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Occurrence of carbonate build-ups within Cretaceous-Paleocene volcanics & its significance in hydrocarbon exploration in deep water area of Kerala-Konkan Basin, West Coast of India

Abstract

Kerala-Konkan basin has been elusive in terms of discovering hydrocarbons, in spite of exploratory inputs spanning over nearly four decades. Understanding the sedimentation style and identifying a petroleum system has been difficult due to two episodes of volcanism. In pursuit of sub-basalt Mesozoic basin and petroleum system, many wells have landed in thick sequence of basalts against the prediction of sediments. Recently, drilled well in southern part of deep water of Kerala-Konkan basin has encountered a layer of 85m of carbonates within a drilled section of 1270m of volcanics. The carbonate facies (packstone and occasional boundstone) with coralline algae, bryozoan and foraminifera is indicative of shallow marine high energy depositional environment.

In the mapped seismic sequences, the carbonate interval matches with a regional marker coinciding with the Cretaceous-Paleocene boundary (KTB). In shelf area one well has confirmed Late Cretaceous (Santonian-Maestrichtian) sediments with a recorded unconformity at Cretaceous top, overlain by finer clastics and thin carbonates of Early-Late Paleocene age. The volcanic sequences in deep water occur as wedge shaped body with growth accommodation along major continent ward dipping faults and has created flexural/rollover highs over which the carbonate body exists.

Overall faunal and textural characters signify the growth of carbonate buidups on paleohighs over the Cretaceous unconformity represented by break in Late Cretaceous volcanism in deep water area.

The carbonates possess moderate porosity at certain intervals indicative of fair reservoir potential to hold hydrocarbons. Absence of hydrocarbons in this well as well as nearby wells raises a question for a viable petroleum system in deep water due to occurrence of thick volcanics and absence of potential source rocks.

Introduction

Kerala-Konkan basin, part of western continental margin of India is a passive margin evolved through rifting and separation of various continental masses viz. Africa, Madagascar and Seychelles. Two episodes of volcanism have been established related to Madagascar separation (Marion Hotspot) and Seychelles separation (Re-union hotspot track). Sedimentation history begun as early as Jurassic period corresponding to African separation, but wells drilled till date have penetrated sediments upto Late Cretaceous only.

Hydrocarbon exploration activity by national and private companies for nearly four decades has generated good amount of data and their analysis by several geo-scientists has helped in understanding the stratigraphy, sedimentation and tectonic history of the basin. Still there are some grey areas. The Pre-Tertiary geological activities are less understood as only a few wells have penetrated through the trap to establish Mesozoic province

One well recently drilled in deep water area to prove the envisaged Mesozoic half-graben system, has passed through thick section of trap with intervening 90m of carbonates. This paper analyses this carbonate succession vis-a-vis volcanics by integrating seismic, log and laboratory data. Emphasis is also given to understand the origin and its suitability as good reservoir for hydrocarbon entrapment.

Data & Methodology

The study area lies in the southern part of Kerala-Konkan basin where six wells in shelf area and three wells in deep water area have been drilled (Fig.1). Over the years number of seismic API campaigns

have been taken up including important GXT (2006), long-offset (2009, 2012). For this study the long offset seismic data having 12km offset and 10 sec record length has been utilized for better visualization and interpretation of the pre-Tertiary section. The electro-logs, sedimentological and biostratigraphic data of few key wells were taken in to consideration. The information from the latest well B in deep water is the key in present analysis.

The lithological, biostratigraphy and log data of shelfal well A and the deep water well B has been integrated with the seismic data so as to correlate different depositional sequences and find out the temporal and spatial variations of sedimentation vis-à-vis volcanism from shelf to deep water.

