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Three evolutionary stages of the collision orogenic deformation in the Middle Yangtze Region

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Abstract A discussion of collision orogenic deformation has been made for the Middle Yangtze Region. Based on its deformation assemblage orders, three developing stages are classified successively as compression thrust uplift, strike-slip escape rheology and tension extension inversion. The collision orogenesis of the studied region has been divided into three developing periods of initial, chief and late orogeny. Based on the data from Wugong Mts., Jiuling Mts. and Xuefeng Mts., for each stage, its variation of stress and strain axes, the conversion of joint fractures and their relative tectonic evolution are described, models are plotted and corresponding explanations are made for the rock chronology dating value in the same tectonic period.

Keywords: collision orogenesis, deformation, tectonic evolution, the Middle Yangtze Region.

Since the 1980s, in the course of collision geotectonic research[1—3], Guo et al.[4,5], Hsü et al.[6], Li et al.[7—9] have carried out a further study on the collision orogenesis in South China based on their studies on plate tectonics and the model shown by Sengör[10]. It is considered that South China is of Altay style or Turkic type, demonstrating that its characteristics are the regression of submarine trench toward ocean and island arc magmatism advances toward accretonary complex.

During the 1990s, the Chinese and French geologists carried out geological investigations for five times in Jiangxi, Hunan and Hubei provinces of the Middle Yangtze Region. Based on the previous studies with special emphasis on the crust composition, facial belt blocking and macro-structure of the collision orogenic zone, special attention is paid to the discussion of the stress and strain, the deformation and micro-mechanism of movement properties[11—15]. Based on its deformation assemblage orders, three developing stages are classified successively as compression thrust uplift, strike-slip escape rheology and tension extension inversion; and the process of the collision orogenesis are divided into three developing periods of initial, chief and late orogeny.

1 Stage of compression thrust uplift

(1) In the Middle Yangtze Region, the trench, arc and basin systems and geotectonic facies in

collision orogenic zone were developed very completely in the Middle Neoproterozoic to early Palaeozoic (fig. 1)[4,5,8,9].

During the survey of regional great sections (fig. 1, Dayong-Lengshuijiang section in Xuefeng Mts.; Xiushui-Ji'an section in Jiuling and Wugong Mts.), the authors found the phenomena of early inversion and late obversion, tension and extension produced by bedding slipping[16]. In fact, the inherent law can be sought from the complete process of collision orogenesis with combination of explanation to deformation evolutionary dynamics[17].

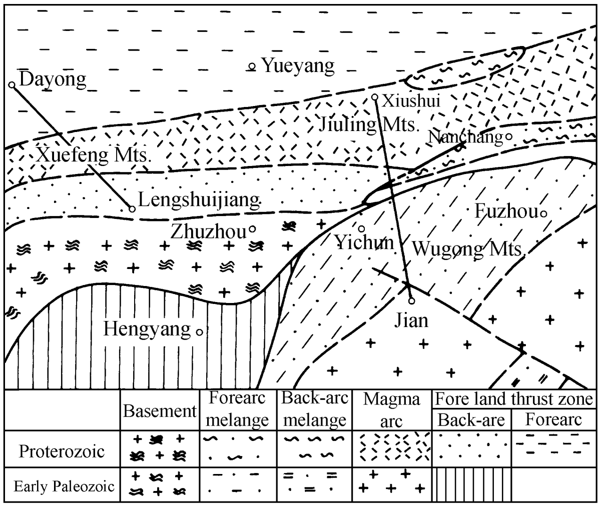

Fig. 1. General distribution sketch of geotectonic facies in collision orogenic zone, the Middle Yangtze Region (simplified from ref. [7]). The straight lines are profiles of regional survey.

(2) In the Middle Yangtze Region, the both collision orogenic zones (Jiuling Mts. and Xuefeng Mts.) in Neoproterozoic and early Palaeozoic (Wugong Mts.) are linked mountains of finished and ripe forms. They belong to an evolutionary process of continuous development instead of being built once only. Either from formation or from deformation, they can be divided into initial, chief and late orogenic periods, and there might occur superimposed orogenesis or re-orogenesis when they acted continually. From the viewpoint of deformation, it can be recognized from the alteration of stress axis and strain axis. It is clear that $\sigma_2 \parallel B$ was altered from vertical state to horizontal one and then returned back, showing that $\sigma_2 \parallel B$ is the boundary of initial period, earlier period and later period of chief orogenesis. However, $\sigma_1 \parallel A$ of the late orogenic period is vertical, bearing characteristics quite different from the previous two periods (table 1). In addition, the plane joint X in early stage and section joint X in late stage also serve as important recognition marks for the initial period and earlier stage of the chief orogenesis. From compression to strike-slip, section X, instead of plane joint X (overthrust and thrust faults) is converted to slip structure parallel to the mountain bodies (table 1). In the Middle Yangtze Region, during the first deformation stage, corresponding to the collision orogenic and developing stages, e.g., compression thrust uplift stage, the layer-slip and dip-slipping are especially active on different rocks and litho-interfaces, resulting in the formation of ramp and opposite types of structures (fig. 2) by compressive fold including longitudinal flexed folds of overturn, recumbent, convolute, thrusting nappe structure (para-autochthonous change of rock plate, imbricate and poly-superimpostion), different from those of backthrusting and deviate types in the Tianshan Mts. and Dabie Mts.[18]. Fig. 2 only plots one side of the mountain. From Jiuling Mts. northward to

