METAMORPHIC REACTIONAL CORONAS IN THE PERIDOTITIC ANGRITE NWA 3164, INTERPRETATIONS AND IMPLICATIONS. B. Baghdadi[1], G. Godard[2] and A. Jambon[1], [1] UPMC Institut des Sciences de la Terre Paris, UMR 7193 CNRS, 4 Place Jussieu 75005 Paris, France, (bashar.baghdadi@upmc.fr), [2] Institut de Physique du Globe, Sorbonne Paris Cité, Univ. Paris Diderot, UMR 7154 CNRS, F-75252 Paris, France.

Introduction: Angrites are an unusual group of achondrites. Their ancient age of about 4.556 Ma implies that they are some of the oldest rocks in the solar system. Their strange mineralogy and chemistry are characterized by high content in Ca, relatively low in Si, and negligible in alkalies. Their petrogenesis remains controversial. In this work, we describe metamorphic coronas in the peridotitic angrite Northwest Africa (NWA) 3164, and discuss their significance in terms of the rock evolution. These microstructures, which are almost unique among achondrites, could provide important insights into the parent body and its history.

Northwest Africa 3164: Olivine [Ol] and clinopyroxene [Cpx] are the dominant phases. The grain size of olivine is in the 1–2 mm range. Cpx grains are about twice smaller. Medium-sized plagioclase [An] and small spinel [Spl] grains seldom occur; together with Cpx, they are interstitial to olivine grains. Kamacite patches, ranging from 1 µm to 0.5 mm, and sulphides are highly oxidized. Secondary iron oxide also fills numerous veins, up to 10 µm in thickness (Figs. 1–3). **Olivine** grains are homogeneous and do not display any significant zoning. Its forsterite content is 57.6 ± 0.3 [1 σ] mol% with a relatively high Ca-content (1.8 ± 0.1 mol% of monticellite). The olivine from the coronas that developed at the Spl-Cpx interface (Fig. 1) is slightly richer in Mg (X_{Mg} = 0.583 ± 0.007) and poorer in Ca (X_{Ca} = 0.016 ± 0.002). **Clinopyroxene** grains are homogenous with an average composition of $En_{33.8\pm0.4}$ $Fs_{8.4\pm0.7}$ $Wo_{39.9\pm0.5}$ Ca-Al-$Ts_{13.8\pm1.0}$ Ca-Ti-$Ts_{3.9\pm0.3}$, and an X_{Mg} ratio of 0.797 ± 0.015. This pyroxene is mainly characterized by an unusually high content in the Tschermak's end-members. The secondary Cpx that developed at the Ol-An interface (Fig. 2) has a slightly different composition ($En_{32.9\pm0.3}$ $Fs_{7.4\pm1.4}$ $Wo_{37.9\pm0.5}$ Ca-Al-$Ts_{20.8\pm5.0}$; X_{Mg} = 0.817 ± 0.033). **Spinel** is a solid solution of spinel and hercynite with minor quantities of chromite, magnetite and ulvöspinel ($Spl_{48.1\pm0.4}$ $Hc_{44.2\pm0.8}$ $Mag_{1.2\pm0.3}$ $Chr_{4.9\pm0.3}$ $Usp_{1.1\pm0.1}$). The secondary Spl that seldom occurs at the Ol-An interface (Fig. 2) also shows a slightly different composition ($Spl_{44.1\pm0.5}$ $Hc_{48.7\pm0.9}$ $Mag_{1.1\pm0.5}$ $Chr_{5.7\pm0.3}$ $Usp_{0.0\pm0.1}$). **Plagioclase** is nearly pure anorthite ($An_{99.5\pm0.2}$ $Ab_{0.5\pm0.2}$), with a substantial quantity of Fe^{3+} (Fe_2O_3 = 0.59 ± 0.37 wt.%). The plagioclase from the coronas is also almost pure anorthite. Kamacite has a NiO content of ~6.5 wt.%.

