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Analysis of Fault Pattern within Rohtas Limestone, Son Valley, Vindhyan Basin, India

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Abstract

A detailed analysis of fault pattern within Rohtas Limestone in Son Valley was carried out to understand the tectonic framework and associated fracture development which plays a dominant role in hydrocarbon accumulation in the area. Two main fault alignments are observed namely faults parallel / sub parallel to SNL (E-W to ENE-WSW) and oblique to SNL (NW-SE to WNW-ESE). Most of the faults exhibit composite signatures of extensional and shear stress regimes due to poly phase deformation history. Genetically, two major types of faults are evident. The faults originating from the early extensional regime form basement controlled horst and graben features. In the later part of tectonic evolution, compressional and shear stresses under wrench related movements has led to repeated reactivation and slip reversals along these faults. A number of collinear step faults have developed parallel to SNL and many of such faults are seen to intersect / join with each other In the northern part of the study area, four prominent ENE-WSW trending normal graben bounding faults, down thrown to the south, are seen to the north oh Hatta. Along the Damoh Fault, both normal and reverse separations are observed at places depending on the magnitude of inversion related compressive shear stresses. NW-SE trending oblique fault F-F/ demarcates the Nohta platform area from a prominent gravity high (Begamgunj ridge) to its west. Damoh Fault is an arcuate oblique fault having a WNW-ESE alignment in the western part. As the fault approaches the SNL, it tends to aquire subparallel attitude (E-W) and ultimately joins with Fault to the south of Kharkhari. Restoration of Damoh Fault, carried out during structural analysis, reveals that it originated as a normal fault having considerable throw and created the Damoh sub basin to its north, which was separated from the Jabera sub basin by the intervening Nohta high.

Key words: *SNL, graben, oblique fault.*

Introduction

The Son Valley, Vindhyan Basin has been under active exploration by ONGC for the last five decades. The initial success in the form of establishing presence of gas within Jardepahar Formation of Lower Vindhyan age in Jabera area was followed by significant discovery of gas within fractured reservoirs of Lower Vindhyan Rohtas Limestone and Upper Vindhyan Kaimur Sandstone spread over a large area in the exploration acreage (Fig.1). The reservoirs are unconventional with very low primary porosity and ultra-low permeability. Gas accumulation and flow potential is largely dependant on the presence of fault induced fracture corridors. The present paper aims to bring out the results of detailed analysis of fault pattern within Rohtas Limestone in Son Valley to understand the structural framework, tectonic evolution and associated fracture development.

Tectonic Setting

The Vindhyan Basin is genetically associated with two mega tectonic elements: Great Boundary Fault (GBF) to the northwest and Son-Narmada Lineament (SNL) to the south. The Vindhyan strata of Son Valley define a broad ENE–WSW trending regional syncline in the central part. The axis of the syncline is slightly curved (convex towards north) and plunges gently towards west. Detailed account of tectonic framework including the fault systems, paleo-structures, structural inversion and deformation history have been described by many workers from time to time (Jokhan Ram et al., 1996, Mahendra Pratap et al., 1999). Initial tectonic evolution of Vindhyan Basin is controlled by basement related rift tectonics, which formed a number of horst and grabens along planes of weakness. Two main fault trends are evident, faults parallel to the SNL (E-W to ENE-WSW) as well as along NW-SE aligned oblique faults. The major half grabens are located along the down thrown side of these rift related faults. Some of these faults show syn-sedimentary vertical movements. In later phase of evolution, compressional reactivation of pre-existing extensional faults under the influence of wrench related strike–slip movement along the Son-Narmada Lineament (SNL) resulted in the formation of inversion structures like Damoh, Jabera and Kharkhari.Major oblique faults divide Son Valley into a number of tectonic blocks (Fig.2), notable among them are the Udaipur-Tendukhera block, Jabera-Damoh block and Satna-Rewa-Kaimur block (Mahendra Pratap et al., 1999). Among these blocks, the Jabera-Damoh block is tectonically the most disturbed.

