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Protolith ages and deformation mechanism of metamorphic rocks in the Zhangbaling uplift segment of the Tan-Lu Fault Zone

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Protolith ages and Indosinian deformation mechanism of metamorphic rocks in the Zhangbaling uplift segment of the Tan-Lu Fault Zone are important, unsolved problems. Our LA-ICP-MS zircon dating work indicates that protolith ages of the greenschist-facies Zhangbaling Group are 754–753 Ma, and those of the amphibolite-facies Feidong Complex are 800–745 Ma. These rocks belong to the earliest cover of the Yangtze Plate. Their ages and metamorphic features suggest that the rocks did not come from the Dabie Orogen. The Indosinian structures in the Zhangbaling Group and lower Sinian strata formed in a flat-lying ductile detachment zone with a shear sense of top-to-the-SSW whereas those in the underlying Feidong Complex are characterized by ENE-WSW inclined folds developed under a ductile regime. It is suggested therefore that the sinistral Tan-Lu Fault Zone of the Indosinian period is buried under the Hefei Basin west of the Zhangbaling uplift segment and the uplift segment is a displaced block neighboring the fault zone. Detachment deformation between the upper rigid and lower ductile crust during displacement of the Zhangbaling uplift segment resulted in the formation of the flat-lying ductile detachment zone and its underlying drag fold zone of a ductile regime. The protolith ages and deformation mechanism in the Zhangbaling uplift segment further prove sinistral origination of the Tan-Lu Fault Zone during the continent-continent collision of the North China and Yangtze plates and support the indentation model for the two-plate collision that considers the Tan-Lu Fault Zone as an oblique convergence boundary.

Tan-Lu Fault Zone, Zhangbaling uplift zone, Zhangbaling Group, Feidong Complex, zircon dating, deformation mechanism

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The Zhangbaling uplift segment of the Tan-Lu Fault Zone lies along the western boundary of the Yangtze Plate between the Dabie and Sulu orogens. The low-grade Zhangbaling Group is exposed in the northern uplift segment whereas the high-grade Feidong Complex, previously referred to as the Feidong Group, outcrops in the southern uplift segment. Protolith ages and deformation mechanism of the metamorphic rocks are important for understanding origination of the Tan-Lu Fault Zone and convergence history of the North China and Yangtze plates.

The Zhangbaling Group and Feidong Complex in the Zhangbaling uplift segment were considered as metamorphic basement rocks for a long time, but their protolith ages were uncertain. Mesoproterozoic protolith ages were proposed for the Zhangbaling Group (Anhui Geological Survey, 1987), but most researchers correlated it with low-temperature, high-pressure metamorphic rocks at the southern margins of the Dabie and Sulu orogens, such as the Hongan Group and Yuntai Formation of the Haizhou Group (Sun et al., 1991; Tang et al., 2002a). Zhang et al. (1995) obtained single zircon grain Pb-Pb ages of 927±24 Ma and 975±31 Ma from meta-volcanic rocks of the Xileng Formation, the lower part of the Zhangbaling Group, and interpreted them

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as representing protolith ages of Early Neoproterozoic. The Feidong Complex was considered as being of Paleoproterozoic protolith ages (Anhui Geological Survey, 1987) and correlated with the Susong Group and the Jinping Formation of the Haizhou Group at the southern margins of the Dabie and Sulu orogens (Xu et al., 1987a; Sun et al., 1991; Tang et al., 2002a). Ge et al. (1993) obtained an U-Pb upper intercept age of 1995±102 Ma and lower intercept age of 688±30 Ma from orthogneiss of the Feidong Complex, and interpreted the former as representing a protolith age of Paleoproterozoic and the latter as a metamorphic age related to the Jinning Movement. Tang et al. (2002a) argued from comprehensive analyses that the Feidong Complex should be of Neoproterozoic protolith ages.

Earlier deformation mechanism of the Zhangbaling uplift segment has been studied for a long time, but controversies still remain, leading to different views about origination of the Tan-Lu Fault Zone. Ductile fabrics in the northern Zhangbaling uplift segment are characterized by flat-lying foliation and N-S gentle mineral lineation. Muscovite $^{40}Ar/^{39}Ar$ ages of 245–236 Ma from them (Li et al., 1993; Chen et al., 2000; Zhang et al., 2007) indicate that the fabrics result from the Indosinian deformation. Proposed deformation mechanism for the fabrics includes a strike-slip ductile shear zone (Xu et al., 1984), low-angle ductile thrusts (Xu et al., 1985,1987b; Shen et al., 1993; Zhang et al., 1997, 1998; Lu et al., 2004), ductile attachment zone between the basement and cover (Xu, 1987c), extensional detachment shear zone (Lin et al., 2005), and ductile attachment zone neighboring a strike-slip shear zone (Zhang et al., 2007). The southern Zhangbaling uplift segment is widely overprinted by sinistral ductile shear belts of the Late Jurassic (Zhu et al., 2005, 2010), and earlier deformation structures are only preserved among the later shear belts in the south. No detailed study has been conducted on the earlier structures. Lin et al. (2005) speculated that the earlier structures are formed through an evolution from earlier deep subduction to later extension-related exhumation that is similar to that in the Dabie Orogen. Origination of the Zhangbaling uplift segment also remains controversial. It has been proposed that metamorphic rocks in the uplift are remained slices of the Dabie-Sulu Orogen displaced by the Tan-Lu Fault Zone (Xu et al., 1987a, 1994). Some authors argued that the uplift zone represents an original oblique boundary of the Yangtze Plate and the uplifting took place during the oblique convergence of the Indosinian period (Xu et al., 2002b). Other authors proposed that the uplift zone is a strike-slip deformation zone along an oblique convergence boundary between the North China and Yangtze plates (Zhang et al., 2007).

In summary, protolith ages and earlier deformation mechanism of the Zhangbaling uplift segment are still in debate. This paper presents LA-ICP-MS zircon U-Pb dating results of metamorphic rocks in the uplift segment, detailed analyses of the earlier deformation and summary of foreland deformation features neighboring the Tan-Lu Fault Zone. The results offer important constraints on origination mechanism of the fault zone.

1 Geological setting

The Zhangbaling uplift segment of the Tan-Lu Fault Zone extends along the western margin of the Yangtze Plate in the lower Yangtze region (Figure 1). It strikes NNE with a length of 150 km. The Zhangbaling uplift is named after its wide exposures of metamorphic rocks of the Zhangbaling Group and Feidong Complex. The Hefei Basin in the North China Plate lies to the west of the uplift segment, and west-dipping later brittle normal faults separate the basin from the uplift segment. The lower Yangtze foreland deformation belt with the Subei Basin in the northeast is situated to the east of the uplift segment.

The Zhangbaling Group is exposed mainly in the northern uplift segment (Figure 2) and locally on the eastern side of the southern uplift. The group is divided into the Xileng Formation and Beijiangjun Formation from bottom to top. The Xileng Formation is dominated by intermediate metavolcanic rocks, and its protoliths include rhyolite, andesite, and tuff interlayered with mudstone. A representative mineral assemblage of the Xileng Formation is feldspar+quartz+muscovite+/−epidote+/−riebeckite, indicating metamorphic grades of medium to high greenschist facies (Liou et al., 1992; Xu et al., 1996; Zhang et al., 2007). The Beijiangjun Formation is metamorphosed clastic rocks of low-greenschist facies, and its main rock types are phyllite and low-grade meta-sandstone. Its lithology is similar to the lower Sinian strata to the east of the uplift segment. Zhang et al. (2007) divided the Xileng Formation into the white mica schist unit (ZH-U), quartz-feldspar schist unit (ZH-M), and blue amphibole schist unit (ZH-U) from bottom to top (Figure 2). The Beijiangjun Formation is dominated by a chlorite-epidote schist unit (ZH-H). Metamorphic grades in the Zhangbaling Group decrease gradually from bottom to top (2007).

The Feidong Complex outcrops only in the southern Zhangbaling uplift segment (Figure 3) and includes high-grade ortho- and para-metamorphic rocks. The ortho-metamorphic rocks are biotite-plagioclase gneiss, amphibole-plagioclase gneiss, plagioclase amphibolite, amphibolite, and deformed, metamorphosed plutons such as the Donggang and Huolongshan plutons dated in this work. The para-metamorphic rocks are dominated by dolomite marble and mica schists. Their rock types and mineral assemblages indicate low to medium amphibolite facies for the Feidong Complex (Jing et al., 1991; Zhang et al., 2007; Shi et al., 2009). The complex can be divided into the Fuchashan, Dahengshan, marble-bearing Shuangshan and Qiaotouji units.

