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Conceptual Model of Tura-Sylhet-Kopili Depositional Systems, Upper Assam Basin, India using Seismic Sedimentology

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Summary

The work described the principles of Seismic sedimentology applied to conceptualize the Tura -Sylhet- Kopili depositional system of Upper Assam Basin. Tools of seismic sedimentology include 90°phasing of seismic data, seismic lithology, stratal slicing and seismic geomorphology is described in the work. Applying depositional and stratal slice model to analyze real data, stratal slices comprising coastal plain to outer shelf depositional facies is also discussed in general and in particular to study area. Different types of slicing and its geological significance is also discussed briefly. Acoustic impedance (AI) for sandstone encased in shale formation was described in the present work. The different type of wavelet phase and geological interference to map thin bed reservoirs is also discussed. The seismic sedimentological principle applied particularly in transgressive sequences of Kopili and Sylhet formations beneficial for facies mapping for further exploration in the study area.

Introduction

In recent years, seismic reflection data have provided petroleum geoscientists with a new source of information to map not only structure and stratigraphy but also Hydrocarbon reservoirs in sedimentary rocks. The development of seismic sedimentology enables the interpreter to predict the quality and extent of reservoir with improved resolution. Seismic sedimentology by definition, is the use of seismic data to study the sedimentary rocks and the processes by which they form. It provides an alternative way to interpret time – transgression prone seismic events for high frequency sequence Stratigraphy. Seismic sedimentology make easier to start from stratal slices or plan view geomorphology of depositional systems instead of guessing where to pick seismic events between and beyond well control. It differs from classic seismic stratigraphy in that it uses mainly the horizontal, instead of the vertical, character of seismic data to provide high resolution images of seismic attribute patterns that is related to geomorphology and depositional model. Display of seismic attributes on geologic time surfaces is the fundamental tool of seismic sedimentology.

Further mapping of thin deeply buried reservoirs using seismic and sequence stratigraphy has limited scope and challenging in the structurally and seismically complex areas like upper Assam basin. Further with increased depth, seismic frequency decreases and seismic velocity increases leading to reduced resolution and seismic noise becomes more intense. Reservoirs at greater depth i.e. Tura, Sylhet and Kopili are generally thin, multilayered and are below seismic resolution. Reflection from multiple litho facies of different, adjacent depositional sequences interfere with each other to form merged events making volume based imaging less useful for interpretation. Auto tracing does not help thinly inter bedded sandstone-shale formations that contain few surprises in seismic anomalies. Therefore manual 3-D correlation become inaccurate and impractical for identifying and mapping most of the deep seated reservoirs in frontal thrust areas of upper Assam basin. Though adequate well control available for shallow reservoirs and few wells penetrated through deep reservoirs of the study area hence seismic attribute data is very helpful for interpreters to extrapolate known reservoir facies. Therefore, the objective of this work is for exploring deeper



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prospects and associated depositional systems in the basin using seismic sedimentology principles.

Geology of the Study Area.

The upper Assam basin is a foreland basin that is located between the eastern Himalayan foot hills and Assam-Arakan thrust belt. On Assam shelf majority of discovered hydrocarbon accumulations are confined to Naga frontal fold belt and Brahmaputra arch. In Main Central High Paleocene- Eocene : Tura-Sylhet-Kopili petroleum system has been successfully established by Oil India PEL and Lakwa, Panidihing and recent Disangmukh prospects of ONGC PEL/ML areas. However in Geleki and frontal thrust areas, the deeper prospect is partially to yet to be explored and remain an area of opportunity for exploration (Fig.1).

