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Possibility of CO_2 Sequestration in Basalt and Sub-Basalt Sediments in and Around Peninsular India

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ABSTRACT
The present study brings out the recent geological findings concerning Cretaceous volcanism. These findings are very significant, not only for hydrocarbon exploration, but also in CO_2 sequestration in vast areas in and around peninsular India. The peninsular India is transected by several rift and grabens extending to offshore areas, which started subsiding since the beginning of Proterozoic times. During Proterozoic period sedimentary rocks were deposited within rift and grabens. This phase was followed by deposition of coal bearing sediments during Gondwana period, when the central parts were down faulted. The Cretaceous volcanism has taken place in pulses along these rift and grabens. These phased depositional episodes are more pronounced in their intersectional areas. The volcanic units are inter-layered with thick marine sediments in offshore regions and inter-trappean beds inland areas. The entire package of volcano-sedimentary rocks is sandwiched between the older Mesozoic and younger Tertiary sediments. This package laterally extends from land to offshore and beyond to the oceanic regions, covering the entire Bay of Bengal and the eastern half of the Arabian Sea.

INTRODUCTION

The Cretaceous volcanism comprises several felsic and mafic units, which are interlayered with sedimentary successions and represent entire ninety million years, from the beginning to the end of Cretaceous. These volcano-sedimentary sequences are invariably present in both producing as well as potential petroliferous basins of peninsular India. The producing basins include Barmer-Cambay, Bombay off-shore, Kaveri, Krishna-Godavari and Mahanadi. The potential basins include Kutch-Saurashtra and their off-shore components, Deccan Volcanic Province (DVP) of Maharashtra and Madhya Pradesh, Kerala, Mannar, Bengal oceanic basins with oceanic ridge components.

Earlier, it was not possible to ascertain the lithological characteristics of volcanic units and underlying sediments. Seismic studies for hydrocarbon exploration followed by drilling contributed significantly to our understanding of lithological characteristics and stratigraphy. Pre-Stacking and Depth Migration (PSDM) and Pre-Stacking and Time Migration (PSTM) processing techniques have facilitated better understanding of sub-basalt stratigraphy. The basaltic units form technical basement, over which uninterrupted Tertiary sequences are deposited on land, offshore and oceanic regions have been noticed in different parts of the globe, including India. The heat coming up along fractures provided environment for hydrocarbon generation. These fractures were later sealed by the flowing lava to provide an ideal trapping mechanism. The primary porosity of vesicles and cavities in basalts and secondary porosity developed due to cooling and fracturing, holds a fairly good amount of hydrocarbons in them. The space created by extraction of hydrocarbons in the volcano-sedimentary package can best be utilized for CO_2 sequestration and enhanced recovery. In the present study all the basins and areas containing Cretaceous volcanic sequences, whether occurring on land, subsurface or oceanic regions, have been taken into account. Attempts have been made to map the lateral continuity along with the underlying and overlying sequences. Drill hole logs available from hydrocarbon exploration, have been utilized to know the thickness and nature of such volcanic units.

CRETACEOUS VOLCANICS AND CO_2 SEQUESTRATION

Earlier the volcanic flows exposed in the Deccan region of western India, were described as the Deccan Traps. Field mapping assisted by aerial photographs and satellite imagery (Misra, 1999, 2002, 2007) has brought out that the Deccan Traps form only a very small portion of Cretaceous volcanism. They cannot be stratigraphically separated from the other units, as they have similar petrological characteristics and wedge into each other. Recent studies (Misra and Misra, 2010; Misra and Joshi, 2013; Misra and Misra, 2013) have shown that in all the cases, entire package of stratigraphic successions laterally continues from land to offshore and later to oceanic regions. They cover almost entire Bay of Bengal in the east and up to Lakshadweep ridge in the west (Fig. 1), and are overlain by an uninterrupted Tertiary sequence. It has emerged that tectonic activity has largely affected rocks up to the Cretaceous period.

