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Cover photo: *Diploria strigosa*, the common brain coral, preserved in growth position at the Cockburn Town fossil coral reef site (Sangamon age) on San Salvador Island. Photo by Al Curran.

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PALEOCLIMATIC INTERPRETATION OF PALEOSOLS ON SAN SALVADOR ISLAND, BAHAMAS

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ABSTRACT

The mineralogy and petrography of paleosols and modern soils on San Salvador Island, Bahamas was investigated, and the paleoclimate at the time of soil formation was determined. Two distinct types of paleosols were identified on the bases of mineralogy and petrography; paleo-caliche/terra rossa and paleo-latosol.

Paleosols from North Pigeon Creek Quarry, Pigeon Creek Indian Site, the Gulf, Cockburn Town Reef and Watlings Quarry all fit into the paleo-caliche/terra rossa category. The insoluble residue mineralogy of the paleo-caliche/terra rossa paleosols is similar to the modern soils on San Salvador and consists of kaolinite, illite, chlorite, quartz, hematite and plagioclase. This mineral assemblage is characteristic of terra rossa soils which form in a subhumid climate. Superimposed on the terra rossa mineralogy of these paleosols are petrographic features characteristic of caliche, such as laminated micritic crust, rhizocretions, aveolar textures, caliche pisoliths, and voids filled with random needle fiber low-Mg calcite. Caliche forms under arid to semiarid climatic conditions. After formation of terra rossa in a subhumid environment the climate became more arid, resulting in cementation of the terra rossa by caliche.

The mineralogy of the Singer Bar Point paleosol is distinctly different from the other paleosols on San Salvador, consisting of boehmite, gibbsite, kaolinite, hematite and vermiculite. This mineral assemblage indicates that it is a paleo-latosol which formed in a climate much more humid than the present day climate on San Salvador.

INTRODUCTION

Paleosols are an important stratigraphic tool because they indicate periods of subaerial exposure and, as such, they can be helpful in unravelling the stratigraphy of San Salvador (Carew and Mylroie, 1985). Paleosols may also be used as paleoclimatic indicators by comparing the products of modern soil forming processes to the mineralogy and petrography of ancient paleosols and applying the principle of uniformitarianism.

In a tropical environment three factors determine the type of soil formed; parent material, climate, and topography (Kalpage, 1974). The parent material of all the Bahamian paleosols is air born dust derived from North Africa (Glaccum and Prospero, 1980; Eaton and Boardman, 1985; and Mann, 1986) plus carbonate sediment. Because all the paleosols have the same parent material, variations in the mineralogy and petrography among paleosols on San Salvador must be due to climatic and/or topographic factors. In this paper I will be focusing on climatic controls on the mineralogy of San Salvador paleosols.

METHODS

The mineralogy of the insoluble residue and petrography of a number of paleosols and modern soils from San Salvador Island, Bahamas was determined. Paleosols were collected from the following locations; the floor of North Pigeon Creek Quarry, the Gulf, Cockburn Town Reef, Watlings Quarry, a solution hole near the Pigeon Creek Indian Site, and Singer Bar Point. Modern soils were collected near Lime Hole Sink, Lighthouse Cave, the causeway south of Storrs Lake and a solution hole near the Pigeon Creek Indian Site (see index map 2).

The petrography was observed using standard petrographic techniques. The percent insoluble residue was determined by treating the samples with 5% HCl overnight and determining the weight loss. Free iron

