The Role of Fault Interactions in the Generation of the 1997 Jiashi Strong Earthquake Swarm, Xinjiang, China

S. Zhou[1] *R.Robinson*[2] *M. Jiang*[1]

[1] *Geophysics Department, Peking University, Beijing 100871, China*
[2] *Institute of Geological & Nuclear Sciences, Box 30368,Lower Hutt, New Zealand*

Abstract: *A swarm of 15 large earthquakes occurred near Jiashi, western China, in 1997. This is a geologically stable area with very little previous seismicity. Using results from detailed relocations of events and focal mechanisms, we develop a synthetic seismicity model for the region involving two NNW striking en echelon faults. The purpose is to see if elastic stress interactions can reproduce the swarm like nature of the seismicity. The results indicate that they can do so. Some associated normal faulting mechanisms can be explained as well. We speculate that the rapid change in crustal thickness under the swarm region may have caused the localization of the seismicity.*

1. Introduction

A sequence of strong earthquakes occurred in Jiashi County, Xinjiang, western China in 1997 (Figures 1 and 2). From 21 January 1997, through 18 October 1997, 15 earthquakes occurred with Ms greater than or equal to 5.0, seven of which had Ms greater than or equal to 6.0. This earthquake swarm was located in the marginal region of the Tarim basin, which is the second largest inland sedimentary basin in the world and is thought to be a tectonically stable block by most geologists. Since instrumental seismograph records came into being in the 20th century it has been a rare phenomenon around the world that so many strong earthquakes clustered within a small area in a stable intraplate region. Another remarkable phenomenon is that the seismicity had been quite inactive in the swarm area and only 6 small earthquakes, all with magnitude $ML \leq 3.0$, had been recorded in that area from 1970 (when a local seismic network was established) to the date when the swarm occurred in 1997.

In recent years it has been shown that elastic interactions within fault networks can play an important role in determining the features of seismicity, such as event triggering, clustering of events, and inhibition of events. Here we study the Jiashi earthquake sequence in the light of a synthetic seismicity simulation using a modified version of the methods of Robinson & Benites (1996). Comparing the seismic features simulated with fault interactions and without fault interactions, we find that the elastic interactions between the seismogenic fault segments associated with the Jiashi swarm may play an important role in determining the swarm's characteristics.

2. Data and Simulation of the Synthetic Seismicity in the Jiashi Swarm Region

Based on the focus mechanisms and the relocations of Jiashi swarm earthquakes, a pair of en echelon strike-slip fault segments with NNW strike and a pair of en echelon normal-slip fault segments with NE strike (Figure 1 and 2) are inferred as the seismogenic fault network of the swarm in this study. Considering that the thickness of Quaternary sedimentation in the swarm region reaches 4,000~7000 meters and all earthquakes of the swarm occurred almost below a depth of 6.5 km, it should be reasonable to take 6.5 km as the burying depth of the fault segments associated with the Jiashi swarm. In any case, the results are not sensitive to this, judging from lots of numerical tests. The dip angles of the fault segments are taken from the average fault solutions of the focus mechanisms of the swarm earthquakes. All pertinent parameters of the seismogenic faults are given in Table 1.

Table 1. *Fault Parameters*

Fault	Length (km)	Width (km)	Strike (deg)	Dip (deg.)	Depth (km)	End 1 (Lat, Lon)	End 2 (Lat, Lon)
Northern Strike-slip Segment	20	20	-34.97	73.0	6.5	77.05° E 39.65° N	76.91° E 39.78° N
Northern Normal-Slip Segment	15	15	60.0	45.0	6.5	77.05° E 39.65° N	77.18° E 39.70° N
Southern Strike-Slip Segment	25	20	-52.46	76.5	6.5	77.08° E 39.51° N	76.92° W 39.63° N
Southern Normal-Slip Segment	15	15	65.0	45.0	6.5	77.08° E 39.51° N	77.20° E 39.55° N

The synthetic seismicity model used here is developed from the model presented by Robinson & Benites (1996, 2001). The basic idea is that a network of faults can be defined geometrically, a loading mechanism applied, and then use the physics of fault failure and elastic dislocation theory to track the evolution of failure and slip. Each fault is subdivided into smaller patches and when the first patch of a slip episode occurs, it induces stress changes on all other patches. Thus the slip can be confined to the single initial failure or cascade onto other patches, resulting in a larger earthquake. The end result is a synthetic catalog of seismicity.

The main modification we use here is in the way of specifying the loading. We take the loading to be defined by strain increments, constant along the fault and in the same direction as the desired slip, instead of taking constant stress increments. Thus, we could use GPS observation data directly as a constraint on the model.

