AN ACHONDRITIC MICROMETEORITE FROM ANTARCTICA: EXPANDING THE SOLAR SYSTEM INVENTORY OF BASALTIC ASTEROIDS.

M. Gounelle[1,2,3], C. Engrand[2], M. Chaussidon[4], M.E. Zolensky[5] and M. Maurette[2]. [1]Université Paris XI, 91 405 Orsay, France (gounelle@csnsm.in2p3.fr), [2]CSNSM. Bâtiment 104, 91 405 Orsay, France.[3]Department of Mineralogy, The Natural History Museum, London, UK. [4]CRPG-CNRS, BP20, 54501 Vandoeuvre les Nancy, France. [5]KT, NASA Johnson Space Center, Houston, Texas 77058, USA.

Introduction: Micrometeorites with sizes below 1 mm are collected in a diversity of environments such as deep-sea sediments and polar caps [1]. Chemical, mineralogical and isotopic studies indicate that micrometeorites are closely related to primitive carbonaceous chondrites that amount to only ~2 % of meteorite falls [1]. While thousands of micrometeorites have been studied in detail, no micrometeorite has been found so far with an unambiguous achondritic composition and texture. One melted cosmic spherule has a low Fe/Mn ratio similar to that of eucrites, the most common basaltic meteorite group [2]. Here we report on the texture, mineralogy, Rare Earth Elements (REEs) abundance and oxygen isotopic composition of the unmelted Antarctic micrometeorite 99-21-40 that has an unambiguous basaltic origin.

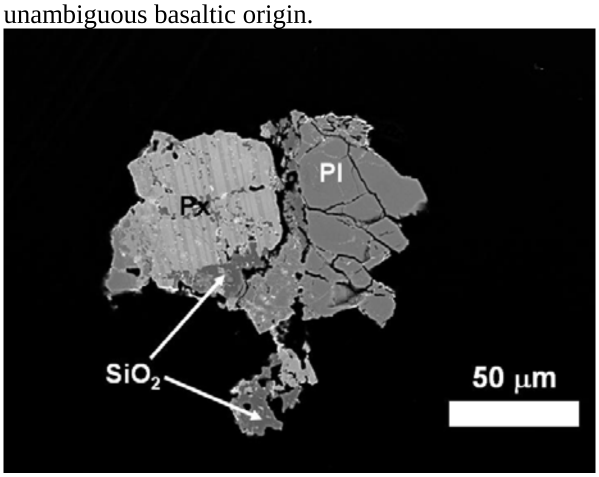

Figure 1: BSE image of MM40. Px and Pl stand for pyroxene and plagioclase respectively.

Results: Micrometeorite 99-21-40 (MM40) was collected at Cap Prudhomme, Antarctica during the 1994 field party [3]. It is 140 x 100 µm wide (Fig. 1). It consists of high-calcium pyroxene, plagioclase, silica as well as minor oxides and iron sulfide. Plagioclase has variable composition ($An_{87.1-88.9}Al_{10.8-12.6}Or_{0.28-0.45}$, average $An_{87.9}Al_{11.8}Or_{0.30}$). High-calcium pyroxene is made of pigeonite with augite exsolutions lamellae ranging in size from 1 to 3 µm. The pyroxene mg# (MgO/(MgO+FeO)) varies between 0.30 and 0.40, and TiO_2 content varies between 0.25 and 1.18 wt%. Numerous submicrometer-sized oxide and iron sulfide inclusions are present within the pyroxene, too small to obtain reliable electron probe analyses.

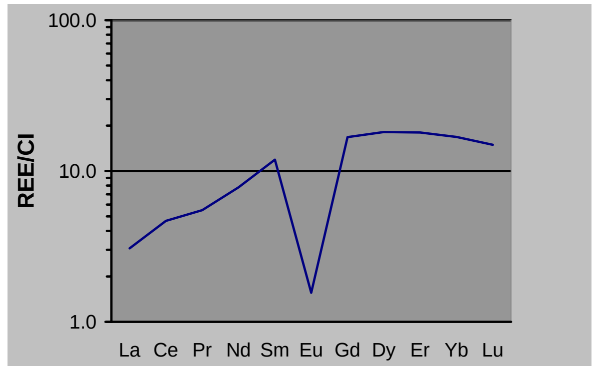

Figure 2: REE abundance pattern of pyroxene in MM40 measured with the ims3f ion microprobe at CRPG Nancy.

