Revised Gravity Maps of India (2006 series) – A Cartographic Perspective

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ABSTRACT

Geological Survey of India (GSI), National Geophysical Research Institute (NGRI), Oil and Natural Gas Commission Limited (ONGC), Survey of India (SOI) and Oil India Limited (OIL) have jointly taken up a collaborative project to revise the Gravity Map of India Series (1:5,000,000) published in 1975. Basic gravity data collected over 143,786 stations by these organizations during the last two decades was synthesized for generation of Revised Gravity Map Series. Map Printing Division, Geological Survey of India, which has the *state of art* facilities in GIS and Digital Cartography, has been entrusted with the digital cartographic processing and final publication of Revised Gravity Maps of India (2006 series). The series comprises Free-air Gravity Map of India (1:2M), Bouguer Gravity Map of India (1:2M), Bouguer Gravity superposed over Geological Map of India (1:2M) and Gravity Image Map of India (1:5M).

The gravity anomaly contour data (both Free-air and Terrain-corrected Bouguer) in the DXF format, terrain-corrected Bouguer data as a perspective TIFF image and gravity station distributions as x, y ASCII data were the main inputs for digital cartographic processing and subsequent publication of these maps. Gravity anomaly contour, gravity image and station distribution data has been converted into geospatial format on Lambert Conformal Conic (LCC) projection by employing Intergraph's MGE suite and ESRI's ArcGIS applications and has been combined with the existing geospatial data (point, line and polygon) such as geology, drainage, transportation network, administrative boundaries, bathymetry etc. The various contour intervals have been suitably depicted with appropriate symbolization styles for Free-air and Bouguer gravity maps. Representation of the Bouguer gravity contour data over geology polygon data from published Geological Map of India (1998) is a challenging task and has been accomplished keeping in view of the importance and potential of this map for the utility of the geoscientists at large. The terrain-corrected Bouguer gravity perspective image was generated by interpolating the point-anomaly data through GeoSoft application at a resolution of 800 DPI. The cartographic designing process adopted for on-screen visualization and paper printing of all these maps especially Gravity Image Map of India is significant for its quality reproduction within a shortest period.

Introduction

The utility of regional gravity maps for interpretation of geological information is well recognized by Ram Babu (1986), Qureshy and Warsi (1980), Verma (1985, 1991) etc. In fact, correlation of gravity image of India with geology is spelt out by Ram Babu (1986) who opined the extension of Dharwar Craton up to Tapti River and the extension of Bundelkhand Craton below alluvium etc. However these geological and tectonic interpretations are based on the limited gravity data available for different parts of the country. The regional gravity maps of India brought out by NGRI in 1975 on 1:5 million scale were not serving fully the aspirations of modern geosceintific community in the light of recent trends in interpretation techniques and newer tools and data products. The five premier geosceintific organisations in India namely Geological Survey of India (GSI), National Geophysical Research Institute (NGRI), Survey of India (SOI), Oil and Natural Gas Commission (ONGC) and Oil India Limited (OIL) have together decided to revise the existing regional gravity map (Gravity Map, 1975). The aim of this collaborative effort was to publish a series of gravity maps on a slightly larger scale i.e. 1:2 million by collating the enormous amount of gravity data collected during the last four decades in various parts of the country by these organizations. Geological Survey of India and the National Geophysical Research Institute, Hyderabad, played a pivotal role in geophysical processing of the huge collection of gravity data. Geological Survey of India which has published several national thematic maps on 1:2 million scale took the responsibility of processing and printing of the Revised Gravity Map 2006 Series.

Revised Gravity Map of India 2006 Series published under restricted (for distribution) category include 4 maps viz. Free Air Gravity Anomaly Map of India, Bouguer Gravity Anomaly (Terrain Corrected) Map of India and Bouguer Gravity Anomalies (Terrain Corrected) Superposed on Geological Map of India on 2 million scale and Gravity Image Map of India on 5 million scale. The 2 million scale maps are four-sheeted (35 x 45 inches) maps where as the Gravity Image Map of India on 5 million is a single-sheeted (30 x 40 inches) map. The objective of the present paper is to explain the methodology adapted in digital cartographic processing of the anomaly data supplied and subsequent publishing of the 2006 Series, utilizing the in-house *state of the art* facilities in geospatial data processing and digital cartographic processing at Map Printing Division, GSI.

