BLACK BEAUTY: A UNIQUE 4.4 GA, WATER-RICH METEORITE FROM MARS

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Northwest Africa (NWA) 7034, and its pairings, is a new type of Martian meteorite discovered recently in Western Sahara. NWA 7034, also known as "Black Beauty" because of its dark, shiny appearance (Fig. 1), contains ten times more water than other Martian meteorites. This, combined with its anomalous oxygen isotope values and ancient zircons, makes it an extraordinarily valuable specimen for understanding surface processes, aqueous alteration, and atmosphere–lithosphere exchange reactions that existed on Mars as far back as 4.4 billion years ago. Black Beauty appears to be the first Martian meteorite to match the surface geochemistry of Mars, as seen by landers and orbiters, and as such, it has particular relevance to the current Mars Science Laboratory mission at Gale Crater.

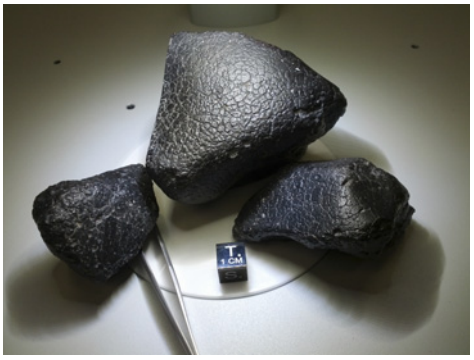

Figure 1 Three hand samples of NWA 7034, the Martian meteorite known as Black Beauty due to its shiny black appearance. Photo credit: University of New Mexico

Reported last year by a consortium of over a dozen workers (Agee et al. 2013), NWA 7034 is the first and only Martian meteorite breccia (Fig. 2). The original 320 g mass of NWA 7034 was found by an anonymous nomad meteorite hunter in 2011 in Western Sahara (considered by Morocco to be part of its country). The meteorite changed hands between the nomads and meteorite dealers, who sent it to the University of New Mexico for classification. A Martian origin was suspected based on Fe/Mn ratios, which are often used to distinguish planetary basalts (Agee et al. 2013), and was confirmed by the presence of noble gases matching those of the Martian atmosphere (Cartwright et al. 2013; Grady et al. 2014). This technique has been the practice since Bogard and Johnson (1983) confirmed EETA 79001 as being Martian by comparing noble gases trapped in pockets of impact melt glass with measurements of the composition of the Martian atmosphere as measured directly by Viking landers. Black Beauty has a basaltic bulk composition but is made up of numerous clasts of various lithologies set in a fine-grained matrix (Figs. 3, 4).

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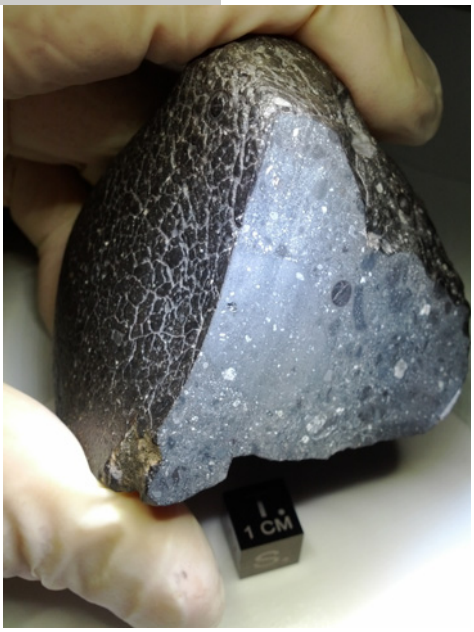

Figure 2 The main mass of NWA 7034. Both the fusion-crusted exterior and a sawn face showing the interior breccia are visible. Photo credit: University of New Mexico

At present, at least six different igneous rock types have been found in the 1–2 kg of the breccia now identified as NWA 7034 (owing to new finds). These include basalt, trachyte, and andesite. These compositions are remarkably similar to the rocks analyzed by APXS on the Spirit Rover at Gusev Crater and more recently with ChemCam on the Mars Science Lab at Gale Crater. Thus Black Beauty is the first tangible sample of the surface of Mars as determined by NASA missions. Secondary alteration products in clasts, spheres, and pebbles of Martian origin are abundant in Black Beauty, and the water-bearing phases include maghemite, ferrihydrite, phyllosilicates, and apatite, which sum to approximately 6000 ppm bulk water—10 to 30 times higher than in other Martian meteorites.

Age determinations on Black Beauty reveal the breccia's diversity and its complex origin, which likely reflect 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; however, bulk Sm/Nd dating done at NASA Johnson Space Center gave an age of ~4.4 Ga. Humayun et al. (2013) reported ancient zircon U–Pb ages of ~4.4 Ga, but they also found a younger population of zircon with ages of ~1.7 Ga, and subsequent studies have found many apatite, zircon, and baddeleyite grains with ages of ~1.4 Ga. Luckily for the chronologists, Black Beauty has populations of apatite and zircon throughout the matrix and in most clasts, which is offering the opportunity to date individual lithic domains, thus revealing the sequence of events that brought this breccia together, prior to its being blasted off Mars around 11 million years ago. Indeed, NWA 7034 is not simply a single meteorite sample; it is more like a Martian geologic field area all contained within one rock—and there is still much to explore!