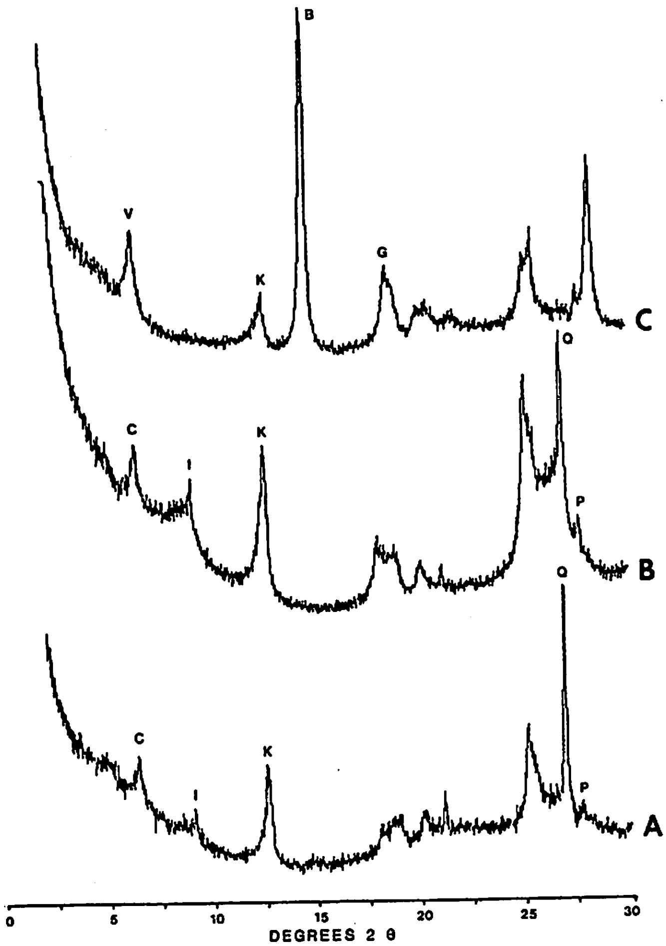


Fig. 1. Representative X-ray diffraction patterns of the insoluble reside from modern soils (A), paleo-caliche/terra rossas (B) and paleo-latosol (C). (c-chlorite, i-illite, k-kaolinite, q-quartz, p-plagioclase, v-vermiculite, b-boehmite, g-gibbsite)

oxides were removed from the samples using the citratebicarbonate-dithionite method of Jackson (1969). The amount of iron removed (Fe_d) was measured on a Perkin Elmer 460 atomic absorption unit.

The mineralogy of the samples was determined with X-ray diffraction on a Philips APD 3720 instrument with Ni-filtered CuKα radiation. The untreated sample, insoluble residue and clays after free iron oxide removal were X-rayed. The clays were also treated with ethylene glycol and heated to 400 and 550° C to aid in their identification.

RESULTS

Based on the mineralogy and petrography two end member types of paleosols were observed; paleo-caliche which forms in an arid to semiarid climate and paleo-latosol which forms in a humid climate. Intermediate between these two end members are the terra rossa paleosols and modern soils which form in a subhumid environment and are commonly associated with paleo-caliche.

Modern Soils

Soils from San Salvador contain the following minerals: calcite, kaolinite, illite, chlorite, quartz, hematite and plagioclase (Fig. 1a). The percent insoluble residue ranged from 43% to 84% and the Fe_d values ranged from 1.0 to 4.6%. There was no correlation between the percent insoluble residue and the Fe_d values. The ratio Fe_d/insoluble residue was low ranging from 0.02 to 0.07 with a mean of 0.05.

The mineralogy of San Salvador soils is typical of terra rossa soils (also called red and brown Mediterranean soils). Terra rossa soils typically form on limestones in a subhumid climate (Buringh, 1970). The dominant process in the formation of terra rossa soils is the leaching of carbonates and accumulation of insoluble residues.

Paleo-caliche/terra rossa

The Paleo-caliches and terra rossa paleosols are very closely associated, with caliche characteristics superimposed on a terra rossa mineralogy. The paleosols collected from North Pigeon Creek Quarry, Pigeon Creek Indian Site, the Gulf, Cockburn Town Reef and Watlings Quarry all fit into the paleo-caliche/terra rossa category.

