Present-day crustal movement in China continent and its southeast coast region*

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Abstract Based on the observations of global positioning system (GPS), a movement model for quantitatively describing the seven continent blocks in China, Tibet, Sichuan-Yunnan, Gansu-Qinghai, Xingjiang, the South China, the North China and Heilongjiang is established, and the derived velocity field (1994—1996) is consistent with the focal mechanism "P" stress axis field and the geological model on the whole. China continent moves toward east (including NNE, NE, E, EES and ES). Furthermore, the intrablock deformation model for Fujian and its neighboring sea region is also established. The derived velocity field and strain rate field (1995—1997) show that along with the southeast coastal region, the whole China moves toward southeast. There are compression from sea to continent in the northwest direction and extension in the northeast direction. The direction of principal stress axis at present is NW (NWW)—SE (SEE). The collision of India plate with Eurasian plate plays a major role in the crustal movement of China continent, while the collision and pushing of Philippine plate play the direct and important role in the crustal movement and strong earthquake gestation in the southeast coastal region of China continent.

Keywords: GPS survey, China continent and its southeast coastal region, block intraplate movement, intrablock deformation, plate collision.

China continent lies in the southeast of Eurasian plate. It is affected by the collision from the India plate and the subductions from the Philippine plate and the pacific plate. Therefore, it is a most ideal region for studying intraplate crustal motions and continent dynamics[1]. The results provided by geology are the averages of millions of years. If we try to determine the present-day continental crustal movement, we must resort to new spatial surveying techniques. Progress has been made in studying global plate movement using the global positioning system (GPS)[2, 3], whereas the study on the intraplate crustal movement of China continent has just made its first step in recent years.

We established the model of intraplate block movement and the model of intrablock deformation using the GPS national network survey (1994—1996) and the regional network survey (1995—1997). Then we quantitatively studied the present-day crustal movement in China continent and its southeast coastal region, and compared our results with the ones from other relating subjects.

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1 Movement velocity field in China continent (1994—1996) and comparison with the results from geology and seismology

In GPS observation network of the State Climb Project, there were 21 sites where repeated GPS surveys were carried out. Nine Leica 2000 GPS receivers and seven Ashtech Z-12 GPS receivers, and seven Rogue 8000 GPS receivers were used in the surveys. Continual observations were carried out for 6 to 8 days on every site, and 12 to 24 hours everyday, with a sampling span of 30 seconds. The satellite-truncating angle was 15 degrees. The international GPS Service (IGS) satellite calendar and the International terrestrial reference frame (ITRF) coordinates were used. The data were processed using SNAPS software, which was an improvement of GAMIT software. The relative precision of baseline length weight mean value and adjusted value reached 10^{-9} [4]. Researches in geology showed that Heilongjiang Block is the relatively stable one in China continent[5]. Taking it as the relatively fixed block[6], and Changchun station as the fixed point, which is among the 21 sites for repeated observations in the state GPS network. Applying rigid body motion law, we can make out the six Euler vectors of the other six blocks relative to Heilongjiang block. Thus we can derive the present-day movement velocity of any site relative to the reference site.

The velocity field on a time scale of several years derived from GPS observation data is fairly consistent as a whole with the one on a time scale of millions of years derived from geological data, but the values of velocity of the former are greater than the latter's (see fig. 1). It indicates that, under the joint action of the collision zone of India plate and the west pacific subduction zone, the movement velocities of the blocks in China continent decrease gradually from south to north and from west to east, and their directions turn gradually from north-northeast to east, even to southeast and east southeast.

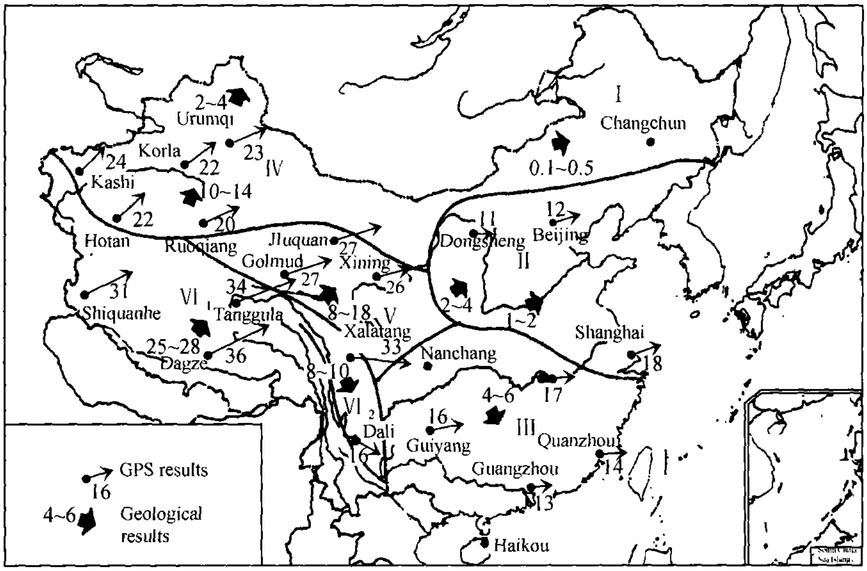

Fig. 1. Movement velocity field (based on GPS data from 1994 to 1996) and geological model in China continent.

