to Andrew Wyrobek of Lawrence Livermore Laboratories, the shapes of sperm seem to indicate their genetic content. For example, mice exposed to known teratogens subsequently produce abnormally shaped sperm. Abnormally shaped sperm may be unable to fertilize an egg, or if they do fertilize an egg, the resulting embryo may not be viable. This should not be taken to mean that normally shaped sperm necessarily have normal chromosomes, Wyrobek points out. When the proportion of abnormally shaped sperm in a semen sample is high, all the sperm in the sample are more likely than usual to have defective chromosomes. Wyrobek notes that men with certain genetic diseases, such as cystic fibrosis, tend to produce sperm with poor morphologies and in one case, two brothers who were infertile both had only abnormal round-headed sperm.

There are a few specific conditions causing male infertility that can be corrected, but, according to Steinberger, what researchers need is "a very careful, fundamental study of the male reproductive system." As of now, the best hope for treating infertile couples is to correct female infertility.—GINA BARI KOLATA

Isotopic Anomalies in Meteorites: Complications Multiply

For more than 5 years, cosmochemists and astrophysicists have been considering the possible implications of the isotope chemistry of meteorites for the creation of the solar system. The simple existence of variations in the isotopic composition of meteorites demonstrated that, contrary to the assumptions of the previous 20 years, the ball of gas and dust that evolved into the sun and planets was not a thoroughly mixed, homogeneous collection of all the final ingredients of the solar system; some additions of unusual isotopic composition had not been completely stirred in before the rocks of the meteorites formed.

More recently, strong evidence has suggested that not only did some exotic material fail to mix in completely, but at least one isotope had only shortly before been synthesized from other elements. All elements heavier than helium must have been created in processes associated with the lives and deaths of stars other than our own, but there had never been any reason to suppose that such processes occurred close to the time (within 1 million years) and place of the solar system's creation. Now, a hypothetical nearby supernova has gained favor as a possible trigger for the collapse of the presolar nebula and as a site of new element synthesis (*Science*, 21 May 1976, p. 772). But the mushrooming number of elements with anomalous isotopic compositions discovered in the last year has been associated with numerous possible nucleosynthetic processes, not all of which bear an obvious relation to the proposed nearby supernova. New isotopic evidence has only added to the uncertainty felt by some investigators about where these processes occurred and how their products entered the presolar nebula. As one researcher puts it, "It's a very exciting field, but it's still very confusing."

Adding to the frustration, one of only two marble-sized chunks of meteorite that have yielded numerous anomalies has been almost completely consumed and searches for similar samples have failed so far. Of more immediate concern to researchers, Congress may drastically reduce the funding for the moon rock studies on which much isotopic anomaly work depends.

The game of fitting observed isotopic anomalies to astrophysical predictions of how anomalies might be created has become increasingly difficult, some would say impossible, as analysis of the available samples has become more thorough. Detailed analysis of several parts of the Allende meteorite by Gerald Wasserburg and his colleagues at the California Institute of Technology has shown that separate, apparently independent processes produced some of the isotopes. Also, Wasserburg's group believes that a connection between the isotopic evidence supporting the role of a supernova and some of the recently discovered anomalies has not yet been demonstrated.

The Allende meteorite has attracted so much attention in part because it was found to contain two 1-centimeter nuggets, or inclusions, that differed from numerous other inclusions only in their isotopic compositions (Fig. 1). It had been thought, after extensive searches, that wherever in the solar system a sample was collected, it would contain isotopes in the same proportions that are observed on the earth. The complete homogenization of the presolar nebula was supposed to take care of that.

Meteorites such as Allende, a carbonaceous chondrite, are considered to be the least altered samples of presolar material, and their inclusions probably represent some of the first material to condense from the presolar dust and gas. But even these have only grudgingly yielded anomalous isotopic patterns. The two tiny Allende inclusions are the only samples found so far that show a number of anomalies. The list of anomalies from all meteorite samples analyzed so far now includes, in addition to the first clear examples of oxygen and neon, the elements magnesium, silicon, calcium, barium, and strontium, the rare earth elements neodymium and samarium, and the inert gaseous elements helium, krypton, and xenon.