Data Source

Basic gravity data collected under various projects by the five collaborative organisations forms the main data source for the present work. The total number of stations from where gravity anomaly data was recorded is 143,786 and of these only 51,356 gravity stations at a uniform 3 minutes arc interval were selected for interpolation and subsequent contouring. GSI and NGRI together carried out the geophysical data processing and the input digital data supplied for map-making include gravity anomaly (contour) data in DXF format, station distribution data in the ASCII file and perspective Bouguer gravity image as unprojected and uncompressed tiff file. Besides, the digital data (MicroStation DGN format) of already published geological map (Geological Map of India, 1998) along with topographic base data on 2 m scale also constitutes the input data source.

Methodology

The main tasks associated with publication of revised gravity map 2006 series include i) Importing of contour data in DXF format, projecting the data on Lambert

Conformal Conic (LCC) projection so as to match it with existing digital topographic base, ii) Converting the station distribution data in ASCII format into geospatial point data on LCC projection, iii) Conversion of Bouguer image in TIFF format as GeoTiff on LCC projection, iv) Designing a suitable map layout keeping in view the different map scales and map sizes, devising a suitable map symbology and finalizing various other map and non-map elements for incorporation etc. and finally v) Generation of EPS files for printing of the maps through offset press.

The application software chosen in the present study include MicroSation95, Intergraph's MGE 7 with MapFinisher extension and ArcGIS 9.x (ArcInfo) ArcMap.

The gravity station distribution data which was in ASCII format comprises longitude and latitude values of each station as x-y coordinates separately for each of the collaborative organization. This data was transformed into point features on Lambert Conformal Conic projection by feature loader tool of ASCII loader application in MGE (Modular Geographic GIS Environment) software. Separate design files, thus generated were combined into a single DGN file and station distribution map of India on 2 million scale was generated. The point features were symbolized as open circles of 0.2 mm size in five different colors viz. red, blue, magenta, green and brown, to retain the identity of each organization's data (Fig.1).

The gravity anomaly contours covering the entire country both the free air and Bouguer at 5 mGal interval in the DXF format was imported to generate DGN file. Since the topographic base data such as drainage, transportation network, administrative boundaries, locations of major cities and towns, India's external boundaries, one degree latitude-longitude grid and bathymetry was already available in DGN format on LCC projection and therefore the imported anomaly data was also projected to LCC projection through affine transformation in MGE Projection Manager so as to ensure a perfect match with existing data (Fig.2). The anomaly values in the contour data range from the negative through zero to positive at 5 mGal interval. The negative and positive contours were symbolized as 2 mm thick lines in red and blue colors respectively. Each 50 mGal contour whether negative or positive, is depicted as 4 mm thick line to appreciate the gravity gradient. The zero contours were shown as 4 mm thick black lines. The map layout aesthetically designed include cartographically symbolized Station distribution data and base topographic data organized in various DGN layers combined with the contour data, respective titles, legend and organizational logos and thus composite Free Air Gravity Anomaly Map of India, Bouguer Gravity Anomaly (Terrain Corrected) Map of India were generated.

Geological Survey of India has published the Geological Map of India (1:2 M) in 1998. In this map various litho-units were represented as multi-colored polygons based on the standard CMYK color-scheme adapted by GSI. The DGN files of the Bouguer

