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Sedimentation and Hydrocarbon prospectivity of Panna Formation of Tapti Daman sector in Western Offshore Basin.

Keywords: Syn-rift, Panna, Prospectivity, Drainage Pattern Post-rift

Abstract

Tapti Daman tectonic block falls in the NE part of Mumbai offshore basin. It is flanked by Saurashtra Peninsula to the NW and western ghat range to the east. It covers an area of about 27,000 Sq.km. Sediments up to 6.5 km thickness exists at the depocenter. Wells have been drilled mainly for the exploration and exploitation of Daman, Mahuva and Miocene basal sediments of Oligocene and Early Miocene age. In total 27000 Sq Km area, 71 wells have been drilled to explore Panna formation. In 33 wells complete Panna section has been penetrated. Most of the wells are located on the Rift shoulders due to structural advantages and has less Syn-rift Panna section. 7 wells have shown HC indication in testing. In most the wells where Panna has been drilled the reservoir development is poor. The Panna formation deposited during Paleocene and of early Eocene age has been sparsely explored due to overpressured Panna, Diu, Belapur and Mahuva formation. In addition, it has been envisaged that Rift sediments of Panna section are Trap derived and are either Weathered Trap or Trap wash which lack reservoir development.

Paleocene-Early Eocene sediments of Panna Formation overlying the Basaltic Deccan Trap are overlain unconformably by Diu/Belapur Formation. The upper boundary of Panna Formation coincides with H4 seismic marker. Two Units have been identified within Panna Clastics which includes some Carbonates:

1. Unit 1: Consists of mainly Early Syn-Rift sediments.
2. Unit 2: Consists of mainly Postrift sediments

An attempt has been made to bring out a regional understanding of syn-rift architecture, depositional pattern by integrating available geo-scientific data and to analyze hydrocarbon prospectivity of syn-rift sediments in Tapti Daman Sector of Western Offshore Basin. Within the synrift sediments, two syn-rift units have been identified representing distinct seismic facies. The seismic expression of these syn-rift units gives an idea about the linkage of their deposition with different stages of rift evolution. The lower unit have wedge shaped reflector packages and hummocky internal reflection configuration, representing early rift stage. The overlying unit comprising divergent reflection pattern with aggradations on footwall represents rift climax stage and the topmost two units with sub-parallel reflection configuration represent the late rift phase. The units deposited during rift climax stage have good source rock potential, whereas the units deposited in late rift stage possess favourable reservoir facies making a complete petroleum system within syn-rift sediments. Postrift Panna unit is subdivided in three sub units. These units have dominantly shale and non-reservoir facies.

Introduction

The Mumbai offshore basin, a passive margin basin on the continental shelf of western India continues into the on-land Cambay basin toward the northeast. On the north it is bounded by the Saurashtra Peninsula and on the east by the Indian craton. Its southern limit is marked by the east-west trending ridge south of Ratnagiri.

Hydrocarbon accumulations generaly occur in carbonate reservoirs ranging in age from Middle Eocene to Middle Miocene which are structurally controlled. However stratigraphic / combination plays in Paleocene - Lower Eocene and Oligocene clastic reservoirs are also significant. The area under study covers Tapti Daman sector of Western Offshore Basin which lies in the north and North west of Mumbai high, Southeast of Saurashtra craton and west of Deccan basalt area. **(Fig: 1).** In nearby Central Graben area of Mumbai offshore basin hydrocarbon discovery has been made and exploitaion from Panna formation has established its potential. However in Tapti Daman sector commercial hydrocarbon discovery has been made from Daman and Mahuva formation of Oligocene age. Althogh Hydrocarbon shows in form of GYF(Golden Yellow Fluorescence) and Cut alongwith minor gas flow from panna formation has been observed but commercial discovery from Panna formation is yet to be established. Present study is the result of integrated interpretation of the 2D and 3D seismic data alongwith integration of Well log data and laboratory studies.