The Sinian strata overlie the Zhangbaling Group in the

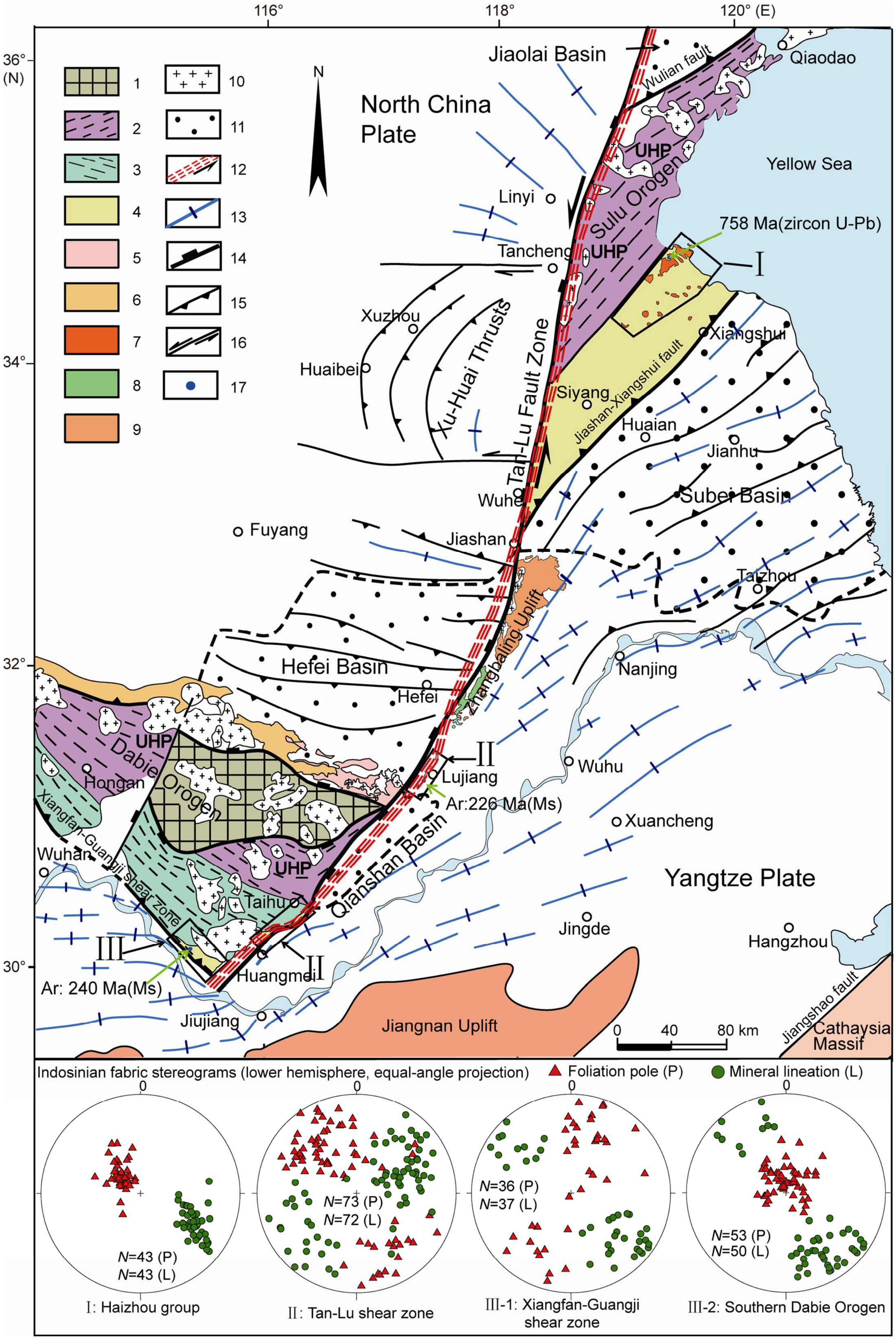

Figure 1 A sketch map for structures of the Indosinian period in and around the southern segment of the Tan-Lu Fault Zone (data of the Subei Basin are from the Jiangsu Oil Company). 1, Northern Dabie unit; 2, UHP eclogite facies unit; 3, HP amphibolite facies unit; 4, HP blueschist facies unit; 5, Luzhenguan Complex; 6, Fuziling Complex; 7, Haizhou Group; 8, Feidong Complex; 9, Zhangbaling Group; 10, Early Cretaceous pluton; 11, Meso-Cenozoic basin; 12, Indosinian Tan-Lu ductile shear zone; 13, fold axis; 14, brittle Tan-Lu normal fault; 15, brittle thrust; 16, brittle strike-slip fault; 17, previous dating sample locality.

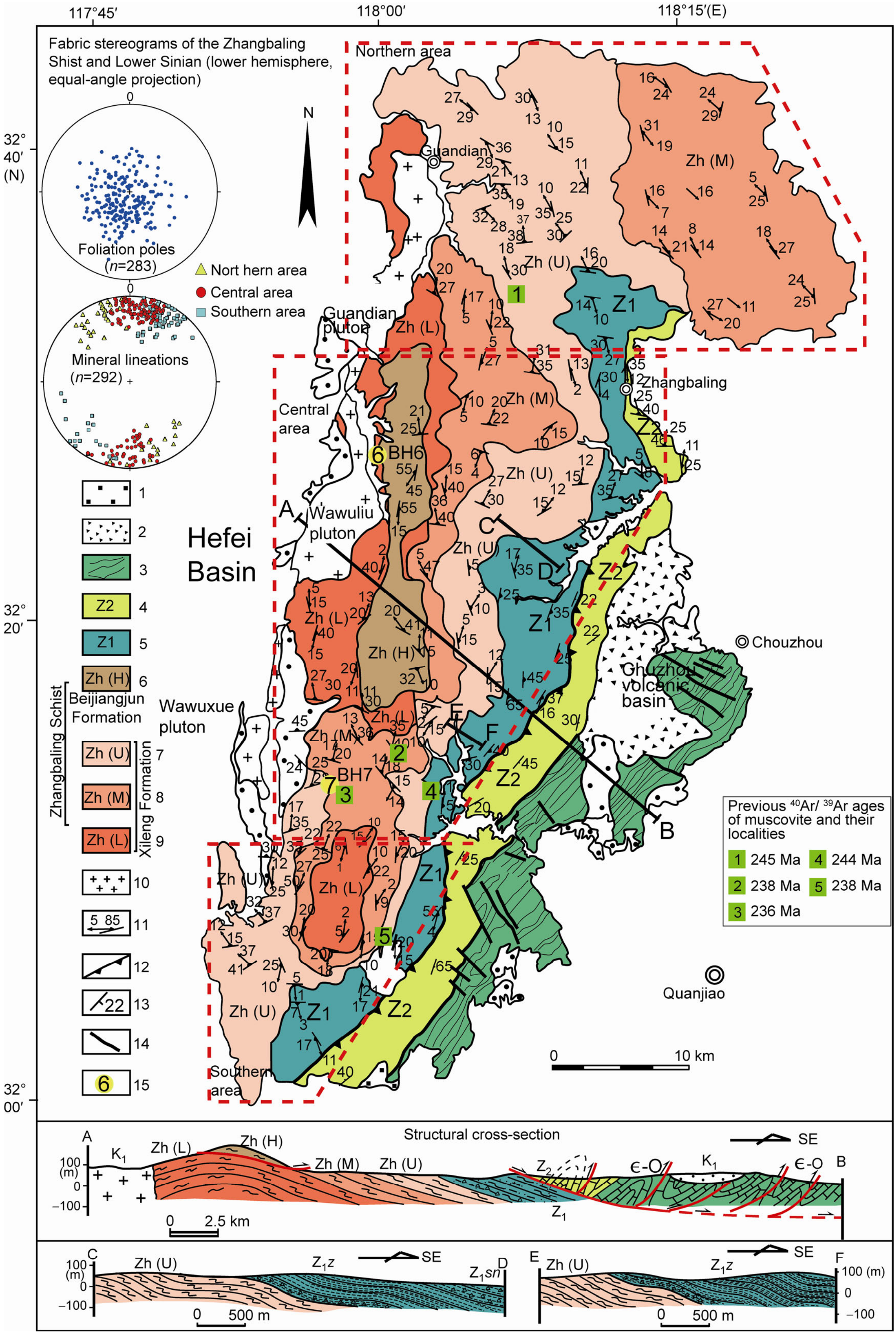

Figure 2 Structural map, cross-sections, and fabric stereograms of the northern Zhangbaling uplift segment (modified from Zhang et al., 2007). 1, Cretaceous red beds; 2, Early Cretaceous volcanic rocks; 3, Paleozoic; 4, Upper Sinian strata; 5, Lower Sinian; 6, chlorite-epidote schist unit; 7, blue amphibole schist unit; 8, quartz-plagioclase schist unit; 9, white mica schist unit; 10, Cretaceous pluton; 11, attitude of foliation and lineation; 12, thrust; 13, attitude of strata; 14, secondary faults; 15, zircon dating sampling locality for this study.

