MARS SCIENCE LABORATORY SEARCH FOR ORGANICS: POTENTIAL CONTRIBUTION FROM INFALL OF METEORITES. A.T. Basilevsky , Vernadsky Institute, Kosygin Str., 19, 119991 Moscow, Russia, atbas@geokhi.ru.

Introduction: A major goal of the Mars Science Laboratory (MSL) mission is to search for past and present habitable environments at Gale crater [1]. To achieve this goal MSL has, in particular, the capability to detect complex organic molecules in rocks and soils using the Sample Analysis at Mars instrument (SAM). A primary goal of the SAM investigation is to carry out a search for organic compounds and to measure the isotopic composition of carbonaceous material [2]. As stated in [2], sources of organic compounds that SAM might detect could be indigenous (that is the desired target of the mission), exogenous (which we touch on in this paper), and terrestrial contamination (which will hopefully not be the case). The authors of [2] consider as exogenous sources the organic compounds which are derived from the in-fall of meteorites, interplanetary dust particles, and larger volatile-rich impactors such as comets or carbonaceous asteroids.

Meteorites observed by MERs: In this work we briefly consider the issue of organic compounds brought by in-fall of meteorites. The atmosphere of Mars with its 17 g of mass per cm^2 of its surface and significantly lower (comparing to Earth) velocity of entry of meteoroids into atmosphere of Mars, seem to provide favorable conditions for entry and recovery for meteorites of centimeters to decimeters in diameter either through direct deccelleration at highly oblique entrees, or fragmentation of larger impactors [3, 4]. This suggestion is supported by the observations of the two Mars Explorations Rovers (MER). The latter, during the 42 km cumulative traverse identified 17 meteorites candidates: 10 irons and 7 stones (Fig. 1) [5, 6].

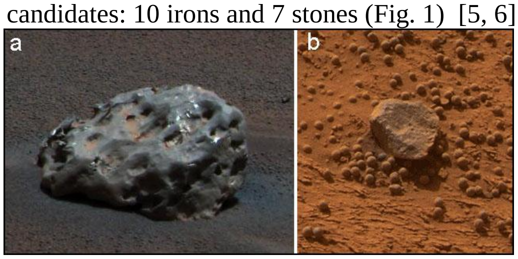

Figure 1. a) Iron meteorite Meridiani Planum, ~30 cm long; b) HED meteorite candidate Barberton, ~3 cm across. Image credit NASA/JPL/Cornell.

Two of the ten irons (Zhong Shan and Alan Hills at Gusev crater) are within a half of meter from each other, possibly being fall-paired meteorites, while others are separated by hundreds of meters to kilometers from each other and probably represent individual falls, not strewn fields. The seven stones mentioned are considered by [7] to represent the howardite, eucrite, and diogenite (HED) group. They were united in so-called Barberton group cobbles and may be members of a large meteorite strewn field [5]. So the 17 meteorites can probably be considered as resulting from 9 falls of irons and one strewn field of stones probably belonging to the HED group. The irons observed by MER are typically larger than stones probably because stones are crushed more easily at landing than irons.

Irons and achondrites (including the HED group) are rare among meteorites reaching Earth and as a rough approximation this may be applicable to meteorites falling on Mars. According to [8], among registered 1079 meteorite fall on Earth there are 48 irons, 12 stony-irons, 74 achondrites (including 46 HEDs, SNCs are excluded) and 940 are various chondrites. As another way to understand what the distribution of meteorites of different groups falling on Mars may be, one can look at the distribution of spectral classes of asteroids which are the sources of meteorites: Asteroids of class M (probable source of iron meteorites) compose less than 10% of the total population, asteroids of class V (probable source of HEDs) – less than 1%, and strongly dominating (≥90%) are asteroids of class S (source of ordinary chondrites) and those of classes C, P and D (source of carbonaceous chondrites) [9,10].

So the discovery along the MER routes of iron meteorites resulting from 9 falls and one strewn field of probable HEDs, is an indication that more than 100 chondrite meteorites were probably left unidentified on the routes. If Barberton group cobbles are not HEDs, but instead are chondrites, this does not change significantly the above estimate. If we assume that the MERs were able to do reliable observations within an 50=100 m-wide zone, then along the 42 km cumulative distance the observations covered an area 2-4 km^2, and the areal density of hypothetical unidentified chondrite meteorites can be estimated as more than 25-50 chondrites per 1 km^2. We believe that these estimates are completely applicable to the MSL study area.

Organics in chondrites: Chondrite meteorites, both ordinary and carbonaceous, contain organic matter, a subordinate part of which is represented by the so-called soluble fraction which is a mixture that includes amino acids as well as aliphatic and aromatic hydrocarbons, and a much more abundant (70-95%) insoluble fraction, which is a complex macromolecular material, rich in polycyclic aromatic hydrocarbons often described as kerogen-like [e.g., 11, 12]. If we consider analogies with weathering of meteorites in terrestrial deserts [e.g., 13], then it is logical to suggest that in the Martian environment the organic compaunds should suffer from weathering. This conclusion is supported by the Viking landers which found an absence of detectable organic compounds [14] at levels three or four orders of magnitude lower than what is predicted to be there from meteoritic input alone and is a clear indicator of surface or atmospheric processes that have destroyed organic compounds [15]. The soluble fraction of meteorite organic matter is obviously more vulnerable to the highly oxidizing surface environment of Mars and thus probably has less chance to be sampled and studied by the SAM instrument. The kerogen-like material appears to be more resistant to the Martian environment and thus has a higher chance to be studied by SAM. The contents of insoluble organic compaunds in various chondrites (including carbonaceous ones) vary from a few tenths of percent to a few percent with higher contents in CI and CM2 meteorites [e.g., 11, 12, 16, 17].

