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SEISMIC-SEQUENCE STRATIGRAPHY AND PALEO-STRUCTURE ANALYSIS OF PROTEROZOIC SEDIMENT WITHIN GANGA BASIN, INDIA.

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Summary

Gas discovery in Nohta-2 well from Proterozoic play in Vindhyan basin has been a significant lead to suggest that Proterozoic sediments underneath Ganga basin could be prospective. Present study has been carried out to understand the paleo-structures and depositional environment of the Proterozoic sediment within the Ganga basin.

The Paleo-tectonic and Seismic-sequence stratigraphy analysis reveals that the Proterozoic sediments are deposited in the passive margin setting in shallow marine and tidal conditions. With the variation of sea level and shoreline shifts, these sediments go through several progradation and retrogradation cycles. This study shows that the Proterozoic sediments underwent two stages of progradation with varying sedimentation rate followed by a retrogradation resulting several local unconformities and hydrocarbon traps. After the retrogradation, the basin observed a long hiatus (>500~ Ma) spanning from Paleozoic to Mesozoic ages. As a result, a regional unconformity has been formed throughout the basin. The lithological characteristics of these sequences vary greatly among themselves from clastic to carbonate rich sediments. The lithology and the paleo-environment made these sequences important for hydrocarbon generation and preservation. Consequently, some structural/stratigraphic plays might contain hydrocarbon and would be attractive for detailed exploration which might change the proceptivity perception of the basin.

Seismic-Sequence Stratigraphy and Paleo-Structure Analysis of Proterozoic Sediment within Ganga Basin, India.

Introduction

Ganga basin is a part of Himalayan foreland basin system and comprises of sediments of Proterozoic and Cenozoic age with a large hiatus spanning from Paleozoic to Mesozoic ages. The study area is located within the Indo-Gangetic Plain, (Figure 1) covers of about 41,000 sq.-km of the Ganga basin. A numbers of ridges/highs and large depressions/lows lie within the Ganga basin. The regional ridges, depressions and major fault trends are shown in figure 2.