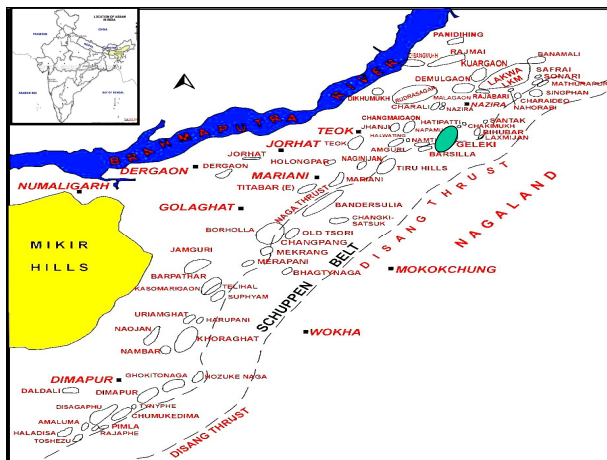
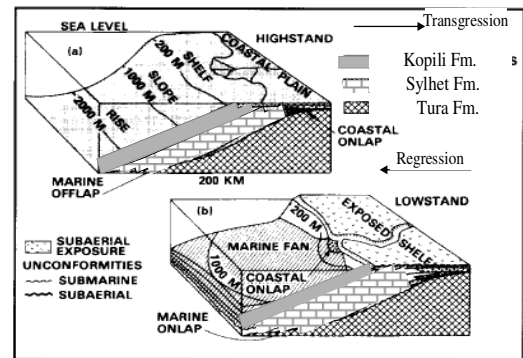


Fig.1 Prospect map of upper Assam

Depositional System and associated lithofacies:



Schematic diagram of Tura-Sylhet-Kopili Depositional System

Fig.2 Schematic diagram of Tura- Sylhet- Kopili depositional system

Tura Formation: This is pebbly; poorly to moderately sorted sandstones with associated lithomeric clays or kaolin bands are interpreted to be fluvio-deltaic conditions. Further represents the lowstand wedge systems as incised valley fill deposit (Fig.2). On seismic this formation is difficult to recognize as it is a reflection free zone. On log it is marked by distinct drop in resistivity, density and increase in transit time.

Sylhet Formation:

It is pinkish grey, massive hard crystalline limestone and represents the parasequence in transgressive system tracts. On seismic, its base and top are marine flooding surfaces. On log it is easily identified with sharp base.

Kopili Formation:

The kopili shales are grey to dark grey, brownish grey or reddish brown in colour, hard compact and splintery. Thin limestone presents are of cream to buff coloured, argillaceous and fossiliferous. Sandstones are light grey, brownish grey, fine to very fine grained, well sorted quartzose in character. This formation deposited in transgressive phase. The sand within kopili shows coarsening upward sequence and serrated log motif and generally thin and discrete nature.



Seismic Data Background of the Area:

Seismic data provides high density spatial sampling and control on structural geometries and lithofacies distribution of reservoir bodies. Owing to logistic difficulties as well as geological complexities in upper Assam basin, though seismic imaging has provided some control over the structural configuration with very little constraining on the lithofacies distribution. Further the seismic data in frontal thrust and fold areas is affected by rapid velocity variations due to juxtaposed lithotypes (House, 2004). The magnitude of inversion reduces as we move away from the frontal thrust belt. The deeper basinal part is having inherited passive margin with cascade normal faulting.

Theory and Methods Seismic Sedimentology:

Seismic lithology and seismic geomorphology is the backbone of seismic sedimentology. 3-D seismic volume converted into lithology volume then lithological logs are tied with nearby seismic traces ensuring best possible integration with seismic data at reservoir level. Using seismic geomorphology, we further converted seismic data into depositional facies images with lithologic identification. The methods are given below:

A. 90° Phasing of Seismic data and seismic Lithology

In a standard 0° phase data set the Acoustic impedance (AI) of the same lithology is tied to opposite polarities (peak-trough couplet). The correlation between impedance curves in the model and seismic traces is very poor. In contrast, the 90° phase data are symmetric impedance curves, making the main seismic event (either a trough or peak) coincide with geologically defined sandstone bed. As a result seismic polarity is better tied to lithology and correlation between AI curve and seismic traces increased. Therefore seismic sections look like a geologic section

B. Stratal Slicing:

Usefulness of seismic geomorphologic information increased by picking seismic attributes on a depositional surface (geologic time surface). Hence any attribute extractions on such surface represented a lithogenetic depositional unit. Such a seismic surface display is called stratal slicing (Zeng and Hentz, 2004) or proportional

slicing (Posamentier et al., 1996). The reference events must be geologic time equivalent and should be picked with less difficulty on seismic section. In principle, no major angular unconformities (truncations) or other discordant reflections should occur between reference events.

