Gravity-Magnetic Studies for Uranium Exploration Over Manbazar-Kutni Area of South Purulia Shear Zone (SPSZ), West Bengal, India Using Hydro-Uranium Anomalies as Guidance

Correlation between gravity-magnetic and hydro-uranium anomalies for prospecting of uranium mineralization

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Abstract*—Both tectonic belt, the South Purulia Shear Zone (SPSZ) and the Singhbhum Shear Zone (SSZ) within the Singhbhum craton of East Indian Shield, has been identified with similar geometrical shape and mineralization. The mineralization of these regions is mainly structural guided and hydrothermally generated. An integrated gravity-magnetic study has been conducted around Manbazar-Kutni area across SPSZ to decipher the subsurface configurations, presence of faults/fractures. These structural features may form favourable condition for mineralization. The first degree trend surface separated residual gravity as well as the Bouguer gravity and magnetic anomaly maps depicted the ESE-WNW trending SPSZ on the SW part of the area. The observed negative gravity and moderately high magnetic anomalies around Dighi, Chepua villages are also characterized by medium to high hydro-uranium anomaly from earlier hydro-uranium anomaly studies. Therefore, the negative gravity and moderate positive magnetic anomaly zones are concluded to be hydrothermally altered brecciated zone and the possible uranium mineralized zone. The interpreted faults /lineaments from the gravity-magnetic anomaly maps show good correlation with the exposed one and with the hydro-uranium anomalous zones. Further, the 2D gravity model across the shear zone depicts three low density altered zones (most likely sheared granite and mineralization zone) over the granitic basement along SW-NE profile from Kutni to Chepua village under a thin cover of granitic schist of CGGC. Since surface signature of nuclear radiation has not been observed, uranium mineralized zone could be at a large depth within these altered zones. Thus, the study demonstrates the effectiveness of gravity-magnetic methods in delineating subsurface configuration and to identify the altered zones/faults/lineaments which will act as favourable factors for structural guided radioactive mineralization in conjunction with other know mineralization indication.

(Keywords–SPSZ, Gravity, Magnetic, 2D model, hydro-uranium)

I. INTRODUCTION

India's main uranium producing mines are located along the Singhbhum Shear Zone (SSZ) of Eastern Indian Shield [1] which is also popularly known as Singhbhum copper-uranium belt (IAEA, 1986; Gupta and Sarangi, 2005). South Purulia Shear Zone (SPSZ) on the north of Singhbhum Shear Zone (SSZ) has been identified with similar geometrical shape and mineralization like SSZ. Both the tectonic belts are characterised by intense shearing, brecciation and hydrothermal alteration zones associated with significant mineralization of uranium-copper-apatite-magnetite–REE [2], [3], [4], [5]. The identified mineralization at SPSZ mostly hosted by ferruginous kaolin rocks and highly altered quartz-magnetite-apatite rocks (Katti et al., 2010). These similarities among the two shear zones increase the possibility of the existence of uranium mineralization along South Purulia Shear Zone. Again, Dwivedi et al. [6], identified some hydro-uranium anomalous zones within the study area through hydro geochemical study on the water samples collected from the hand pump of the area. But there was no surface signature of radioactivity within the study area. This clearly indicates that the possible radioactive mineralization is deeply seated. This may be guided by some structural features like, subsurface faults, fractures or alteration zone. This can only be inferred by geophysical studies. However, till now no detail geophysical study has performed in this region in search of uranium mineralization. Therefore, the present geophysical study focuses to delineate the subsurface configuration, the alteration zones, and their correlation with the hydro-uranium anomalous zones for the exploration of uranium mineralization. This correlation will ultimately help to plan the future subsurface exploration programme.

