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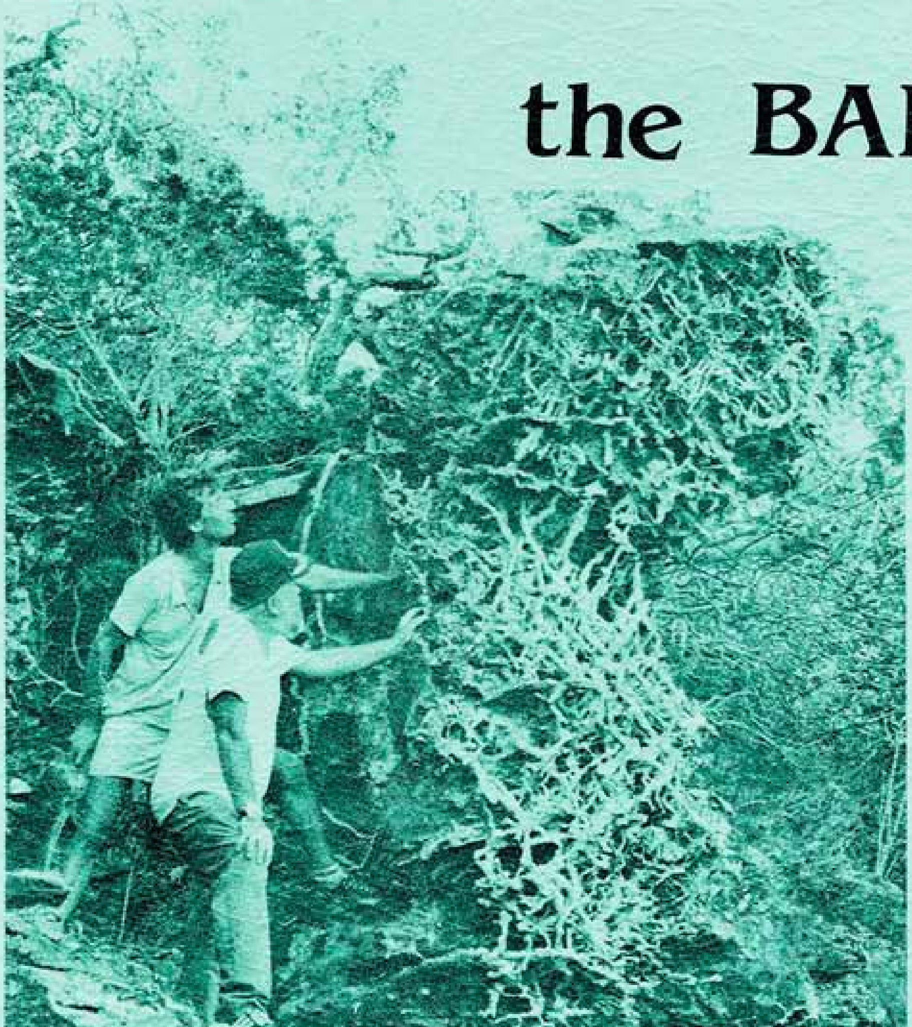

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DIAGENETIC ORIGIN FOR SAN SALVADOR MICRITE PEBBLES

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Abstract

Clasts of micrite varying from dense to porous, light gray to black, and containing ooids or fossil material have been reported by several workers on San Salvador. These clasts are especially abundant at or above "unconformable contacts" and in sinkhole and cave deposits. It has been suggested that these clasts are remnants of a widespread micrite which once covered the island and which represents a quiet shallow water environment of deposition in contrast to the high energy environments of younger calcarenites and oolites.

Black or dark micritic clasts contained within a more porous grainstone are not uncommon either in recent or ancient carbonates. Numerous authors discuss such black micritic clasts as evidence of terrestrial formation. Detailed observations of "black pebbles" on San Salvador from quarries at Pigeon Creek and Watling's Castle as well as from the shore of Granny Lake, have lead to the conclusion that pebbles are not derived from an eroded widespread unit which was deposited in a shallow water environment. Instead, the micrite is of diagenetic origin having formed in a subsoil environment through micritization of pre-existing grainstone. Subaerial or subsoil weathering leads to micritization of grainstone affecting clasts of grainstone as well as forming a micritic crust (subaerial laminated crust) over the grainstone surface. Micritization is most complete near root traces where original texture (ooids, grains, or fossils) is totally obliterated, however, in areas removed from root traces original granular texture remains.

