EVIDENCE FOR A VOLATILE-RICH LAYER ON THE WINDJANA ROCK TARGET, THE KIMBERLEY, GALE CRATER, MARS G.M. Perrett\textsuperscript{1}, S.W. Squyres\textsuperscript{1}, M.E. Schmidt\textsuperscript{2}, L.M. Thompson\textsuperscript{1}, M. Fisk\textsuperscript{4}, J. Berger\textsuperscript{3}, J.L. Campbell\textsuperscript{6}, E. Desouza\textsuperscript{6}, R. Geller\textsuperscript{6} and the APXS Science Team, \textsuperscript{1}Cornell University, Ithaca, NY, USA (gmp74@cornell.edu); \textsuperscript{2}Brock University, St. Catharines, ON, Canada; \textsuperscript{3}University of New Brunswick, Fredericton, NB, Canada; \textsuperscript{4}Oregon State University, Corvallis, OR, USA; \textsuperscript{5}University of Western Ontario, London, ON, Canada; \textsuperscript{6}University of Guelph, Guelph, ON, Canada

Introduction: Since 2012 the Mars Science Laboratory (MSL) rover has been studying various geologic waypoints on its traverse to Mount Sharp to determine if Gale Crater, Mars, was once a habitable environment [1]. The Kimberley was selected as a waypoint due to observations of distinct strata viewed from orbit [2]. Upon arrival at the Kimberley, rover images confirmed that this location is composed of distinct sedimentary facies. The strata, composed of conglomerates, cross-bedded sandstones, and fine-grained cross-laminated sandstones capped by butte-forming and dark-toned fine-grained units, represent a prograding deltaic system with possible long-term, cyclic aqueous and aeolian activity [2,3]. A Mn-rich layer on the Stephen target was detected by ChemCam [4,5], which is located near the drill target Windjana (Fig. 1). Examination of as-is, brushed, and drilled alpha particle X-ray spectrometer (APXS) integrations of the Windjana target indicate that there is also a layer present here composed of volatile elements (Br, Cl, Mn).

Context: The Windjana target is a potassic, Fe-rich, cross-stratified sandstone located in the Dillinger member (50 cm thick) and is of uncertain origin but is most likely aeolian [6]. It overlies the deltaic and pebbly sandstones of the Squaretop member and is overlain by the massive sandstones of the Mt. Remarkable member. Windjana is primarily composed of igneous minerals (feldspars, pyroxenes) with low temperature alteration products [6]. The Dillinger member underwent diagenetic alteration and was cemented with Fe-rich material [6]. Subsequent erosion exposed the Windjana rock to the surface. Evidence for a salt and Mn-rich layer at this location was found on the Stephen target, which is also a part of the Dillinger member. Lanza et al. [5] determined that Stephen is oriented subparallel to sedimentary bedding planes and could represent bedding-parallel fracture fill.

Figure 1. Windjana (a) and Stephen (b) targets. (NASA/JPL-Caltech/MSSS)

APXS at the Kimberley: 24 APXS integrations were taken at the Kimberley waypoint from four of the stratigraphic members representing deltaic sandstones, fluvi-conglomerates, and possibly aeolian materials [6]. The majority of the integrations were taken at Windjana and Stephen. The Windjana rock was systematically studied by the APXS at its surface (as-is and brushed integrations) down to approximately 20 mm (drill tailings) to 50 mm (dump pile) [7]. The APXS concentrations of Mg, K, Zn, and Br at Windjana are among the highest measured at Gale crater up to sol 1200, and the Na concentrations are among the lowest [7,8]. The APXS also confirmed ChemCam’s high-Mn observation on Stephen, although was incapable of confirming the presence of a layer since this target was not drilled [9,10]. In order to directly detect layers, the APXS needs to have surface layers mechanically removed. Previously, the APXS has been used to identify layers on as-is, brushed, and RAT-ground rocks studied by the Mars Exploration Rovers [11,12,13].

Details of the Windjana Layer and Geologic Interpretation: Windjana has the strongest
indication of a layer for all MSL APXS targets studied up to sol 1200 and is primarily composed of Cl, Br, and Mn. The concentrations of these components increase with brushing and drop below the as-is concentrations with drilling (Fig. 2). Mn is not nearly as abundant at Windjana (0.52±0.02 wt%) as at Stephen (3.12±0.07 wt%), yet is enriched relative to other bedrock targets. Cl and Br are correlated (Fig. 3); however, there is no correlation to Zn, Mn, Cu, and Ni, which was observed with Stephen [9]. Since Br and Cl are correlated, it suggests that aqueous fluids were likely responsible for the deposition of this layer as Br and Cl fractionate in the presence of ice [14].

Yen et al. [15] suggest that associated decreases with depth of Br, K, Na, and Cl at Gusev are due to the redistribution of salts by aqueous transport at some point after the emplacement of the underlying rock. The high solubilities of these elements in aqueous fluids suggest that the layer at Windjana was deposited by aqueous processes. Two possible hypotheses can describe the formation of this layer. First, the layer was deposited before the erosional event that exposed the Windjana rock surface. The layer represents a zone where injected fluids precipitated Br, Cl, and Mn-rich compounds and in the process could have made the rock more resistant to erosion [16]. Second, the layer was deposited after the erosional event, perhaps by acid fog [17]. The first hypothesis is preferred here and was also the method of formation proposed by Lanza et al. [5] for the Mn-rich layer formed on Stephen. Element enrichment variability and difference in element correlation trends between Stephen and Windjana could indicate an alteration gradient or varying conditions of alteration.

Figure 2. Cl, Mn, and Br trends with depth at Windjana.

Conclusions: The APXS instrument is capable of determining the presence of layers on rocks when integrations are taken in various configurations (as-is, brushed, drilled). Upon examining MSL APXS targets with a suite of as-is, brushed, and drilled integrations, evidence for a layer on the Windjana rock surface was discovered. This layer is Br, Cl, and Mn-rich and is likely a result of fracture filling of salts by low-temperature secondary fluids as they permeated the Windjana outcrop.


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