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TITLE: The Mineralogical and Chemical Case for Habitability at Yellowknife Bay, Gale crater, Mars

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ABSTRACT BODY: Sediments of the Yellowknife Bay formation (Gale crater) include the Sheepbed member, a mudstone cut by light-toned veins. Two drill samples, John Klein and Cumberland, were collected and analyzed by the CheMin XRD/XRF instrument and the Sample Analysis at Mars (SAM) evolved gas and isotopic analysis suite of instruments. Drill cuttings were also analyzed by the Alpha Particle X-ray Spectrometer (APXS) for bulk composition. The CheMin XRD analysis shows that the mudstone contains basaltic minerals (Fe-forsterite, augite, pigeonite, plagioclase), as well as Fe-oxide/hydroxides, Fe-sulfides, amorphous materials, and trioctahedral phyllosilicates. SAM evolved gas analysis of higher-temperature OH matches the CheMin XRD estimate of ~20% clay minerals in the mudstone. The light-toned veins contain Ca-sulfates; anhydrite and bassanite are detected by XRD but gypsum is also indicated from Mastcam spectral mapping. These sulfates appear to be almost entirely restricted to late-diagenetic veins. The sulfate content of the mudstone matrix itself is lower than other sediments analyzed on Mars. The presence of phyllosilicates indicates that the activity of water was high during their formation and/or transport and deposition (should they have been detrital). Lack of chlorite places limits on the maximum temperature of alteration (likely <100 C). The presence of Ca-sulfates rather than Mg- or Fe-sulfates suggests that the pore water pH was near-neutral and of relatively low ionic strength (although x-ray amorphous Mg-and Fe- sulfates could be present and undetectable by CheMin). The presence of Fe and S in both reduced and oxidized states represents chemical disequilibria that could have been utilized by chemolithoautotrophic biota, if present. When compared to the nearby Rocknest sand shadow mineralogy or the normative mineralogy of Martian soil, both John Klein and Cumberland exhibit a near-absence of olivine and a surplus of magnetite (7-9% of the crystalline component). The magnetite is interpreted as an authigenic product formed when olivine was altered to phyllosilicate. Saponitization of olivine (a process analogous to serpentinization) could have produced H2 in situ. Indeed, early diagenetic hollow nodules (“minibowls”) present in the Cumberland mudstone are interpreted by some as forming when gas bubbles accumulated in the unconsolidated mudstone. Lastly, all of these early diagenetic features appear to have been preserved with minimal alteration since their formation, as indicated by the ease of drilling (weak lithification, lack of cementing phases), the presence of 20-30% amorphous material, and the late-stage fracturing with emplacement of calcium sulfate veins and minibowl infills, where they were intersected by veins. A rough estimate of the minimum duration of the lacustrine environment is provided by the minimum thickness of the Sheepbed member. Given 1.5 meters, and applying a mean sediment accumulation rate for lacustrine strata of 1 m/1000 yrs yields a duration of 1,500 years. If the

aqueous environments represented by overlying strata are considered, such as Gillespie Lake and Shaler, then this duration increases. The Sheepbed mudstone meets all the requirements of a habitable environment: Aqueous deposition at clement conditions of P, T, pH, Eh and ionic strength, plus the availability of sources of chemical energy.

KEYWORDS: 3672 MINERALOGY AND PETROLOGY Planetary mineralogy and petrology, 5200 PLANETARY SCIENCES: ASTROBIOLOGY, 6225 PLANETARY SCIENCES: SOLAR SYSTEM OBJECTS Mars.

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