Depositional bodies are commonly characterized by much greater horizontal dimension than vertical dimension (Galloway and Hobday, 1983). Considering that seismic detectable limit is significantly smaller than the resolvable limit (0.04λ versus 0.25λ , Sheriff, 2002) potential for new information is enormous. If a pseudo geologic timescale is applied (Zeng et al., 1998a), a stratal slice volume can be viewed as a relative geologic-time volume. All the reference events and all stratal slices are flattened in display time. The relative geologic time means that all stratal slices above are younger than those below. Vertical sections from the volume illustrate the time stratigraphic sequences. When the interference of a complex structural background is removed, subtle stratigraphic features is viewed clearly otherwise difficult to identify.

The methods for choosing different slices for structural and stratigraphic conditions for interpretation is:

- A. When the formation is sheet like and flat lying probably time slice is suitable
- B. If the formation is sheet like but not flat lying horizon slicing is most appropriate.
- C. If the formation is neither sheet like and nor flat lying, stratal slicing is necessary (Fig.4)

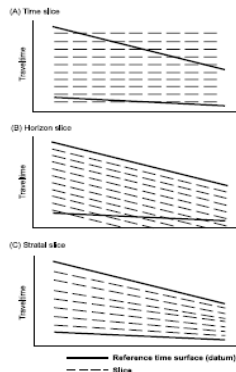


Fig.4 Different types of slices

(C) Acoustic Impedance (AI) Vs Facies Variation

In Kopili formation, the sand and siltstone generally encased in shale section, therefore the 0° synthetic section of wedge based acoustic impedance model of this type sandstone, symmetrical wave form observed whose thickness is thicker than wavelength (λ). When the thickness of sandstone is seismically thin, then reflection amplitude is composite seismic responses are mixed reflections (Fig.5).

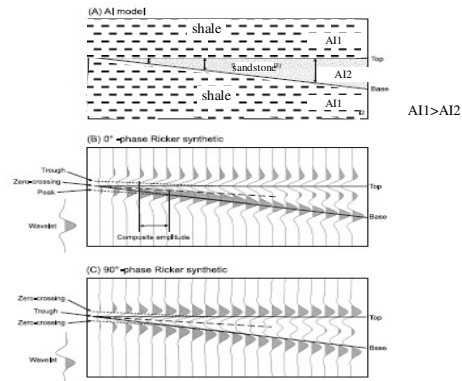


Fig.5 AI model for sandstone encased shale sequence (modified after Zeng et.al., 1998)

(D) Wave phase vs Geological Interference

When the sand units are deposited in coastal stream plain environment and delta front environment like kopili sequence, the geological interference is due to lateral variation of rock properties (Fig.7). This can be minimized by determining different phases of wavelet used for seismic response. A zero phase wavelet is symmetrical and has maximum energy in central part. Its side lobes have less influence on target reservoir, making zero phase wavelet better than minimum and maximum phase wavelet for detecting reservoirs vulnerable to geological interference. However a 90° phase shift Ricker wavelet having shorter side lobes and is better than zero phase equivalent resolution. If the geological interference from one direction a minimum phase wavelet is better because it has side lobe in one direction (Fig.6).



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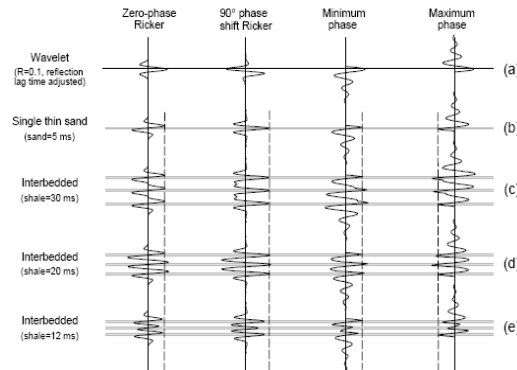


Fig.6 Different wavelet vs geological interference

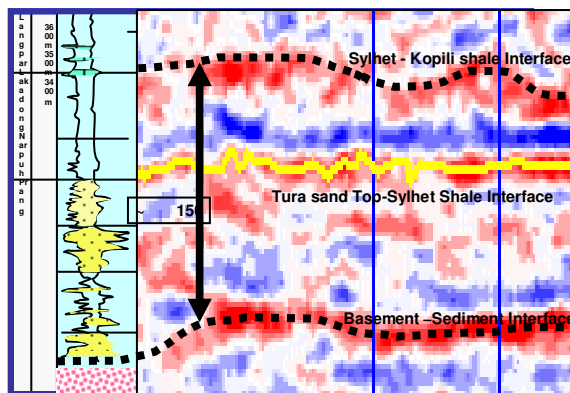


Fig.7 Seismic Section and Log motif showing sand shale interface and formation boundary