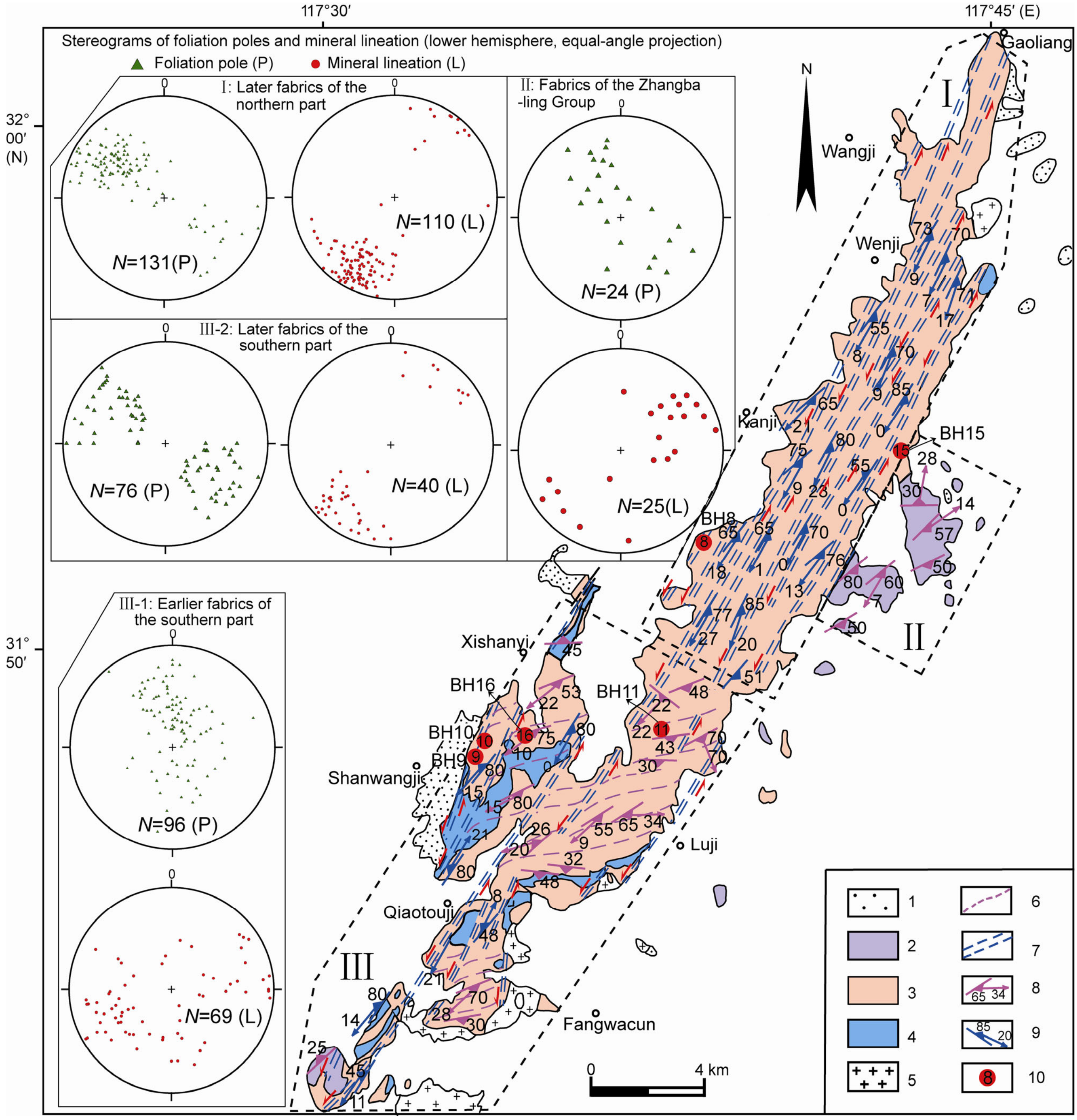

Figure 3 Structural map and fabric stereograms of the southern Zhangbaling uplift segment. 1, Cretaceous red beds; 2, Zhangbaling Group; 3, Feidong Complex; 4, marble in the Feidong Group; 5, Early Cretaceous intrusion; 6, earlier foliation trajectory; 7, later ductile sinistral shear zone; 8, attitudes of earlier foliation and lineation;9, attitudes of later foliation and lineation; 10, sampling locality for this zircon dating.

east, and the two show similar attitudes and upward reduction in metamorphic grades without any metamorphism in the upper Sinian. The lower Sinian strata, i.e., the Zhougang and Sujiawan formations, are low-greenschist facies and dominated by phyllite, pebble-bearing phyllite, and low-grade meta-sandstone. Protolith of the pebble-bearing phyllite in the Sujiawan Formation is tillite (Anhui Geological Survey, 1987). The upper Sinian strata, i.e., the Doushantuo and Dengying formations, are dominated by limestone, dolomite limestone, and dolomitite. Exposed Cambrian and Ordovician strata in the area are mainly carbonatite.

Following an earlier phase of deformation, the Zhangbaling uplift segment experienced sinistral faulting of the Tan-Lu Fault Zone in the Late Jurassic with overprinting of several NNE-striking, sinistral ductile shear belts in the Feidong Complex in the southern segment (Zhu et al., 2005, 2010) and local NNE-striking, brittle sinistral faults in the Zhangbaling Group in the northern segment that was exposed to shallow levels during the faulting. The Tan-Lu Fault Zone was subjected to normal faulting under the extensional setting of whole East China since the Early Cretaceous, leading to development of the Hefei Basin to the east and Chuzhou volcanic basin of the Early Cretaceous in the northeast as well as intrusion of the Early Cretaceous Guandian, Wawuliu and Wawuxue plutons along the western margin (Niu et al., 2005; Xie et al., 2007, 2009; Ma et al., 2011). A major NNE-striking, west-dipping normal fault formed along the western margin of the Zhangbaling uplift segment during the normal faulting and controlled formation of the Hefei Basin on its hanging-wall.

2 Zircon U-Pb dating of metamorphic rocks

2.1 Sample description

To date protolith ages of metamorphic rocks in the Zhangbaling uplift segment, eight samples were collected from the Zhangbaling Group in the northern segment and the Feidong Complex in the southern segment for zircon U-Pb dating. Two meta-volcanic samples of the Zhangbaling Group are muscovite-feldspar-quartz schist (BH6) and feldspar-quartz schist (BH7), and from the lower and middle parts of the Zhangbaling Group respectively. Six high-grade samples of the Feidong Complex include three samples of the deformed, metamorphosed Donggang pluton (BH9, BH10, BH16, mylonitized granitic gneiss) in the Dahengshan unit, one sample of the deformed, metamorphosed Huolongshan pluton (BH11, monzonite granitic gneiss), one biotite granitic gneiss sample of the Fuchashan unit (BH8), and one granitic gneiss sample of the Dahengshan unit (BH15). The Donggang and Huolongshan plutons show similar deformation fabrics and metamorphic grades to their country rocks. The sample of the Huolongshan pluton has earlier deformation fabrics whereas other samples show mylonitization related to later sinistral ductile shear belts (Table 1). Characteristics of the samples and microscopic observation results are listed in Table 1.

2.2 Analytical methods

Zircon grains from the dated metamorphic rock samples were separated using conventional heavy liquid and magnetic techniques. Representative zircon grains were handpicked under a binocular microscope and mounted in an epoxy resin disc, and then analyzed for Cathodoluminescence (CL) images and U-Pb isotopes at the State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Wuhan. Laser ablation ICP-MS (LA-ICP-MS) U-Pb analyses of the magmatic zircon grains were conducted on an Agilent 7500a ICP-MS equipped with 193 nm Geo-Las2005 Laser. Zircon 91500 was used as an external standard. The external standard silicate glass NIST SRM 610 and internal standard ^{29}Si were used to correct element contents. The detailed analytical technique and machine data are described by Yuan et al. (Yuan et al., 2004). Zircon U-Pb age calculations were made by using the ICP-Ms DataCal 6.2 program (Liu et al., 2010). Common Pb correction was made by using the Andersen method (Andersen 2002). Concordia diagrams and weighted mean calculations were made by using an Isoplot 3.0 Program.

Binocular microscopic observation and CL images demonstrate that, except for the sample BH15, dated zircon grains from the Zhangbaling Group and Feidong Complex are magmatic zircon (Figure 4). Binocular microscopic observation shows that the dated zircons are idiomorphical or

Table 1 Sample description of metamorphic rocks in the Zhangbaling uplift segment used for LA-ICP-MS dating

Sample No.	Locality	Sample type	Rock type	Foliation/ lineation	Mineral assemblage	Protolith age (Ma)
BH6	32°27′33.1″N 118°01′45.5″E	Lower Xileng Formation	Muscovite feldspar quartz schist	251°∠28°/ 204°∠22°	Qz+Fel+Ms	752.5±3.2
BH7	32°14′47.0″N 117°56′38.9″E	Middle Xileng Formation	Feldspar quartz schist	28°∠24°/ 21°∠24°	Qz+Fel+Ms	753.9±2.4
BH8	31°51′00″N 117°38′37.9″E	Fuchashan unit	Mylonitized biotite granitic gneiss	317°∠40°/ 234°∠18°	Qz+Fel+Bi	746.0±8.8
BH9	31°47′43.3″N 117°33′21.5″E	Donggang pluton	Mylonitized granitic gneiss	319°∠74°/ 221°∠22°	Qz+Fel+Ms	744.8±4.7
BH10	31°48′3.3″N 117°33′43.1″E	Donggang pluton	Mylonitized granitic gneiss	139°∠82°/ 229°∠13°	Qz+Fel+Ms	800.0±3.1
BH16	31°48′23.2″N 117°34′30.3″E	Donggang pluton	Mylonitized granitic gneiss	335°∠70°/ 225°∠23°	Qz+Fel+Ms	766.8±5.2
BH11	31°48′40.9″N 117°37′37.4″E	Houlongshan pluton	Monzonite granitic gneiss	193°∠42°/ 243°∠27°	Fel+Qz+Bi	750.5±5.6
BH15	31°53′50.3″N 117°42′41.4″E	Dahengshan unit	Granitic gneiss	120°∠35°/ 200°∠5°	Fel+Qz+Bi	upper intercept: 2337±21 lower intercept: 242±26

Note: Qz–quartz; Fel–feldspar; Bi–biotite; Ms–muscovite

Figure 4 Cathodoluminescence images and ages of representative zircon grains from metamorphic rocks in the Zhangbaling uplift segment.

subhedral, long-column grains with aspect ratios of 1∶1 to 3∶1. They are colorless with slightly yellow, and transparent or semitransparent. The zircon has a core-mantle texture with oscillatory zoning in the core. Some zircon grains of samples BH8, BH9, BH10, and BH16 have metamorphic growth edges with widths less than 10 μm. BH15 zircon samples show larger crystals with aspect ratios of 1∶1 to 2∶1, dark cores with oscillatory zoning and bright edges of metamorphic growth.

2.3 Dating results

Contents of U and Th, Th/U ratios and ages for the dated zircon are listed in Appendix 1(available at:www.springer.com/scp). Zircon U-Pb age concordia diagrams are shown in Figure 5. Except for the sample BH15, the dated zircon has higher contents of U and Th as well as higher Th/U ratios, which mostly are higher than 0.6 and about 1.0, indicating a magmatic origin. The sample BH15 shows lower contents of U and Th and lower Th/U ratios ranging from 0.1 to 0.3.

Total 24 analytical data for the sample BH6 from the Zhangbaling Group have U-Pb ages of 837±5–709±6 Ma (Figure 5(a)). Only one plot is away from the concordia line, and other 23 data have ages from 837±5 Ma to 709±6 Ma. The sample has two plot concentration areas in its concordia diagram with one area of 5 data giving a ^{206}Pb/^{238}U weighted mean age of 803.6±5.6 Ma (MSWD=0.41) and another area of 11 data yielding a ^{206}Pb/^{238}U weighted mean age of 752.5±3.2 Ma (MSWD=0.3). The latter is interpreted as representing its protolith age and the former as being an age of an earlier magmatic event recorded by captured zircon. Some younger ages from 729±6 Ma to 709±6 Ma for the dated zircon might result from influence of later thermal events.

