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GEOMORPHOLOGY AND GEO-ARCHEOLOGY AT ELANDSBAAI WESTERN CAPE, SOUTH AFRICA

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SUMMARY

The external geomorphic record of the Elandsbaai area includes a variety of slope rubbles, colluvia, littoral-eolian deposits, fossil beaches, cambic paleosols and calcretes. Cave deposits additionally include frost-weathered spall, eolian sands, and cultural components, in part dated by ^{14}C. Several mid-Pleistocene cold intervals led to large-scale frost-weathering of cliff faces and mobilization of 15° block rubbles or grèzes litées along footslopes. During the late Pleistocene cold intervals (deep-sea isotope stages 5b and 4) slope transfer was limited to stony colluvial deposits with some block talus, while frost-weathering was subdued. A +6m sea level with thermophile mollusca, marking isotope stage 5e, includes lagoonal gypsum, indicative of drier climate. Most eolian deposits were related to marine transgressions and the last major eolian phase occurred 12,500 - 8000 B.P., with probable parallels at the very beginning of isotope stages 7 and 5e. Deep cambic paleosols formed during part of isotope stage 7 and during 5c or 5d, while calcretes formed later during stage 7 and again during 5a. Middle Stone Age occupation is recorded during isotope stages 6 and 5b, while Later Stone Age settlement began well before 21,000 B.P., with a major shift from continental to littoral subsistence after 11,000 B.P..

ZUSAMMENFASSUNG

Die geomorphologische Entwicklung des Elandsbaai-Gebietes ist ablesbar aus Hangschuttdecken, Kolluvien, littoral-äolischen Sedimenten, fossilen Stränden, Paläoböden und Kalkkrusten. Höhlensedimente umfassen Frostschutt, Flugsand und Kulturschichten, die teilweise ^{14}C datiert wurden. Mehrere mittelpleistozäne Kaltphasen führen zu beträchtlicher Frostverwitterung an Kliffwänden und Bildung von grèzes litées an Unterhängen. Während der jungpleistozänen Kaltphasen (Tiefsee-Isotopen-Stadien 5b und 4) waren Transportprozesse an Hängen begrenzt auf steinhaltige Kolluvien mit etwas Blockschutt während Frostverwitterung abgeschwächt war. Ein 6 m-Meeresspiegelstrand mit warmer Fauna (Stadium 5e) ist mit lagunären Gipsakkumulationen verknüpft, was auf trockene Klimabedingungen schließen läßt. Die meisten äolischen Sedimente sind an Meerestransgressionen gebunden. Die letzte größere äolische Phase ist auf 12500-8000 B.P. zu datieren, mit wahrscheinlichen Parallelen zu Beginn der Isotopen-Stadien 7 und 5e. Tiefgründigere Paläoböden bildeten sich in Abschnitten der Stadien 7 und während der 5c oder 5d, wohingegen Kalkkrusten während der Stadien 7 und während 5a. Hinweise auf Mittleres Paläolithikum finden sich während der Stadien 6 und 5b; jungpaläolithische Siedlungen begannen vor 21000 B.P. mit einer Tendenz von kontinentaler zu littoraler Lebensweise nach 11000 B.P.

Fig. 1: Location map of Elandsbaai and the western Cape.

1. INTRODUCTION

Elandsbaai (32°19' S) is located on the Atlantic coast 180 km north of Cape Town, at the mouth of the Verlorevlei River (Fig. 1). The climate is subarid, with 225 - 275 mm of precipitation, mainly during the cooler half of the year (22-yr mean for Het Kruis 262 mm, CLIMATE OF SOUTH AFRICA 1965). Daily and annual temperature amplitudes are small (6.9° and 4.3° C respectively), with the average daily maximum of the warmest month (February) 21.1° and the average daily minimum of the coldest month (July) 10.0° at Cape Columbine (32°50' S, 60 m elevation), where the lowest temperature on record is +3.9° C (CLIMATE OF SOUTH AFRICA 1954). A vegetation of sparse grass and sclerophyllous shrubs is characteristic.

