Leonid shower and 'recovered objects'*

In the aftermath of the great excitement created by the media about Leonid meteor shower on 17–18 November 1998, a lot of objects believed to be remnants of meteors were collected by enthusiasts all over the country. The Physical Research Laboratory, Ahmedabad, received about 22 such pieces for authentication, from Geological Survey of India; Birla Institute of Astronomy and Planetary Science, Calcutta; Navsari; Nehru Planetarium, Delhi; Meerut; Bhuj; and Pudukkotai. None of the specimens has fusion crust, a typical feature of frictional heating during atmospheric passage of extra-terrestrial matter. A preliminary examination revealed that several specimens of the Calcutta collection consisted of dark coal-like material and two of them were rich in zinc and sulfur. The Navsari specimen was a piece of Kota stone and one of the Delhi pieces was a fire cracker. The Meerut piece turned out to be a pottery chip and the Pudukkotai material was black cotton soil. The Bhuj specimen is probably an iron slag. Neither did these specimens have any resemblance to known meteorites (mainly iron-rich stones, stony irons and iron–nickel alloy) nor did they exhibit any of the characteristics of cometary material (Campins, H. and Swindle, T. D., *Meteoritics Planet. Sci.*, 1998, **33**, 1201–1211). Carbonaceous chondrites and some rare xenoliths in meteorites are considered to be similar to cometary matter. The composition of the comet Tempel-Tuttle, the source of Leonid shower, is not known. It is generally believed, based on analysis of the comet Halley, that they are rich in carbon, nitrogen, oxygen and hydrogen. Whereas most of the specimens could be rejected *prima facie*, the coal-like specimens invoked some interest and a series of isotopic studies were carried out on them.

The purpose of this letter is to help develop criteria for identification of cometary matter since the Leonid shower may again be seen later this year, i.e. on 17 and 18 November 1999. From the past rendezvous of the earth with its orbit, it appears that the peak shower activity may occur with a delay of one year after the perihelion passage of the comet, which was in February 1998. A picture of the meteor trail taken in the morning of 18 November 1998, did show a definite evidence of multiple fragmentation and possible fall of some fragments, which could not be recovered.

Petrographic details of the recovered specimens by scanning electron microscopy did not reveal any similarity to meteoritic textures. The isotopic studies (carbon, neon, argon) and radioactivity measurements were therefore undertaken for further diagnosis. $\delta^{13}C$ (a measure of $^{13}C/^{12}C$) of biogenic materials on the earth is about $-25‰$ (w.r.t. PDB) and abiogenic (e.g. carbonates) is about 0‰. In case of comets the $\delta^{13}C$ has a large spread and this value can be as high as $\pm 100‰$. Four samples were analysed for $\delta^{13}C$ and the values are -23.4, -23.1, -26.7 and $-23.3‰$. These values are all close to $-25‰$ and indicative of terrestrial organic matter. Neon and xenon in earth materials are expected to have atmospheric composition ($^{20}Ne/^{22}Ne = 9.8$; $^{129}Xe/^{132}Xe = 0.983$; $^{40}Ar/^{36}Ar = \sim 295$) whereas in meteorites (where they may have components of solar origin) these ratios are distinctly different. For example, the trapped Ar and Xe in meteorites have $^{40}Ar/^{36}Ar \sim 0$ and $^{129}Xe/^{132}Xe = 1.03$, very distinct from the terrestrial atmosphere. In two pieces of the Calcutta collection, the rare gases (neon, argon and xenon) were found to have atmospheric isotopic composition. Also nitrogen is found to be very abundant, several thousand micrograms per gram with a distinct terrestrial sedimentary signature ($\delta^{15}N$) of around $+15‰$. The noble gas elemental ratios are also very typical of terrestrial sediments.

Meteoroids as they go through the interplanetary space, are irradiated by solar and galactic cosmic rays which produce stable and radioactive isotopes in the near surface region. In case of Tempel-Tuttle, there is uncertainty about the time of exposure since any material with an overburden of more than 2 m does not get irradiated by cosmic rays. We can, however, assume that the cometary debris was exposed to the cosmic radiation at least since February 1998, when the comet passed the perihelion. In the few months of exposure, the only isotope which will be produced in measurable amount from carbon, which forms the bulk of most of the specimens collected, is ^7Be ($t_{1/2} = 53.9$ days).

We therefore looked for the 477.6 keV gamma ray characteristic of ^7Be and indeed some samples gave a distinctly measurable signal. The estimated activity is ~0.5 dpm/g. However, ^7Be is also copiously produced in the earth's atmosphere by interaction of cosmic rays with atmospheric nitrogen and oxygen. In rain water, in India, the values measured range between 10 and 200 dpm/l. The ^7Be found in the Calcutta specimens is attributed, to adsorption from rain water. No other radioisotope, e.g. ^{26}Al, commonly found in meteorites, were detected.

Thus we come to the conclusion that none of the specimens collected during the Leonid meteor shower and examined by us have any characteristic chemical, isotopic or radioactive signatures which can be attributed to their extraterrestrial origin. The large collection was made because of great media hype.

*Based on the work done by N. Bhandari, J. N. Goswami, S. K. Bhattacharya, S. V. S. Murty, A. D. Shukla, V. G. Shah, P. Ghosh, V. K. Rai (PRL); S. K. Acharyya, A. Chaudhury, S. Ghosh (GSI); P. Pandey, R. Subramanian (BIAPS, Calcutta); N. Raghavan (Nehru Planetarium, Delhi).