Total 31 data of the sample BH7 from the Zhangbaling Group have U-Pb ages ranging from 792±8 Ma to 722±6 Ma (Figure 5(b)). Two of them are away from its concordia line, and others lie around the line and have ages from 792±8 Ma to 722±6 Ma. Only one plot concentration of 22 data in its concordia diagram yields a ^{206}Pb/^{238}U weighted mean age of 753.9±2.4 Ma (MSWD=0.21). This age is interpreted as being a protolith age. Several younger ages from 738±5 Ma to 722±6 Ma obtained from this sample may result from influence of later thermal events.

U-Pb ages of 36 analytical data for the sample BH8 from the Fuchashan unit of the Feidong Complex range from

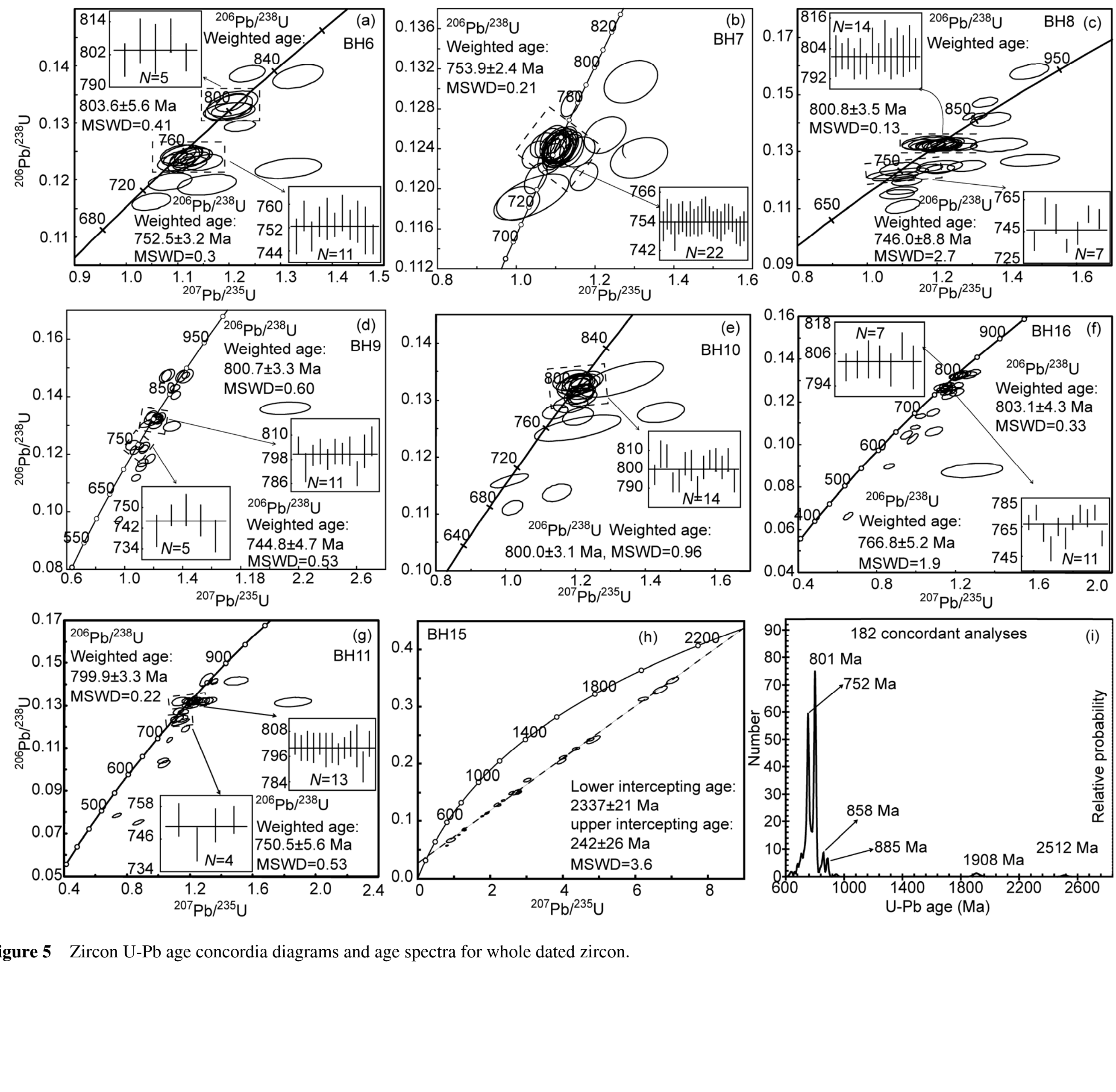

Figure 5 Zircon U-Pb age concordia diagrams and age spectra for whole dated zircon.

1921±19 Ma to 677±5 Ma (Figure 5(c)). Five plots are away from its concordia line, three data of captured zircon show extremely older ages of 1921±19 Ma,1905±21 Ma, and 899±17 Ma, and other 31 plots with ages of 946±10–702±6 Ma lie around the concordia line. One plot concentration of 14 data gives a $^{206}Pb/^{238}U$ weighted mean age of 800.8±3.5 Ma (MSWD=0.13) and other 7 data yield a $^{206}Pb/^{238}U$ weighted mean age of 746.0±8.8 Ma (MSWD=2.7). The younger age of 746.0±8.8 Ma is interpreted as its protolith age whereas the older age of 800.8±3.5 Ma is treated as time of an earlier event recorded by captured zircon. Several younger ages of 709±5–702±2 Ma from the dated zircon may be related to influence of later thermal events.

U-Pb ages of 30 analytical data for the sample BH9 from the Donggang pluton in the Feidong Complex are from 887±8 Ma to 597±5 Ma (Figure 5(d)). Two of their plots are away from its concordia line, and other 28 data around the concordia line have ages of 837±5 Ma to 683±4 Ma. One plot concentration of 11 data gives a $^{206}Pb/^{238}U$ weighted mean age of 800.7±3.3 Ma (MSWD=0.6) and another concentration of 5 data yields a $^{206}Pb/^{238}U$ weighted mean age of 744.8±4.7 Ma. The latter is interpreted as being an intrusion age while the former is as representing an earlier magmatic event recorded by captured zircon. Several younger ages of 739±6 Ma to 683±4 Ma from the sample are related to influence of later thermal events. U-Pb ages of 20 data around the concordia line for the sample BH10 from another locality of the Donggang pluton range from 808±7 Ma to 679±5 Ma (Figure 5(e)). Their plot concentration of 14 data give a $^{206}Pb/^{238}U$ weighted mean age of 800.0±3.1 Ma (MSWD=0.96) that is interpreted as being an intrusion age. U-Pb ages of 25 data around the concordia line for the sample BH16 from the Donggang pluton range from 811±15 Ma to 651±8 Ma (Figure 5(f)). One plot concentration of 7 data gives a $^{206}Pb/^{238}U$ weighted mean age of 803.1±4.3 Ma (MSWD=0.33) whereas another concentration of 11 data yields a $^{206}Pb/^{238}U$ weighted mean age of 766.8±5.2 Ma (MSWD=1.9). The latter is interpreted as being an intrusion age whereas the former is as being an age of an earlier magmatic event recorded by captured zircon.

U-Pb ages of 33 analytical data for the sample BH11 from the Huolongshan pluton in the Feidong Complex range from 2512±16 Ma to 487±4 Ma (Figure 5(g)). Eight of them are away from the concordia line, one has an extremely older age of 2512±16 Ma, and other 24 data around the concordia line have ages from 855±7 Ma to 696±5 Ma. One plot concentration of 13 data gives a $^{206}Pb/^{238}U$ weighted mean age of 799.9±3.3 Ma (MSWD=0.22) while another concentration of 4 data yields a $^{206}Pb/^{238}U$ weighted mean age of 750.5±5.6 Ma (MSWD=0.53). The latter is interpreted as being a protolith age while the former is as being time of an earlier event recorded by captured zircon. A few ages of 726±6 Ma to 696±5 Ma are treated as results of later thermal influence.

Twenty two analytical data for the sample BH15 from the Dahengshan unit of the Feidong Complex are away from the concordia line, but their plots form an inconcordant curve with an upper intercepting age of 2337±21 Ma and lower intercepting age of 242±26 Ma (Figure 5(h)). The former is treated as representing its protolith age whereas the latter is interpreted as being an age of the Indosinian metamorphic event.

The dated samples are ortho-metamorphic rocks of the Zhangbaling Group and Feidong Complex. Except for the sample BH15, the dated zircons are of magmatic origin. Therefore, our dating results can effectively constrain protolith ages of the dated metamorphic rocks. The dated samples of the Zhangbaling Group are from the lower (BH6) and middle (BH7) Xileng Formation. They give protolith ages of 752.5±3.2 Ma (BH6) and 753.9±2.4 Ma (BH7) respectively, and the two are consistent within their errors. The dating results demonstrate that protolith ages of the dated meta-volcanic rocks in the Zhangbaling Group are 754–753 Ma, i.e., middle Neoproterozoic, rather than Mesoproterozoic or earlier Neoproterozoic as proposed before.

