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Morphotectonic Analysis based on High Resolution Remote Sensing images of KG onland Basin and Integration with collateral Geophysical and other data to identify prospective areas

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Abstract

The KG basin has been classified as a major intra-cratonic rift within the Gondwana land until the Early Jurassic period and it later transformed into a pericratonic rift basin. This basin had undergone multiple phases of tectonism during different episodes of its tectonic evolution. However at present the basin is still found to be neotectonically active with a lot of evidences of active tectonics in the prevalent geomorphology of the area. This study aims to delineate subtle and exposed tectonic as well as structural features in Krishna-Godavari Basin to decipher morphotectonics and tectonic elements to identify areas for hydrocarbon exploration. The Krishna and Godavari deltas constituting the study area, although built by two major rivers of the peninsular part of India, appear to coalesce into one large delta complex. Neotectonic activity in the basin leads to formation of a number of drainage anomalies which are indicative of structural control. These areas of drainage anomalies along with image analysis have been used to delineate a fault network and geomorphic highs which had been subsequently validated by field checks. The geomorphic highs assumed to be manifestations of subsurface structural highs had also been classified into higher and medium degree of confidence of being underlain by a structural high. The fault pattern of the Godavari delta is found to be different from that of the Krishna delta which might be because of a different basement fabric underlying both the deltas. The Godavari delta might have a basement of granulite series whereas the basement of the Krishna delta might be constituted of Cudappah series. The Chintalapudi cross trend may be considered to be a boundary of the two separate tectonic zones. Fault analysis indicates that the Godavari delta has a more prominent NE-SW trend with a subsidiary NW-SE cross trend whereas in the Krishna delta part the NE-SW trends are more anticlockwisely rotated. Most of the NE-SW faults mapped in the surface are found to be penetrative down to the basement level. However the NW-SE faults are found to be more pronounced in the basement of the offshore part than in the onshore part though they are found to be continuous with the surface trends. The NE-SW faults are supposed to be reactivated more than the other trends and might be considered to act as conduits of vertical migration. Geomorphic highs that had been categorized as per these studies as high and medium confidence and associated with these faults can be considered as areas of exploratory significance.

Introduction

The Krishna-Godavari (KG) basin is a multitectonic basin with a sedimentary thickness of about 6000 m in onland areas and characterized by sedimentary sequences ranging in age from Permian to Recent over high grade Pre-Cambrian metamorphics. This basin initiated as a major intra-cratonic rift within the Gondwanaland until the Early Jurassic period but subsequent to the breaking up of the Gondwanaland it transformed into a pericratonic rift basin extending further offshore. Though this basin forms a promising petroliferous basins with about 141 onland prospects and functional petroleum systems occurring in all of Permo-Triassic, Late Jurassic-Cretaceous and Post-Trappean sediments, in the present exploration strategy, other than the existing pools, shallow and subtle structures which are yet to be explored might also be interesting exploratory targets. In this paper, a morphotectonic approach had been attempted to identify and delineate structural elements based on remote sensing derived geomorphic and other spatial data.

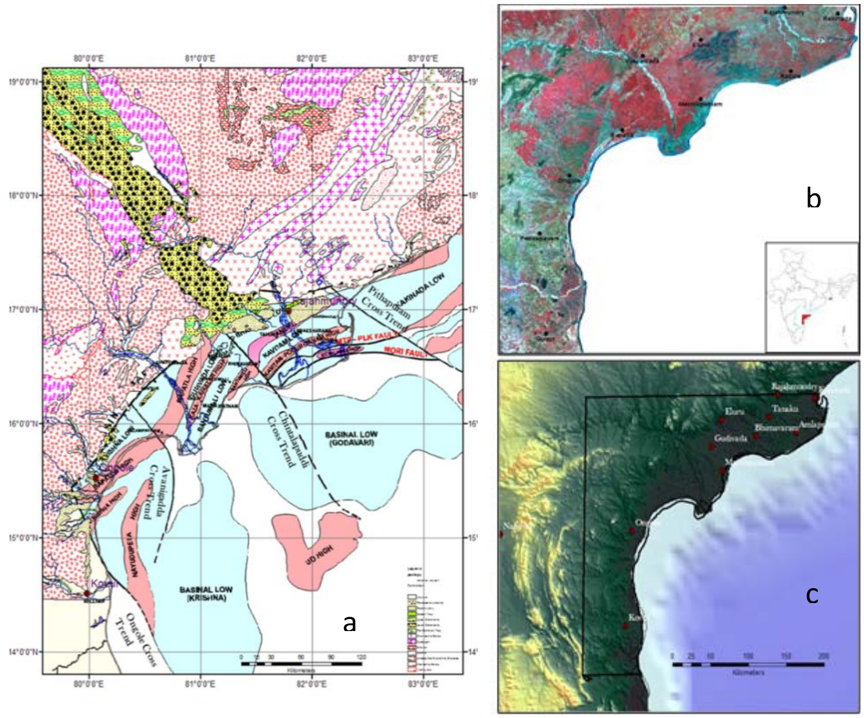


Fig 1. a) Tectonic Map of the study area, ***b****) LANDSAT ETM+ image mosaic of the area of band combination 7, 3 and 2 and* ***c)*** *DEM of the area*

