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A Relook into Tectono-Sedimentation of Chambal Valley, Vindhyan Basin

Abstract

Various tectono-sedimentary models have been suggested for the Proterozoic Chambal Valley sub basin, principally based on regional residual & bouguer gravity and Deep Seismic Sounding data ranging from intra-cratonic sag to intra-cratonic rift as well as peripheral foreland basin. A relook into the tectono-sedimentation of north eastern part of Chambal Valley has been made integrating earlier as well as recently acquired G&G data.

Detailed interpretation of the subsurface data acquired through recently drilled wells in conjunction with the available gravity-magnetic and seismic datasets suggests a peripheral foreland basin style of tectono-sedimentation for this sub-basin. It is envisaged that collisional subsidence of Bundelkhand craton beneath the Delhi-Aravalli craton during Early Proterozoic created compressional upwarping and flexures on the leading edge of Bundelkhand craton, resulting in tectonic subsidence and deposition of about 6km thick Lower and Upper Vindhyan sedimentary sequences on warped crust in front of Delhi-Aravalli orogenic belt. Subsequent basement upliftment in Jhalawar and Baran areas towards southwestern & northeastern part respectively during deposition of Upper Bhander sediments resulted the formulation of major reverse faults forming a major 'V' shaped depression in the study area. This depression coinciding both in Lower and Upper Vindhyan might have acted as the principal kitchen for GME of hydrocarbons.

Chambal Valley sub-basin is asymmetric in shape, generally deepening towards southwest. Contrary to the argillo-calcareous facies within Lower Vindhyan in type area around Chittaurgarh, Rajasthan, a dominant argillo-arenaceous facies is established through recently drilled wells around Kota-Jhalawar area towards NW in the basin. Association of these facies is likely to form viable petroleum systems. It is inferred that identified strati-structural prospects close to these flexures within the available acreages are prolific targets to establish the major exploratory leads in the sub-basin.

Keywords: Tectono-Sedimentation, Chambal Valley, Foreland Basin

Introduction

Vindhyan Basin, the largest 'Purana' basin of India, is situated at the central part of Indian subcontinent, occupying an area of about 1,62,000 sq. km (Figure 1). The basin is cradled in a circumventing manner around the Bundelkhand Massif (3.3 - 2.5 Ga) which apparently occurs at its centre. Based on the outcrop data, the basin is divided into two sub-basins, i.e., the Son Valley towards the east and the Chambal Valley to the west. Most of the southern and south-western part of Chambal Valley is covered by the Deccan trap, which has concealed much of the geological evidences regarding evolution of Chambal Valley.

Current exploration area lies in the north-western part of Chambal Valley near Kota-Jhalawar (Figure 1). Based on the data of recent exploratory wells and integration with available G & G data in the NELP acreages, in the north-western part of Chambal Valley, particularly the boost in confidence following the gas indication from thin sand layer within Suket Formation (Lower Vindhyan) in exploratory well C-1, an improved understanding of the basin evolution, tectono-sedimentation and petroleum system of the Chambal Valley sector of Vindhyan Basin have been evolved.

Basin Evolution and Tectonics

The Vindhyan Supergroup covers an important period of geological evolution during Palaeo-Neoproterozoic eras. The maximum thickness of Vindhyan sediments is reported to be more than 6000m near Bhopal (KDMIPE MT Report 2010), comprising mainly sandstone-shale-limestone sequences of shallow marine origin. The margins of the basin are demarcated by two thrust belts: Aravalli-Delhi Fold Belt (ADFB) along Great Boundary Fault (GBF) in the northwest and the Satpura Orogenic Belt (SOB) along Son Narmada Lineament (SNL) in the east-southeast.

The entire sedimentary succession of the sub-basin is divisible into four groups: Semri, Kaimur, Rewa and Bhander from bottom to top. The Semri Group is referred to as the Lower Vindhyan and the Kaimur, Rewa and Bhander Groups as the Upper Vindhyan (Table 1). Lower Vindhyans is dominantly argillo-calcareous in nature, while Upper Vindhyans is mainly argillo-arenaceous in nature. Chittorgarh is considered as a type area for Vindhyan sediments in Chambal Valley and has been used for stratigraphy and lithofacies analysis in current exploration area. Mukundara Reverse Fault (MRF) is the major tectonic element of Chambal Valley, it accounts for structural evolution and major structurisation in the exploration area (Figure 5 and 6).

