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# Late Cenozoic geomorphic evolution in response to inversion: Evidence from field and GPR studies in Kim drainage basin, western India

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**Abstract**

This study presents field and ground penetrating radar (GPR) data for understanding geomorphic evolution of the Kim-drainage basin in response to tectonic inversion of the Narmada–Ankleshwar block of the Cambay rift basin located on the western-continental margin of India. The Narmada–Ankleshwar block underwent continuous sedimentation up to Mio–Pliocene and subsequently was subjected to compressional inversion. Four geomorphic surfaces are recognised that formed in response to the varying degrees of tectonic activity related to phases of inversion. These are the early Pleistocene erosional surface (EPES), late Pleistocene depositional surface (LPDS), early Holocene erosional surface (EHES) and the late Holocene depositional surface (LHDS). The phases of increased tectonic activity relate to two erosional episodes, while two depositional periods relate to waning tectonic activity or quiescent periods. We show that the Narmada–Ankleshwar block suffered inversion earlier than other parts of the Cambay basin to the north of the NSF. Localisation of early inversion movements occurred in an area characterised by thinner crust and involved the development of new reverse faults and transformation of the NSF from a normal to a reverse fault. GPR studies indicate the reverse nature of the various faults in the Kim drainage basin and provide evidence of their late reactivation under compression. The study demonstrates that the parts of a large sedimentary basin can undergo inversion at different times depending on the orientation of pre-existing crustal discontinuities with respect to the controlling stress trajectories.


*Keywords:* Late Cenozoic; Geomorphic evolution; Geomorphic surfaces; Ground penetrating radar (GPR); Tectonic inversion; Kim-drainage basin; Western India

## 1. Introduction

Studies on the evolution of sedimentary basins generally centre on identifying mechanism controlling basin subsidence and the resulting development of the basin fill sediments. However, changes in stress conditions may cause variations in the pattern of tectonic behaviour of the basin and the associated faults (Turner and Willaims, 2004). The long-term evolutionary history of such basins can record phases of inversion. The term 'basin inversion' refers to reversal of the subsidence patterns of a sedimentary basin, which had developed under a tensional or transtensional tectonic regime, in response to the build-up of compressional or transpressional stresses (Ziegler, 1987a). According to him, this generally involves uplift of the basin floor and deformation of the basin fill whereby the throw on tensional faults controlling the original structural relief of the respective graben or trough become partly or totally reversed. Basin inversion has long been recognised as an integral part of the long-term evolution of sedimentary basins (Ziegler et al., 1995; Sandiford, 1999; Nilsen and Hansen, 2000; Hansen and Nielsen, 2003). Numerous studies have described the evolution of sedimentary basins and dated the tectonic inversion phenomena which have been

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observed on seismic sections as well as field studies (Betz et al., 1987; Liboriussen et al., 1987; Ziegler, 1990; Welbon, 1992; Ziegler et al., 1995; Bayer et al., 1999; Marotta and Sabadini, 2003). However, the study of basin inversion in terms of geomorphic development has received scant attention. Mather (1993) showed that inversion tectonics plays a key role in long-term landscape formation in reactivated sedimentary basins. Sedimentary basins, which have undergone tectonic inversion show that the variations in tectonic activity play an important role in landscape development by controlling erosional and depositional phases (Mather, 1993; Chamyal et al., 2002; Marotta and Sabadini, 2003).

The present study documents the late Pliocene–Holocene geomorphic evolution of the Narmada–Ankleshwar block of the Cambay rift basin (Fig. 1) in response to its inversion. This study provides evidence from the Kim drainage basin that is located on this block which is bounded by the seismically active ENE-WSW trending Narmada–Son fault and the Tapti fault to understand the inversion history of the Narmada–Ankleshwar block (Fig. 1). Previous research in the area concentrated on sedimentary and stratigraphic aspects of the petroliferous Eocene to early Pliocene sequences deposited in the Cambay rift (Babu, 1984; Ahuja et al., 1990; Agarwal, 1986). The present study centres on an understanding of the late Pliocene–Holocene inversion and the geomorphic evolution of the Kim drainage basin. We also attempt to evolve an integrated model for landscape development of the Kim river basin. This is achieved by critical evaluation of available structural data, detailed geomorphic, stratigraphic and ground penetrating radar (GPR) studies.

