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# EVIDENCE FOR PALEOMAGNETIC STABILITY OF PALEOSOLS ON SAN SALVADOR ISLAND, BAHAMAS

Bruce C. Panuska and John E. Mylroie
Department of Geology and Geography
Mississippi State University
P.O. Drawer 5167
Mississippi State, MS 39762

## ABSTRACT

Paleomagnetic signatures of Bahamian paleosols offer some promise for correlation of these units across the San Salvador Island and potentially to other Bahamian islands. Before such a technique can be used confidently, magnetic stability must be demonstrated. Application of the paleomagnetic fold and reversal stability tests are precluded by geologic and geochronologic considerations. However, the conglomerate test may be employed to provide some evidence for paleomagnetic stability.

The paleomagnetic conglomerate test seeks to show that previously magnetized units, redeposited as clasts have random paleomagnetic remanence directions (and therefore, have not been remagnetized since clast deposition). Cobbles of carbonate paleosol have been sampled along Fernandez Bay, on the western coast of San Salvador. Vigorous storm waves undoubtedly transported and deposited the paleosol clasts.

Paleomagnetic directions for the clasts were measured using a spinner magnetometer and various components of magnetization were isolated using alternating field (AF) cleaning techniques. Directional scatter within clasts is low, while between block scatter is very high. The directions determined for 11 clasts are statistically random. Thus, a positive conglomerate test is suggested, indicating paleomagnetic stability since the time of clast deposition. Although the time since clast deposition probably does not exceed a few centuries, there is at least some evidence for paleomagnetic stability.

## INTRODUCTION

Paleosols on San Salvador Island occur at two stratigraphic positions and mark the boundary between each of the three formations on the island: the Owl's Hole and overlying Grotto Beach Formations and the Grotto Beach and overlying Rice Bay Formations (Carew and Mylroie, 1985). Thus, the paleosols are important stratigraphic markers. However, the similarity of paleosol appearance and variable thickness has limited their utility.

Foos (1986) examined the mineralogy and petrography of several paleosols and identified 2 basic paleoclimate types. McCartney and Boardman (1986) recognized 4 distinct paleosol types based on lithologic description. These different types were attributed to localized variations in depositional environment and therefore have no relevance as a time-dependant correlation criterion. A minimum of 5 different paleosol forming periods were suggested (McCartney and Boardman, 1986) on the basis of insoluble residue mineralogy. However, the liklihood of paleosol redeposition and mixing makes correlation somewhat equivocal.

In an attempt to develop an additional correlation tool, Hudson and Panuska (1990) and Panuska and others (1991) employed paleomagnetic techniques to determine magnetic field signatures of the paleosols. Observed paleomagnetic directional dispersion within individual paleosols is moderately low to very low, suggesting good magnetic recording properties. The fact that paleosols at some localities gave statistically similar directions, while others gave statistically distinct directions offered some promise for correlation. If the magnetic directions accurately reflect the geomagnetic field at the time of pedogenesis, then a temporal correlation tool could be developed, as the paleosols record different portions of the secular variation of the geomagnetic field. However, for this technique to be reliable, paleomagnetic stability must be demonstrated.

The commonly used stability tests are not applicable in the case of San Salvador. The island is tectonically quiescent, precluding the fold test. Rock ages on San Salvador appear to be entirely restricted to the Brunhes normal polarity chron. Thus, the stability test of finding antiparellel reversals is very unlikely. With these tests being effectively ruled out, we sought to obtain some evidence for stability using the conglomerate test.

The conglomerate test is based on sampling individual clasts within a conglomerate. If the clast lithology is magnetically stable, the clasts will yield statistically random paleomagnetic directions, since the mechanical forces involved in transporting clasts are far greater than magnetic alignment forces. If uniform paleomagnetic directions are obtained, it can be concluded that the clasts had been remagnetized at some point after deposition of the conglomerate. As conglomeratic units on the island are rare and difficult to distinguish from solution pit paleosol infillings, paleosol-bearing clasts on the present day surface were selected for study.

## SAMPLING

Samples were collected from cobble to boulder size paleosol-bearing slabs, at southern Fernandez Bay on the west coast of the island, on a traverse that extended north from Hall's Landing for 100 m (see location map, front of this volume). Slab sizes range from 0.1-1.5 m to 0.2-2.0 m in areal dimensions. Slabs vary from 5-20 cm in thickness. Most clasts are slab-like, that is, one dimension is significantly smaller than the other two. The smaller clasts tended to be more equant in terms of similarity of dimensions; however, these clasts are best described as blocky, owing to planar sides and right angle corners.

The slabs were weathered out of the Grotto Beach Formation and assume a variety of orientations on the currently active back beach/dune surfaces, 5 to 10 meters from the present beach. Vigorous storm waves were undoubtedly responsible for transporting the clasts onto the dunes. No geopetal indicators were observed in the clasts; thus, there is no independant evidence for the effectiveness of randomization of slab orientation following removal from the local outcrops.

