Bharathidasan University

Tiruchirappalli – 620 023, Tamil Nadu

6 Yr. Int. M.Tech. Geological Technology and Geoinformatics

Course Code : MTIGT1003 4 Credits

GIS BASED 3D VISUALIZATION IN GEOLOGICAL TECHNOLOGY

Unit-3: 3D Visualisation of Geophysical Data

Dr. K.PALANIVEL

Professor, Department of Remote Sensing

Course Objectives

- To learn the fundamentals of 3D visualization in GIS
- To study the possible methods of visualizing various Geological data
- To understand the ways and means of representing topographic relief in a 3 dimensional pattern
- To learn the methods of generating 3D images and interpretation of important geological structures using Geophysical data
- To learn the application of Geoinformatics in natural disaster mitigation.

MTIGT1003: GIS BASED 3D VISUALIZATION IN GEOLOGICAL TECHNOLOGY 4 Credits

Unit-1: Principles of 3D Visualization: Data Input (x, y, z) – Monoscopic and Stereoscopic 3D visualization; TIN – Vertical Exaggeration – DEM based visualization – Concepts of Shaded Relief mapping. **12 Hrs.**

Unit-2: 3D Visualisation of Topographic Data: Generation of x, y, z data – 3D visualization of topography – DEM based topographic analysis – shaded relief – applications. **12 Hrs.**

Unit-3: 3D Visualisation of Geophysical Data: X, Y, Z data from different sources – Generation of DEM, Different processed outputs of DEM, Shaded relief maps of Gravity, Magnetic and Resistivity data – Its applications. **16 Hrs.**

Unit-4: 3D Visualisation of Subsurface Lithology: Collection of borehole data – working out lithology and lithotop of various horizons – DEM of shaded relief of thickness of various formations, Depth of various formations and litho top of various formation – their interpretations. **12 Hrs.**

Unit-5: 3D Visualisation of Groundwater: Collection of water level and other aquifer variables (Transmissivity, Permeability, Storage co-efficient, etc.) – Generation of x, y, z – Generation of DEM and shaded relief of groundwater systems and interpretation. **12 Hrs.**

Unit:6. Current Contours: (Not for Final Exam only for Discussion): Step-by-step procedures for generation of high resolution DEM using CARTOSAT Stereo data; Derivation DEM products like Anaglyph and 3D Fence Diagram. Use of DEM for automated mapping of Geological Structures in GIS.

Course outcomes

After the successful completion of this course, the students are able to:

- Understand the concepts, develop GIS database and generate 3D visualization of Geological and other terrain features
- Know the fundamentals pertaining to volume estimation, drainage mapping, watershed delineation, slope classification using 3D visualization techniques
- Learn the method of 3D visualization of topographic data
- Understand the method of visualization of Geophysical data and their application
- Learn the method 3D visualization of subsurface lithology and its applications
- Understand the method of 3D visualization of groundwater and its applications.

References

- Burrough, PA., Principles of Geographical Information Systems, Oxford University Press, 1997.
- DeMers, Michael N, Fundamentals of Geographic Information Systems, John Wiley and Sons, 1999.
- David J., Bringing Geographical Information Systems into Business, Second Edition Grimshaw, John Wiley and Sons, 1999.
- Christian, Serving Maps on the Internet: Geographic Information on the World Wide Web Harder, ESRI Press, 1998.
- Graeme F. Bonham-Carter, Geographic Information Systems for Geoscientists: Modelling with GIS, Pergamon Publications, 1994.
- Sabins, F.F.Jr., Remote Sensing Principles and Interpretation, Freeman, Sanfrancisco. 1978.
- Lillisand, T.M. and P.W. Kiefer, Remote Sensing and Image Interpretation, John Wiley & Sons, New York, 1986.

Unit-3: 3D Visualisation of Geophysical Data

Unit-3: 3D Visualisation of Geophysical Data:

X, Y, Z data from different sources – Generation of DEM, Different processed outputs of DEM, Shaded relief maps of Gravity, Magnetic and Resistivity data – Its applications. **16 Hrs.**

Interpretation of 3D Visualised Geophysical Data

- **Identify indicators** – geological features formed over the surface due to the alteration of the subsurface economic mineral / ore deposits – Gangue,
- **Locate anomalous corridors** – Minimum, Maximum and abnormal values derived due to the proper functioning of the instruments
- **Locate abnormal changes in data** – sudden changes in the values – either decreasing or increasing from a normal value.

Interpretation of 3D Visualised Geophysical Data … contd…

- Areas with criss-crossing structural features
- Areas with folded geological structures – axial planes – areas of thickening and thinning of folded beds
- Areas with sudden variation in relief – increased – positive relief or decreased – negative relief
- Geomorphic landforms of specific nature – colluvial fills, alluvial fans, meander scars, palaeochannerls where placer deposits are located.
- Lithological contacts – bedding planes that are weaker – weathered – caved-in or having higher relief like a ridge.

Interpretation of 3D Visualised Geophysical Data … contd…

- Axes of maxima / minima values
  - To draw such axes, it is necessary to scan the value range for the entre study area in 3D
  - Identify the zones of minima and maxima and the isolines
  - Locate the acute curvatures of such consequent isolines
  - Connect such acute curves to get relevant axes.
- Alignment of such maxima and minima values

3D Layer Stacking with Layer Separation in GIS

- Geophysical seismic sounding, resistivity and bore hole logging surveys provides data for different depths,
- Depthwise layers can be generated for the area as 3D layers and stack them in GIS using **Layer stacking** option in GIS
- Provide proper ratio to the layers in different depths according to the spatial units using **layer separation** option in GIS platform
- So that it is easy to establish the connectivity of the subsurface structures

3D Visualization of GRAVITY Data

Case Study: 1

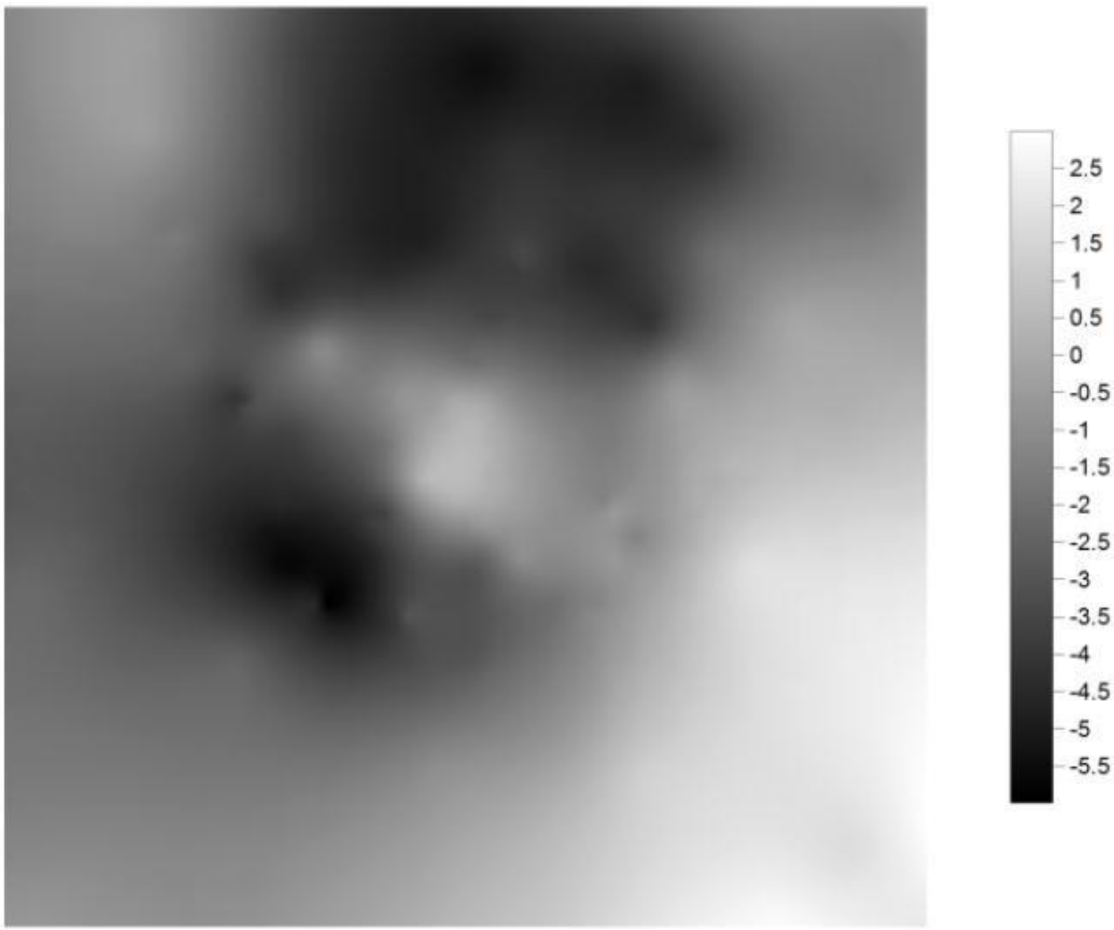
Visualization tips for geoscientists: Surfer

January 25, 2012 · by Matteo

- A part of the Apennine belt (in the Monti Romani of Southern Tuscany), a Paleozoic metamorphic basement (density ~2.7 g/cm3) is overlain by a thick sequence of clastic near-shore units of the Triassic-Oligocene Tuscany Nappe (density ~2.3 g/cm3).
- The Tuscan Nappe is in turn covered by the Cretaceous-Eocene flysh units of the Liguride Complex (density ~2.1 g/cm3).
- During the deformation of the Apennines, NE verging compressive thrusts caused doubling of the basement.
- The tectonic setting was later complicated by tensional block faulting with formation of horst-graben structures generally extend along NW-SE and N-S trends which were further disrupted by later and still active NE-SW normal faulting.

Visualization tips for geoscientists: Surfer

Figure 1 – Grayscale residual anomalies in milligals. This version of the (grey scale representation)map was generated using the IMAGE MAP option in Surfer.



Complex tectonic history can place the basement in lateral contact with the less dense rocks of the younger formations and this is reflected in the residual anomaly map of Figure 1. Roughly speaking, there is a high in the SE quadrant of ~3.0 mgal corresponding to the location of the largest basement outcrop, an NW-SE elongated high of ~0.5 mgal in the centre bound by lows on both the SW and NE (~-6.0 and ~-5.0 mgal, respectively), and finally a local high in the N.W. quadrant of ~-0.5 mGal. From this we can infer that in this area can infer that the systems of normal faults caused differential sinking of the top of basement in different blocks leaving an isolated high in the middle, which is consistent with the described tectonic history.

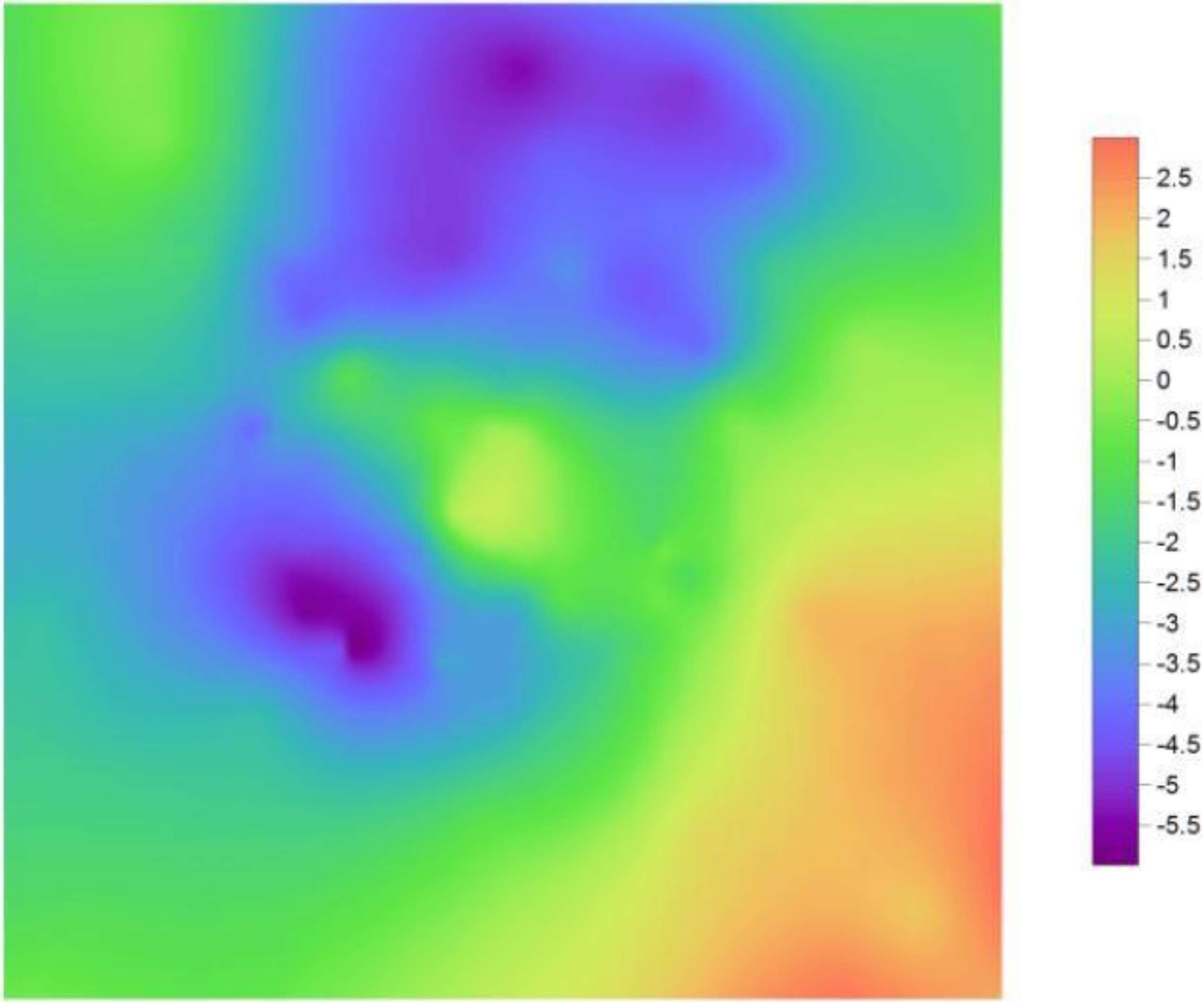


Figure 2 – Colored residual anomalies in milligals. This version of the map was generated using the IMAGE MAP option in Surfer.

