Cretaceous-Tertiary Tectono-Magmatism in the NW Indian shield: A fragmenting continent

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Introduction

Continental fragmentation under an extensional tectonic regime during Cretaceous-Tertiary (K-T) time resulted in magmatism and basin tectonism in the northwestern Indian shield. Sedimentary rift basins developed in the Barmer, Jaisalmer and Bikaner regions at this time in western Rajasthan. Rift evolution resulted in alkaline magmatism along the rift margin at Mundwara, Sarnu and Tavidar. Mundwara and Sarnu magmatism is dated at 68.53 ± 0.16 Ma and interpreted by some to be pre-outburst plume activity associated with Réunion plume activity (*Basu et al.,* 1993; *Raval & Veeraswamy*, 2000, 2003; *Raval*, 2003; *Roy & Jakhar*, 2002; *Roy* 2003, 2004). However, the presence of ultra-basic, calc-alkaline circular plutons, carbonatite and lamprophyre dykes at Mundwara and Sarnu signify the development of deep crustal fractures. This initiated decompressional melting in the northwestern Indian shield under an extensional tectonic regime during K-T time. Geodynamic changes in the northwestern Indian shield from the Jurassic to the K-T boundary were a response to fragmenting continents rather than plume-lithosphere interactions.

K-T magmatism

K-T magmatism occurs at Mundwara, Tavidar and Sarnu along the northern margin of the Barmer-Sanchor-Cambay rift basin (Figure 1). The Mundwara igneous complex consists of plutonic, hypabyssal and volcanic members ranging in composition from ultrabasic to alkaline, and forming three ring complexes. These are the Musala, Mer and Toa complexes and they occupy an area of ~12 km^2. The presence of lamprophyre and carbonatite dykes indicates a deep-seated crustal fracture system in the region. *Basu et al.* (1993) dated olivine gabbro of the Mundwara complex at 68.5 Ma. This age has been interpreted as indicating an early phase of Réunion hotspot activity (*Basu et al.,* 1993; *Raval & Veeraswamy*, 2000; *Roy & Jakhar*, 2002; *Roy*, 2003). *Rathore et al.* (1996), using the $^{40}Ar/^{39}Ar$ method, analyzed igneous rocks of the Mundwara region and reported an age of 70 Ma for the mafic rocks and 64 Ma for the syenite. The ages reported for the Mundwara rocks are inconsistent and cannot be interpreted as Réunion plume activity.

Figure 1 Map of northwest-central India showing the K-T magmatism and rift basins (after Campbell & Griffiths, 1990).

The Tavidar volcanics (64-66 Ma; *Rathore*, 1995) form an almost north-south-running outcrop along the Precambrian Malani fracture system (*Sharma*, 2005; Ed: See also Malani page). They are divided into two groups:

a. rhyolite, quartz-trachyte and trachyte, and

b. basalts, including hawaiite and mugerite (*Upadhyaya et al.*, 1988).

The igneous rocks outcropping in the Sarnu-Dandali region evolved in two separate phases:

1. the mildly alkaline igneous rocks developed at ~120 Ma, below Lower

Cretaceous sandstone in the Sarnu region (Chandrasekaran, 1987), and

2. a variety of acidic, intermediate and alkaline magmatism occurred during K-T time.

Basu et al. (1993) obtained a mean age for the Sarnu-Dandali alkali pyroxenite of 68.57 ± 0.08 Ma and interpreted the volcanism as Réunion plume activity.

K-T sedimentary basins

The evolution of Jaisalmer, Barmer, and the Bikaner-Nagaur basins (Figure 2) in western Rajasthan began in the Mesozoic and continued into the Tertiary. The Jaisalmer basin covers over 30,000 km^2 in the northwestern Indian shield, extending as far as the Mari region of Pakistan, and forms part of the Indus Basin (Figures 1 & 2). The basin is controlled by wrench-fault tectonics (*Misra et al.,* 1993) and divided into the Mari-Jaisalmer high shown by the Kanoi and Ramgarh faults, the Shahgarh sub-basin, the Miajalar sub-basin and the Kishangarh sub-basin (Figure 2). The basin fill indicates sedimentation from the Jurassic to the Tertiary.