## PALEOMAGNETIC DATA AND DISCUSSION

Three paleomagnetic specimens were analyzed from each block sample collected. Magnetic measurements were made on a Schonstedt SSM-1A spinner magnetometer. Specimens were subjected to stepwise alternating field (AF) cleaning after each measurement of magnetic direction, in order to remove secondary components of magnetization.

Almost half of the specimens displayed nearly straight-line decay of intensity towards the origin, indicating absence of a secondary component of magnetization (figure 1A).

Other samples contained a significant secondary component, which was eliminated by cleaning at 50-75 oersteds AF intensity (figure 1B). Limited measurements of samples stored in various orientations in the ambient laboratory field suggest that at least some of the secondary magnetic components are temporary magnetizations acquired on a time scale of hours, during storage.

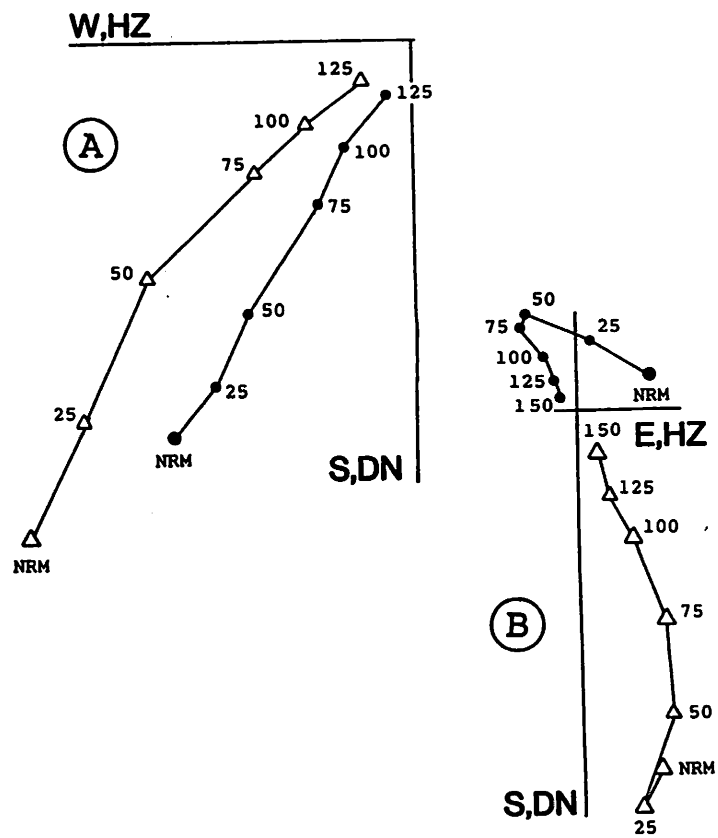


Figure 1. Vector diagrams showing demagnetization behavior of two representative specimens. Open triangles plot the vector inclination in the vertical plane (HZ-horizontal, DN-down). Dots plot vector declination in the horizontal plane denoted by cardinal compass directions.

Many specimens were largely free of secondary components of magnetization, showing nearly straight line decay towards the origin, with alternating field (AF) cleaning (A). Other specimens displayed a significant secondary component of magnetization, which was usually removed by 50-75 oersteds of AF demagnetization (B).

Table 1
Mean Directions for Paleosol Clasts

| Specimen | Demag Level | In Situ Dec | In Situ Inc | Block | Mean Dec | Mean Inc | Kappa | $A_{95}$ | N |
|---|---|---|---|---|---|---|---|---|---|
| 1A | 100 | 171 | -16 | 1 | 178 | -15 | 101.4 | 12.3° | 3 |
| 1B | 100 | 187 | -15 | | | | | | |
| 1C | 100 | 176 | -13 | | | | | | |
| 2A | 125 | 155 | 39 | 2 | 158 | 37 | 530.4 | 5.4° | 3 |
| 2B | 100 | 161 | 34 | | | | | | |
| 2C | 100 | 157 | 37 | | | | | | |
| 3A | 75 | 215 | 64 | 3 | 219 | 49 | 37.0 | 20.6° | 3 |
| 3B | 125 | 217 | 42 | | | | | | |
| 3C | 100 | 224 | 41 | | | | | | |
| 4B | 150 | 165 | 42 | 4 | 173 | 44 | 150.8 | 10.1° | 3 |
| 4C | 150 | 174 | 41 | | | | | | |
| 4D | 150 | 180 | 48 | | | | | | |
| 5A | 100 | 324 | 61 | 5 | 311 | 56 | 96.4 | 12.6° | 3 |
| 5C | 150 | 305 | 56 | | | | | | |
| 5D | 150 | 307 | 49 | | | | | | |
| 7C | 125 | 211 | 32 | 7 | 206 | 32 | 74.9 | 14.3° | 3 |
| 7D | 125 | 213 | 31 | | | | | | |
| 7E | 125 | 193 | 32 | | | | | | |
| 8A | 100 | 270 | -65 | 8 | 285 | -67 | 87.3 | 13.3° | 3 |
| 8B | 125 | 277 | -66 | | | | | | |
| 8C | 125 | 310 | -66 | | | | | | |
| 9A | 100 | 332 | 24 | 9 | 327 | 26 | 84.4 | 13.5° | 3 |
| 9B | 100 | 322 | 34 | | | | | | |
| 9D | 125 | 327 | 19 | | | | | | |
| 10A | 175 | 146 | -8 | 10 | 144 | -6 | 246.9 | 7.0° | 3 |
| 10C | 150 | 142 | -1 | | | | | | |
| 10D | 150 | 143 | -10 | | | | | | |
| 11B | 100 | 229 | 45 | 11 | 240 | 51 | 49.9 | 17.6° | 3 |
| 11C | 125 | 256 | 48 | | | | | | |
| 11E | 75 | 235 | 58 | | | | | | |
| 12A | 125 | 126 | 10 | 12 | 130 | 12 | 178.9 | 9.2° | 3 |
| 12C | 100 | 128 | 12 | | | | | | |
| 12D | 125 | 137 | 14 | | | | | | |
| | | | | Kappa = 1.8 | | R = 5.491 | | N = 11 | |

