Tectonophysics 661 (2015) 38–48

Contents lists available at ScienceDirect

Tectonophysics

journal homepage: www.elsevier.com/locate/tecto

Seismological evidence for monsoon induced micro to moderate earthquake sequence beneath the 2011 Talala, Saurashtra earthquake, Gujarat, India

A.P. Singh [a,*], O.P. Mishra [b]

[a] Institute of Seismological Research (ISR), Raisan, Gandhinagar, Gujarat, India
[b] ESSO — Ministry of Earth Sciences (MoES), Lodhi Road, New Delhi, India

ARTICLE INFO

Article history:
Received 6 March 2015
Received in revised form 23 July 2015
Accepted 25 July 2015
Available online 15 August 2015

Keywords:
Crack attributes
Pore pressure
Seismic velocity
Poisson's ratio
Microearthquakes
Monsoon-induced earthquakes

ABSTRACT

In order to understand the processes involved in the genesis of monsoon induced micro to moderate earthquakes after heavy rainfall during the Indian summer monsoon period beneath the 2011 Talala, Saurashtra earthquake (Mw 5.1) source zone, we assimilated 3-D microstructures of the sub-surface rock materials using a data set recorded by the Seismic Network of Gujarat (SeisNetG), India. Crack attributes in terms of crack density (ε), the saturation rate (ξ) and porosity parameter (ψ) were determined from the estimated 3-D sub-surface velocities (Vp, Vs) and Poisson's ratio (σ) structures of the area at varying depths. We distinctly imaged high-ε, high-ξ and low-ψ anomalies at shallow depths, extending up to 9–15 km. We infer that the existence of sub-surface fractured rock matrix connected to the surface from the source zone may have contributed to the changes in differential strain deep down to the crust due to the infiltration of rainwater, which in turn induced micro to moderate earthquake sequence beneath Talala source zone. Infiltration of rainwater during the Indian summer monsoon might have hastened the failure of the rock by perturbing the crustal volume strain of the causative source rock matrix associated with the changes in the seismic moment release beneath the surface. Analyses of crack attributes suggest that the fractured volume of the rock matrix with high porosity and lowered seismic strength beneath the source zone might have considerable influence on the style of fault displacements due to seismo-hydraulic fluid flows. Localized zone of micro-cracks diagnosed within the causative rock matrix connected to the water table and their association with shallow crustal faults might have acted as a conduit for infiltrating the precipitation down to the shallow crustal layers following the fault suction mechanism of pore pressure diffusion, triggering the monsoon induced earthquake sequence beneath the source zone.

1. Introduction

Talala in the Saurashtra area of the Gujarat state of India is regarded as one of the seismically active areas, showing high rate of intraplate seismicity in recent years (Yadav et al., 2011; Rastogi et al., 2013; Singh et al., 2013, 2015). The study area falls under seismic zone III of the seismic zoning map of India (Bureau of Indian Standards, 2002) with a likely earthquake of magnitude 6.0. This area was rocked by three perceptible damaging earthquakes of moderate magnitudes between 2007 and 2011. Two moderate-sized earthquakes (Mw 4.8 and Mw 5.0) in 2007 and an earthquake (Mw 5.1) in 2011 caused severe panic among the inhabitants of Talala (Yadav et al., 2011; Rastogi et al., 2013; Singh et al., 2013, 2015). Recent occurrences of earthquakes rekindled the fear of catastrophic damages of the region similar to those caused by the 2001 Bhuj earthquake (Mw 7.7) in the peninsular India (Gupta et al., 2001). The source zone of the 2001 Bhuj earthquake is associated with deep seated crustal heterogeneities as mapped in the seismic velocity, crack attributes, density variation as well as in the electrical conductivity structure assessed for the Kachchh basin of Gujarat (Kayal et al., 2002; Chandrasekhar and Mishra, 2002; Mishra and Zhao, 2003; Mishra et al., 2008, 2014; Mishra, 2013; Rao et al., 2014; Singh et al., 2012, 2015).

The 2011 Talala earthquake (Mw 5.1) was felt for about 25 s in Junagardh district of Gujarat and people rushed out of their houses in panic (Fig. 1). The whole Saurashtra region was jolted. There were reports of the collapse of the walls of about 30 houses, while several wide cracks were observed in a few hundred houses in the Saurashtra region. The tremors of this quake were also felt across the Gujarat state, including Mumbai, the capital city of the neighboring state of Maharashtra (Rastogi et al., 2013; Singh et al., 2013, 2015). These three earthquakes were accompanied by long sequences of aftershocks (Yadav et al., 2011; Rastogi et al., 2013; Singh et al., 2013, 2015). The moderately damaging earthquake of 20th October 2011 beneath Talala (21.09°N 70.45°E) at 10.42 IST was located about 8 km southwest of the

* Corresponding author at: Institute of Seismological Research (ISR), Raisan, Gandhinagar 382009 Gujarat, India.
E-mail address: apsingh07@gmail.com (A.P. Singh).

