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Tectonics and Geodynamics of South China: an introductory note

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Introduction

Together with North China, Tarim, Qiangtang, Indochina or India, the South China Block (SCB) is one of the main continental pieces derived from Gondwana that assembled together and with Siberia to form the present Eurasia (e. g. Metcalfe, 2013; Fig. 1). The SCB is a composite continent. In its northeastern part, in Jiangxi and Zhejiang Provinces, the Jiangnan collisional orogen that welded together the Yangtze and the Cathaysia blocks, to the North and South, respectively is well acknowledged by the presence of ophiolites, subduction complexes, and HP rocks (e.g. Shu et al., 1994, 2006; Li et al. 2007a; 2009). The E-W striking Jiangshan-Shaoxing fault (JSF, Fig. 2) is commonly recognized as the Jiangnan ophiolitic suture. To the West, due to the Phanerozoic sedimentary cover, it southwestern extension is not fixed yet. Furthermore,

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Neoproterozoic events are also recognized in the western part of the SCB. The precise timing of the tectonic events related to the Jiangnan orogeny remains disputed, from 1Ga to 850 Ma (e.g. Zhou et al., 2006; Shu et al., 2006, 2011; Wang et al., 2007; Li et al., 2007a, 2008, 2009, 2014). Whatever the exact location of the suture, and the age of the collision, the Neoproterozoic Jiangnan collision gave rise to the SCB. Since that time, the SCB continent experienced a complex geological history both along the block margins, but also within it indicating that it did not behaved as a rigid craton.

During the last decades, many petrological, geochronological, geochemical, and structural works provided a large amount of new data improving the understanding of the Phanerozoic evolution of the SCB. It is now widely recognized that during the Late Neoproterozoic (Cryogenian to Ediacaran), the SCB experienced a continental-scale rifting, responsible for the formation of the Nanhua rift that controlled a thick silico-clastic sedimentation coeval with a bimodal magmatism (e.g. Wang and Li, 2003; Shu et al., 2011; Li et al., 2014). The general NE-SW strike of this rift, though oblique to the Jiangnan suture, suggests a structural control of the rift development by ancient faults. This domain corresponds also to a Cambrian-Ordovician paleogeographic transition between carbonated and silico-clastic sediments in the former Yangtze and Cathaysia blocks, respectively. More generally, inherited structures played an important role to control the Paleozoic, and younger events experienced by the SCB.

The Early Paleozoic evolution of the SCB

The Middle Devonian detrital formations unconformably overlying granitoids, metamorphic rocks, and folded Sinian to Ordovician sedimentary rocks, recognized nearly one century ago at the beginning of geological investigations in South China (e.g. Grabau, 1924), argue for the existence of Early Paleozoic tectonic, metamorphic and

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magmatic events. This orogen has been often referred to as "Caledonian", however, this term is just taken as a time interval, thus "Early Paleozoic" must replace "Caledonian". This age, which is presently supported by a wealth of radiometric data, shall become more easily understandable to the international community than a regional name borrowed to a very distant orogen of Northern Europe and unrelated to the geodynamics of SE China. Due to the lack of ophiolites, accretionary complexes, subduction related magmatism, the NE-SW striking Early Paleozoic Orogen of South China that develops along more than 1500 km, *from Zhejiang to NE Vietnam*, is now interpreted as an intracontinental belt (e.g. Faure et al., 2009; Charvet et al., 2010; Li et al., 2010; Wang et al., 2013).

In this volume, Wang et al. (**this issue**) carried out petrographic, mineralogical, geochemical, and zircon U-Pb geochronological studies in the Longyou garnet amphibolite in Zhejiang Province (Fig. 1). These investigations document that some of the mafic igneous rocks emplaced at ca 880 Ma, underwent a plurifacial metamorphic evolution, with a Silurian (ca 446±5 Ma) amphibolite facies metamorphic peak around 0.90-0.97 GPa and 765-780°C. This event corresponds to the North-directed continental subduction that characterizes the early Paleozoic orogen of S. China (e.g. Faure et al., 2009; Charvet et al., 2010; Li et al., 2010).

