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Morphotectonic Analysis of Khubal Area to probe the Probable causes of the Limitation of Khubal structure from Remote Sensing and Geomorphic data

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Abstract:

Khubal field in the eastern part of Tripura is located between the Hararganj and the Langai Anticline. Though a number of wells had been drilled it is very difficult to delineate the spatial extent of the structure. In view of the above, a detailed neotectonic based approach was taken up for analysis from remote sensing and geomorphic data. As a part the drainage of the area had been analyzed in detail for localized drainage anomalies which would be indicative of structural control both by faults and structural highs. From this analysis a number of structural features had been delineated that had been joined based on their disposition, trend and continuity to build up regional faults. In a similar pattern, the drainage of a terrain can be analyzed to interpret and identify underlying structural highs that are manifested on the surface as geomorphic highs showing either a radial drainage or a peripheral drainage. A comparison with the seismic shows that the faults interpreted from morphotectonic data that are oriented N-S, NE-SW and NW-SE showing some amount of correlation with the faults interpreted from seismic data. However the morphotectonic faults oriented E-W doesn't have any correlative in seismic data. A trend analysis based on the interpreted faults of the area shows that the dominant fault direction of the area is E-W though a high proportion of NE-SW faults are also observed in the area. However, the vergence of the E-W thrusts here is found to be northwards which is different from the adjoining Cachar basin. This might be due to strike slip fault related to the Hail Haikalula lineament that might be responsible for the Khubal anticline branching out from the Hararganj anticline and occupying the synclinal space in between the Hararganj and Langai Anticlines, subsequently causing a clockwise rotation of it. This might have created some sort of compressional force in the synclinal area in the frontal or foreland part of it resulting in the development or reactivation of the E-W trending thrust faults that display a northward vergence and are also responsible for the compartmentalization of the Khubal field thus delimiting its spatial extent.

Introduction

The Khubal field in the eastern part of Tripura is one of its commercial gas bearing structures apparently located in part of Khubal anticline as well as its down plunge side underneath the Chambabari syncline nested in between the thrust bound Hararganj and Langai anticlines. The Khubal anticline here does not extend in the north upto the limit of its surrounding two anticlines but is found to be truncated midway (Fig 1a & b). A total of nine wells had already been drilled in the Khubal field of which the fourth and fifth wells are considered discovery wells in Lower and Middle Bhuban Formations. In view of the above, this paper is an attempt in using Remote Sensing & GIS based studies for the morphotectonic analysis of the area with an objective of delineating the probable spatial extent of the structure, the causes of its compartmentalization as well as a feasible geological model that explains the above features.

Tectonically, the Khubal field is a part of the eastern and more tightly folded Assam-Arakan Fold Belt that is considered to be affected by three major tectonic elements- the Kaladan Fault in the east, the Haili Hakalula Fault in the North-west and the Dauki Fault in the north. Based on passive seismic studies as well as geomorphic studies of different workers in this area (Kunte, 1989, Angelier et al, 2009) all of these elements are believed to be tectonically active even at present rendering the area to be neotectonically active. This implies that the structural elements in this area constituting the anticline bounding thrusts as well as other associated structures also might be tectonically active under the present state of stress.