Pyroxene in MM40 is enriched by a factor of 10 in REEs relative to CI chondrites. The REE abundance pattern is fractionated with a gradual increase from light to heavy REEs. It displays a large negative Eu anomaly.

Pyroxene from MM40 has $\delta^{18}O$ = (-0.1 ± 0.5)‰ and $\delta^{17}O$ = (-0.4 ± 0.6) ‰ (Fig. 3), with $\Delta^{17}O$ = (-0.4 ± 0.6) ‰ (errors are 1 σ). The possibility that the terrestrial-like oxygen isotopic composition of MM40 be due to isotopic exchange with the Antarctic water is excluded since Cap Prudhomme Antarctic ice has an average $\delta^{18}O$ = -18 ‰ [4], and because timescales for oxygen isotopic exchange greatly exceed the particle residence time in the ice (~50 000 yr, [5]).

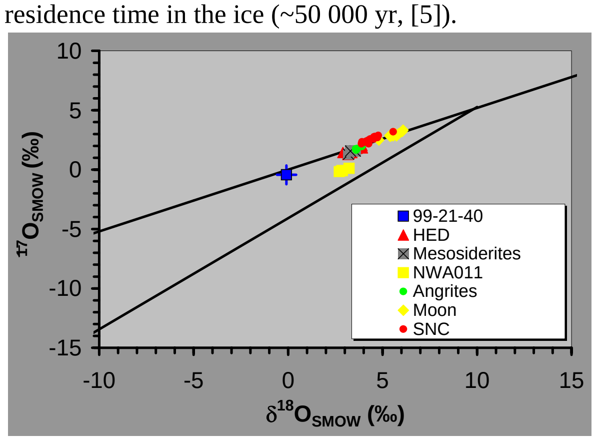

Figure 3: Oxygen isotopic composition of pyroxene from MM40 measured with the ims1270 ion microprobe at CRPG (Nancy), using the procedures of [6]. Data for whole rock meteorites are from R. N. Clayton laboratory.

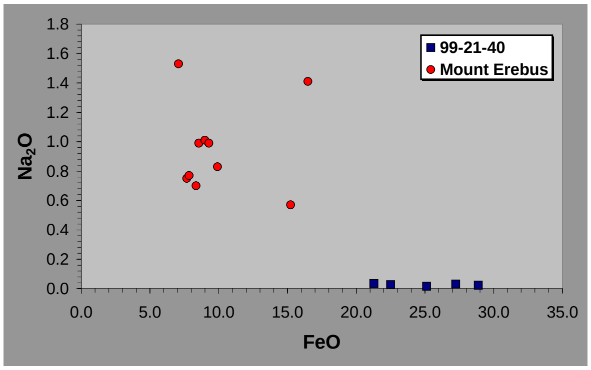

Figure 4: Comparison of pyroxene elements in MM40 and Mount Erebus basalts [7].

Discussion: The texture and mineralogy of MM40 is characteristic of basaltic rocks that result from partial melting of the mantle of rocky planets, or asteroids large enough to have endured metal-silicate differenciation.

Basalts are absent from the Terre Adélie region where the micrometeorite was collected (RP Menot, personal communication). It is unlikely that MM40 was transported to Terre Adélie as volcanic ash, since the major and minor elements of pyroxene in MM40 are radically different from those of Mount Erebus [7], and other active volcanos in Antarctica (Fig. 4). More generally, the Fe/Mn atomic ratio of pyroxene in MM40 (~25) is significantly lower than those of terrestrial basalts (~40) [8].

The high REEs abundance, comparable to that of the highly metamorphosed eucrite EET90020 suggests that MM40 has been thermally metamorphosed [9].