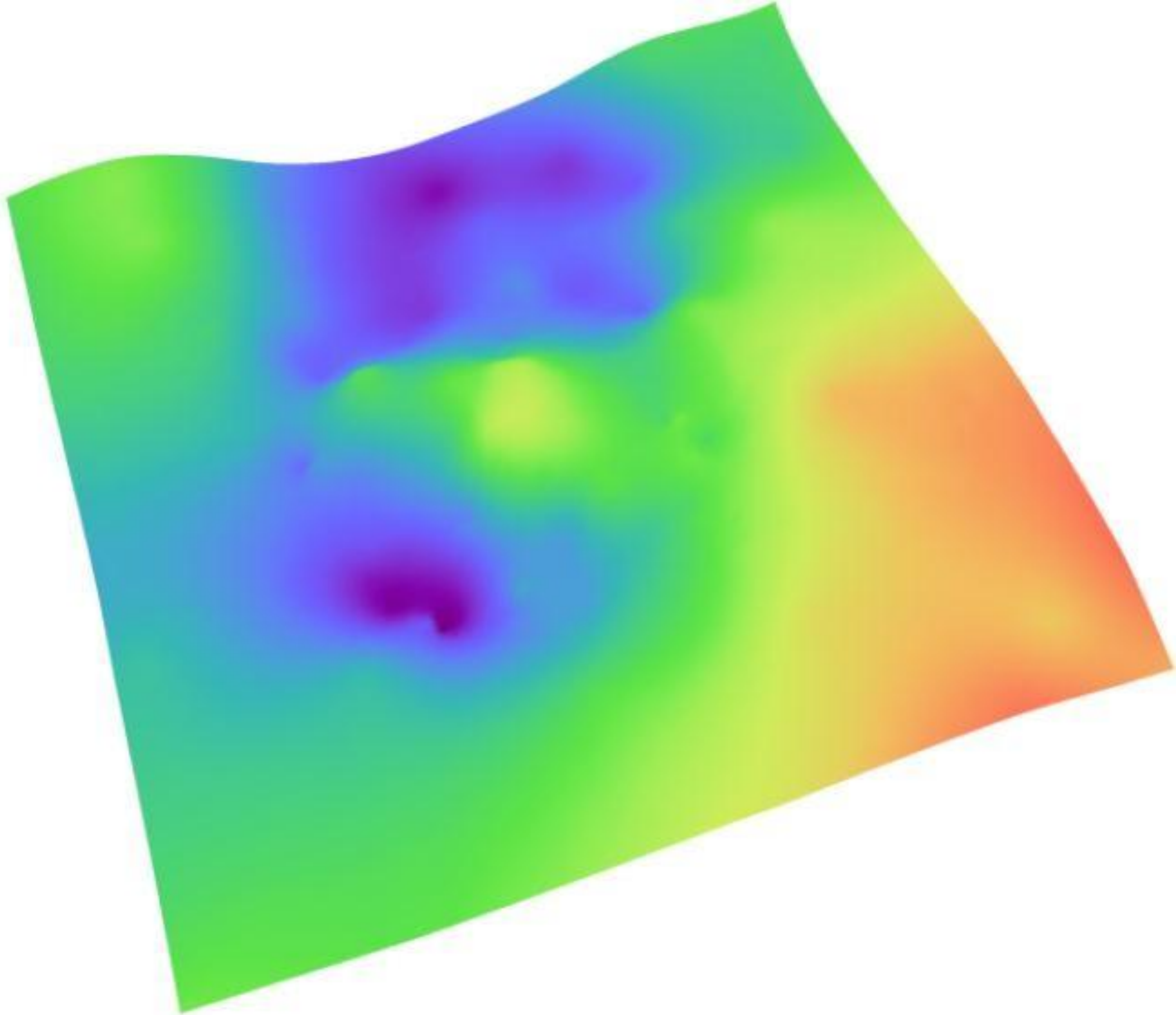


Figure 3 – Colored 3D residual anomaly map in milligals. This version of the map was generated using the SURFACE MAP option in Surfer.

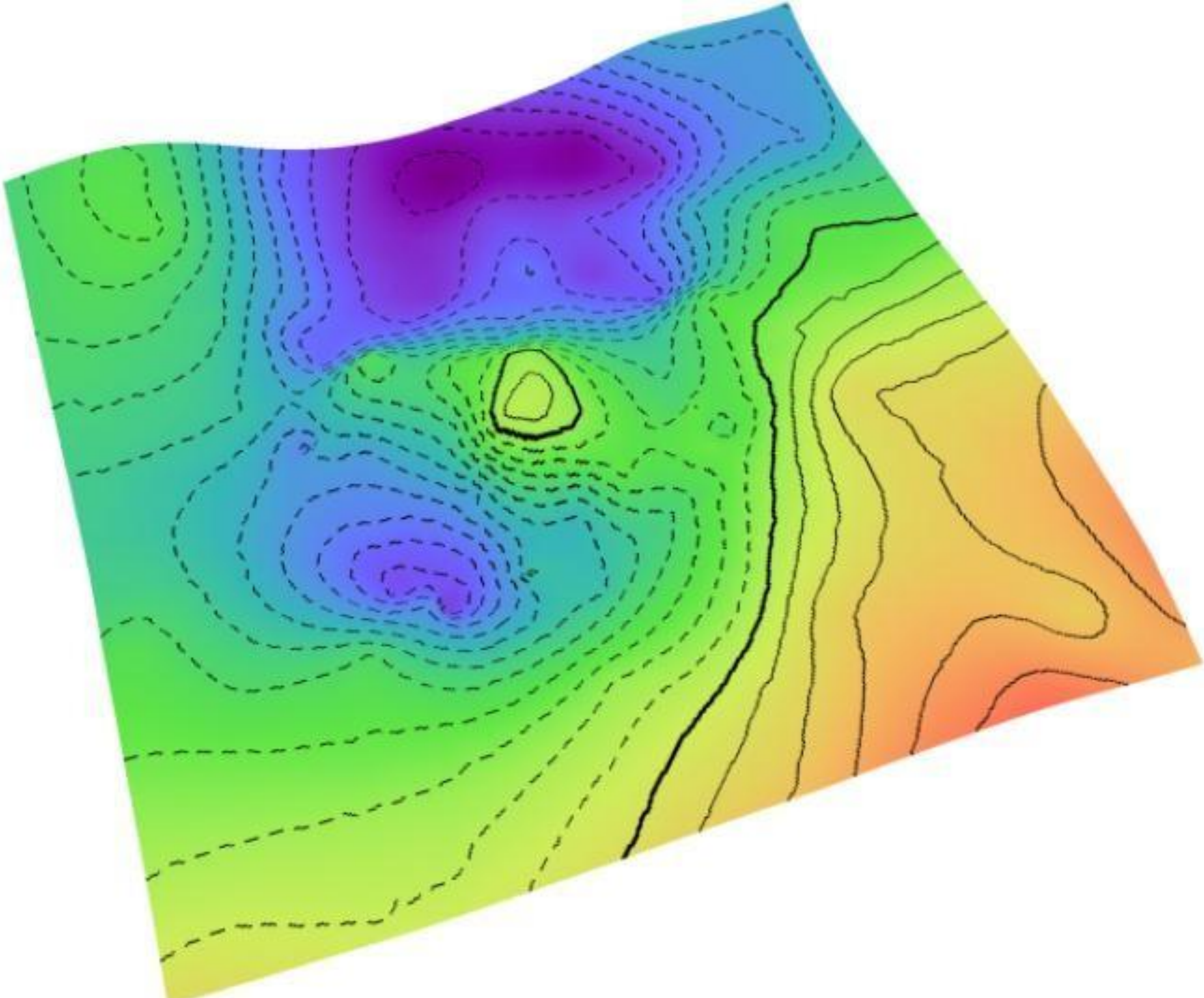


Figure 4 – Colored 3D residual anomaly map in milligals. Contours were added with the the CONTOUR MAP option in Surfer.

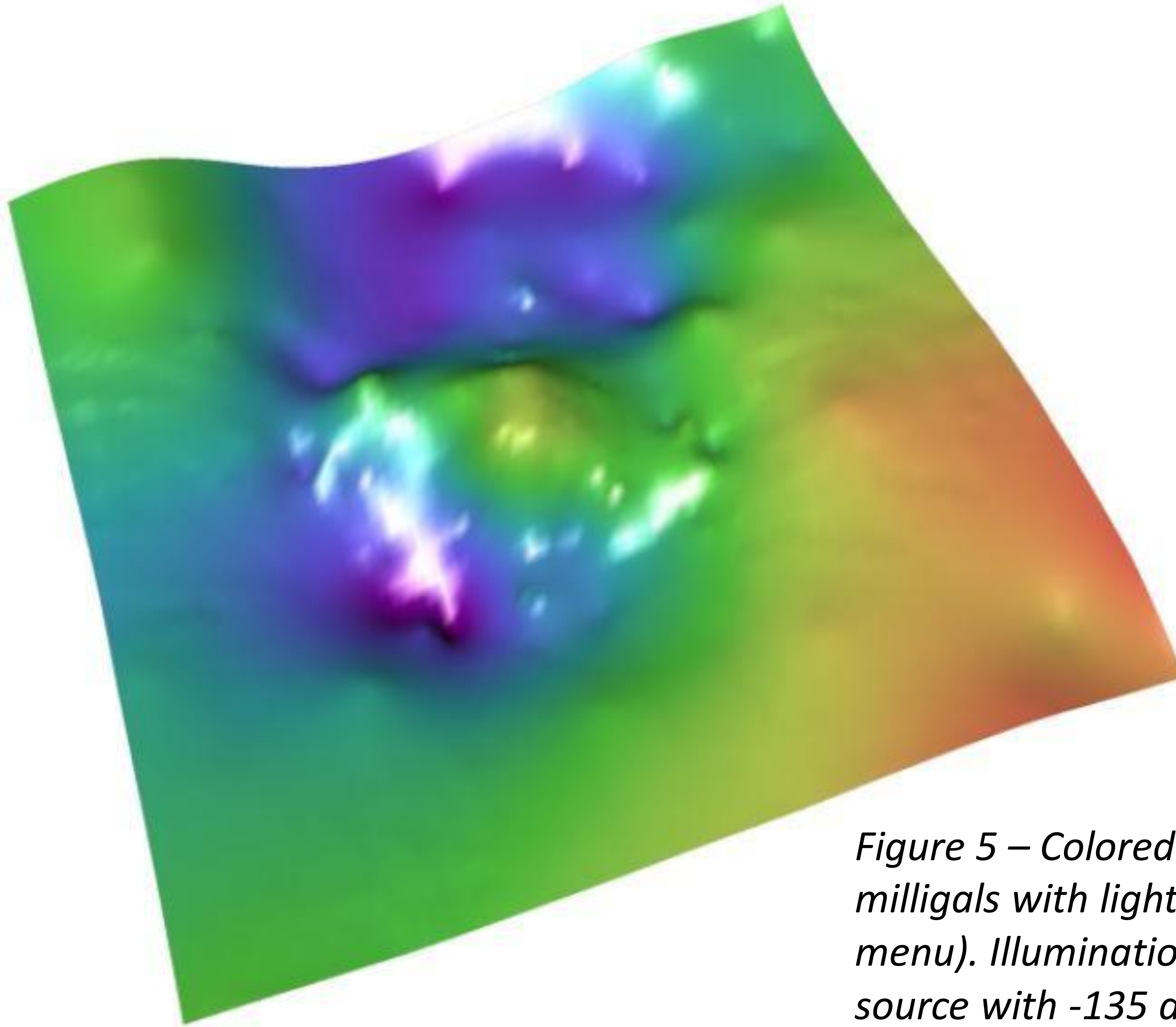


Figure 5 – Colored 3D residual anomaly map in milligals with lighting (3D Surface Properties menu). Illumination is generated by a point source with -135 deg azimuth and 60 deg elevation, plus an additional 80% gray ambient light, a 30% gray diffuse light, and a 10% gray specular light.

