

Kremydilites: Sedimentary-, biogenic structures formed in the Urucum Ediacaran to Cambrian manganese ores (MS, Brazil)

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The Urucum region (MS, Brazil) contains Neoproterozoic iron and manganese deposits, the original resources of which were estimated at 36,000 Mt of iron-bearing rock and more than 600 million tons of rocks with a high manganese content. Three layers containing manganese, designated layers Mn-1, Mn-2 and Mn-3, are interbedded with banded iron formations and ironstones of the Santa Cruz Fm., both of which belong to the Jacadigo Group, and are surrounded by carbonate rocks of the Bocaina and Tamengo Formations of the Corumbá Group. This geometry and these geological characteristics suggest the presence of an ancient sedimentary basin formed by a graben, with the Santa Cruz Fm. sediments being deposited in the depocenter over fluvial deposits of the Urucum Formation, and limestones of Bocaina and Tamengo Formations being deposited in edge regions. As the graben deepened, it was flooded with seawater, thereby forming a marginal basin. The seawater precipitated iron followed by manganese in the pores of arkosean sandstones along a front between continental and marine phreatic zones, thereby forming the Lower Mn-1 layer, which is a diagenetic ore layer. The remaining manganese precipitated on the basin floor simultaneously with deposition of clastic material by turbidity currents, thereby forming the Upper Mn-1. Two other water influx, which occurred during periods of volcanic quietness, flooded the Urucum basin with water with many bacteria, Fe, Mn, SiO₂, P, Co, Ni and Cu. The micro-organisms oxidized Mn²⁺ and Fe²⁺ to form Mn (OH)₄ and Fe (OH)₃, died and settled to the floor of the gulf, thereby forming a biomass permeated by iron and manganese hydroxides at depths reached by solar radiation next to and below the oxycline. Kremydilites, which are oblate-, zoned structures, products of bacteria colonies, developed within this biomass, and during their development CH₄ and/or H₂ was produced and expelled in gas bubbles, which left the kremydilites up towards the surface. In the early diagenesis, worm-like organisms inhabited biomass. These organisms separated iron from manganese producing cryptomelane microbialites, which agglutinated in manganese micro-nodules that coalesced to form layer Mn-2, containing massive cryptomelane. This process ended with the disappearance of the microorganisms and the precipitation of the BIFs. A new water influx generated layer Mn-3 via the same process that generated Mn-2. The last upwelling of seawater precipitated iron formations in the basin depocenter while limestone of the Bocaina and Tamengo Formations was deposited in shallow water regions. Since the first flooding and spanning to the present, water infiltrating the Urucum Formation has formed concretionary minerals and recrystallized cryptomelane as hollandite.