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Spring Sediments from the Acheulian Site of Amanzi (Uitenhage District, South Africa)

INTRODUCTION

The important Acheulian site at Amanzi Springs (25°29'E, 33°42'S) was first tested by R. R. Inskeep (1965) in 1963, followed by two seasons of extensive excavation by H. J. Deacon (1970) in 1964-66. The occurrences are found within a thin mantle of Pleistocene deposits on a hillside within the open, gently-sloping valley of the Coega River, some 19 km above its embouchure into the Indian Ocean, at Algoa Bay (Fig. 1). The local bedrock consists primarily of marly limestones ("Variegated Marl" of Engelbrecht *et al.*, 1962), sandstones, and shales of Cretaceous age that form an artesian basin underlain at depth by quartzites (of the mid-Paleozoic Table Mountain Series). The valley has an average relief of 100 m, cut below isolated remnants of a Tertiary planation surface (the Grassridge Plateau of Ruddock, 1968) at ca. 165-210 m elevation. The former springs of Amanzi erupted along the 3-8° slope of an 187-meter hill that represents a silcrete-capped outlier of this controversial surface.

The hydrogeology of the Amanzi Springs is known in a rudimentary fashion only (see discussion by Deacon, 1970: 91 ff.). Unlike other artesian springs of the Uitenhage Basin, they are thermal (32 °C) and rich in iron, probably deriving from pyrite-rich sandstones at the base of the local Cretaceous; relationships to regional surface and subsurface fault patterns are obscure. As a result of intensified bore-hole pumping in the Coega Valley, the waterhead now is some 18 m below the natural spring vents, and the limited nature of the reservoir is further indicated by rapid diminution of pump discharge at Amanzi only one week after tapping of new wells some 18 km away.

In Pleistocene times the eruption of the Amanzi Springs created a random scatter of elliptical or circular depressions, several meters deep and some 10-50 m in diameter; there are restricted to the north face of Amanzi Hill at ca. 135-165 m elevation. After the initial erosion of these hollows, several generations of spring sediments accumulated in this restricted area and now form a mantle as much as 7 m thick (Deacon, 1970). Acheulian occupations are recorded from some of the oldest of these depositional units.

The Deacon excavations of parts of two spring depressions established a detailed stratigraphy of the spring sediments that also appears to be reflected in other existing exposures. The present writer examined the sites briefly in 1969

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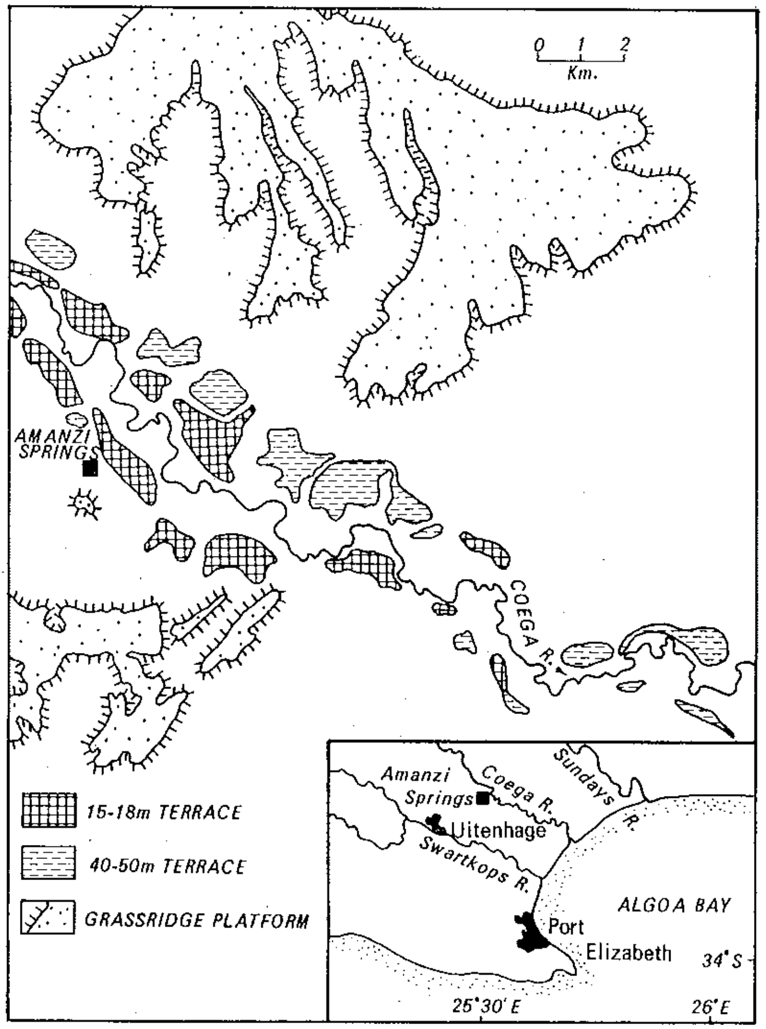

FIG. 1. - Amanzi Springs and the Coega Valley. Geomorphology modified after Engelbrecht *et al.* (1962).

and 1970, subsequently analyzing a suite of sediment samples in the Paleo-Ecology Laboratory of the University of Chicago. The results confirm and amplify the stratigraphic scheme of Deacon, which is as follows:

Amanzi Springs Formation

Balmoral Member	Several facies
Rietheuvel Member	(b) Grey-Black Silts
	(a) Brown Sands
Enqhura Member	(c) Marginal Clays
	(b) White Sands
	(a) Basal Clays

The sediments of the Amanzi Springs Formation are the subject of this paper.

The Sedimentary Analysis

A total of 39 samples were studied in detail (see Tables 1, 2, 4). In addition to macroscopic examination of structure, consolidation and bedding, color (dry) was determined by the *Munsell Soil Color Charts*, texture by hydrometer and wet-sieve analyses (see Butzer and Hansen, 1968, Appendix A, for methodology and grade units determined); textural classes and boundary definitions are given according to the U.S. Department of Agriculture classifications (Soil Survey Staff, 1960), with the sorting criteria following Payne (1942). Carbonate content was determined by the Chittick gasometric apparatus; pH (electrometrically) and electrical resistance in distilled water; and organic matter by an approximation technique involving titration after application of sulfuric and hydrofluoric acids. Microscopic scanning of sand-sized residues included a semi-quantitative estimate of quartz grain frosting and rounding: in view of the dubious value of elaborate, statistical quartz micromorphologies (see Butzer and Gladfelter, 1968), it was felt that more detailed studies were not warranted in a suite of relatively undistinguished sands.

The Sedimentary Column at Area 2

The more complete of the two stratigraphic sequences is exposed in Area 2 (Fig. 2, Table 1). The sediments can be described as follows.

