New Rules for AAAS–Newcomb Cleveland Prize

The AAAS–Newcomb Cleveland Prize, which previously honored research papers presented at AAAS annual meetings, will henceforth be awarded annually to the author of an outstanding paper published from September through August in the Reports section of *Science*. The first competition year under the new rules starts with the 3 September 1976 issue of *Science* and ends with that of 26 August 1977. The value of the prize has been raised from \$2000 to \$5000; the winner also receives a bronze medal.

To be eligible, a paper must be a first-time presentation (other than to a departmental seminar or colloquium) of previously unpublished results of the author's own research. Reference to pertinent earlier work by the author may be included to give perspective.

Throughout the year, readers are invited to nominate papers appearing in the Reports section. Nominations must be typed, and the following information provided: the title of the paper, issue in which it is published, author's name, and a brief statement of justification for nomination. Nominations should be submitted to the AAAS–Newcomb Cleveland Prize, AAAS, 1515 Massachusetts Avenue, NW, Washington, D.C. 20005. Final selection will rest with a panel of scientists appointed by the Board of Directors.

The award will be presented at a session of the annual meeting at which the winner will be invited to present a scientific paper reviewing the field related to the prize-winning research. The review paper will subsequently be published in *Science*. In cases of multiple authorship, the prize will be divided equally between or among the authors; the senior author will be invited to speak at the annual meeting.

Reports

Black Magnetic Spherule Fallout in the Eastern Gulf of Mexico

Abstract. *Large numbers of black metallic spherules ranging in diameter from a few micrometers to over 800 micrometers are raining into the eastern Gulf of Mexico and adjacent areas of western Florida. The composition of the flux, its association with glass spherules and coky particles, and its magnitude point to industrial pollution, probably coal- and coke-burning facilities around the perimeter of the gulf, as the source. Since metallic particles represent only a small fraction of most fly ash, such an influx of large numbers of black magnetic spherules must be symptomatic of a much higher rate of sedimentation of fly ash. The internal microstructures and the general appearance of spherules derived from industrial processes are similar to those of particles derived from cosmic sources. Because of the high potential for contamination in micrometeorite studies, a complete compositional verification of each "cosmic" particle may be necessary.*

The study of extraterrestrial particles has intrigued investigators for years. It is tempting to identify any small, shiny, black, magnetic spherules found in sediments, the atmosphere, or the oceans as micrometeorites. Investigation of an influx of such particles to the eastern Gulf of Mexico suggests that the assignment of an extraterrestrial source may often be unwarranted.

In August 1972 and August–September 1974, while aboard the R.V. *Bellows III*, we measured the concentrations of plankton and particulate constituents in the water column at 27°N, 86°W in the eastern Gulf of Mexico. We collected samples by taking hydrocasts with 30-liter Niskin bottles deployed at intervals to 1000 m. The contents of the bottles were dumped into a plastic tub that had been stored on deck, then funneled into a bag made of 28-μm gauze. The resulting sample was microscopically examined, and, where possible, all organisms and inorganic particles were identified and counted. Two sets of samples from these cruises contained over 8000 black metallic spherules larger than 28 μm in diameter. The spherules were attracted to an unmagnetized steel probe and hence are magnetic. The large number of relatively large, dense particles suggested the probability that the plankton samples had been contaminated. The only obvious potential source was infall of particles to the tub from the atmosphere. In an effort to test this possibility, we conducted an experiment in October 1974 in which the R.V. *Narvaez* occupied a station at 27°35′N 83°53′W, 80 km west of the sea buoy marking the entrance into Tampa Bay, Florida. Plastic buckets, 28 cm in diameter by 36 cm deep [prior to exposure these buckets had been thoroughly cleaned with soap and water, brushed, and stored inverted (not stacked) inside until all machinery on the ship was shut down on station], were exposed on top of the cabin for 4 hours. Then they were brought inside and washed with water that had been filtered through a 0.45-μm Millipore filter. The wash water with the particles collected in the buckets was then refiltered through a 0.45-μm Millipore filter. The contents of two buckets were washed through one filter; therefore, each filter had a load on it which represented a surface area of 1231 cm^2 exposed to the atmosphere for 4 hours. Black magnetic spherules on the filter pads were counted under an Olympia stereo microscope at ×56. Similar collections were made at Bayboro Harbor, St. Petersburg, an area characterized by light industry, and at the Florida Power Marine Research Laboratory at the mouth of the Anclote River, a relatively pristine area west of Tarpon Springs. All these samples were found to contain hundreds of black magnetic spherules like those collected in the eastern gulf. We also observed similar spherules in water samples obtained from Escambia Bay, Pensacola.

