

Unit:3 - 3D Visualization of Geophysical data

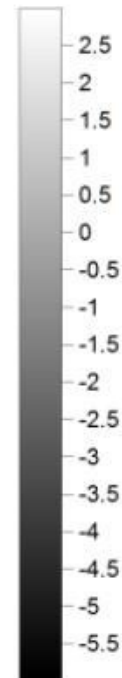
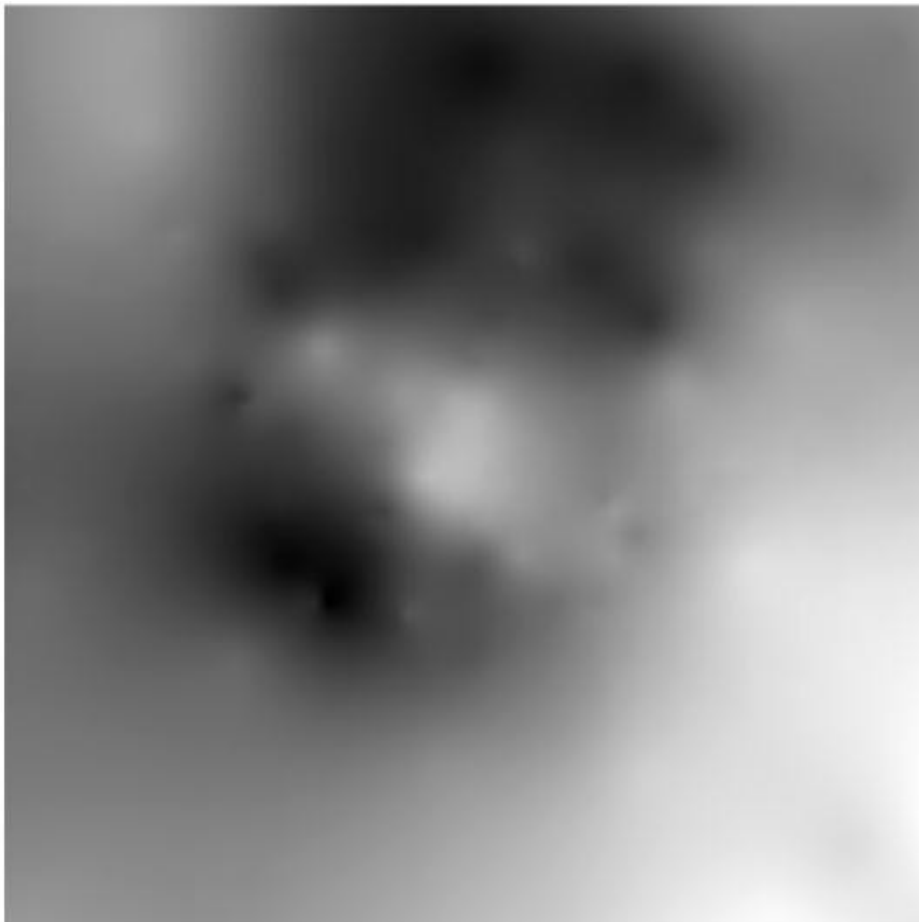
Visualization tips for geoscientists: Surfer

January 25, 2012 · by Matteo

- A part of the Apennine belt (in the Monti Romani of Southern Tuscany), a Paleozoic metamorphic basement (density $\sim 2.7 \text{ g/cm}^3$) is overlain by a thick sequence of clastic near-shore units of the Triassic-Oligocene Tuscany Nappe (density $\sim 2.3 \text{ g/cm}^3$).
- The Tuscan Nappe is in turn covered by the Cretaceous-Eocene flysh units of the Liguride Complex (density $\sim 2.1 \text{ g/cm}^3$).
- 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.

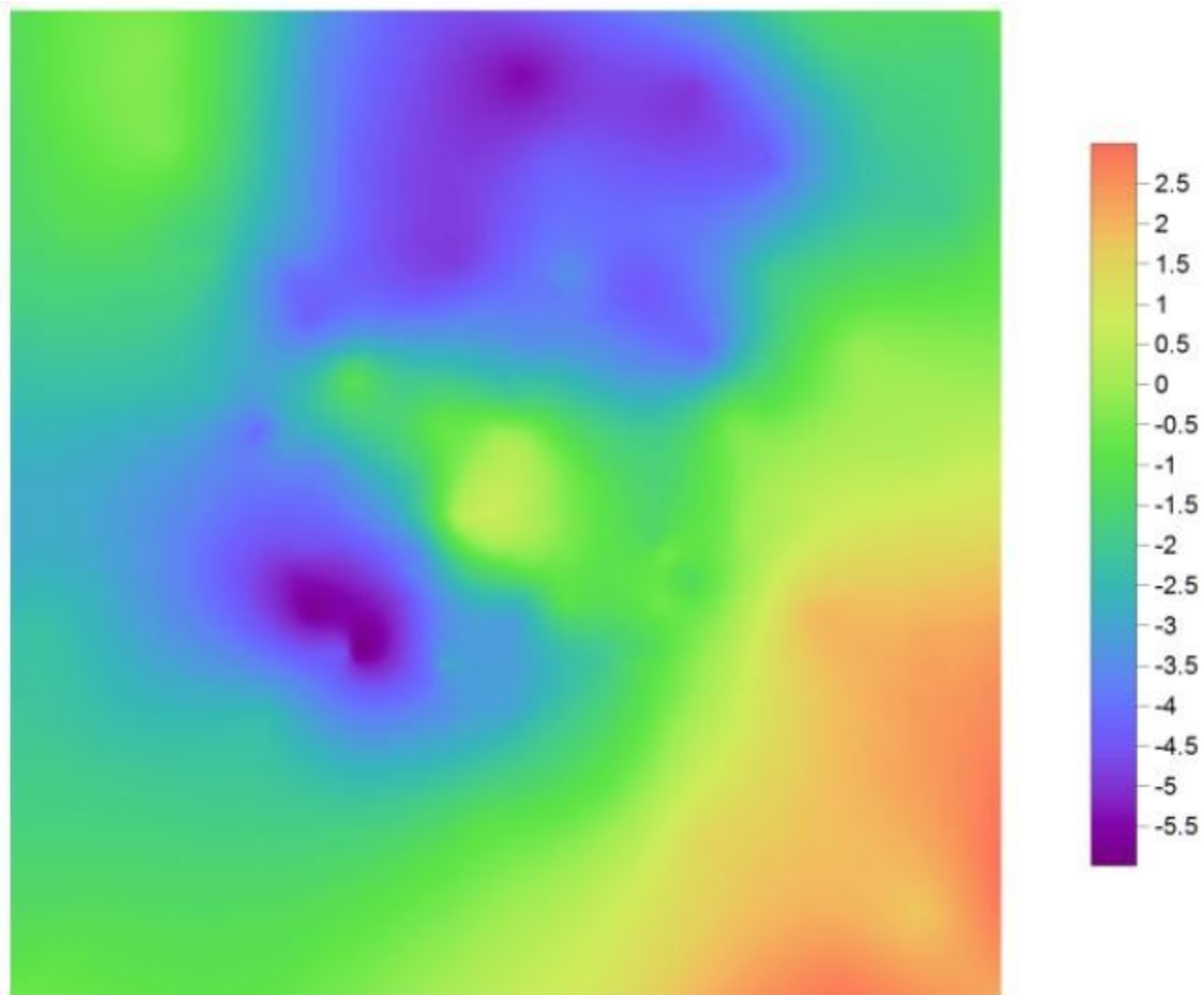


Figure 2 – Colored residual anomalies in milligals. This version of the map was generate using the IMAGE MAP option in Surfer.

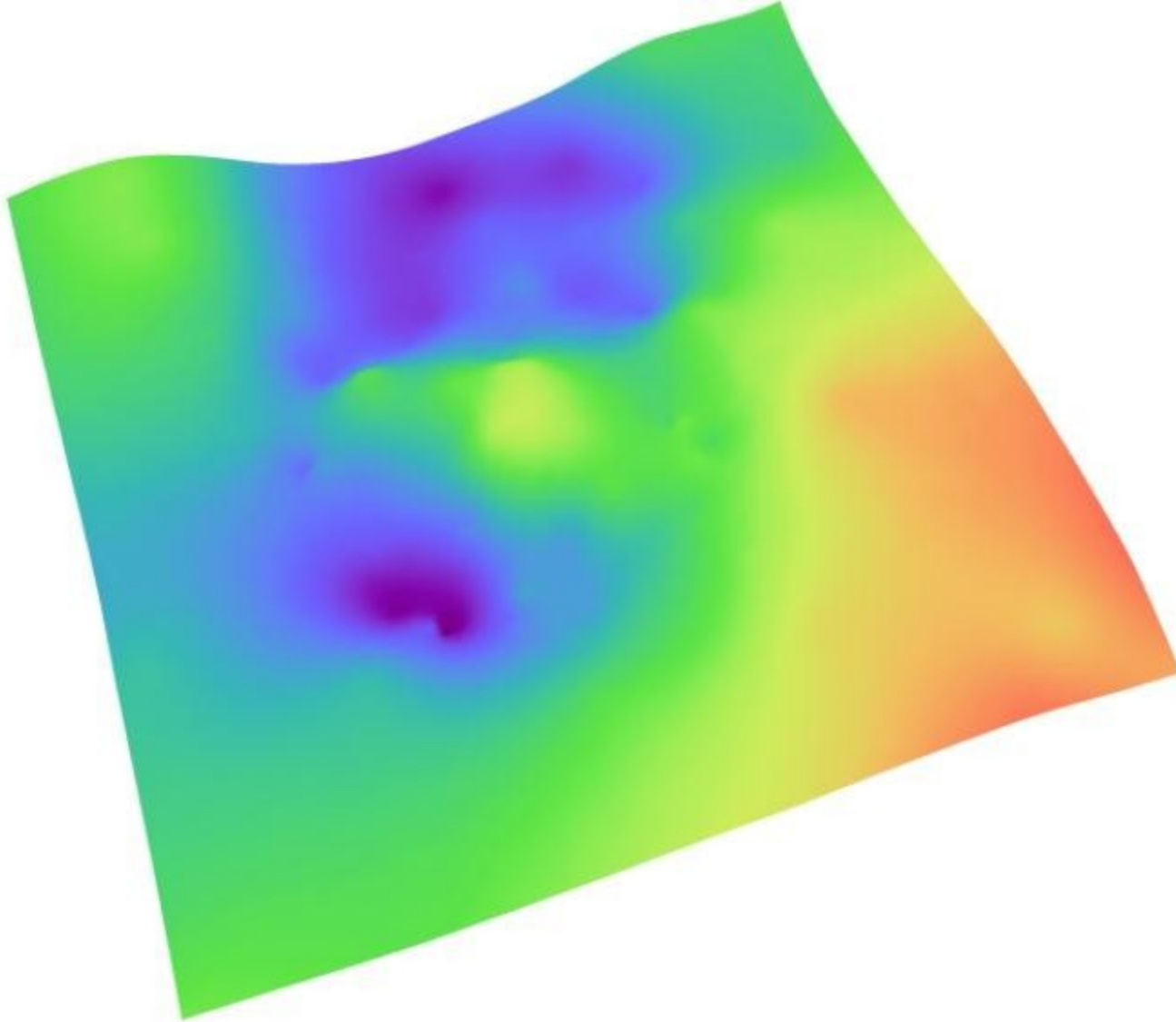


Figure 3 – Colored 3D residual anomaly map in milligals. This version of the map was generate using the SURFACE MAP option in Surfer.

