No. 47 – March 1987

New Meteorite Finds At Imilac

H. PEDERSEN, ESO, and F. GARCIA, c/o ESO

Introduction

Stones falling from the sky have been collected since prehistoric times. They were, until recently, the only source of extraterrestrial material available for laboratory studies and they remain, even in our space age, a valuable source for investigation of the solar system's early history.

It is estimated that, on the average, each square kilometre of the Earth's surface is hit once every million years by a meteorite heavier than 500 grammes. Most are lost in the oceans, or fall in sparsely populated regions. As a result, museums around the world receive as few as about 6 meteorites annually from witnessed falls. Others are due to accidental finds. These have most often fallen in prehistoric times.

Each of the two groups, 'falls' and 'finds', consists of material from about one thousand catalogued, individual meteorites. The total number of fragments is considerably higher, since many break up when hitting the atmosphere. Mineralogically, they can be divided into three classes: stones, irons and stony-irons. Falls are largely stony, while finds have a high percentage of irons. This is due to the stony meteorites' faster erosion and lesser visibility. The geographical pattern of falls is strongly correlated with population density: most are reported from Europe and North America. Finds, on the other hand, depend more on the preserving conditions of the terrain, and the extent to which it allows meteorites to be spotted. Most meteorites are found by chance. Active searching is, in general, too time consuming to be of interest. However, the blue-ice fields of Antarctis have proven to be a happy hunting ground. During the last two decades some 7,500 meteorites were recovered by Japanese and American expeditions. They come from a smaller, but yet unknown number of independent falls. The meteorites appear where glaciers are pressed up towards a mountain range, allowing the ice to evaporate. Some have been lying in the ice for as much as 700,000 years.

Supernova 1987 A in LMC: see pp. 26–35

Figure 1: *The 19-kg fragment in its 80-cm diameter crater. The meteorite protrudes about 5 cm above the crater floor and reaches approximately 18 cm below. It is remarkable that such a small structure has resisted erosion during 166 years, possibly much longer.*

Imilac Meteorites

Other areas where many meteorites are found are some of the world's desert regions, e.g. Western Australia, the North American prairies, and the Atacama desert in Chile. At the latter, the annual precipitation is lower than anywhere else on the earth, less than 5 mm, which obviously eases the meteorites' preservation. As a result, one of the Atacamenean meteorites, found at Tamarugal, has a terrestrial age of 2,700,000 years, the oldest known. During the last century, many mineral prospectors travelled through Atacama, in search for precious ores. Occasionally, they came upon iron meteorites which they brought home, often unaware of the material's true character. They gave much less attention to stony meteorites, though these undoubtedly also have been preserved in large numbers.

The Atacama desert is noted for its deposits of nitrates. These were exploited, on a huge scale, during the first decades of this century. In the process, several meteorites were found.

Many Chilean meteorites are of the rare Pallasite type (see box), for which reason they most likely stem from a single fall. They carry names which correspond to geographical locations scattered over a 100 by 100 km area. In most cases, however, the find site was reported without precision and, until recently, it was believed that the meteorites had been picked up inside a 100 by 500 metre area near the small salt-pan Salar de Imilac, about 170 km from Antofagasta. At this place, there is a crater-like excavation, 8 metres in diameter. This may have been made by Indians in search for the fancied iron vein. Several minor excavations on the neighbouring hills indicate places where, in the past, meteorites have been collected. Still, the top-soil contains many small iron fragments, weighing typically 1 gramme.

There is no reliable account of the meteorite's fall. The first fragments were found around 1820. Buchwald (1975) estimates that the fall occurred several hundred years earlier. From geological considerations, Martínez (private communication) deduces an age of about 500 years before present. Nearby, ancient Indian populations could conceivably have forged tools or ornaments from meteoritic iron. This might put a minimum age to the fall. However, no such artifacts have yet been identified. Another dating method relates to the decay of radioactive isotopes, activated by cosmic ray irradiation prior to the fall. To our knowledge, no such measurements have been published.

Imilac meteorites have made their way to many museums and private collections, all over the world. The largest specimen known, 198 kg, is in the British Museum. Another fragment, originally 95 kg, is in Copiapo. The total amount of recovered material, plausibly originating at Imilac, is calculated at 500 kg (Buchwald, 1975).