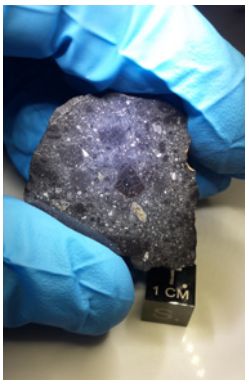

Figure 3 A polished surface of the interior of NWA 7034 clearly exhibiting clasts of various lithologies set in a fine grained matrix. Photo credit: University of New Mexico

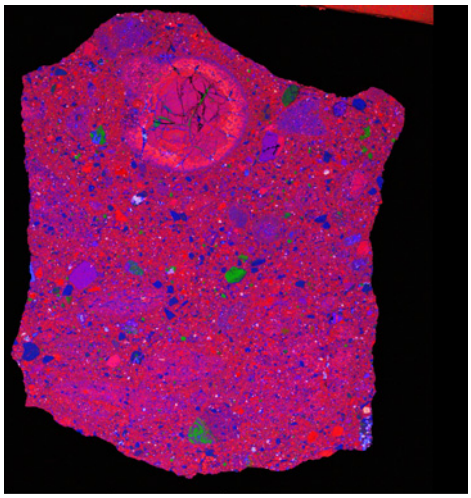

Figure 4 Elemental SEM map of a thin section of NWA 7034 showing clasts with clear compositional differences. Red = Mg, green = K, blue = Ca. Image courtesy of Romain Tartèse, Open University

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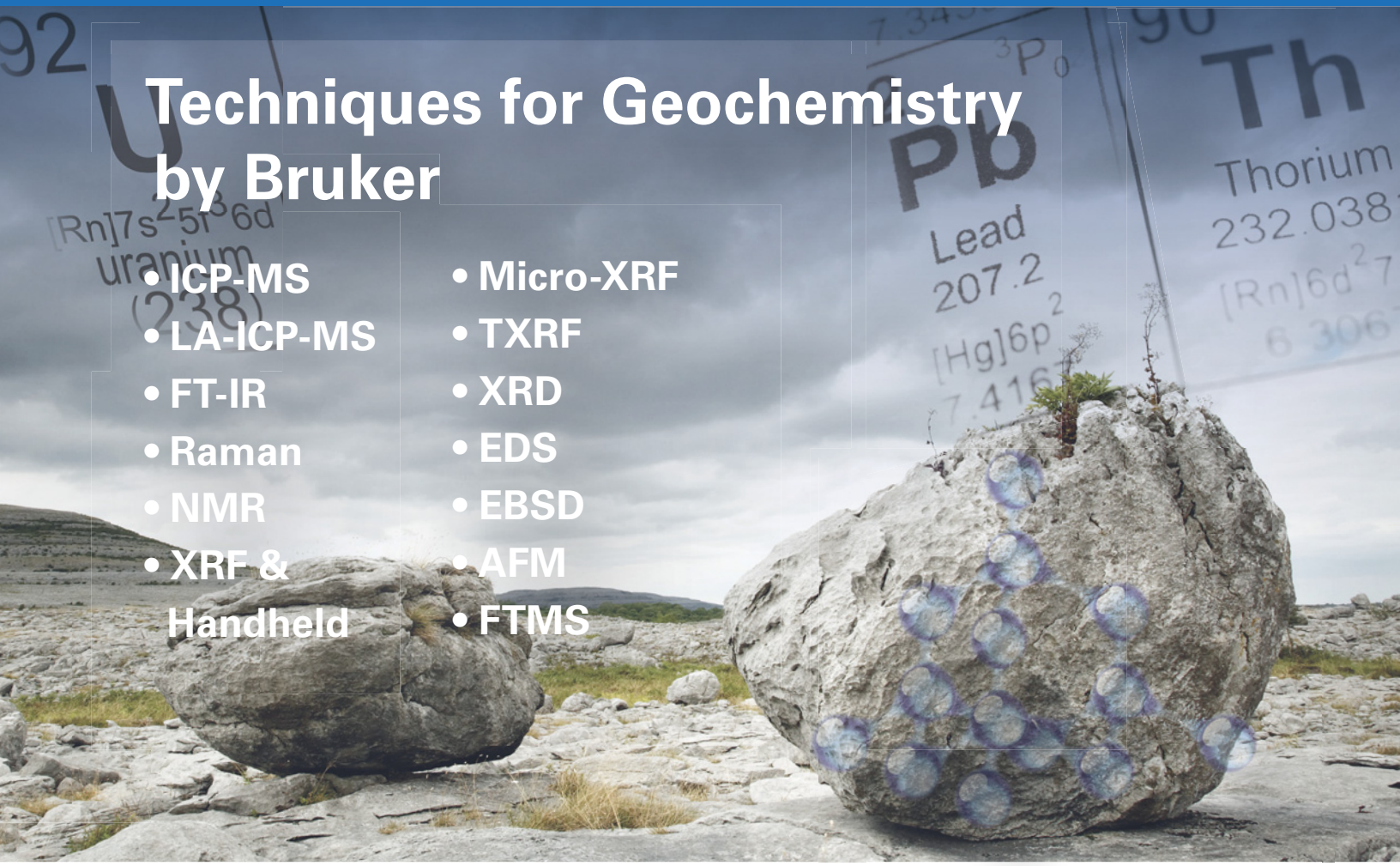
Elucidating Questions of Geochemistry



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