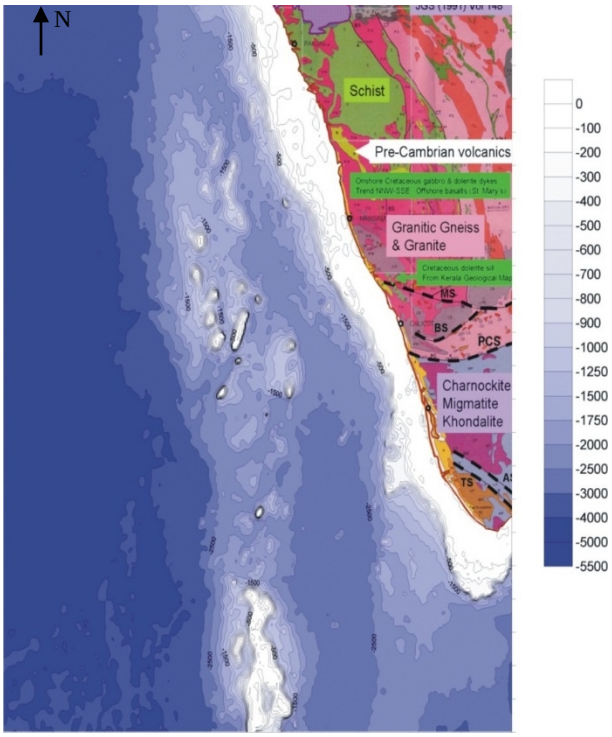

Fig.1: Location map of Kerala-Konkan Basin showing the seismic line and well (Bathymetry & onshore geology in the background)

Well Data

The well A drilled in the shelf has proved the presence of about 700m of Late Cretaceous (Santonian-Maestrichtian) sediments with thin (about 20m) Paleocene trap and terminated in thick section (600m+) of older traps (90Ma). The sediments of Late Cretaceous section are represented by thin trapwash to red claystone at the base overlain by dominantly calcareous sandstone and siltstone facies with thin shale layers (Fig.2). Depositional environment for the succession is open marine middle to outer shelf with a bathymetry of 200m. Towards top the bathymetry shallows with deposition of sandstones and an unconformity with a duration of 1.8 Ma has been recorded at the Cretaceous top (Ravindran et al., 2006). Overlying the unconformity 65m thick highly fossiliferous Early Paleocene finer clastics with planktic

foraminifera along with thin limestones representing deeper marine conditions(>200m) were deposited. The Late Paleocene sequence represented by shale, limestone and thin basalt was deposited in a shallow shelf setup.

The well B has been drilled to a depth of 4874m in a deep water set up at water depth of 1578m (Fig.2). It encountered significant thickness of volcanics from 3560m with intervening 85m carbonate in the interval 4540-4625m. The basalt below the limestone is light grey, moderately hard, fine to medium crystalline with amygdaloidal nature. The basalt overlying the carbonate shows distinct layered nature with frequent intertrappeans consisting of volcaniclastics/ tuffs with high gamma characters. These basalts exhibit a different relatively softer, brittle and altered facies. The gamma ray character also shows variations with lower readings and less serrated as compared to the basalt below the limestone.

