Graphite within carbonaceous phyllite, Mahakoshal Group, Central Indian Tectonic Zone

The Precambrian crust of Central India comprises two Archaean cratonic domains, namely, Bundelkhand in north and Bastar in south, which were accreted along the ENE–WSW trending Proterozoic Central Indian Tectonic Zone (CITZ) bounded between the Son–Narmada North Fault (SNNF) and the Central Indian Shear Zone (CIS), and extending for more than 800 km in length and 120–150 km wide. The CITZ contains low- to medium-grade Proterozoic supracrustal belts set amidst migmatitic gneisses and granitoids. The Mahakoshal supracrustal belt, a northern part of CITZ is a prominent fault-controlled asymmetrical rift basin[1]. It extends for more than 600 km along strike and forms an E–W to ENE–WSW trending terrain along the Son–Narmada lineament, wherein it is bounded by SNNF in the north and South Narmada South Fault (SNSF) in the south. It comprises chemogenic and volcano-sedimentary sequences of Greenschist facies (Roy *et al.*[2] and Acharyya[3], and references therein).

The carbonaceous phyllite (CP) of Agori Formation, Mahakoshal Group which is confined within the shear zone was first observed by Kanchan and Pandhare[4]. The presence of graphite based on softness and finger soiling within this CP was vaguely speculated. Subsequently, CP was mapped at 1 : 25,000 (ref. 5). Random samples of CP analysed gave fixed carbon values up to 3.2%.

An exploration programme was formulated to undertake 'mapping of the area, confirmation and delineation of graphite, its systematic channel/groove sampling, ore microscopy, EPMA studies, fixed carbon analysis and Major-Trace-REE geochemistry'. During the course of mapping at 1 : 12,500, it was observed that CP (Figure 2 *a* and *b*) extends intermittently over cumulative strike length of ~10.3 km and ~40 m average width (Figure 1). The steep inclinations of ~80°–85°SSE, extensive brecciation, crushing, secondary ferruginization, numerous quartz veins, quartz porphyroclasts and large-scale silicification were observed in the shear zone trending ENE–WSW and having strike length of about 8 km. The flaky carbon lenses within the CP, were systematically sampled at 25 × 5 m interval. They were distinguished by their greyish-black colour, flaky and splintery nature, metallic lustre and comparatively low specific gravity. The possibility of flaky carbon lenses being graphite was checked in the field (powder was immersed in a glass full of water, wherein flakes were found to float), which strongly suggested the