Steep-sided hills of Table Mountain quartzite (mid-Paleozoic) rise 100 - 300 m above an undulating plain at 20 - 75 m elevation. This plain is mantled by a thick cover of surficial sediments, including weathered, reddish brown (5-7.5 YR Munsell hues, dry), partly cross-bedded eolian sands, commonly dotted with low hummocks, as well as areas of active, white dunes, e.g. north of Elandsbaai. Near the base of the quartzite mesas and buttes, slope rubbles interfinger with recent or weathered eolian sands on footslopes of 4 - 10°, but as steep as 25° where undercut by recent Pleistocene wave activity. South of the rocky headland at Cape Deseada, the coast is formed by a prominent beach ridge that merges with foreshore dunes and locally demarcates strings of calcareous, freshwater marsh. North of the long but shallow Verlorevlei estuary, eolian sands are far more abundant and sweep many kilometers inland.

Since 1969, JOHN PARKINGTON (1972, 1976a, 1976b) excavated two caves near Elandsbaai, and demonstrated significant changes in prehistoric subsistence patterns during the Pleistocene and Holocene, at least partly related to environmental changes. Preliminary observations on the geomorphic context of these sites were made by the writer in September, 1977. A number of sediment samples were subsequently analyzed at the University of Chicago (see Fig. 2; for an outline of the methodology used see BUTZER, BEAUMONT & VOGEL 1978, and FOLK 1966). The results serve to confirm a complex environmental history that deserves more detailed study.

2. LITTORAL SANDS AND SLOPE RUBBLES

Landward of the coastal marshes south of Cape Deseada there frequently are low outcrops of cemented, white eolianites that are lithologically comparable to the late Pleistocene sequence far better exposed between Melkbos and Van Riebeeckstrand (BUTZER unpublished; KLEIN 1976). Their relationships to the +6 - 7 m shelly,

Fig. 2: Selected laboratory results from Elandsbaai, Elands Bay Cave and Diepkloof.

transgressive sandstone and lagoonal gypsum found 4 km south of Cape Deseada (TANKARD 1976) remains to be established. But this gypsum, deposited in brine lagoons, argues for much less groundwater seepage than today. Intermediate in age between the active foreshore deposits and the eolianites are sheets of coarse, backshore sands with brown (7.5 YR), incipient cambic horizons up to 60 cm thick. These weathered eolian sands (Fig. 2) are locally linked to eroding ridges rich in mussel shell, valves articulated, at 1 - 2 m above modern high tide; although some of these occurrences represent Later Stone Age middens, others deserve more careful study as potential shorelines of mid-Holocene age.

A critical link between marine and terrestrial deposits is provided on the southern margin of the Verlorevlei estuary, around the hamlet of the same name, now 4.5 km ESE from the open sea. Masses of marine shell rest among beach shingle on abraded sandstones (Klipheuvel Formation, mid-Paleozoic, GEOLOGICAL SURVEY OF SOUTH AFRICA 1969), locally preserving traces of a wave-cut nip at +5 - 6 m. The mollusca are described by TANKARD (1976) as a decidedly thermophile assemblage, characteristic of deep-sea isotope stage 5e (ca. 125,000 B.P., SHACKLETON 1975) and of an estu-

arine sandy substrate; the infratidal oyster *Ostrea stentina* was found attached to rock at +5 m. The shell bank is overlain by up to 4 m of slope wash, incorporating reworked molluscan fragments and derived from intensively weathered eolian sediments and fine local debris. This moderately sorted colluvial unit includes two facies, a reddish brown (2.5.5 YR), oxidized sandy loam (Fig. 2) and a light reddish brown (2.5 YR) sandy loam with fine, faint mottling, possibly indicative of estuarine conditions. The reddish colluvium is weakly calcified at the top and covered by up to 1.5 m of brown (7.5 YR), stony wash that extends well up the slope; here it may underlie thin, eroding aprons of eolian sand with the same incipient cambic soil profile found south of Cape Deseada on the immobile backshore sands.