Table 1 Collision orogenic periods and the deformation evolutionary stages in the Middle Yangtze Region

	Collision orogenic period	Deformation stage	Stress axis (σ_1 σ_2 σ_3) and strain axis (A B C)	Fissure joint fault	Linear, planar and fabric	Rock rheology	Change of crust
Chief orogenic stage	Initial orogenic period	compression thrust uplift	$\sigma_1 \parallel C$ (horizontal) $\sigma_2 \parallel B$ (vertical)	a c cross joint, normal fault, early plane joint X	oriented fabric was just developed compressive foliation and schistosity, mostly S.R fabrics	bed-cut viscous rheology	①napping, shrink thickening ② melting temperature of rocks increases to metamorphism ③magma of same tectonic time emplaced on a large scale ④ductile thrusting shear zones
	earlier period		$\sigma_3 \parallel A$ (vertical) $\sigma_2 \parallel B$ (horizontal)	late section joint X, overthrust and thrust faults			
	later period	strike-skip escape rheologic stage	$\sigma_1 \parallel C$ (horizontal) $\sigma_2 \parallel B$ (vertical)	section joint X, thrust fault converts to strike-slip fault	fabric R is of superiority	ode-type rheology	①the strike parallel to the mountains extends and migrates ② shear converting to pull-apart basins
Late orogenic stage	earlier period	tension extension inversion stage: sub-stage of layer slip decollement extension	$\sigma_1 \parallel A$ (horizontal) $\sigma_2 \parallel B$ (vertical)	thrust and strike-slip faults convert to negative reversed structure and positive tensional faults	stretched lineation and foliation, S,B fabrics are distinct	rheology of bedding ductile gliding type	① gliding overburden, stretching thinned ②retrograde metamorphism ③magma of same tectonic time emplaced on a small scale ④ductile positive shear zones ⑤mountain swell, thrusting took place on both sides on a small scale
	later period	sub-stage of gravity decollement extension	same as above or partly variable		partially oriented fabrics	ditto or not distinct	

Xiushui (fig. 2(a)), and from Wugong Mts. southward to Yuanbei (fig. 2(b)), ramp types are formed along the mountains. In the late orogenic period, negative faults shifted to positive movement, being called opposition.

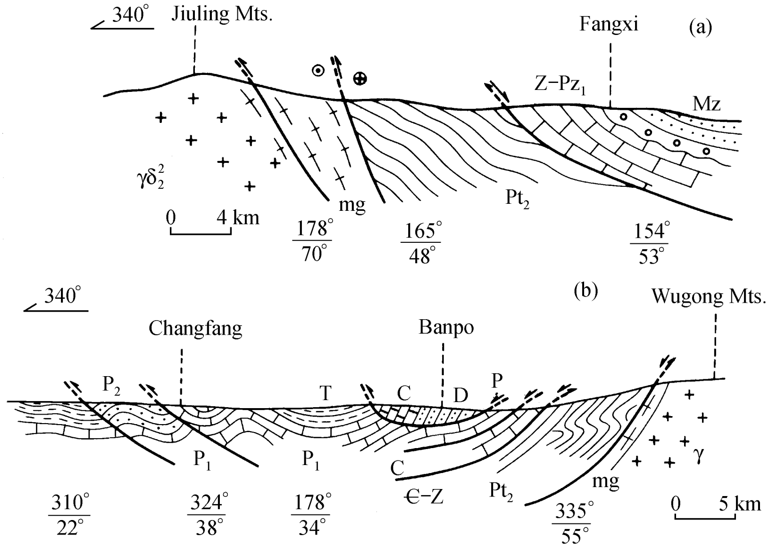

Fig. 2. Tectonic profile from Jiuling Mts. to Fangxi, Changfang to Wugong Mts., northern Jiangxi. Mg, mylonitic gneiss; γ, granite; $\gamma\delta_2^2$, granodiorite of Middle Proterozoic; 165°/48°, layer or foliation occurrence corresponding to surface measurements, showing dip and dip angle (the same below); the trending of early period is signed by the dotted arrow (the same below).

