CHOTEAU MAKES THREE: A CHARACTERIZATION OF THE THIRD MEMBER OF THE VERMILLION SUBGROUP. J. D. Gregory[1], R. G. Mayne[1], J. S. Boesenberg[2], M. Humayun[3], A. P. Silver[3], R. C. Greenwood[4], and I. A. Franchi[4] . [1]School of Geology, Energy, and the Environment, Texas Christian University, TCU Box 298830, Fort Worth, TX. 76129, [2]Dept of Earth, Environmental, and Planetary Sciences, Brown University, 324 Brook Street, Providence, RI. 02912, [3]Dept of Earth, Ocean, and Atmospheric Science, Florida State University, P.O. Box 3064520, Tallahassee, FL 32306-4520. [4]Dept of Physical Sciences, The Open University, Walton Hall, Milton Keynes, MK7 6AA, UK.

Introduction: The Choteau pallasite was discovered in Montana in 2011 when it was purchased at an estate sale. Choteau was initially classified as an ungrouped pallasite based on the unusual oxygen isotope composition, which appeared to be similar to that of the acapulcoites and lodranites [1].

The purpose of the present study is to gain a better understanding of Choteau's petrogenesis and establish whether it can be linked to any previously classified pallasites or pallasite groupings.

Methods: A slab of Choteau was provided by the Oscar E. Monnig Meteorite Collection at TCU and three 1-inch round thin sections were produced from it. Back-scattered electron imaging was undertaken using the SEM in the Mineral Sciences Department at the Smithsonian's NMNH. Using these images, locations were selected for electron microprobe analysis, at the University of Oklahoma. Lastly, one of the thin sections was sent to Florida State University for LA-ICP-MS to obtain rare earth elemental data for both the metal and silicate phases. New oxygen isotope data was also collected at the Open University following the methods of [2].

Results: The oxygen isotope composition of Choteau measured in this study ($\delta^{17}O$ = 0.211±0.091‰; $\delta^{18}O$ = 2.52±0.21‰; $\Delta^{17}O$‰ = -1.102±0.017‰; where $\Delta^{17}O = \delta^{17}O - 0.52\delta^{18}O$) is very similar to pyroxene pallasites Vermillion and Yamato-8451 (Figure 1) [3].

Olivine compositions were found to be homogenous throughout, with an average value of Fe/Mn = 33.5±2.5 and $Fo_{89.7\pm0.6}$ (Figure 2). Olivine grains ranged from highly angular to subhedral with lengths up to 1 cm.

Both orthopyroxene and clinopyroxene are present in Choteau. Orthopyroxene was found as individual grains or along the boundaries of the clinopyroxene, which was strictly observed as inclusions within the olivine. The orthopyroxene composition of $En_{88.0\pm1.1}Wo_{1.9\pm0.5}$ and the average clinopyroxene composition of $En_{56.4\pm3.9}Wo_{38.7\pm4.8}$ (Figure 2) are very similar to those found in Vermillion and Y-8451[3].

Merrillite was observed in highly anhedral shapes most often adjacent to an olivine crystal with Fe/Mg = 0.03±0.01. Chromite was common throughout each thin section, appearing as euhedral to subhedral crystals along the borders of olivine crystals or as anhedral inclusions within the olivine and pyroxene. The composition was homogenous with Mg# (Mg/(Mg+Fe) x 100) = 38.9±9.5 and Cr# (Cr/(Cr+Al) x 100) = 86.9±4.0. Both of these values are very similar to the chromite compositions found in Vermillion (Mg# ≈ 40 and Cr# ≈ 94) [3].

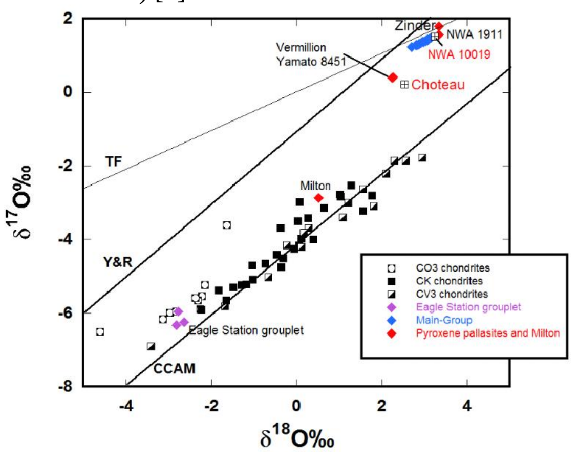

Figure 1: Oxygen isotope composition of Choteau compared with Vermillion and Y-8451.

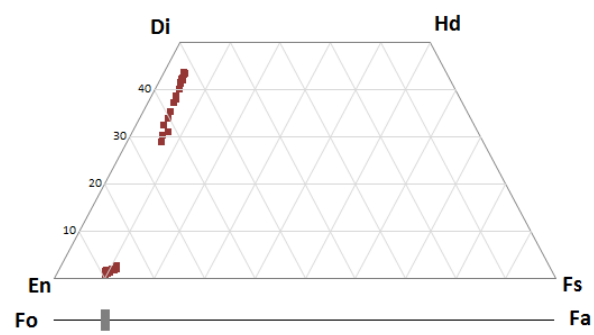

Figure 2: Pyroxene and olivine compositions measured in Choteau.

