GIS BASED 3D VISUALIZATION OF SUBSURFACE AND SURFACE LINEAMENTS / FAULTS AND THEIR GEOLOGICAL SIGNIFICANCE, NORTHERN TAMIL NADU, INDIA

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ABSTRACT:

The study area falls in the southern part of the Indian Peninsular comprising hard crystalline rocks of Archaeozoic and Proterozoic Era. In the present study, the GIS based 3D visualizations of gravity, magnetic, resistivity and topographic datasets were made and therefrom the basement lineaments, shallow subsurface lineaments and surface lineaments/faults were interpreted. These lineaments were classified as category-1 i.e. exclusively surface lineaments, category-2 i.e. surface lineaments having connectivity with shallow subsurface lineaments and category-3 i.e. surface lineaments having connectivity with shallow subsurface lineaments and basement lineaments. These three classified lineaments were analyzed in conjunction with known mineral occurrences and historical seismicity of the study area in GIS environment. The study revealed that the category-3 NNE-SSW to NE-SW lineaments have greater control over the mineral occurrences and the N-S, NNE-SSW and NE-SW, faults/lineaments control the seismicities in the study area.

1. INTRODUCTION

All over the world, metallic mineral deposits were found mostly in fold closures, faults / lineaments and their intersections. Hence, the Geoscientists have been concentrating more in mapping the folded structures and lineaments for mineral exploration. The Purulia, West Bengal base metal mineralization in proximity to Ranchi Mega lineament (Ashok Kumar et al., 1994), the Olympic Dam Cu-Au-U-Rare Earth Element deposits, Australia (Woodall, 1994) along the surface and geophysical lineaments, copper mineralization, Khetri district, India 320 km long NE-SW Kaliguman lineament (Knight et al., 2002) and the low grade uranium deposit again along the above Kaliguman lineament in the north Delhi fold belt in the states of Rajasthan and Haryana (Yadav et al., 2002) and the metallogeny in Uchur-Maya Basin, Southeastern Siberian Platform is control by the lineaments derived from SRTM (Shuttle Radar Topographic Mission) data (Gil'manova et al., 2012), etc. are certain significant studies in this direction.

Similarly, the seismicities were also mostly found along the lineaments and their intersections. The major and disastrous earthquake episodes of Himalayas were found to be concentrated in Main Central Thrust (MCT) (An Yin, 2006), the Bhuj-Kutch (2001) earthquake along the E-W trending faults (Biswas, 2005) which swing into NE-SW direction as Luni-Sukri lineaments extend for several hundred kilometres and exhibit sinistral displacement in Siwaliks in the foot hills of Himalayas (Bakliwal and Ramasamy, 1987), the large number of earthquakes of central India fell along the Son-Narmada lineament (Kaila et al., 1985), clusters of earthquakes along NNE-SSW to NE-SW lineaments/faults systems in northeastern parts of India (Kayal, 2010), the seismicities found along the N-S trending lineaments (Singh and Venkatesh Raghavan, 1989) and ENE-WSW lineaments (Nair, 1987) in parts of Kerala and the spatial modeling in between the lineaments and historical seismicities which revealed that the lineaments falling in azimuthal direction of $N31^0$-80^0E are seismogenic (Ramasamy et al., 2008) are proven facts indicating the control of lineaments over the seismicities. In the earlier studies also, lineaments were mapped from field, aerial and satellite remote sensing images, gravity and magnetic datasets. But the advanced virtues available with modern Remote Sensing and GIS technology like 3D visualization of SRTM revealed topography which enhances the lineaments and evaluation of depth persistence of the lineaments using the Digital Elevation Models (DEM) of geophysical datasets to explore its control over resources and hazards have not been done. So the present study has been carried out to map the lineaments at surface, shallow subsurface and deep seated levels using Remote Sensing and geophysical datasets and integrate them to elucidate their control over the mineralization and seismicity and therefrom identify the probable target areas for mineral exploration and probable seismogenic lineaments/faults of the study area (Figure 1).

2. MAPPING OF SURFACE AND SUBSURFACE LINEAMENTS

2.1 Surface Lineaments

The surface lineaments were interpreted visually at the first level using IRS P6 LISS 3 satellite data (Figure 1A). Further, the SRTM data which provides topographic elevation of the earth surface with 90 m spatial resolution was studied using ENVI image processing software and the shaded relief image was generated by giving imaginary light source at 135^0 azimuth and 40^0 altitude over SRTM data which gave different shades to the topography according to the relief of the earth surface. Such relief variation and related various shades aided in the precise mapping of the surface lineaments which were expressed as long and linear well-defined depressions (Figure 1B&1C). The lineaments deduced through visual interpretation of satellite FCC data and the lineaments interpreted so from SRTM based shaded relief image were integrated and the GIS layer on surface lineaments was prepared (Figure 1D).