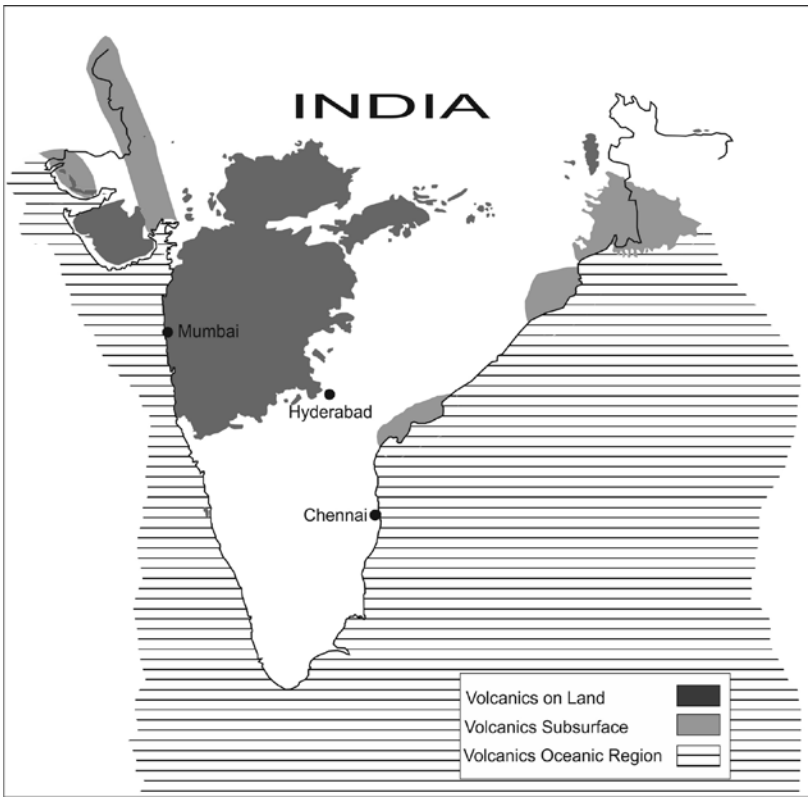

Figure 1. Outline map of Peninsular India, showing the distribution of Cretaceous volcanic units on land, in offshore and oceanic regions. (After Misra and Misra, 2013)

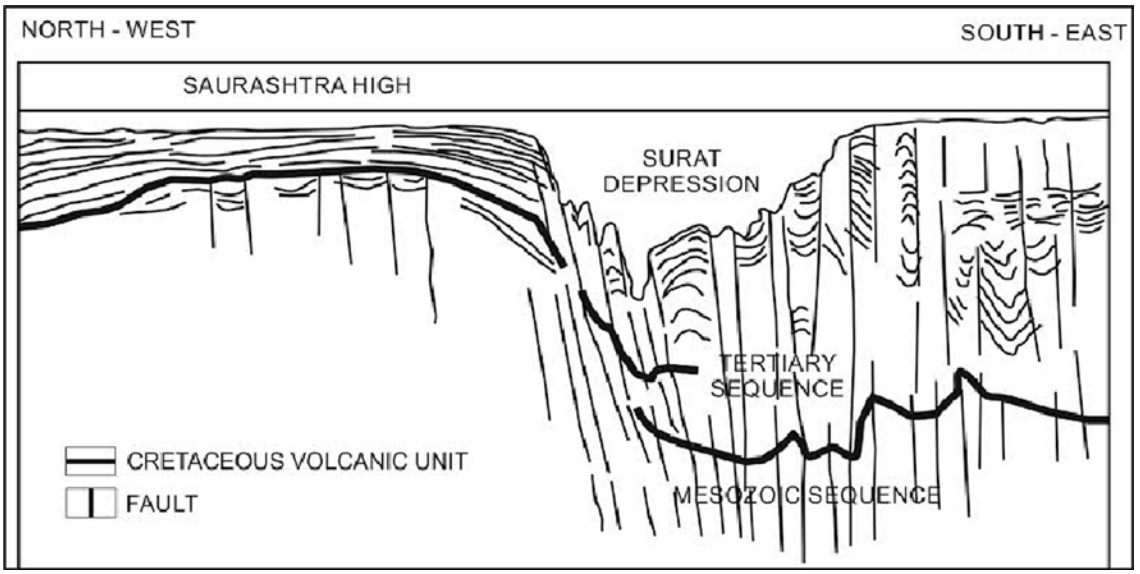

Figure 2. Interpretation of seismic profile across Narmada-Tapti Tectonic Zone in offshore region. Subsidence of blocks along vertical faults has increased the thickness of Tertiary sequence. (Modified after Misra and Misra, 2010)