The insoluble residue mineralogy of this group is characterized by kaolinite, illite, chlorite, quartz, hematite, and plagioclase (Fig. 1b). The concentration of insoluble residue is variable, ranging from 1.2% at the Gulf to 12.6% at Cockburn Town Reef. Large variations in the percent insoluble residue can be observed in a single paleosol. At Pigeon Creek Quarry the bulk of the paleosol is carbonate rich with an insoluble residue content of 1.4%; however, pockets with as much as 12.4% insolubles occur. The ratio Fe_d/insoluble residue is variable, ranging from 0.02 to 0.08 with a mean of 0.06. The characteristics of the insoluble residues in these paleosols are similar to the modern soils on San Salvador and represent

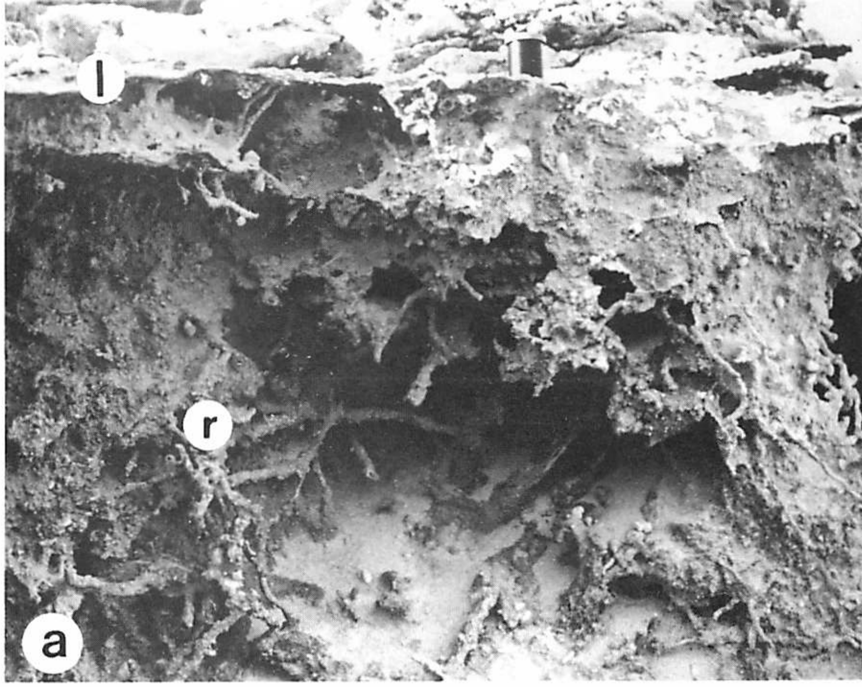


Fig. 2a. Caliche profile located at the Gulf showing laminated micritic crust (1) and rhizocretions (r).

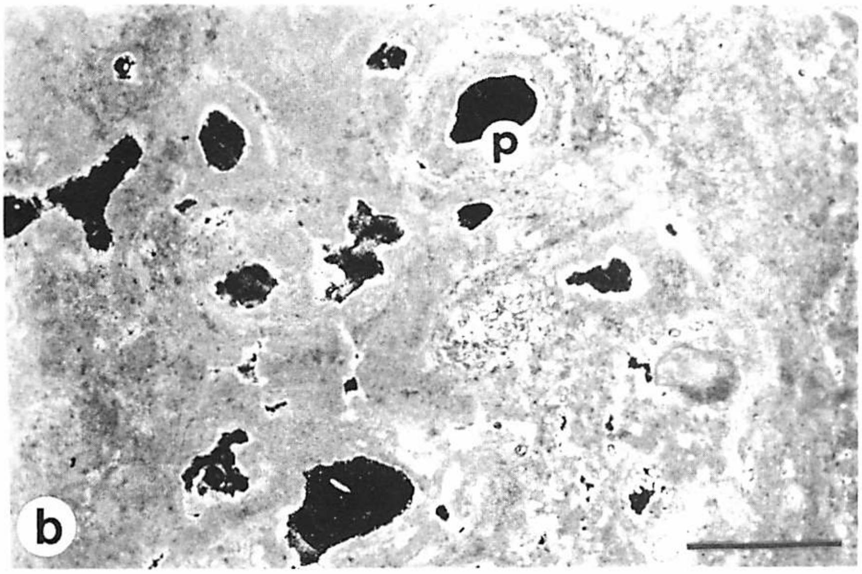


Fig. 2b. Laminated caliche crust from near the North Pigeon Creek Indian Site. Note the poorly developed caliche pisolites (p). Scale bar = .5 mm., X-nicols.

