

Remote Sensing and GIS Tool to Detect Hydrocarbon Prospect in Nagapattinam Sub Basin, India

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Abstract Cauvery Basin is one of the pericratonic rift basins located in the east coast of Tamilnadu. The rifting has resulted in a series of horsts and grabens. The present study uses a new technique which was devised with the help of GIS by analyzing the surface lineaments and subsurface linearities effectively. In this present study, a satellite image based analysis was conducted for extracting surface lineaments, and for the subsurface linearities, the basement linearities were extracted from seismic, magnetic, and gravity data. An orientation analysis of these surface and subsurface linear features was performed to detect the basic structural grains of the study area. The correlation between these structural grains and subsurface oil and gas traps was performed to understand the connectivity to the reservoirs. This article discusses in detail about the same and the importance of using surface and subsurface lineament analyses for

delineating hydrocarbon reservoirs in the Nagapattinam Sub-Basin of Cauvery Basin.

Keywords Lineaments · Structural grains · IRS P-6 · LISS III · Cauvery Basin

1 Introduction

Cauvery Basin, formed during late Jurassic period by sagging of a part of the Indian shield mainly along the dominant NE–SW eastern ghats trend, is located in the southern part of east coast of India between the northerly plunging Sri Lanka basement massif and the peninsular craton (Subramanyam et al. 1995). It occupies an area of 25,000 sq km on land basin and 35,000 sq km offshore (Kumar 1983). Subsurface studies over onshore parts of the basin have revealed the basinal trend and the main NE–SW structural features, viz., Pondicherry, Tranquebar, and Nagapattinam depressions, separated by Kumbakonam–Shiyali ridge, Karaikal high and Vedaranyam high (Sastri et al. 1973; Kumar 1983; Venkatarengan 1987). Geomorphological and morphotectonic studies have been carried out by many earlier researchers based on air photos and landsat images (Varadarajan 1969; Varadarajan and Balakrishnan 1982; Mahajan et al. 1984; Mitra and Agarwal 1991). The surface linear features have been used to search for additional reserves in mature oil gas fields (Herman et al. 1986; Guo and Carroll 1995).

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2 Study Area

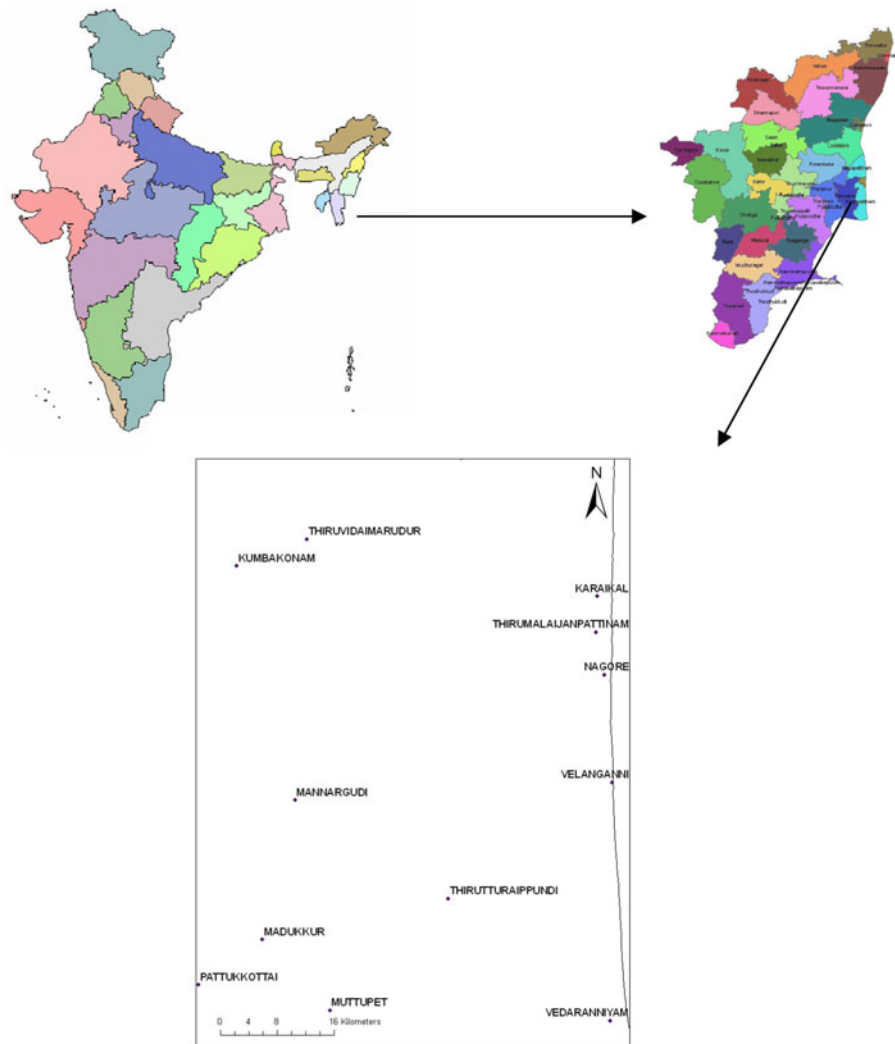
The study area lies between North Latitudes $10^{\circ}16'41''$ – $10^{\circ}59'14''$ and East Longitudes $79^{\circ}15'26''$ – $79^{\circ}51'56''$ covering parts of Survey of India topo maps 58°N–5,6,7,9,10,11,13,14 and 15. Nagapattinam Sub-Basin covers Thiruvarur, Thanjavore, and Nagapattinam. The total study area occupies 5,249 sq km. The study area location map is shown in Fig. 1.

