A geophysical model for intraplate seismicity in the Kachchh region of NW India

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Abstract

The Kachchh rift basin in the northwestern part of India not only experienced major devastating earthquakes like the 2001 Bhuj earthquake (Mw7.7), but was also jolted by a couple of moderate magnitude events, causing considerable seismic hazard in this active intraplate region. The continued aftershock shock activity of the 2001 quake is primarily confined to the eastern part of the region, suggesting a subsequent reactivation of faults. The major E-W trending seismogenic faults namely, the Katrol Hill fault (KHF), the Kachchh Mainland Fault (KMF), South Wagad Fault (SWF), North Wagad Fault (NWF) and the Gedi Fault (GF), where high amounts of tectonic stresses are inferred to be accumulated, bound the various uplifts in the region.

Joint interpretation of magnetotelluric and the seismic tomography results in the highly seismogenic locales of the rift basin suggest presence of an upper mantle fluid reservoir in the close vicinity of the Moho. Also, deep-penetrating and steeply dipping faults like the SWF, seem to provide a pathway for fluid migration from the mantle reservoir to the seismogenic depths. The interconnection between the deep magma sourced fluids and the upper crust is consistent with the extensional mantle melting model of the Kachchh rift basin. The epicentral zone of the 2001 main shock is characterized as a fluid saturated zone at the rooting of the NWF onto the SWF. Further, the northeast orientation of the horizontal maximum compressive stresses estimated in the region together with the south dipping geometry of the NWF might stimulate the flow of the fluids from the reservoir, leading to micro to moderate seismic activity in this region. The release of fluids into the upper crustal levels with high pore pressures giving rise to the phenomenon of the hydrofracturing resulted in the formation of a mid-crustal shear zone (MSZ). Based on geoelectric strikes and the seismicity distribution pattern, a NNW-SSE trending transverse structural feature is identified in the Wagad uplift, at mid crustal depths. The transverse feature that apparently coincides with the MSZ might be playing a key role in the flow of these fluids from the reservoir towards the surface that in turn get trapped at the Brittle-Ductile transition zone in the vicinity of the GF, thereby triggering earthquakes in the region, including the Mw5.6 2005 event. In the southern portion of the seismogenic area, the KMF breaches down to 15-20km along with the shallow level KHF and their branches are associated with mafic and basaltic intrusions, resulting in a high level of heterogeneity in the upper to mid crustal levels. The presence of trapped fluids at 15-20km depth in the close vicinity of the hypocentre of the 1956 Anjar earthquake (Mw6.0) and their flow towards adjacent regions might be a possible mechanism for the genesis of this event.

In a nutshell, fluidised zones in the crust together with the geometry of the associated faults, crustal scale rheological heterogeneities ensuing from earlier magmatic activities seems to be responsible for seismicity in this active intraplate region of the world.