Based on geological, structural and geophysical data, various tectono-sedimentary models have been suggested for the Proterozoic Chambal Valley sub basin. A brief summary of all envisaged tectonic models are depicted in Table 2.

Tectono-Sedimentation: A Relook

At about 1800–1600 Ma (lower part of Lower Vindhyan), collision occurred between Bundelkhand craton and Aravalli craton in the west and between Bundelkhand craton and Bhandara–Bastar craton in the south (Figure 2A), (Mishra, 2000). During early stage of collision, the leading passive margin of underthrusted Bundelkhand craton had undergone extensional deformation due to "flexural extension" resulting in the formation of normal faults (initiation of Mukundara Fault) and half grabens (Figure 2B). In the post extensional regime, collisional subsidence of Bundelkhand craton beneath the Delhi-Aravalli craton created compressional upwarping and flexures on the leading edge of Bundelkhand craton, resulting in deposition of about 6km thick Lower and Upper Vindhyan sedimentary sequences on warped crust in front of Delhi-Aravalli orogenic belt (Figure 3).

The Bouguer anomaly map of the north Indian shield that includes the Vindhyan Basin (Figure 4) shows a distinct gravity low L4 which is attributed to a significant thickness of Chambal Valley sediments in the western part encircling the part of Bundelkhand Craton. Bordering the gravity low L4 is the gravity high H4 that is related to high density rocks of the ADFB. Sub parallel nature of the gravity anomalies due to Chambal Valley sediments with those due to collision zones suggests its genetic relationship and this basin formed as a foreland basin to the ADFB. The gravity low L4 along the ADFB may represent its fore deep similar to the L1 and L2 fore deeps of the present day Himalayan fold belt (Mishra, 2011).

Residual gravity map (Figure 5) indicates that sub-basin is dipping towards south and southwest. Basement upliftment during deposition of Upper Bhander sediments in Jhalawar and Baran areas within the exploration acreage, led to the reactivation and slip reversal along major faults giving rise to a major 'V' shaped depression. This depression might have acted as the principal kitchen area for GME of hydrocarbons during both Lower and Upper Vindhyan times. Mukundara Reverse Fault (MRF) is the major tectonic element, along which major entrapment structures occur. The gravity map indicates the possibility of Mukundara Fault being an offshoot of Son Narmada Lineament (SNL) (Figure 5). During the deposition of Upper Vindhyan Bhander time *sensu-stricto* post Samaria Shale (Figure 6A) NE – SW directed compressive stresses generated probably due to Delhi – Sausar orogeny at about 1100 – 1000 Ma or presumed to have been caused by the counter strike-slip movement along SNL and GBF. These compressive stresses caused the reactivation of Mukundara Fault and changed it to reverse fault in the south and uplifted the Baran High along Baran Reverse Fault (BRF) in the north. Compressive stresses with attendant transpressive stress forms the en echelon pattern of Chechat, Suket and Jhalawar anticlines in the hanging wall of MRF.

Structural modelling along line RFB-01-20 shows that there is thickness difference across the Mukundara and other faults in hanging wall, suggesting strike-slip movement across the Mukundara (Figure 6B). Due to these compressive and transpressive stresses, NNW-SSE conjugate fault system was developed in the 'V' shaped low between these two highs (Figure 5). These conjugate faults led to the development of a number of pop-ups (Kalpa and Palaita structures) and broad anticlines (Jagpura) within the low forming the suitable entrapment condition.The regional NE-SW oriented seismic section (Figure 7) shows the deepening of the sediments towards the ADFB depicting the wedge shaped sediment fill typical of a foreland basin. During the Upper Vindhyan period, the basin possibly took a northerly tilt. This caused a widespread transgression inundating even the interior of the Bundelkhand craton over which the Upper Vindhyan succession was deposited.

Based on the data of drilled wells it is found that there is remarkable difference in lithofacies. Lower Vindhyans calcareous facies i.e. Bhagwanpura and Nimbahera Limestone of type area turned dominantly into arenaceous facies in exploration area. The dominance of clastic facies in this part of Chambal Valley may be attributed to closeness to active provenance. In the Upper Vindhyans, lithology is dominated by clastics, only calcareous deposit occurs in the form of Lakheri Formation (Table 2). Chambal Valley sediments are derived principally from the adjacent fold belt with contributions from the cratonward side of the basin.

