

Prospect Maturation using Seismic and Offset Well Data: The Osemu-Niger Delta Case Study

Isaac Aigbedion¹ and Innocent Okogbue²

¹ Ambrose Alli University

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Abstract

The AVO Fluid Inversion (AFI) technique to predict the probability of oil and gas occurrence in OML-X and quantify the uncertainties associated with the fluid prediction using Seismic sections and some well picks from nearby Ose Field. The seismic data interpretation of the Osemu prospect was based mainly on the picking of seven horizon layers (including the sea bottom). Four deeper horizons (C, D, E & F) were analysed for prospect generation and volumetric estimation. Results showed a major NW-SE trending growth fault controlled sedimentation and structural deformation in the study area. The seismic interpretation has identified two main prospects in the Osemu area. These are named Osemu-Main and Osemu-Upper. From the study two wells are recommended to be drilled on the structure. The two are expected to pierce all the four reservoirs considered in the volumetrics mid way between the crest and the flank.

Index terms—

1 Introduction

The Osemu anomaly is one of the three major structures identified in OML-X (approx. 725 Sq.km) in water depth ranging between 60 and 160 meters in the Niger Delta-Nigeria. The other prospects are the Osno and Ose in the north and east respectively. The latter have been drilled and are currently producing and providing the referenced logs and well information used for the Osemu prospect study.

A recent acquisition of approximately 360 km² 3D seismic data over the Osemu prospect and the subsequent delivery of the processed seismic data prompted the interpretation of the data.

The seismic data interpretation of the Osemu prospect was based mainly on the picking of seven horizon layers (including the sea bottom). Four deeper horizons (C, D, E & F) were analysed for prospect generation and volumetric estimation. All the four horizons are considered to lie within the prolific Agbada formation of the Niger Delta basin. Integration of 3D seismic model with petrophysical data has been a beneficial endeavor in use in the petroleum industry for some years now (Adeoye and Enikauselu, 2009; Aigbedion and Iyayi, 2007; ??mujakporu and Faluyi, 2015) in petroleum provinces where exploration and production strategies merge, detailed understanding of petrophysical properties is highly desired. Landmark's software and computer hardware located in-house were used in the interpretation of the seismic sections. The Geophysical data consisted of approximately 360 Km² of conventional 3D seismic and a depth model for the entire volume. The closest well with a check shot (Ose-5) is about 17km away from the prospect. The overall aim of this study is to use the AVO Fluid Inversion (AFI) technique to predict the probability of oil and gas occurrence in OML-X and quantify the uncertainties associated with the fluid prediction.

2 II.

3 Objectives of the Study

The overall aim of this study is to determine whether drillable anomalies exist in the Osemu prospect. The specific objectives of the study are as follows:

- i. Identify and interpret the potential hydrocarbon bearing anomalies of interest in the study area
- ii. Mature the prospect anomalies into drillable targets
- iii. Compute the hydrocarbon in place.

4 III.

5 Location of Study

The Osemu prospect is located in the southern part of the Niger Delta within OML-X (Oil Mining Lease) approximately 80 kilometers from the coastline (Figure ??). It is within the shallow offshore Niger delta. T Fig. ??1: Location Map of Osemu Field

6 Geology of the Study Area

The Niger Delta is situated in the Gulf of Guinea (fig. ??) and extends throughout the Niger Delta Province as defined by Klett et al (1997). From the Eocene to the present, the delta has prograded southwestward, forming depobelts that represent the most active portion of the Delta at each stage of its development (Doust and Omatsola, 1990). These depobelts form one of the largest regressive deltas in the world with an area of some 300,000 km² (Kulke, 1995), a sediment volume of 500,000 km³ (Hospers, 1965), and sediment thickness of over 10 km in the basin depocenter (Kaplan et al. 1994).

Three geological formations are considered as part of the petroleum system in the Niger Delta. The basal one composed of marine shales, called the Akata Formation. This unit ranges in thickness from 600 m to more than 6000 m (Weber and Daukoru, 1975; Igbedion and Hafiz, 2017). The overlaying formation is named Agbada. This formation consists of interbedded sands and shales and is known as the hydrocarbon bearing zone. The cap unit is the Benin Formation and comprises continental fluvial sands. This unit is a nonhydrocarbon bearing formation. Two structural patterns can be observed in the Osemu area from the fault orientations, and shape of the mapped levels. The main structural controls are the arcuate NW-SE trending, synthetic growth faults. The Osemu area faults are subvertical with expressions at the seabed. This could be attributed to fault rejuvenation caused by tectonics of the underlying under-compacted massive Akata shales. Deformation takes place by gravitational gliding of rigid block along a decollement horizon above underlying shale as result of sedimentary loading (Figure ??).

Another remarkable feature in the Osemu geology is the pattern of termination of the NW-SE crystal faults which also corresponds to the point of bifurcation of the major fault into a bigger down dip component and a splinter at the up thrown. This arrangement suggests that the crystal collapse also initiated the extension of the major fault SE in a stress release mechanism. Subsequent sediment loading led to the SW rotation of the major fault to form an arcuate limb that supports the high zone of the Osemu closure (figure ??5) Lithostratigraphy: The Tertiary section of the Niger Delta is divided into three formations, representing prograding depositional facies that are distinguished mostly by the lithofacies mix. It is possible to summarise the stratigraphic column of the Niger Basin in three main diachronous lithologic formations; Benin, Agbada, and Akata (Figure ??).

Benin is the youngest formation and is comprised of continental, fluvio-alluvial and upper coastal plain sediments with good porosity, but generally low permeability, this fact limits to oil production from the Benin Formation in the Basin. The sequence passes laterally into the paralic / deltaic sandstone of the Agbada Formation.

The majority of hydrocarbons produced in the basin come from the alternating sandstone and siltstone that make up the Agbada Formation. A shelf to the deltaic/lagoonal environment characterized the sequence deposits. The observed small and large scale sedimentary cyclicity is probably mainly related to climatic change effects. Growth faults control/influence the sedimentation patterns. The paralic sandstone of Agbada Formation passes offshore into the distal prodelta/deep marine shale of the Akata Formation.

The Akata Formation at the base of the delta is of marine origin and is composed of thick shale sequences (potential source rock), turbidite sand (potential reservoirs in deep water), and minor amounts of clay and silt. Beginning in the Palaeocene and through the Recent, the Akata Formation formed during low stands when terrestrial organic matter and clays

7 Osemu Area

8 Main Structure Building (MSB) Fault

were transported to deep-water areas characterized by low energy conditions and oxygen. Turbidity currents likely deposited deep-sea fan sands within the upper Akata Formation during the development of the Delta. The Akata Formation (Eocene -Early Miocene) is dark grey marine shale throughout the basin and is typically considered to be the source rock for most of the hydrocarbon production in the area.

Deposition of the three formations occurred in each of the five of flapping siliciclastic sedimentation cycles that make up the Niger Delta. These cycles (depobelts) are 30-60 kilometers wide, prograde southwestward 250 kilometers over oceanic crust into the Gulf of Guinea, and are defined by syn-sedimentary faulting that occurred in response to variable rates of subsidence and sediment supply. The interplay of subsidence and supply rates resulted in the deposition of discrete depobelts. When further crustal subsidence of the basin could no longer be accommodated, the focus of sediment deposition shifted seaward, forming a new depobelt. Each depobelt is a separate unit that corresponds to a break in the regional dip of the delta and is bounded landward by growth faults and seaward by large counter-regional faults or the growth fault of the next seaward belt.