Fig. 1: Location Map

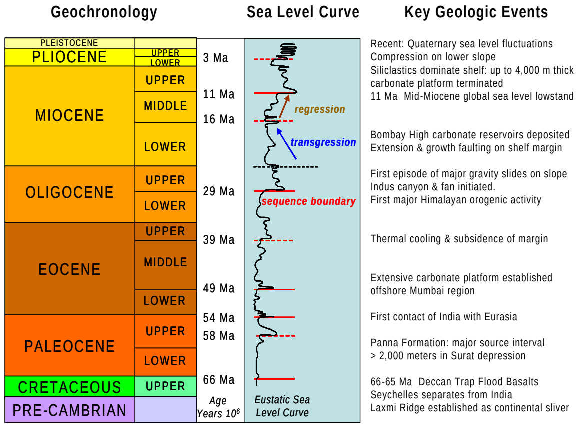


Fig. 2: Geo-chronological chart, Sea Level Cur and Key Geologic Events

Stratigraphy and Depositional Setting

Mumbai Offshore basin is limited by the exposures of Deccan Trap in the east. A thin veneer of Neogene and Quaternary limestone, marl and clay forms the outcrops along the coastal belt of Saurashtra Peninsula in the north. The subsurface sedimentary section ranges in age from Paleocene to Holocene and overlies non-conformably the Deccan Trap / Granitic / Metamorphic basement. Deccan Trap represents the basin floor geology with a few granitic/metamorphic inliers. Seismic sections and Cretaceous exposures in Wadhawan and Dhrangadhara areas of Saurashtra block reveal the presence of a sub Deccan Trap Mesozoic basin.

Significant Geologic and Tectonic Events

“Crustal scale” tectonic events affecting the passive margin in the study area include:

1. Long period of stable emergent craton from Pre-Cambrian to early Mesozoic. Initial rifting and separation of India from Africa in the mid-Jurassic.
2. Continuous rifting, and separation of Madagascar from west India in the mid-Cretaceous.
3. Northward drift of western India over a mantle plume at K/T boundary.
4. Outpouring of Deccan Trap flood basalts over a large area between 66 and 65 Ma.
5. Last major rift as Seychelles moves away from western India in the Early Tertiary. Deposition of Paleocene-Eocene source rocks in accommodation caused by rifting.
6. Continued igneous activity along southward moving track of hotspot. Thermal cooling and subsidence after rifting event & movement away from plume.
7. Localized wrench tectonics and intrusive & extrusive igneous activity in the Eocene.
8. Initial contact of Indo-Australian and Eurasian plate in mid-Eocene.
9. Significant subduction and first major Himalayan orogenic event in mid-Oligocene.
10. Extension & block faulting in some areas of western Indian margin in Late Paleogene.
11. Thermal-isostatic subsidence of margin appears to accelerate around mid-Miocene.

A geo-chronological chart showing some of the above events and a global sea level curve is shown in **Fig: 2**.

Indian Plate was part of the southern Gondwanaland Land between the Africa, Antarctica and Australian plates right from Permian (Paleozoic) to Mid. Jurassic time. During late Jurassic (~180 to 160 Ma), the Gondwanaland Land broke-up and formed the passive margins along eastern Africa & western Madagascar, as revealed by the JOIDES exploration in Indian Ocean.

Discussion:

Panna section has been divided in two units. Lower unit correspond to Synrift part wheras Upper unit correspond to Postrift sediments. Synrift section is further subdivided into two subunits corresponding to early synrift and Late Synrift whreas Postrift panna section is subdivided into three units based on seismic reflector and log correlation**(Fig: 3)**. Equivalent seismic markers could be traced and were mapped regionally along with Basement top. The markers corresponding to Syn-rift units and Postrift sag phase sections of the Panna formation and seismic markers were named as unit 1, unit 2, unit 3 , unit 4 & unit 5, from older to younger.