Coronas: Various complex coronas are observed: (i) At contacts between Spl and Cpx (Fig. 1), an Ol + An complex corona occurs. The An corona, 10 to 80 µm wide, lies on the Spl side, whereas the Ol corona, of less than 20 µm in thickness, is at the contact with Cpx and discontinuous, forming peninsulas within the An corona, suggesting that it was partly resorbed. This microstructure indicates the occurrence of the following metamorphic reaction (R1): Spl + Cpx → An + Ol.

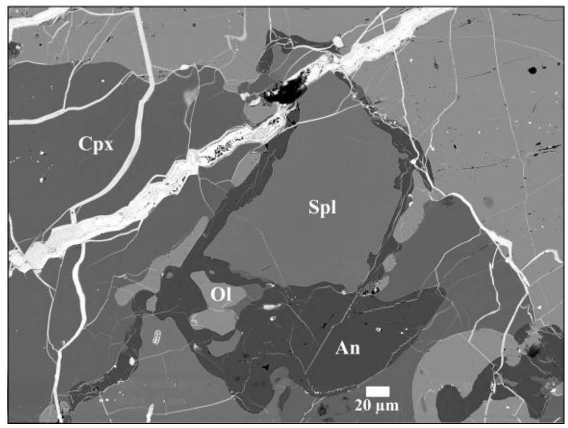

Figure 1. BSE image showing Ol+An coronas between reacting grains of Cpx and Spl.

(ii) Irregular Cpx + Spl coronas developed at contacts between Ol and An grains (Fig. 2): The Cpx corona, from 5 to 35 µm in thickness, lies on the Ol side, whereas isolated grains of Spl, of 20 to 40 µm in size, penetrate within anorthite, especially towards kamacite grains (now almost completely oxidized) previously included in anorthite. These coronas are evidence of the R1 reaction in reverse: An + Ol → Spl + Cpx (i.e., R2).

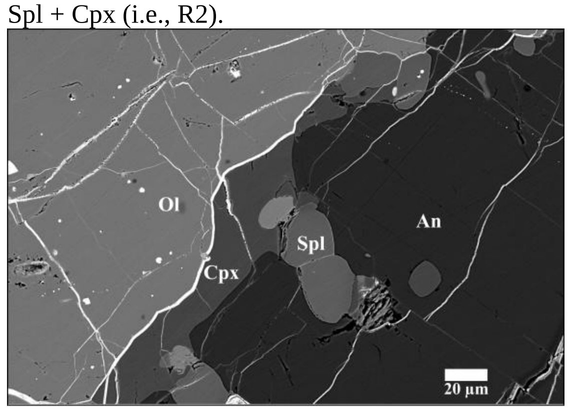

Figure 2. Irregular coronas of Cpx+Spl between reacting crystals of Ol and An.

Thin films of secondary spinel (Spl_3 in Fig. 3) and clinopyroxene (Cpx_3 in Fig. 3) appeared as products of reaction R2 between the Ol_2+An_2 coronas already produced by reaction R1.

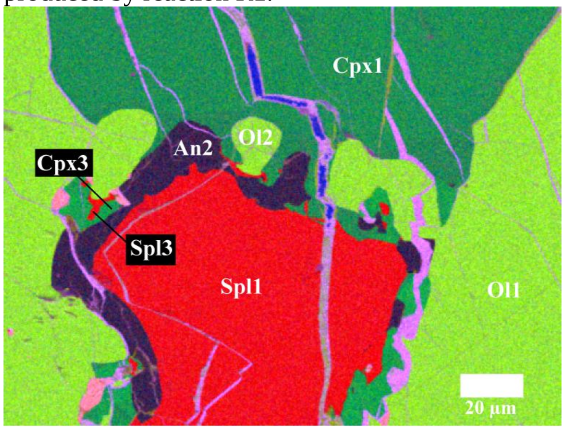

Figure 3. False coloured Image showing the observed reactions. Note the thin films of secondary Spl_3 and Cpx_3 that appeared during reaction R2 between Ol_2 and An_2, already produced by reaction R1 at the Cpx_1-Spl_1 contact.

