Phosphate and phosphide in mesosiderites

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Introduction: Abundant phosphate is a characteristic feature of mesosiderites. It formed by reheating after the mixing of metal with silicates. Hence it reflects the reheating process. Phosphide (schreibersite) is complementary to phosphate, forming from the remaining phosphorous in the metal during cooling from the peak temperature. Hence it also provides information on the reheating event(s). Here we describe phosphate and phosphide in 16 mesosiderites. Note that mineral identification is solely based on the compositions which were obtained by nominal EDS and hence not very accurate.

Observations and interpretation: The most abundant phosphate is merrillite. Stanfieldite ($Ca_4Mg_5(PO_4)_6$) and farringtonite ($Mg_3(PO_4)_2$) are rather rare, found only in a few mesosiderites. Nearly pure Ca-phosphate (called Ca-merrillite following Xie X. +, 2015, Am. Min., 100, 2753-2756) was found in two type-C mesosiderites. Apatite is very rare; only one grain was found in a Bondoc metal nodule. As for the morphology, the Bondoc nodule contains idiomorphic merrillite which presumably formed from an immiscible melt. The Bondoc nodule also contains irregularly shaped merrillite in the peripheral part of globular inclusions, detached from metal, suggesting formation by partial melting of pre-existing merrillite. Otherwise, merrillite mostly occurs on the surface of metal, suggesting formation at lower temperatures. Two types of schreibersite morphology are observed. One is in direct contact with taenite and another is close to but not in contact with taenite. The latter formed by quick cooling and the former formed by slower cooling. This interpretation is supported by the Ni/Fe ratios. A distinct occurrence of schreibersite is observed in Dong Ujimquin Qi; schreibersite is associated with troilite and kamacite. This mineral assemblage suggests its formation from a eutectic Fe-Ni-S-P melt. The abundance ratios of phosphide to phosphate is controlled by the closure of the phosphate formation reaction and are related to the cooling rate. NWA 2924 and Estherville show high phosphide/phosphate abundance ratios, suggesting that they cooled quickly. Their schreibersite morphology also suggests quick cooling. Na/Ca atomic ratios in merrillite ranges from less than 0.02 to higher than 0.07. The lowest ratio is observed in Dong Ujimquin Qi, which is characterized by high Fe-Ni metal abundance, presence of cordierite and stanfieldite. The exact mechanism to make the low Na/Ca ratio is not clear but a relatively low abundance of plagioclase (hence Na), and a high metal abundance (which produces more merrillite) probably conduced to the low Na/Ca ratio. High Na/Ca ratios are observed in merrillite that formed from (or in contact with) a melt at high temperatures. The high ratios are probably due to Na/Ca partition between phosphate and silicate melt at high temperatures. The stanfieldite in Dong Ujimquin Qi was probably formed at low temperatures under a low Ca-activity. The low Ca-activity is suggested by the presence of cordierite. Farringtonite is always located at the silicate-metal interface, protruding into the metal. This suggests its formation at very low temperatures. Na-free Ca-merrillite in type-C mesosiderites coexists with merrillite with normal Na/Ca ratios. The coexistence of two Ca-bearing phosphates suggests disequilibrium caused by a quick reheating event. We suggest that initially apatite existed which disintegrated by the reheating, resulting in Ca-merrillite. Phosphate is supposed to disintegrate by reheating to high temperatures (Harlow G.E. +, 1982, GCA, 46, 339-348.). But in many mesosiderites that were heated to high temperatures, some phosphate remains without disintegration, suggesting that the reheating event was short. This allows us to recognize multiple reheating events that were experienced by mesosiderites.

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