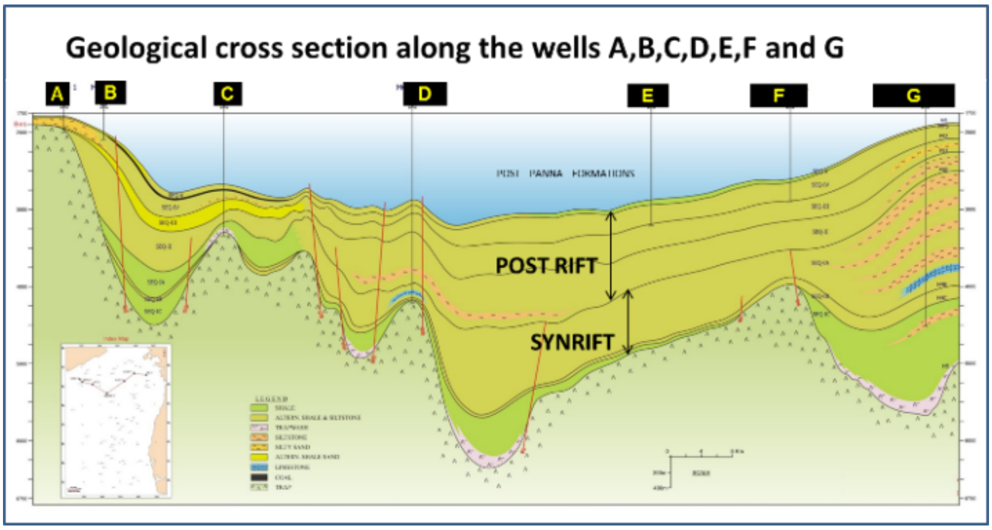


Fig. 3: Cross section along the wells for Panna formation.

These unit tops were dated with the available paleontological/ palynological informations. The seismic facies (Fig: 4) within the units indicate their depositional environment associated with the stage of rifting and passive margin sedimentation.

The time structure map at Basement level indicates high and lows formed due to Synrift and Postrift tectonic activity (Fig: 5).

Time thickness map of Synrift sequence indicate presence of independent lows formed by rifting and subsequent deposition in these lows. The lows of synrift sediments are aligned in NW-SE and NNE-SSW direction in Dharwarian and Delhi system trend (Fig: 6).

The time thickness map of post rift panna sequence indicates that during sag phase the Eastern and western lows were filled and got peneplained. However the central low continued to remain low and receive sediments from all the direction. This central low was connected to open sea in the west by a narrow low and through central graben area in the south(Fig: 7).

In approximately 27000 Sq Km area 33 wells have been penetrated upto Basalt. Thus well density for Synrift Panna exploration is 850 skm per well. However total 71 wells have penetrated through completely or partially through Postrift Panna section. Thus well density for Postrift Panna exploration is only 394 skm per well. It has been observed that most of the well penetrated through Synrift and Post rift Panna sequence lie on the rift shoulders where very less thickness and non-reservoir grade sequences were encountered (Fig: 8). The limited available core data indicates that the sediments were originally transported by fluvial drainage with considerable length of transportation and deposited in the shallow marine setup. The sedimentation was later dominated by Transgressive sequences in the Postrift.

1D- Petroleum system modeling study along one seismo-geological cross section has brought out favorable hydrocarbon accumulation spots along the Panna time.

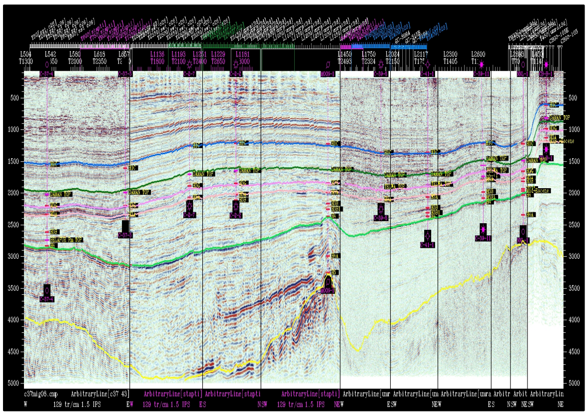
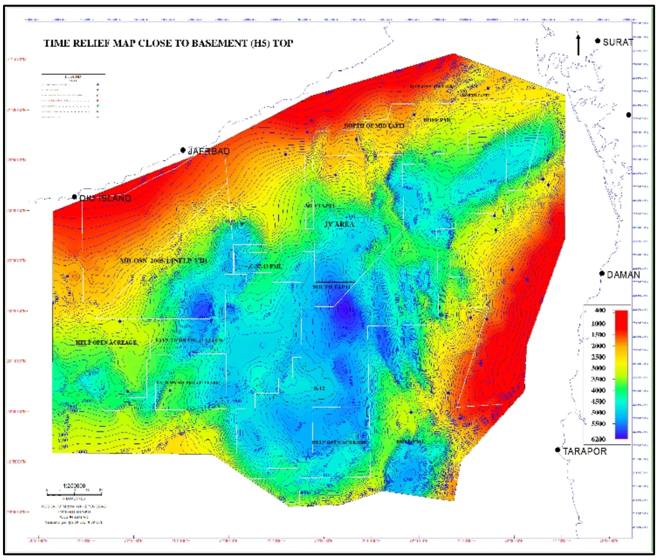


Fig. 4: Seismic section along the wells for depicting Panna formation.



