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Front Cover: Lee-side exposure of a fossil parabolic dune viewed from the Grahams Harbour side (west) of North Point, San Salvador, Bahamas. These Holocene carbonate eolianites have been assigned to the North Point Member of the Rice Bay Formation (Carew and Mylroie, 1995). The eolian cross-stratification dips below present sea level, proving that late Holocene sea-level rise is real. Top of the dune is about 7 meters above the sea surface. Photo by Al Curran.

Back Cover: Dr. Noel P. James of Queen's University, Kingston, Ontario, Canada, keynote speaker for this symposium. Noel is holding a carving of a tropical fish created by a local artist and presented to him at the end of the symposium. Photo by Al Curran.

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# PETROLOGIC ANALYSIS OF CUEVA DE AGUA, PUNTE LOS INGLESES, ISLA DE MONA, PUERTO RICO

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## ABSTRACT

Isla de Mona, Puerto Rico is a tectonically-uplifted island composed of predominantly Mio-Pliocene carbonates (Mona Dolomite and the overlying Lirio Limestone) that form cliffs to the sea on the north and east with a low-lying fringe of Pleistocene limestone on the southern and western coasts. There is a very high density of flank margin caves exposed in these cliffs. These caves developed near the discharging margin of past fresh-water lenses, and are now drained as a result of tectonic uplift. The caves are found primarily in the Lirio Limestone, at the contact with the underlying Mona Dolomite. Cueva de Agua Punte los Ingleses lies within both the Lirio Limestone and onlapping late Pleistocene reef-rubble facies. The cave was sampled to take advantage of the access it provides to the interior of these rock units. The information obtained from the analyses of these rocks could shed light on lateral facies changes as well as diagenetic features associated with cave formation.

Previous workers (e.g. Gonzalez et al., 1997 and references therein) have examined surface samples from pre-Pleistocene Isla de Mona carbonates and noted that secondary porosity within these units results primarily from the dissolution of aragonitic gastropods and corals. The samples from Cueva de Agua Punte los Ingleses contain an abundance of red algae, and lesser amounts of foraminifera, echinoderms, and corals. These analyses of the cave wall rocks indicate that dissolution of aragonitic coral allochems has produced some of the total rock porosity, but dissolution of high-Mg red algae appears to be of greater importance in cave wall rock samples than has been reported from surface samples studied by previous workers. This difference may result from dissolution in the mixing zone at the base of the fresh-water lens, versus near the surface by meteoric water. These observations are similar to those reported earlier by the authors for another cave on this island, Cueva del Aleman (Schmoll et al., 1997). It is notable that the observations reported here in Cueva de Agua Punte los Ingleses were virtually identical in both the Mio-Pliocene Lirio

Limestone and in the onlapping late Pleistocene reef-rubble facies.

## GEOGRAPHIC SETTING

Isla de Mona is an isolated carbonate island located in the Mona passage about midway between Puerto Rico and Hispaniola at 18° 05' N, 67° 53' W (Figure 1). The island has a semi-arid tropical marine climate with an average rainfall of about 810 mm, and an estimated temperature range of 20.5° to 29.1° C (Calvesbret, 1973). It is a kidney shaped island that is 12 km long and 5 km wide. The approximately 55 km$^2$ area of the island consists of an upland plateau (meseta) bounded by a relatively narrow, discontinuous low-lying coastal plain along its western and southern coast. On its northern and eastern sides there are 60 to 80 m vertical cliffs that extend below sea level for at least another 20 to 40 m. On the south and west sides there are lower, less steep cliffs that ramp down to the coastal plain. The coastal plain consists of late Pleistocene reef tract and related facies that have been U/Th-dated to the last interglacial, circa 125 ka (Taggart and Gonzalez, 1994). It ranges in elevation from 1-3.5 m, and the highest elevations are where the coastal plain abuts the meseta (Figure 1).

## GEOLOGY

The carbonates of the meseta of Isla de Mona were formerly thought to be Miocene in age (Kaye, 1959; Briggs and Seiders, 1974), but they are now considered to be both Miocene and Pliocene in age (Gonzalez et al., 1997). The Miocene-Pliocene rocks have been divided into two units, the Isla de Mona Dolomite, and the overlying Lirio Limestone (Kaye, 1959; Briggs, 1974). Both units contain large flank margin caves, but the majority are concentrated at the contact between the Lirio Limestone and the Mona Dolomite (Frank et al., 1998).