Conclusions

The Chambal Valley sub-basin is interpreted as a peripheral foreland basin. Collisional subsidence of Bundelkhand craton beneath the Delhi-Aravalli craton created compressional upwarping and flexures on the leading edge of Bundelkhand craton, resulting in tectonic subsidence and deposition of Lower and Upper Vindhyan sedimentary sequences. Basement upliftment in Jhalawar and Baran along major reverse faults formed a major 'V' shaped depression on the footwall block of MRF besides few local depressions in hanging wall block, which are envisaged as kitchen areas for generation, migration and entrapment of hydrocarbons. Thick argillo-arenaceous sequence of Lower Vindhyan and argillo-arenaceous and calcareous sequence of Upper Vindhyan strata in the 'V' shaped depression within the available acreages are prolific targets to establish the major exploratory leads in the sub-basin.

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SUPER GROUP	GROUP	SUBGROUP	WEST OF VINDHYAN BASIN (CHAMBAL VALLEY)				
			CHITTOR-BUNDI AREA (After Prasad, 1976)	KOTA AREA (After Drilled Wells)	JHALAWAR AREA (After Drilled Wells)		GROSS LITHOLOGY
			STRATIGRAPHY	P-1 THICKNESS (m)	C-1 THICKNESS (m)	S-1 THICKNESS (m)	
VINDHYAN SUPERGROUP	UPPER VINDHYAN GROUP	BHANDER	DHOLPURA SHALE		UPPER VINDHYAN ERODED/ NOT DEPOSITED	UPPER VINDHYAN ERODED/ NOT DEPOSITED	
			BALWAN LIMESTONE				
			MAIHER SST.	223			SST WITH SILTSTONE, SHALE AND MINOR LIMESTONE
			SIRBU SHALE	284			SHALE WITH EVAPORATIC DOLOMITIC LIMESTONE
			BUNDI HILL SST.	318			SST & SILTSTONE WITH INTER BEDS OF SHALE AND LIMESTONE
			SAMARIA SHALE	392			SHALE WITH INTERLAMINATIONS OF SILTSTONE & SANDSTONE
			LAKHERI LST.	132			LIMESTONE WITH THIN BEDS OF SHALE
			GANURGARH SHALE	120			SHALE , THIN BEDS OF SST & SILTSTONE
		REWA	GOVINDGARH SST.	282			SST WITH MINOR SHALE & SILTSTONE
			JHIRI SHALE	156			THINLY LAMINATED SHALE WITH INTERBEDS OF SST & SILTSTONE
			INDARGARH SST.	225			SST WITH SHALE & SILTSTONE
			PANNA SHALE	46			SHALE WITH MINOR SILTSTONE & SST
		KAIMUR	AKODA MAHADEV SST.				
			CHITTAUR FORT SST.	325			SST ALTERNATION WITH SHALE, THIN BEDS OF SILTSTONE
	LOWER VINDHYAN GROUP		SUKET SHALE	775	480	310	SHALE , THIN BEDS OF SILTSTONE & SST
			NIMBAHERA LST.	NOT DEPOSITED	210	254	MAINLY SST, FEW SHALE AND SILTSTONE
			BARI SHALE		140	130	MAINLY SHALE WITH MINOT SST
			JIRAN SST. WITH CONGL.		246	167	SST WITH SILTSTONE AND BANDS OF SHALE
			BINOTA SHALE		210	76	DOMINANT SHALE WITH MINOR SST & SILTSTONE
			KALMIA (GLAUC.) SST		76	190	SST WITH MINOR SILTSTONE AND SHALE
			PALRI SHALE WITH PORCL.		188	264	SHALE WITH SILTSTONE & SST INTERLAMINATIONS
			SAWA SST. WITH CONGL.		182	129	SST WITH INTERLAMINATIONS OF SILTSTONE & SHALE
			BHAGWANPURA LST.			171	SST WITH MINOR SHALE
			KHARDEOLA SST.		109	61	SHALE WITH THIN SST BEDS
			KHARMALIA ANDESITE				
ARAVALI GROUP/ BUNDELKHAND GNEISS				GRANITIC BASEMENT	GRANULITIC BASEMENT	GRANITIC BASEMENT	

Table 1: Generalised and well encountered Stratigraphy of Chambal Valley

Tectonic Model	Author	Basis
Continental Interior Basin	Soni et. al.,1987	• Basin thickness and extent • Typpically unmetamorphosed sediments • Varying deformed sedimentary strata