9 Materials and Methods

10 a) Materials

The Geophysical data consisted of approximately 360 Km² of conventional 3D seismic and a depth model for the entire volume. The closest well with a check shot (Ose-5) is about 17km away from the prospect. Since realistic check shot data was not available, it was necessary to use the RMS velocities provided by the processing company for conversion of the time generated maps to depth. The second order polynomial equation was used for the conversion.

The geological data and the petro physical information referenced here were some well picks from nearby Ose field.

11 AKATA Fm

12 Methodology

The simplified workflow is as outlined below:

? An overview of the entire seismic volume was taken before deciding which reflectors should be mapped.

Reference was also made to the depth at which hydrocarbon was found at nearby Ose and Osno fields.

? Horizons and faults were then mapped on crosslines and inlines. ? The mapped horizons were then exported along with their respective fault polygons to the mapping software. ? The time maps were then converted to depth by the RMS-Velocity equation for the seismic volume ($y=0.0001x^2+0.9453x-97.214$).

13 a) Fault Picking

The major NW-SE (Osemu F1) controlling fault was mapped across the area. The throw of fault decreases gradually towards the SE until it is truncated by a major arcuate, south dipping fault.

14 b) Horizon Mapping

A total of seven horizons were mapped. They represent the top of seismic sequences identified within a time zone of 1200 ms-2600ms. This is considered as the zone of interest by reference to the prospect levels in the adjacent Ose-Osno fields.

Seven Horizons were mapped including the sea bed. Four Horizons are considered prolific (C, D, E & F) due to their situation within the Agbada depth ranges. All Horizons were interpreted in time, then gridded and converted to depth. Figures ??8, 10, 12, 14, 16, 18, & 20) shows Sea Bed, Horizons A, B, C, D, E & F in time. Figure ??9, 11, 13, 15, 17, 19 & 21) shows the respective horizons map in depth.