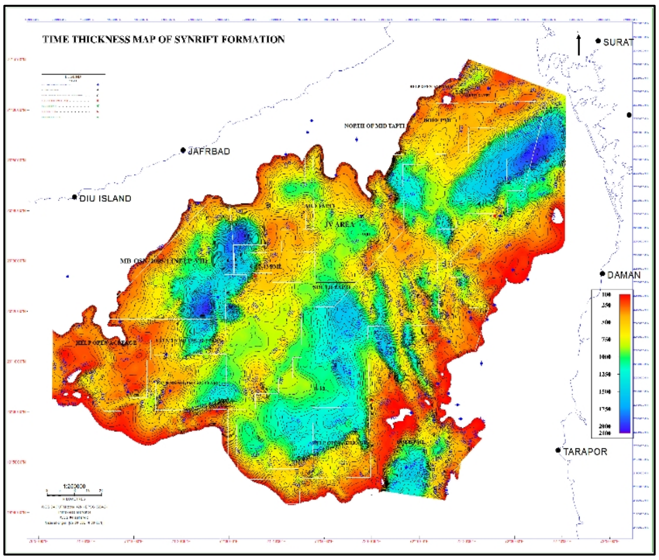


Fig. 6: Time Thickness map of Synrift section

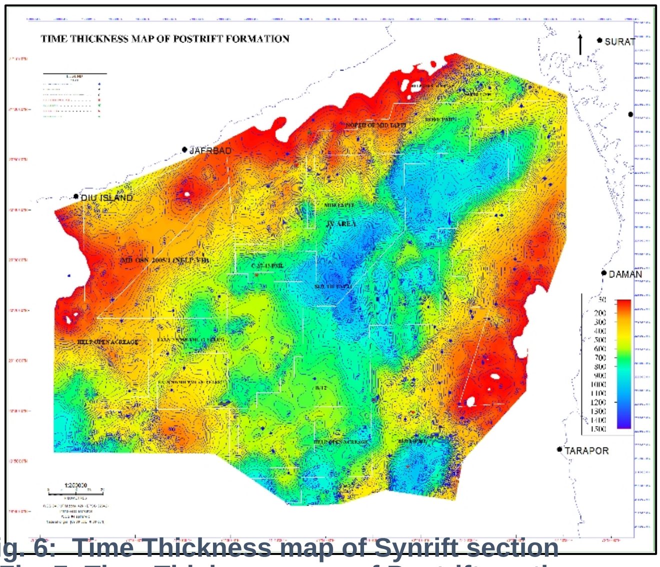


Fig. 7: Time Thickness map of Postrift section

Log Analysis

Electrolog analysis and correlation of syn-rift sediments, encountered in the wells from the basin, has been carried out. Log correlation profile are prepared in N-S & E-W direction to understand the sedimentation of synrift sediments.

The syn-rift sequence on the elctrologs is characterised by typical lower gamma, higher resistivity indicating presence of more coarser clastics with respect to younger sediments. This typical sysnrift top log marker is correlatable in all the wells.

The syn-rift sediments are further subdivided into two units, namely unit-1 and unit-2. The top of these units on electrolog are also correlated on the seismic section through these wells, where they are characterized by regionally developed strong reflectors. The tops of these units are also calibrated.

