3-D finite element modeling for evolution of stress field and interaction among strong earthquakes in Sichuan-Yunnan region*

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Abstract

Based on the latest achievement about activities of geological structure, a 3-D finite-element model containing four layers of upper crust, lower crust (two layers) and upper mantle is established in the paper. By repeated tests and revisions, the boundary conditions of the model are determined. And then the background stress field, the stress field caused by fault creep and the stress field triggered by strong earthquake in Sichuan-Yunnan region, as well as their dynamic variations are calculated. The results indicate that the latter earthquake often occurs in the area with positive Coulomb rupture stress change associated with the former one, the former earthquake has a triggering effect on the latter one to a certain extent, and strong earthquake often occur in groups under the background of high stress, which is of great significance for distinguishing seismic anomalies, as well as for improving the level of earthquake prediction.

Key words: 3-D finite element model; background stress field; stress field caused by fault creep; stress field triggered by strong earthquake

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Introduction

Sichuan-Yunnan region is a major area with frequent strong earthquakes in Chinese mainland, especially the middle-southern segment of South-North Seismic Zone, where many strong earthquakes occurred in history. In the past 30 years, Sichuan-Yunnan region has two seismically active periods: one is from Tonghai earthquake in 1970 to Longling-Songpan earthquake in 1976, the other is from Lancang earthquake in 1988 to now. During this two periods, the $M$=7.7 Tonghai, $M$=7.1 Daguan, $M$=7.3 Longling, $M$=7.4 Lancang, $M$=7.3 Menglian, and $M$=7.0 Lijiang earthquakes occurred in Yunnan region; the $M$=7.6 Luhuo and $M$=7.2 Songpan earthquakes, as well as many $M$=6 earthquakes occurred in Sichuan region. Therefore, a great number of highly effective
observations and researches of seismology, active structure and crustal deformation have been carried out in Sichuan-Yunnan region. And abundant data and scientific achievements have been accumulated.

From 1970’s, Molnar and Tapponnier (1975), Tapponnier and Molnar (1976, 1977) proposed the motion pattern of lateral squeezing slip of Qinghai-Xizang Plateau and its dynamic mechanism. Their theoretical frame of continental dynamics is of great significance for recognizing the crustal movement in Eurasia and the inter-movement of crustal blocks in Southwest China. YAN (1979) and DENG, et al (1979) described the general characteristics of tectonic stress field in China. LUO (1979) depicted the arc-shape strike-slip fault system in western China using slip line field and analyzed tectonic stress field related to earthquake activity. Based on focal mechanism solution of strong earthquakes and data of seismic surface fracture zones, KAN (1977, 1980) presented the inference of SSE-trending shift of Sichuan-Yunnan rhombic block bordered by Xianshuihe, Anninghe, Zemuhe and Xiaojiang faults on the east, and Jinshajiang and Honghe faults on the west, which has drawn great attentions in the geoscientific field. Then, QIAN, et al (1980) discussed the tectonic stress field in Southwest China based on experiments and focal mechanism solutions of strong earthquakes; XU, et al (1987) analyzed the direction characteristics of crustal stress field in Sichuan-Yunnan region from large amounts of small earthquakes; CUI and XIE (1999) made a preliminary study on the stress field in Southwest China and the adjacent areas with convergent procedure by using focal mechanism solution of strong earthquakes.

Owing to the function of Assam wedge under the collision of Indian Plate and Eurasian Plate, heterogeneous motion appeared on many (crustal) blocks including Sichuan-Yunnan block. In the crustal stress field with multiple stress-concentrated sites, the movement patterns of different blocks and boundary zones differ greatly, because different locations have different loadings. ZHANG (1986) presented the definite results of crustal blocks and dynamic analysis, which are used in the geotectonic analysis in China; DING and LU (1986) studied the active structures and block motions inside the sub-plates in China and the adjacent areas; and MA (1989) summed up the principal bases for tectonic block zoning. Considering from the interior structure of each block, activity as an entire block, and zoning features of seismicity along boundary, as well as the distribution of Quaternary active faults and local deformation zones, CHENG, et al (2003) divided Sichuan-Yunnan region and the adjacent areas into five secondary blocks: Yajiang block, Dianzhong block, Chuanqing block, Chuanzhong block and Myitkyina-Dianxi block.

From 1895, the intensive seismicity in Sichuan-Yunnan region showed five active periods. In the former four active periods, great earthquakes occurred alternatively or successively along the boundaries of sub-blocks. In the fifth active period since 1988, the east boundaries of these blocks were quiet without strong earthquakes, while the west boundaries of Myitkyina-Dianxi block and Dianzhong block showed active seismicity. A number of strong earthquakes or earthquake clusters occurred along Jinshajiang and Lancangjiang fault system, they were the M=7.4 Lancang earthquake in 1988, M=7.3 Menglian earthquake in 1995, M=6.5 Batang earthquake cluster in 1989, M=7.0 Lijiang earthquake in 1996 and several M=7 earthquakes in Myitkyina, Myanmar.

There are many strong earthquakes in Sichuan-Yunnan region, which distribute mainly along the fault zones. Anninghe-Zemuhe-Xiaojiang fault is a famous seismically active zone. Isointensity curves of ≥VIII extend along major boundary zones of blocks, and the remaining un-ruptured segments along the zone are risk locations of potential strong earthquake. The distribution of current medium and small earthquakes in the period of 1965~2002 are similar to the historical shocks