

REACTIVE SURFACE AREA OF SEDIMENTS FROM END-MEMBER CLIMATES: IMPLICATIONS PALEOCLIMATE ON EARTH AND MARS. R. Funderburg¹, M.E. Elwood Madden¹, YJ Joo¹, K. Marra², GS Soreghan¹, ¹University of Oklahoma (rfunderburg@ou.edu), ²USGS.

Introduction: Throughout Mars' history, the planet has experienced varied climate conditions. Clay minerals in the Noachian suggest significant aqueous alteration; sulfates indicate a wet, acidic conditions; and finally a change to the modern cold, dry conditions [1]. Stratigraphic deposits indicative of a lacustrine environment in Gale Crater suggest that standing water persisted on Mars' surface, allowing ample time for chemical weathering [2].

While traditionally, higher temperatures correlate to higher rates of chemical weathering, previous work has shown that glacial sediments are more reactive than hot, arid environment sediments [3]. Polar weathering processes may affect sediment reactivity [4]. Fine grained sediments formed by glacial grinding (rock flour) are often observed in both wet-based glacial systems [5] and may also form in cold-based glacial systems [6].

This study uses terrestrial sediments from field areas with similar bedrock lithologies, but differing end-member climates to directly compare the effects of temperature, precipitation, and glacial physical weathering on sediment reactive surface area. These results can be used to better understand chemical weathering fluxes throughout Mars' and Earth's history when glacial systems may have strongly impacted physical and chemical weathering fluxes.

Methods: Alluvial sediment samples were collected from drainage basins of similar size, relief, and bed-rock lithology in Puerto Rico (hot and wet); Anza Borrego, CA (hot and dry); Jostedalbreen, Norway (cold and wet) and Onyx River, McMurdo Dry Valleys, Antarctica (cold and dry). Sediments were wet sieved and treated to remove organics and carbonates. The mud fraction was freeze dried. The surface area of each size fraction was determined using the BET method. Single point batch reactor dissolution experiments were used to compare the chemical reactivity of the sand (125-2000 μ m) and mud (<62 μ m) size fraction. Samples were dissolved in pH 8-9 Tris buffered aqueous solutions and constantly agitated on a shaker table. Batch reactors were removed and filtered at pre-determined time intervals, and then refrigerated prior to ICP-OES analysis.

Results: Glacial sediments from Antarctica and Norway released more Al & Si into solution than the non-glacial sediments from Puerto Rico and Southern California. This suggests that more primary mineral weathering occurs in glacial systems than in warmer climates, despite the lower temperatures. This is likely

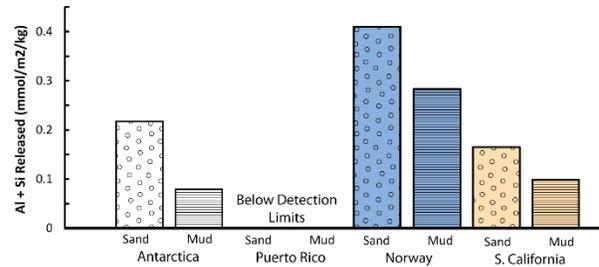


Figure 1. Combined Al and Si released per m² mineral surface area in all single point batch reactor experiments. Overall, sand-sized sediments released more Si and Al compared to mud-sized sediments, likely due to presences of some unreactive clay minerals in the mud-sized fraction. However, mud-sized sediments from Norway were almost as reactive per m² as the sand, demonstrating that fine grained sediments produced in wet glacial systems have significantly higher reactive surface area than muds produced in other climate systems. While chemical weathering fluxes in tropical systems are high, results from Puerto Rico show that fluvial sediments have extremely low reactive surface area, even in sand-sized sediments, likely due to abundant chemical weathering in corestones and saprolite prior to sediment transport into stream systems. Sand-sized sediments have been previously leached and altered forming less-reactive reaction rims, while mud-sized sediments are dominated by unreactive clay minerals and quartz. Sediments collected from the hot, arid Anza Borrego desert and cold, arid Antarctic Dry Valleys displayed intermediate reactive surface area, likely due to incipient weathering of sand-sized sediments and the presence of some clay minerals in the mud-sized fraction.

because of fresh mineral surfaces created glacial grinding and other polar processes in wet-based and cold-based glacier systems. Other major element solutes released, such as Ca, K, and Na, vary with climate, but these solute fluxes may also be related to cation release from or sorption onto secondary clay minerals, and are likely not a reflection of primary mineral weathering. Dissolution of primary minerals in glacial systems provides chemical sediments which may precipitate as clay minerals or evaporite deposits. Ions released from glacial systems may also serve as nutrients for biological activity [7 Stumpf, 2012; 8 Lyons 2015]

Implications for Mars: When liquid water is available, significant chemical weathering can occur. There is significant geomorphological evidence for glaciation on Mars [9 Head]. Amazonian age glacial deposits were widespread, and erosion rates for those glacial deposits were similar to terrestrial cold-based glacial systems [10 Levy]. Wet-based glacial systems may have also been present during the Late Amazonian [11 Gallagher]. If glacial grinding occurred on Mars, these glacial systems could produce higher than expected solute fluxes. This chemical weathering could occur in a localized area and affect the secondary mineralogy produced, including evaporite and clay mineral deposits.

Implications for Icehouse Earth: During icehouse periods, higher than expected rates primary mineral weathering could persist due to high reactive surface area produced in proglacial sediments. Higher than previously presumed chemical weathering rates could lead to greater CO₂ sequestration via silicate weathering, creating a positive feedback system which may aid in maintaining icy conditions over thousands to millions of years.

References:

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