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The Diyodar meteorite fall in India

A meteorite fall was witnessed by the villagers of Rantila and Ravel, Diyodar taluka, Banaskantha district, Gujarat, India, at around 19:30 h (IST) on 17 August 2022. Here we discuss the circumstances of the fall and provide a brief description of the meteorite in hand specimen and a few preliminary examinations.

The meteorite fall was observed in two nearby villages, i.e. Rantila and Ravel, about 10 km apart. Figure 1 shows the location of the fall areas. The meteorite was observed to fall at Rantila village (24°14′26″N; 71°46′45″E) in a soft, clayey agricultural land. One of the villagers mentioned that he did not witness any trail, but a thunderous sound was heard, like the passing of a jet plane. During the fall, a large piece of the meteorite hit a neem tree branch and broke into several fragments due to the impact. The tree branch also broke into several large pieces (Figure 2). Several fragments of the meteorite were found scattered in the field (Figure 2). The villagers collected the large pieces immediately after the fall. The mass of the largest piece was around 200 g and about 12 cm × 6 cm × 4 cm in size (Figure 3). The large pieces of the meteorite were handed over to the local Tehsildar (Mamlatdar) office of Diyodar taluka. The next day after the meteorite fall, both the villages witnessed heavy rainfall and the strewn field was almost submerged in water. A few smaller pieces of the meteorite were recovered beneath the soil cover after the flood-like situation improved and the farmland became relatively dry. At Ravel village (24°09′55″N; 71°42′45″E), a fragment fell close to a villager while she was cleaning her porch (Figure 2). A loud sound was heard by her and many residents of the village. The fragment had damaged the floor tiles of the porch, creating a small crater (~14 cm diameter and ~4–5 cm deep) (Figure 2). According to the villagers, the meteorite fragments yielded a strong, pungent smell similar to the sulphur gas.

A group of Physical Research Laboratory (PRL), Ahmedabad scientists visited the fall areas and collected two large fragments (about 200 and 20 g) from the Tehsildar office at Diyodar on 23 August 2022 (Figure 3). They also did a thorough search in the vicinity of the fall sites to look for more meteorite fragments. After interviewing several eyewitnesses and plotting the fall locations on a map, the trajectory of the meteorite was predicted from the southwest to the northeast direction (Figure 1). This direction of impact and the spread indicate that there could be more fragments in between and away from these villages along the trajectory of the meteorite.

The hand specimen of the meteorite fragments appeared as fragmental/regolith breccia and were similar in both locations, suggesting that they were likely part of a single meteorite mass before breaking during its passage through the Earth's atmosphere, perhaps at low height in a low-angle trajectory. The fragments were fragile, and the inner material was brittle. A light brown fusion crust (apparent thickness ~0.5 mm) has been partly preserved over small areas in both fragments (Figure 3), which indicates that the fragments are part of a larger meteorite chunk. The sample was a stony achondrite breccia with predominantly white pyroxene grains of various sizes and shapes. Large pyroxene grains (up to 2.0 cm) occurred as bright white translucent crystals with two perfect sets of prismatic cleavages (Figure 3). The pyroxenes appeared to be predominantly enstatitic in the hand specimen.

The main fragment of the collected meteorite was examined for the presence of

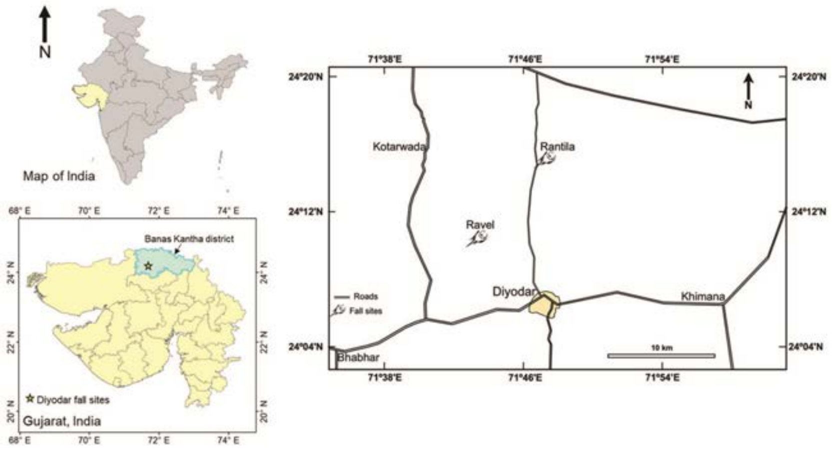

Figure 1. Location map of the Diyodar meteorite fall on 17 August 2022 at Rantila and Ravel villages, Diyodar taluka, Banaskantha district, Gujarat, India.

Figure 2. Field photographs showing the impact due to the meteorite fall. ***a***, Broken branch of a tree on which the meteorite impacted before falling on the ground as pieces at Rantila village. ***b***, A small fragment of the meteorite (a few centimetres) taken by a local resident in the evening at Rantila village. ***c***, Close-up of the impact crater on the tiles of a porch at Ravel village. The impact damaged the tiles and created radial fractures.

