International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Customised Octacopter Drone-based Magnetic Survey for Exploration of Mn-Fe ores in Sidhan Area, Jabalpur District, Madhya Pradesh, India

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Abstract:

Encouraged by Digital Initiatives of the Government of India and NMDC's Version 2.0 plans, we have carried out Magnetic Survey and Hyperspectral Remote Sensing using Unmanned Aerial System (UAS) for the first time in India for Mineral Exploration. This paper briefly presents the findings of the Unmanned Aerial Vehicle (UAV; Customised Octacopter Drone) magnetic survey to explore Mn-Fe ores in Sidhan Block, Jabalpur District, Madhya Pradesh, India. The specifications of the UAV, flight parameters and magnetometer used for mineral exploration are also discussed in this paper.

Introduction:

Drone-based magnetic survey is an innovative method used in geophysical exploration to map subsurface magnetic properties. They offer several advantages over traditional ground-based and manned aerial surveys. Drones reduce the need for expensive manned aircraft or extensive ground crews, leading to significant cost savings in data acquisition; fewer personnel are required to operate drones compared to traditional survey methods, further lowering expenses and rapid deployment to survey areas, allowing faster data collection. Drones can cover large areas more rapidly than ground surveys, increasing the overall efficiency of the exploration process. Drones can fly at lower altitudes than manned aircraft, allowing for higher-resolution magnetic data acquisition, and the proximity to the ground ensures better resolution and more detailed magnetic anomaly detection. Drones can easily navigate and survey areas challenging for ground-based teams or manned aircraft, such as steep slopes, dense forests, and remote regions. Drones can fly in complex patterns and maintain consistent altitudes over varied terrains, ensuring comprehensive coverage (Yaoxin Zheng et al., 2021). The Unmanned Aerial Vehicle (UAV; Customised Octacopter Drone) magnetic surveys do not have an environmental impact as drones have a smaller environmental footprint than ground surveys, which may require cutting through vegetation or disturbing the landscape. They are quieter than manned aircraft, reducing noise pollution in sensitive areas. This is the first attempt in the country to utilise low-flight UAV-based magnetic surveys for identifying mineral potential targets, viz., Mn-Fe ores in Sidhan Block of Jabalpur, which belongs to Agori Formations of Mahakoshal Supergroup. In the future, these cost-effective and environmentally friendly UAV surveys will create a boom in mineral exploration.

Geology of Mahakoshal Supergroup:

Mahakoshal Supergroup is composed of schists, phyllites, quartzites, and metabasites. Schists are typically medium-grade metamorphic rocks with pronounced foliation, indicating significant pressure and temperature conditions during their formation. Quartzites are hard, non-foliated metamorphic rocks from pure quartz sandstone (Bandyopadhyay et al., 1990).

Banded Iron Formations (BIFs) within the Mahakoshal Supergroup are significant due to their geological and economic importance. BIFs are distinctive sedimentary rocks notable for their alternating layers of iron-rich minerals and silica (chert or jasper). The BIFs in the Mahakoshal Supergroup date back to the Proterozoic Eon, approximately 1.8 to 2.5 billion years ago (Bandyopadhyay et al., 1990). These were formed in ancient oceanic settings where iron was deposited from seawater in the presence of oxygen, creating alternating layers of iron oxides and silica.

BIFs within the Mahakoshal belt are primarily found in the districts of Balaghat, Jabalpur, and surrounding regions where these formations are exposed. The BIFs in the Mahakoshal Group have undergone metamorphism and deformation, resulting in folded and faulted structures. The BIFs and Manganese reported in Mahakoshals belong to the Agori Formation. The study area is shown in Figure 1.

Banded Iron Formations in Sidhan Block of Mahakoshals:

Banded Hematite Jasper (BHJ) in the area occurs mainly as a simultaneous layering of hematite and jasper. Hematite is dark reddish-black in colour, and Jasper is dark pinkish. The band thickness of hematite varies from 0.2 cm to 5 cm, and the jasper bands range from 0.1 cm to 3 cm. *In situ* Banded Hematite Quartzite (BHQ) bodies are found in the study area. The hematite layer is dark reddish-black, and the quartz is whitish-coloured in the hand specimen. The band thickness of hematite and quartz in BHQ is almost identical to that of BHJ.

