IRON OXIDATION PRODUCTS IN MARTIAN ORDINARY CHONDRITE FINDS AS POSSIBLE INDICATORS OF LIQUID WATER EXPOSURE AT MARS EXPLORATION ROVER LANDING SITES J. W. Ashley[1,2] and S. P. Wright[2], [1]Minor Planet Research, Inc., Box 17131, Fountain Hills, AZ, 85269-7131; jwashley@minorplanetresearch.org, [2]Department of Geological Sciences, Arizona State University, Box 871404, Tempe, AZ 85287, Shawn.P.Wright@asu.edu.

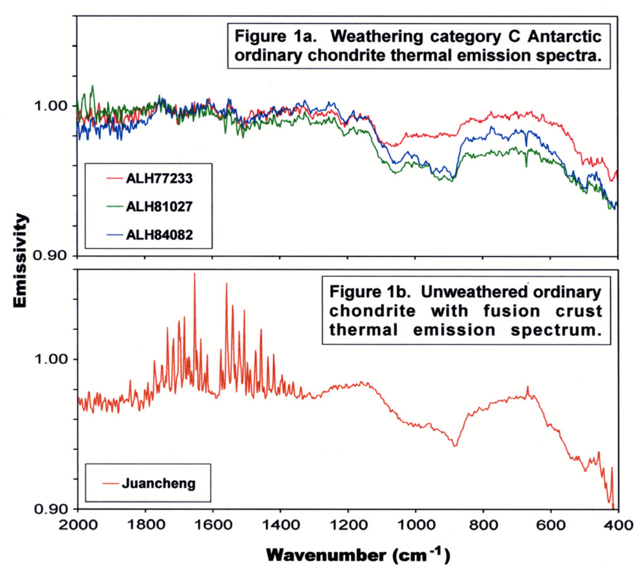
Introduction: The oxidation of reduced iron-nickel metal grains and ferrous iron in ordinary chondrite meteorites (OC) is observed in both hot [1] and cold (e.g. [2]) desert terrestrial environments, where liquid water is implied (and may be required) to produce their more recognizable effects. The study of such a meteorite in a Martian setting, should one become available to Mars Exploration Rover (MER) science packages, could contribute to our database of information concerning the past availability of liquid water on the planet. This abstract reviews the viability of using secondary iron oxides in OC meteorites as markers for Martian climatic behavior. We conclude that predicted concentration mechanisms for asteroidal material on Martian surfaces, combined with the capabilities of the MER Athena instrument payloads, yield promising expectations for this manner of investigation.

Background: Of the many factors relating to the geomorphological, geochemical, and potentially biological histories of Mars, widely agreed upon as the most compelling is the role of liquid water. With the question of extraterrestrial life riding on the 'Follow the Water' theme, the MER Athena payloads are outfitted to evaluate the effects of liquid water on Martian surfaces, and the search for these effects comprises the focus of MER objectives. The aqueous alteration of primary minerals constitute a suite of processes that can provide clues to past climatic behavior. [1] used the well-known starting chemistries and normative mineralogies of OC to evaluate terrestrial climatic behavior as a function of iron oxidation intensity in hot desert environments. OC oxidation might be similarly used as a kind of litmus test for the past availability of water on Mars.

Nomenclature: The identification of SNC association meteorites as having a Martian origin resulted in a rethinking of meteorite parent bodies in the planetary research community at the time. In the present case of exploring the possibility of asteroidal materials surviving a fall to the Martian surface and being available for MER reconnaissance, an element of confusion is introduced. Therefore, to address the need to distinguish in discussion such finds from SNC association specimens, often referred to as 'Martian meteorites,' the meteorites in question will be here referred to as Martian finds.

Discussion: OC are comprised chiefly of high-temperature phases formed in reducing environments (olivine, pyroxene, plagioclase, sulphides, and reduced iron-nickel metal), and constitute some 82 percent of terrestrial meteorite falls [3]. As with most mafic rocks, their normative mineralogy plotting near the end of Bowen's reaction series means they tend to be among those most aggressively weathered in terrestrial environments (e.g. [4]). However, studies of OC weathering in both hot and cold arid regions show that secondary products are dominated by limonites generated by the oxidation of the iron-nickel and sulphide phases without producing clay minerals [2,5]. These materials fill pore space volumes until cessation of weathering results from pore space reduction [1,5]. Liquid water is necessary for the mobilization of the constituents involved in the process, which is demonstrated by the production of amorphous stains filling grain interstices, fractures, and cleavage planes well-removed from the reduced metal source grains. However, crystalline oxides tend to form in direct contact with primary phases [4,5].