Although the late orogenic plutonism is conspicuously developed in the Early Paleozoic belt (e.g. Wang et al., 2013), the volcanic rocks are rarely investigated. The Mashan and Hekou dacite and rhyolite formations in Guangdong Province yield U-Pb zircon ages at ca 445-435 Ma (**Zhang et al. this issue**). Geochemical analyses indicate that partial melting of the underlying Paleoproterozoic continental crust was responsible for the generation of these rocks. Furthermore, the Chayuanshan basalts, also in Guangdong province, were probably derived from partial melting of

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subcontinental lithospheric mantle. It is worth to note that the calc-alkaline geochemical signature of these rocks does not reflect an oceanic subduction setting. This result complies with the intracontinental subduction mechanism responsible for the formation of the Early Paleozoic orogen.

In Fujian Province, the Xiqin pluton is an A-type granite dated at 410 Ma (**Cai et al., this issue**). Geochemical studies suggest that the partial melting of Mesoproterozoic metavolcanites and metasediments generated the parental magma of the Xiqin granite. A lithospheric delamination model is proposed to account for the asthenospheric upwelling responsible for heat transfer and subsequent crustal melting of the lower crust.

The Shedong W-Mo district of Guangxi Province consists of the Baoshan and Pingtoubei deposits hosted in granodioritic plutons. These rocks yield zircons dated at ca 440±3 Ma by U-Pb LA-ICP-MS method (**Jiang et al. this issue**). Initial 87Sr/86Sr ratios (0.7162 to 0.7173), εNd (t) values (-8.7 to -12.3), and εHf (t) values (7.8 to 1.3) suggest a crustal magmatic source for these rocks. Melting of Mesoproterozoic crust triggered by mantle-derived magma formed during the late orogenic stage can account for magma genesis and ore deposition.

Early Paleozoic events are also pervasively developed in the Qinling orogen along the northern boundary of the SCB. The age of the collision between the South and North China blocks is a long lasting controversy (e.g. Mattauer et al., 1985, 1991; Xu et al., 1986; Zhang et al., 1996; Faure et al., 2008; Dong et al., 2015; Xu et al., 2015). Near Shangnan, the Fushui gabbro-dioritic complex experienced a greenschist facies metamorphism during the South China-North China blocks collision. Zircons from these rocks yield U/Pb LA-ICP-MS ages at ca 500 Ma interpreted as those of the magmatic emplacement of the mafic rocks (**Shi et al., this issue**). εNd (t) values (-0.20 to -6.7) and

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the T_{DM2} model age between 1.7 and 1.5 Ga, indicate that the mafic magma was extracted from a partially melted lherzolitic lithospheric mantle. A supra-subduction or an island arc setting is put forward to account for the formation of the Fushui mafic intrusion. These results comply with the interpretation that oceanic closure and subsequent collision between the South and North China blocks took place before 415 Ma.

The Late Permian intraplate magmatism

In the SW part of the SCB, the Emeishan Large Igneous Province (ELIP, Fig. 2) is acknowledged as a major global geodynamic event that dramatically influenced the Late Permian hydrosphere, atmosphere, and biosphere (e.g. He et al., 2003; Ali et al., 2005; Deng et al., 2010). The mafic lavas, dyke, and gabbro of Western Guangxi analyzed by **Liu X. et al. (this issue**) have extremely high Ti/Y ratios. The εNd (t) and REE patterns suggest a deep mantle source with a low degree of partial melting at pressure greater than 3.5 GPa. These data support the view that the Western Guangxi mafic rocks generated in a mantle plume and represent the outer extension of the ELIP. Therefore, the interpretation of these rocks as "ophiolites" can be definitely ruled out.

Late Paleozoic-Early Mesozoic tectonic evolution of the SCB

The Triassic is the main tectonic period in the SCB during which this continent collided with the Indochina-Lanping-Simao-Qiangtang one along the Jinshajiang-Ailaoshan-Song Ma ophiolitic suture that likely extends to the Song Chay-Hainan suture if a ca 800 km left-lateral offset along the Cenozoic Red River fault is assumed (Leloup et al., 1995; Faure et al., 2016a). This orogen was initially defined in N. Vietnam and Laos by the Late Triassic (Norian) unconformity of sandstone and conglomerate overlying folded and metamorphosed rocks as the "Indosinian" chain (Fromaget, 1941).

