DIVERGENCE OF PARALLEL WORLDS: EVIDENCE FROM AQUEOUS CHEMICAL DEPOSITS ON EARLY EARTH AND MARS.

J. S. Kargel[1], James K. Crowley[2], C.R. de Souza Filho[3], Simon J. Hook[4], Giles M. Marion,[5] [1]Dept. Hydrology & Water Resources, Univ. Arizona, Tucson, AZ, kargel@hwr.arizona.edu, [2]U.S. Geol. Surv., Reston, VA; [3]Univ. Campinas, Brazil; [4]JPL, Pasadena, CA; [5]Desert Research Inst., Reno, NV.

Summary: The latest Archean (~2.5 Ga) history of Earth and Noachian/Early Hesperian (~3.9 Ga) of Mars included some parallelism of aqueous environments. We draw insights from the Wittenoom formation (Western Australia) and Martian salts. The Wittenoom's carbonates (Fig. 1) and other coeval carbonates mark a revolution in Earth environmental history not followed very far by Mars.

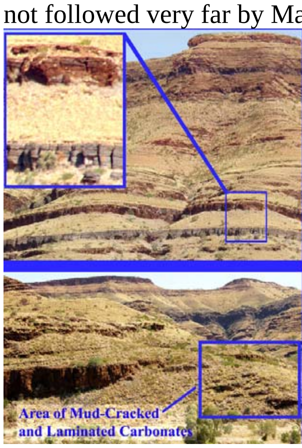

Figure 1. Wittenoom Formation (lower part of bedded sequence) at Bee Gorge looking (top) southward and (bottom) westward from the canyon mouth. In the top panel and inset, note the color contrast of weathered beds of carbonates, a visual hint of the chemically heterogeneous nature of the formation. Outline in bottom panel shows the main sample locality for materials highlighted in this abstract.

Introduction: The Wittenoom Formation (Hamersley Basin) is a sedimentary unit of Fe-Mn-rich carbonates, tuffaceous shale, arenaceous beds, chert, and banded iron-formation. An important locality near Bee Gorge (Fig. 1) contains chemical and physical evidence for rapidly oscillating oxygenation and transition metal content of shallow basinal waters, for shallow water and desiccation, and possible microbial activity. This rock unit occurs on the Archean-Proterozoic boundary and, with bended iron-formation units with which it is interbedded, appears to mark a major transition in Earth history. The transition included sporadic movement toward a more life-rich and oxygenated hydrosphere and dominance of the ecosystem by photosynthetic life, and away from Fe-Mn-rich chemical sedimentation of silica- and iron minerals in marine environments to carbonate- and sulfate-dominated marine chemical sedimentation. Mars appears to have gone partway through this transition but never deposited thick carbonate beds.

Shallow water and microbial activity

The prevalent water depth and other aspects of the depositional environment of the Wittenoom formation has been controversial, with some workers favoring a shallow-water platform [1-3], some favoring a continental shelf and slope environment [4], and others favoring a deep-sea/mid ocean ridge environment [5]. In our view, the strong lateral continuity of bed and lamination sequences in the Hamersley Group is a simple, compelling argument that this is basically a shallow-water, platformal sequence [1,2]. However, there is more direct physical evidence of this, although we acknowledge evidence reported by Hassler, Simonson and colleagues [4] of high-energy turbidty flows.

Figure 2 shows some new evidence for mud desiccation cracking in a laminated part of the Wittenoom formation exposed in Bee Gorge. Abundant new evidence at this locality supplements that reported by Kargel et al. [6]. The desiccation features occur in discrete beds and were syndepositional in the laminated sequence. Many horizons exhibit similar crack morphologies, indicating that as the sequence aggraded, subsidence maintained the unit near water level so that repeated subaerial exposure took place. The cracked sequences in some cases are associated with flat-pebble conglomerates, oolitic crack-filling materials, and severely contorted laminae. These features and the associations of them are of a type which [7] reported from the nearby Carawine Dolomite and which Simonson considered to be evidence for shallow water, desiccation, and microbial activity. We agree with his interpretation and apply it also to this locality in the Wittenoom formation.