The case of magnesium illustrates the difficulties encountered recently in correlating the various anomalies. Magnesium of atomic weight 26 is the decay product of the relatively short-lived, radioactive isotope aluminum-26. If a meteorite sample is enriched in magnesium-26 with respect to its content of stable aluminum-27, it is assumed that newly synthesized, unstable aluminum-26 was present when the rock formed. The magnesium-26 provides a "fossil" record of a now vanished meteorite component. It is the only anomaly providing information on the timing of a supernova. Some individual mineral grains separated by the Caltech researchers from the less anomalous inclusion, designated C1, failed to show the high levels of magnesium-26 found by previous analyses. Other Allende inclusions, with no anomalies in calcium, strontium, or barium, do have a record of relatively high initial levels of radioactive aluminum-26. In contrast, inclusion C1 as a whole has a number of anomalous elements but little excess magnesium-26. All this variability has muddled the question of how aluminum-26, which is generally associated by theorists with a supernova, was mixed with other anomalous isotopes and eventually distributed among the mineral grains of meteorites.

Further complicating the game, the isotopic compositions of some of the heavier elements in the Allende inclusions indicate that there was more than one set of nucleosynthetic processes and that the separate processes were not necessarily linked to one another. The Caltech group and G. Lugmair and colleagues at the University of California at San Diego have analyzed the Allende inclusion having the larger and more numerous anomalies, inclusion EK 1-4-1. They found that the abundance patterns

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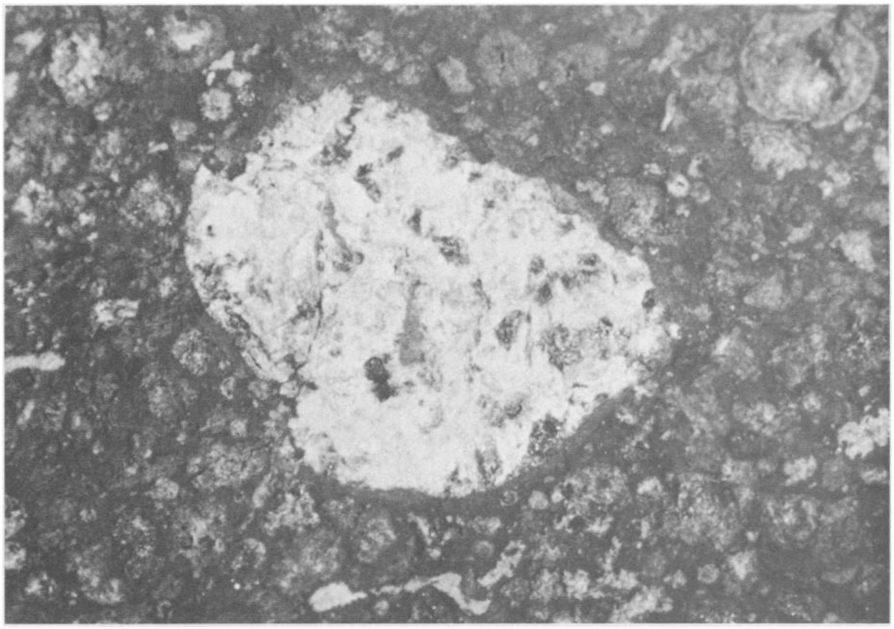

Fig. 1. A broken face of the Allende meteorite showing the isotopically anomalous inclusion designated C1. The diameter of the inclusion is about 1 centimeter. [Source: California Institute of Technology]

of 12 isotopes of barium, neodymium, and samarium were generally consistent with their production by a rapid, neutron-rich process, or *r* process. This process is thought to occur in association with supernovas.