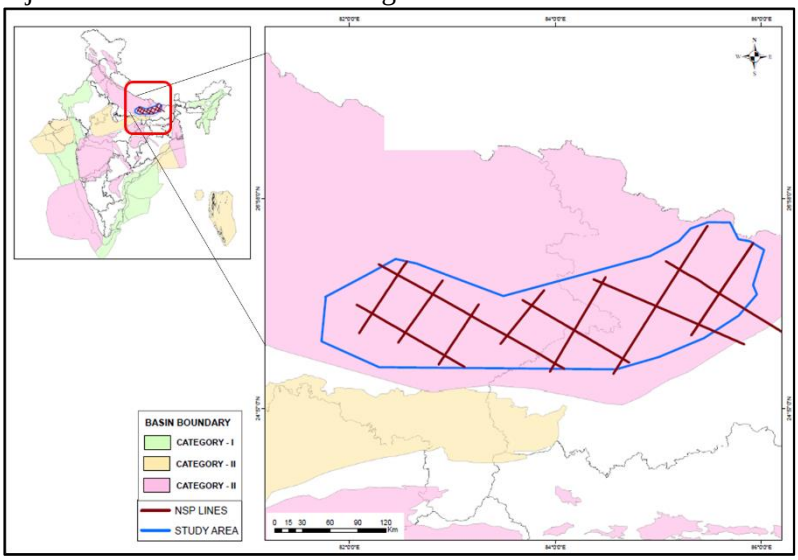

***Figure 1**: Location map of the study area. The study area covers an area of more than 40k SKM.*

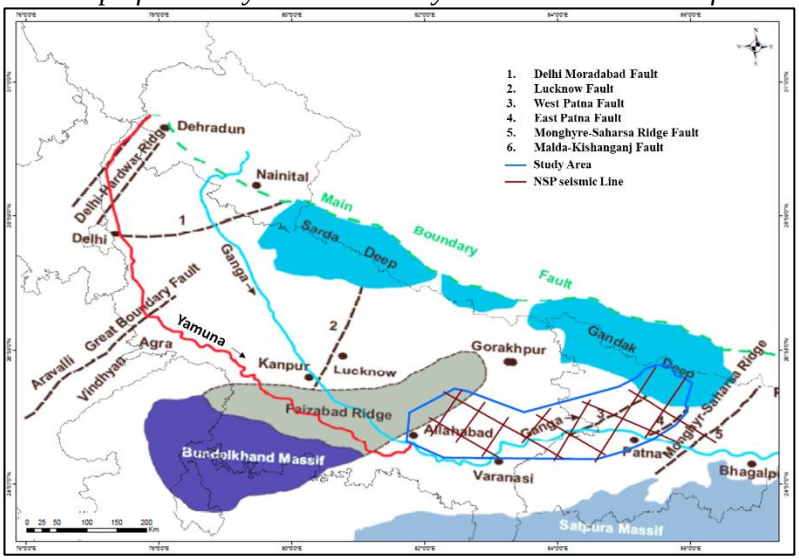

***Figure 2**: Tectonic map of Ganga Basin. The map highlights major high, lows and fault trends in the Ganga basin ((modified after Sinha et al., 2005).*

Shukla et al., 1993; Jokhan Ram et al.1996; Pramanik et al. 1996 and others opined that the pre-Tertiary sequence of the Ganga basin is the northern subsurface extension of the Proterozoic Vindhyan sediments. Figure 3 shows a seismo-geological section passing from Vindhyan basin to Ganga basin. The schematic illustrates Proterozoic (Upper Rohtas limestone) play is extended from Vindhyan basin to Ganga basin and it enhanced the exploration activities in Vindhyan basin as well as in Ganga basin. As no well is drilled within the study area and the nearest well (Havidih-1) is far apart from any seismic line, building Time-Depth (T-D) relationship is not possible. However, the seismic data quality is moderately good, and the regional unconformity is easily identifiable throughout the study area.

Assuming this regional unconformity as reference, other geological markers like; Mesoproterozoic, Neoproterozoic-Paleozoic and Tertiary sequence are identified based on their reflection character and geological occurrence.

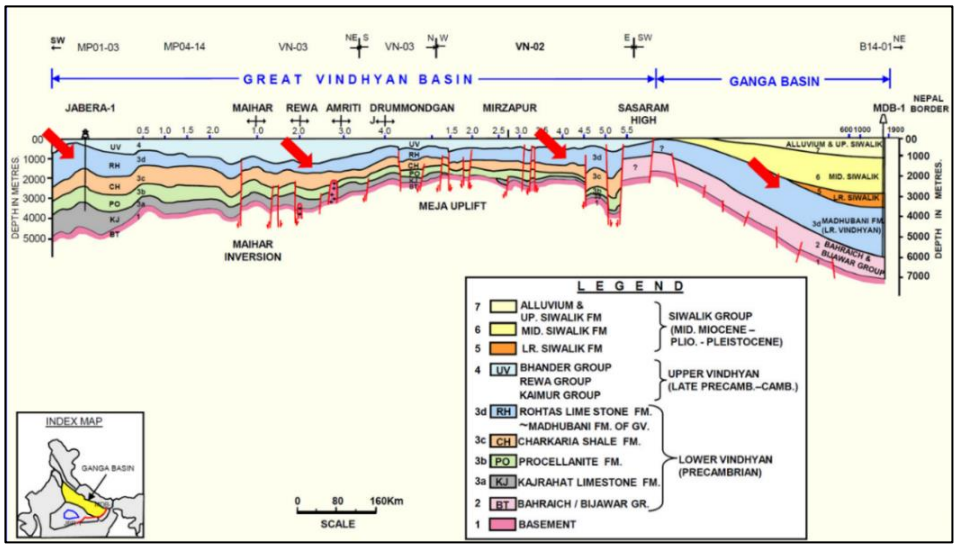

***Figure 3**: Schematic section from Vindhyan to Ganga Basin. The red arrows show that the Rohtas Limestone/Madhubani Formation equivalent of Neoproterozoic- Paleozoic system is extended from Vindhyan Basin to Ganga basin (DGH, 2017).*