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II. REGIONAL GEOLOGY OF THE AREA

The boundary between the North Singhbhum Mobile Belt (NSMB) and the Chottanagpur Granite Gneissic Complex (CGGC) in East Indian Shield is marked by a roughly E-W trending, narrow zone (average width of 4-5 km) commonly referred as South Purulia Shear Zone (SPSZ) (Figure 1). The present study area mainly falls in the southern side of Chhotanagpur Granite Gneissic Complex (CGGC) and also forms a part of a large shear zone, north of South Purulia Shear Zone (SPSZ). The major part of SPSZ is covered by felsic volcanics accompanied by mafic and ultramafic rock with subordinate metapelites [4]. Along the contact of SPSZ and CGGC, thin linear bands/lenses of tourmalinite, quartz reef, quartz breccias, ferruginous breccias, schroll and mylonitic rocks are profusely developed. The general trend of the foliation along the shear zone is E-W to ESE-WNW with steep dip due north or south or vertical at places. The shear zone shows ductile to brittle-ductile deformational pattern [4] associated with intense brecciation, mylonitization and hydrothermal alterations accompanied by development of apatite, magnetite, base metal, rare metals, rare earth and uranium [2], [3], [5]. The metabasic rocks composed of dolerite and amphibolites occurring as sills /dykes are exposed in the southeastern part of the area. Thus, the target mineralization may be found within the granitic basement and along some altered zones may be associated with magnetic material. These zones can be identified with gravity-magnetic study.

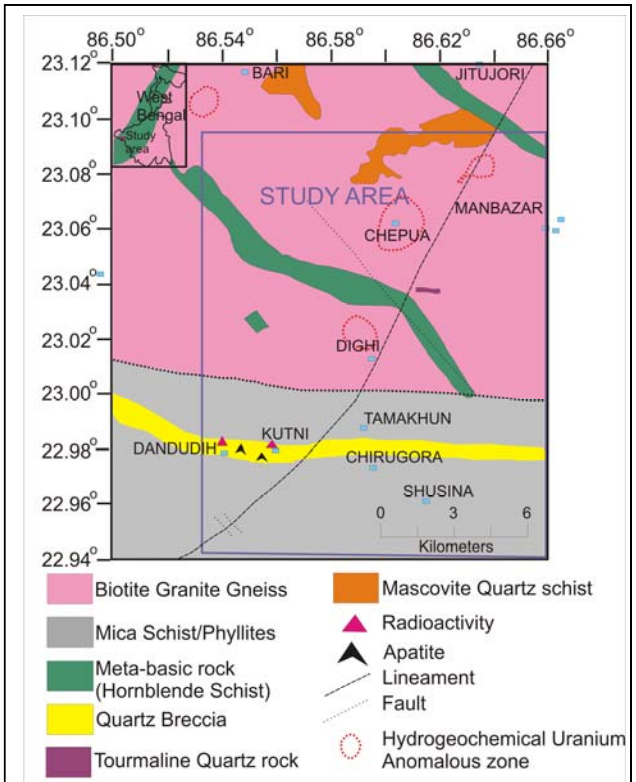

Figure 1: Geological map of the study area (modified after Dwivedi et al. [6]).

III. GEOPHYSICAL DATA

A. Gravity

All total 460 gravity observations were performed across the South Purulia Shear Zone along different approachable paths over Manbazar-Kutni area (Figure 1). This study was executed by a W. Sodin gravimeter (sensitivity 0.01 mGal) with a station spacing of nearly 200-250 m. The gravity measurements obtained from the study area were tied to the nearest absolute gravity base station at Purulia railway station (Absolute gravity value (g_n) = 978796.73 mGal) [7]. All the recorded gravity data were reduced to the datum plane value following the standard procedures to keep the effect of subsurface mass only. Theoretical gravity value was calculated using Geodetic Reference System 1967 (GRS67). To compute the Bouguer correction, the average crustal density was taken as 2670 kg/m^3 (Hinze, 2003; Lawal and Akaolisa, 2006). Bouguer anomaly map after the data reduction is shown in Figure 2. Using first degree polynomial as the regional trend in the trend surface analysis [8], the residual anomaly (Figure 3) is obtained from Bouguer anomaly.