Coloration of micritic clasts to black or dark gray occurs in the subaerial or subsoil environment due to enrichment of organic matter within the clasts caused by boring algae and fungi. This blackening apparently progresses more commonly along shores of hypersaline lakes but may also be caused by heat, either from forest fires or smoldering humus, which chars the organic matter within clasts.

Erosion of the soil or micritized crust leads to the transportation of micrite pebbles and their deposition over unconformities or discontinuites. Black micritic pebbles therefore are reliable indicators of unconformities, discontinuites or the nearby existence of a terrestrial environment.

Introduction

The occurrence of exotic clasts, principally black micritic pebbles, has puzzled geologists working on San Salvador and has been the subject of discussion by geologists finding such clasts throughout the Bahamas and Caribbean (Ward et al, 1970; Bain & Teeter, 1975; Perkins, 1977; Titus, 1980; and Garrett & Gould, 1984) (Fig. 1a). Similar black micritic pebbles have been reported from the Paleozoic (Bickley, 1976) and Mesozoic (Ward et al, 1970; Seyfried, 1980). In Pleistocene and Holocene deposits, these exotic clasts stand in striking contrast to the generally porous, weakly cemented grainstone in which they commonly occur. The exotic clasts consist of pebbles, generally less than three inches in diameter, ranging from black to brown to dark gray and varying texturally from micrite to biomicrite and oomicrite. It is not uncommon for clasts to range in color from white to black within a single deposit. Rarely clasts display black rinds which grade to white toward the center of the clast (Fig. 1b). Clasts are well cemented and generally are subangular to subround.

On San Salvador exotic clasts occur at many locations of which the most easily accessible and most often visited are Pigeon Creek Quarry, Little Lake Quarry and exposures along French Bay on Sandy Point. In general, clasts occur along bedding surfaces, perhaps unconformities (Titus, 1980) and in paleosols near sea level. However, they also occur in cave deposits and deposits filling karst depressions from near sea level up to forty feet elevation. The latter occurrences have been observed along the cliffs on Sandy Point along French Bay and in caves in the ridge east of Great Lake (Mylroie, pers. comm.). Black micritic clasts occur in great abundnce on the southeast shore of Granny Lake. In contrast to other occurrences on San Salvador, these clasts are not incorporated into rock strata or paleosols but occur as loose pebbles resting among gray pebbles of bedock and caliche (Fig. 1c). This occurrence is very similar to that reported by Ward et al (1970) from Yucatan.

It has been suggested by several workers in conversation and published by Titus (1980) that these darkened micritic pebbles are remnants of a marine unit which no longer exists on San Salvador or is buried beneath the rocks presently exposed on San Salvador. There are several problems with these interpretations. First, it is difficult to believe that this black micritic unit would have been completely eroded not only from San Salvador but also from all the other localities throughout the Caribbean where clasts have been reported. Second, if the micritic unit is buried beneath all exposed rock on the island then how do clasts of this buried unit find their way into paleosols and cave deposits at least forty feet above sea level. A third problem regarding the existence of a widespread micritic unit on San Salvador is that the environment in which such a unit might form does not exist on or near San Salvador presently and it would be difficult to envision such an environment during the Pleistocene. Fourth, the micrite pebbles are entirely calcite which indicates a nonmarine origin.

Petrographic examination of pebbles collected from bedrock occurrences at Sandy Point exposures, quarries at Little Lake and Pigeon Creek, Windley Key Quarry in the Florida Keys as well as the shore of Granny Lake lead to the recognition of

Figure 1a: Deposit of clasts of Pleistocene limestone in a depression on Key Largo, Florida Keys. Subaerial laminated crust lines bottom of depression overlain by clasts and shells of varying sizes and color. Dark and black clasts are of crust and bedrock.

Figure 1b: Sample of paleosol from Little Lake Quarry, San Salvador. Clasts are of oolitic bedrock and subaerial laminated crust. Note clasts range from white to black and several (arrows) show blackening descreasing inward from edge of clast.

Figure 1c: Loose deposit of pebbles in bedrock depression along southeast shore of Granny Lake, San Salvador. Pebbles are broken pieces of oolitic bedrock and subaerial crust which covers much of bedrock and which is also visible in photo (arrow). Pebbles range from brown to gray to black. (Photomicrographs of pebbles in figures 1d, e & 2). Scale is 15 cm.