Analysis of fault pattern

In the area of present study, two main fault alignments are observed (Fig.3), namely faults parallel / sub parallel to SNL (E-W to ENE-WSW) and oblique to SNL (NW-SE to WNW-ESE). Most of the faults exhibit composite signatures of extensional and shear stress regimes due to poly phase deformation history. Genetically, two major types of faults are evident. The faults originating from the early extensional regime form basement controlled horst and graben features. In the later part of tectonic evolution, compressional and shear stresses under wrench related oblique strike slip movements has led to repeated reactivation and slip reversals along these faults.

The southernmost fault in the study area is A-A$^{/}$ to the south of Jabera, which runs parallel to the Son-Narmada Lineament (ENE-WSW). The SNL has acted as a major basin margin fault zone and remained active throughout the geological history. Continued basin subsidence along this fault zone created sufficient accommodation space for deposition of thick Lower Vindhyan sediments in the half grabens located on the down thrown side of these faults. As a result of this, a number of collinear step faults have developed parallel to SNL and many of such faults are seen to intersect / join with each other (Faults A1, A2, A3 and A4). Although these faults originated as normal faults during rifting stage, they were subsequently reactivated under inversion related compressional stress leading to slip reversal during the formation of Jabera anticline. In the northern part of the study area, four prominent ENE-WSW trending normal graben bounding faults, down thrown to the south, are seen to the north oh Hatta (Faults B-B$^{/}$ to E-E$^{/}$). The alignment of these faults is parallel to the trend of Rajgarh-Banda ridge on the fringe of Bundelkhand massif.

Faults F-F$^{/}$, G-G$^{/}$ and H-H$^{/}$ are the three major faults oriented oblique to the trend of SNL. Fault G-G$^{/}$, located to the north of Damoh High, is a normal fault with down thrown side to the north. Fault H-H$^{/}$ (Damoh Fault) is an arcuate oblique fault having a WNW-ESE alignment in the western part. As the fault approaches the SNL, it tends to aquire subparallel attitude (E-W) and ultimately joins with Fault A-A$^{/}$ to the south of Kharkhari-A. Restoration of Damoh Fault, carried out during structural analysis, reveals that it originated as a normal fault having considerable throw and created the Damoh sub basin to its north, which was separated from the Jabera sub basin by the intervening Nohta high. Subsequent compressive tectonic episodes associated with oblique strike-slip movement have created slip reversals along this fault. It is worth mentioning here that along the Damoh Fault, both normal and reverse separations are observed at places depending on the magnitude of inversion related compressive shear stresses. Fault F-F$^{/}$ is another arcuate fault located in the western extremity of the study area. Although the southward continuity of this oblique fault could not be clearly mapped due to poor seismic imaging, the fault is likely to extend further south and merge with the SNL as brought out by the regional fault trend. A zoomed Residual Gravity map of the present study area superimposed with mapped faults (Fig.4) reveals that NW-SE trending oblique fault F-F$^{/}$ demarcates the Nohta platform area from a prominent gravity high (Begamgunj ridge) to its west. In the Nohta area, which is located in close proximity to the junction of Damoh Fault and fault F-F$^{/}$, a number of closely spaced faults showing sharp change in orientation are observed. These faults may be inferred as linkage fault system caused by changing orientation and magnitude of stress distribution due to interaction of two or more fault alignments during different phases of the polyhistoric deformation.

