Characterization of Diapir-Associated Complex Structural Geometries in Neogene Sequence, Indus Offshore Delta, Pakistan*

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Abstract

Seismic interpretation in the Neogene sequence of Indus Offshore delta has revealed that this sequence represents complex structural geometries, owing to active shale diaprism in the area. This diaper, named as "Kuchwa Diapir", exhibit a peculiar orientation and position in the space; i.e., striking perpendicular and very closely to present day shelf-slope break. It has also been observed that, in the vicinity of the diapir, the interplay of two distinct genetically independent fault sets:

(1) originating from the peripheral sink associated with the diapirc rise,
(2) conventional listric faults that are typically related to gravity sliding in delta systems.

These have segmented the rock volume into several upthrown and downthrown blocks/compartments, which may also provide a mechanism for the hydrocarbon entrapment.

An attempt has been made to review and understand the possible triggering mechanism for this diapir and to define the genetic relationship for the resulting structural geometries.

Since the subject area exhibits complex fault geometries, fault correlation has been an intricate procedure. In this regard, in order to avoid any misinterpretation, a cross check of "Seismic Variance Attribute" was also utilized as an effective tool.

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Characterization of Diapir Associated Complex Structural Geometries in Neogene Sequence, Indus Offshore Delta, Pakistan

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Introduction & Background

- Seismic Interpretation in the Neogene sequence of Indus Offshore delta has revealed that this sequence represents **complex structural geometries** owing to the **active shale diaprism** in the area.

- This diapir, named as “Kuchwa Diapir”, exhibits a **peculiar orientation** and **position** in the space; i.e., striking perpendicular and very close to present day shelf-slope break.

- It has also been observed that, in the vicinity of the diapir, the **interplay of** different **genetically independent fault sets has segmented** the rock volume into several compartments.

Study Objectives & Methodology

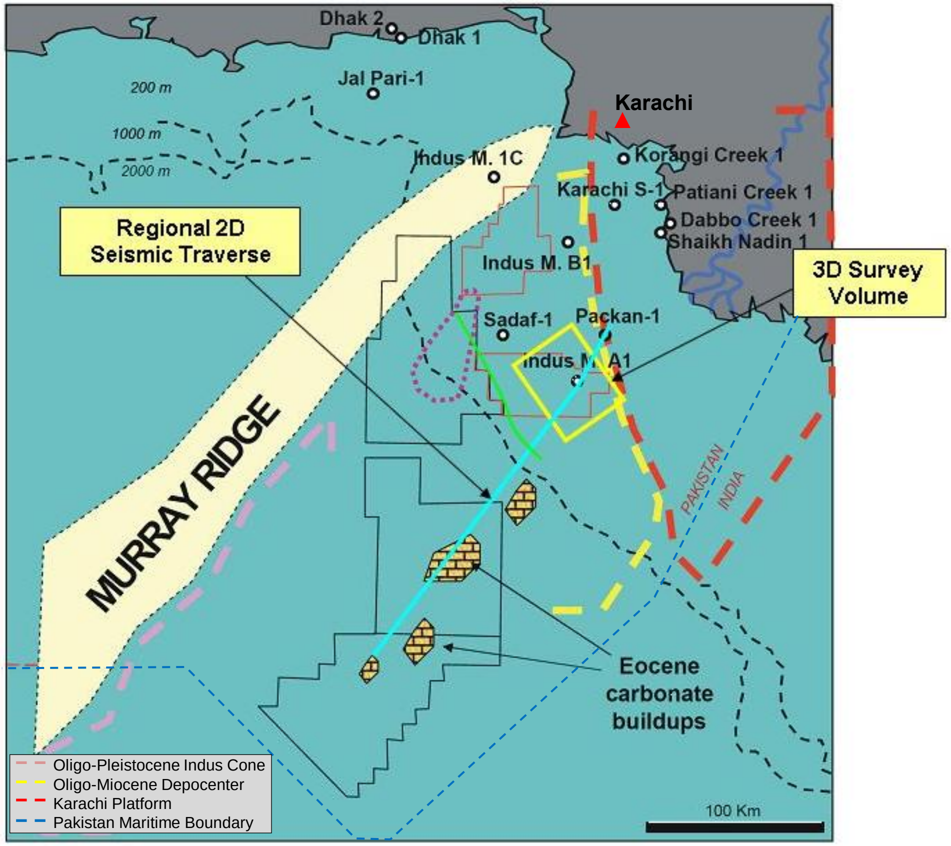
- The main objectives of the present study is to review and understand the possible **triggering mechanism** for this diapir and to define the **genetic relationship** for the resulting structural geometries.

- For the said purpose, detailed **conventional seismic interpretation** has been carried out using the available data.