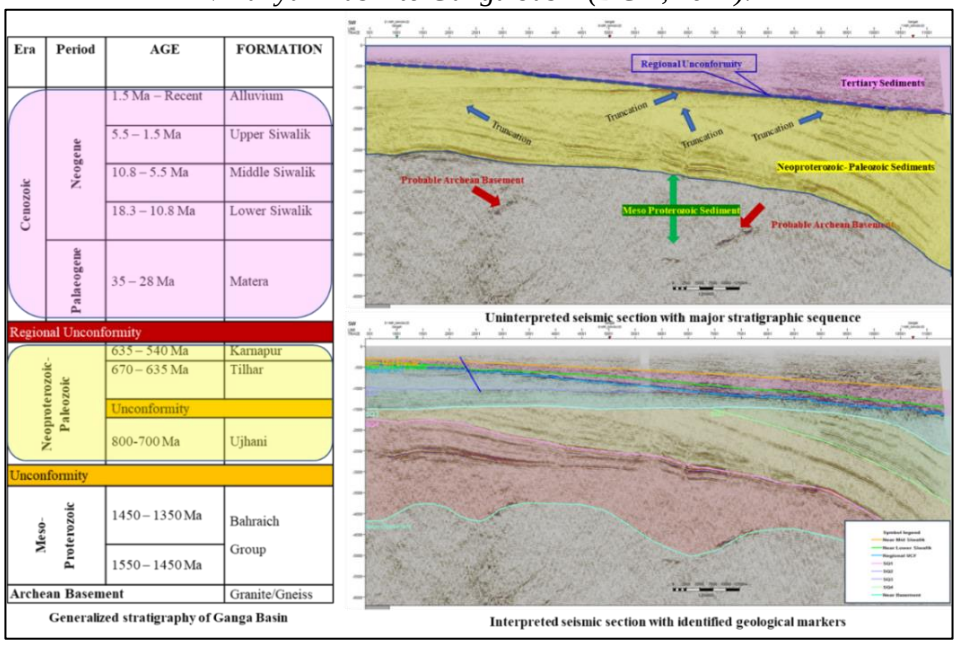

***Figure 4**: Major stratigraphic sequence with identified geological markers.*

Several other local unconformities can also find in the seismic sections. Figure 4 illustrates the identified geological markers and their corresponding geological age.

Paleo-tectonic Analysis

The Ganga basin is originated as a result of the formation of a depression in front of the uplifted Himalayas due to intensive orogeny of the Pliocene-Pleistocene age. The depression was filled with sediments carried by rivers, flowing from the Himalayas to the peninsula. The granitic Archean basement formed the base for the sediments. During Mesoproterozoic, the sedimentation initiated, and the Bahraich group was deposited around 1450±100 Ma. Paleo flattening along SQ-4 equivalent Bahraich group is shown in figure 5(a). The figures show that a small-scale paleo-structure was present during the Late Proterozoic sedimentation.

On the paleo flatterning along SQ-2 (figure 5(b)) and the regional unconformity (figure 5(c)) of Neoproterozoic age show that the deposition of Paleozoic sediments over the Bahraich group sediments. Neoproterozoic succession consists of Ujhani, Tilhar and Karnapur formations deposited in the passive margin setting in shallow marine environment. The lithology of the formations varies greatly. Ujhani and Karnapur formations are predominantly clastic sediments whereas the Tilhar formation is carbonate rich with subordinate proportions of clastic sediments.