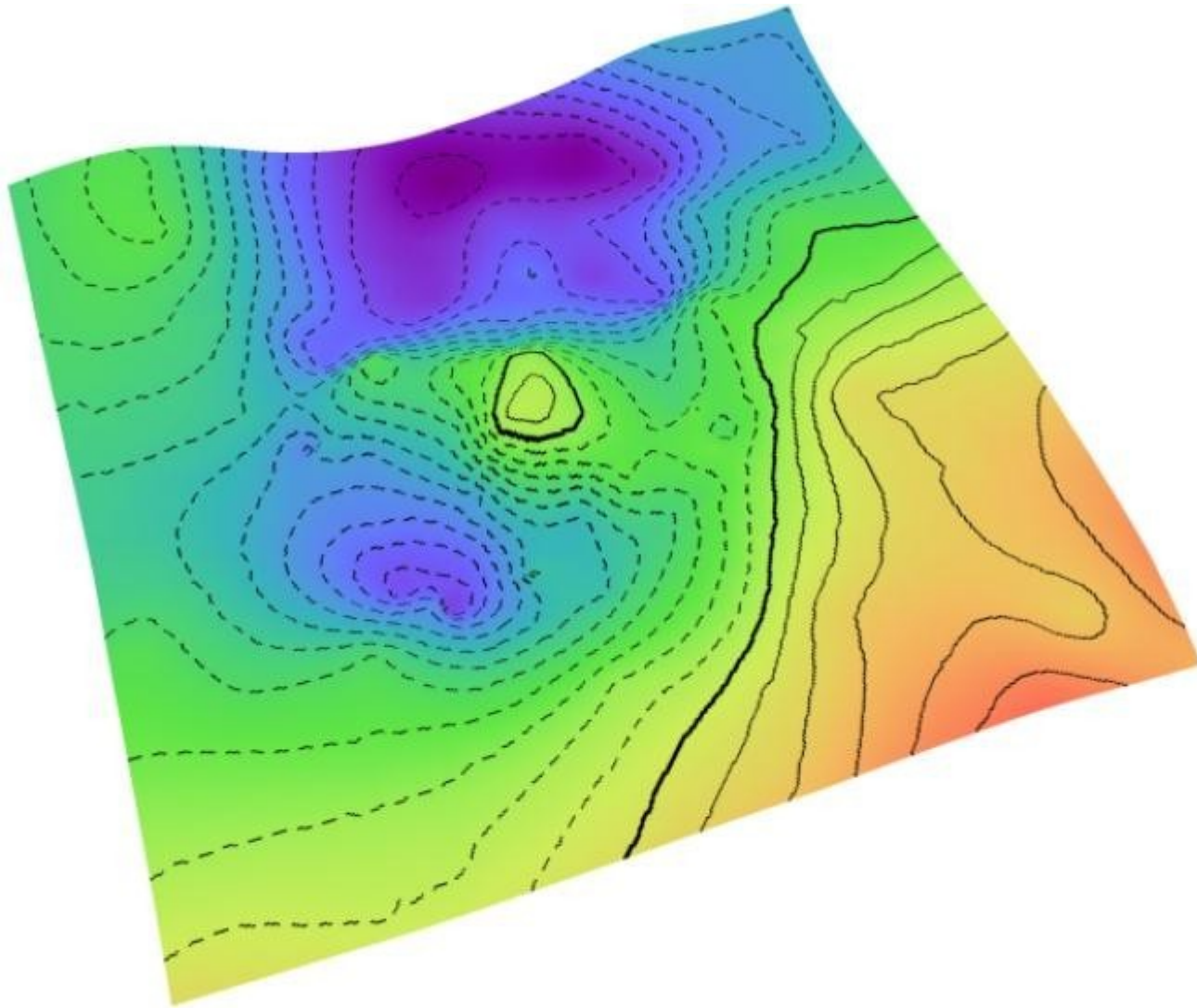


Figure 4 – Colored 3D residual anomaly map in milligals. Contours were added with the the CONTOUR MAP option in Surfer.

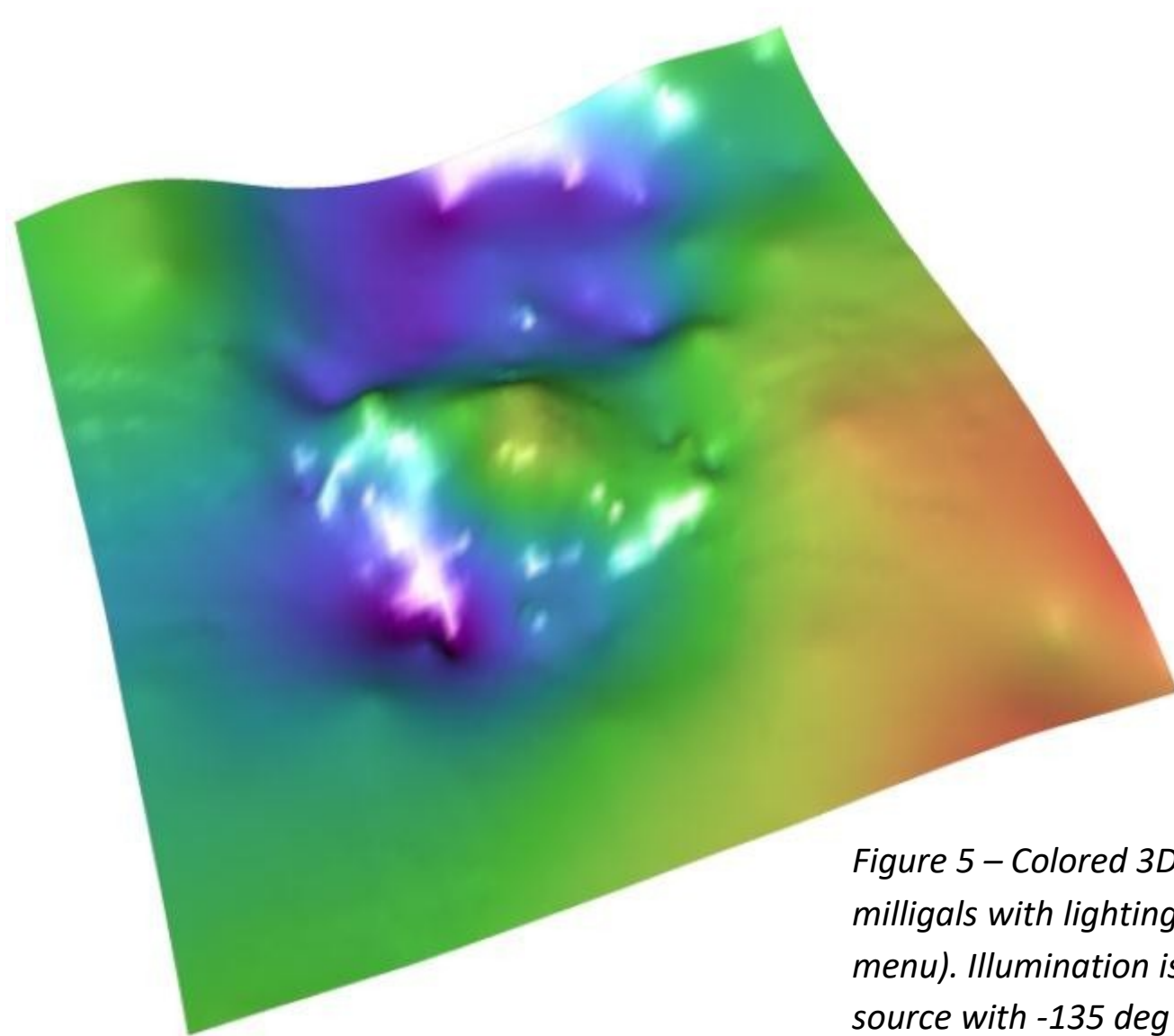
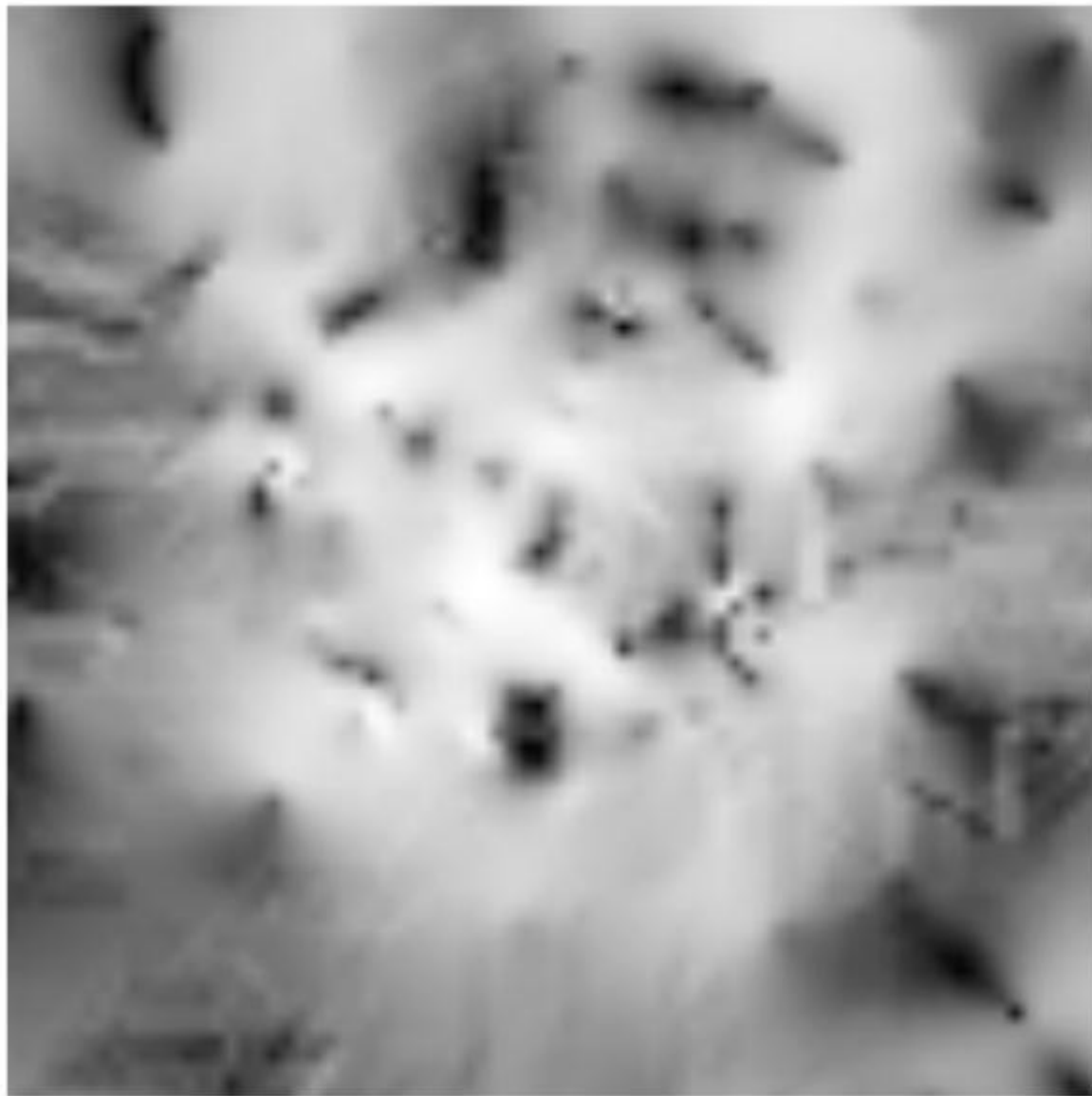
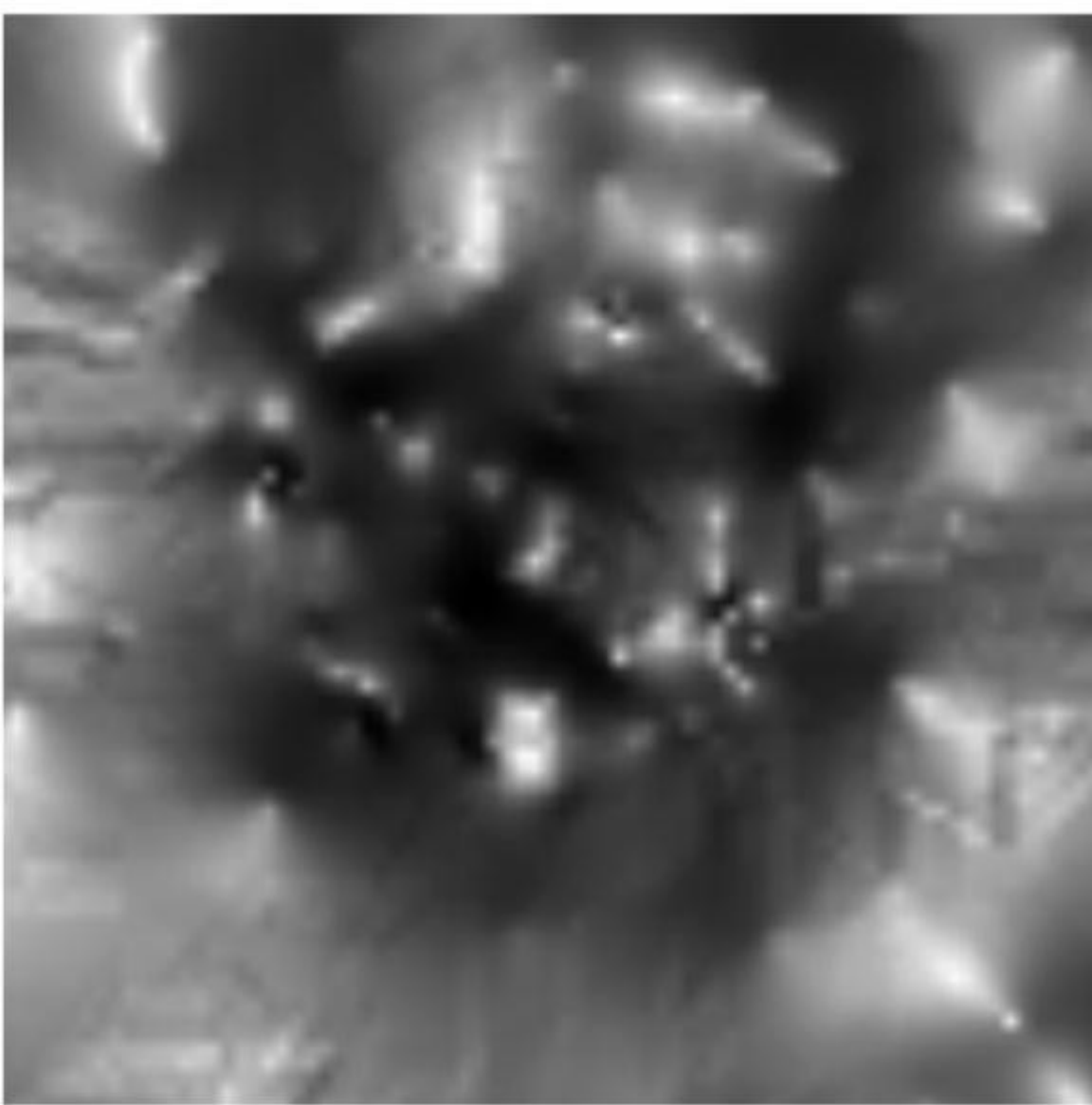