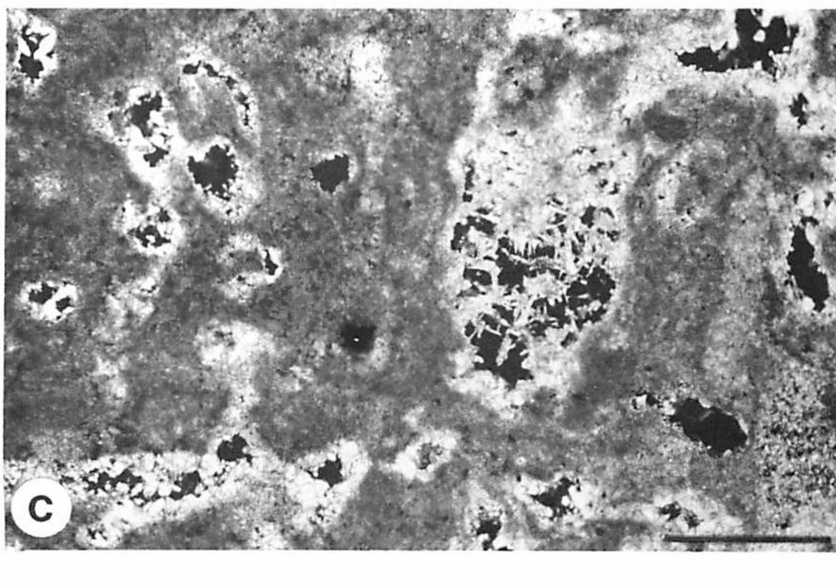


Fig. 2c. Paleo-caliche/terra rossa at Watlings quarry showing aveolar texture and a pore filled with random needle fiber low-Mg calcite. Scale bar = .2 mm., X-nicols.

