26Al CHRONOLOGY OF ERG CHECH 002, THE OLDEST ANDESITE IN THE SOLAR SYSTEM. M. Chaussidon[1], J.A. Barrat[2], A. Yamaguchi[3], P. Beck[4], J. Villeneuve[5], D.J. Byrne[5], M.W. Broadleye[5], B. Marty[5], [1]Université de Paris, Institut de physique du globe de Paris, CNRS, F-75005 Paris, France (chaussidon@ipgp.fr); [2]Univ Brest, Institut Universitaire Européen de la Mer (IUEM), UMR 6539, Place Nicolas, Copernic, F-29280 Plouzané, France, [3]National Institute of Polar Research, Tokyo, 190-8518, Japan; [4]Universite Grenoble Alpes, CNRS, Institut de Planetologie et d'Astrophysique de Grenoble (IPAG), Saint-Martin d'Heres, France; [5]Université de Lorraine, CNRS, CRPG, F-54000 Nancy, France.

Introduction: ^{182}Hf-^{182}W studies of magmatic iron meteorites have shown that their parent bodies melted and differentiated very early in the history of the Solar system, from 0.7±0.3 Myr for the IIAB to +3.1±0.3 Myr for the IIB, after the formation of the Ca-, Al-rich refractory inclusions (CAIs) having canonic ^{26}Al/^{27}Al ratios [1]. An early differentiation of these protoplanets, presumably of chondritic composition, due to the heat generated by ^{26}Al decay, implies that they accreted (or started to accrete depending on the models) even earlier, in some cases nearly 100-300 kyr after the formation of CAIs [e. g. 1, 2]. Metal-silicate differentiation in these protoplanets took place at temperatures in the range 1325 C to 1615 C depending on the S content of the protoplanets and thus on the liquidus temperature in the Fe-FeS system [3]. Because these temperatures are higher than the solidus of chondritic silicates at low pressure [e. g. 4], partial melting would inevitably take place during the process.

There are however very few samples among differentiated meteorites that could correspond to the crust formed on a protoplanet undergoing differentiation as early as indicated by the ^{182}Hf-^{182}W ages of magmatic iron meteorites. Most differentiated meteorites come from the crust of the asteroid 4-Vesta and from the mantle of the ureilites parent body. Achondritic lavas are thus restricted mostly to eucrites (basalts from 4-Vesta) and to a few other basaltic rocks angrites and ungrouped achondrites (such as NWA 011, Ibitira) originating from yet unknown parent bodies. The lack of samples from very old basaltic crusts could be due either to the fact that early differentiated protoplanets were disrupted by collisions and thus that their crust was not preserved [5], or to the fact that partial melting was followed by global melting leading to a magma ocean that solidifies a crust much later.

Here we present ^{26}Al-^{26}Mg ages for a recently-found differentiated meteorite, Erg Chech 002 (EC 002). The petrology and mineralogy of EC 002 is reported in [6]. EC 002 has a bulk andesitic composition that is different from that of all the other andesitic achondrites. Its composition indicates that it represents a primary melt (with a high partial-melting rate of ≈ 25%) of a chondritic source. The melting temperature can be estimated to be 1224±20 C, the crystallization temperature of the Ca-rich pyroxene to be in average 1186 C, and the cooling rate to be ≈ 5 C/yr between 1200 and 1000 C [6].

Analytical techniques: The Mg isotopic composition and the Al/Mg ratios were measured in CRPG-CNRS (Nancy, France) with the ims 1280-HR2 ion microprobe. Settings were different for plagioclases and pyroxenes. Because of the low Mg content of plagioclase, Mg isotopic ratios and Al/Mg ratio were measured in mono-collection mode, while measurements were made in multi-collection mode for pyroxenes. We used classical analytical conditions for this kind of measurements (5-6 nA O^- primary beam rastered over 15×15µm, M/ΔM=5000). Mg isotopic ratios are reported in the delta' notation with $\delta'^{25,26}Mg=[\ln(^{25,26}Mg/^{24}Mg)/(^{25,26}Mg/^{24}Mg)_{standard}]\times1000$ with $(^{25}Mg/^{24}Mg)_{standard}=0.12663$ and $(^{26}Mg/^{24}Mg)_{standard}=0.13932$. The ^{26}Mg excesses are calculated as $\delta^{26}Mg^*=\delta'^{26}Mg-\delta'^{25}Mg/0.521$. The Miyake-Jima plagioclase and the gold enstatite were used for the calibration of instrumental mass fractionation of Mg and ion yields of Al relative to Mg. Two sigma standard errors on the mean on δ^{26}Mg* were of ±0.45‰ and ±0.04‰ for the standard plagioclase and enstatite, respectively.

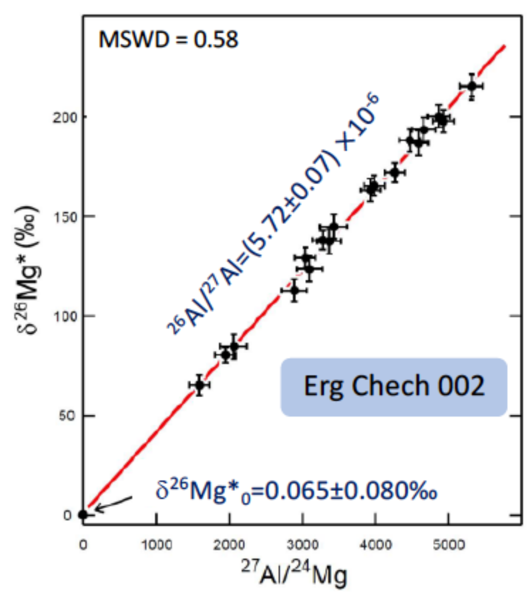

Fig. 1: ^{26}Al isochron diagram for all spots (in plagioclase for high ^{27}Al/^{24}Mg ratios and in pyroxene for ^{27}Al/^{24}Mg ratios close to 0) in EC 002.