Search for organics in Gale crater: As mentioned above, during its mission MSL will try using the SAM instrument to detect complex organic molecules in rocks and soils and to measure the isotopic composition of carbonaceous material. The SAM instrument is able to detect volatile organics down to the level of 1-10 ppb and refractory organics to the level of ppm [2]. This means that if organic material derived from meteorite infall (which is expected to be present in the study area) will be sampled by SAM even being diluted by three orders of magnitude the refractory organics have a chance to be detected. For the case of meteorite-derived volatile organics, the chances of being detected by SAM are even higher.

Role of meteorite infall in the potential organic contents of surface materials of Mars was briefly considered by [18]. Analyzing a number of data, including Ni contents measured by the APXS instrument along the MER routes, these authors concluded that Martian soil contains 1 to 3% of chondritic influx, corresponding to 100 to 300 ppm Ni. Then assuming that the meteorite influx is dominantly represented by CI chondrites they estimated an associated content of carbon delivered to Mars by meteorites as 330 to 990 ppm C.

We suggest the technique of using the contents of organics and Ni in chondrite meteorites as a tool to detect admixtures of meteoritic material in the samples studied by MSL. In the latter, organic matter is to be studied by the SAM instrument, while Ni concentrations are to be measured by the APXS instrument [19]. As stated above, the contents of insoluble organic compounds in chondrites vary from a few tenths of percent to a few percent, while Ni contents in chondrites are typically within 1.1 to 1.8 % by mass [11, 12, 16, 17]. Based on this and suggesting that dilution of chondritic material by Martian surface materials should decrease both C_{org} and Ni contents in the samples studied, we have compiled a diagram which may help to distinguish indigenous Martian organics from those brought by meteorites (Fig. 2).

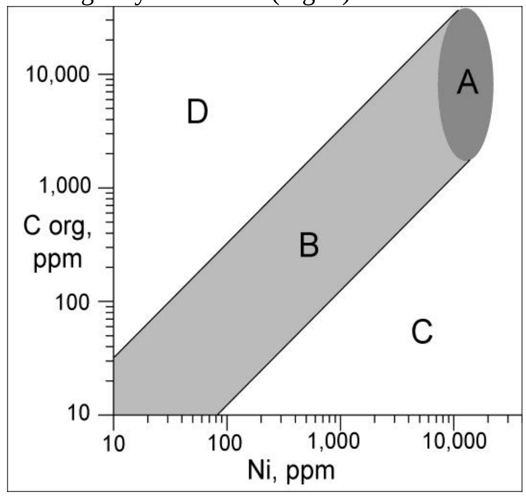

Figure 2. A – Ni and C_{org} concentrations in chondritic meteorites. B – zone of dilution of meteoritic concentrations by the organics- and nickel-free materials. C – field of meteoritic organics loss. D – field suggesting presence of Martian organics.

Conclusion: Correlation of organic matter measured by the SAM instrument with Ni contents in the samples may help to distinquish indigenous (Martian) organics (field D in Fig. 2) from that brought by infalling meteorites (fields A, B, C).

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References: [1] Grotzinger J.P. et al. (2012) *Space Sci Rev., 170*, 5–56. [2] Mahaffy et al. (2012) *ibid*, 401–4768. [3] Schroeder C. et al. (2008) *JGR, 113*, E06S22. [4] Brownlee D.E. (1985) *Ann. Rev. Earth Planet. Sci. 13*, 147-173. [5] Ashley J.W. (2012) *Meteorite magazine, 18*, No. 2, 37-41. [6] Ashley J.W. et al. (2011) *JGR, 116*, E00F20. [7] Schroeder C et al. (2010) *JGR, 115*, E00F09. [8] Grady M.M. (2000) Catalogue of Meteorites. 5th edition, Cambridge Univ. Press, 696 p. [9] Chapman C. (1999) In: *The New Solar System*, 337-364. [10] Britt D.T.and Lebofsky L.A. (1999) In: *Encyclopedia of the Solar System*, Academic Press, 585-605. [11] Vdovykin G.P. (1967) *Carbon Matter of Meteorites*, Nauka Press, 272 p. [12] Alexander 1998. [13] Bland P.A. et al. (2006) In: *Meteorites and the Early Solar System II*. D.S. Lauretta et al eds, The University of Arizona Press. 853-867. [14] Biemann, K., et al. (1977) *JGR, 82*, 4641-4658 [15]. Yen A.S. (2000) *Science, 289*, 1909-1912. [16] Dodd R.T. (1981) .*Meteorites: A petrologic-geochemical synthesis*, Cambridge University Press, 368 p. [17] Palme H. and Jones A. (2003) In: *Treatise in Geochemistry. V. 1. Meteorites, Comets and Planets.* 41-61. [18] Yen A.S. et al. (2006) *JGR, 111*, E12S11. [19] Campbell J.I. et al. (2012) *Space Sci Rev., 170*, 319-340.