Origin of the ungrouped achondrite NWA 4518: mineralogy and geochemistry of FeNi-metal

Conference or Workshop Item

ORIGIN OF THE UNGROUPED ACHONDRITE NWA 4518: MINERALOGY AND GEOCHEMISTRY OF FeNi-METAL.
C. A. Lorenz[1], S. N. Teplyakova[1], M. Humayun[2], M. A. Ivanova[1], I. Franchi[3] and R. Greenwood[3] [1]Vernadsky Institute of Geochemistry and Analytical Chemistry RAS, 119991, Kosygin St. 19, Moscow, Russia, c-lorenz@yandex.ru, [2]Florida State University, 1800 E. Paul Dirac Drive, Tallahassee, FL 32310, USA, [3]Open University, Walton Hall, Milton Keynes MK7 6AA, Bucks, UK.

Introduction: Ungrouped achondrite NWA 4518 is an ultramafic polymict breccia with abundant FeNi-metal. The silicate chemistry of NWA 4518 is similar to that of winonaites, HEDs and silicate inclusions from IIE irons. However, its oxygen isotopic composition is very different from all known types of meteorites. Two thin polished sections of NWA 4518 were studied with optical microscopy and EMPA. Petrography suggests that breccia probably was formed by impact mixing of molten metal with solid silicates and suffered a high temperature metamorphism and reducing metasomatism. *In situ* elemental compositions of 13 metal particles were determined by LA-ICP-MS in one thin section of NWA 4518. The metal is enriched in refractory siderophile elements (RSE) and W by ~100xCI and does not correspond to any other groups of iron meteorites.

Results: The NWA 4518 is a recrystallized equigranular polymict breccia, consisting of olivine Fo_{68} (Fe/Mn=36) and minor pyroxenes $En_{45}Wo_{42}$ (Fe/Mn=29) and $En_{72}Wo_{2}$ (Fe/Mn=42) [1]. FeNi-metal (2 vol%) occurs among silicates as polygonal grains of 50-800 µm size. These metal grains are interconnected by a network of thin metal-sulfide veins, which locally contain metal-silicate melt pockets. The majority of metal grains has a mosaic internal texture and consist of several polygonal areas, only slightly different in Ni content (6.5-7.2 wt%), but obviously visible in BSE images. Tiny Ni-rich inclusions are widespread in the metal grains. Taenite lamellae, up to 7 µm in width, occur on the borders of polygonal areas inside the metal grains and along the contacts of the metal with surrounding silicates. The lamellae have M-shaped profiles of Ni concentration from 22.5 wt% on the borders to 15 wt% in the center. The Ni content in kamacite varies in different grains in the range 4 - 7 wt% (average 6.24 wt%, Ni/Co=8.7). The metal in the veins has similar composition. All of metal phases lack Si and have constant P concentrations ~ 0.2 wt%.

Sulfides in NWA 4518 occur among silicates as polygonal grains of Ni-poor troilite, up to 500 µm in size, interconnected by thin troilite veins with higher Ni content (0.2-0.3 wt% Ni). The large grains of troilite locally have straight sharp contacts with metal grains.

The numerous troilite-filled veins are running through the whole rock. The olivine around these veins is everywhere replaced by a fine-grained aggregate of troilite and orthopyroxene.

The large fragment of orthopyroxenite consists of FeNi-metal inclusions, up to 500 µm in size, enclosed in pyroxene crystals. The texture and composition of these metal inclusions are similar to those of other metal grains in NWA 4518. The metal often associates with chromite and sulfide. The chromite contains rare small inclusions of Ni-rich troilite, pentlandite and metal (Ni 1.5 wt%; Ni/Co=6).

Discussion: Previous petrographic observations showed that olivine and pyroxene grains from NWA 4518 are fragments of cumulate ultramafic rocks [1], free of feldspathic component. A complicated internal texture of metal grains and their compositions are probably the result of extensive nucleation of taenite during the relatively quick crystallization of the metal with slow cooling from ~700 to 500°C. The quick cooling at high temperatures could take place on the surface of parent body after impact mixing of molten metal with silicate breccia. The metal inclusions in pyroxenite fragment are similar in texture and composition to metal grains, distributed among silicate fragments in the breccia, and could have originated from the same source. The metal enclosed in pyroxene, appears to be indigenous. However, the compositions of metal and silicates are not in equilibrium and crystallized from the different sources. Therefore all of NWA 4518 metal is exotic. In this case magmatic-like texture of metal in the pyroxenite fragment could be formed due of impact injection of metal into fine cracks, similar to mechanism proposed for metal-bearing eucrites [2]. Occurrence of melt pockets and metal-troilite veins, running along the margins of recrystallized silicates indicate that NWA 4518 experienced a shock event after the thermal metamorphism, resulting in the equigranular texture. Observed replacement of olivine by aggregate of pyroxene and troilite is probably result of reducing metasomatic reactions of olivine and S-rich gas, that was noted before in lodranites [3].

Four analyses of oxygen isotopes were performed on silicate portions of NWA 4518 using techniques described in [4]. The average oxygen isotopic composition of NWA 4518 is (‰): $\delta^{17}O$ 2.62; $\delta^{18}O$ 5.38; $\Delta^{17}O$ -0.17. The composition is on the far prolongation of the HED trend, near, but out of IAB-IIICD-winonaites field, and indicates unusual oxygen reservoir (Fig. 1).