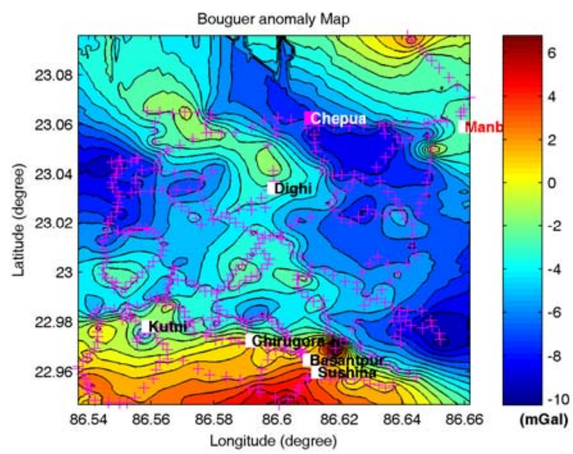

Figure 2: Bouguer gravity anomaly map of the study area.

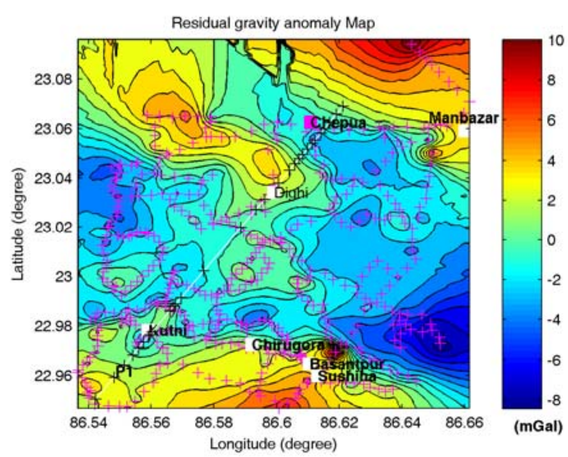

Figure 3: Residual gravity anomaly map of the study area after first degree trend surface polynomial separation from Bouguer anomaly. P1 is the profile line.

B. Magnetic

The magnetic observation was performed using a proton precession magnetometer (sensitivity = 1 nT) at nearly 368 locations over the present study area. The magnetic data were subjected to diurnal and International geomagnetic reference field (2011) model [9], corrections to derive the magnetic anomaly. The magnetic anomalies do not appear vertically above the anomalous body and are asymmetric in nature due to the dipolar nature of magnetic field and inclination-declination of the Earth's magnetic field (Roest and Pilkington, 1993). These distortions in magnetic anomalies can be removed by the reduction-to-pole (RTP) method. The reduced to pole magnetic anomaly map (Figure 4) is obtained by the analytical signal approach using a Hilbert transform [10].

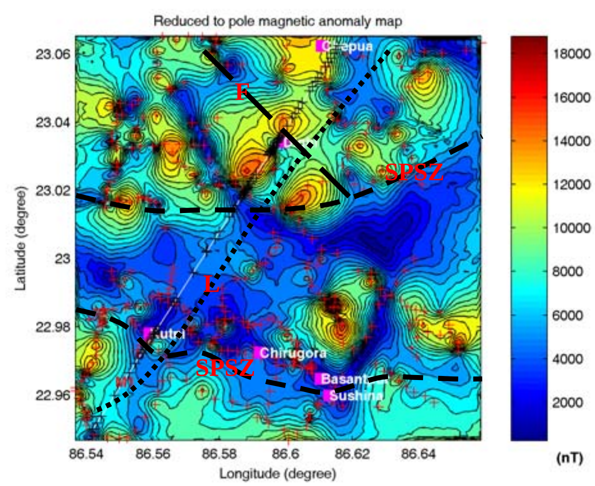

Figure 4: Reduced to pole magnetic anomaly map of the study area. 'F' is the existing fault and 'L' is the existing lineament. M1 is the profile line.

IV. RESULTS

The gravity-magnetic anomaly maps show good correlation with the exposed metabasic rocks and the shear zone extension. The southern boundary of SPSZ is depicted as WE trending high-low transition region in the gravity (Figures 2 and 3) and reduced to pole magnetic anomaly map (Figure 4) of the present study area. The NE to NS trending moderate high gravity anomaly through Dighi village of the study area is due to the present of high density metabasic rocks within CGGC (Figures 1, 2, and 3). Reduced to pole magnetic anomaly depicts high-low anomaly regions throughout the study area. These anomaly patterns are indicating the intense brecciation, mylonitization, hydrothermal alterations and brittle to ductile nature of SPSZ. These high-low transition regions may also be the altered zones associated with mineralization. The existing fault between Chepua and Dighi villages is depicted in the residual gravity and reduced to pole magnetic anomaly maps (black dashed line, Figure 4). The lineament passing through Kutni, Dighi and Chepua villages also identified in the reduced to pole magnetic anomaly map (Figure 4). The low gravity regions near Dighi, Kutni, SE of Kutni (north of Basantpur) correlated well with the corresponding magnetic high anomalies at the same regions.