		• Shallow water depositional conditions
Intra-continental Rift Basin	Ram et al. 1996	Interpretation of limited seismic and GM data on Chambal Valley (Lower Vindhyan)
Foreland Basin	Radhakrishna & Naqvi, 1986; Raza et al, 2009, Mishra, 2011	• In front of Delhi-Aravalli Mobile belt, • Tectonic transport along GBF towards Chambal Valle • Asymmetric shape, deepening in SW towards basin margin. • Geochemical Modelling • Geophysical evidences (Regional GM and seismic da

Table 2: Tectonic Models for Vindhyan Basin

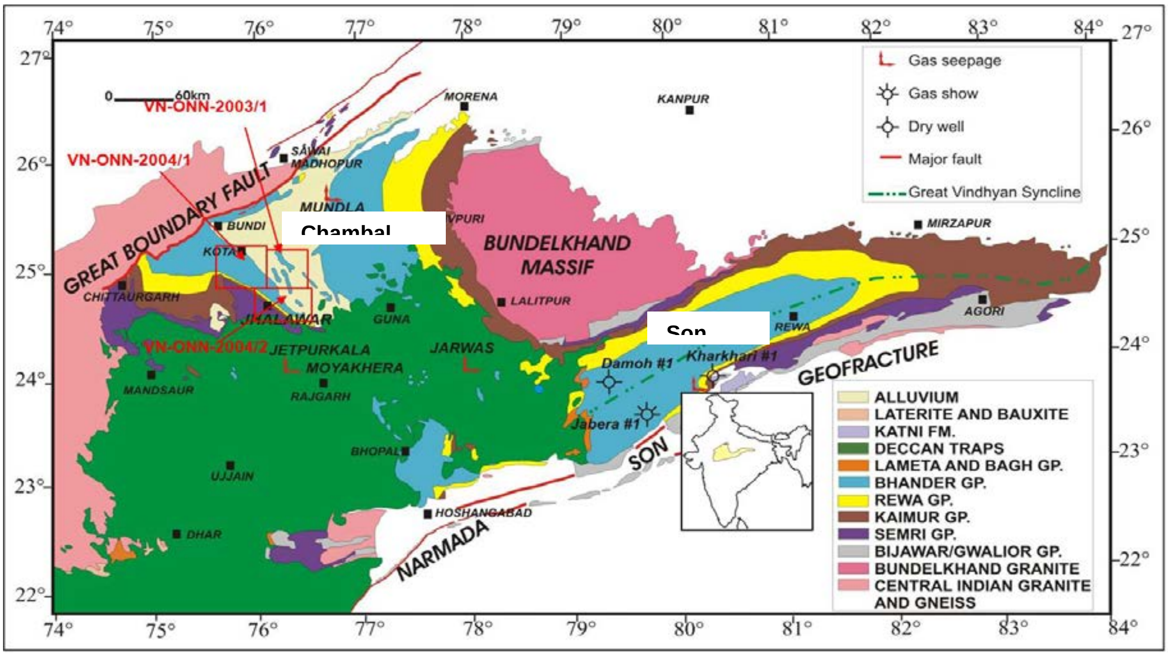
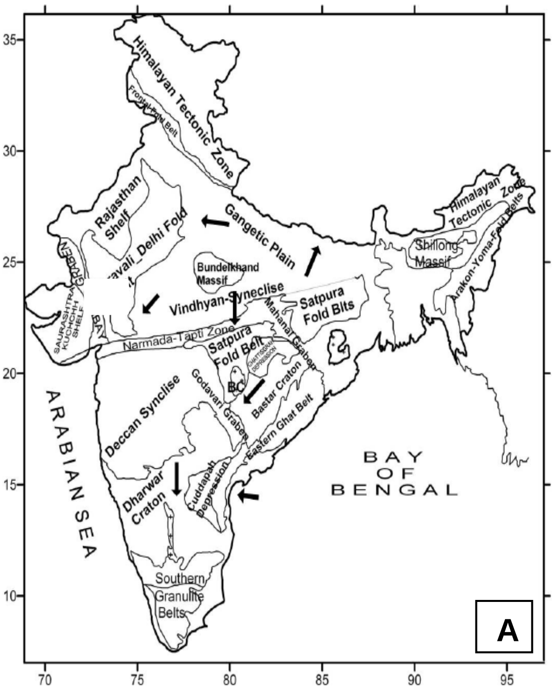