On a pyroxene Fe/Mn ratio *vs* An plot (Fig. 5), MM40 defines its own field, away from any other basalt. Although the oxygen isotopic data for MM40 was collected on a single mineral with ion microprobe, they can be compared to whole rock analyses of other extraterrestrial basalts since the intra mineral fractionation in such rocks is of the order of ion microprobe error bars [10]. The oxygen isotopic composition of MM40 is far removed from any other known planetary or asteroidal basalt (Fig. 3). MM40 is a hitherto unsampled basalt originating from a large asteroid or planet. Because it does not come from Mars, and because it is dynamically very unlikely that it originates from Mercury or Venus, it is probably of asteroidal origin.

Papike et al. [8] have proposed that the Fe/Mn ratio of pyroxenes (and olivines) of planetary and asteroidal basalts decreases with increasing helicocentric distance. The Fe/Mn ratio of 99-21-40 is significantly lower than that of HED meteorites believed to come from the asteroid Vesta located at 2.4 AU [11]. The source of MM40 could be the 30 km-large basaltic asteroid 1459 Magnya located at 3.15 AU from the Sun [12], or closer basaltic asteroids such as 17 Thetis, 808 Merxia or 847 Agnia [13].

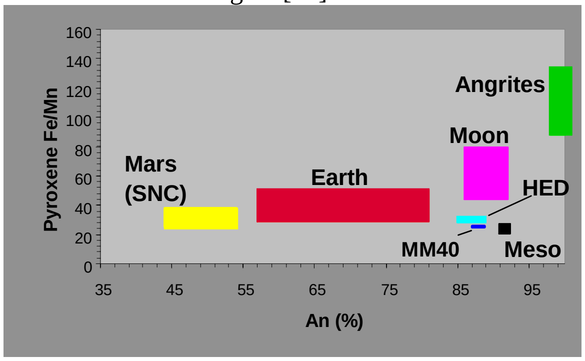

Figure 5: Adapted from Papike et al. [8]. Data for mesosiderites from [14].

Conclusions: We have studied in detail the ~120 μm large Antarctic micrometeorite 99-21-40. Its texture and mineralogy are typical of basaltic rocks. Its mineral chemistry and oxygen isotopic composition indicate it is not related to any other known basalt of planetary or asteroidal origin. MM40 samples a new basaltic asteroid, bringing the inventory of basaltic asteroids present in meteorite collections to 5 (in addition to HED meteorites, angrites, NWA011 and basaltic clasts in mesosiderites). The high REE abundance indicates it is thermally metamorphosed. On the basis of the Fe/Mn pyroxene ratio, we speculate that MM40 parent-body orbits further away from the Sun than asteroid 4 Vesta. Asteroid 1459 Magnya is a possible source for MM40.

References: [1] C. Engrand & M. Maurette, *MAPS* 33 (1998) 565-580.[2] J.S. Delaney, et al., *LPSC* 35 (2004) #1895.[3] M. Maurette, et al., *Meteoritics* 29 (1994) 499.[4] J.-M. Petit, et al., *JGR* 96D (1991) 5113-5122.[5] M. Maurette, et al., in: Analysis of Interplanetary Dust, AIP Conf. Proc 310, American Institute of Physics, Houston, 1994, pp. 277-289.[6] C. Engrand, et al., *GCA* 63 (1999) 2623-2636.[7] P.R. Kyle, et al., *Journal of Petrology* 33 (1992) 849-875.[8] J.J. Papike, et al., *American Mineralogist* 88 (2003) 469-472.[9] C. Floss, et al., *Antarct. Meteorite Res.* 13 (2000) 222-237.[10] J.M. Eiler, in: Stable isotope geochemistry, J.W. Valley and D.R. Cole, Eds. Mineralogical Society of America, Washington DC, 2001, pp. 319-364.[11] R.P. Binzel and S. Xu, *Science* 260 (1993) 186-191.[12] D. Lazzaro, et al., *Science* 288 (2000) 2033-2035.[13] J.M. Sunshine, et al., *MAPS* 39 (2004) 1343-1357.[14] D.W. Mittlefehldt, et al., in: Planetary Materials, J.J. Papike, Ed. Mineralogical Society of America, Washington D.C., 1998, pp. 4.01-4.195.