Structural Restoration of Damoh Fault

Structural restoration of Damoh Fault, through sequential restoration along seismic line MP-19-07 helped in understanding the kinematic evolution of the structure with time (Fig.5). Two major structural highs are observed along the profile covered by the extents of the seismic section. These are the Damoh high in the Northwest and the Jabera structure in the Southeast. These are observed to be essentially fault related structures with the Damoh high clearly showing signs of being an inverted half graben structure. The Jabera structure appears as a compressional structure pushed up by converging fault sets that are semi-vertical in nature. From an analysis of Jardepahar Formation, and its overlying units – Charkaria, Mohana, Basuhari and Rohtas formations – and their evolutionary stages as brought out by the sequential restoration, there are suggestions of an initial compressive pulse during Post-Jardepahar time, followed by relative tectonic quiescence during Charkaria, Mohana, Basuhari and Rohtas time and finally a major tectonic compressive event in post Rohtas time (end of Lower Vindhyan era) which led to erosion of an appreciable thickness of Lower Vindhyan strata along the extents of the selected profile. On this 'unconformity surface' the Upper Vindhyan sequence was deposited.

Structural restoration of Damoh Fault followed by unfolding and back stripping at the top of Jardepahar Formation reveals that Damoh Fault originated as a normal fault of considerable throw after deposition of the Kajrahat Limestone Formation (Fig.6). The observed thickness variation across the Damoh Fault in Jardepahar Formation is attributed to the changed basin configuration in the Damoh area (more accommodation space). Restoration of Damoh Fault at Kajrahat level restores only part of Damoh Fault. The thickness variation in the Kajrahat and underlying Arangi Shale unit is positively controlled by movement along the Damoh Fault, which points towards syn sedimentary growth along this fault. Flattening at Kajrahat top level and back stripping indicate that along this profile the Arangi Shale unit was not connected and a positive 'basement high' (Nohta high) separated the Damoh and Jabera sub-basins. Damoh Fault has affected the Arangi Shale unit too. The thickness variation across this unit, the perceivable throw across the fault, and the 'drag' on the hanging wall block is evidences of the fault being an 'active' one at this stage (Fig.7). Restoration of the Damoh Fault at top of Arangi Shale and subsequent back stripping of Arangi sequence clearly reveals Damoh Fault as a normal fault with considerable throw involving the basement, thus creating the Damoh sub basin (Fig.8). Finally, the Damoh Fault was restored at top of Basement to look at the original basement configuration. The basement, thus arrived at, shows that the regional low as per the orientation of the selected profile, was to the Southeast. An intervening 'high' is indicated to have pre-existed in the Nohta corridor, in the central part of the profile.

Conclusions

Fault analysis suggests two major structural trends, viz. ENE-WSW (parallel or sub parallel to SNL) and NW-SE (oblique to SNL). A detailed analysis of fault pattern and their genesis, along with structural modelling through sequential restoration in part of the Son Valley, Vindhyan Basin has revealed the kinematics of poly phase tectonic evolution of the basin, beginning with an extensional tectonic regime followed by episodic post Jardepahar and post Rohtas compressional events, leading to the formation of major inverted structures (Damoh, Jabera and Kharkhari) besides small structures.

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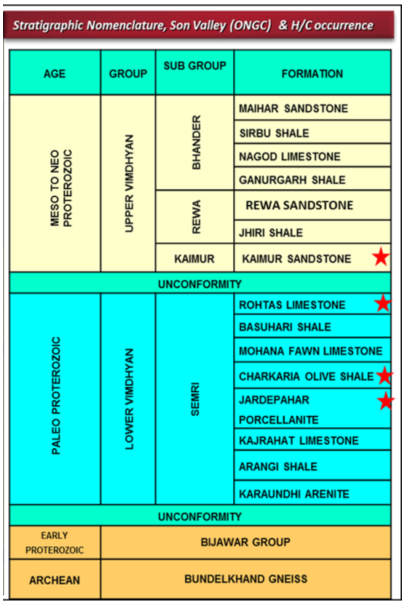