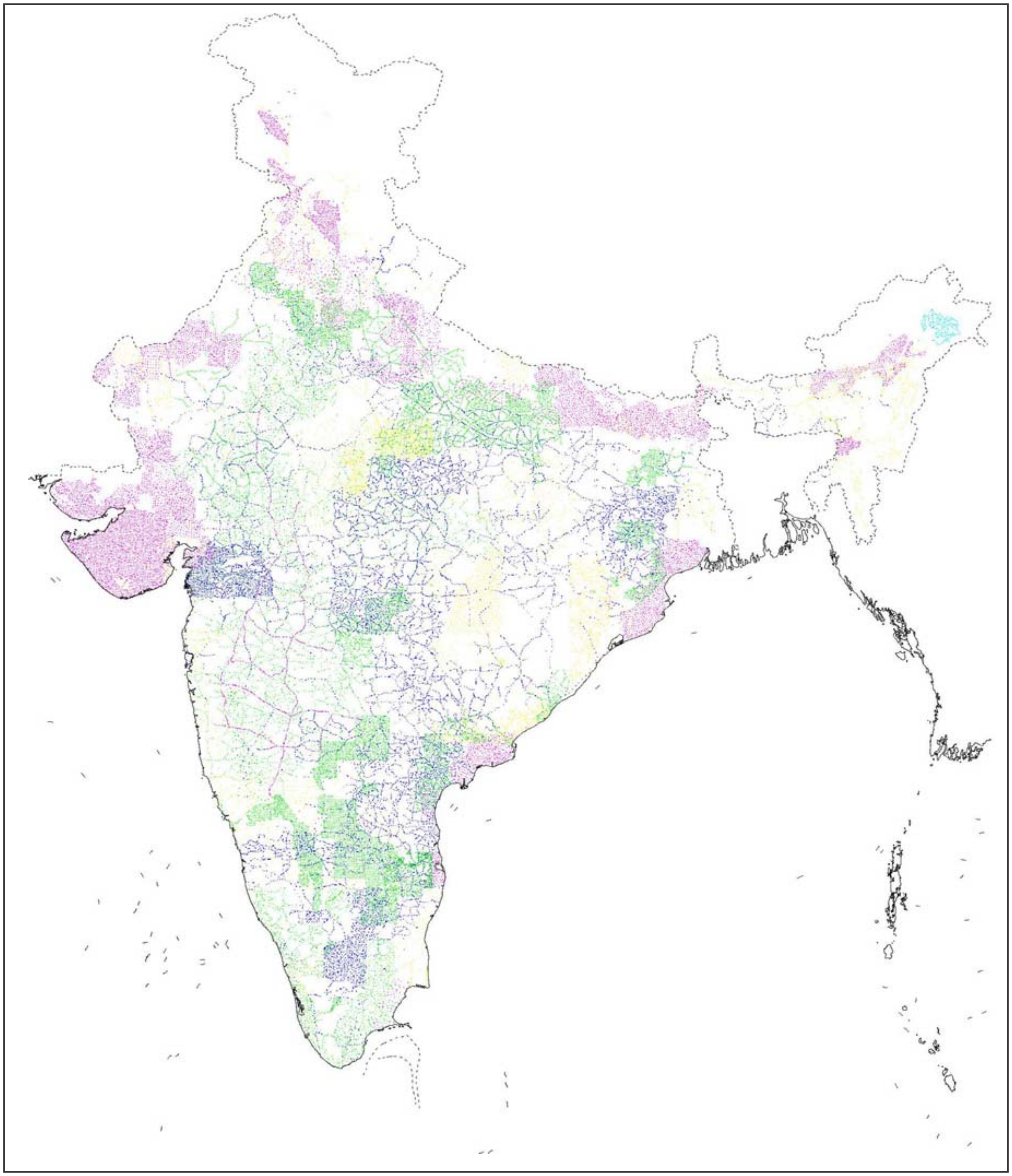

Fig.1**.** Gravity Station Distribution Map where in the collaborative Organization's stations are symbolized in distinctive colors.

Gravity Anomaly (Terrain Corrected) Map devoid of station distribution data was superimposed on the DGN files of geological map and thus 'Bouguer Gravity Anomalies (Terrain Corrected) Superposed on Geological Map of India' was generated. In order to appreciate the significance of gravity anomaly contours with the geological units, the