The velocity model for the depth conversion was built into the respective time horizons to produce a depth equivalent using the RMS velocities (figure ??). Volume XVIII Issue IV Version I c) Amplitude Extraction Amplitude extraction was done on all the mapped time horizons. Maximum Negative Amplitude maps were produced (figure ??a & 3b). The amplitudes did not show any hydrocarbon related anomalies as observed by their non-conformance to structure.

The angle stacks were also examined for possible AVO effects. There was slight amplitude boost with offset.

15 VII.

16 Discussion of Results

17 a) Prospects Identification o

The seismic interpretation has identified two main prospects in the Osemu area. These are named Osemu-Main and Osemu-Upper. (Figure ??1) ? The Osemu-Main prospect is a tongue-like NW-SE trending formed at the downthrown block of the structure building fault. The structure is fault assisted at shallower levels (A-C) and faults dependent at depth. The areal extent of Osemu prospect is enhanced by the termination of the controlling fault against a south-dipping synthetic fault. The sealing capacity of the termination point impacts significantly on the prospectivity of the Osemu-Main. ? The Osemu-upper prospect is formed as a wedge between the bigger branch of the major fault and the northern splinter fault.

18 b) Estimation of Hydrocarbon-In-Place

The deterministic estimation of oil in place for the Osemu Field was completed using 3-D geological modeling in the Zmapp software package. This procedure involves bringing structural surfaces in from the geophysical package (Landmark), building a detailed fault model, and then modeling both facies distributions and the distribution of petrophysical parameters within the facies model ??Deutsch and Hallstrom ,2000).

Probable areas measured from depth maps for the prospective horizons ranges from 726 acres in Horizon E.0 to 3975 acres for Horizon C.0 (Table 1). Three cases were considered in determining the possible closure area. These are minimum, most likely and maximum contour closures representing varying sizes.

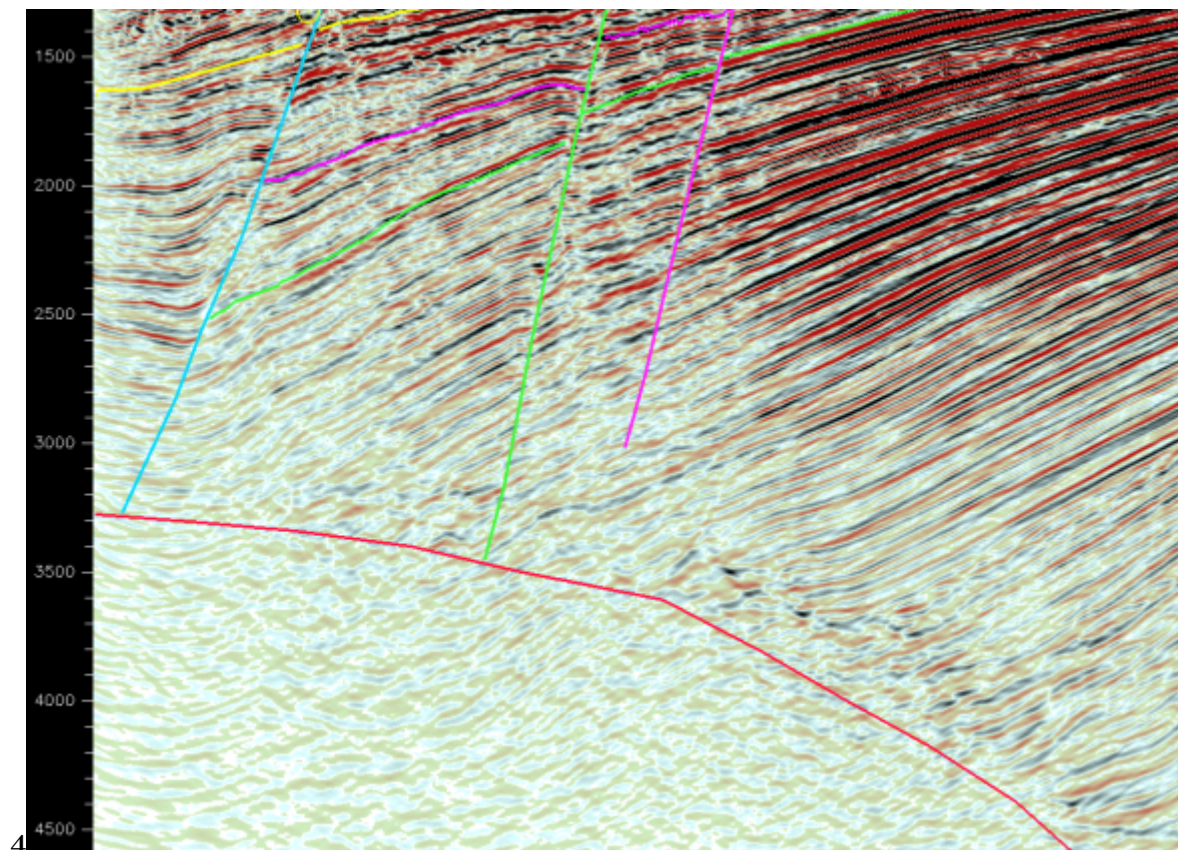
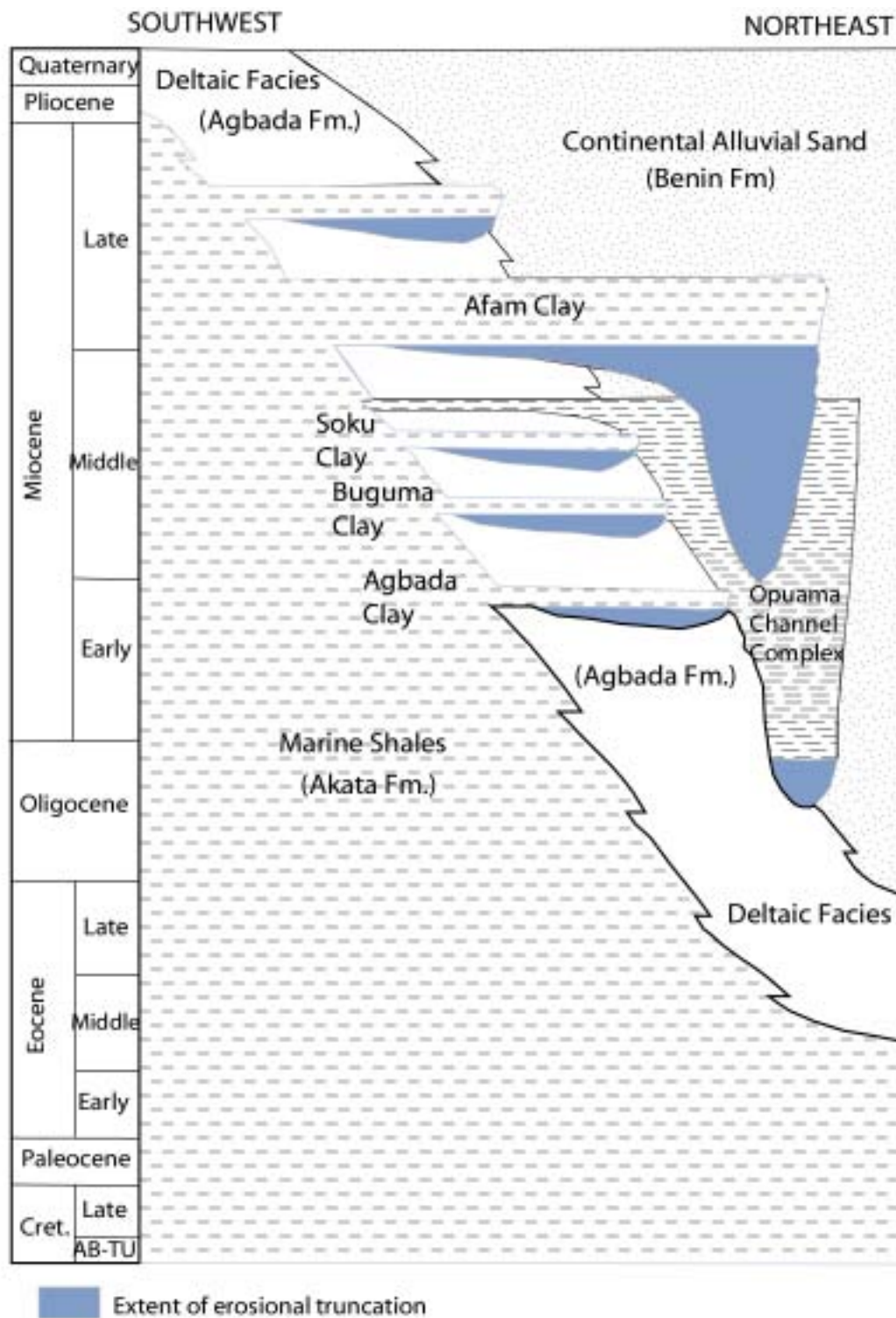