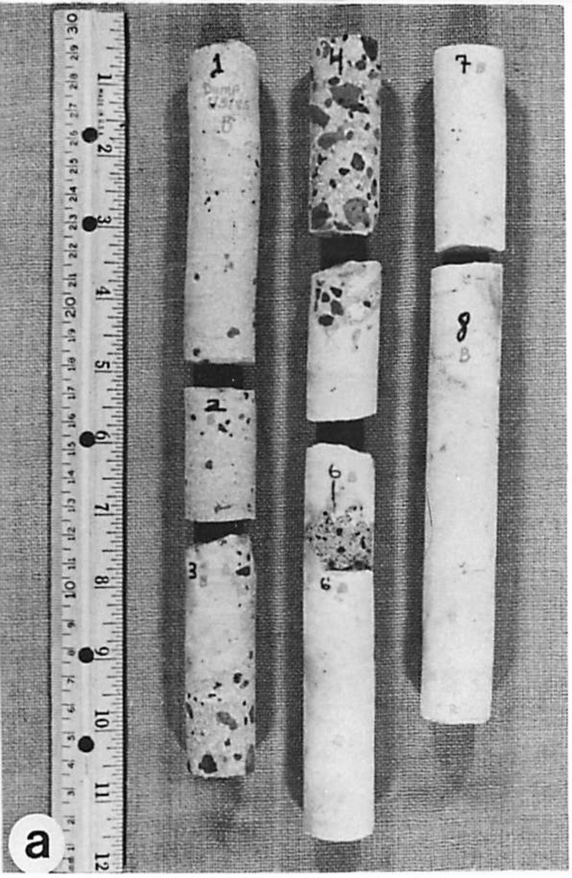
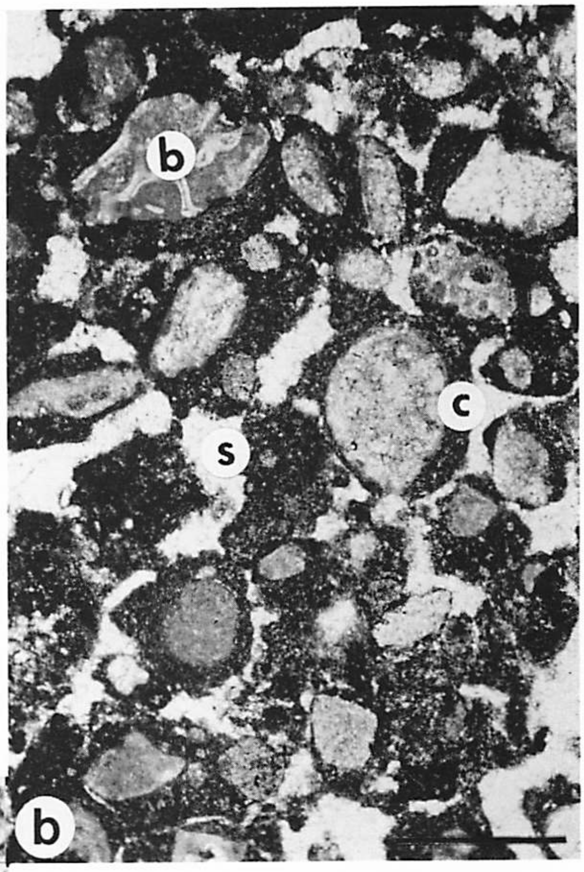


Fig. 3a. Core of the Singer Bar Point paleo-latosol.

Fig. 3b. Paleo-latosol at Singer Bar Point showing clay cutans (c), bioclastic grains (b) and sparry calcite cement (s). Scale bar = .4 mm., plane light.



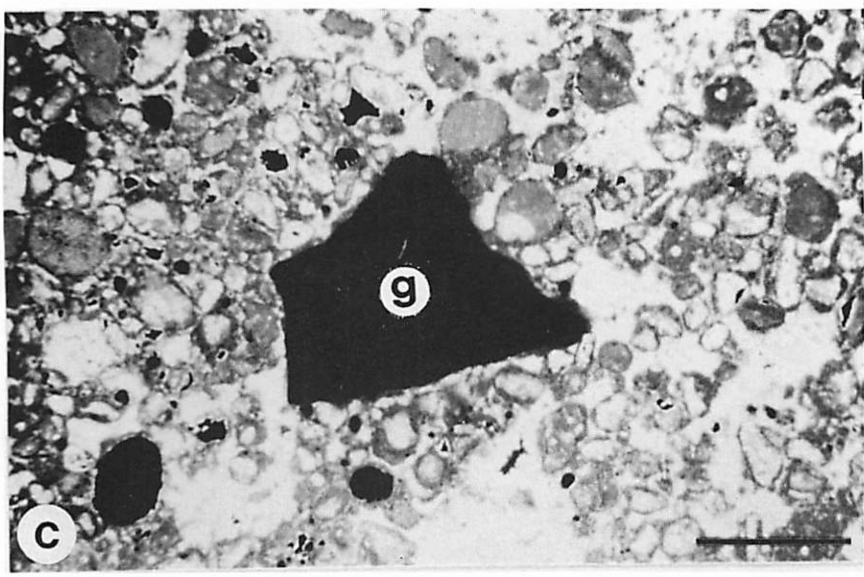


Fig. 3c. Paleo-latosol at Singer Bar Point showing an iron-rich glaebule (g). Scale bar = 1 mm., X-nicols.

a terra rossa paleosol that formed in a subhumid environment.