Figure 1A shows a group of relatively large typical black magnetic particles. Although the vast majority are spherical, occasionally other forms are found. Most of the particles are hollow and range in diameter from a few micrometers to over 800 μm, with a median grain size of 18 μm. Ninety percent of the particles are less than 40 μm in diameter.

Figure 1B shows one of the larger particles magnified under a scanning electron microscope (SEM). The surface is relatively smooth, although the particle appears somewhat knobby. A number of small ridges form a swirl pattern on the surface, perhaps an artifact of a once molten state. The hollow center of a broken particle is shown in Fig. 1, C and D. In Fig. 1C, conchoidal fracturing is apparent. A well-formed hexagonal crystal is present in the center of the hollow, and

Table 1. Spherule composition in percentage by weight.

Sample number	Spherule weight (mg)	Element									
		Fe	Ni	Cu	Mn	Mg	Ca	Al	Cr	V	Si
1	1138	67	0.04	0.04	0.62	0.01	0.13	0.01	0.03	< 0.18	< 1.8
2	767	71	0.05	0.01	0.12	0.04	0.38	< 0.002	0.01	< 0.26	< 1.8
3	120	60	< 0.80	0.72	0.07	< 0.60			< 0.02		< 1.8
4	359	70	< 0.30	0.03	0.32	0.10	0.58	0.04	0.02	< 0.56	< 1.8
5	65	72	< 1.50	1.44	0.25	< 1.10			< 0.03		< 1.8
6	55	67	< 1.80	1.90	0.53	< 1.20			< 0.04		< 1.8

there are several less well-formed crystals below that (see arrows, Fig. 1C). Figure 1D shows the hexagonal crystal and the surrounding area in greater detail. The hexagonal crystal and the other crystals are surrounded by an interlocking system of plates whose long axes tend to radiate away from the crystals which appear as center points.

In an attempt to determine the source of the spherules, we carried out chemical analyses of six of the larger particles according to the method of Eggimann and Betzer (*1*) (Table 1). We measured Fe, Ni, Mn, Ca, Al, V, Cr, and Cu by flameless atomic absorption, Mg by flame atomic absorption, and Si by a standard colorimetric technique on a Technicon II Autoanalyzer. The analytical results are consistent with a magnetite composition (Fe_2O_3) with associated impurities.

Black magnetic spherules have been collected and analyzed from a wide variety of sedimentary regimes (*2*), for example, pelagic sediments (*3*), Mn nodules (*4–6*), beach sands (*7*), high-latitude ice sheets (*8*), and the atmosphere (*9, 10*). Several natural sources have been suggested: (i) micrometeorites formed as ablation products of Ni-Fe meteorites, (ii) micrometeorites formed as ablation products of stony meteorites, and (iii) terrestrially derived particles of volcanic origin. In addition, an industrial source is possible. Parkin *et al.* (*10*) have found black magnetite spherules as minor components of fly ash derived from the combustion of coal.

Possible sources have been assigned on the basis of the chemical composition. A high Ni content is generally considered a good indication of extraterrestrial origin, as is the presence of the mineral wüstite. The absence of Ni does not necessarily rule out an extraterrestrial origin, however, because the Ni content may be depleted during the ablation process as the meteorites pass through the atmosphere (*11*). Detectable amounts of Si, Mg, Al, and Ca, along with Fe, were thought by Finkelman (*5*) to indicate stony meteorites as a source, and the presence of Mn and Ti along with Fe to indicate a terrestrial volcanic origin. The chemical composition of the black magnetic spherules raining onto western Florida and into the eastern gulf does not closely match that of either terrestrial or extraterrestrial particles as described above. The presence of Mg, Ca, and Al in the particles (Table 1) argues against Ni-Fe meteorites as a source. The absence of Si, the predominance of Fe, and the presence of Mn and Cu are not consistent with derivation from stony meteorites. Nor is the composition consistent with volcanically derived material. Volcanic particles often vary in their composition, many containing large amounts of Si. They are often irregular in shape. In addition, wind patterns in the upper atmosphere do not favor transport to the north, the direction necessary for the possible introduction of Caribbean and Central American volcanic debris to the West Florida continental shelf.

The black magnetic spherules in our collections are associated with assorted glass spherules and coky ash. Figure 1E shows one black magnetic spherule and a glass particle cupped to receive the metallic sphere. Such relationships are further indications of a nonmeteoritic source.

