Meteorite fall in Bhojade village, Kopargaon taluk, Ahmednagar district, Maharashtra, India

The chondritic meteorites are building blocks of undifferentiated asteroids. They are one of the oldest known rocks that record the events and processes during the early stages of the evolution of the Solar System comprising condensation of the first solid objects, accretion of parent fragments and subsequent physico-chemical processing within the planetesimals. The ordinary chondrites, accounting for around 85% of total meteorite falls, are the most common extraterrestrial materials readily available for laboratory studies to understand the origin and formation of the early Solar System, reconstruction of shock-thermal excursion and the cosmic-ray interactions during their journey in space. Every new meteorite fall, therefore, is always important due to its pristine essence and dynamic dataset on primary mineralogy, texture and whole-rock chemistry. Here, we report a recent meteorite fall (the second fall during the last decade since Katol L6 in 2012) in Bhojade village (~120 km from Pune), Kopargaon taluk, Ahmednagar district, Maharashtra, India. The preliminary description of its morphology, mineralogical and chemical composition is presented to identify the meteorite class and type.

The Indian subcontinent has an exceptional record of meteorite falls (>700 reported falls and finds), since the first report in Jalandhar, Punjab, way back in 1621 (Meteoritical Bulletin Database). In the morning, around 6:50 am IST on 24 January 2023, a meteorite fell piercing through the roof of a resident of Bhojade Chauki in Kopargaon taluka, Ahmednagar district, Maharastra (Figure 1). It pierced through the flat metal roof of the house, shattered into several fragments upon hitting the floor of the bedroom, and left an impact scar of ~2 inches in diameter. The total accumulated mass of the fragments was about ~1 kg. The villagers panicked after witnessing this unusual event. A neighbour and eyewitness mentioned that he saw some bright objects falling from the sky at a distance accompanied by a hissing sound. Additionally, the police inspector of Kopargaon taluka also shared information that while someone exercising on the banks of River Godavari, had seen a fireball trail in the sky. Collating all these facts, it appears that the meteorite fireball probably travelled towards Bhojade village from the west. Later, the police personnel of Kopargaon Taluka Police Station visited the site of the fall and collected fragments of the possible meteorite specimens. Finally, the specimens were sealed in a box and handed over to the Tehsildar's Office in Kopargaon.

Preliminary inspection of the object by us showed that the Kopargaon meteorite is a stony meteorite because it has silicate minerals and some shining specs (could be metal and troilite). Texturally, it resembled an ordinary chondrite. A uniform, dull, black

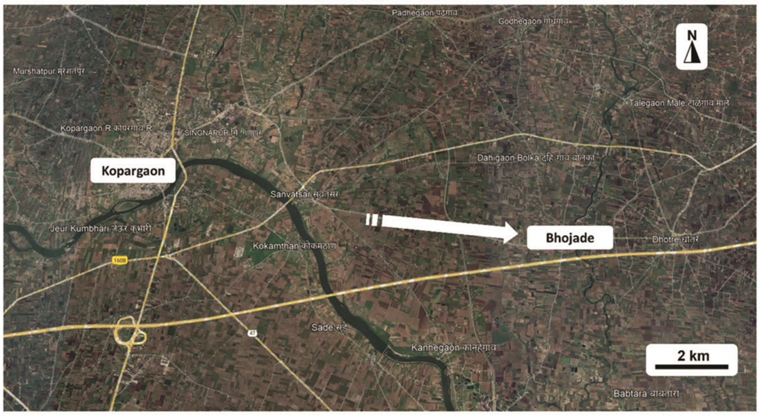

Figure 1. Google Earth image showing the location of Bhojade village, Kopargaon taluk, Ahmednagar district, Maharashtra, India.