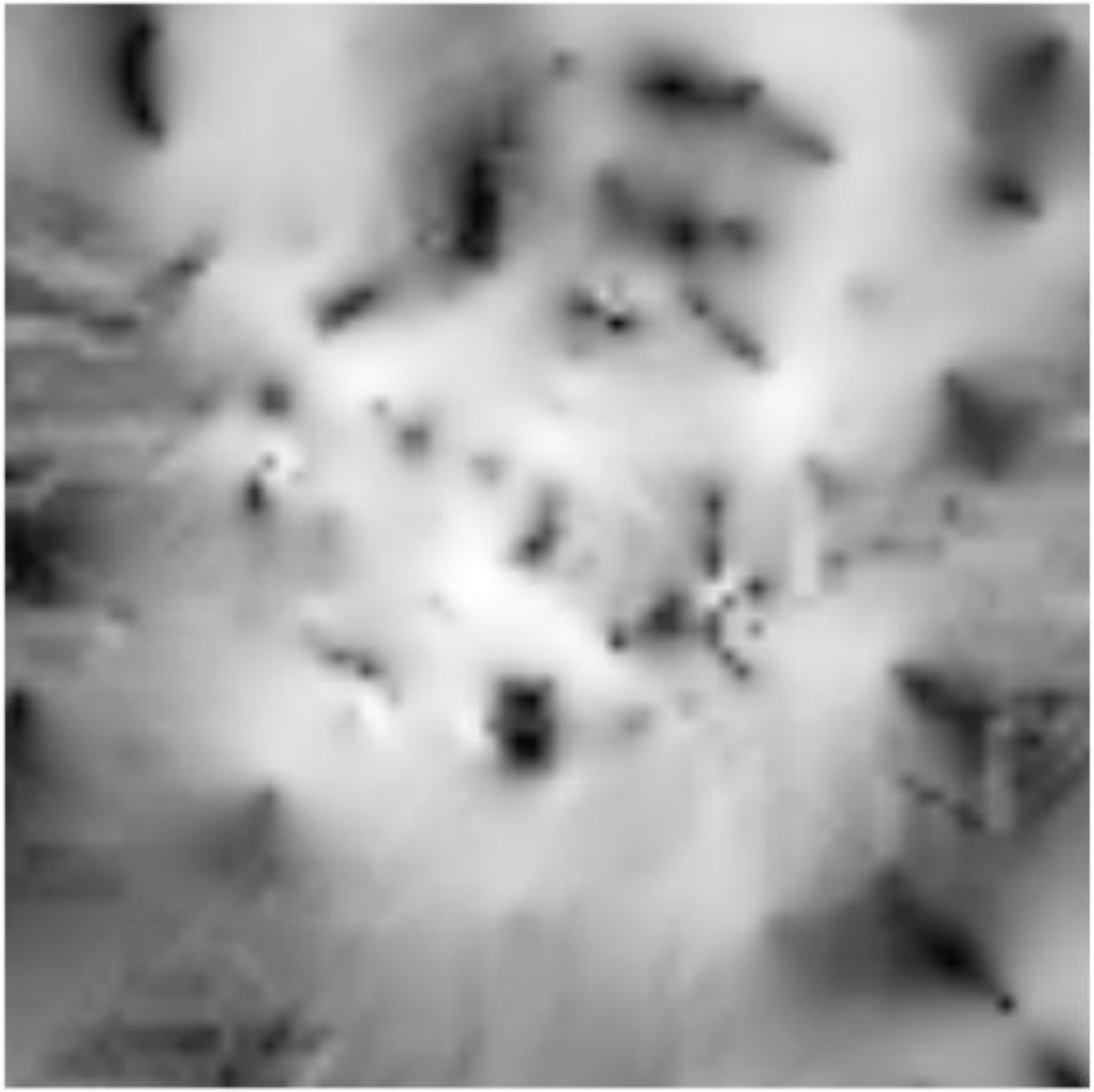


Figure 6 – Terrain slope of residual anomaly. Black for low gradients, white for high gradients. Displayed using IMAGE MAP option.

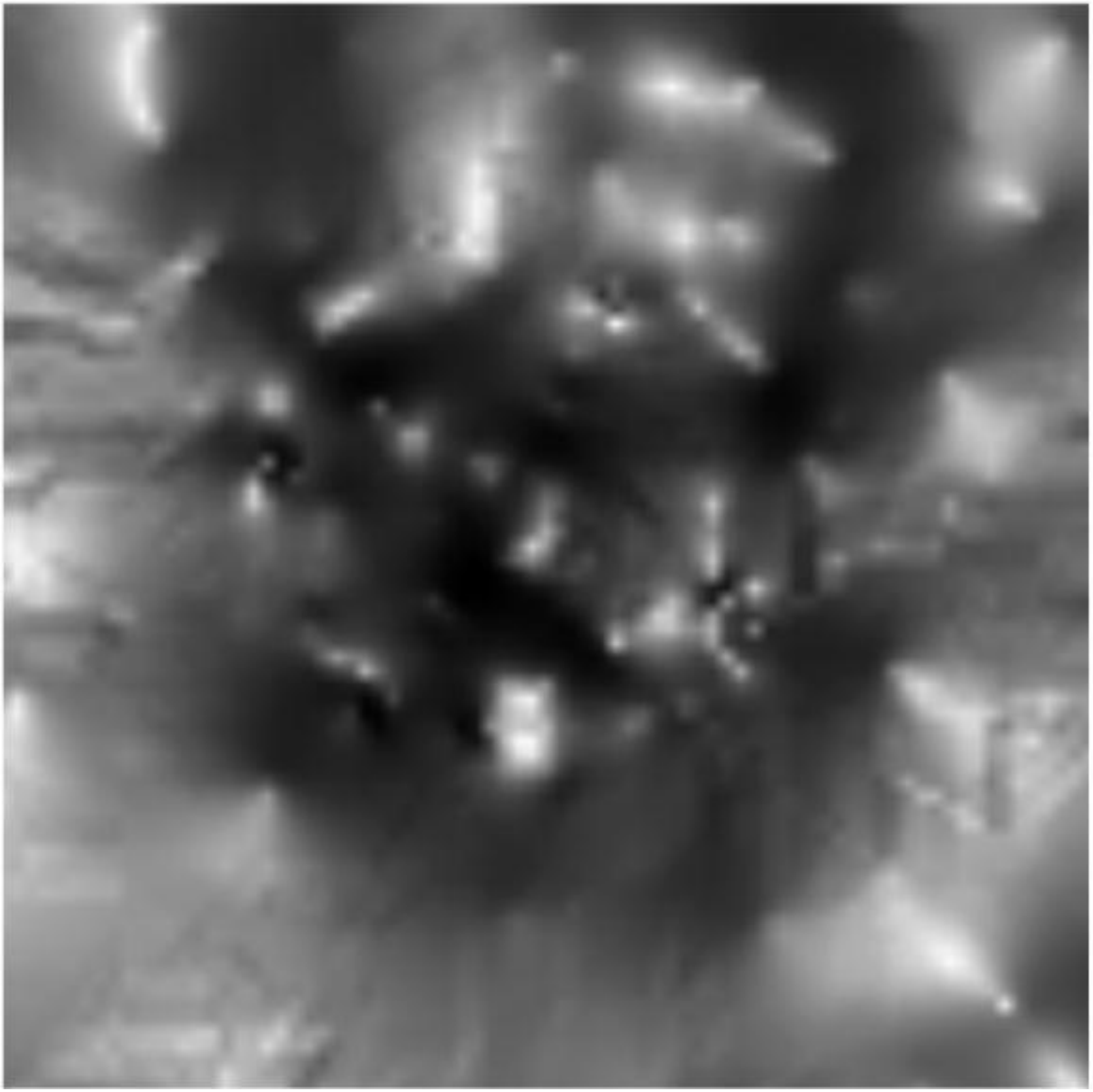


Figure 7 – Complement of the terrain slope. White for low gradients, black for high gradients. Displayed using IMAGE MAP option.
Figure 8

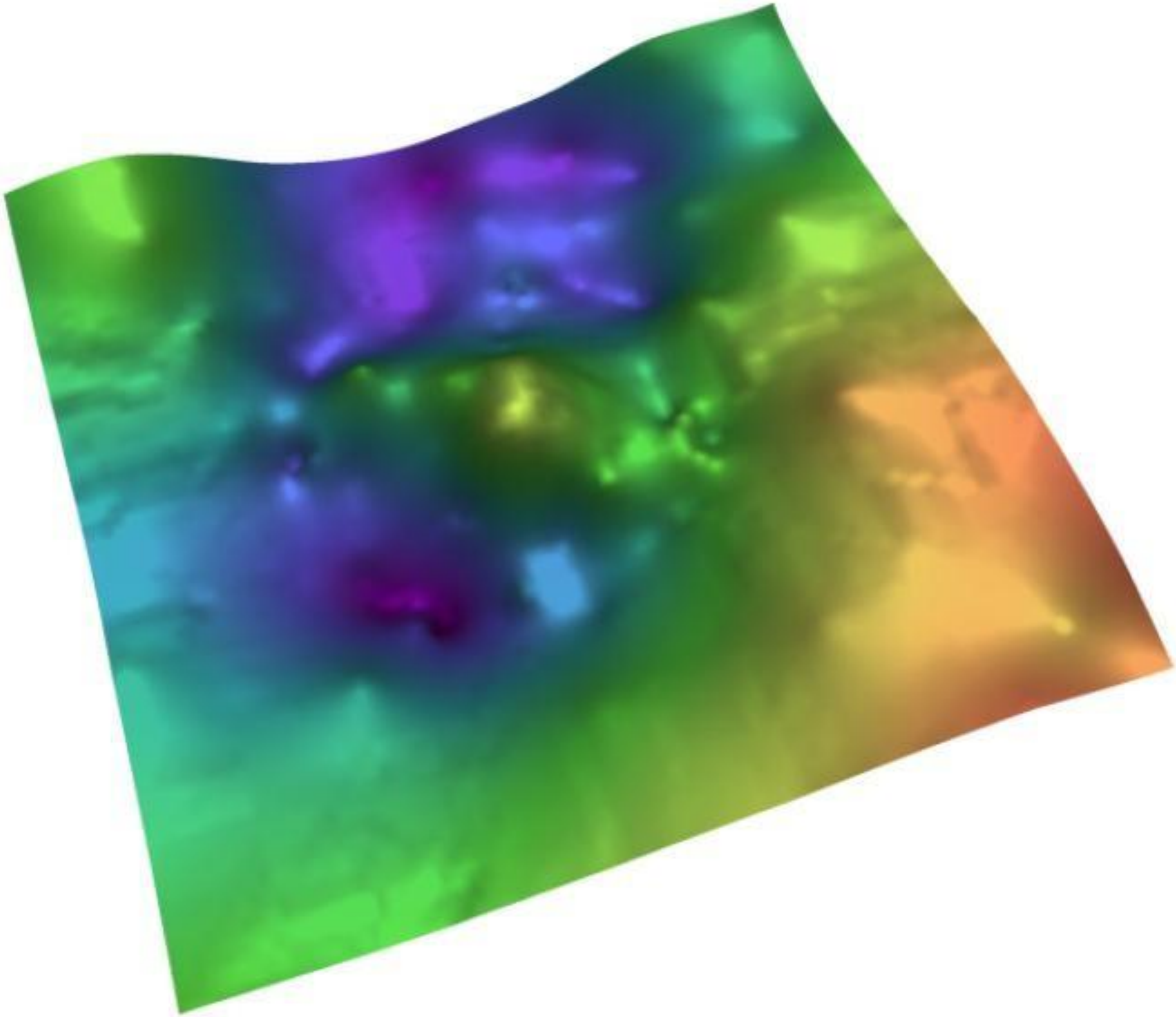


Figure 8 – Complement of the terrain slope with color added back.

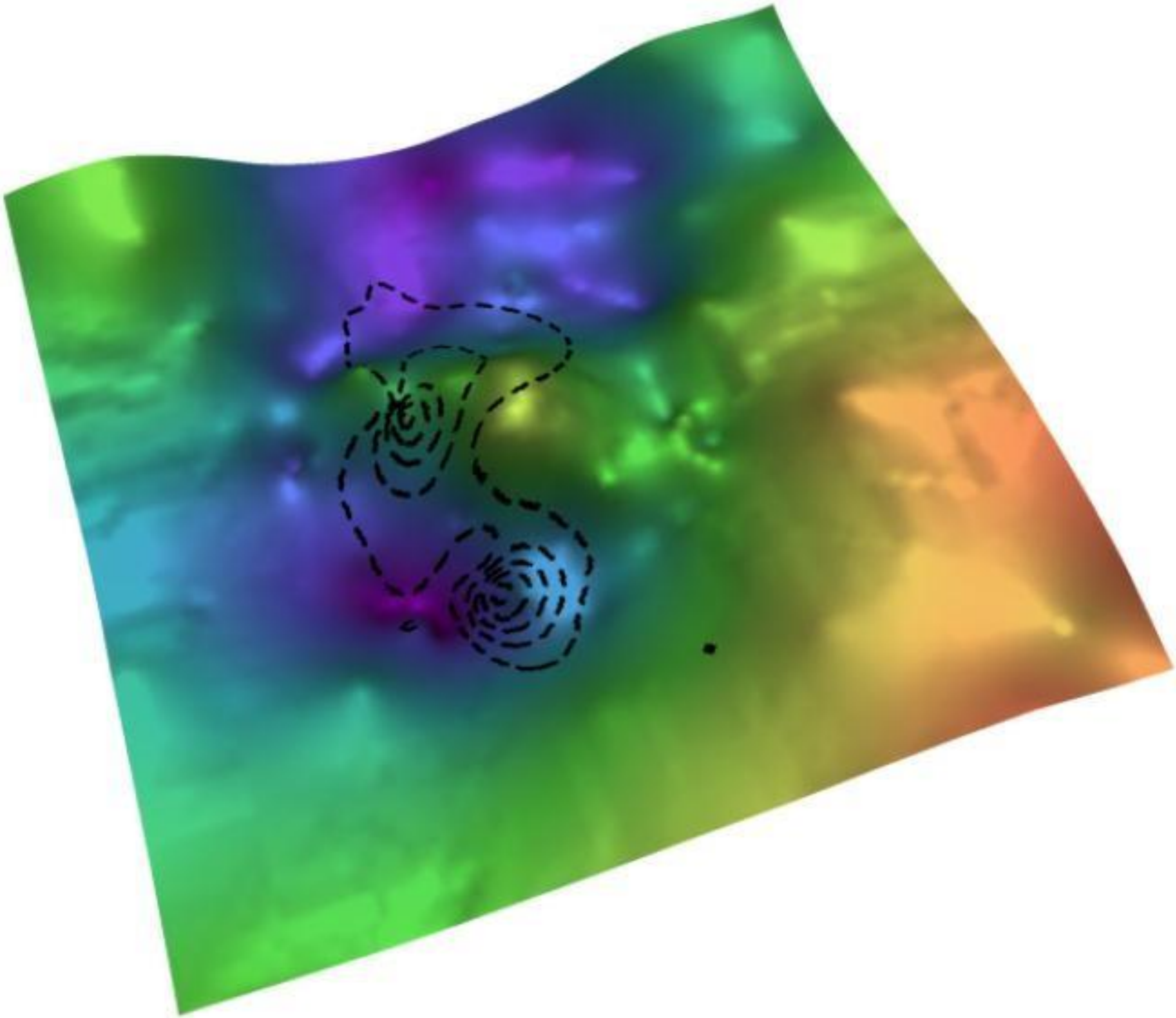


Figure 9 – Complement of the terrain slope with color added back and contour overlay of gold pathfinders in stream sediments.