Superimposed on the terra rossa paleosols are paleo-caliches. Caliche soils are characterized by pedogenic accumulations of low-Mg calcite. Previous studies by Brown (1984) and Hale and Ettensohn (1984) described in detail the caliches occurring on San Salvador. Caliche features observed in this study include laminated micritic crust, rhizocretions, aveolar textures, caliche pisoliths, and voids filled with random needle fiber low-Mg calcite (Fig. 2). All of these features have been identified by Esteban and Klappa (1983) as diagnostic caliche features. The presence of caliche is strong evidence for arid to semiarid climates where evaporation exceeds precipitation (Esteban and Klappa, 1983).

Terra rossa soils normally have a low preservation potential; however, because the terra rossa soils on San Salvador were subsequently cemented by caliche, they have been preserved as paleosols. The occurrence of an insoluble residue with a subhumid signature in a soil characterized by an arid environment is not uncommon. When there is a change from a more humid to an arid climate the clay minerals will retain the signature of the more humid climate (Singer, 1980).

Paleo-latosol

The mineralogy of the paleosol at Singer Bar Point is distinctly different from the other paleosols on San Salvador Island and is interpreted to be a paleo-latosol. The insoluble residue is composed of boehmite (aluminum oxyhydroxide), gibbsite, kaolinite, hematite, and vermiculite (Fig. 1c). Chlorite, illite, quartz, and feldspar which are present in the terra rossa paleosols are absent from these samples. The concentration of insoluble residue increases from 9.0% at the top of the paleosol to 22% at the base. The amount of free iron oxides also increases from 0.9% at the top to 2.6% at the base. There is an excellent correlation (r=.99) between Fe_d and percent insoluble residue. The ratio Fe_d/insoluble residue of 0.09 is higher than the terra rossa soils indicating that there was an enrichment of iron in this paleosol.

The presence of boehmite and gibbsite indicate that this paleosol is a latosol (also referred to as an oxisol) which forms under a humid tropical climate. Latosols are characterized by a lack of weatherable minerals such as chlorite, illite, and feldspar and a dominance of kaolinite and hydroxides of iron and aluminum. The dominant process in the formation of a latosol is desilicification which involves the leaching of bases and silica resulting in a relative accumulation of iron and aluminum hydroxides (Mohr and others, 1972).

Macroscopic and petrographic evidence indicates that after the latosol formed it was eroded and redeposited in a karst depression. Petrographically the paleosol consist of well rounded bioclastic grains, clays and iron-rich glaebules which are cemented by sparry calcite (Fig. 3b). The clays occur as coatings on the bioclatic grains. These clay coatings are referred to as cutans by soil scientists and are evidence for translocation or migration of clays.

The Singer Bar Point paleosol contains iron-rich glaebules which range in size from 0.3 to 6 mm. The frequency and size of the glaebules increases from the top to the base of the paleosol (Fig. 3a). The edges of the glaebules are sharp and angular indicating that they were transported as lithoclasts over short distances (Fig. 3c). The glaebules are believed to represent a fragmented plinthite. A plinthite is a layer in a latosol where there is a relative accumulation of iron and aluminum hydroxides, which becomes hardened on exposure to air (Mohr and others, 1972).

The contact between the paleosol and the underlying limestone is very sharp and abrupt. This type of contact suggests that the limestone was well lithified prior to deposition of the paleosol and represents a paleo-karst surface.

Also observed was the development of moldic porosity and cementation by sparry calcite cement. Cutans surrounding pores and grains replaced by sparry calcite suggest that the development of moldic porosity and cementation by sparry calcite was a subsequent diagenetic event, unrelated to the soil forming processes.

CONCLUSIONS

The majority of the paleosols on San Salvador Island formed under climatic conditions similar to the present climate on San Salvador. The present climate on San Salvador can be characterized as subhumid which results in the development of terra rossa soils. Caliche could develop during intermittent periods of semiarid conditions. The Singer Bar Point paleo-latosol formed under a climate much more humid than the present climate on San Salvador.

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