The LA-ICP-MS analyses of FeNi-metal grains from the main mass of the NWA 4518 have shown that compositions of analyzed metal grains vary in a narrow range and characterize single homogeneous source of metal. The metal of NWA 4518 is enriched in RSE, up to 100xCI. The RSE are not significantly fractionated from one another, and are present in chondritic relative abundances (Fig. 2). The Ir/Os (1.06) and Re/Os (0.1) ratios of the average metal are close to those of CI (0.98 and 0.075 respectively). The Mo is depleted relative to RSE and probably was partly distributed into sulfide. The less refractory elements are strongly depleted relative to RSE. Ni/Co ratio (10) is lower then that of CI. The metal is enriched in Au and Ge and depleted in Ga. Average concentrations of siderophile elements do not correspond to any known group of iron meteorites: Ni (6.44 wt%), Ir (26.3 ppm) Ga (10.3 ppm) Ge (555 ppm). Chondritic ratios of RSE could correspond to fractionation controlled by volatility rather than magmatic fractionation. However nonchondritic Ni/Co ratio probably indicate another mechanism of fractionation. The Os is slightly depleted relatively to Re and Ir, that is sign of some fraction crystallization. Therefore, NWA 4518 metal could crystallize from metal liquid after removing of small solid metal fraction in the interior of large differentiated body.

The metal of NWA 4518 is unique by HSE enrichment. The most RSE-rich group of IVB irons [5] is not related to NWA 4518 metal because IVB irons are Ni-rich and poor in moderately volatile siderophile elements. The NWA 4518 metal could have some affinity to the Ni-poor, W, RSE-rich iron meteorites of IIA group that were not oxidized during nebular evolution [6]. Concentrations of Re, Ir and Os of the NWA 4518 metal correspond to fractionation trend of IIA irons [7] and indicate that these two types of metal could be genetically linked. The NWA 4518 metal appears to be crystallized on the stage of fractional crystallization after the Bennett County but probably before Coahuila crystallization.

The enrichment of metal by W relatively to HRS could be a result of partial reduction of tungsten from silicates and redistribution of W into the metal phase during the high temperature metamorphism [8]. Depletion in Ga probably also is result of metamorphism.

Conclusion: The most probably, silicate lithology of NWA 4518 was formed on differentiated asteroid, which was not represented by meteorites before, while metal component is originated from metal body, probably genetically linked to IIA iron meteorites.

References: [1] Lorenz C. A. et al. (2007) *MAPS, 42,* 5169. [2] Yamagushi A. et al. (2006) *LPSC 37,* 1678.pdf. [3] Papike J. J. et al. (1995) *GCA, 59,* 3061-3070. [4] Miller M. F. et al. (1999) *Rapid. Comm. Mass. Spectrom., 13,* 1211-1217. [5] Campbell A. J., Humayun M. (2005), GCA, 69, 4733-4744. [6] Kelly W. R., Larimer J. W. (1977) *GCA, 41,* 93-111. [7] Humayun M., Campbell A. J. (2000), *LPSC 31,* Abstract 2031.pdf. [8] Newsom H. E., Drake M. J. (1979) *LPSC 10,* 910-912. [9] Petaev M. I., Jacobsen S. B. (2004) *MAPS, 39,* 1685-1697. [10] Wasson J.T. et al. (2007) GCA, 71, 760-781. [11] Cook D. L. et al. (2004) GCA, 68, 1413-1431. [12] Kong P. et al. (1998) *MAPS, 33,* 993-998. [13] Clayton R. N. and Mayeda T. K. (1996) *GCA, 60,* 1999-2018.

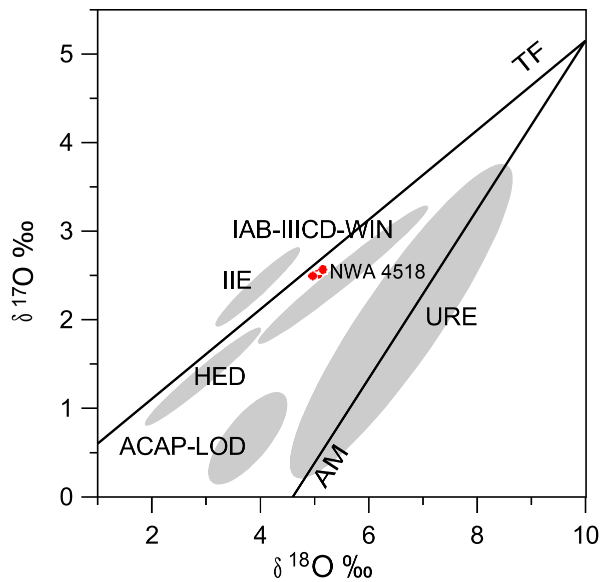

Fig. 1. Oxygen isotopic compositions of NWA 4518 (red circles), the data fields from [13].

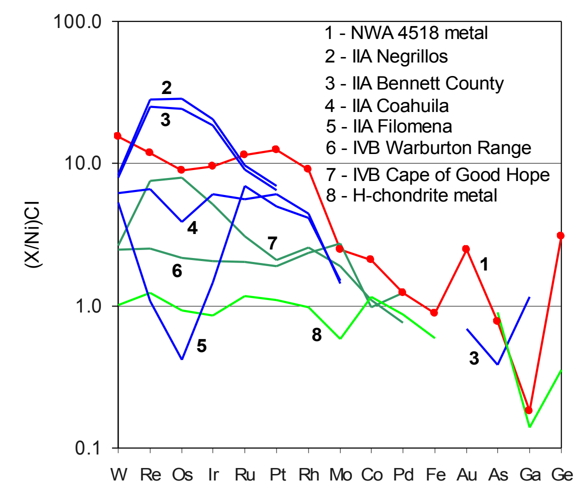

Fig. 2. Composition of the NWA 4518 metal in comparison with IIA [9-11], IVB [5] irons and H-chondrite metal [12] (normalized to Ni and CI).