Manganese (Mn-Fe) Deposits and Occurences in Sidhan Mn-Fe block of Mahakoshals:

The manganese deposits in the Mahakoshal Group are primarily associated with Precambrian rocks, particularly within the Proterozoic sequence of the Agori Formation. The Sidhan block deposits are typically found in stratiform to strata-bound layers, often associated with banded iron formations (BIFs) and other sedimentary rocks. The manganese ores generally exhibit colloidal, meta-colloidal or stalactitic textures. The zonal growth of different manganese minerals, i.e., psilomelane and pyrolusite, is apparent in the colloidal texture. In contrast, the meta-colloidal texture is represented by concentric bands with minute shrinkage cracks developed during crystallization. The stalactitic texture shows cyclic concentric stalactites of psilomelane and pyrolusite. The samples from the study area are shown in Figures 2 a to d.

Specifications of the Customised Octacopter Drone and Magnetometer:

The Unmanned Aerial Vehicle (UAV) was a customised Octacopter Drone by Marut (Figure 3 a). Specifications of the customised octacopter drone include a payload capacity of 8 kgs, endurance of 15-20 minutes, range of 1 km LOS, altitude of 1 km LOS, position accuracy of less than 2 m, stability at a location of <0.5 m (as measured in altitude hold mode) and frame and propeller of carbon frame material. The magnetometer used for the survey was Geometrics-Magarrow (USA make) with an operating principle of Laser-pumped Cesium vapour (Cs^{133} non-radioactive). The major specifications of the Magarrow magnetometer, as specified during the purchase of the instrument, are an operating range of 20,000 to 1,00,000 n T, gradient tolerance of 10,000 n T, noise/sensitivity 0.005 n T/√Hzrms, sample rate of 1000 Hz synchronised to GPS1PPS, GPS commercial grade with typical 1m accuracy and heading range/error +/- 5 n T over entire 360^0 equatorial and polar spins, the bandwidth of 400 Hz and weight of 950 gms (Figures 3 b and c).

Flight Planning and Processing of UAV Magnetic Data:
Before flying the UAV for magnetic data acquisition, the site topography, access roads and launch stations, weather conditions, flight line spacings, flight height, area coverage, geology and mineralization zone and survey duration were planned. The flight lines are kept in the N-S direction, oblique to the formation trends (ENE-WSW) in the Sidhan Mn-Fe block in Jabalpur District. The flight height was 30 m AGL (above ground level) with a line spacing of 50 m. The distance of the launch station was within a 500 m radius. The UAV flight planning was done using Mission Planner Software (Figure 3d).

Results of Customised Drone-based Magnetic Surveys for Mn-Fe par block in Sidhan area, Jabalpur District, Madhya Pradesh:
For the first time in India, an Unmanned Aerial Vehicle (Customised Octacopter Drone) was used to conduct ground magnetic surveys in the Sidhan block for exploration of Mn-Fe ores in Jabalpur District, Madhya Pradesh (Figure 4). The magnetic data acquired was processed using the Geometrics software. The Relative Magnetic Field anomaly map was generated (reading concerning a base station), and the anomaly map generated is shown in Figure 4. The anomaly map shows an ENE-WSW trend that corroborates with the trend of the formations. The Mn-Fe ore body is characterised by magnetic high. The same was corroborated with drilled Borehole BH-8A. The geochemical samples in the magnetic high also indicated Mn grades ranging from 5.9 to 52 % Mn. The phyllites also have an ENE-WSW trend characterised by magnetic lows. The geological map and Mn-Fe mineralisation correlate well with the Relative Magnetic Field anomaly map. Based on the results of UAV-based magnetic surveys in this region, the same method could help identify more such prospects in different Archean and Proterozoic terrains in India in general and Agori Formations of the Mahakoshal Belt in Jabalpur District in particular.

ACKNOWLEDGEMENTS
The authors thank Shri Amitava Mukherjee, CMD, and Shri D. K. Mohanty, Director (Production), for their support and encouragement in conducting the surveys and publishing this paper. The views expressed in this paper are those of the Authors and do not represent those of the Organization/Institute they are working with.