Case study-2

Prediction of gravity anomaly from calculated densities of rocks

Omosanya K. O.[1,2*], Mosuro G. O[1], Laniyan T. A[1] and Ogunleye D.[1]
[1]Department of Earth Sciences, Olabisi Onabanjo University, Ago-Iwoye, Nigeria
[2]Cardiff University, School of Ocean, Earth and Planetary Science, United Kingdom

Pelagia Research Library, Advances in Applied Science Research, 2012, 3 (4): pp 2059-2068

- The force of gravity at the earth surface is affected by lateral changes of density due to the total mass of the earth.
- Two components of gravity forces are measured at the earth’s surface, a general and relatively uniform component due to the total earth and a smaller size which varies due to lateral density changes.
- The latter generally referred to as gravity anomaly is the difference between the observed earth’s gravity and a value predicted from a model (Fricke & Schön 1999, Rider 1996, Serra 1984).

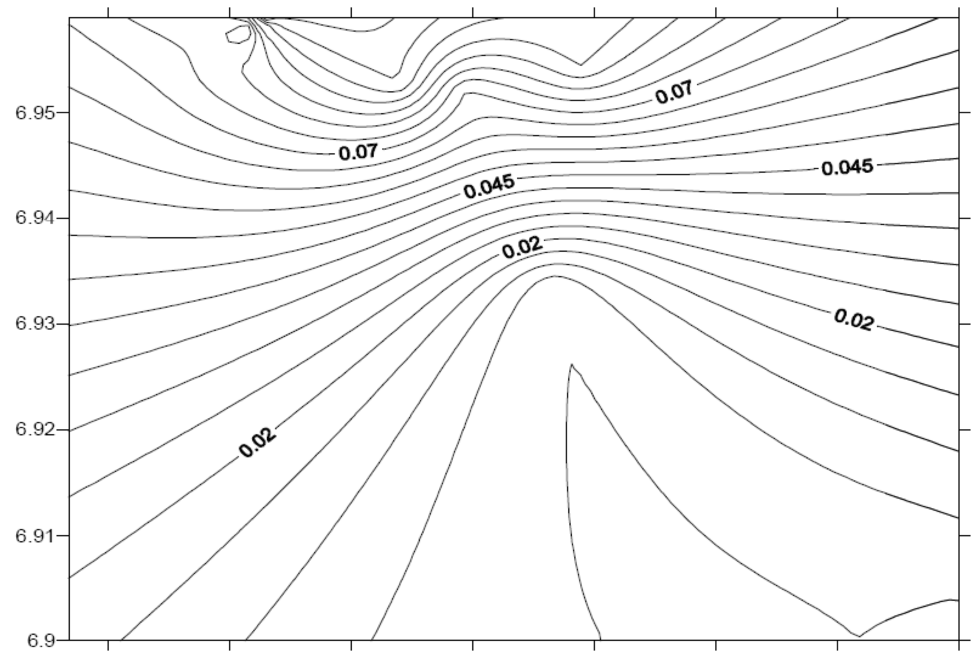
- The density of a rock is the ratio of its mass per volume.
- For specific rock types, density has less percent variability especially at specific places.
- Due to the low porosity and permeability of igneous and metamorphic rocks, the densities are considered close approximate of the field values (Subrahmanyam and Verma, 1981).
- Unconsolidated materials such as alluvium and stream channels materials may have significant variation in density, due to compaction and cementation.
- The influence of porosity on density in hard rocks is usually less than one per cent (Henkel, 1976); low density values from igneous rocks may be due to the weathering (Ranganai, 1995) of such rocks.

- Direct knowledge of density has been used to predict gravity anomalies without any need for time, elevation, instrument drift, and other gravity corrections especially in basement complex environment.
- When accurately calculated, densities of rock is essential in petrological and geological studies and more so for a meaningful structural interpretation of gravity anomalies (Ajakaiye & Burke 1972, Ajakaiye & Sweeney, 1974).
- For the density measurements the following parameters were determined for each of the samples: **pore volume, bulk volume, or grain volume** and **weight.**

Gravity Anomalies can be calculated from difference in various rock densities and can be associated with tectonics, mineralization and variation in the porosity & moisture content of different rocks.

Ambiguity in the anomalous areas can be mapped based on their shapes and types can also be described along selected gravity profiles such as:

- S,
- M,
- Concave up,
- UL,
- Zig-Zag Flat top
- Peak
- Stair case anomalies
- High
- Low and
- Break.



The 3D anomaly map of the upper part of the study area (Fig. 5a) shows a very high density anomaly at the NNW part and significant decrease in density contrast at the extreme SE end. At the eastern and western boundaries, it is moderately high. The areas of very high density contrast coincides with the upward concave trend on anomaly profile AB and CD..

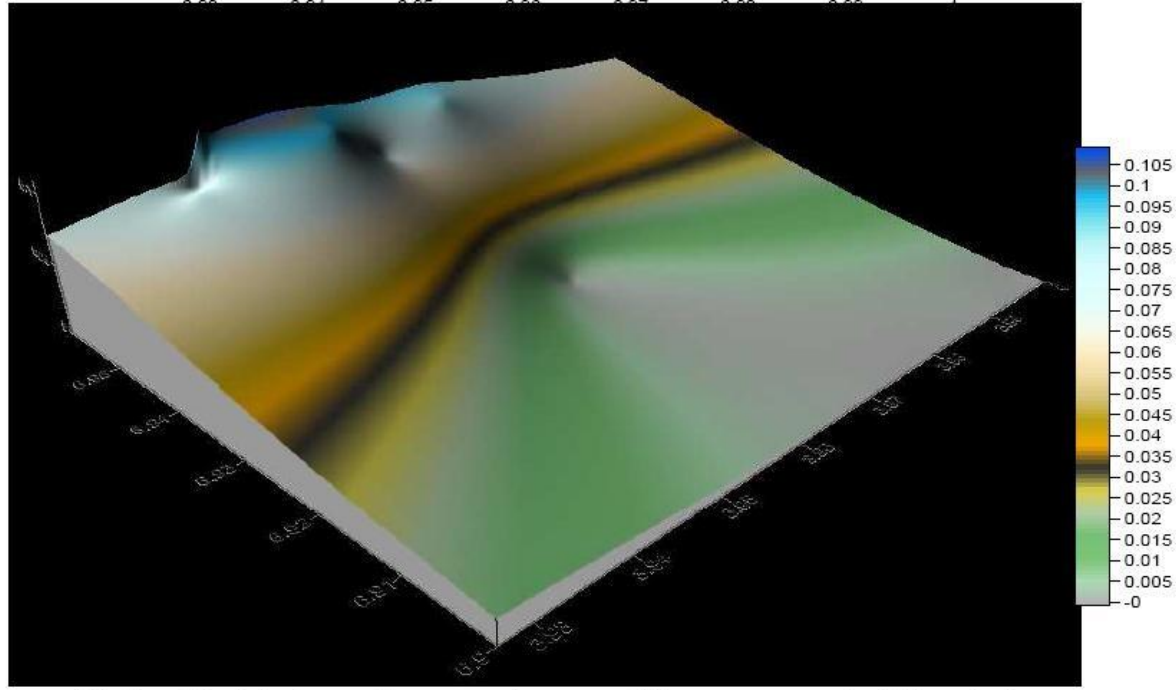
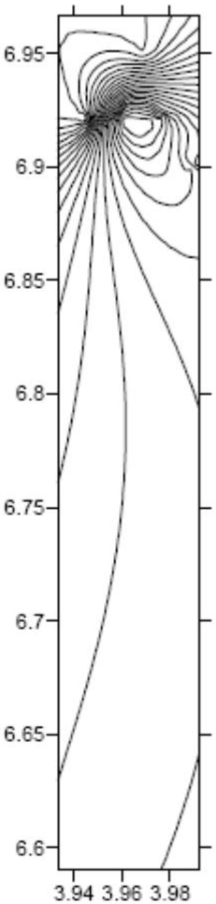


Fig 5a: Modeled gravity anomaly map of the upper part of the study area.



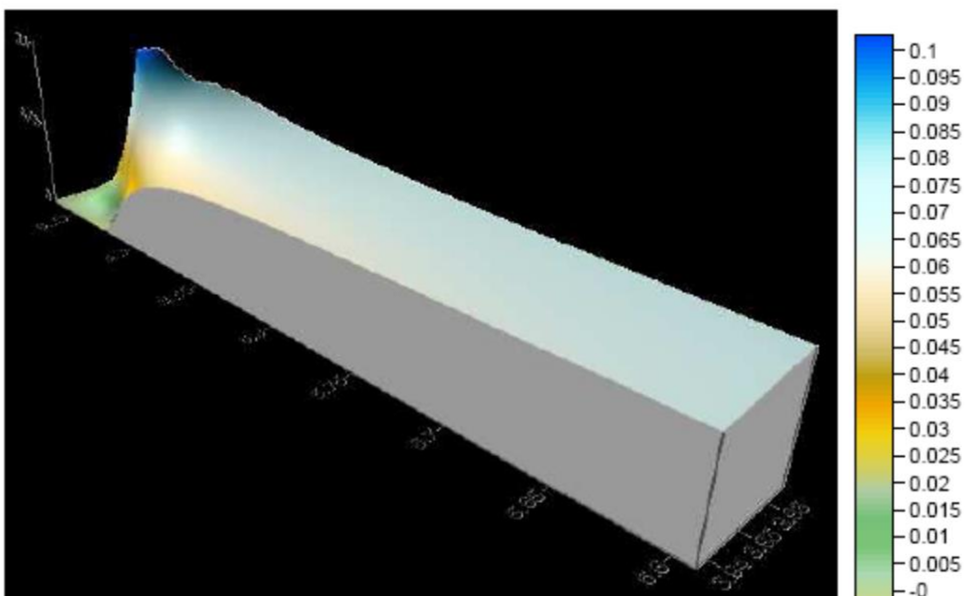


Fig.5b: Modeled gravity anomaly map of the lower part of study area.

On the lower map of the study area (Fig. 5b), the peak in density contrasts recorded on the N on the map may overlap with the lowermost boundary of the pegmatite outcrop. This trend coincides with IJ profile of Fig 4. The density value flattens out on the other part of map suggesting homogeneity of the density contrast

The anomaly profiles when inverted would express the geometry of the continental crust at each of the places. The density contrast between the continental crust and rocks suggests that the outcrops are buried approximately 16km below the earth surface, before the granite solidus. Over the pegmatite outcrop, the profiles are concave upward suggesting the continental crust to be concave down. This means the pegmatite intrusion are not tabular (vertical dykes) but circular intrusion in map view. It is circular intrusion in the host rock, biotite granite and granite.

Determining what factor controls the density of the rock type is important in the accurate prediction of gravity anomaly. From the plot of density against porosity, the amount of pore spaces in the rock of the study area has no direct linear relationship with porosity as suggested by the low linear correlation between them (Fig.5). In places where porosity is high the moisture content is also high and sometimes the density (Fig. 6), the relationship between moisture content and porosity is envisaged as the amount of water in a rock is governed by the availability of pores to contain them.

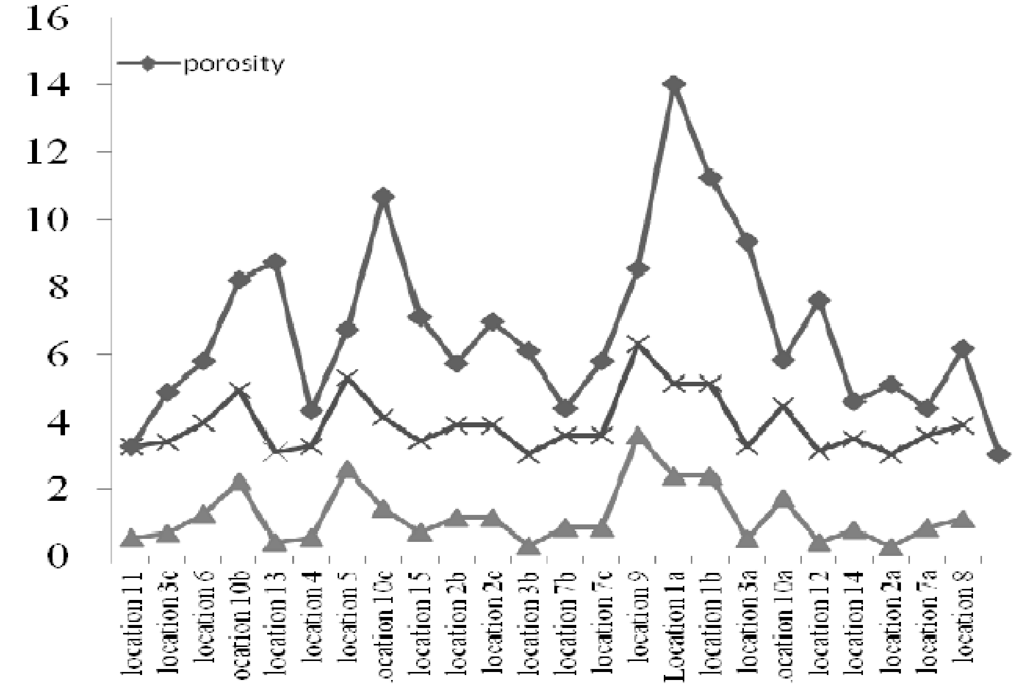


Fig 6: Plot of Porosity, density and Mositure content highlighting the dependence or variation of the varibale.

