EPSC Abstracts
Vol. 7 EPSC2012-921 2012
European Planetary Science Congress 2012

Discovery of Framboidal Magnetites in the Murchison meteorite

N. Miyake, M. K. Wallis and N. C. Wickramasinghe
Buckingham Centre for Astrobiology, Buckingham University, Buckingham MK18 1EG, UK (miya_kentaro@yahoo.com)

Abstract

Framboidal magnetites are discovered in the Murchison CM2 meteorite for the first time. We discuss them as a biomarker. Their bacterial colony-like uniform-size and irregular structures indicate that they are involved in biotic process that date to the beginning of the solar system.

1. Introduction

The Murchison CM2 meteorite is a carbonaceous chondrite (CC) that fell in Australia in 1969. The CCs are organic–rich fragments probably from comets, as distinct from stony meteorites which are related to asteroids and have remained relatively unaltered since their formation 4.6 Gyr ago. The primitive materials from our early solar system give particular interest to studies of CCs through the decades.

Analysis via scanning electron microscopy and energy dispersive X-ray spectrometry (SEM-EDX) show inclusions of pyrite (FeS_2) and magnetite (Fe_3O_4) grains in many CCs. In CI meteorites (Alais, Ivuna, Orgueil and Tagish Lake), some magnetite grains are exhibited in a spectacular framboidal form, named after the raspberry-like morphology [1].

Framboids found in the terrestrial rocks and sediments have been intensively studied, with focus on biotic or abiotic nucleation. In a case of pyrite, there are reports of discovery of framboids in microbial biofilms [2,3] and in cavities and cell lumen of degraded leaves [4]. On the other hand, framboidal pyrites were found to form abiotically in a supersaturated solution at high temperature (60°C) [5]. However, pyrite has higher solubility than magnetite, so possible formation of magnetite framboids in hot, magnetite-rich sediments is unknown.

Mukhopadhyay et al. [6] discovered that magnetite framboids in the Orgueil CI meteorite are associated with biodegraded (kerogen) material. Hoover [1] added that there are no known abiotic production mechanisms, which suggests it's a secure biomarker, despite these magnetites being 4.56 Gyr old.

This paper presents the first discovery of framboidal magnetites in the Murchison CM2 meteorite by using SEM-EDX.

2. Figures

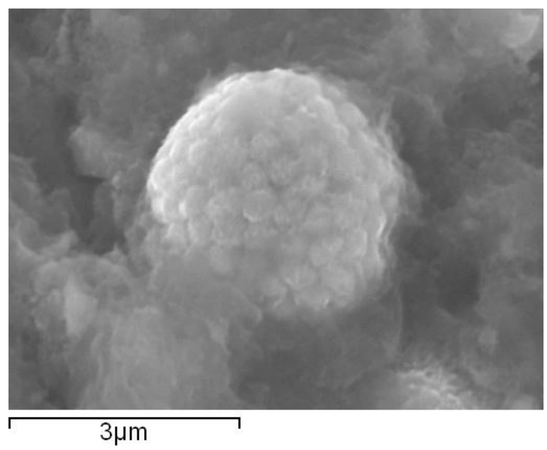

Figure 1: A single ~3μm magnetite framboid. The magnetite grains have uniform size of ~0.5μm with irregular grain structures and are packed in a bacterial-like colony, a typical morphology of framboids.

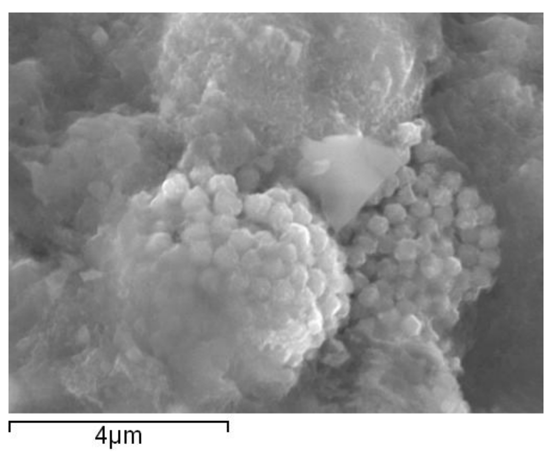

Figure 2: Two ~4μm framboidal magnetites with some loosely packed grains. A framboid on the left is half covered with some thin film. The sphere above has Fe_3O_4 elemental abundance, suggesting it is a third framboid that is fully covered with thicker film.

