AUTOMATED SEM ANALYSIS OF FINE-GRAINED DUST FROM ANTARCTICA ICE CORES.

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The use of appropriate geochemical diagrams to quickly screen the dominant terrestrial dust should help glaciologists in investigating past volcanic activities and quantifying changes in atmospheric circulation patterns. Automated analysis of two dust samples from Antarctic ice cores shows that the small particles (0.3-5 μm) are of crustal and probably volcanic origin. The abundance of interplanetary dust is very low. Only 1 particle in about 1500 is possibly of extraterrestrial origin. This is in sharp contrast to the fairly high abundance of interplanetary dust particles in the stratospheric dust and among the larger (50-300 μm) dust particles from Antarctic blue ice.

Introduction. Last year [1] we reported on a search for very small micrometeorites by automated SEM analysis of 4400 grains with sizes ranging from 0.1 to 10 μm (these grains were collected from ~30 g of melt ice water from an annual ice layer recovered from one of the ice cores drilled in central Antarctica at Dome B). The signal integration time of 5 s for EDS analysis turned out to be too short for reliable results. Furthermore, we did not analyze for Na and Ti, two important elements for tackling the other important terrestrial problems.

We improved these automated analysis by increasing the integration time to 10 s, and analyzing simultaneously the contents of Na, Mg, Al, Si, S, K, Ca, Ti, Mn, Fe, and Ni in grains with sizes > 0.3 μm. We selected two of the most favourable ice layers available to search for micrometeorites (samples A and B). They show low levels of volcanic fall-out and the concentration of continental dust in sample A (about 10 times smaller than in sample B) was one of the lowest ever recorded in Antarctica ice. The total number of grains analyzed was about 2,000 and 3,900 for sample A and B, respectively. We also exploited our previous analyses of both Antarctica micrometeorites (AMMs, see [2]), interplānetary dust particles collected in the stratosphere (SIDPs, collaboration with M. Zolensky; see [3]), and volcanic dust in Antarctica ice cores [4], to select geochemical diagrams that could be used as efficient "finger printings" of these annual ice layers for their contents of objects of interest (micrometeorites, volcanic ashes. etc.) worth a more detailed study.

Results. In Figure 1a and 1b, we show the projection of 3900 analyses from sample B onto the Si-Mg-Fe plane for two different size ranges. This type of diagram has already been useful in comparing various families of extraterrestrial samples. In particular, the zone delineated by a full line corresponds to the analyses of AMMs with sizes of about 100 μm, recovered from the blue ice fields of Cap-Prudhomme, Antarctica. This specific cluster outlines the major finding that AMMs are mostly made of a material related to CM and CR carbonaceous chondrites. Analyses of 10 μm-size SIDPs are also mainly contained in the same cluster.

Micrometer-sized volcanic glasses extracted from Antarctica ice cores, as well as crushed fragments with similar sizes from tephras collected in 3 major volcanic provinces (Taupo, Tambora, El Chichon) were previously analyzed by [5]. These data form well separated clusters for different volcanic provinces if projected into ternary planes (Fig. 2).

Discussion. A quick comparison of annual ice layers can be made relying on both the Si-Mg-Fe and Si-Al-K diagrams used with a scale of a least 5 colors to sort out the grains reported in these diagrams in 5 distinct size (area) ranges. This procedure yields an amazingly fast "visual" assessment of their differences and/or potential for both searching for micrometeorites and investigating the past activity of volcanic eruptions as well as changes in patterns of atmospheric circulation.

For example, sample A was initially thought to be the most promising one to search for micrometeorites because its parent ice layer had the lowest dust concentration. However, comparison of the Si-Mg-Fe diagrams of both samples indicates that sample B looks much more favourable for this search. Indeed, the micrometeorite area of the diagram turns out to be both well populated with μm-sized grains and strongly depleted in larger grains. This feature is in good agreement with the sharp decrease (by number) of micrometeorites with increasing dust size. In contrast, the number of grains found in the micrometeorite area of sample A is at least 20 time lower than that of sample B.

