Pyroxene-plagioclase pallasite Northwest Africa 10019: Where does it belong?

Conference or Workshop Item

PYROXENE-PLAGIOCLASE PALLASITE NORTHWEST AFRICA 10019: WHERE DOES IT BELONG?

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Introduction: Northwest Africa 10019 was first reported by [1] at the 2015 Meteoritical Society meeting. It is the first pallasite reported to contain plagioclase (Choteau is a second pyroxene-plagioclase pallsite [2]) . In addition, it contains significant pyroxene, yet again expanding the number of pyroxene pallasite parent bodies. We have begun an intensive study of this unusual pallasite to determine its petrological, chemical and oxygen isotopic history and its implications for the differentiation of protoplanets in the early solar system.

Analysis: Two, one-inch round mounts of NWA 10019 were made from a sample at Texas Christian Univ. Microprobe analysis and sample characterization was performed at Brown Univ., trace element data were gathered by laser ablation ICP-MS at Florida State Univ., and laser fluorination oxygen isotopic analysis was carried out at The Open University.

Results: NWA 10019 is a complex pallasite. Modal mineralogy varies dramatically from section to section despite the two samples having been taken from areas separated by only about an inch (Table 1). Section -1 contains significantly higher abundances of pyroxene, phosphate, taenite, chromite, and plagioclase than section -2. The most unusual aspects of this rock however are 1) the plagioclase, which occurs both as single coarse grains (up to 2mm x 2mm) inside orthopyroxene or olivine and fine-grained inclusions (10-50 microns) within orthopyroxene, 2) an enclave having slightly more primitive material than the remaining sample, and 3) the most evolved metal (Ni= 93 mg/g, Ga= 9.1 µg/g, Ge= 7.7 µg/g, Ir= 0.009 µg/g, Au= 1.90 µg/g) yet measured in a pallasite. Glorieta Mountain, the most evolved Main Group pallasite (PMG) has 0.014 µg/g of Ir.

Table 1. NWA 10019 mode

Section	-1	-2
Olivine	42.9	50.9
Pyroxene	17.4	8.9
Plagioclase	1.1	0.0
Kamacite	25.1	28.3
Taenite	8.6	4.4
Schreibersite	0.7	0.4
Chromite	1.9	0.8
Phosphate	2.2	1.5
Troilite	0.1	4.8

NWA 10019 silicates and oxides show both fractionated and primitive characteristics. The olivine, which is subhedral to angular and up to 6 mm in diameter is $Fo_{84.3-82.8,}$ similar to that found in Springwater [3,4] with Fe/Mn ratios of 28-37. Orthopyroxene ($Wo_{0.2-7.2}En_{85-77.4}$) is found as subhedral to anhedral grains up to 5 mm in diameter, while clinopyroxene ($Wo_{44.3-48.9}En_{45.9-48.0}$) occurs as small ~100 micron inclusions in orthopyroxene. The coarse-grained plagioclase has a fairly uniform composition ($An_{69.4-73.4}Ab_{29.8-25.9}$) (Fig. 1). Merrillite, stanfieldite and farringtonite are all found within this pallasite, which is unusual, as individual PMG typically contain only one or two phosphate minerals and not all three. Chromite is also atypical as the compositions plot completely outside the normal PMG range (Fig. 2), reflecting a very Al-rich environment.

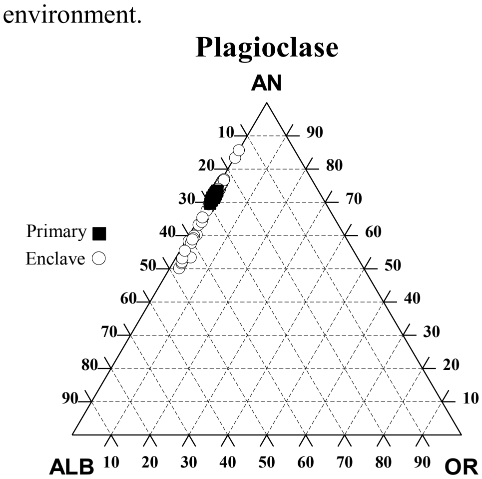

Figure 1: Ternary plot of the enclave and primary plagioclase compositions in NWA 10019.

The enclave material in section -1 was found to be slightly more primitive than the rest of the sample. It contains fine-grained plagioclase that has a much wider compositional range ($An_{50.1-85.6}Ab_{47.4-14.3}$) compared to the coarse plagioclase grains found in the rest of the meteorite (Fig. 1), an Mg-rich chromite (Fig. 2), orthopyroxene, mildly more Mg-rich olivine (Fo_{84}), and merrillite (the early crystallizing Ca-phosphate). This is the first enclave noted in a pallasite.

The metal within NWA 10019 is the most fractionated in any pallasite yet measured (Fig. 3), having very depleted Re, Os, Ir and Pt and enriched Au and As concentrations. The metal is lower in Ir than that of

Glorieta Mountain [5], but plots along an extension of the IIIAB trend on Ir vs. Au, unlike most PMG which plot to higher Au abundances [5]. In addition, the Ga and Ge contents of NWA 10019 are less than half that found in the PMG [5], and do not plot on an extension of the IIIAB fractionation trend [5] implying that NWA 10019 may be from a distinct parent body lower in volatile element abundances (Ga, Ge, As and Au) than that of the PMG.