Results: All the measurements on pyroxene (11 spots) and plagioclase (19 spots) define precisely a ^{26}Al isochron (Fig. 1) indicating a $^{26}Al/^{27}Al$ ratio at the time of Mg isotopic closure in plagioclases and pyroxenes of $(5.72\pm0.07)\times10^{-6}$ (2 sigma error) and a Mg isotopic composition $\delta^{26}Mg^*$ of +0.065±0.08‰ (2 sigma error). This value of $\delta^{26}Mg^*$ calculated by linear regression is not significantly different from the average of the 11 spots in pyroxene (+0.067±0.076‰).

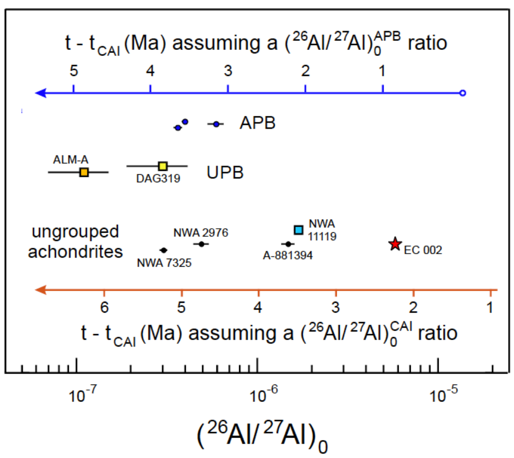

Fig. 2: ^{26}Al chronologies for samples of the angrite parent body (APB [9]), the ureilite parent body (UPB [12, 13] and ungrouped achondrites [14-17]. The blue scale is anchored to angrites, the red one to CAIs.

Discussion: The age that can be inferred for EC 002 depends on the assumption which is made for the distribution of ^{26}Al in the accretion disk. Assuming a homogeneous distribution of ^{26}Al with an initial $^{26}Al/^{27}Al$ ratio of 5.23×10^{-5} [7] gives an age of 4565.0±0.013 Myr (i. e. 2.255 Myr after CAIs). Alternatively, anchoring the ^{26}Al chronology to the D'Orbigny angrite [8, 9] gives an age of 4566.1 Myr (i. e. 1 Myr after CAIs). Because EC 002 can be classified as related to the non-carbonaceous chondrites (NC) group from its Tm negative anomaly (Tm/Tm*=0.973) [6, 10], and because even in the scenario of heterogeneous distribution of ^{26}Al NC parent bodies from the inner solar system are considered to have formed ^{26}Al-rich [11], the age of 4565.0±0.013 Myr (i. e. 2.255 Myr after CAIs) seems the most likely for the closure of the Mg isotopic system in EC 002. As EC002 can be inferred to have cooled rapidly [6], this age dates the crystallization of the parent melt of EC 002. EC 002 is thus the oldest known differentiated crust of a protoplanet and it formed contemporaneously with the formation of the cores in the parent bodies of magmatic iron meteorites (Fig. 2).

The initial $\delta^{26}Mg^*$ of +0.065±0.08‰ defined by the ^{26}Al isochron is significantly higher than the canonic initial of the Solar system of ≈-0.034 [7, 18]. This value can be understood in a simple model where the bulk $^{27}Al/^{24}Mg$ (1.29) of EC 002 is produced by partial melting of a chondritic source ($^{27}Al/^{24}Mg$=0.101) at 1.4 Myr after CAIs (Fig. 3). The long duration between melting at 1.4 Myr and crystallization at 2.255 Myr is consistent with the recent inference [4] that the velocity of extraction of andesitic melts from the mantle of a protoplanet is at least 3 orders of magnitude lower than that of basaltic melts. The mantle of the EC 002 parent body was thus at 1224 C 1.4 Myr after CAIs, but its temperature at 2.255 Myr was not high enough for global melting (it must avoid magma ocean to preserve the andesitic crust). This would be consistent with very early accretion following the universal accretion law of [2] developed from thermal models of protoplanets heated by ^{26}Al.

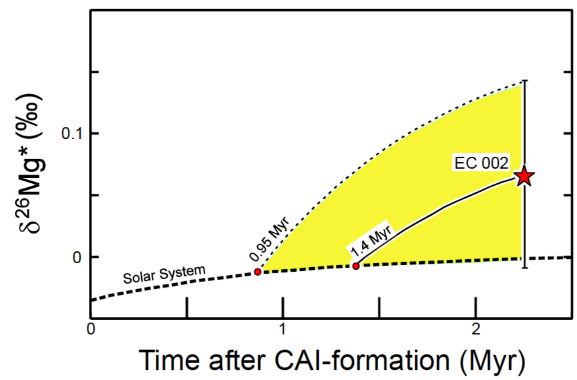

Fig. 3: Evolution curve of $\delta^{26}Mg^*$ in the parent body of EC 002 (see text for explanations).

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