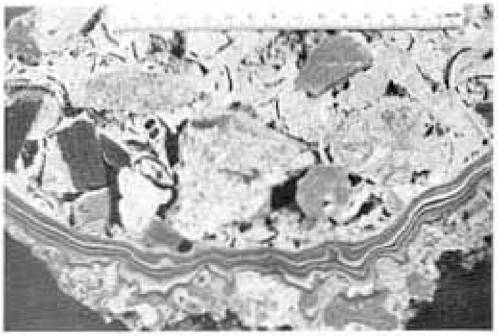
Figure 1d: Photomicrograph of black pebble from shoreline of Granny Lake showing micritized ooids and sparry calcite cement. Ooids are .3mm in diameter. Relict ooids are adjacent to totally micritized rock (not pictured).

Figure 1e: Photomicrograph of black pebble of subaerial crust from shore of Granny Lake, San Salvador. Root structure (upper right) is 1mm in diameter. Tangential section through root structure is along lower edge of photo. Micrite containing less than 1% carbon is dark area.

Figure 1f: Photomicrograph of graduational contact between rhizocretion and oolitic host rock from Watlings Quarry on San Salvador. Rhizocretion to right is micrite and micritization extends into host rock with decreasing effect of micritization of ooids to the left. Ooids are .3mm.

Figure 1g: Photomicrograph of gradational contact between subaerial crust (right) and oolitic bedrock (left) from shore of Granny Lake, San Salvador. Note most cores of most ooids are micritized and only ghosts exist in contract area (center). Scale is 0.5mm.

Figure 1h: Micritic layers within individual beds of porous calcarenite and cutting across (arrow) beds. Exposure is in cliffs along French Bay, San Salvador. Layers are 15 to 20 feet beneath surface.



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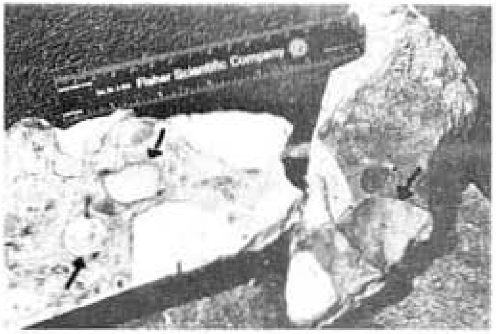

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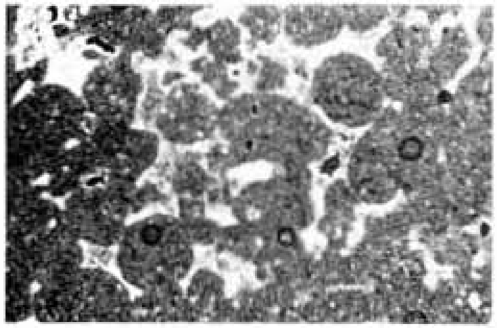

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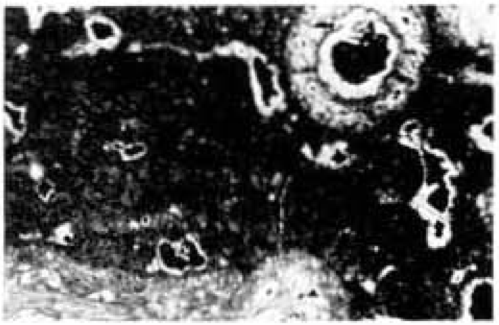

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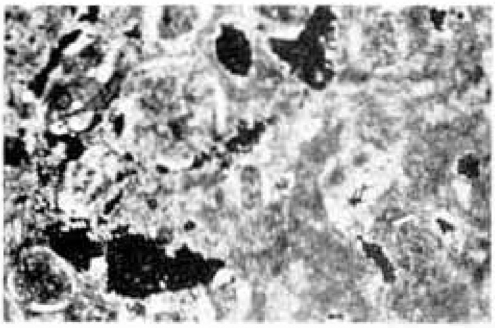

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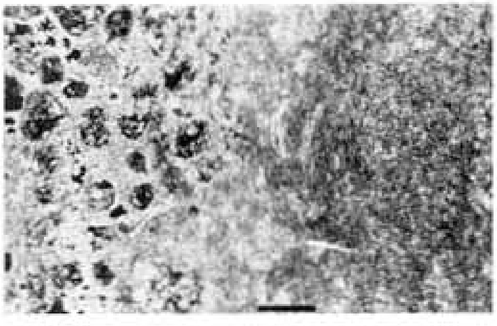