Re-analyzing the most promising grains for 200 s allowed the identification of 1 and 3 possible micrometeorites with sizes of about 1 μm in samples A and B, respectively. This set of very small micrometeorites, never observed before, includes one olivine grain with a very low Fe and a high Cr content, and 3 grains with chondritic composition. An interesting feature is that none of these grains appear to be similar to the group of the very fine-grained anhydrous-porous particles that represent ≈ 40% of the SIDPs of the 10-25 μm size range. This

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observation can be associated with the lack of the same type of SIDPs in an aliquot of 150 AMMs with sizes of 25-50 µm collected at Cap-Prudhomme. Consequently, as the ice should collect all types of micrometeorites, these SIDPs might be quite rare in the micrometeorite flux. Their greatly enhanced abundance in the stratosphere is probably due to their long gravitational settling time, a consequence of their high porosity.

The distinct clusters associated with the tephras of 3 distinct volcanic provinces are found in a narrow strip somewhat "parallel" to the Si-Al side of the Si-Al-K ternary diagram. The large grains from the two ice layers clearly populate this strip (see Fig.3 for sample B), where their clusters are quite distinct.

Finally, the most densely populated cluster of grains appearing in both types of diagrams for these two samples (selected specifically to be "depleted" in volcanic fall-out) represents a complex mixture of dust with high silica and aluminium contents originating from the continent nearest to Antarctica. Again, there are major differences between our two samples as revealed by the Si-Al-K diagrams: the position of the dense cluster observed for sample B (Fig. 3) is clearly shifted to higher aluminium contents and lower silica contents as compared to sample A.

The next steps in these analyses are to run a sample heavily loaded with volcanic fall-out of a well identified origin and to use mathematical techniques for cluster analysis (such as those already applied to a population of SIDPs, see [6]) to both separate into distinct clusters the data points originating from a given ice layer and to assess the extent of cluster overlap between different ice layers.

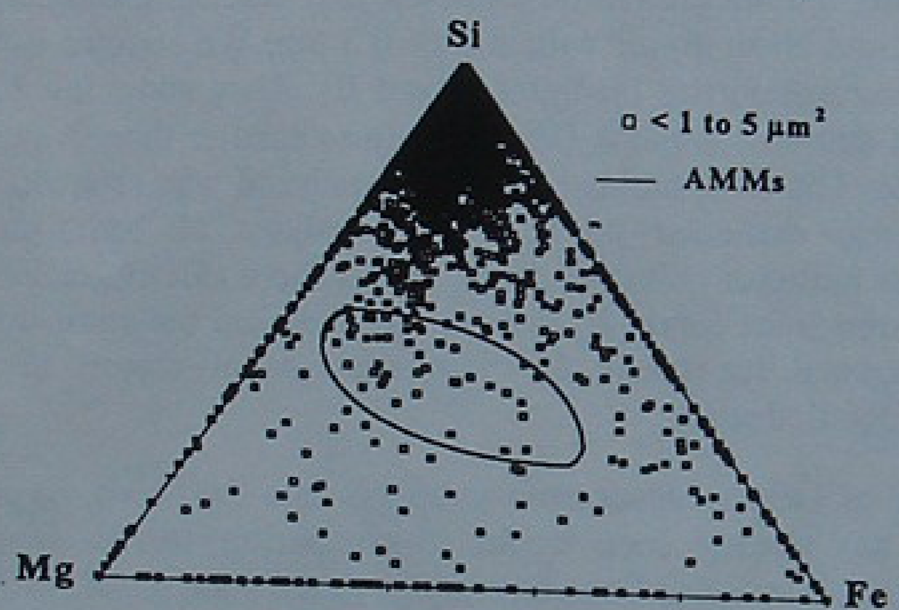

Figure 1a : Mg-Si-Fe ternary diagram for Antarctic dust (sample B)