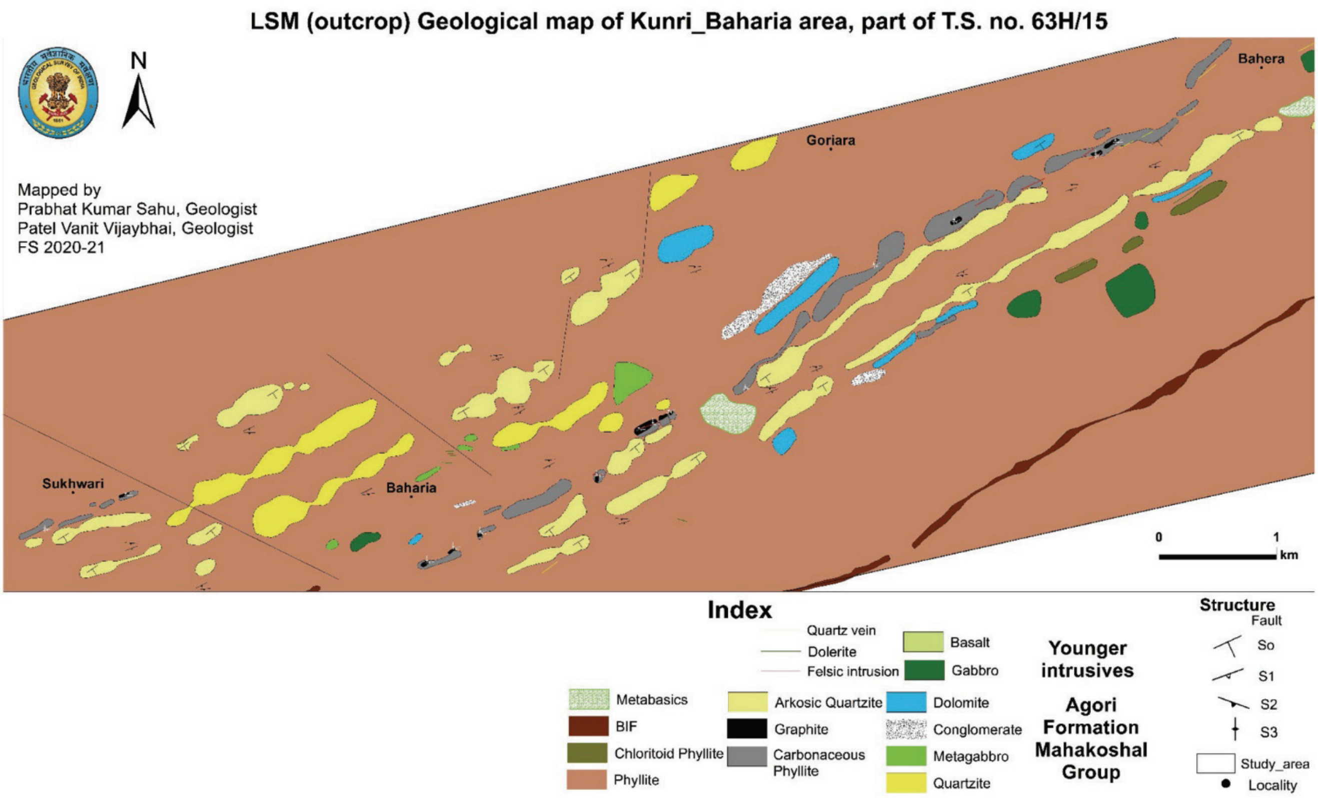

Figure 1. Part of a large-scale geological map (1 : 12,500) representing the disposition of actual outcrops of Agori Formation of Mahakoshal Group and younger intrusives in the Kunri–Baharia study area, part of toposheet no. 63H15 trending N60°E direction along with altitude measurements and two sets of faults. Lat.–long. of the map is removed deliberately. The map is cropped for a better view of graphite lenses and host-rock carbonaceous phyllite (CP).

Table 1. Fixed carbon values of carbonaceous phyllite host and graphite lenses

Sample no.	% Fixed carbon
ME/JBP/2020/BRS83/29805	2.90
ME/JBP/2020/BRS84/29805	2.25
ME/JBP/2020/BRS85/29805	2.40
ME/JBP/2020/BRS86/29805	3.15
ME/JBP/2020/BRS87/29805	1.15
ME/JBP/2020/BRS88/29805	1.60
ME/JBP/2020/BRS89/29805	2.55
ME/JBP/2020/BRS90/29805	2.80
ME/JBP/2020/BRS91/29805	2.90
ME/JBP/2020/BRS92/29805	3.40
ME/JBP/2020/BRS93/29805	2.65
ME/JBP/2020/BRS96/29805	2.35
ME/JBP/2020/BRS97/29805	4.05
ME/JBP/2020/BRS105/29805	2.45
ME/JBP/2020/BRS109/29805	5.10
ME/JBP/2020/BRS110/29805	4.40
ME/JBP/2020/BRS111/29805	4.45
ME/JBP/2020/BRS112/29805	5.85
ME/JBP/2020/BRS113/29805	4.40
ME/JBP/2020/BRS114/29805	5.45
ME/JBP/2020/BRS115/29805	2.50
ME/JBP/2020/BRS116/29805	4.25
ME/JBP/2020/BRS118/29805	5.70
ME/JBP/2020/BRS119/29805	4.40
ME/JBP/2020/BRS120/29805	4.15
ME/JBP/2020/BRS121/29805	2.55
ME/JBP/2020/BRS122/29805	3.65
ME/JBP/2020/BRS123/29805	3.10
ME/JBP/2020/BRS124/29805	4.60
ME/JBP/2020/BRS125/29805	2.45
ME/JBP/2020/BRS127/29805	4.25

Note: Each sample represents 5 m channel/groove sampling. Fixed carbon results of 81 samples are awaited. The lat.–long. of each sample are deliberately removed.