Hence, the sedimentologial and geochemical features recorded here relate to atmospheric and basinal water conditions. The strong lamination and bedding recorded here pertains in part to possible microbial activity—perhaps cyanobacterial—and in part to strongly fluctuating oxygen fugacity. Chemical variation may be related to global mixing of anoxic ocean waters with an oxygenic surface layer, or may be related more to local oxygen generation by the microbial forms that might have produced the domal laminae.

Many of the domal lamination structures are built on mounds of flat pebble conglomerates and other mounds. A possible interpretation is that these are not microbial mats but instead are soft-sediment domes formed by intrusion/extrusion of clastic dikes. We do not exclude this possible origin and are studying these materials further. We stand by unequi-vocal evidence for repeated mud desiccation and infer that this locality was aggrading near water level; it was a shoal or lagoonal environment of some sort. If the lamina are cryptalgal or cyanobacterial, it suggests that local carbonate-precipitating life had become abundant.

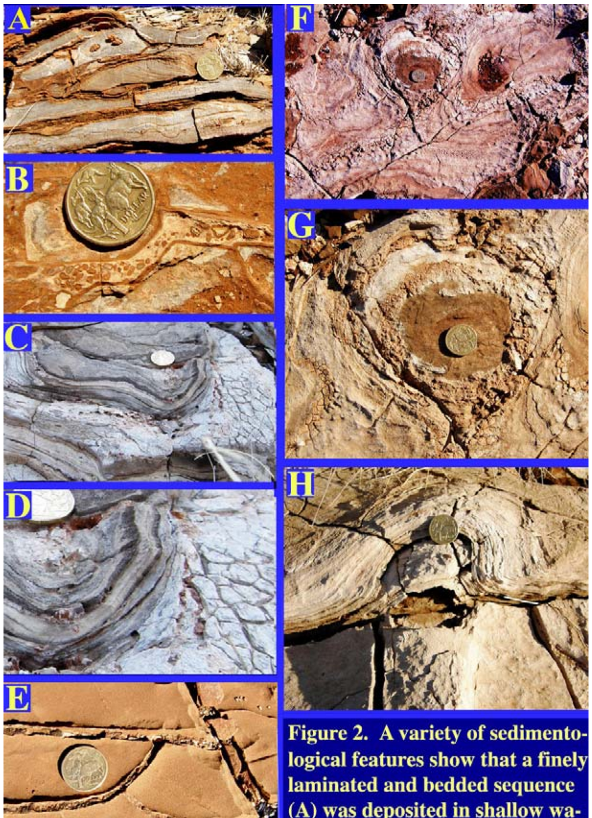

Figure 2. A variety of sedimentological features show that a finely laminated and bedded sequence (A) was deposited in shallow water of variable high energy. Depth repeatedly zeroed and the carbonate muds desiccated (B-G). Oolitic sediment fills cracks (B). Desiccation cracks (C-G) show syn-depositional relationships (C-D, F-G). Rip-up clasts and cross lamination (not shown) as well as the ooids indicate high wave or current energy. Chert beds (not shown) and fine laminae indicate quiescent water at times. Domal laminations built on mounds of flat-pebble conglomerates and other mounds may be evidence of microbial activity.

Oscillating brine composition

Figure 3 shows that the Wittenoom formation is chemically strongly heterogeneous. This was already known from the data of Veizer et al. [3] (blue fields in Fig. 3). Kargel et al. [7] found that carbonates at this particular locality at Bee Gorge far exceed the entire chemical variation seen by [3], seen also on the micro-scale in chemical zoning of carbonate rhombs (Fig. 4).