Figure 5 – Colored 3D residual anomaly map in milligals with lighting (3D Surface Properties menu). Illumination is generated by a point source with -135 deg azimuth and 60 deg elevation, plus an additional 80% gray ambient light, a 30% gray diffuse light, and a 10% gray specular light.

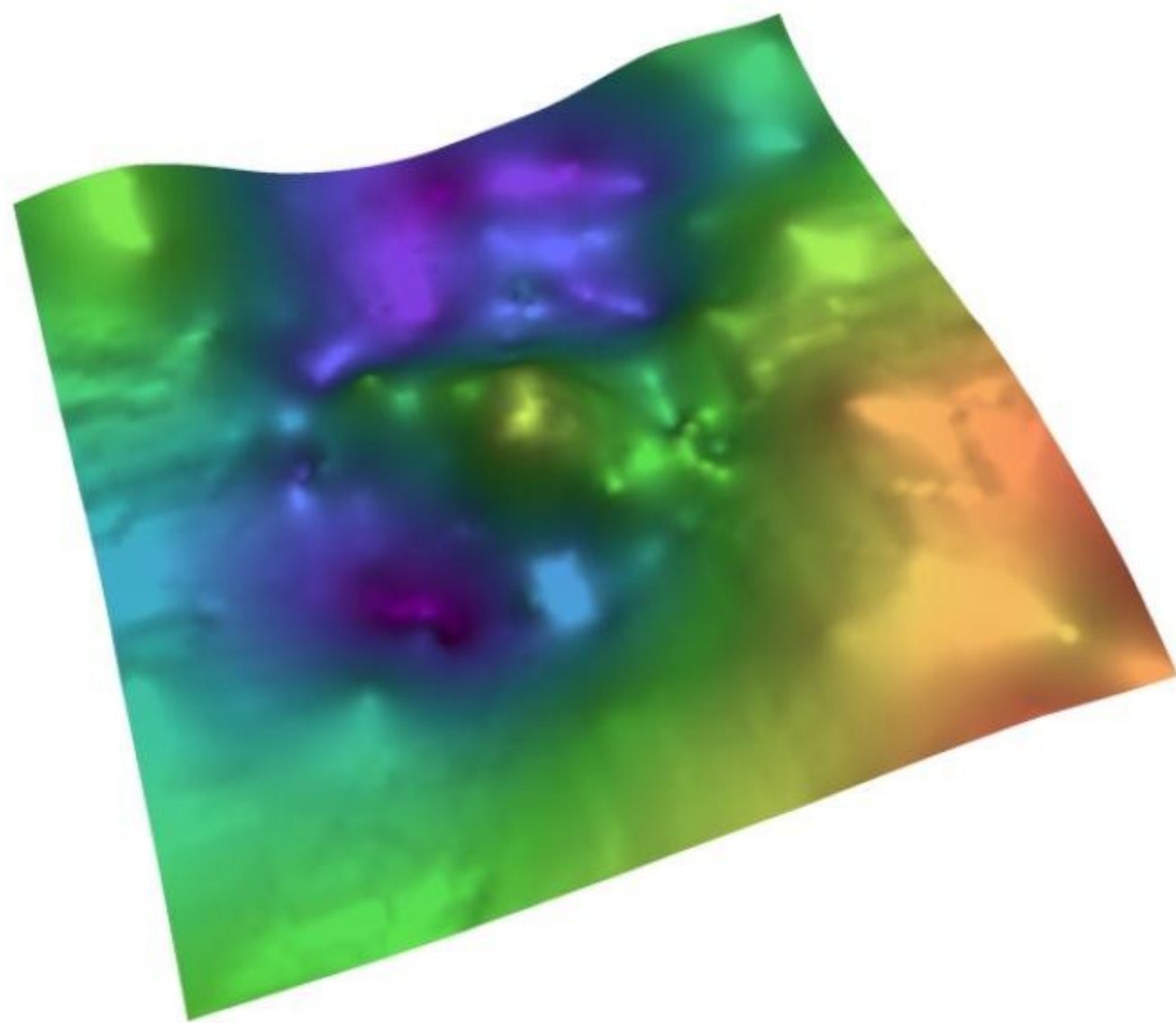


*Figure 6 – Terrain slope of residual anomaly.
Black for low gradients, white for high
gradients. Displayed using IMAGE MAP option.*



*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.*

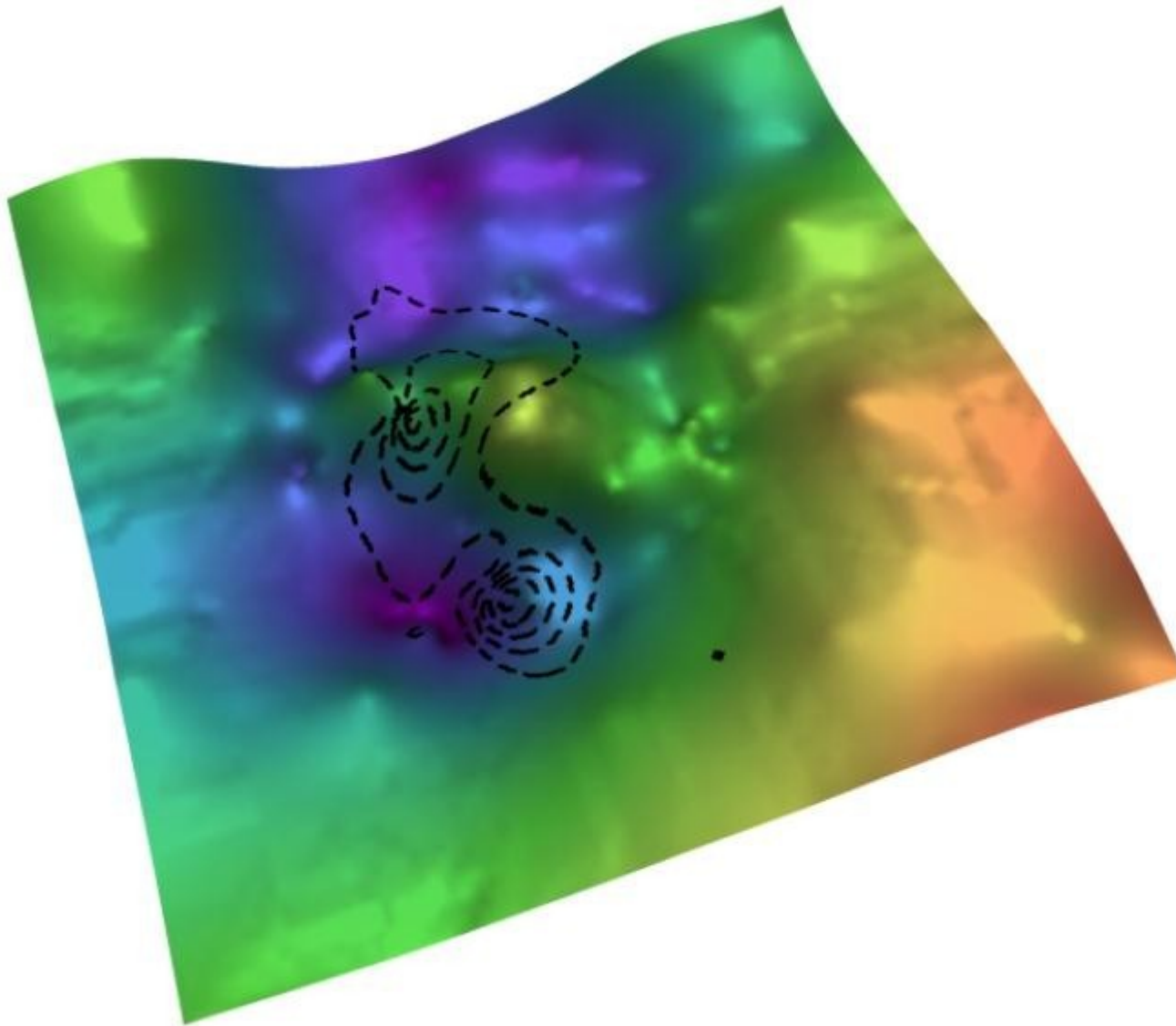


Figure 9 – Complement of the terrain slope with color added back and contour overlay of gold pathfinders in stream sediments.

3D Visualization of GRAVITY Data

Prediction of gravity anomaly from calculated densities of rocks

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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).