Biotite granitic gneiss from the Fuchashan unit of the Feidong Complex has a protolith age of 746.0±8.8 Ma (BH8), which belongs to the middle Neoproterozoic also. Three samples from different localities of the deformed, metamorphosed Donggang pluton give intrusion ages of 800.0±3.1 Ma (BH10), 766.8±5.2 Ma (BH16), and 744.8±4.7 Ma (BH9) respectively, i.e., middle Neoproterozoic. The results show that the Donggang pluton is a composite intrusion, and at least experienced three phases of intrusion. An intrusion age of the deformed, metamorphosed Huolongshan pluton is 750.5±5.6 Ma (BH11), which is consistent with the youngest intrusion time of the Donggang pluton. It is suggested that protolith ages of ortho-metamorphic rocks in the Feidong Complex range from 800 Ma to 745 Ma, and igneous rocks in the complex are dominated by products of two phases of magmatic events at 800 Ma and 750 Ma. The second phase of magmatic event in the Feidong Complex is synchronous with volcanic eruption of the Xileng Formation in the Zhangbaling Group. The dating results show that although the Feidong Complex (amphibolite facies) has a higher metamorphic grade than the Zhangbaling Group (greenschist facies), they have similar protolith ages. It is noteworthy that the dating result for the sample BH15 from the Dahengshan unit shows an Indosinian metamorphic event of 242±26 Ma experienced by the Feidong Complex.

3 Deformation features of the Zhangbaling uplift segment

3.1 The northern segment

Exposed rocks in the northern Zhangbaling uplift segment are dominated by the Xileng Formation. Lithological units of the Zhangbaling Group show a N-S trending open antiform (Figure 2). The Beijiangjun Formation is preserved as a N-S trending narrow belt in the middle of the uplift. The Xileng Formation is covered by the Sinian and then the Cambrian-Ordovician strata at the eastern margin of the northern segment. Earlier deformation structures are well preserved in the northern segment that was exposed to shallow levels and affected by local brittle sinistral faults during the Late Jurassic sinistral faulting of the Tan-Lu Fault Zone.

The Xileng Formation in the northern segment is dominated by meta-volcanic rocks, and shows wide-spread mylonitization (Figure 6(a)), greenschist facies metamorphism, parallelism between compositional layers, and foliation and high strain features. Fabrics in the Zhangbaling Group are characterized by flat-lying foliation with dip angles mostly less than 30°. The deformed rocks have gentle mineral elongation lineation trending NNE-SSW in the southern part, N-S in the middle part, and NNW-SSE in the northern part (Figure 2). The lineation trend change may be related to its approaching the Sulu Orogen northwards. As another deformation feature, kink bands (Figure 6(c)) and quartz veins or tensile cracks are common in the Zhangbaling Group. The kink bands often cause angular folds of foliation with axes parallel to mineral lineation and vergence directions consistent with the earlier shear sense, suggesting origin of a later progressive deformation stage. The quartz veins and tensile cracks are perpendicular to the mineral lineation, and their progressive rotation is consistent with the earlier shear sense, also indicating an origin of a later progressive deformation stage. The wide presence of the kink bands, quartz veins or tensile cracks indicates that the northern Zhangbaling segment experienced earlier deformation at upper ductile regime levels and later deformation at brittle-ductile transition levels during one phase of progressive deformation. S-C fabrics (Figure 6(b)), tails of feldspar porphyroclasts, small-scale shear folds, and rotated quartz veins in the Zhangbaling Group indicate a shear sense of top-to-the-S, SSW or SSE, which is consistent with observations by Hou et al. (2004) and Zhang et al. (2007). It is suggested therefore that the northern Zhangbaling segment, exposed mostly with the Xileng Formation, shows a flat-lying ductile detachment zone with a shear sense of top- to-the-SSW generally.

The Xileng Formation in the northern segment is covered by the Lower Sinian strata, i.e., the Zhougang and Sujiawan formations, and the two show parallel, compositional layering (Figure 2), similar fabrics, and upward reduction of metamorphic grades. The Lower Sinian strata are dominated by phyllite and pebble-bearing phyllite interlayered with low-grade, metamorphosed conglomerate. The low-grade strata show flat-lying foliation with varied dip directions and shallow mineral elongation lineation and elongated pebbles trending NNE-SSW (Figure 6d). Various kinematic indicators in the strata indicate a shear sense of top-to-the-SSW, which is the same as that in the neighboring Zhangbaling Group. It is noted that the preserved Beijiangjun Formation in the middle uplift has similar lithology and fabrics to those in the Lower Sinian strata and is also involved in the low-angle ductile detachment deformation like the underlying Xileng Formation.

The Late Sinian and Cambrian-Ordovician strata east of the northern uplift segment are normal cover of the Yangtze Plate (Figure 2) and dominated by limestone and dolomitite without metamorphism. They show NE-SW tight, inclined folds with SE-ward vergence. The strata are often cut by NE-striking, NW-dipping thrusts. The steep carbonatite folded intensely contact the underlying Lower Sinian strata with a flat-lying detachment zone.

3.2 The southern segment

Exposed rocks in the southern Zhangbaling uplift segment are dominated by the high-grade Feidong Complex. The Zhangbaling Group only occurs at its eastern and southern margins (Figure 3). The northern part of the southern segment was at deep levels during the Late Jurassic sinistral faulting of the Tan-Lu Fault Zone, leading to wide-spread overprinting of the NNE-striking ductile shear belts (Figure 6(e)) and total transposition of earlier fabrics (Figure 3-I) (Zhu et al., 2005, 2010). The southern part was at shallower levels during the Late Jurassic and affected by a few of sinistral ductile shear belts, which led to preservation of earlier fabrics (Figure 3-III) among the later shear belts that can be used for understanding the earlier deformation.

Foliation in the Feidong Complex is commonly parallel to compositional layering. Lithological unit distribution, especially the marble mark layers (Figure 6(g)), clearly shows earlier structures and their reworking by the later shear belts in the southern part (Figure 7). These lithological ribbons, including the marble mark layers, strike ENE away from the later shear belts (Figure 6(f)), and NE to NNE with approaching the sinistral shear belts. Preference strikes of the earlier structures are ENE-WSW or nearly E-W with various dip directions. Many measurements of the earlier fabrics (Figure 3-III) show that the foliation strikes preferably ENE-WSW and dips NNW or SSE (mostly) with dip angles of 30°–70° mostly. Mineral elongation lineation is mostly parallel to strikes of the foliation, and trends ENE-WSW shallowly, gently plunging WSW in most cases (Figure 7). S-C fabrics (Figure 6(g)), tails of porphyroclasts (Figure 6(f)), and asymmetrical folds produced by the earlier deformation indicate sinistral shearing. In summary, the earlier structures in the southern part of the southern segment are characterized by ENE-WSW tight folds formed under a ductile regime.

The locally outcropped Zhangbaling Group at the southern margin of the southern segment shows flat-lying foliation and NNE-SSW gentle lineation, which are similar to the fabrics of the Zhangbaling Group in the northern segment (Figure 3-III). Outcrops for the local Zhangbaling Group at

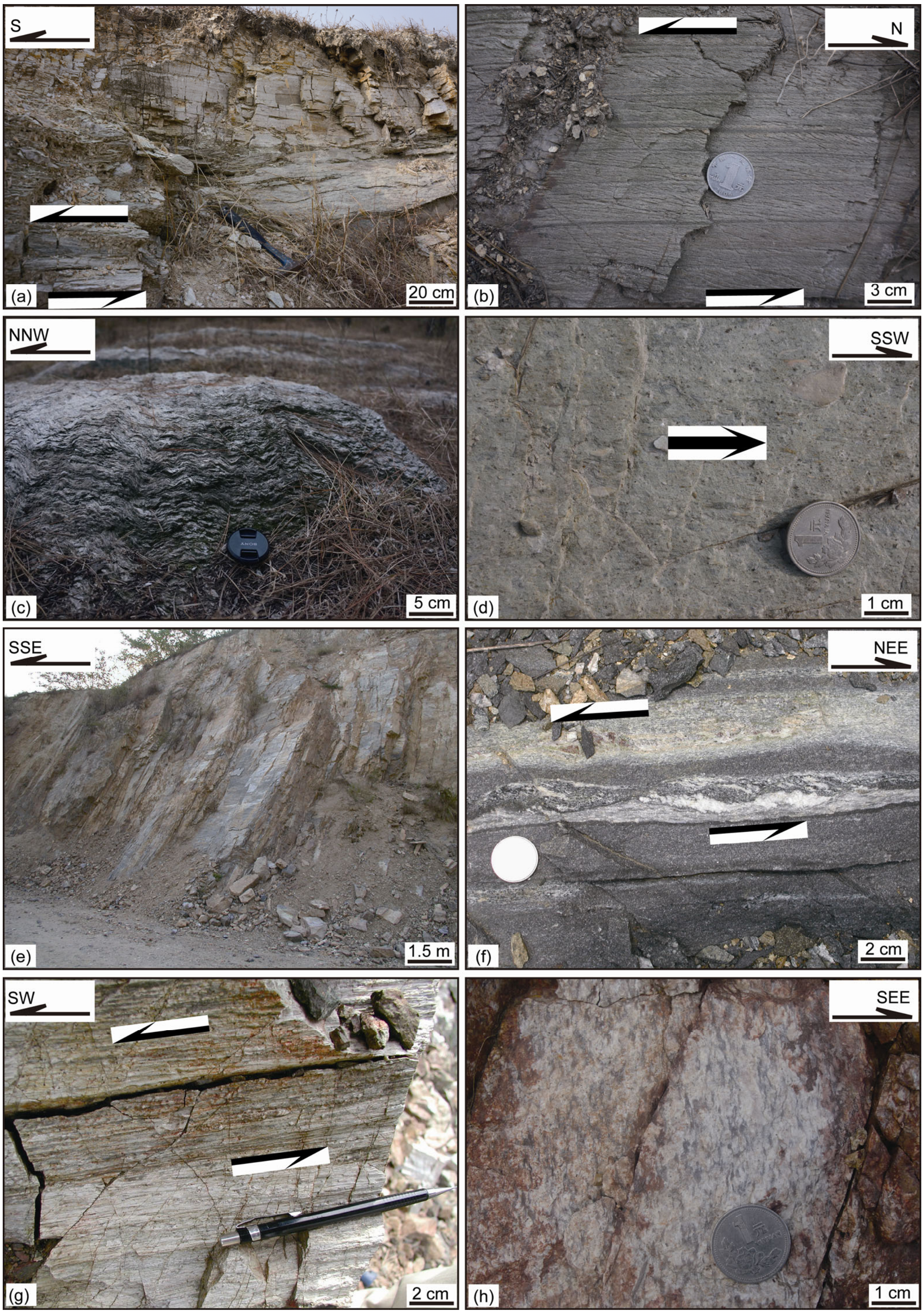

Figure 6 Outcrop photographs for structures in the Zhangbaling uplift segment. (a) A flat-lying mylonite belt in the Zhangbaling Group in the northern segment; (b) flat-lying foliation and S-C fabrics in the Zhangbaling Group in the northern segment, showing the shear sense of top-to-the-S; (c) kink bands in the Zhangbaling Group in the northern segment; (d) pebble-bearing phyllite of the Sujiawan Formation of Lower Sinian in the northern segment, showing elongated pebbles and the shear sense of top-to-the-SSW, a surface picture; (e) steep, sinistral ductile shear belts of the Late Jurassic in the Feidong Complex in the southern segment; (f) earlier S-C fabrics in plagioclase amphibolite of the Feidong Complex in the southern part of the southern segment, showing sinistral shearing; (g) intensely foliated marble of the Feidong Complex with S-C fabrics showing sinistral shearing in the southern part of the southern segment; (h) the mylonitized Donggang pluton (sample BH9) in the Feidong Complex in the southern segment.

