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Cover Photo: Outcrop showing Pleistocene soil profile,
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CORRELATION OF PALEOSOLS ON SAN SALVADOR ISLAND USING PALEOMAGNETIC DIRECTIONS

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ABSTRACT

Correlation of paleosol deposits on San Salvador, based on paleomagnetic directions, has been a goal for several years. This technique relies on being able to distinguish small but statistically different paleomagnetic directions recorded in various paleosols. Different paleomagnetic directions would arise by paleosols recording different periods of the normal secular variation of the geomagnetic field. Similar directions would presumably indicate formation and magnetization during a specific time period of secular variation and thus provide a basis for correlation. Sufficient data now exist to be able to attempt stratigraphic correlation of individual paleosol deposits.

Statistical comparisons of paleomagnetic directions suggest that it is possible to identify two general groups of paleomagnetic directions, separated by about 5°. These groups appear to be correlated with paleosols occurring above and below the late Pleistocene Grotto Beach Formation (last interglacial or oxygen isotope substage 5e, circa 125 Ka). Although this work is preliminary, the initial results are encouraging.

INTRODUCTION

Paleomagnetic work on San Salvador Island, Bahamas began in 1985 when Mylroie and others (1985) attempted to apply paleomagnetic reversal dating to the paleosol overlying the Owl's Hole Formation. The Owl's Hole Formation is an eolianite deposited prior to the last interglacial (oxygen isotope substage 5e, circa 125 Ka), with an age associated with oxygen isotope stages 7 (220 Ka), 9 (330 Ka) or older (Carew and Mylroie, 1994) The evidence for a reversal was equivocal and was reexamined by Panuska and others (1991). These investigators found that initially reversed magnetic directions cleaned to normal magnetization with alternating field demagnetization; thus, these data carried no specific implications for the initial age of the paleosol. However, Hudson and Panuska (1990) and Panuska and others (1991) found that some of the paleosols gave statistically different mean paleomagnetic directions suggesting that paleomagnetic correlation of paleosols might be possible.

With the recent circumstantial evidence for paleomagnetic stability at two localities and demonstrable stability at a third locality (Panuska and Mylroie, 1993; Kirkova, 1994; Panuska and others 1995, this volume), the paleomagnetic directional correlation of paleosols appeared to be an attainable goal. Here we present new paleomagnetic data for Singer Bar Point and Miller Pond (Figure 1), compile existing data sets and make some preliminary paleosol correlations based on these data. While the potential for a useful correlation tool is quite good, it must be emphasized that paleomagnetic data should be