Figure 1: Fig. 4 .



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Figure 2: Fig. 4 . 1 :

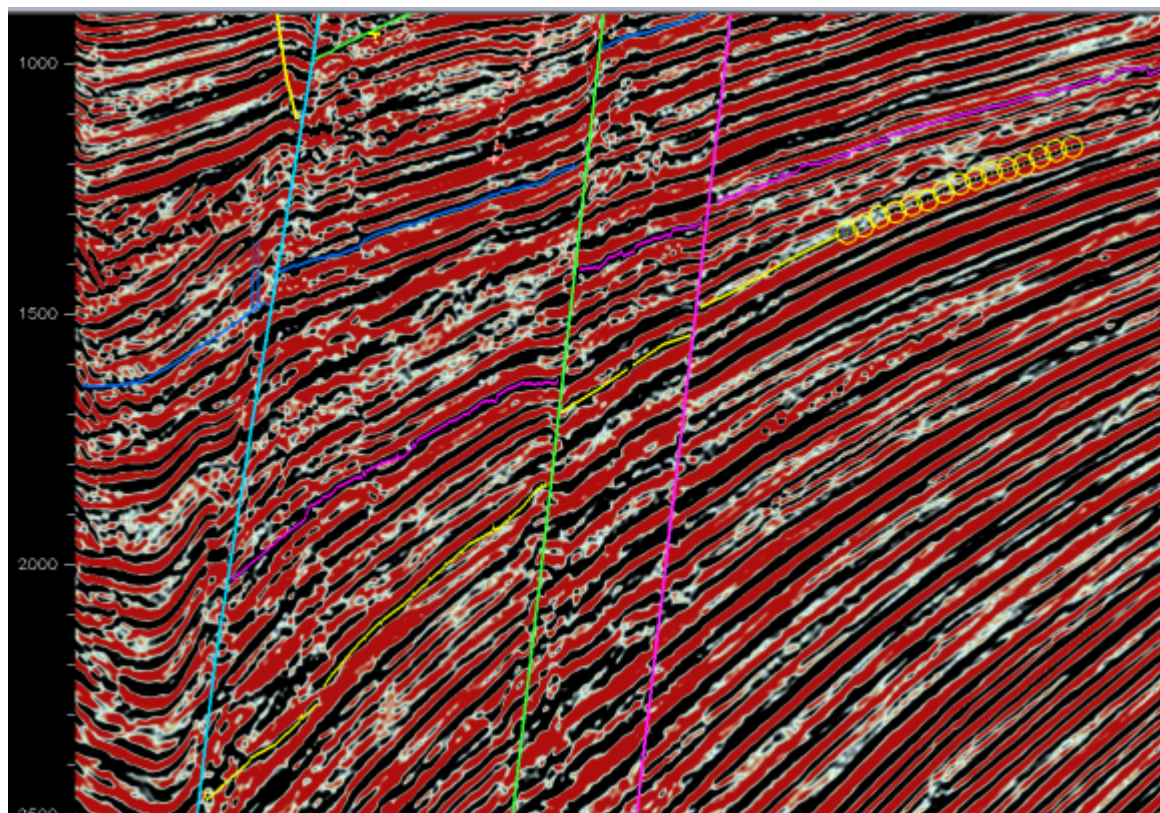


Figure 3: Prospect

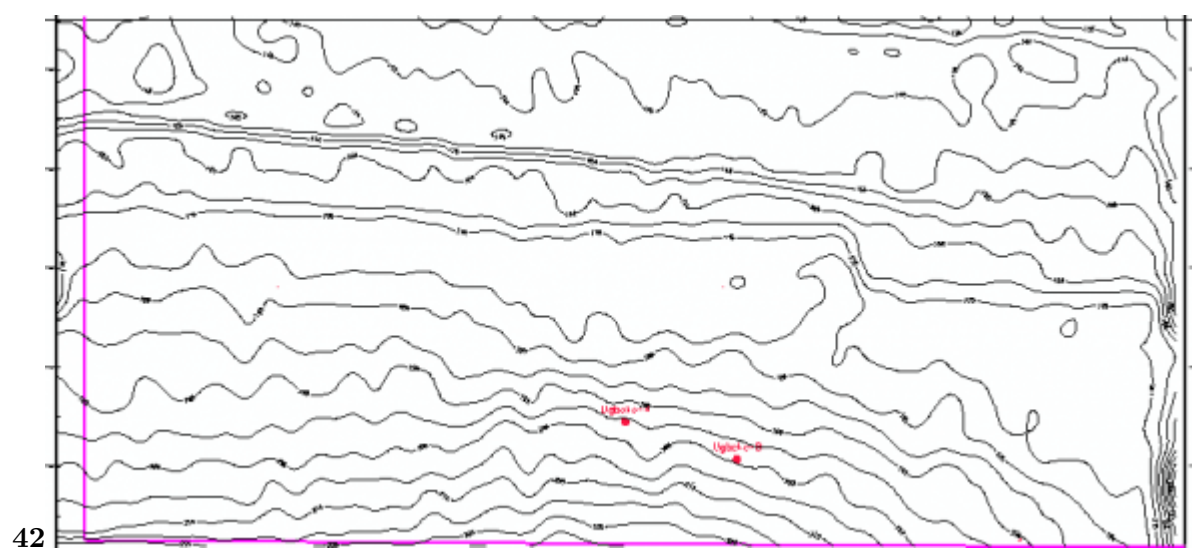


Figure 4: Fig. 4 . 2 :

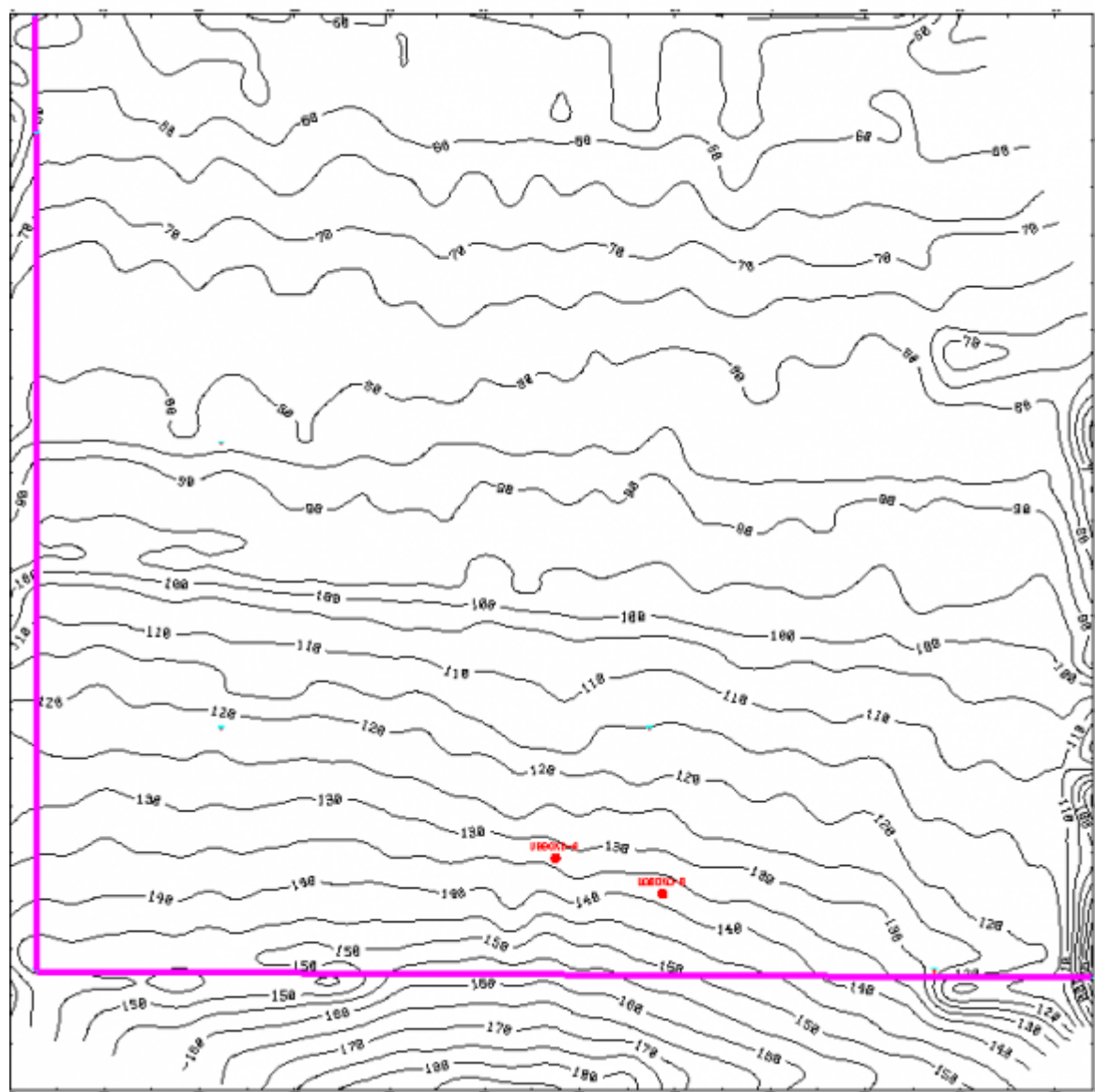


Figure 5:

