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Role of flexure in earthquake triggering along the Western Ghat escarpment, India

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Abstract

The occurrence of earthquakes near reservoirs in the region of the Western Ghat escarpment far exceeds the reported rate in other areas of peninsular India. Reservoir loading and induced pore pressure are generally thought to be triggering earthquakes, but in order to explain the anomalous rates of occurrence in the Western Ghat, we invoke the additional effects of elastic plate flexure. The height of the escarpment is usually considered to be maintained by flexure in the east–west direction. Intense erosion and sediment loading further control its evolution. We propose that this promotes failure at shallow depth by a reduction of the normal stress on escarpment-parallel sub-vertical planes in the region. The same mechanism has been proposed to operate globally in several other escarpment regions along passive margins.

Keywords: Continental margins; Rifted margins; Flexure of the lithosphere; Earthquakes

1. Introduction

Worldwide increases in the frequency of earthquakes, due to the impoundment of several reservoirs built for hydroelectric power generation, have been reported. It has been suggested that induced stresses and pore pressure due to the reservoir water load may cause triggering of earthquakes in the region where ambient stresses are already at a critical level for failure (Simpson, 1976; McGarr and Simpson, 1997; Gupta, 1992). Several reservoirs in peninsular India are known to have been associated with the occurrence of earthquakes. Presently there are about 61 large reservoirs in peninsular India (Fig. 1), out of which 28 are located in the Western Ghat escarpment (WGE) region. The WGE is a 1500 km long linear topographic feature, which runs along the western margin of peninsular India. Interestingly, out of 28 reservoirs in the WGE region, 15 are reported to be associated with earthquakes (Table 1) (Guha, 2000; Rastogi, 2003), while out of the remaining 33 large reservoirs, which are located elsewhere in peninsular India, only six are associated with earthquakes (Table 1). The most notable site of reservoir triggering of earthquakes is Koyna in the WGE region (Fig. 1), where impounding of a reservoir began in 1961 and an earthquake of M 6.3, the largest ever recorded globally near a reservoir, occurred on December 10, 1967 (Gupta, 1992, 2002). The earthquake activity in the Koyna–Warna region still continues today, more than 40 years after the reservoir's impoundment.

The above observation that the triggering of earthquakes is associated with 53% of the reservoirs situated in the WGE region, but with only about 18% of the reservoirs, situated elsewhere in peninsular India, suggests that reservoir impoundment is not the only cause of earthquake triggering near reservoirs that are located on the escarpment. In this article, we suggest that east–west flexure of the Indian lithosphere in the WGE region, which has been proposed to support and maintain the height of the WGE, plays a definitive role in the occurrence of earthquakes in the region by bringing the stresses to a critical level for failure.