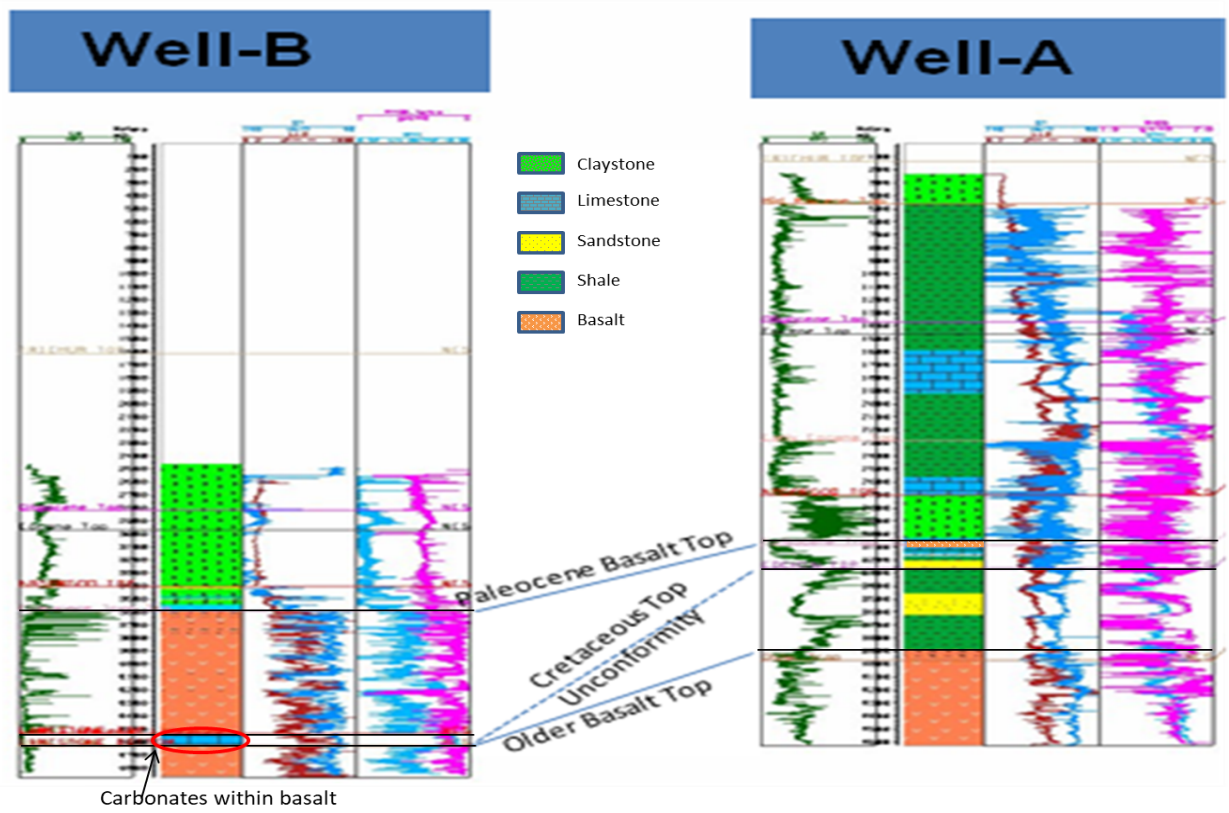

Fig.2: Log correlation and the lithology encountered in the Well A & B.

The carbonate interval between the two basalts is represented by high energy grain dominated foraminiferal-bryozoan-algal packstone with bioclastic wackestone towards bottom part (Dave et al., 2014). Even though fragmented red algal grains dominate the carbonate constituents, at places these algae along with bryozoans show encrusting nature with insitu growth framework features (Figs.3A & B). The fossil grain composition and the textures point the carbonate deposition in low energy condition and own with build-up features characterized by growth of encrusting algae and bryozoans in a high energy set up. The fragmental nature with packstone texture is due to break down of algae due to wave action and bio-erosion.

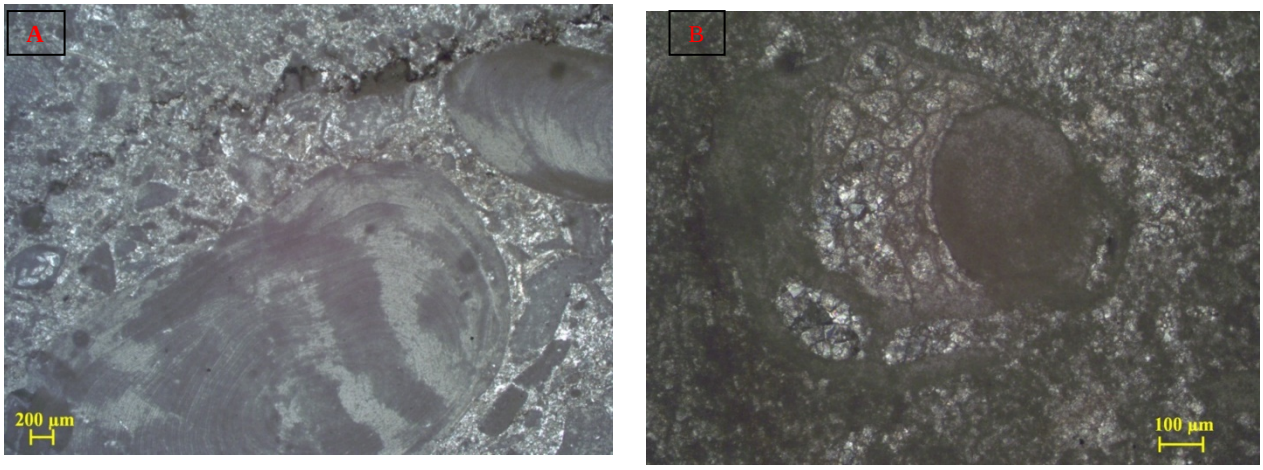

Fig.3: A.Photomicrograph of algal packstone showing algal fragments and algal pisolites along with few foram grains. B.Photomicrograph of algal-bryozoan showing encrusting and insitu growth of carbonate secreting organisms.