The ambiguity of interpreting the potential gravity anomalies is dependent on an infinite number of sources. The ambiguity can be reduced by utilizing all external constraint on the nature and form of the anomalous body (Lines *et al.* 1988). The estimation of the gravity anomaly along profile is one way of reducing ambiguity associated with the 3D anomaly maps.

The relative variation in the density of rocks in the study area is relatively small, 0.0075g/cm3 and there is considerable overlap in the measured densities. Hence knowledge of rock density alone will not suffice to determine the gravity anomaly. The small variation in rock densities implies that the spatial variation in the observed anomalies caused by geological structures will be quite small and difficult to detect.

Case Study: 2

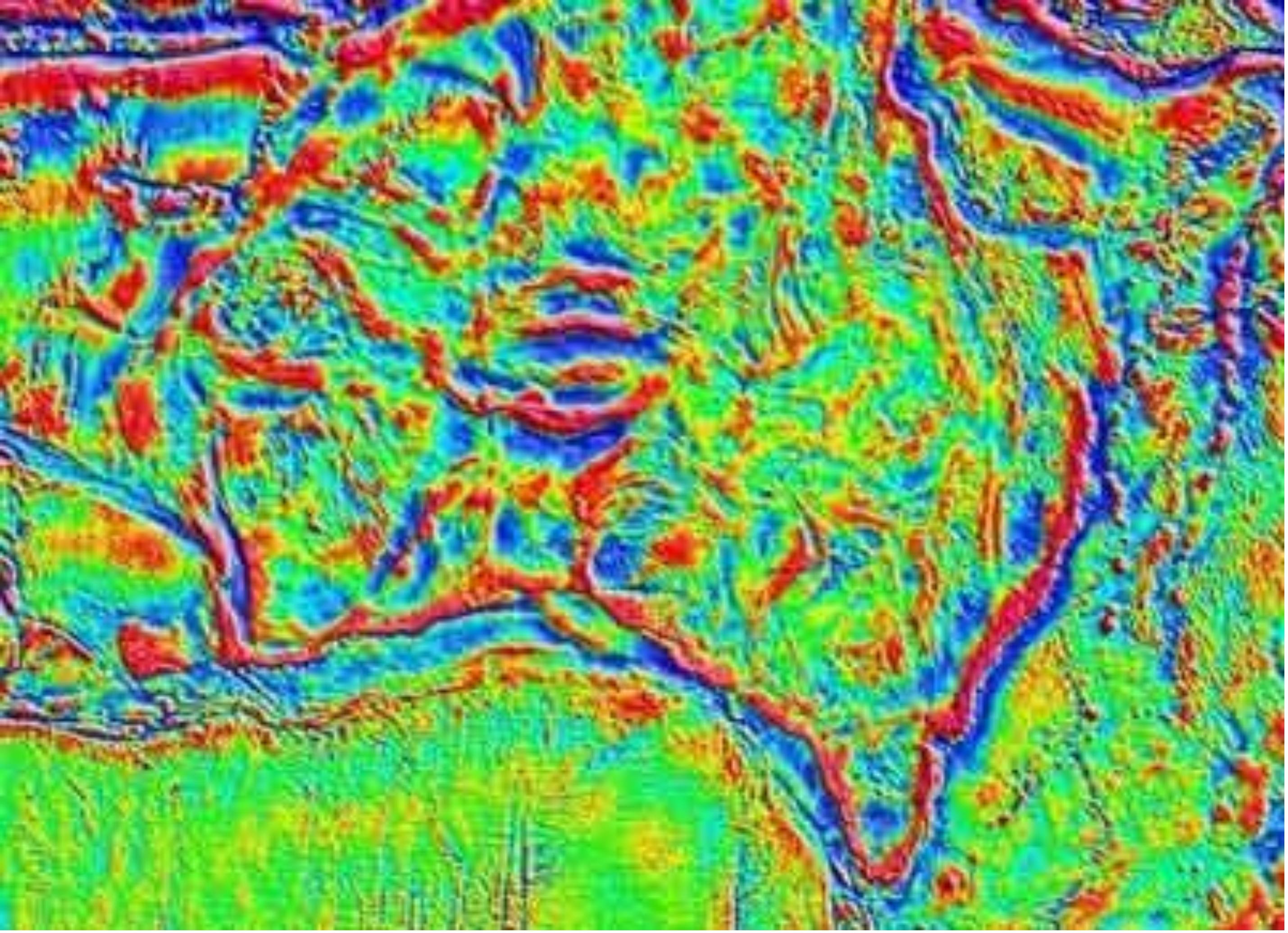
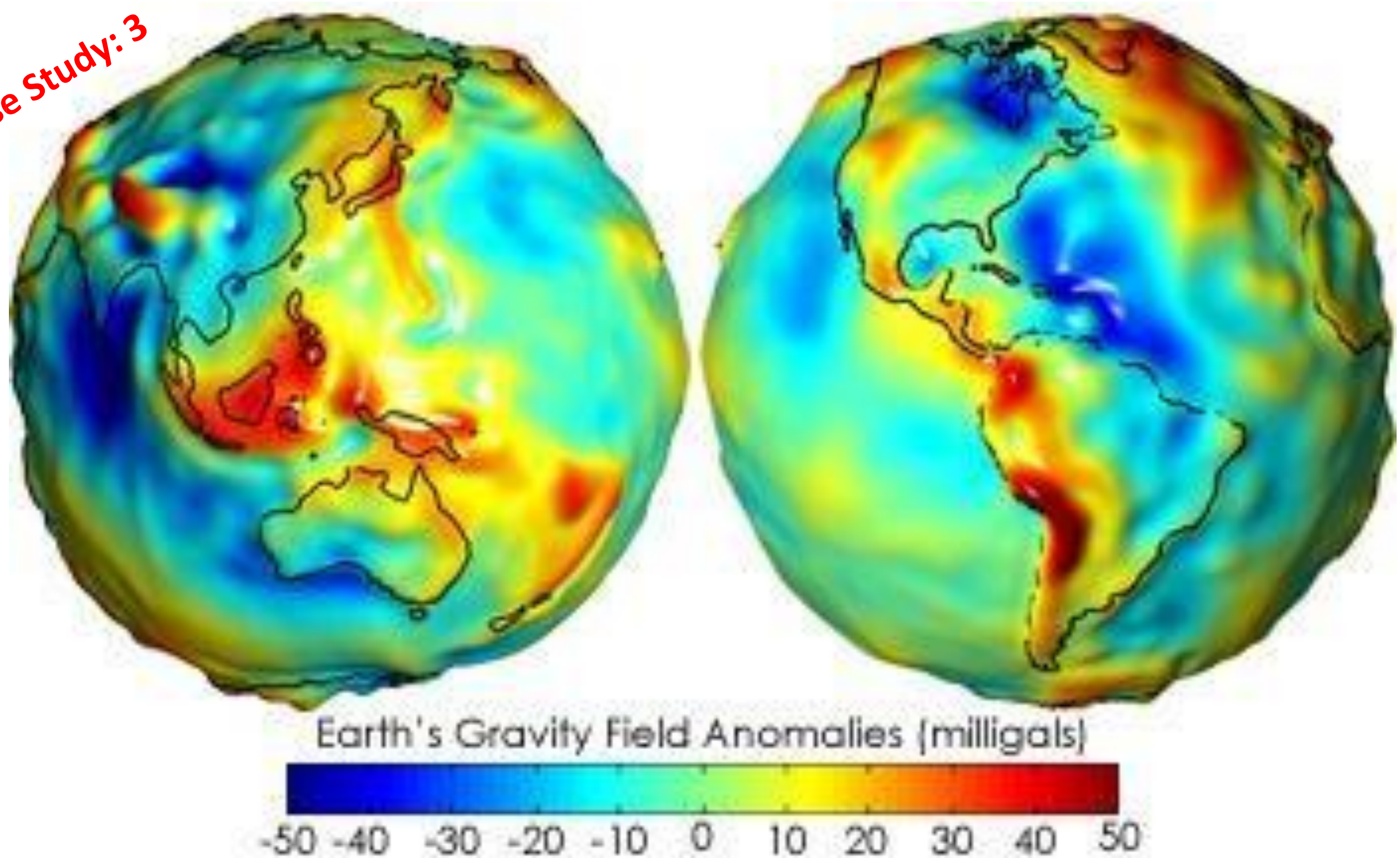


Fig. Section of the new Gravity Anomaly Map of Australia

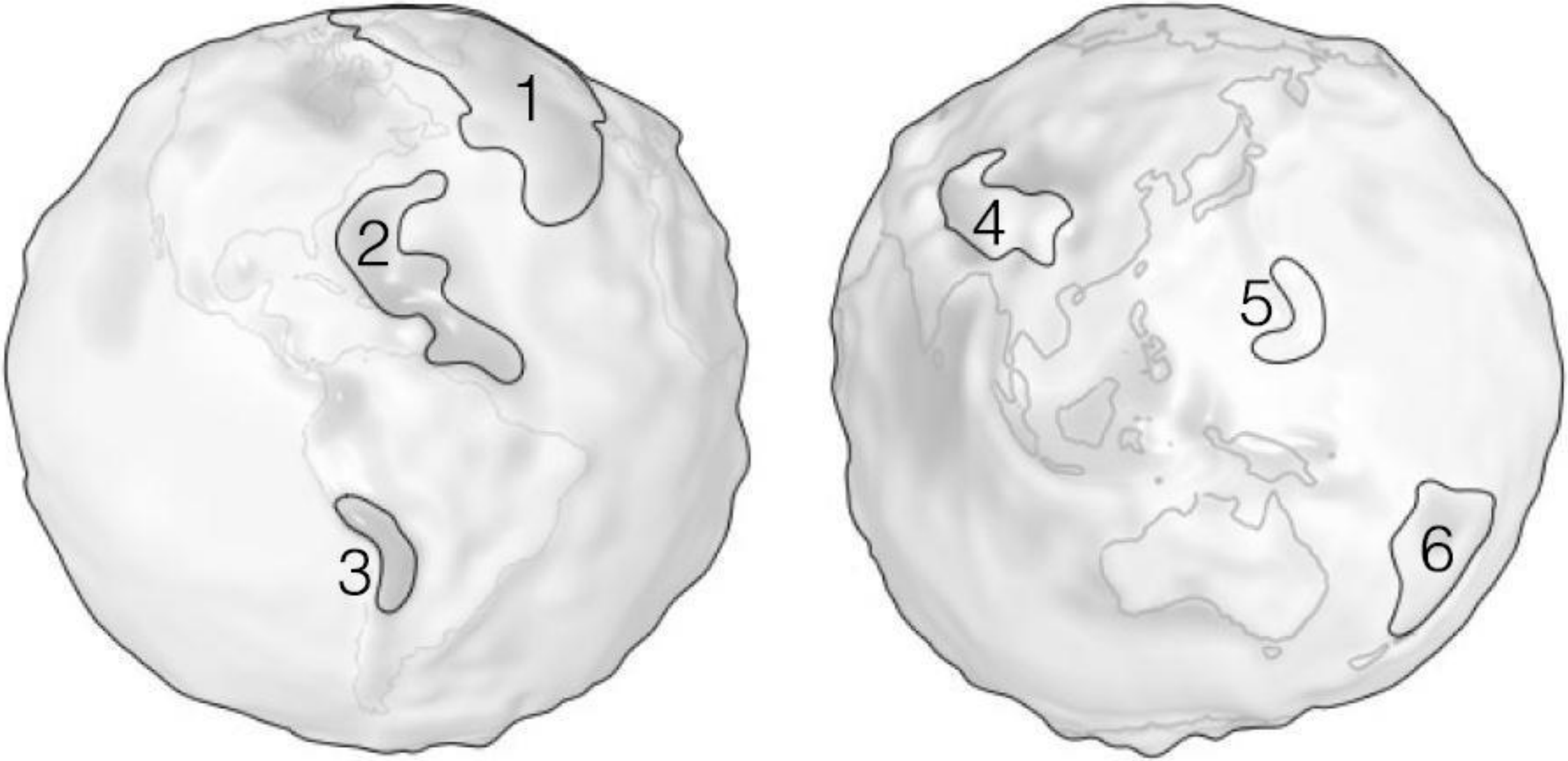
New Gravity Anomaly Map of the Australian Region - Mario Bacchin, Peter Milligan, Ray Tracey and Phillip Wynne, AusGeo News September 2008 Issue No. 91

Gravity anomalies effectively show the density variations in the Earth's crust. **High anomalies** (red colours) indicate areas of **above-average crustal density** or a **thinner crust** (the crust is lighter than the underlying mantle); **low anomalies** (purple colours**) indicate below-average crustal density** or **thicker crust**. The depth of the crustal bodies having the anomalous density is indicated by the anomaly wavelength: finer, sharper anomalies indicate shallower bodies while broader, diffuse anomalies indicate deeper bodies.