Stratigraphic Nomenclature, Son Valley (ONGC) & H/C occurrence

AGE	GROUP	SUB GROUP	FORMATION
MESO TO NEO PROTEROZOIC	UPPER VINDHYAN	BHANDER	MAIHAR SANDSTONE
			SIRBU SHALE
			NAGOD LIMESTONE
			GANURGARH SHALE
		REWA	REWA SANDSTONE
			JHIRI SHALE
		KAIMUR	KAIMUR SANDSTONE ★
UNCONFORMITY			
PALEO PROTEROZOIC	LOWER VINDHYAN	SEMRI	ROHTAS LIMESTONE ★
			BASUHARI SHALE
			MOHANA FAWN LIMESTONE
			CHARKARIA OLIVE SHALE ★
			JARDEPAHAR PORCELLANITE ★
			KAJRAHAT LIMESTONE
			ARANGI SHALE
			KARAUNDHI ARENITE
UNCONFORMITY			
EARLY PROTEROZOIC	BIJAWAR GROUP		
ARCHEAN	BUNDELKHAND GNEISS		

Fig.1 Stratigraphic succession in Son Valley, Vindhyan Basin

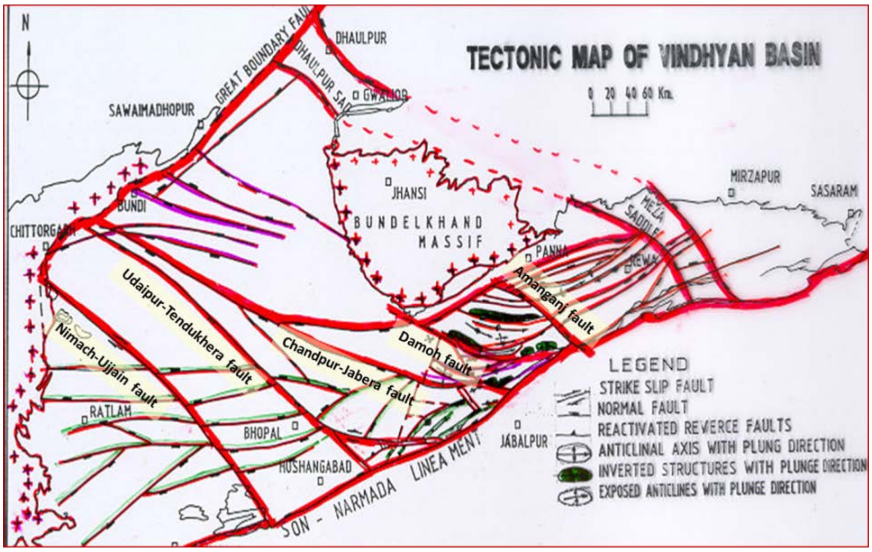

Fig.2 Tectonic Map of Vindhyan Basin (after Mahendra Pratap et al., 1999)