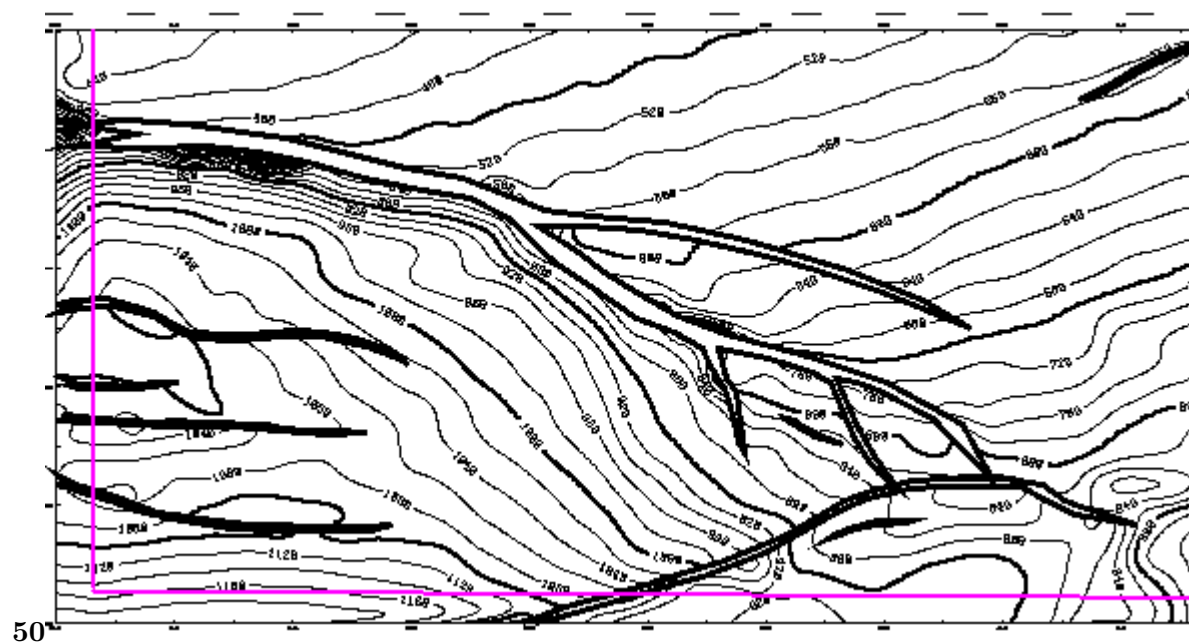
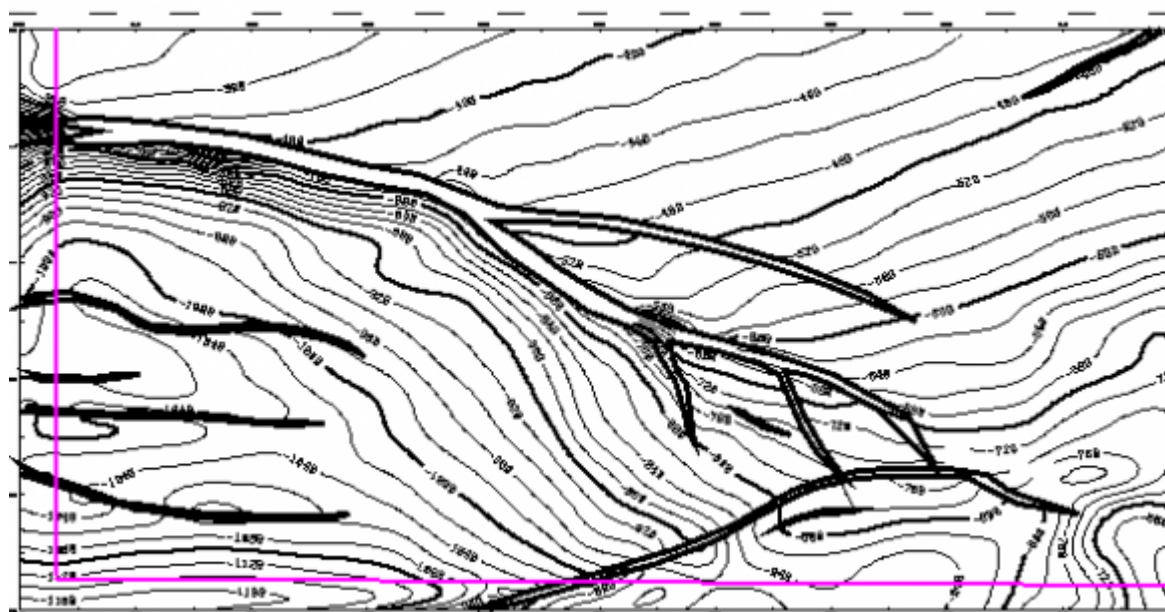


Figure 6: Fig 5 . 0 :



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Figure 7: Fig. 7 :Fig. 8 :Fig. 9 :Fig. 10 :Fig. 11 :Fig. 13 :Fig. 14 :Fig. 15 :

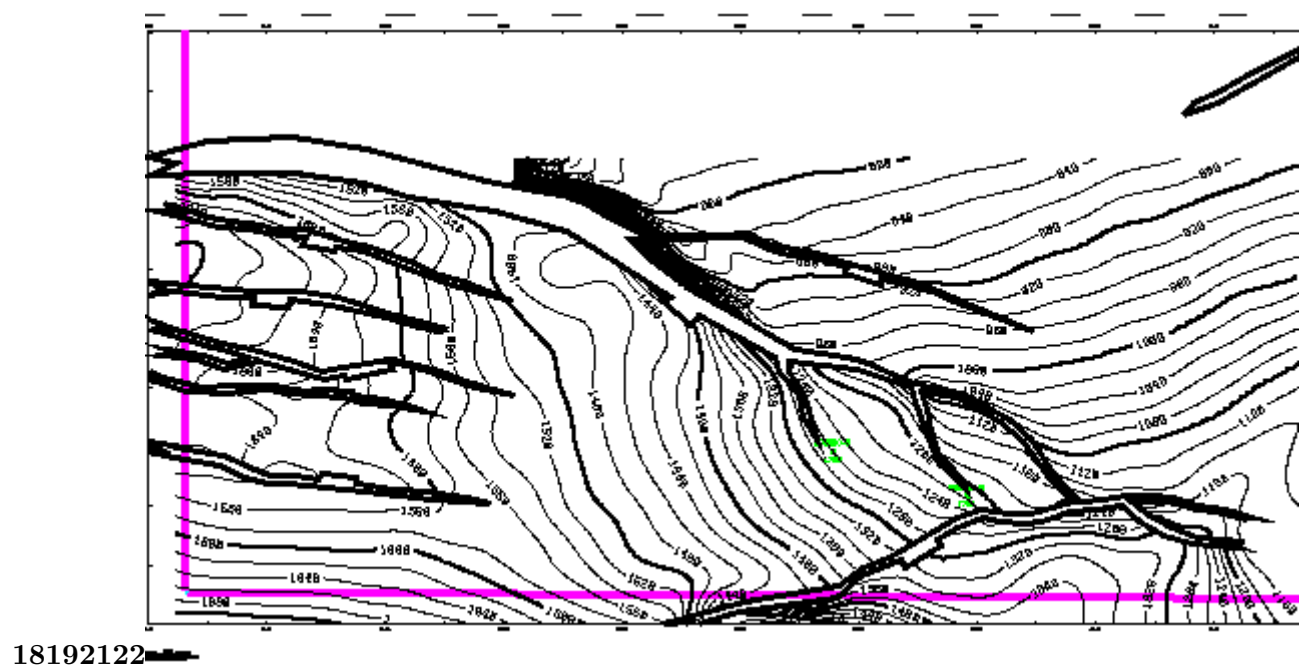


Figure 8: FigFig. 18 :Fig. 19 :Fig. 21 :Fig. 22 :

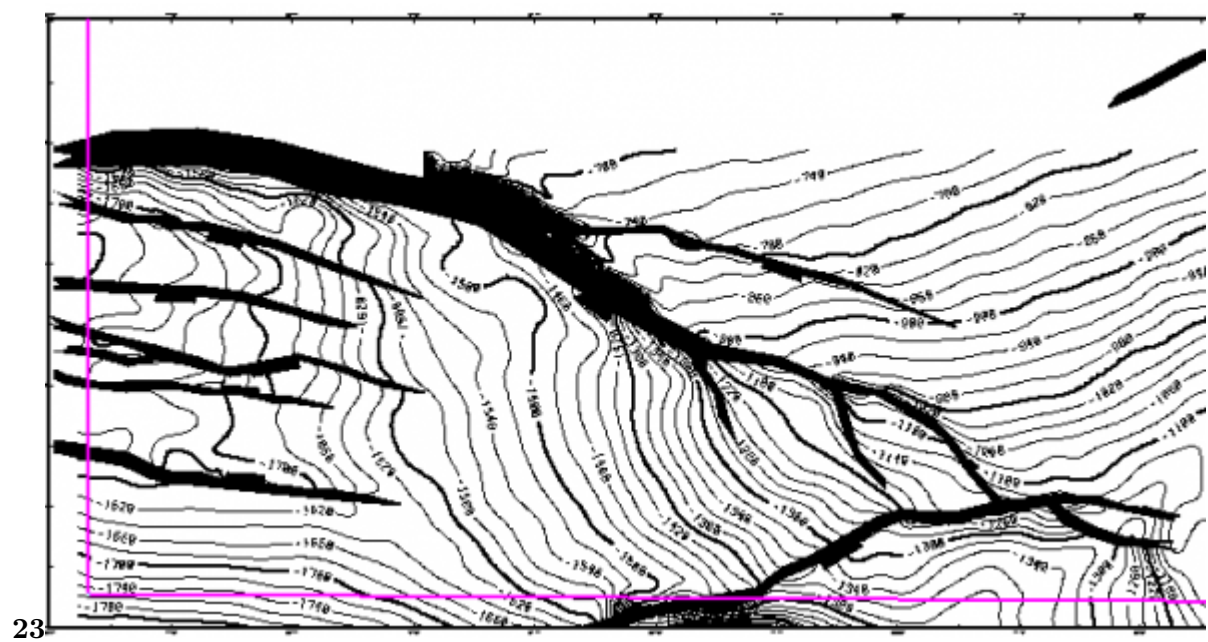


Figure 9: Fig. 23 :