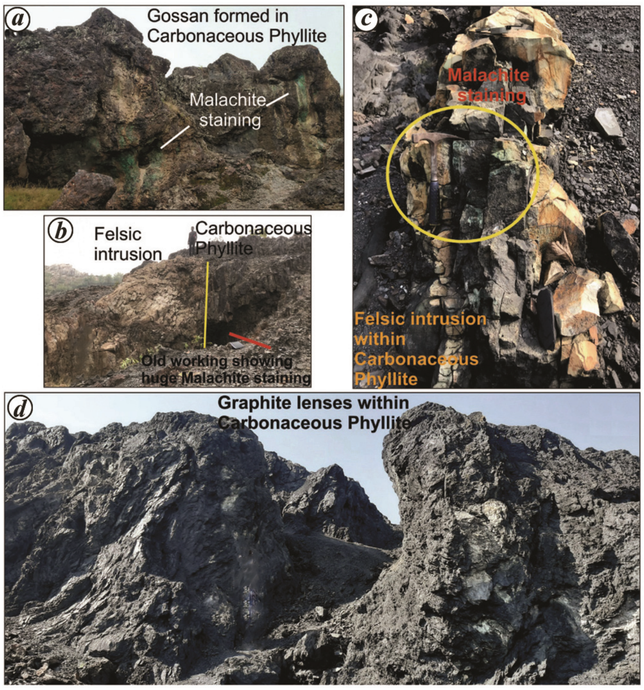

Figure 2. ***a***, The Gossan formed in CP showing huge Malachite stains and boxworks. It is highly ferruginized and limonitized. ***b***, ***c***, Felsic tuff observed in CP. ***b***, Old working showing huge malachite stains deep inside. ***d***, Graphite lenses within CP near the contact between mafic intrusion and CP.