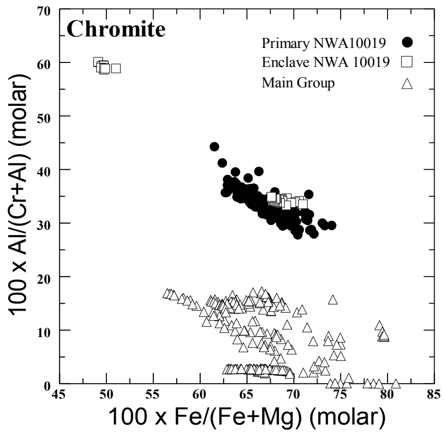

Figure 2: Fe/(Fe+Mg) vs Al/(Al+Cr) plot showing chromite of NWA 10019 and MG pallasites

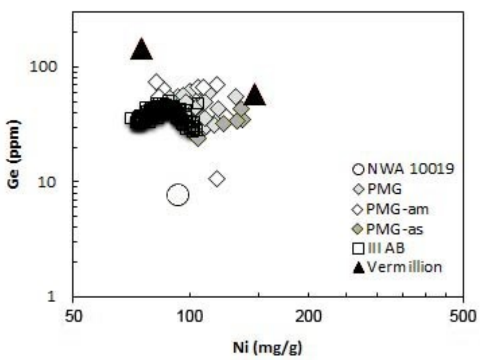

Figure 3: Ge vs. Ni plot for NWA 10019 compared with pallasites [5] and IIIAB irons [6].

Oxygen isotope analysis was first performed by [1] which placed NWA 10019 in the region of the three isotope oxygen diagram occupied by the mesosiderites. However, our new analysis (Fig. 4) places it at the δ^{18}O-rich end of PMG. NWA 1911, another pyroxene pallasite that seems to be within Main Group, has similar oxygen [7] to NWA 10019.

Discussion: Plagioclase within the NWA 10019 pallasite is a confusing piece of evidence. The FeNi metal indicates extreme fractional crystallization of the core, while the plagioclase indicates the presence of crustal or upper mantle material. There are two possible modes of formation. One, a very small differentiated parent body where plagioclase is stable in the lower mantle and extreme metal fractionation can occur in the nearby core. Two, an impact has mixed fractionated metal with crust or upper mantle.

An interesting aspect of the plagioclase and metal relationship is that the two phases are never in direct contact with one another anywhere in the analyzed sections. Both the large 2x2 mm grains, as well as, the small, 10-50 micron inclusions occur inside either olivine or pyroxene, possibly forming some type of nodule. This "nodule" may make it possible to transport the plagioclase within the mantle and finally interact with the fractionated metal.

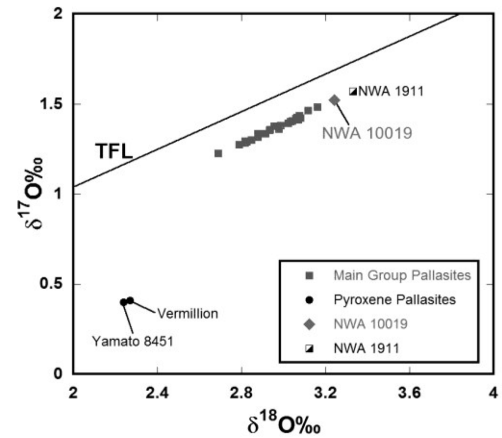

Figure 4: Oxygen isotopic composition of NWA 10019 relative to PMG [8] and pyroxene pallasites [9].

Although NWA 10019 has the same oxygen isotopic composition as PMG, mineralogical and compositional links are extremely hard to make. First, the presence of plagioclase sets NWA 10019 apart from PMG. Second, the modal mineralogy is quite distinct, particularly with abundant pyroxene. Third, chromite compositions have dramatically higher Al contents than any found in PMG. Finally, trying to reconcile the extreme fractionation of NWA 10019 metal and its different Ga and Ge contents with a member of the PMG is difficult at best. It therefore seems unlikely that this pallasite derives from the PMG parent body, but instead comes from a different parent body that has a similar oxygen isotopic composition to PMG, and has experienced a remarkably different petrologic evolution.

References: [1] Agee C. et al. (2015) *MaPS 50,* abstract 5084. [2] Gregory J. D. et al. (2016) *LPSC XLVII*, this volume. [3] Davis A. M. (1977) Ph.D. dissertation, Yale University. [4] Scott E. R. D. (1977) *GCA 41*, 349-360. [5] Wasson J. T. and Choi B.-G. (2003) *GCA 67*, 3079-3096. [6] Wasson J. T. (1999) *GCA 63*, 2875-2889. [7] Bunch T. et al. (2005) *MaPS 40*, abstract 5219. [8] Greenwood R. C. et al. (2015) *GCA 169*, 115-136. [9] Boesenberg J. S. et al. (2000) *MaPS 35*, 757-769.