BLACK BEAUTY: UNIQUE MARTIAN METEORITE – A MATCH FOR AVERAGE MARTIAN CRUST.

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Introduction: Northwest Africa (NWA) 7034 aka "Black Beauty" is the first and only Martian meteorite breccia in existence, and with the exception of the singleton orthopyroxenite ALH 84001, it is arguably the rarest of the approximately 132 Martian meteorites in the world's collections. Although Black Beauty is unique among martian meteorites and has a distinctly different composition than the common SNC (Martian) meteorites, it is a surprisingly good match for the average Martian crust as analyzed by orbiter and rover missions [1]. This is in contrast to the rather poor compositional match that exists between SNC meteorites and the observed Martian surface, which has been a longstanding enigma. Thus Black Beauty is the first tangible sample on Earth of the surface material of Mars as determined by NASA missions.

Figures 1&2. NWA 7034 "Black Beauty".

Diversity of Lithologies: The major element bulk composition of Black Beauty is basaltic as shown in figure 3 and overlaps with many of the AXPS measurements of rocks and soil done by the Spirit Rover at Gusev Crater [2]. However, Black Beauty, being a polymict breccia, consists of multiple lithologies, and to date we have identified up to a half a dozen igneous rock types in the breccia [3]. These lithologies span the range from basanite to basalt to basaltic trachyte/andesite, some of which have compositional similarities to the high-alkali rocks analyzed recently at the Gale Crater outcrops with APXS and ChemCam on the Mars Science Lab Curiosity Rover [4,5].

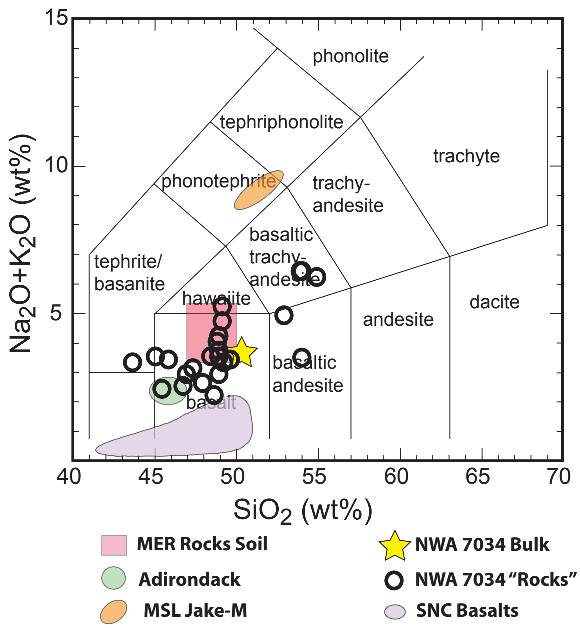

Figure 3. Total Alkali vs. Silica (TAS) diagram showing bulk composition of NWA 7034 (yellow star) and its various igneous lithologies identified up to now (black circles). Pink field-MER rocks and soil, purple field-SNC meteorites, green field-MER Adirondack class basalts, orange field- MSL Jake M.

In addition to the materials that are unequivocally of primary igneous origin, a significant portion of Black Beauty consists of secondary alteration products in the form of clasts, spheres and pebbles. There are also numerous water-bearing phases that include maghemite, ferrihydrite, phyllosililcates, and apatite, which sum to approximately 6000 ppm bulk Martian water – 10 to 30 times higher than other Martian (SNC) meteorites [1]. NWA 7034 is not simply a single meteorite sample – it is more like a Martian geologic field area all contained within one rock – analogous to the rich lunar geology preserved in the highland breccias from the Moon.

