A Geoarchaeological Analysis of Sediments from Sites 14 and 26

Mahlon Leonard

In addition to his goal of establishing a cultural sequence based on ceramics and other artifacts, Prof. E. W. Gifford was interested in documenting other aspects of past lifeways in New Caledonia, including the use of natural resources. Gifford and Shutler pursued this objective in part by carrying out analyses of site "composition" (1956:16-18, tables 1-12). For this purpose, they took "samples of midden deposit from pit walls," noting that "no selection was exercised." "Whatever came--stone, shell, sand, earth, coral, potsherds, etc.--was bagged for the samples" (1956:16). Sediment samples were taken every 6" starting at 3" below surface. Fortunately, along with artifactual material, Gifford and Shutler curated these sediment samples from their excavations on New Caledonia, including the residue left over after these samples had been screened in the laboratory through 3 mm mesh. Gifford and Shutler commented that these curated residue samples might have "future use for chemical analysis of ash and powdered charcoal content" (1956:18). Indeed, their foresight in keeping these sediment samples has allowed us to carry out additional analyses, with the aim of better understanding the basic stratigraphy and formation processes of these sites.

Site 14 lies 1 mile from the Lapita Site 13 on the northern side of the Foué Peninsula. At Site 14 Gifford and Shutler dug two pairs of 6 by 3 foot grids into a beach midden above the sea at high tide and below an artifact bearing hillside. Site 14 was known in historical times as a fishing camp, and may have been so in Lapita times. Column C2-D2 comprises 13 samples taken at 6" intervals beginning at 3" below surface and extending to the last excavated level at 75" below surface (Table 1). The sediment samples from Site 26 were taken from pit B1-B2, and extend to 39" below surface (Table 2). I analyzed all samples for chemical content, Munsell color, grain size, and micro-constituents. The primary goal was to understand site formation processes and the context of the cultural material.

Methods

pH Analysis

The pH of sediment samples from archaeological contexts can be used as an aid to defining layers in an otherwise homogeneous stratigraphic section (Deetz and Dethlefsen 1963), and to assess post-depositional conditions contributing to artifact and midden preservation, especially bone and shellfish. The acidity, neutrality, and alkalinity of sediment is measured by pH. Twenty grams of air-dried sediment measuring less than 2 mm per particle was placed in a 50 ml beaker. Twenty ml of distilled water was added to the sample, stirred, and allowed to sit for one hour. The sample was then measured three times with an electronic pH meter which had been calibrated with standard solutions of pH 7 and pH 4. The average of the three readings was recorded as the pH of the sample, and these data are presented in Tables 1 and 2.

Table 1
Analytic Data for Sediment Column C2-D2, Site 14

Sample Depth	Color Dry	Color Moist	pH	Phosphate %	Organic Matter %	Carbonates %
3"	10YR 2/1	7.5YR 2/0	7.13	52.01	14.36	5.68
9"	10YR 2/1	7.5YR 2/0	7.28	62.09	11.31	5.64
15"	10YR 3/1	7.5YR 2/0	7.29	61.79	9.28	6.01
21"	2.5Y 3/0	10YR 3/1	7.41	58.06	7.45	7.05
27"	10YR 4/1	10YR 3/1	7.45	47.31	5.68	7.25
33"	10YR 4/2	10YR 3/2	7.77	47.89	3.30	7.22
39"	10YR 5/2	10YR 3/2	7.79	41.24	3.60	8.14
45"	10YR 6/3	10YR 3/3	7.67	46.20	3.89	9.18
51"	10YR 7/2	10YR 5/3	7.80	59.75	3.96	11.66
57"	10YR 6/3	10YR 5/4	7.91	73.01	3.68	11.68
63"	10YR 6/2	10YR 5/4	8.01	66.76	4.23	10.71
69"	10YR 5/2	10YR 5/4	8.65	77.68	3.69	10.71
75"	10YR 5/2	10YR 5/4	8.48	60.51	3.49	9.30

Table 2
Analytic Data for Sediment Column B1-B2, Site 26

Sample Depth	Color Dry	Color Moist	pH	Phosphate %	Organic Matter %	Carbonates %
3"	5YR 5/1	10YR 2/1	7.15	67.93	9.09	22.29
9"	5YR 5/1	10YR 2/1	7.87	64.89	12.84	9.90
15"	5YR 6/1	10YR 3/2	7.76	68.92	12.69	9.98
21"	5YR 4/1	7.5R 2.5/0	7.65	58.99	16.64	8.03
27"	5YR 3/1	10YR 2/2	7.61	57.41	17.98	5.23
33"	5YR 2.5/1	7.5YR 2/0	6.53	47.14	19.70	2.09
39"	7.5YR 4/2	10YR 3/1	6.53	13.69	13.49	1.51

