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Shale Gas Evaluation of Cambay Shale Formation in Tarapur Syncline, Cambay Basin, India – A Seismo-geological approach

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Summary

The technological success of Shale Gas exploration and exploitation in USA has encouraged several countries for the development of "Shale Gas Play", which has the potential to change any nation's natural gas demand-supply scenario. The potential of this "Game Changer" has already been established approximately by various international agencies. Owing to this, an attempt has been made through the present study, to evaluate the potential of Cambay Shale Formations that would form as attractive targets for Shale Gas exploration in Cambay-Tarapur tectonic block. A multi-disciplinary approach in the study has so far led to the identification of at least three source rocks, which are widely distributed in the entire study area and shows considerable thickness with high shale gas potential.

Keywords: *Shale Gas, Source Rock, Cambay Shale Formation, Tarapur Syncline, Cambay Basin*.

Introduction

The Cambay Basin is an intra-cratonic basin, located along the western continental passive margin of Indian platform, in the western Indian state of Gujarat (Fig. 1). The evolution of this basin is essentially related to the break-up of the Gondwana super-continent, followed by drifting, which resulted in the initiation of rift grabens and the counter-clockwise movement of the Indian Craton (Fig. 2).

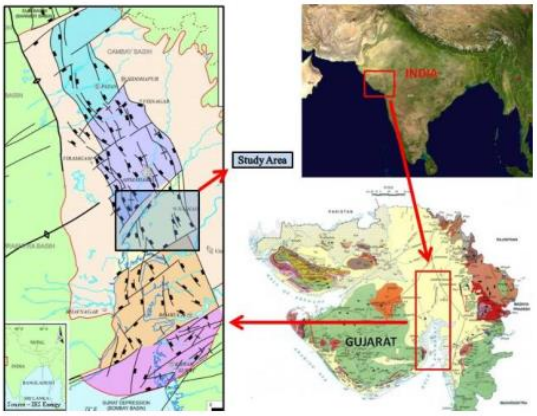

Figure 1: Location Map of the Study Area.

The configuration of this Tertiary basin is controlled by three major tectonic trends of Pre-Cambrian Era viz. Aravalli (NE – SW), Satpura (ENE – WSW) and Dharwar (NNW – SSE) (Biswas, 1982). Based on the fault system, the Cambay Basin has been divided into 5 tectonic blocks, with their unique structural styles and patterns. Cambay- Tarapur block, wherein the study area forms a part, is one such tectonic block.

The Cambay basin is important from the point of view of oil and gas exploration as significant discoveries within this basin has placed it at the forefront of the Indian oil industry. Kalol, Sanand, Nawagam, North Kadi, Sobhasan and South Kadi, Hazira, Santhal-Balol-Lanwa heavy oil belt and Gandhar are some of the major oil/gas discoveries. In Tarapur-Cambay Block, all components of Petroleum system exists, however, the discoveries are few in number and that too on the peripheries only. The block is a major depocenter, embracing maximum thickness (3000+m) of Cambay Shale Formation, which is the primary source rock in the region. This has given a momentum to look into the Cambay Shale Formation in detail and establish the presence of "Shale Gas" adsorbed and trapped within the source rock.

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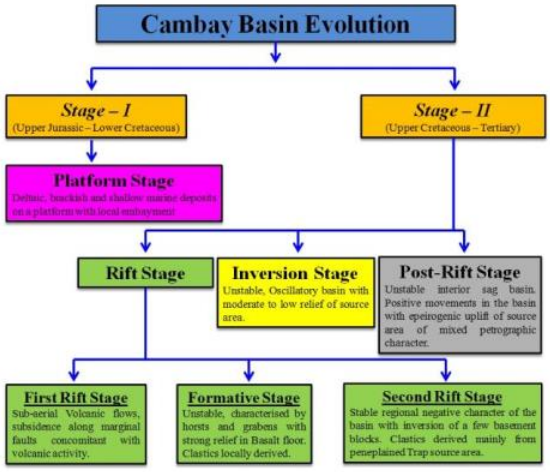

Figure 2: Stages in evolution of the Cambay Basin (Adapted from Chowdhary, 2004).