Enqhura Member

(a) *Basal Clays.* Massive-bedded, pale yellow clay, with slickensides and very coarse, angular blocky structure (No. 1610). Intensively gleyed, with yellow mottling and diffuse staining. Ped faces show clay skins, with intrusive sandy materials filling old dehydration crack-networks. Patterns of limonitic discoloration in part suggest replacement of organic structures. The vertical range of over 3.3 m exposed by soudings and auger holes (Deacon, 1970, Fig. 13) probably gives a minimum estimate of true cumulative thickness prior to erosion and intrusion of younger sands. Contact abrupt and wavy.

(b) *White Sands.* At least three subunits of white to light gray, sandy loams, consisting primarily of medium-grade sands (Nos. 1600, 2039) with micro-pockets or lenses (many marking post-depositional infiltration) of clayey materials. Coarse prismatic structure in main part. The two youngest units rest on dipping lines of Acheulian artifacts and apparent manuports, while the oldest predates a period of spring activation. Several small spring vents are indicated by bulbous zones of light brown ferricretion (12-20 cm in diameter) that terminate in contorted lenticles of dark reddish brown, reddish yellow and white sandy loams. Intrusive micro-lenses of limonitic discoloration permeate much of the oldest sediment body while fine but distinct mottles in the younger subunits simply reflect soil water oxidation. Long vertical zones of fine, carbonized roots in younger part. Total thickness in

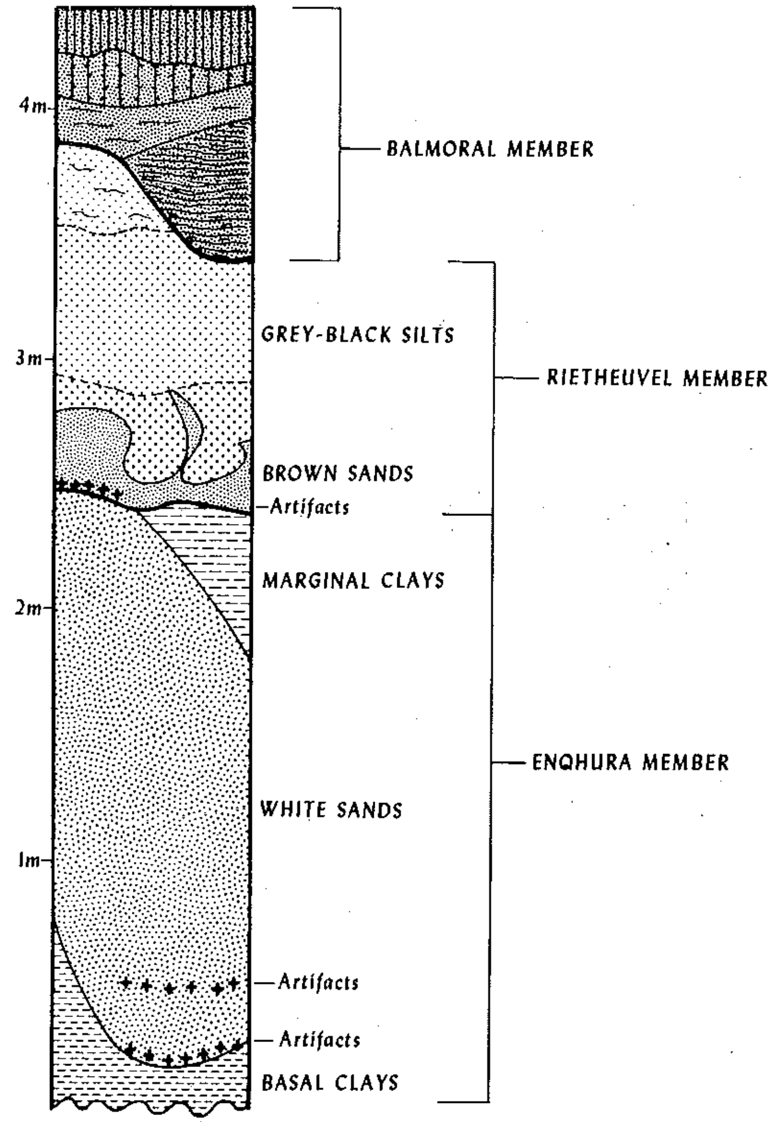

FIG. 2. - Composite Stratigraphic Profile of Area 2, Amanzi Springs (Based in part on Deacon, 1970: Fig. 13).

section 2.1 m (see Deacon, 1970: Fig. 13), but cumulative thickness at least 1 m more. Internal and subsequent contacts abrupt and wavy.

(c) *Marginal Clays.* Massive-bedded, white clays with some slickensides and coarse, angular blocky structure (No. 1162). Intensively gleyed, with yellowish-brown limonite deposited on ped faces. Rests on an unidentified subunit of white sands, with thickness in excess of 0.8 m (see Deacon, 1970: Fig. 13). Contact abrupt and irregular.

TABLE 1. - QUANTITATIVE SEDIMENT PROPERTIES OF AREA 2 SAMPLES

Lab. No.	Color (Dry)	pH	mV	Sand	Silt	Clay	Sorting
	Balmoral Member						
1614	10 YR 7/3	3.0	+ 390	62.5	24.0	13.5	Poor
1609	7.5 YR 4/2	5.1	270	59.5	27.5	13.0	Poor
1608	10 YR 6/3, 5 Y 8/1	3.7	350	49.5	40.0	10.5	Poor
2036C	7.5-10 YR 6/4	3.3	395	49.0	33.5	17.5	Poor
2036B	10 YR 7/2	3.6	390	74.5	14.5	11.0	Mod.
1603	7.5 YR 5/2	3.0	410	59.0	33.5	7.5	Poor
	Grey-Black Silts						
1613	10 YR 8/1	3.9	390	40.0	46.0	14.0	Poor
1611	7.5 YR 7/1	3.6	400	38.5	52.5	9.0	Poor
1612	10 YR 7/1.5	3.9	380	32.0	49.5	18.5	Poor
1607	2.5 Y 8/0	3.7	390	31.5	52.0	16.5	Poor
1606	10 YR 6/1	4.0	400	27.0	62.0	11.0	Poor
1605	10 YR 5/1	3.4	390	15.5	68.0	16.5	Poor
2037A	10 YR 3.5/1	2.6	420	9.0	73.5	17.5	Mod.
1602	10 YR 3/1	1.9	420	22.5	63.0	14.5	Poor
	Brown Sands						
1604	10 YR 7/2	3.9	400	56.5	23.5	20.0	Poor
2040B	10 YR 4.5 5/3	2.8	420	59.0	23.5	17.5	Poor
2040A	7.5. YR 4.5/2	2.9	395	50.5	27.5	22.0	Poor
1601	7.5 YR 4.5/3	2.8	380	55.0	27.5	17.5	Poor
	Marginal Clays						
1632	5 Y 8/2	3.2	400	0.5	34.0	65.5	Mod.
	White Sands						
1600	5 Y 7/2	3.6	410	80.0	7.5	12.5	Mod.
2039	10 YR 7-8/2	3.3	410	74.5	14.0	11.5	Mod.
	Basal Clays						
1610	5 Y 7/3	2.8	400	20.5	21.0	58.5	Mod.