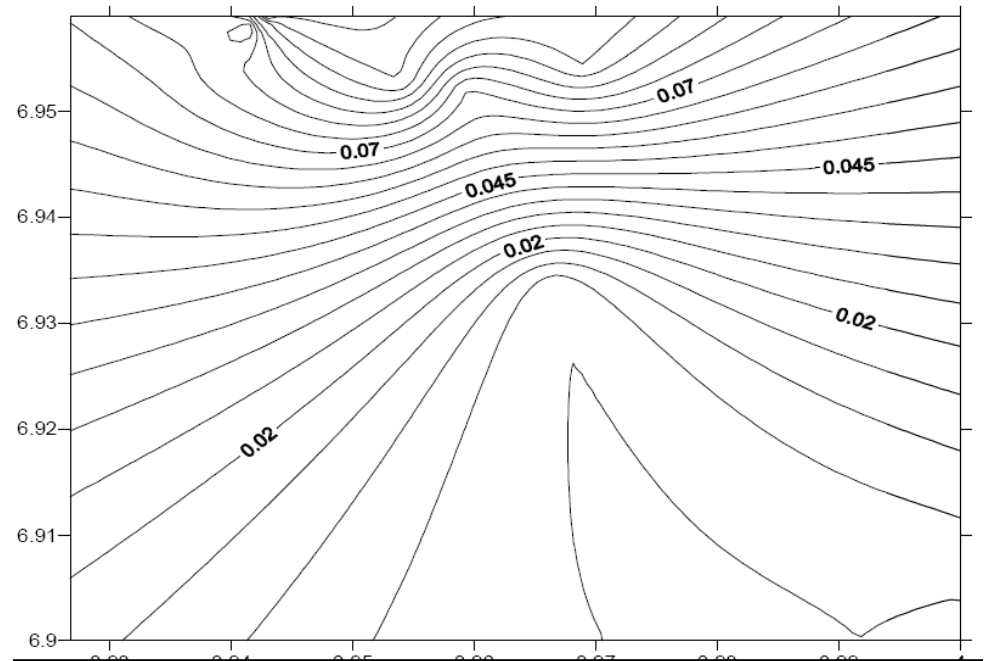
- The density of a rock is the ratio of its mass per volume.
- For specific rock types, density has less percent variability especially at specific places.
- Due to the low porosity and permeability of igneous and metamorphic rocks, the densities are considered close approximate of the field values (Subrahmanyam 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..

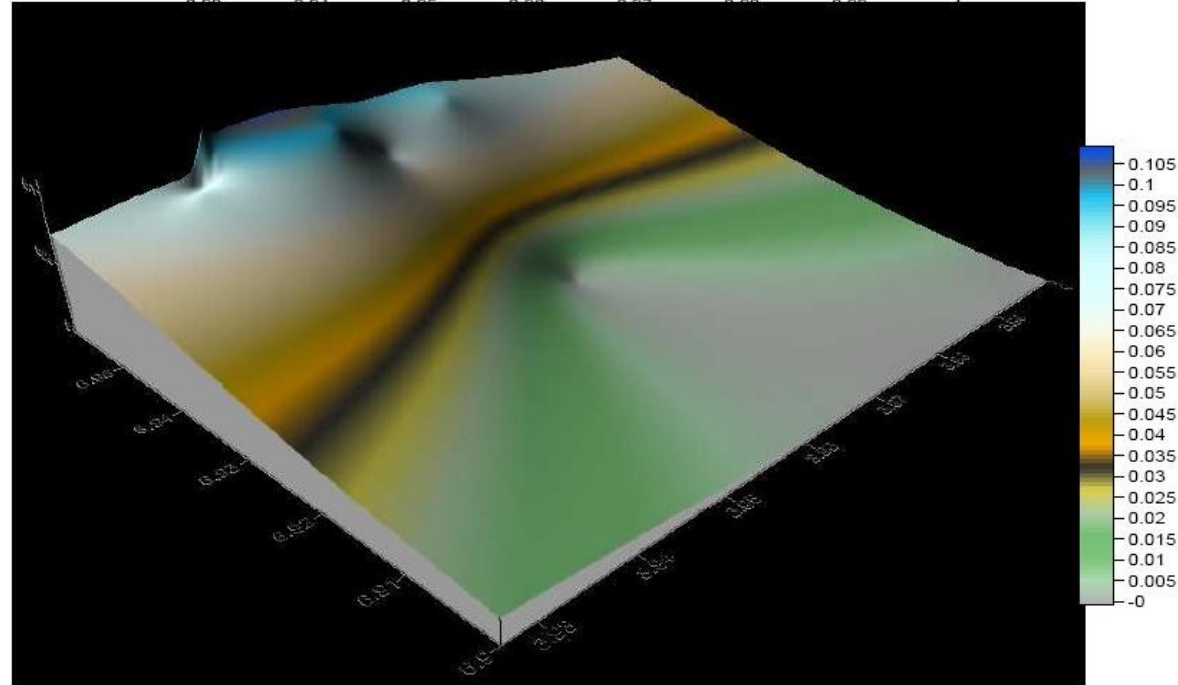
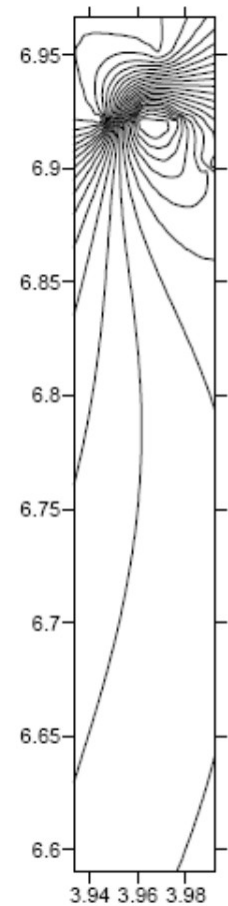


Fig 5a: Modeled gravity anomaly map of the upper part of the study area.

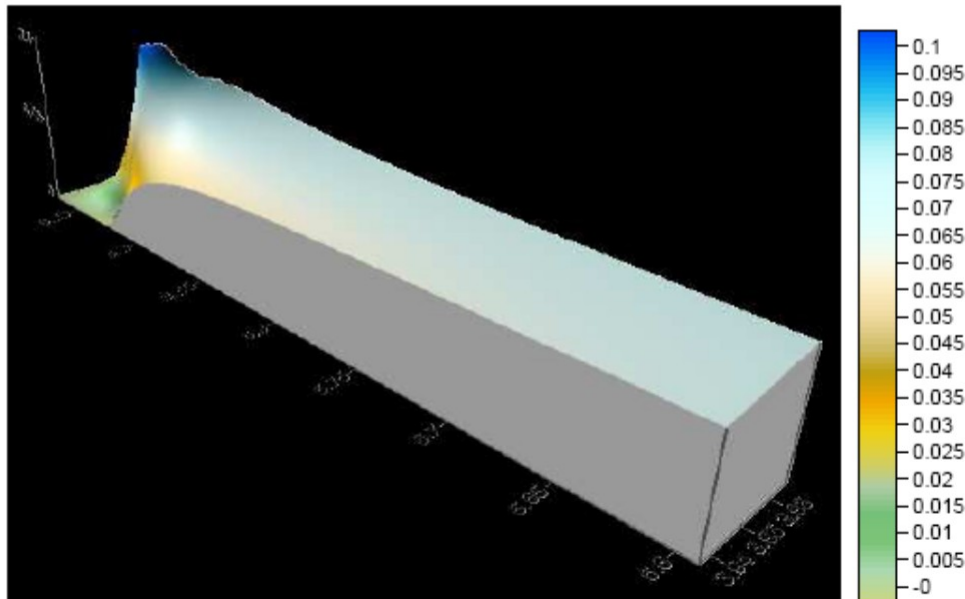


Fig.5b: Modeled gravity anomaly map of the lower part of study area.

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.

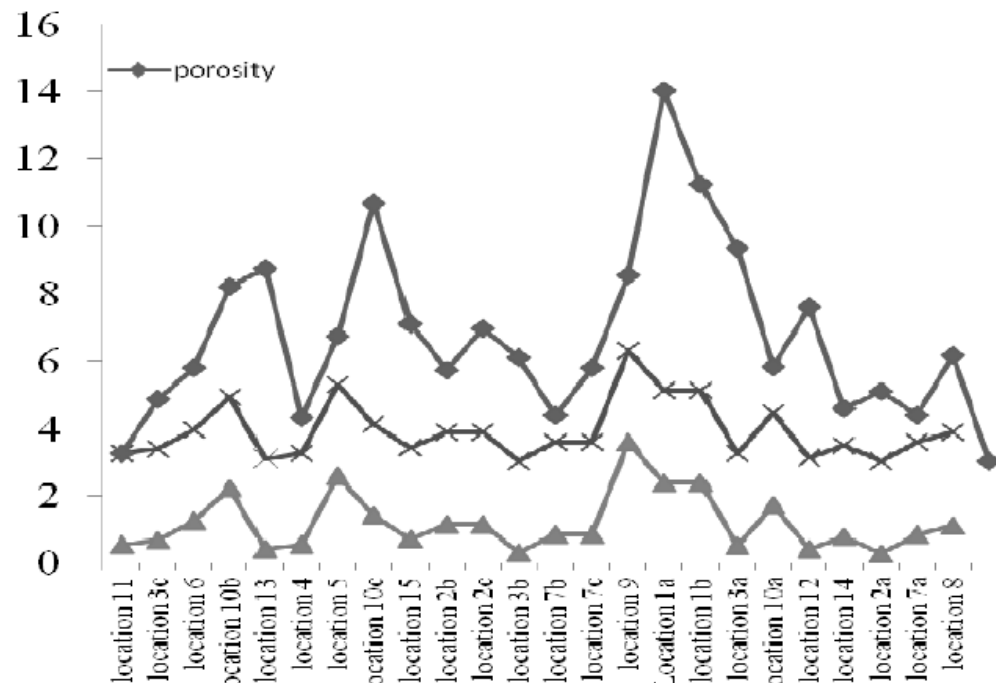


Fig 6: Plot of Porosity, density and Moisture content highlighting the dependence or variation of the variable.