A. 2D residual gravity modeling

Two-dimensional modeling of the residual gravity anomaly along profile P1 (Figure 3) of the study area has been carried out by using GRAVMAG software [11]. This software calculates the gravity effect for solids of infinite strike length and polygonal cross-section using the solution of Hubbert (1948) and Talwani et al. (1959). The gravity modeling was constrained by the known surface geology. Most of the study areas are covered by the biotite granite gneiss and mica schist/phyllites whose average density is modeled as 2650 kg/m^3. The brecciated quartz channel almost parallel to the shear zone is modeled with a density of 2500 kg/m^3. The density of the exposed metabasic rocks (Hornblende schist) on the north of Dighi village and the phyllites, metabasic schist on the south Kutni village is taken in the range between 2970–2800 kg/m^3. The basement layer density is taken as 2670 kg/m^3. The best fitted 2D model with root-mean-square (r.m.s) misfit of 0.15 mGal along profile (P1) is shown in Figure 5. The gravity model reveals the steeply dipping structures with dip due north or south or mostly vertical at places. The SPSZ is identified as the lowest density zones (with density 2500 kg/m^3) due to its intense brecciation, mylonitization, hydrothermal alteration and brittle to ductile nature. The total width of the shear zone is nearly 12 km but it is frequently disturbed/intervened by the intrusive metabasic rocks along its length. The highest depth of the low density shear zone is ~900 m near to Chepua village.

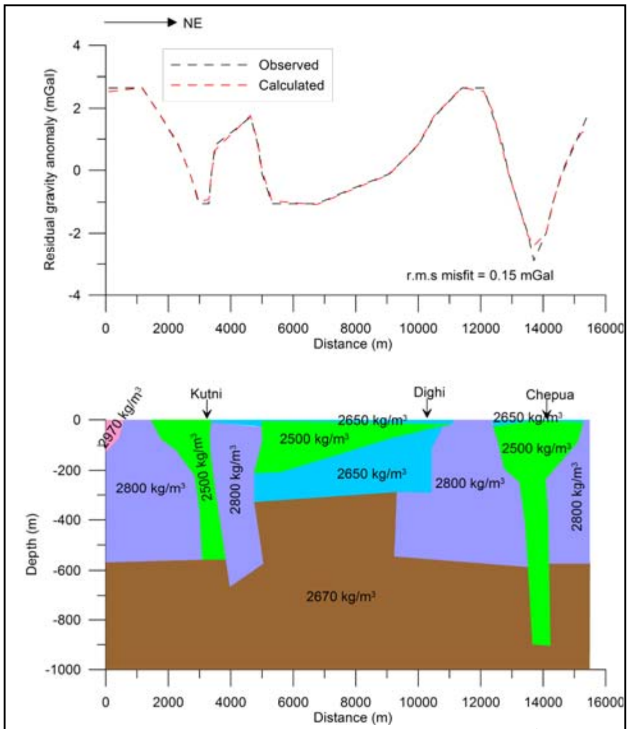

Figure 5: Two-Dimensional residual gravity model along profile P1.

V. DISCUSSION

The high horizontal gravity gradient at Chepua, Dighi, Kutni and Chirugora shows good correlation with the corresponding localized magnetic highs (Figures 3, 4 and 6). These types of correlations between gravity and magnetic anomalies are also observed exactly on the uranium mineralization zones at around 100 m depth over the Beldih apatite mines [12], on the western side of the SPSZ. Two-dimensional model along profile P1 also depicted highly altered low density zones in the subsurface geology exposed or under the granite gneiss over the same locations (Figure 5). These alteration zones are the favourable regions for hydrothermal activities and hydrothermally altered mineralization. According to Katti et al. [13], the ferruginous kaolin rocks and quartz-magnetite-apatite rocks are the host rocks for the mineralization of this region. Thus, the coincidences of the high horizontal gravity variation with the localized magnetic high indicate the mineralization zones (Figure 6).