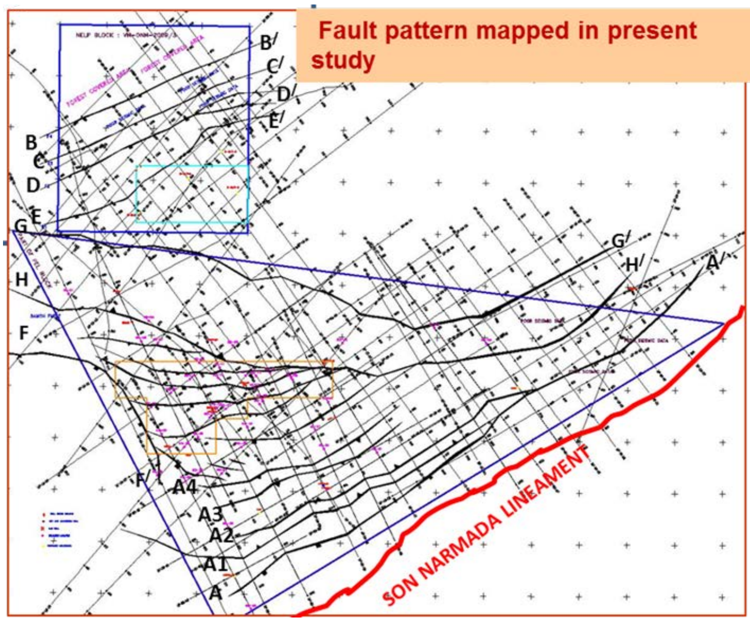

Fig.3 Fault pattern mapped in the study area

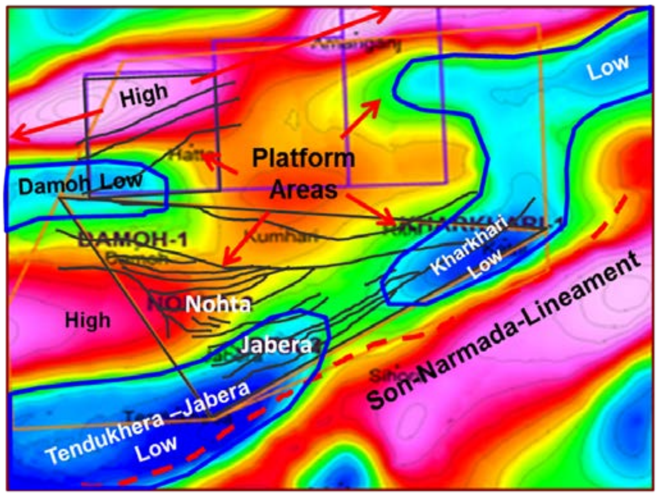

Fig.4 Mapped faults superimposed on Zoomed Residual Gravity Map of the study area

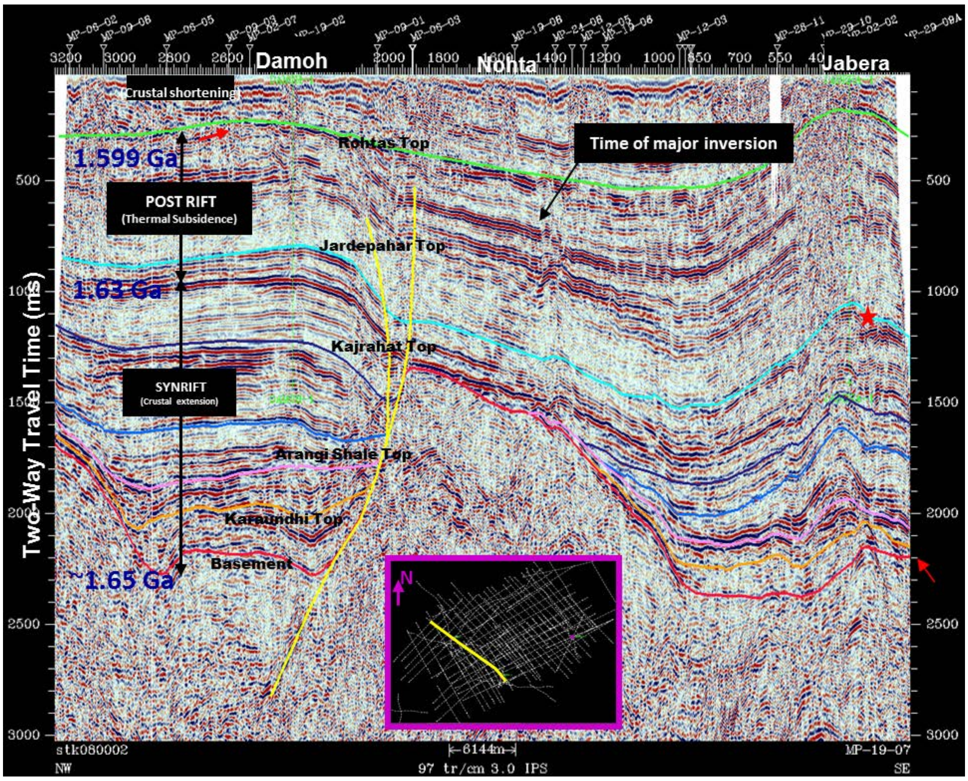

Fig.5 Polyphase evolution of Vindhyan Basin demonstrated along seismic line MP-19-07