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

Case Study: 2

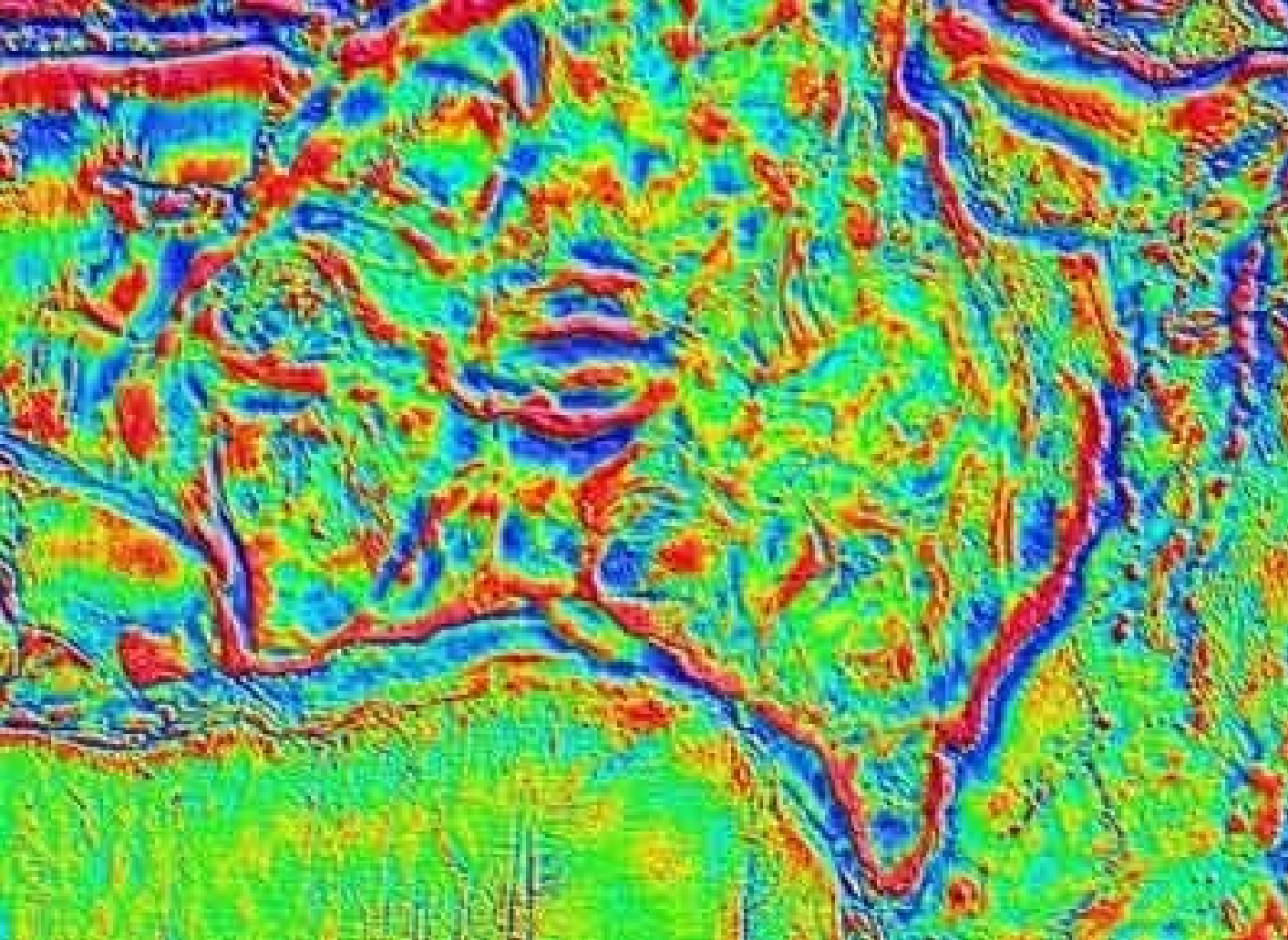
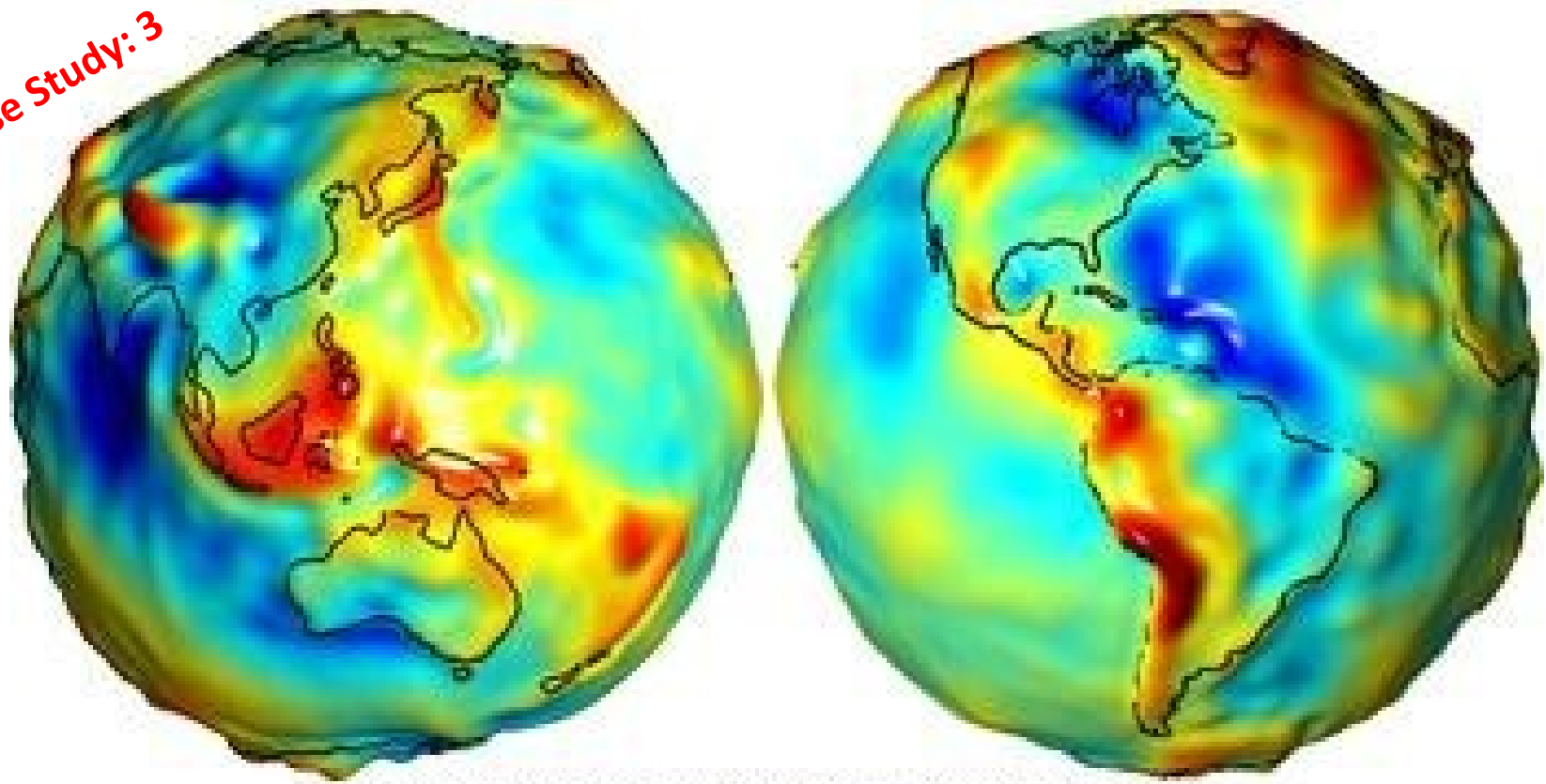


Fig. Section of
the new
Gravity
Anomaly Map
of Australia
**New Gravity Anomaly
Map of the Australian
Region** - Mario Bacchin,
Peter Milligan, Ray
Tracey and Phillip
Wynne, AusGeo News
September 2008 Issue
No. 91

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.

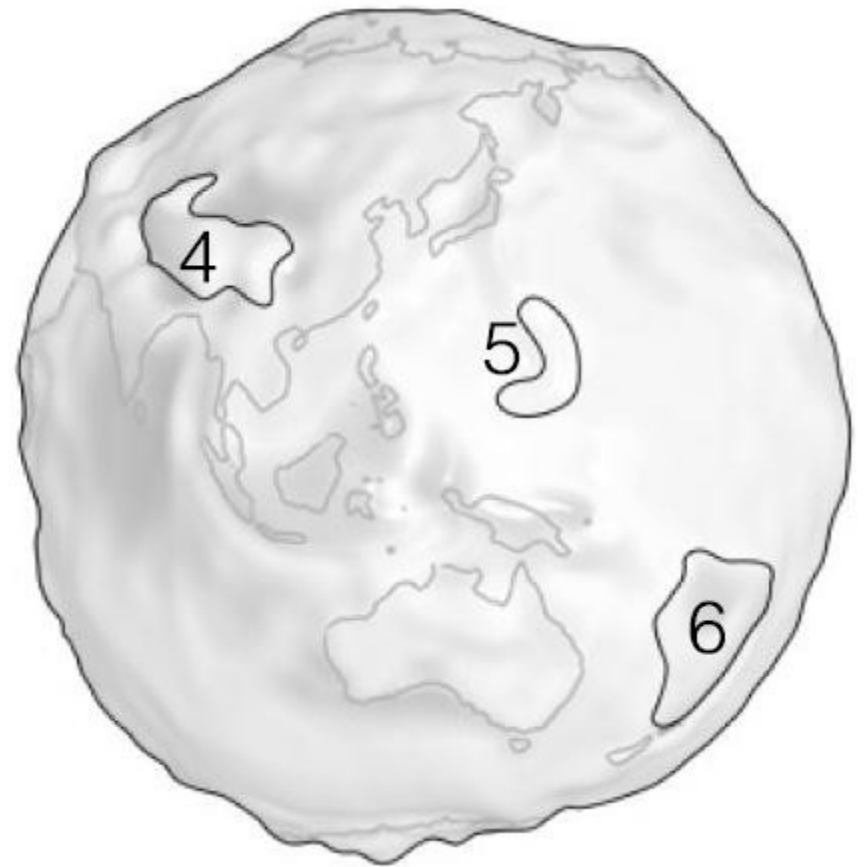
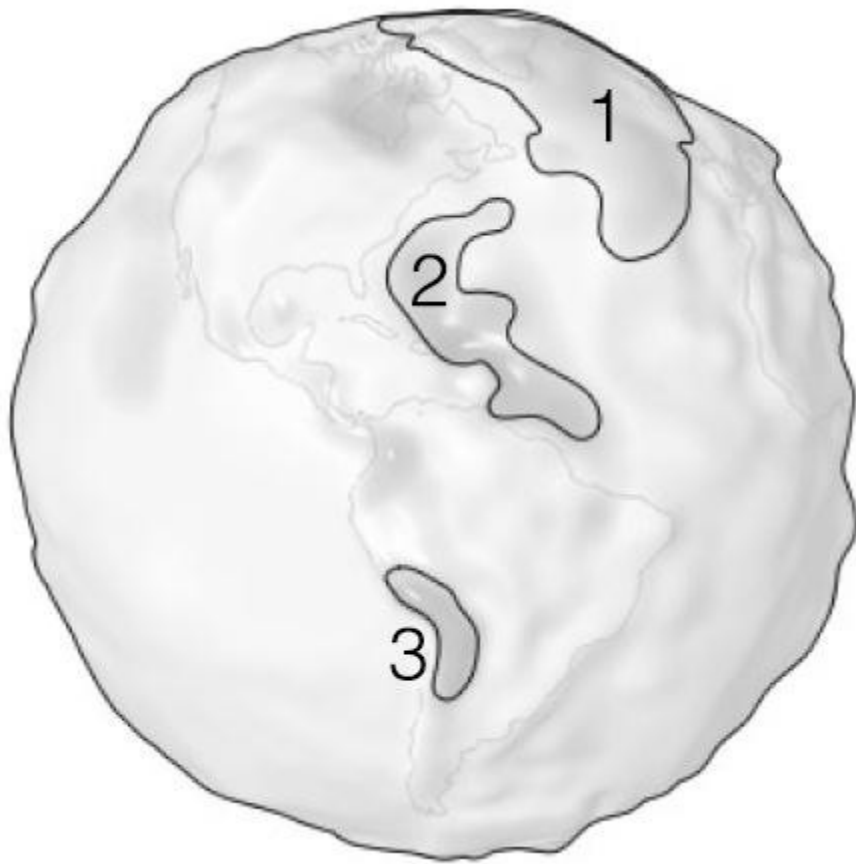
Case Study: 3



Earth's Gravity Field Anomalies (milligals)



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

3D stereoscopic visualization

Constrained 3D forward modeling using advanced interpretation and visualization

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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.

