CORRESPONDENCE

Spherules from the Late Cretaceous Phosphorite of the Fatehgarh Formation, Barmer Basin, India

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(Manuscript received February 10, 2005; accepted April 15, 2005)

Abstract

A first report of discovery of spherules, glassy balls, highly magnetic fine dust and microbracciated matrix in the Fatehgarh Formation of Barmer Basin, Rajasthan, India is being presented in this paper. The Fatehgarh Formation is a mixed siliciclastic, carbonate and phosphorite formation of Cretaceous age in the Barmer Basin that comprises sediments of Middle Jurassic to Lower Eocene age. The phosphorite zone in the Fatehgarh Formation is ~8 metre-thick zone that comprises phosphatic sandstone, bone bed, bedded phosphorite and phosphatic and non phosphatic gastropod beds. The spherules occur in a thin phosphatic-clay mud and silt band of bone bed, which also yielded a very rich and diverse microvertebrate assemblage with a dominant Late Cretaceous (Maastrichtian) form of Igdabatis along with forms comprising of Semionodontid, Lapisosteum and Enchodontid. The end Cretaceous is marked for a mass extinction of numerous species including dinosaurs. An extraterrestrial impact is interpreted as the reason for this mass extinction. Whether these spherules are related to the volcanic source or K/T Boundary impact ejecta found at Caribbean and Gulf of Mexico region needs detailed chemical and age characterization for which study is in progress.

Key words: Fatehgarh Formation, Barmer Basin, phosphorite, spherules, KTB.

Introduction

The occurrence of unusual glassy objects, especially spherules and microtectites in the sedimentary terrains generate keen interest and curiosity amongst the geologists because they have mostly been interpreted as one of the signatures of unusual events that brought significant biological changes in the geological history, specifically at the geological boundaries. We report here a very new find of the occurrence of millimetre-sized magnetic spherules and microtectites in the Barmer Basin of West Rajasthan, India. This scientific finding becomes more important because: (1) this is for the first time that the spherules have been found in India; (2) these spherules occur in Fatehgarh Formation of Cretaceous age and significantly in a bed that is rich with fossils of Maastrichtian age. It is to be noted that one of the major mass extinctions in geological record took place at the end Maastrichtian when dinosaurs along with many other species were wiped off from the earth (Sepkoski, 1992).

Geology of the Area

The Barmer Basin in Western Rajasthan is a result of the break up of the Indian craton in the latest Cretaceous–early Palaeocene that led to the formation of the Cambay rift and constituent basins (Dutta 1983 and Mathur and Kumar, 2003). It is a narrow north-south trending graben that comprises sediments of Middle Jurassic to Lower Eocene age (Dasgupta, 1974; Pareek, 1981). For detailed stratigraphy of the Barmer Basin, see Dasgupta (1974), Sisodia and Singh (2000) and Mathur (2002). The sediments of Cretaceous age in this basin are named the Fatehgarh Formation, which are represented by fluviodeltaic to shallow marine mixed siliciclastic, carbonate
and phosphorite facies (Mathur et al., 2005a). The phosphorite facies is highly fossiliferous and is correlated with global Late Cretaceous phosphogenic event (Mathur and Kumar, 2000). Type section of the Fatehgarh Formation, exposed at Lordi Nala in the vicinity of Fatehgarh (N 26°26'.087'' E 071°12'.519'') and the generalized lithostratigraphic section of the Fatehgarh Formation is shown in figure 1. It is overlain by Siliceous-Earth and bentonite of Akli Formation of Palaeocene age. The phosphorite zone is very interesting, being ~8 metre thick, interbedded with intensely burrowed phosphatic sandstones, bedded phosphorite and carbonate rich with gastropod shell and phosphatic moulds and highly fossiliferous phosphatic bone bed. Mathur et al. (2005a) reported microvertebrates from the bone bed. Their report was based on the abundant morphological characterization of primitive myliobatiform teeth along with Seminotidae indet., Lepisosteus indicus, Enchodontidae indet., Labridae indet. and Stephanodus sp. Siluriformes indet., and suggested an overall Maastrichtian age to bone bed. As such it shows mortality en masse of such species. In the thin phosphatic-clay mud and silt interbeds of bone bed, we found some extraordinary material that includes magnetic spherules, other glassy balls and highly magnetic fine dust.

**Spherules**

The phosphatic-clay mud and silt interbeds in the phosphatic zone yielded mostly sand-sized, that is...
60-2,000 µm-diameter spherules, along with fossils, bioclasts and detrital quartz. Most of these spherules are perfectly spherical but some of them are elliptical, ovoid, tear-drop shaped, dumbbell-shaped, or two are fused together to form a 'figure 8', while some are agglutinated (Fig. 2a, b, c). Most of these spherules have a tough, shining black crust and a lighter, transparent glassy interior. One such spherule that has a black crust enclosing a glassy interior, which got quenched in the atmosphere but still has retained its viscous flow structure is shown in figure 2d. In many cases the glassy interior has been replaced by quartz or ferruginous material of the host.