Seismic Facies & Sequence Analysis

The new long-offset data having 10 seconds record length has brought out the some of the pre-Tertiary reflections including the crustal events. The Paleocene trap top is correlatable across the basin. While observing from deep water regime reflection packages are distinctly seen to be wedging out towards shelf area and finally becoming absent (Figs.4&5). Two wedge shaped bodies with a clear-cut reflector in between are observed. The well B has completely penetrated the upper wedge and only top part of the lower wedge. The carbonate layer overlying the lower wedge shows transparent to chaotic seismic reflection. Areal extent of these reflections are limited and restricted only to the crestal part of the structure at Cretaceous Top reflector. The wedges mostly consisting up of volcanic layers with thin inetrtrappeans of volcaniclastics and tuffaceous material shows high amplitude parallel reflections. The wedge-shaped body is developed by a continent ward dipping fault with growth accommodation near the fault, creating flexural fold away from the fault (Figs.4A, B & 7) (Das et.al., 2015). The sites are filled with volcanic rocks as it lies at an active volcanic margin due to shallowing up of Moho and easy source of magmatic material through the continent ward dipping major faults.

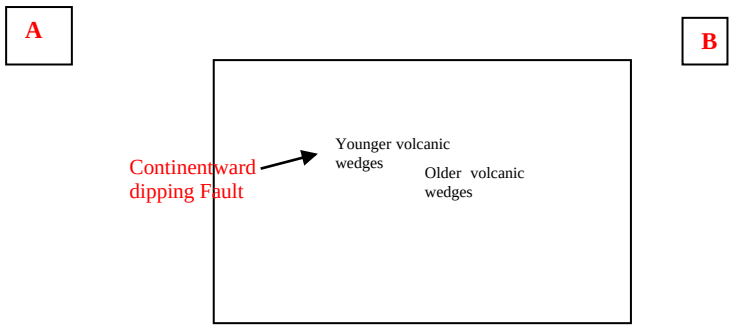

Fig.4: A. NE-SW seismic section showing crustal boundaries and overlying wedge type reflection with strong reflector in between older & younger packages. B. NE-SW seismic section showing close view(rectangle area of Fig.4A) of the wedge type reflections with strong reflector in between older & younger packages and the carbonate in between overlying the older package at Well B.

Fig.5: Seismogeological section showing stratigraphic units and structural disposition with the carbonates growth over the flexural highs (red dashed circle) (Figure from Das et.al., 2015)

The 85m carbonate layer sandwiched between the two basalts is significant as it represents a break in volcanism and corresponds to a conducive environment for carbonate growth.
The well A in shelf area has shown that after the Cretaceous top unconformity, deposition of shale, siltstone and limestone took place in water depth up to >200m during Paleocene and have given the clues that the basin was under widespread marine transgression resulting in carbonate growths in shallow platforms and isolated highs.
This carbonate occurs at the boundary of the regional seismic marker close to top Cretaceous. Flexural highs are responsible for creating shallower bathymetry than the surroundings for growth of carbonate secreting organisms.

Dominance of red algal and bryozoan grains in the facies also suggest an original insitu growth frame building and subsequent reworking and fragmentation in an overall high energy environment.

Reservoir Properties & Hydrocarbon Prospectivity

The log and litho-microfacies of the carbonates show indurated tight nature with at places moderate porosity. The depositional nature and facies criteria of these carbonates are suggestive of presence of a good reservoir. Even though these carbonates can act as good reservoir, the occurrences within thick sequence of volcanics particularly in deep water areas make them poor targets due to absence of source rock and a petroleum system. Homotaxial section in shelfal area with presence of limestones along with shales and underlain by Late Cretaceous sediments can form suitable targets for hydrocarbon exploration.

Conclusions

- The strong reflector between the two volcanic wedges marks the top of Cretaceous and separates the older and younger basaltic activities in the basin.
- This is a well-defined KTB unconformity in the shelfal well A at the top of the Late Cretaceous and in deep water area corresponds to top of the Lower volcanic wedge.
- The carbonate deposition before the onset of younger volcanic activity represents marine transgression conducive for carbonate sediments in shallow platform and volcanic highs.
- The accommodation style of the older volcanic wedges has flexural highs away from the continent ward dipping fault and has been ideal locale for the growth of carbonate.
- The dominant carbonate grains of coralline algae and bryozoans also suggest a buildup facies development and subsequent fragmentation in a high energy condition.
- The carbonates can act as good reservoirs in the area but the dominance of volcanics raises a doubt about the presence of source rocks particularly in the deep water of Kerala-Konkan Basin.

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