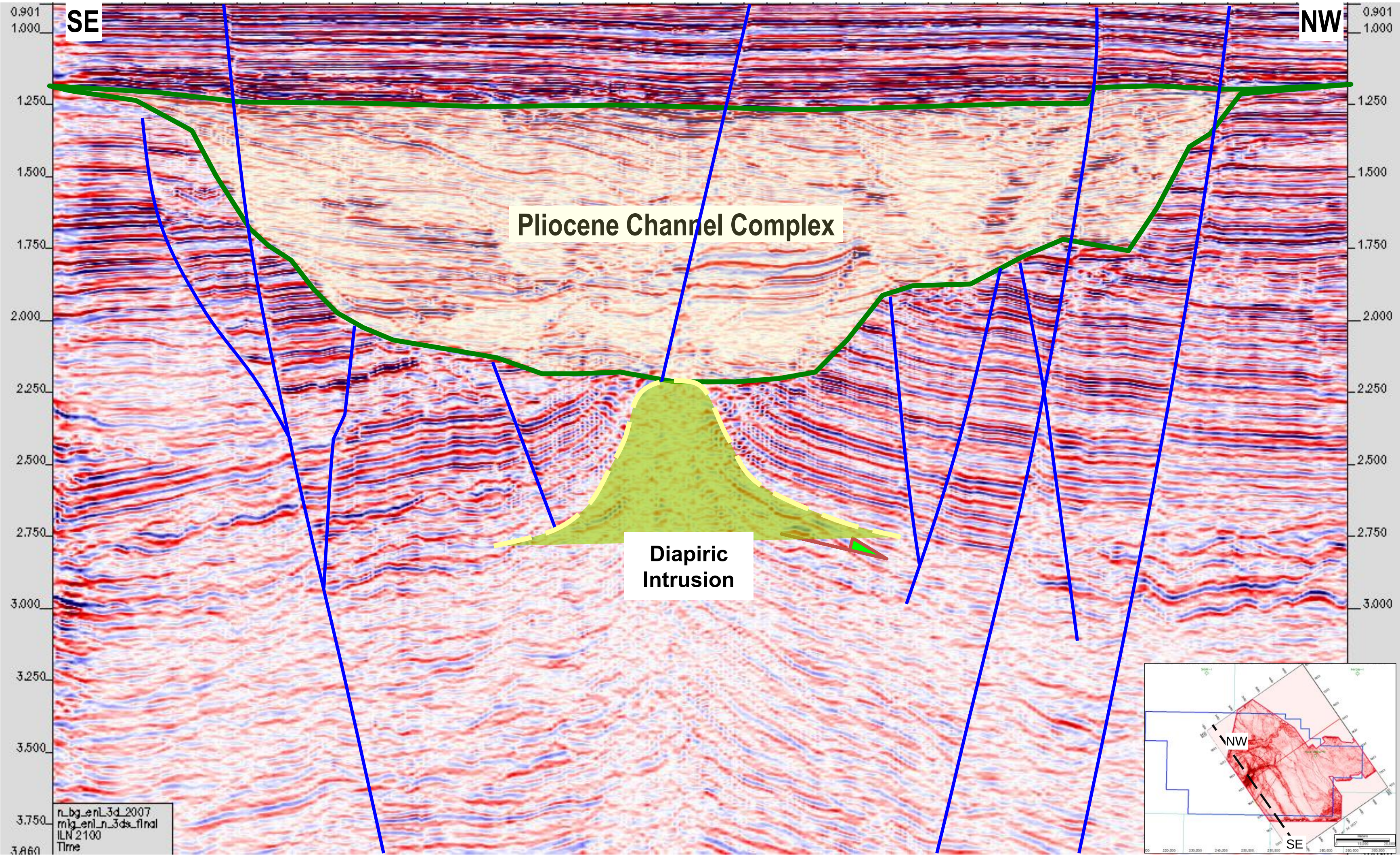
- Since fault correlation has been an **intricate procedure** in the subject area, in order to **avoid any missinterpretation** a cross check of "**Seismic Variance Attribute**" was also utilized as an effective tool.

Study Area & Dataset

- Study area is located some 150km southwards from Karachi Coast.
- For the interpretation purpose, a 3D Seismic PSTM volume with 1300 sq.kms full fold coverage was used.
- The survey area is located in water depths ranging from 40-150m.
- The present day shelf edge is located some 15kms further southwest of the survey boundary.



Key Geological Features of the Area



Shale Diaprism - General Considerations

- In the sedimentary sequences normally two types of lithologies can exhibit the diapirism; i.e., Salt and Shales.

- Unlike the salts, shale diapirism occurs mainly as a result of development of overpressures which may be either due to:

  (1) Overpressures Related to Sedimentation Rate or

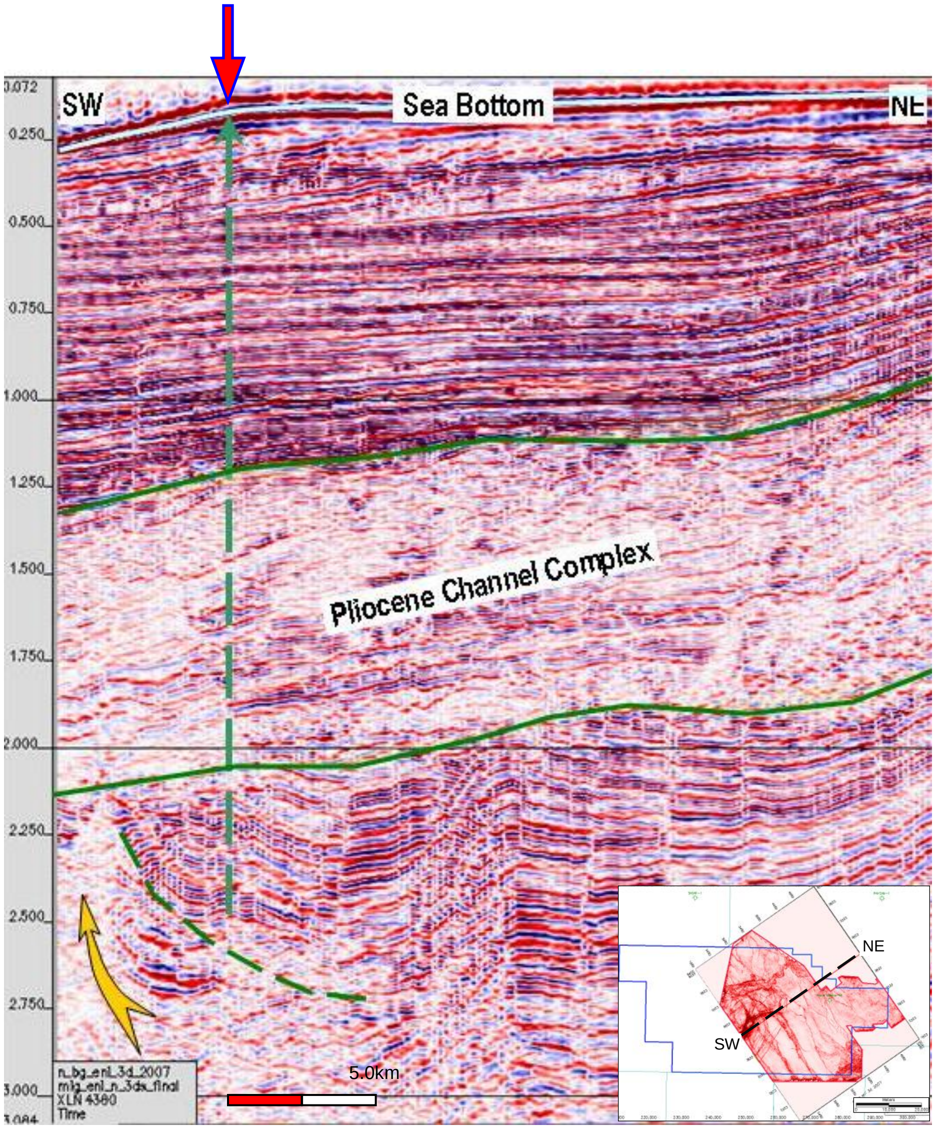
  (2) Overpressures Related to HC Generation or

  (3) Combination of (1) & (2)

- Whatever the reason may be, **once the overpressures are attained**, the shales **cannot sustain** this state of **pressure disequilibrium** for an **infinite time.** Any tectonic or non-tectonic process at this stage can be helpful in achieving this objective by breaking the pressure seal.

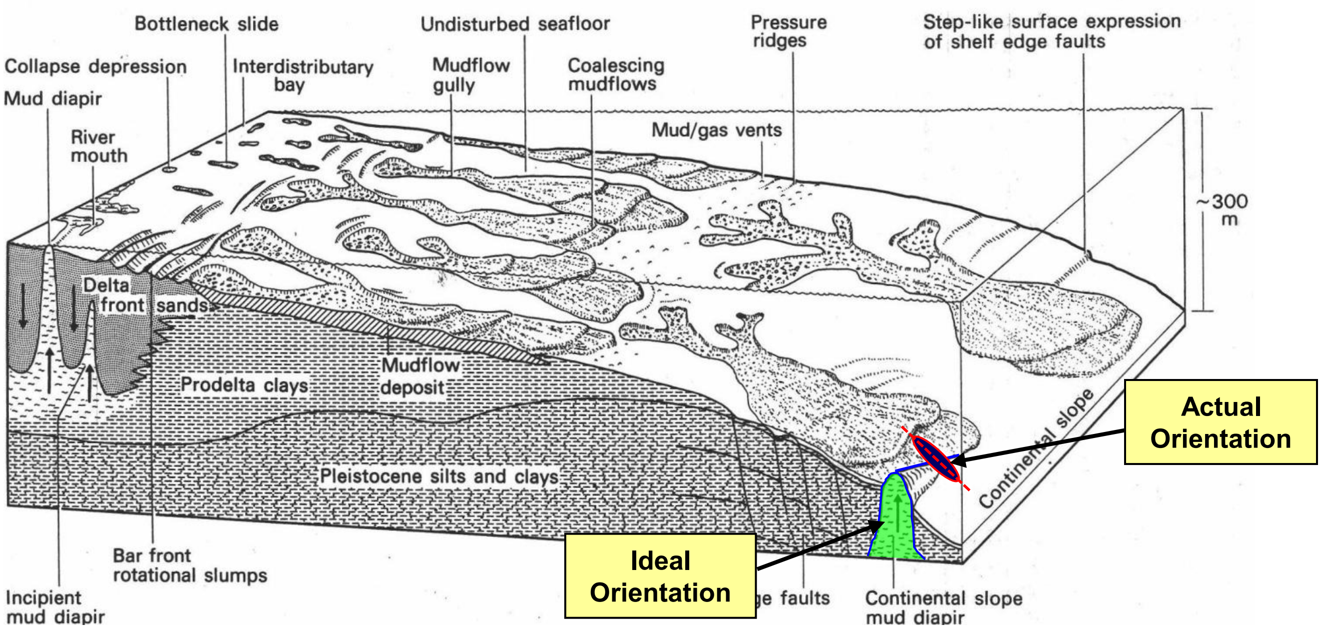
Origin of the Kuchwa Diapir

- In the deltaic settings diapirism can be initiated by the **differential loading** of the sediments.
- The difference in the overburden and variation in facies cause the **isostatic instability**. Overpressured shales hence start to flow laterally away from the depocentre towards the basin.
- Since the present day shelf edge marks a point where a **sudden change** in **overburden** occurs, it can serve as a location where these overpressured shales can attain a diapir-like geometry by moving vertically.