Case Study: 3



These "gravity anomaly" maps show where models of the Earth's gravity field based on GRACE satellite data differ from a simplified mathematical model that assumes the Earth is perfectly smooth and featureless. Areas colored yellow, orange, or red are areas where the actual gravity field is larger than the featureless-Earth model predicts—such as the Himalayan Mountains in Central Asia (top left of the left-hand globe)—while the progressively darker shades of blue indicate places where the gravity field is less —such as the area around Hudson Bay in Canada (top center of right-hand globe).



Detail of Features from Front:

1) North Atlantic Mid-Atlantic Ridge
2) Puerto Rico Trench / Lesser Antilles Region
3) Andes Mountains
4) Himalayan / Tibetan Plateau Region
5) Mariana Arc-Trench Region
6) Tonga / Kermadec Region

Case Study: 4

3D stereoscopic visualization

Constrained 3D forward modeling using advanced interpretation and visualization

H.-J. Götze, T. Damm, B. Gutknecht, N. Köther, V. Giszas
Institute of Geosciences, University of Kiel, Germany
Contact Email: hajo@geophysik.uni-kiel.de

EGM 2010 International Workshop on
"Adding new value to Electromagnetic, Gravity and Magnetic Methods for Exploration"
Capri, Italy, April 11-14, 2010

Christian-Albrechts-Universität in Kiel

Optical tracking was integrated, making especially modeling of volumetric underground structures more interactive. Using this setup for geophysical forward modeling, various types of additional information (points, lines, polygons, surfaces and bodies) can be seen and evaluated by a scientist at the same time to refine a model.

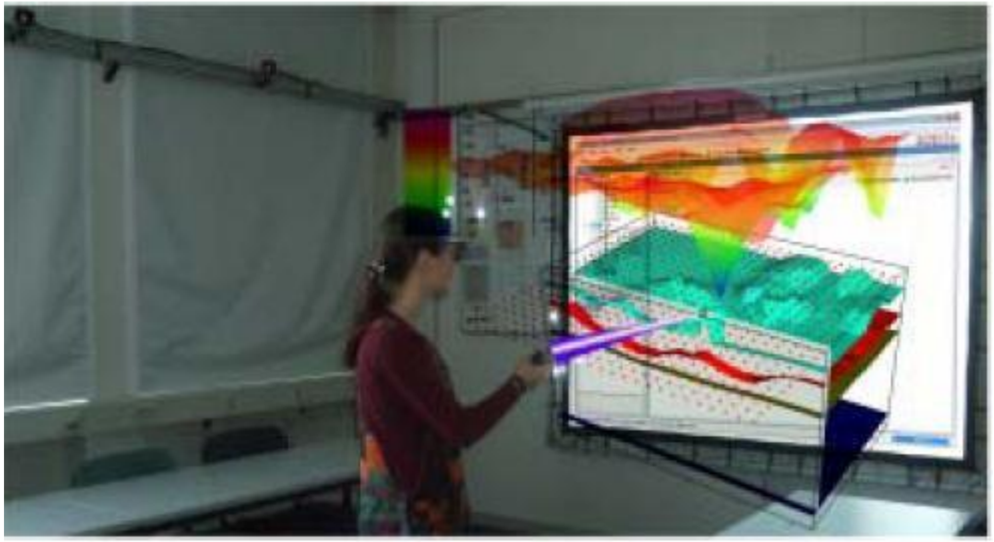


Fig 1: Immersive 3D forward modeling

Incorporating tracking technology with stereoscopic visualization, the possibility to manipulate the model directly e.g. through a virtual pointing stick (violet in Fig. 1) arises. As constraining data can be seen all the time and directly at the scientists 'hands', decisions based on these additional data – e.g. from seismology, geology or geochemistry – can be made instantaneously and intuitively (Damm and Götze, 2009).

Additionally the process of doing the 3D geometry modifications in a forward modeling process can be improved using such an immersive 3D visualization system. Points at body corners or on edges can be moved to the exact desired position. Using a 2D input scenario, the same modifications are clearly possible, but limited to the particular 2D working plane used in that moment. In the area of miniaturized video glasses with two small video elements, the organic LED technology (OLED) is still evolving. These video glasses can become a working-place alternative to the room mounted stereoscopic projection setups and hence making immersive 3D modeling the normal procedure in the future, as it brings more information and a more intuitive model access.

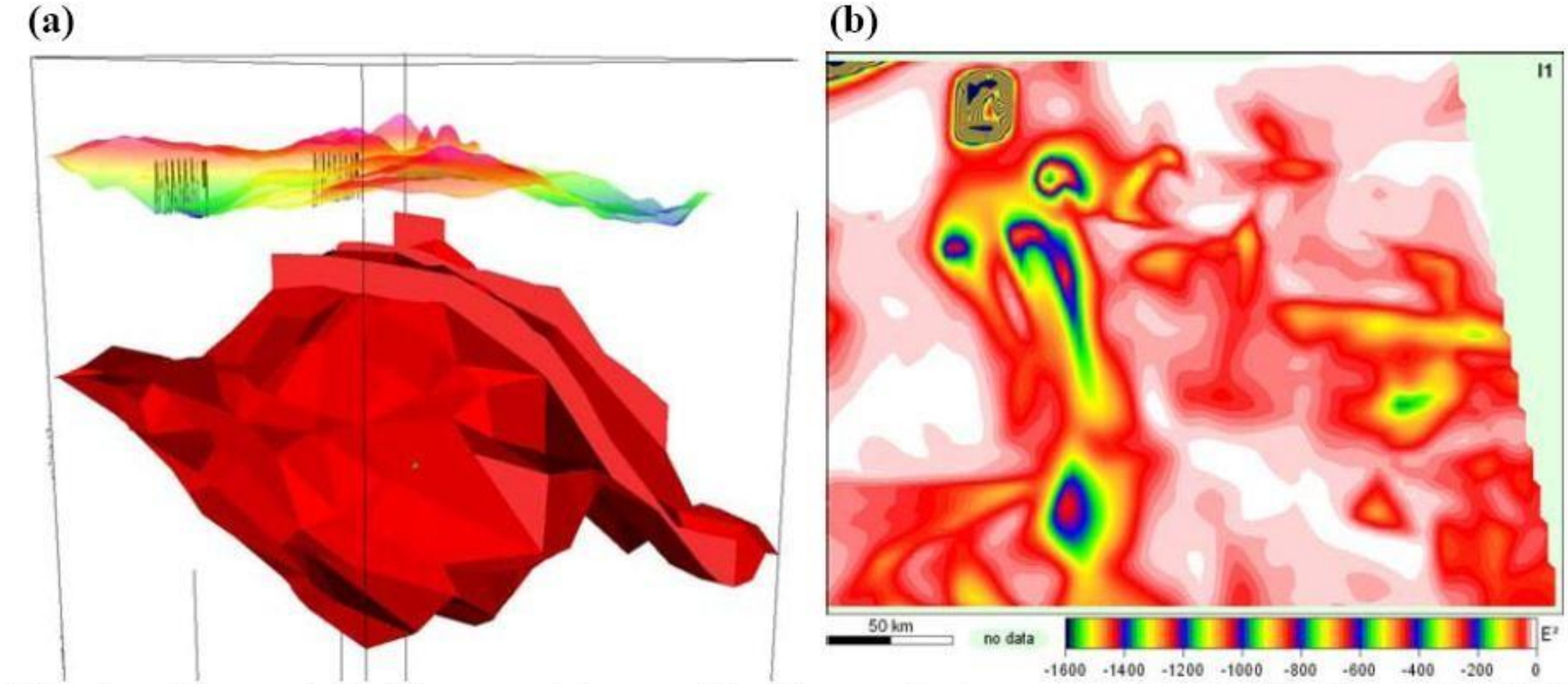


Fig. 2a: *The modelled basement top in 3D. The vertical exaggeration is 25. From North (back) to South (front) a slight dip is visible which is predicted by geology. To East (right corner) a basement depression was modeled. During 2D modeling the depression was not recognized because it is a local feature. The 3D overview facilitates a reliable interpretation of the whole basement structure. Thus the depression could be interpreted as an isolated trough. Therefore the 3D modeling and visualisation improves the interpretation.* ***Fig. 2b:*** *shows the* I_1 *invariant field for the same model. A granite plug in the northwest produces a strong local gravity anomaly with steep gradients that cause high invariant amplitudes.*

Case Study: 5

Technical Note: Integration of Gravity, Magnetic, Well and Seismic Reflection Data in the National Petroleum Reserve, Alaska (NPRA)

By Gerry Connard, NGA, Inc., Corvallis, OR, USA and

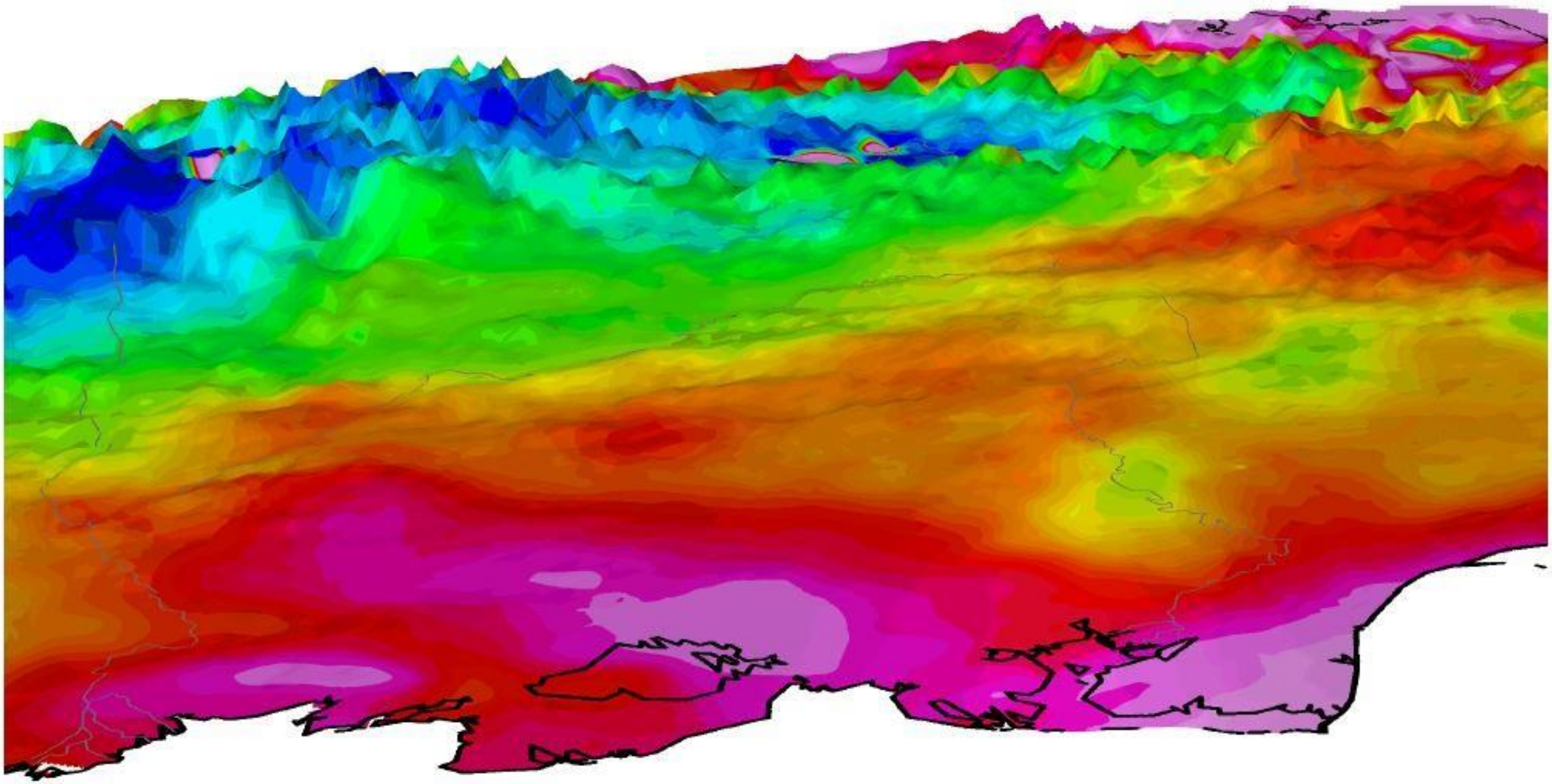
Ash Johnson, Geosoft Europe, Ltd.

Overview

This technical note provides a brief description of using gravity, magnetic, well, and seismic data for exploration in the National Petroleum Reserve in Alaska (NPRA). This note also demonstrates how modern PC-based software can be used for QA/QC and enhancement of gravity and magnetic data and how gravity and magnetic data can be integrated with exploration well data and seismic reflection data. These data are now freely available online in digital format from the US Geological Survey web site.

below shows a 3D view of the Complete Bouguer gravity anomaly grid draped on the topography of the NPRA. The view is looking south from the Beaufort Sea (declination = 210°, inclination = 20°).

The strong correlation between the higher elevations of the Brooks Range Mountains and the negative Bouguer gravity anomalies masks some of the gravity signal from the upper-crustal structures of interest in exploration.