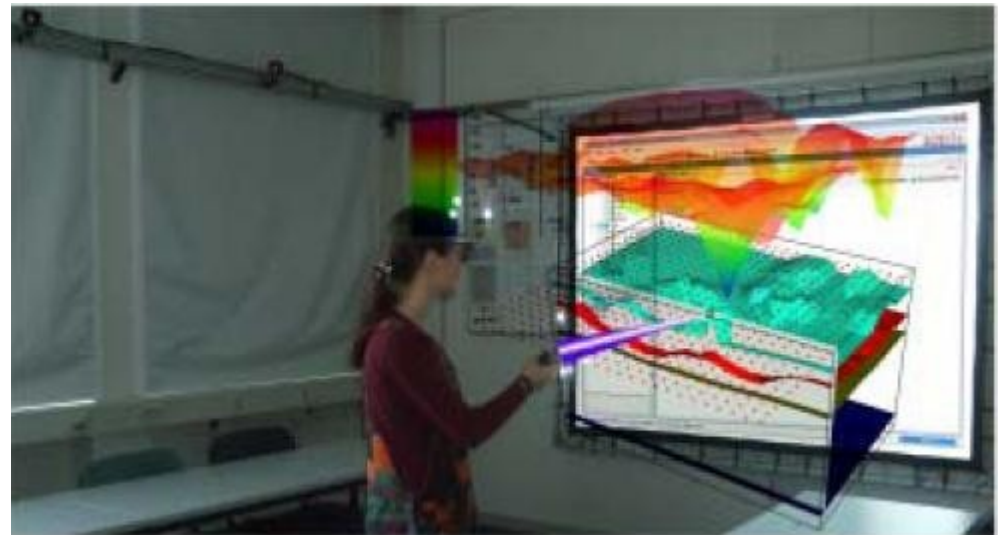
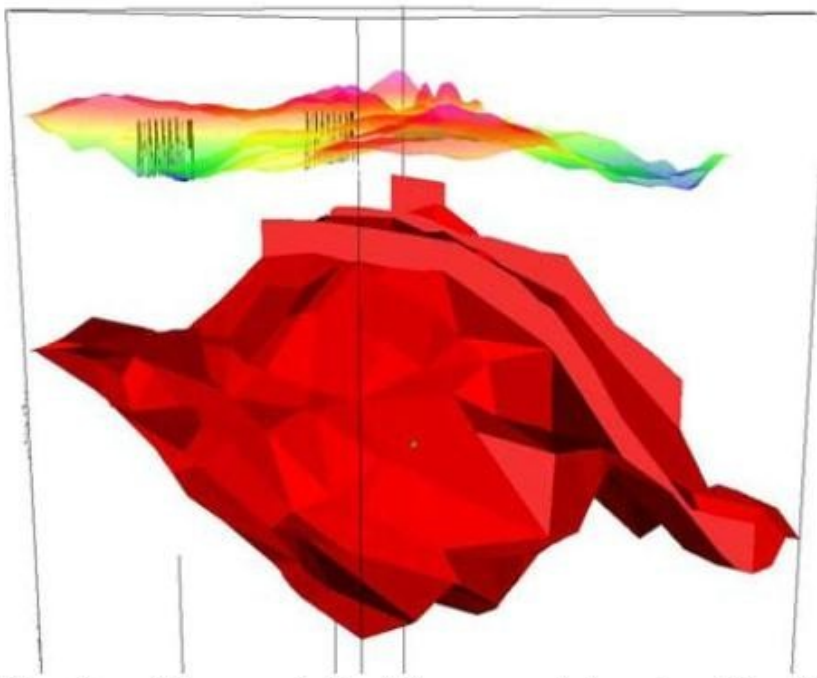


Fig 1: Immersive 3D forward modeling

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.

(a)



(b)

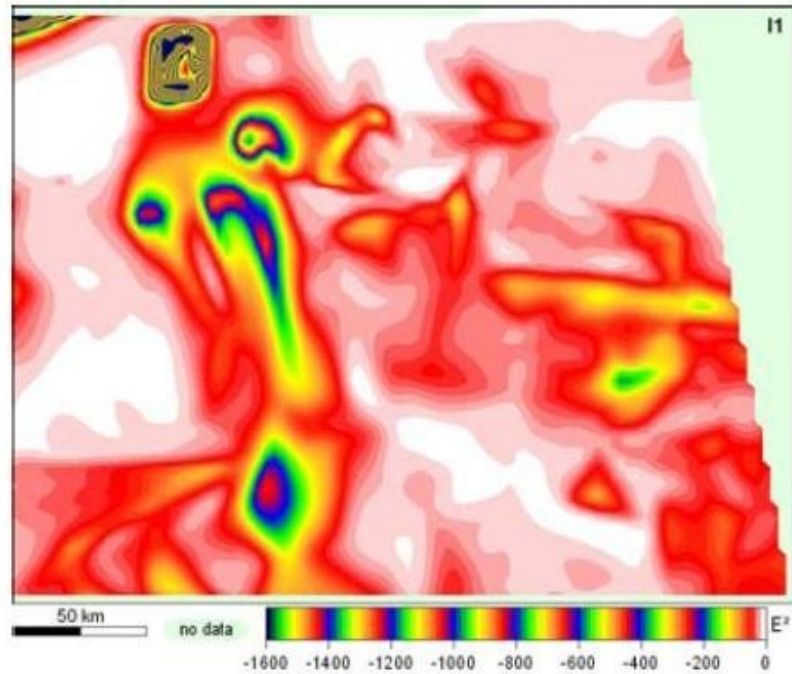


Fig. 2a: The modelled basement top in 3D. The vertical exaggeration is 25. From North (back) to South (front) a slight dip is visible which is predicted by geology. To East (right corner) a basement depression was modeled. During 2D modeling the depression was not recognized because it is a local feature. 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.

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

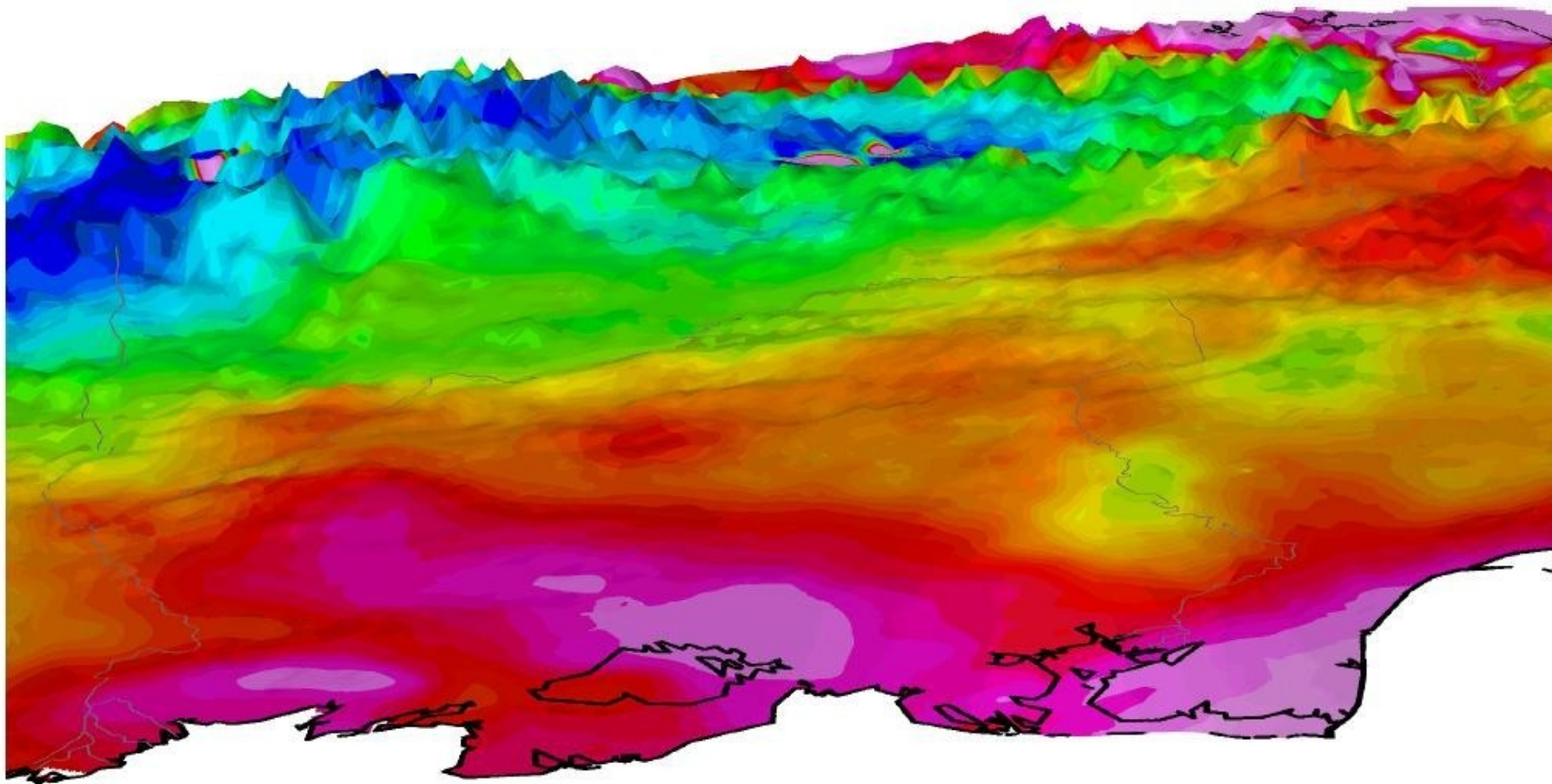
*By Gerry Connard, NGA, Inc., Corvallis, OR, USA and
Ash Johnson, Geosoft Europe, Ltd.*

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.



