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Tectonic implications and seismicity triggering during the 2015 Nepal earthquake sequence

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ABSTRACT

An earthquake of M_w 7.8, having an epicenter 80 km northwest of Kathmandu, struck the Pokhara region in central Nepal, causing widespread damage. After 16 days, a second earthquake with a magnitude of M_w 7.3 followed the mainshock. The focal mechanism solution and the distribution of aftershocks indicate that the earthquake occurred on an oblique thrust fault, oriented in a NW-SE direction. In this study, we estimated statistical seismological parameters, including the spatial fractal dimension D-value, the aftershocks temporal decay p-value, the b-value of the G-R relationship, and coseismic stress modelling to analyze the tectonic implications and triggering during this sequence. The sequence had aftershocks of greater magnitude because of the large asperities within the rupture zone, as indicated by the determined b-value of 0.89, which shows that the mainshock struck in a highly stressed zone. The high decay of aftershock activity indicated by the high p-value of 1.10, is likely an indication of a higher value of the surface heat flow. In the fault zone, high heat results in shortened stress relaxation time. A spatial fractal dimension value (D-value) of 2.14, indicates a random spatial distribution and a source of a two-dimensional plane filled with fractures. Using the slip model, the estimated coseismic coulomb stress shows a butterfly-like distribution, and the majority of aftershocks occur in the positive coulomb stress zone. This implies that the majority of aftershock activity has been caused by the transfer of positive coulomb stress as a result of the mainshock's coseismic slip. This also validates that the Nepal earthquake raised the possibility of a large aftershock that occurred on 12 May 2015. For future seismic hazard assessments and risk mitigation in Nepal and the adjacent areas, the estimated results of this study may be helpful.

Keywords: Static earthquake triggering, Coulomb failure function, b-value, Omori law, Spatial fractal dimension, Nepal earthquake.

INTRODUCTION

Two of the most fundamental physical parameters controlling the earthquake process are the level of stress and its temporal variation (Deng and Sykes, 1997). Tectonic loading and stress variations from previous events, particularly from large earthquakes or other local shocks, have an impact on each event. It appears that the seismicity rate changes, and that the rate on one fault influences the probability of earthquakes on another (Scholz, 1990). Seismicity relies significantly on earthquake interaction, which produces clusters, aftershocks, and earthquake sequences. One interaction criterion that offers a more detailed and precise explanation of earthquake occurrence is coulomb stress transfer. This study employs two approaches: the initial strategy relies on the immediate correlation between stronger earthquakes and subsequent smaller ones, while the latter approach considers the long-term connections between larger earthquakes. These coulomb stress variations are estimated using information on the slip of the source fault. The fundamental idea is that, on receiver faults, movement in the elastic crust provides a tensorial stress disturbance that needs to be divided into shear and normal components. If the normal stress decreases in the compressive direction and the shear stress increases in the slip direction, then future events are more likely to occur. An earthquake can thus enhance or suppress events, depending on their location and orientation. Viewed in this light, aftershocks are simply sites of seismicity rate increase, occurring where the stress has increased. Sites of seismicity rate decrease, or where the rate was higher before the earthquake than after, might logically be called ‘antishocks’, because antishocks precede rather than follow the mainshock. Dynamic coulomb stress changes can sometimes be a factor of magnitude greater than static stress changes as a result of the seismic waves stimulated by earthquakes. The dynamic stresses are positive in time everywhere because they oscillate. Since every site has been shaken, there should be no stress shadows or anti-shocks. The final fault offset determines the static coulomb stress changes, which are constant and independent of the rupture process. Compared to the dynamic stress change, it decreases with distance from the source significantly more rapidly.

Strong qualitative relationships between static stress changes and the locations of ensuing events, such as the pair of aftershocks and mainshocks, have been observed in numerous investigations. After the 1992 (M_w 7.3) Landers earthquake, Stein et al. (1994) made the public aware of this connection. Lesser events in the years before had raised stress at the lander focus and along a considerable portion of its rupture length, as the analyst of that analysis showed, and the number of aftershocks occurred in areas of enhanced stress. In order to compare the geographic distribution of the ΔCFF transmitted by the three megathrust earthquakes (the 2011 Tohoku-Oki M_w 9.1, the 2010 Chile M_w 8.8, and the 2004 Sumatra-Andaman M_w 9.0) with the distribution of their aftershocks, Miao and Zhu (2012) assumed that optimally orientated faults would serve as receiver faults. They concluded that there was insufficient evidence to support the idea that changes in coulomb stress, boosted the subsequent activity. The percentage of aftershocks that happened in the positively stressed areas after the earthquakes in Chile,