



Lithofacies and geochemical analysis of intertrappeans of the Ninama Basin, Saurashtra, Western India: An integrated approach for paleolake depositional system

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The sedimentary sequence of the Ninama Basin is associated with the latest phase of the continental Deccan volcanism of the Indian peninsula. It occurs as inter-, intratrappeans with a 39-m thick sequence comprising Sukhbhadar Formation and Ninama Limestone. The investigation aims to reconstruct its depositional setting based on the lithofacies and inorganic geochemistry to understand the influence of paleosalinity, paleoredox, paleodepth, provenance and paleoclimate on the sedimentation pattern. It is characterized by clastic and chemically formed rocks, including shale, mudstone, siltstone, sandstone and limestone. Facies analysis has revealed seven lithofacies, amongst which four are clastic facies, shale (SH), calcareous shale (CSH), silty mudstone (SM) and lithic greywacke (LGW), and three are carbonate facies, namely, grey-black limestone (GBL), cherty limestone (CL) and marlite (ML). Using geochemical analysis of major oxides and trace elements, ratios of Ca/(Ca+Fe), Sr/Ba, V/(V+Ni), V/Cr, Fe/(Ca+Mg), Ti/Al, Na/K, K/(Fe+Mg), CIA-K and MAP were determined and used to interpret and note the changes in the depositional system. The combined results of the lithofacies and geochemistry indicate that the deposition occurred in three phases. Phase 1 is characterized by high energy conditions in the shallow to moderate depth brackish-saline lake with oxic to dysoxic conditions; Phase 2 is characterized by anoxic deep fresh to the brackish water basin; and Phase 3 is characterized by semiarid conditions, saline, anoxic waters, high evaporation leading to shallowing of the lake, and low to moderate terrestrial input. This lacustrine basin in the paleotopographic low of the Deccan Volcanic Province is characterized by distinct lithology governed by various depositional parameters. A composite depositional model is constructed for the Ninama Basin, reflecting three phases of evolution that are dominantly controlled by the paleoenvironment.

Keywords. Geochemistry; geosciences; intertrappean; lacustrine; paleoenvironment; petrology; Saurashtra; sedimentary; sedimentology.

1. Introduction

The Saurashtra–Kachchh sub-province of the Deccan Volcanic Province (Mittal *et al.* 2021) exposes exemplary intra- and intertrappean

sediments in Anjar (Khadkikar *et al.* 1999; Bajpai and Prasad 2000; Parthasarathy *et al.* 2008; Srivastava *et al.* 2017), Lakshmipur (Samant and Bajpai 2005; Bajpai *et al.* 2013), Ninama (Borkar 1973, 1986; Chiplonkar and Badve 1976; Samant

A new superfamily of freshwater mussels *Deccanoidea* nov. (Mollusca: Unionida) from an intertrappean deposit of Saurashtra province (Gujarat state, western India): An example of disjunct distribution

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Abstract

The Cretaceous-Palaeogene intertrappean deposits of the Deccan Volcanic Province of India comprise vertebrate, invertebrate and plant fossils of the dominantly continental realm. A 3–4 m thick shaly-sandstone lacustrine intertrappean sequence of Early Palaeogene (Palaeocene-Early Eocene) Bamanbor Formation, Chotila Basin (Saurashtra province, Gujarat State, western India) has yielded a collection of molluscans (bivalve and few gastropods) fauna. High-resolution digital photography and radiography of the recovered bivalves allowed us to gain detailed inferences on shell morphology. In a taxonomical context, we herein propose a new unionid molluscan superfamily *Deccanoidea* nov. represented by a single new family *Deccanoidea* nov. that includes two new subfamilies, that is, *Deccanoidea* nov. (represented by two new genera *Deccanoidea* gen. nov. [including four new species: *D. conrugis* sp. nov., *D. aleta* sp. nov., and *D. costaria* sp. nov.] and *Bamanboria* gen. nov. [including one new species *Bamanboria oblongis* gen. et sp. nov.] and *Chotiloidea* nov. [represented by one new genus *Chotilia* gen. nov. and three new species: *Chotilia trappeensis* sp. nov., *C. tuberculata* sp. nov. and *C. deccanensis* sp. nov.]). Inorganic geochemistry of host (unionid-yielding) lithologies reveals oxic-freshwater conditions, humid-climate and moderate rainfall. The data on historical biogeography reveals that the Indian subcontinent hosted unionids during the late Cretaceous; however, the presence of new (at family/generic level) unionid fauna during the Early Palaeogene (Palaeocene-Early Eocene) in India indicates changes in the geographic position and ecologic condition linked to northward drift and lava outpouring, respectively. A disjunct distribution of unionid fauna in the erstwhile Gondwanan continents and insular India during the Cretaceous-Palaeogene interval can be explained in terms of both vicariance and dispersal.

