How 'unique' can meteorites be?

from Robert Hutchison

ALL meteorites may be considered 'unique' with respect to their time of fall, which determines when the radionuclides produced by cosmic radiation begin to decay and when terrestrial weathering sets in. However, 'uniqueness' of meteorites is usually defined in terms of chemical composition and mineralogy, although oxygen isotopic ratios may be significant. No meteorite has properties which suggest that it came from outside the Solar System.

The most recently fallen meteorite to qualify as 'unique' landed near Acapulco, Mexico, on 11 August 1976. The single, 1.9 kg stone was extensively studied by Palme and colleagues in Mainz and Paris (*Geochim. cosmochim. Acta* **45**; 727, 1981). Like members of the H-group of chondritic meteorites, it has 22.7 wt per cent metal and 3.6 per cent sulphide (the remainder being essentially silicate), but differs from them in that it lacks chondrules and is coarse grained. A more fundamental difference lies in the oxidation state of Acapulco, which is intermediate between that of the highly reduced enstatite chondrites and the more oxidized H-group.

In major element chemistry Acapulco closely resembles the H-group, but the careful analyses undertaken at Mainz show that it differs in its content of some minor and trace elements. It has three times more phosphorus than have H-group chondrites; the mineralogical work, carried out in Paris, attributes this to a high abundance of chlorapatite, a calcium mineral known to accept uranium, and which is an order of magnitude more abundant in Acapulco than in H-group chondrites. These and other chemical properties of the meteorite suggest that the mineral assemblage has undergone some fractionation by partial melting. Enrichment in the refractory siderophile elements rhenium, osmium and iridium is taken as an indication that pre-accretionary, nebular processes also played a part in determining the chemical composition of Acapulco. But herein lies a problem. The chemistry and mineralogy of the meteorite seem to have been determined first by nebular condensation, then by accretion and igneous processes. During the igneous event it is estimated that the temperature was about 1,100°C, yet the planetary noble gases ^{36}Ar, ^{84}Kr and ^{132}Xe were not driven off. The K–Ar age of 4.7±0.3 Gyr indicates an uneventful history thereafter, until the potential meteorite was broken from its parent body during a collision some 5 Myr ago, when it became exposed to cosmic radiation. The cosmic-ray exposure age is based on the contents of the spallogenic isotopes ^{3}He, ^{21}Ne and ^{38}Ar. Histories such as this are not uncommon among stony meteorites.

Chemically and mineralogically the Acapulco meteorite is certainly unusual and interesting, but is it really unique? Palme and his co-workers identify six meteorites, plus silicate inclusions in an iron meteorite, which have chemical affinities both to Acapulco and to H-group chondrites. The only meteorite of the six which has chondritic structure, Kakangari, is itself unique in several respects (*Nature* **251**, 128; 1974; **265**, 230; 1977; and *Earth planet. Sci. Lett.* **40**, 168; 1978). The remaining meteorites or silicate inclusions differ from each other in their detailed chemistry (such as total Fe contents and/or Al/Si ratios), but igneous differentiation can conveniently account for differences other than in oxidation state. The oxygen isotopic data of R.N. Clayton and co-workers seem to provide the best test of inter-relationships. Acapulco is apparently related to the 'unique' stony-iron, Lodran, although the latter is richer in metal and greatly impoverished in aluminium. Finally, Acapulco most closely resembles an Antarctic meteorite, Allan Hills 77081. The Antarctic stone has over twice as much sulphide as Acapulco, but in other chemical and mineralogical properties the match is excellent. Oxygen isotopic data were not available for Allan Hills 77081.

Technically, we may conclude that Acapulco is different from all other known meteorites, although the difference between it and Lodran or Allan Hills 77081 may be compared with that between neighbouring rocks from the top of the Earth's upper mantle. Philosophically, it is by studying rare or 'unique' meteorites that we increase our knowledge of the spectrum of planetary compositions and of the processes which took place on minor planetary bodies.

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towards the determinant that actually causes the phenotype — a linkage, of course, may be a long way away, but new techniques such as those described originally by Goss and Harris (University of Oxford), where chromosomes are caused to fragment after irradiation, or 'microcells' and cells transiently incorporating cloned DNA segments, which were discussed by Ruddle (Yale University), can be used to bridge the gap between the 50,000 bp clone and the 5 megabase pair chromosome band. Unlike traditional 'gene walking' methods, these new techniques ('jogging the genome') may allow a chromosome to be roughly sequenced in a few months, using random clones and a computer.

When a total gene map exists, McKusick predicted that it will be possible to carry out 'reverse diagnosis', from gene to phenotype. This will be particularly useful in the diagnosis of dominant diseases, such as Huntington's chorea, where persons at risk live with anxiety for many years before finding out whether the disease develops in middle age.

A clear example of the remarkable advantages of combining cellular and molecular analysis was presented by Francke (Yale University). Using a human insulin gene clone provided by Rutter's laboratory (University of California, San Francisco), she showed that this gene is on the short arm of chromosome 11, almost adjacent to the human β-globin gene. It may even be possible to diagnose sickle cell anaemia using a gene probe for insulin in the future! The insulin gene is of interest in another respect: it is one of the few genes (another on chromosome 14 was described by White, University of Utah) shown to have a polymorphic short sequence of DNA which can be inserted either in a variable number of copies, or in a number of discrete sizes, at a single position on the chromosome. This is another indication that there may be 'transposons' in the human genome, similar to those that have been found in bacteria and *Drosophila*.

Evolution can also be studied by gene mapping. Not only do primates and man share chromosome assignments, but these often hold true when comparing man with mouse, kangaroo and, in some remarkable cases, even the fruit fly. Attardi (California Institute of Technology) gave a comprehensive account of the structure of the mitochondrial genome (the twenty-fifth chromosome, or 'little brother'), showing not only its extreme economy of function, but also the way in which it gives clues as to the evolution of living things, particularly by the study of the relatively unsophisticated mitochondrial tRNAs.

The meeting was supported by the World Health Organization as well as by the United States 'March of Dimes', and it is very encouraging that the WHO is beginning to take a major interest in the control of human genetic disease. Genetic diseases are a major cause of ill health in developing countries, and Kuliev (University of Moscow), who has recently taken responsibility for the WHO Genetics Programme, has been approached by many health workers from developing countries encouraging WHO to start a world programme to control genetic diseases, especially those affecting maternal and child health. □

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