Although the general agreement with a supernova process has been reassuring, there are inconsistencies that disturb some researchers. The abundance patterns of three of the isotopes of heavy elements in EK 1-4-1 differ significantly from those expected for the average *r* process. The Caltech group suggests that either the exotic material added to the presolar nebula was not the same as average *r*-process material or the nebular material did not have an average solar system composition before the addition was made. An excess of samarium-144 in EK 1-4-1 would suggest that a proton-rich process, or *p* process, may have affected the isotopic composition of the presolar nebula. Noting that this interpretation is not consistent with the normal abundances of two barium isotopes produced only by the *p* process, the Caltech group suggests that the effects of the classical *p* process are different for different elements, perhaps reflecting different conditions within a supernova.

Whatever the details of the modified *p* process responsible, it was the only one affecting the compositions of the three elements in the less anomalous C1 inclusion. Samarium-144 from the *p* process was the only anomalous isotope of the three elements found in C1; all other heavy element isotopic abundances were normal. Thus, two inclusions within the same meteorite apparently sampled parts of the presolar nebula having different compositions. Since different nucleosynthetic processes occur at different depths within supernovas, a single supernova could conceivably produce such heterogeneity, but multiple sites of nucleosynthesis are another possibility.

Recent analyses of the heavier elements have also introduced a new phenomenon to the field—a "negative anomaly," or a deficiency rather than an excess relative to terrestrial abundances. Negative anomalies observed so far include those of barium and calcium in C1 and strontium and mangesium in both C1 and EK 1-4-1. Whether a particular isotope is considered to be anomalously deficient or in excess depends on which of an element's isotopes is, somewhat arbitrarily, chosen as the standard for comparison to terrestrial abundances. For example, this choice determines whether there may be a deficiency in *p*-process strontium-84 or *r*-process strontium-88, or an excess in strontium-86, which is produced in a slow, neutron capture process, the *s* process.

Not being associated with supernova processes in any way, the presence of *s*-process products would complicate any scenario for the beginning of the solar system. The *s* process has been suggested as the possible source of a recently detected pattern of anomalies in the nine stable isotopes of the rare gas xenon. These were found along with anomalies in krypton, neon, and helium in the Murchison carbonaceous chondrite by B. Srinivasan, now at Washington State University, and Edward Anders of the University of Chicago. They believe that the xenon anomalies are possibly evidence of the injection into the presolar nebula of dust grains from red giants—huge, cool stars in a late evolutionary stage. Srinivasan and Anders suggest that the other anomalous gases collected at the same time could have resulted from nuclear burning of helium and hydrogen in red giants as well. Although such an interpretation is considered plausible by some, others see it as only one of many possibilities.

Some encouragement in this perplexing situation has been offered by Jean-Claude Lorin of the University of Paris and his colleagues. They report finding excess magnesium-26 in proportion to aluminum in another Allende inclusion and two inclusions of the Leoville carbonaceous chondrite. Thus, the injection of freshly synthesized aluminum-26, and possibly some associated nucleosynthetic anomalies, seems to have been recorded by other meteorites. The catch is that some crystals of the mineral hibonite may possibly contain even more magnesium-26 than expected, reinforcing the Caltech group's contention that there is as yet no strong correlation between aluminum-26 and some of the more general isotopic effects.

The idea that a nearby supernova was a trigger for the formation of the solar system has been rather widely accepted as a reasonable working hypothesis, but it has not provided a straightforward explanation of the burgeoning number of isotopic anomalies. How much of this difficulty can be attributed to a poor understanding of the hydrodynamics of an exploding supernova is not known. In addition to this basic problem, more attention is being given to finding more inclusions with a variety of anomalies. It is not a purely academic question. Inclusion EK 1-4-1 has been reduced to a few milligrams of sample. Searches for new samples are continuing, based on the reasoning that if there are two, there must be more. Of more immediate concern to researchers is a congressional conference committee's decision to reduce the National Aeronautics and Space Administration's funding of moon rock research from $5.7 million to $1 million. Indirectly, NASA moon rock money is a major source of funding for meteoritic anomaly work. The sharp reduction in funding would, according to one researcher, be "catastrophic" for isotopic studies of the origin of the solar system.—Richard A. Kerr