Phosphate Analysis

Phosphate is deposited in the soil by excrement and other organic debris, and as such is an indication of occupational intensity (Cook and Heizer 1965; Davidson 1973). Phosphate analysis has proved especially useful in locating occupational sites and animal paddocks (Craddock et. al. 1985). The purpose in performing this analysis on the New Caledonian sediment samples was to confirm occupational layers as supported by artifactual evidence. The percent phosphate in 1 gram of sediment was determined. This test required the preparation of three solutions: a 6 N HCl solution, an acid molybdate solution, and an ascorbic acid solution.

One gram of sample was added to 15 ml of 6 N HCl, shaken, and then allowed to stand for 30 minutes. Twenty ml of the acid molybdate solution was then added to the mixture, followed by 15 ml of the ascorbic acid solution, then shaken and allowed to settle. The extract was then measured in a colorimeter at 600 angstroms. The values from the colorimeter were then added to a formula to determine the percentage of phosphate in the sample (see Tables 1 and 2).

Organic Matter and Carbonate Analysis

The analysis of organic matter and carbonate content in the sediment samples helps to describe and document potential occupational layers as well as naturally occurring phenomena. The loss-on-ignition technique was used to estimate organic matter and carbonates in the sediment samples. The theory behind this method is that when a sample is heated, all organic matter burns off completely at or below 550° C, and calcium carbonate ($CaCO_3$) evolves into carbon dioxide gas completely between 800 and 1000° C (Stein 1984). A 3-5 gm sediment sample of less than 2 mm grain size was ground with a mortar and pestle and placed in a pre-weighed crucible. The sample was then dried for 1 hour in a 100° C furnace, removed to cool, then placed in a desiccating cabinet for 1 hour. The sample was then weighed and placed in a 550° C furnace for 1 hour. After cooling and desiccating, the sample was weighed and the percentage of organic matter calculated. This process was then repeated at 1000° C, and the percentage of carbonates calculated. The results are presented in Tables 1 and 2.

Color Analysis

The sediment sample colors were recorded using the Munsell system. This was done by comparing air dried and moist samples to the *Munsell Soil Color Charts* (1988) and recording the code. This test was done mainly for descriptive purposes.

Grain-size Analysis

Grain-size analysis was performed by the combination of two procedures. The "residue" samples were first recombined along with other sediment materials (originally disaggregated by screening through 3 mm mesh in Gifford and Shutler's analysis) into bulk form according to depth. The samples were then randomly split and half the sample was then treated to remove organic matter. This was done by adding 30% hydrogen peroxide to the samples and letting the organics burn-off over a period of several days. After the mixture no longer fizzed upon addition of more hydrogen peroxide, the mixture was heated in a water bath to 80° C, and left until no more reaction was observed. The sample was then dried in a 80° C oven. The sample was then wet-screened through a 4 phi (ϕ) sieve using a dispersant, or peptizing agent, to help break up the sample into its individual grains. The smaller than 4 phi particles were then reserved for pipette analysis. Upon drying, the larger than 4 phi particles were placed in a sieve shaker to separate the particles into individual phi sizes from -2 phi to 4 phi; that is, sand-sized sediments. The phi classes were then weighed.

The second procedure of grain-size analysis utilized the pipette to determine the weights of phi classes between silt and clay or 4 phi and 11 phi. This was done by suspending the <4 phi particles in 1 liter of peptizing agent by shaking the sample tube, and taking pipette withdrawals of 20 ml at precise times and depths. The withdrawn material was then dried and weighed. The percent totals of phi classes were calculated, and from these a mean phi size at one standard deviation was calculated. The results of the grain-size analysis are presented in Tables 3 and 4.

