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Geological appraisal over the Singhbhum-Orissa Craton, India using GOCE, EIGEN6-C2 and in situ gravity data

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ABSTRACT

The gravity field and derivatives generated with the high resolution EIGEN-6C2 gravity model which includes satellite gravity data of GOCE (Gravity field and steady-state Ocean Circulation Explorer) has been utilized for geological appraisal of the Singhbhum-Orissa Craton, India. The GOCE only field gravity data and in situ gravity data of the same area have been utilized for comparative assessment to validate the results derived by EIGEN-6C2 gravity data. The GOCE and EIGEN-6C2 Bouguer gravity data have been generated from GOCE and EIGEN-6C2 Free-air gravity data, respectively, after removing topography effect. The result shows that correlation coefficient and covariance between the Bouguer gravity anomaly distribution of in situ and EIGEN-6C2 data of the entire study area are 0.68 and 93.9 $mgal^2$, respectively. The GOCE field compares well to the terrestrial derivative fields in the long-wavelength part of the signal. Further, EIGEN-6C2 and in situ Bouguer gravity data have been analyzed using the 1st and 2nd Vertical Derivatives, Analytical Signal and Tilt Derivative mapping techniques. Published geological and structural maps of the area have been overlapped over different derivative maps and the analytical signal map to analyze the correlation with the subsurface geology and geological structures of the area. Major distinct geological signatures, on different derivative maps and analytical signal map, are correlated well with the existing geological map. The TDR derived from the EIGEN-6C2 Bouguer anomaly has been used to map geologic contacts. The source boundaries and depths are determined from the zero contours, and the half distance between $\pm\pi/4$ contours or the distance between zero and $+\pi/4$ or $-\pi/4$ contour of TDR, respectively. The gravity data generated from EIGEN-6C2 model provides sufficient resolution for understanding of the geological setting of the Singhbhum-Orissa Craton.

Introduction

The understanding of gravitational imprint of different lithological units, lineament, dykes, faults and their interpretation from the satellite gravity data for geological exploration and tectonic studies is an emergent area of research. With advancement of recent technology, different state-of-the-art satellite based gravity models are developed by various researchers (Andersen, 2010; Andersen et al., 2009; Bruinsma et al., 2009, 2010; Bouman et al., 2009; Förste et al., 2008, 2013; Pail et al., 2010, 2011; Pavlis et al., 2008; Stammer et al., 2002; Tapley et al., 2007; Braitenberg and Ebbing, 2009; Braitenberg et al., 2011) for understanding Earth's geological and geodynamical processes.

The GOCE is a satellite gravity mission of the European Space Agency (ESA) launched in March 17, 2009, for measuring the Earth's gravity field and modeling the geoid with extremely high accuracy and spatial resolution. The payload instruments of GOCE satellite are the Electrostatic Gravity Gradiometer (EGG), a set of six 3-axis accelerometers mounted in a diamond configuration in an ultra-stable structure. Each accelerometer pair forms a gradiometer arm of 50 cm long, with the difference in gravitational pull measured between the two ends. Three arms are mounted orthogonally: along-track, cross-track and vertically. The gradiometer measures gravity gradients in all directions. It is specifically designed for the stationary gravity field – measuring the geoid and gravity anomalies with high accuracy and high spatial resolution (http://www.esa.int/Our_Activities/Observing_the_Earth/GOCE/Payload).

The EIGEN-6C2 (European Improved Gravity model of the Earth by new techniques) is a new combined global gravity field model including GOCE data up to degree and order 1949. Although, GOCE