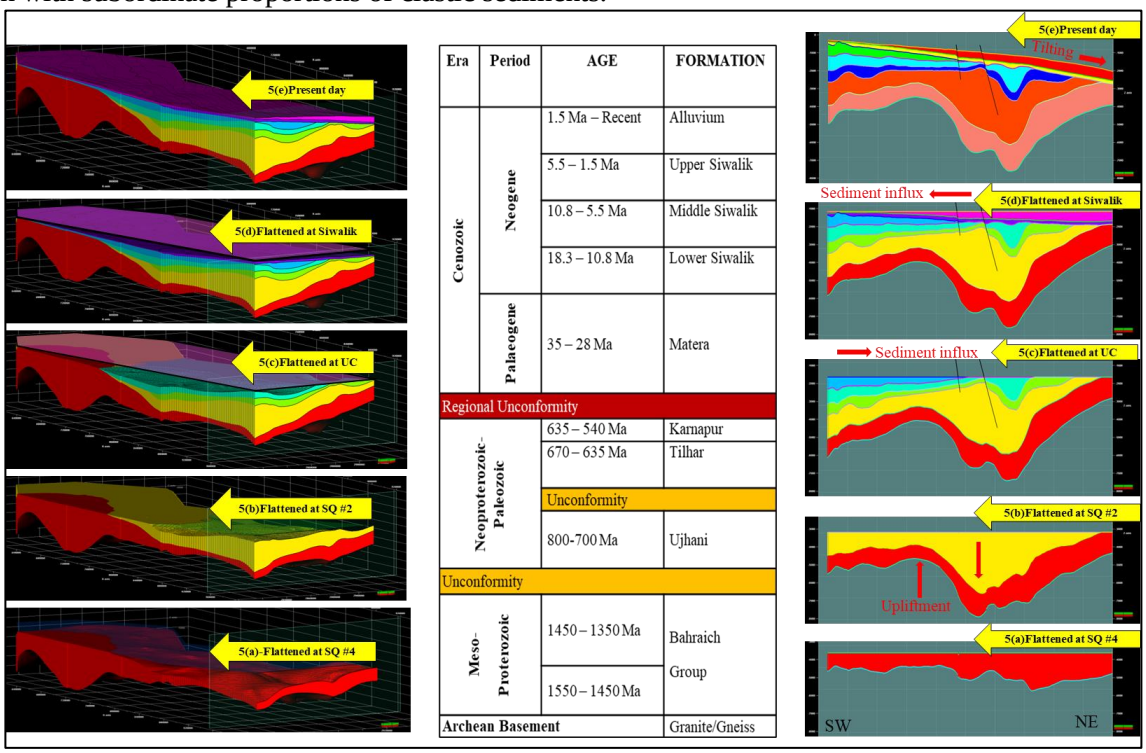

***Figure5**: Paleo-structure analysis of the Ganga Basin. The maps highlight the paleo-structures, basinal configuration and sedimentation orientation with geological time.*

The lithology and the paleo-environment made this sequence important for hydrocarbon generation and preservation. Consequently, any structural/stratigraphic play might contain hydrocarbon and attracts geo-scientist for detailed exploration. Paleo flatterning at Siwalik of Cenozoic age (figure 5(d)) shows that the basin acquired the configuration of the frontal trench, which led to formation of thick fluvial sediments (Siwalik) sloped to the northeast. These sediments were less prone to subsequent tectonic effects. At present day, the basin is tilted towards NE direction and sedimentation is still on (Figure 5(e)).

Seismic-sequence Stratigraphy Analysis

Seismic sequence stratigraphy analysis shows that the study area has four different sedimentary packages. Figure 6 highlights the identified seismic sequence stratigraphy. The oldest sedimentary package above the Archean basement is termed as Bahraich group. This group of sediments are deposited during Mesoproterozoic age in shallow marine and fluvial environment. These sediments are mostly metamorphosed and show low stage of sedimentation. Above the Bahraich group three distinct cycles of sedimentation are observed. This group of sediments are also deposited in shallow marine environment between Neoproterozoic to Paleozoic which are mostly interbedding of shales, siltstones, sandstones, and limestones. As shown in figure 5(b) accommodation space is created by the upliftment of basement high and two cycles of progradation (Progradation I & II) are noticed (Figure 6).