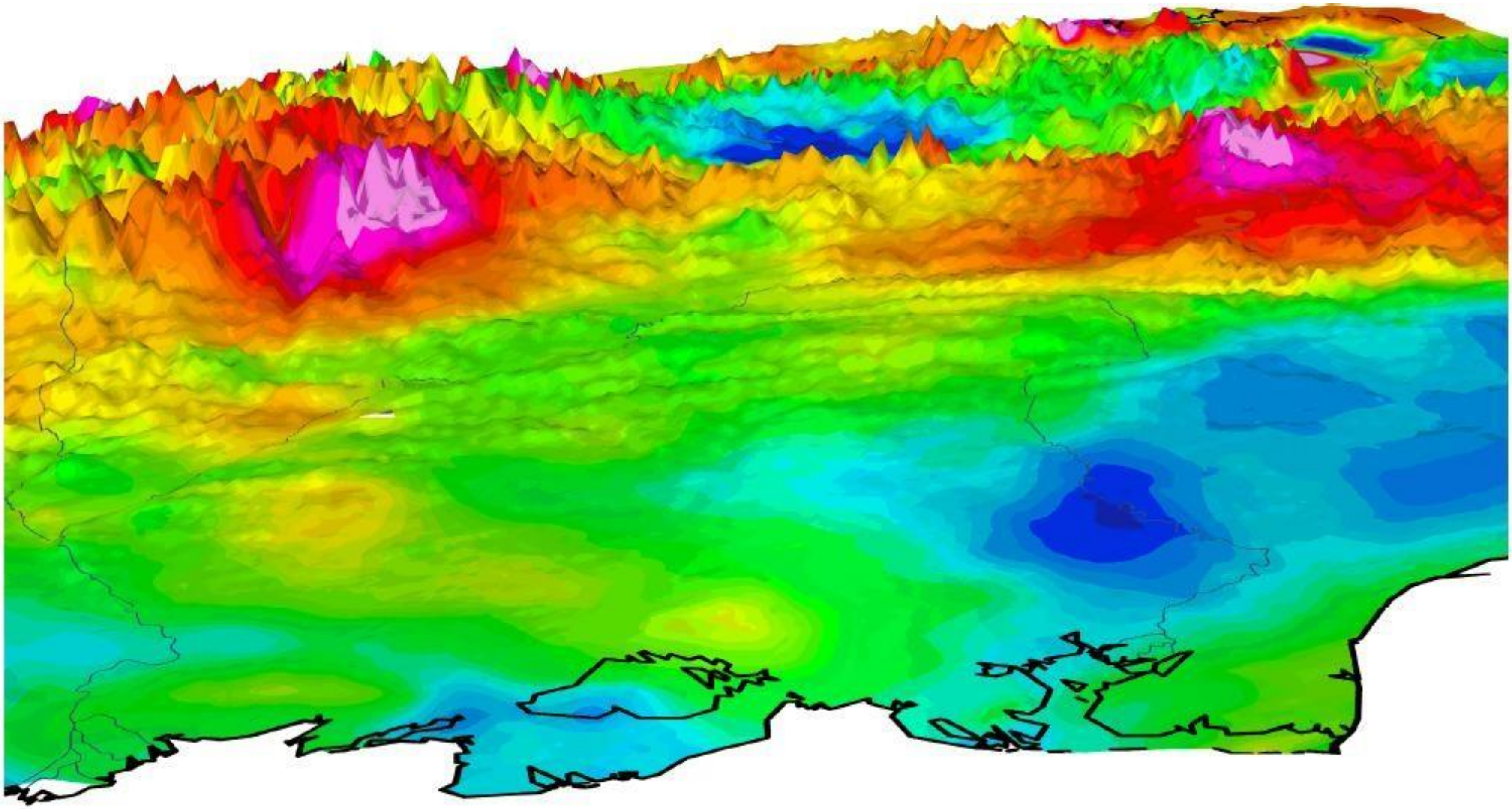
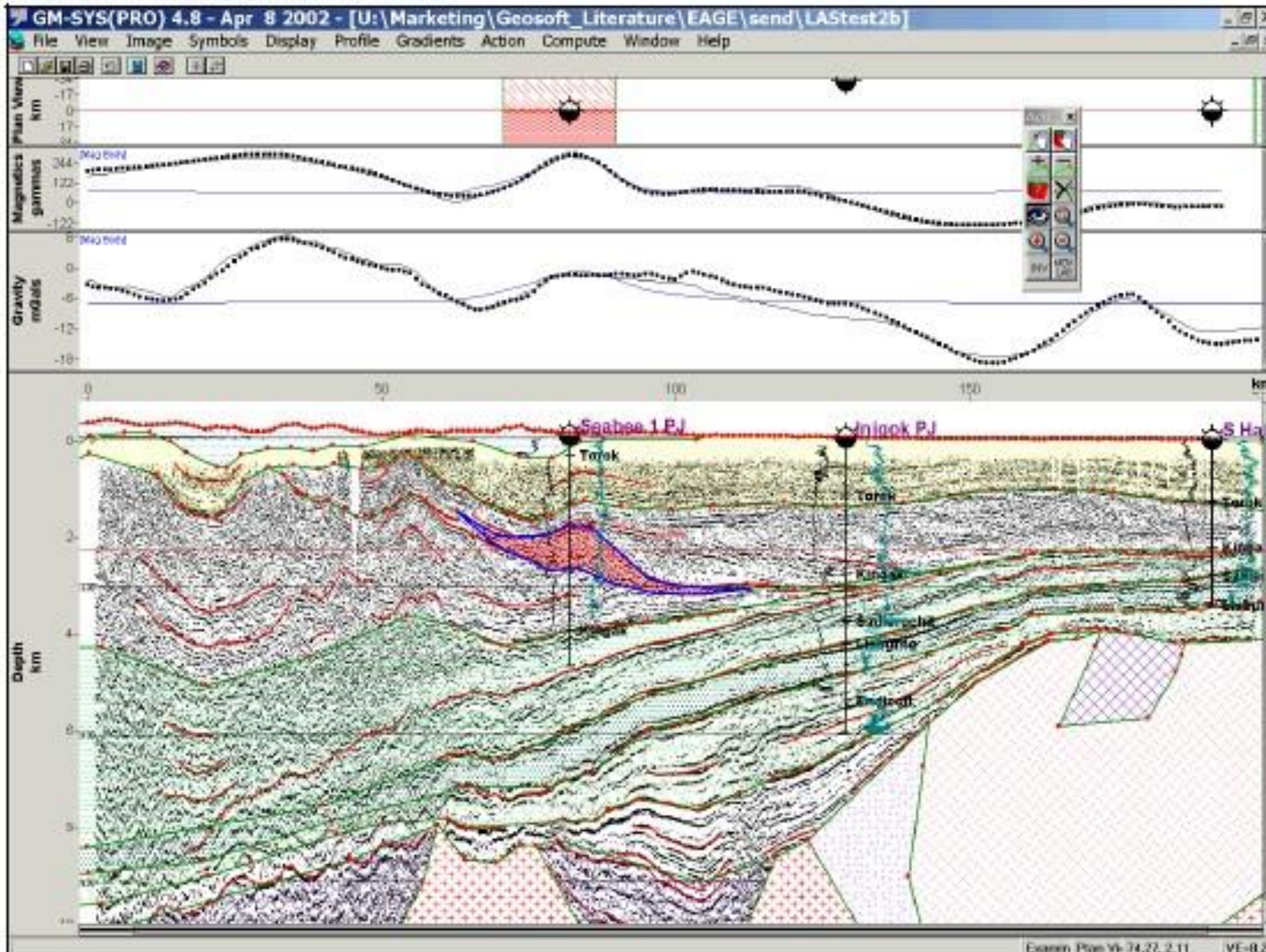


Figure 6 shows the Isostatic Residual gravity anomaly draped on topography viewed from the same point as Figure 5. The isostatic residual process has removed most of the gravity signal caused by the deeper Moho under the Brooks Range, thereby enhancing the gravity signal from upper-crustal sources.

Modeling provides a tool for integrating gravity and magnetic data with seismic data, exploration wells, and surface geology. Using modern PC-based modeling tools, interpreters can easily test a wide range of geologic models and examine the sensitivity of the gravity and magnetic response to the variation in those geologic models. Figure 9 shows an example of a model integrating seismic, gravity, magnetic, and exploration well data along NPRA Regional Seismic Line 9.



Case Study: 6

Significance of Surface Lineaments for Gas and Oil Exploration in Part of Sabatayn Basin-Yemen

- Arafat Mohammed, Palanivel K & C.J.Kumanan

Journal of Geography and Geology, Vol. 2, No. 1; September 2010

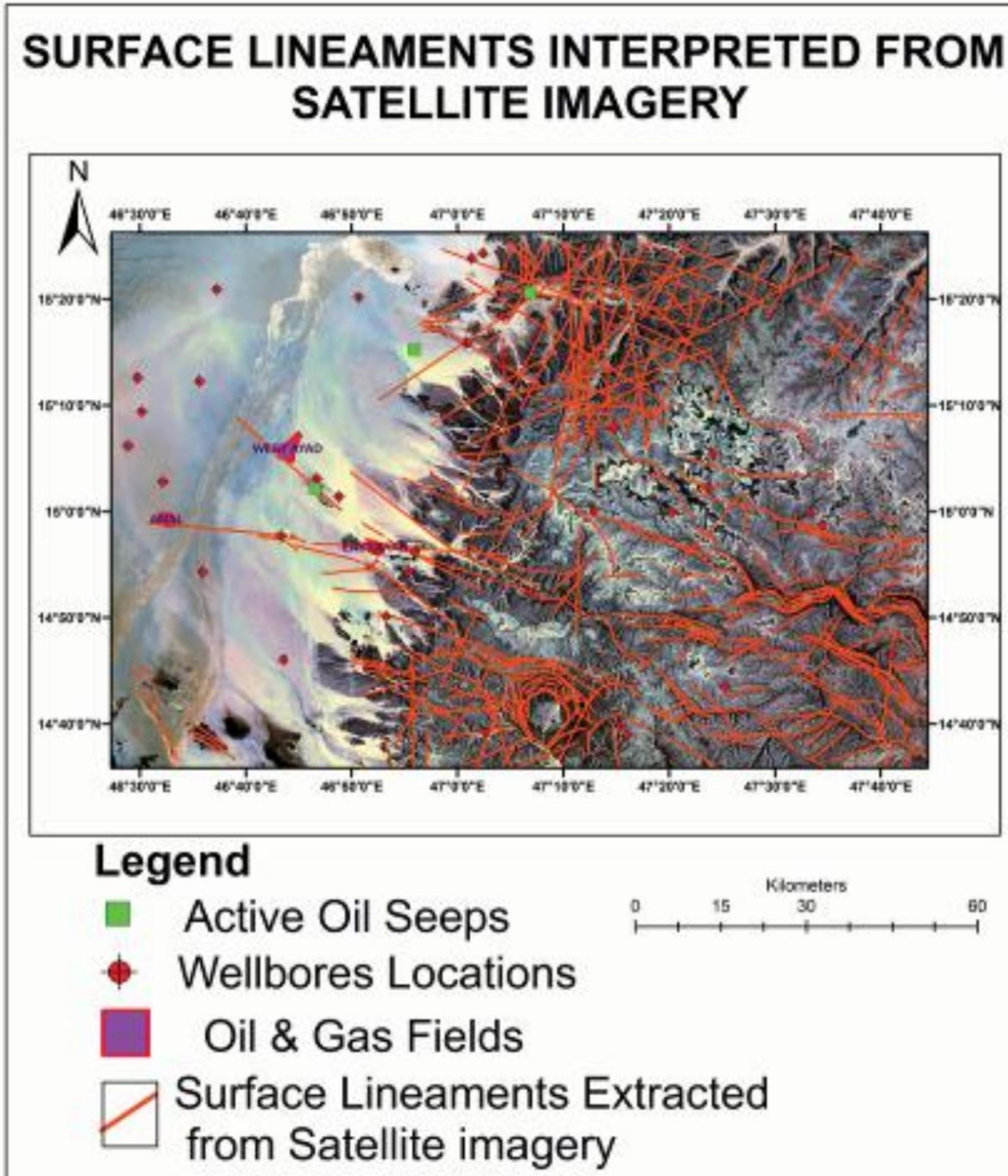


Fig. Lineament Map superimposed over Landsat satellite image of the study area showing locations of Oil fields, Exploration Wells and oil seeps9