Conclusions

Planetary divergence may relate to the development on Earth through the Archean (3.8-2.5 Ga) of widespread conditions where rainfall became increasingly common and finally at the Archean-Proterozoic boundary, where oxygenic photosynthetic surface microbial life (cyanobacteria) finally could thrive in shallow nearshore waters on Earth; this never happened on Mars, which took some early steps similar to those of the Archean Earth toward oxidative hydrogeochemistry and surface-driven hydrogeology. However, from an early wet epoch (~3.9 Ga) Mars became increasingly locked into a dry, cryogenic state. Never particularly warm, Mars became a world dominated by subsurface hydrogeology and hydrogeochedmistry with episodic transient water outbursts, whereas Earth became increasingly driven by surface hydrogeology and hydrogeochemistry and photosynthetic biochemistry.

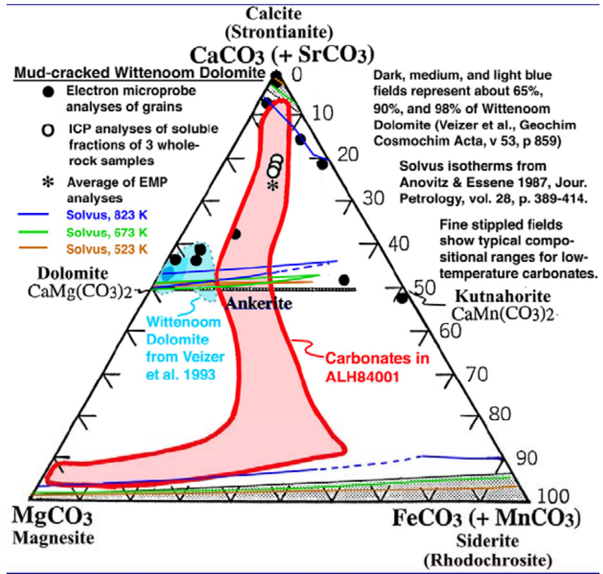

Figure 3. Ternary Fe-Mg-Ca-carbonate compositions, with added Mn and Sr components. Water can be implicit in the phase equilibria. There is wide disagreement of published phase equilibria, which points to the propensity toward metastable conditions in this system. Disequilibria is evident in the Wittenoom formation's carbonates, because it was never heated above low-grade metamorphic/diagenetic conditions, yet the carbonate composiions would require near-magmatic temperatures to achieve under equilibrium. This also is the conclusion of Treiman [8] for carbonates (red field) in Martian meteorite ALH84001.

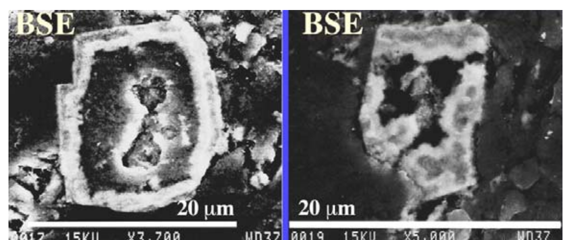

Figure 4. SEM BSE images of two typical zoned carbonate rhombs from a mud-cracked bed of the Wittenoom formation near Bee Gorge. The one on the left was described by [7]. Zonations include a slightly hollowed core of Fe-Ca-Mn-carbonate (Fe >Ca); a broad dark (low backscatter) zone with Ca>Fe; a thin bright zone with Fe>Ca with some Mn and extremely hematite-rich; and an outer dark zone of Ca-Fe carbonate. Many rhombs also are zoned in Mg. Images obtained by Joseph Schreiber, Jr.

References: [1] Trendall and Blockley 1970, W. Aust. Geol. Surv. Bull. 119, 366 p. [2] Morris and Horowitz, 1983, Precamb. Res. 21: 273-297. [3] Veizer et al. 1990, GCA 54, 2717-2729. [4] Hassler, Robie, and Simonson, 2000, Sedim. Geol. 135, 283-294. [5] Naraoka et al., 1991, Eos, 1991 AGU Fall Meeting, Prog. w/Abstracts. [6] Kargel et al., 1995, Global Planet. Change, 14, 73-96. [7] Simonson et al. 1993, Precamb. Res. 60, 287-335.