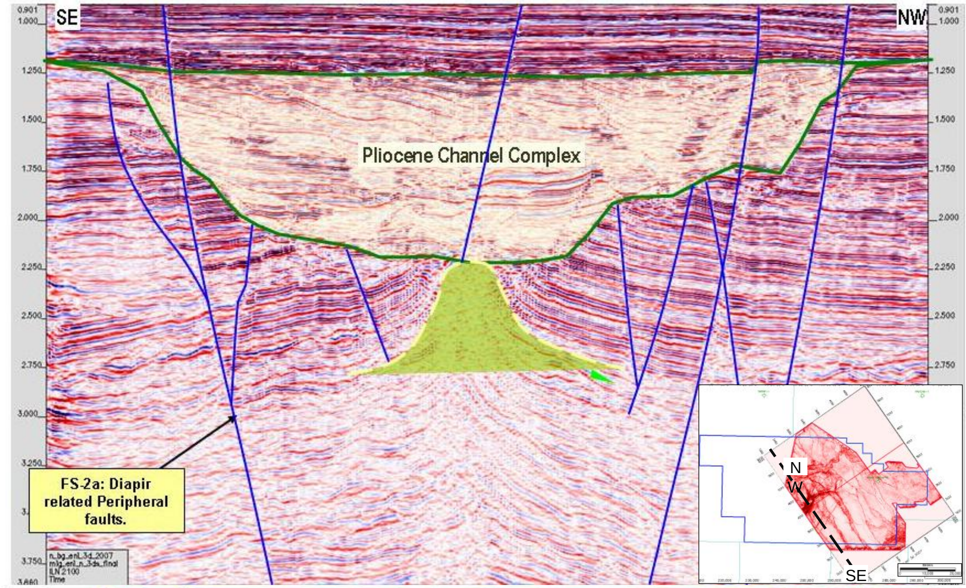
Origin of the Kuchwa Diapir

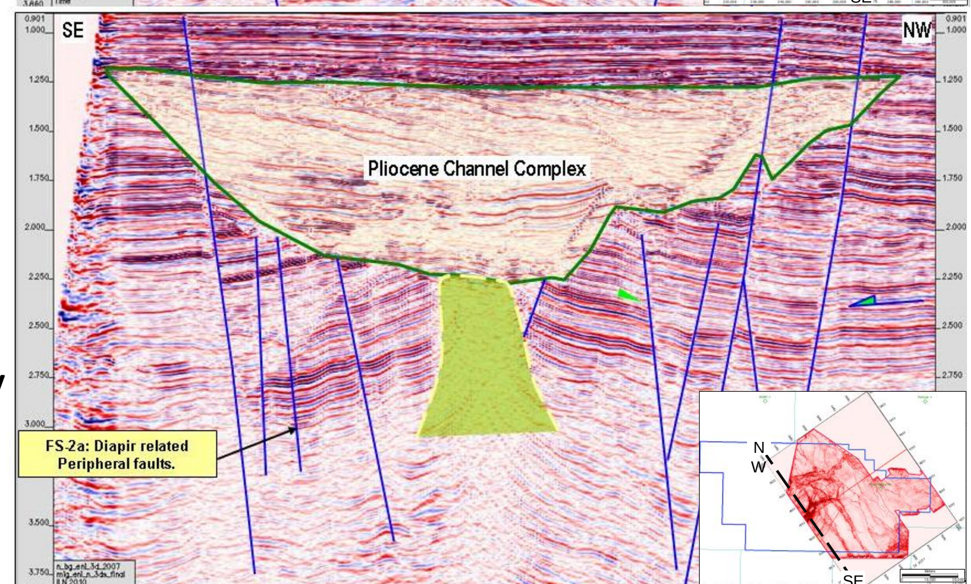
- Considering this assumption to be valid, the diapir was **supposed to exhibit a NW-SE striking trend;** i.e., somewhat parallel to the shelf-slope break.
- However, this is not the case and **diapir strikes almost at the right angle** to the anticipated trend.
- Considering the **elongated geometry** and its peculiar **counter-regional strike**, it is most likely that this diapir is at least **partly controlled** by some underlying fault.



Description of Structural Geometries – The Diapir

- Kuchwa diapir is a **spire shaped, elongated body** of shale; attitude of the country rock is controlled by the penetrating shale mass.
- Near the **northern tip**, the diapir seems to be less piercing in nature.
- Towards the **south** the "tightness" gradually diminishes into **more mature piercement**-type geometry.
- This change in **trend is evident** in both **cross sectional and map views** and may be attributed towards the changes in **confining pressures**.