Figure 1: Geological Map showing the major elements of Vindhyan Basin



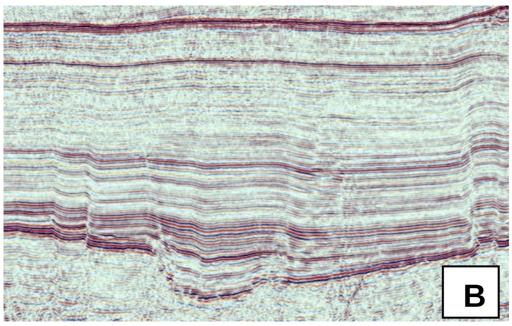


Figure 2: (A) Simplified tectonic map of India, arrows showing the direction of convergence in Proterozoic (Mishra, D.C., 2013, NGRI). (B) Seismic section showing half graben structure

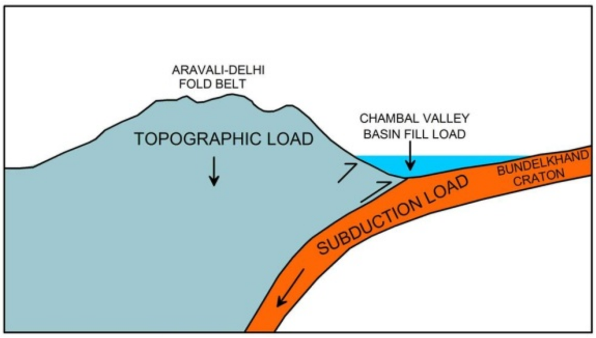


Figure 3: Peripheral Foreland Basin Tectonic Model for Chambal Valley (modified after DeCelles and Giles, 1996)