The spatial distribution of the principal stress axes—"P" axes, which are derived from focal mechanism resolutions of several hundred years[7], is consistent as a whole with the distribution of present-day movement directions derived from GPS observation data, though they orient eastward more greatly (see figure 2).

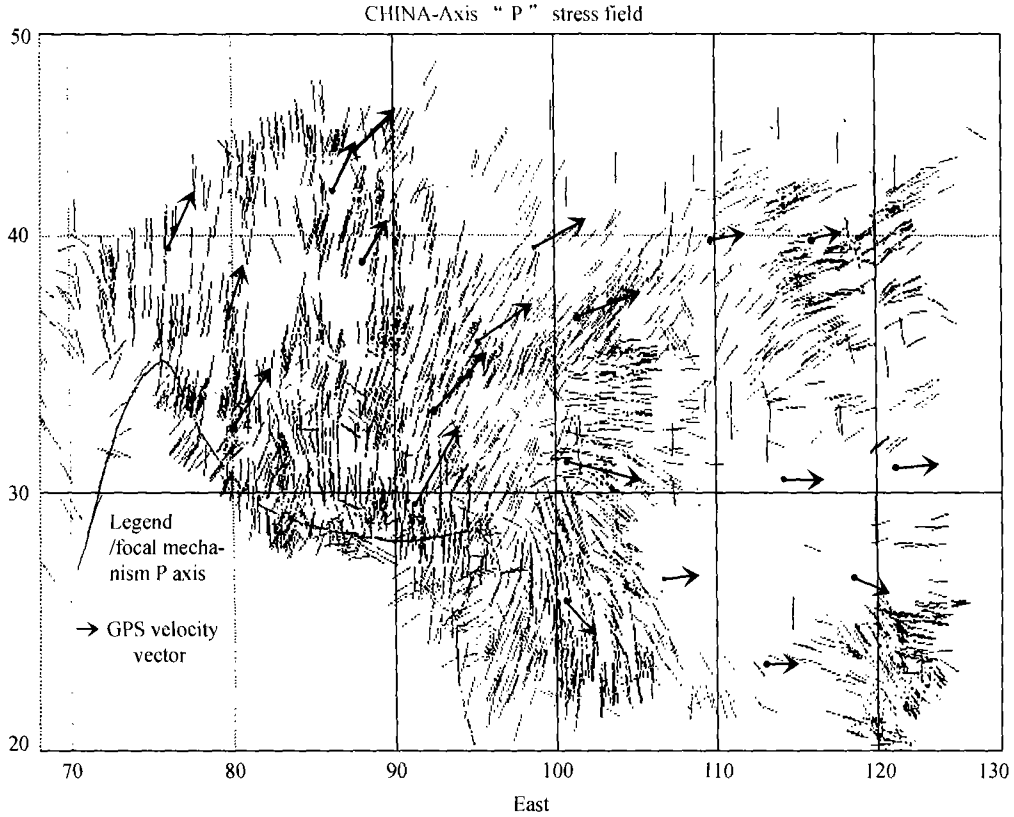

Fig. 2. Movement velocity field (based on GPS data from 1994 to 1996) and field of focal mechanism "P" stress axis.

Similar to the results of global plate movement, the present-day movements of the blocks in China continent on a time scale of several years determined by GPS observation are roughly consistent with the results derived from the focal mechanism resolutions of several hundred years and the average movements derived from geology over millions of years. It shows that the joint action of India plate and west pacific subduction zone has been existing continually since several millions years ago.

2 Velocity and strain rate field in Fujian and its neighboring sea and comparison with results of relating subjects

There were ten sites for the repeated survey in Fujian GPS regional observation network (1995—1997). Six Ashtech Z-12 GPS receivers were used. The data were processed with GAMIT software. The relative precision of base-line length is 10^{-8}, and the precision of horizontal sub-vectors of point coordinates is 0.8—2.6 mm. Based on Fujian regional GPS observation network and the synchronous observations in IGS stations such as TAIW (Taibei), SHAO (Shanghai) and so on, applying the intrablock deformation model[8], we determined the present-day velocity fields respectively taking Taibei (fig. 3(a)) and Nanping (fig. 3(b)) as the reference points. The vectors with arrow denote the actual observed values, and the ones with error ellipse denote the modeling values. The standard error of the subtractions of the two is ± 2.6 mm/a, which shows that the model is credible. The principal strain rate field with a density of 1(°) × 1(°) derived from the model is shown in figure 3(c).