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Subsequently, the term "Indosinian" was pervasively used for all Triassic events recognized in Asia. Nevertheless, strictly speaking, "Indosinian orogeny" must be reserved for the orogens bounding the southwestern and southeastern parts of the SCB. Other Triassic belts results of different lithospheric plates interactions.

The existence of a magmatic arc on the Indochina side (e.g. Liu Jet al, 2012; Roger et al., 2012), the N, NE or E verging folds and thrusts in NE and NW Vietnam, Ailaoshan and Jinshajiang areas (Lepvrier et al., 2011; Zi and Cawood, 2012; Liu et al., 2015; Faure et al., 2016a,b) argue for a south-directed subduction of the SCB below the Indochina one. In the Ailaoshan segment, of the Middle Triassic suture, a magmatic arc is well documented (Fan et al., 2010; Lai et al., 2014). The Dalonkai mafic-ultramafic layered intrusion is petrographically and geochemically well characterized (**Liu H. et al., this issue**). Zircons from the gabbro and plagioclase pyroxenite yield U/Pb ages at 266±6 Ma and 272±2 Ma, respectively. The geochemical features (Cr, Ni content, Mg#) of the Dalongkai intrusion are analogous to the typical back-arc basin rocks suggesting that this body emplaced during the West-directed Middle Permian Paleotethys subduction.

North, or East, of the Song Chay suture, Triassic turbidites are widely distributed in the Song Hiem basin of NE Vietnam or the Youjiang-Nanpanjiang basin of Yunnan and Guangxi Provinces (Fig. 2). In spite of several sedimentological and detrital zircon distribution studies (e.g. Enos et al., 2006; Yang et al., 2012; Hu et al., 2015; Lehrmann et al., 2015) the geodynamic setting of this basin, either as a back-arc or foreland basin, remains controversial. **Qiu et al. (this issue)** provide new geochemical arguments to constrain the provenance of the clastic sediments. Both argillaceous and arenaceous sedimentary rocks yield major elements features identical to continental arc continental arc basins. The low Chemical Index of Alteration, and high Index of Compositional

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Variability values indicate that these rocks experienced a weak chemical weathering. The geochemical Th-Sc-Zr, and La-Th-Sc discrimination diagrams suggest that the Middle Triassic clastic rocks record the evolution from an active continental margin to a collisional foreland basin.

As pointed out since a long time (e.g. Mattauer et al., 1985, 1991; Xu et al., 1986), after the Early Paleozoic collision between the NCB and SCB, the Qinling-Dabie belt experienced a major Triassic reworking. In the Dabashan and Wudanshan, the Neoproterozoic to Early Triassic formations are folded and thrust to the S or SW (e.g. Li et al., 2007c; Faure et al;, 2008; Shi et al., 2012; Xu et al., 2015; Dong et al., 2016). Locally in the Wudangshan, Susong, and Zhangbaling areas (Fig. 2), a HP/LT metamorphism dated at ca 230 Ma coeval with a top-to the SW shearing. Then, a top-to the-North ductile shearing, coeval with the greenschist facies retrogression, overprints the top-to-the-S shearing (e.g. Lin et al., 2005; Faure et al., 2008). The detailed petrological and geochronological investigations in the Feidong-Zhangbaling area (**Shi et al., this issue**) place important thermo-barometric and time constraints on the evolution of the Zhangbaling massif. The HP metamorphism formed at ca 230 Ma, and 210 Ma retrogression coeval with exhumation. Shi contribution in this volume brings also new insights on the location of the NCB-SCB in the central part of the Tan-Lu fault zone, along the Zuding-Shimenshan fault.

West of the Tan-Lu fault, the southern margin of the NCB underwent also a Mesozoic (Triassic or Jurassic) deformation. The NW-directed Xu-Hai fold-and-thrust belt developed in the Neoproterozoic-Early Paleozoic formations of the NCB accommodated a ca 30 km decollement of the upper crustal series shortening interpreted as the consequence of a SE-ward under-thrusting of the NCB below the SCB (**Shu et al., this issue**).