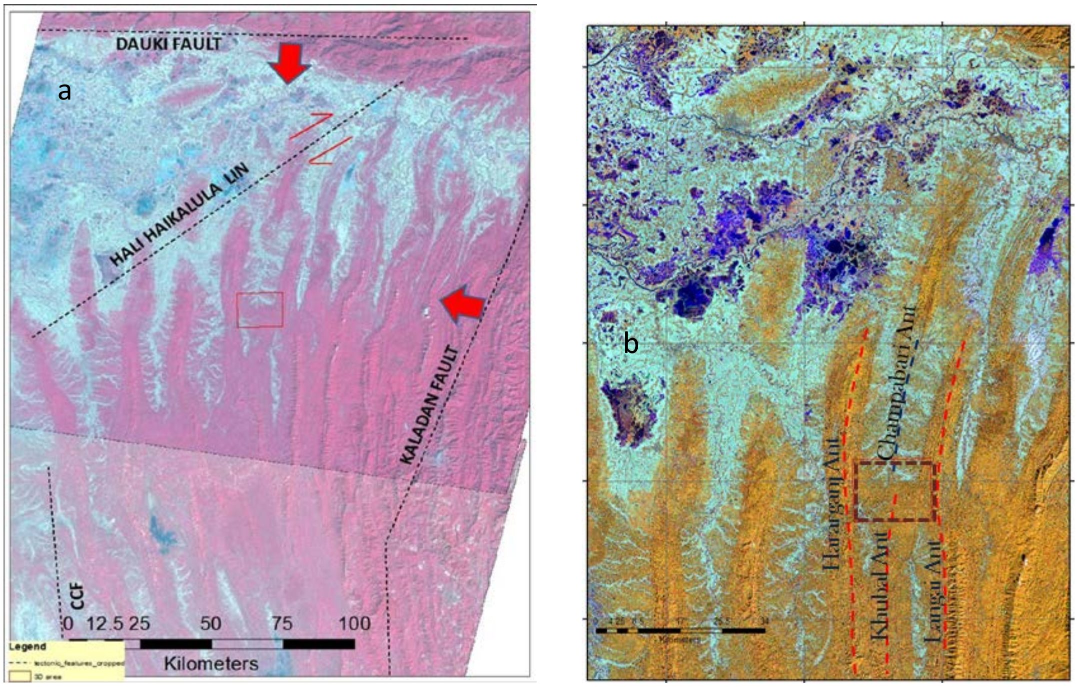
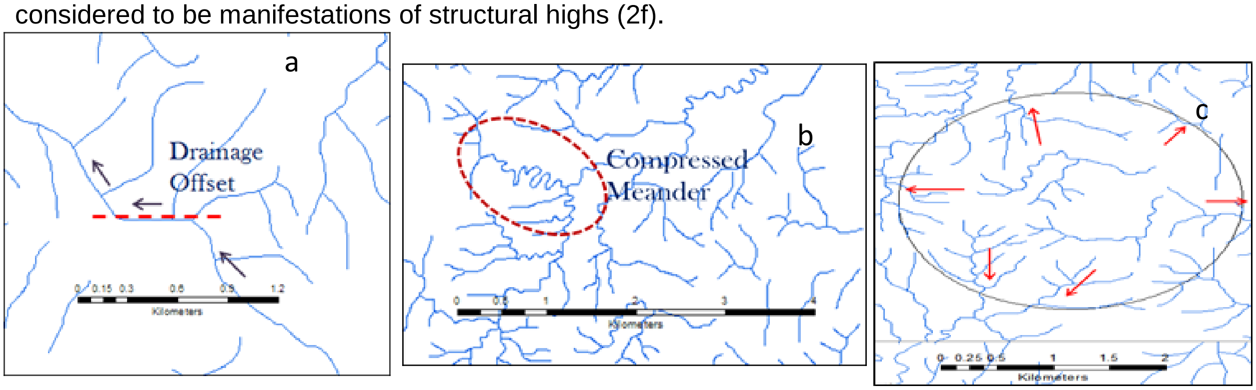


Fig 1a)LANDAT ETM+ image of band combination 4,3 and 2 depicting the Assam Arakan fold belt along with its main tectonic elements, respective stress directions and b) LANDSAT ETM+ image of band combination 5,4 and 3 depicting the area around Khubal structure in detail (dotted area)

Methodology

Based on the above premise, a detailed morphotectonic study had been carried out in this area to delineate structural features both prominent as well as subtle in terms of faults as well as structural highs that are manifested on the surface. Here again it is assumed that older structures in the area will be reactivated under present stress conditions with a predominantly vertical component of deformation in them. This will in turn be recorded as drainage anomalies (Ouchi, 2005) on the overlying drainage of the terrain. Such anomalies are manifested and recorded in terms of localized structure controlled features like drainage offsets, rectilinear drainages, sinuosity variations, compressed meanders as well as peripheral and radial drainages (Fig 2 a,b and c) in the area. Based on this hypothesis, the drainage map covering entire Khubal area is extracted from 1:50000 toposheets as well as LANDSAT imageries. This is then analyzed in detail as per principles discussed in Mazumder et al, 2013 to delineate drainage anomalies as mentioned above reflecting neotectonic structural control. These drainage offsets, rectilinear drainages, compressed meanders can be translated into their causative probable micro-faults or small elemental parts of a fault (2d) that are later joined as per their trend and continuity to define a regional fault (2e). Similarly geomorphic highs delineated from peripheral and radial drainages here are considered to be manifestations of structural highs (2f).



