Seismic Expressions of Submarine Channel - Levee Systems and Their Architectural Elements

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Summary

A 3D seismic volume of approx 1000 Sq. Km (40Km X 25Km) is studied to understand the Channel Levee Systems (CLS) of different ages in deep water environment. Out of identified CLS three most prominent were considered to understand their depositional environment and internal architectural elements. The study was divided into two categories, identification of macro level CLS morphology from seismic volume and thickness maps, and visualization of micro level CLS features through time slices, seiscrops, windowed amplitude attribute studies and spectral decomposition studies etc.

Introduction

Various authors documented many studies on out crops of Ancient deep water Channel Levee Systems (CLS). Wide range of architectural styles of these ancient channel-levee systems are the benchmarks to understand them in subsurface. Three types of submarine channels i.e., erosional, depositional and mixed were proposed by Normark (1970), depending upon channel sedimentation with respect to intrabasin tectonic and sea level controls. The erosional channels are associated with low sinuosity, steep slopes (Clark et.al, 1996), and turbidity currents having high concentrations of coarser sediments. These channels commonly show cut downs, scours and may be associated with coarse-grained sediments and channel bars. The aggradational or depositional channels are associated with high sinuosity in lower slopes and fine-grained sediments suspended in turbidity currents. These channels commonly have well-developed levees made up of relatively fine-grained material spilled over from the channel part. The aggradational channels grow with deposition along channel axis concurrently depositing finer sediments in the levees. In this process vertical aggradations of channel levee complex takes place. In the mixed type, erosion and aggradations go on hand –in-hand. On many occasions the well-developed depositional CLS are partly eroded by younger erosional channels due to sea level changes or sudden huge discharge by feeding rivers. In all cases due to reasons mentioned above, major avulsion may take place. These avulsions in the channels some time may lead to deposition of coarser sediments in the levees or some times breach the levees forming splays. Splays, depending on their relative position to parent-channel, can be defined as crevasse-splay, avulsion or terminal lobes.

Seismic expressions

In general, we experience decrease in seismic frequency with depth as vertical resolution decreases. In seismic the geometries of the shallow geobodies are seen relatively better than the older/deeper features. Some of the seismic attributes help in bringing out geometries of geobodies of deeper strata. Similarly, the seismic attribute studies like spectral decomposition and coherency slices will bring out subtle features what cannot be resolved through seismic volume.

The 3D seismic volume is useful in defining architectural elements of large-scale features like channels, over bank deposits and lobes (Macro level). They can be seen in a seismic sections passing through these bodies. Fig 1 shows typical channel levee systems at different stratigraphic levels with high amplitude reflections (HAR) within the channel. The High Amplitude Reflection Packets (Fig.1) at base of CLS are hummocky and mounded reflections with poor to fair continuity and variable amplitude. The hummocky and mounded facies below channels are interpreted to be disorganized slides and debris flows deposited prior to the development of the channel. These seismic facies interpreted as Mass Transport Complex, which has highly compacted sediments of variable grain sizes.

With the help of seismic facies and internal principal architecture the channel-levee systems can be classified as Mud, sand or mixed Systems (Reading and Richards, 1994). Several seismic facies of deepwater channel levee system have been discussed by Mitchum et.al. (1977). Channel valley is defined as the general trend of the individual

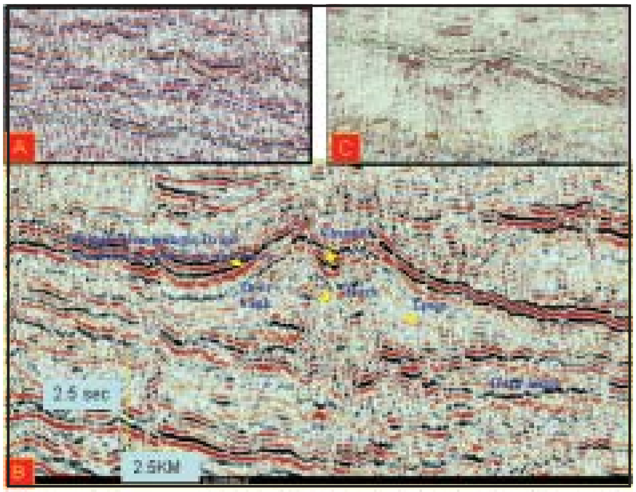

Fig.1: Typical channel levee systems at different stratigraphic levels showing different elements