Table 3
Grain Size Analysis for Sediment Column C2-D2, Site 14

Sample Depth	Sand %	Silt %	Clay %
3"	88.6	11.0	0.4
9"	68.3	29.4	2.3
15"	72.7	19.8	7.5
21"	69.3	16.9	13.8
27"			
33"	96.9	0.5	2.6
39"	95.8	1.4	2.8
45"	95.8	2.9	1.3
51"	93.4	5.6	1.0
57"	95.2	2.7	2.1
63"	96.4	1.5	2.1
69"	98.2	0.5	1.3
75"	98.8		

Table 4
Grain Size Analysis for Sediment Column B1-B2, Site 26

Sample Depth	Sand %	Silt %	Clay %
3"	72.4	22.0	5.6
9"	59.4	35.5	5.1
15"	39.0	53.7	7.3
21"	76.1	19.1	4.8
27"	66.1	30.1	3.8
33"	87.2	9.1	3.7
39"	79.6	16.5	3.9

Point Count Analysis

The point count analysis was conducted with the materials in the -2 phi, -1 phi, and 0 phi classes. This analysis was performed using a microscope to count 300 grains, when present, in each phi class and identify them to class; that is, angular shell, water-rounded shell, rock, coral, bone, ceramic, or miscellaneous objects. These data were then used to spot trends in naturally and culturally-occurring items in relation to depth, and to confirm a cultural or sterile layer. I have combined the figures from the separate phi classes and presented a percentage frequency chart to help examine the data. Point count data are presented in Tables 5 and 6.

Table 5
Point Count Data for Sediment Column C2-D2, Site 14
(numbers expressed as % of total sample)

Sample Depth	Shell	Rounded Shell	Rock	Coral	Bone	Ceramic	Misc.
3"	6.6	64.5	23.2	2.9		1.7	1.2
9"	9.3	35.9	46.6	6.4	0.02	0.02	0.02
15"	17.3	31.6	42.5	8.0		0.05	
21"	28.7	18.4	43.7	8.5	0.05	0.02	
27"	27.5	16.7	45.0	8.9	0.09		1.1
33"	11.7	12.9	68.0	5.3	1.5		0.06
39"	16.2	12.4	50.0	20.4			
45"	24.1	20.6	25.2	28.5	1.1		0.05
51"			29.7	30.1		0.06	0.09
57"			24.4	37.1	0.01	0.01	0.01
63"	11.4	26.8	31.7	29.2	0.01		0.07
69"	8.3	25.0	40.2	25.8	0.01		0.06
75"	4.9	17.6	63.4	13.7			0.05

Table 6
Point Count Data for Sediment Column B1-B2, Site 26
(numbers expressed as % of total sample)

Sample Depth	Shell	Rounded Shell	Rock	Coral	Bone	Ceramic	Misc.
3"	35.9	8.6	42.0	9.9	1.9	0.02	1.6
9"	38.8	1.3	23.6	2.3	10.2		23.8
15"	33.3	4.0	26.6	1.7	16.2		18.1
21"	45.4	2.9	24.4	0.09	12.4		14.0
27"	34.1	3.7	39.4	4.1	3.6		15.1
33"	14.1	10.4	62.5	5.9	0.09		6.6
39"	5.5	6.6	85.5	1.5			0.08

Results and Interpretations

Site 14, Column C2-D2

The first 5 levels of Site 14, column C2-D2, 3-27" below surface, are dark in color. The samples become progressively lighter in color, more yellow, from 27-45". A concreted layer between 51-63" exhibits a dull yellow color, as do the successive levels down to the bottom at 75".

As expected, the results of the loss-on-ignition tests show that the top levels of the column are the richest in organic matter, and the bottom levels are uniformly the poorest. The organic matter percentages exhibit an inverse relationship to the calcium carbonate percentages. Calcium carbonate is found in shells and coral, and the highest calcium carbonate readings are logically found in the cemented layer and in the levels below it.

The pH levels of the column start with a neutral 7 at the top and gradually increase to an alkaline 8.5 at the base. This is to be expected here for the organic matter at the top of the column makes the sediment more acidic, and the heavier concentrations of calcium carbonate in the base levels cause the soil to become more alkaline. A pH level of between 7.8 and 8.2 is an indicator of the presence of calcium carbonate. Indeed, at the cemented layer which is rich in calcium carbonate, one notices that the pH levels range from 7.8 to 8.01 (51-63"). The pH at this site should have little bearing upon artifact preservation since the artifact bearing levels are towards the top of the column where the pH is almost neutral.