the eastern margin of the southern part are too poor to be observed. The Xileng Formation at the eastern margin of the northern part contacts a Late Jurassic sinistral mylonite belt in the Feidong Complex with a NNE-striking, brittle sinistral fault. The formation has NE-striking foliation dipping NW or SE with varied dip angles and NE-SW gentle mineral

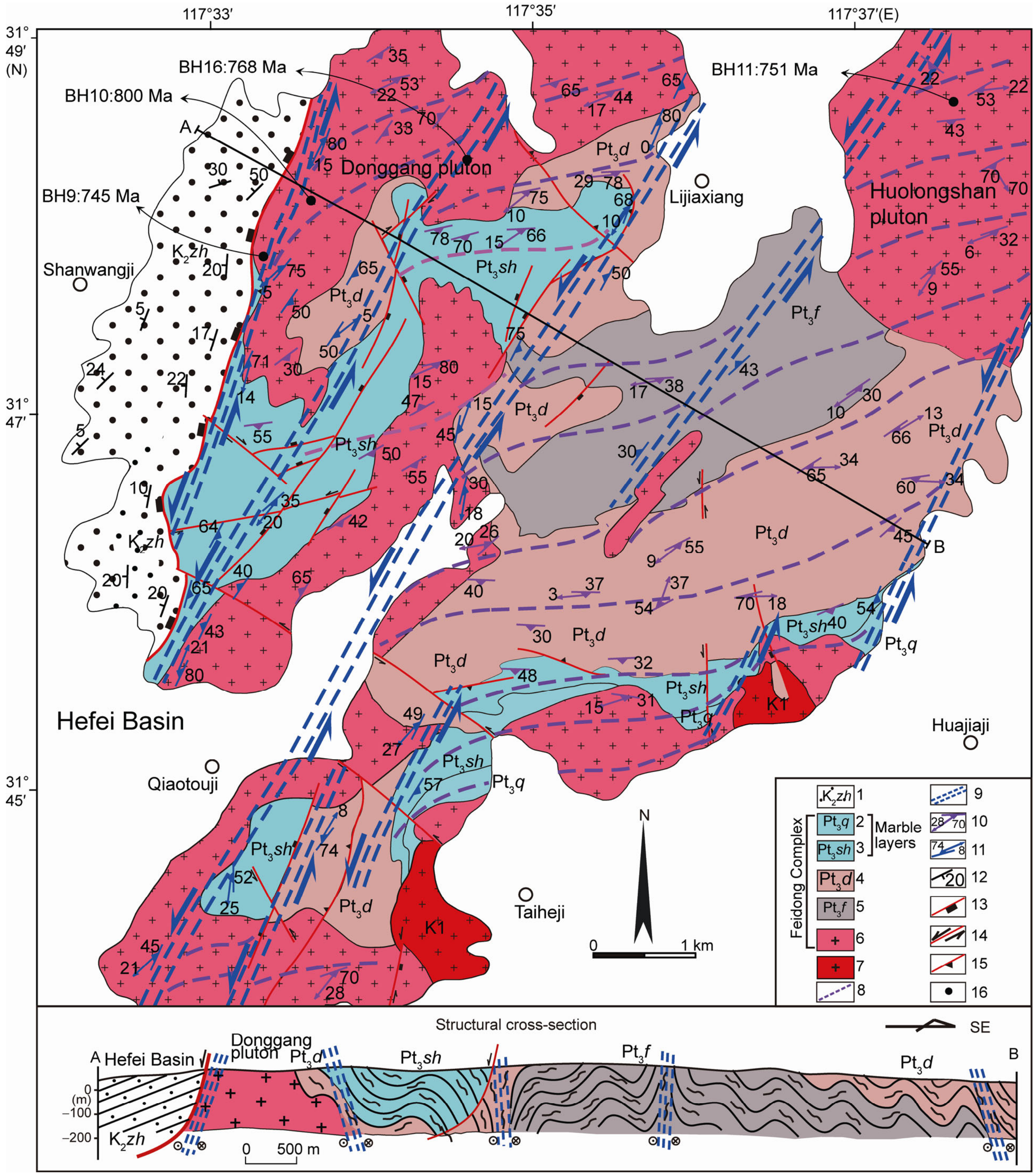

Figure 7 Structural map and cross sections for the southern part of the southern Zhangbaling uplift segment (modified from the Tongyanghe Geological Map of 1:50000). 1, Zhangqiao Formation of Late Cretaceous; 2, Qiaotouji unit; 3, Shuangshan unit; 4, Dahengshan unit; 5, Fuchashan unit; 6, Neoproterozoic deformable and metamorphic pluton; 7, Early Cretaceous granite; 8, earlier foliation trajectory; 9, later ductile shear zone; 10, attitudes of earlier foliation and lineation; 11, attitudes of later foliation and lineation; 12, attitude of strata; 13, brittle normal fault; 14, brittle strike-slip fault; 15, brittle thrust; 16, sampling locality for this zircon dating.

lineation that plunges NE mostly. Lineation attitudes in the Xileng Formation at the eastern margin of the northern part are similar to those in the Zhangbaling Group in the northern segment and foliation is affected by NE-SW folds probably caused by intense sinistral faulting of the Late Jurassic to the east.

3.3 Characteristics of peripheral Indosinian structures

Structures of the Indosinian period around the Tan-Lu Fault

Zone are significant for understanding an earlier deformation history in the Zhangbaling uplift segment. The Haizhou Group outcropping in the low-temperature, high-pressure metamorphic belt in the southern Sulu Orogen is affected by ductile thrusting structures with a shear sense of top-to-the NW and related to the orogenic exhumation (Figure 1-I). Foliation in the group strikes NE-SW and dips SE whereas mineral lineation plunges SE. Various kinematic indicators in the deformed rocks suggest NW-ward thrusting. The southern Dabie Orogen also shows NW-ward ductile thrusting structures, and its southern margin is affected by the Xiangfan-Guangji dextral ductile shear zone (Figure 1-III). These structures resulted from the orogenic exhumation (Hacker et al., 2000; Faure et al., 2003; Wang et al., 2012). Owing to intense transposition of earlier fabrics by the exhumation structures, earlier fabrics related to the deep continent subduction are seldom preserved in the Dabie-Sulu orogenic belt.

The Huainan-Bengbu uplift and Hefei Basin of Jurassic to Paleogene appear in the North China Plate just west of the Zhangbaling uplift segment. Exposed rocks in the uplift and oil exploration data (Zhao et al., 2000; Zhu et al., 2004) show that the Indosinian structures occur as WNW-ESE folds and NNW-ward thrusts (Figure 1). The special Xu-Huai arcuate structures thrusting WNW (Zhu et al., 2004; Zhang et al., 2008) lie north of the Huainan-Bengbu uplift, and NW-SE shortening structures predominate in the western Shandong to the north (Figure 1).

The marine cover of Sinian to Middle Triassic south of the Dabie Orogen shows generally E-W trending, tight folds (Figure 1) (Li et al.,2010; Wang et al., 2012), and the fold strikes change into NW-SE with approaching the orogen due to being affected by the later exhumation (Wang et al., 2012). Tight folds and longitudinal thrusts of the Indosinian period predominate in the marine cover in the lower Yangtze region east of the southern Tan-Lu Fault Zone. Strikes of the Indosinian shortening structures are NNE-SSW with approaching the Tan-Lu Fault Zone and ENE-WSW, i.e., parallel to the Sulu Orogen, away from the fault zone, showing an arcuate change (Figure 1). Reverse faults north of the Yangtze River show SE-ward thrusting mostly (Zhu et al., 1998, 2004).

Systematic observations on the Tan-Lu Fault Zone along the eastern margin of the Dabie Orogen demonstrate that its earlier structures are preserved only in the locally exposed Zhangbaling Group in the Lujiang and Huangmei-Taihu areas (Figure 1-II). Mylonitization is common in the Zhangbaling Group. The deformed rocks have NE-SW steep foliation dipping SE preferably and NE-SW shallow mineral lineation (Figure 1-II). Various kinematic indicators in the rocks suggest sinistral shearing. The ductile structures in the Zhangbaling Group are products of a sinistral ductile shear zone, i.e., the Tan-Lu shear zone. A muscovite sample from the Zhangbaling Group in the Lujiang area gives a $^{40}Ar/^{39}Ar$ cooling age of 226.0±0.4 Ma (Late Triassic) (Chen et al., 2000), demonstrating that the earlier deformation took place during the Indosinian period. The Zhangbaling Group was exposed to shallow levels during the Late Jurassic sinistral faulting of the Tan-Lu Fault Zone, and affected locally by brittle sinistral faults, such as a contact fault between the Susong and Zhangbaling groups at the eastern margin of the Dabie Orogen, and drag folds. The Late Jurassic sinistral mylonite belts of the Tan-Lu Fault Zone occur only in the Dabie Complex at the eastern margins of the Northern Dabie unit and ultra-high-pressure unit (Zhu et al., 2005, 2010).