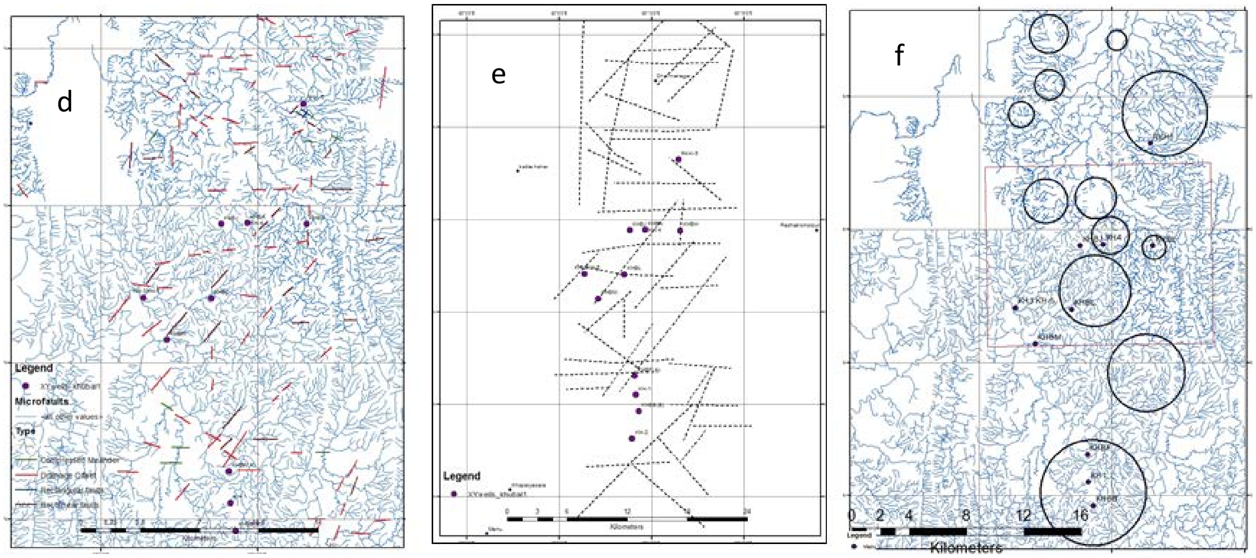


Fig 2. Instances of drainage anomalies delineated in the area in terms of drainage offsets (a), compressed meanders (b) and radial drainages (c). A composite map of the delineated anomalies that had been translated into probable microfaults (d) that are joined to form regional faults (e) and probable structural highs (f)

To define continuity with subsurface data, these faults are overlain with faults that had been interpreted from 3D seismic data on top of Middle Bhuban. This overlay indicates that though the NE-SW as well as the N-S faults interpreted from morphotectonic data are found to show a fair amount of correlation with the subsurface faults from seismic data, the E-W faults interpreted do not show any correlative with the faults from seismic data (Fig 3a). All this morphotectonic interpretations when plotted on the geological map of the Khubal area shows that Khubal field encompasses both the anticlinal as well as synclinal areas with the geomorphic highs in the northern part overlying the younger Dupitila formation in the synclinal area whereas the southern geomorphic highs are found to overlie the older formations of Tipam, Bokabil and Upper Bhuban in the anticlinal area (Fig 3b).