Rietheuvel Member

(a) *Brown Sands.* Unstratified, brown to dark brown, variable sediment of intermediate texture (sandy loam, loam, sandy clay loam) and coarse prismatic structure. Sorting is poor with bimodal peaks in the 75-150 micron (sand) and the clay fractions (Nos. 1601, 2040A, 2040B). Diffuse and macroscopic organic matter abundant (to over 3%), with vertical rootlet structures still preserved.

Laterally this unit grades upwards into a light gray sediment (No. 1604) of slightly finer texture, with common and distinct yellow mottles; this facies probably already pertains to the overlying Grey-Black Silts. The contact of the Brown Sands and Grey-Black Silts is abrupt and wavy in Cutting 6, abrupt and irregular in most of Cutting 5, although locally gradual or interdigitated. These complications reflect on the cutting of one or more rills, and lateral slipping of the lower Grey-Black Silts, leading to the development of festoons and other distortions along the contact (in Cutting 5). This gravity deformation was probably contemporary with the micro-faults (vertical displacements up to 10 cm) that intersect the White Sands in the Deep Sounding (see Deacon, 1970: Fig. 14). Both phenomena suggest undermining near the center of the spring vent of Area 2, probably as a result of an episode of flush flow early in the period of the Grey-Black Silts. Consequently sedimentation was continuous in the marginal section of Cutting 5, despite erosional contacts elsewhere. The original thickness of the Brown Sands was in excess of 1.1 m.

(b) *Grey-Black Silts.* Massive-bedded silt loam, varying in color from black through gray to white in proportion to organic content. Organic materials include diffuse and macroscopic, carbonized forms, up to over 9% by weight, decreasing in importance upward through the sediment column as well as away from the former spring center. Samples 2037A and 1605-1607 show such a vertical shift in Cutting 5 with the color value moving from N3 to N8 as sand increases from 8 to 32%. Similarly samples 1602, 1612, 1611 and 1614 show a lateral cross-section outward from the former spring center through the uppermost beds of this unit: color value also decreases from N3 to N8 while sand content increases from 22 to 40% (to loams). Sorting is generally poor, with peaks in the 20-60 micron grade for the more organic samples, in the 50-150 micron grade for the less organic ones. Structure also varies from coarse prismatic (organic suite) to very coarse, angular blocky (sandy suite). Fine but distinct yellow mottles are evident in the less organic facies, indicating ground moisture oxidation. Part of the brownish yellow, ferricrete micro-lenses that impregnate the Grey-Black Silts (as well as the Brown Sands in Cutting 6) are related to mineral waters emanating from the spring " eye " active at that time, while others, including a discontinuous capping ferricrete, are much younger. Total thickness at least 1.3 m. Upper contact abrupt and wavy.

Balmoral Member

Perhaps the most representative section is that exposed in Cutting 5.

(a) *Channel Fill.* Well-stratified to laminated, in part turbulent-bedded, light gray, sandy loam with coarse, angular blocky structure (No. 2036B). Horizontal bands of strong brown, limonitic staining. To 50 cm thick in local pockets marking old channel. Abrupt, wavy contact.

(c) *Truncated Soil.* Pale brown loam with medium prismatic structure and traces of diffuse and macroscopic humus (No. 1608). Some fine distinct mottles (10 YR yellow), particularly in former organic structure and several small pockets or micro-lenses of more clayey texture that are due to penetration by mineral waters. This AC-horizon is some 20-25 cm thick, with an abrupt wavy contact above.

(d) *Colluvial Soil.* Bedded, dark brown, sandy loam with crumb structure and 8% organic content (diffuse and macroscopic) (No. 1609). A trimodal textural distribution (maxima in 100-150 microns, 5-20 microns, and clay fraction) and a higher pH (5.1) support the field indications for extensive reworking of surface materials. Some 18-25 cm thick.

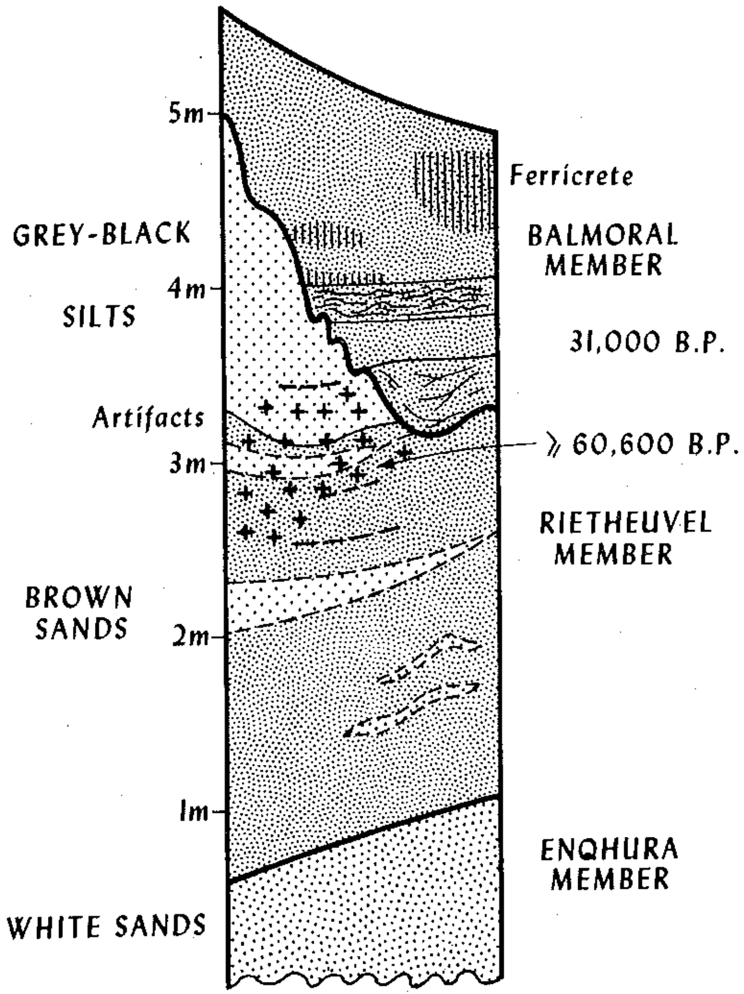

FIG. 3. - Composite Stratigraphic Profile of Area 1, Amanzi Springs Based in part on Deacon, 1970: Fig. 7.