During the first cycle of progradation, there was a small raise in sea level and shoreline moved north eastward. Subsequently, the basin suffered a small hiatus with a lowering of sea level and several local unconformities are formed within the study area. After the small hiatus, the basin observed the 2nd cycle of progradation and again the shoreline is moved north eastward with a small raise in sea level but with an increased rate of sedimentation. After the two prograding sequence the basin suffered a retrogradation which is around Neoproterozoic time. During this time, the shoreline moved landward with a small raised in seal level. After the retrogradation, the basin observed a long hiatus spanning from Paleozoic

to Mesozoic ages and a regional unconformity is formed throughout the basin. Above the regional unconformity Tertiary sediments are deposited which are mainly driven by fluvial system with variable energy and occasionally lacustrine environment of deposition.

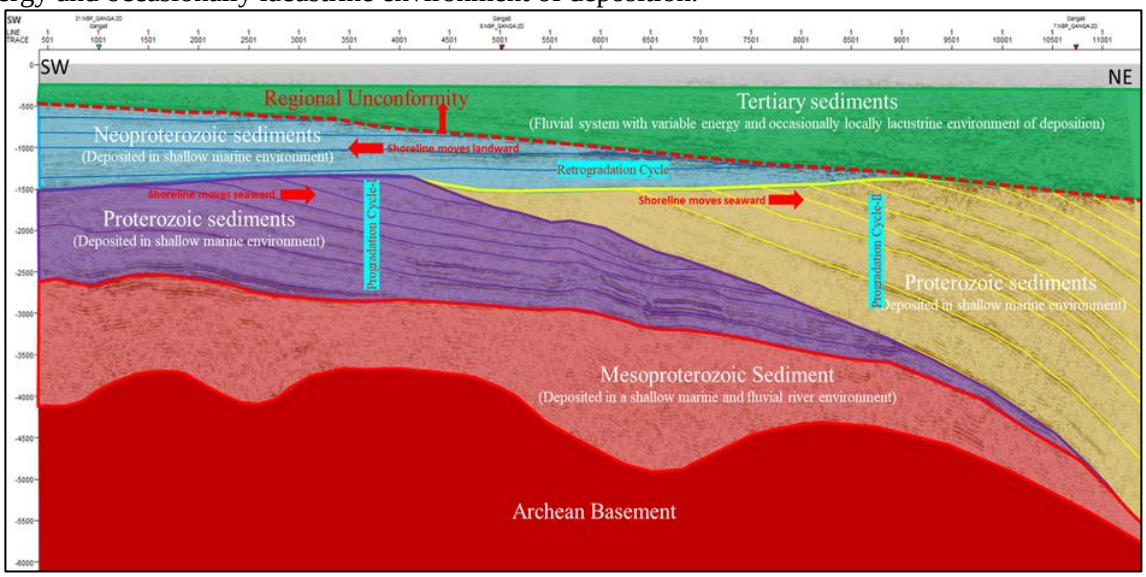

***Figure 6**: Seismic sequence stratigraphic analysis of Ganga Basin.*

Conclusions

The paleo-tectonic and seismic sequence stratigraphy analysis reveals that the basin has three different sequence of sedimentation. The oldest sedimentary package, the Bahraich group are deposited during Mesoproterozoic age in shallow marine and fluvial environment. These sediments are mostly metamorphosed and show low stage of sedimentation. The Proterozoic sediments consists of Ujhani, Tilhar and Karnapur formations are deposited in the passive margin setting in shallow marine and tidal conditions. These sediments suffered two stages of progradation with varying sedimentation rates followed by a retrogradation resulting several local unconformities and hydrocarbon traps. After the retrogradation, the basin observed a long hiatus spanning from Paleozoic to Mesozoic ages and a regional unconformity is formed throughout the basin. Above the regional unconformity Tertiary sediments consists of Siwalik group of sediment are deposited which are mainly driven by fluvial system with variable energy and occasionally lacustrine environment of deposition.

The facies of the Proterozoic sequence are varying widely from clastic to carbonate rich sediments with a favorable entrapment condition of hydrocarbon whereas Bahraich group of Meso-Proterozoic age has limited chance of reservoirs unless fractured by intensive tectonics and development of secondary porosity.

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