Investigation of rupture process of the 1999 $M=5.4$ Xiuyan, Liaoning, earthquake sequence

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As is well known, researches on rupture process of earthquakes can not only deepen our understanding of earthquake occurrence, but also help to achieve earthquake prediction, which is one of the most difficult scientific problems in the world. Seismologists always pay great attention to it. Since the beginning of 1990s, they have aimed at the time-space variation of earthquake source rupture during the mainshock. In their works the digital data of seismic waves are inverted for the rupture process of seismic sources. They have found the complexity of the rupture process: the fault slip distributes inhomogeneously in space and diversely in time. Based on these results, the process of earthquake occurrence can be better understood than before (Chen, et al, 1996; XU, CHEN, 1997, 1999).

Based on the faulting mechanics, the concept of earthquake nucleation of foreshocks, which is paid much attention, has been put forward. The earthquake nucleation is a phase prior to mainshock. Research on the phase is beneficial to earthquake prediction. Despite the theoretical and experimental studies have revealed the existence of nucleation process prior to an earthquake, it is necessary and important to verify it by using the seismic data and bring its characteristics to light. Some works have been done in this aspect (Ohnaka, Kuwahara, 1990; Ohnaka, 1992; Hurukawa, 1998; Rastogi, Mandal, 1998; CHEN, et al, 2001).

The researches mentioned-above aimed at only a section of the whole rupture process of earthquakes, did not involve the whole phase of the rupture process. If the whole phase of the rupture process is made clear, much more knowledge about the rupture process could be attained. This knowledge will be significant to earthquake prediction. However, it is difficult to invert the seismic waveform for the whole rupture processes of an earthquake sequence. For an earthquake sequence, the occurrence of middle and small earthquake is the result of local rock fractures in the nearby region. If the earthquakes of a sequence are located precisely, the relative locations between all earthquakes can be determined, and the whole rupture process of the sequence will be revealed. This thought has been used to investigate the nucleation process of foreshocks (Ohnaka, 1992; Hurukawa, 1998; Rastogi, Mandal, 1998; CHEN, et al, 2001). On November 29, 1999, there occurred an earthquake of $M_s=5.4$ in Xiuyan, Liaoning Province, North China. Before this earthquake notable foreshocks occurred. After the mainshock of $M_s=5.4$ another...
earthquake with $M_s=5.1$ occurred on January 12, 2000, at the same location. This is a good earthquake case for investigating the whole rupture process of an earthquake sequence. In this study, earthquakes of this sequence are relocated, the variations of relative location between all the earthquakes are analyzed in virtue of time-space pattern analysis, and the rupture process of the sequence are revealed further.

One of the relative location methods is the master event method. Its fundamental is to choose an earthquake with more precise hypocenter determination as master event, then find the relative locations between other earthquakes and the master event. Since the master event location method depends less on the given crust model, the results by using this method are better than by absolute location method. For the research on rupture process of earthquakes it is enough to know the variation of relative locations of earthquakes in a sequence. Therefore, this method is adopted to study rupture process of an earthquake sequence.

1 Data and location results

The November 29, 1999, Xiuyan, Liaoning, earthquake with $M_s=5.4$ occurred in a region with complicated geological structure and preponderant NE-SW striking faults, and was located on the verge of the focal region of the February 4, 1975, Haicheng earthquake of $M=7.3$. The epicenter of the $M=5.4$ mainshock is situated on a NWW-SEE fault. It seems to indicate that this earthquake could occur on the NWW fault, which coincides with the node plane striking N64°W from the focal mechanism solutions of the mainshock. But it is not certain that this earthquake did occur on that fault. It should be determined from the epicentral distribution of aftershocks.

This earthquake sequence is of a fore-shock-mainshock-aftershock type. The Shenyang telemetric network in Liaoning Province can detect the earthquakes of this sequence very well. In this study, the data from this network are used, the earthquakes with $M_t \geq 2.0$ are relocated, the epicentral distribution of aftershocks is given, and the rupture process of the sequence is analyzed. The farthest station is about 315 km away from the epicenter region and the closest one is about 34 km away. During the process of relocation, 34 stations at most are used for locating one earthquake, 3 at least, and 20 on the average. The $M_s=5.4$ mainshock is chosen as the master event, of which the epicenter is at 40°32'N, 122.1'122.2°E.