channel, down fan. They consist of the zone of high amplitude reflection (HAR) and other facies lying in between the flanking levees. The CLS consists of hummocky to sub parallel HAR, flanked by levees with sub parallel to slightly convergent reflections with moderate to high amplitude. The lateral migration of HARs in the CLS probably reflects migrating channels at different times. In Fig.1 we see the older HARs are in the western portion then moved to east then to central part. The relative younger HARs are confined to the central part with smaller oscillations. This initial and final positions of HARs reveal a migrating pattern for channel evolution. The average peak amplitude map shows higher values concentrated in central to eastern part of CLS. The depression within the channel is flanked by topographic highs of the proximal levee, which slopes down towards the distal part. The continuous and high amplitude reflector enveloping the CLS is of a marine condensed section. The HARs within the channels in plan view will reflect continuity/ discontinuity of reservoir facies. HAR may develop due to presence of isolated bodies having relatively coarser sediments. These HARs with concave upward shapes indicate possible presence of coarser sediments at the center. However, convex upward HARs may form due to post depositional modifications.

The thickness map of the channel – levee systems can be used for broad understanding of the depositional set-up. The channels generally show low thickness, flanked by high thickness in the levees. Sinuosity of the channels may suggest whether the area falls in upper, middle or distal part of the fan. The sinuosity of a channel increases as it moves down from the proximal to distal part of the fan (Wiemer 2004). The thickness maps do give the idea of preservation of these bodies and show breaches in the levees, erosion of channel as well as levees, if any (Fig.2).

Window-based amplitude attributes like Absolute Average Amplitude maps shows the relative higher

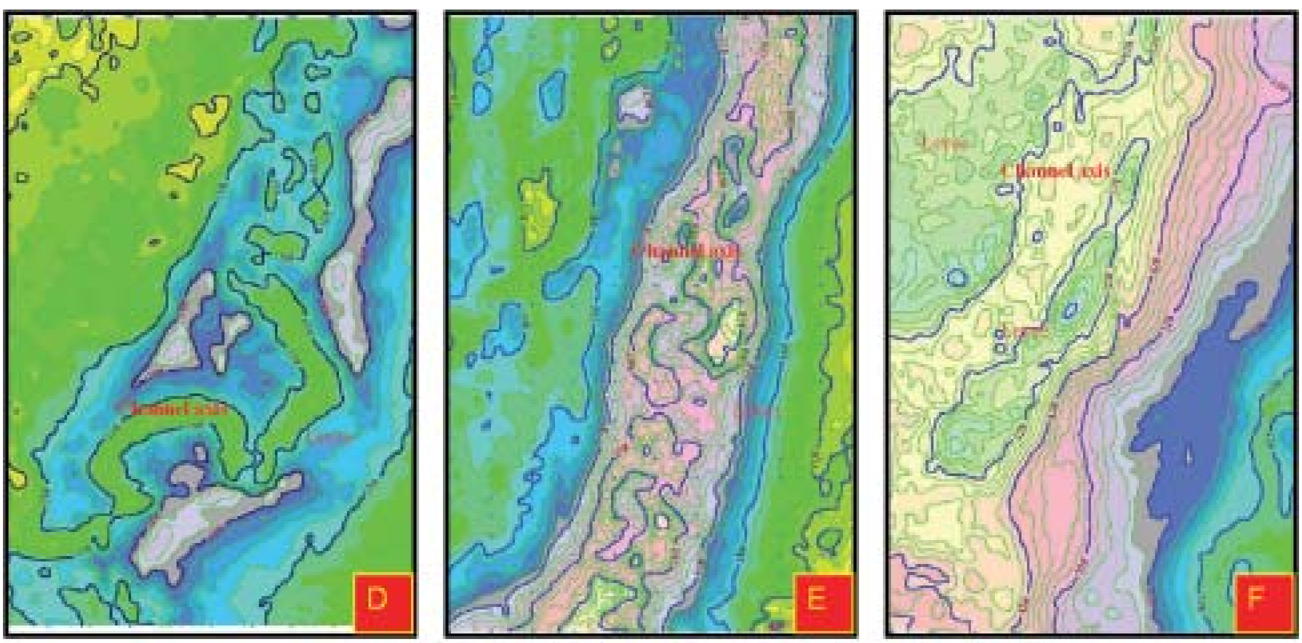

Fig. 2: Thickness maps between base and top of channel-levee systems at different stratigraphic levels (D to F in order of younging) (areal coverage 40 Km X 25 Km.)