Methodology

The Krishna and the Godavari deltas, although built by two major rivers of the peninsular part of India, appear to coalesce into one large delta complex along its eastern coast, the basement of which is divided into a number of ridges and basins as a consequence of post rift vertical tectonics associated with the evolution of the east coast passive margin (Fig 1a). Since the Krishna-Godavari delta region overlies a complex tectonic basement setting, ongoing vertical motion due to neotectonics representing the post collision adjustments of the Indian plate might have some influence on the morphologies of these deltas. In a neotectonically active province, it is assumed that older structural features are reactivated by younger deformations and subsequently these reactivated features are manifested on the surface as geomorphic anomalies especially in case of drainage and topography (Shurr, 1982). Based on these premise and the principles dealt in detail in Mazumder et al, 2013, the area comprising the KG Basin had been analyzed for geomorphic anomalies.

For this study, drainages were extracted form SOI toposheets and Landsat ETM+ image (Fig 1b), whereas slope and aspect were extracted from SRTM digital elevation models (DEM) (Fig 1c). Detailed analysis of the drainage led to the identification of anomalous features such as drainage offsets, rectangular drainages, rectilinear drainages, compressed meanders and abnormal sinuosities (Fig 2a) which have been translated into micro-faults thus acting as building blocks to regional faults. Probable faults have also been extracted by identifying abrupt slope breaks and lines of similar aspect from DEM of the area. As a complementary data-set, lineament analysis was carried out on edge enhanced fused image of LANDSAT Bands 7, 3 and 2 that had been sharpened with band 8 to obtain a higher resolution of 15m. Also small faults mapped in the field from geomorphic and neotectonic studies done by Varadarajn et al, 1977, had also been incorporated in this study. All of these small elements that are supposedly surface manifestation of faults extracted from different processes (as mentioned above) have been put together in a GIS platform and then joined as per their trend and continuity maintaining Law of Convergence (Fig 2c) and then validated in field to derive the probable fault network (Fig 2d and e).

In a similar way geomorphic highs have been identified based on drainage showing either curved/ peripheral drainage or radial drainage (Fig 3a and b) that might be surface representations of subsurface structural highs. Also, probable structural highs had been delineated from tonal difference in the image with the premise that moisture content in the soil overlying a structural high is lower than the moisture content of adjoining lower surrounding areas. Now in an image, areas with higher moisture content appear dark while the areas with less moisture appear brighter (Fig 3c). Hence such enclaves of lighter tone surrounded by a darker one in the study area may be probable areas of structural highs. Again, areas which are underlain by structural highs related to buckling might be associated with pondings and rectangular drainages due to tensional crestal fractures (Trenchard, 2007). Based on this premise such areas in the study area are demarcated to represent probable manifestations of structural highs. Based