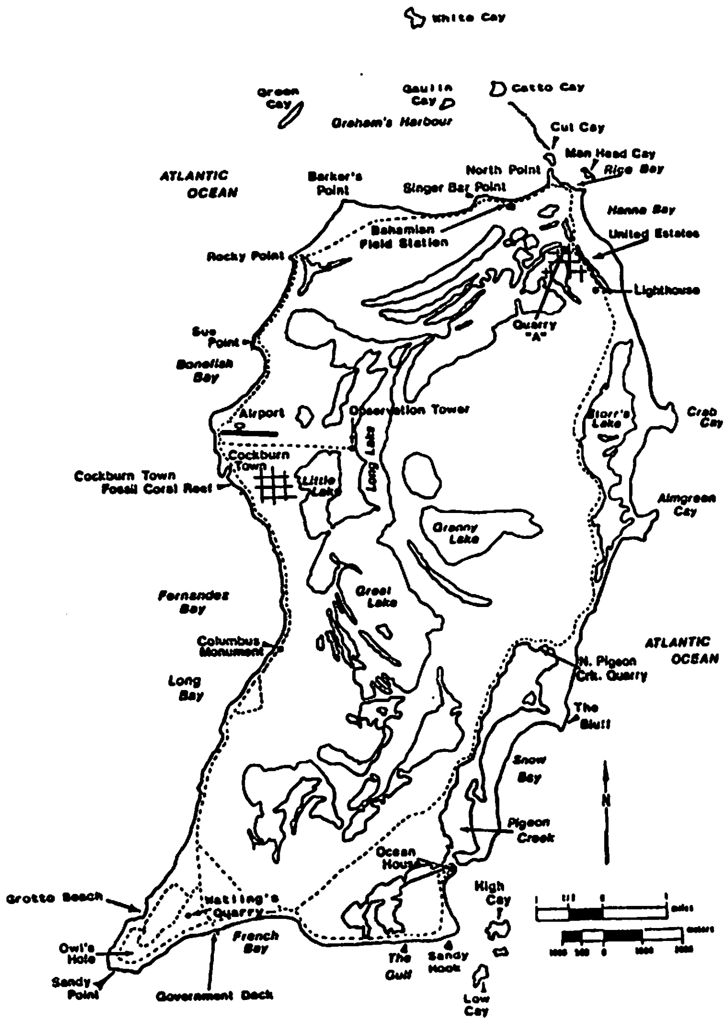

Figure 1. Map of San Salvador Island, showing key landmarks and sample locations.

used as one criterion for correlation and should not be considered to supersede stratigraphic evidence.

NEW PALEOMAGNETIC DATA

Singer Bar Point

Seven samples were collected from Singer Bar Point, located approximately one kilometer west of the Bahamian Field Station (Figure 1). Initial intensities were fairly strong, measuring about 2 x 10^{-5} emu/cm^3. Characteristic remanence directions were isolated after cleaning to peak AF field intensities of 100-200 Oersteds (Oe).

Most samples began to show modest effects of RRM at cleaning intensities of 150 Oe. In general, the angular variation due to RRM acquisition in opposite orientations at the same cleaning intensity were 5° or less. Averaging the directions obtained from normal and inverted sample orientations appeared to remove the effects of RRM adequately, giving nearly linear demagnetization plots (Figure 2). Individual sample remanence directions showed good agreement, with the mean direction kappa value in excess of 100 and a circle of 95% confidence of only 6° (Table 1).

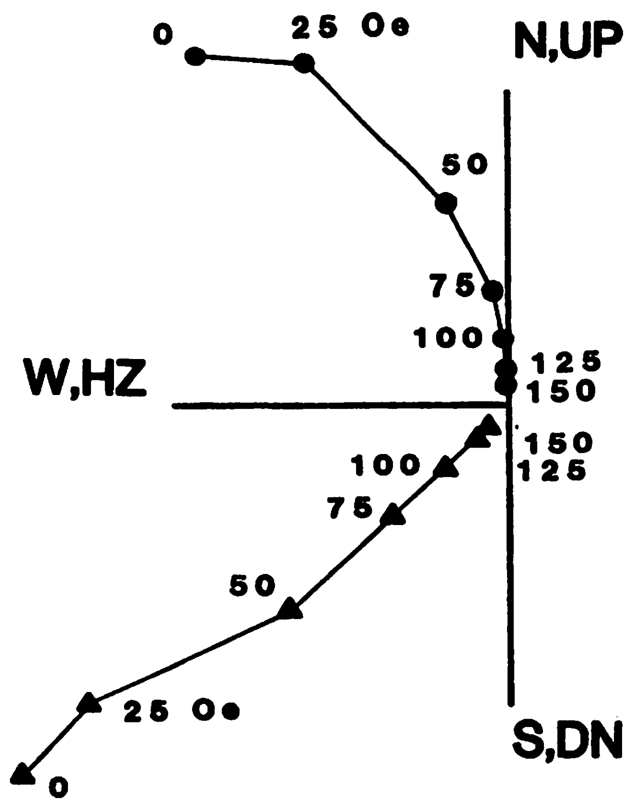

Figure 2. Demagnetization plot of a representative sample from Singer Bar Point. Higher demagnetization levels are averages of directions measured after both normal and inverted sample orientation in the AF demagnetization unit. The excellent linear trend towards the origin indicates that the modest effects of RRM have been removed.