3 Geological History and General Stratigraphy

The rifting of Cauvery Basin was initiated during late Jurassic (Blanford 1865). The detailed tectonic map of

the Cauvery basin is as shown in Fig. 2. However, the oldest sediments recorded in the subsurface by Oil and Natural Gas Corporation palynologists are Neocomian. The Neocomian sediments are devoid of micro-fauna and are dated with palynofossils. Therefore, it is evident that Cauvery Basin has not experienced marine transgression until Aptian. Granitic wash sediments derived from granitic provenance are rich in Biotite mica and Potash feldspar, and as a result, these sandstones with thin micaceous and carbonaceous shale intercalations exhibit a serrated high ' γ ' in the ' γ ' ray log. As these sands are tight, compacted, calcareous cemented with quartz overgrowth, chloritized mica occupying interstices form the Andimadam reservoirs that are of poor quality (Mani 1999).

Fig. 1 Location map



The Cenomanian transgression has resulted in the deposition of finer clastics (Sathapadi Shale) followed by a fall in sea level producing in sandy sediments (Bhuvanagiri Formation) during Turonian, and the top of Turonian is an Unconformity.

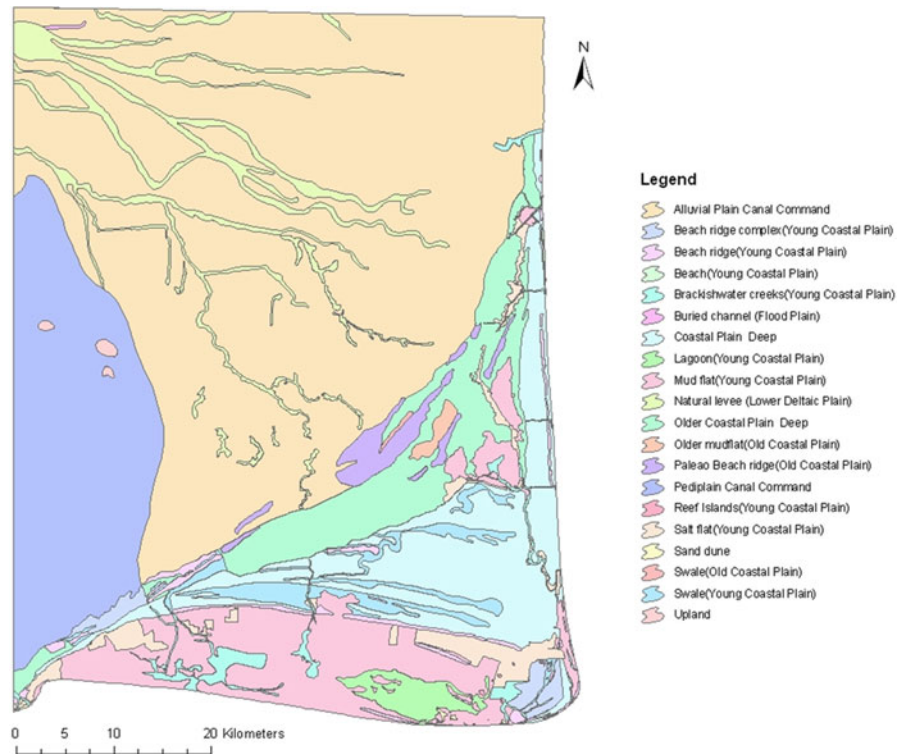
Coniacian to Maastrichian is mostly finer clastics shaly with frequent input of sand (Nannilam reservoirs are sandwiched in shale. Again, the top of Maastrichian is an unconformity surface. Late Paleocene, Early Eocene period witnessed a major transgression in the Tri-junction area as witnessed by brown colored

