Marine and Petroleum Geology 68 (2015) 258–268

Contents lists available at ScienceDirect

Marine and Petroleum Geology

journal homepage: www.elsevier.com/locate/marpetgeo

Research paper

# Early Eocene carbonaceous shales of Tadkeshwar Formation, Cambay basin, Gujarat, India: Geochemical implications, petrogenesis and tectonics

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ARTICLE INFO

*Article history:*
Received 21 May 2015
Received in revised form
19 August 2015
Accepted 24 August 2015
Available online 28 August 2015

*Keywords:*
Cambay basin
Shale
Source rock
HR-ICPMS
Provenance
Tectonics
Paleo-redox conditions

ABSTRACT

We report the early Eocene Cambay sedimentation, petrogenesis and tectonics of a rift graben basin of western India using geochemistry. The carbonaceous shales of Tadkeshwar Formation from Tadkeshawar and Rajpardi lignite mines of Cambay basin were studied using major, trace and rare earth elements. The study reveals that the protolith of these shales is likely to be mafic to ultramafic in nature based on the high abundance of $Fe_2O_3$ (avg. of 8.68%), MgO (avg. of 5.78%) and $TiO_2$ (avg. of 8.80%) with a lower $SiO_2$ content (avg. of 44.74%) when compared to PAAS values. PAAS normalized REE distribution patterns of carbonaceous shales indicate relatively depleted LREE with enriched HREE coupled with small magnitude of Eu/Eu* strongly supports the protolith of these shales to be mafic to ultramafic. Weathering indices confirm these shales were derived from a source subjected to intense weathering. Low $Na_2O$ and high perseverance of $Al_2O_3$ are proxies for Smectite to Illite transformations of shales in a gaining temperature regime across the basin. We speculate that the high geothermal gradients prevailed during 60–65 Ma along the western margin of Indian plate might be responsible for the intense weathering of the marine mafic protolith. Redox-sensitive trace element ratios and negative Ce-anomalies suggest that the shales were deposited under suboxic to oxic environment. The link between early Eocene marine transgression followed by basin subsidence is inferred for the deposition of these carbonaceous shales in suboxic to oxic environments. The immobile trace element ratios and geochemical discrimination diagrams ($K_2O/Na_2O$ vs. $Si_2O$; La–Th–Sc) reveals, the protoliths of the Tadkeshwar Formation were derived from a transitional domain of intra ocean island arc to active continental margin followed by convergence, leading to the deposition of immature shales.



## 1. Introduction

The geochemistry of shale is a useful tool in the study of provenance, tectonic setting and palaeoclimatic conditions of sedimentary sequences (Feng and Kerrich, 1990; Wronkiewicz and Condie, 1987) and has provide important constraints on the evolution of continental crust through time (McLennan and Taylor, 1991). Elements Such as La, Ce, Nd, Y, Th, Zr, Hf, Nb, Ti and Sc are used as proxies for deciphering the provenance and tectonic setting determinations in shaly horizons. They possess relatively low mobility and transported quantitatively into clastic sedimentary rocks during weathering and transportation and their low residence time in sea water (Holland 1978) hence preserve the geochemical signature of their source rocks (McLennan et al. 1983, Taylor and McLennan, 1985).

However, such studies relating to the provenance and tectonic setting are very few (Bhatia and Taylor, 1981; Peterman et al., 1981). Very little geochemical work has been carried out on carbonaceous shales from various Indian sedimentary basins. The purpose of the present paper is to document the major, trace and rare earth element (REE) geochemistry and petrogenesis of carbonaceous shales from Tadkeshwar Formation of Western Cambay basin, Gujarat and to propose criteria for the discrimination of source, provenance, alteration/weathering characteristics, tectonic setting and Paleo-redox conditions of the basin.

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http://dx.doi.org/10.1016/j.marpetgeo.2015.08.028
0264-8172/

## 2. Geology and stratigraphy of the study area

The Cambay rift basin, is a narrow, elongated rift graben, extending from Surat in the south to Sanchor in the north. In the north, the basin narrows, but tectonically continues beyond Sanchor to pass into the Barmer Basin of Rajasthan (Mathuria et al., 2011). The evolution of the Cambay Basin began following the extensive outpour of Deccan Basalts during Late Cretaceous covering large tracts of western and central India. It's a narrow half graben trending roughly NNW-SSE filled with Tertiary sediments with rifting due to extensional tectonics (Merh, 1995) and it is intracratonic rift basin. The Cambay rift valley is bounded by well demarcated basin margin step faults. The Early Tertiary sediments ranging in age from Paleocene to Early Eocene represent syn-rift stage of deposition that was controlled by faults and basement highs in an expanding rift system. These sediments are characterized by an assortment of ill sorted, high energy trap derived materials. Subsidence of the basin resulted in the accumulation of a thick sequence of euxinic black shales with subordinate coarser clastics. During Paleocene-Eocene there was widespread marine transgression in western India due to weathering of Deccan basalt. This marine transgression consists of carbonaceous shale, lignite and carbonates extended over the mainland of Gujarat, eastern margin of Saurashtra and Kutch region. Oligocene – Lower Miocene marks another phase of tectonic activity with extensive deposition of coarser clastic sediments in the central and southern blocks.

