COSMIC DUST LAYERS IN EPICA-DOME C DEEP ICE CORE. C. Engrand[1], B. Narcisi[2], J.-R. Petit[3], E. Dobrica[1], J. Duprat[1]. [1]CSNSM CNRS-Univ. Paris Sud, F-91405 Orsay Campus, France (Cecile.Engrand@csnsm.in2p3.fr), [2]ENEA, Centro Ricerche Casaccia, Via Anguillarese 301, I-00123 Roma, Italy (narcisi@casaccia.enea.it), [3]LGGE CNRS-Univ. J. Fourier, BP 96, F-38402 Saint Martin d'Hères, France.

Introduction: First thought to be tephra layers, two important dust layers recently discovered in the EPICA-Dome C deep ice core (75°06'S, 123°21'E, East Antarctic Plateau) turned out to be of extraterrestrial origin [1]. These two extraterrestrial dust layers correspond to distinct meteoritic events that occurred at 434 ± 6 ka and 481 ± 6 ka, respectively [e.g. 1]. The corresponding incoming flux increases to up to 10^4 times the sporadic cosmic dust flux measured for cosmic dust particles larger than 30 µm at Dome C [2]. We have further studied the characteristics of these samples in order to place better constraints on the nature of the impactors of these two events.

Samples and Methods: The dust layers were observed and documented at the time of EPICA core logging, but were first thought to be of volcanic origin. The dust layers (L1 and L2, as in [1]) are located at 2788 m and 2833 m in the core, respectively, and are accurately dated through glaciological models at 434 ± 6 ka and 481 ± 6 ka, respectively [3]. For both L1 and L2, we used particles deposited on 8µm opening nucleopore filters which were further embedded in epoxy and polished for electron microprobe work (EMPA) at 15 kV and 10 nA. Forty random grains from each dust layer were analyzed, with 2 to 5 analyses per grain. Additional L1 and L2 samples were deposited by filtration on 0.4 µm opening nucleopore filter for investigation of their external surface and composition by analytical scanning electron microscopy (SEM + EDXS).

Results and discussion: Dust particles in L1 and L2 show different morphologies: L1 sample is dominated by angular fragments with a maximum size of ~ 100 µm (Fig. 1 left). Some grains in L1 have fluffy aggregate textures (Fig. 1 right) which seem to result from compaction of micrometer-sized grains.

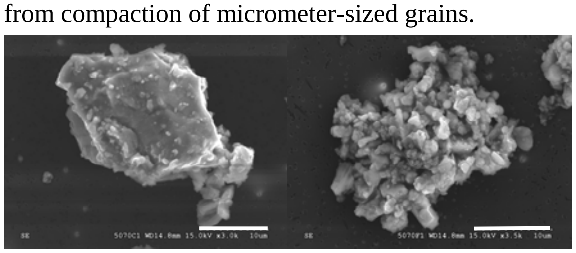

Figure 1: Secondary electron images of external surfaces of a compact grain (left) and a fluffy grain (right) in L1. Scale bars are 10 µm.

L2 sample is dominated by spherules with sizes up to ~ 30 µm (Fig. 2) and contains only a few angular fragments.

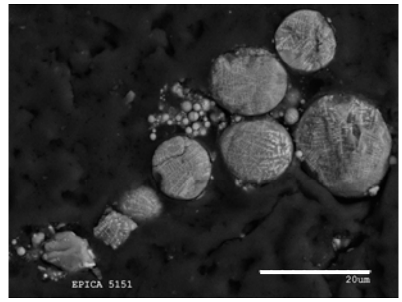

Figure 2: Backscattered electron image of polished sections of cosmic spherules from sample L2. Scale bar is 20 µm.

Over the 40 particles analyzed for each sample, the grains are broadly chondritic in composition with only a minor fraction of them showing a possible terrestrial signature with low Mg and high Al contents: only 2 such grains were found for sample L1 and 3 for sample L2. This very high abundance (> 95%) of extraterrestrial over terrestrial particles has to be compared to the ratio of extraterrestrial/terrestrial grains in an ice core sample uncontaminated by such events, which is on the order of 1/4000 for grains smaller than 10 µm [4, 5]. The sizes of extraterrestrial grains found in L1 and L2 are also much larger than statistically expected from the sporadic cosmic dust flux.

Cosmic spherules in L2 exhibit denser dendritic magnetite networks than usually observed in Antarctic cosmic spherules (ACSs) of comparable sizes (~ 25 µm). There is also no evidence for the presence of olivine bars in L2 spherules, as is usually the case for ACSs when dendritic magnetite is present. This suggests a rapid quenching of the spherules after melting, thus inhibiting crystalline growth and favouring dendritic textures. One has to note also the presence of very small spherules, with sizes < 1µm, which suggest an efficient fragmentation (explosion?) and melting mechanism during atmospheric entry of L2 precursor.

A few olivine minerals have been analyzed in both samples. Their iron contents are typical of secondary olivines (Fig. 3).