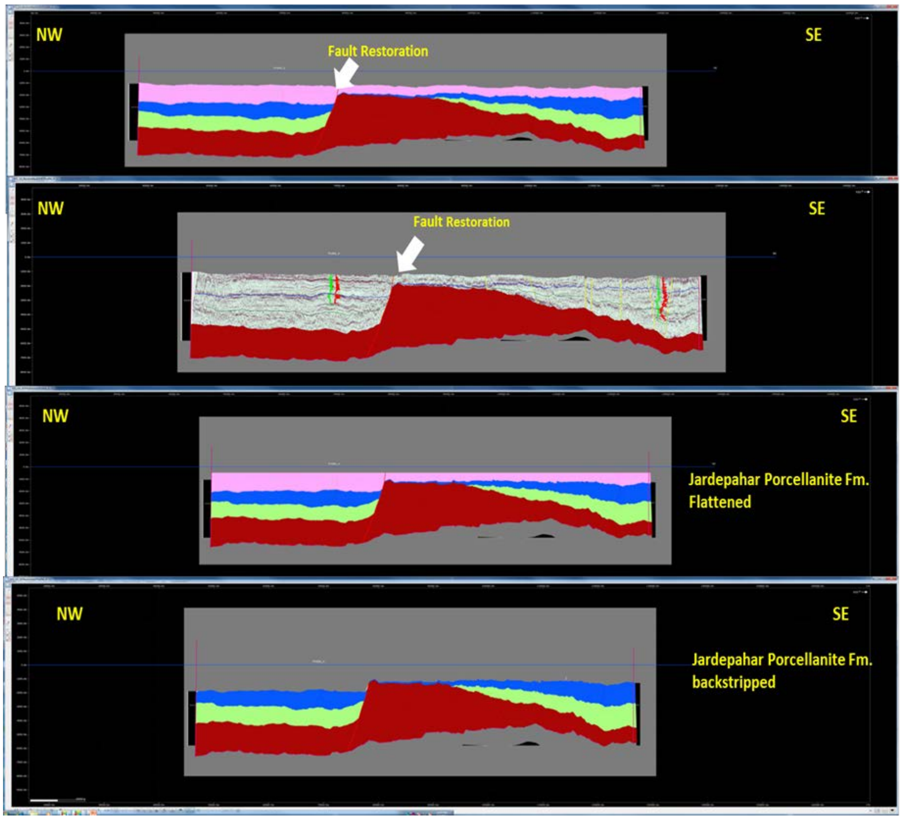

Fig.6 Restoration of Damoh Fault followed by Unfolding and back stripping at top of Jardepahar Formation