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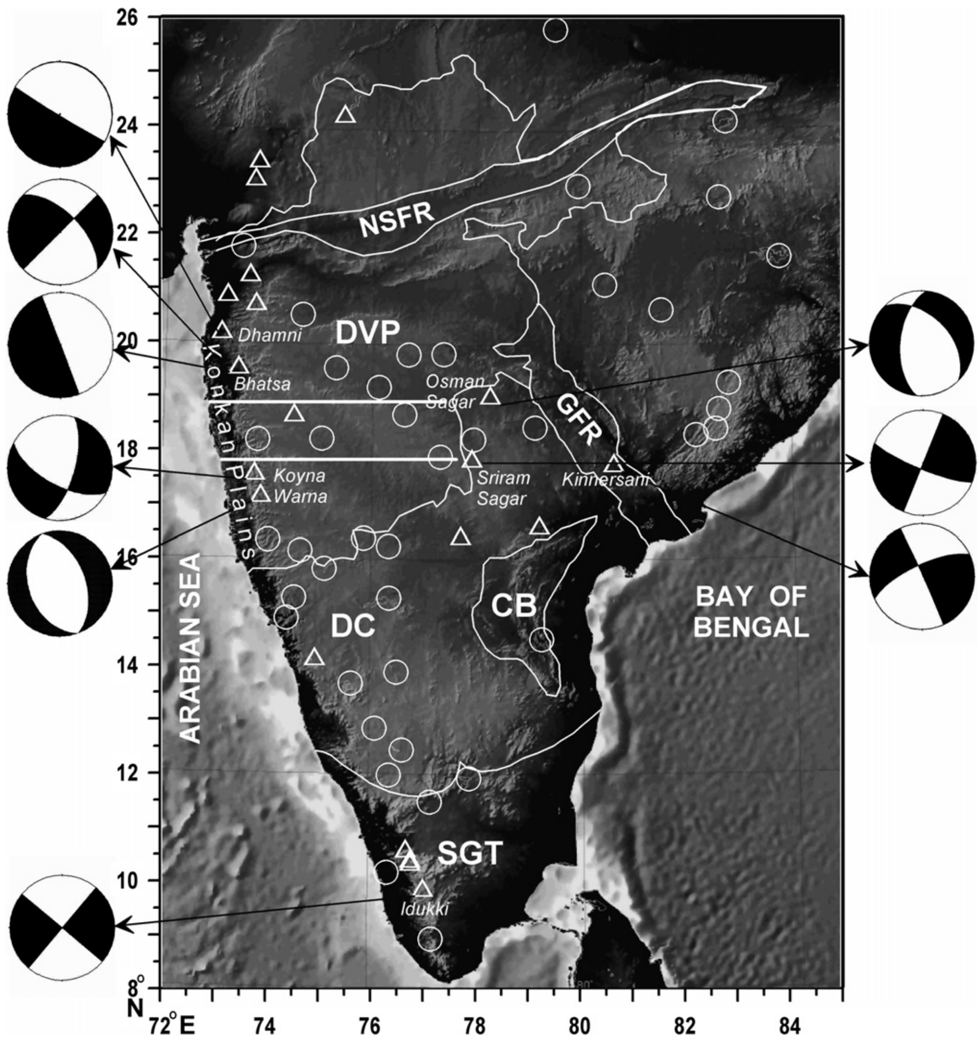

Fig. 1. Large reservoirs in peninsular India. The Western Ghat Escarpment (WGE) can be traced along the west coast, which is marked with abrupt height changes of about 1 km. Low lying regions of the Konkan plains, not wider than 60 km, lie between the west coast and the WGE. Reservoirs associated with earthquake activity are shown with triangles, available focal mechanism solutions of earthquakes occurring at the reservoirs are also shown (Table 1). The solutions shown on the left side correspond to the reservoirs located on the WGE and those on the right side correspond to the reservoirs located elsewhere. Two east–west trending straight lines denote the location of topography profiles shown in Fig. 3. DVP, Deccan Volcanic Province; DC, Dharwar Craton; CB, Cuddappah Basin; SGT, Southern Granulite Terrain; NSFR, Narmada Son failed rift; GFR, Godavari failed rift.

2. The Western Ghat escarpment (WGE) and its evolution

The passive margin mountains, the Western Ghats (also known as Sahyadri mountains in Indian literature) along the west coast of peninsular India form a great escarpment. They border on the Deccan plateau and overlook the Konkan and Malabar strips of coastal lowlands (Gunnel and Fleitout, 2000). The Western Ghats can be followed continuously from latitude 8°N to 20°N. The average distance between the west coast and the WGE is about 65 km. The topography is complicated by isolated hills but the average elevation difference between the low lying Konkan plains and Malabar strips to the west and the high land to the east is about 1 km (Ollier, 1985). Along-strike variation in relative topography and detailed sinuosities are due to the varying lithology comprising the late cretaceous flow basalts of Maharashtra in the north, the Archean Dharwar craton in Karnataka in the central part, and the Paleozoic granulite fold belt in southern Kerala in the south (Gunnel and Fleitout, 2000). The escarpment is regarded as the rift shoulder, which formed in about 65 Ma during the India–Madagascar–Africa rifting (e.g. Ollier, 1985; Subramanya, 1987; Widdowson, 1997; Gilchrist and Summerfield, 1994; Gunnel and Fleitout, 2000; Chand and Subrahmanyam, 2003). The persistence of the present day Western Ghats shoulder amplitude, wavelength, and the length and continuity of the escarpment, despite the intense erosion since the time of rifting, remains an important issue, suggesting a single post-cretaceous process responsible for uniform scarp recession and shoulder uplift (Gunnel and Fleitout, 2000). Marginal uplift of passive rifts is very common, though the precise mechanism causing uplift has been extensively debated (Ollier, 1985; Widdowson, 1997).