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'Star Dust Memories' — A Brief History of the Murchison Carbonaceous Chondrite

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Abstract: The rare carbonaceous chondrite which fell around the township of Murchison in northern Victoria, Australia, in 1969 has probably been the subject of more scientific publications than any other meteorite. The discovery of grains formed in a presolar environment and the abundance of organic molecules within the Murchison meteorite have facilitated studies of the formation of the Solar System, the development of stars and the origins of life.

Keywords: history and philosophy of astronomy — Murchison meteorite

1 Introduction

The Murchison meteorite fell in September 1969, just two months after the first moon landing. Professor John Lovering, head of the Geology Department at the University of Melbourne, declared to the press that '*this is almost as exciting as moon dust*'. A recognised meteorite expert, Lovering was one of three Australian scientists to receive lunar samples from the Apollo 11 mission. In hindsight, the information gleaned from Murchison has made it more exciting then moon dust.

2 The Fall

On Sunday 28th September 1969, between 10:45 and 10:50 am (GMT +9 h), a meteorite shower fell around the small town of Murchison, some 80 km north of Melbourne, Victoria (36°41′S, 145°14′E). The fall was recorded in Volume 48 of the Meteoritical Bulletin in November 1969 with full details of the fall described by Lovering, Le Maitre & Chappell (1971). The fall is commemorated in Murchison by a small display in Meteorite Park.

The transit of the meteorite was witnessed as far away as Canberra, 360 km to the north and at Mildura, 410 km to the west. From eyewitness accounts, the meteorite was travelling in a north-westerly direction. It was reported as a bright orange ball with a dull orange conical tail leaving a blue smoke trail which lasted one to two minutes. Heralded by a sonic boom, several hundred small fragments fell around Murchison ranging in size from a few grams to the largest fragment, which weighs 7 kg. At least one hundred kilograms of meteorite fragments were recovered from an area about 11 km long by 3.2 km wide orientated north-west–south-east. Only minor property damage was sustained by the fall, with one fragment puncturing a hayshed roof.

Lovering organised students to search the Murchison area for fragments of the meteorite and many locals recovered pieces. The bulk of the recovered material went to the Field Museum of Natural History Museum in Chicago (51.6 kg) and the Smithsonian Institute in Washington (19.8 kg). The University of Melbourne retained about 7 kg most of which subsequently came to Museum Victoria in 1990. Museum Victoria has about 3.5 kg including two large fragments weighing 1.02 and 1.32 kg (Fig. 1).

Figure 1 Large fragment of the Murchison carbonaceous chondrite. Specimen weighs 1.3 kg and is 200 mm across. MV collection, E4480. Photo: D. Henry.

Most of the fragments recovered are surrounded by fusion crust. This indicates the meteorite broke up while still travelling at high speed, ensuring the fragments continued to melt as they travelled through the atmosphere. Many fragments broke on impact (Fig. 2). Specimens generally show desiccation cracking presumably due to the loss of volatiles, as the meteorite contains up to 8% H_2O and approximately 2% C.

3 Composition

Initial chemical classification of the meteorite was carried out by Ehmann et al. (1970), Jarosewich (1971) and Lovering et al. (1971). Fuchs et al. (1973) provided a full mineralogical description. Murchison is now classified as

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Figure 2 Broken fragments of Murchison carbonaceous chondrite showing chondrules and dark matrix. MV E12320 collection. Photo: R. Start.

a carbonaceous chondrite, type CM2, and is the largest known fall of its type. Murchison is believed to represent a chunk of cometary material with similarities having been drawn between the compositions of Murchison and the Comet Hyakutake.

In the 1960s, radioastronomy indicated the presence of carbon-rich molecules in space. These molecules are generally referred to as 'organic compounds' as they predominate in living organism, although they may have a non-biological origin. By this time, scientists had been examining and detecting organic compounds in meteorites for over a century. Generally results were inconclusive as to the origin of these compounds, with contamination by Earth-derived biomolecules considered likely. The Murchison meteorite played a pivotal role in confirming the presence of carbon molecules elsewhere in the universe. Amino acids are, in general, chiral, and form left- or right-handed molecules. Living organisms on Earth contain left-handed amino acids. When synthesized in the laboratory amino acids always form equal amounts of left- and right-handed molecules, referred to as a racemic mixture.

Kvenvolden et al. (1970) determined that the amino acids and hydrocarbons in Murchison had formed before the meteorite reaching Earth. This was largely based on the racemic nature of the organic compounds, their isotopic composition and the presence of organic compounds rare or absent on Earth. Additional work by Oró et al. (1971) confirmed the racemic nature of the organic molecules in Murchison. Epstein et al. (1987) examined the isotopic compositions of amino acids and other organic molecules, confirming their extraterrestrial origin and suggesting they formed in interstellar clouds.

Subsequently, much research has focused on the wide variety of organic molecules present in Murchison. Many of the protein amino acids found in biological system occur in Murchison but not all. Studies by Cronin & Pizzarello (1997) showed these to be racemic, indicating a non-biological origin. In addition, numerous amino acids unique to meteorites have been identified (e.g. Cronin & Pizzarello, 1986; Cooper et al., 2001). Some show a slight preponderance for left-handed forms (Cronin & Pizzarello, 1997) suggesting there may be a natural process for preferentially generating left-handed molecules.

Figure 3 Members of the Sixth Torino Workshop at Museum Victoria examining the Murchison meteorite. Left to right: Roberto Gallino, Maurizio Busso, Marco Limongi, Ernst Zinner. Photo: J. Lattanzio.

In recent years, claims of the presence of structures believed to be primitive life-forms, such as bacteria, have been made (Zhmur & Gerasimenko, 1999). Mautner et al. (1995) and Mautner (2002) showed that bacteria and algae can live in nutrients extracted from Murchison. Mautner cited this as evidence that carbonaceous asteroids can support and disperse microorganisms.

4 Presolar Grains

The Murchison meteorite is a rich source of presolar grains, grains which were born in star systems before the formation of our own solar system. As discussed by John Lattanzio and Roberto Gallino in the introduction to this Sixth Torino Workshop, much of the data generated from presolar grains have been derived from the Murchison meteorite (e.g. Hoppe & Zinner, 2000; Amari et al., 2000). The unusual isotopic properties of individual grains of silicon carbide, diamond, graphite, aluminium oxide, spinel and silicon nitride have been important in unravelling the history of the solar system. Some grains have formed in carbon stars, some in nova or supernovae while others are of indeterminable origin. The data derived from these grains have formed the basis for studies on the development of element formation by stellar nucleosynthesis and

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of motions inside stars and the migration of stars (e.g. Clayton 1997). In addition, the study of these presolar grains led to the development of better separation techniques and analytical procedures (e.g. Amari et al. 1994). An excellent review of presolar grains is provided by Zinner (1998).

5 Conclusions

The 100 kg of fragments of Murchison meteorite has been widely studied by scientists across the world. The importance of the meteorite to stellar astrophysics was evident in the excitement it generated in the participants of the Torino Group's tour of Museum Victoria's collection. Many of the astrophysicists had never seen a sample of this unusual black rock which had inspired and informed their scientific work (Fig. 3).

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