Comparison of Manganese Abundance in Gale and Jezero Craters. P. J. Gasda (gasda@lanl.gov)[1], J. Comellas[1,2], A. Essunfeld[1,3], N. Lanza[1], R. Anderson[4], A. Udry[5], A. Cousin[6], J. Lasue[6], A. Ollila[1], C. Legett IV[1], R. C. Wiens[1], S. Maurice[6], O. Gasnault[6], S. M. Clegg[1], D. Delapp[1], A. Reyes-Newell[1]; [1]LANL; [2]UH; [3]YU; [4]USGS; [5]UNLV; [6]IRAP

Introduction: Manganese is important as a geochemical tracer of pH and redox in martian sediments, as well as its potential as a biosignature [1–6]. Manganese is typically a minor element in mafic minerals (olivine and pyroxenes) and does not typically enter the plagioclase structure. It is assumed that the partition coefficient is ~1 for Mn in olivine and pyroxene, and that the composition of MnO in bulk silicate Mars is 0.44 wt% MnO [7]. When these mafic materials are chemically altered, the relatively water soluble Mn^{2+} will go into the fluid and remain there unless conditions become very oxidizing or very alkaline [1–6]. Hence, Mn-rich phases indicate aqueous alteration followed by strongly oxidizing or high pH conditions has occurred to concentrate Mn. A calibration for MnO using ChemCam has been recently developed [8], and a similar calibration model is being developed for SuperCam [9]. This work will compare the data for Gale with the preliminary model being developed for SuperCam.

Methods: SuperCam and ChemCam are laser induced breakdown spectroscopy (LIBS) instruments onboard the *Perseverance* and *Curiosity* rovers, respectively [10–13]. LIBS uses a laser to induce a plasma on the surface of a rock or regolith target, which atomizes and ionizes the elements from the target. These elements then emit light that is collected by the instrument telescope. The atomic emission spectrum recoded by the instrument spectrometers can be used to determine the major, minor, and trace elemental composition of the target [14,15].

Data sources. For both sets of mission data, float rocks, out of focus points, and diagenetic targets were removed from the database. The compositions have not had volatiles removed nor are they normalized to 100% total oxides. The median composition of MnO was determined for major rock units. In Gale crater, regolith targets include soils and Bagnold dunes, which have very similar composition in terms of MnO. Siccar Point includes Stimson unit targets from Marias Pass (high silica targets were removed) through the Greenheugh Pediment. Mount Sharp group targets do not include targets from the Pahrump Hills, Hutton, or Mary Anning locations, all of which have anomalously high MnO contents. In Jezero crater, the data covers up to sol 259, targets >6 m distance have been removed, and the rock units are split into 4 categories: Crater Floor Fractured Rough Unit (Cffr) high-standing rocks (‘other’), Cffr low-standing rocks (‘pavers’), Artuby Ridge (from sol 170 to sol 201), and Seitah (after sol 201) [16]. High oxide total targets (e.g., >110 wt.%) have not been removed [e.g., 16] as we did not observe a relationship between Mn and oxide totals for the targets.

Results: A summary of the median MnO composition of major members in both Gale and Jezero craters are listed in Table 1. An AS-FM-CNK and A-CN-K ternary diagrams (Figure 1) with MnO that scales with color/symbol size visualizes the chemistry of SuperCam observation points up to sol 259.

Table 1. Median MnO content of major units in Gale and Jezero craters.

	Gale MnO wt%	*Jezero MnO wt%*
Regolith	0.12	0.32
Bradbury	0.20	
Siccar Point	0.16	
Mount Sharp	0.05	
Cffr pavers		0.33
Cffr other		0.32
Artuby Ridge		0.32
Seitah		0.44

Discussion: Jezero has clearly higher MnO content than all of the materials in Gale crater. The Seitah rocks are especially interesting as many targets contain essentially unaltered olivine and pyroxene rich rocks and is interpreted as a cumulate [16,17]. The median MnO value of Seitah is consistent with the bulk silicate Mars composition [7], likely reflecting a primitive igneous source region. Cffr and Artuby Ridge MnO compositions are indistinguishable, lower than Seitah, and likely reflect slightly less primitive basalt [16].

In Gale crater, the fluvial and lakebed stratigraphic groups, Bradbury and Mount Sharp, have clearly undergone aqueous alteration [e.g., 18]. This is reflected in the overall lower MnO contents of the sediments. In addition, the Southern Highlands near Gale crater is likely more felsic; igneous float rocks and igneous clasts within the Bradbury are feldspar-rich [19–21]. Hence, the primary source of MnO in Gale is likely depleted in Mn compared to Jezero.