Sediments comparable to those of the truncated soil are exposed in Cutting 6 and elsewhere, e.g. the brown sandy loam of No. 1603. On the other hand, the recent " waterhole fill " accumulating in Square 3 is a well-stratified to laminated very pale brown, sandy loam (No. 1614) that has similarities with the channel fill.

The Sedimentary Column at Area 1

Most of Area 1 has been disturbed, with the White Sands exposed at shallow depths. Other parts of the stratigraphic sequence are only preserved on the north-western sdie of the ancient spring depression. Units comparable to most of those in Area 2 are present here, but there are no heavy clays, and these are several facies differences (see Fig. 3). The sediments can be described as follows (see Table 2).

Enqhura Member

Represented exclusively by 2 m or so of White Sands, the Enqhura Member is poorly developed. The White Sands are well-sorted and stratified but weakly-structured, coarse sands (No. 1627). Acheulian implements were found on top of these sands, with some undiagnostic materials within them (Deacon, 1970). However, no subunits are in evidence here, and the silty or clayey inclusions typical of Area 2 are absent. Some macroscopic, carbonized organic matter is present. Abrupt, wavy contact.

Rietheuvel Member

(a) *Brown Sands.* A rather complex succession of facies variants, cumulatively in excess of 3 m but with few points of direct comparability with the Brown Sands or Area 2. Most characteristic are light gray sandy loams, poorly to moderately sorted with coarse subangular blocky structure (No. 1619). Colors, however, range from gray to white depending on the presence of organic matter (both macroscopic and diffuse). Contorted lenticles of clean sands occur in the lower half, where a distinct vertical decrease of humification is evident with time (see Deacon, 1970: Fig. 7). The upper half of the sequence is interbedded with gray lenses of laminated silt loam, with an organic content of up to 4% or more (No. 1620). Beds dip as much as 35° away from the spring center as texture becomes finer and organic matter is reduced, e.g. the well-stratified, pale yellow silt loam of No. 1621. Altogether the vertical sequence suggests two hemicycles of increasingly finer sedimentation. All of the facies show fine but distinct mottles to some degree, ranging from reddish yellow to yellow (7.5 YR-2.5 Y) in color, some diffuse and gleyed (in silty facies), some horizontally banded, and many related to former organic structures. Acheulian occurrences appear to be dispersed through sectors of the upper half of the Brown Sands. Clear to gradual, wavy contact to the Grey-Black Silts, abrupt and wavy or irregular to the Balmoral Member.

(b) *Grey-Black Silts.* The vertical succession of sediments (upwards from 1623 to 1625) in the west side of Cutting 10 shows a gradation of white, moderately-stratified silt loams to loams, the upper beds also weakly ferruginized (10 YR

Table 2. - QUANTITATIVE SEDIMENT PROPERTIES OF AREA 1 SAMPLES

Lab. No.	Color (Dry)	pH	mV	Sand	Silt	Clay	Sorting
	Balmoral Member						
1615	10 YR 6/2	3.2	+ 400	58.5	27.5	14.0	Mod.
1616	2.5 Y 6.5/2	3.5	400	85.0	*	*	Mod.
1617	10 YR 6/2	3.5	390	80.5	*	*	Mod.
	Grey-Black Silts						
1626	10 YR 5.5/1	2.9	400	33.5	51.5	15.0	Poor
1625	10 YR 6-8/2	3.4	400	51.0	38.0	11.0	Poor
1624	7.5 YR 8/0	3.6	400	36.0	57.5	6.5	Poor
1623	10 YR 8/1	3.9	400	18.5	72.5	9.0	Poor
	Brown Sands						
1622	10 YR 7/2	3.3	400	47.0	35.0	18.0	Poor
1618	10 YR 8/2	3.5	400	61.5	31.0	7.5	Poor
1621	10 YR/5Y 8/3	3.3	400	8.5	63.5	28.0	Mod.
1620	10 YR 5-6/2	3.3	400	38.5	53.0	8.5	Poor
1619	10 YR 7/2	3.4	400	58.5	24.5	17.0	Mod.
	White Sands						
1627	10 YR 7-8/2	4.3	320	99.8	0.2	0.0	Good

* Sieve analyses only.

brownish yellow) on ped faces, presumably in relation to the later ferricretion of parts of the overlying Balmoral sequence. Local fine, distinct mottles are mainly related to former organic structures. The lowest unit includes a gray, silty and organic lense, as well as dispersed, macroscopic humus and Acheulian artifacts. At the eastern end of Cutting 10, sample 1626 is a gray, silt loam with 2% organic matter similar to the standard facies in Area 2, so fitting the general pattern of lateral and vertical facies change. Cumulative thickness 1.6 m or more. Contact abrupt and wavy.

Balmoral Member

The Balmoral sediments above the striking unconformity in Cuttings 1 and 10 are well developed and may originally have represented a vertical column in excess of 3 m. Some basal contacts suggest erosion (the " pothole fill " of Fig. 7 in Deacon, 1970), others imply some mass-movement over clayey or silty substrata. In general the sediments are weakly-structured but conspicuously stratified, grading upwards from loamy sands to sandy loams (Nos. 1617-1615), all with a fair amount of macroscopic humus (to 1%). The upper units show yellow or brownish yellow

(10 YR) mottles in former organic structures, while some segments are cemented in a post-depositional ferricrete.

Altogether the Area 1 and 2 sections complement each other. The Enqhura clay units are probably not preserved in Area 1 since peak flow here was apparently greater, in view of notably greater sorting of the White Sands as well as the repeated erosion of a somewhat larger spring depression. The Brown Sands are much better developed than in Area 2, where a subsequent phase of flush flow removed most of the sediment record in the restricted area of original development. On the other hand, the Grey-Black Silts are best preserved in Area 2, where there has only been limited younger disturbance. Finally, the Balmoral subunits, restricted to a surficial mantle in Area 2, are preserved in a more complex sequence on the margins of Area 1.

Direct Interpretation of the Sedimentary Sequence

The preceding analysis of the stratigraphy and sedimentology of the Amanzi Springs Formation at Areas 1 and 2 is summarized in Table 3. Minimum cumulative sediment thickness in each area is close to 10 m while that of the formation itself is 13.8 m.

In order to evaluate the origin and nature of the sediments, a number of surficial deposits and soils (from test pits 1 and 2) were also analyzed, in conjunction with a bedrock sample of marly limestone, all exposed on the hillside above (see Table 4).