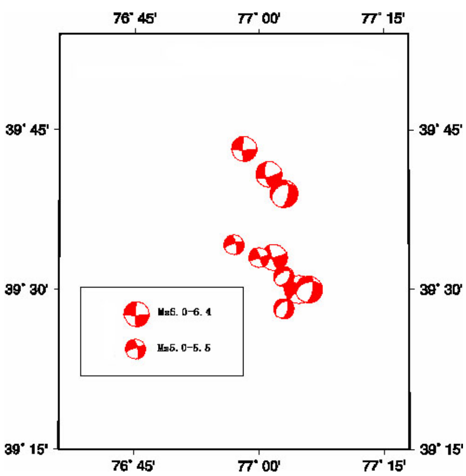

Figure 1. *Details of the positions and mechanisms of the Jiashi swarm events.*

The epicenter distribution, magnitude vs. time plot, and b-value vs. time plot of a resulting synthetic catalogue of 5,000 years duration is shown in Figure 2. We can see that the seismicity versus time is quite inhomogeneous, and the seismicity of the earthquakes with Ms ≥ 6.0 especially shows clusters like swarms. Moreover, we can see that there are few earthquakes in the 2,000-3,000 years before 7 of 8 strong earthquake clusters, which is very consistent with the phenomenon that the seismicity had been quite inactive in the Jiashi swarm area before the swarm started in 1997. However, can we say that such seismicity clusters are caused by the fault interactions?