Over a 2-year period, we have found large numbers of the magnetic spherules at widely spaced locations around the eastern gulf. On 28 October 1974, about 5.5×10^7 μm^3 of black magnetic particles fell at one station in a 4-hour period

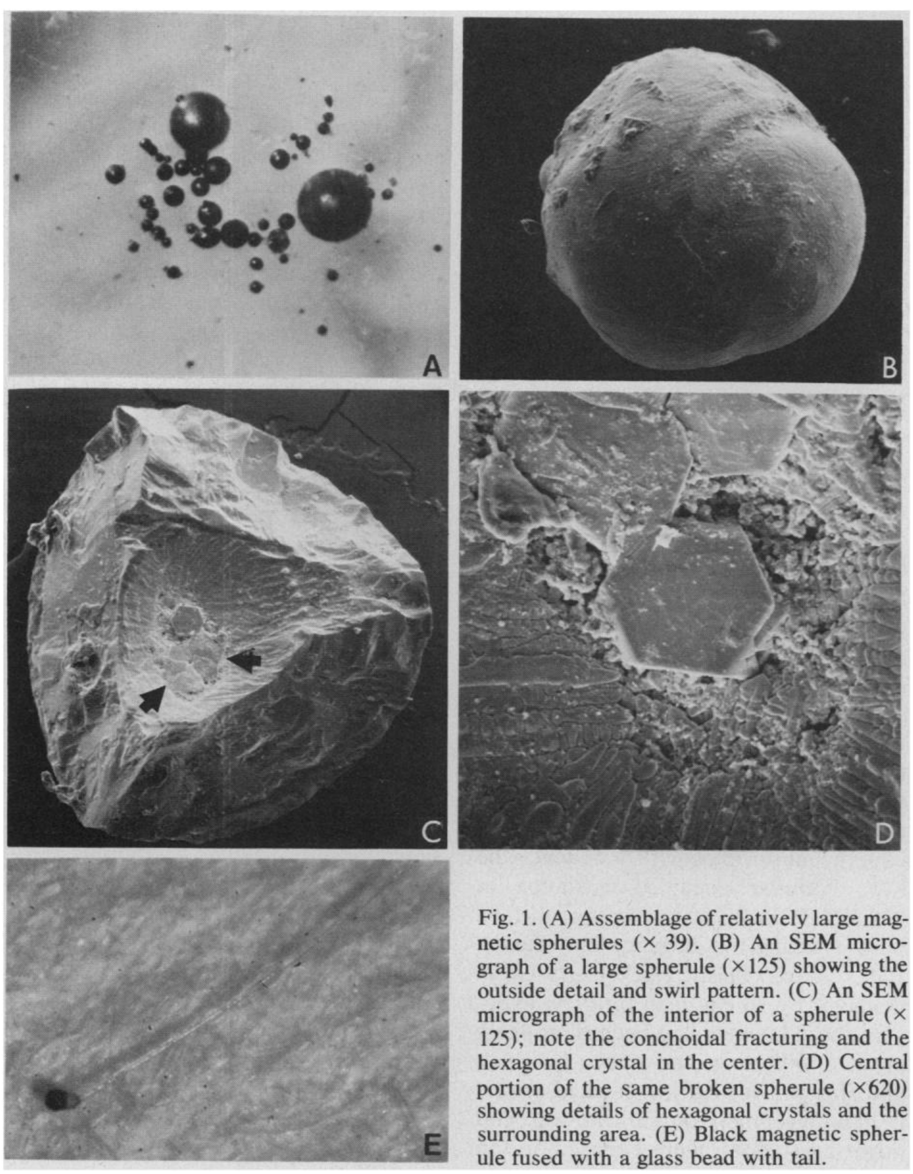

Fig. 1. (A) Assemblage of relatively large magnetic spherules (× 39). (B) An SEM micrograph of a large spherule (×125) showing the outside detail and swirl pattern. (C) An SEM micrograph of the interior of a spherule (× 125); note the conchoidal fracturing and the hexagonal crystal in the center. (D) Central portion of the same broken spherule (×620) showing details of hexagonal crystals and the surrounding area. (E) Black magnetic spherule fused with a glass bead with tail.

over an area of about 7 × 10^3 cm^2. If we extrapolate conservatively over the eastern gulf (an area of about 8 × 10^5 cm^2), we estimate that about 650,000 metric tons of the black magnetic particles would be raining out per year. This figure is orders of magnitude higher than estimates of rates of infall of iron meteoritic material over the entire earth (*2*). Although the flux is probably spotty, not constant, and limited to an area considerably less than the whole of the eastern gulf, it is significant.