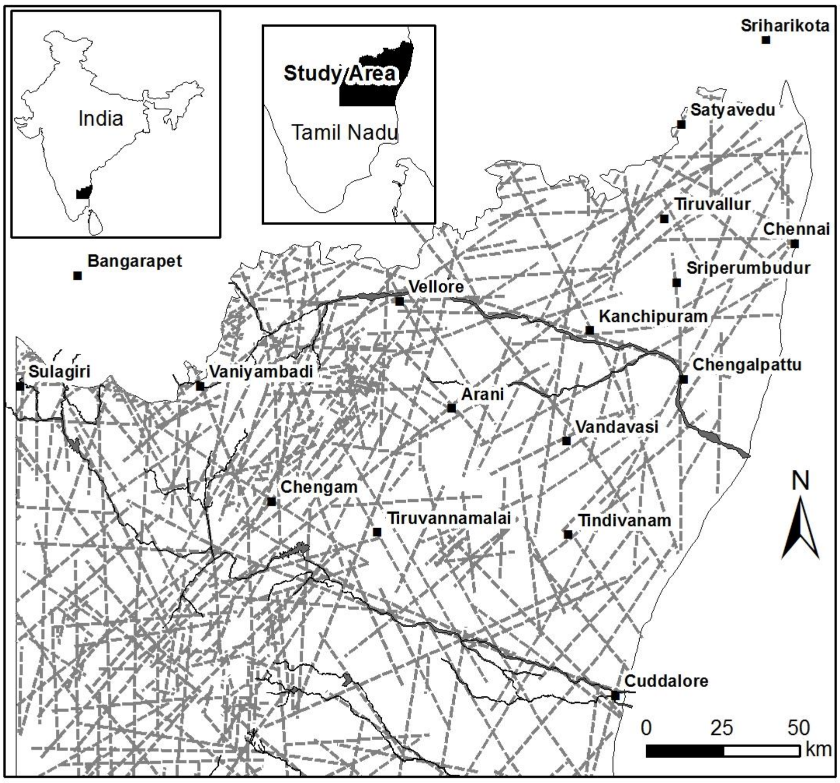


Figure1D. Surface Lineaments

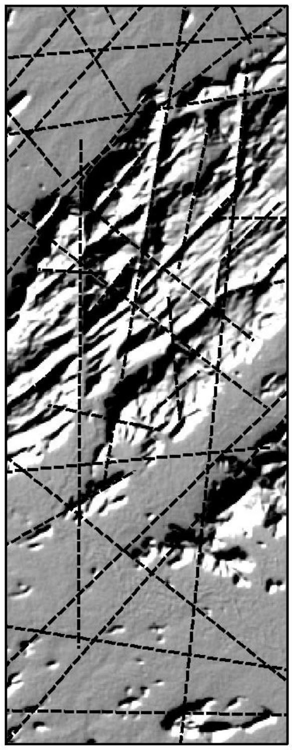


Figure 1C

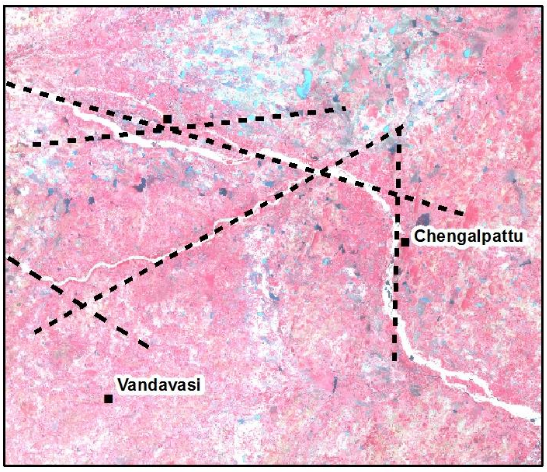


Figure 1A . Surface lineaments derived from satellite FCC data

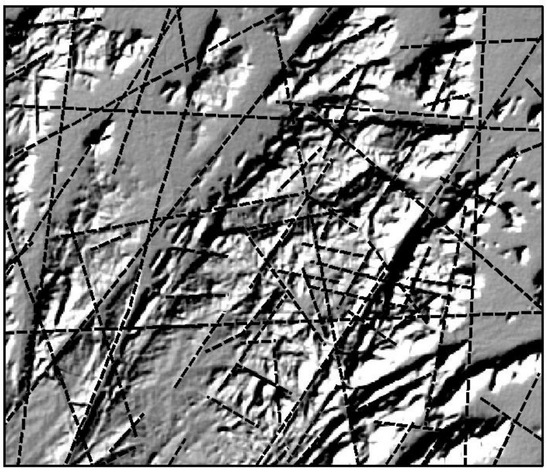


Figure1B& 1C . Surface lineaments derived from SRTM shaded relief image

Figure 1. Surface lineaments derived from satellite FCC data and SRTM based shaded releif image

2.2 Shallow Subsurface Lineaments

To map the shallow subsurface tectonic features, resistivity data have been used widely by the geoscientists (Caputo et al., 2003; Rizzo et al., 2004; Balaji and Ramasamy, 2005). In the present study also, to map the shallow subsurface lineaments at 100 m depth, the depth probe electrical resistivity data were collected from state PWD (Public works Department), Tamil Nadu for over 1000 locations of the study area. The depth versus apparent resistivity graph for the each location was studied to remove the noises. Then longitude (x), latitude (y) and apparent resistivity at 100 m depth (z) for all the locations were fed into 3D analyst module of GIS software and DEM on apparent resistivity at 100 m depth was generated (Figure 2). The DEM showed the resistivity highs as linear ridges and domes and low as linear valleys and basins. From the DEM, the conspicuous break in slopes were interpreted as lineaments which continued along linear resistivity valleys also at places (Figure 2).