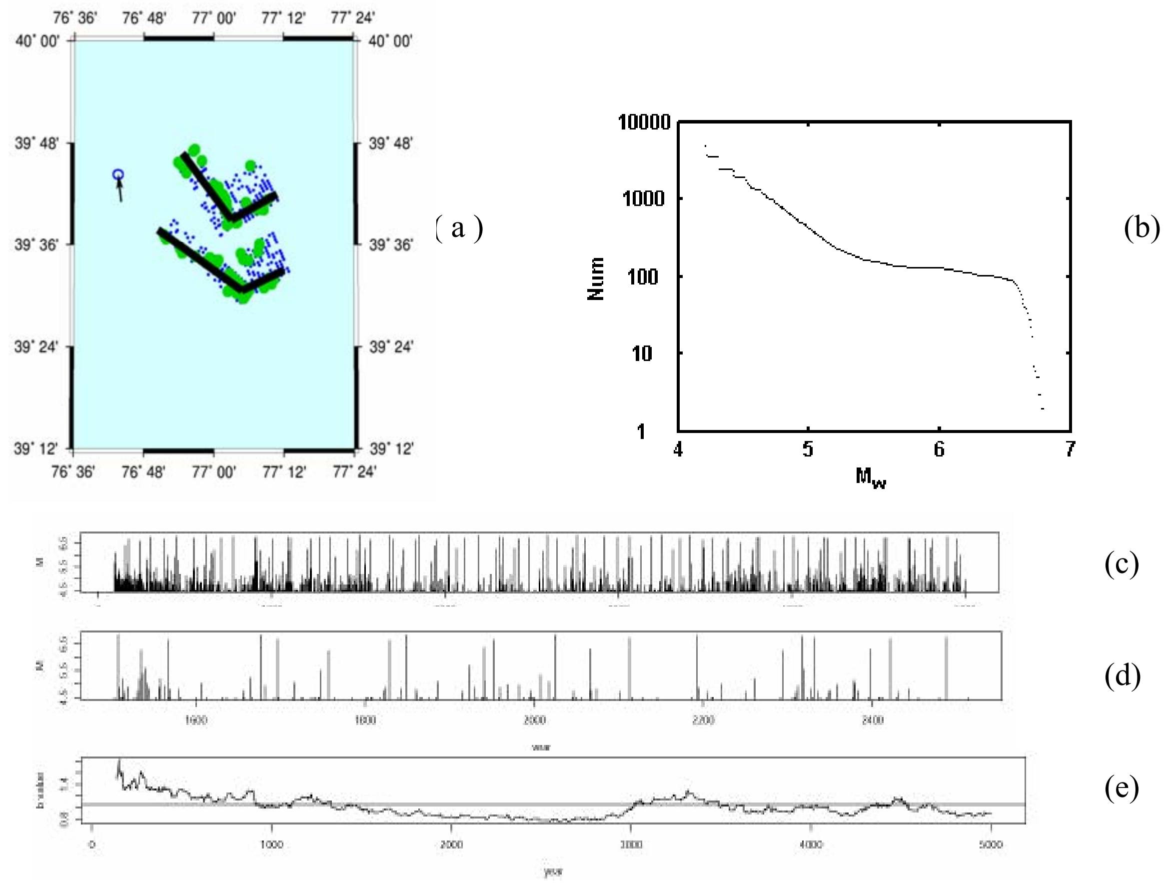

Figure 2: *Results of the synthetic seismicity model. (a) The epicenters of the synthetic events; (b) The frequency-magnitude distribution, indicating a b-value of 1.05; (c) Fluctuation of the b-value with time; each value is based on 100events; (d) Magnitude vs. time for 5000 years; (e) An expanded section of 1000 years.*

To examine the effect of the fault interactions, we have also simulated synthetic catalogues with inter-fault elastic interactions suppressed. All model parameters are otherwise the same as above. We present our results in terms of the distributions of interevent times, dT, for "large " events (Ms≥6.0) in the region. We then compare these distributions with the corresponding distributions when interactions have been suppressed. The ratio of these numbers will be about 1.0 for all dT if interactions have no effect. Clustering of events represented by ratios > 1.0 for small dT would occur if the interactions promoted the formation of secondary fractures. Conversely, mutual inhibition of large events would be represented by a ration <1.0 for small dT. In order to get enough number of "large " events for statistical analysis, 50 different models with the same fault parameters, some same fixed mechanical parameters, but some different random mechanical parameters chosen within reasonable ranges listed in Table 2, are used to generate catalogues of 5,000 years duration each. Figure 4 shows the comparison of the distribution of inter-event times dT of Ms≥6.0 events, taking all 50 models together. The dT bin size is taken 1.5 years in the plot based on the considering that the 9 large earthquakes with Ms≥6.0 of Jiashi swarm occurred within 1.5 years.

Figure 3 indicates that there is an enhancement in the risk of multiple events within a short time (dT < 1.0 year), as compared to the corresponding cases with no interactions. The case where interaction is suppressed has a distribution of dT that closely matches that for a Possion random process with the same mean dT.

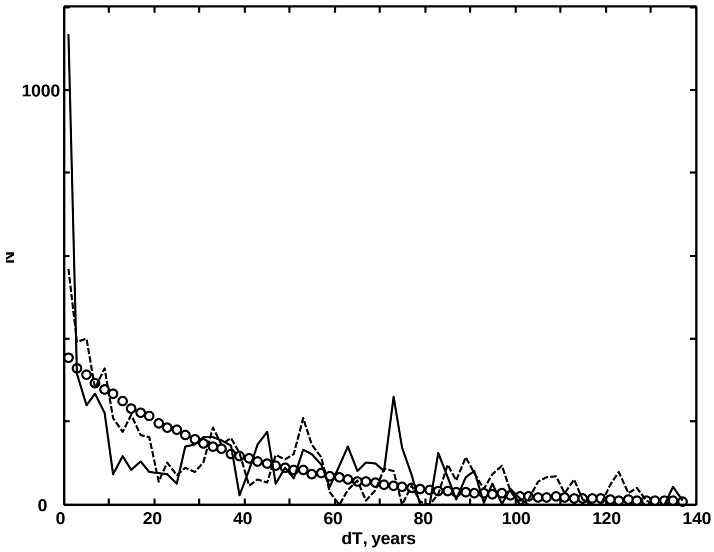

Figure 3. *Comparison of the distribution of inter-event times (dT) of large earthquakes with Ms≥6.0, taking all 50 models together. The solid line is for the case with interactions; the dashed line is for the case of no interactions. The open circles are the expected distribution for a random process with the same mean dT as the case without interactions.*

3. Conclusion

Considering the above results it seems likely that elastic fault interactions played an important role in determining the character of the 1997 Jiashi strong earthquake swarm. So this study adds still further to the strong evidence for the importance of static stress interactions in general.

4. Acknowledgement

This work was jointly supported by the National Basic Research Program of China under grant number 2004CB418401, and the New Zealand Foundation for Research, Science and Technology.

5. References

Okada, Y., 1992. Internal deformation due to shear and tensile faults in a half-space, Bull. Seis. Soc. Am., 82, 1018-1040.

Robinson R. and Benites R., 1996. Synthetic seismicity models for the Wellington region, New Zealand: Implications for the temporal distribution of large events, J. Geophy. Res., 101, 27,833~27,844.

Robinson R. and Benites R., 2001, Upgrading a synthetic seismicity model for more realistic fault ruptures, Geophy. Res. Lett., 28, 1843−1846