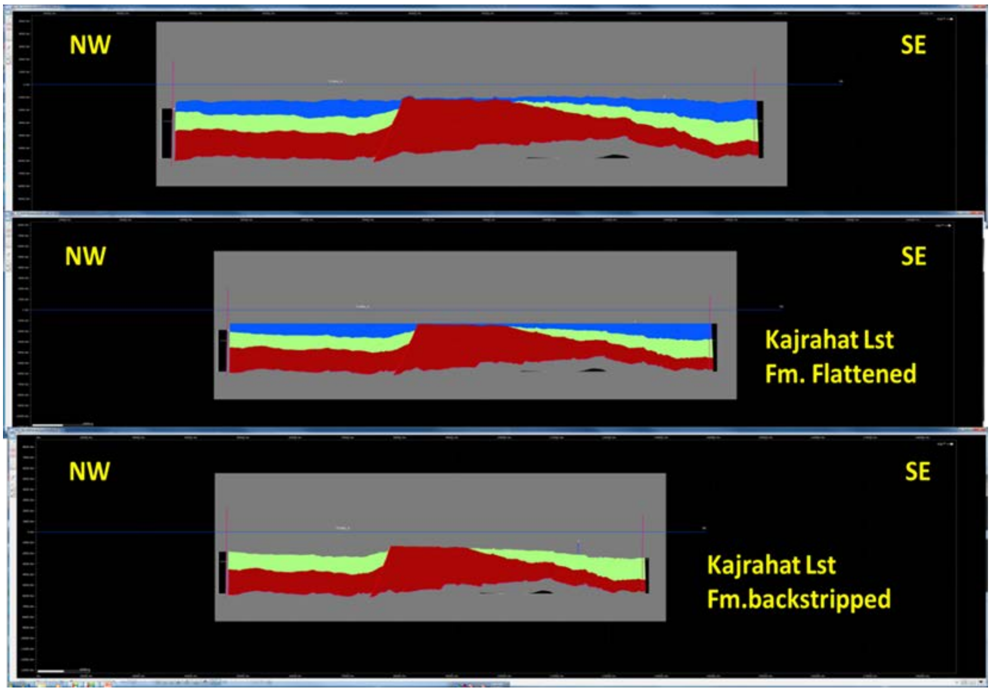

Fig.7 Restoration of Damoh Fault Fault followed by Unfolding and back stripping at top of Kajrahat Formation

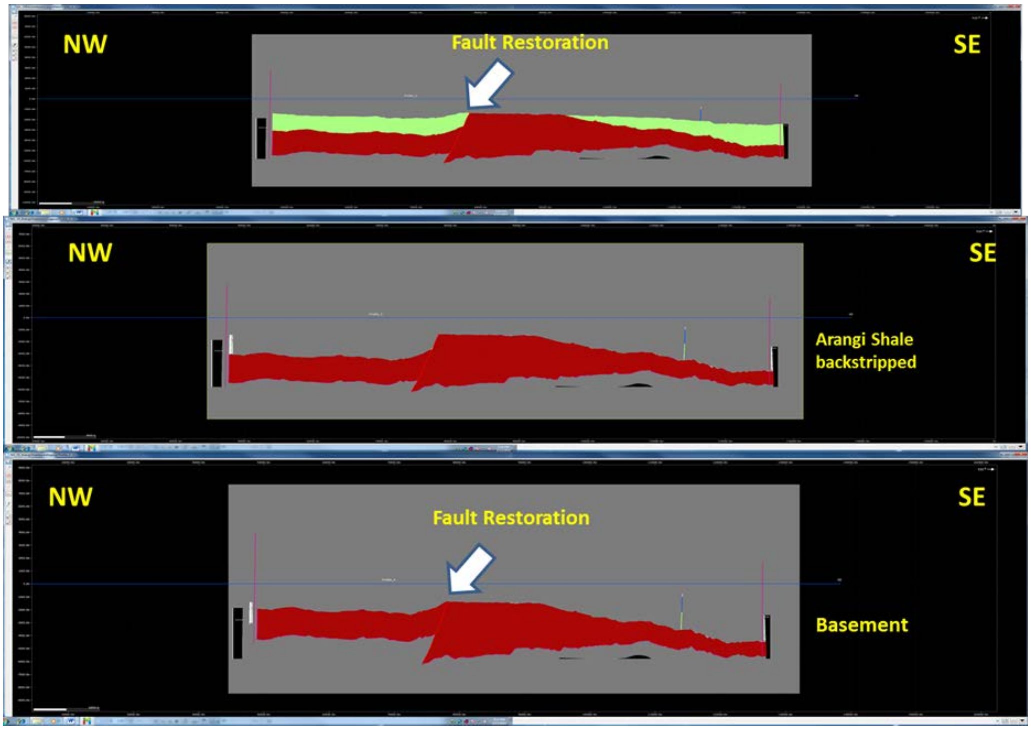

Fig.8 Restoration of Damoh Fault at the top of Arangi Shale followed by back stripping of Arangi Shale and final restoration of Damoh Fault at top of Basement