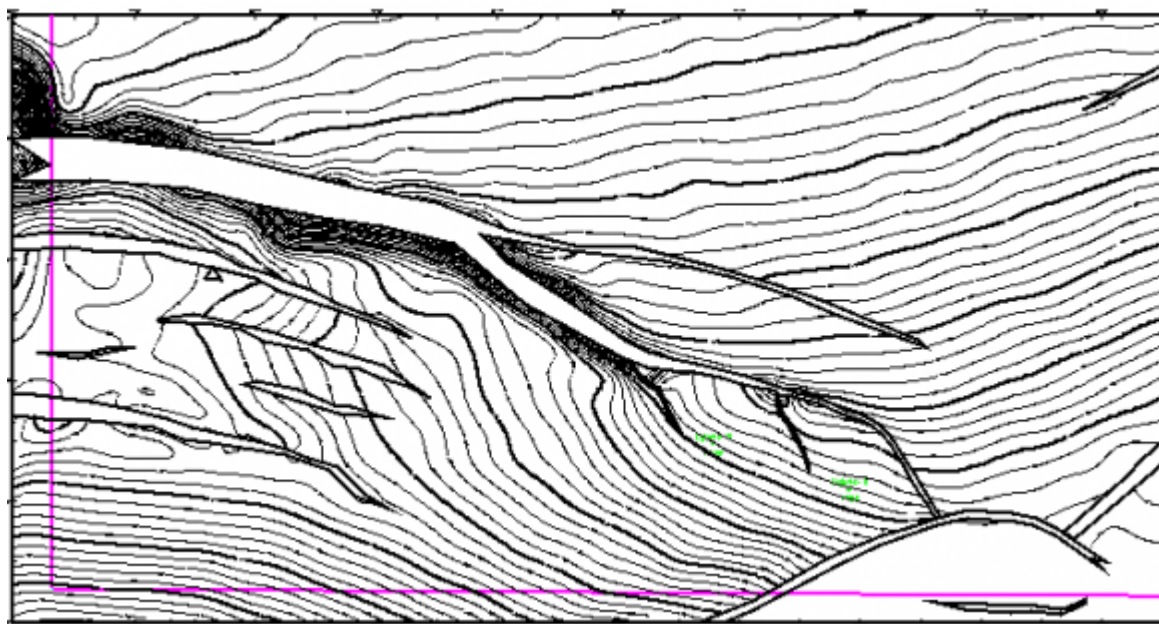


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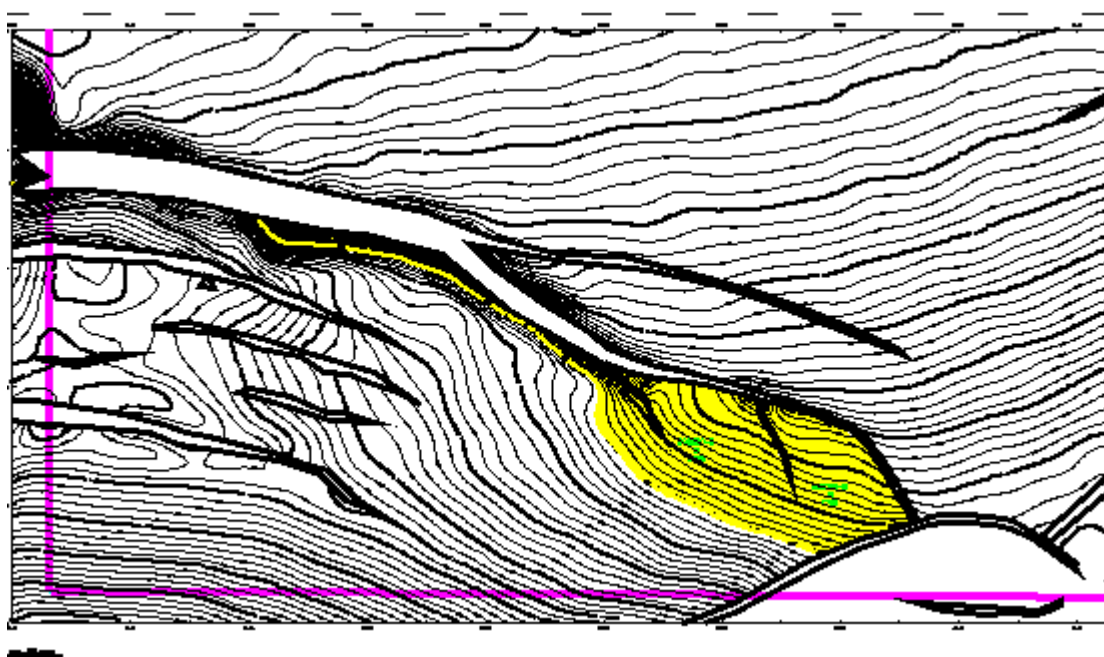


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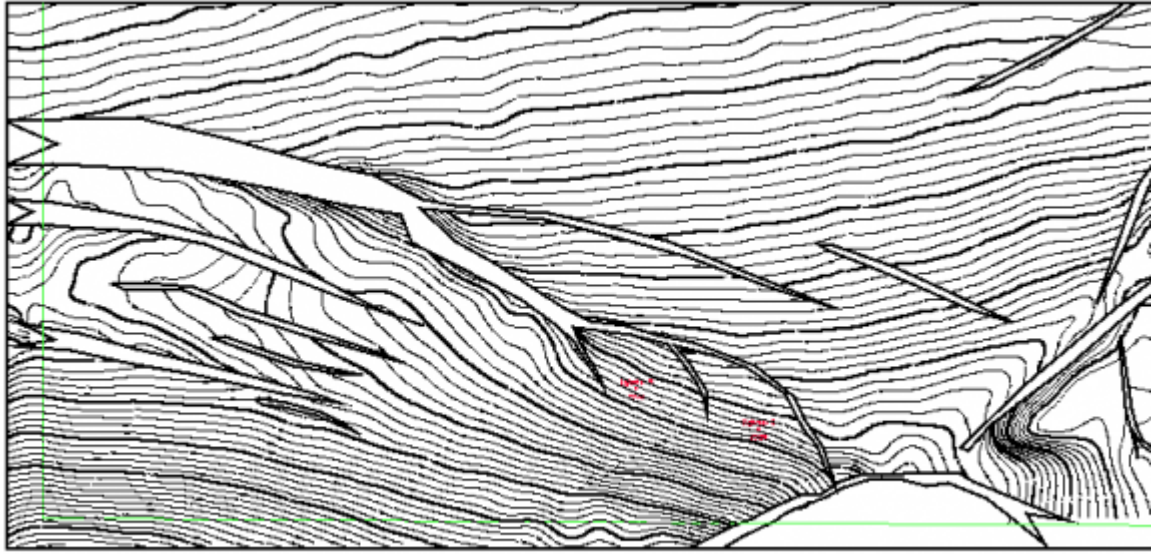


