NICKEL ABUNDANCE IN BARRED-OLIVINE COSMIC SPHERULES. C. Cordier[1], L. Folco[1] and M. van Ginneken[1], [1]Museo Nazionale dell'Antartide, Università di Siena, Via Laterina 8, 53100 Siena, Italy (cordier@unisi.it).

Introduction: Extraterrestrial microscopic spherules comprise both cosmic spherules (CS) produced by the melting of micrometeoroids during their atmospheric entry, and meteorite ablation spheres (MAS) that separated from the fusion crust of meteorites. CS and MAS record the flux of extraterrestrial matter with contrasting sizes (i.e. micrometeoroids and meteoroids) and their distinction is required to accurately determine the relative proportion of micrometeoroid sources. CS and MAS show similar textures but MAS have higher alkali metal contents (Na_2O>1 wt.%), and contain Ni-rich olivines and spinels [1]. Here, we examine the NiO contents in 47 barred-olivine (BO) spherules and their olivines collected in the Transantarctic Mountain (TAM) and South Pole Water Well (SPWW) micrometeorite traps, Antarctica [2-3].

Samples and analytical methods: Major element compositions of bulk spherules and olivines were determined by EPMA using a JEOL JXA 8200 Superprobe (INGV, Rome) and a CAMECA SX50 microprobe (CNR-IGG, Padova).

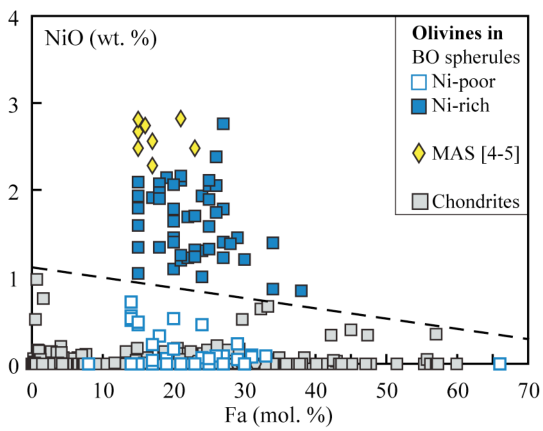

Figure 1. NiO versus Fa contents measured in olivines.

Results:

Olivine composition. Olivine composition varies from Fa_{10} to Fa_{66}. NiO contents range gradually from 0.03 to 2.76 wt.%. (Fig. 1) We defined Ni-poor olivines those olivines with NiO contents similar to those reported for chondrite olivines (<0.70 wt.%, Fig. 1), whereas Ni-rich olivines have higher NiO contents, up to values similar to those measured in MAS olivines (NiO>2 wt.%, Fig. 1). The NiO contents reached in the Ni-rich group have never been reported for olivines in CS (NiO<0.43 wt.%; [6-7]). Olivines of the two groups are not distinguishable on the basis of their Fa or minor element contents.

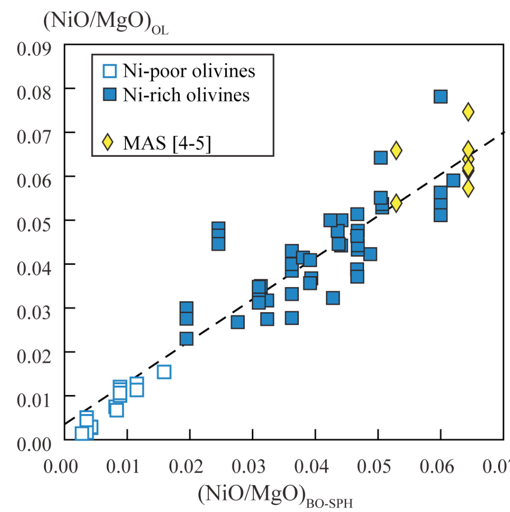

Figure 2. NiO/MgO in olivines (OL) and in bulk BO spherules (BO-SPH).

Barred-olivine spherule composition. Based on their Fe-Mn-Mg relationship, all the studied spherules are chondritic. Their bulk NiO content directly correlates with the NiO content of their olivines, with Ni-poor olivine-bearing spherules being depleted in NiO (<0.81 wt.%) relative to Ni-rich olivine-bearing spherules (0.58-1.34 wt.%, Fig. 2). BO spherules show reproducible major composition regardless of their compositional group (Fig. 3). They differ from MAS and fusion crust for their systematic depletions in volatile elements (Fig. 3).

Discussion:

Origin of Ni-rich olivines and spherules. The excellent correlation between NiO/MgO in olivines and bulk spherules (Fig. 2) suggests that variable NiO contents in olivines result from variable NiO content in the parent melts. The formation of Ni-rich CS and the crystallization of Ni-rich olivines require that the precursor materials contain appreciable amount of Ni-bearing phases (metals and/or sulfides), and that siderophile elements are not massively lost during atmospheric entry processes. The degree of siderophile loss during atmospheric entry depends on the oxidizing conditions allowing or not for the immiscibility between metal and silicate liquids. To maintain oxidizing conditions, two processes can be envisioned. First, spherules can form at low altitudes, as typically proposed for MAS. But MAS experience little evaporative loss and have high alkali metal contents [1] that are not observed in Ni-rich and Ni-poor spherules (Na_2O< 0.03 wt.%, Fig. 3). Thus, the NiO content in olivine cannot be used alone as a discriminative criterion for the distinction between MAS and CS, and volatile behavior has to be examined.