At Site 14 the phosphate levels are highest at the bottom and top with a dip in phosphate values in the middle levels. The lowest phosphate levels occur just above the concreted layer at 51-63", and then rise toward the bottom. These data approximate the model that when the acidity is high--a lower pH value--the phosphate level will be low. I cannot explain why the phosphate levels are high (indicating decayed occupational debris) in the culturally sterile levels other than to posit that it might have to do with the high calcium carbonate content of these levels.

The grain-size data for column C2-D2 exhibit an amazing uniformity below the 21" level. The levels between 27-75" exhibit >90% sand. This indicates that one type of depositional process is responsible for the sediment below 21", and other processes for the higher levels.

The point count data exhibit artifactual evidence of a human presence from the top level down to 27". Ceramics are found in all levels from 3-21". At 27" charcoal is evident. Gifford and Shutler reported a hearth at the 45" level, so human occupation is evident. The levels between 27-45" exhibit no artifactual material, nor do they exhibit a high percentage of fractured shells. Occupation of these levels is neither proved nor disproved by the point count data. The cemented layer contains some ceramics, so occupation is possible. The bottom three levels contain no artifacts and are culturally sterile.

In summary, the levels between 3-27" represent the intensively-occupied cultural layer and have the darkest sediment color, highest organic matter, high phosphorous, neutral pH, and high silt-clay content relative to the culturally-sterile levels below. The sterile levels are lighter in color, have low organic matter, relatively higher pH, high phosphorous possibly due to leaching, and more sand. The point-count data identified more coral in the lower levels, probably representing beach-building episodes.

Site 26, Column B1-B2

Site 26 lies in the hills above Site 13. It has been continually occupied in historic times. Since Site 26 is not on the coast, its sediment resembles its terrigenous parent soil which is most likely from the hills above. Site 26 is a large site, and column B1-B2 is a sampling of one wall of one pit dug over a large area. Therefore caution must be exercised when generalizing about the site formation processes over the entire site.

The color of the sediment samples from Site 26 is dark gray when dry, black when wet. The sediment appears to become darker near the bottom of the pit. Column B1-B2 pH levels exhibit a steady drop from 7.87 at the top to 6.53 at the lowest level. This pit demonstrates the inverse relationship pH levels have with phosphate levels. The high phosphate levels at the top of the excavation are in concert with the fact that occupation is, and has been, continuous. The higher acidity of the lowest levels could have an effect on artifact preservation.

The loss-on-ignition data exhibit high levels of organic matter at all levels increasing with depth. The calcium carbonate levels exhibit an inverse relationship to the organic matter levels, as they begin high and drop to very little at the base level. The high calcium carbonate levels in the upper levels are due, I believe, to a higher concentration of shell, most likely transported by human agents.

The grain-size data for Site 26 demonstrate that significant amounts of silt occur at most levels reflecting the setting of the site at the base of a ridge slope. Lateritic soils contribute a relatively higher proportion to the site matrix than at Site 14. I believe that the grain-size data for site 26 are entirely in keeping with site 26 being in a setting whose depositional history is dependent upon parent material from terrigenous source.

Evidence for occupation at all levels can be found in the point count data. Charcoal is found in abundance from 3-33". It also occurs at the base level, but in small numbers. A high percentage of angular shell is also found from 3-33". The percentage of angular shell at the base level is small. From this evidence it is unclear whether the base level was an occupational one. Some of the material in the 39" level may have derived from the upper cultural levels.

Conclusions

As Kirch observes in the Introduction to this volume, a major problem with Gifford and Shutler's field methods was their use of arbitrary 6-inch levels to control their excavations. Fortunately, however, they saved sediment samples taken from their pit walls, and these can be analyzed as a means to reconstruct the natural stratigraphy and depositional histories of their sites. At Site 14 my analysis shows that there were major changes in the nature of deposition over time. The occupation levels appear to extend from the top of the midden down to 45" where Gifford and Shutler found a hearth. A concreted layer occurs between 51-63", and occupation at this layer seems unlikely. My analytical evidence suggests that the bottom three levels of the excavation are entirely sterile. Long term, sustained occupation at this site seems unlikely based upon the chemical and loss-on-ignition evidence. I believe that Site 14 was a part-time settlement, used intermittently. At site 26 the occupational periods extend throughout the levels. The bottom level may not have been occupied, although I believe it was. All the evidence for the other levels suggest long and extended occupation. These results provide an independent check on the analyses of ceramics and other materials from sites 14 and 26, presented elsewhere in this volume.