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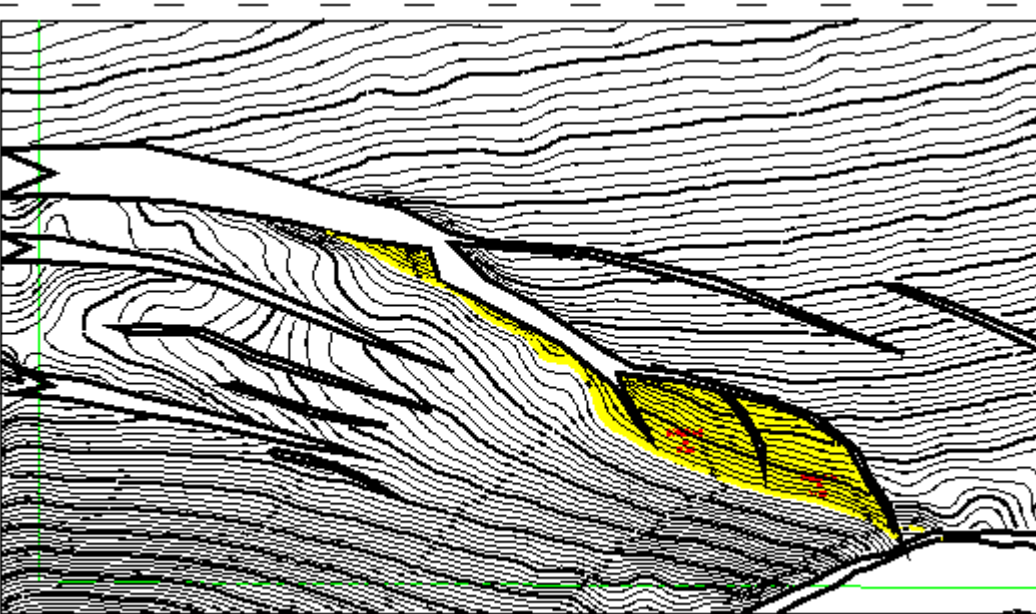


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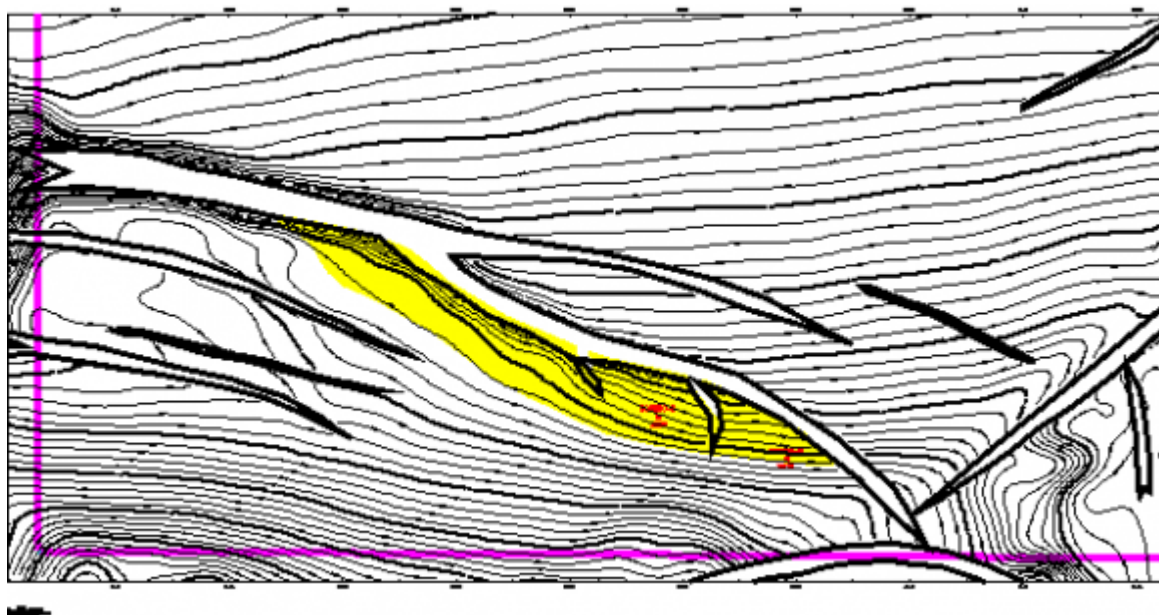


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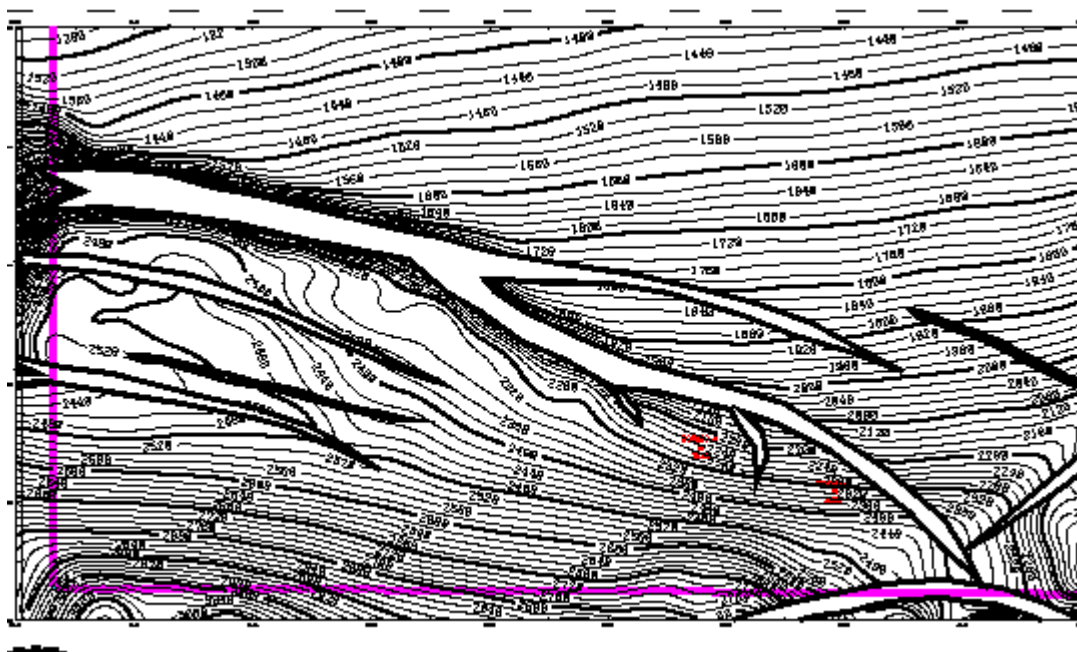