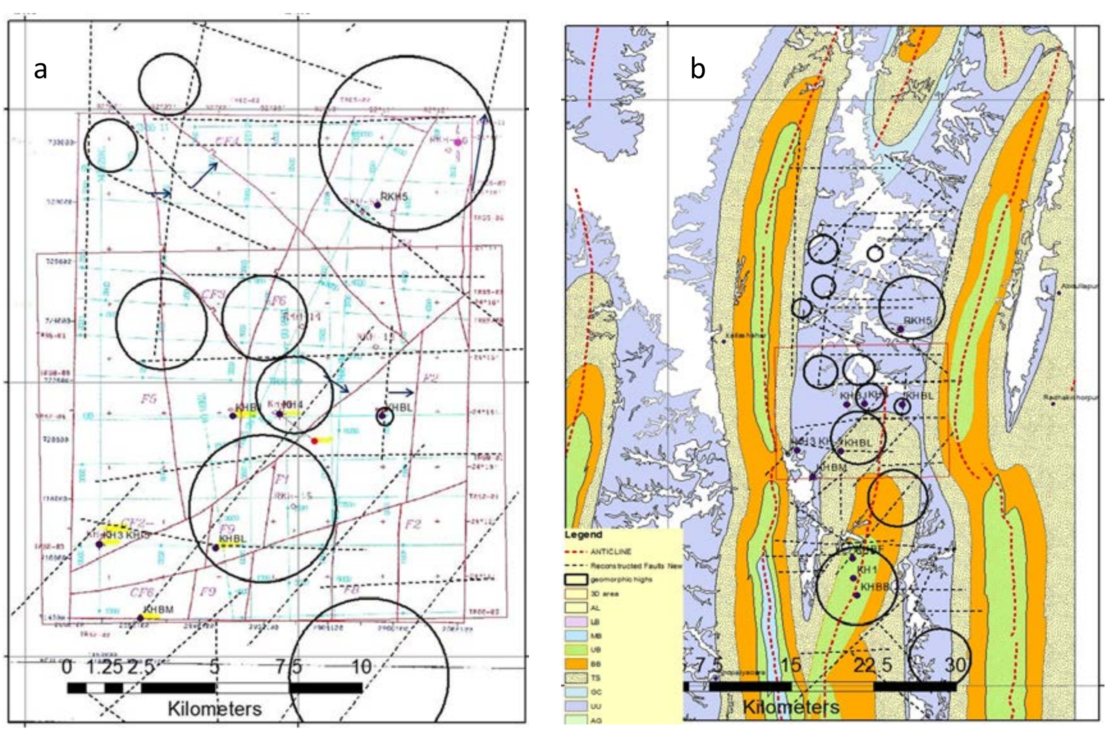
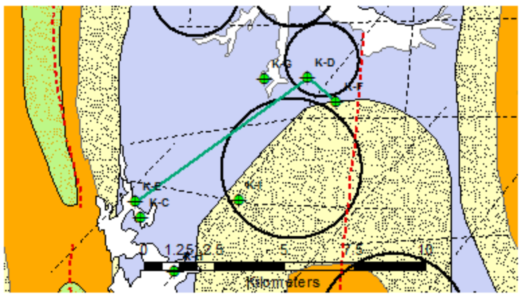


Fig 3a) Comparison with faults interpreted from seismic data shows that though the other trends show some amount of correlation (marked with arrows) with subsurface faults the E-W trend is not represented in seismic b) Overlay on the geological map showing Khubal field extending in both anticlinal and synclinal part. Geomorphic highs in the northern part of the Khubal area overlie the younger Dupitila formation in the synclinal area whereas the southern geomorphic highs are found to overlie the older formations of Tipam, Bokabil and Upper Bhuban in the anticlinal area.

A further validation of these interpreted faults is also done from structural correlation of electrologs between different pairs of wells where a vertical separation/offset is observed between equivalent horizons/ makers suggesting the existence of these faults (A & AA Basin, 2012). Correlation of K-D and k-F both of which lie in the tectonically similar synclinal area affected by E-W faults depicts that K-D in the north is structurally downthrown w.r.t. K-E in the south.



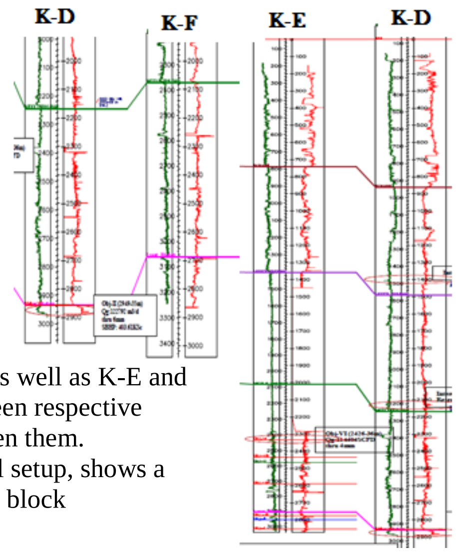


Fig 5. Structural correlation of wells k-D and K-F as well as K-E and K-D depicting a structural vertical separation between respective horizons validating the existence of faults in between them. Noteworthy that K-D and K-E in a similar synclinal setup, shows a northern downthrown block and southern upthrown block