Earlier workers (Biswas, 1982, 1987; Gupta et al., 1970) opined that the sedimentation is controlled by block pattern based on the regional structure of the Cambay basin which manifests five dissected major tectonic blocks (Fig. 1) due to the vertical faults extending into the sediment pile from the basement (Deccan Traps). These features are observed on the surface as well as in the lignite mines (Tadkeshwar and Rajpardi) characterized by different sets of folds and fault trends.

In the present study, shale formations associated with Tadkeshwar lignite mines (Surat district) and Rajpardi lignite mine (Bharuch District) of Cambay basin (Fig. 2) in Gujarat have been assessed for their geochemistry. Subsurface lignite bearing sequences are exposed in these open cast mines.

Deccan traps forms the basement for the NNW-SSE trending Cambay basin. Early Eocene Vagadkhol formation consisting of Bentonic shale, friable sandstones and conglomerates are resting on

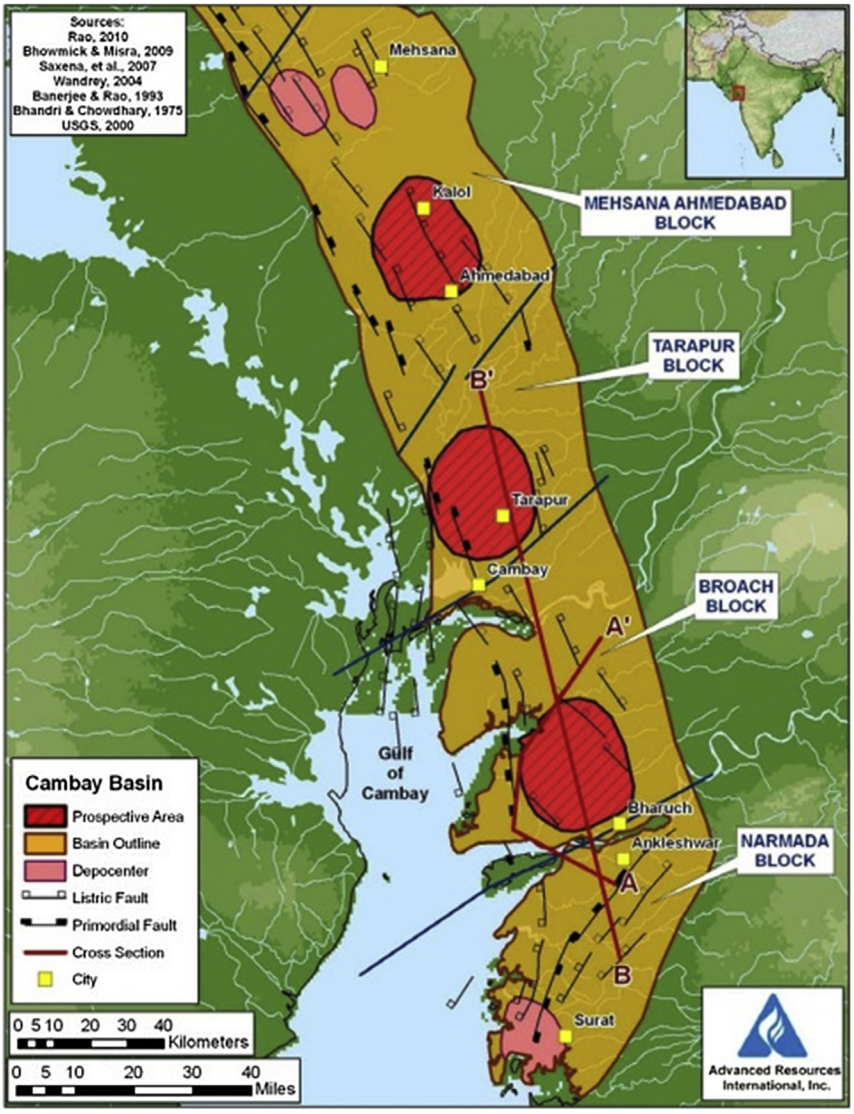


**Fig. 1.** General outlay of the various blocks in Cambay basin. (after Biswas, 1982, 1987).