THE ELEMENTS OF LIFE AT A 3.5 Ga SUBAERIAL HOTSPRING: EVIDENCE FROM THE DRESSER FORMATION, PILBARA CRATON, AUSTRALIA.
M. J. Van Kranendonk[1], T. Djokic[1], G. Poole[1] and E. Nakamura[2]. [1]Australian Centre for Astrobiology, University of New South Wales Australia, Kensington, NSW, 2052 Australia, m.vankranendonk@unsw.edu.au. [2]Institute for Study of the Earth's Interior, Okayama University, Misasa, Tottori 682-0193, Japan, eizonak@misasa.okayama-u.ac.jp.

Introduction: The c. 3.48 Ga Dresser Formation in the Pilbara Craton, Australia, hosts the earliest convincing evidence of life in the form of macroscopic stromatolites, putative microfossils, and $\delta^{34}S$ and $\delta^{13}C$ anomalies [1-3]. Whereas previous work suggested a quiet, shallow marine environment, more recent work identified an active volcanic caldera setting floored by a network of chert-barite hydrothermal veins [4,5].

Our continuing work in the area has identified stratigraphic, mineralogical, chemical, and isotopic evidence of diverse habitats within the Dresser Formation, including periods of subaerial exposure when life thrived in hotsprings. This paper outlines that evidence, reviews the elemental transfers and mineralogical changes set up by the hydrothermal system, and considers the possible metabolic pathways of what appears was already a diverse microbial community.

Habitats: The previous identification of rapid lateral stratigraphic thickness variations across active growth faults filled by hydrothermal veins has now been augmented by the identification of rapid lateral facies variations (metres to tens of metres) of subaerial deposits. These include: centimeter-layered Mn-rich ankerite and ankerite-chert, with radiating diagnetic crystal splays of probable aragonite deposited in a restricted basin (volcanic caldera lake?) [6]; geyserite, identified by 20-50 µm black-white siliceous laminae (anatase-rich and kaolinite-rich) and columnar textures, identical to modern counterparts [7]; conglomerates with well-rounded cobbles, deposited in fluvial channels; cm-thick encrustations of fluvial cobbles that are packed with small, euhedral, tourmaline crystals, interpreted as hotspring crusts (Fig. 1); overlying edgewise conglomerates with vertically-oriented angular plates to 30 cm long x 1 cm wide of the tourmaline-bearing crusts and of geyserite, interpreted as fluvial storm/flood deposits (Fig. 1); cm-thick siliceous units with dendritic Fe-oxides resembling *Frutexites*, restricted to hydrothermal vent areas.

Elemental transfers and mineralogical changes: Circulating hydrothermal fluid during initial uplift relating to magma recharge formed hydrothermal vein set 1 and altered footwall komatiitic basaltic volcanics to carbonate-chlorite-white mica (+paragonite: low-sulfidation-type). Subsequent caldera collapse formed vein set 2 in listric growth faults and locally intense kaolinite-quartz assemblages, typical of steam-heated acid sulfate (high-sulfidation-type) alteration. Barite that is restricted to the upper 150 m of the system was precipitated during both stages. S from magmatic degassing was transformed into SO_4^{2-} by acid-sulfate alteration and concentrated in the restricted caldera basin where it combined with Ba^{2+} to form the barite. Hydrothermal fluid circulation liberated Si, Fe, Mg, Na, Ca, Ba, Mn, B, and Ti from footwall basalts, whereas low-sulfidation alteration precipitated K, Ca, Mg & CO_3. B was concentrated in hotsprings and Ti in geyserite, whereas Na went into seawater. B isotopic analyses of tourmaline is underway. Fe-Mn was concentrated in hotspring vents and the caldera lake. Significantly, this environment provided many of the elements necessary for life.

Diverse microbial life: In addition to morphological and stable isotopic suggestive of an early diversity of life [2,3,8], new discoveries of geyserite and hotspring crusts in subaerial settings and dendritic Fe structures suggest additional metabolisms may have been in operation early in Earth history and that life, once established, flourished quickly.

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Fig. 1: Plane polarized light thin section view of tourmaline-bearing crusts (black with green tourmaline) overlain by edgewise conglomerate with geyserite clasts.