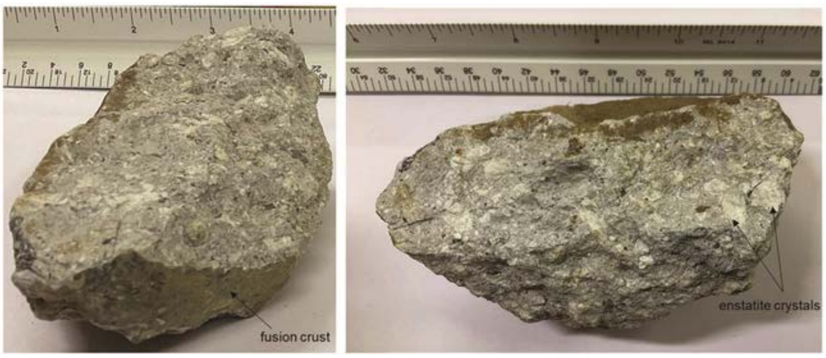

Figure 3. Meteorite sample in hand specimen. (Left) Light brown fusion crust is visible. (Right) Large enstatitic pyroxene grains occurring as bright white crystals. Scale is in inches.

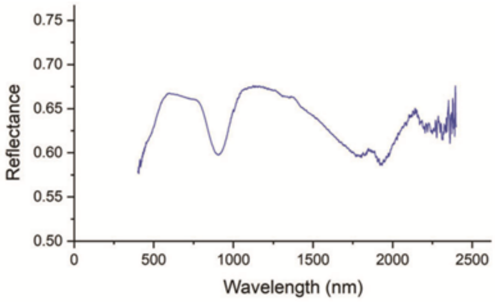

Figure 4. Reflectance spectra of the Diyodar meteorite.

cosmogenic radionuclides using a low background gamma-ray spectrometer. We observed the presence of ^{22}Na and ^{26}Al isotopes, apart from the natural radioactive elements K, Th and U.

Results of reflectance spectroscopy obtained at the Planetary Remote Sensing Laboratory, PRL using a spectroradiometer (ASD Fieldspec 4 Hires) revealed that the bulk meteorite sample showed the presence of two shallow absorption bands with band centres at ~900 and ~1900 nm (Figure 4), which is typical of Mg-rich pyroxene enstatite. The shallow nature of the absorption bands and blue slope beyond 1 μm suggest that the meteorite is an enstatite achondrite (Figure 4). A bifurcated cable accessory was used to acquire the reflectance spectrum under normal incidence and collecting angles. Spectralon was used as a standard in the reflectance measurement.

We mounted and polished a few small chips (0.5–1.5 cm) from the larger fragment of the Diyodar meteorite for *in situ* chemical analysis of the constituent phases. The mineral grains were extensively fractured (Figure 5). Typically, the fractures were along the cleavage planes in the pyroxene grains. Back-scattered electron imaging and mineral chemical analysis were carried out at PRL using an electron probe microanalyser (EPMA; JEOL JXA-8530F Plus Hyperprobe). The composition of the mineral phases was derived quantitatively using wavelength dispersive spectroscopy in EPMA. The modal abundance of the dominant mineral phase (~90%) is enstatitic pyroxene (average value: Mg# 99.7, $En_{98.4}Wo_{1.0}$), while diopsidic pyroxene (average value: Mg# 99.8, $En_{54.5}Wo_{45.1}$) is present as the next dominant phase (~5%). Since similar Mg-rich pyroxene occurred dominantly, the sample was identified as a monomict breccia. Olivine is forsteritic (average value: Mg# 99.7) and plagioclase albitic (average value: $Or_{3.3}Ab_{95.9}$). The mounted grains contain various sulphides, e.g. troilite ($Fe_{1-x}S$), alabandite ([Mn,Fe]S), heidite ($FeTi_2S_4$), daubréelite ($FeCr_2S_4$), oldhamite (CaS) and Fe–Ni alloys.

Our preliminary description and study suggest that the meteorite is a rare, unique specimen of aubrite (enstatite achondrite)[1,2]. The Indian subcontinent witnessed an exceptional record of meteorite falls (>450 reported stony meteorite falls till date). However, this is the second reported aubrite fall in India, after the Bustee fall in 1852 at Gorakhpur, Uttar Pradesh. Aubrites are the rare achondrite group of meteorites originating from an extremely reduced differentiated

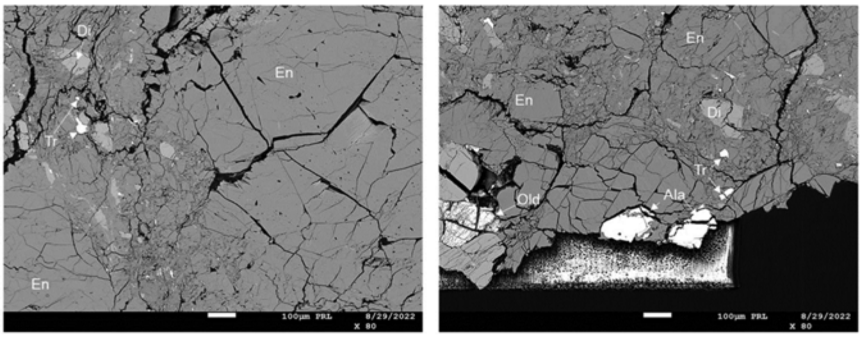

Figure 5. Back-scattered electron images of the polished sections of Diyodar meteorite showing the constituent phases. En, Enstatite; Di, Diopside; Tr, Troilite; Old, Oldhamite; Ala, Alabandite.

parent body in our solar system[3,4]. The similar and unique characteristics of highly reducing conditions on the surface of planet Mercury and aubrite often suggest that enstatite meteorites are the potential petrologic and geochemical analogs of planet Mercury[5], even though we do not have any known Mercurian samples in our collection. Therefore, this rare specimen of meteorite not only improves the existing meteoritic database, but will be important for understanding the planetary processes in the future.

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