http://dx.doi.org/10.1016/j.tecto.2015.07.032
0040-1951/

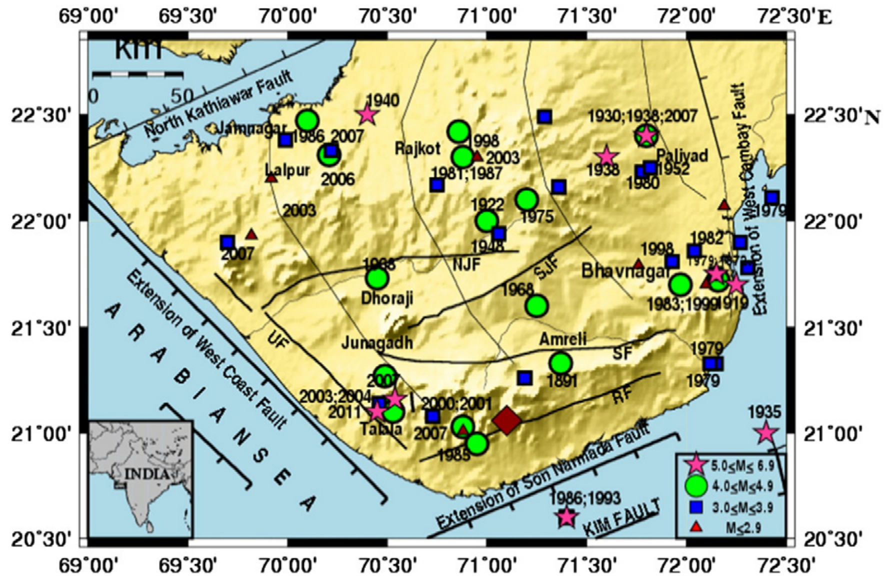

Fig. 1. Earthquake distribution in the Saurashtra region of Gujarat (India) occurred within last 200 years. The tectonic features which are responsible for the seismic activity in the region are also shown. The thick lines show faults which are identified by geophysical surveys. Lines with indentations show faults identified by geological evidences. The thin lines indicate Precambrian trends. Diamond shows the location of a hot spring at Tulsishyam near Una. UF: Umrethi Fault, RF: Rajula Fault, SF: Saverkindala Fault, SJF: South Junagadh Fault, NJF: North Junagadh Fault. The rectangular box at lower left corner of map shows the location of the study region in the map of India.

2007 earthquake epicenter and 200 km south of the most devastating 2001 Bhuj earthquake (Singh et al., 2013). Over 236 aftershocks were recorded by the Seismic Network of Gujarat (SeisNetG), as shown in Fig. 2. Nine earthquakes of magnitude (Mw 3.0–3.9) and two of different magnitudes (Mw 4.0 and Mw 4.1) were recorded during the period of 20th October to 30th November 2012 (Singh et al., 2013). The fault plane solution of the mainshock of the October 2011 Talala showed left-lateral strike–slip fault, which was similar to that of 2007

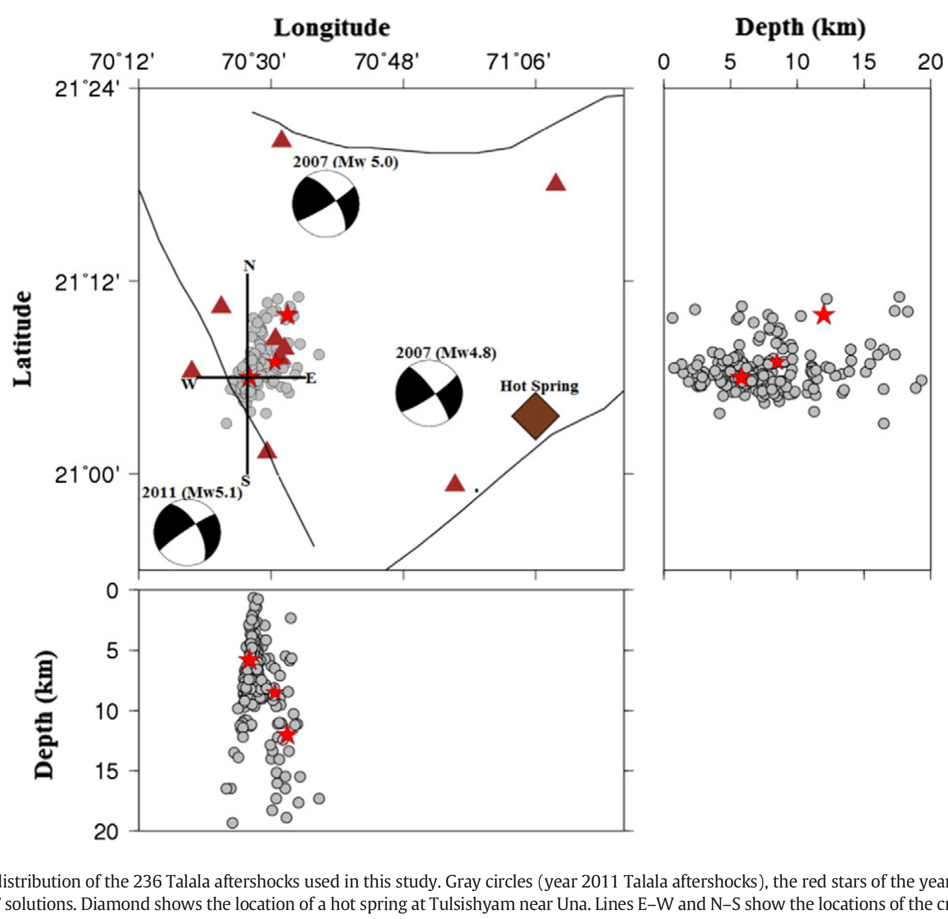

Fig. 2. Relocated epicentral distribution of the 236 Talala aftershocks used in this study. Gray circles (year 2011 Talala aftershocks), the red stars of the year 2007 (Mw 4.8; Mw 5.0) and 2011(Mw 5.1) with the CMT solutions. Diamond shows the location of a hot spring at Tulsishyam near Una. Lines E–W and N–S show the locations of the cross-sections in Figs. 5a–c and 6a–c and 5d–f and 6d–f, respectively. The figure also shows the identified faults of the regions. Seismograph stations are shown in brown triangles.