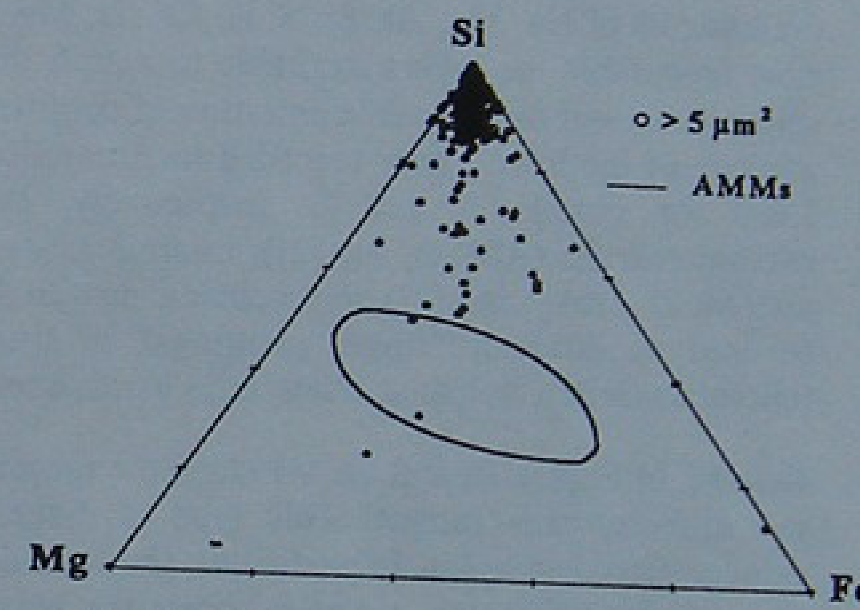

Figure 1b : Mg-Si-Fe ternary diagram for Antarctic dust (sample B)

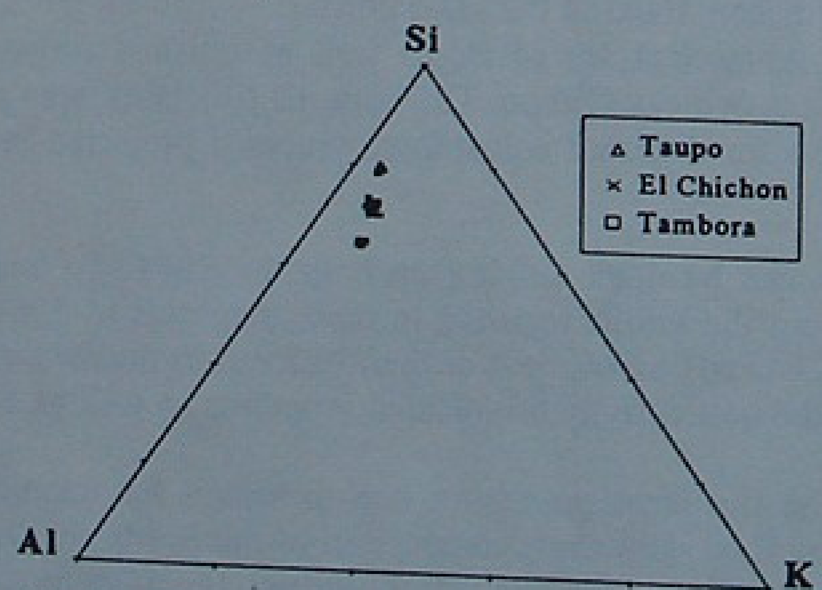

Figure 2 : Si-Al-K ternary diagram for volcanic ashes

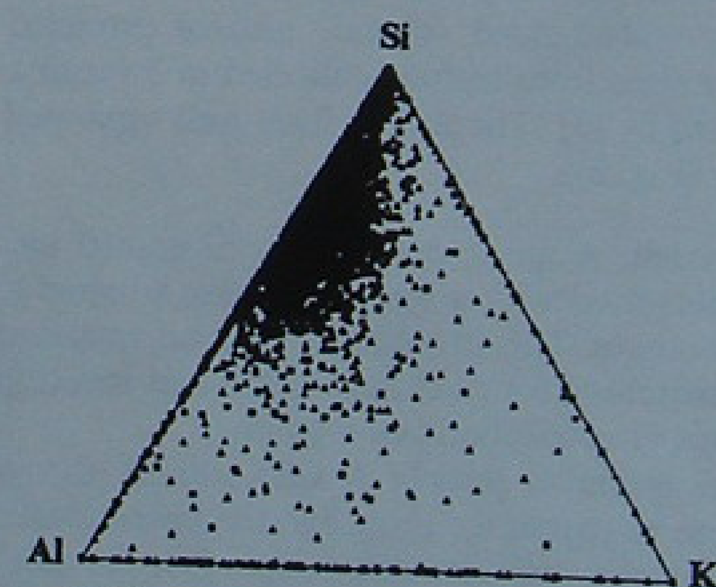

Figure 3 : Si-Al-K ternary diagram for Antarctic dust (sample B)

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