Figure 2: *The 35-kg fragment before excavation. The diameter of the crater is 125 cm. The meteorite reached about 6 cm above and 14 cm below the crater floor.*

The New Finds

Following the visit of several expeditions, it was believed that all large meteorites had been collected. We can, however, report the recent discovery of three more meteorites, totalling 59 kg. The find was made by one of the authors (F.G.) who is a geologist*. During water prospection for a mining enterprise he learned about the meteorite fall at Imilac. A local resident told him that some meteorites had been found several kilometres south-west of the 'crater'. During his own search he managed to locate a further three. They have masses of 5, 19 and 35 kg, respectively.

The new meteorites were spotted at 3,250 metres altitude, on some promontories which stretch towards east and north-east from a 3,870 m high mountain, Morro de La Mina. The find locations form an approximately equilateral triangle, with side lengths of 900 metres. The centre of that triangle is 7 km south-west of the 'crater'. The two largest meteorites were lying, only partially exposed, in circular impact craters (Figure 1 and 2) of diameter 80 and 125 cm. In both cases, the crater floors were about 15 cm below level and covered with smaller pebbles than the surrounding desert. The edges were white, bringing into view a soft underground material, rich in gypsum. The crater of the 35-kg meteorite did not have an elevated rim, except possibly towards east. This can be concluded from the inspection of a stereo-photo taken prior to the excavation. Its depth is estimated at 5 to 10 cm. The 5-kg iron was lying, nearly fully exposed, on top of the desert surface, and apparently not 'in situ'. Therefore, we cannot exclude the possibility that it is a transported mass, originally found somewhere else.

The 5-kg meteorite measures 16 by 13.5 by 10 cm. It is an elongated lump without any sharp corners. The 19-kg meteorite is roughly cubic, 23.5 by 18.5 by 18 cm. One of its edges is quite sharp, clearly indicating the meteorite as a fragment. The 35-kg meteorite is slightly banana-shaped and measures 50 by 24 by 15 cm. All three meteorites have specific gravities near 4.6 grammes/cm^3, which is typical for Pallasites.

The submerged parts of the two large specimens are covered by a thin crust of corrosion products, due to the presence of nitrates in the soil.

Universidad del Norte in Antofagasta has inspected two of the meteorites and classified them as Pallasites. For reasons of similar surface texture and specific gravity, we believe that also the third meteorite belongs to that group.

* Editor's note: F.G. is the husband of ESO's secretary in Santiago, Mariam G., through whom scientists at La Silla were informed about the find.

Since, from the whole Earth, only 33 Pallasite-finds (and 2 falls) have been described, this is a strong indication that the new specimens are part of the well-known Imilac fall.

The site of the old crater-like excavation was also visited. In the 'splinters area' about 1 kg of minor fragments (0.1 to approximately 250 grammes were collected. A few particles were found up to 1,000 m north-east of the 'crater'. Otherwise, we can confirm Buchwald's statements as to the shape and extent of the area. We estimate that it still holds of the order of 1,000 kg of meteoritic iron.

The Imilac Strewn-Field

The existence of the splinters area indicates that a large chunk of the meteorite suffered a violent break-up. This must have happened at a late point of the trajectory through the atmosphere. Its mass exceeded, by far, those which fell further to the south-west. Therefore, it seems likely that the parent body arrived from south-west, rather than opposite. The splinters area is approximately aligned with the new find locations, giving a further argument for their association. Measured from north over east, the azimuth of the combined strewn-field is 47°+/–3°.

The new finds show that the strewn-field is at least 8 km long and about 1 km wide. It cannot be excluded that some of the meteorites collected a long time ago were found in the 'new' area. We did, in fact, notice a small number of minor holes from where it is conceivable that specimens (in the 10-kg class) have been picked up. Indications are that the strewn-field is even longer than mentioned. This topic, and other aspects of the Imilac fall, are discussed in a forthcoming thesis work by E. Martínez, Universidad del Norte. The total weight of recovered material is now about 560 kg. To this adds the estimated 1,000 kg of small meteorite particles still left in the top-soil. Although impressive, at least one other Pallasite find is larger. That at Brenham, USA, had a mass of 4.5 tons (Nininger, 1957, Peck, 1979). It too suffered violent fragmentation.

Asteroidal Origin for Pallasites

Pallasite meteorites form a rather homogeneous group, clearly distinct from the other type of stony-irons, the mesosiderites. They may hold clues to the origin of solar-system bodies. Their creation is therefore a much debated issue between 'cosmogonists'. One theory says that they formed in asteroids, at the interface between a molten core and a partially molten mantle, rich in olivine silicates (Greenberg and Chapman, 1984). Following the asteroid's colling, the top layer of silicates may have been stripped off, exposing the now contracted and cracked Pallasitic layer to erosion.