A series of technological developments have significantly improved our understanding of structural disposition of Cretaceous volcanics. These developments include, improved resolution of multispectral and radar satellite imagery; processing of seismic data by PSDM and PSTM techniques. Pre-stack partial migrations are required when there are conflicting dips with varying velocities or a large lateral velocity gradient (Gadallah and Fisher, 2009). Interpretation of these seismic profiles (Fig. 2) has helped to not only estimate the thickness of volcano-sedimentary

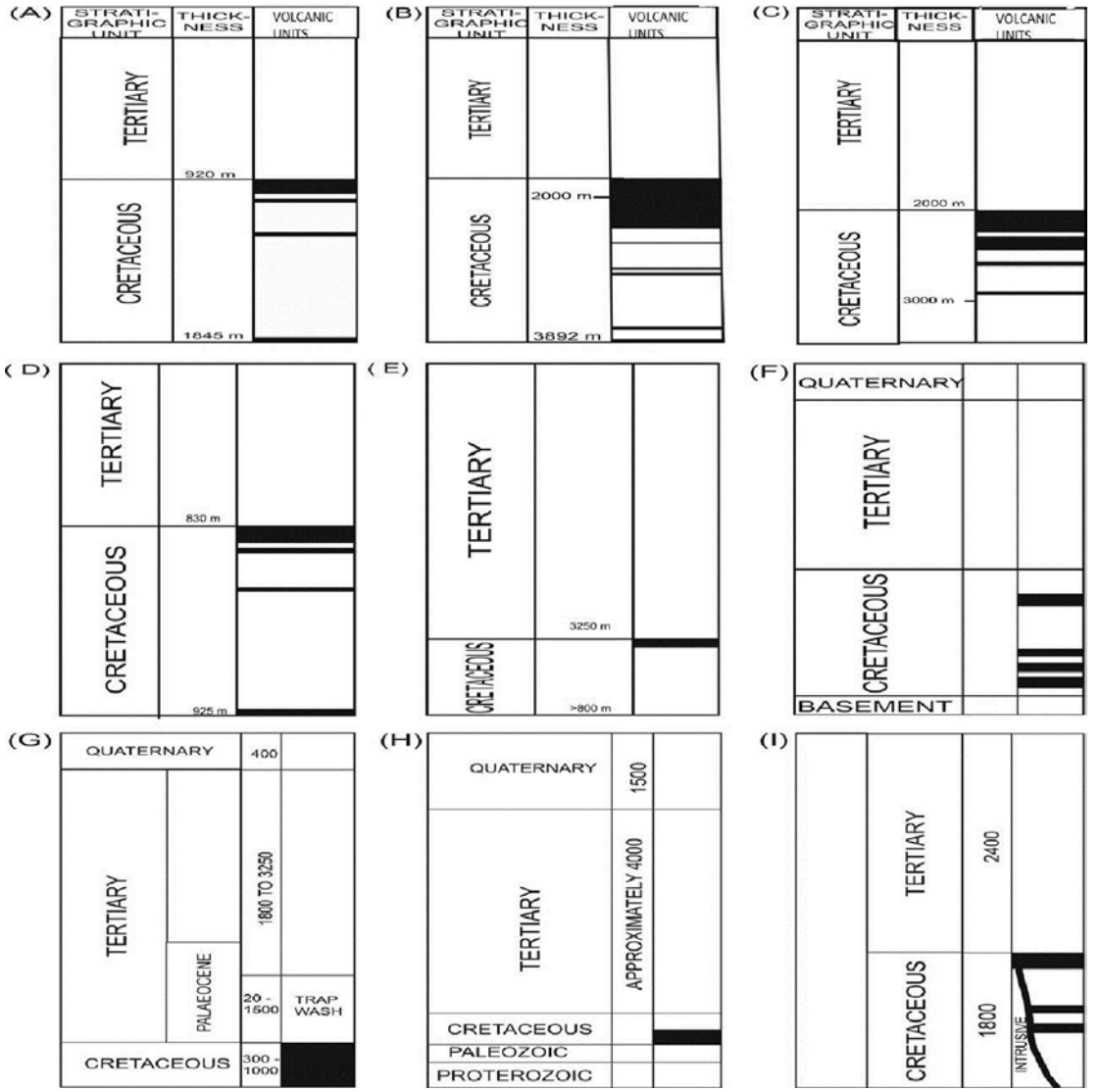

Figure 3. Generalized well logs of different basins, added and modified after Berger, et al., (1983), Fig. 3A Off-shore Kutch, Fig. 3B On-land Kutch, Fig. 3C. Off-shore Saurashtra, Fig. 3D. Cambay basin, Fig. 3E Krishna-Godavari basin, Fig. 3F Off-shore Mahanadi basin, Fig. 3G Lakshadweep basin, Fig. 3H Bengal basin, Fig. 3I Andaman basin.

sequence but also the details of underlying older sediments. Furthermore, innumerable borehole logs obtained during hydrocarbon exploration, have also established that the Cretaceous volcano-sedimentary sequence is integral part of stratigraphy in all the basins (Fig. 3). Evidences suggest that eruption of volcanic units have taken place along the major rifts and grabens, transecting the peninsular India (Misra, 2008). Both Mesozoic and Tertiary sequences along with the volcanic units are thicker in intersectional areas, due to compounding effects of subsidence along them. The temperatures of volcanics are estimated to have been around 750° to 800° C. These lava units spread over the earlier Mesozoic successions have sealed the earlier cracks like epoxy. It is because of this reason; higher pressures are noticed in hydrocarbon pools below the volcanic units. Such sealed sedimentary basins are believed by the authors, to form ideal reservoirs for CO_2 sequestration, following the hydrocarbon extraction. These findings could be applicable to any of the peninsular basins.