shales with abundant planktons such as globigerina and Orbulina (Rajagopalan 1965 Govindan and Chidambaram 2000. During Oligocene, shelf edge delta front sands were cyphoned into the slope, and ultimately, these high-density currents deposited their load and got frozen as sand pods one over the other at repeated intervals. Mio-Pliocene witnessed the development of the present delta with upland area occupied by laterite and lateritic soil. In the subsurface, Mio/Pliocene is dominated by deltaic sand, minor Kaolin-itic clay, and lignite belt from Neyveli–Jayankondam–

Fig. 2 Tectonic map of Cauvery basin



Fig. 3 Geomorphology map



Mayavaram and end up at Mannargudi which is covered up by the Holocene Delta.

4 Geomorphology

The lateritic uplands occur along the western margin of the basin and form the regional erosional plains. The Cauvery River, flowing through the uplands, has migrated anticlockwise from a pivotal point within the uplands, before occupying its present position, as evident from the positions of various paleochannels. The Cauvery delta lacks the protuberance which is regarded as one of the most essential elements of a delta. The recent long shore wave action has made a smooth and straight coastline fringed by beach ridges and swales. A few estuaries and lagoons have developed along the coast indicating submergence. (Mitra and Agarwal 1991) The detailed geomorphic map is shown in Fig. 3.

5 Methodology

The surface lineaments are interpreted using the raw and digitally processed IRS LISS III and Landsat satellite