3. Discussion

The Murchison CM2 meteorite has been intensively studied in the past and there is growing evidence of biomarkers for which there is no alternative abiotic production mechanism. These include protein amino acids with significant enantiomeric excess [7], nucleobases [8] and morphological biomarkers with size, size range and recognizable features diagnostic of known orders of *Cyanobacteriaceae* and other prokaryotic microfossils [9].

The discovery of spectacular framboidal magnetite with extremely well preserved uniform-sized grains with irregularities in structure in the Murchison meteorite (Fig. 1 and 2) adds to this list of biomarkers. Abiotic nucleation of framboids is distinguished by the uniform angular shape of individual grains [5]; however, the magnetite framboids discovered in the Murchison do not have this characteristic. In view of framboidal formation from biodegraded material [2-4, 6, 10], we suggest the magnetite framboids in Murchison indicate a biological origin.

Nanocrystals of magnetite are formed by microorganisms such as magnetotactive bacteria [11]. The magnetite grains in the Martian meteorite ALH84001 are said to resemble magnetofossils formed by those bacteria. Also magnetite nanocrystals are known to be produced via biologically-induced mineralization by dissimilatory iron-reducing bacteria [12]. Since there are no known abiotic production mechanisms of magnetite framboids in the Murchison, its nucleation could have started with those activities of microorganisms.

4. Conclusion

Magnetite framboids have been discovered in the Murchison CM2 meteorite for the first time, with uniform-sized grains and irregularities in structure. This biomarker is further evidence of primitive life in the early solar system, possibly within the first comets which underwent internal radiogenic melting a Myr or so after formation 4.56 Gyr ago.

References

[1] Hoover, R.B.: Fossils of Cyanobacteria in CI1 Carbonaceous Meteorites: Implications to Life on Comets, Europa and Enceladus, *J. Cosmol*, **16**, pp. 7070-7111, 2011.

[2] Large, D.J., Fortey, N.J., Milodowski, A.E., Christy, A.G. and Dodd, J.: Petrographic observations of Iron, Copper, and Zinc Sulfides in freshwater canal sediments, *J. Sedimentary Res.*, **71**, No. 1, pp. 61-69, 2001.

[3] Maclean, L.C.W., Tyliszczak, T., Gilbert, P.U.P.A., Zhou, D., Pray, T.J., Onstott, T.C. and Southam, G.: A high-resolution chemical and structural study of framboidal pyrite formed within a low-temperature bacterial biofilm, *Geobiology*, **6**, pp. 471-480, 2008.

[4] Bajpai, U., Kumar, Shukla, M., Prakash, A. and Srivastava, G.P.: Nature and composition of pyrite framboids and organic substrate from degraded leaf cuticles of Late Tertiary sediments, Mahuadanr Valley, Palamu, Bihar, *Current Science*, **81**, pp. 102-106, 2001.

[5] Ohfuji, H. and Rickard, D.: Experimental synthesis of framboids – a review, *Earth-Science Reviews*, **71**, pp. 147-170, 2005.

[6] Mukhopadhyay, P.K., Mossman D.J., and Ehrman, J.M. A universal, unconventional petroleum system exists throughout our solar system, *SPIE Newsroom*, DOI: 10.1117/2.1200907.1699, 2009.

[7] Pizzarello, S., Huang, Y. and Fuller, M.: The carbon isotopic distribution of Murchison amino acids, *Geochimica et Cosmochimica Acta*, **68**, pp. 4963–4969, 2004.

[8] Martins, Z., Botta, O., Fogel, M.L., Sephton, M.A., Glavin, D.P., Watson, J.S., Dworkin, J.P., Schwartz, A.W. and Ehrenfreund, P.: Extraterrestrial nucleobases in the Murchison meteorite, *Earth and Planetary Science Letters*, **270**, pp. 130–136, 2008.

[9] Hoover, R.B.: Microfossils of Cyanobacteria in Carbonaceous Meteorites, *Proc. SPIE*, **6694**, p. 669408, 2007.

[10] Rozanov, A.Y., Astafieva, M.M. and Hoover, R.B.: The early Earth and its environments, *Proc. SPIE*, **7097**, pp. 709708-709708-15, 2008.

[11] Faber, C.: Living Lodestones: Magnetotactic bacteria, *Strange Horizons*, 2001.

[12] Jimenez-Lopez, C., Romanek, C.S. and Bazylinski, D.A.: Magnetite as a prokaryotic biomarker: A review, *J. Geophys. Res.*, **115**, p. 19, 2010.