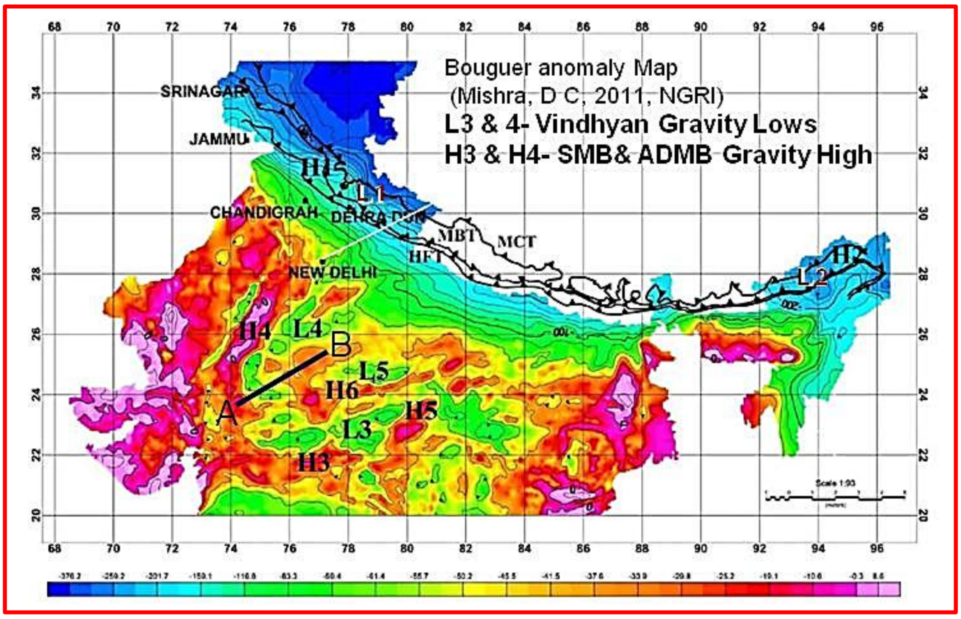


Figure 4: Bouguer Gravity map of north Indian shield

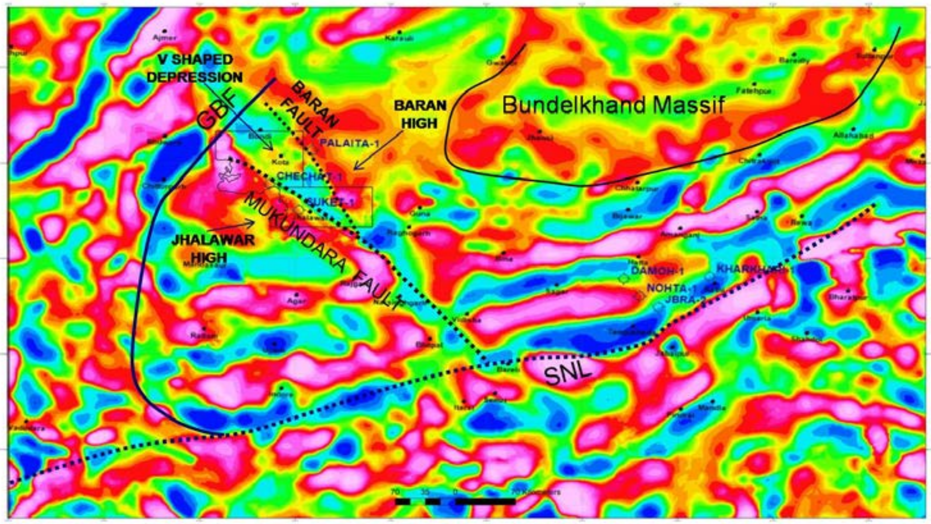


Figure 5: Residual Gravity Map of Vindhyan Basin (KDMIPE, 2014)

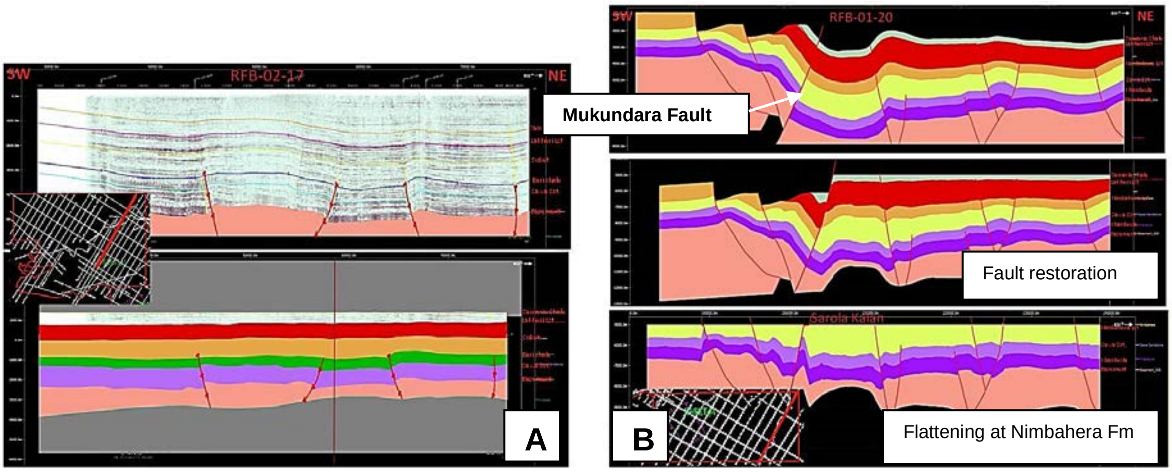


Figure 6: (A) Part of seismic line RFB-02-17 showing the footwall of Mukundara, and after flattening at Samaria shale Formation top (B) Modelling results along Seismic section RFB-01-20

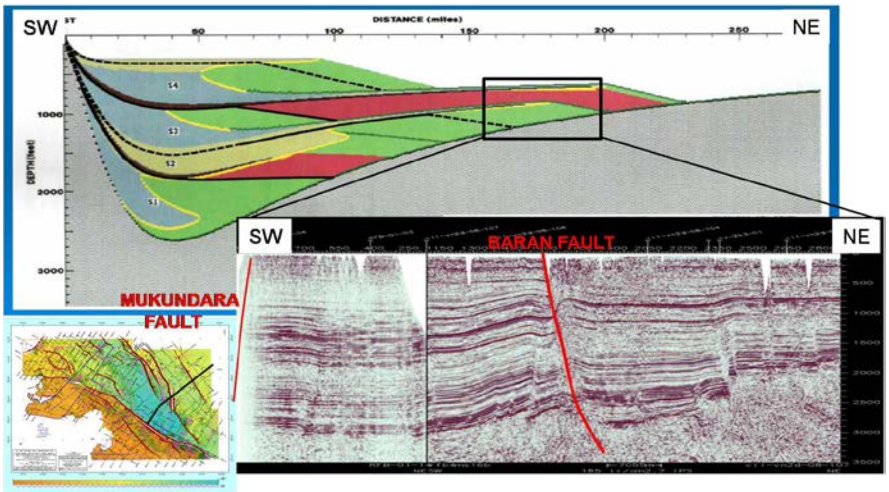


Figure 7: Asymmetric or wedge shaped geometry of basin: an evidence of foreland basin