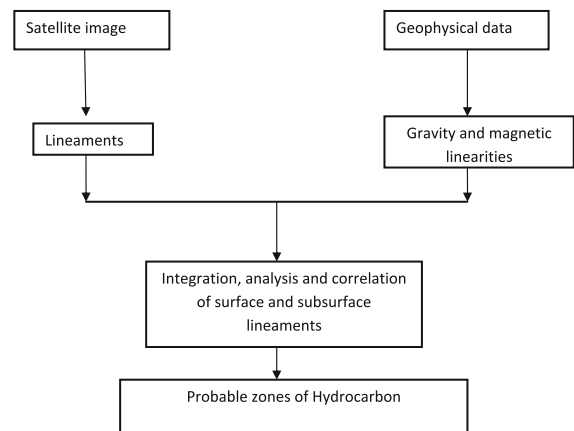


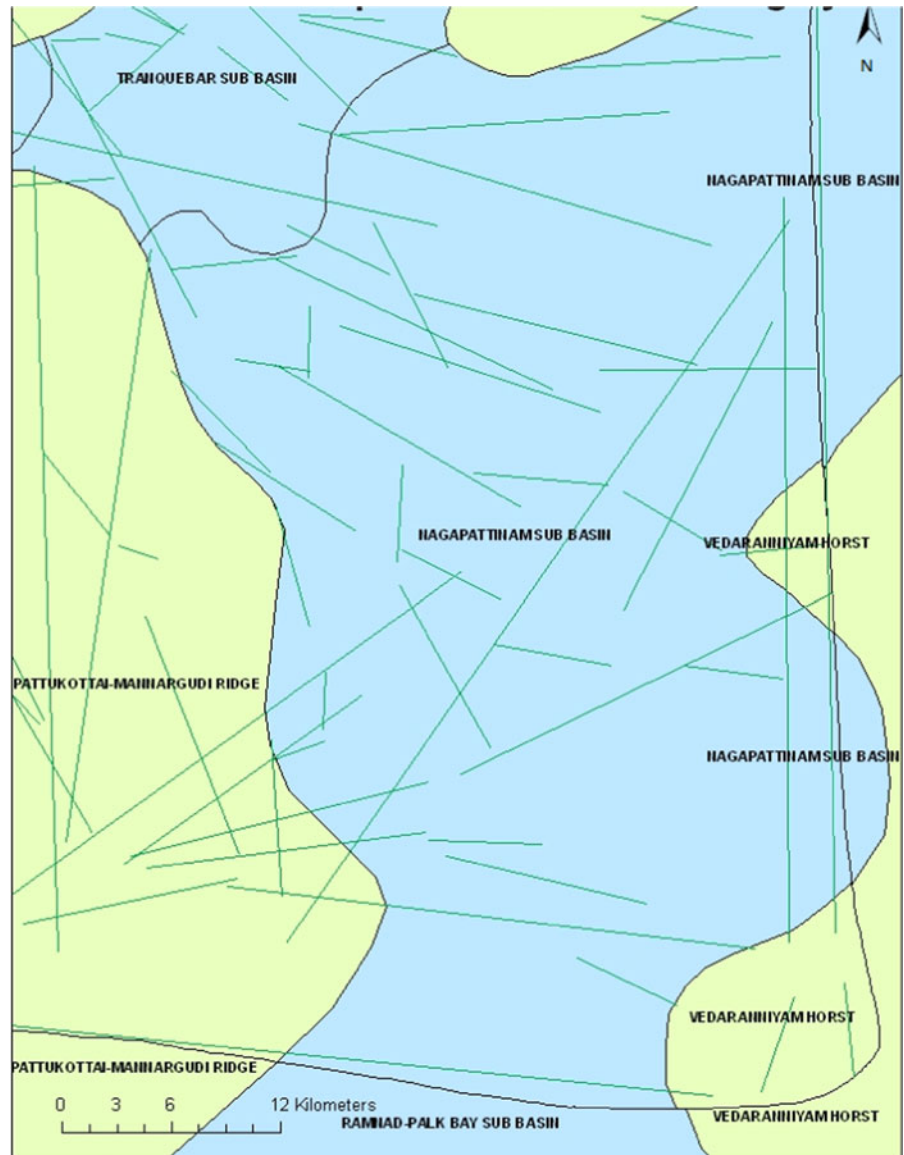
Fig. 4 Methodology

data on 1:50,000 scale. These lineaments/faults are interpreted on the basis of tonal linearities, straightness of river course, soil tonal lineaments, vegetation alignment, etc. The flow chart methodology is shown in Fig. 4.

5.1 Lineament

Owing to many capabilities, such as, the synoptic aerial coverage, multi spectral captivity of data,

Fig. 5 Lineaments interpreted from satellite imagery



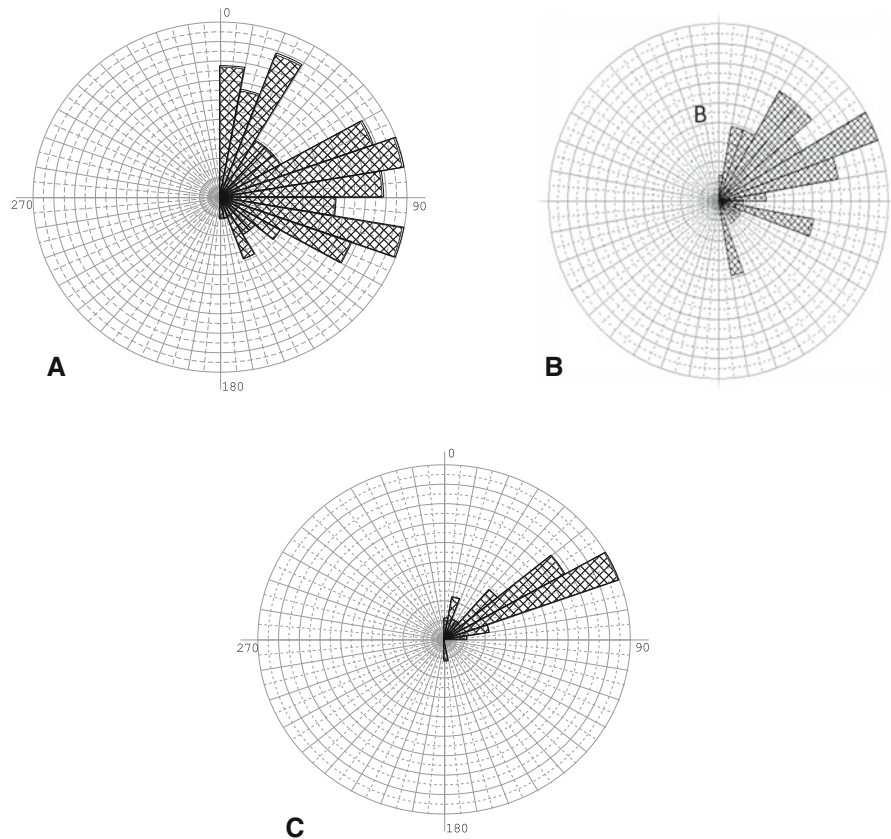
temporal resolution, the satellite images produce better information than conventional aerial photographs (Lillesand and Keifer 1999). Hence, the same has been selected for the task of extracting surface lineaments. The digital image enhancement technique can contribute significantly in extracting the lineaments, the same had been attempted using the software ENVI 4.3. Among different image enhancement techniques, the filtering operations (Suzan and Topark 1998; Chang et al. 1998; Mah et al. 1995), principal component analysis (Qari 1991; Nama 2004), and spectral rationing (Arlegui and Soriano

1998) are the most commonly used ones, and the same have been applied in this study. The final lineament map has been generated by integrating all the lineaments interpreted using raw, FCC, and enhanced satellite data, and GIS layer has been generated as shown in Fig. 5.