(3) As late orogenesis may damage, disturb and cover its early tectonic features, the Sino-French cooperators paid much attention to the study of the following microstructures, their functions of orientation in defining ductile shear zones to improve the research precision[19,20]: 1) σ-δ porphyroid rotation and shearing, with δ-type well developed in the studied region; 2) *S-C* planar gliding which is rather popular in mylonite and gneissic mylonite; 3) *P-Q* micro-area differentiation, with feldspar and quartz differentiating dynamically and forming pressure shadow and margin; 4) *L-F* fabric orientation, with clear and definite lineation and fabric structures. In the studied area, the former two indicate tendency, and the latter two indicate orientation. The application of the composite features of *R-P* planes in brittle deformation belt is helpful to accurately differentiate the middle- and small-sized structures in three deformation stages as well as even some negative, translational and positive movement of regional structure. On lots of tectonic profiles from Xiexi, Yichun located on south slope of the Jiuling Mts. to Xiashihe, northward thrusting features can be found in mylonite gneissic belts, and through σ quartz porphyroid, the trend of mineral lineation L in foliation can be recognized accurately. More important is that in the slightly metamorphic strata of the Middle Proterozoic Shuangqiaoshan Group (fig. 3) near Linghuxiang, early thrusting fractures converted into positive stretching faults in late tectonic period. Near the distinct fractures parallel to the positive faults, the relict thrusting drag folds are found. Comparing the thrusting drag of the early fracture with that of the late period, it can be found that the inter-

sected angle between axial plane and section from the derived fold is quite small (fig. 3B). This phenomenon is also evident in the Xuefeng and Wugong Mts. In a word, for the tectonic features in the stage of compressive thrusting uplift in the studied area, the closer they are to the mountains, the clearer the features are, and undoubtedly, the thrusting structures on both sides of the mountains must be the products of late orogenic period (fig. 2(b), Changfang area).

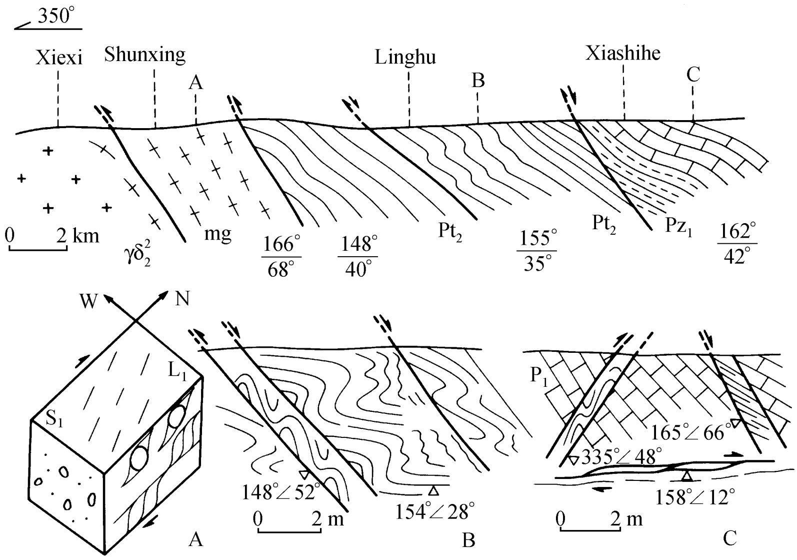

Fig. 3. Tectonic profile of Xiexi to Xiashihe in Yichun Region, northern Jiangxi. A, Mould map of thrust direction; B, C, profiles of local structure details (legends the same as in fig. 2).

2 The stage of strike-slip escape rheology

(1) As the relics of deformation and features in this stage are minor, the sizing and determination are rather difficult compared with the rest two stages. In the studied area, the strike-slip structures within the joined zones of island arc and basin, i.e. basin and range intermediate zone, are pretty evident, and progressively reach a certain scale in the ductile fracture zones from Pingxiang to Leping of the Middle Proterozoic island and basin system in Jiuling Mts., with a width of 2—4 km and intermittent extension of 200 km. Taking Wanli-Fangxi section as an example, where many times of studies have been made (fig. 4), the rock composition in the section is mainly mylonitic gneiss, associated with gneissic mylonite and mylonite composed of quartz, K-feldspar, plagioclase (An 5—20), biotite, muscovite, sericite and penninite, and with orthogneiss as primary rock. Within the high strain domains of the ductile shear zone, lineation and foliation are extremely developed, deformations of different generations are inter-superimposed, the structures of different types are inter-composed, and the phenomena of spatial and temporal evolution are plentiful. Based on the field observation and projection analyses on ductile micro-structures of σ-δ, *S-C*, *P-Q*, *L-F*, it is found that the mineral lineation occurrence is $60^\circ\angle 20^\circ$, and mylonitic foliation occurrence is $70^\circ\angle 65^\circ$ (fig. 5)[15]. In the studied area, most of the