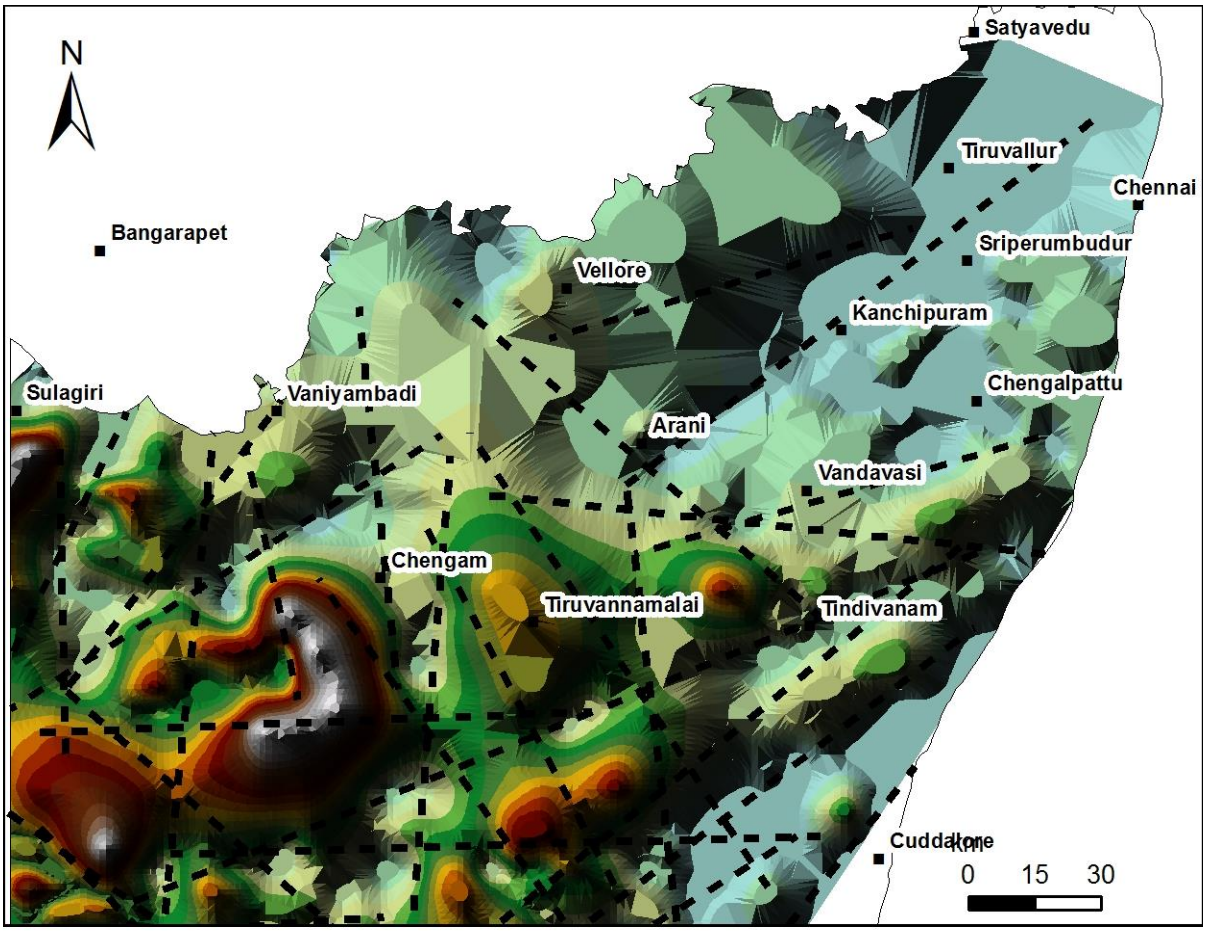


Figure 2. DEM on resistity data at 100 m depth and mapping of shallow subsurface lineaments

2.3 Basement lineaments / Faults

As many Geoscientists have used gravity and magnetic data for the delineation of basement structures (Paterson and Reeves, 1985; Kumar et al., 2009, Naganjaneyulu and Santosh, 2010). In the present study, the gravity data collected from the http://topex.ucsd.edu/cgi-bin/get_data.cgi was fed into 3D analyst module of ArcGIS and DEM (Digital Elevation Model) on gravity was prepared. The gravity DEM (Figure 3) of the study area was visualized in multiple angle and the gravity breaks were demarcated as basement lineaments / faults (Figure 3A). Similarly, the magnetic data collected from the World Digital Magnetic Anomaly Map (Maus et al., 2007) was used to generate a magnetic DEM of the study area. This magnetic DEM was similarly visualized in 3D analyst module of ArcGIS for the extraction of magnetic breaks or magnetic lineaments (Figure 3B). The gravity lineaments and magnetic lineaments derived from the DEM's were integrated and single GIS layer showing the basement lineaments deduced from the gravity and magnetic data.