4 Discussions

4.1 Properties of the Zhangbaling Group and Feidong Complex

The South China Plate experienced large-scale, rift-related magmatism under the break-up setting of the Rodinian supercontinent. Therefore, ages of 800–700 Ma can be used as a valid sign for the South China Plate. Our dating results indicate protolith ages of 800–745 Ma for the Zhangbaling Group and Feidong Complex, and suggest that the dated rocks belong to the Yangtze Plate. Age spectra of the dated rocks (Figure 5(i)) show common ages in the Yangtze Plate (Li et al., 2003; Zheng et al., 2008). Our dating work proves that the Zhangbaling uplift segment between the Yangtze and North China plates belongs to the Yangtze Plate, and a boundary line between the two plates lies under the Hefei Basin west of the uplift segment (Figure 1).

The South China Plate formed through a collage of the Cathaysia and Yangtze blocks. Previous studies demonstrate that collision of the two blocks, i.e., the Sibao Movement, took place at ca. 820 Ma or earlier (Zheng et al., 2008; Wang et al., 2008; Zhou et al., 2009; Li et al., 2009; Zhao et al., 2012). The South China Plate switched into an intracontinental evolution stage after the collision, and the cover was developed till the Middle Triassic. Wide-spread rifts and magmatism occurred in the Yangtze Plate during the earlier cover deposition of 820–740 Ma (Ye et al., 2007; Li et al., 2008; Wang et al., 2011). Therefore, the 754–753 Ma volcanic rocks of the Zhangbaling Group and 800–745 Ma igneous rocks of the Feidong Complex are magmatic products of intracontinental rifts developed during the earlier cover formation, and the volcanic rocks and interlayered sediments are the earlier cover of the Yangtze Plate, rather than the basement rocks as previously suggested. The magmatic zircon samples from meta-volcanic rocks of the Haizhou Group, which can be correlated with the Zhangbaling Group in lithology, in the southern Sulu Orogen give the youngest weighted mean age of 758 Ma (Zhou et al., 2012), suggesting that the dated rocks also belong to the earlier cover of the Yangtze Plate.

The Banxi Group and Middle Neoproterozoic granite plutons synchronous with the Zhangbaling Group and Feidong Complex widely appear in the Jiangnan-Xuefeng Uplift in the southern Yangtze Plate. Pellites of the Banxi Group have been metamorphosed into slates due to burial metamorphism and their metamorphic grades are not higher than low-greenschist facies. Phyllite of the Banxi Group occurs locally around plutons. In contrast, the Zhangbaling Group and Feidong Complex were metamorphosed into high-greenschist to amphibolite facies. It has been proposed that metamorphic rocks in the Zhangbaling uplift segment came from high-pressure rocks of the southern Dabie Orogen (Xu et al., 1987a, 1994). However, Al piezometer analyses of riebeckite and hornblende by Shi et al. (2007, 2009) suggest that metamorphic pressures for the so-called blueschist of the Zhangbaling Group, without glaucophane actually, are less than 0.3 GPa whereas metamorphic pressures for the garnet grunerites of the Feidong Complex are less than 0.49 GPa, demonstrating their belonging to low- pressure rocks that are different from high-pressure rocks of the southern Dabie-Sulu orogens. Metamorphic grades of the Zhangbaling uplift segment show gradual reduction from lower to upper levels. The metamorphic grade reduction can be observed from the Feidong Complex to the overlying Zhangbaling Group at the southern and eastern margins of the southern segment. The Zhangbaling Group in the northern segment clearly shows lower metamorphic grades than the Feidong Complex in the southern segment. The Xileng Formation exhibits higher metamorphic grades than the overlying Beijiangjun Formation and Sinian strata in the northern segment. The changing pattern of metamorphic grades in the Zhangbaling uplift segment is obviously different from that of the Dabie-Sulu orogens, which is controlled by exhumation polarity and intensity, implying that the Zhangbaling segment is not from the orogenic belt. The higher metamorphic grades and their increases with depths are consistent with metamorphic features at an oblique convergence boundary of plates (Teyssier et al., 2002, 2004). Exhumation of the Zhangbaling uplift partially results from hanging-wall uplifting of the normal faults at the eastern margin of the Hefei Basin during the Cretaceous to Paleogene rifting, which is testified by the present exposures of Early Cretaceous plutons in the uplift segment. The Late Jurassic sinistral faulting of the Tan-Lu Fault Zone can also contribute to certain uplifting of the Zhangbaling segment cut by the fault zone.

4.2 Deformation model of the Zhangbaling uplift segment

Previous dating work (Li et al., 1993; Chen et al., 2000; Zhang et al., 2007) shows that the Zhangbaling Group in the northern segment gives muscovite $^{40}Ar/^{39}Ar$ ages of 245–236 Ma (Middle Triassic), which were interpreted as representing deformation and metamorphic time. The metamorphic age of 242 Ma obtained from the Feidong Complex in this work is consistent with the deformation and metamorphism time of the Zhangbaling Group. Therefore, deformation and metamorphism of the Zhangbaling Group are synchronous with the peak collision of the North China and Yangtze plates and deep subduction of the Yangtze crust (Hacker et al., 2006; Wu et al., 2006; Zheng et al., 2009; Liu et al., 2011). The earliest and strongest deformation of the Yangtze cover took place in the Indosinian period, as shown by related angular unconformities at many localities (Dong et al., 1994; Zhu et al., 1998). This fact also supports that the earlier structures in the Zhangbaling uplift segment formed in the Indosinian period (Middle Triassic) when the North China Plate collided with the Yangtze Plate.

The Indosinian structures in the Zhangbaling uplift segment show three types for different levels (Figure 8). The Late Sinian to Ordovician strata at the eastern margin show NE-SW steep, tight folds of the upper levels, the Zhangbaling Group to Early Sinian strata exhibit a flat-lying ductile detachment zone of the middle levels with a shear sense of top-to-the-SSW, and the Feidong Complex is characterized by ENE-WSW inclined folds of the lower ductile levels.

Origin of the flat-lying detachment zone at the middle levels is a key for understanding deformation mechanism or model of the Zhangbaling uplift segment. The detachment zone is different from a strike-slip ductile shear zone and not affected by steep strike-slip ductile shear belts. Its shear sense is parallel to the nearby boundary of the North China and Yangtze plates, i.e., the Tan-Lu Fault Zone. This kinematics is not concordant with NE-ENE trending foreland folds in the lower Yangtze region away from the Tan-Lu Fault Zone, and therefore the detachment zone is different from a deep detachment zone of normal foreland. It is inferred that the flat-lying detachment zone in the Zhangbaling uplift segment is a side structure of the Indosinian Tan-Lu sinistral shear zone that is buried under the Hefei Basin (Figures 1, 8). As mentioned before, this phase of the Tan-Lu shear zone can be found in the Zhangbaling Group at the eastern margin of the Dabie Orogen (Figure 1-II). The marine cover younger than the Late Sinian and overlying the uplift originally was in a brittle regime during the Indosinian deformation and deformed by NE-SW folds and thrust (Figure 8). These brittle strike-slip faults disappeared gradually away from the Tan-Lu Fault Zone. In contrast to the Zhangbaling Group, the Feidong Complex contains many Neoproterozoic plutons, and the overlying detachment zone could not extend into the complex. The complex was deformed mainly by ENE-WSW folds of a ductile regime that belong to drag folds aside a major shear zone. It is worth noting that NE-SW folds are expected in the Feidong Complex if the folds are only controlled by the NNE-striking Tan-Lu shear zone, but the actual ENE-trending folds in the complex are also reasonable if considering overprinting of another simple shear imposed by the flat-lying detachment deformation and resultant triclinic deformation.

The shear sense of the Indosinian Tan-Lu Fault Zone cannot be constrained by structures of different levels in the Zhangbaling uplift segment. The arcuate changing of the

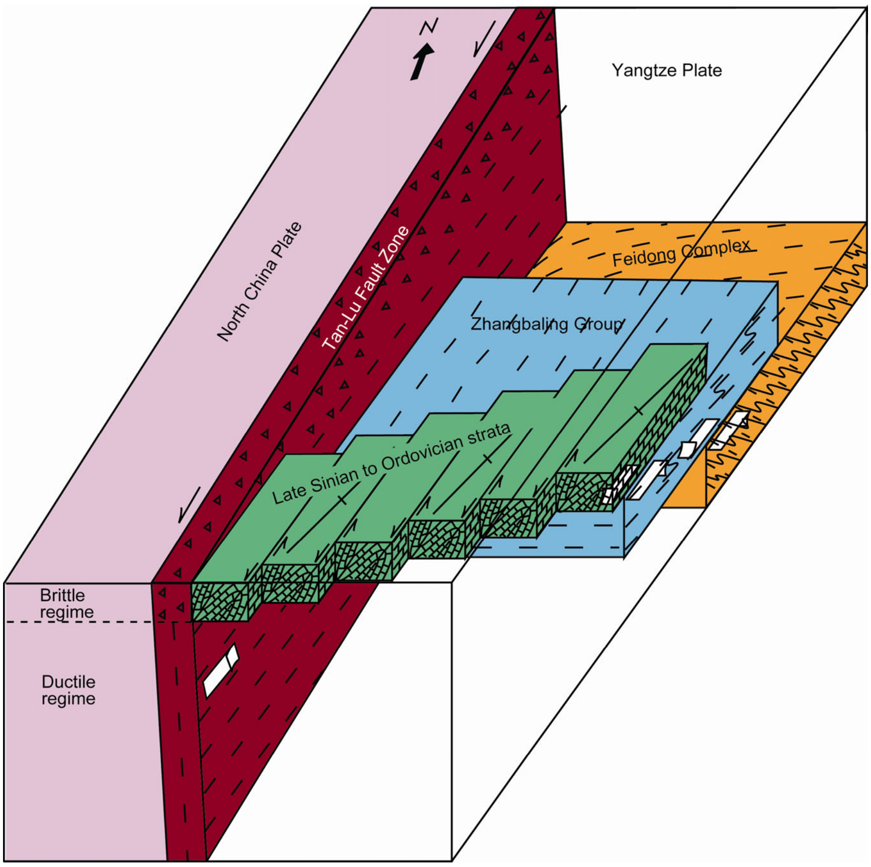

Figure 8 A deformation model for the Zhangbaling uplift segment of the Tan-Lu Fault Zone.