When Taibei is taken as the reference point, the Philippine plate's pushing effect from sea to mainland is roughly counteracted. The present-day velocities on these observation sites show homogenous and consistent directions of southeast (fig. 3(a)), which is consistent with the movement directions of South China block from mainland to sea as a whole, which is included in the model of intraplate blocks movement in China continent (figure 1).

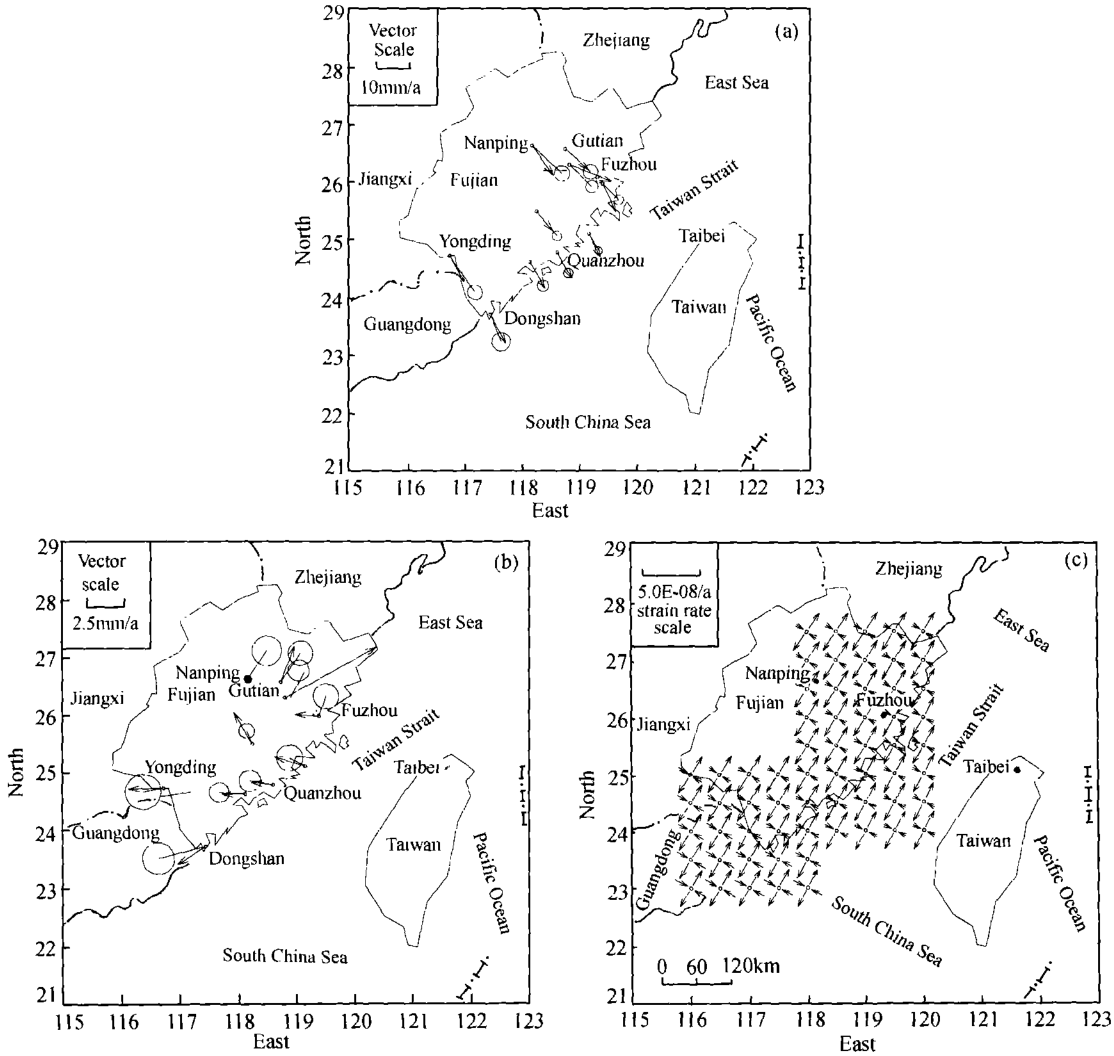

Fig. 3. Fields of velocity and principal strain rate (1995—1997) of present-day crustal movement in Fujian and its neighboring sea region. Velocity fields taking Taibei (a) and Nanping (b) as the reference points, and strain rate field (c) taking Nanping as the reference point.