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Other Triassic belts, such as Longmenshan or Xuefengshan, exposed in the SCB, are also intracontinental orogens, however, they are not considered in this Special Issue.

Jurassic-Cretaceous magmatism of the SCB

Mesozoic magmatism is widespread in the SE part of the SCB. Although it is often proposed that the plutons are related to the oceanic subduction of the Paleo-Pacific plate below the SCB continental margin, (e.g. Zhou and Li, 2000; Li and Li, 2007), this simple model does not account for the variety of petrological types and emplacement settings of the plutonic rocks. Some Triassic plutons are probably related to the Xuefengshan intracontinental belt, or to the SCB-Indochina collision (e.g. Chu et al., 2012; Wang et al., 2013; Faure et al., 2016a). However, there are still controversies on the geodynamic significance of the Jurassic and Cretaceous plutons. Indeed, there is no unequivocal evidence for a Jurassic subduction below the SCB SE margin (Li et al., 2007b; Chen et al., 2008; Jiang et al, 2009; Huang et al., 2013),

In Hunan Province, the Taohuashan, Dayunshan-Mufushan, Wangxiang, and Lianyunshan biotite granite plutons yield zircons dated at 151-146 Ma, 132-127 Ma, and ca 117 Ma (**Ji W. et al., this issue**). The geochemical investigations support a source originated by the partial melting of metasedimentary rocks, possibly the Neoproterozoic Lengjiaxi group and the underlying formations. The Early Cretaceous magmatism is attributed to the slab roll-back of the Paleo-Pacific plate while the Late Jurassic early stage might be a response to slab foundering, although the subduction sense is not settled yet.

Cenozoic evolution

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The Western part of the SCB has been significantly reworked during the Cenozoic as a consequence of the India-Eurasia collision. With respect to the Cenozoic tectonics, "Sundaland" that includes also a part of Indochina must be preferred to SCB, which is used to account for the Paleozoic and Mesozoic tectonics. In SE Tibet (Yunnan Province), the Ximeng complex studied by **Chen et al. (this issue)** provides an example of the Miocene (ca 23-20 Ma) shearing that accommodated the exhumation of the Neoproterozoic and Paleozoic formations. Together with the sinistral Ailaoshan-Red River and dextral Sagaing shear zones, the Ximeng dome documents the internal deformation of Sundaland during its Southeastward extrusion. This study also highlights the importance of intraplate deformation that generally follows a continental collision. Localized crustal flow is a possible process to account for the extrusion tectonics.

The knowledge of the structure of the middle and lower continental crust is essential to understand the rheological behavior of continents. The Cenozoic opening of the South China Sea is also a consequence of the extrusion of Sundaland. The petrophysical study of representative rocks from the Yunkai massif conducted by **S. Ji et al. (this issue)** documents the P-wave velocity and the anisotropy of the SCB continental margin. Twelve seismic profiles have been reinterpreted. The high velocity (ca 7.0 to 7.6 km/s) of the lower continental crust can be viewed either as representative of mafic rocks constitutive of the initial SCB lower crust or alternatively as underplated mafic magma emplaced from mantle melting during the opening of the South China sea.

Conclusion

The South China Block is one of the most diversified continental pieces that constitute the Eurasian continent. Although not covering all the tectonic and

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geodynamic aspects experienced by this block, the contributions gathered in this Special Issue will shed light on the evolution of this complex continent.

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Figure captions

Fig. 1. Tectonic map of Asia with the main continental blocks and large-scale faults. In the South China Block (SCB), the purple dashed line represents the Jiangnan suture, the green dashed line depicts the Early Paleozoic "scar of the intracontinental orogen, and the pink dashed line outline the Middle Triassic Indosinian orogen slip by the Red River fault (RRF), and the intracontinental Xuefengshan orogen (XFS) in the central par of the SCB. Other Triassic belts are nor represented. TLF: Tan-Lu fault. MCT: Main Central Thrust.

Fig. 2. Structural map of the SCB showing the main tectonic elements. Black squares show the location of the articles presented in this Special Issue.