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List of Figures:

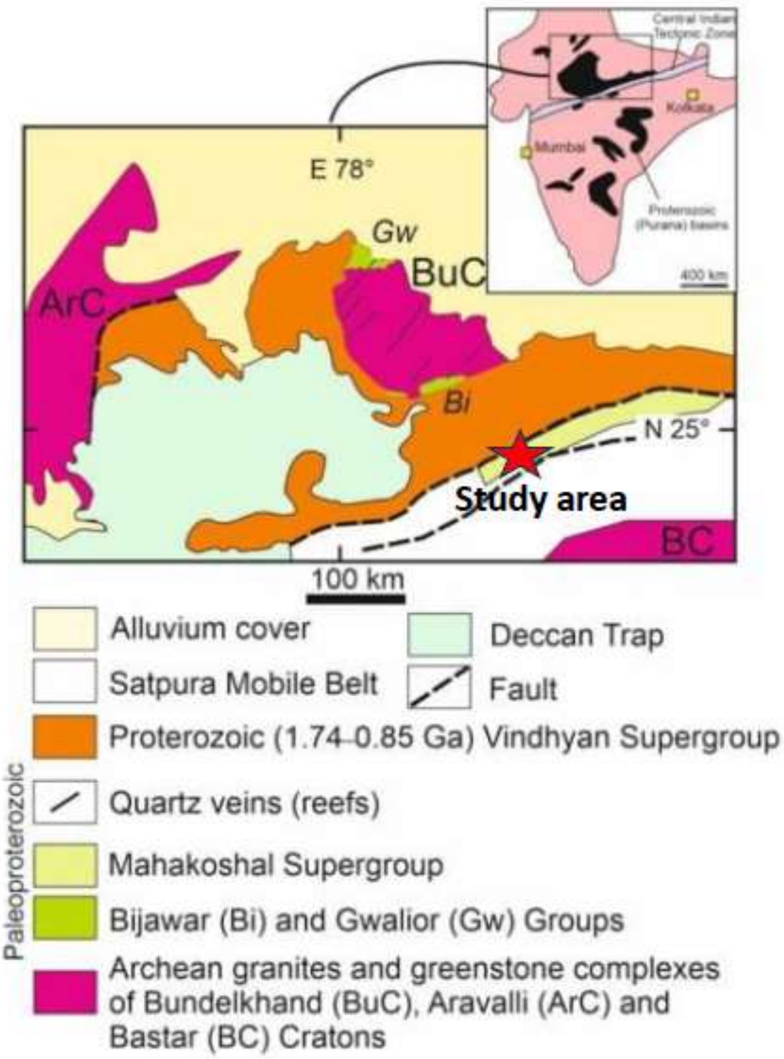

Figure.1 Map showing the study area which was flown for UAV-based magnetic surveys in Sidhan Mn-Fe block, Jabalpur District(map modified after Slabunov and Vinod Singh,2022)