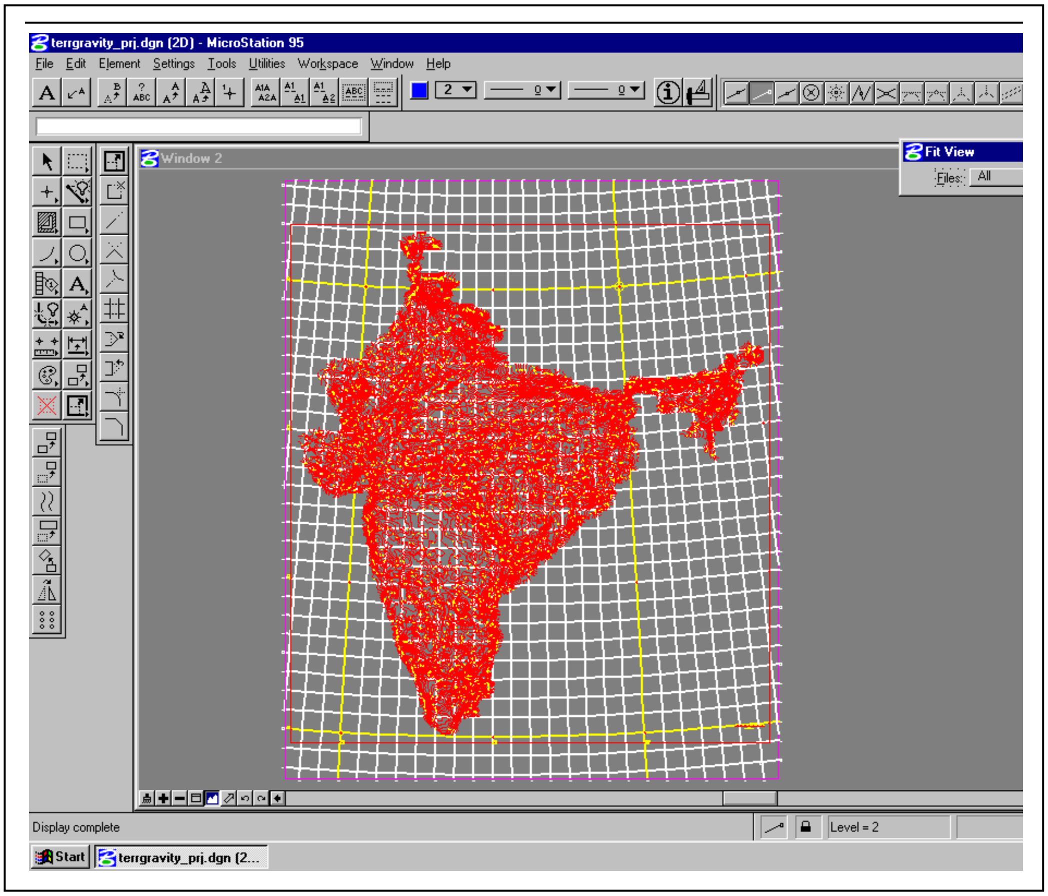

Fig.2 Gravity Contour Map being converted to LCC Projection in MGE-MicroStation.

colors of the background base geology including the alpha numerals were toned down in comparison to the original published map.

In view of the limitation of 35 x 45 inches as the maximum printing page size in Indian offset printing presses, each of the above three maps has been logically divided into NE, NW, SW and SE sheets of 35 x 45 inches size with 1.5 inches lateral overlap. Necessary markings were inserted to depict each part in the composite map. Encapsulated Postscript (EPS) files map-wise and sheet-wise were created from the DGN files through MGE MapFinisher and Intergraph's I/Plot Offline driver utility. CMYK color-separates were generated from these EPS files for offset plate making and final printing through 5-color offset press.

Based on the constraints experienced in MGE particularly in handling the image data, ArcGIS 9.x (ArcInfo) ArcMap application has been chosen for geospatial data processing, cartographic symbolization and subsequent publication of the Gravity Image Map on 5 million scale. The input supplied for this process was an unprojected Bouguer gravity (terrain corrected) perspective tiff image at 800 DPI generated by the interpolation point anomaly-point data through GeoSoft application. The first task was to georeference the unprojected image with the existing digital topographical base on LCC projection. Prior to this, all the base topography data which was in DGN format was imported to a new ArcGIS Personal Geodatabase on LCC spatial reference system. The main objective in generating this image map was to bring out a distinct 3D / perspective gravity image which aids the professional geoscientists, academia and researchers to visualize at a glance the various geological and tectonic features on the basis of gravity anomalies. The bathymetry data encircling the entire Indian coast available as a polygonal feature class has been introduced in this map so as to enhance the visibility of the image. The various bathymetry classes were depicted in shades of cyan. Apart from the coast line and International boundary, all the state capitals and a few important cities