The above lines of evidence indicate that the source of most of these spherules is probably industrial. Parkin *et al.* (*10*) detected a small proportion of black (magnetite) fly ash spherules (0.2 part per thousand) in their airborne dust collections; these spherules were thought to be derived from coal-burning facilities. Handy and Davidson (*12*) have remarked upon the similarity between meteoritic dust and fly ash. Therefore, the black magnetic spherules raining into the eastern gulf and western Florida are probably derived from coal-burning power plants bordering the eastern gulf and from the heavy concentration of industrial facilities which utilize coal and coke in the areas bordering the northern and northeastern gulf. Parkin *et al.* (*10*) have estimated the sedimentation rate in the North Atlantic Ocean from fly ash pollution at only 1 mg/cm^2 per 10^3 years, or 0.01 mm per 10^3 years. On the basis of our calculations, the contribution of black iron magnetic particles alone could be greater than that found by Parkin *et al.* for all fly ash pollutants to the North Atlantic Ocean (magnetite spherules make up only a small percentage of the total solids pollution in the atmosphere). The presence of black metallic spherules in such quantities in the eastern gulf may signify a much more serious particulate pollution, especially on the West Florida continental margin which is relatively isolated from any input of clastic sediment. If the flux of airborne magnetic metallic particles were even two orders of magnitude less than our extrapolation to the eastern gulf, it would contribute about as much particulate Fe per year as the 14 rivers with significant flow that empty into the gulf on the western Florida coast; this estimate is based upon the mean annual discharges and mean Fe contents of these rivers (*13*).

The internal structures of interlocking plates that we observed in the noncosmic particles (probably fly ash) from the eastern gulf (see Fig. 1, B and C) are similar to those described by Aumento and Mitchell (*6*) as characteristic of cosmically derived particles. It follows that any predominantly molten iron droplet thrown into the atmosphere from a terrestrial or nonterrestrial source may develop similar internal structures, which therefore are not diagnostic of origin. Great care must be taken in studies of cosmic particles to assure that samples from the air, in the water column, or in the sediments are not contaminated by industrially derived particles. Even large particles (up to 800 μm) deep within the sediment may be suspect; particles may migrate slowly down into the sediments as a result of animal reworking, thus contaminating the upper portions of cores.

We have found some large particles (up to 800 μm in diameter) hundreds of kilometers from potential industrial source areas. Handy and Davidson (*12*) pointed out that most smokestacks are designed to transport the fly ash high into the air. They reported smog, containing particles up to 200 μm in diameter, at altitudes of over 6000 m in the Chicago area, and they pointed out that convection currents have been known to carry terrestrial dust as high as 11,000 m. Even large metallic spherules of high density would require many hours to fall from such heights, and in that time particles could be transported several hundred kilometers by winds from the point at which they were introduced.

Industrially derived black magnetic spherules pose a problem for studies of particulate Fe concentrations in water masses, in recent sediments, in the atmosphere, and even on the surfaces of older rocks. In many studies it may be necessary to determine the chemical composition of virtually each "cosmic" particle in order to establish that its source is extraterrestrial. One wonders how many studies of micrometeorites and cosmic particles have really dealt with a component of fly ash.

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Electron Plasma Oscillations Associated with Type III Radio Bursts

Abstract. *Plasma wave electric field measurements with the solar orbiting Helios spacecraft have shown that intense (approximately 10 millivolts per meter) electron plasma oscillations occur in association with type III solar radio bursts. These observations confirm the basic mechanism, proposed in 1958, that type III radio emissions are produced by intense electron plasma oscillations excited in the solor corona by electrons ejected from a solar flare.*

Plasma wave electric field instruments on the German-American Helios 1 and Helios 2 spacecraft, in orbit around the sun, have detected intense electron plasma oscillations in association with type III solar radio bursts. These observations confirm a well-known mechanism, proposed by Ginzburg and Zheleznyakov (*1*) in 1958, for the generation of these radio emissions. In this report we briefly describe the essential features of the plasma oscillation mechanism for generating type III radio bursts and present the recent Helios results, which show the occurrence of intense electron plasma oscillations in association with type III radio bursts.

Type III radio bursts are produced by particles ejected from a solar flare and are characterized by an emission frequency which decreases with increasing time. These radio bursts are observed