3.0 CLASSIFCATION OF LINEAMENTS / FAULTS

Subsequent to preparation of surface lineaments from satellite FCC and SRTM based shaded relief image, shallow subsurface lineaments from DEM of electrical resistivity data of 100 m depth and basement lineaments from the DEM of gravity and magnetic data, such multi-depth lineaments were integrated and classified the surface lineaments as follows

- Category-1: Exclusive surface lineaments,
- Category-2: Surface lineaments having connectivity with shallow subsurface lineaments and
- Category-3: Surface lineaments having connectivity with shallow subsurface lineaments and basement lineaments (Figure 4&5).

The category-3 lineaments i.e. Surface lineaments having connectivity with shallow subsurface lineaments and basement lineaments, which can be also called as growth faults / lineaments as this group lineaments have continuity from basement to surface.

4.0 CLASSIFIED LINEAMENTS vs MINERAL OCCURRENCES AND SEISMICITIES

To elucidate the relation between the three categories of lineaments and mineral occurrences, the GIS layer on known mineral occurrence was overlaid with the GIS layer having these three categories of lineaments (Figure 5).

The same GIS overlay analysis shows that the

- 12 mineral occurrences are fell along the category-1 lineaments
- 15 mineral occurrences in close proximity to the category-2 lineaments
- 31 mineral occurrences along the category-3 lineaments

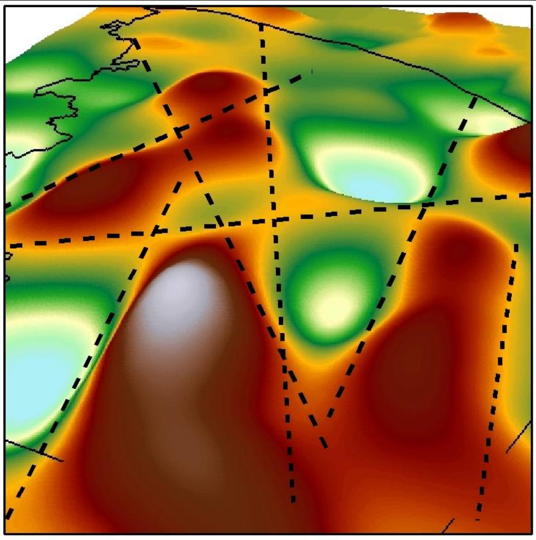


Figure 3A. DEM of gravity data shows the Gravity lineaments (basement lineaments)

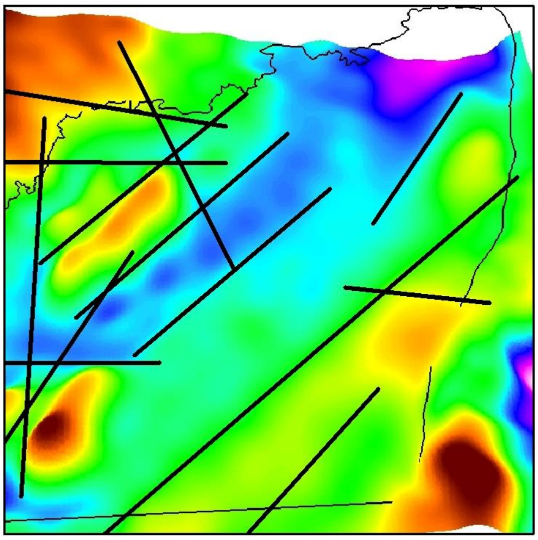


Figure 3B. DEM of magnetic data shows the magnetic lineaments (basement lineaments)

