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An alternative interpretation for the carbonate "chimneys" from The Gulf of Cádiz as concretions around burrows

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More than 200 carbonate concretions, crusts and slabs were dredged from the Gulf of Cadiz during cruises ANASTASYA 00/09 and ANASTASYA 01/09 (years 2000 and 2001). These concretions have diverse shapes, sizes and mineralogies. The external shape of the concretions may be irregular to nodular with more than two empty tubular cavities. Tubular cavities, however, are sometimes not easily differentiated in some of these irregular concretions, as they are filled with sediment, or not obviously seen at the outer surface of the concretion. Other concretions show cylindrical / conical shapes with an inner cavity, frequently empty, though sometimes filled with sediment.

Preliminary investigations by several groups focused on the study of the second type of concretions. These were interpreted as methane-seeping conduits ("chimneys") mostly because of their shapes and very low δ^{13}C values. The later suggests that significant amounts of CO_2 were derived from methane oxidation. The role of these structures as zones with increased permeability that might have favoured fluid circulation cannot be ruled out, however their origin and depth of formation is still an unsolved issue. Nevertheless, the study of more than 150 selected concretions that were cut in different directions allows proposing an alternative explanation at least for some of them. The central tubular cavities may represent fossilised dwelling burrows. The higher permeability of open (or partly sediment-filled) burrows, compared to the fine-grained

sediment where they were excavated, would have favoured lithification around them and the formation of the concretions.

The analysis of the concretions reveals a composite ichnological assemblage resulting from the overprinting of three successive trace fossil suites controlled by the changing nature of the substrate from a softground to a firmground and finally a hardground. The softground ichnosuite records ichnofauna typical of a pelagic depositional settings. The assamblage is dominated by the branching trace fossil Chondrites, and it has to be considered previous to the earlier stages of lithification. The firmground ichnosuite was developed during early cementation of the substrate, probably related to sediment starvation. This ichnosuite consists of open dwelling burrows corresponding to the tubular cavities of the concretions. It is not easy to characterise their 3-D configuration due to their partial preservation but the presence of occasional branches suggests that they could be comparable to Thalassinoides. The concretions formed during or immediately after this stage by carbonate precipitation around the dwelling burrows and in some cases around other bioturbation structures such as Zoophycos. The third (hardground) ichnosuite consists of bivalve, worm and sponge bioerosion structures (Gastrochaenolites, Trypanites, Caulostrepsis, Maeandropolydora, Entobia) bored from the surface of the carbonate concretions after they had been exhumed.

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