Geology

The study area, consist of a complete Tertiary sequence, ranging in age from Palaeocene to Holocene, sub- surfacially (Fig. 3). The Tertiary sequence rests over thick basaltic lava flows of Cretaceous age, which are, in turn, underlain by a Mesozoic sequence.

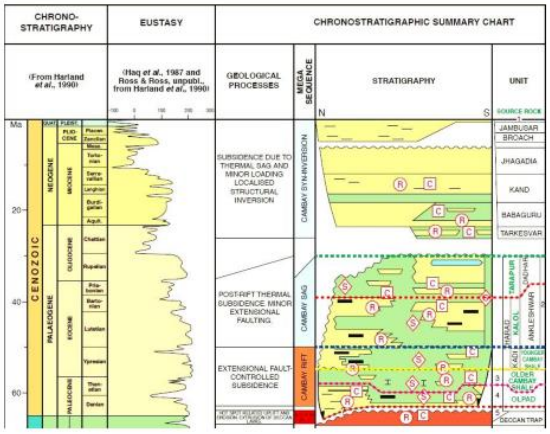

Figure 3: Generalised Stratigraphy of the Study Area.

Cambay Shale Formation (Upper Paleocene – Lower Eocene) – This unit comprises of a thick shale sequence overlying the Olpad Formation (Lower Paleocene – Lower Paleocene), with unconformable/gradational contact and underlying the Kalol Formation (Middle Eocene) (Fig. 4). This formation is deposited during the first major marine transgression of the basin in the late Palaeocene-early Eocene times and represents the primary source rock in the study area. The formation is dark, fissile, rich in organic matter, pyritic in nature and often carbonaceous. The Cambay Shale Formation has been divided into two units – the Lower (or older) Cambay Shale and the Upper (or Younger) Cambay Shale, which are separated by an erosional unconformity – known as neck marker on electro- logs (Pandey and Dave, 1998). The nature of the clasts suggests that the deposition took place in a transitional (lagoonal/paludal) to shallow marine environment (Chowdhary, 2004).

Methodology

An integrated and multi-disciplinary approach is used in the present study.

- All the 2D and 3D seismic data pertaining to the study area were loaded in interpretation software.
- The seismic data was calibrated using the available VSP and check-shot data and simultaneously, synthetic seismograms and time-depth relations were generated for all other drilled wells within the study area.
- The Cambay Shale Formation (Upper as well as Lower) was identified and interpreted in this seismic data in order to delineate the extension and distribution of the same in the study area.
- Detailed petrophysical analysis of drilled wellsswas carried out to identify the organically rich and matured "target" shales within the Cambay Shale Formation.
- These "target" shales were mapped to understand their distribution in the study area.

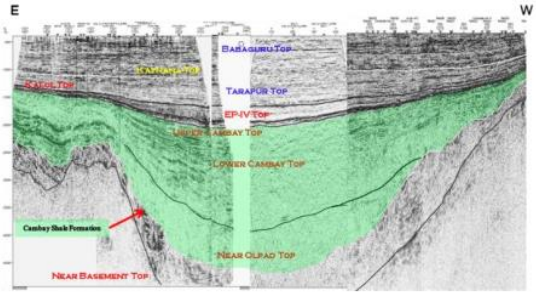

Figure 4: E – W Profile of the Study Area.

Results

A detailed petrophysical analysis of all drilled wells was carried out and the organically rich shale units were identified in the Cambay Shale Formation. Total Organic Carbon (TOC) content as well as Vitrinite Reflectance

(VRo) logs was generated from the well logs, which were calibrated with the available core data. The zones with TOC > 2 wt% & VRo > 1.0 were then identified and demarcated. Further, these high TOC & high VRo zones were transformed in the seismic data with the help of synthetic seismogram. The seismic facies corresponding to high TOC and VRo were mapped in the entire study area. Three such identified horizons namely, SG-1, SG-2 and SG-3 were mapped in the study area (Fig. 5, 6 & 7).