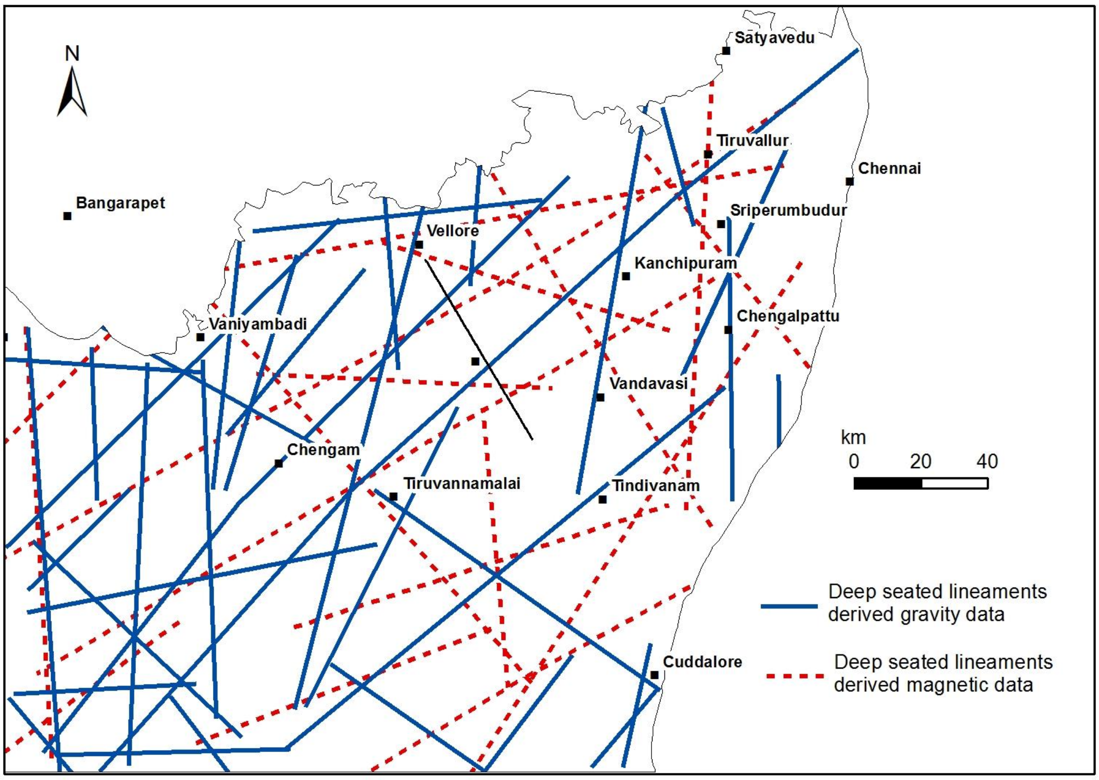


Figure 3C. Basement lineaments/faults derived from Gravity and Magnetic data

Figure 3. Basement lineaments

Similarly, the analysis of these three categories of lineaments in conjunction with the historical seismicity data in GIS environment revealed that the

- 18 Earthquake epicenters fell along the category-1 lineaments
- 15 Earthquake epicenters in close proximity to the category-2 lineaments
- 29 Earthquake epicenters along the category-3 lineaments (Figure 5)

From the above GIS analysis in between such classified lineaments and metallogeny and seismicities, it can be said that the Category-3 lineaments i.e. Surface lineaments having connectivity with shallow subsurface lineaments and basement lineaments (Figure 5) have more control over the mineralization as well as seismicity of the region.

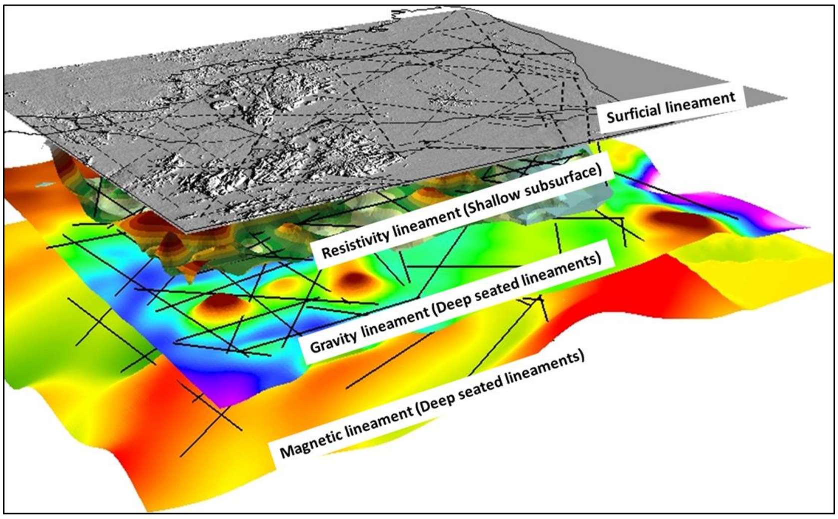
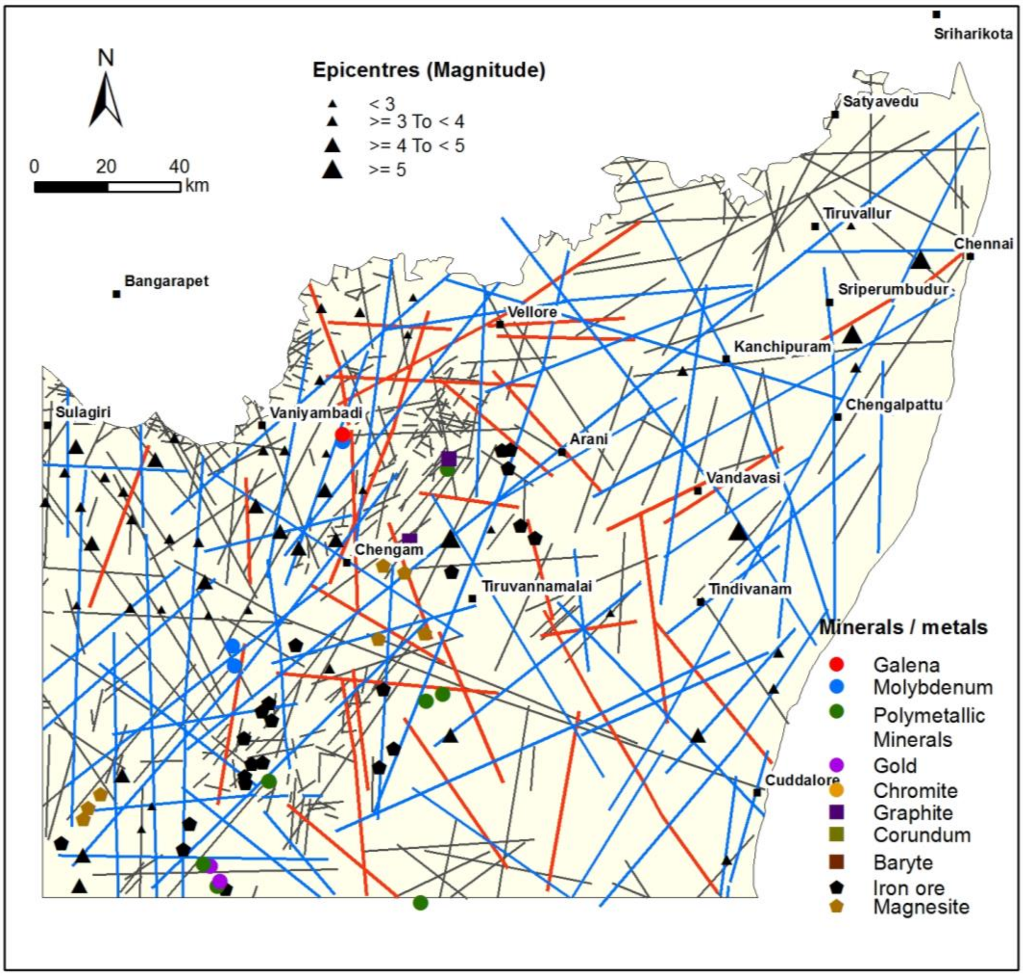


