

Smith, P.P.K. and P.R. Buseck, 1981. *Science* **212**, 322-324.
 Yang, J., R.S. Lewis and E. Anders, 1982. *GCA* **46**, 841-860.

Al-PRIME PARTICLES IN THE COSMIC DUST COLLECTION: DEBRIS OR NOT DEBRIS?

Ian D.R. Mackinnon, David S. McKay, GeorgeAnn Nace and Andrew M. Isaacs, *NASA Johnson Space Center, Houston, TX 77058*

The presence of aluminum-rich particles in cosmic dust collected from the stratosphere has led to some speculation on their origins. These particles, termed Al-primes (Brownlee *et al.*, 1976), are characterized by a high concentration of Al and variable, minor amounts of Mg, Si, S, Ca, Ti, Fe, Ni and Cu. Other elements may also be present in minor quantities. On the basis of Mg/Si ratios, and relative abundances in the U2 collection, Flynn *et al.* (1982) have suggested that Al-prime particles are unlikely to be from natural terrestrial sources, and propose an extraterrestrial origin. The relative abundance of Al-primes in the Johnson Space Center collection has been documented by Mackinnon *et al.* (1982) using similar criteria to Flynn *et al.* (1982). The relative abundance of Al-primes is not unlike that of certain groups of known extraterrestrial particles in the JSC collection (Mackinnon *et al.*, 1982). Al-prime particles in the JSC collection may be classified into three smaller sub-groups; one of which is similar to the group of Al-prime particles reported by Flynn *et al.* (1982).

We have analysed in detail a selection of Al-prime particles allocated from the JSC collection using high resolution SEM and backscattered imaging. Materials rich in high atomic number elements (e.g. $Z > 20$) are readily distinguished from those with low-Z elements using backscattered electron imaging. In this study, we have observed Al-prime particles which show (a) a homogeneous elemental distribution, (b) light element "cores" with heavy element nodules randomly distributed, and (c) aluminum and/or silicon spheres with a heavy element (Fe,Cu) aggregate attached. Two particular observations lead us to suggest that not all Al-primes are extraterrestrial in origin. An Al-rich sphere with a Si and Ca abundance similar to refractory materials has a high concentration of Cu which cannot be attributed to instrumental spherical contamination. Backscattered imaging indicates that the Cu concentration corresponds to small mounds or nodules ($< 1 \mu\text{m}^2$ area) on the surface of the sphere. A high Cu abundance in the absence of other heavy elements may be consistent with a terrestrial source. The second observation concerns an Al-prime particle in close contact with a typical Al_2O_3 rocket exhaust sphere. High resolution imaging shows that the Al-prime and Al_2O_3 sphere are connected by small grains ($< 1 \mu\text{m}$) with a low atomic number (i.e. $Z < 26$). Material resembling a coating or "glue" is not apparent in our observations. We suggest that this observation links the source of some Al-prime particles to that of the Al_2O_3 spheres.

Possible terrestrial sources of aluminum- or silicon-rich materials include spacecraft ablation products, explosion debris, volcanic ash and industrial ash. All of the above sources may place large quantities of material into the stratosphere over variable periods of time. For example, the volume of spacecraft debris entering the stratosphere in recent years probably exceeds the current yearly meteoritic influx (D. Kessler, personal communication). Therefore, in the search for a source of Al-prime particles, we suggest terrestrial alternatives should be thoroughly examined.

We conclude from this study that (a) many Al-prime particles are from man-made sources though a few Al-primes may have an extraterrestrial origin. (b) Bulk composition and morphology alone are not adequate criteria to identify Al-primes. A knowledge of elemental spatial distribution may be necessary to distinguish "composite" particles from true Al-primes. (c) Some Al-prime particles may be related to solid fuel rocket exhaust.

Brownlee *et al.*, 1976. NASA TMX-73.

Flynn *et al.*, 1982. *LPSC XIII*, 223-224.

Mackinnon *et al.*, 1982. *Proc. LPSC 13th*, JGR supplement, in press.

