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南北地震带北部5次（1561~1920年）$M\geqslant7$级地震触发关系研究

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摘要 以南北地震带北部的青藏高原东北边缘与华北构造区过渡部位为例，通过建立地震构造模型，计算静态库仑破裂应力改变量（ΔCFS），研究了该区1561~1920年360年间5次$M\geqslant7$级地震之间的触发过程.结果表明，在1561年罗山东麓$7^1/_4$级地震之后，下一次地震无一例外地发生在前面地震产生的应力触发区（ΔCFS>0）.在4条被触发的发震断裂中，有3条发震断裂的平均ΔCFS>0.2×10^5 Pa，最大可达0.62×10^5 Pa，超出目前普遍认为触发应力阀值（0.1×10^5 Pa）.根据断裂库仑破裂应力变化量（ΔCFS）和构造应力累计率（$\delta\tau$），计算获得了下一次地震发生的提前量（ΔT），地震活动提前量最大可以达到160a.在一条重要活动构造带或地区上，一次地震发生对下一次地震的触发缩短了地震重复发生所需要的累积时间，使得地震可以提前发生，这一方面使得某一特定的发震断裂在时间尺度表现出准周期性，另一方面使得空间上不同发震断裂的地震活动表现出丛集发生的现象.此项研究有助于认识断裂间相互作用特点、揭示地震丛集发生规律以及预测未来地震危险区.

关键词 地震触发 库仑破裂应力改变量（ΔCFS） 地震丛集 南北地震带
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Earthquake triggering by static stress: the 5 major earthquakes with $M\geqslant7$ (1561~1920) in the northern section of South-north seismic zone, China

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Abstract Taking five major, $M\geqslant7$ earthquakes occurred in the northern section of South-north seismic zone, an inter-region between northeast Tibetan Plateau and North China block, during 360a from 1561 to 1920 as examples, the Coulomb failure stress changes (ΔCFS′s) caused by the previous earthquakes are calculated on the rakes of fault surfaces of the later earthquakes to study earthquake triggering by building seismotectonic models, based on our knowledge about the seismogenic faults. The results suggest that, after the 1561 Luoshan M $7^1/_4$ earthquake happened, the next four events would occur in the stress triggering area (ΔCFS>0). ΔCFS′s related to the Yunwushan fault, the Helanshan fault and the Haiyuan fault are larger than 0.2×10^5 Pa, surpassing the triggering threshold of 0.1×10^5 Pa. It means that the distribution of ΔCFS has a significant indication on the location of earthquakes in the future. According to ΔCFS and tectonic stress accumulation rate ($\delta\tau$), the periods reduced by ΔCFS are calculated, which can be as large as 160a for the corresponding earthquakes. The triggering caused by the previous earthquake to the next shortens the accumulation time of earthquake re-occurrence, which makes the earthquake happen ahead. It can cause that earthquake activity shows temporally the feature of quasi-cycle for a seismogenic fault and spatially the phenomenon of clustering for different seismogenic faults. This study contributes to our understandings about fault interaction, relationship among strong earthquakes even at different seismotectonic provinces and seismic risky areas in the future.

Key words Earthquake triggering; Coulomb failure stress change (ΔCFS); Earthquake clustering; South-north seismic zone

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