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Front Cover: View to the SSE on White Cay in Grahams Harbour off the north coast of San Salvador, Bahamas. At this spectacularly scenic site one can see that marine erosion has removed the entire windward portion of these early Holocene eolianites (North Point Member, with an alochem age of ~5000 radiocarbon years B.P.) that were deposited when sea level was at least 2 meters below its present position.

Back Cover: Stephen Jay Gould, keynote speaker for this symposium, holds a *Cerion rodregoi* at the Chicago Herald Tribune's 1891 monument to the landfall of Christopher Colombus, which is located on the windward coast of Crab Cay on the eastern side of San Salvador Island, Bahamas. The monument consists of an obelisk constructed from local limestone which houses a carved rock sphere depicting the globe with the continents. The inscription carved in a marble slab, reads: "On this spot, Christopher Columbus first set foot upon the soil of the New World."

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PRELIMINARY PETROLOGIC ANALYSIS OF CUEVA DEL ALEMAN, ISLA DE MONA, PUERTO RICO

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ABSTRACT

Isla de Mona, Puerto Rico is a tectonically-uplifted island of predominantly Mio-Pliocene carbonates with a low-lying fringe of Pleistocene limestone. These carbonates have been divided into the Mona Dolomite and the overlying Lirio Limestone that commonly form up to 80 m near-vertical cliffs to the sea, or ramps to the limited coastal plain. There is a very high density of caves exposed in these cliffs. They are flank margin caves that 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 its reported contact with the underlying Mona Dolomite. Cueva del Aleman lies within the zone reported to be Lirio Limestone, and it was extensively sampled to take advantage of the access provided to the interior of the rock unit. The information obtained from analyses of these rocks could shed light on lateral facies changes within the Lirio Limestone, and diagenetic effects of exposure to the mixing-zone environment that produced the cave, including secondary porosity development.

Previous workers have examined surface samples from the pre-Pleistocene Mona carbonates and noted that secondary porosity within these units results primarily from the dissolution of gastropods and corals. The samples from Cueva del Aleman contain a great abundance of red algae, with foraminifera, echinoderms, corals, and peloids in lesser amounts. The micritized margins seem to have selectively impeded the process of dissolution responsible for the microporosity observed. Preliminary results indicate that while substantial dissolution of primary aragonite has occurred in the foraminifera and coral allochems, dissolution of the red algal allochems is significant and accounts for a major portion of the total rock microporosity. The dissolution of red algae appears to be of greater importance in the Cueva del Aleman samples than in surface samples studied by previous workers, and may indicate the greater importance and greater influence of the mixing zone of a past fresh-water lens on the diagenesis of the cave-wall rock. Analysis of the thin sections indicates that dolomite is present only in minor amounts.

INTRODUCTION

The geology of Isla de Mona has been the subject of limited petrologic study by previous researchers (Kaye, 1959; Briggs and Seiders, 1972) whose work consisted largely of mapping the island via field reconnaissance. Ruiz (1993) examined surface samples from the pre-Pleistocene carbonates of Isla de Mona, and showed that the dissolution of skeletal components in Isla de Mona is mostly fabric selective. He noted that aragonitic grains such as corals and gastropods are primarily affected by the processes of dissolution, but he also found that red algae fragments resisted dissolution. The purpose of this study is to determine whether petrologic differences exist between samples taken from within a cave on Isla de Mona and those from surficial samples examined by previous workers (Ruiz, 1993).

GEOGRAPHIC SETTING

Isla de Mona is an isolated carbonate plateau located in the Mona passage about midway between Puerto Rico and Hispaniola at latitude 18° 05' N 67°53' W (Figure 1). The island has a semi-arid tropical maritime climate with an average annual rainfall of about 810 mm, and an estimated temperature range of 20.5° to 29.1° C (Calvesbert, 1973). It is a kidney shaped island that is 12 km long and 5 km wide (Peck and Peck, 1981). The ~55 km^2 area of the island consists of an upland plateau (meseta) bounded by a relatively narrow, discontinuous coastal plain along its western and southern coast. On its northern and eastern sides there are 60-80 m vertical cliffs that extend below sea level for at least another 20-40 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.