(a) It is immediately apparent that the local limestone (No. 1630) contributed little sand to either the surface soils (Nos. 1628, 1629, 1631) or to the Amanzi Springs Formation. This is verified by examination of the sand grains: those of the bedrock consist predominantly of the " milky " cryptocrystalline quartz that is almost entirely absent from any of the other samples. The dominance of sand grades in the surface soils raises the question of where these sands were obtained; in detail they are notably more rounded than those in the Amanzi Springs Formation, as well as a little more polished. It is probable that the surface soils are derived in appreciable part from now-eroded fluvial sediments once present on more extensive uplands. By contrast, the predominantly frosted and subangular sand grains of the spring sequence were presumably derived from the Cretaceous rocks in the artesian aquifer. There is no indication of eolian components, either in terms of micro-morphology or of grain-size distinction.

b) In regard to the silt fraction, it is impossible to demonstrate whether or not silt from dissolved marly limestones contributed significantly to the high silt content both of the surface soils and in subunits of the Rietheuvel Member. There is, however, some likelihood that this is indeed so.

(c) The clay fraction in the bedrock is associated with colloidal silica and is montmorillonitic. Similarly, the clays of the Enqhura Member ar expandable. Thus, although a series of X-ray diffractogram tests might demonstrate systematic characteristics of diagnostic value, it was not felt to be either productive or economical to make such tests at this time.

TABLE 3. - STRATIGRAPHY AND SEDIMENTOLOGY OF THE AMANZI SPRINGS FORMATION (with minimum thickness of units in meters)

Area 1 (9.6m)	Area 2 (9.8m)
Balmoral Member	
3.0*m* Several facies variants, with brownish grey loamy sands (mod. sorted, well strat.) and sandy loams (poorly sorted, massive). Top units subsequently ferricreted. Undiagnostic artifacts; C^{14} date 31,000 B.P. in lower third.	1.2*m* Several facies variants, with light grey or very pale to dark brown sandy loams and loams (poorly sorted, massive to well strat.; commonly mottled). Truncated, prismatic, *AC*-horizon at top.
Rietheuvel Member	
1.6*m* *Grey-Black Silts*. White loams and silt loams (poorly sorted, mod. strat., commonly mottled), with grey, organic silt loams at base near spring center. Acheulian near base.	1.3 *Grey-Black Silts*. Black to gray or white, silt loams and loams (poorly sorted, massive bedded, in part prismatic structure), highly organic near center and in lower units. Some mottling, ferricreation at top.
3.0*m* *Brown Sands*. Gray to white sandy loams (mainly poorly sorted, mod. strat., commonly mottled) with lenses of gray organic silt loam, white loamy sands, and gleyed, pale-yellow silt loam. Two cycles of increasingly finer and less organic deposition. Acheulian occupation in upper sequence; C^{14} date $\geq$ 60,600 B.P.	1.1*m* *Brown Sands*. Brown to dark brown sandy loams and loams (poorly sorted, massive with prismatic structure), moderately organic. Upper units eroded by later spring eruption. Acheulian occupation near base.
Enqhura Member	
(absent)	0.8*m* *Marginal Clays*. White, slickensided, gleyed clays.
2.0*m* *White Sands*. White, coarse sands (well-sorted, strat.). Some undiagnostic artifacts.	2.1*m* *White Sands*. White to light gray, sandy loams (mod. sorted, massive with prismatic structure, commonly mottled). With intrusive spring vents and at least 2 "surfaces" with Acheulian occurrences.
(absent)	3.3*m* *Basal Clays*. Pale yellow, slickensided, gleyed clays.

In sum, it is felt that the great bulk of the Amanzi Springs Formation must be attributed to sediments that welled up from deep, subsurface strata. What then can be said about the nature of spring flows through time?

The Basal and Marginal Clays suggest periods of quiet but protracted flow, during which very limited amounts of sand and silt were brought up from the aquifer. These fine suspended sediments contrast abruptly with the coarse-grained White Sands that indicate vigorous flow with effective sorting, during which the silt and clay components were swept away in surface runoff. Nonetheless, water velocities were variable and not uniform everywhere around the spring eyes. As a result, clayey pockets were formed at times of reduced discharge or in marginal sectors, particularly in Area 2. Flushing in Area 1 may have sporadically been more violent than in Area 2, thus accounting for erosion of the Basal and Marginal Clays, and any intercalated clayey beds in the White Sands. Alternatively, the spring(s) of Area 1 were generally more vigorous during the accumulation of the Enqhura Mb., leaving only a limited depositional record of well-sorted and well-stratified sands.

The Rietheuvel Mb. was deposited after an episode of effective flush flow. On the whole, the rate of spring discharge was intermediate, but two cycles of decreasing flow are indicated within the Brown Sands at Area 1, while the initial Grey-Black Silts in both areas suggest the waning hemicycle of another general incident of flush flow. A fair amount of stagnation and slow rates of accumulation are suggested by the presence of small quantities of flocculating soda salts in these fine sediments. However, discharge subsequently began to accelerate again and the terminating disconformity may mark a concluding episode of flushing and erosion. The complex lateral and vertical variations of organic matter versus grade coarseness indicate differential rates of accumulation and oxidation that indicate zonal arrangements around individual spring eyes as well as temporal fluctuations of a secular nature in discharge velocity. Altogether the complexities of the Rietheuvel Mb. must be rated primarily as facies variations, although stratigraphic implications are evident in a qualified way.

The Balmoral Mb. suggests multiple episodes of moderate discharge velocity, each of more limited duration than those reflected in the earlier sedimentary record. This would best explain the rapid alternations of facies, overall good stratification, and variable degrees of sorting. The abrupt vertical facies changes also indicate repeated episodes of erosion. The preserved facies of the Balmoral Mb. are on the whole also more peripheral to the spring eyes than those of the Rietheuvel, which further explains the limited evidence for organic materials. Ultimately little or no sediment was brought up by the springs., and the surface deposits were, in part, impregnated by iron precipitated from waters that issued gently from the now-quiet spring vents.

TABLE 4. - QUANTITATIVE SEDIMENT PROPERTIES OF TEST PIT SAMPLES

Lab. No.	Color (Dry)	$CaCO_3$	pH	mV	Sand	Silt	Clay	Sorting
	B-Horizon							
1628	5 YR 3.5/4	0%	7.3	+ 170	48.5	41.5	10.0	Poor
1629	5 YR 3/2.5	9%	7.7	170	52.0	48.0	0.0	Mod.
1631	5-7.5 YR 5/4	29%	7.7	180	41.0	47.5	11.5	Poor
	BC-Horizon (*bedrock*)							
1630	10 YR 9/2	68-77%	8.8	160	4.0	78.0	18.0	Mod.

