NOBLE METAL ARSENIDES AND GOLD INCLUSIONS IN NORTHWEST AFRICA 8186.

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Introduction: CK carbonaceous chondrites are a highly thermally altered group of carbonaceous chondrites [1], experiencing temperatures ranging between ~576-867 °C [2]. Additionally, the mineralogy of the CK chondrites record the highest overall oxygen fugacity of all chondrites, above the fayalite-magnetite-quartz (FMQ) buffer [3]. Metallic Fe-Ni is extremely rare in CK chondrites, but magnetite and Fe,Ni sulfides are commonly observed [1, 3-6]. Noble metal-rich inclusions have previously been found in some magnetite and sulfide grains. These arsenides, tellurides, and sulfides, which contain varying amounts of Pt, Ru, Os, Te, As, Ir, and S, are thought to form either by condensation from a solar gas, or by exsolution during metamorphism on the chondritic parent body [6].

Northwest Africa (NWA) 8186 is a highly metamorphosed CK chondrite. This meteorite is predominately composed of NiO-rich forsteritic olivine (Fo_{65}), with lesser amounts of plagioclase (An_{52}), augite ($Fs_{11}Wo_{49}$), magnetite (with exsolved titanomagnetite, hercynite, and titanohematite), monosulfide solid solution (with exsolved pentlandite), and the phosphate minerals Cl-apatite and merrillite [9-10]. This meteorite contains coarse-grained, homogeneous silicates, and has 120° triple junctions between mineral phases, which indicates a high degree of thermal metamorphism. The presence of NiO-rich olivine, oxides phases all bearing Fe^{3+}, and the absence of metal, are consistent with an oxygen fugacity above the FMQ buffer. We also observed noble metal-rich phases within sulfide grains in NWA 8186, which are the primary focus of the present study.

Methodology: A 1 cm x 0.5 cm thick section of NWA 8186 set in a 1-inch epoxy plug was used for our study. A few arsenide inclusions were observed within sulfide grains. We chose one representative arsenide to examine with the scanning transmission electron microscope (STEM).

We used focused ion beam (FIB) techniques with a FEI Quanta 3D SEM/FIB at Johnson Space Center to prepare for TEM analysis. To minimize ion beam damage, a carbon protective strap (3 µm thickness) was deposited prior to FIB sample preparation. We cut a section ~10 µm in length of a sulfide grain containing an arsenide inclusion by gallium ion milling at an ion beam voltage of 30 kV and beam currents ranging from 7 nA down to 0.1 nA. The sample was then removed from the thick section using an Omniprobe 200 micromanipulator and was transferred to a Cu TEM half grid. Final milling was then carried out to reach electron transparency at 5 kV and 48 pA. A JEOL 2500SE field-emission STEM at Johnson Space Center was used to obtain selected area diffraction (SAED) patterns, bright-field STEM images, X-ray maps, and energy dispersive X-ray spectroscopy (EDX) measurements.

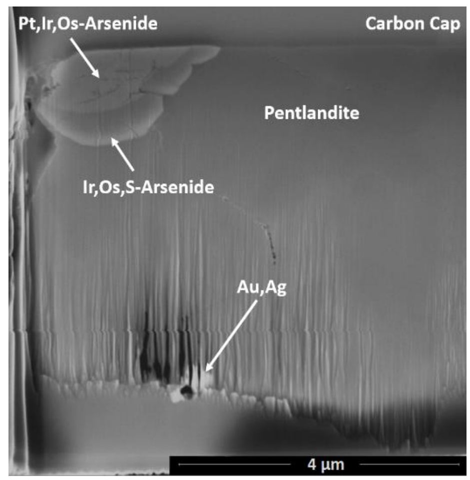

Figure 1. A bright-field STEM image of a FIB section from NWA 8186 showing a zoned arsenide and Au,Ag inclusion within pentlandite.

Results: Spot analyses on selected areas of this section confirmed the presence of noble metals in NWA 8186. A ~2 µm arsenide was observed within a sulfide grain (Fig. 1). SAED patterns confirmed the host sulfide phase is polycrystalline pentlandite ($(FeNi)_9S_8$). X-ray maps and EDX measurements revealed an abrupt chemical interface within the arsenide, in which the core was Pt-rich with lesser Ir, and Os, and the outer rim was Ir-rich, containing As, Ir, Os, and minor S. A sharp diffusion boundary was seen between the core and rim. A 0.5 µm-sized Au inclusion (containing minor Ag) was also observed in the pentlandite host phase.

Discussion: Noble metal-rich phases are known from CK chondrites [6], CAIs in CVs [7-8] and in R chondrites [11-12]. The arsenides detected in CKs were thought to be homogeneous, and diffusion profiles were not previously observed, leading authors to disregard a primary origin for these phases [6]. The arsenide and gold inclusions likely formed by exsolution following a metamorphic event on the CK parent body. The rim of the arsenide, which contains minor S, is likely an overgrowth. Future TEM investigations on the crystallographic relationship between the arsenide and pentlandite host will further clear this issue.

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