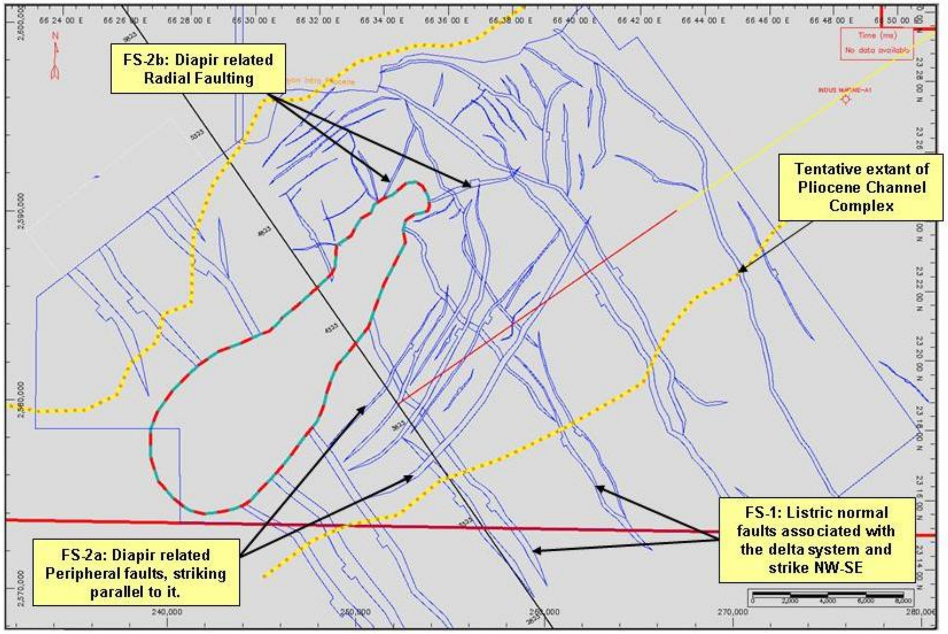


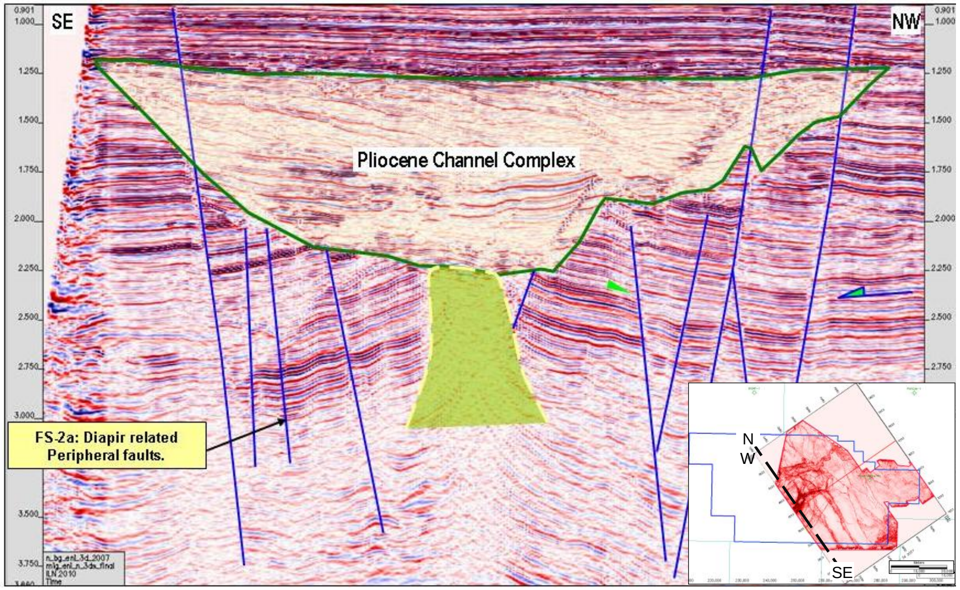


Description of Structural Geometries – Fault Sets

- **Fault Set-1: *Listric Normal Faults***
  These are parallel to the coast and down-to-the-basin type faults which are typically associated with the delta systems.

- **Fault Set-2a: *Ring or Peripheral Faulting***
  These faults are concentric to arcuate in nature and are developed in the strata surrounding the diapir. These are formed in response to **flexing phenomenon** caused by the **growth of the rimmed synclines**.





Description of Structural Geometries – Fault Sets

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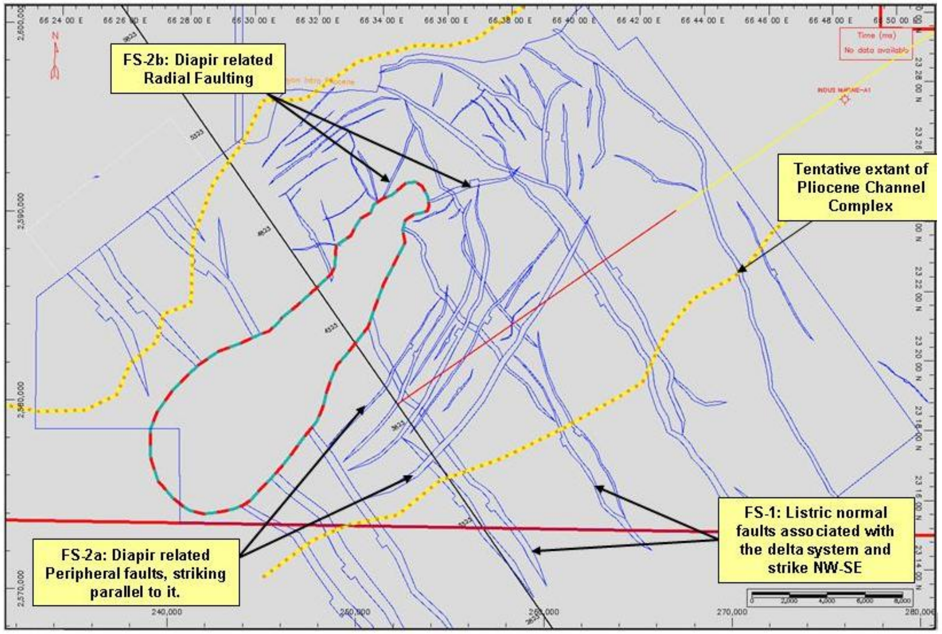
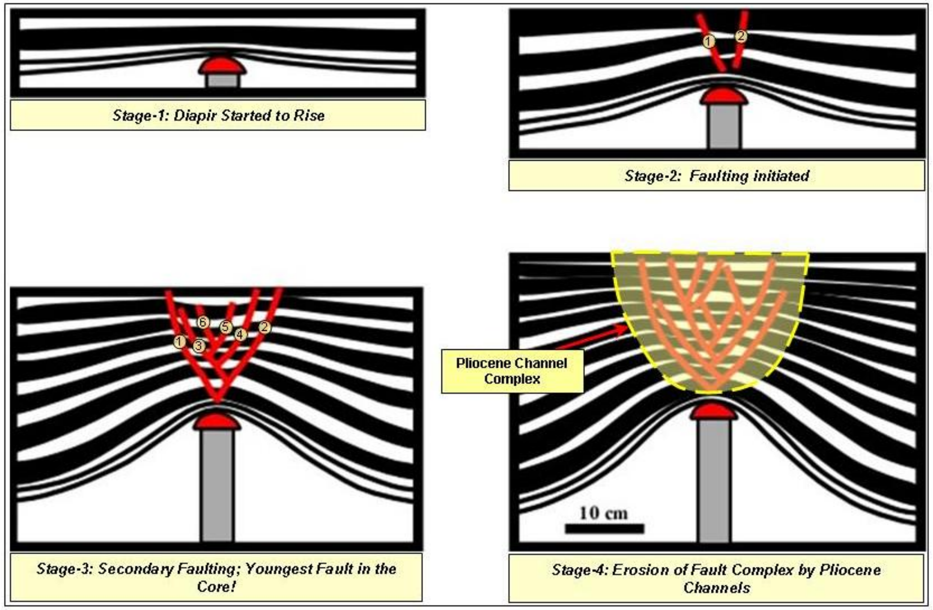
- **Fault Set-2b: *Radial Faulting***