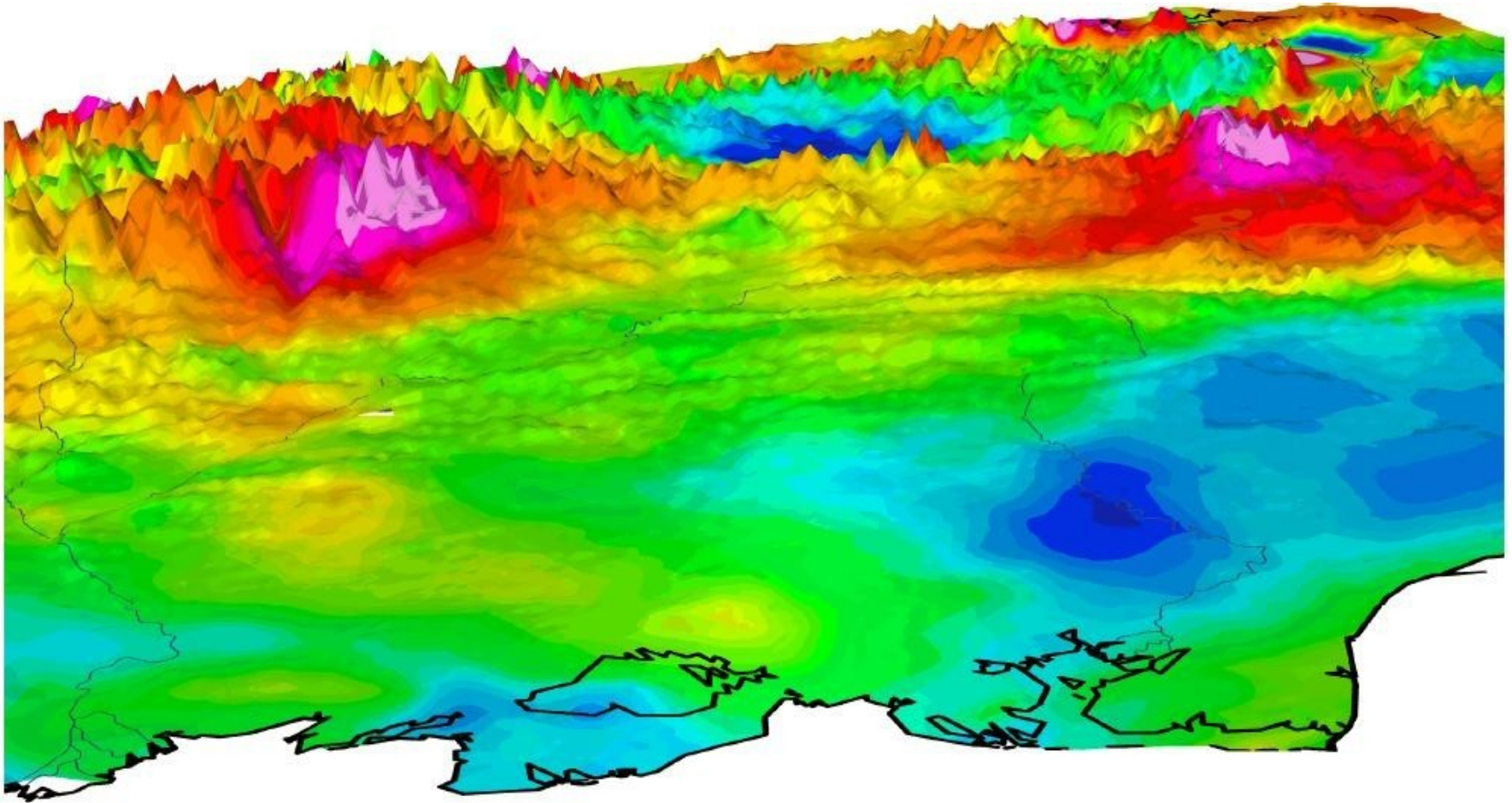
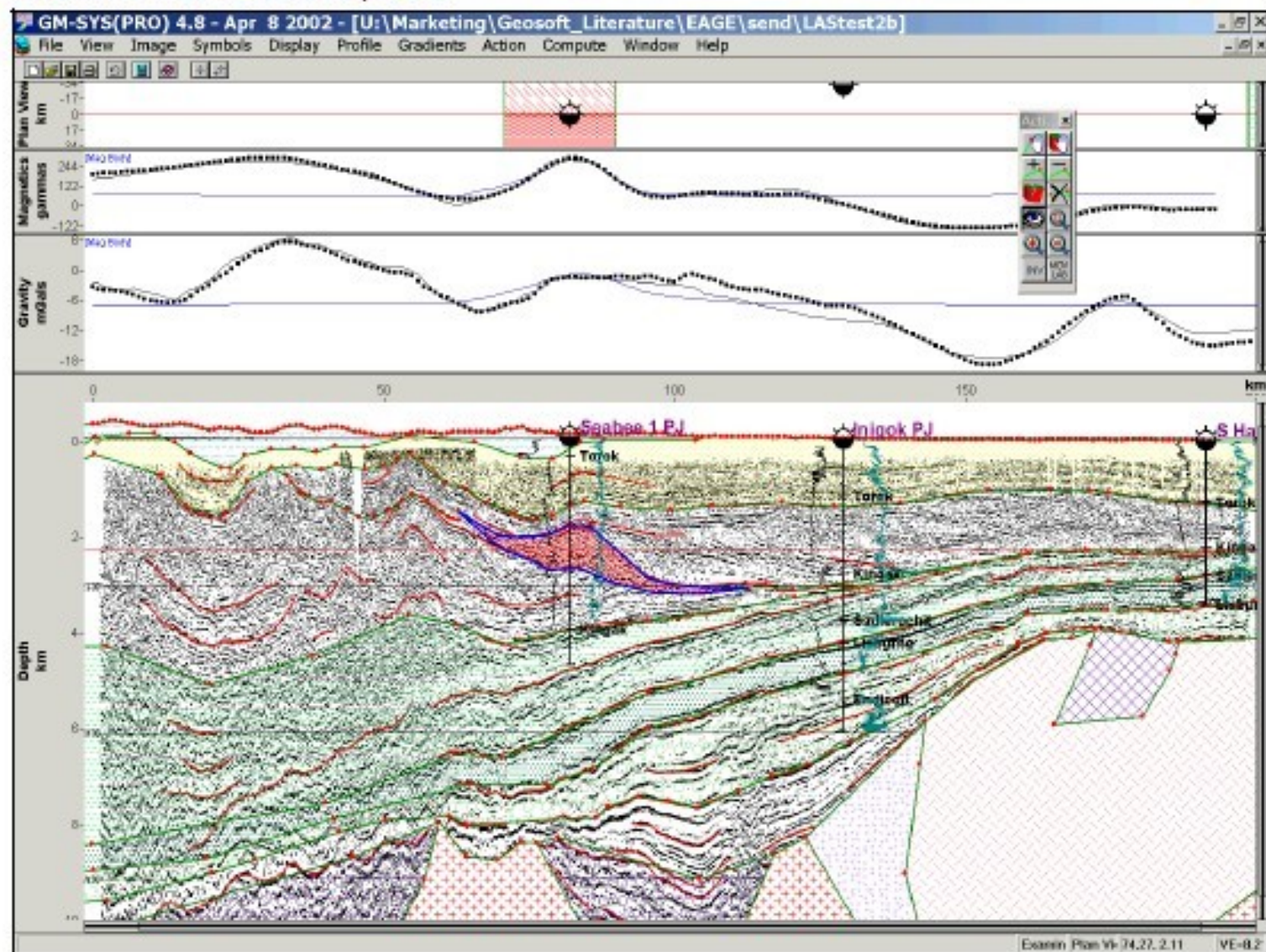


Figure 6 shows the Isostatic Residual gravity anomaly draped on topography viewed from the same point as Figure 5. The isostatic residual process has removed most of the gravity signal caused by the deeper Moho under the Brooks Range, thereby enhancing the gravity signal from upper-crustal sources.

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

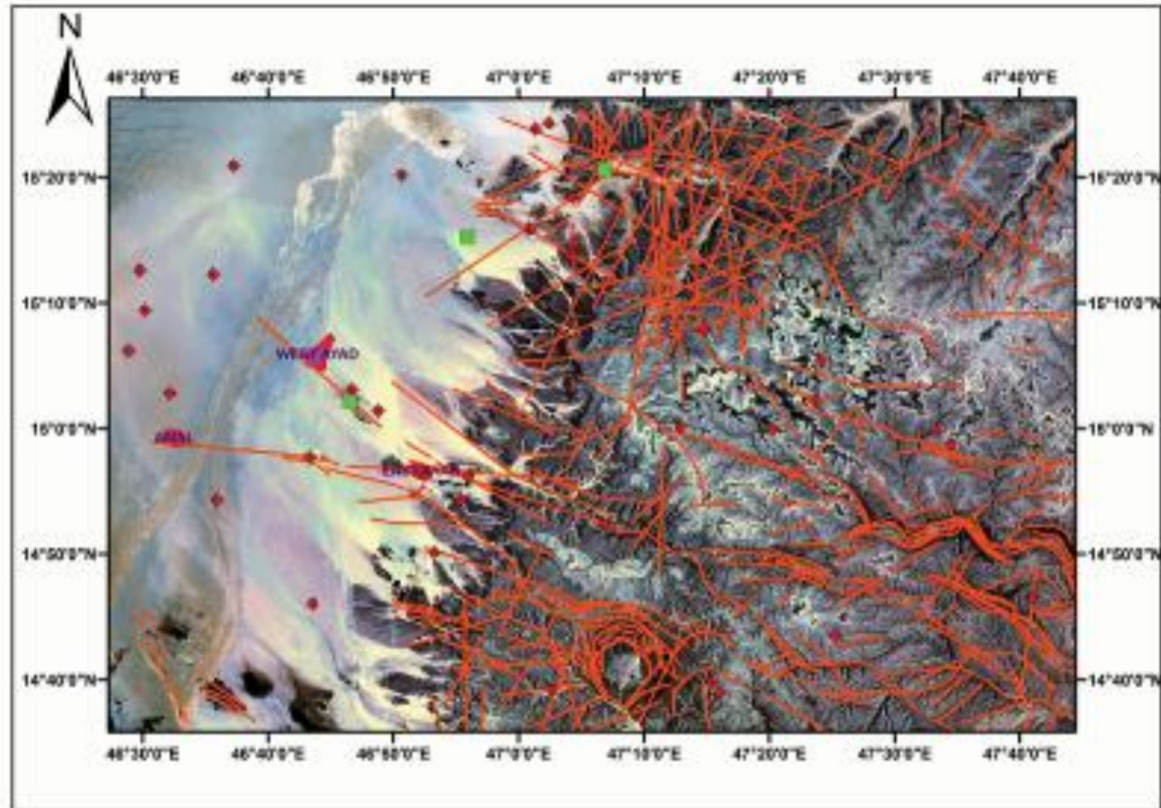
Significance of Surface Lineaments for Gas and Oil Exploration in Part of Sabatayn Basin-Yemen

- 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

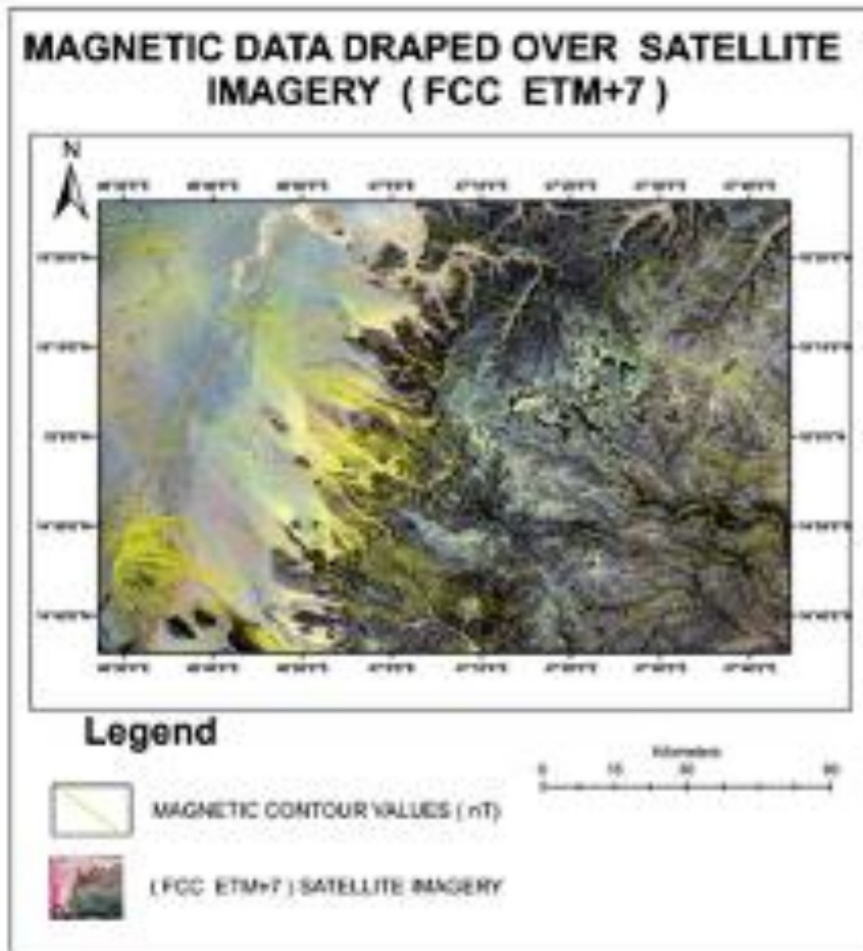
SURFACE LINEAMENTS INTERPRETED FROM SATELLITE IMAGERY



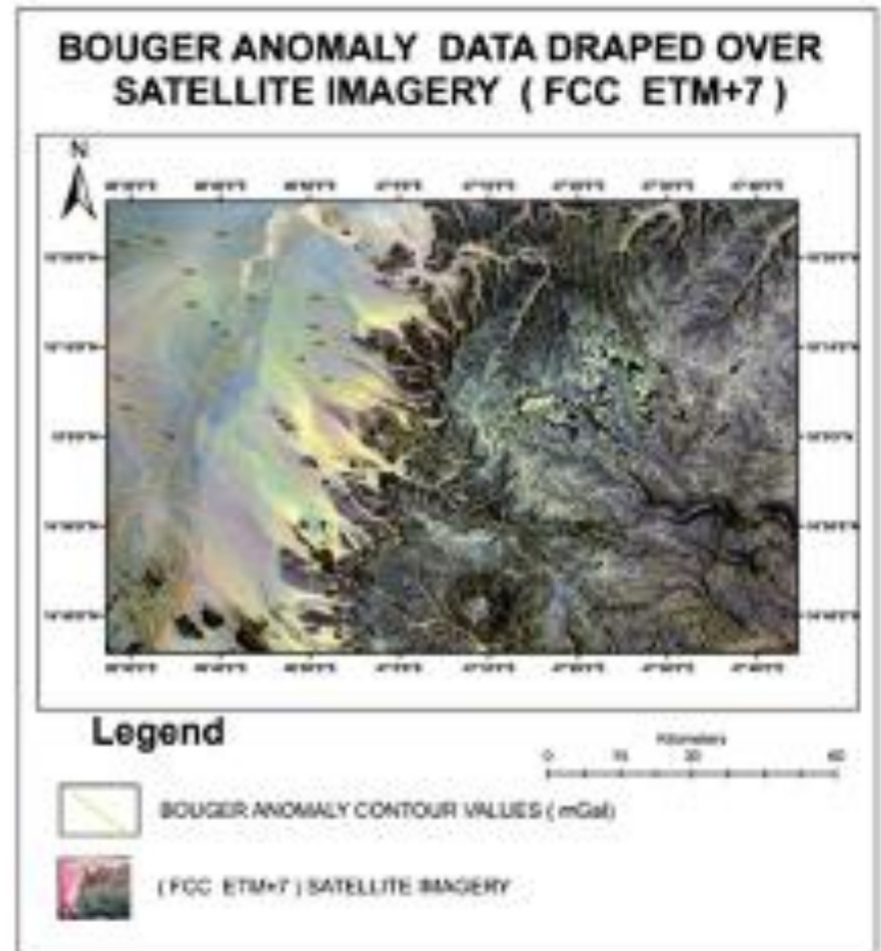
Legend

- Active Oil Seeps
- Wellbores Locations
- Oil & Gas Fields
- Surface Lineaments Extracted from Satellite imagery