GEOLOGY

The carbonates of the meseta of Isla de Mona were thought to be Miocene in age (Kaye, 1959; Briggs and Seiders, 1974), but they are now considered to be of both Miocene and Pliocene age (Gonzalez et al., 1993; Ruiz, 1993; Taggart and Gonzalez, 1994). The Miocene-Pliocene rocks have been divided into two units, the Isla de Mona Dolomite, and

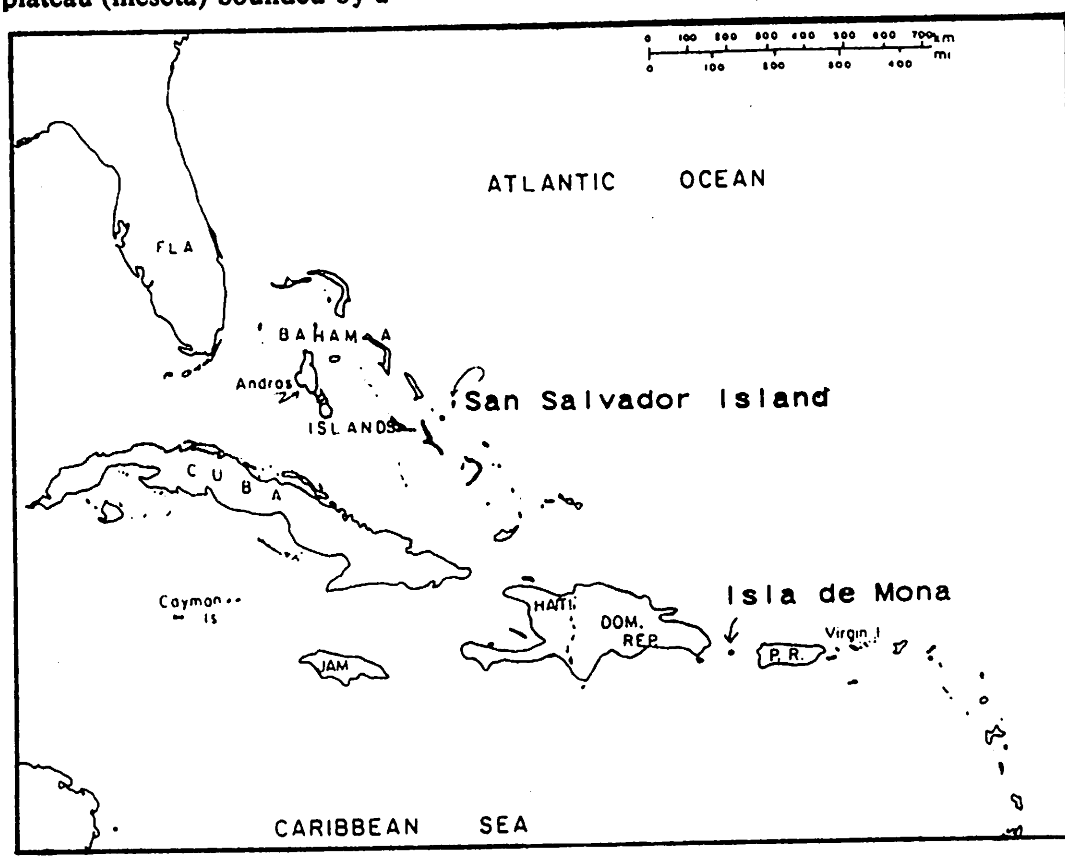

Figure 1. Map showing the location of Isla de Mona, Puerto Rico.

the overlying Lirio Limestone (Kaye, 1959, Briggs, 1959). Both units contain large flank margin caves, but the majority are concentrated at the designated contact between the Lirio Limestone and the Mona Dolomite.

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 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). Cueva del Aleman is on the southwest side of Isla de Mona, slightly west of the western end of the airport runway, where the Pleistocene coastal plain abuts the Miocene cliff (Figure 2).

METHODOLOGY

A total of 24 cave wall and ceiling samples were taken within Cueva del Aleman (Figure 3). Location and 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