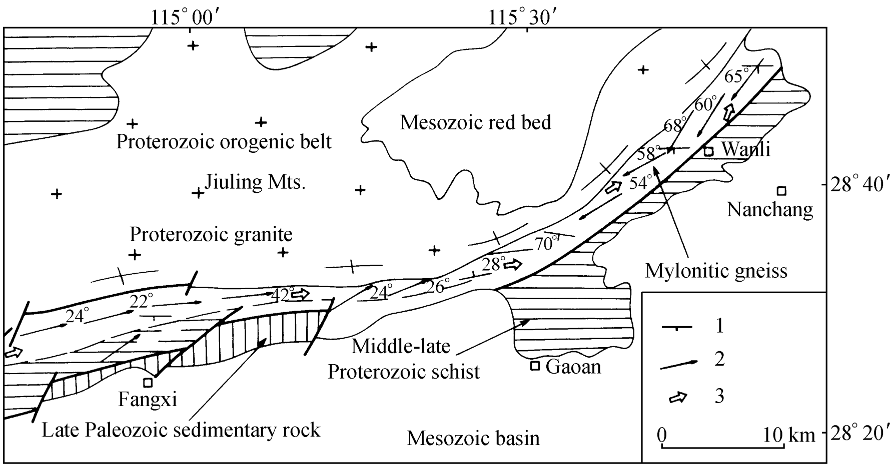

Fig. 4. Geological tectonic sketch map of ductile shear zone in the basin and range joined blocks (Wanli-Fangxi), northern Jiangxi[15].

asymmetric porphyroids are type σ, the porphyroids of rigid quartz, feldspar and muscovite are usually 2—3 mm, with the tail part composed of sericite and chlorite of stress minerals formed by dynamic metamorphism. For the penetrative mylonitic foliation of *S-C*, the closer to the shear surface, the smaller their inclined angles will be. With the help of porphyroid system and mylonitic foliation, the strike-slip shear movement translated (strike-slipped) left-laterally from southwest to northeast can be accurately determined.

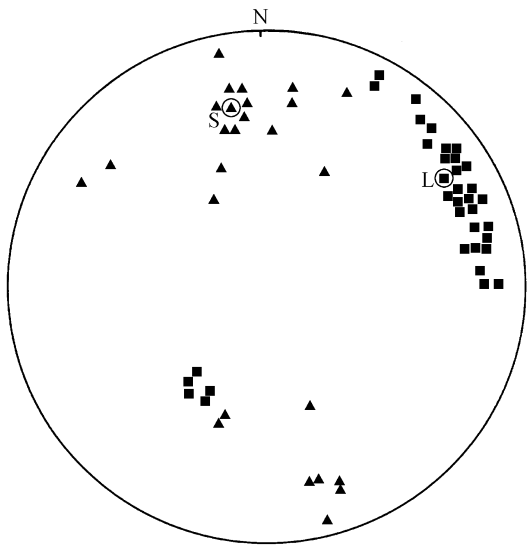

Fig. 5. Shi's projection net map of the ductile shear zone of the joined blocks in basin and range. ■, Lineation, ▲, foliation. L and S show the lineation and foliation maximum respectively.

(2) During the late period of chief orogenesis, because of the geometric nonlinearity, the unevenness of loading distribution and anisotropism of the physical change of rocks around the collision orogenic boundaries, the nature of the earlier thrusting faults was converted to longitudinal movement along the strike of the mountains. Besides, as far as the whole process of the collision orogenic dynamics is concerned, the conversion of mechanical energy and thermal energy weakened the interfacial friction and intensified the rheological creeping[21]. In addition, when the mineral density difference, linear defect in ductile shear zones and the hidden fissures in ductile and brittle deformations were pressed in a vertical direction, the stress would be focused on their ends on the contrary. In this case, movement would occur in a vertical direction with pressure exertion, i.e., the H.Odë rheology[22], which helped to bring about the new movement of shear gliding and strike slipping.

In the joined basin and range zones at the south edge of Jiuling Mts., the landmass on south side of the sinistral strike-slip fracture of ductile shearing was pressed out from SWW to NEE, i.e. from Pingxiang to Leping. The landmass creeped along strike-slip fracture from high to low stress, and its resulted deformation was called escape structure[23,24]. In addition, toward Nanchang and Leping between Jiuling Mts. and Wugong Mts., there was a wedge-shaped block narrow in the west and wide in the east. Although the dextral strike-slip is not evident in the ductile shear zone on the south slope of Wugong Mts., it is obviously shown in a large area of cold lineation in the Middle Palaeozoic along Pingxiang, reflecting exactly the eastward movement of the wedge-shaped block. This phenomenon is matchable to the escape structure in the Lower Yangtze Region[25].

