Geol. Mag. **138** (*1*), *2001, pp. 89–91. Printed in the United Kingdom © 2001 Cambridge University Press*

RAPID COMMUNICATION

Palaeoproterozoic assembly of the North China Craton

GUOCHUN ZHAO*

Tectonics Special Research Centre, School of Applied Geology, Curtin University of Technology, GPO Box U1987, Perth, W.A. 6845, Australia

(*Received* 4 July 2000; *accepted* 22 November 2000)

Abstract. The basement of the North China Craton consists of the Eastern and Western blocks, separated by the Central Zone. Both the Eastern and Western blocks are dominated by late Archaean tonalitic–trondhjemitic–granodioritic gneiss complexes interdigitated with minor supracrustal rocks metamorphosed at ~2.5 Ga, with anticlockwise P–T paths. The Central Zone is composed of reworked late Archaean components and Palaeoproterozoic juvenile crustal materials that underwent regional metamorphism at ~1.85 Ga, with clockwise P–T paths involving isothermal decompression as a result of collision between the Eastern and Western blocks, which resulted in the final assembly of the North China Craton.

1. Introduction

2.0–1.8 Ga collisional orogens around the world have been considered to record a global-scale event that led to the development of a supercontinent from a jumble of smaller Archaean cratons and Palaeoproterozoic arcs (Hoffman, 1989; Van Kranendonk, St-Onge & Henderson, 1993). Hoffman (1989) proposed that the supercontinent assembling between 2.0–1.8 Ga was the first long-lived supercontinent on Earth, because before 1.8 Ga, the total mass of continental crust may have been insufficient to form a true supercontinent. This hypothesis is supported by the occurrence of 2.0–1.8 Ga collisional orogens in nearly every Archaean cratonic block, e.g. the Transamazonian Orogen in South America, the Eburnean Orogen in West Africa, the Limpopo Orogen in South Africa–Botswana, the Trans-Hudson Orogen in North America, the Svecofennian and the Kola–Karelian orogens in Baltica, the Nagssugtoqidian Orogen in Greenland, the Capricorn Orogen in Western Australia, etc. This paper presents lithological, structural, geochronological and metamorphic P–T data indicating that, like most other cratonic blocks, the North China Craton formed by amalgamation of two smaller cratonic blocks along a Palaeoproterozoic collisional orogen at ~1.85 Ga.

2. New tectonic division of the North China Craton

Traditionally, the North China Craton has been considered to be composed of a relatively uniform Archaean to Palaeoproterozoic basement, and its tectonic history was explained using pre-plate-tectonic geosynclinal models (Huang, 1977). This early model was abandoned in the late 1980s and the early 1990s following the discovery of fragments of ancient oceanic crust, mélanges, high-pressure granulites, retrograded eclogites and crustal-scale ductile shear zones in the central zone of the craton (Li & Qian, 1991; Zhai, Guo & Yan, 1992; Liu, Shen & Geng, 1996; Wang *et al.* 1996; Bai & Dai, 1998; Wu & Zhong, 1998). These discoveries make the central zone of the craton distinct from the eastern and western zones, in which the basement is dominated by Archaean tonalitic–trondhjemitic–granodioritic domiform batholiths tectonically interdigitated with minor supracrustal rocks. In addition, petrographic, thermobarometric and geochronological data reveal that mafic granulites in the central zone differ in metamorphic timing and P–T evolution from those in the eastern and the western part of the craton (Wu & Zhong, 1998; Zhao *et al.* 2000). The former underwent granulite facies metamorphism at ~1.85 Ga, with clockwise P–T paths involving isothermal decompression, reflecting a continental collisional environment (Zhai, Guo & Yan, 1992; Zhao *et al.* 2000). In contrast, the latter experienced granulite facies metamorphism at ~2.5 Ga, with isobaric-cooling anticlockwise P–T paths, reflecting an origin possibly related to underplating of mantle-derived magmas (Zhao *et al.* 1998). These differences have led Zhao *et al.* (1998, 1999, 2000) to propose a new three-fold tectonic subdivision for the North China Craton. According to this proposal, the basement of the craton can be divided into two distinct blocks, named the Eastern Block and Western Block, separated by a 100–300 km wide crustal boundary zone, defined as the Central Zone (Fig. 1).