P–T evolution: a *P–T* isochemical modelling for the bulk-rock composition (Fig. 4), using the Thermocalc dataset, indicates that there is a wide range of *P–T* conditions where the observed mineralogy is stable, i.e. 700–1200°C and 0–1 GPa. In order to further constrain the *P-T* conditions at which the rock equilibrated, X(Fe) isopleths for the mafic phases (Ol, Cpx and Spl) were calculated. The three isopleths (X(Ol) = 0.418, X(Cpx) = 0.421 and X(Spl) = 0.548: dashed lines in Fig. 4) should ideally intersect at the *P–T* conditions of equilibration. As this is not the case, we looked for possible explanations. Mineral models in the dataset of Thermocalc do not include the fassaitic (Al-Ti rich) clinopyroxene; likewise, there is no for the chromite spinel end-member. Nevertheless, we consider that the isopleths give an idea of the *T* range at which these minerals were equilibrated (1000–1200°C). The pressure, on the other hand, is not constrained by the isopleths (Fig. 4).

Discussion: By analogy with similar textures in terrestrial rocks, we attribute the first reaction R1 to a *T* increase with or without decompression [e.g., 1], while the reverse reaction R2 could be attributed to a *T* decrease [e.g., 2]. The simultaneous occurrence of anorthite and Al-rich spinel results from the low silica content (no orthopyroxene), which is a significant difference with terrestrial peridotites where Al-rich spinel is restricted to pressures in excess of 1 GPa [3]. The granulitic texture results from annealing at high temperature (1000–1200°C) for a significant time, which can only occur at depth. A thermal event is required to promote prograde coronitic reaction R1 followed by retrograde reaction R2 upon cooling. This thermal event is unlikely to be a shock, as the only visible shock effect in the rock is a late fracturation that clearly postdates the R1 and R2 coronas (Fig. 3). The thermal event is however of short duration compared to the annealing process (thin coronas).

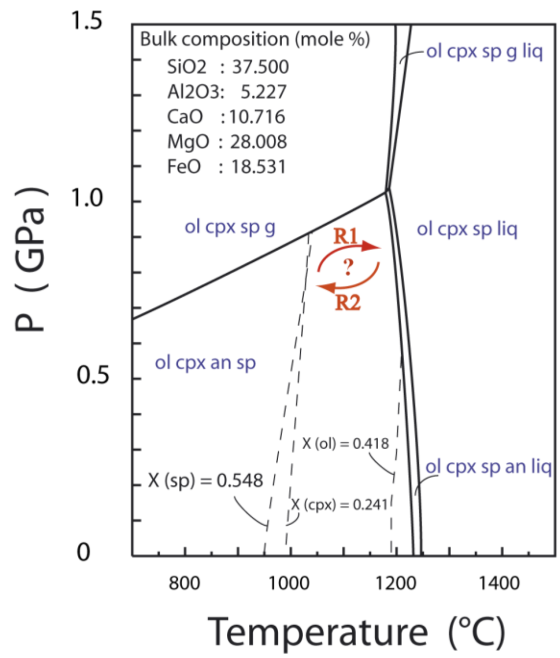

Figure 4. P-T isochemical modelling showing the parageneses that can be stable for the bulk-rock composition.

Conclusion: There is no other achondrite known with such metamorphic reactions, which are another unique feature of angrites. The spectacular coronitic microstructures in NWA 3164 require some preliminary stage of annealing at depth in the angrite parent body followed by a thermal event of short duration. Unfortunately, the pressure conditions for this metamorphic evolution cannot be constrained at present.

References: [1] Odashima N. et al. (2008) *J. Miner. Petrol. Sci.*, *103*, 1–15. [2] Ikeda T. (2007) *Lithos*, 97, 289–306. [3] Della-Pasqua F. N. (1995) *Miner. Petrol*, *53*, 1–26.