Figure 4. Stacking and classification of lineaments



Type of Lineaments	Mineral occurrences	Earthquake epicentres
Category-1 Lineaments	12	18
Category-2 Lineaments	15	15
Category-2 Lineaments	31	29

Figure 5. Classified Lineaments vs Metallogeny and Seismicities

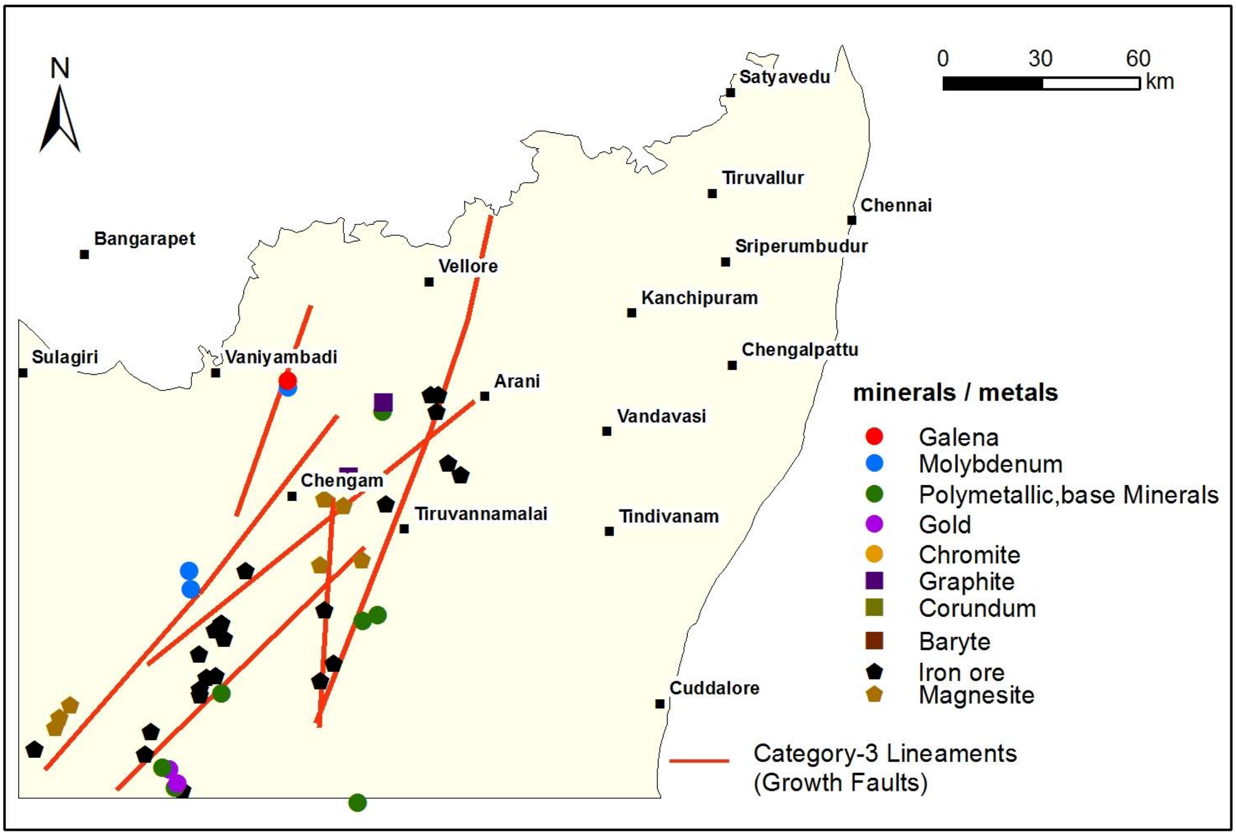


Figure 6. Target areas for mineral prospecting in the study area

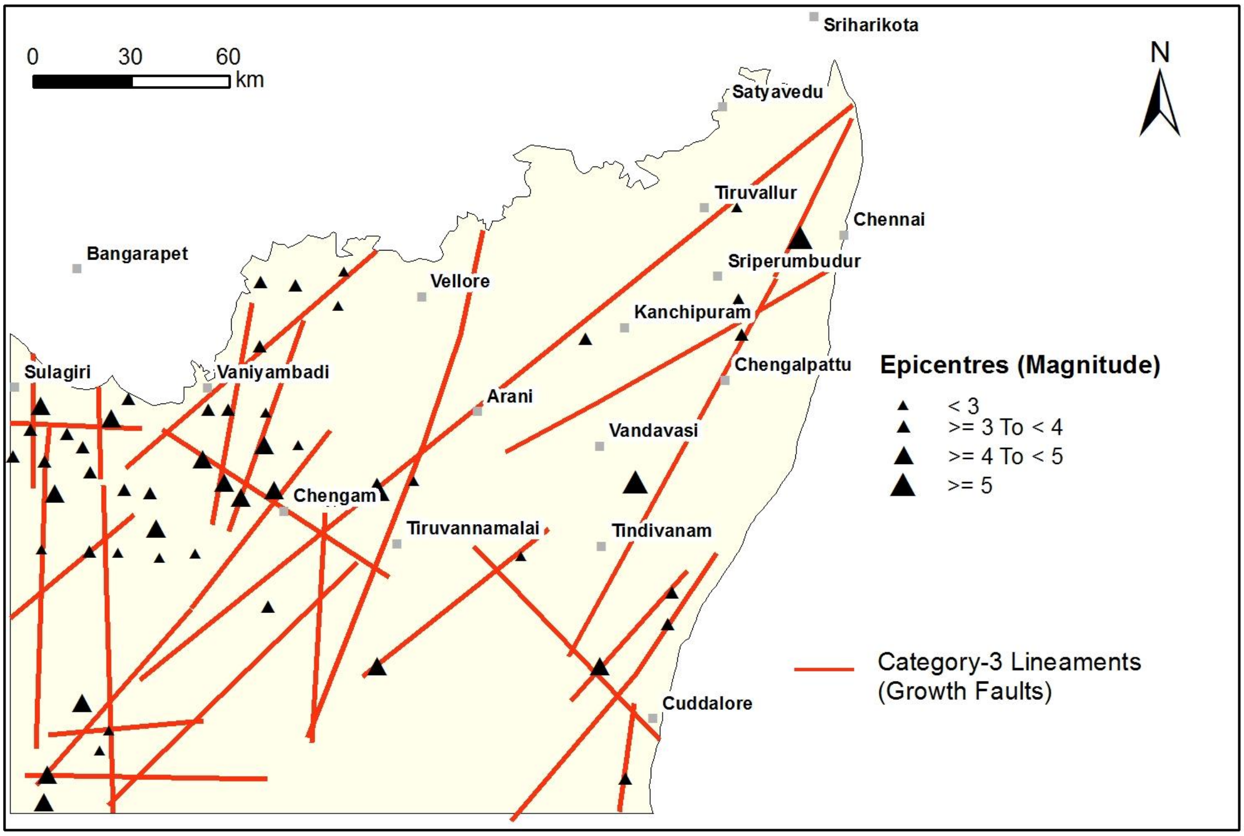


Figure 7. Seismogenic corridors of the study area

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5.0 DISCUSSION

Thus the above GIS analysis showed that the only the Category-3 lineaments i.e. growth faults are having greater control over the mineral occurrences. Further, most of the known mineral occurrences fell in proximity to the NNE-SSW to NE-SW lineaments. Those lineaments were filtered out and demarcated as target areas for mineral exploration (Figure 6).

Similarly, the lineaments those were controlling the seismicities were separated out as probable seismogenic corridors of the study area (Figure 7). The same showed that in the western part of the study area the N-S lineaments, in the central part the NE-SW lineaments and in the eastern coastal area NNE-SSW faults/lineaments are seismogenic. The seismogenic NNE-SSW coastal faults which also act as the contact between the crystalline in the west and the sedimentary in the east as inferred by the earlier worker (Vemban et al., 1977).

6.0 CONCLUSION