Miller Pond

Miller Pond is located approximately 0.5 km west of the Bahamian Field Station. Nine samples were collected but a computer malfunction destroyed the data for 5 samples. The four surviving data sets displayed very well behaved linear vectors. All secondary components were removed by 50-100 Oe of AF cleaning. Initial intensities were somewhat

TABLE 1
SINGER BAR POINT - PALEOMAGNETIC DATA

Sample	*Demag Level (Oe)*	*%NRM*	*NRM Intensity*	*Geographic*	
				Dec	*Inc*
187A	150	8	2.2E-5	355	53
188A	200	4	2.6E-5	337	56
189A	100	12	2.3E-5	349	46
190A	150	5	2.6E-5	351	45
191A	200	2	2.2E-5	354	51
192A	150	4	1.9E-5	8	50
193A	175	3	2.1E-5	3	42
Mean Direction: (κ = 102.1; α_{95} = 6.0°; R=6.971; N= 7)				354	49

TABLE 2
MILLER POND - PALEOMAGNETIC DATA

Sample	*Demag Level (Oe)*	*%NRM*	*NRM Intensity*	*Geographic*	
				Dec	*Inc*
169A	300	29	3.5E-6	1	34
170A	200	63	1.9E-6	0	42
171B	225	30	3.7E-6	1	39
172A	500	20	2.7E-6	356	43
Mean Direction: (κ = 335.0; α_{95} = 5.0°; R = 3.991; N=4)				0	40

weaker than the Singer Bar Point samples, about 3 x 10^{-6} emu/cm^3. No significant RRM was detected and directional clustering of remanence directions was very tight, kappa = 335 and a 5° circle of 95% confidence. The summary data are shown in Table 2.

PALEOMAGNETIC CORRELATIONS
Pre-Grotto Beach paleosols

As a starting point, it is first necessary to establish paleosol correlations based on firm stratigraphic evidence before attempting any paleomagnetic correlations. Two paleosols are exposed in Watling's Quarry (Figure 1); the geology of this exposure is outlined by Carew and Mylroie (1994). The lower paleosol overlies bioclastic eolianite of the Owl's Hole Formation. This paleosol is overlain by oolitic eolianite of the Grotto Beach Formation. The Grotto Beach Formation is in turn capped by a calcrete paleosol.

Pigeon Creek Quarry (Figure 1) also has two paleosol units exposed. The lower paleosol is deposited on top of Owl's Hole eolianite. This lower paleosol is overlain by oolitic subtidal deposits of the Grotto Beach Formation. A second paleosol caps the Grotto Beach Formation.

The lower paleosols of the Watling's Quarry and Pigeon Creek Quarry localities are stratigraphically correlative as these paleosols mark the boundary between the Owl's Hole and Grotto Beach Formations. Panuska and others (1991) suggested that the paleomagnetic directions of these two localities might be similar (see Table 3 for a compilation of mean paleomagnetic directions). However these original directions are not statistically the same, possibly due to drastically different dispersions (kappa). In a subsequent study, Kirkova (1994) produced an additional 12 data points from the Watling's Quarry locality and reported a revised mean direction. Although the revised mean direction is only about 3° from the original value, the new mean direction is statistically similar to the Pigeon Creek Quarry direction according to the test of McFadden and Lowes (1981), at 95% confidence. Unfortunately, the revised Watling's Quarry data are not conducive to a straight forward interpretation.

Kirkova (1994) reported that the new data set and the original data give statistically similar directions; however, this is true only at the 0.01 level of significance (99% confidence). If the more routine 0.05 level of significance is used, the directions are different. This discrepancy may arise from the fact that the original data are from a paleosol filled pit and the new samples were collected from a more laterally extensive paleosol blanketing the Owl's Hole dune. It is possible that these two sample suites are slightly diachronous, with the pit filling being slightly older and perhaps representing a slightly shorter duration of soil accumulation. Regardless of the origin of the directional dissimilarity, it is not clear which direction should be used in paleomagnetic correlation.