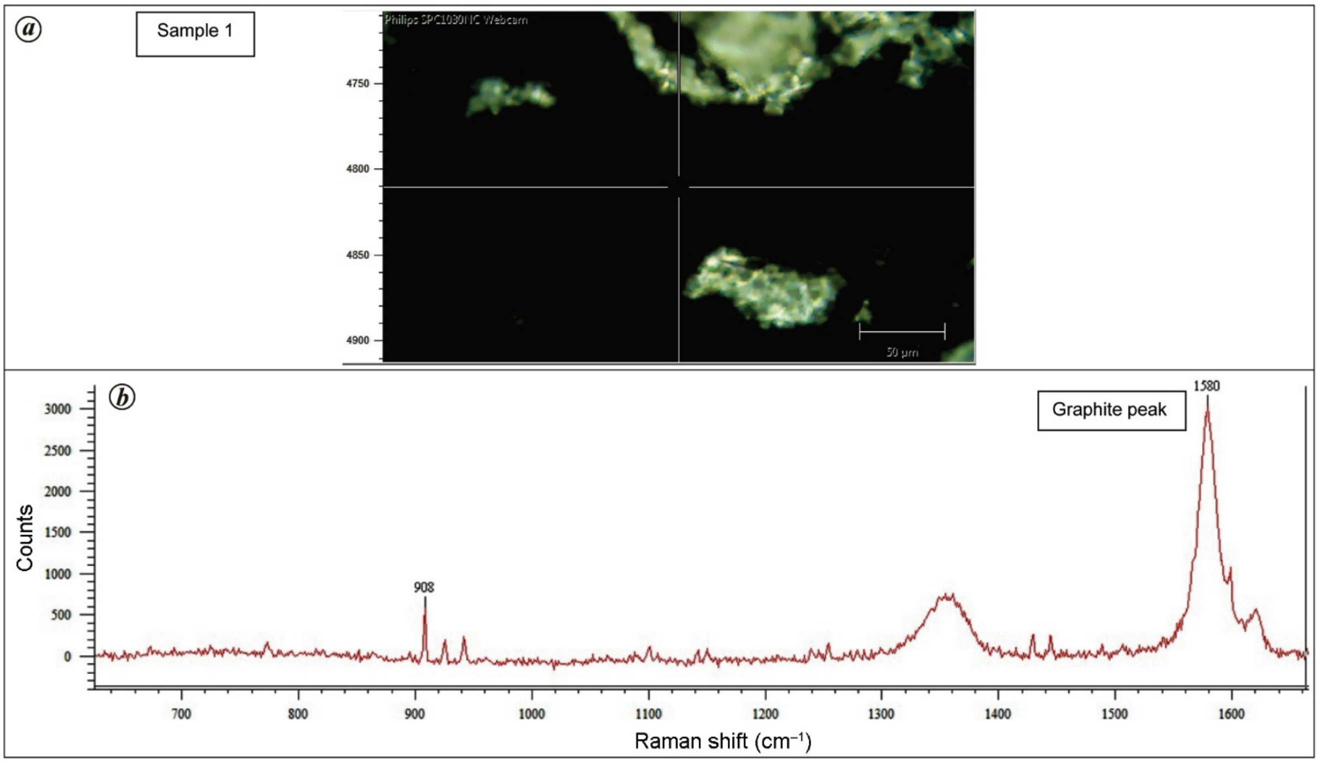

Figure 3. ***a***, Raman spectroscopic analysis at National Centre of Excellence in Geoscience Researches (NCEGR), GSI, Kolkata of sample 1 of graphite lenses associated within CP. ***b***, Graphite band (G) at 1580 cm^{-1}.