5.2 Subsurface Fault, Gravity, and Magnetic Lineaments

Avasthi et al. (1977) and Sahu (2007) have analyzed the gravity, the magnetic data, and the basement

Fig. 6 **a** Lineament orientation of surface. **b** Lineament orientation of gravity data. **c** Lineament orientation of magnetic data



depth. The above published gravity, magnetic, and basement depth maps were georeferenced and rectified using ArcGIS 9.3 and created a database. The gravity and magnetic lineaments have been extracted from visualized breaks of converted 3D maps of both gravity and magnetic contour maps, and the same were digitized and GIS layers have been generated. Another GIS layer on basement faults system was prepared as a result of seismic interpretations of top basement horizon of the area. The basement linearities and other identified linearities were correlated with the surface lineaments interpreted from IRS P-6 LISS III image, SRTM, and Landsat image.

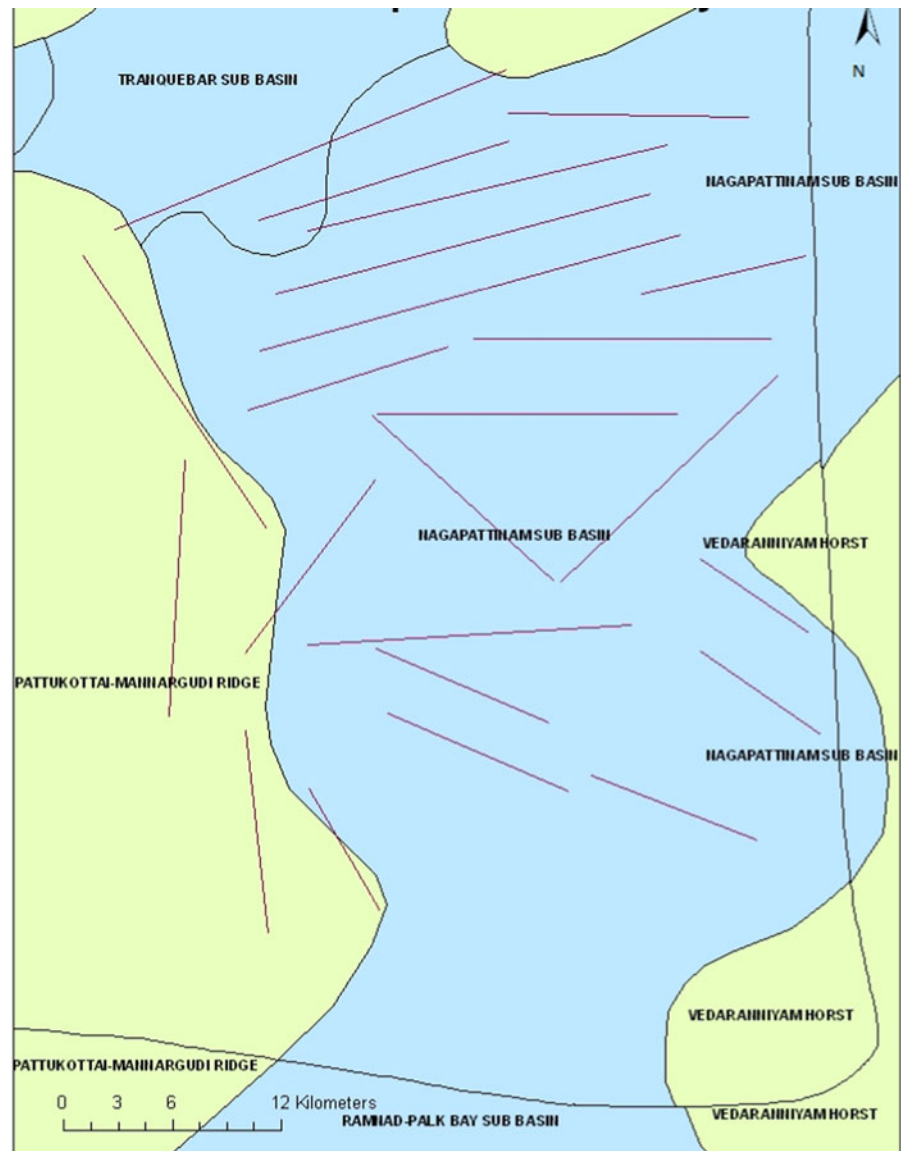
6 Results and Discussions

Lineament feature orientation is considered as one of the most important characteristics as far as petroliferous locales are concerned. In the present study, the