3. Eastern Block

The basement rocks of the Eastern Block are dominated by a late Archaean lithological assemblage, with minor early to middle Archaean rocks including 3.3–3.8 Ga granitic

---

* Present address: Department of Earth Sciences, The University of Hong Kong, Pokfulam Road, Hong Kong, China; E-mail: gzhao@hkucc.hku.hk.

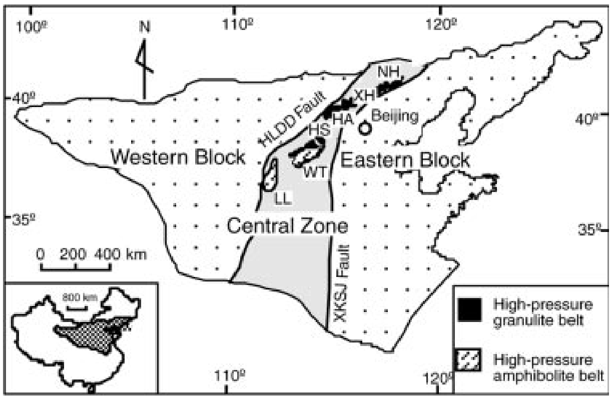

Figure 1. Distribution of the Eastern and Western blocks and the Central Zone in North China Craton. HLDD: Huashan–Lishi–Datong–Duolun Fault; XKSJ: Xinyang–Kaifeng–Shijiazhuang–Jianping Fault; HA: Huaian; HS: Hengshan; LL; Lüliang; NH: Northern Hebei; WT: Wutai; XH: Xuanhua.

gneisses and 3.85 Ga fuchsite-bearing quartzites (Liu *et al.* 1992). The late Archaean basement rocks include 2.6–2.5 Ga tonalitic–trondhjemitic–granodioritic gneisses, ultramafic to mafic igneous intrusives and dykes, and ~2.5 Ga syntectonic charnockites and granites, with minor amounts of ~2.5 Ga supracrustal rocks (Bai & Dai, 1998; Kröner *et al.* 1998; Zhao *et al.* 1998). Of these rocks, tonalitic–trondhjemitic–granodioritic gneisses make up 85% of the total exposure of the late Archaean basement. Ultramafic rocks are mainly of peridotitic and komatiitic affinities (Bai & Dai, 1998; Zhao *et al.* 1998). The supracrustal rocks comprise sedimentary and bimodal volcanic rocks, metamorphosed from greenschist to granulite facies at 2.48–2.50 Ga (Bai & Dai, 1998; Kröner *et al.* 1998). Structurally, the late Archaean basement in the Eastern Block is dominated by tonalitic–trondhjemitic–granodioritic gneiss domes that are separated by linear belts of supracrustal rocks (Zhao *et al.* 1998). The domes are generally circular, elliptical or oval in plan, 10–50 km in diameter, and consist of broadly uniform tonalitic–trondhjemitic–granodioritic gneisses, locally associated with ~2.5 Ga syntectonic granites in the cores of the domes.

Mafic granulites, amphibolites and pelitic gneisses or schists in the Eastern Block preserve prograde, peak and post-peak mineral assemblages. The prograde assemblage is indicated by inclusions within minerals of the peak stage, represented by the assemblages of hornblende + plagioclase + quartz ± biotite in mafic granulites, chlorite + actinolite + epidote + plagioclase + quartz in amphibolites and biotite + plagioclase + quartz in pelitic gneisses. The peak assemblage is shown by the assemblages of orthopyroxene + clinopyroxene + garnet + plagioclase + quartz in mafic granulites, hornblende + plagioclase + quartz + garnet in garnetiferous amphibolites and garnet + sillimanite + plagioclase + quartz + biotite in pelitic gneisses. The post-peak assemblage is characterized by garnet + quartz symplectic coronas in mafic granulites, actinolite + garnet retrogressive rims around garnet or hornblende grains in amphibolites, and kyanite replacing sillimanite or staurolite replacing sillimanite + garnet in pelitic gneisses. These mineral assemblages and their *P–T* estimates define isobaric-cooling-type anticlockwise *P–T* paths (Zhao *et al.* 1998), possibly reflecting an origin related to the intrusion and underplating of large amounts of mantle-derived magmas.