The Lirio Limestone contains numerous large flank margin caves at several elevations. The morphology and great size of these flank margin caves indicate that they must have been developed by dissolution in the mixing zone of a large fresh-water lens, or lenses, over an extended period of time (Mylroie et al., 1995; Frank et al., 1998). Cueva de Agua, Punte los Ingleses is located at the base of the meseta cliffs just west of Punte los Ingleses on the southeast side of the island (Figures 1 and 2).

## METHODOLOGY

A total of seven cave wall and ceiling samples were taken within Cueva de Agua, Punte los Ingleses (Figure 2). The location and the original orientation of the samples were noted along with relative position to cave survey stations. Thin sections, with blue epoxy to indicate pore space, were cut from these samples. Petrologic analysis was done using a Nikon PH-1 petrologic microscope. A minimum of 400 points were counted using a Swift automatic point counter.

## RESULTS

The results of the petrologic analyses are presented in Table 1. The data show that while some of the samples taken from the cave contain information on allochem composition, most of the samples are so highly altered that only limited data could be ascertained. These highly altered rocks may reflect enhanced diagenesis due to being subjected to mixing zone chemistry for a considerable interval during the time the caves developed. Therefore, they may not necessarily reflect the true diagenetic condition of the interior of the Lirio Limestone throughout Isla de Mona. Although this petrologic study reveals that dissolution of corals and forams accounts for a minor portion of the secondary porosity, unlike the results reported by Ruiz (1993), in some cave rock samples dissolution of red algae accounts for an even higher percentage of the total dissolved allochems. Vuggy porosity, which is the most common porosity