The discovery of plagioclase makes Choteau unique in that it is only the second known pallasite to contain plagioclase, following NWA 10019 [4, 5]. However, the plagioclase found in Choteau ($An_{9.0}Ab_{85.6}Or_{5.4}$) is nearly endmember albite, while NWA 10019 plagioclase is more calcic (An_{50} to An_{84}) (Figure 3). The plagioclase occurs as highly irregular inclusions in both orthopyroxene and clinopyroxene and small veins filling fractures were also observed in orthopyroxene (Figure 4).

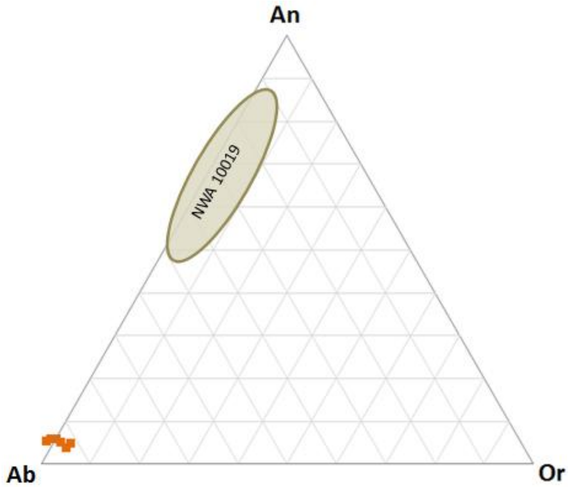

Figure 3: Plagioclase compositions of Choteau as compared with those of NWA 10019 [5].

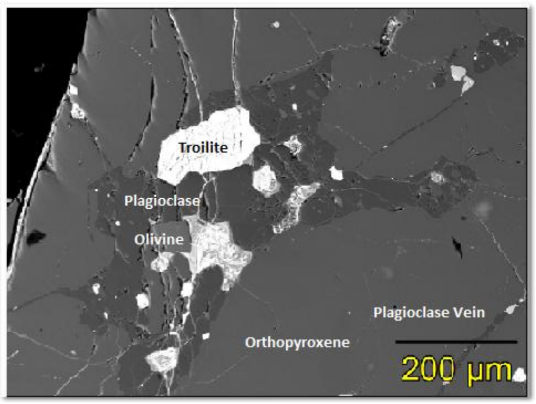

Figure 4: Plagioclase inclusions and veins within the orthopyroxene of Choteau pallasite.

LA-ICP-MS results showed a strong positive Eu anomaly in plagioclase and a strong negative Eu anomaly in pyroxene. The olivine REE-contents were too low to be quantified. When compared with other pallasites, Choteau metal shows compositional similarities to Vermillion with Ni, Ga, Ir, Ge, and Au having remarkably similar values (Figure 5).

Discussion: Choteau is currently classified as an ungrouped pallasite. The oxygen isotopic composition and mineral chemistry strongly suggest it is related to both Vermillion and Y-8451. LA-ICP-MS analyses of the metal within Choteau (Figure 5) confirm that it has a composition between that of Vermillion and Y-8451, lying closer to or overlapping Vermillion for every element examined so far.

Based on the similarities of chemistry, petrology, and oxygen isotopic data between Choteau and Vermillion and Y-8451, we suggest that this be formally recognized as a new grouplet, and known as the Vermillion pallasites. However, Choteau does have an $\Delta^{17}O$ value that lies >0.3‰ away from the other two grouplet members. This indicates that isotopic equilibrium was not achieved during their formation. which may indicate they were formed over short timescales.

Perhaps most significant, however, is the presence of plagioclase in Choteau, which was not noted during its classification or in any other member of its grouplet. The only other plagioclase-bearing pallasite, NWA 10019, has a different oxygen isotope composition [5]. The identification of plagioclase in two pallasites hailing from different parent bodies may require a shift in our current thoughts on pallasite petrogenesis.

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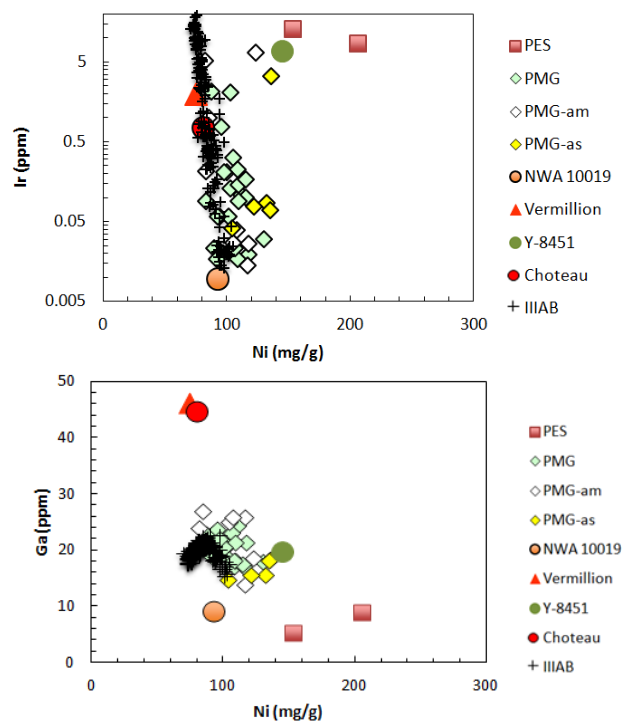

Figure 5: Comparison of Choteau's metal composition with the IIIABs [6], the main-group pallasites (PMGs [7]), and the pyroxene-bearing pallasites Vermillion and Y-8451. A). Ni vs Ir. B). Ni vs Ga.