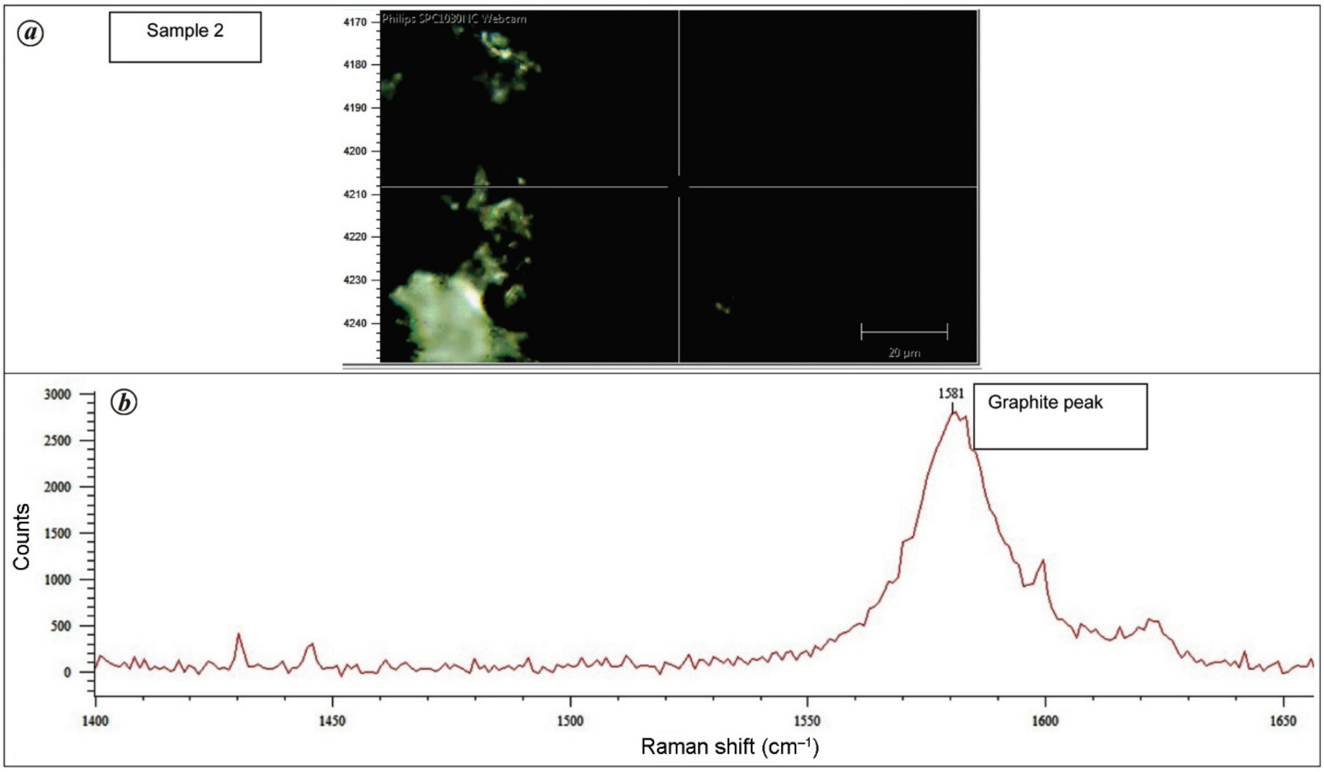

Figure 4. ***a***, Raman spectroscopic analysis at the NCEGR, GSI, Kolkata of sample 2 of graphite lenses associated within CP. ***b***, Graphite band (G) at 1581 cm^{-1}.

same. The polished sections for selective samples of the flaky carbon lenses were analysed using Raman spectroscopy at National Centre of Excellence in Geoscience Researches, GSI Kolkata. Three point measurements each for two polished sections gave graphite band (G) (Figures 3 and 4; 1580 and 1581 cm^{-1} respectively)[6] establishing the prevalence of graphite (Figure 2 *d*). The graphite lenses extend for a cumulative 650 m length and 20 m average width. The fixed carbon values of systematic channel/groove sampling of graphite lenses ranged from 2.06% to 5.85% (Table 1), against the Indian Bureau of Mines cut-off of 2% for crystalline flake variety.

The documentation of graphite lenses within the Palaeoproterozoic Mahakoshal Group increases the possibility of unearthing of rare earth elements and vanadium usually associated with graphite. In addition, the presence of huge malachite stains (Figure 2 *b* and *c*) and at places malachite and azurite encrustations supported by encouraging copper values up to 1.4% in the CP, suggest the multi-mineral potential of the area. Although earlier explorations carried out in this area for base metals did not result in delineating any significant resource[7,8], the confirmation of graphite in this domain opens up new opportunities for re-evaluating graphite potential of the area.

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Light-weight unmanned aerial vehicle surveys detect dugongs and other globally threatened marine species from the Andaman and Nicobar Islands, India

Unmanned aerial surveys are used across the globe to study marine megafauna as they cover large spatial scales, reduce survey effort and time, and are cost-effective[1,2]. Due to their utility in covering large areas and accessing remote locations, aerial surveys act as excellent tools to monitor several marine taxa such as elasmobranchs[3,4], marine turtles[5], pinnipeds[6], cetaceans[7], and sirenians including manatees[8] and dugongs[9,10].

Dugong is a globally threatened species of order Sirenia, assessed as vulnerable according to IUCN Red List of threatened species[11]. Its distribution spans from the east coast of Africa, parts of the Red Sea to the Indo-Pacific region, including India, Sri Lanka, Indonesia, Thailand, Malaysia and Australia[12]. In India, dugongs are found along the coasts of Gulf of Kutch (Gujarat), Gulf of Mannar and Palk Bay (Tamil Nadu), and Andaman and Nicobar Islands[13,14]. Also, their population in the country is considered regionally endangered[11] and is estimated to be less than 200–300 individuals[14]. This has prompted the Government of India to initiate the Endangered Species Recovery Programme for their long-term conservation and persistence[15]. However, estimating dugong population through traditional methods such as boat surveys is difficult in India due to their low detectability on the sea surface (lack of a prominent dorsal fin like dolphins) and rare occurrence (low population size)[14]. Aerial surveys have been previously utilized to study dugong distribution, estimate populations and determine their habitat use patterns in Australia[10,16,17]. In India, though aerial surveys were recommended to study dugongs[12,18], no efforts were undertaken prior to this study.

In the present study, we conducted reconnaissance aerial surveys to detect dugongs with an aim to systematically estimate their populations from known habitats. These areas have been identified with the help of dugong volunteering network established at the Andaman and Nicobar Islands consisting of fisherfolk, divers, boat operators and other regular seafarers[15]. The surveys were carried out with the involvement of the Department of Environment and Forests, Andaman and Nicobar Islands within the Marine Protected Areas of Mahatma Gandhi Marine National Park and Rani Jhansi Marine National Park, and