. More 'catastrophic' was the vent eruption after unit 4A, that disrupted all the then-existing beds above the 'Western (Spring) Eye' (see Fourie 1970: Fig. 5, for the only reliable documentation), apparently injecting the well-known hominid skull into a position just above Peat I (Dreyer 1938, Oakley 1954). The compression of Peat II and the intrusion of unit 7B into Sand 3 probably relates to this eruption, which generated microfaults adjacent to the vent filling (Fourie 1970: Fig. 5).

The raw textural data of Figure 1 are complemented by the Folk textural parameters for mean grain size (Mz) and sorting (σ), which show a tight correlation between fine-grained sediments and poor sorting. The skewness and kurtosis indices, not shown in Figure 1, relate primarily to this same, large-scale pattern: all but some of the best sorted samples are strongly positively skewed, while all but the poorest sorted samples are strongly leptokurtic.

Sand 3 stands out as a moderate to high-energy deposit, Sands 2 and 4 as primarily low-energy, with Sand 5 in an intermediate position. The basic parameters for Sand 2 show little variation through time, but significantly, they do not begin with a burst of energy that slacks off, and they are consistently interlaminated with fine organic materials and fine to medium grade sands. This argues for a long-term, rhythmic accumulation, rather than one or more 'catastrophic' events.

Macroscopically, the profile is dominated by the organic horizons, customarily labelled as 'peats'. The organic matter values, shown on a logarithmic scale, determined by the Walkley-Black method, complement the Munsell colour in identifying the key horizons. In detail, the palaeovegetation structures vary considerably, and in part coincide with evidence for pedogenic structure. Each of the exposed organic horizons represent multiple 'soils', and the upper contacts of units 4B and 6C mark particularly clear and long-term land surfaces. Minor but distinct soil horizons are also indicated by the rooting systems below units 9B, 6A, 4Ai and 2. In the 1982 excavations, unit 8 does not appear to represent a typical soil, as opposed to a semi-aquatic muck of protracted development, but it forms a more distinctive surface elsewhere.

It is significant that these soils do not always coincide with fine sediments. This is especially so in the case of unit 6C, which indicates that spring deposition ceased abruptly, rather than tapering off, as in the case of Peats II and IV. As Dreyer (1938) already recognized, the 'peat' level demarcate spring flow cycles. However, the sum of the evidence discussed here shows that these cycles varied considerably in terms of energy, did not necessarily wax and wane in a predictable fashion, and they comprised several subcycles. The controlling factor or factors were therefore complex.

The sand-grain mineralogy of the Florisbad deposits has been studied in detail by Fourie (1970). Quartz is almost exclusive, with traces of altered plagioclase in Sands 2 and 4 (upper), of altered microcline in Sands 3 and 4 (upper), and of fresh plagioclase in Sand 3. The paucity of other minerals probably reflects the corrosive nature of the micro-environment near the warm, slightly saline spring waters; a much broader range of minerals, including pyroxenes, is present in more calcareous sediments peripheral to the spring eyes or beyond the mound.

The great bulk of the quartz grains are subangular and matte, and represent detrital sands released from the Ecca sediments as well as phenocrysts from subsurface dolerite rocks. There are no rounded or well-rounded grains, except in the mid-part of unit 7A and in the >0.5 mm fraction (contra Fourie 1970, who apparently classified our 'subrounded' category as 'rounded'). Subrounded quartz grains probably also derive in the main part from underlying Ecca shales. A few of the subrounded grains in units 1A, 3 and 5B have traces of the ferruginous plasma characteristic of Kalahari-type sands, a feature not surprising because aeolian sands are well-developed along the western and southern perimeter of the spring mound. But this does not imply a significant aeolian component in the spring sequence, even during periods of relative quiescence.

The pH curve for the Florisbad is of great interest. It decreases steadily from 8.21 in unit 1A, near the surface, to 5.76 in unit 5B, then trends upward again to 8.22 in unit 9B. This unusual shift – in terms of both amplitude and depth – cannot be explained by cheluviation, even though the mound sediments tend to be sandy and the pH decline tends to coincide with the zone of greatest organic enrichment. For one, the clay loam textures of units 4B and 4C do not arrest the pH decline, as they should. For another, the zone approaching the lowest pH levels is not eluvial in nature, while the subjacent zone of rising pH is not illuvial.

An explanation must therefore be sought in the geochemical history of the sedimentation process. Important here is that, although there is no calcium carbonate in the present profile, Fourie (1970) found Peat I to be calcareous. Since the spring water, which now has a pH of 8.3, is greatly undersaturated in calcium and bicarbonate (87 and 49 mg/liter, Fourie 1970), any such carbonate enrichment must derive from direct or indirect external sources during a period of subaerial weathering. Further, low pH values show no systematic correlation with the major organic horizons, that might be expected to yield higher levels of carbonic acid through root decomposition, despite a general coincidence between the highest acidity and Peat III. The pH curve consequently suggests a long-wave response to fundamental environmental parameters. Whether such changes reflect a very different vegetation cover in the aquifer recharge zone, or differences in precipitation amount/seasonality or temperature regime, is impossible to isolate through my particular methodology.

A few scattered fossils have been retrieved from the lower half of unit 7A. Their absence in higher levels can be readily explained by the low pH of the higher units and the corrosive action of the oligohaline waters. The concentration of fossils reported under Peat I (Fourie 1970, Klein 1980, Butzer 1984a: Table 6, Kuman & Clarke 1986) is explicable in terms of a calcareous and presumably alkaline environment.

INTERPRETATION

We first offer interpretations for units 1 through 6B, of apparent Holocene age.