The resultant vector (R) is random at 99% confidence according to Watson's (1956) test for randomness.

Kappa is the Fisher precision parameter K given by:

$$K = \frac{N-1}{N-R}$$

where R is the resultant vector magnitude and N is the number of specimens or means. $A_{95}$ is the circle of 95% confidence.

Within block kappas are large indicating a tendency towards parallelism of specimen directions within a block. The block mean kappa is rather low demonstrating a tendency towards random orientations.

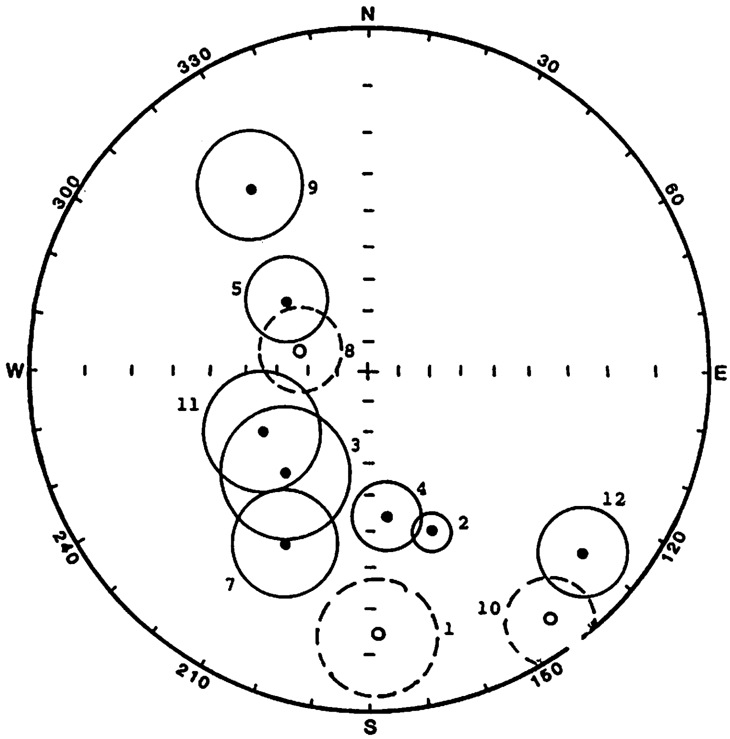


Figure 2. Sterographic projection (Wulff) showing block mean directions and circles of 95% confidence, in the present geographic frame of reference. Solid dots indicate positive (downward) inclination. Open circles indicate negative (upward) inclination, with associated circles of confidence shown as dashed circles. Within block directional variation is fairly low, while between block variation is large.

Dispersion of paleomagnetic directions within each block sample is generally low, with Fisher precision parameters (kappa) varying from 37-530 (Table 1). Corresponding circles of 95% confidence vary between 5° and 20° and average about 12°. Within-block directional dispersion is low, while the among-block dispersion is very high (kappa=1.8). Although the mean directions are statistically random at the 0.01 level of significance (Watson, 1955), there is a crude clustering of directions on a sterographic projection (figure 2). This is almost certainly due to the slabby nature of the clasts, which imposes a preference for the clast's planar dimension to be oriented parallel to the beach/dune surface. The fact that only three of eleven blocks have negative magnetic inclinations is probably related to the size of the slabs and insufficient wave strength to overturn clasts with large dimensions.

The apparent randomness of clast orientation suggests paleomagnetic stability since the time of clast removal from the outcrop. The proximity of clasts and outcrops to the present beach makes it unlikely that the clasts were last moved more than a few centuries ago. Thus, stability is only implied for periods of time up to centuries and perhaps less. While a more rigorous conglomerate test including smaller clasts with better rounding is desirable, these data provide at least circumstantial evidence for paleomagnetic stability.

## CONCLUSION

Paleomagnetic directions measured for eleven paleosol-bearing blocks appear to yield random directions. This suggests stability of the magnetic carriers in the paleosols for a period of time equivalent to the age of last disturbance of clast orientation. Proximity of the blocks to the present beach makes it unlikely that the age of last disturbance exceeds a few centuries. While a more rigorous conglomerate test is needed, this study provides some evidence for paleomagnetic stability of paleosols for time scales on the order of decades to centuries.

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