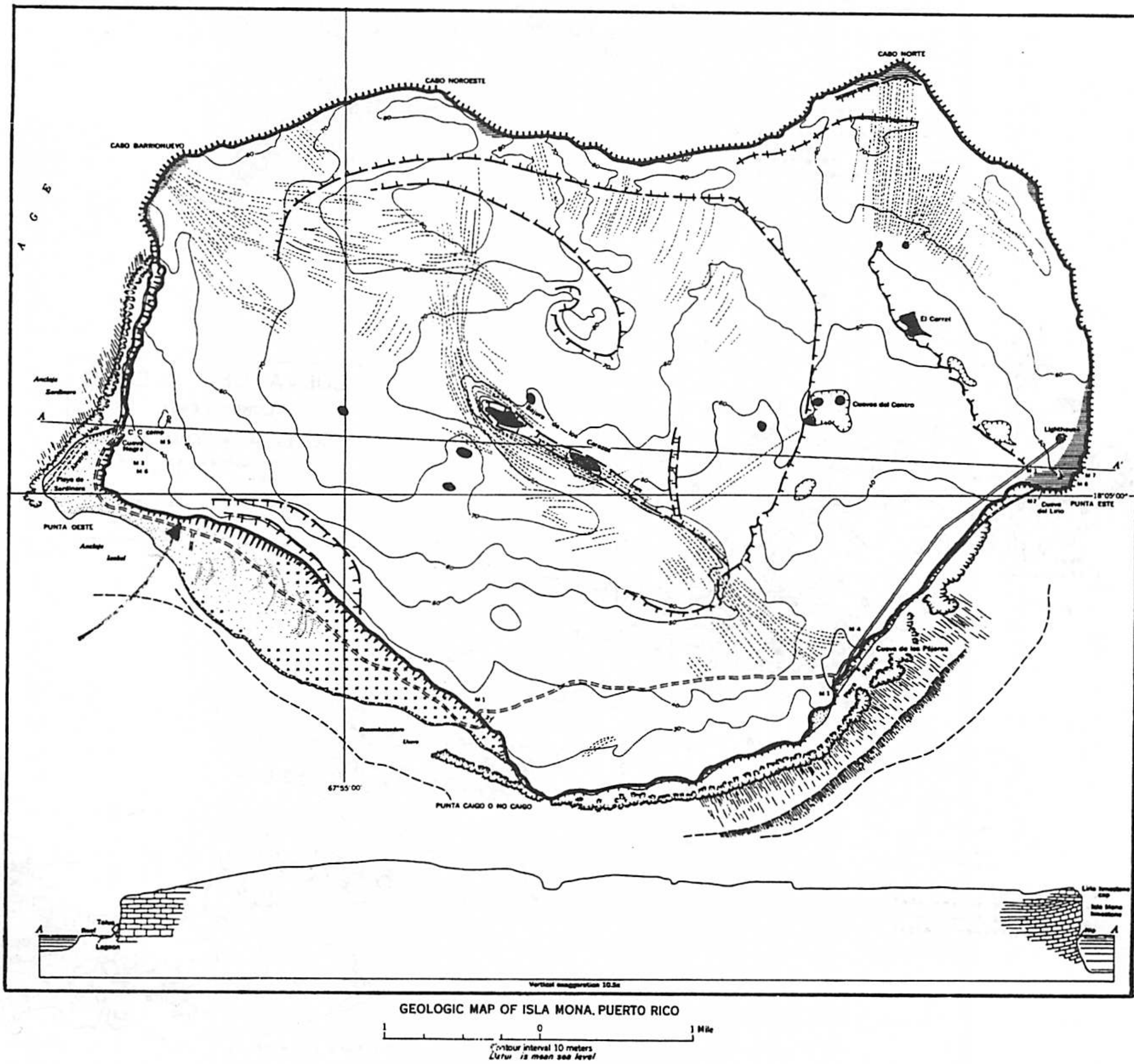

Figure 2. Geologic map of Isla de Mona. Puerto Rico (Modified from Kaye, 1959). The arrow points to the location of Cueva del Aleman.