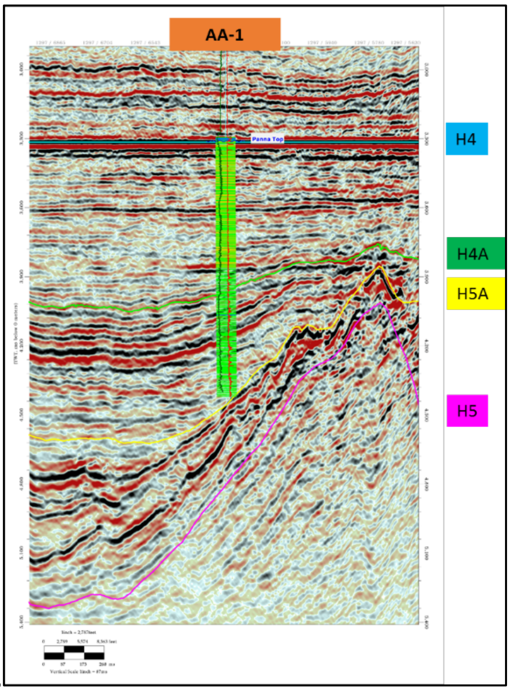


Fig. 8: Well AA-1 drilled on the Rift shoulder

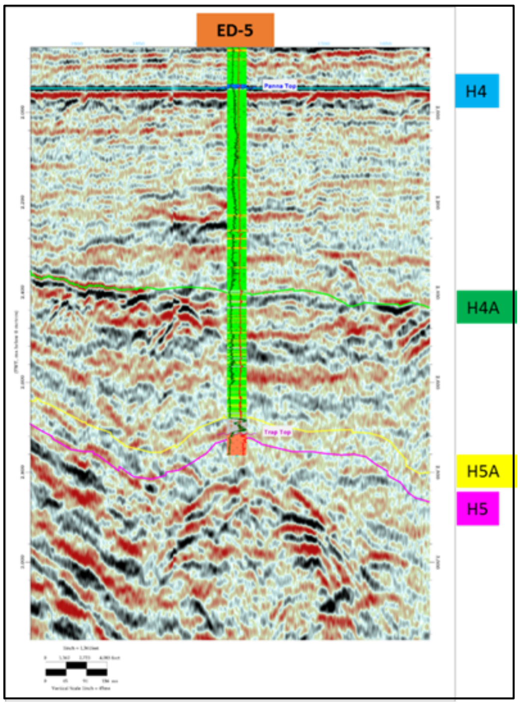


Fig. 9: Seismic Reflector signature

Seismic expression and its linkage to rift cycle

The seismic expression of different syn-rift units gives an idea about the distinct stages of rift evolution and associated depositional system.
The Syn-rift sediments are clastic deposits calibrated with Seismic data wherein the seismic facies unit showing chaotic to sub-parallel reflection (Fig: 9) onfiguration showing high amplitude and impendence anomaly confirming the presence of porous reservoir is observed on the eastern rising flank of Navsari low.

The drainage pattern corresponding to western offshore basin and in particular to Tapti Daman sector is important to understand the provenance, sediment input direction, drainage quality, deposition set up and basin configuration which leads to the sediment dispersal pattern and reservoir development. The drainage pattern brought out based on different parameters by various institutes indicate that Northeastern provenance (Fig: 10) rivers also caters the sediment supply to North heading rivers thus giving lesser sediment supply to Tapti daman sector. As it is understood that Panna formation has potential source rock which has filled hydrocarbon to different structures at different level is likely to fill the Panna reservoir wherever developed. To understand the depositional model after analysis of the G&G data a model has been perceived which is derived from the various Synrift sedimentary basins.

