

AXFORD MEDAL TALK

Artificial Water Reservoir Triggered Earthquakes, with Special Emphasis on the Triggered Earthquakes at Koyna, India

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Artificial water reservoirs are created globally for flood control, irrigation and power generation. Reservoir triggered seismicity (RTS) is an anthropogenic effect of filling artificial water reservoirs. The first scientifically accepted case of RTS is from Lake Mead in USA where starting from smaller earthquakes an $M \sim 5$ earthquake occurred on June 11, 1939. By early 1970's over a dozen cases of RTS were known. A major question had been to discriminate RTS events from normal earthquakes. Detailed investigations of the characteristics of the RTS sequences led to discovery of their common characteristics which discriminate them from normal earthquake sequences, occurring in the same or near by regions but not triggered. These are: 1) increase in 'b' values in the foreshock and aftershock sequences, 2) ratio of the magnitude of the largest aftershock to the main shock being much higher, 3) the foreshock-aftershock pattern changing from Type I of Mogi's model to Type II and 4) the duration of the RTS earthquake sequence being longer than the normal earthquake sequences. These characteristics are governed by the mechanical properties of the media, and their deviation from the normal implies that filling of the reservoir has increased heterogeneity in the media. Over the years many more cases of RTS have been reported and by now some 120 RTS sites are known globally. Damaging earthquakes exceeding magnitude 6 have occurred at Hsingfengkiang, China; Lake Kariba at the border of Zambia and Zimbabwe; Lake Kremasta, Greece and Koyna, India. The largest RTS earthquake of $M 6.3$ occurred at Koyna on December 10, 1967. It claimed ~ 200 human lives and the Koyna Town was in shambles. RTS started soon after filling of the lake at Koyna in 1962 and has continued till present. 22 $M \geq 5$, more than 200 $M \sim 4$ and several thousands smaller events have occurred till now. Although geological and geophysical probing during the past decades has given the basic information of the region, a model to explain the triggering of the earthquakes remains elusive. Two International Continental Drilling Program (ICDP) Workshops were held in 2011 and 2014 and it was realized that Koyna is the most suitable location to investigate physical properties of rocks and fluid pressure in the fault zone in the near field and study the genesis of earthquakes in stable continental region and to elucidate the role of artificial water reservoirs in triggering earthquakes by setting up a deep bore hole observatory. 9 bore holes drilled to ~ 1500 m have revealed the absence of the sediments below the basalt cover, a more or less flat basement at a depth of ~ 300 m below the present sea level. Temperatures at a depth of 6 km are inferred to be no more than 150 degrees C. For a better estimation of hypocentral parameters, a network of 8 deep bore hole seismometers at depths of ~ 1500 m was planned and 7 of these have been installed. This has considerably improved the location of earthquakes. The site of a 3 km deep Pilot Bore hole has been finalized and the drilling is scheduled in 2016. This will be followed by setting up of a deep borehole laboratory at ~ 5 km depth and detailed near source earthquake investigations.