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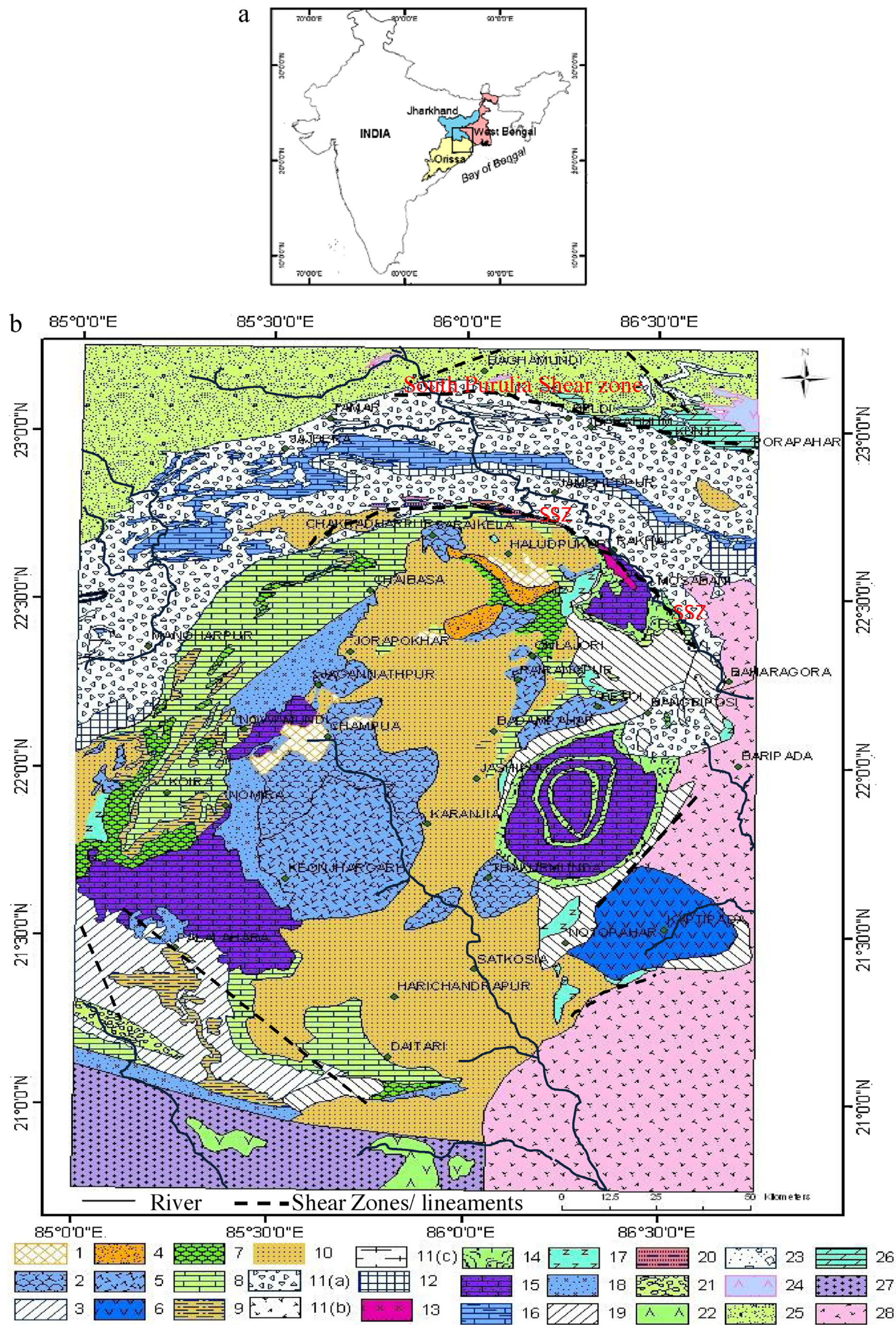

Fig. 1. a: Location map of the study area covering parts of Jharkhand, Orissa and West Bengal States. b: Geological map of the study area (after Saha, 1994). 1—Older Metamorphic Group; 2—Older Metamorphic Tonalite-gneiss; 3—Pala Lahara Gneiss; 4—Singhbhum Granite-Phase-I; 5—Singhbhum Granite-Phase-II and xenolith-dominated areas of Bonai Granite; 6—Nilgiri Granite; 7—Iron Ore Group lavas, ultramafics; 8—Iron Ore Group shales, tuffs, phyllites; 9—BHJ, BHQ and sandstone-conglomerate of Iron Ore Group; 10—Singhbhum Granite–Phase-III, Bonai Granite, Chakradharpur Granite; 11(a)—Singhbhum Group pelites(111), 11(b)—mafic bodis(112), 11(c)—carbon phyllite(113); 12—Singhbhum Group quartzites; 13—Dhanjori Group(unclassified); 14—Quartzite-conglomerate-pelite of Dhanjori Group; 15—Dhanjari-Simlipal-Jagannathpur-Malangtoli lavas; 16—Dalma Lavas; 17—Proterozoic Gabbro-anorthosite-ultramafics; 18—Kolhan Group and equivalents; 19—Mayurbanj Granite; 20—Soda granite, Arkasani Granite, Kuilapal Granite, alkaline granite; 21—Charnockite; 22—Khondalite; 23—Amphibolite enclaves (within CGG); 24—pelitic enclaves within CGG; 25—Chhotanagpur granite-gneiss (CGG); 26—Porphyritic member of CGG; 27—Gondwana sediments; 28—Alluvium, Tertiaries.