Calcreted, subangular breccias are common on the cliffs behind the Cape Deseada promontory. For example, there is 75 cm of breccia on the 20° slope below Elands Bay Cave. Modal rubble size is 2 - 6 cm, with crude stratification and subparallel, wavy calc laminations. The matrix (Fig. 2) is a distinctly and extensively mottled, light yellowish brown (10 YR), cemented sandy loam. The matrix sands are fine, partly well-rounded, and suggest water reworking of eolian veneers, perhaps filling interstitial voids after rubble mobilization. A similar but angular rubble is found directly upslope, lining the floor of the cave to a thickness of 30 cm; the detritus is generally coarser here (2 - 12 cm), lacks an original matrix (Photo 1), and finds no parallels in later sedimentation patterns. This frost-shattered debris (see discussion of potential weathering agents in quartzite, BUTZER 1973a) includes numerous artifacts. The assemblage is dominated by large, broad flakes (made from discoid cores), debris, and cores; formal retouch and diagnostic artifacts are absent; made 93 % on quartzite, this represents an early Middle Stone Age industry (T.P. VOLMAN, in preparation).

3. THE ELANDSBERG TUNNEL SECTION

A complex, 15 - 20 cm rubble sequence is exposed in the Elandsberg Tunnel, 1.2 km further east. Five major generations of deposits can be identified, from bottom to top, resting against a quartzite slope of 25°:

(1) Up to 12 m of subangular block rubble, chaotically bedded with a stony, sandy to loamy matrix, initially created an extensive footslope accumulation. The final equilibrium slope of 10 - 15° has swales later filled with up to 1.5 m of light brown (7.5 YR) loamy sand, homogeneous except for some dispersed quartzite blocks (unit 1a) (Photo 2). Subsequent pedogenesis within these terminal sands formed a 50 - 100 cm thick, laminated calcrete over a prismatic-structured cambic horizon.

(2) A 1 m-unit of crudely stratified, subangular rubble (4 - 15 cm), with voids only partly filled with sandy, calcareous matrix, represents a typical grèze litée (Photo 3), inclined at 15° and comparable in development to the oxidized breccia below Elands Bay Cave. Upslope this bedded talus grades into a lense of block rubble.

(3) Up to 1.5 m of homogeneous, light brown (5-7.5 YR), loamy coarse sand comprises discontinuous lenses, marked by thin, wavy calcite horizons and massive, vertical calcrete fissures (related to initial prismatic structure) (Photo 3).

(4) Sandy loam, with a dense, calcrete honeycomb and dispersed blocks, forms aprons up to 3 m thick. One calcification episode appears to have cemented both units 3 and 4.

(5) An unconsolidated 1 - 2 m sheet of brown (7.5 YR), stony wash with much coarse rubble, inclined at 15°, is littered with large surface blocks and a veneer of eolian sand or finer, semimobile talus.

The Elandsberg Tunnel sequence still requires detailed study. TANKARD (1976, 84) refers to it as "a prominent horizon of large wave-generated boulders against the

Photo 1:
Frost-weathered basal rubble, Elands Bay Cave.

Photo 2:
Elandsberg Tunnel section, showing top of unit 1, unit 1a (with 50 - 100 cm calcrete and 100 - 150 cm prismatic horizon), and unit 2.

Photo 3:
Elandsberg Tunnel section, showing calcrete top of unit 1a, the grèze litée of unit 2, and calcified unit 3 sands.

foot of the cliff at 13 m a.s.l." The subjacent 25° quartzite is indeed characteristic of wave-undercut midslopes, but even unit (1) is not a wave generated deposit: the angular blocks, typically at 10 - 15°, have a penecontemporaneous matrix of soil derivatives, all atypical of a shoreline. Instead, the dominant facies at Elandsberg are reworked eolian sands and crude talus, in good part due to frost-shattering or frost-wedging along the 60° cliffs above. Periodic mobilization seems to have been due to frost and water assisted gravity movements (rubbles) or to colluvial transfer (sands). However, there is little evidence of plastic deformation, of contorted, festoon or flame structures, or of lenticular textural sorting. Together with the sandy nature of the deposit, this rules out true congelifluction, a process nowhere verfified at low elevations in South Africa (BUTZER & HELGREN 1972, BUTZER 1973b, BUTZER et al. 1978, FITZPATRICK 1978).