lineaments, fractures, and their traces seen on the surface lineaments, gravity, magnetic linearities, and basement faults are analyzed for their orientations. Rose diagrams are one form of the most informative ways of representing orientation data. Rose diagrams for all the linear features acquired in the study area are shown in Fig. 6. They are generated based on their trends and frequency. However, one can see from these rose diagrams that the surface linear features in the study area have four preferred orientations: Northwest–Southeast, Northeast–Southwest, North–South, and East–West. Majority of the surface linear features in the area are oriented in two directions, i.e., one along Northwest–Southeast and the other along Northeast–Southwest. However, those surface linear features oriented in the North–South and/or East–West are less prevalent.

The rose diagram of the basement fault system in the area shows that they are preferably oriented in Northwest–Southeast direction. The gravity lineaments appear primarily in four sets: two major sets

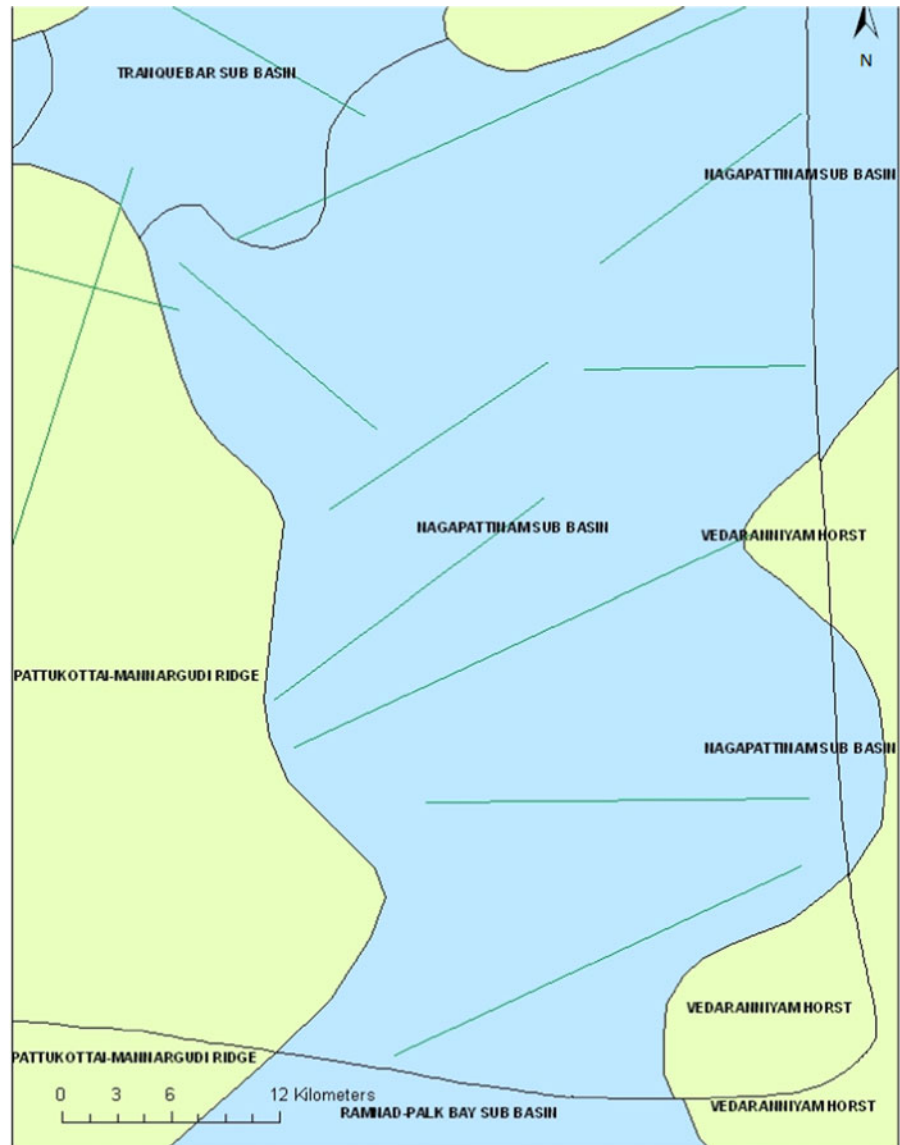
Fig. 7 Lineaments interpreted from gravity data