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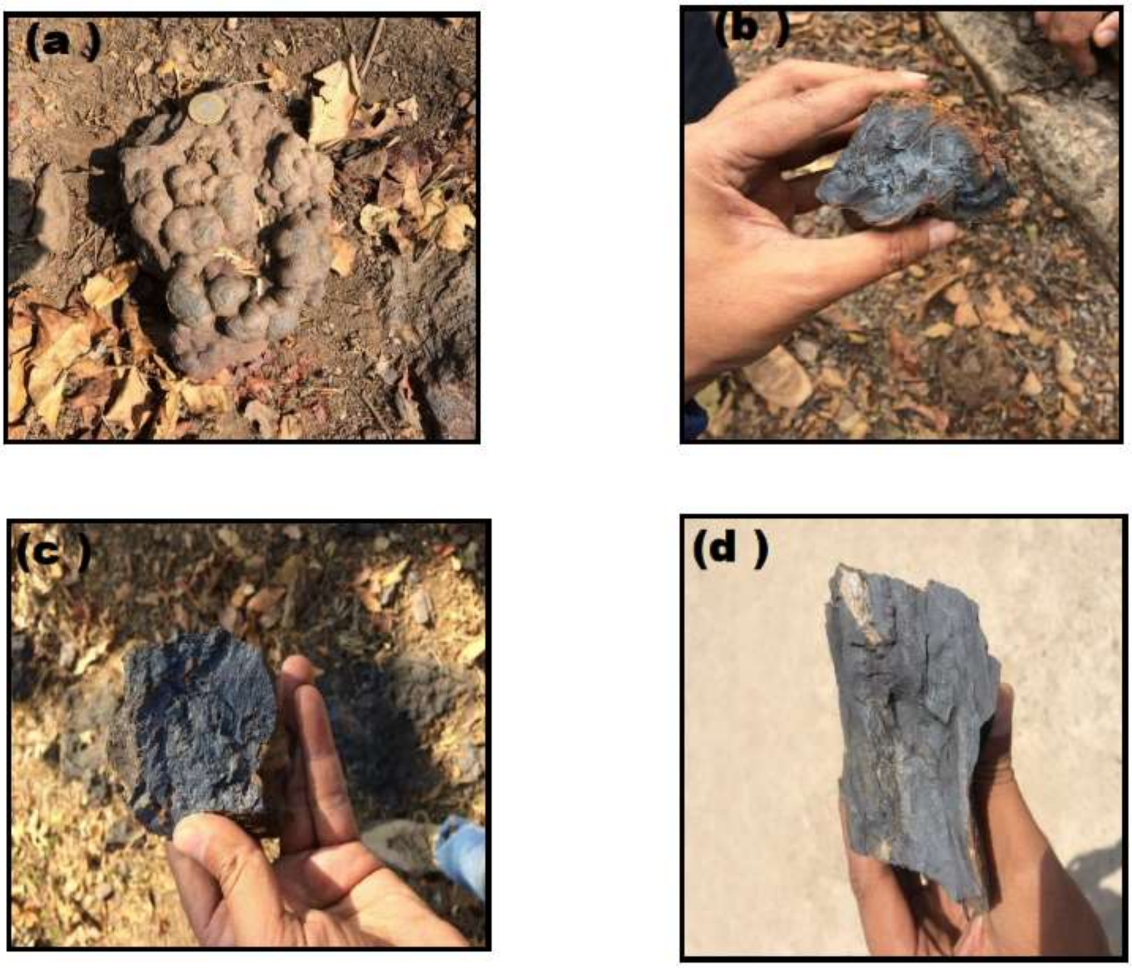

Figure 2 Manganese bearing samples from Sidhan Mn-Fe block, Jabalpur District (a) Psilomelane in the field (b) Hand specimen of pyrolusite (c) Siliceous hand specimen (d) Ferruginous manganese ore