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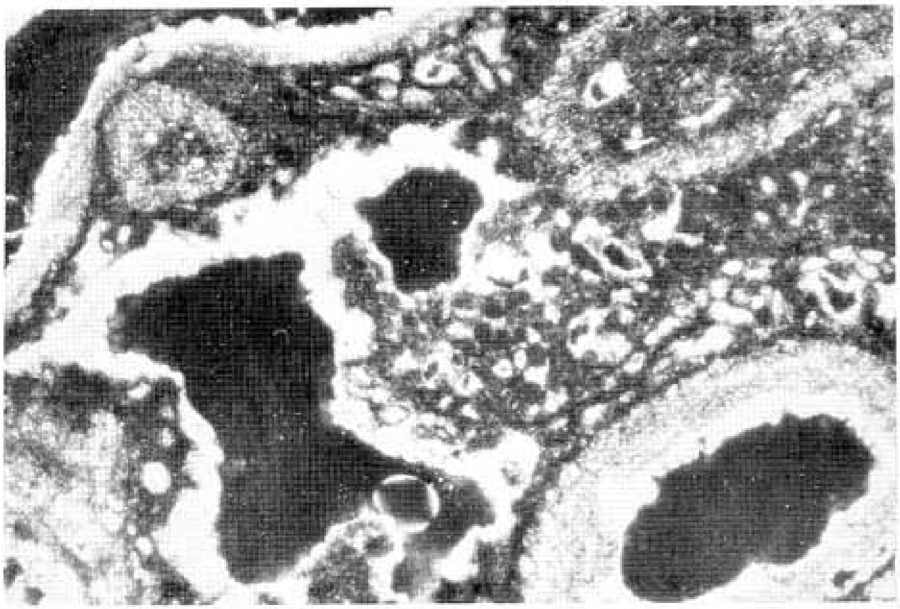

Figure 2a: Photomicrograph of black micrite pebble from south shore of Granny Lake, San Salvador showing root structures. Cross section (lower right) and tangential section (upper right) of root structures display some remnant porosity (dark areas). Clotted or "pelleted" micrite fills inter-root area. Clear sparry calcite rims most voids. Root structure in lower right is 1mm in diameter.

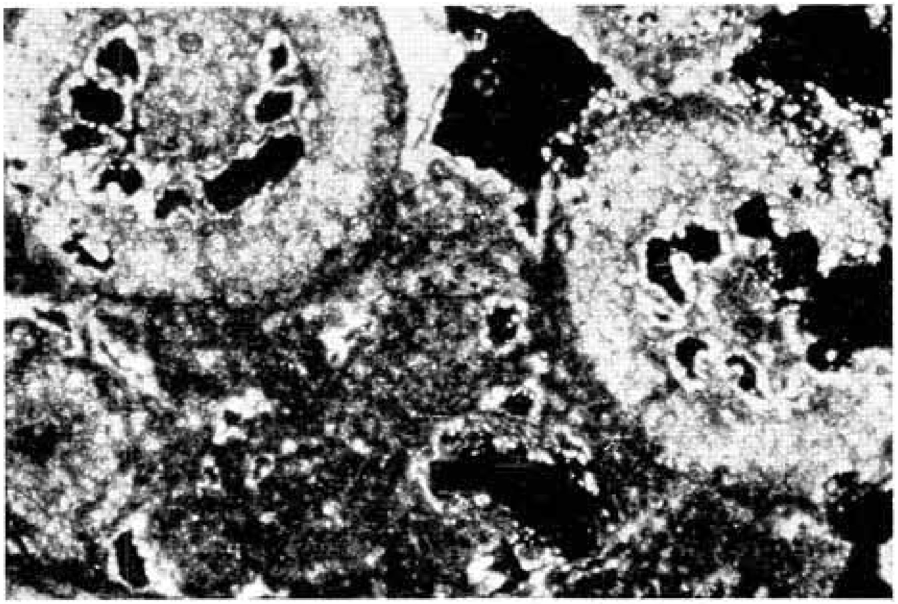

Figure 2b: Photomicrograph of black micrite pebble from south shore of Granny Lake, San Salvador showing root structures. Root tubules displaying internal porosity. Inter-root area filled with micrite. Tubule at upper left is 1mm in diameter.

characteristics which indicate the darkened micritic clasts are formed through diagenesis of bedrock in a subaerial or vadose environment and later erosion and deposition.

In order to discuss these characteristics and interpret their origin, the two most striking characteristics, petrography and coloration, will be discussed separately.