Fig. 2. Magnified images of the spherules and associated unusual material; (a) Perfectly spherical, sub-millimetre to millimetre sized spherules with shining black covering. (b) Two spherules are fused together. (c) Agglutinated spherules. (d) Spherule showing glassy material quenched probably in the atmosphere oozing out of the tougher, shining black, metallic covering but still retaining the viscous flow structure. (e) and (f) Spherules of different compositions such as quartz, calcite, limonite, magnetite, hematite, etc. (g) Microgeode composed of chalcedonic silica and drusy quartz. (h) Microbreccia composed of heterogeneous mixture of clasts of quartz, calcite, sandstone and limestone, etc. (i) Highly magnetic fine dust, note its magnetism with the steel needle. It consists of submicroscopic to very fine spherules.
rocks while sometimes the spherules are hollow. In addition there are some spherules that are composed of calcite, magnetite-quartz, goethite, hematite, clay minerals etc (Fig. 2e, f). Many of the spherules are highly altered but still bear a striking similarity to the types of spherules that occur at the Cretaceous/Tertiary boundary sediments in and around the Caribbean and Gulf of Mexico region (see Montanari et al., 1983; Izett et al., 1991;

Fig. 3. Photomicrographs of the spherules (a) Spherule cut transversely shows opaque rim enclosing the glassy interior. The photograph is taken in the polarized light; under crossed polarizer the glass is isotropic. (b) A quartz fragment in the spherule showing unoriented fractures developed due to shock; crossed polarizers. (c) Transverse section of a spherule showing opaque rim and a glass fragment in the interior, note its saw-tooth margins. The two off-centered grains have probably been filled in the vesicles or have replaced the glass; polarized light. (d) Microbreccia showing opaque iron-rich glass flowing through siliceous glass material that encloses spherules and numerous quartz fragments; polarized light. (e) The same iron-rich glass in higher magnification shows flow banding, note the devitrification at the peripheries; polarized light. (f,g) Quartz grains in the host rocks showing irregular extinction and two to three sets of parallel developed cleavage fractures; crossed polars.
Bohor and Glass, 1995) and breccias associated with impact structures (Graup, 1981; French, 1987). Rarely, mini-geodes with banded chalcedonic and fine drusy quartz and microbreccia composed of clasts of quartz and glass fragments, as well as sandstone clasts cemented by siliceous and calcareous matrix are also found associated with spherules (Fig. 2g, h). Such material is found to occur at many sites around the Chicxulub impact basin (Sharpton et al., 1996; Adatte et al., 1996). Microgeodes in the impact ejecta form as melt glass formed due to high pressure/temperature effect, has vugs and cavities in which the wet solutions crystallize during weathering processes forming geodes. The soil formed presumably as a weathered product of the phosphorite zone, yielded highly magnetic fine dust (Fig. 2i).

In thin section, these spherules are composed of a thin opaque rim enclosing transparent glass. The rim is composed of Fe- and Ti-rich glass (Mathur et al., 2005b). The rim has distinctly segregated itself from the Si-rich melt (Fig. 3a). Similar shock metamorphic/melting texture is noted in impact glasses in Ries, Wabar (El Goresy, 1968) Manson (Koeberl and Anderson, 1996). In many cases quartz grains having unoriented fractures are seen in the spherules (Fig. 3b). These quartz grains actually form the fabric of the host sandstones that have been included in the spherules by replacing their less consistent glassy material. Some spherules show clear spots of glassy or quartz fragments lying away from the centre (Fig. 3c). Simonon (2003) interpreted such off-centre spots as fillers in the former gas bubbles and the most effective criterion for the identification of impact spherules. The microbreccia grains are composed of heterogeneous mixture of recrystallized spherulitic glass and small fragments of quartz, sandstone, limestone, magnetite, limonite, etc. They show flow banding and disseminated vesicles (Fig. 3d, e). These microbreccias have striking similarity with the glassy breccia associated with impact structures (French, 1998). The quartz grains in the host rocks are highly fragmented and have highly irregular or serrated margins. They invariably show undulose extinction and some of these quartz grains show parallel-developed planar fractures in two or more sets along cleavages (Fig. 3f, g). These fractures however are not very closely spaced and no glasses filling these fractures are visible.

**Significance of the Spherules**

The occurrence of these spherules in the Fatehgarh Formation of Cretaceous age in the Barmer Basin of India, and that too along with fossils of Maastrichtian age warrants a thorough discussion in light of their source and significance. The end Cretaceous is marked by a mass extinction of numerous species including dinosaurs. Alvarez et al., (1980) based on an anomalously high concentration of iridium found in the sediments deposited at the Cretaceous/Tertiary boundary, hypothesized that an extraterrestrial impact event caused major geochemical changes in the atmosphere, leading to mass extinction. At the K/T boundary, one large crater at Chixulub is well documented (Hildebrand et al., 1991) to have formed during a bolide impact 65.1 Ma ago (Izett et al., 1991). Its ejecta, however, is not expected to reach India. According to the fall out model of Alvarez (1996), India was located in the “forbidden zone” of the ejecta during the terminal Cretaceous. It is to be noted that from the Caribbean and Southern North America, K/T-related probable impact-wave deposits have been reported (see Hildebrand and Boynton, 1990 and references therein). The phosphorite bed under discussion, as described above, is also a turbidity current deposit, probably a giant turbidity current. If we take into consideration the palaeogeography and geological history of the Indian plate, we know that the Indian Peninsula was placed totally isolated in the Indian Ocean in the Maastrichtian before its collision with Eurasia in the Early Eocene (Trelolar and Coward, 1991). A detailed geochemical and age characterization study of these spherules found at Fatehgarh in India is in progress to find whether they are the outcome of impact and/or volcanic origin.

**Acknowledgments**

The authors express their gratitude to Profs. B.S. Paliwal, D.S. Chauhan, and A. Sahni and Drs. R.P. Tripathi and S.K. Trivedi for the valuable comments. We are thankful to Drs. Gyanesh Lashkari and Shanker Lal Nama for their help in the preparation of figures and text. S.C. Mathur acknowledges DST, New Delhi for financial support in form of a research project (SR/S4/ES-58).

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