Micro-petrological analysis of Shergottite Meteorite 4468

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This study investigates the chemical variations within mineral phases in the Martian meteorite sample North West Africa (NWA) 4468. Meteorites are of course the only samples of Martian rocks that can be studied directly. Their geochemical and mineralogical compositions provide key evidence for magmatic processes occurring on Mars. Recent observations of volcanic areas on Mars, e.g., the Athabasca Valles, suggest that Mars is in fact still a volcanically active planet. Application of micro-petrology, i.e. processes represented and recorded on a mineral-scale, is the only effective way to study meteorites, which are exceedingly rare and found only as very small-volume samples. Meteorite NWA 4468 is an example of a Shergottite, a group of 150–220 Ma Martian meteorites, typically basaltic in composition, coarse-grained and enriched in incompatible elements. NWA 4468 is an olivine-phyric sample with large pyroxene oikocrysts, oxides, and plagioclase grains. The later have been shock-altered to maskelynite. Shergottites are generally thought to represent cumulates fractionated from high-volume melting of the lower, primitive, Martian mantle. Samples were examined using reflected light microscopy and back-scattering electron-imaging, followed by detailed X-ray mapping of both the large olivine and pyroxene crystals. The olivine crystals are generally not zoned in Fe and Mg, but do preserve phosphorus (P-) zoning. This occurs in about 20% of the olivine crystals and suggests early skeletal growth and subsequent ripening of the crystals, which in turn overprinted any Fe and Mg zoning that may have originally occurred. This type of P-zoning has been noted in terrestrial basaltic samples and can be used to make predictions about the growth history and cooling rates recorded. In this case, the olivine crystals formed early in the crystallization history but also at elevated temperatures. Pyroxene oikocrysts show distinct zoning from pigeonite to augite, i.e. from Ca-rich and Capoor sectors within individual grains. Zoning in Fe and Mg is also partially preserved in the pyroxene crystals. This can be used to determine the minimum recorded crystallization temperatures and relative cooling rates. The pyroxene crystals in this example likely formed later and at cooler temperatures than the olivine crystals. Analyses of oxides and plagioclase (maskelynite) have also been carried out to enable as wide a range of mineral thermobarometers as possible to be applied. Applied thermometry and barometry, combined with characterization of preserved micro-textural features in NWA4468, will provide further insight into the overall formation of large magmatic systems on Mars.

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