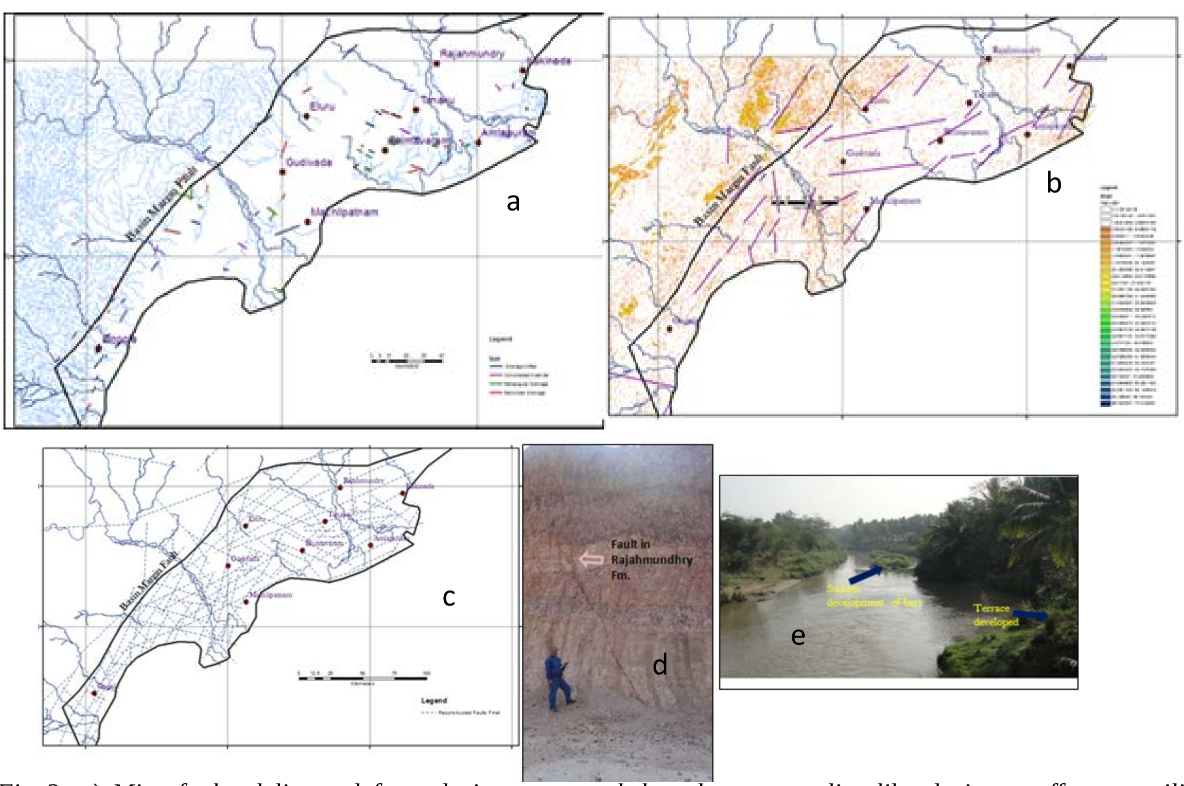
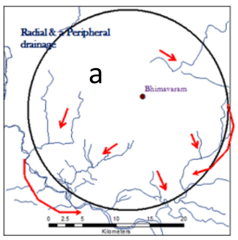
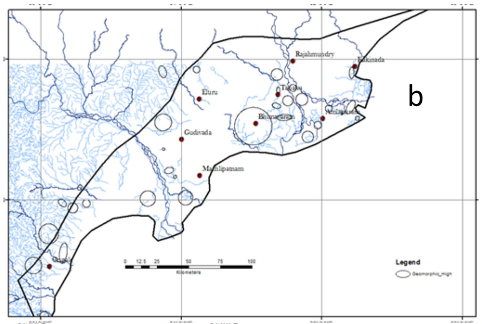


Fig 2. a) Microfaults delineated from drainage network based on anomalies like drainage offsets, rectilinear drainages, compressed meanders and rectangular drainages, b) Abrupt slope breaks delineated from DEM of the area delineating probable faults, c) Probable fault network derived from all parameters in a GIS platform and d and e) Field check of the faults in outcrop and in geomorphic surfaces.

on the association of these interpreted geomorphic highs with either one of the two latter parameters or both, these geomorphic highs can be classified as per their degree of confidence into high, medium and low to represent subsurface structural highs. These classified map of geomorphic highs when correlated with the present day prospects show that though most of the high and medium confidence geomorphic highs coincide with the established prospects, a few of these geomorphic highs are still yet to be explored and might be prospective areas (Fig 3d).





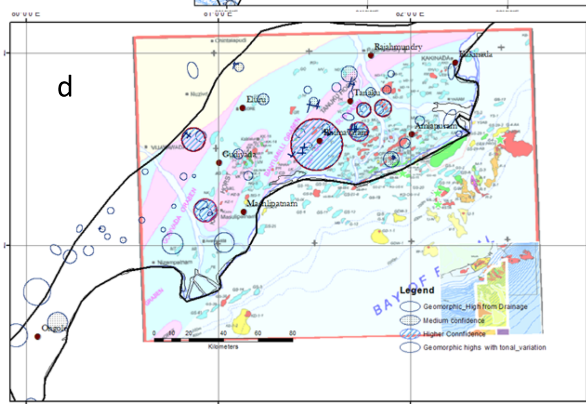


Fig 3. a) Combination of semi radial and peripheral drainage in the area, b) Geomorphic highs interpreted from drainage pattern of the area, c) Areas of tonal anomalies delineated in the area suggesting underlying structural highs, d) Geomorphic highs classified as per their degree of confidence to represent subsurface structural highs overlain on prospect map of KG Basin Areas where they don't coincide with prospects may be areas worthwhile for exploration.

