PERIDOTITIC ANGRITES ARE CHIMEROLITES A. Jambon[1], B. Baghdadi[1] and J-A. Barrat[2].[1] UPMC-Paris 6, CNRS UMR7193, Institut des Sciences de la Terre Paris. albert.jambon@upmc.fr. [2] UBO-IUEM, CNRS UMR 6538, place Nicolas Copernic, 29280 Plouzané France.

Introduction: Angrites are achondritic meteorites with an unusual mineralogy/chemistry **[1,2]**. Among those, *magmatic angrites* are typical lavas with a quench texture (e.g. D'Orbigny, SAH 99555, Northwest Africa (NWA) 1296). *Picritic angrites* enclose, in a magmatic matrix, xenocrysts of mostly olivine (e.g. NWA 1670, A-881371, LEW 87051). *Angra dos Reis* is unique and interpreted as a clinopyroxene cumulate. Finally a series of paired rocks [3], sometimes called peridotitic angrites, because of their high olivine content (NWA 2999/3158/3164/4569/4662/4931/5167/6291) are quite different. Besides a typical angritic chemistry and mineralogy, they contain 5-10% kamacite in a coarse grained rock with equilibrated texture and homogeneous crystals. As discussed next, the presence of metal could result from either imperfect core separation, iron reduction or metal introduction from an exogenous source after impact. Analytical data discussed here are for NWA 3164 and 5167. Bulk rock major and trace elements were analysed by ICP-AES and ICP-MS respectively according**.**

The case of residual metal. Core separation is the first and major fractionation episode of planetary differentiation. According to **[4],** NWA 2999... is younger than magmatic angrites (<4.537 Ga as opposed to > 4.563Ga). The oldest angrites already exhibit the siderophile depletion characteristics of core fractionation **[5]**. The oxygen isotopic composition indicates unambiguously that angrites derive from one single, well homogenized parent body **[6]**. From a chondritic composition, a Fe-S melt of high density can percolate down to form a core leaving a silicate residue. If the mechanical separation is incomplete, pockets of metal could be trapped at the silicate crystal boundaries. In this case, however, the residual silicate must be primitive with chondritic Si/Mg, Ca/Mg and Al/Mg ratios. In NWA 2199 these ratios are approximately 0.63, 6.7 and 4.5 times the chondritic value (fig.1). All incompatible trace elements are enriched as well. The Fe/Mg ratio is 1.2 times the CI value, the opposite of what would ensue from the (incomplete) separation of an Fe-S melt. This scenario is therefore inconsistent with chemical evidences and must be discarded.

Partial reduction of iron. This process is rather unusual but angrites are odd rocks, and this reduction process is observed in ureilite meteorites on the one hand **[2** and references therein] and terrestrial basalts from Disko island (Greenland) on the other. In this latter case a basaltic intrusion through coal deposits, yielded iron nuggets containing variable amounts of Ni. In magmatic angrites, there is no evidence of reduced carbon but the presence of calcium carbonate and CO_2 vesicles indicates that the possible reduction by carbon should not be rejected too hastily. The metal so formed should trap Ni efficiently and EMPA analyses of Disko metal reveal variable amounts of Ni in the range 0.5-2.5 % wt %. Kamacite in NWA 3164/5167 contains 6.5 % Ni, and the olivine content of 400 ppm represents about 10 % of the bulk rock Ni. After partial reduction, a small amount of iron metal could contain several % Ni; actually 0.5% iron could contain up to 5% Ni if all Ni were transferred from silicates to metal. There we meet a serious difficulty since olivine and pyroxene in NWA 3164/5167 contain more Ni (not less) than metal-free angrites. Magmatic angrites contain carbonate, no metal, and no reduced carbon, whereas peridotitic angrites contain metal but no carbon, either reduced or oxidized. In this budget, a closed system is considered, as the bulk Ni content should not vary. The bulk rock Ni of 4400 ppm is far higher than that of any magmatic angrite, which is always less than 100 ppm. In other words, the bulk rock is unlike a magmatic angrite as far as its Ni content is considered. If, according to their bulk chemistry, NWA 3164/5167 are linked to magmatic angrites, there must

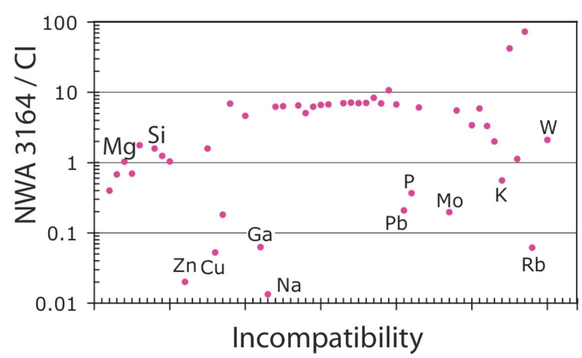

Fig 1. CI normalized concentrations for NWA 3164.

have been some Ni addition from the outside and simple reduction by C or CO is not an adequate explanation. All this clearly does not support the reduction scenario.