Early Noachian and Amazonian Ages: Age-dating of NWA 7034 reveals the breccia's diversity and its complex origin that likely reflects surface processes operating during a span of a few billion years of Martian history. Rb/Sr dating of the bulk sample done at the University of New Mexico gave an age of ~2.1 Ga [1], however bulk Sm/Nd done at NASA JSC [6] gave an age of ~4.4 Ga. Humayun et al. [7] reported ancient zircon U-Pb ages of ~4.4Ga, but they also found a younger population of zircons with ages of ~1.7 Ga and subsequent studies by Yin et al. [8] have identified four major age groups in NWA 7034: 4.44 Ga, 4.35 Ga, 1.44 Ga for zircons and baddeleyites, and 1.35 Ga in phosphates. Black Beauty has ubiquitous populations of apatite and zircon throughout the matrix and in most clasts, which is offering the opportunity to age-date individual lithic domains, revealing the sequence of events that brought this breccia together – prior to it being launch off Mars around 11 million years ago [9]. Along with ALH 84001, NWA 7034 differs from SNC meteorites in that it records ancient igneous processes operating on early Mars. However, NWA 7034 is unique among Martian meteorites because it records age-dated events in both the Noachian and Amazonian Epochs.

Multiple Oxygen Isotope Reservoirs on Mars: Black Beauty stands apart from other Martian meteorites in its oxygen isotope composition, which is higher in both δ17O and δ18O [1] (figure 4).

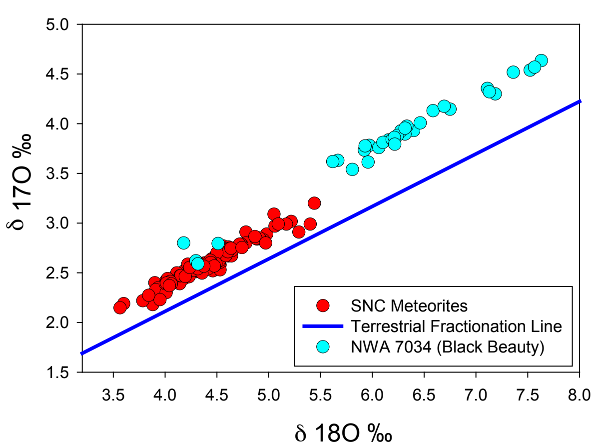

Figure 4. Oxygen isotope diagram showing the difference between NWA 7034 and SNC meteorites. Data from [1] and references therein and new data personal communication K. Ziegler.

There are several explanations for Black Beauty's "anomalous" oxygen values – all of them argue for Mars having multiple oxygen isotope reservoirs. One possibility is that the surface rocks on Mars represented by NWA 7034, have equilibrated with the Martian atmosphere/hydrosphere which is thought to have oxygen isotope values higher than SNC – suggesting that SNC meteorites represent Martian subsurface rocks that are isolated from the atmosphere.

Another possibility is that the solid planet Mars is not homogeneous or well mixed with repsect to magma source regions and that NWA 7034 and the average Martian crustal rocks such as Gusev basalts are derived from a different Martian mantle than the SNC basalts. This could mean that during Mars accretion the planet's interior was built from material with different oxygen isotopic compositions and that these regions have remained isolated over Mars geologic history – in accord with Mars lacking a solid planet recycling mechanism such as plate tectonics.

Conclusions: The discovery of NWA 7034 "Black Beauty" greatly expands our understanding of the surface rocks on Mars that is based on studies of Martian meteorites. The multiple lithologies demonstrate the rich diversity of igneous rock types that Mars possesses, as well as the myriad of secondary alteration materials formed by interaction with the hydrosphere. Black Beauty finally forms the first tangible meteorite link to the rocks that NASA's rovers are sampling in outcrop on Mars.

References: [1] Agee C.B. et al. (2013) Science, 339, 780-785. [2] McSween H. Y., Taylor, G. J., Wyatt, M. B. 2009. Science 324, 736. [3] Santos, A. et al. (2014) LPSC XLV, Abstract #2621. [4] Stolper E.M. et al. (2013) Science, 341, DOI: 10.1126/science. 1239463. [5] Schmidt M.E. et al. (2014) JGR: Planets, 119, 64-81. [6] Nyquist L. et al. (2013) MetSoc, Abstract. [7] Humayun M. et al. (2013) Nature, 503, 513-516. [8] Yin Q.-Z. et al. (2014) LPSC XLV, Abstract #1320. [9] Cartwright J.A. et al. LPSC 44, Abstract #2314.