a) Earthquake Epicenters: A historic database of earthquake epicenters of a region might indicate the neotectonic status indicating the fault which might causing it. A correlation of earthquake epicenters with the interpreted faults thus validates the faults on which they overlie. Also since most of the epicenters are clustered on the southern part of the KG basin this implies that faults in the south-western part of the basin are more active than those in north. Also it suggests that NE-SW faults are more active than the rest of the fault directions

b) Shallow Gas, Adsorbed Gas & Microbial Concentrations: All of these three phenomenon are based on existence of a subsurface conduit extending up to surface. Shallow thermogenic gas had been encountered in a number of wells in KG Basin and on a GIS platform these are found to be associated with NE-SW interpreted fault trends (Fig 4a). Such an association validates the interpretation and suggests that the NE-SW fault trends are most reactived and are instrumental in vertical remigration of the hydrocarbon. Similarly, geochemically adsorbed gas surveys in KG Basin depicts that the maxima for the light gases are oriented especially along the NE-SW striking faults (Fig 4b) again implying that these faults might act as a conduit for vertical migration. Microbial prospecting method in hydrocarbon exploration is based on the premise that the light gaseous hydrocarbons migrate upward from subsurface petroleum accumulations by diffusion and effusion, and are utilized by a variety of microorganisms present in the sub-soil ecosystem. Again a positive correlation of microbial or bacterial maxima with the interpreted faults is observed not only suggesting their existence but also their involvement as tertiary migration conduits.

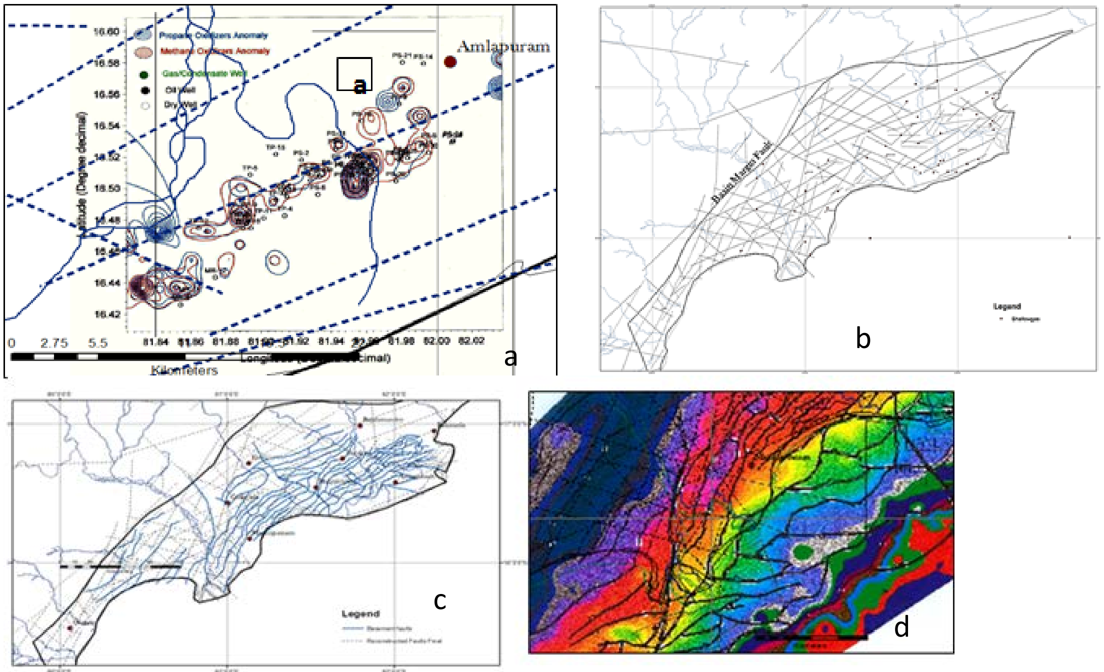


Fig 4. a) Correlation of the faults with geochemical adsorbed gas maxima for validation of faults, b) Shallow gas wells and surface seepages coinciding with the interpreted faults, ***c)*** *Surface morphotectonic interpretations (dotted lines) correlated with faults mapped at basemet top (in blue) validating then and suggesting their continuity, d) NW-SE trend in offshore areas hen extrapolated found to correlate with faults interpreted from morphotectonic data.*

c) Seismic Data: On correlation with seismic time map on top of basement again most of the NE-SW faults are found to correlate in disposition with the morphotectonic faults suggesting continuity upwards from basement (Fig 4c). This correlation also suggests that NE-SW faults are more reactivated than the other fault trends. The NW-SE cross trends especially in the Krishna Delta show little correlation with the seismic data of basement though similar trends are found in offshore part. These NW-SE offshore trends when extrapolated onland are found to coincide with the surface NW-SE trends (Fig 4d) suggesting continuity from offshore to onshore and subtle throw beyond seismic resolution.