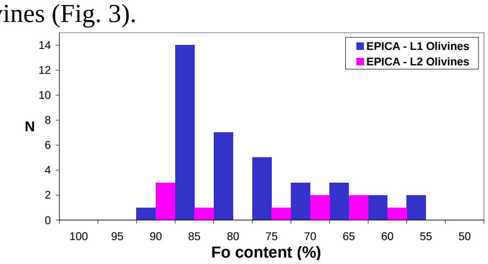

Figure 3: Composition of olivines from samples L1 and L2 expressed as their forsterite content.

The distributions of their Fo contents are different from that of relict olivines of unmelted Antarctic micrometeorites (AMM) or CM2-type materials, which show a prominent peak at Fo_{99}. The AMM&C2-type matter constitutes the dominant extraterrestrial matter accreted by the Earth nowadays [e.g. 6, 7]. There is also a difference between the compositions of olivines from L1 and L2 samples (Fig. 3), hinting for a different nature of the two impactors, or resulting from different conditions of atmospheric entry.

Further differences can be seen in the average compositions of the particles by looking at the distribution of major and minor element contents normalized to Si and CI for both L1 and L2 samples (Fig. 4). Their main characteristics can be summarized as follows: L1 sample shows pronounced depleted Al/Si, Ca/Si, Ti/Si and Na/Si ratios compared to CI. These Al/Si, Ca/Si, Ti/Si depletions are unusual in stony cosmic spherules or unmelted dust samples [e.g. 6, 8-11]. The Na/Si depletion, on the other hand, is usually observed in cosmic spherules and is interpreted as evaporation of volatile components during atmospheric entry. The other elemental ratios in L1 are rather compatible with stony cosmic spherules [8-11], except for Ni/Si which is enriched in L1 while being strongly depleted in cosmic spherules with regard to CI. The L2 sample shows fairly chondritic Mg/Si ratios, with Al/Si, Ca/Si, Ti/Si ratios slightly above CI, and Mn/Si, Fe/Si and Cr/Si slightly below the CI value. All these L2 elemental ratios are compatible with what is observed in average stony cosmic spherules. However, the Ni/Si and Na/Si ratios in L2 are enriched compared to cosmic spherules where these ratios are strongly depleted with regard to CI [8-11].

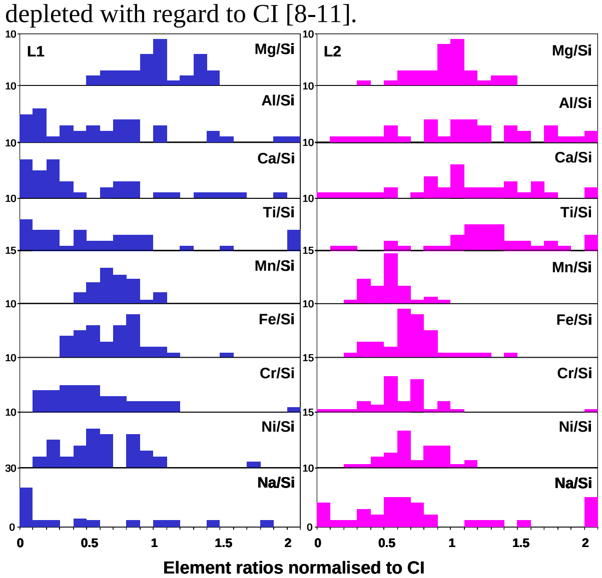

Figure 4: Element to Si ratios normalised to CI for samples from L1 (left column) and L2 (right column).

The Cr vs. Ni correlation noted by Brownlee [8] in cosmic spherules is not seen in either L1 or L2 samples. Brownlee [8] suggested a common mechanism of Cr and Ni loss in cosmic spherules as a possible explanation for this correlation. This is clearly not the case for our samples, as Cr is rather following the cosmic spherule trend, but Ni is not.

Conclusions: The impactors responsible for these two cosmic dust layers seem to have been different in nature and composition, yielding different morphologies and particle compositions in the two samples L1 and L2. These impactors did not produce cosmic dust that is comparable with the dominant C2-type dust accreted by the Earth today. The size distribution of L2 sample seems unusual, as many very small (<1 µm) particles were produced as well as large (10s of µms) grains. An efficient fragmentation and melting process (such as an explosion) during atmospheric may explain this observation, suggesting that L2 was a fairly large and coherent body when entering the atmosphere. In the samples we analysed so far, we did not find relict olivine or pyroxene crystals. All angular fragments seem to result from breaking of larger melted particles. One has still to understand what kind of crushing process can have broken the L1 particles and not the L2 ones. The probability of occurrence of two such events in a time frame of 50 ka is an unsolved crucial issue. Still, at the present state, we have no compositional evidence for a possible return at the time of L1 of a fragment of the body that previously generated the L2 event. More work is required to precisely determine the flux and size distribution of the samples, to calculate the size of the impactors. We are also planning on determining the oxygen isotopic composition of these samples in order to get a better insight on the nature of the impactors.

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