amplitude distribution interpreted as coarser sediment distribution along the channel (Fig 3 G,H,I) and over levees as over bank deposits (Fig 3 J). Time slices also show the distribution of high amplitude in a particular plane indicating likely presence of coarser sediments along the channel. Fig 4 shows HAR packs within a channel in seismic section and their distribution pattern along a particular plane in a channel. The HAR packs seen within channels in seismic sections represent a composite configuration generated by amalgamation of a number of channels present at different time planes. Amplitude extraction and spectral decomposition slices from smaller time windows reveals the presence of the minor channels within the channel complex (Fig. 5) as seen in seismic sections. A comparison of the distribution of coarser clastics and their possible charging within the channel complex can be made by comparing the amplitude pattern in successive windows. Presence of number of minor channels within the master channel can be revealed through extraction of horizon based amplitude (Fig. 6).

Gelogical interpretation

In seismic sections as well as in the amplitude maps, presence of high amplitude is observed in the channel fills and in the proximal levees indicating presence of coarser clastics deposited by flow stripping (Weimer, 2004). Generally the percentage of coarser clastics decreases towards the distal part of the levee. After abandonment, the channel levee system is enveloped by pelagic/hemipelagic sediments forming condensed section. These condensed sections are characterized by high amplitude seismic events

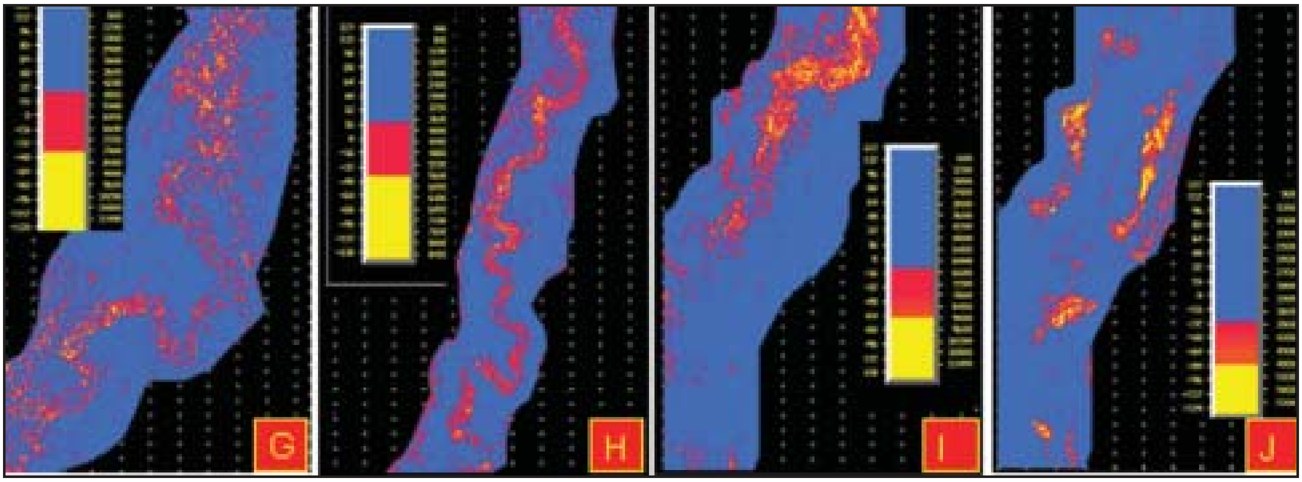

Fig.3 : Average absolute amplitude maps showing channels and levees at different stratigraphic levels. (G to I show channels in order of younging , J shows levee in the youngest CLS) (areal coverage 40 Km X 25 Km.)