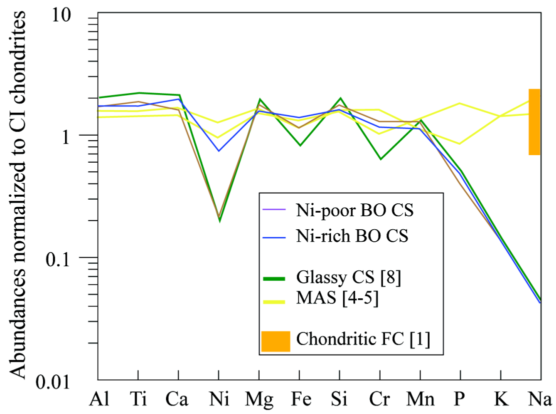

Figure 3. Comparison of average major compositions of Ni-poor (n=21) and Ni-rich spherules (n=26).

The oxidation state of CS can also be internally controlled, in function of the C content of their precursor, C acting as a reducing agent during atmospheric entry [9]. To maintain oxidizing conditions, the spherules have to derive from carbon-poor chondrites, thus belonging to ordinary chondrites or metamorphosed carbonaceous chondrites (C<1 wt.%), and they cannot be related to primitive chondrites (CI, CM2 and CR2, C=2-6 wt.%). Precursors of the Ni-rich spherules have also to be rich in Fe,Ni metals. Thus, the primitive chondrites, depleted in metal, cannot be the source of the Ni-rich spherules. Then, in metal-bearing chondrites, metal grains are small and their spatial distribution can be very heterogeneous at the submillimeter scale of CS. A disaggregated metal-rich chondrite could thus produce precursors with different concentrations of metal and thus Ni.

Constraints on cosmic spherule sources. Ni-rich BO CS can hardly be related to primitive carbonaceous precursors (CI, CM2, and CR2), which are both carbon-rich and metal-poor. This result supports recent studies of unmelted micrometeorites and CS that suggest that ~ 25 % of them could be related to ordinary chondrite parent bodies [10-11]. It is, however, in contradiction with the conventional belief that most of the micrometeorites derive from CM2-like precursors [9, 12-13]. The TAM and the SPWW collections, which contain abundant Ni-rich BO CS (25-55 %; this study, [14]), both differ from the other Antarctic collections by the significant proportion of large CS they contain (200-1000 µm in diameter [2-3]). Thus, a relation between micrometeorite source and size could exist, with CM2-related micrometeorites dominating only the population of small micrometeorites. This is consistent with mechanical processes occurring during hypervelocity impacts in the asteroid belt, during which disruption of hydrous asteroids produces smaller fragments compared to anhydrous targets [15].

Conclusions: Olivines in BO spherules show a large range of NiO content. An ablation origin for the spherules bearing Ni-rich olivines is disregarded due to their systematic depletion in volatile elements. The NiO abundance in olivines and bulk spherules correlate, suggesting that melts with variable NiO content are produced during atmospheric entry. The formation of Ni-rich CS requires that their precursors contain appreciable amount of Fe,Ni metals and/or sulfides, and that the oxidizing conditions prevailing during atmospheric entry inhibited the loss of siderophile elements. NiO contents in olivines and in CS reflect the mineralogical and compositional diversity of the micrometeoroids. Out of the 47 barred-olivine CS we studied, 55 % cannot derive from primitive carbonaceous precursors but rather from ordinary chondrite parent bodies.

References: [1] Genge M. J. and Grady M. M. (1999) *Meteoritics & Planet. Sci., 34,* 341-356. [2] Taylor S. et al. (2000) *Meteoritics & Planet. Sci., 35,* 651-666. [3] Rochette P. et al. (2008) *Proc. Natl. Acad. Sci., 105,* 18206-18211. [4] Harvey R. P. et al. (1998) *Geology, 26,* 607-610. [5] van Ginneken M. et al. (2010) *Earth Planet. Sci. Lett., 293,* 104-113. [6] Koeberl C. and Hagen E. H. (1989) *Geochim. Cosmochim. Act., 53,* 937-944. [7] Gounelle M. et al. (2005) *Meteoritics & Planet. Sci., 40,* 917-932. [8] Cordier C. et al. (2011) *Geochim. Cosmochim. Act.,* in press. [9] Brownlee D. E. et al. (1997) *Meteoritics & Planet. Sci., 32,* 157-175. [10] Genge M. J. (2008) *Earth Moon Planet*, 102, 525-535. [9] Suavet C. et al. (2010) *Earth Planet. Sci. Lett., 293,* 313-320. [11] Kurat G. et al. (1994) *Geochim. Cosmochim. Act., 58,* 3879 - 3904. [12] Engrand C. and Maurette M. (1998) *Meteoritics & Planet. Sci., 33,* 565-580. [13] Engrand C. et al. (1999) *Geochim. Cosmochim. Act., 63,* 2623-2636. [14] Taylor S. et al. (2005) *Geochim. Cosmochim. Act., 69,* 2647-2662. [15] Flynn G. J. et al. (2009) *Planet. Space Sci., 57,* 119-126.

Additional Information: This work was supported by the Programma Nazionale Ricerche in Antartide and by the European Commission through the Marie Curie Actions-RTN ORIGINS project (ID: 35519). Authors are grateful to Susan Taylor for the loan of cosmic spherules from the South Pole Water Well collection.