3 The stage of tension extension inversion

(1) In the studied area, the tension extension tectonic features in the late orogenic period were better preserved and sized easily compared with those of the former two periods. Fig. 2, fig. 3 and figs. 6—8 show characteristics of positive extension, especially compression first and then extension.

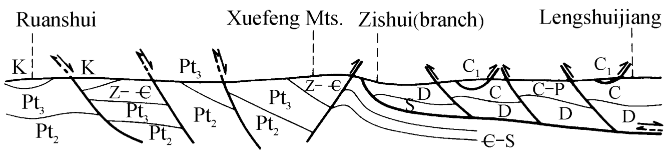

Fig. 6. Geological tectonic sketch profile from Yuanshui to Lengshuijiang, western Hunan. Early tendency was signed by dotted arrow.

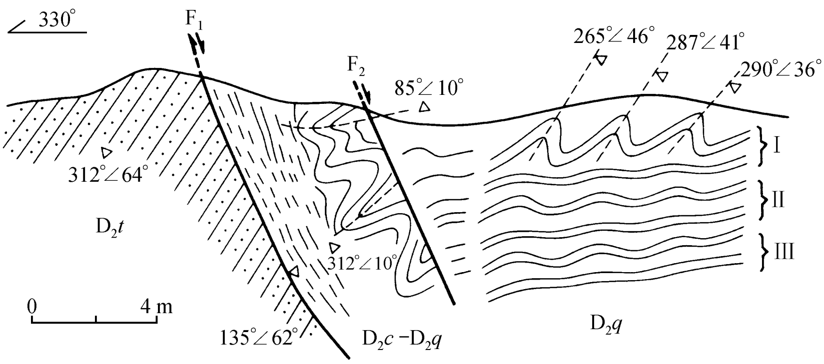

Fig. 7. Dip-slip fracture structure of compression first and then extension between Middle Devonian Tiaomajian Fm. and Qiziqiao Fm. by the highway of Longkou, Dongkou region, western Hunan. F_1, Primary fracture plane; F_2, late associated fracture plane.

In fig. 7, between the quartz sandstone of the Tiaomajian Fm. (D_2t) and siltstone shale of the Qiziqiao Fm.(D_2q), there existed an obvious phenomenon of compression first and then extension for the dip-slip fracture. A small drag fold is developed in siltstone shale. From transversal viewpoint, the occurrences of axial plane are 265º∠46º, 287º∠41º and 290º∠36º respectively and become gentle in proper order as far away from the section. From longitudinal viewpoint, the dip angle of axial plane is wavy and gets more gentle from surface layer downward, three series of

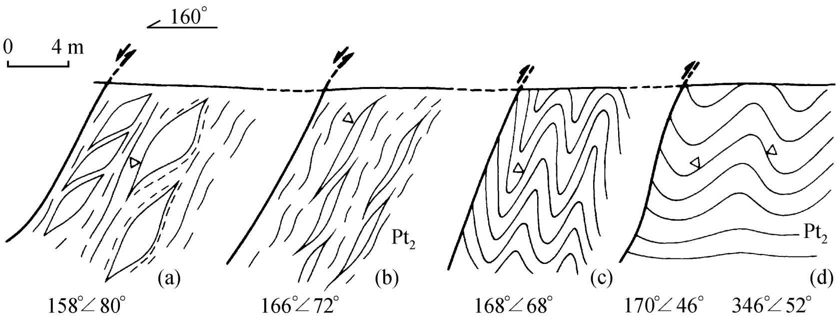

Fig. 8. Negative inversion change of the late thrusting fracture zones along lenticule and foliation zones in Shuangqiao Fm. of Middle Proterozoic by the highway of Diaofeng, Yifeng, northern Jiangxi.

gliding structures could be classified according to its disharmonic development and bedding slipping, and the gliding structures become more gentle when they dip downward. In the blent layer sections of the Qiziqiao Fm. and Tiaomajian Fm., there is another series of disharmonic folds with their axial planes nearly horizontal: 85º∠10º and 312º∠10º. Towards the main section, there occur 2 m of faulted breccia and pudding sandstone with the cleavage destroyed near fault and local schistosity. They are fine-grained, mylonitic rocks, with stress mineral developed microscopically. These are resulted from the thrust in the early period. In the above two groups of disharmonic folds, the former was formed by late tension with axial dipping NWW; the latter was formed by early thrust and compression, and the late gliding was the source of the disorder of axial dip (the gliding was also mingled in F_1 and F_2). Besides, the foliation fabric and porphyroid traces remaining on F_1 and F_2 surfaces can be helpful to discriminate the tendency. The conversion of the mechanical property is a typical case of the negative inversion tectonics of faults[26].