The initial Watling's Quarry lower paleosol direction was found to be different from the lower Pigeon Creek Quarry direction. The revised direction, using all 20 data, is statistically the same as Pigeon Creek. However, the revised direction is also the same as the direction for Fernandez Bay (figure 1), which should not be the case on stratigraphic grounds (see next section). If only the new data for Watling's Quarry are used, we get a different direction from Pigeon Creek at 95% confidence although a similar direction is obtained at the 99% confidence level. Nevertheless, this direction is similar to the Fernandez Bay direction and the predicted directional discrimination is not obtained. At this point in the study, we defer the correlation of the Watling's Quarry locality until a more thorough analysis of its directional idiosyncrasies can be developed.

The paleomagnetic direction of the stratigraphically well established lower paleosol of Pigeon Creek Quarry is provisionally referred to as the pre-Grotto Beach direction. Statistical analysis of the currently available data shows similar directions for both the upper and lower Gaulin Cay (Figure 1) paleosols (interpreted as penecontemporaneously deposited soils; Kirkova, 1994; Panuska and others, 1995, this volume) and Singer Bar Point. Thus, both Gaulin Cay and Singer Bar Point paleosols are tentatively assigned to a pre-Grotto Beach stratigraphic position.

Gaulin Cay is mapped as undifferentiated Pleistocene deposits (Carew and Mylroie, 1994). The paleomagnetic correlation predicts that the paleosols at this locality are overlying Owl's Hole Formation rock. This prediction might be testable with petrographic data.

Carew and Mylroie (1994) mapped the Singer Bar Point area as Cockburn Town member of the Grotto Beach Formation. This designation, however, was based on extrapolation of field relationships exposed in a small bay, approximately 0.5 km west of Singer Bar Point. The paleomagnetic direction correlation suggests that Singer Bar Point is capped by a pre-Grotto Beach paleosol; thus, the paleosol should overlie Owl's Hole rocks.

In order to test the assignment of the Singer Bar Point paleosol to a pre-Grotto Beach position, we have collected samples from below this paleosol for petrographic

TABLE 3
MEAN PALEOMAGNETIC DIRECTIONS

Pre-Grotto Beach Directions.

Locality	Geographic Dec	Geographic Inc	κ	α_{95}	N	R
Pigeon Creek Quarry	350	45	1054.5	2.4°	5	4.996
Singer Bar Point	354	49	102.1	6.0°	7	6.941
Upper Gaulin Cay	354	47	1779.5	2.2°	4	3.998
Lower Gaulin Cay	355	51	130.9	8.1°	4	3.977
Watling's $Quarry_1$	347	40	96.6	5.7°	8	7.928
Watling's $Quarry_2$	358	44	83.4	4.8°	12	11.868
Watling's $Quarry_3$	353	42	73.5	3.8°	20	19.742

Post-Grotto Beach Directions.

Locality	Geographic Dec	Geographic Inc	κ	α_{95}	N	R
Fernandez Bay	356	40	116.7	2.5°	28	27.769
Miller Pond	0	40	335.0	5.0°	4	3.991

Table 3. A compilation of mean paleomagnetic directions reported in the literature. Using these data, we have evaluated the similarities of the mean directions using the statistical tests of McFadden and Lowes (1981). Unless otherwise stated, all directional discriminations were made at the 95% confidence level. Watling's $Quarry_1$ is the initial data reported by Panuska and others (1991); Watling's $Quarry_2$ is the results reported by Kirkova (1994); Watling's $Quarry_3$ is the composite mean of the previous two data sets.

analysis (work currently in progress). Hand specimen examination, of the rocks below the sampled paleosols (approximately 30 m east of the point), appear to consist of grains of bioclastic origin and apparently lack ooids. This suggests an Owl's Hole lithology as predicted by the paleomagnetic data. However, rocks below paleosols occurring at and to the west of Singer Bar Point appear to contain ooids in hand sample. The occurrence of ooids suggests that these rocks belong to the Grotto Beach Formation and further suggests an abrupt transition from Owl's Hole to Grotto Beach lithologies at Singer Bar Point. The apparent contact between Owl's Hole and Grotto Beach units can be narrowed down to approximately 10 m of beach, immediately east of Singer Bar Point. We have collected additional paleomagnetic localities in the vicinity of Singer Bar Point, supplementing the petrographic samples, to test the hypothesis of a contact between two formations.