Keywords

Bivalve, Deccan volcano-sedimentary, dispersal, freshwater, palaeogeography, palaeogene

INTRODUCTION

The fossil record of freshwater bivalves is sparse, particularly with limited evidence of their early evolutionary phases due

to taphonomic constraints in continental depositional systems. The early record of the nonmarine bivalve of Pangea and subsequent records from the Gondwana exemplify vicariant species. The earliest nonmarine bivalve *Archanodon*

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Lithostratigraphy of the Paleogene Deccan Intra-, Intertrappeans of the Saurashtra, Western India and their Prevalence in Large Igneous Provinces

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ABSTRACT

The periphery of the Deccan Volcanic Province (DVP) of India comprises sedimentary succession deposited during the waning phase of volcanism across the Cretaceous-Paleogene boundary which preserves the continental biota. The Saurashtra Peninsula, a part of the Saurashtra-Kachchh sub-province, exposes thick intertrappean sedimentary successions, systematically described to understand the stratigraphic framework with respect to the lava flows and their geographic distinctness. The thickness of the exposed sections is measured, and contact and continuities are marked, revealing two different, small geographically isolated but adjacent, coeval basins, named the Ninama Basin and Chotila Basin, initially comprising fine grain sediment, followed by thick conspicuous limestone and chert deposits respectively. Formal lithostratigraphic unit names are proposed for both basins: Ninama Basin comprises lithic arenite, fossiliferous limestone, bedded siltstone, mudstone and claystone, and is divided into Sukhbhadar Formation and Ninama Limestone. Chotila Basin comprises calcareous sandstone, bedded siltstone, silty shale and mudstone, claystone and chert divided into Rangpar Formation, Chotila Chert, and Bamanbor Formation. Lithology and palynofossil evidence suggest restricted continental environments with varying salinities during the Paleogene.

INTRODUCTION

The large igneous activities of the Mesozoic-Cenozoic eras comprise continental and oceanic flood basalts (Ernst, 2014) with long quiescence periods between the lava flows, represented by thin sedimentary succession, observed from Parana of South America - Etendeka of South Africa, British Tertiary Volcanic Province (BTVP), a part of the North Atlantic Igneous Province (NAIP) of Greenland and North Europe, Mahajanga Basin of Madagascar and Deccan Volcanic Province (DVP) of India. The DVP of India hosts these sedimentary deposits mostly along its periphery (Kapur and Khosla, 2018) in the form of intra-, intertrappeans which preserves the evidences of the influence of volcanism on the biota, climate and sedimentary systems (Cripps et al., 2005). The intertrappeans of the DVP are extensively studied by Hislop (1860); Sahni et al. (1984); Prasad and Khajuria (1995); Singh (2000); Cripps et al. (2005); Samant et al. (2013); Adatte et al. (2014); Font et al. (2016); Keller et al. (2018); Prasad et al. (2018); Kapur and Khosla (2019) and many more.

The Maastrichtian-Paleogene intertrappean are studied for fossilized terrestrial biota by Assefa and Saxena (1984); Jolly (1997); Mountney et al. (1998); Tandon (2002); Khosla and Verma (2015); Fantasia et al., (2016) and for marine biota by Ambwani (1982); Keller et al. (2008); Prasad et al. (2018), etc.

The north-western part, the Saurashtra - Kachchh sub-province (Mittal, 2021) of the DVP of India comprises the Cretaceous-Paleogene intra-, intertrappeans exposed around Chotila, Anjar, Matanomad, Naredi (Fig. 1a) studied by Borkar (1973); Khadkikar et al. (1999); Bajpai and Prasad (2000); Samant and Bajpai (2005); Saxena and Ranhotra (2009); Samant et al. (2014); Fantasia et al. (2016); and Srivastava et al. (2017). The Anjar succession is studied for Maastrichtian dinosaurian remains (Ghevariya, 1988; Bajpai et al., 1993) and Paleogene intra-, intertrappeans for microinvertebrates (Bhandari and Colin, 1999), palynofossils (Dogra et al., 2004) and depositional environment (Srivastava et al., 2017). The intertrappean of the Saurashtra Peninsula are studied for palynofossils (Samant et al., 2014), vertebrates including fish (Fedden, 1884; Borkar, 1973, 1975, 1984, 1986; Arratia et al., 2004) and turtle remains (Shringarpure, 1985). These intra-, intertrappeans are exposed around the Chotila, Ninama, Rangpar, Garida and Bamanbor villages (Fig. 1b), comprising fine clastic and non-clastic rocks but lack formal stratigraphic classification. We aim to classify according to ISSC and describe them systematically.

GENERAL CHARACTERISTICS OF THE SEDIMENTARY SUCCESSIONS ASSOCIATED WITH VOLCANIC IGNEOUS ROCKS

The association of sedimentary succession with the LIP is observed throughout the Phanerozoic era (Ernst, 2014) which preserves the biota of the continental, marginal marine and marine realm. The mode of occurrence of these rocks is unusual, largely controlled by the availability of the space and the agency bringing the sediments from the source area. The younger lava flows may affect sedimentary succession, modifying their original position and resulting into discontinuous nature with varying thickness, but contains endemic fauna and flora. Deposits occurring with lava flows can be differentiated, into four types of sedimentary units, identified based on their position which includes, Infratrappean, Intertrappean, Intratrappean and Supratrapean (Fig. 2). These informal terminologies are used by paleontologists, stratigraphers, sedimentologists and