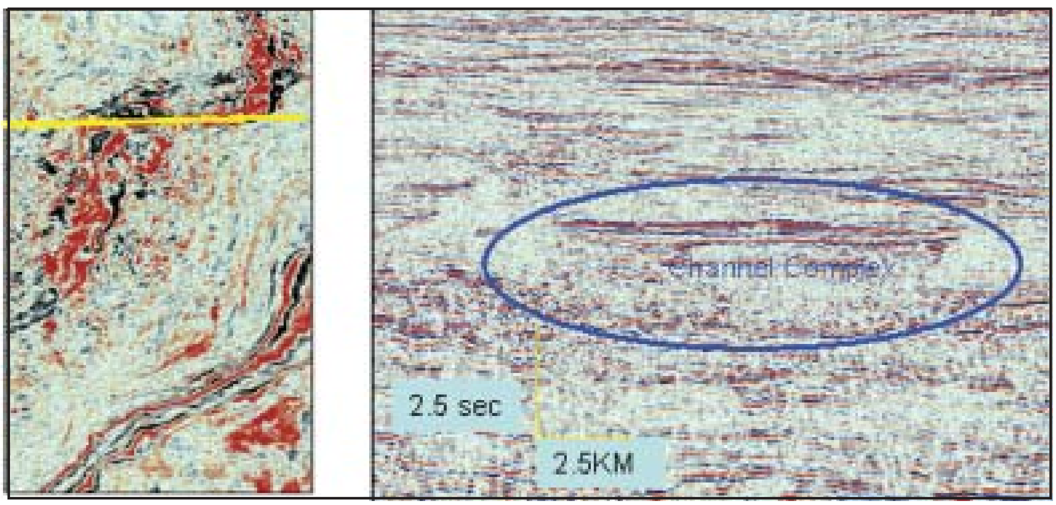

Fig. 4: Distribution of high amplitude reflection in time and space within the channel in CLS 1. K (25 km X 15 Km) – Time slice showing top part of the channel, L – Seismic section showing amplitide distribution within channel.

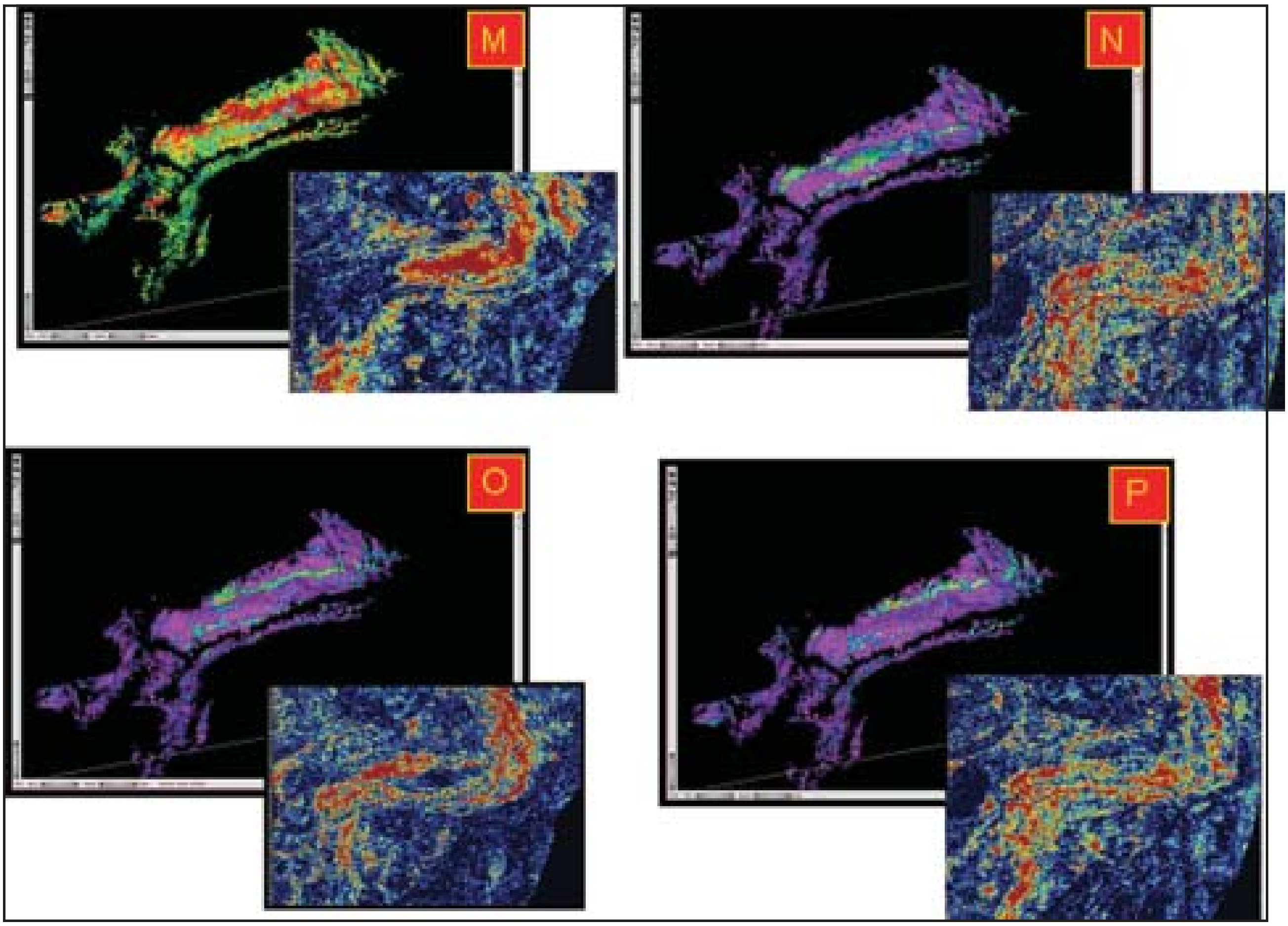

Fig. 5. Voxel view of different channels within CLS 1. Inset shows respective spectral decomposition slices. P - M show channels of younger generation with variations in amplitude distribution. Spectral decomposition slices reveal ribbons (P), Bypass (O), anastomosing (N) and bending inrespective channels.