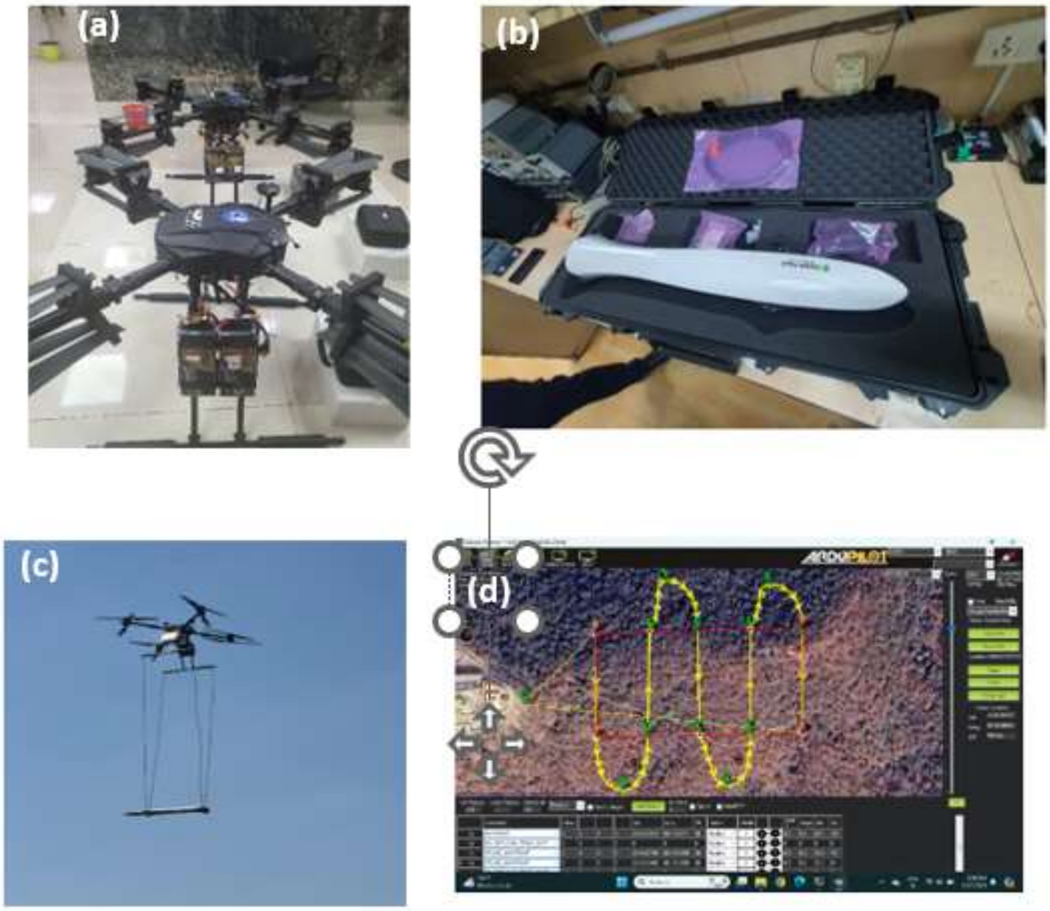

Figure 3 (a) Octacopter Drone used for the survey (b) Geometrics-Magarrow cesium vapour magnetometer (c) Octacopter drone with magnetometer flown at 30m AGL(d) Mission planning using Mission Planner for the survey

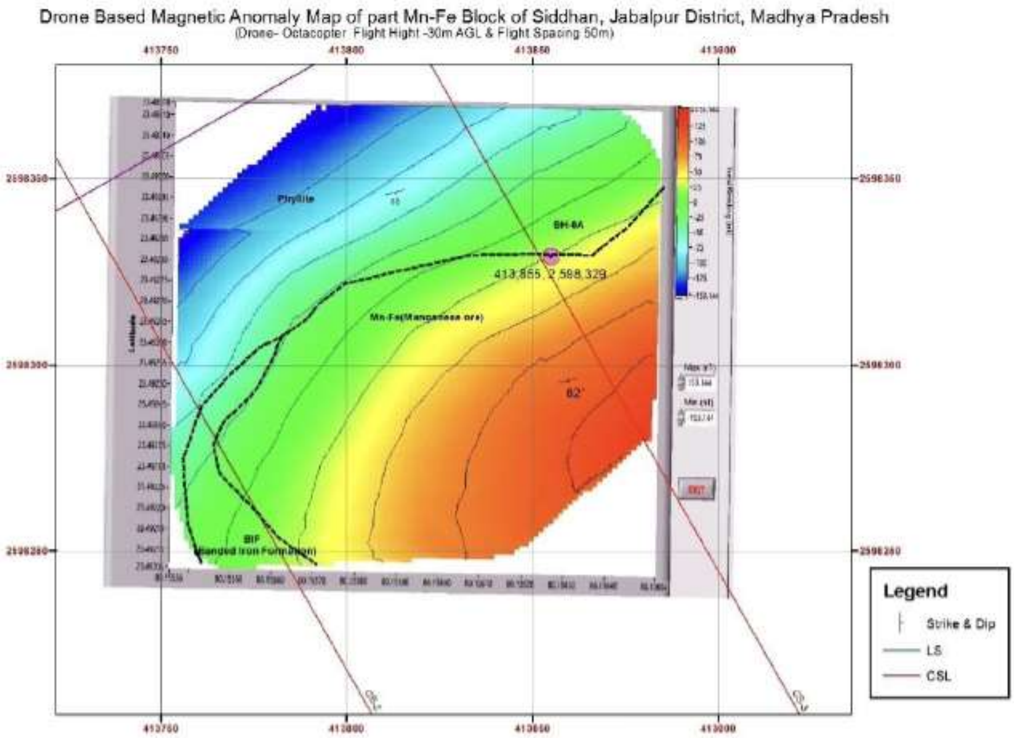

Figure 4. UAS-based Relative Magnetic Field Map over Sidhan Mn-Fe block using Geometrics software