are oriented in Northeast–Southwest and East–West; and the other two minor sets are oriented in Northwest–Southeast and North–South. Fig. 7. Magnetic lineaments appear primarily in three sets: one major set oriented Northeast–Southwest, and two minor sets oriented in Northwest–Southeast and East–West, Fig. 8. A comparison of the surface and subsurface linear features indicates that the basement faults are very much congruent in orientation with the gravity, magnetic and surface lineaments in the region of study. The Precambrian basement fault system

consists of a major set trending in the Northeast–Southwest direction, Fig. 9. These faults later were reactivated, and thus they acted as conduits for the upward propagation of hydrocarbon and were entrapped in the shallower/younger rocks, as reflected by the geophysical anomalies and the surface lineaments. During the process of reactivation and propagation, additional sets of faults and fractures were developed because of local structural and tectonic disturbances and their complications. The connectivity from the basement fault systems upward till the

Fig. 8 Lineaments interpreted from magnetic data



surface provides a mechanism for hydrocarbon migration and entrapment.

In GIS overlay analysis, satellite lineaments have been parallelism with subsurface magnetic linearities, gravity breaks, coincided with existing oil/gas fields. Based on the analysis, new prospective zones were identified and marked Fig. 10. Some of the locations of the oil fields are bounded by major surface linear features from both sides shaping the boundary of sub graben and sub basins in the area. Thus, the surface lineaments can be used as a guide to structural

contouring, facies mapping, and delineation of areas of fracture-enhanced permeability. Also, their trends were used directly to conduct seismic programs and to select deeper exploration candidates in the area. Remote sensing and GIS can reduce the conventional method, be cost effective, and narrow down the study area while comparing with the geophysical method.