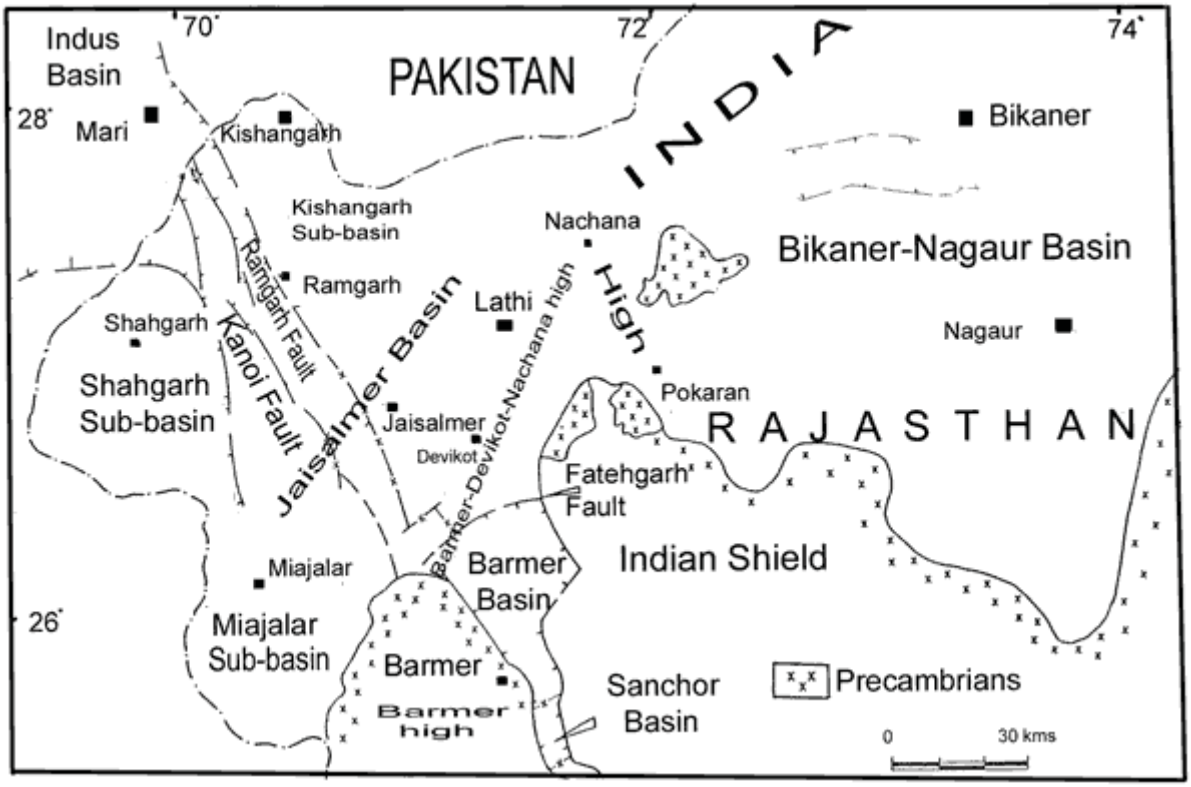

Figure 2 Tectonic map of western Rajasthan (after Misra et al. 1993).

Sedimentation in the Bikaner-Nagaur basin began with the coal bearing Palana Formation, which was deposited during the Paleocene in subtropical swampy conditions on the continental part (*Ghosh*, 1983). Marine sedimentation indicates encroachment of the sea during the Upper Paleocene to Lower Eocene.

The Cambay rift basin extends northward through the Sanchor and Barmer basins (Figure 2). The presence of Cretaceous-Paleocene volcanogenic sediments indicates that the Barmer basin developed as a composite, second-order graben.

The plume model

K-T magmatism and sedimentary basin development in northwestern Indian have been considered to represent the pre-outburst phase of the Réunion plume, with continental lithosphere interaction (*Raval & Veeraswamy,* 2000), with the main plume outburst phase represented by Deccan volcanism at 65.5 ± 0.5 Ma (*Baksi*, 1994; *Basu et al.,* 1993). The K-T magmatism at Mundwara and Sarnu (Figure 1) is interpreted as representing the earliest expression of the Réunion mantle plume in northwest India (*Basu et al.,* 1993).

Roy & Jakhar (2002) and *Roy* (2003, 2004) approved of the Réunion plume model (Raval & Veeraswamy, 2000, 2003) and opined that the Cambay-Barmer, Jaisalmer and Bikaner-Nagaur basins, Deccan volcanism and alkaline magmatism in Sarnu, Tavidar and Mundwara, represent manifestations of plume activity. High gravity anomalies, high heat flow and a seismic low-velocity zone beneath the Cambay-Barmer region were interpreted as the geophysical characteristics of Réunion plume impingement on the base of the Indian lithosphere.