It appears that periods of slope stability repeatedly coincided with formation of cambic paleosols, in part with strong prismatic structure. The calcretes are less readily interpreted since molluscan debris is the only source of carbonates in the modern environment: $CaCO_3$ values of 20 - 35 % in active littoral deposits decline rapidly to 1 % in weathered surficial sands. Significantly, calcretes are best developed in coastal proximity and on windward, southwesterly slopes. Accelerated littoral deflation south of Cape Deseada would be most effective if foreshore dunes were less vegetated, or if sea level was falling a little, to provide a broader shore zone with a fresh supply of shelf sediment, or if sea level were rising, so inhibiting stabilization of littoral sands. Eolian accretion on hillslopes during a phase of drier climate would subsequently allow release of leached carbonates into throughflow waters until precipitated within sediments further downslope. Whether eolian activity was contemporaneous with or earlier than calcification is uncertain, but the presence of indurated ca-horizons over prismatic B-horizons does suggest a temporal sequence.

Environmental and stratigraphic interpretation of the external rubbles and littoral deposits at Elandsbaai will be discussed after consideration of the cave sediments.

4. SEDIMENTS IN ELANDS BAY CAVE

Elands Bay Cave is in a quartzite cliff face at 42 - 45 m elevation, with southwesterly exposure. Possibly of marine origin, it formed in relation to subhorizontal bedding discontinuities and ancient shear-zones along master joints. Enlargement now involves undermining and exfoliation of the roof: spall blocks are broken off at very long intervals, judging by their widely dispersed occurrence within a sedimentary sequence that spans well over 45,000 years according to ^{14}C evidence (PARKINGTON, pers. comm.). Uninterrupted ferromanganese streaking and prehistoric paintings on the walls and overhang indicate very slow change except for a little microsplicing of sand and grit along friable joint and bedding planes.

The sedimentary fill is fairly shallow, with several phases of occupation concentrated in different sectors of the flat, cave floor. Three major fill sequences can be recognized (see PARKINGTON 1976b, and pers. comm.):

(a) Basal frost-shattered quartzite rubble, up to 30 cm thick, has an early Middle Stone Age industry, that may be as old as the beginning of deep-sea stage 6, i.e. 200,000 B.P. (see SHACKLETON 1975), judging by dating of the Acheulian-Middle Stone Age interface in South Africa (see BUTZER, BEAUMONT & VOGEL 1978; SZABO & BUTZER 1979).

(b) An intermediate, mixed mineral-cultural deposit with next to no rubble or mollsuca, is composed of lenticular hearth and refuse deposits rich in charcoal powder; up to 1.3 m thick, the excavated section (80 cm as of 1977) spans ca. 21,000 to 10,800 ^{14}C years, with a date of greater than 45,000 B.P. in the underlying rubble, possibly on intrusive charcoal.

(c) A thin, upper sequence of shell middens, interstratified with limited mineral-cultural sediment, dates ca. 10,800 to 7900 B.P.; following an occupation break of several millennia, marked by an artificial disconformity, a smaller body of interstratified shell, hearths and ash lenses accumulated, with interruptions, ca. 3900 to 300 B.P..

Six samples were selected from the intact 21,000 to 10,800 B.P. section, which documents a major shift from terrestrial to marine subsistence patterns by the cave occupants. The results are presented in Fig. 2 and indicate a sandy loam throughout. The basic textural curve and the geochemical record essentially document the cultural component. Fired shell begin to appear ca. 15,000 B.P., raising the $CaCO_3$ and pH levels, while bone phosphates drop off sharply. By 11,000 B.P. intact shell debris becomes a major component, leading to accelerated accretion of less and less compact deposits.