The present research study has brought out newer information on how the depth persistence of the remote sensing revealed surface lineaments can be assessed using GIS based digital elevation modeling of resistivity, gravity and magnetic data.

The study has brought out further newer information that the only surface lineaments having connectivity with shallow subsurface lineaments and basement lineaments / growth faults / reactivated basement faults are have greater control over the mineralization as well as seismicity of the region. The present conclusion also gains support from the various earlier studies that the reactivated basement faults have acted as loci for the earthquakes in Latur in 1993 (Rajendran et al., 1996) and Bhuj-Kutch in 2001 (Biswas, 2005; Karanth and Gadhavi, 2007). Further, present study has also provided a lead that it can be used for groundwater and engineering foundation related issues.

REFERENCES

An Yin., 2006. Cenozoic tectonic evolution of the Himalayan orogen constrained by along-strike variation of structural geometry exhumation history, and foreland sedimentation. *Earth-Science Reviews* 76, pp. 1 –131

Ashok Kumar, Deepak Srivastava and Sanjay Kumar Srivastava., 1994. Ranchi mega lineament and its correlation with geological and geophysical data. *Journal of the Indian Society of Remote Sensing*, 22(1), pp. 57-64

Bakliwal. P.C. and Ramasamy, S.M., 1987. Lineament fabric of Rajasthan and Gujarat. *Geol. Surv. India Rec.* 113 (7), pp. 54 – 64.