FINE-GRAINED SPINEL-RICH AND HIBONITE-RICH ALLENDE INCLUSIONS

G.J. MacPherson and L. Grossman, *Dept. Geophysical Sci., U. of Chicago, Chicago, IL 60637*

The overall textures and structures of the many types of Allende fine-grained inclusions (FGI) indicate a complex history of condensation, aggregation, alteration and, finally, accretion into the

Allende parent body. Spinel (*sp*)-rich FGI are distinguished by their pink to purple hue and concentric color zonation. Of the seven “pink” FGI studied by us, no two are identical in detail, but all share many common features. One good example is a cm-sized object with four distinct color zones. Its pale-grey to pink core is a porous aggregate of *sp*, perovskite (*pv*), nepheline (*ne*), Al-diopside (*di*), anorthite (*an*) and grossular (*gr*) grains (all 1-20 μm). These phases show few clear intergrowths with one another; mostly, the grains lie loosely next to each other with void space between them, suggesting that the grains formed separately and were randomly aggregated together. Surrounding this porous core, however, is a dense grey zone of *sp* crystals and crystal chains, *pv* and rare hibonite (*hib*), each mantled by a multilayered rim sequence of $ne \pm an$, and *di* or *gr*. Numerous cavities are lined with *di*, *gr*, sodalite (*so*), or rare hedenbergite (*hd*). The rimming of the *sp* and *hib* in this zone occurred after the FGI was formed, because the rim layers are continuous from one *sp* or *hib* crystal to the next. This dense zone grades outward to a red zone in which the mantled *sp* are more sparse, the *sp* is more Fe-rich than that nearer the inclusion center, and *hd* grains and interstitial *so* and *ne* are very abundant. The outermost white to pale-green zone of the inclusion is similar to the red one except that *sp* is nearly absent. The inclusion is partly mantled by a clastic rim sequence similar to those on coarse-grained inclusions (CGI) (MacPherson and Grossman, 1981). Melilite (*mel*) is absent from most FGI, making it difficult to relate them to the *mel*-rich CGI. We have found one pink FGI, however, with abundant *mel*. Its core consists of mantled *sp* grains in a matrix of *so*, *hd* and cavities, similar to the red zone of the inclusion noted above. Outside of this is a dense zone of *sp* patches mantled by *di*. The outermost parts of this dense zone contain *mel*, as highly embayed patches mantled by *gr*, *an* and *di*. Where *mel* contacts *sp*, it generally encloses the latter; only rarely are tiny patches of *mel* enclosed within *sp*. These relationships indicate that the *sp* in FGI is not equivalent to the *sp* in rim sequences on CGI as suggested by others (Wark and Lovering, 1977). Rather, it is equivalent to the primary *sp* in the interiors of the CGI. The loosely-packed and porous textures of FGI cores cannot easily be explained by origins involving melting (cf. Armstrong and Wasserburg, 1981; Kornacki, 1982) or metamorphism. The presence of *di* and *hd* grains sitting loosely-packed next to each other in the outer zones of FGI argues further against any wholesale melting or recrystallization of these objects. More likely, they are random aggregates of independently solidified grains. The zones of densely intergrown *sp* and *di* in some FGI do indicate that post-aggregation alteration has occurred. The pervasive interstitial filling by *so* and *ne* must also have occurred after aggregation, and at much lower T's than those at which the *sp* and *mel* formed. Both secondary processes must have predated incorporation into the parent body, however, since: *a* the secondary phases are rare or absent in the Allende matrix; and, *b* in places the inclusions are broken, exposing inner zones to direct contact with the matrix. Finally, we have found an entirely new type of FGI, noteworthy for the abundance of *hib*. One of our two specimens has a porous core consisting almost entirely of Ti-Mg-poor hibonite plates that are loosely packed next to one another with no intergrowths. This aggregate could not have formed from a liquid or by metamorphism; it must have resulted from aggregation of independently solidified crystals that probably condensed from the solar nebular gas.

Armstrong, J.T. and G.J. Wasserburg, 1981. *LPS XII*, 25.

A MULTIELEMENT STUDY OF UNGROUPED IRON METEORITES HAVING Ge CONTENTS BETWEEN 20 AND 70 $\mu\text{g/g}$

D.J. Malvin and J.T. Wasson, *Institute of Geophysics and Planetary Physics, University of California, Los Angeles, CA 90024*

The compositional classification of iron meteorites is mainly based on the clustering observed on Ga-Ni and Ge-Ni diagrams; Ir is used to identify a meteorite's relationship to other group members. We used instrumental neutron activation analysis (INAA) to determine Cr, Co, Cu, As, W, Re, and Au in addition to redeterminations of Ni, Ga and Ir in a number of IIIAB irons and in others having similar Ge and Ni concentrations.

Copper shares many of the properties that make Ga and Ge such excellent taxonomic parameters, and we have increased our file of Cu data by a new reduction of INAA data published by E. Scott. Within magmatic groups low negative slopes are found on log Cu-log Ni diagrams; the