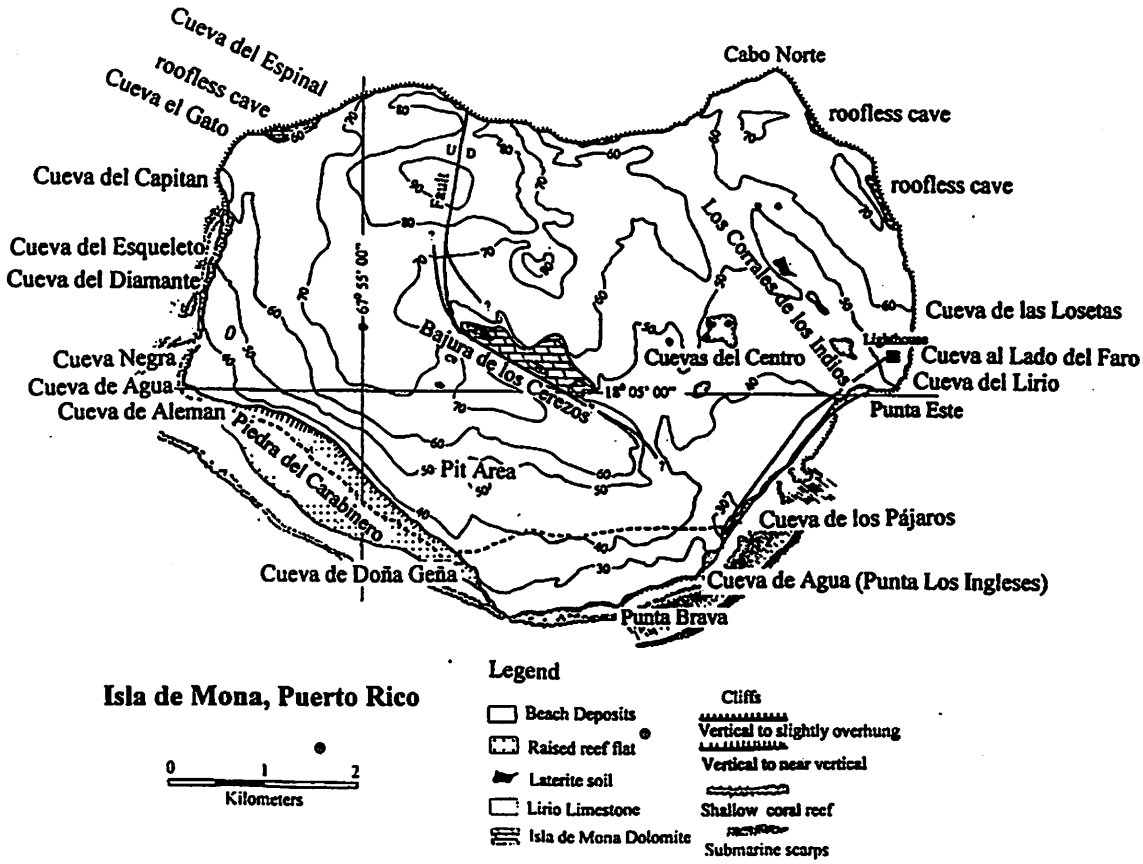


*Figure 1: Map of Isla de Mona, showing topography, geology, and locations of important caves. Cueva de Agua, Punte los Ingleses is shown on the southeast side of the island (adapted from Frank et al., 1998).*

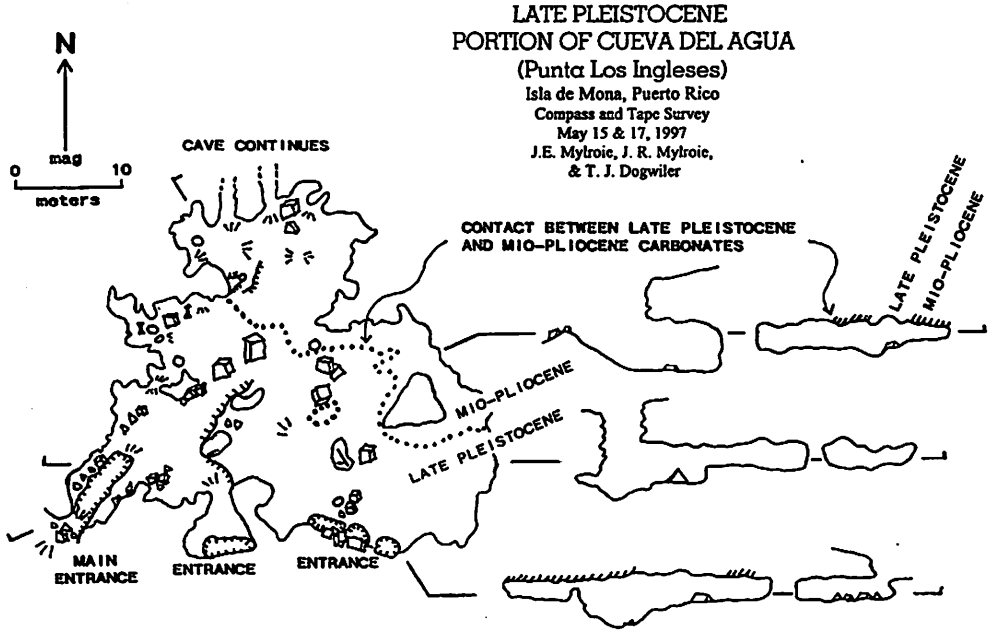


*Figure 2: Map of Cueva de Agua, Punte los Ingleses, showing contact of the Mio-Pliocene carbonates (Lirio Limestone) with the Late Pleistocene reef rubble facies. The cave is developed through both units.*

type, ranges from 1.5% -17.2%. Intra-particle, Inter-particle, and moldic porosity were also observed, but are not common. Average porosity for all samples is 11.29%.

## DISCUSSION

The majority of the samples taken within Cueva de Agua, Punte Los Ingleses indicate that the rocks that form the margins of the cave have been highly altered. Therefore, many of the allochems observed in thin section are unidentifiable, or are totally obliterated; much of the rock can only be identified as micrite. From the evidence in those rocks that do contain identifiable allochems, it appears that the rocks of Cueva de Agua, Punte Los Ingleses are characterized by the presence of corals, forams, algae, and a few echinoderm fragments.

Cementation is generally by microcrystalline calcite and lesser amounts of sparry calcite. This micrite accounts for 73.56% of the total points counted on the seven thin sections; five samples had greater than 70.9% micrite matrix. Isopachus calcite cement, which consists of bladed crystals along the inside of the rims of a few coral allochems, was noted in a few samples.