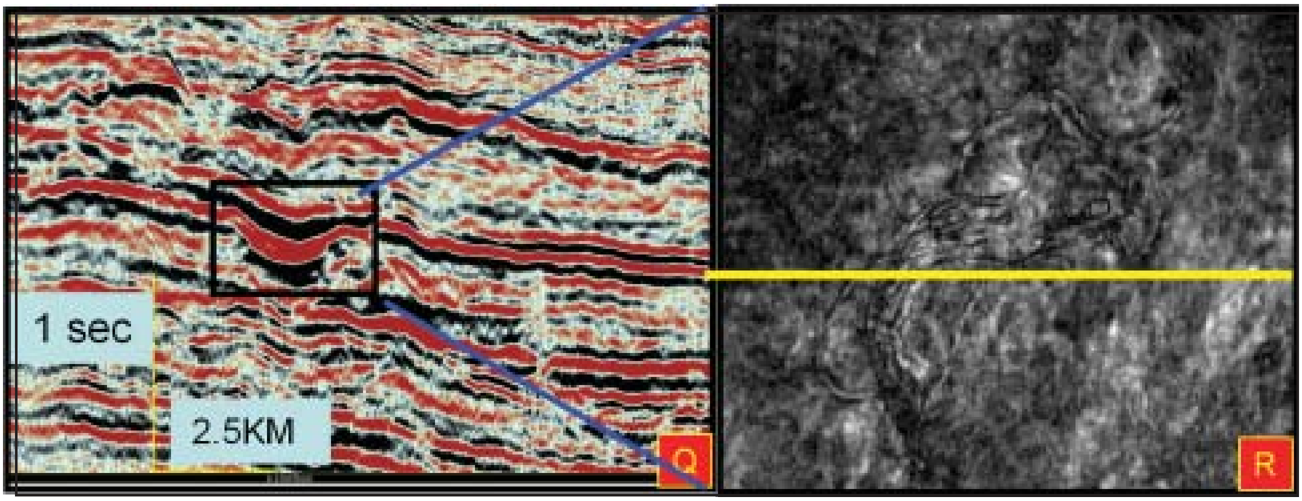

Fig 6. RMS amplitude derived from horizon slice (event shown in black box in Q) showing anostamosing channels (R)

with good lateral continuity. Spectral decomposition analysis at different levels reveals a number of subtle channels and crevasses splays. The crevasses splays may contain reservoir grade clastics. Fig 5 shows different stacks of channels within the CLS. The spectral decomposition slice (Fig. 5M) shows bending of the channel which are the favorable sites for accumulation of coarser clastics. High amplitude observed in this part may be interpreted as hydrocarbon charged geobody. Spectral slices showed in Fig 5 N, O, and P reveals thin ribbons within the master channel indicating presence of discontinuous thin reservoir bodies. Voxel views of extracted amplitudes show shifting of the reservoir bodies in time and space. In RMS amplitude maps (Fig. 6 R) older anastomosing channel pattern is seen within a seismically resolved channel (Fig. 6 Q). This phenomenon suggests oscillatory migration of the channels.

Conclusions

Seismic volume reveal deepwater channel levee complex by their distinguishing features.

- With the help of seismic facies and internal principal architecture the channel-levee systems can be classified as Mud/Sand/Mixed System.
- The hummocky and mounded facies below channels are interpreted to be disorganized slides and debris flow deposited prior to the development of channel.
- Channel occupies the central depression of the complex whereas the proximal levees generally formed topographic highs on their flanks.
- Presence of coarser clastics in channel fills, proximal levees, crevasse levees are generally characterized by high amplitude reflections.
- The subtle features like anastomosing channels, splays etc. can be revealed through window-based attributes and spectral decomposition slices.
- Volume visualization helps in understanding possible reservoir distribution through time and space.

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Views expressed in this paper are that of the author(s) only and may noy necessarily be of ONGC.

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