Discussions

An overall analysis of faults from morphotectonic studies shows a dominant NE-SW trend along with a subsidiary NW-SE trend. However, if the Krishna and the Godavari delta areas are viewed separately it is observed that the Godavari delta has a more prominent NE-SW trend whereas the NE-SW trend in the Krishna part is more anticlockwisely rotated than Godavari. Since the tectonics affecting the entire area is same, this variation might be explained as a variation in the basement configuration of the two deltas. The Chintalapudi cross trend may be considered to be the boundary of the two separate tectonic zones.

Also, as dealt upon in the earlier sections of the study, the NE-SW faults are observed to be reactivated more than the others and hence are manifested more than the other trends. Faults which are more reactivated are more prone to act as conduits of migration. Also under the present state of stress determined from focal plane solution, the maximum horizontal stress is found oriented in NNE-SSW direction. As per Zhang et al, 2011, zones of low sealability or faults acting as conduits of migration either coincide with the direction of the regional maximum horizontal stress or occur at low angles to it. Based on this proposition, it can be deduced that the NE-SW faults probably act as channels of short distance vertical or tertiary migration. This is also evident from the occurrence of shallow gases along these trends or from occurrence of geochemical adsorbed gas maxima and bacterial maxima along these trends.

Considering the NE-SW faults as channels of vertical migration, shallow structural highs associated with these trends might be acting as areas of entrapment of the re-migrated hydrocarbons. Since geomorphic highs are manifestations of structural highs, it can be said geomorphic highs that had been categorized as per these studies as high and medium confidence and associated with these faults can be considered as areas of exploratory significance in the study area.

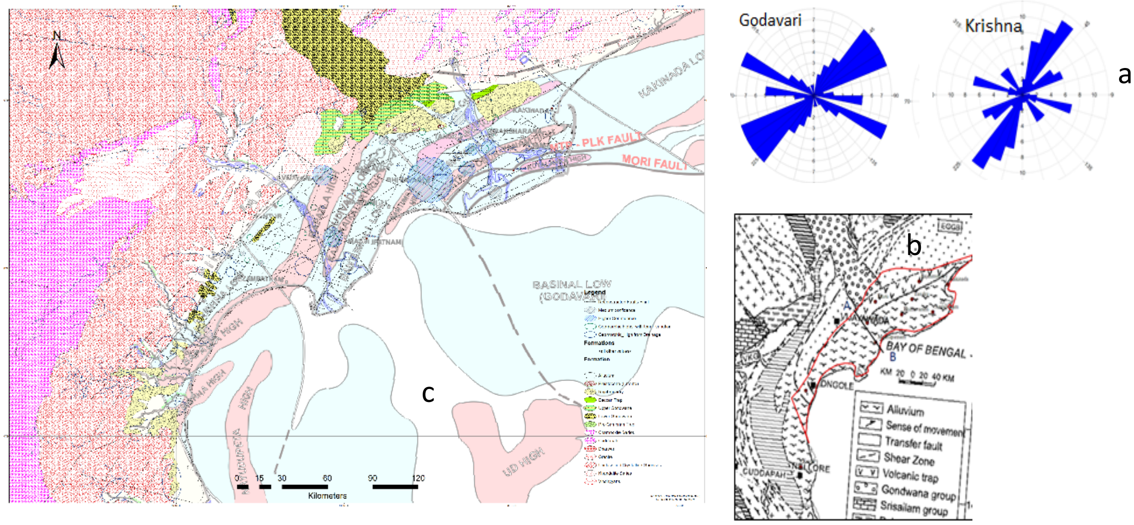


Fig 5. a) Rose diagram showing variation of fault trends in Krishna and Godavari basin with the fault trends showing a anticlockwise rotation in Krishna part, b) Two separate basements premised in Krishna and Godavari delta separated by Chintalapudi cross trends, c) Probable areas of exploratory interest demarcated by high (in blue) and medium (in grey) confidence geomorphic highs associated with interpreted faults (dotted lines).

Conclusions

In the KG basin, the fault pattern of the Godavari delta is different from that of the Krishna delta which might be because of a different basement fabric underlying both the deltas. The Chintalapudi cross trend may be considered to be a boundary of the two separate tectonic zones.Geomorphic highs that had been categorized as per these studies as high and medium confidence and associated with these faults can be considered as areas of exploratory significance.

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