## 2. The Kim drainage basin

The Kim river rises at about 200 m elevation in the uplands of the Deccan Trap near Phulwadi and flows westward to the Gulf of Cambay (Fig. 2). It is located between the two major drainage basins of western India, the Narmada basin to the north and Tapti basin to the south, and forms an independent drainage basin in an area where all the other rivers join either the Narmada or Tapti rivers. The area is characterised by diversity of the landscape and tectonic pattern. It exposes a nearly complete sequence of Tertiary sedimentary rocks (Table 1). The Kim river follows a general E–W trending course, which is in conformity with the dominant structural trends of the area. This drainage basin is narrow, elongated and shows an overall dendritic pattern (Fig. 2). The Kim drainage basin is asymmetric. All the major tributaries of the Kim join it from the south, i.e., its left bank (Fig. 2). The major streams joining the Kim river on its left bank are the Tokri and Bhaga rivers. The courses of the Kim river and its tributaries show high sinuosity, entrenched meanders, several waterfalls and knickpoints all along their courses, which testify to their rejuvenated nature. They exhibit typical characteristics of confined channels with 15–20 m high vertical cliffs along their banks.

## 3. Regional geology and structural setup

The Kim drainage basin is floored by the Palaeocene basaltic flows of the Deccan Trap formation; limestones, shales and conglomerates (300–1700 m thick) of Tertiary age; and Quaternary sediments (Fig. 3). The Deccan Trap,

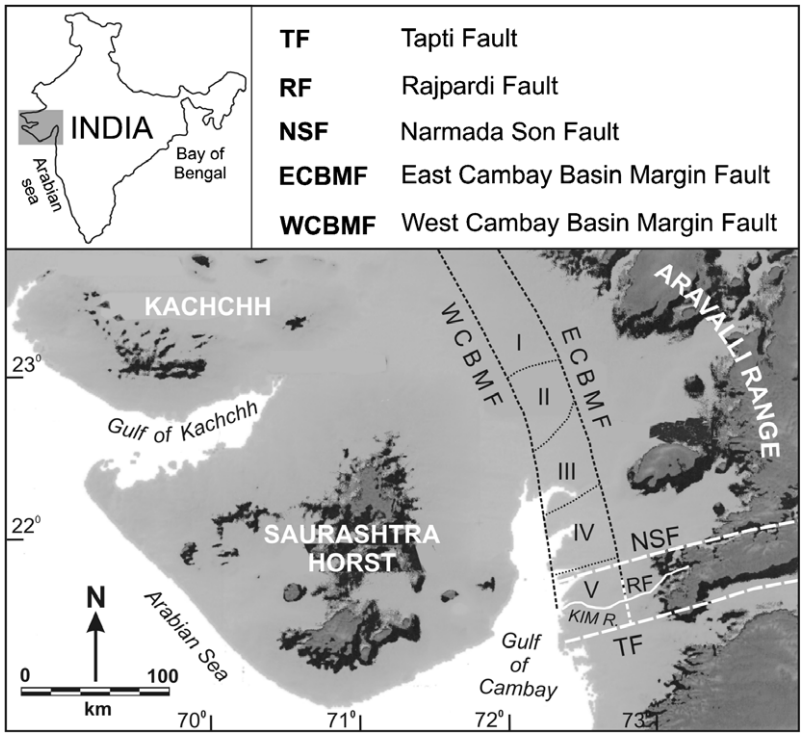


Fig. 1. Physiographic map of Gujarat state showing the location of the Kim drainage basin, Cambay basin and related faults. (I) Sanchor–Patan block, (II) Ahmedabad–Mehsana block, (III) Cambay–Tarapur block, (IV) Broach block and (V) Narmada–Ankleshwar block. Inset: Location map.