MINERAL CONSTRAINTS ON ANCIENT AQUEOUS CONDITIONS AND HABITABILITY AT YELLOWKNIFE BAY, GALE CRATER

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Introduction: The Mars Science Laboratory (MSL) Rover, Curiosity, spent ~150 sols studying a section of fluvio-lacustrine sedimentary rocks in the Yellowknife Bay (YKB) formation. Sedimentological and stratigraphic observations are consistent with the YKB formation being distal fan deposits that could be as young as middle Hesperian to early Amazonian in age (~3.5 to 2.5 Ga) [1].

During this investigation, particular attention was paid to a lacustrine mudstone unit informally known as the Sheepbed member, and MSL obtained two powdered rock samples that were analyzed by X-ray diffraction (XRD) in the CheMin instrument. XRD patterns show that the mudstone contains up to ~20 wt.% clay minerals, a suite of typical basaltic phases (plagioclase feldspars, pyroxenes and olivine), Fe-oxides, Ca-sulfates and an X-ray amorphous component [1,2]. Olivine content is low (~1 wt.%) compared with regional basalt compositions derived from orbital data (~11 wt.% [3]) and CheMin analysis of a local soil [4]. Magnetite levels of 4-5 wt.% are high considering the quiescent depositional conditions of the Sheepbed [1].

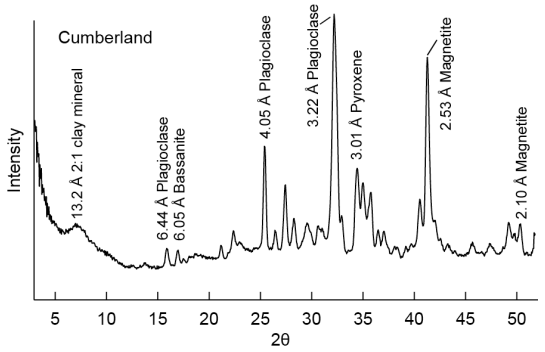

Fig. 1. *XRD pattern of the Cumberland sample of the Sheepbed member with major phases labeled.*

Early Diagenesis of Clays and Magnetite: The clay mineral component of the Sheepbed member consists of trioctahedral smectite. Comparison of XRD patterns with terrestrial analogues suggest that smectite is a ferrian saponite [5]. The smectite is thought to have formed with magnetite *in situ* through aqueous alteration of olivine because the bulk chemical composition of the Sheepbed member is similar to average martian basalt [1,2,6]. Mass balance calculations are permissive of such a reaction [2,7]. Moreover, the Sheepbed mudstone mineral assemblage is consistent with minimal inputs of detrital clay minerals from the crater walls and rim [7]. Early diagenetic fabrics suggest clay mineral formation prior to lithification [1,8].

Implications for Habitability: The formation of clay minerals and magnetite from olivine in surfical sediments has implications for the duration and nature of aqueous conditions at YKB. Thermodynamic modeling indicates that the production of authigenic magnetite and Fe saponite via aqueous alteration of olivine at surficial temperatures requires a moderate supply of oxidants [7]. Unlike other areas of Mars, such as Meridiani Planum where reduced iron leached from a basaltic aquifer was extensively oxidized, generating acidic conditions [9], the moderately oxidizing conditions at YKB allowed circum-neutral pH to persist.

As a result of MSL's investigations at YKB, broad constraints on the main factors governing rates of olivine alteration, including pH, grainsize and olivine chemistry can be inferred. Reaction kinetics suggest the presence of fluids for thousands to hundreds of thousands of years at YKB [7], consistent with depositional durations based on stratigraphic architecture [1].

Mineralogical evidence of the persistence of benign aqueous conditions at YKB for extended periods indicates a potentially habitable environment. In addition, early diagenetic reactions suggest that biologically mediated oxidation of Fe(II) in olivine to Fe(III) in magnetite, and perhaps in smectites could have potentially provided an energy source for chemolithoautotrophic organisms.

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