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Microbial-mediated carbonates in the Gulf of Cádiz: data of Ibérico, Hespérides, Cornide and Fila de Hormigas

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Giant fields of submarine carbonate concretions, crust, slabs and mounds were discovered around seafloor seep areas in the Gulf of Cádiz at 1000 m depth. These giant fields formed through the release of methane to the ocean floor and its anaerobic oxidation by methane oxidizing microbes. The study area (more than 8.500 km2) was intensively surveyed during several cruises carried out by the Spanish research vessels BIO Hespérides and Cornide de Saavedra from 1999 to 2002 by means of multibeam echosounder, ultra high-resolution reflection seismics, underwater TV camera, dredging and coring. Images of the sea -floor show a variety of mounds some rising more than 250 m above sea floor with steep slopes up 25º. Underwater camera images revealed a high density of carbonate tubular concretions at the crest and along the flanks of mounds. In this work some of the results for Ibérico, Cornide, Fila de Hormigas and Hespérides samples are shown.

The first stage of collaborative projects by the Spanish groups has been to characterize the dredged materials in terms of their mineralogical, chemical and textural variability. Studies have included the analysis of underwater images, hand specimen descriptions, optical microscopy, catholuminiscence, XRD, SEM, δ^{13}C, δ^{18}O and ^{87}Sr/^{86}Sr determinations and U/Th dating. The study of both external shapes and sections of more than 350 fragments shows mainly concretions and crusts. A wide range of concretion

shapes are observed ranging from 1) irregular to nodular with empty tubular cavities to 2) cylindrical/conical shapes with inner cavities. The samples can be up to 80 cm in length for the irregular concretions and up to 70 cm in length and 30 cm in diameter for the tubular ones. A comparative study of the samples from the different sites suggests that at the Ibérico and Fila de Hormigas sites, thin walled (<5 cm) tubular geometries and crusts are most common with internal cavities ranging from 2 to 8 cm in diameter. In contrast, at the Cornide site, irregular to nodular and tubular geometries are present, with the most remarkable feature of these concretions, being the much greater thicknesses of the walls and the smaller diameters of the inner cavities. The outer walls of the studied samples also show differences for the 4 sites and are black to red stained and clearly bio-eroded for Ibérico and some of the Cornide samples, but grey with no signs of external oxidation for Fila de Hormigas and Hesperides sites. Other characteristic features from all sites, include twisted joints, incisions and striations.

XRD data, petrography and SEM studies reveal differences in nature and size of both authigenic and detrital minerals between the different sites. The general texture of most of the concretions is massive (both at hand sample and microscopic scale) and made of fine grained carbonates (micrite and microspar) with abundant detrital grains (feldspars, kaolinite, chlorite, smectite, calcite, dolomite, and minor amounts of Ti oxides and apatite). Coarse silt quartz content in Fila de Hormigas samples can be up to 40%. The mineralogy of authigenic carbonates is dolomite, calcite and high magnesium calcite. Glendonite after ikaite has also been observed in Ibérico site in the SEM images. Framboidal pyrite fills foramminifera test in some samples. δ^{13}C values ranging from -20 to -48 permil PDB suggests CO_2 derived from the oxidation of thermogenic and/or biogenic methane. ^{87}Sr/^{86}Sr values of Hespérides and Ibérico sites 0.708747$\pm$ 10 to 0.709099 $\pm$10 respectively indicate seawater ages from 16 to 1.6 Ma but could be consistent with precipitation from Holocene to recent seawater at both sites, if significant non-seawater derived primitive Sr is present. U/Th dating of two selected samples yield ages of 19142 $\pm$4270 and 13851 $\pm$ 1481 yr. A significant contribution of deep-seated fluids can be inferred from the ^{87}Sr/^{86}Sr values and the δ^{18}O data suggesting the supply of fluids enriched in ^{18}O.

Following the results obtained from the first stage of these collaborations, new studies will investigate the genesis of these tubular structures and the timing, origin and path of the fluids. The study of ichnological assemblages and its relation to the formation of carbonate from the concretions as well as the study of magnetic anisotropy of the concretions or microbiological studies, will provide insights on the growth mechanisms of these structures. The wide range of fine grained carbonate minerals found in most of the samples, made necessary a detailed geochemical analysis of microsam-

ples to constrain both the nature and the source of fluids and the diagenetic process that occurred in the carbonates.

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