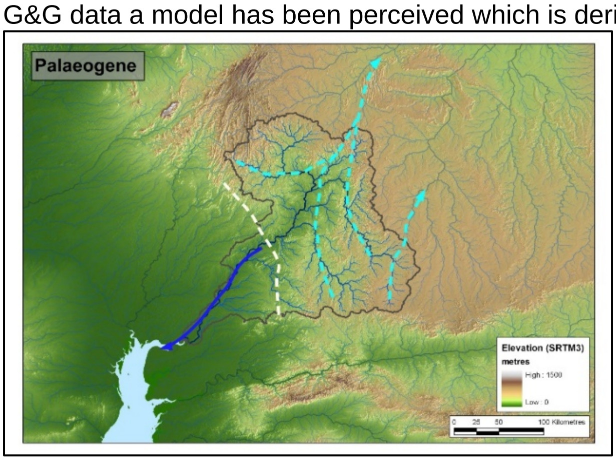


Fig. 10: Drainage pattern during Palaeogene

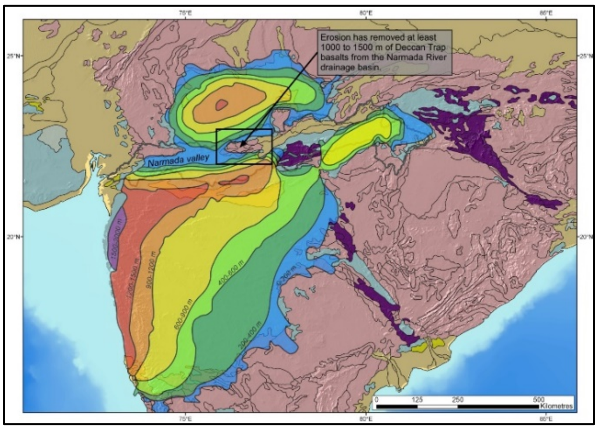


Fig.11: Envisaged Deccan Trap erosion thickness

Thick cover of Deccan basalt has been eroded and deposited in the lows by Narmada and other rivers (**Fig: 11).**

The axial drainage pattern (Fig: 12) is envisaged to have deposited the Synrift Panna sediments. It has been observed that most of the wells have been drilled on the shoulders of the rifts where fan deposits are expected which form the poor reservoirs whereas the axial drainage pattern brings out the coarser clastics and sorts the sediments in such a way that better reservoir quality sand are deposited which are potential for hydrocarbon exploration and exploitation.

Conclusion:

1. In nearby Central Graben area of Mumbai offshore basin hydrocarbon discovery has been made and exploitaion from Panna formation has established its potential. Althogh Hydrocarbon shows in form of GYF and Cut alongwith minor gas flow from panna formation has been observed but commercial discovery from Panna formation is yet to be established.
2. In approximately 27000 Sq Km area 33 wells have been peneterated upto Basalt. Thus well density for Synrift Panna exploration is 850 skm per well. However total 71 wells have peneterated(completely or partialy) through Postrift Panna section. Thus well density for Postrift Panna exploration is only 394 skm per well.
3. It has been observed that most of the well peneterated through Synrift and Post rift Panna sequence lie on the rift shoulders where very less thickness and non reservoir grade sequences were encountered (Fig: 8).
4. Panna section has been divided in two units. Lower unit correspond to Synrift part wheras Upper unit correspond to Postrift. Synrift section is further subdivided into two subunits corresponding to early synrift and Late Synrift whreas Postrift panna section is subdivided into three units based on seismic reflector and log correlation. Thus total Five units in Panna section has been identified in which lower two units correspond to synrift and upper three units correspond to Postrift Panna section.
5. Panna formation has potential source rock which has filled hydrocarbon to different structures at different level is likely to fill the Panna reservoir wherever developed.
6. The drainage pattern corresponding to western offshore basin and in particular to Tapti Daman sector is important to understand the provenance, sediment input direction, drainage quality, deposition set up and basin configuration which lead to the sediment dispersal pattern and reservoir development. The drainage pattern brought out based on different parameters by various institutes indicate that Northeastern provenance.
7. The axial drainage pattern (Fig: 12) is envisaged to have deposited the Synrift Panna sediments. It has been observed that most of the wells have been drilled on the shoulders of the rifts where fan deposits are expected which form the poor reservoirs whereas the axial drainage pattern brings out the coarser clastics and sorts the sediments in such a way that better reservoir quality sand are deposited which are potential for hydrocarbon exploration and exploitation.

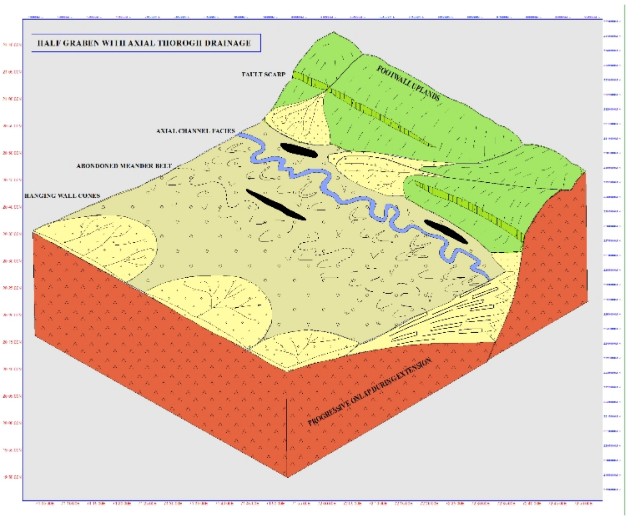


Fig. 12: Depositional Model for Synrift Panna sediments.

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The opinion expressed in this work is of the authors and not of the organization they belong to.

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