The asteroidal origin could, in principle be ascertained by orbital calculation of meteorite falls. This has been done on three occasions (the falls at Příbram, Lost City, Innisfree) but none of the meteorites in question were Pallasites. Ground-based observations may nevertheless help solving the question. By infrared spectroscopy three candidate parent-asteroids have been found: 246 Asporina, 289 Nenetta, 446 Aeternitas (Cruikshank and Hartmann, 1984, Scott, 1984). Their spectra show an absorption band at 1.06 μm, as does olivine in its meteoritic form. Also the general trend of the spectra is consistent with the presence of a metallic phase.

It is rare that asteroids can be associated with one particular type of mineral. Detailed studies of asteroids and comets will, in general, require spacecraft to do "sample-return" missions. Such are, in fact, being considered. But perhaps it is superfluous to include Asporina, Nenetta or Aeternitas in the itinerary: the stuff may already be in our hands . . .

Tentative Time-table of Council Sessions and Committee Meetings for First Half of 1987

May 18	Users Committee
May 19	Scientific Technical Committee
May 20–21	Finance Committee
May 26–27	Observing Programmes Committee, Venice
June 3	Committee of Council, Bruges
June 4	Council, Bruges

All meetings will take place at ESO in Garching unless stated otherwise.

References

Buchwald, V.F., 1975, *Handbook of Iron Meteorites,* University of California press, Berkeley, vol. 1–3.

Cruikshank, D.P., and Hartmann, W.K., 1984, *Science* **223,** 281.

Greenberg, R., and Chapman, C.R., 1984, *Icarus,* **57,** 267.

Nininger, H.H., 1952, *Out of the Sky,* Dover, New York.

Peck, E., 1979, *Sky and Telescope,* **58,** p. 126.

Scott, E.R.D., *Nature,* **311,** 708.

Pallasite Meteorites

Meteorites can be divided into three classes: Stones, Irons, and Stony Irons. A subgroup of the latter is quite peculiar: an iron/nickel mixture forms a sponge-like structure. Olivine crystals, of cross-section 1 to 10 mm fill out the holes, so that the volume ratio metal/olivine is about 1 : 1. The first such meteorite was found in 1771/72 by the German explorer Peter Simon Pallas, during his travels through East Russia. Pallasite meteorites are quite rare: less than 1 per cent of all falls and 3.5 per cent of all finds belong to this group.

Meteorite Craters

Upon hitting the ground, a large meteorite may form a crater. If the terminal velocity is sufficiently high, the conversion of kinetic energy will lead to the meteorite's instantaneous evaporation. An explosion crater is thereby formed. Smaller masses may form impact craters. 13 genuine meteor craters (or crater fields) are known and some 100 others are considered probable. The largest is the meteorite crater in Arizona, USA, which has a diameter of 1,200 metres. Third on the list is the more than 100,000-year old, 370-m diameter crater at Monturaqui. This is only 60 km from the location mentioned in the article, but unrelated. European probable meteorite craters include the 15-million-year-old, 27-km-diameter Nördlinger Ries structure in West Germany and the nearby 3.5-km diameter Steinheim Basin. There is geological evidence that both are meteoritic, but the proof (meteoritic material) is not yet found. It may long since have weathered away.

Strewn-fields

The hyper-sonic velocity, 15 to 72 km/sec, with which meteorites enter the Earth's atmosphere, creates a shock, which often forces the meteorite to break up. Masses less than a few tons will reach the ground with sub-sonic speed, 100–300 metres per second. Small particles tend to fall along steeper trajectories than heavier ones. This creates a characteristic elliptic distribution pattern, with particle size increasing along the major axis, in the direction of flight. This simple picture holds, if just one event of fragmentation took place. Strewn-fields can reach considerable sizes. The Gibeon-fall at South-West Africa covered approximately 100 by 400 km.

Meteorite Collections

Collections of meteorites exist at many museums. Prominent between these are the museums of natural history in London, Paris, Vienna, and the Academy of Sciences, Moscow. The heaviest meteorite on display in Europe is 'Agpalilik', a 14-ton iron from Greenland, now at the Geological Museum, Copenhagen.