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Fig. 9 Basement fault map

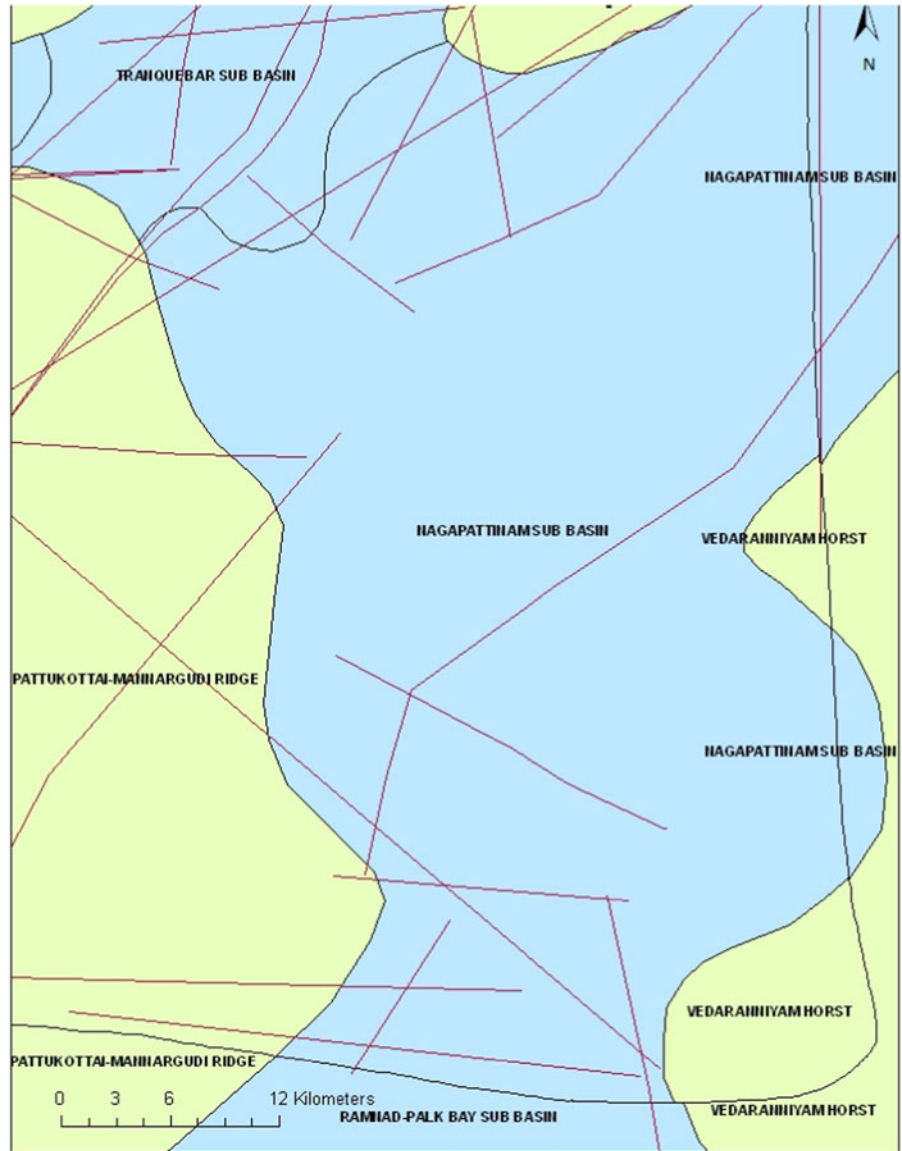
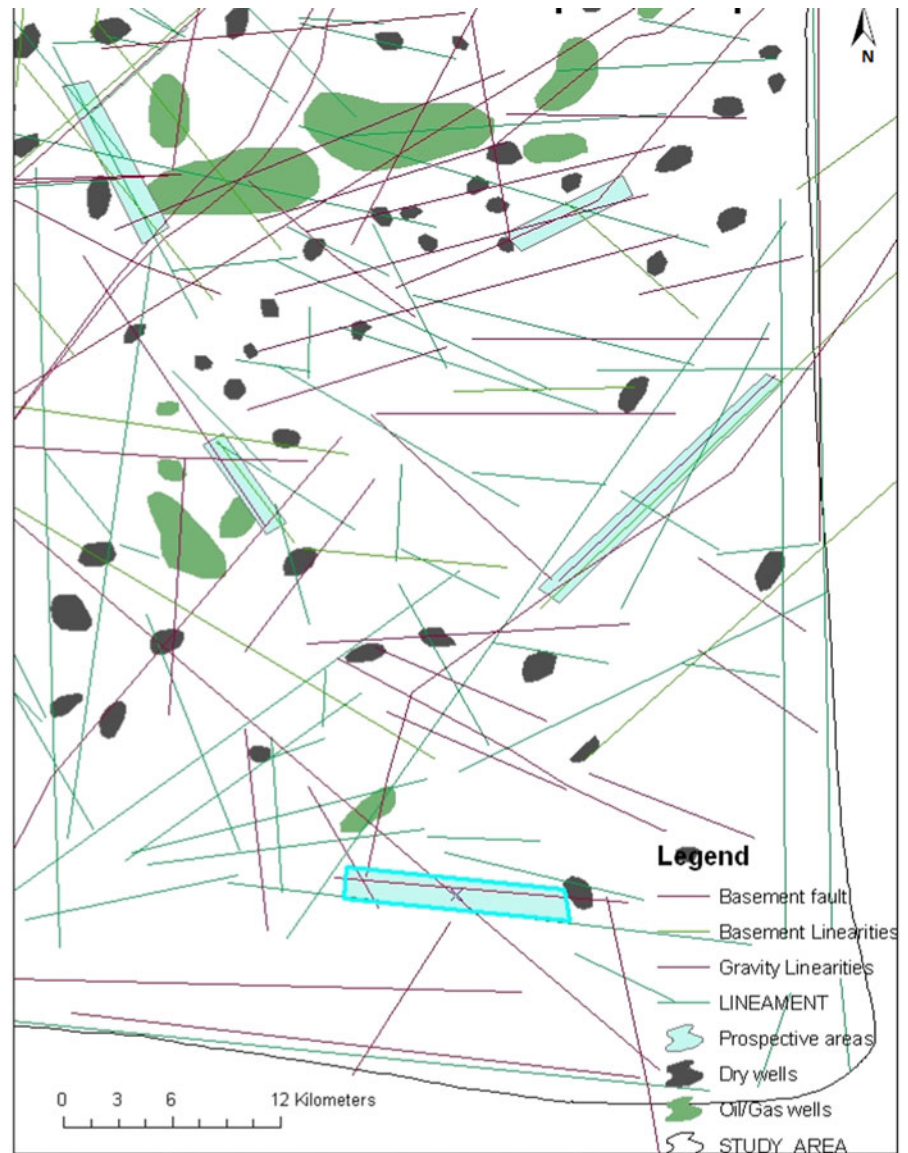


Fig. 10 Lineaments based prospective map



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