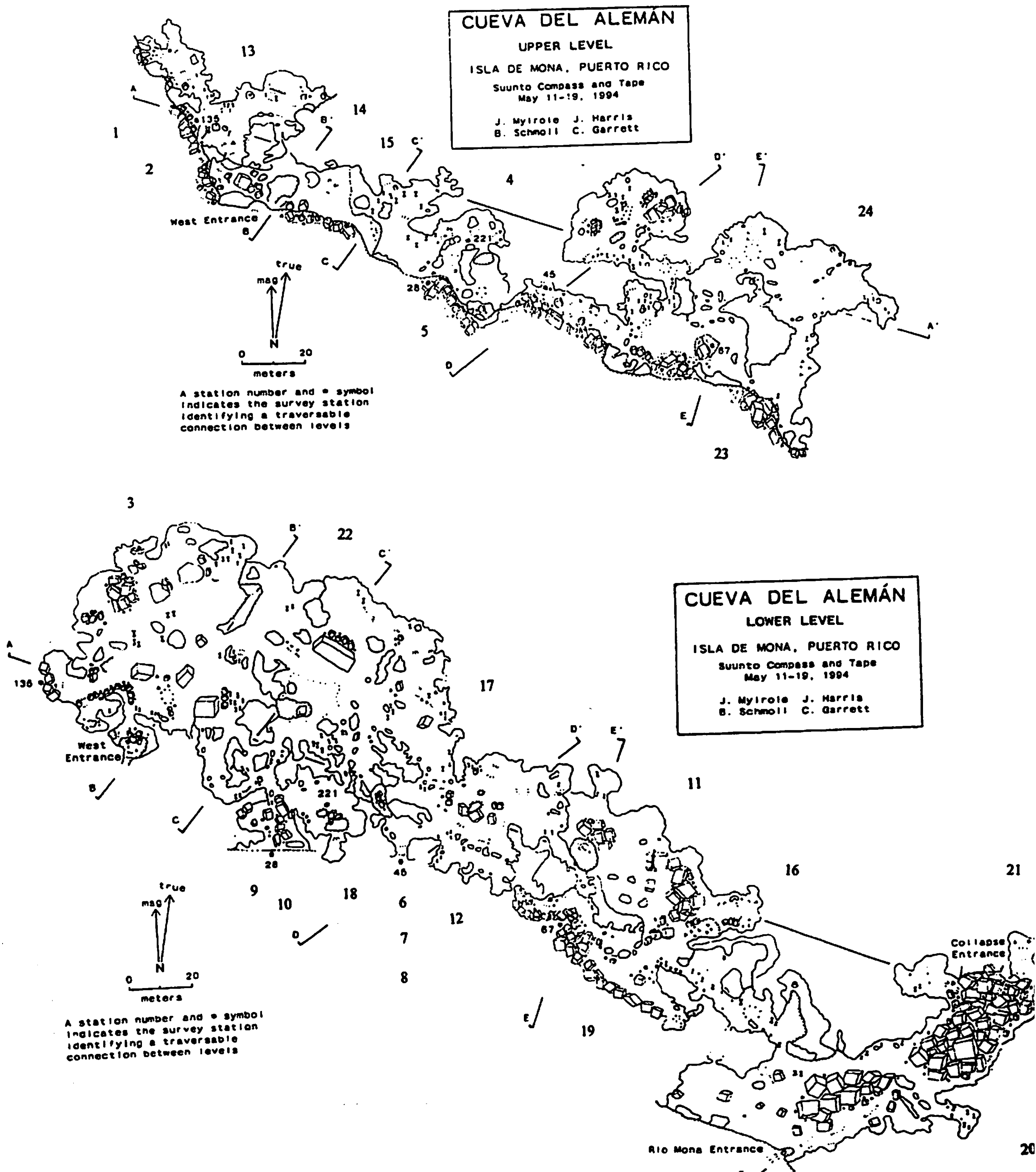

Figure 3. Maps of the upper and lower levels of Cueva del Aleman. Sample locations are indicated by number.

cut of these samples. Petrologic analysis was done using a Nikon PH-1 petrographic microscope. A minimum of 320 points were counted for each thin section 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 information could be ascertained. In most of these samples, skeletal fragment identification was impossible. These highly altered rocks may reflect enhanced diagenesis from being subjected to mixing zone for a considerable interval during the time the caves developed, and they may not necessarily reflect the true diagenetic condition of the interior of the Lirio Limestone throughout Isla de Mona. Although this petrologic study, like that of Ruiz (1993), reveals that the dissolution of corals and gastropods accounts for a significant portion of the secondary porosity, in some cave rock samples algal fragment dissolution accounts for an even higher percentage of total dissolved allochems.

Vuggy porosity, which is the most common porosity type, ranges from 0-46.9 %, and averages 18.9 %. Intra-particle porosity ranges from 0-21.7 % with an average of 5.0 %. Moldic porosity is common in some samples, but averages only 3.0 %. Inter-particle porosity is the least common and averages just 1 %. Average porosity for all samples is 25.9 %.

DISCUSSION

The majority of the samples taken within Cueva del Aleman 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; so, much of the rock can only be counted as micrite. From evidence in those rocks that do contain identifiable allochems, it appears that the lithology of the rocks of Cueva del Aleman are characterized by the presence of corals, forams, and algae, with lesser amounts of echinoderm fragments. Dolomite is present only rarely. Some samples show excellent moldic, intra-particle, and inter-particle porosity.

Cementation generally is by a matrix of microcrystalline calcite containing a low number of nearly obscured pellets. This matrix accounted for 64.5 % of the total points counted on the 24 thin sections; and twelve samples have greater than 70 % of this 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. A very few acicular crystals were observed on the fringes of some of the allochems. The presence of these crystals may imply that the original cement may have been composed of Mg-calcite, but these crystals are so scarce that no conclusions should be based on their presence.