Stratigraphic Position

The Amanzi Springs Formation can be broadly related in time to the evolution of the Coega valley. The latter is now cut an average of 100 m below the Tertiary Grassridge Plateau, which further west appears to find an equivalent in the 200-meter Coastal Plateau, a great planation surface of probable Pliocene or early Pleistocene age (Butzer and Helgren, 1972). Bedrock incision of the Coega River to its present level was interrupted at least twice, with the formation of alluvial terraces and related erosional platforms at about 40-50 m and 15-18 m above the present river bed (see Engelbrecht *et al.*, 1962, and compare geological map with contours of 1 : 50,000 topographic sheet).

The 40 to 50 meter terrace has been completely eroded on the southern side of the river in the Amanzi area and appears only to be recorded by widely scattered, well-rounded quartzite pebbles or cobbles found on the hillsides. The 15 to 18-meter terrace is well-preserved and consists of similar gravels in a matrix of unconsolidated, deeply oxidized, reddish brown sands. The Acheulian occupants at Areas 1 and 2 almost exclusively utilized and worked pebbles and cobbles of quartzite (see Deacon, 1970: 98 ff.) derived either from the hillside veneer or from the 15 to 18-meter terrace proper. Thus the spring deposits are younger than one or both of the terraces.

The excellent preservation of the Amanzi Springs Formation argues strongly for an age appreciably younger than the intensely denuded 40 to 50-meter terrace. However, there is no geomorphologic argument to relate the spring deposits to the 15 to 18-meter terrace, since the former are situated some 60 to 90 m higher than the latter and separated by considerable expanses of bedrock veneered with nothing but thin soil mantles. The weathering profiles are also of little comparative use since soil formation on the spring deposits was strongly modified by local edaphic factors, including highly acid parent materials, fine-textured sediments, spring discharge, and ferricretion. If the implication of Deacon (1970: 99, 107 f.), that the disturbed archeological horizons (surfaces 2 and 3) within the White Sands at Area 2 are related to colluvial reworking of hillslope deposits, is indeed correct (see further discussion below), then the White Sands might possibly be contemporary with the 15 to 18-meter terrace.

Four C^{14} determinations have been made of samples from the Amanzi Springs Formation (see Deacon, 1970: 112, 116 f.). These consist primarily of a *minimum* date of 60,600 ± 1100 B.P. (GrN-4407 and 4546, Vogel and Waterbolk, 1967) on wood from the upper part of the Brown Sands (Area 1, Fig. 3) and an age of 31,000 ± 1200/1100 B.P. (I-2241) from a wood fragment 30 cm above the base of the Balmoral Member (Area I, Fig. 3). Two earlier determinations on wood samples from the Brown Sands gave apparent ages of 32,900 ± 600 B.P. (SR-103, Area 1) and 38,100 ± 2000/1600 B.P. (Sr-107, Area 2). As Deacon (1970: 112) points out, these determinations are unacceptable since no particular efforts appear to have been made to eliminate contamination by younger organic acids: only 1% recent humic contaminant in a carbon sample of true age greater than 70,000 B.P. will simulate an apparent age of 38,000 B.P. Furthermore, the Salisbury dates are contradicted by the meticulously processed Groningen determinations, as well as by the date of 31,000 from the stratigraphically much younger Balmoral Mb.

Effectively the entire Rietheuvel accumulation should be considered beyond the dating range of the " enriched " radiocarbon techniques of the Groningen laboratory, and this writer feels that even the terminal beds must be older than 60,000 B.P. The unconformity between the Rietheuvel and Malmoral members would appear to represent a hiatus of 30,000 years or more. However, the available date on the Balmoral deposits may also be a minimum date, and Deacon (1970: 112) questions whether the two aberrant dates from the Brown Sands may be related to the Balmoral phase of spring reactivation, presumably either by humic contamination or by intrusion of younger wood fragments into older sediments during a violent spring eruption. One way or another 30,000 B.P. seems to be a reasonable central date for the Balmoral Member.

Assuming that the C^{14} attribution favored above is correct, the Balmoral phase would mark the Würm Interpleniglacial (in the terminology of van der Hammen *et al.*, 1967), while the Rietheuvel Member would be no younger than the Early Würm, being either early Upper or late Middle Pleistocene. In either instance the Enqhura sediment may well date from the Middle Pleistocene.

The apparent evolution of the Coega valley at and near Amanzi can be restated as follows:

(1) Formation of the Grassridge Plateau (165-210 m) by planation (? subaerial and littoral) with limited terminal sedimentation (? littoral). Pliocene or early Pleistocene?

(2) Protracted bedrock dissection, probably interrupted by several periods of dynamic equilibrium, as suggested by inconclusive bedrock benches poorly preserved on the higher hillslopes.

(3) Formation of the 40 to 50-meter terrace, marked by broad, stream-cut platforms (northern valley flanks only) and veneers of coarse to cobble-grade gravels. Valley floor locally at approximately 125 m elevation for a considerable period of time.

(4) Protracted bedrock dissection with erosion of much of 40 to 50-meter terrace.

(5) Eruption of Amanzi spring vents in 135-165 m elevation. Deposition of the Enqhura Member, well before 60,000 B.P., probably during Middle Pleistocene times. Possibly coeval with the formation of the 15 to 18-meter terrace, at which time the local valley floor was near 95 m elevation.

(6) Deposition of the Rietheuvel Member on the Amanzi hillside presumably during the early Upper Pleistocene (? Early Würm or Last, Eem Interglacial).

(7) Local and probably also general erosion, lasting 30,000 years or more (Lower Pleniglacial of the Würm Glacial).

(8) Deposition of the Balmoral Member on the Amanzi hillside during mid-Upper Pleistocene times (Würm Interpleniglacial).

(9) Limited deposition with erosion dominant to the present day.

ENVIRONMENTAL IMPLICATIONS

The previous discussion has implicitly admitted a broad parallelism of spring activity at two centers some 60 m apart. Within the normal range of local peculiarities this is indeed so, and the deep section of the Long Furrow (Fig. 4) confirms this from a third spring-complex over 100 m further away. The Long Furrow shows that a stratigraphic thickness of at least 4.5 m of Enqhura clays (? Marginal Clays) was impregnated by iron compounds prior to a period of major erosion. Susequently sands and silts of the Rietheuvel Mb. were deposited to a similar thickness in a peripheral, downvalley location by swift-flowing spring run-off, at first in a steep surfaced (7°) fan with inclined interbeds (at 12-22° angles), then in a larger, gentler (4°) fan-like zone of diffuse surface flow.

The field evidence consequently indicates repeated cycles of spring activity of a regional validity than can only be interpreted with reference to tectonics or to more general vicissitudes of the water supply of the artesian basin itself. There is no evidence of faulting in the Amanzi Springs Formation other than a few microfaults (see above) related to sediment slumping around the eroded cores of spring eyes. Faulting and other deformations are also not apparent in the Pleistocene terrace suites of the Swartkops, Coega and Sundays rivers, if the possible large-scale warping associated with continental flexure is neglected (see Engelbrecht *et al.*, 1962; Ruddock, 1947, 1968). Equally unlikely to produce repeated cycles of artesian output within relatively brief time spans are the glacio-eustatic fluctuation of sea level, between perhaps + 30 and — 150 m during the period represented (see Butzer and Helgren, 1972). Furthermore, it remains to be proven that the local artesian basin is even indirectly affected by sea level at the adjacent coast.