(2) The late orogenic period can be further divided into two sub-periods: layer slip decollement and gravity decollement tension extension (table 1). The first sub-period is generally developed in the studied area (fig. 2, fig. 3B and fig. 6), and figs. 7 and 8 also show the dip-slipping fractures and glide-overburden structures from bedding to tangential, evolving into negative inversion tectonics along compressive schistose and lenticule zones of thrusting fracture belt (fig. 8). From the folds derived from the faults shown in figs. 7 and 8, it can be observed that the deeper the folds go downward, the more gentle they become, i.e. a large-sized main decollement fault could be found in the deeper parts[16]. The second sub-period (gravity decollement), however, brings about some brittlely deformed tectonics, which are scattered if there are no regional big decollement faults.

(3) In view that the tension extension inversion stage is the product of late orogenic period, it inevitably contains some features of the previous two stages, which is also shown clearly in the micro-fabric diagram (fig. 9). The azimuth of quartz axis c was tested with INEL 309 X-ray texture gonimeter in the Department of Earth Sciences, Orleans University, France. The fabric diagram for the main part and east and west sides of the Wugong Mts. shows a B-type tectonite of orthorhombic symmetry, and axis b shows a secondary maximum and present as the remains of

previous stages.

(4) In the tension extension inversion stage, frontal edge in the orogenic zone can convert from tension to thrusting to nappe structure and even ramp structure, which is clearly seen between the Jiuling and Wugong Mts. As shown in fig. 6, the Lower Carboniferous has been evolved into a klippe. In addition, large-sized regional decollement tectonics are rather popular in the ductilely deformed zones of metamorphic layers, with gentle occurrence. But the horizontal decollement occuring in the Permian limestone as shown in fig. 3C are rare.

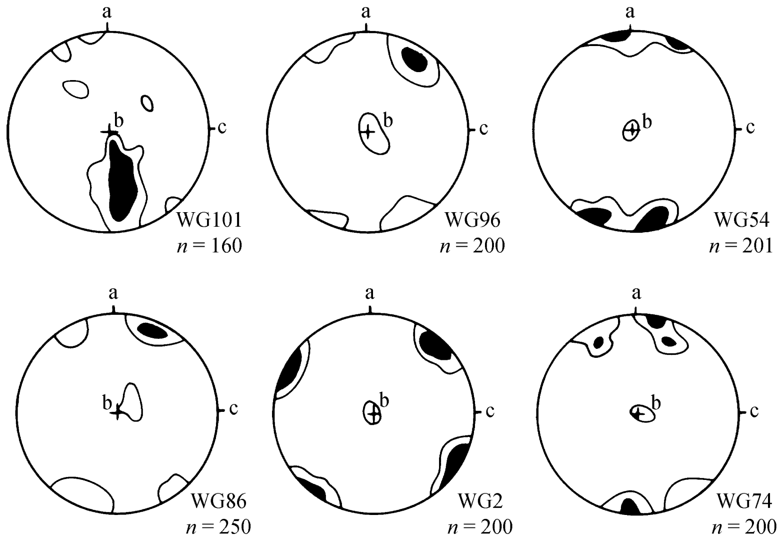

Fig. 9. Simplified maximum diagram of quartz fabric azimuth in ductile deformed layers of the extensional structures, Wugong Mts., northern Jiangxi. The upper three diagrams are the main parts of the mountain range, the lower three are sampled from east and west sides of the mountain rage. WG101, Serial No. of samples; *n*, frequency of measurements.

4 Discussion and conclusions

The developing process of southeast China landmass, including collision orogenesis in the Middle Yangtze Region is complicated, and related marks are abundant[7]. In terms of the deformation rather than the formation, a law of the spatial-temporal evolution of some principal marks such as thrust and ductile shear zones have been described in this paper.

(1) From the viewpoint of deformation, the collision orogenic period can be divided into initial, chief and late orogenic developing periods and three evolving stages of compression, strike-slip and extension. The initial and chief orogenic stages can be merged into the former early orogenic period (table 1). In space, the variation of tectonic stress field and compound of tectonic system of the orogenic zone can be compared with the model made for the deformation growing process of the Wugong Mts. (fig. 10), so the spatial-temporal evolution frame chart of three great deformation composition orders are constructed.