4. Western Block

The Western Block has a basement characterized by late Archaean rocks in the northwest, flanked to the southeast by Palaeoproterozoic khondalite belts. Early and middle Archaean rocks have not been reported from the Western Block. The late Archaean basement of the block has a lithological assemblage, structural style and metamorphic history similar to those of the Eastern Block, comprising tonalitic–trondhjemitic–granodioritic gneiss complexes associated with minor supracrustal rocks metamorphosed from greenschist to granulite facies at ~2.5 Ga, with isobaric-cooling-type anticlockwise *P–T* paths (Zhao *et al.* 1999). The Palaeoproterozoic khondalites consist of graphite-bearing sillimanite–garnet gneisses, garnet quartzites, calc-silicate rocks and marbles, representing stable continental margin deposits, with a maximum depositional age of ~2.3 Ga and a metamorphic age of ~1.85 Ga (Zhao *et al.* 1999). Al-rich gneiss from the khondalites preserves decompression assemblages represented by cordierite coronas and cordierite + orthopyroxene or cordierite + spinel symplectites, replacing the peak assemblages of garnet + sillimanite + biotite + quartz. These mineral assemblages and their thermobarometric estimates define isothermal-decompression-type clockwise *P–T* paths (Zhao *et al.* 1999), reflecting a continental collisional environment.

5. Central Zone

Between the two *blocks* is the Central Zone that extends as a roughly north–south trending belt and is separated from the Eastern and Western blocks by major faults (Fig. 1). The zone consists of reworked Archaean basement and late Archaean to Palaeoproterozoic sedimentary and igneous rocks metamorphosed in subgreenschist to granulite facies (G. Zhao, unpub. Ph.D. thesis, Curtin Univ., 2000). Nd isotope and other geochemical data indicate that no significant amount of continental crust existed before 2.6 Ga in the Central Zone and much of the basement formed in continental magmatic arcs (Sun, Armstrong & Lambert, 1992; Wu & Zhong, 1998). As shown in Figure 2, the basement rocks from most metamorphic complexes in the Central Zone have positive ε_{Nd} values and Sm–Nd whole-rock isochron ages younger than 2.6 Ga. Minor amounts of the basement rocks have been interpreted to be fragments of ancient oceanic crust and mélange (Bai & Dai, 1998; Wu & Zhong, 1998). The zone also contains high-pressure granulites, high-pressure amphibolites and retrograded eclogites (Zhai *et al.* 1995), which occur along the central part of the zone (Fig. 1). These high-pressure rocks are interpreted to be retrograded eclogite-facies rocks generated at considerable depths and subsequently exhumed to higher crustal levels.

The structural style of the Central Zone is characterized by linear belts which are primarily outlined by a number of NNE–SSW trending ductile shear zones, and much of the tectonic history of these linear belts was related to Phanerozoic-style collisional tectonics. One of the best studied of these collision-related structural belts is the Wutai Complex. The complex consists of three distinct lithotectonic units, named the Shizui, Taihuai and Gaofan/Hutuo assemblages (Bai & Dai, 1998). The Shizui assemblage contains metamorphosed peridotites, gabbros, oceanic tholeiites and cherts, interpreted to be relics of ancient oceanic crust (Bai & Dai, 1998; Wu & Zhong, 1998). The Taihuai assemblage comprises felsic volcanic rocks and tholeiites of volcanic-arc affinity, intruded by 2.5–2.1 Ga calc-alkaline