Consequently the most likely agency capable of producing massive changes in spring discharge are variations in the quantity of rainwater percolating to what appears to be a fairly small artesian reservoir. This is tantamount to saying that spring discharge was probably proportional to the amount of effective rainfall received over the basin. Most effective for groundwater replenishment are rains of moderate intensity with a duration of several hours, promoting optimal and

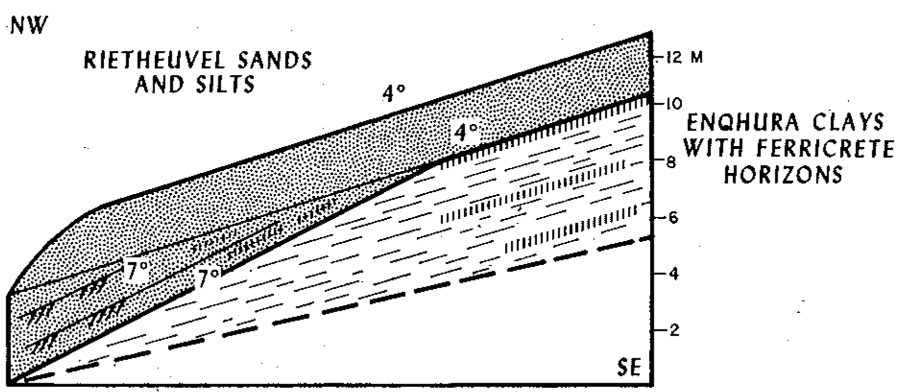

FIG. 4. - Schematic Section of the Long Furrow, Amanzi Springs.

protracted soil and bedrock infiltration. Brief rainfalls are subject to greater evaporative losses while high intensity rains, especially when of more than a few hours duration, lead to high runoff ratios.

At present the most reasonable explanation for the activity cycles recorded by the Amanzi Springs Formation appears to be a climatic one: more " effective " rains during the periods of accelerated flow, less during the periods of quiescence. The recent conspicuous behavior of the waterhead at Amanzi Springs suggests that any time lag will have been small, probably in the order of a few years or decades. Nonetheless, however plausible, this hypothesis can only be verified or rejected by a thorough hydrogeological investigation.

In view of the total absence of fossil bone in this highly acid yet aerated sedimentary environment, the only complementary evidence on environmental conditions is provided by the paleobotanical record. The section descriptions above show abundant " geological " indications for vegetation associated with the Rietheuvel Member and, in a rather more limited way, the other horizons. Yet the macro-botanical remains proved to be relatively uninformative. The wood fragments recovered from the Rietheuvel Member remain unidentified, although they do not pertain to *Podocarpus*, *Widringtonia*, or *Acacia karroo* (Deacon, 1970: 115). Wells (1970) has recognized the stems and roots of unidentified herbaceous but aquatic plants from the White Sands, as well as fruit segments similar but not identical to those of *Grewia occidentalis*. In the case of the Rietheuvel deposits he suggests the presence of dicotyledonous trees and shrubs morphologically similar to those now growing nearby, but prickle bases of an arborescent *Erythrina* species (? *E. caffra*) imply a more mesic environment but one no drier than at present (Wells, 1970). By contrast, leaf remains from the Balmoral Member suggest the presence of a woody community including xerophytic elements and imply a climate perhaps as dry as at present (Wells, 1970).

Equally rewarding should be an investigation of the surficial deposits and general geomorphology of the Coegá valley. The former include the alluvial terraces and silcretes referred to above, as well as calcareous cruts (*croûtes zonaires*) and colluvial red silts (*limons rouges*) such as are found in the Mediterranean Basin (see Butzer 1971a: 306 ff.). Cursory examination of the terrace gravels suggests periods of torrential discharge with greater stream competence than at present and probably accompanied by accelerated slope denudation. For this reason, the possible presence of colluvial " stone lines " in the White Sands of Area 2 provides a potential relationship to the 15 to 18-meter terrace. Whether or not the Coega terraces are related to the higher base levels provided by glacial-eustatic transgressions, as suggested by Ruddock (1957, 1968), does not alter the fact that these gravels would not accumulate with the contemporary hydrologic-geomorphologic balance. Hopefully there will soon be systematic study of the Coega valley.

Whatever the regional climatic interpretation ultimately suggested by palynological and regional geomorphological studies, the wet, spring settings of the Amanzi Acheulian remain unique among Acheulian paleo-environments in southern Africa. These springs differ from the habitation levels of Montagu Cave, with their apparent eolian interbeds (Butzer, 1973), from the pan-margin sites of Rooidam and Doornlaagte in the Kimberley District, from the probable spring-seep sites among fixed coastal dunes at Brakkloof (Robberg) and Geelhoutboom (Butzer and Helgren, 1972), and the various riverine sites of the Vaal Valley, where riverbank or gravel-bar loci were, in the main part, reworked by geomorphic agencies (Butzer, *et al.*, 1973, also 1971b).

Geo-Archeological Problems

The Amanzi Springs sites are among the very few Acheulian concentrations in southern Africa that have been systematically recovered from a geological context. Yet the peculiar milieu of a spring setting, with its syn- and epigenetic dynamics, has profoundly affected the archeological context. Deacon (1970: 107 ff.) describes three major forms of disturbance:

(1) Some artifactual materials are concentrated within various erosional irregularities and at the base of " pothole " fill. In such cases context is disturbed with some degree of selective sorting by fluvial action.

(2) Several of the major artifact concentrations (in the Brown Sands and Grey-Black Silts of Cutting 10, Area 1, and of Cutting 5, Area 2) are vertically dispersed (through 120 cm and 60 cm of sediment respectively), with a greater ratio of large (> 10 cm) to small artifacts towards the top. This and the varying attitudes of elongated tools suggest settling.

(3) The vertical concentration of artifacts on Surfaces 2 and 3 within the White Sands of Area 2 is associated with high concentrations of " natural stone " (75% and 67% respectively) in the pebble and cobble grade (14% longer than 6.4 cm on Surface 2, 35% on Surface 3). This selective sorting and the anomalous proportions of " natural stone " on these inclined surfaces (with angles of up to 25°) suggest differential transport and disturbed context. In addition, it is suspected that Surfaces 1, 2, and 3 converge laterally in Cutting 5 of Area 2 (Deacon, 1970: 108).