An alternative model

The mantle plume model has been invoked to explain various phenomena of northwest India including development of the Cambay-Barmer rift, Deccan volcanism, sedimentary basins in the Jaisalmer, Barmer and Bikaner regions, and alkali magmatism on the rift shoulders at Barmer, Tavidar and Mundwara. However, important factors such as continental fragmentation, the origin of the Arabian Sea, plate tectonics, and pre-K-T basin tectono-magmatism in western Rajasthan have not been adequately addressed.

Basin evolution began in western Rajasthan prior to Deccan volcanism and K-T magmatism. The Jurassic basin of Kutch Jaisalmer in Rajasthan (Figure 1) resulted from separation of the Indian continent from eastern Gondwana. The next phase of basin renewal and alkali magmatism in western Rajasthan coincides with separation of the Seychelles from India, large-scale Deccan volcanism (*Sheth*, 2005a, 2005b) and formation of the Arabian Sea at K-T time. Extensional tectonics resulted in deep fractures as manifested by the development of rift basins, alkali magmatism and lamprophyre-carbonatite dykes.

All the three K-T sedimentary basins of western Rajasthan have a different type of tectonism, unrelated to one another. The Jaisalmer basin is tectonically related to Indus basin evolution. It is separated from the Bikaner-Nagaur basin (Figure 2) by the Pokaran-Nachana high to the northwest (Figure 2) and from the Barmer basin by the Barmer-Devikot-Nachana high in the south (Figure 2). A pronounced NW-SE-trending regional step-faulted Jaisalmer-Mari high zone traverses the center of the basin. The Indus basin developed as an extensional basin (*Zaigham & Mallick*, 2000) as a result of divergence of the Indo-Pakistan subcontinent from Gondwanaland. The origin of Jaisalmer basin is related to Indus basin evolution at the beginning of the Triassic (*Pareek*, 1984) and not to Réunion plume activity.

The Barmer basin and associated magmatism at Mundwara, Tavidar and Sarnu along basin margins during the K-T period is interpreted as evidence for Réunion plume activity in western Rajasthan (*Basu et al.,* 1993; *Raval & Veeraswamy*, 2000; *Roy*, 2003, 2004). *Sharma* (2004a, 2004b, 2005), however, has explained these Tertiary alkaline complexes as the result of reactivation of the Precambrian Malani fracture system during the development of the Cambay-Barmer rift under an extensional tectonic regime.

The Bikaner-Nagaur basin in northwest Rajasthan is attributed to a plume by *Roy & Jakhar* (2002) and *Roy* (2003). The basin developed along east-west striking fault blocks in the Bikaner-Nagaur region, which extends westward into Pakistan. Mafic and alkaline magmatism and other plume manifestations (*Campbell*, 2005) are also absent in the

region, disagreeing with the model of plume-lithosphere interaction there. *Naqvi* (2005) opined that the Bikaner-Nagaur basin formed in relation to collision between the Indian plate and Tibet at around 55-50 Ma.

Conclusions

Separation of the Indian landmass from eastern Gondwana during the Jurassic resulted in formation of rift basins in the Kutch (Gujarat) and Jaisalmer (Rajasthan) regions, and no plume has been hypothesized for this. This fragmentation caused alkaline magmatism at ~120 Ma in the Sarnu region. This date is not within the 65-68 Ma timeframe and thus excluded from Réunion plume activity. Sedimentary basin evolution in plume-affected regions is generally explained as the result of crustal sagging after volcanism. However, Barmer and Jaisalmer basin tectonism started during the early Mesozoic, and thus cannot be interpreted as a consequence of K-T plume-lithosphere interactions.

The geodynamic changes in the northwestern Indian shield from the Jurassic to the K-T boundary were a result of fragmenting continents rather than plume interactions. Gondwana breakup at K-T time resulted in an extensional tectonic regime and separation of the Seychelles from India, formation of the Arabian Sea, Deccan volcanism, Cambay-Sanchor-Barmer rift basin formation and associated magmatism. The presence of ultrabasic circular plutons, carbonatite, and lamprophyre dykes at Mer-Mundwara and Sarnu-Dandali signify the development of deep crustal fractures. This initiated decompressional melting in the northwestern Indian shield under an extensional tectonic regime during K-T time.

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