The environmental background is better recorded in the 37 μ to 6.4 mm sieve residues that exclude organic components. Two depositional modes are apparent: sediments since 12,500 B.P. are better sorted in the coarse silt to sand grade, with a maximum in the 100 - 200 μ size range; sediments before 12,500 B.P. have more coarse components and a maximum in the 200 - 500 μ fraction. Semiquantitative quartz-sand microscopy shows that about two-thirds of the 11,000 B.P. sample matches with Holocene backshore sands in terms of rounding, while only one third of the 20,000 B.P. sample is of littoral-eolian type; the other samples are intermediate. In effect the local, cave contribution to the mineral sediment declined by 50 % between 20,000 and 11,000 B.P.. Although mechanical weathering in the cave may have declined a little, the increasing sedimentation rates with time argue that eolian deposition must have accelerated, presumably in response to the glacial-eustatic transgression then underway.

The terminal Pleistocene sediments of Elands Bay Cave do not document any local change of climate. Instead they record a fundamental change in proximity of the littoral environment, and so confirm the economic interpretation of the cultural record proposed by PARKINGTON (1976b).

5. SEDIMENTS IN DIEPKLOOF CAVE

Located 10 km ESE of Elandsbaai is another cave, Diepkloof, tested by PARKINGTON in January, 1973. This one faces north, but is otherwise similarly situated in a quartzite cliff face, just above a 25° slope leading down to Verlorevlei, 40 m below. Exposures are poor and the 1.5 m test pit had been largely backfilled when visited. There is a surface layer, 10 to 20 cm thick, of quite recent Later Stone Age materials, below which is an accumulation of at least 1.3 m with Howieson's Poort, a silcrete industry with crescents that forms a distinctive component of the Middle Stone Age sequence in South Africa, correlating with the cool, deep-sea isotope stage 5b, ca. 95 - 90,000 B.P. (BUTZER 1978a, BUTZER, BEAUMONT & VOGEL 1978). A finite Pretoria ^{14}C date of 29,400 B.P., obtained from the top of this unit (PARKINGTON 1976b), is presumably contaminated with younger charcoal; the date obtained at -60 cm is infinite ("greater than 45,270 B.P.") (PARKINGTON, pers.comm.)

The 3 sediment samples, extracted at -5, -25 and -55 cm, were intended to be no more than exploratory (see Fig. 2). They serve to show that the deposits differ from those in Elands Bay Cave. The Later Stone Age level is an organic loamy sand, disposed in a lenticular hearth and occupation deposit. The Howieson's Poort unit has a matrix of unusually organic loam, with bedding dominated by lenticular hearths, and increasing amounts of fine angular roof spall at depth. Salt laminae are present and largescale cementation is encountered at greater depths (PARKINGTON, pers.comm., and removed samples examined at the University of Cape Town). Also unusual in the Diepkloof samples are available potassium values of 13,500 - 15,250 parts per million (Fig. 2); these may reflect on abundant wood ash and slow

The 37 μ to 6.4 mm quartz-quartzite fraction shows a general peak between 200 and 500 μ, with the Howieson's Poort matrix increasingly poorly sorted with depth. Eolian-form sands are primarily found in the 100 - 1000 μ size range, compared with 200 - 2000 μ at Elands Bay Cave; this reflects greater distance from the sea. Eolian components decline from roughly a third, in the Later Stone Age level, to less than a quarter midway in the Howieson's Poort sequence. The conspicuous, frost-spliced roof spall of the lowest levels is paralleled in other South African caves (BUTZER 1978a, BUTZER, BEAUMONT & VOGEL 1978, DEACON & BROOKER 1976).

Tab. 1: A PROVISIONAL HISTORY OF GEOMORPHIC EVENTS NEAR ELANDSBAAI

14. Modern beach ridge, foreshore dune and calc-marsh development in littoral zone; local deflation of weathered eolian soils on upland plain or activation of coastal dunes due to degradation of vegetation, also rill-cutting in weathered eolian mantles on hillslopes; slow fluvial aggradation of upper estuarine zone. (Last several centuries).