Incorporation of meteoritic metal. We need to consider two aspects of the problem : a mechanical one and a geochemical one. Fe-Ni can be introduced from two types of material : iron meteoritic material or chondritic material. Iron would be a simple solution, as it would not affect the geochemistry of the angritic target, except for the addition of metal (and all siderophile elements). This, however, implies that iron projectiles were available at the time of silcate crystallization. According to **[4],** NWA 3164/5167 are younger than the magmatic angrites (e.g. D'Orbigny or NWA 1296). The angrite parent body, as advocated previously, had already segregated a core implying that

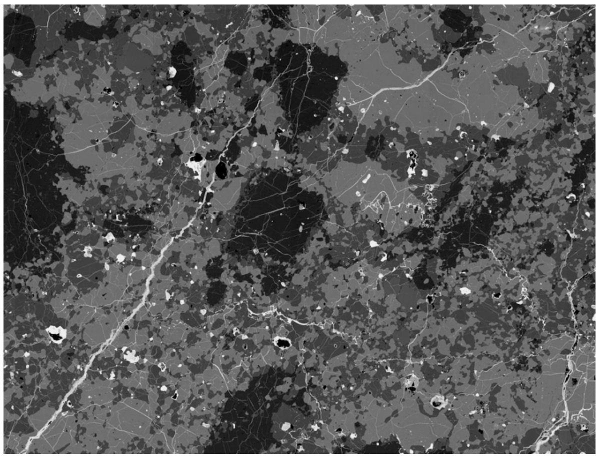

Fig 2. BSE image of NWA 5167, illustrating the bimodal grain size distribution and the random distribution of metal mostly at grain boundaries.

other bodies could have proceeded that far as well by the time the angrite parent body was impacted. A chondritic impactor seems unlikely, as it would leave a geochemical signature. According to their mode, NWA 3164/5167 contain 4-10 vol. % of metal + sulfide, corresponding to the addition of at least 20% of H chondritic type material (or more if another chondritic type with less metal is considered), a significant fraction. For a difference of 1‰ in $\Delta^{17}O$, this would change the composition of the products after impact by 0.2‰, whereas NWA 3164/5167 exhibit angritic compositions within 0.02‰ **[6]**. One can think of an impactor with a closer isotopic composition (say 0.1 ‰), in which case the compositional change would be close to the analytical uncertainty. Still the Fe/Mn ratio and the alkali content should have been affected, which is not the case: Na is depleted relative to CI and Lu (with a similar incompatibility) by more than 100 times. We therefore consider that a chondritic impactor is unlikely.

The puzzling aspect of the introduction of metal from outside is that texturally, NWA 3164/5167 is not a regolithic breccias, unlike most eucrites or lunar breccias where iron metal can be found (fig. 2). In its texture we see obvious marks of some shock. Many thin fractures filled with iron oxides (former sulfide and metal) indicate a moderate shock level. These features correspond to a late impact, not the one which introduced metal into the angritic parent body. The granulitic texture indicates that the originally magmatic rock was annealed severely under some confining pressure, that is at some depth in the parent body. The fine grained areas correspond to granular parts (brecciated areas) which have been similarly subject to annealing. The tiny iron/sulfide globules forming trails inside silicates are the remnants of healed microfractures previously filled with metal and sulfide. Iron is distributed randomly as fine grains either at grain boundaries (large grains) or poikilitically inside olivine or pyroxene. This indicates that the metal was introduced as small particles into a solid matrix (regolith) and that the target rock, mother of the present sample, did not melt, which would have resulted in coalescence and separation of metal, separation of cumulates within a short time, whereas the composition of NWA 3164/5167 after metal removal, is comparable with that of NWA 1670. In addition, a melt would never have crystallized with a bimodal size distribution as in the presently observed texture. We can therefore think of a sideritic impactor, either comminuted to fine grains or vaporized and back condensed and mixed to impact debris of the target , forming a regolith.

Conclusion : The introduction of iron into an angritic picritic target explains the textural, mineralogical and geochemical characteristics of NWA3164/5167. As such it deserves the name of Chimerolite a rock formed from unrelated bits and pieces. The Hf/W and Ni/Fe ages of peridotitic, metal bearing angrites [7, 8] are therefore meaningless, as they record the geochemical characteristics of a mixture. Finally, this indicates that angrites were not equilibrated at a high oxygen fugacity (before metal incorporation) in which case kamacite would have reacted with silicate to leave a Ni rich metal.

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