Petrography

The texture of these exotic clasts varies considerably from dense, well-cemented micrite to oolitic grainstone, the latter of which, if it were not dark gray or black, would not be significantly different from the normal San Salvador rock. Micritic clasts, although quite dense, generally show features such as lamination, root tubules, micritized ooids and shell material. Commonly, pebbles are relatively porous and pores are partially to totally filled by sparry calcite. X-ray analyses indicate pebbles consist entirely of calcite. Micritic clasts generally possess a pelleted appearance and in some instances are pisolitic. In thin section, relict textures of ooids and shell fragements can be recognized, although most grains have been heavily micritized (Fig. 1d). Figures 1d and 1e illustrate textural features of several micritic pebbles, in which root structures and micritized ooids are recognizable.

A comparison of the texture of micritic clasts and other micritic rock on San Salvador demonstrates the origin of the micritic clasts. Figures 1d-g are photomicrographs of micritic rhizocretions and subaerial laminated crust (term from Multer &

Hoffmeister, 1968; also referred to as calcrete, caliche, calcareous crust and soilstone). In Figure 1f the progressive micritization of ooids can be traced from the oolitic host rock into the rhizocretion. Likewise, in Figure 1g micritization has nearly totally obliterated the original texture of the host rock in the formation of subaerial laminated crust. Kahle (1977) described and explained a process which he terms "sparmicritisation" whereby granular material of the Miami Oolite has been converted to micrite. He describes a process whereby under vadose conditions endolithic fungi and algae invade underlying bedrock and upon their death and decomposition, rock is dissolved and reprecipitated as micrite. Hence a retrograde neomorphism or degrading recrystallization occurs. Perkins (1977) describes calcification of root and root tubules as a process in South Florida whereby a micritic crust is formed by the precipitation of very fine-grained muddy calcite around small root tubules. Supko (1970) likewise describes a micritization process near root structures or rhizocretions from a core on San Salvador.

However, other occurrences of micrite exist on San Salvador which appear to be unrelated to roots or soil formation. Within exposures along French Bay micritic layers can be observed following bedding as well as cross cutting bedding in layers 10-20 feet below the surface (Fig. 1h). Similar micrite can be seen filling fractures in the Cockburn Town Reef. Obviously this micrite is of a diagenetic origin, probably having formed in the vadose environment but the exact origin is not fully understood.

Perhaps migration of groundwater along once more porous strata and along fractures, and precipitation of micritic calcite was responsible.

In any event, micrite does form diagenetically in the vadose environment and more commonly in the subsoil region where plant root action as well as fungal and algal activity is high. Micrite also forms along bedding planes within strata, but again more commonly, it forms as subaerial laminated crust or rhizocretions. Once formed, it exists as a more resistant, well-cemented rock material which, upon erosion, will produce durable clasts to be concentrated along erosion surfaces or deposited in sediments offshore. Titus (1980) suggested the significance of these clasts when he used them as evidence for unconformable surfaces. He mistakenly thought the micrite was from an older rock strata which was beneath San Salvador, rather than recognizing that it was principally a subaerial crust being stripped from the land surface and concentrated as a lag deposit. Perkins (1977) cites diagenetic soilstone and soil breccias (essentially subaerial laminated crust and broken crust) as criteria for recognition of what he termed discontinuity surfaces (small unconformities) in South Florida. Garret and Gould (1984) describe and conclude a similar origin and significance for micritic clasts on New Providence Island, Bahamas.

Color

The color of nearly all rock on San Salvador is a slight variation of white, ranging to yellow brown and light gray.

Clasts of brown, dark brown, dark gray and black therefore, stand in sharp contrast where included within light colored rock. Because strata of dark color are not seen on the island at present, Titus (1980) suggested the darkened clasts are derived from an older unit which underlies all strata presently exposed. Generally darkened or black clasts are micritic, however, some clasts are oolitic and/or bioclastic. On close examination all clasts can be reasonably explained as being darker colored examples of rocks presently exposed on the island. Oolitic and bioclastic clasts closely resemble grainstone, and micritic clasts are identical to micritic crusts which occur below paleosols or within strata and along fractures. Therefore, the coloration only requires further explanation.

Along the southeast shore of Granny Lake, black, gray and brown clasts of subaerial laminated crust occur as loose gravel in depressions in the bedrock surface (Fig. 1c). A patchy but extensive surficial deposit of light gray to brown subaerial laminated crust covers much of the bedrock surface. Comparison of thin sections of these clasts and crust leaves little doubt that the clasts are derived from subaerial laminated crusts. Both clasts and crust are composed of micritic calcite containing abundant root structures (Figs. 1e & 2).