0 15 30 60 Kilometers



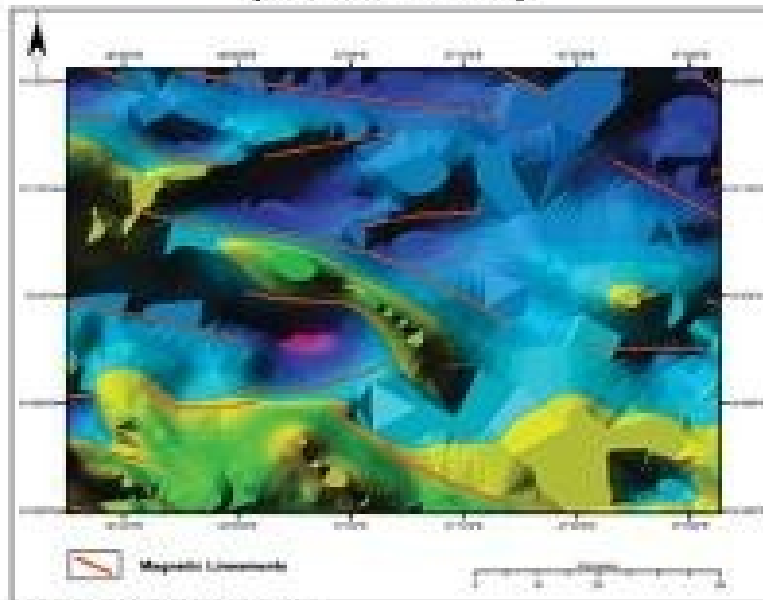
A



B

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

MAGNETIC DEM MAP WITH BREAKS (LINEAMENTS)

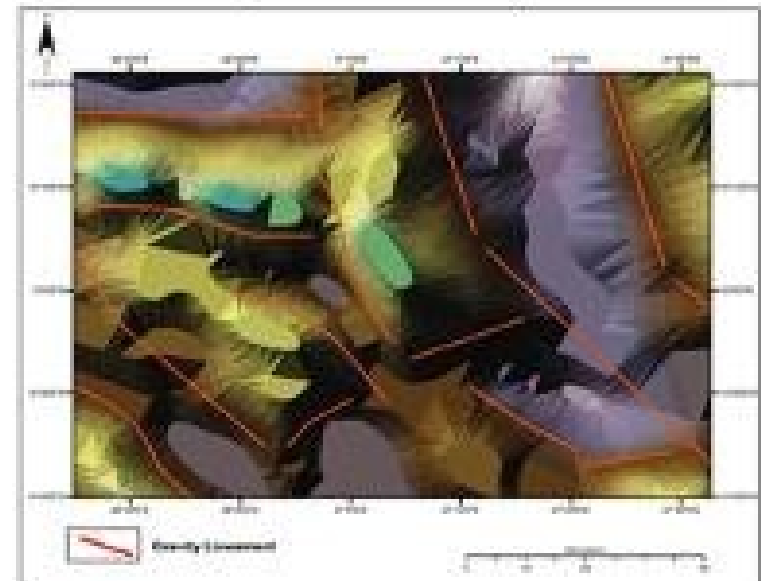


MAGNETIC VALUES-(nT)

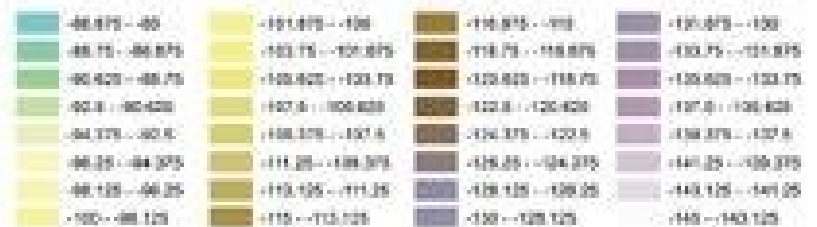


C

GRAVITY DEM MAP WITH BREAKS (LINEAMENTS)



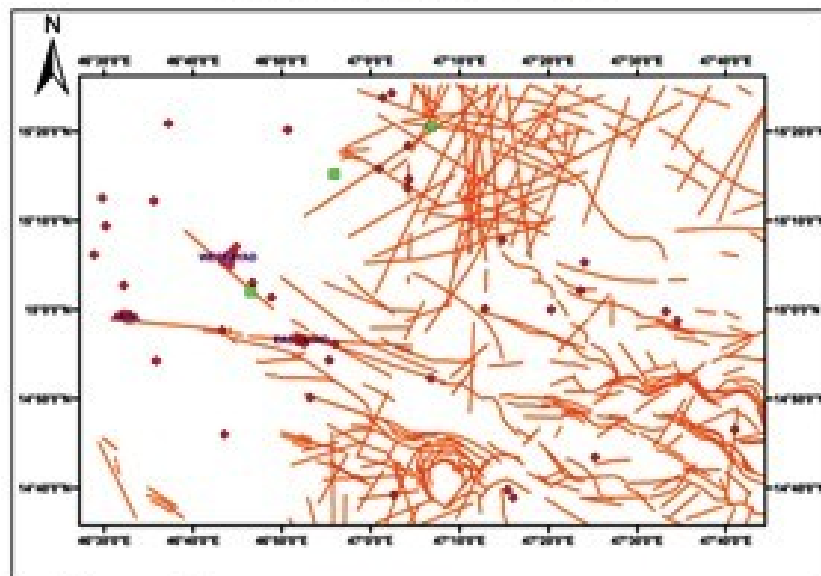
GRAVITY VALUES-(MGAL)



D

C,D)Magnetic and Gravity DEM models

SURFACE LINEAMENTS INTERPRETED FROM SATELLITE IMAGERY

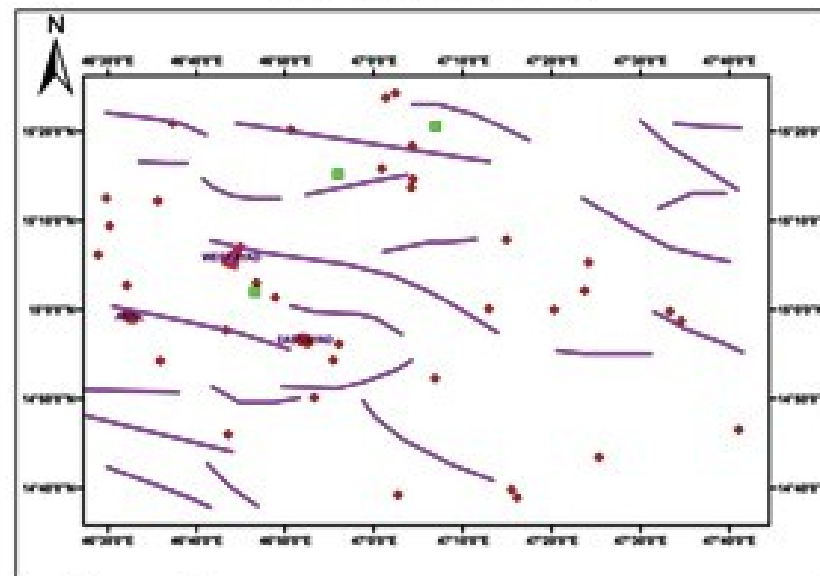


Legend

- Active Oil Seeps
- ◆ Wellbores Locations
- Oil & Gas Fields
- ▬ Surface Lineaments Extracted from Satellite imagery

A

LINEAMENTS INTERPRETED FROM MAGNETIC DATA



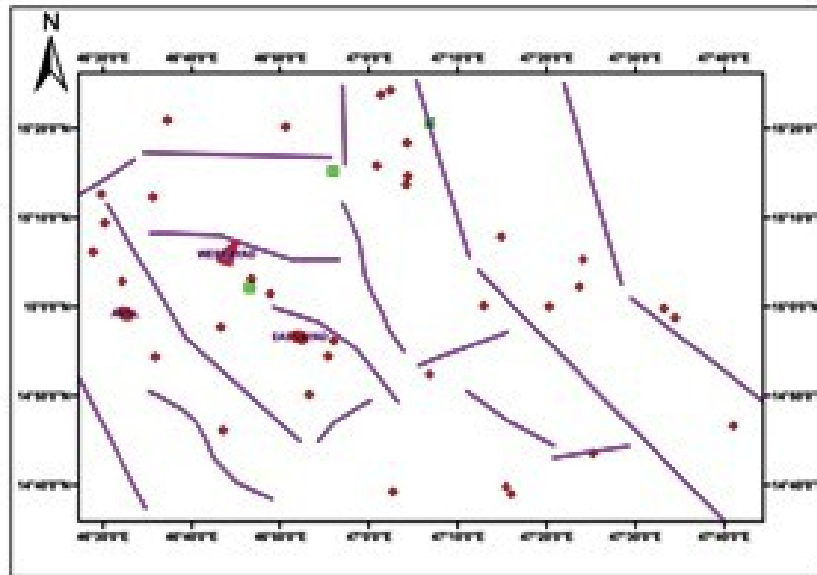
Legend

- Active Oil Seeps
- ◆ Wellbores Locations
- Oil & Gas Fields
- ▬ Magnetic Lineaments

B

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

LINEAMENTS INTERPRETED FROM BOUGER ANOMALY DATA

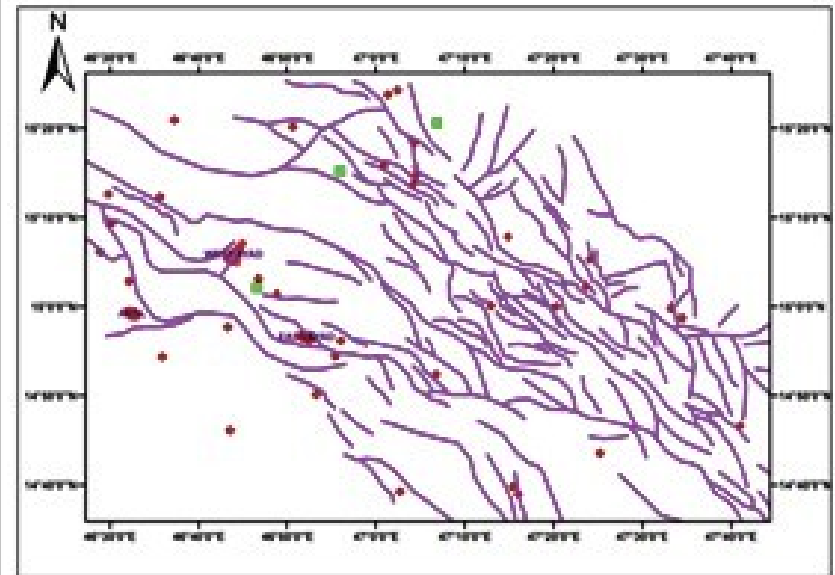


Legend

- Active Oil Seeps
- Wellbores Locations
- Oil & Gas Fields
- ▬ Bouguer Anomaly Lineaments

C

BASEMENT LINEAMENTS INTERPRETED FROM SEISMIC DATA



Legend

- Active Oil Seeps
- Wellbores Locations
- Oil & Gas Fields
- ▬ Basement Lineaments

D

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