MAGNETOFOSSIL ABUNDANCES ARE ASSOCIATED WITH DISTAL DELTAIC BOTTOMSETS AND LOW SEDIMENTATION RATES IN THE GUADALQUIVIR BASIN, SPAIN; IMPLICATIONS FOR THE RECOVERY OF BIOSIGNATURES FROM JEZERO CRATER AND OXIA PLANUM, MARS.

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Introduction: Jezero Crater in Mars is a structure that was filled by a Noachian phase of fluvial activity in its headwaters and lacustrine sedimentation in its interior [1,2]. Reactivation of this fluvial-lacustrine system during the early Hesperian (3.2-3.6 Ga) led to formation of a crater paleolake, where two inlet fluvial channels debouched to form fan-deltas that have been identified from their prograding clinoforms and distal bottomsets. A similar context, with Noachian clay-rich sediments overlain by a later, still Noachian fluvio-deltaic sequence, is also found in Oxiam Planum [3]. Fluvio-deltaic bottomsets in Jezero Crater and Oxia Planum are of prime astrobiological interest for the Mars 2020 and ExoMars missions, respectively, because of their flat geometry and fine-grained, clay-rich composition, which offer good landing conditions and the highest potential for accumulation and preservation of organic materials and other biosignatures [1-3]. Here we present new results from the Guadalquivir Basin, SW Spain, which we propose as a terrestrial analogue where insights into biosignature preservation in Martian fluvio-deltaic bottomset sediments can be gained.

The Guadalquivir Basin: this basin is an ENE-WSW elongated trough that formed in the southern Iberian margin in response to rapid late Miocene tectonic uplift and emergence of the Betic orogen [4,5]. This basin might be a useful analogue for the Jezero Crater fluvio-lacustrine sediments for two main reasons. First, rapid basin drowning led to formation of sand-rich deltaic sediments sourced mainly from the NE corner of the basin, that graded to clay-rich, distal bottomsets through a set of prograding clinoforms characterized by mixed clay-silt lithologies [4]. Moreover, this basin was fed by acidic, metal-rich runoff (e.g. Río Tinto [6]) and groundwaters [7] sourced from the massive sulfide deposits of the Iberian Pyritic Belt. Second, the magnetic mineral assemblage of clay-rich sediments that typify the distal bottomsets (e.g. Gibraleón Clay formation) is dominated by magnetite magnetofossils, which are the post-mortem remains of magnetotactic bacteria [5]. Here we present a record of magnetofossil abundances obtained from two boreholes drilled in the westernmost part of the basin. These records have a high-resolution cyclostratigraphic framework [8,9] that enables calculation of sedimentation rates to establish links between magnetofossil abundances and sedimentary conditions.

The magnetofossil record of the Guadalquivir Basin: magnetofossils have been identified in selected sediment samples from the Gibraelón Clay formation using a distinctive central ridge signature observed in first-order reversal curve diagrams (FORC) and a Verwey transition observed at 105 K in low-temperature measurements [5]. Here we determine whether magnetofossils dominate the magnetic signal of these sediments by using the ratio of the susceptibility of anhysteretic remanent magnetization (χ_{ARM}) to the magnetic susceptibility (χ); values higher and lower than 5-10 signal the presence of single-domain (SD, 30-120 nm long) magnetite that occurs as magnetofossils and of coarser, detrital magnetic grains, respectively [10]. Temporal χ_{ARM}/χ variations from core MT-1 indicate a magnetofossil dominance in sediments aged 7.25 to 5.85 Ma, during deposition of bottomsets in distal, deep basinal (e.g., 300 m deep [11]) positions with slow (<0.1 m/kyr) sedimentation. A sharp transition from magnetofossil-dominated to detrital-dominated magnetic assemblages at 5.85 Ma coincides with a shift to siltier and shallower (150 m deep [11]) sediments that preceded a sedimentation rate increase and coarsening at 5.6 Ma. χ_{ARM}/χ ratios from core HU-1 transition more gradually from those representative of magnetofossil-dominated to detrital-dominated magnetic assemblages. Yet, by 5.55 Ma, and coinciding with a sharp accumulation rate increase, magnetofossils are no longer identified from χ_{ARM}/χ values.

Implications for Jezero Crater and Oxia Planum: although the transition from magnetofossil-dominated to detrital-dominated magnetic assemblages in the two studied boreholes is not coeval, possibly due to a combination of factors, our data clearly relate preferential magnetofossil formation and preservation to clay-rich sediments that accumulated slowly in distal, deep water bottomsets (Figure 2). These results have two important implications for the sampling strategy that might be followed by the Mars 2020 and ExoMars missions. First, they reinforce the view that clay-rich sediments from prodeltaic bottomsets within Jezero Crater and Oxia Planum have the highest potential for accumulation and preservation of biosignatures [1-3]; thus, the more distal the sampling position within the fluvio-lacustrine bottomset, the larger the chances of finding biosignatures. Second, magnetofossils are the fossilized remains of magnetotactic bacteria, which are primitive prokaryotes that emerged on Earth between 3.4-3.2 Ga [12]. The presence of a planetary magnetic field at that time conferred these organisms, through natural selection, the ability to synthesize magnetic particles that assisted navigation [12]. Conditions conductive to the emergence of magnetotactic bacteria (e.g., chemically stratified aquatic environments shielded by a planetary magnetic field [12]) also occurred in Noachian and early Hesperian Mars [13], so whether magnetotactic bacteria emerged by convergent evolution or through panspermia, there is the possibility that they were also present in Mars.

The presence of magnetofossils in distal deltaic bottomset sediments of the Guadalquivir Basin suggests that magnetofossils might need to be considered of prime astrobiological interest when studying returned samples from Jezero Crater and Oxia Planum [13].

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