Much of the formal speculation on the topic of meteorite fall accumulations on Mars can be attributed to the work of [6], who calculated an existing presence of 5 x 10^2 to 5 x 10^5 meteorites greater than 10 g in mass per square kilometer, with a survivability of more than 10^9 years. An additional study by [7] suggested that meteorites only a few centimeters in radius might reach the surface at hypervelocity. [8] considered the singular possibility that Mars' general surface REDOX state and associated color might be attributable to oxidized iron-bearing dust particles of meteoritic origin. Differences between Earth and Martian meteoroid source regions should be negligible with respect to their type frequency distributions, the two zones being well-mixed [9].



Based on a review of Athena payload instrument descriptions [10-13], the MER package appears to be ideally suited to the proposed experiment. Preliminary testing of OC by thermal emission spectroscopy at Arizona State University's Mars Space Flight Facility shows them to be at least distinguishable from Shergottites (Martian basalts). Continued testing of weathered and unweathered OC from both hot and cold terrestrial deserts remains ongoing to build a library of thermal emission spectra for OC of various classes and petrologic types, and in various stages of weathering, for recommended use during Miniature Thermal Emission Spectrometer (Mini-TES) reconnaissance. For initial reference purposes, Figure 1 presents the thermal emission spectra of three weathering category C Antarctic OC, together with Juancheng, an unweathered and fusion-crusted OC. The sample emission spectra were acquired using a Nexus 670 TIR spectrometer from ~2000 to 339.5 cm^{-1} over 4 cm^{-1} wavenumber. Mini-TES operates over a similar spectral range with a spectral resolution of ~10 cm^{-1} [10].

The chances for identifying OC by Mini-TES within the nominal exploration range of either MER rover may be enhanced or discouraged, depending on the prevailing geological and/or meteorological processes in effect at the landing site. Based on crater counts for both Gusev Crater and Meridiani Planum, surfaces within the MER landing ellipses may be old enough to support significant meteorite accumulations. Because such populations are by genetic definition independent of locally derived rocks, they might even stand out in taxonomic relief, as is the case in several terrestrial examples (i.e. Antarctica). The relative geologic age of both landing sites are estimated as Noachian (4.5 – ~3.2 Ga) [14,15].

If OC are identified (intentionally or inadvertently) during Mini-TES studies, they may be worth a second look with the Mössbauer spectrometer to determine iron-bearing primary and secondary mineralogies. Mössbauer spectroscopy has already been used to evaluate weathered [16], and unweathered [17] OC, and is the intrument of choice for iron-bearing mineral identification. Additional instruments within the Athena payload that should be suitable for the evaluation of Martian finds include the rock abrasion tool to remove weathering rinds or varnish, and the microscopic imager, which may be able to resolve important alteration features.

The rationale for wanting to determine Martian find weathering intensity will follow not from testing the climatic conditions of any specific epoch, but from a coarser inquiry into cumulative liquid water exposure throughout the residence time of the find in question. Following the successful identification of an OC Martian fall, there will then be two broad possibilities: 1) The meteorite is unaltered, in which case one can only speculate on the climatic implications, a single stone being insignificant statistically; or 2) The meteorite exhibits secondary iron oxides, readily recognizable with the Mössbauer spectrometer, in which case a significant conclusion may be inferred on the availability of liquid water at that location at some time during Mars history. If we learn that Martian finds are abundant on the surface, in the proportions estimated by [6], then a statistical evaluation becomes possible for making more definitive assessments. Keeping certain assumptions about Martian fall residence times squarely in the forefront, if four or five well-separated (to avoid paring questions) Martian OC finds exhibit no signs of weathering, we may find ourselves speculating more heavily on the historical role of liquid water in local, regional, and global contexts. Naturally, the larger our sample database, the more valid will be our conclusions.

Summary: Martian finds are likely to be comprised of OC by some 82 percent. If identified, their study with respect to secondary oxidation products could yield valuable insights into the past availability of liquid water at the MER landing site locations. Based on our current level of understanding, several possible weathering states for OC may be likely on Mars, ranging from unaltered to moderately weathered to passivated as a function of porosity reduction. Several considerations, including aqueous alteration kinetics, residence time as an unknown, analytical limitations, and ambient oxygen fugacities will need to be accounted for before an understanding of any Athena instrument results is possible.

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