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Figure 1

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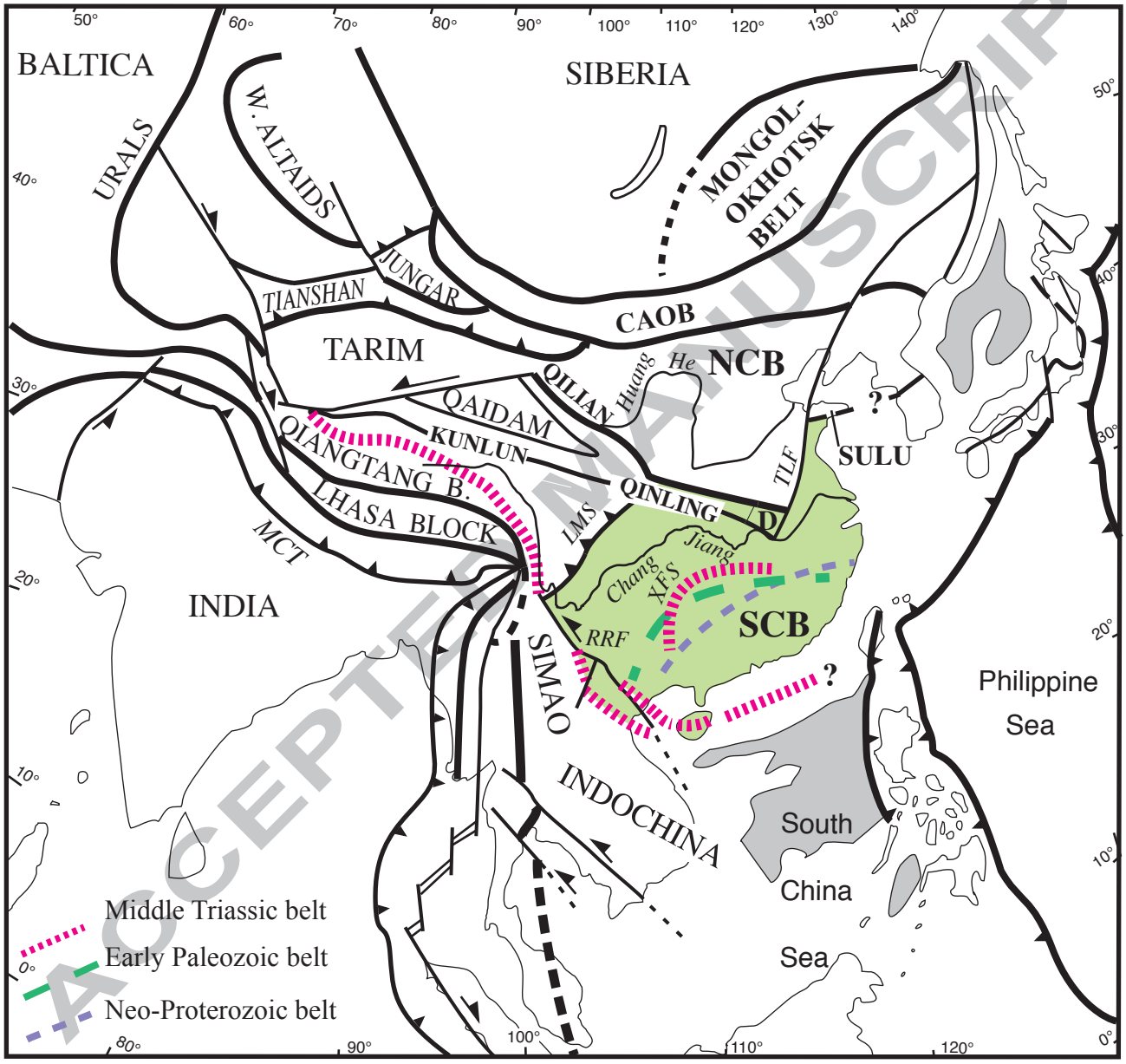