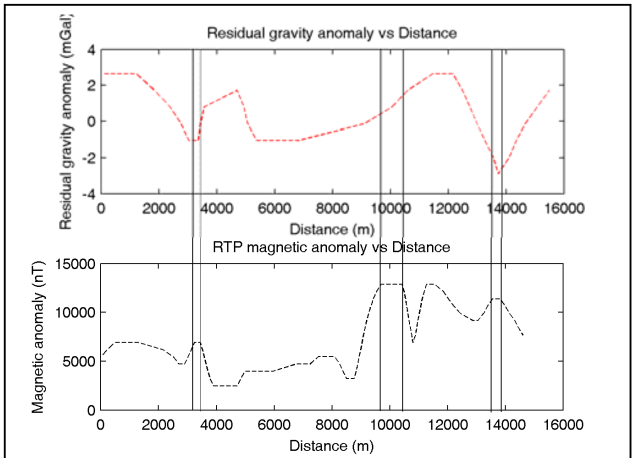

Figure 6: Correlation of residual gravity and reduced to pole magnetic anomalies over gravity profile P1 and magnetic profile M1.

Diwedi et al. [6], also identified some hydro-uranium anomalous zones at some locations over SPSZ form the water samples of tube well of ~30 m deep. The high hydro-uranium anomalies are observed near to the SE of Chepua (15-20 ppb) as well as towards the south of Dighi (10-40 ppb) villages of the study area (Figure 7). Thus, the high horizontal gravity gradient and localized high magnetic anomalous zones are coinciding with the high hydro-uranium anomalous zones near to Chepua and Dighi villages. This gives the signature of uranium mineralization at depth over these altered zones.

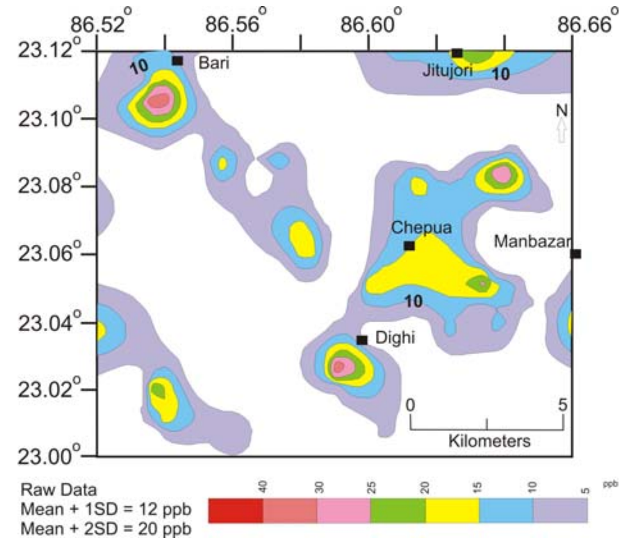

Figure 7: Hydro-uranium anomalous zones over Manbazar area after Dwivedi et al. [6].

VI. CONCLUSIONS

The regional gravity-magnetic study over the Manbazar-Kutni area of the SPSZ depicts good correlation with the surface geology and anomaly maps. The alteration zones, interpreted faults/lineaments are well agreement with the surface observation. The maximum possible depth of the alteration zones are concluded as 900 m from the 2D residual model. This study concluded that the coincidence of high horizontal gravity variation with the localized magnetic high may be the signature of hydrothermally altered radioactive mineralization over the study region. Three uranium prospective zones namely, near to Kutni, SW of Dighi, and Chepua villages have been identified based on the present study. Hence, the study shows the effectiveness of gravity-magnetic methods to delineate the subsurface features and uranium prospective zones in conjunction with other indication of radioactive mineralization. This study also provides thorough understanding about the area to help the future exploration porgramme over the prospective zones.

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