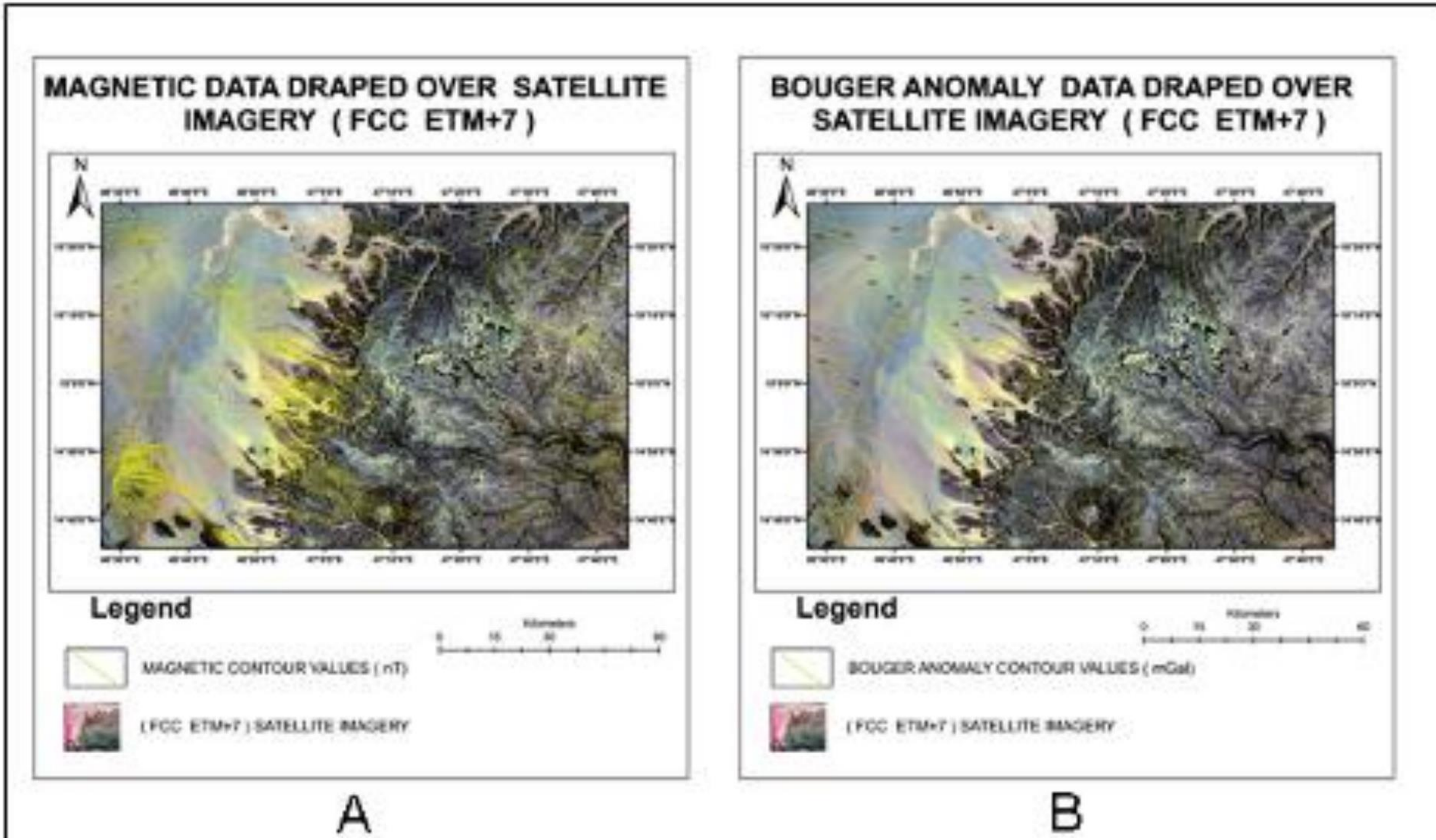
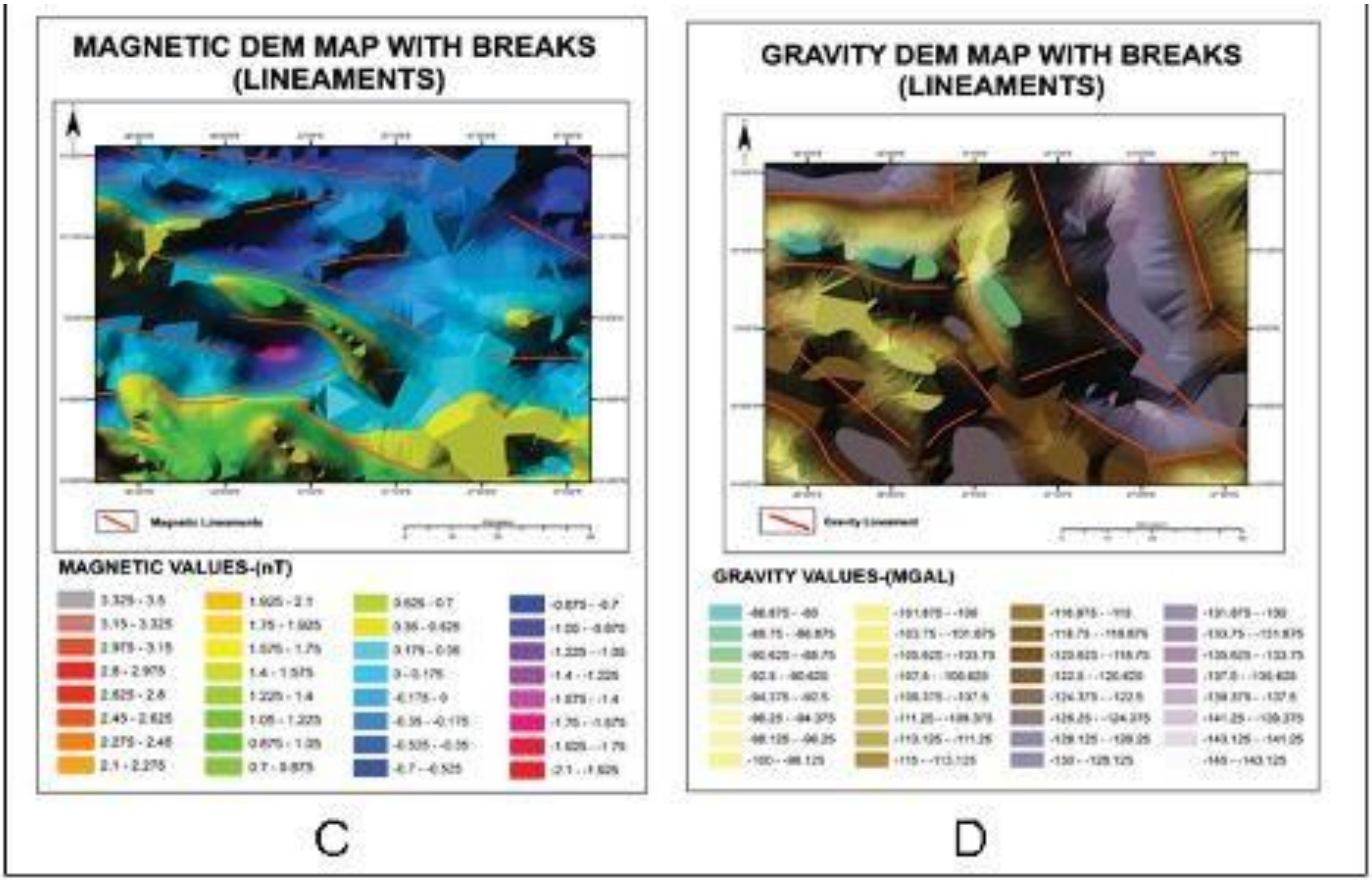


Figure 4. Shows A,B)Magnetic and Gravity contour values superimposed over Landsat satellite image of the study area,



C,D)Magnetic and Gravity DEM models

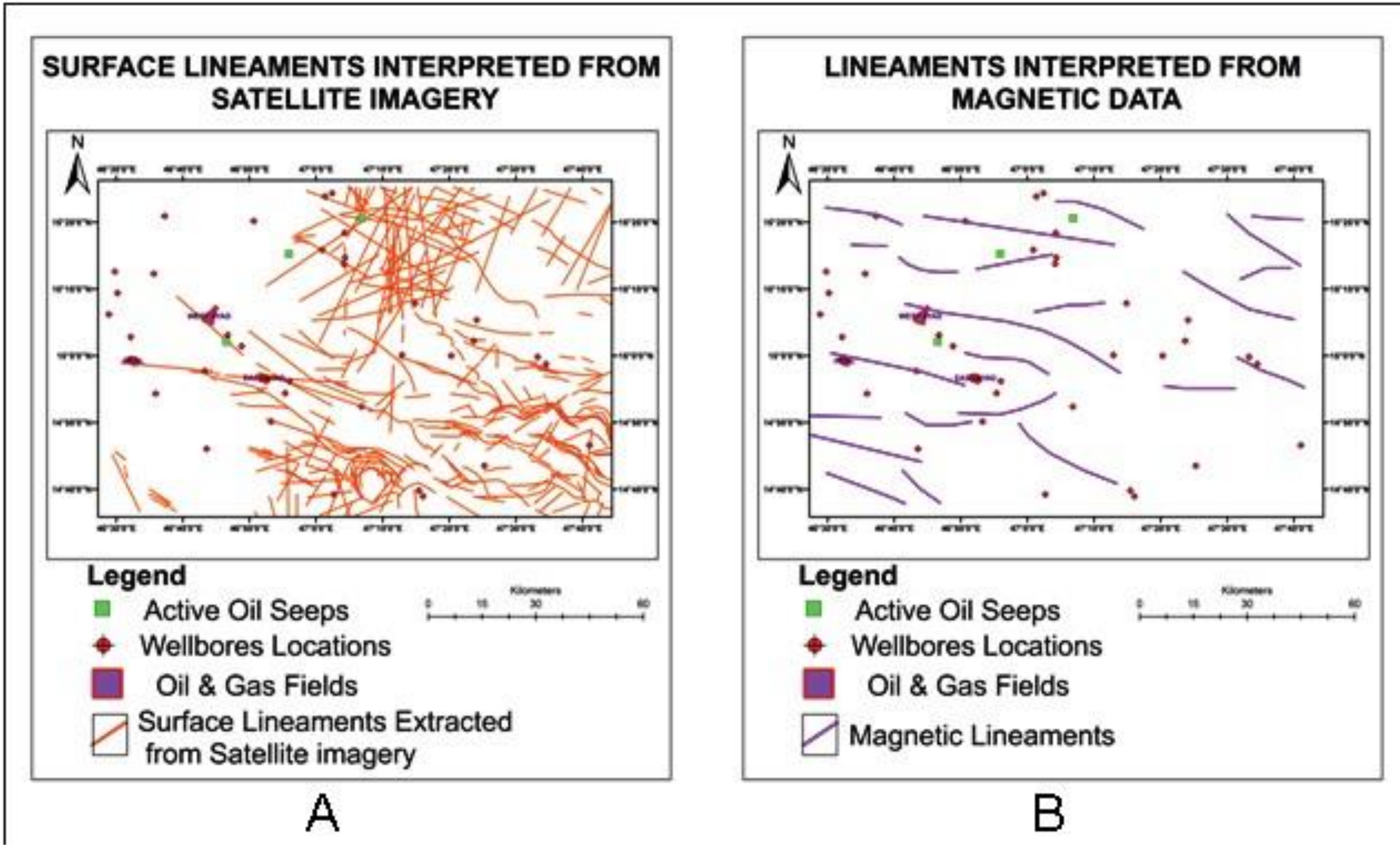


Figure 5. Plate showing Surface and Magnetic lineaments of the study area

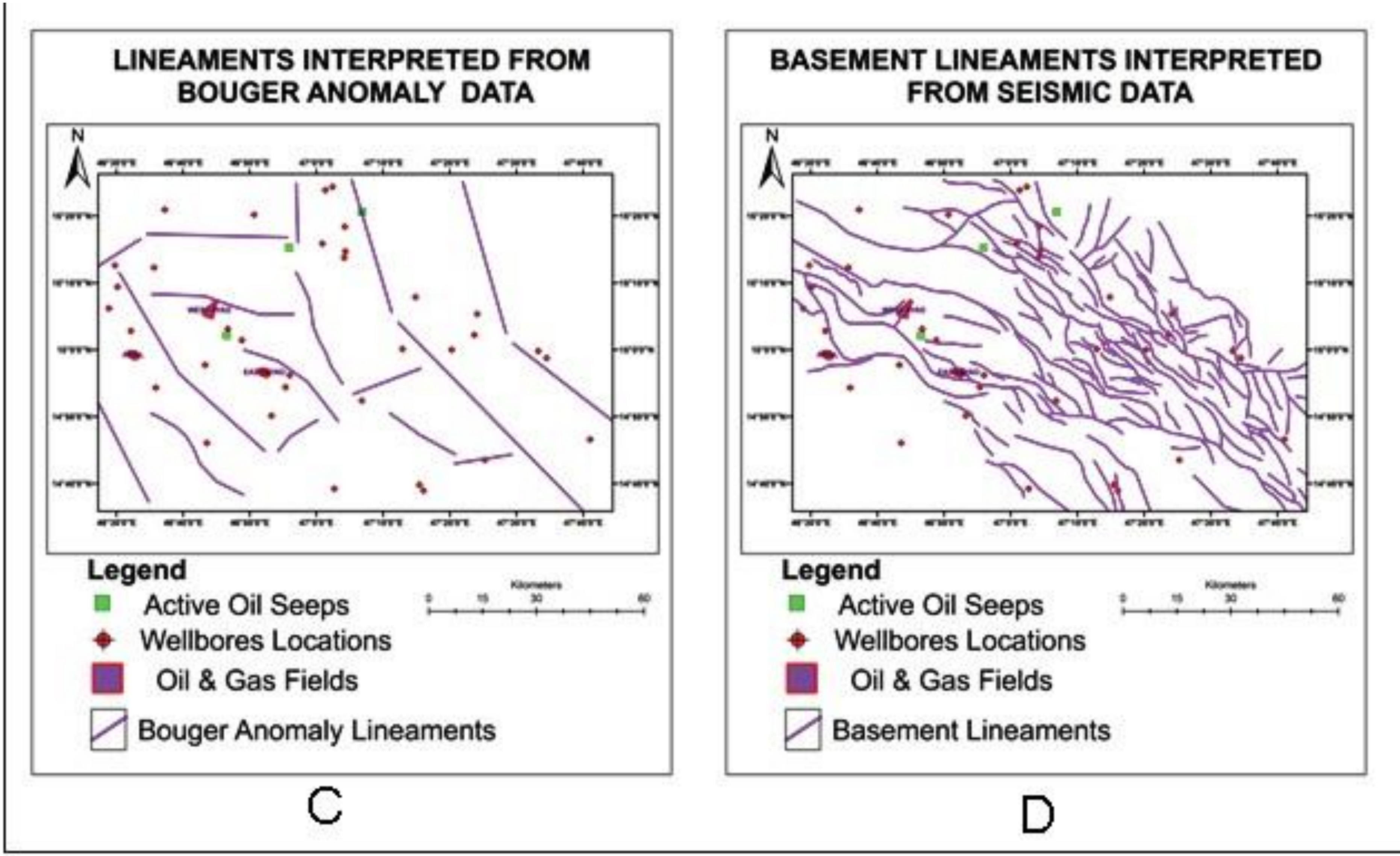


Figure 5. Plate showing Gravity lineaments And Basement faults of the study area

Thank you