The present writer unfortunately did not see the artifacts of Amanzi Springs in place, nor were the crucial Surfaces 2 and 3 clearly visible in 1969-70. Consequently, the subsequent commentary is offered by way of suggestion and caution only.

(1°) Selective, fluvial sorting of artifacts is a strong probability in the vicinity of spring vents liable to violent fluctuations of discharge. Nonetheless the occurrence of erosional hollows and undulations does not necessarily indicate disturbance since (i) the surface may have been denuded by erosive action prior to occupation, and (ii) size sorting of artifacts can equally well be a product of artifact function in relation to specific tasks and activity areas (see Freeman and Butzer, 1967). To actually prove disturbance by flush flow it would be necessary to (i) demonstrate differential sorting at the scale of micro-stratifications (laminae), preferably in asssociation with wavy laminations, such as demonstrably occur in the Balmoral Member of Area 1, and to (ii) document systematic orientation of elongated tools.

(2°) Artifacts, particularly those of considerable mass, can and do subside in wet, muddy sediments such as those the Rietheuvel Member once provided.

However, artifacts can also be pushed down by human or animal trampling, and marshy spring peripheries are often intensely disturbed by such biological factors. It may also be impossible to recognize multiple sequential occupations in one locus if the sediments lack both adequate consistency and differential, horizontal sorting. Thus the well-stratified, sandy strata of the Acheulian site of Torralba (central Spain) provided clear evidence of multiple and distinct occupations (Freeman and Butzer, 1967), while massive marly beds at the same site allowed no such differentiation and their limited cultural inventory appeared to be dispersed randomly. Similar problems of apparent or real, diffuse vertical occurrence are provided by the sites of Rooidam (Fock, 1968) and Doornlaagte (Mason, 1967). At Rooidam there are multiple and discrete artifactual concentrations in a horizontal, lenticular suite reflecting alternations of subaqueous and subaerial conditions in a pan; there is only limited indication of lateral movements (Butzer, 1974). In the case of Doornlaagte, artifacts are dispersed through an incdined sedimentary medium (dipping at 1-5°) that suggests disturbance by colluvial agents or even by wave action (Butzer, 1974).

(3°)Photographs of Surfaces 2 and 3 at Amanzi Area 2 (Deacon, 1970: Plates 9, 10, as well as unpublished) show beyond doubt that both of these surfaces are disturbed. Artifacts and rocks commonly indicate systematic downslope orientation with their long axis either parallel or perpendicular to the incline, suggestive of sliding and rolling in response to washing, creep, or other mass-movements. Orientation diagrams would surely prove this point in quantitative terms. It is less apparent how these concentrations developed and whether they are indeed pavements. Only further excavation of a larger area, giving adequate three-dimensional perspective, will show whether a combination of spring-flushing, followed by colluvial redistribution of higher-lying " residues ", was indeed responsible. Altogether " natural stone " poses a major interpretative problem at Acheuloan open air sites. Such rocks—without evidence of flaking or utilization—are increasingly often considered to be manuports, e.g. at Latamne, Syria (Clark, 1968), at Melka-Konture, Ethiopia (J. Chavaillon, F. Hours and M. Taieb, unpublished), at Isimila, Tanzania (Hansen and Keller, 1971), and in various occurrences at Olduvai (Leakey, 1967, 1971). However, great caution is advised since both man and natural agencies, such as soil frost, can rearrange a surface litter of natural stones that were originally introduced by sheetwash, creep, etc. Thus at Torralba the size distribution of unmodified stone (> 1.5 cm) amid undisturbed cultural horizons produced identical histograms to modern slope screes (Butzer, 1965; 1971a: 456 ff.; also Butzer and L. G. Freeman, unpublished), while at the late Pleistocene site of Budiño, northwest Spain, 58% of the artifactual collection from primary occupation floors consisted of minimally-modified local quartz pebbles that were comparable in all morphometric aspects to pebbles in non-cultural segments of the same sedimentary medium, a footslope colluvium (Butzer, 1967). The " manuport problem " is no less perplexing at Amanzi Springs. Of 6639 artifacts from Area 2, totalled on Deacon's bar-graphs (1970: Figs. 18, 19), some 59% are classified as natural stone while the ratio is 34% of 1354 artifacts from Area 1 (Deacon, 1970: Fig. 17). Cobbles (> 6.4 cm) vary from 15 to 67% of the natural stone within the different assemblages. Yet these rocks are lithologically limited to quartzite and silcrete (87.4% and 12.6% respectively on surface 3, Deacon, 1970: 99), and lack the rounded ferricrete pebbles/concretions now common in subsoil colluvial components found upslope of Area 2. In fact there are very few quartzite pebbles in modern soils or colluvia at Amanzi, suggesting that their concentrations on Surfaces 1-3 are rather abnormal. However, to obtain more conclusive evidence for either point of view it will be necessary to sample and study the interstitial material of these " pavements ".

Altogether it would seem that spring sites are geologically — and contextually — neither more difficult nor more simple to interpret than are alluvial or slope sites (see Butzer, 1971a: chap. 15). The basic problem at Amanzi Springs is that there is a serious possibility of disturbance in almost all the occurrences, yet in most instances the unstable sediment type is unsuitable for confirmation or rejection of this possibility while mammalian fauna is unfortunately absent — precluding potential associations between artifacts and bone. Thus the correspondence of handaxe densities per 60-centimeter square with expected Poisson frequencies, as calculated for Surface 1 (Cutting 6, Area 2) (Deacon, 1970: 108), might obscure the fact that specific different artifacts may once have been found in meaningful functional association with specific, different bones on this very surface. Perhaps spring sites without adequate bone preservation are less than ideal for excavation.

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ZUSAMMENFASSUNG

Die Amanzi Springs Serie setzt sich aus 14 m. oligohaliner Sedimente zusammen, die überwiegend von artesischen Gewässern abgesetzt wurden. Drei stratigraphische Komplexe (mit untergeordneten Faciesbildungen) werden beschrieben und interpretiert. Altsteinzeitliche (Acheul-) Besiedlung war gleichzeitig mit Ablagerungen von Einheiten, die älter als 60.000 C^{14} Jahre sind und wahrscheinlich dem ausgehenden Mittelpleistozän zugehören. Geo-archäologische Probleme dieser Quellensedimente werden besprochen.

RÉSUMÉ

La Formation Amanzi Springs comprend 14 m. de sédiments oligohalines, qui ont été déposés par des eaux sousterraines artésiennes. Trois complexes stratigraphiques (avec des faciés subordonnés) sont identifiés et discutés. Des occupations acheuléennes sont associées avec des couches qui ont plus que 60,000 ans et qui appartiennent probablement aux dernières étapes du Pléistocène Moyen. Quelques problèmes géo-archéologiques des sédiments des sources artésiennes sont analisées.