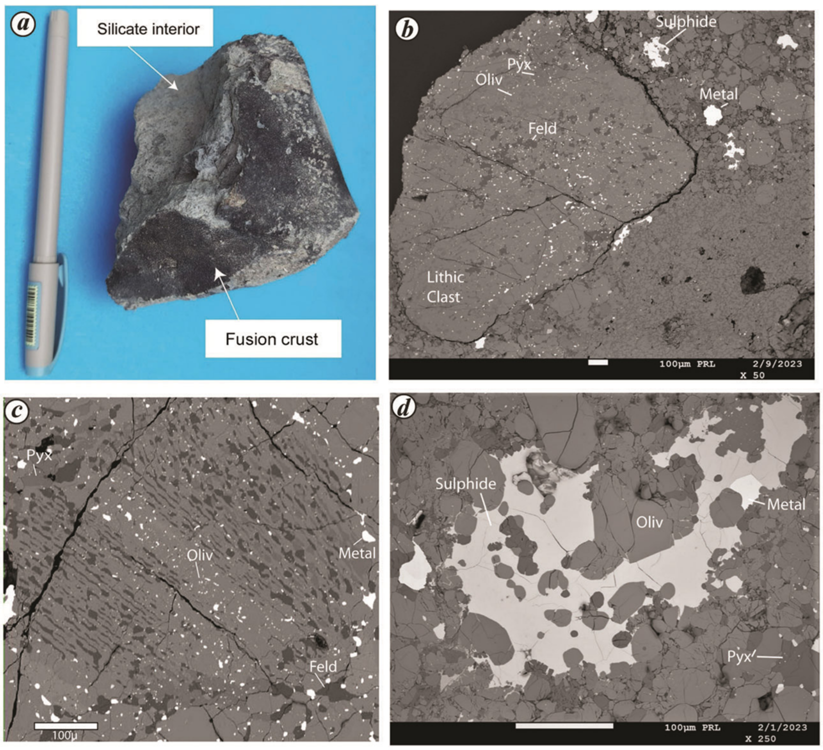

Figure 2. ***a***, Hand specimen of Kopargaon meteorite. Black fusion crust and grey silicate interior are shown. Length of the pen is 14 cm. ***b***, ***c***, Back-scattered electron (BSE) images of Kopargaon fragmental breccia. Lithic clasts and chondrule clasts are shown. Oliv, Olivine; Feld, Feldspar; Pyx, Pyroxene. ***d***, BSE image of sulphide (troilte) and metal (Fe–Ni alloy) in Kopargaon chondrite.

Table 1. Representative EPMA analyses of mineral phases

Oxide (in wt%)	Olivine	Low-Ca pyroxene	High-Ca pyroxene	Feldspar	Chromite	Element (in wt%)	Troilite	Kamacite	Taenite
	$N = 12$	$N = 8$	$N = 5$	$N = 7$	$N = 4$		$N = 5$	$N = 3$	$N = 4$
SiO_2	38.16	56.18	55.69	68	0.05	Fe	62.33	92.79	72.25
TiO_2	n.d.	n.d.	n.d.	n.d.	4.77	Co	0.04	1.1	0.5
Al_2O_3	n.d.	0.17	0.60	21.66	5.34	S	36.79	n.d.	n.d.
Cr_2O_3	n.d.	0.35	1.35	n.d.	55.70	Ni	n.d.	5.79	27.3
FeO	26.89	15.37	2.95	0.39	31.91	Cr	n.d.	n.d.	n.d.
MnO	0.48	0.46	0.16	n.d.	0.54				
MgO	35.30	27.04	16.45	n.d.	2.17				
CaO	n.d.	0.43	21.74	001					
Na_2O	n.d.	n.d.	0.50	8.41					
K_2O	n.d.	n.d.		2.31					
Fa (mol%)	29.95								
Wo		0.86	46.34						
En		75.17	48.76						
Fs		23.97	4.90						
An				0.04					
Ab				84.67					
Or				15.28					
Cr#					87.50				

n.d., Not determined.

fusion crust (~a few millimetres thick) was preserved in several fragments (Figure 2 *a*). Shallow, thumb-like impressions on the fusion crust (known as regmaglypt) and a few fractured surfaces were also recognized. The relatively larger specimen showed traces of striated, radiating flow lines, which indicated the top and bottom of the meteorite during its flight. The ash-grey, recrystallized silicate matrix with limonitic brown spots suggested oxidation of the metal-sulphide grains. There were many lithic fragments in the matrix. Several irregular fractures across the specimen enclosed clast-size fragments of variable sizes, suggesting its brecciated nature.

Backscattered electron (BSE) image showed that the Kopargaon meteorite resembled a brecciated meteorite with abundant fragments, clasts (chondritic) with recrystallization texture, chondrule and lithic clasts (Figure 2 *b*). The overall texture resembled that of breccia.

The mineral composition was determined using a field emission electron probe micro analyser (JEOL JXA 8530F plus, Japan) at the Physical Research Laboratory, Ahmedabad, India, applying an accelerating voltage of 15 kV, sample current 15 nA and 1 μm beam diameter. Natural and synthetic mineral standards were used for calibration and the data were corrected for absorption, fluorescence and atomic number effects. The major constituent minerals identified were olivine and low-Ca pyroxene of almost homogeneous composition with ~Fa 29.95 mol% and Fs 23.97 mol% respectively (Table 1). The per cent mean deviation of olivine and low-Ca pyroxene was within 4%. The Ca-pyroxene had a much lower modal abundance compared to low-Ca pyroxene, which was also homogeneous in composition. The other phases included albitic plagioclase feldspar, troilite, Fe–Ni alloy and chromite. Metal and sulphide minerals occurred in variable grain sizes (often as conjugate grains) distributed throughout the thin section. Sulphide minerals were more abundant than other metallic minerals (Figure 2 *c*).

Based on the mean olivine and low-Ca pyroxene composition of Fa: 29.95 and Fs: 23.97 respectively, the rocky meteorite can be assigned to LL-group ordinary chondrite and petrologic type-5, according to the classification scheme of Van Schmus and Wood[1]. Based on the undulatory extinction in olivine and plagioclase and the presence of planar fractures in olivine, the chondrite appears to be weakly shocked (S3)[2]. The texture of the rock was that of a breccia (Figure 2 *b*). On the basis of petrochemical characters as described, the Kopargaon meteorite is identified as LL%, S3, ordinary chondrite breccia.

The parent body of this ordinary chondrite is not known. However, ordinary chondrite spectrally resembles the S-type asteroids of the Main Asteroid belt. To date, the nature of the parent asteroid was only understood through a sample return mission from the near-Earth S-type asteroid (25143 Itokawa) by Hayabusa-1 mission (JAXA, Japan), and the observed mineral and isotopic composition was similar to the LL type of ordinary chondrite class[3]. Therefore, the Kopargaon LL chondrite could be the fragmental breccia of an S-type asteroid that was probed by the Hayabusa-1 mission.

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