Indosinian fold strikes in the foreland east of the uplift segment indicates sinistral faulting of the fault zone (Figure 1). The Indosinian deformation of the Zhangbaling uplift segment took place in the eastern, displaced wall of the Tan-Lu shear zone. Zhang et al. (2007) proposed that the shear sense of top-to-the-SSW for the flat-lying detachment zone in the Zhangbaling Group results from faster flow velocities with depths. When the northwards moving Yangtze Plate collided with the North China Plate at the Sulu Orogen, shortening of rigid upper crust is more difficult than ductile lower crust, leading to moving velocity reduction of the upper crust and resultant top-to-the-S shearing between the upper and lower crust. A top-to-the-SE sense of shear is also expected at deep, ductile levels in the foreland belt east of the Tan-Lu Fault Zone, which shows SE-ward thrusts and SE-vergent folds at shallow levels.

The deformation model and protolith ages demonstrate that metamorphism of the Zhangbaling Group and Feidong Complex took place in a wall block offset by the Tan-Lu major strike-slip shear zone during the Indosinian period. The Indosinian, NNE-striking Tan-Lu shear zone at the eastern margin of the Dabie Orogen dips SE steeply and contains NE-plunging mineral lineation. It is inferred that the Tan-Lu Fault Zone west of the Zhangbaling uplift segment has the similar attitude and kinematics to the fault zone at the eastern margin of the Dabie Orogen, and its eastern wall became deepening with NNE-ward moving and experienced increasing metamorphism. The Yangtze Plate cover is as thick as 7–10 km. Displacement of 300 km with a 5° pitching angle along a strike-slip shear zone can deepen its wall rocks to 26 km. Therefore, the amphibolite facies metamorphism of ca. 600°C for the Feidong complex could be caused by this kind of strike-slip faulting.

On the basis of natural examples and theoretical deformation analysis, Teyssier et al. (2002) set up a flat-lying ductile detachment model between upper rigid crust and lower ductile crust aside a major strike-slip shear zone and summarized fabric changes at different levels. Deformation features of the Zhangbaling uplift segment are consistent with the theoretical model in general, and show a good example for this deformation model. Our interpretation for the Indosinian deformation of the Zhangbaling uplift segment is roughly similar to the model proposed by Zhang et al. (2007), but views for a deformation method in the Feidong Complex are different. Zhang et al. (2007) proposed that the Indosinian detachment zone in the Zhangbaling Group gradually changed into steep foliation and spaced strike-slip shear belts in the underlying the Feidong Complex downwards. However, our studies suggest that the Zhangbaling Group and underlying Feidong Complex have totally different fabrics, and the fabrics show a sudden change from the detachment zone to underlying Feidong Complex. The present NNE-striking ductile shear belts in the Feidong Complex formed during the Late Jurassic (Zhu et al., 2005, 2010), and no strike-slip shear belt occurred in the exposed complex during the Indosinian period. The complex was a ductile deformation belt right aside the Tan-Lu shear zone during the Indosinian faulting. This can account for the absence of steep strike-slip shear belts in the overlying detachment zone in the Zhangbaling Group (Figure 8).

4.3 The active mode of the Tan-Lu Fault Zone during the orogeny

The earlier deformation model and dating results (Li et al., 1993; Chen et al., 2000; Zhang et al., 2007) for the Zhangbaling uplift segment of the Tan-Lu Fault Zone demonstrate that the fault zone originated from the collision of the North China and Yangtze plates and its activity is synchronous with the deep continent subduction in the Dabie-Sulu orogens. However, how the fault zone offsets the Dabie and Sulu orogens and the convergence model of the North China and Yangtze plates remain controversial. The proposed models include the transform fault model (Zhang et al., 1984; Watson et al., 1987; Xu et al., 1987a; Wan et al., 1996; Zhu et al., 2004, 2009; Zhang et al., 2008), oblique convergence boundary model of indentation collision (Yin and Nie, 1993), rotated collision boundary model (Lin et al., 1990; Zhang et al., 1997; Gilder et al., 1999; Xiao et al., 2000), and tear fault model (Okay et al., 1992; Li et al., 1994).

The interpretation that the Indosinian structures of the Zhangbaling uplift result from side deformation of the Tan-Lu sinistral shear zone can deny the inference for its rotated collision boundary origin. It is well known that the Tan-Lu Fault Zone terminates at the southeastern end of the Dabie Orogen, and no sinistral offsetting appear in continuous E-W folds of the Yangtze cover south of the southeastern end (Figure 1) (Dong et al., 1994; Li et al., 2010; Wang et al., 2012). If the Dabie and Sulu orogens were an unified orogenic belt during the earlier collision and then sinistrally offset by the Tan-Lu Fault Zone in a transform or tear fault way, it is expected that the southward extension length of the fault zone should not be less than the offsetting distance of the two orogens (Figure 9(a)). The fact that the fault zone terminates at the southeast end of the present Dabie Orogen rules out the possibility that it originated as a transform or tear fault. The activity mode of the Tan-Lu Fault Zone and its surrounding structures (Figure 1) support the oblique convergence boundary model. Yin and Nie (1993) inferred that the Yangtze Plate in the lower Yangtze region was originally a northward projecting part and the Tan-Lu Fault Zone represents the oblique convergent boundary at the western margin of the projecting part. Given the consistent collision time and similar continent subduction intensity in the Dabie and Sulu orogens, northward concaving of the North China Plate at the Sulu Orogen and southward projecting of the North China Plate at the Dabie Orogen are required (Figure 9(b)). The Indosinian Xu-Huai arcuate structures may result from point collision at the NW-ward projecting Yangtze Plate. Irregular boundaries of natural, continental plates are common. The Dabie-Sulu orogens and Tan-Lu Fault Zone just formed through the indentation collision. It is the incredible coincidence that leads to long-term controversies about the convergence model of the North China and Yangtze plates.

5 Conclusions

(1) Our LA-ICP-MS zircon U-Pb dating work demonstrates that protolith ages of the greenschist facies metavolcanic rocks of the Zhangbaling Group are 754–753 Ma, and those of the Feidong Complex are 800–745 Ma. They are parts of the Middle Neoproterozoic Yangtze cover, and their metamorphic features suggest that they do not come

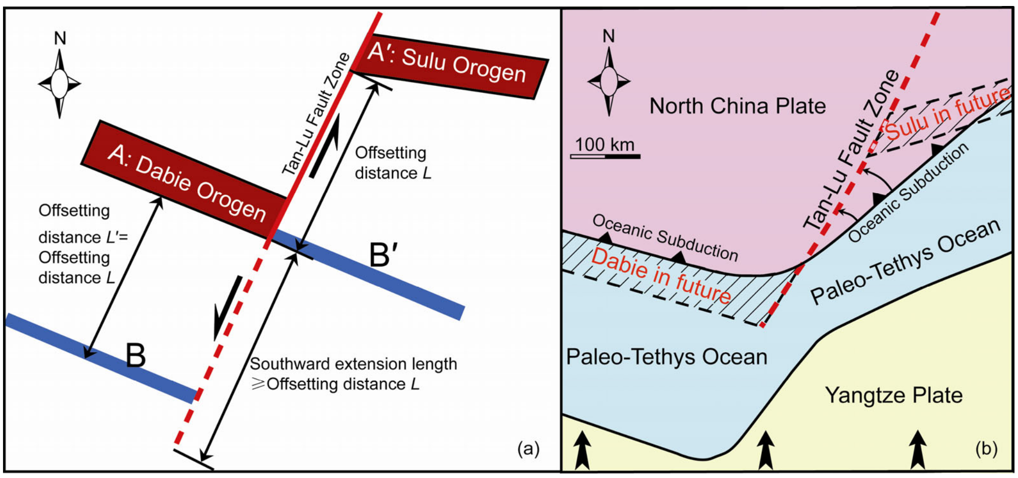

Figure 9 Comparison of two formation models for the Tan-Lu Fault Zone during the orogeny. (a) Southward extension length of the Tan-Lu Fault Zone in the transform fault or tear fault model; (b) oblique convergence boundary model of indentation collision.

from the Dabie Orogen.

(2) The Zhangbaling uplift segment and its eastern margin present three types of deformation at three levels. The Late Sinian to Ordovician strata at the upper levels show NE-SW steep folds, the Zhangbaling Group and Lower Sinian strata at the middle levels exhibit a flat-lying ductile detachment zone with a shear sense of top-to-the-SSW, and the Feidong Complex at the lower levels is characterized by ENE-WSW inclined folds of a ductile regime.

(3) The Indosinian deformation characteristics in the Zhangbaling uplift segment and its surrounding areas suggest that the exposed uplift lies just east of the Indosinian Tan-Lu Fault Zone, which is buried under the Hefei Basin, and the deformation at the three levels is controlled by the both Tan-Lu sinistral faulting at the western margin of the uplift and top-to-the-S shearing in the displaced wall. The protolith ages and deformation mechanism in the Zhangbaling uplift segment further prove sinistral origination of the Tan-Lu Fault Zone during the continent-continent collision of the North China and Yangtze plates and support the indentation model for the two plate collision that considers the Tan-Lu Fault Zone as an oblique convergence boundary.

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