The porosity observed is largely from the dissolution of several types of skeletal grains including coral, forams, and coralline red algae. Echinoderm fragments were observed, but due to an extremely low number present in the samples none were encountered during the point counting. In most samples where diagenetic alteration has not destroyed allochem identity, dissolved red algae grains are present in higher percentages than other types of dissolved skeletal grains. The porosity is typically vuggy, but intra-particle and moldic porosity are present in much lesser amounts. The average porosity for these samples is 11.29%.

In previous work, it was shown that the dissolution of skeletal grains on Isla de Mona is mostly fabric selective Ruiz (1993). Indeed, surface samples indicate that the high-Mg calcite algal grains resisted dissolution while the theoretically more stable aragonitic grains such as corals and forams dissolved leaving behind ghost remnants (Ruiz, 1993). In contrast, the abundance of dissolved red algal grains observed in the rocks analyzed for this study suggests that the diagenetic processes, which created the cave, led to the selective removal of the algae grains in the cave ceiling and floor samples.

## CONCLUSIONS

The petrologic analyses of seven cave ceiling and floor samples from Cueva de Agua, Punte Los Ingleses, on Isla de Mona show that the porosity consists mostly of vuggy porosity. The porosity is the result of dissolution of aragonitic skeletal grains including corals and forams, but weathered red algae grains account for a greater portion of the porosity observed.

| Sample | Micrite | Un-ID | Spar | Vug | Moldic | Inter | Intra | Coral | Foram | Algae |
|---|---|---|---|---|---|---|---|---|---|---|
| 5-12-1 | 70.9 | 1.6 | 17.6 | 13.6 | 0 | 0 | 0 | 0 | 0 | 9.9 |
| 5-12-2 | 64.2 | 0.8 | 13.5 | 12.2 | 0 | 0 | 0 | 2.8 | 1.8 | 4.7 |
| 5-12-3 | 66.8 | 1.2 | 5.6 | 17.2 | 0 | 0 | 0 | 1.2 | 2.6 | 5.4 |
| 5-12-4 | 74.9 | 0.4 | 0.6 | 14.8 | 0 | 0 | 0 | 0 | 0 | 9.3 |
| 5-12-5 | 83.1 | 0 | 11.8 | 1.5 | 0 | 0 | 0 | 0 | 0 | 3.6 |
| 5-12-6 | 79.5 | 0 | 2.0 | 10.4 | 0 | 0 | 0 | 0 | 0 | 8.1 |
| 5-12-7 | 75.5 | 0.9 | 6.3 | 9.3 | 0 | 0 | 0 | 1.5 | 0 | 6.5 |

(Un-ID = unidentified allochem)

*Table 1. Point count data (%) of ceiling and floor samples from Cueva de Agua, Punte Los Ingleses, Isla de Mona, Puerto Rico.*

This has not been observed in surface samples examined by previous workers. The apparently preferential survival in surface samples, of the theoretically less stable red algal grains, can perhaps be explained by the relative effects of microstructure and mineral stability, as suggested by Walter (1985).

According to that study (Walter, 1985), if carbonates are exposed to solutions that are undersaturated with respect to calcite, the aragonite grains with complex microstructures can dissolve more rapidly than high-Mg calcite grains. Whereas, high-Mg calcite grains will dissolve before aragonite ones if the solution is supersaturated with respect to calcite but undersaturated with respect to aragonite, or if the solution is supersaturated with respect to both calcite and aragonite. As reported by other workers (Ruiz, 1993), the diagenetic pattern seen in thin sections of surface samples is consistent with diagenetic alteration by meteoric water that is undersaturated with respect to calcite. The greater dissolution of the high-Mg calcite red algae grains in the cave rocks is open to a variety of interpretations. It could be that their diagenetic condition reflects exposure to the saline-freshwater mixing zone, as per the flank margin model of Mylroie and Carew (1990). This interpretation is supported by the findings of Walter (1985), because the mixing-zone water is likely to consist of water that was saturated or supersaturated with respect to both calcite and aragonite. Alternatively, the dissolution may reflect exposure of the cave rocks to saturated fresh waters that may have re-invaded the cave after its initial development. The latter is potentially supported by dissolved speleothems seen in nearly all Isla de Mona flank margin caves, including Cueva de Agua, Punte Los Ingleses (Frank et al., 1998).

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