Seismo sedimentological model of Tura-Sylhet- Kopili Depositional system:

Applying depositional and stratal slice model to analyze real data, stratal slices comprising coastal plain to outer shelf depositional facies. The slice represent the upper part of the sequence equivalent to slice B (Fig.8) that indicate the distribution and relationship between lowstand system tract and relict highstand system tract deposits. Limited well penetration at these sequences in the study area and its calibration between seismic amplitude and log lithology that can be extrapolated to areas of seismic volume where no well data available. The extrapolation enables

identification of horizontal distribution of lithofacies with strong negative amplitude (red) indicating sandstone, weak negative amplitude, denoting shaly sandstone and positive amplitude (black) corresponding to shale beds.

The entire Tura-Sylhet-Kopili Formation is divided into transgressive-regressive cycles. The Kopili formation starts with a sequence boundary with deposition of transgressive system tract (TST). The TST divided into four parasequences. The unit is characterized by coarsening up trend to fining up trend towards basinal side. The upper TST unit is characterized by fining upward trend which ends with maximum flooding surfaces (MFS) (Fig.9).

The HST is above MFS is characterized by coarsening upward trend. The sands are fine to very fine frequently interlaminated with silts and shale.

Sylhet is distinct of high amplitude and frequency with continuous reflections bounded by MFS (Fig.10).

Tura deposited marginal marine to continental environment of deposition in wider part of Assam shelf and also characterized by lowstand wedge system tract.

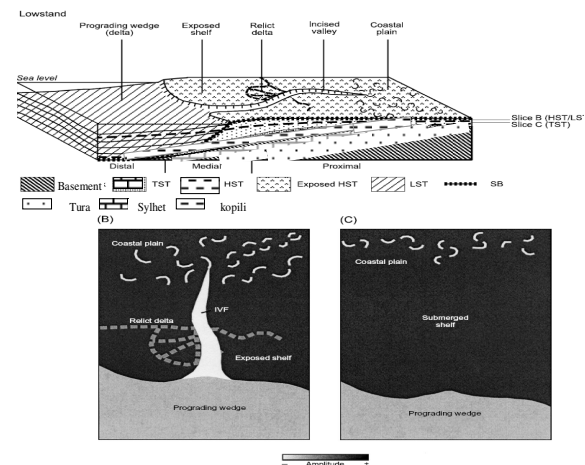


Fig.8 (A).Box model at low stand and high stand depositional model of Tura-Sylhet-Kopili system (modified after Van Wagoner et.al., 1990). (B)Expected Plano form of seismic amplitude pattern of slice-B. (C) Expected Plano form of seismic amplitude pattern of slice-C.

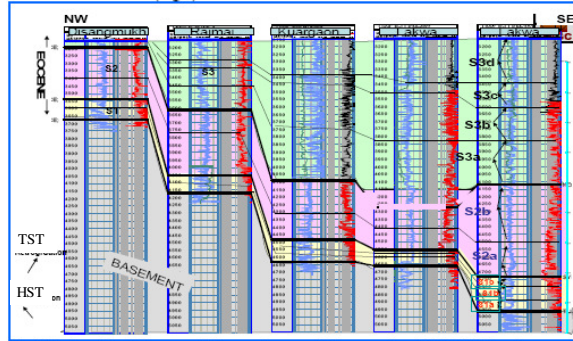


Fig.9 Electro log Correlation along NW-SE direction

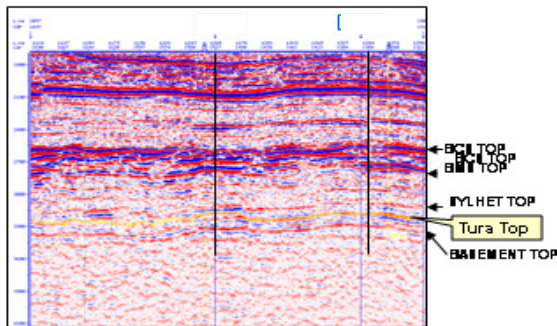


Fig.10 Seismic section showing top of Basement, Tura and Sylhet

Attribute Analysis

The attribute analysis is based on views of earlier workers. Instantaneous frequency, amplitude attributes and spectral decomposition methods are adopted. From the analysis discrete sand geometries are found for Kopili formation. Low to moderate frequency has been observed for corresponding sands within Kopili shales (Fig.11).