Discussion and Analysis

A trend analysis based on the interpreted faults of the area (Fig 5a) shows that the dominant fault direction of the area is E-W though a high proportion of NE-SW faults are also observed in the area. Comparing this trend analysis to the dominant tectonic elements of the area, it is observed that NE-SW trend observed in the study area may be due to the effect of the Hali Hakalula Lineament and hence might show some amount of strike slip component whereas the N-S trend might due the eastward compression related to the Kaladan fault forming the structure bounding thrusts. However the most significant is the E-W trend that can be considered to be an effect of the compression related to Dauki Fault by virtue of parallelism to it and its predominance suggests it to be related to the most prevalent deformation suffered by the area. However, in case of these E-W faults being created due the effect of the Dauki fault, the vergence of the thrust should be southwards resulting the older rocks in the north to be overlain over younger rocks in the south. But in case of the Khubal field, it is observed that the older rocks in the south overlie the younger rocks in the north. This suggests that the tectonic transport direction of these E-W trending thrusts is northwards rather than southwards that is opposite of the assumed cause. This can be better portrayed with a 3D perspective of the area created with the image of the area overlain over the DEM (Fig 5b) which shows that the southward side with older rock lies in a higher relief over the northward side.

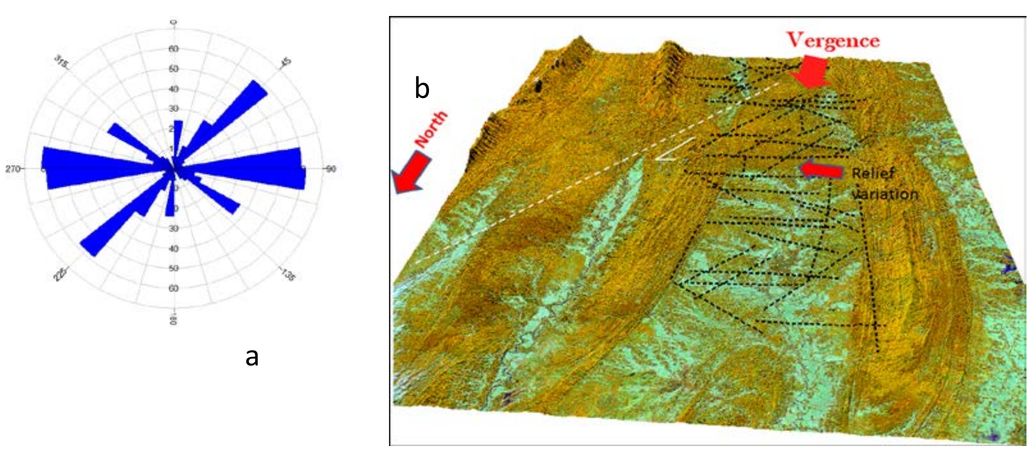


Fig 5a) Rose diagram of the morphotectonic interpreted faults showing a dominant E-W orientation followed by a major NE-SW trends b) 3D model showing a relief difference in the synclinal part with older rocks lying over younger rocks suggesting thrust type tectonics with a northward tectonic transport.

A closer observation of the image data of the area shows that the Khubal anticline seems to branch out of the Hararganj anticline occupying the space in between two anticlines (Fig 6a). This is feasible in case of a NE-SW trending strike slip fault with a dextral sense of movement cutting diagonally across the Hararganj anticline synthetic to the Haili Hakalula Fault. Since strike slip faults are mostly associated with some amount of rotational component, the branched-of Khubal Anticline might show some amount of clockwise rotation in the synclinal space occupied by it, thus causing compression in the sediments in the foreland part of it (Fig 6b).

