THE EVOLUTION OF ASTRONOMICALLY FORCED SILICLASTIC RHYTHMITES OF THE ANCIENT EARTH AND THEIR CORRELATION TO BANDED-IRON FORMATIONS

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Introduction: Modern-day and ancient geologic records contain similar laminae patterns indicative of cyclic events. Observed shallow marine and lagoonal settings produce bedforms known as tidal rhythmites. However, interpretations of ancient depositional patterns (rhythmic or astronomically-forced bedforms) predominately couple rhythmites with large-scale astronomical variations (glacial and eustatic fluctuations) or fluctuations in ocean oxygen content. Ancient banded-iron formations are historically linked to anoxic events [1-2] 1; but, results of current research by many BIF workers, compiled by Trendall and Altermann [3-4], resist Cloud's comprehensive hypothesis of cyclical anoxia as the primary agent of chemical precipitation. In addition, careful reexamination of foreset-laminae thickness within ancient sedimentary successions may reveal closer ties to paleotidal cycles [5].

Although the bulk of past research presumes that metamorphism, Milankovitch or climatic events have annihilated or overprinted any small-scale, orbitally-influenced, ubiquitous laminations, recent research suggests preservation of small scale patterns is possible. Observational acuity would suggest that quartz and iron have resisted extensive overprinting in stable cratonic settings. Experiments have also shown that the presence of dissolved iron enhances the precipitation or polymerization of silica from solution H_4SiO_4 [6]. Thus a chemical, thermodynamic mechanism for early preservation of iron- and chert-dominated rhythmites may exist in addition to the influence of microbial activity.

Discussion: Modern day analogs of tidally-forced rhythmites, preserved in their depositional settings, can be found in the Bay of Fundy in eastern Canada [7], Bay of Mont-Saint-Michel in France [8], and Cook Inlet in south-central Alaska [9] among many others. Lamina patterns reveal diurnal, semidiurnal, fortnightly, monthly, and other annual periodicities. High and low tide, spring and neap tide, and synodic sets establish modern-day sedimentation rates and provide correlations to Paleozoic sequence-stratigraphic successions [10, 3, 5]. Laminae thickness and grain size are amplified during higher tide and minimized during lower tide when silt and clay deposition occurs.

The present deceleration of the Earth's rotation and the recession rate of the Moon dictate that in the past, higher tidal influence – frictional heating and ocean tides – must have prevailed. Reconstruction of recorded historical astronomical data and eclipse records support a shorter Earth day. In addition, well-preserved, Neoproterozoic rhythmites in the Reynella and Elatina Formations [5], contain well preserved tidal signatures reflecting 13.1 $\pm$ 0.1 synodic months/year, 21.9 $\pm$ 0.4 hours/day and a mean lunar recession rate of 2.17 0.3 cm/year, a little more than half the present rate. Present (3.82 cm/yr) and extrapolated lunar recession rates (2.17 cm/yr to ~620 Ma) suggest that shorter, more pronounced periodicities would have existed in the Proterozoic [5]. This supporting evidence of shorter days and months with longer years helps confirm that rhythmite patterns are preserved in the rock record.

The broad global distribution of finely banded-iron formations, of hydrothermally-derived, banded chalcedony, and of low temperature alternating iron and silica cements provides evidence that iron, silicon, and oxygen are not only abundant elements in the earth's crust, but they are also mineralogically compatible under certain situations [11-12]. This study focuses on petrographic evidence from quartz and iron cutans formed in a lagoonal or ponded setting, where preservation of parallel banding patterns was exhibited at a microscopic level.

Preservation of SiO_2 and Fe oxides occurred during precipitation and progressive recrystallization. Multiple iron coatings or rims in the cements indicate separate episodes and possible correlation to the experimental results of Krauskopf [6]. The iron and quartz mineralogy suggests that although diagenesis and evolution of microlaminae of iron and siliciclastic minerals occurred, thermodynamic stability resulted when parallel banding occurred in the cements. Greater surface areas of microcrystalline quartz or chert, with fibrous or elongated crystals surrounded by iron oxides, had higher surface energies which drove the recrystallization process – Ostwald ripening [13] – towards the lower free-energy megaquartz and iron oxide bands.

Large scale migration of iron and silica did not occur. Pressure solutioning and crystalline maturation resulted in the realignment of the crystals perpendicular to stress with little vertical migration. Parallel banding at microscopic levels mimics banding BIF laminae. A symbiosis of sorts appears to exist between iron and silica capable of preserving small scale tidal rhythmite structures.

Summary:
It should be noted that under higher temperature or pressure conditions, the opposite is true. Greater migration of iron and quartz is thermodynamically favored. Thus, thick massive iron formations suggest instability, plutonic or hydrothermal activity, or chemical and biological precipitation under vastly different conditions as suggested by [1-2] than those that exist today.

Based on petrographic evidence, small scale structure of iron and silica banding is energetically favorable and can be preserved early in deposited strata providing additional support for lunar or tidally influence rhythmite preservation. Modest shifts in lunar orbital dynamics, though not conclusive, may yield the best data for the Earth-Moon separation and tidal dissipation through time.

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