These faults are also genetically linked to the diapiric intrusion and is **restricted to the overlying strata**.

In map view this resembles the spokes on a wheel.
Relatively difficult to recognize in cross-sectional view and partially preserved.
Youngest faults exist in the core of the fault complex.





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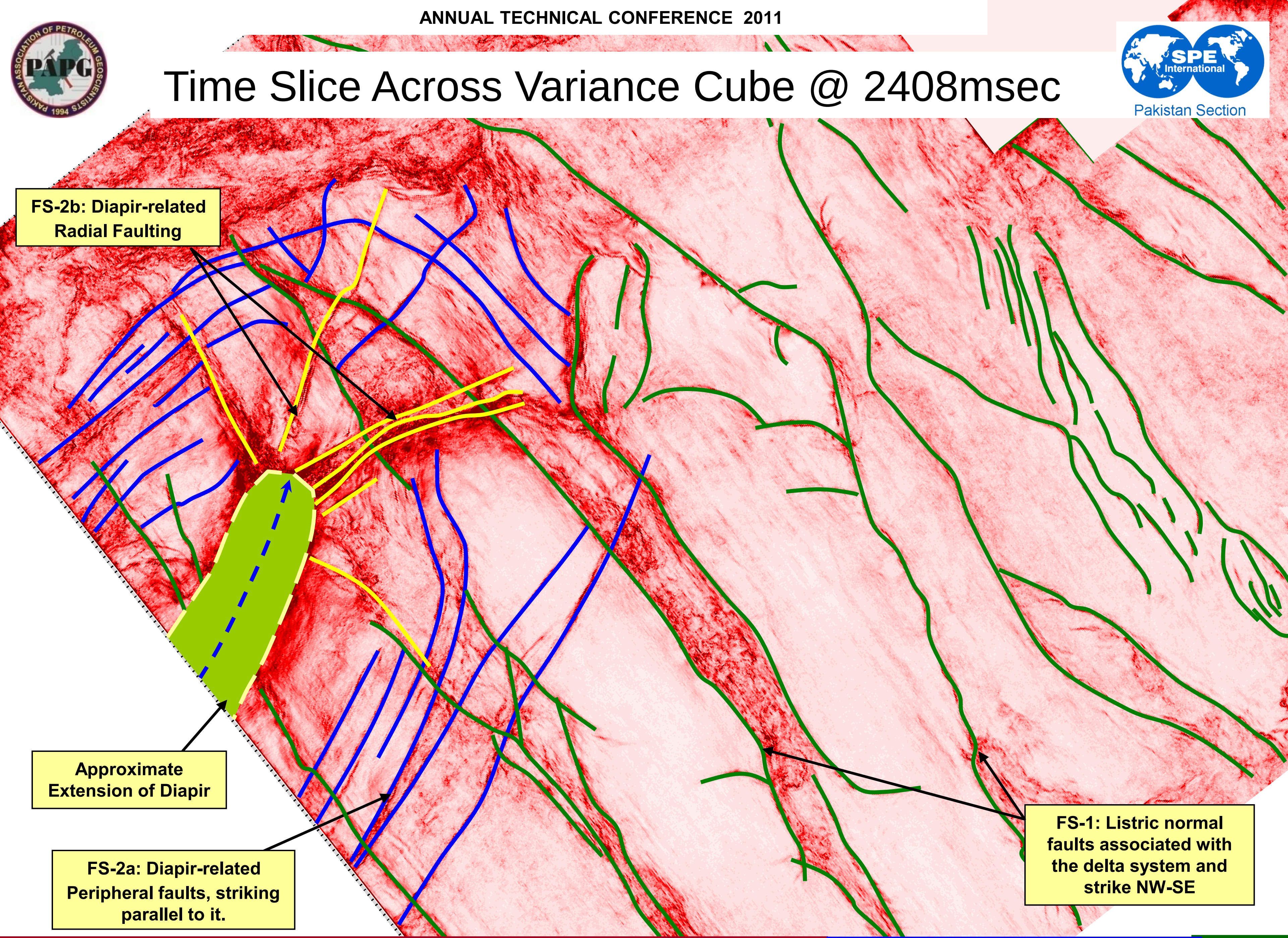
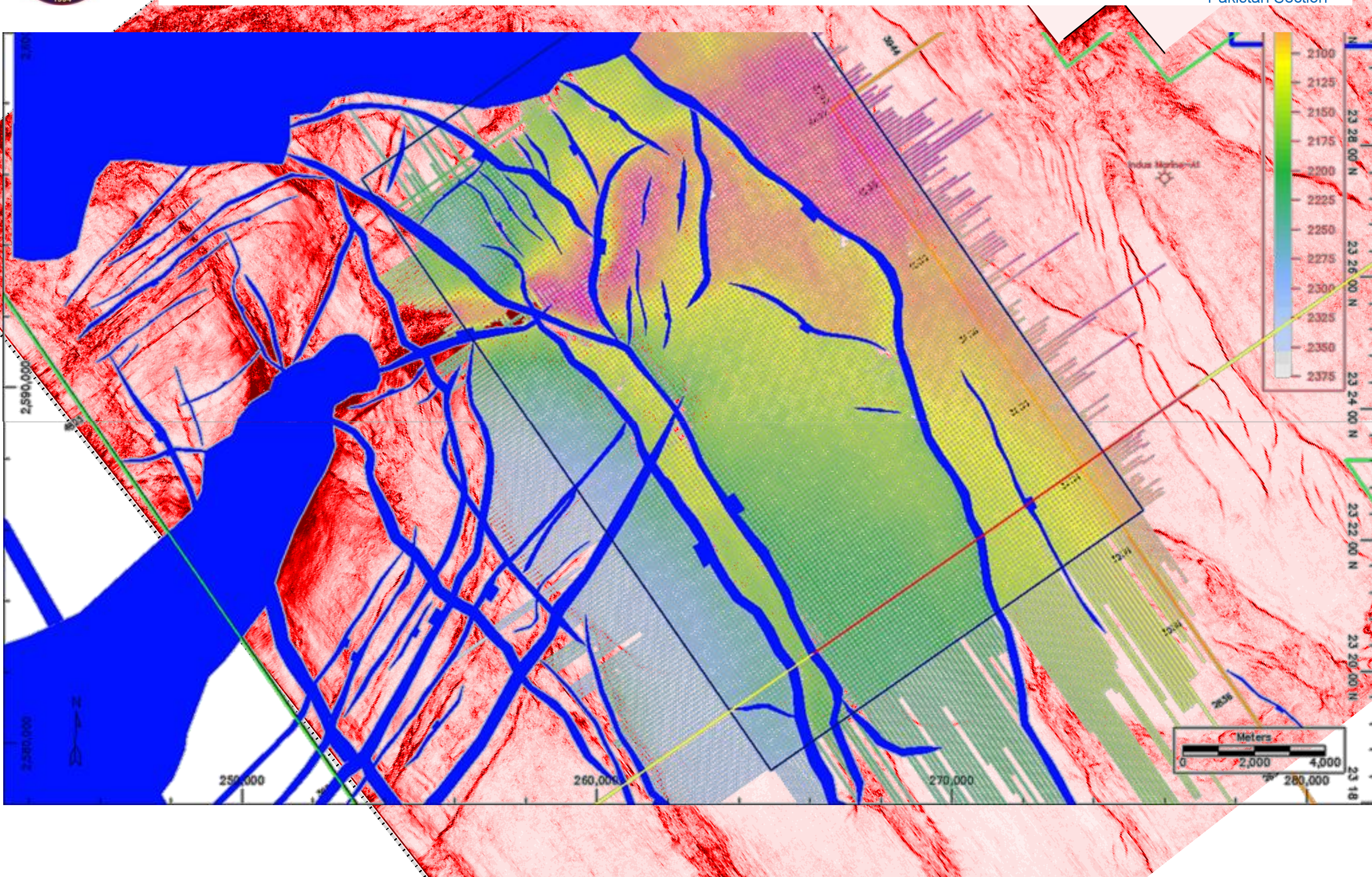
Application of Variance Attribute

- Since the subject area **exhibits complex fault geometries**, fault correlation has been an **intricate** procedure.
- In order to **avoid** the risk of **false correlation** and to make the interpretation more robust, **Variance Attribute** was used as a **cross check** after the conventional seismic interpretation.
- Results were found in **good harmony**, also helped to **uncover additional details**, and in **classification** of different fault sets.