Several units of Cretaceous volcanics are prolific producers of hydrocarbons. For example, Raageshwari field in Barmer, Ingoli and Padhra in Cambay are producing natural gas, while the down faulted Razol formation, which represents Rajahmundry volcanics in the K-G basin, is producing both oil and gas. The original source rock for hydrocarbons could be from both older Mesozoic and older sediments, or the sedimentary horizons interlayered with the volcanic units. In most of the cases, bore holes in Cambay basin are drilled only up to top volcanic unit. It may be rewarding to re-enter suitable wells, to

ascertain the hydrocarbon potential of older volcanic units and interlayered sediments for possible use in CO_2 sequestration.

CONCLUSIONS

The study has led to the following conclusions.

1. Cretaceous volcanic units are invariably associated with petroliferous basins wherein the magma was generated due to decompression melting and erupted along the subsiding rift and grabens. The volcanism was more pronounced in the intersectional areas. Furthermore, due to the compounding effects in these areas, the sedimentary sequences of older Mesozoic and younger Tertiary are also thicker along with volcanic units.
2. Nearly vertical basinal faults were not only responsible for formation of basins but provided heat for distillation of sediments in early stage while at later stages of volcanism, the lava has sealed the fracture system to form unique trapping mechanism.
3. Data processed by PSDM and PSTM techniques have helped to map structures where hydrocarbons are trapped. Such structures can be utilized for CO_2 sequestration and subsequently for hydrocarbon extraction.
4. Sediments below Cretaceous volcano-sedimentary sequence could be favorable for CO_2 sequestration. The most ideal will be those, from where the extractions of hydrocarbons are extracted and enhanced recovery is contemplated.

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