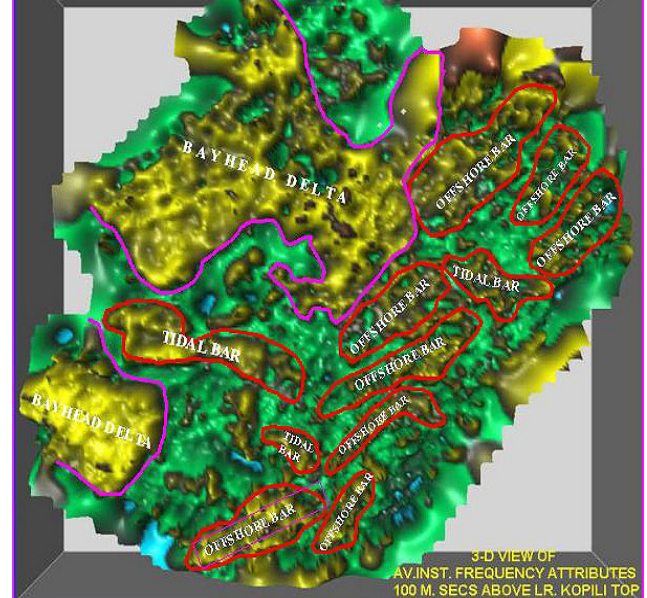


Fig.11 3D view of average instantaneous frequency attributes 100 M. Secs above lower Kopili top (Roy Moulik et.al., 2009)

Based on the attribute analysis composite sand geometry map of Kopili section indicates the environment of deposition. Various sub-environments and sand input direction is also indicated in the map (Fig.12).

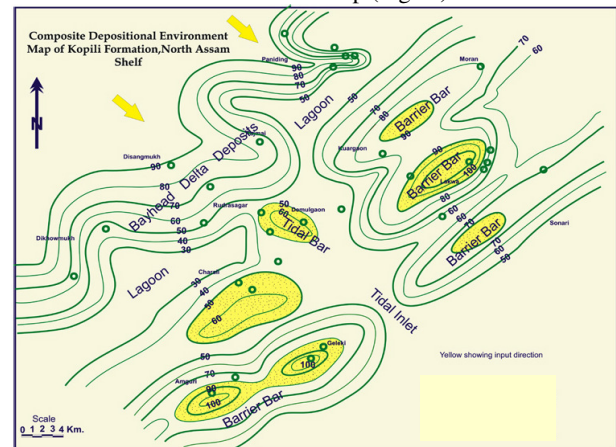


Fig.12. Composite environment deposition map of Kopili Formation (Roy Moulik et.al., 2009)



Limitations of Seismic Sedimentology:

Though seismic sedimentology offers an interpretive advantage in transgression prone seismic events for high frequency sequence stratigraphy. When properly linked to lithology in 90° phase data, the stratal slices are snapshots of 3-D genetically related depositional bodies. However some risks exist in the sensitivity of stratal slices to the accuracy of stratigraphic framework. Great caution should be taken when constructing a geological – time framework by integrating all available sources of data (seismic, core, wire-line log and palaeontological data).

The stratal slice is less useful facies mapping of sheet like sandstone that lack of lateral thickness or impedance changes. When the stratal slice containing lot of geological interference, it provide incorrect information about reservoir facies.

Conclusion:

The seismic sedimentological analysis greatly helps for prediction of reservoir facies in high frequency sequences using well data and 3-D seismic data. Further Seismic sedimentology offers an alternative way to transgression prone seismic events particularly in Kopili-Sylhet-Tura depositional systems for high frequency sequence stratigraphy and associated system tract analysis. The application of seismic sedimentological principle to the study area, particularly in transgressive sequences of Kopili and Sylhet formation beneficial for facies mapping for further exploration in study area.

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Note: Views expressed in this paper are solely of authors and not necessarily match with official views of ONGC.

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