Balaji, S. and Ramasamy, SM., 2005. Remote sensing and resistivity image for the tectonic analysis of Biligirirangam region of Peninsular India. *Geocarto International*, 20(2), pp. 55–61.

Biswas, S. K., 1987. Regional tectonic framework, structure and evolution of the western marginal basins of India, *Tectonophysics, 135*.

Biswas, S.K., 2005. A review of structure and tectonics of Kutch basin, western India, with special reference to earthquakes. *Current Science,* 88 (10), pp. 1592-1600.

Caputo, R., Piscitelli, S., Oliveto, A., Rizzo, E. and Lapenna, V., 2003. The use of electrical resistivity tomographies in active tectonics examples from the Tyrnavos Basin, Greece. *Journal of Geodynamics*, 36, pp. 19-35.

Gil'manova, G., Goroshko, M., Rybas O., and Didenko, A., 2012. Lineament Analysis of Morphostructures of the Uchur-Maya Basin (Southeastern Siberian Platform) from SRTM Data: Relationship with Metallogeny. *International Journal of Geosciences*, 3(6A), pp. 1176-1186.

Kaila, K.L., Reddy, P.R., Dixit, M.M. and Koteswara Rao, P., 1985. Crustal structure across the Narmada-Son lineament, Central India from deep seismic sounding. *Journal of Geological Society of India*, 26(7), pp. 465 – 480.

Karanth, R.V., Gadhavi, M.S., 2007. Structural intricacies: emergent thrusts and blind thrusts of central Kachchh, western India. Current Science, 93, 1271-1280.

Kayal, J. R., 2010. Himalayan tectonic model and the great earthquakes: An appraisal. *Nature Hazards Risk*, 1, pp. 51–67.

Knight, J., Joy, S., Lowe, J., Cameron, J., Merrillees, J., Nag, S., Shah, N., Dua, G. and Jhala, K., 2002. The Khetri Copper Belt, Rajasthan: Iron Oxide Copper-Gold Terrane in the Proterozoic of NW India: in Porter T M (Ed.), 2002 Hydrothermal Iron Oxide Copper-Gold and Related Deposits: *A Global Perspective, PGC Publishing, Adelaide,* 2, pp. 321-341

Kumar, Niraj, Singh, A.P., Singh, Bijendra, 2009. Structural fabric of the southern Indian shield as defined by gravity trends. *Journal of Asian Earth Sciences*, 34, 577-585.

Maus, S., Sazonova, T., Hemant, K., Fairhead, J.D., and Ravat, D., 2007. National Geophysical Data Center candidate for the World Digital Magnetic Anomaly Map. *Geochem. Geophys. Geosyst.*, 8, Q06017, doi:10.1029/2007GC001643.

Naganjaneyulu, K., Santosh, M., 2010. The Cambrian collisional suture of Gondwana in southern India: a geophysical appraisal. *Journal of Geodynamics,* 50, pp. 256-267.

Nair, M.M., 1987. Coastal Geomorphology of Kerala. In: Coastal Geomorphology in India. *Journal of Geological Society of India*. 29, pp 450-458.

Paterson, N.R., Reeves, C.V., 1985. Application of gravity and magnetic surveys: the state of the art in 1985. *Geophysics*, 50, pp. 212-215

Rajendran, C.P., Rajendran, K., John, B., 1996. The 1993 Killari (Latur) central India earthquake: an example of fault reactivation in Precambrian crust. *Geology*, 24, (7), 651-654.

Ramasamy, SM., Kumanan C.J., Saravanavel J., Selvakumar R. and Ramalingeswara Rao., 2008. Geomatics Based Appraisal on the Seismic Status of South India. *International Journal of Geoinformatics*, 5(4), pp. 9-16.

Rizzo, E., Colella, A., Lapenna, V. and Piscitelli, S., 2004. High-resolution images of the fault-controlled High Agri Valley basin (Southern Italy) with deep and shallow electrical resistivity tomographies. *Physics and Chemistry of the Earth, Parts A/B/C,* 29, pp. 321-327.

Singh, H.N. and Venkatesh Raghavan, 1989. A note on earth tremour of Septemper 2, 1988 in Trivandrum district, Kerala. Journal Geological Society of India. 34 (10), pp 4211 -4223.

Vemban, N.A., Subramanian K.S., Goplakrishnan K. and Venkata Rao. V., 1977. Major faults/ dislocations/lineaments of Tamil Nadu. *Geological Survey of India*, 31, pp. 53-56.

Yadav, O.P., Hamilton, S., Rajiv Vimal, Saxena, S.K., Pande A.K., and Gupta, K.R., 2002. Metasomatite-albitite hosted uranium mineralization in Rajasthan. *Exploration and Research for Atomic Minerals*, 14, pp. 109-130.

Woodall, R., 1994. Empiricism and concept in successful mineral exploration. *Australian Journal of Earth Sciences*, 41(1), pp. 1-10