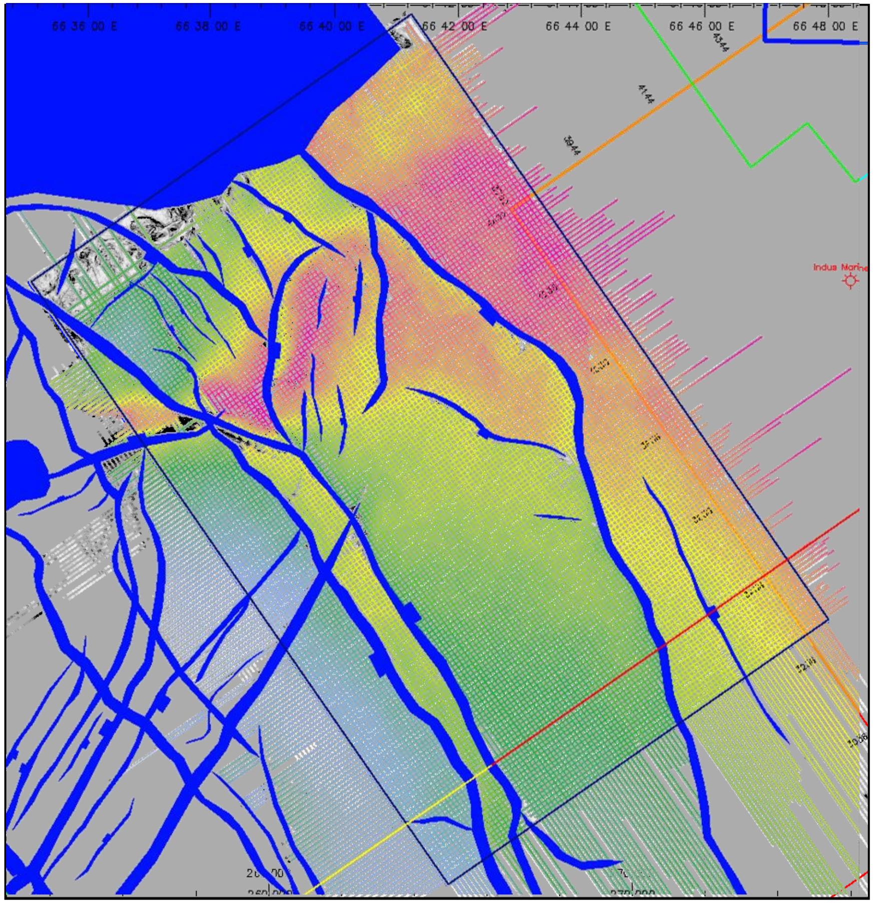
Time Slice Across Variance Cube @ 2408msec

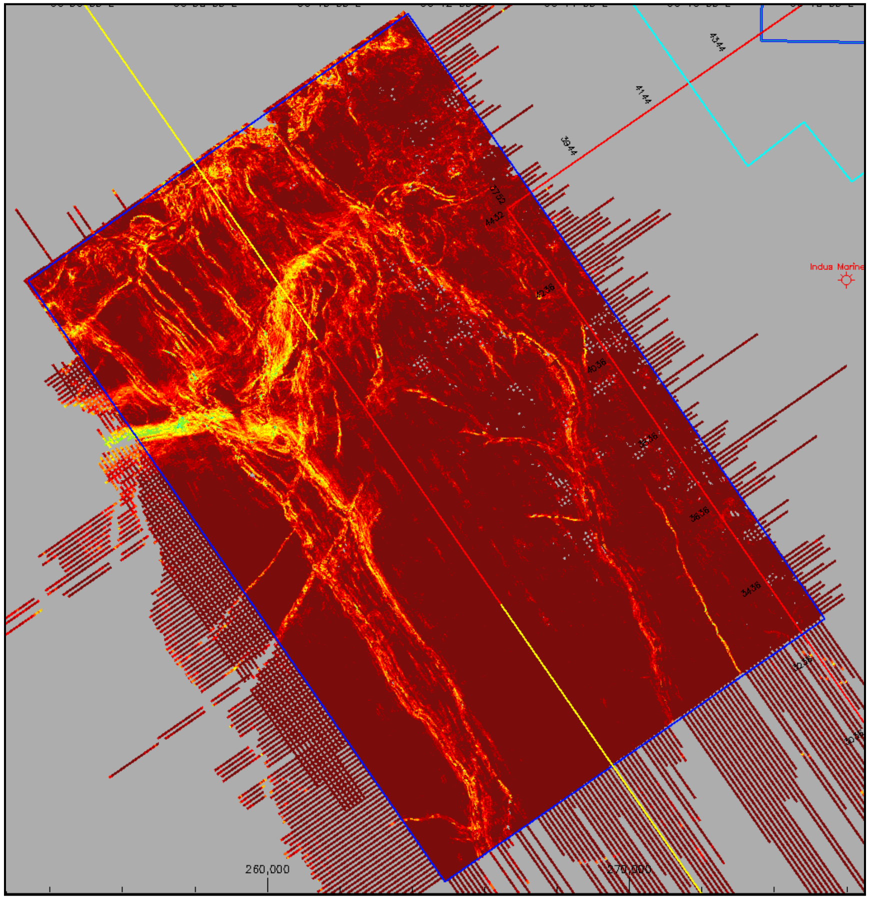


Fault Trend Verification through Variance



Seismic Variance Extraction Along the Interpreted Horizon





Conclusions

- The Kuchwa diapir is classified as a **Shale-type diapir** based on its spire-shape **geometry**, presence of **internal seismic-reflections** and narrower **rimmed synclines**.

- This diapir **occupies a position** close to the shelf-slope break that may possibly be attributed towards the **differential loading** of the sediments. Since the shelf edge marks a point where a sudden **change in overburden** occurs, it also provides a point of ease for the overpressured shales to moving vertically and attain a diapir-like geometry.

- Considering the **elongated geometry** and its peculiar **counter-regional strike**, it is likely that this diapirism is at least **partly controlled** by some underlying **fault**.

Pakistan Section

Conclusions

- A **variety of fault patterns** has been identified in the strata surrounding the diapir and are categorized into different "**genetically independent**" fault sets. The **interplay of these fault sets** has segmented the rock volume into **compartments** which may also serve as traps for hydrocarbons.

- In view of the **prevailing complex structural geometries** in the study area, seismic **Variance Attribute** was also used as an aid to the conventional seismic interpretation. The interpretation of the 3D variance cube not only **confirmed the validity** of the **fault correlation** carried out during the conventional seismic interpretation but also uncovered some additional details. Moreover it also helped to understand and classify the different fault sets with a **higher** degree of **confidence**.

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Pakistan Section

Thank you