Units 1A and 1B, which form a cap on the centre of the mound, lack a recent soil profile, but their consistent fine lamination precludes artificial disturbance or a recent vent eruption. The soil may, therefore, have been removed when the area was landscaped and converted into a health spa. These sediments are similar to units 2 and 3, and suggest a period of intermediate energy discharge, from now-defunct vents emerging near the centre of the mound. The implications are that flow was somewhat greater than at present. Unit 2 represents a minor interval of stability and organic enrichment that could be dated by ^{14}C. At present, Sand 5 appears to be younger than 3 500 years.

The Peat IV complex, spanning the period 5 500-3 500 BP, represents a long episode of low-energy discharge, fluctuating towards the end. A relatively large area on the southern margin of the mound was thickly overgrown by aquatic and fringing vegetation at this time. The former topography has been greatly altered by excavation to locate the bathhouse and pool, but this peat was probably continuous with the clay loam floodplain along the donga 50 m and more downstream. The discharge regime was probably similar to that of today.

Sand 4 (units 4C to 5B) is intermediate in grade between Peat IV and Sand 5, and suggests a slightly greater discharge than today, during the Holocene.

Our present working hypothesis is that units 6A and 6B are roughly 10 000 years old, spanning the Pleistocene-Holocene border. The lower unit (6B) reflects moderate-energy discharge, substantially greater than during any protracted subsequent time. The upper unit (6A) indicates an abrupt slackening off in energy and flow, with an enhanced fringing vegetation.

The lower part of the exposed profile evidently represents the later Pleistocene, although the main horizon of Peat III must be somewhat older than 20 000 BP, judging by the infinite date on the underlying unit 7A. The contact above unit 6C is evidently scoured, and must represent a long depositional hiatus of perhaps ten millennia, during which time spring discharge was similar to or less than that of today. The relatively coarse nature of the sands in unit 6C is also incompatible with the thick mat of vegetation with tightly interlocked roots, responsible for the organic accretion in this prominent horizon. There was, therefore, little primary accretion of sediment as this 'peat' developed, indicating that spring flow was either prone to pulses of energy or very slack. The sediments consequently shed little light on the local environment, so that resolution must be sought by palaeobotanical means.

Sand 3 marks the period of highest energy discharge recorded at Florisbad. The microstratigraphy indicates clear variability, of a secular or seasonal nature, that tended to increase in the upper part of the column. This interlamination with organic material and fine sands, arranged in wavy-bedded laminasets, as well as the coarse grade of the sands precludes other than a spring origin. But water was generally abundant and fast moving, never allowing significant amounts of suspended material to accumulate, except on a seasonal basis. Coarse sand accumulation tends to be fairly rapid, so that Sand 3 may not represent more than ten millennia.

Peat II, also dating well beyond the limits of ^{14}C, suggests energy conditions similar to those of Sand 4, generally with a little more water flow than at present, but prone to considerable fluctuation. The pattern for Sand 2 may have been much the same, but adequate exposures are not available. Unfortunately the profile allows few deductions as to whether the depositional break between units 7C and 8 was long, other than the degree of organic enrichment was broadly similar. Certainly the aquatic environment was fairly extensive while Peat II formed.

As long as Peat I and Sand I remain below the water table, little can be added to the implications derived from the faunal horizon here (Klein 1980, Brink 1988) and from the pollen data (from a core, analyzed by Van Zinderen Bakker 1988).

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REFERENCES

Brink, J.S. 1988. The taphonomy and palaeoecology of the Florisbad spring fauna. *Palaeoecol. of Africa* 19: 169-179.

Broom, R. 1913. Man contemporaneous with extinct animals in South Africa. *Ann. S. Afr. Mus.* 12: 13-16.

Butzer, K.W. 1984a. Archaeogeology and Quaternary environment in the interior of southern Africa. In R.G. Klein (ed.), *Southern African prehistory and palaeoenvironments*: 1-64. Rotterdam: Balkema.

Butzer, K.W. 1984b. Later Quaternary environments in South Africa. In J.C. Vogel (ed.), *Late Cainozoic palaeoclimates of the southern hemisphere*: 235-264. Rotterdam: Balkema.

Dreyer, T.F. 1938. The archaeology of the Florisbad deposits. *Argeol. Navors. Nas. Mus. (Bloemfontein)* 1 (8): 65-77.

Fourie, G.P. 1970. Die Geologie van Florisbad. *Geol. Surv. S. Afr. Rep.* D-144: 1-55.

Grobler, N.J. & J.C. Loock 1988. Morphological development of the Florisbad deposit. *Palaeoecol. of Africa* 19: 163-168.

Klein, R.G. 1980. Environmental and ecological implications of large mammals from Upper Pleistocene and Holocene sites in southern Africa. *Ann. S. Afr. Mus.* 81: 223-283.

Kuman, K. & R.J. Clarke 1986. Florisbad – new investigation at a Middle Stone Age hominid site in South Africa. *Geoarchaeology* 1: 103-125.

Meiring, A.J.D. 1956. The macrolithic culture of Florisbad. *Navors. Nas. Mus. (Bloemfontein)* 1 (9): 205-237.

Oakley, K.P. 1954. Study tour of early hominid sites in southern Africa, 1953. *S. Afr. Archaeol. Bull.* 9: 75-87.

Rubidge, B.S. & J.S. Brink 1985. Preliminary survey of the extent and nature of the Pleistocene sedimentary deposits at Florisbad, *South Africa. Navor. Nas. Mus.* (Bloemfontein) 5 (5): 69-76.

Van Zinderen Bakker, E.M. 1988. Palynological studies of the Florisbad deposits (South Africa). A preliminary note. *Palaeoecol. of Africa* 19: 161-162