The difference between the median regolith compositions between the two craters is likely due to local differences of primary source rocks. While part of the difference in the composition of MnO in the regolith could be due to differences in their volatile contents, regolith grain size also influences the MnO composition. The finest dust, which is thought to be homogeneous across Mars [e.g., 22], has lower MnO [23]. Larger grains have a composition closer to that of local bedrock, and in Gale the bedrock is more felsic, while in Jezero it is more mafic [24]. Thus, the MnO composition of Jezero regolith is closer to that of Seitah, and is greater compared to Gale [24].

Evidence for limited aqueous alteration in Jezero crater floor units. In the majority of targets, especially in Seitah, *Perseverance* has observed mm-sized euhedral crystals that are consistent with olivine and pyroxene compositions [16,17]. Only 17 targets in Jezero so far have >1 wt% MnO (2% of the observation points), and generally these occur in Cffr, evenly split between pavers and high-standing Cffr targets, 2 targets in Artuby Ridge, and 1 target in Seitah.

Three Cffr targets are particularly interesting and have indications that either fluids introduced soluble elements, including Mn, or that very local chemical weathering occurred. One target, Tseebii, has high MnO content up to 12.5 wt% MnO. Other interesting targets include Roubion sample drill hole wall and Alk es disi, both of which have high FeO_T in addition to elevated MnO. This pattern of elevated MnO and other soluble elements has also been observed in Gale crater Bradbury targets, but the targets in Gale crater typically also exhibit much clearer signs of diagenesis (e.g., nodules) [5,6] than those in Jezero. So while this could indicate that fluids brought in soluble elements including Ca, Na, K, and Mn, it is more likely a signature of closed system chemical weathering.

Conclusions: Manganese is an element that is relatively easily mobilized during aqueous alteration and will precipitate from fluids under highly oxidizing and/or alkaline conditions. Overall, the 17 elevated MnO targets are the exception rather than the rule; and points to rather limited aqueous alteration of the Jezero crater floor units observed so far by *Perseverance*. The low to no alteration of the Seitah bedrock allows us to characterize the igneous source region for Jezero floor units, and suggest it is primitive. Gale crater primary source rocks likely are more felsic/evolved, which accounts for the overall lower MnO content in its regolith, Siccar Point formation, and Bradbury formation in addition to the chemical weathering that has occurred.

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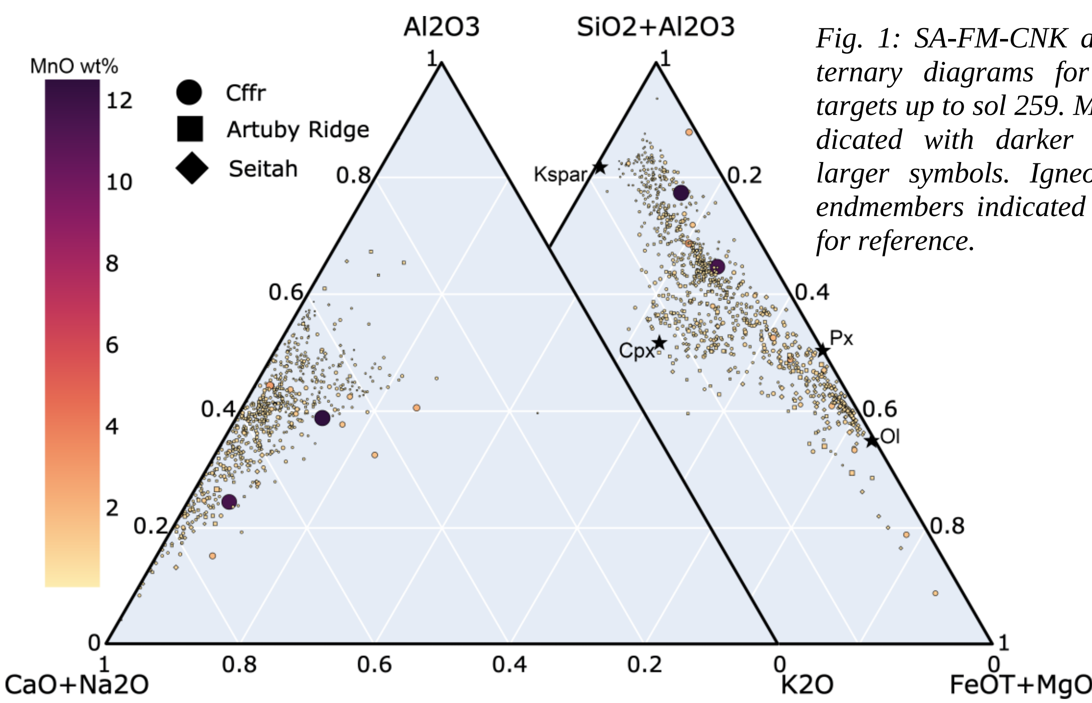

Fig. 1: SA-FM-CNK and A-CN-K ternary diagrams for SuperCam targets up to sol 259. MnO wt% indicated with darker colors and larger symbols. Igneous mineral endmembers indicated with a star for reference.