Fig. 1

Figure 2

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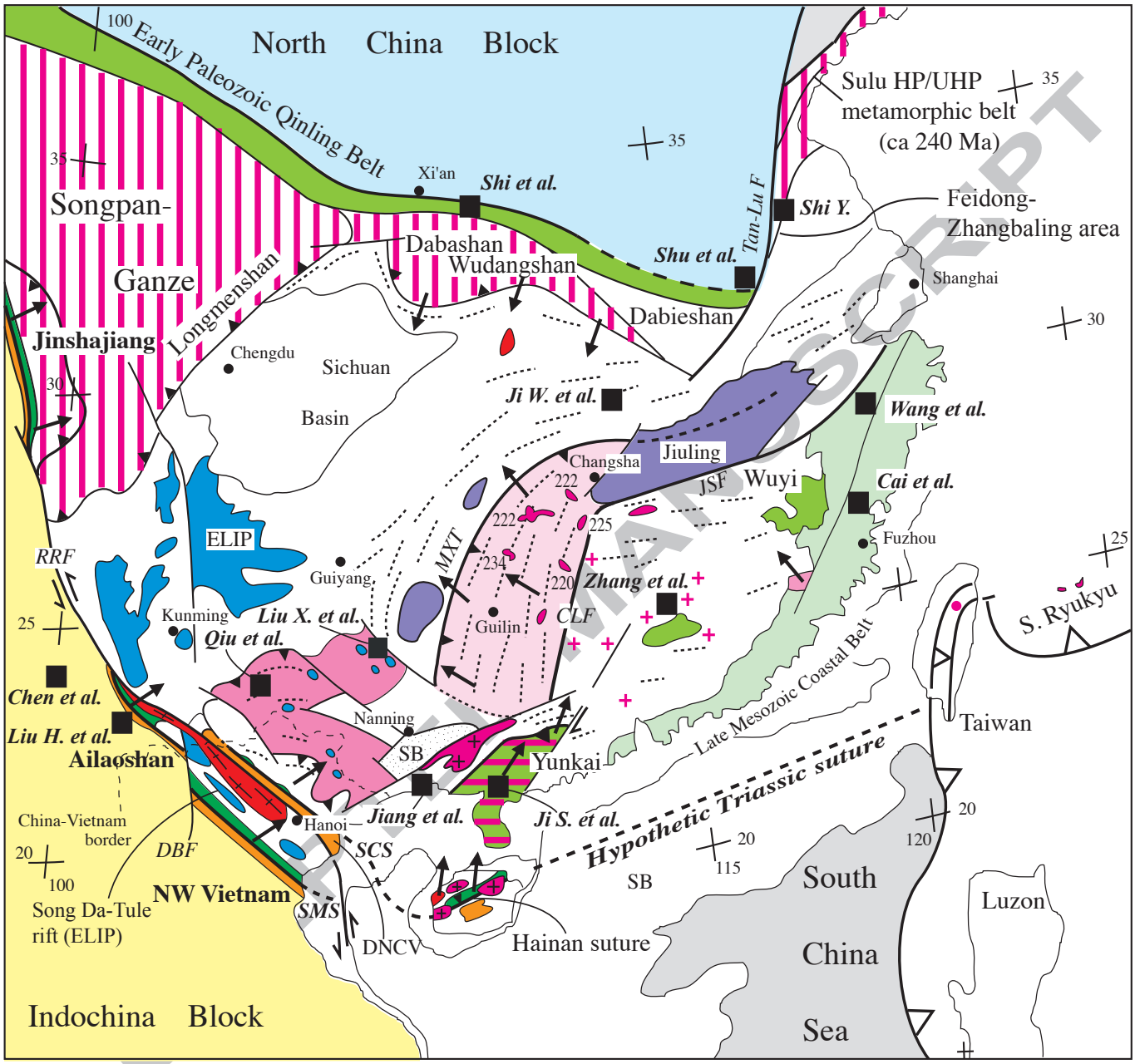

Fig. 2

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Highlights

The Neoproterozoic Jiangnan collision of Cathaysia and Yangtze is responsible for the formation of the South China Block (SCB)

During the Early Paleozoic, the SCB was welded to the North China block along the Qinling belt, and also experienced an intracontinental orogeny that partly reworked the Jiangnan belt

During the Middle Triassic, the SCB was welded to Indochina, the Qinling belt was reworked by N-directed intracontinental subduction.

The Xuefengshan belt is also a Middle Triassic intracontinental orogen

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