Granny Lake is a hypersaline (80-123 o/oo) lake whose shoreline fluctuates with seasonal rainfall. Black pebbles occur only along the high water shoreline. Rocks along the shoreline of Granny Lake are intensely bored by algae and presumably fungi, and their color is thereby altered to red, green, brown and black. Most bedrock surfaces along the shoreline, which are exposed during seasonal low stands of the lake, are black; and this black coloration penetrates the rock to a depth of an inch or more. Small clasts (less than 2 inches in diameter) are blackened throughout.

Ward et al. (1970) describe an almost identical collection of black clasts along the shores of hypersaline lakes on Isla Mujeres in Mexico. Black clasts of eolianite and crust are being produced in situ along the edge of a hypersaline lake. Analyses of black and gray clasts from Isla Mujeres show a significant increase of organic carbon in black clasts. Iron was slightly higher in some samples; however, in most samples iron as well as sulfur and manganese are lower in black clasts than in gray and brown clasts. Ward et al (1970) believe hypersaline conditions provide an environment having a high pH and low Eh, wherein black color is produced by the activity of boring algae and fungi which bore into lithic fragments and a concomitant dissolution and precipitaion of calcite which preserves plant tissue within calcite crystals. This plant tissue is the source of organic carbon which they found as an insoluable residue and which produces the black color. Kendall and Skipwith (1969) proposed a similar mechanism for blackening limestone, namely, fungal and algal borings which enrich carbonates in organic matter. Not all studies however, agree with the Granny Lake or Ward's Isla Mujeres setting for forming black micite clasts.

Perkins (1977) and Garret and Gould (1984) suggest that blackening occurs within soil horizons. Perkins (1977) cites the preserved root tubules as evidence for formation within soil horizons. Unlike Ward et al (1970) who were unable to detect any consistent increase in iron or manganese in black pebbles, Houbolt (1957), Maiklem (1967) and Davies (1967) did report relatively high amounts of iron and manganese in the black fractions of carbonates. Shinn, Robbin and Lidz (1984) blackened clasts of the Miami Oolite by heating samples which caused a charring of organic matter within the rock. They report that only porous rock types such as laminated soilstone crusts (subaerial laminated crusts), coral or weakly cemented oolitic, pelletal and skeletal grainstone were blackened due to cooking. Well-cemented and non-aragonitic lithologies retained their light color. They propose heat from forest fires and/or smoldering humus accumulations could cause blackening.

Common to all the discussed explanations for black limestone pebbles is exposure in a subaerial environment - margin of hypersaline lake, subsoil, smoldering humus or charred rock. Also common is that all authors blacken rock which is not exotic but instead, is common to the environment and is also likely to be similar to the succeeding lithology which will incorporate these clasts. Clasts blackened by these various subaerial processes will probably form a lag deposit along discontinuities or unconformities.

Summary

Clasts of darkened or black limestone, most commonly micrite, occur on San Salvador and throughout the Caribbean in

Pleistocene-Holocene carbonates. They have also been reported from the Paleozoic and Mesozoic. These blackened clasts generally consist of well-cemented micrite and occur in light-colored grainstone. They have been incorrectly interpreted as being remnants of units no longer exposed on San Salvador either due to burial or erosion.

The two most striking characteristics of these clasts are their black color and micritic texture which contrast with the abundant light-colored grainstone covering San Salvador. Black coloration is caused by organic carbon within the clasts as a result of boring algae and fungi and/or roots of land plants. Heat due to forest fires or smoldering humus might also play a significant role in blackening limestone clasts. Hypersaline conditions, as on the shore of Granny Lake, might provide the correct Eh and pH environment which would preserve organic matter within the limestone generating the black color.

Micrite, which is not common on San Salvador, forms through the diagenetic alteration of various carbonates (oolitic or bioclastic grainstone) in the soil and subsoil zone. Such micrite has been referred to as subaerial laminated crust, caliche, calcrete or soilstone and is quite common on bedrock surfaces on San Salvador where soil has been eroded. Similar micrite also forms diagenetically along fractures and within porous layers of calcarenite.

Black micritic clasts represent diagenetically altered country rock which, because it is more tightly cemented and forms at or near the surface, produces a lag gravel of resistant pebbles upon erosion. These pebbles, when found in the stratigraphic record, indicate possible discontinuity surfaces, unconformities or at least the presence of a nearby exposed land surface.

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