(2) The deformation evolving period corresponding to the orogenic stage may be divided into long and short periods based on the analysis of collision orogenesis of the Middle Yangtze Region. In view of the multi-periods and multi-transmigrations for the region, the long period is relatively

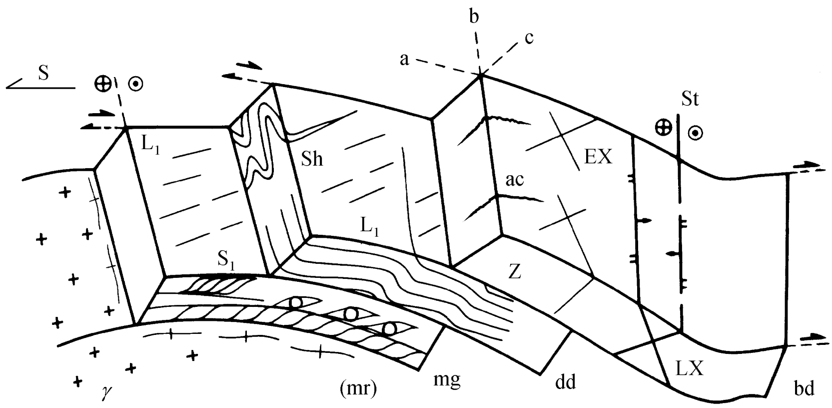

Fig. 10. The tectonic deformation model of collision orogenic zone, the Middle Yangtze Region. γ, Granite; mr, migmatite; mg, mylonitic gneiss; dd, ductile deformed layers; bd, brittle deformed layers; St, strike-slip fracture; Sh, scabbard fold; EX, early joint X(fracture); LX, late joint X(fracture); ac, ac fissure(fracture); a, b, c, coordinate axes.

easy to differentiate. It took a short continuous time for the earlier and later period of the chief orogenesis to convert from compressive thrusting to strike-slip escape, and the stress and strain axis $\sigma_2 \parallel B$ convert from horizontal to vertical. In the synorogenic period, there exists a wide range of emplaced magmatite and hypo-metamorphic rocks of aggradational metamorphism (table 1), and they may be taken as the substantial foundations for the age determination. However, the late-orogenic period will be judged by the magmatite of small-range emplacement and the epi-metamorphic rocks of degradational metamorphism in the tension extension stage of synorogenic period. Based on the above principles, with the magmatite emplacement age determination tested for the chief orogenic period, the age for the Xuefeng, Jiuling and Wugong Mts. in the Middle Yangtze Region is inferred to be 760[27], 805[15] and 403 Ma1), respectively. The former two belong to the Neoproterozoic (Pt_3) and the last belongs to the Early Devonian in age. The age determination for the later orogenic period will be judged by sample measurement from the Wugong Mts. with the $^{40}Ar/^{39}Ar$ method by the Sino-French cooperators at the University of Montpellier, so the ages are 259.0±3.3 and 233.5±5.0 Ma for magmatites, 229.0±2.9, 225.6±2.9 and 131.7±1.7 Ma for metamorphic rocks. All belong to the Late Permian to Late Triassic in age and Early Cretaceous for certain specific rocks, over 144 Ma later than the chief orogenic period[28].

(3) With regard to the three deformation evolving stages of the collision orogenesis, there has been a lot of statement on the pattern of compression first and then extension, earlier traction and later slip as well as the conversion of compression thrusting into tension extension in the orogenic periods[12,13,22], but the study of strike-slip escape stage between the two stages is not enough[29]. The Jiuling Mts. has its age data from the ductile zone of its south edge (figs. 4—6), 410.79±18.69 Ma for dynamic metamorphic rock of Shanggao, and 394 Ma[15] for monzonite of

1) Jiangxi Bureau of Geology and Mineral Resources, Regional Geoloy of Jiangxi Province, The Map of Magmatic Rocks for Jiangxi Province (1∶50000), 1984.

nonmylonization from Fengding Mts. by Rb/Sr method, roughly reflecting that the active time of strike-slip zone in the Jiuling Mts. is prior to the Late Silurian-Early Devonian. In fact, the accurate determination of the tectonics in strike-slip stage needs systematic reconnaissance analysis and age determination not only on lithorheology, tectonic escape, but also on the change of lithosphere and the complete process of the orogenesis.