The porosity observed is largely from the dissolution of several types of skeletal grains including: coral, echinoderms, foraminifera, and coralline algae. In most samples where alteration has not destroyed allochem identity, dissolved algal grains are present in higher percentages than other types of dissolved skeletal grains. It should be noted that in one sample (5-18-18) approximately half of the algal grains were unaltered, while in all other samples they are represented by moldic and intra-particle porosity. This is testimony to the highly variable nature of the diagenetic effects seen in these rocks. The porosity is typically vuggy, but intra-particle and moldic porosity are sometimes prominent. Inter-particle porosity is generally a minor component, and is of significance in only two samples. Average porosity for these samples is 25.9 %, and the range is 7.9-55.8 %.

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 high-Mg calcite red algal grains resisted dissolution while the relatively more stable aragonite grains such as corals and gastropods dissolved leaving behind only ghost remnants (Ruiz, 1993). In contrast, the abundance of dissolved red algal grains observed in this study suggests that the diagenetic processes which created the cave led to the removal of the algal grains in the cave wall rocks.

Table 1. Point count data (%) of ceiling and floor samples from Cueva del Aleman, Isla de Mona, Puerto Rico.

SAMPLE	Micrite	UN-ID	Spar	Vug	Mold	Inter	Intra	Coral	Foram	Shell	Algae
5-18-1	59.0	3.0	0	30.6	0.3	0.3	2.7	1.8	1.8	0	0
5-18-2	60.8	4.2	3.6	22.5	1.5	0	0.3	0	3.3	0	3.6
5-18-3	70.0	1.4	12.1	15.4	0.2	0	0	0	0.5	0	0
5-18-4	70.5	0	0	29.4	0	0	0	0	0	0	0
5-18-5	43.1	3.2	20.1	16.8	10.9	0	0	0	0.8	0	4.7
5-18-6	79.7	0.2	1.1	18.7	0	0	0	0	0	0	0
5-18-7	74.8	0.8	4.1	13.1	1.1	0.8	0.2	2.0	2.3	0	0
5-18-8	77.5	0.9	3.6	12.5	1.8	0	0	2.1	1.8	0	0
5-18-9	81.3	0	0	18.7	0	0	0	0	0	0	0
5-18-10	27.5	8.3	5.6	23.3	0.5	8.0	13.5	0.5	10.0	0	3.5
5-18-11	22.6	5.3	1.3	28.6	9.8	1.1	16.3	0.2	5.7	0	9.9
5-18-12	71.5	3.3	6.7	8.5	10	0	0	0	0	0	0
5-18-13	74.0	0.6	0.9	0.3	0	0	21.7	0	1.9	0	0.6
5-18-14	86.3	4.0	2.5	5.7	1.5	0	0	0	0	0	0
5-18-15	86.7	1.5	0	7.9	3.9	0	0	0	0	0	0
5-18-16	69.9	1.4	0	4.7	21.5	0	0	0	0.2	2.0	0
5-18-17	49.7	0.8	0.2	39.0	0.5	0	4.9	0.5	0.8	0	2.9
5-18-18	58.8	1.1	8.3	8.3	0.8	0	17.6	0	0.2	0	5.0
5-18-19	53.5	0	0	46.9	0	0	0	0	0	0	0
5-18-20	61.3	0.8	0.2	35.6	0	0	0	0	0.5	0	1.1
5-18-21	87.1	0.5	0	11.6	0	0	0.5	0	0	0	0
5-18-22	78.4	0.5	0.8	13.2	0.2	0	6.4	0	0	0	0
5-18-23	42.4	6.1	0.2	39.2	6.4	0.5	0	0	0	0	0
5-18-24	60.0	0	21.5	4.4	0.3	13.6	0	0	0	0	0

CONCLUSIONS

This preliminary petrologic analysis of 24 cave wall and ceiling samples from Cueva del Aleman, Isla de Mona (Table 1) show that porosity is commonly represented by vuggy, moldic, and intra-particle porosity. The porosity is the result of dissolution of skeletal grains including corals, forams and shells; but moldic and intra-particle porosity associated with red algal grains accounts for a significant portion of the porosity observed. 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 Walter's study (1985), if carbonates are exposed to solutions that are undersaturated with respect to calcite, 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 is supersaturated with respect to both calcite and aragonite. The diagenetic pattern reported in thin sections of surface samples is consistent with diagenetic alteration by meteoric water that is undersaturated with respect to calcite. Whereas, the greater dissolution of the red algal 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, or they may reflect their exposure to waters that 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 Aleman.

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