All three organically rich shale horizons (SG-1, SG-2 & SG-3) show similar disposition pattern. They have a well- marked variation in the thickness of their deposition. The basin configuration shows significant shallowing towards the western, northern and southern part and the deepest part is exactly at the centre of the study area. The top of SG-1 surface, oldest of all, ranges between -1700ms at the margins and reaches up to -4100ms at the basinal lows. The top of SG-2 surface varies from -650ms at the margins to - 2750ms at the basinal lows. The top of SG-3 surface, youngest of all, shows a value ranging between -650ms at the margins and reaches up to -2150ms at the basinal lows. The study area has received sediments from four different directions viz., east, west, north and south, each with different provenance and thereby shows different characteristics. The results derived from petrophysical analysis advocate this piece of evidence. All three source rocks are widely distributed across the entire study area and shows considerable thickness.

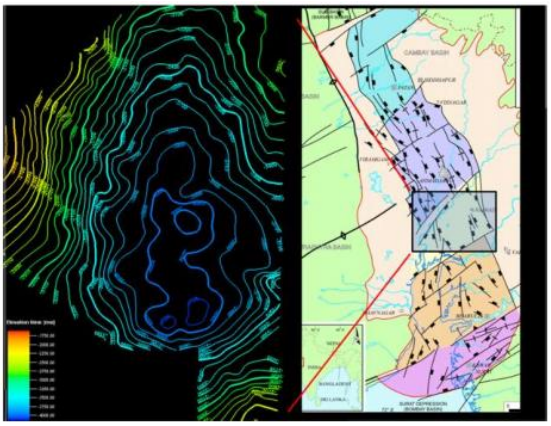

Figure 5: SG-1 Top surface map in the Study Area.

Conclusions

The study carried out in the Tarapur – Cambay tectonic block shows the presence of multi-directional depositional system. The depocenter has received sediments from all the four directions. Geochemical/Petrophysical results also corroborate this result with different TOC/VRo values. Further, at least three organically rich (high TOC and high VRo content) source rock units have been identified within the Cambay Shale Formations. All these three source rock units are widely distributed across the entire study area and shows considerable thickness. The TOC and VRo is estimated based on the well data, which are drilled on the periphery of the basin, therefore, there it is probable that many more source rock units are present at the central part of the study area, which is having more maturity due to the prevalence of high overburden pressure and temperature due to high geo-thermal gradients. However, more drill- cutting samples, core data and geo-chemical data are required to establish correct picture of the shale gas reserves within the study area. In addition to this, the data established from the drilled well within the study area, suggest that the Olpad and Tarapur Shale Formations, which are not dealt with in the present study, also have potential for Shale Gas accumulation.

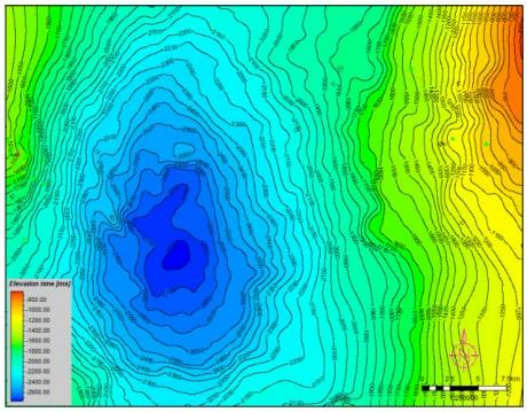

Figure 6: SG-2 Top surface map in the Study Area.

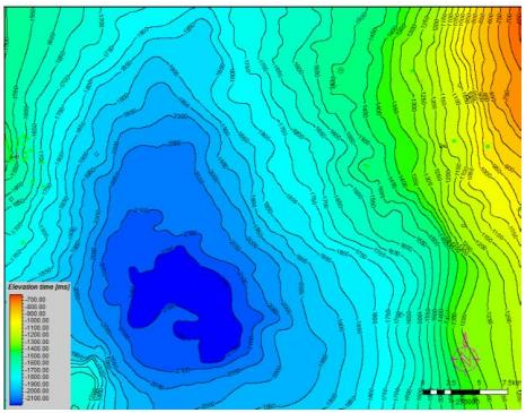

Figure 7: SG-3 Top surface map in the Study Area.

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