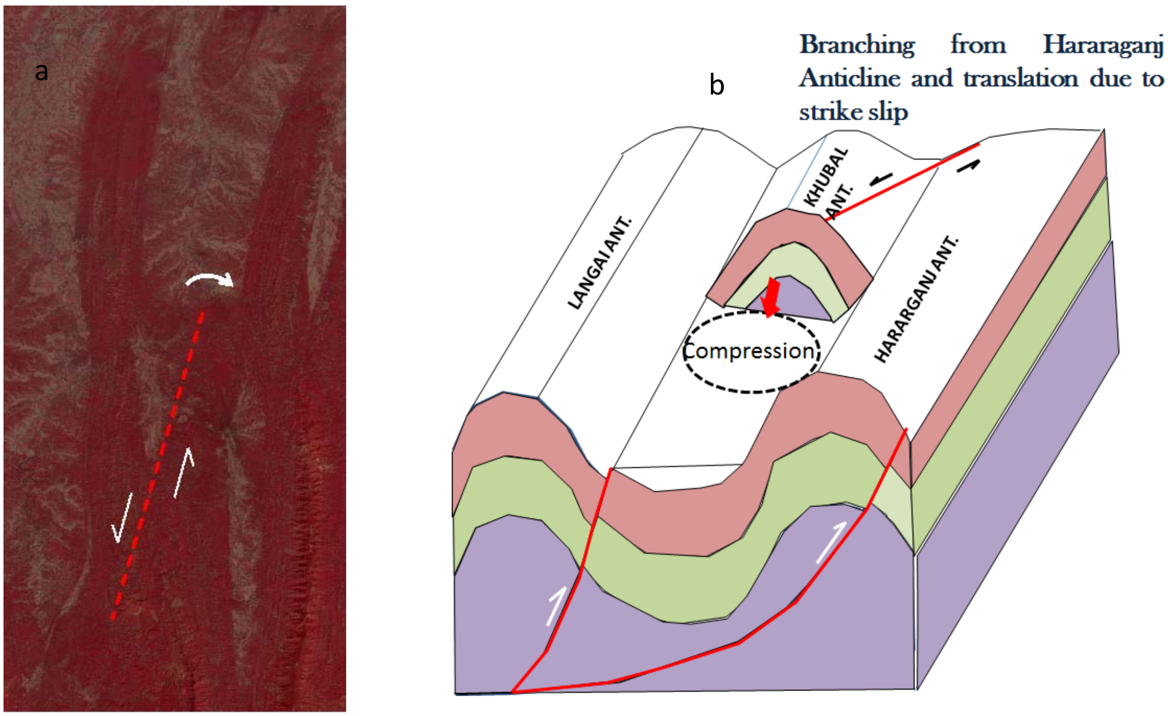


Fig 6a. WiFS image of the area depicting the branching of the Khubal Anticline from Hararganj Anticline probably due to a NE-SW strike slip (b) Schematic model of the area showing development of a compressional component in the synclinal foreland part of the branched Khubal Anticline

This resultant compressional force in the synclinal area due to accommodation of the branched out Khubal anticline might lead to the development or reactivation of the E-W trending thrust faults that display a northward vergence in the frontal part of the anticline. These thrusts however might not be associated with a high amount of displacement enough to be recorded in seismic. However these thrusts might be instrumental in compartmentalization of the Khubal structure into different blocks that might affect the continuity and connectivity of the reservoir and sands in the structure (Fig 7). The NE-SW fault that bounds the Khubal Anticline might also be considered as an effective barrier to the structure with the areas south of the fault may not be as productive as those in the north of it,

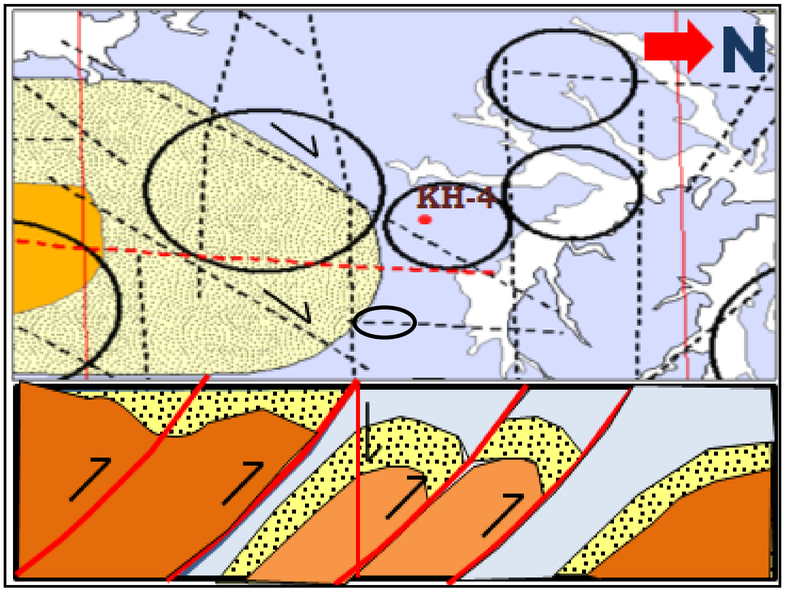


Fig7: Block diagram explaining the probable genesis and effect of the E-W trending thrust faults in compartmentalization of the Khubal structure.

Conclusions

Based on the morphotectonic analysis of Khubal area, it seems probable that the Khubal structure might be compartmentalized by E-W thrust faults that are the products of compression related to the resultant compressional force in the synclinal area due to accommodation of the branched out Khubal anticline in the Champabari synclinal area. A northward location could also be prospective if other factors remain conducive.

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