Post-Grotto Beach Paleosols

Rocks along Fernandez Bay (Figure 1) were sampled over approximately 1 km of beach exposure to test for lateral continuity of paleomagnetic directions from paleosols (Kirkova, 1994). The paleosols at Fernandez Bay are deposited on the Cockburn Town member of the Grotto Beach Formation. Thus these paleomagnetic directions, which are in good agreement with each other and demonstrate lateral continuity (Kirkova, 1994), should provide a reference direction for post-Grotto Beach units.

Directions from the Miller Pond area are statistically the same as the Fernandez Bay directions. This directional similarity suggests that the Miller pond paleosol is also a post-Grotto Beach deposit. Rocks at Miller Pond belong to an inland lake facies, replete with *Anomalocardia* bivalves, which was deposited during the 5e sea level high stand, circa 125 Ka (Hagey, 1991). These deposits are clearly correlative with Grotto Beach rocks, as only Grotto Beach sediments show subaqueous origin above modern sea level.

For these directions to be considered a post-Grotto Beach correlation criterion, it must be shown that the previous deposits shown to be directionally similar to the pre-Grotto Beach, Pigeon Creek direction are statistically distinct from the post-Grotto Beach directions. The paleomagnetic directions from the paleosols at Gaulin Cay, Singer Bar Point and Pigeon Creek Quarry are different from the post Grotto Beach directions at 95% confidence. Thus, both Fernandez Bay and Miller Pond are assigned to the post-Grotto Beach correlation direction.

As stated in the previous section, the Watling's Quarry directions are problematic. The original Watling's data (Panuska and others, 1991) are distinct from the post-Grotto Beach Miller Pond and Fernandez Bay data but are also different from the pre-Grotto Beach directions. The new Watling's data and the composite Watling's data are similar to the pre-Grotto Beach units, as predicted by stratigraphic relationships; however these data are also similar to the post-Grotto Beach directions. Thus, none of the Watling's Quarry paleomagnetic directions satisfy the correlation predictions established by the known stratigraphic relations. Perhaps additional data will be able to shed light on these apparent contradictions, although given the large number of specimens already collected from Watling's Quarry, it is unlikely that more data will be able to "force" the proper correlation. It may be more likely that the Watling's paleosols are not perfect temporal equivalents of the other pre-Grotto Beach deposits. This could be somehow related to the fact that Watling's Quarry is located some 20 m above sea level. At this elevation, the Watling's Quarry would be subaerially exposed when the other localities, closer to sea level were submerged. Additionally, the dune crests may be at greater risk for removal of part of the paleosol record by erosion. Both of these possibilities could contribute to a slightly different recording of the secular field, yielding equivocal correlation results.

CONCLUSIONS

Correlations of paleomagnetic directions from stratigraphically well-constrained paleosol localities with paleomagnetic directions from other paleosols appears to allow the identification of both pre- and post-Grotto Beach Formation paleosols. Field evidence from the stratigraphically uncertain localities tends to support these correlations. Petrographic studies are underway to test these correlations.

The attempt to correlate the stratigraphically well understood Watling's Quarry paleosol was unsuccessful. These problematic results may be related to this locality's high elevation and its resulting potential to record different segments of secular variation of the geomagnetic field. Although most of the results are encouraging, the failure of Watling's Quarry data to produce an unequivocal stratigraphic correlation forces us to view the results with guarded optimism.

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