13. Development of color B-horizon on transgressive backshore sands and slope rubbles. (Probably mid-Holocene)

12. Accretion of eolian littoral sands on footslopes and midslopes, and in Elands Bay Cave, maximum ca. 12,500 - 8000 B.P. during Flandrian Transgression. Later Stone Age settlement is documented since well before 21,000 B.P. (Transition of isotope stages 2 and 1)

11. Mobilization of stony colluvial deposits on footslopes (brown wash at Verlorevlei and Tunnel unit 5), followed by accumulation of block talus on midslopes, in response to accelerated slope denudation and frost-weathering. (Probably isotope stage 4)

10. Formation of massive calcretes in Tunnel units 3 and 4, surface cementation of red Verlorevlei colluvium, perhaps coeval with weak gley development in the latter. (Possibly isotope stage 5a)

9. Slope denudation and mobilization of red soil wash at Verlorevlei and of Tunnel unit 4, with frost-splicing in Diepkloof Cave. Howieson's Poort occupation. (Probably isotope stage 5b)

8. Last interval of major pedogenesis, with deeply oxidized cambic soils (Verlorevlei; strong prismatic soil on Tunnel unit 3; hummocky eolian soils of upland plain). (Isotope stage 5c or 5d)

7. Transgressive 6 m beach at Verlorevlei with warm mollusca, followed by formation of brine lagoons south of Cape Deseada, reflecting a drier climate. (Isotope stage 5e)

6. Midslope accretion of transgressive eolian sands (Tunnel unit 3) (Probably transition of isotope stages 6a and 5e)

5. Major frost-weathering in Elands Bay Cave and formation of grèzes litées (Tunnel unit 2) in response to cold-climate slope denudation. Early Middle Stone Age. (Probably isotope stage 6b)

4. Pedogenesis, including strong prismatic soil and subsequent massive calcrete on Tunnel unit 1a. (Probably representing two parts of isotope stage 7)

3. Midslope accretion of transgressive eolian sands (Tunnel unit 1a). (Possibly transition of isotope stages 8 and 7)

2. Large-scale, cold-climate slope mobilization (Tunnel unit 1). (Probably isotope stage 8)

1. Wave undermining near +13 m at Elandsberg Tunnel. (Possibly isotope stage 9)

6. CONCLUSIONS

The geomorphic record of the Elandsbaai area argues for three recurrent environmental anomalies: episodes with (1) frost-weathering and large-scale mass movements or colluvial deposition, with (2) deep pedogenesis, and with (3) aeolian activation and calcification. A sufficient number of stratigraphic sequences or datum points have been established to allow a provisional tabulation of geomorphic events (Table 1), using the distinctive paleosol horizons for cross-correlation.

This landscape history is necessarily incomplete, and could be readily expanded by the inclusion of older fluvial and eolian features, upstream or north of the Verlorevlei River, and of various littoral deposits south of Cape Deseada. But the present schematic chart, however tentative, allows a degree of external correlation with SHACKLETON'S (1975) deep-sea isotope stratigraphy and so provides a climato-stratigraphic context for the local geomorphic events. It would be premature to attempt to outline a cyclic littoral-continental sedimentation model, as has been possible in the Mediterranean Basin (BUTZER 1975), until the Elandsbaai study has been intensified and areally extended. Nonetheless, Elandsbaai provides critical components to elucidate the pattern of Pleistocene morphogenetic shifts in the western and southern Cape Province (see BUTZER & HELGREN 1972, BUTZER 1973a, 1973b, 1978a, HELGREN & BUTZER 1977, BUTZER et al. 1978). This pattern appears to correspond in many of its essential lines with that of the Mediterranean Basin (BUTZER 1975, 1987b), suggesting a satisfactory measure of hemispheric symmetry.

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