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References

1. Faure, M., Pons, J., Bonneau, M., Ductile deformation and syntectonic granite emplacement during the Late Miocene extension of the Aegean Area, Bull. Soc. Geol., 1991, 162: 3—11.
2. Charvet, J., Lapierre, H., Yu, Y., Geodynamic significance of the Mesozoic volcanism of SE China, J. Southeast Asian Earth Sci., 1994, 9: 387—396.
3. Hsu, K. J., Sun, Sh., Li, J. L. et al., Mesozoic overthrust tectonics in South China, Geology, 1988, 16: 418—421.
4. Guo Lingzhi, Shi Yangshen, Ma Ruishi, Geotectonic framework of the Huanan Area, China, in Proceeding of the International Symposium on the Pre-Cambrian Earth Crust Evolution, Beijing: Geology Publishing House, 1986, 455—463.
5. Guo Lingzhi, Lu Huafu, Shi Yangshen, On the Meso-Neoproterozoic Jiangnan Island Arc: its Kinematics and Dynamics, Geological Jour. of Universities, 1996, 2: 1—13.
6. Hsü, K. J., Sun, S., Li, J. L., It’s the orogenetic belt and it’s not the Huanan Platform, Science in China, Ser. B, 1987, 10: 1107—1115.
7. Li Jiliang, Study on the Structure and Evolution of the Ocean-Continent Lithosphere in SE China, Beijing: Science Technology Publishing House of China, 1992, 3—16.
8. Li Jiliang, Structure and Geological Evolution of the Continental Lithosphere in SE China, Beijing: Metallurgical Industry Publishing House, 1993, 1—13, 190—192.
9. Li Jiliang, Sun Shu, Huo Jie, On the zoning of collisional orogeny, Scientia Geologica Sinica, 1999, 34: 129—138.
10. Sengör, A. M. C., The Palaeo-Tethys suture: a line of demarcation between two fundamentally different architextural styles in structure of Asia, The Island Arc, 1992, 1: 78—91.
11. Sun Yan, Shu Liangshu, The kinematic characteristics of the metamorphic terrane, Comunicasiones, Una Revistade Geologia Andina, Chile, 1991, 42: 211—212.
12. Sun Yan, Shu Langshu, Faure, M. et al., Study on the extensional tectonic and geodynamic evolution of the Wugongshan area, Jour. of Nanjing University (Natural Sciences), 1994, 30: 69—70.
13. Sun Yan, Shu Liangshu, Faure, M. et al., Tectonic development of the metamorphic core complex of Wugongshan in the Northern Jiangxi Province, Jour. of Nanjing University, 1997, 33: 447—449.
14. Faure, M., Sun Yan, Shu Liangshu et al., Extensional tectonics within a subduction-type orogen, the case study of the Wugongshan dome, Tectonophysics, 1996, 263: 77—106.
15. Shu Liangshu, Shi Yangshen, Guo Lingzhi et al., Plate Tectonic Evolution and the Kinematics of Collisional Orogeny in the Middle Jiangnan, Eastern China, Nanjing: Publishing House of Nanjing University, 1995, 14—149.
16. Sun Yan, Shi Zejin, Study on mechanical parameters of rocks and regional layerslip system in Hunan-Jiangxi area, Science in China, Ser. B, 1993, 36(8): 962—975.
17. Xu Zhiqin, Chui Junwen, Tectonic Dynamics of the Continental China, Beijing: Metallurgical Industry Publishing House, 1996, 89—178.
18. Sun Yan, Tectonics and mineralization of Lachlan Fold Belt, Canberra, Geol. Soc. of Australia, 1991, 29: 52—53.
19. Faure, M., The geodynamic evolution of the Eastern Eurasian margin in Mesozoic times, Tectonophysics, 1992, 208: 97—

411.
20. Herwegh, M., Handy, M. R., Heilbronner, R., Evolution of mylonitic microfabric (EMM), a computer application for educational purposes, Tectonophysics, 1999, 303: 141—146.
21. Wiens, D. A., Sliding skis and slipping faults, Nature, 1998, 279: 824—825.
22. Sun Yan, Suzuki, T., Study on the ductile deformation domain of the simple shear in rocks, Science in China, Ser. B, 1992, 35(12): 1512—1520.
23. Molnar, P., Tapponnier, P., Cenozoic tectonics of Asia: effects of a continental collision, Science, 1975, 189: 419—426.
24. Buke, K., Sengör, A. B. C., Tectonic escape in evolution of the continenental crust, in Reflection Seismology, The Continental Crust, Geodynamics Series (14). (eds. Barazangi, M., Brown, L.), Washington D.C.: American Geophysical Union, 1986, 41—53.
25. Shan Yanjun, Xia Bangdong, A preliminary discussion on the Mesozoic secape structure: Lower Yangtze Region, Petroleurn & Natural Gas Geology, 1997, 18: 176—182.
26. McClay, K. R., Inversion tectonics, Geol. Soc. London, Speci. Publi., 1989, 44: 3—104.
27. Sun Yan, Shu Liangshu, Zhu Wenbin et al., Mesozoic tectonic events and the geochronological dating in the Lushan Massif, Jiangxi Province, Jour. Nanjing University (Natural Sciences), 2000, 36: 363—366.
28. Qiu Yuanxi, Zhang Yuchang, Ma Wenpu, The Tectonic Nature and Evolution of the Xuefeng Shan—A Formation Evolution Model of the Intracontinental Orogeny, Beijing: Geological Publishing House, 1999, 10—48.
29. Li Dongxu, Orogenetic mechanism of the shear-compressive action in the intraplate, Earth Science Frontiers, 1999, 6: 317—322.