When Nanping observation station which lies on the South China block is taken as the reference point, the movement of the whole block which directs to southeast is depleted, thus, the intrablock relative movement is observed. We can find that there exists a sort of crustal movement in Fujian and its neighboring sea region that directs from sea to mainland (fig. 3(b)). The basic characteristics of the strain rate field are the compression in northwest direction while extension in northeast direction (fig. 3(c)). The data of deformation observing network for Fujian cross fault from 1982 to 1998 have been processed, which confirms that the faults with northeast azimuth are thrusting at present and are compressive, while the ones with northwest azimuth are tensile. Fig. 4 presents the faults' movement modes, the yearly velocities and their standard errors, which are consistent with the mechanical state of present-day crustal movement (fig. 3(c)) discovered by GPS surveying data. Furthermore, the focal mechanism resolutions in this region indicate that the preponderant direction of principal stress axes is NW-SE or NWW-SEE. The investigations in geology and geomorphology show that the long axes of coastal fault basins, plains and bays are mostly in a direction of northwest and present extension toward northeast. All sorts of data's corroboration show that in southeast coast region of China continent (Fujian and its neighboring region) the direction of principal stress axis of the regional stress field is NW (NWW)-SE (SEE).

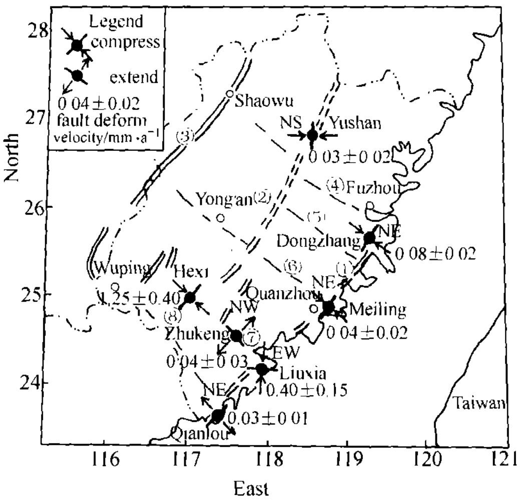

Fig. 4. Compressing or extending state of present-day fault motion and vertical deformation yearly velocities (1982—1998)

Philippine plate moves toward northwest with a speed of 70 mm/a[9] and collides with and thrusts Eurasian plate at north latitude 23°, which is in the east of Taiwan block. Thus the high mountain range of approximate 4000 meters (the highest in west pacific island-arc mountain system) and the east Taiwan earthquake zone[5] with intensive activities formed. The preponderant direction of the maximum principal stress axes (P axises) in focal mechanism resolutions is NW (NWW)-SE (SEE) (see right bottom of fig. 2). The geodetic survey in recent years has discovered that the mountains in east coast of Taiwan rise relative to the east Taiwan longitudinal valley at a speed of 30 mm/a, and that the fault sliding is rather obvious. All these indicate that the pushing toward northwest of Philippine plate still exists[10], the regional stress field of Taiwan belongs to the same system as the one of southeast coast region in China continent (Fujian and its neighboring region), and the preponderant directions of their principal stress axes are both NW (NWW)-SE (SEE) (compare the right bottoms of figs. 2, 3(c) and 4). Furthermore, crustal movement speed, fault sliding speed and earthquake activity decrease gradually from southeast to northwest (from collision boundary to intraplate region, from sea to mainland, from coast to hinterland). Therefore, the main force resource of present-day crustal movement and earthquake activity in southeast coast of China, as same as the one in Taiwan, comes from collision and thrust of Philippine plate to Eurasian plate in the west pacific subduction zone, though a large part of the energy has been depleted in the boundary of the two plates (east Taiwan longitudinal valley and its neighboring region).

3 Conclusion

(i) The present-day crustal movement in China continent and its southeast coastal region determined by GPS observation data is roughly consistent with the average state of longer time determined from geology, geomorphology and seismology. It shows that continent crustal movement presents a kind of dynamic equilibrium that has a characteristic similar to dynamic attractor as a whole.

(ii) The collision of India plate to Eurasian plate plays the main role in the whole movement of China continent, and its influence reaches the southeast coastal region via the side transferring of interblock. Southeast coast and sea region (Fujian and its neighboring sea region) are directly affected by the collision and pushing of Philippine plate to Eurasian plate, which has been existing for millions of years in the west Pacific subduction zone.

(iii) Spatial geodetic survey and crustal deformation observation provide fundamental quantitative relationship with continent dynamics, marginal sea dynamics and earthquake prediction.

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