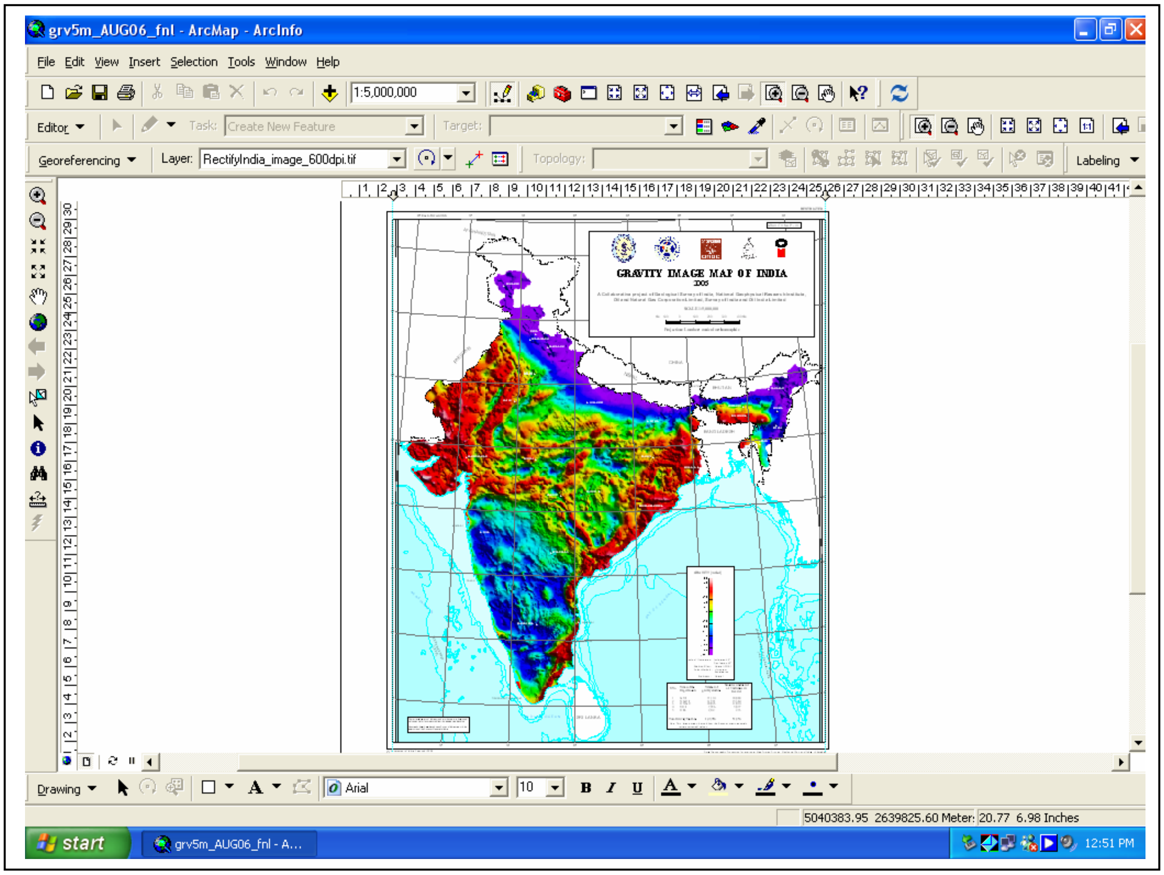

Fig. 3. Gravity Image Map of India.

as point features were depicted over the rectified gravity image. These point features were symbolized as filled 2 mm white circles. Since the map was to be composed on 5 million scale, taking the advantage of the LCC spatial reference system of the image and the feature classes, map scale was fixed or frozen in the data view before proceeding to the lay out view in ArcMap. Majority of the map design and composition including the introduction of labels, titles, legend, foot notes and organizational logos etc was done in ArcMap layout view. The graticule (Lat – Long grid) at 4 degree interval with the required labels were generated automatically in ArcMap based on the reference system of the input feature classes. The perspective Gravity image map thus composed and saved an MXD file is shown in Fig. 3. Here the image is shown in a color spectrum ranging from purple through blue, green and yellow up to red colors with grey shading to provide the three dimensional perspective view.

The finalized ArcMap MXD document of the image map has been exported to an EPS file for the generation of CMYK color-separates and subsequent offset printing. As the gravity image in the MXD file at 800 DPI is of enormous size, necessary care has been taken to choose a suitable DPI while generating the EPS file. The quality of the image in terms of sharpness drastically varied depending on the type of paper media chosen for printing. The Gravity Image Map on 200 gsm glossy / art paper and 8mm laminated board etc is excellent where as the same on a 120 gsm map litho paper is quite drab and 3D effect is not depicted effectively.

Conclusions

It is for the first time that three national level 4-sheeted thematic maps on 1:2 million scale and one on 1:5 million scale were published together within a short period is quite significant. This clearly amplifies the effort and ability of the authors in digital cartographic processing involving the layout designing, symbolization for point, line and polygon features, generation of color separates through Image setter and finally printing by offset press. The present work also provided an opportunity to explore the versatile and popular ArcGIS desktop application for map publishing through geospatial data processing. Further, it has been appreciated through the present work how the map quality changes depending on the type of paper media.

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