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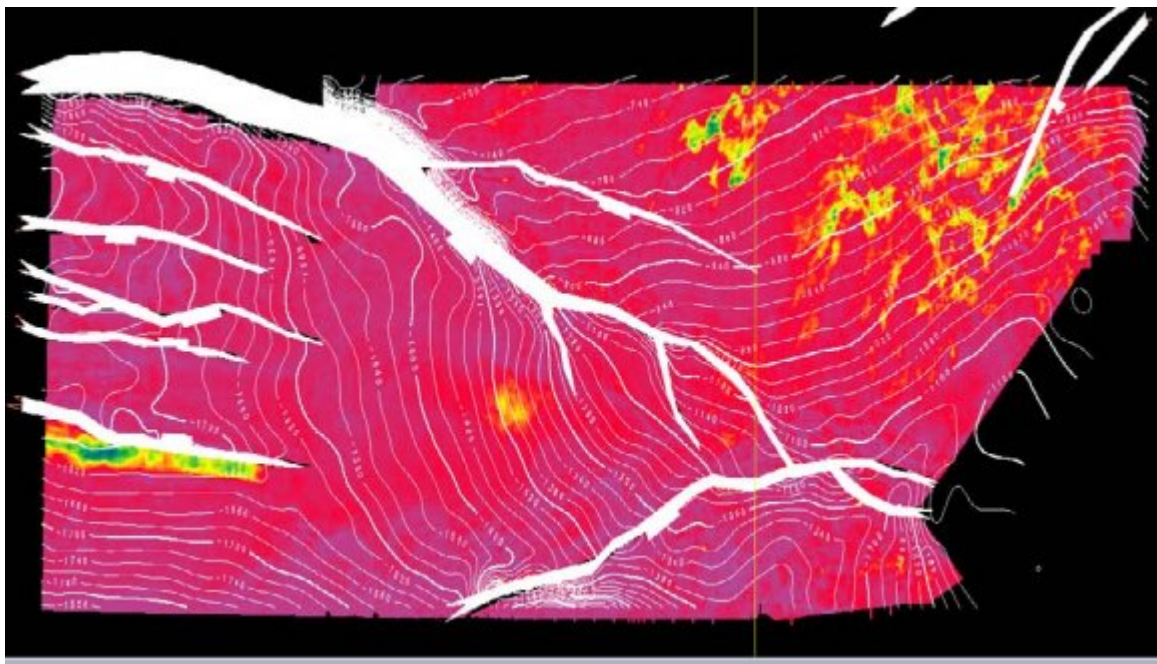


Figure 18:

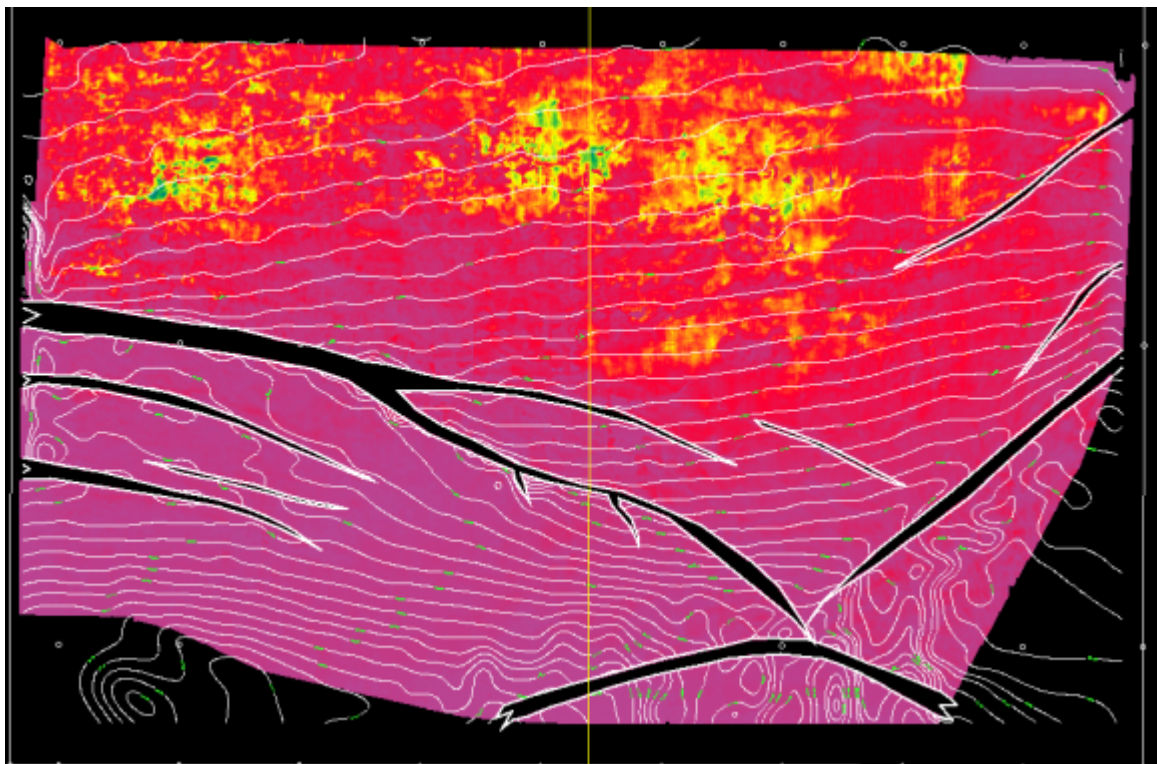


Figure 19:

Late Extension DISTAL REALM	Extension CENTRAL REALM Flank (F) &	Extension PROXIMAL REALM	
Counter Regional (CRF)		Translation	
Shale Early Compression Buried Toe Thrusts	3-10 Simple / Faulted Flank	Deep Rollover or	Shale
Counter Regional Fault Early Phase Toe Thrusts	Deep Rollover	Collapsed Crest	
NO ACTIVE COUNTER REGIONAL FAULT	Simple Flank	Simple Rollover	
Reverse Footwall	Macrostructure Rollover	Simple Rollover	

Figure 20: ACTIVE COUNTER REGIONAL FAULT Late Phase

1

The four (4) Horizons considered for volume estimation (C, D, E & F) have a total of 410.58mmbls as P50, 309.32mmbls P10 and 445.21mmb is as P90.

Figure 21: Table 1 :

SAND VALUE CONTOUR AREA CLOSURE ACRE		AVERAGE NET RK VOL. NET RK VOL. AVG-Ø	
	MINIMUM	45.00 59,490.00	461.52
	(1780		
	1,322		
	MOST -	45.00 117,990.00	915.37
	LIKE 1900		
	2,622		
	MAXIMUM	45.00 178,875.00	1387.71
	2000		
	3,975		
	MINIMUM	45.00 74,475.00	577.78
	(2200		
	1,655		
	MOST -	45.00 106,470.00	825.99
	LIKE 2250		
	2,366		
	MAXIMUM	45.00 156,600.00	1214.90
	2300		
	3,480		
	MINIMUM	45.00 32,670.00	253.45
	(2500		
	726		
	MOST -	45.00 48,240.00	374.25
	LIKE 2550		
	1,072		
	MAXIMUM	45.00 116,235.00	901.75
	2650		
	2,583		
	MINIMUM	45.00 90,990.00	705.90
	(3030		
	2,022		
	MOST -	45.00 93,690.00	726.85
	LIKE 3040		
	2,082		
	MAXIMUM	45.00 96,075.00	745.35
	3050		
	2,135		
TOTAL		MINIMUM (P10)	
		MOST LIKELY (P50)	
		MAXIMUM	
S/N	Parameter	Indication	
1	Trap	Fault assisted. Major fault up to surface	
2	Seal	Top and lateral seal confirmed in Osno/Ose	
3	Timing	Migration after syn-depositional, faulting	
4	Closure	200-1000m structural relief.	
5	Reservoir	High quality sands (adjoining blocks of OPL 90, Osno&Ose prolific.	
6	Porosity	Nearby field in the range of 19-35%	
7	Permeability	As in Osno-Ose production profile	
8	Source	Thick Akata shales. Same for nearby discoveries	16
9	Maturation	Thick overburden. Targets Deeper than nearby Dis	
10	Migration	Migration path through fault systems	
11	Preservation	Unlikelihood of biodegradation due to fault	

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