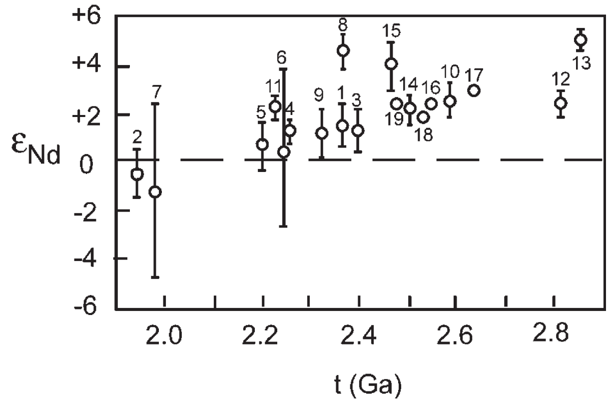

Figure 2. ε_{Nd} versus Sm–Nd whole-rock isochron age diagram for the basement rocks in the Central Zone of the North China Craton, based on compilation given by Zhao *et al.* (2000). 1–2, Fuping Complex; 3–11, Wutai Complex, 12–13, Hengshan Complex; 14, Dengfeng Complex; 15, Lüliang Complex; 16–19, Zhongtiao Complex.

granitoid plutons and metamorphosed in greenschist facies, representing late Archaean to Palaeoproterozoic accretionary arc formation (Wu & Zhong, 1998). The Gaofan/Hutuo assemblage consists of Palaeoproterozoic quartz wacke, siltstone, conglomerate and minor mafic to felsic volcanics, interpreted to have developed in a retro-arc foreland basin (Bai & Dai, 1998). These lithotectonic units were structurally disrupted and juxtaposed along a series of NE–SW trending ductile shear zones. Similar lithotectonic assemblages and structural styles also characterize other low-grade domains (e.g. Lüliang, Northern Hebei, etc.) in the Central Zone.

The mafic granulites, amphibolites and pelitic rocks from the Central Zone record a metamorphic history characterized by nearly isothermal decompression and then retrogressive cooling following peak metamorphism. The decompression textures are represented by worm-like orthopyroxene + plagioclase symplectites or clinopyroxene + orthopyroxene + plagioclase coronas in mafic granulites, hornblende or cummingtonite + plagioclase symplectites in amphibolites, and cordierite coronas and cordierite + orthopyroxene or cordierite + spinel symplectites in pelitic rocks. The cooling textures are shown by hornblende + plagioclase symplectites in mafic granulites, chlorite + epidote + mica retrogressive rims around garnet or hornblende grains in amphibolites, and biotite + K-feldspar ± muscovite ± magnetite replacing garnet, cordierite and sillimanite in pelitic gneisses. These textural relations and their *P*–*T* estimates define clockwise *P*–*T* paths involving near-isothermal decompression and cooling following peak metamorphism (Zhao *et al.* 2000), suggesting that the Central Zone developed in a continental collisional environment.

6. Timing of orogenesis in the Central Zone

The high-grade gneisses, low- to medium-grade granite–greenstone terrains and very-low-grade metavolcanic and metasedimentary rocks in the Central Zone have long been assigned to the products of three different tectonothermal events, named the Fuping (~2.5 Ga), Wutai (2.4–2.3 Ga) and Lüliang (~1.8 Ga) 'movements', respectively (Huang, 1977). This was built up on a few 'unconformities', conventional multigrain U–Pb zircon geochronology, and a misconception that high-grade metamorphic rocks were older than low-grade ones. However, a recent study has shown that the so-called 'unconformities' between these 'movements' are regional-scale ductile shear zones (Li & Qian, 1991). Moreover, recent geochronological data do not support the existence of the Fuping and Wutai 'movements' in the Central Zone. In the Fuping, Wutai and Hengshan areas, for example, SHRIMP U–Pb zircon ages reveal that the high-grade Fuping and Hengshan gneiss complexes are not older than the low-grade Wutai granite–greenstone terrain (Table 1); they are all characterized by the emplacement of major granitoid bodies between 2.55 and 2.45 Ga, deposition of supracrustal rocks from late Archaean to Palaeoproterozoic time, and intrusion of granitic bodies at 2.2–2.0 Ga (Table 1). SHRIMP U–Pb zircon studies combined with cathodoluminescence images and U–Th chemistry confirm the existence of only one phase of metamorphic zircons in nearly all medium- to high-grade lithologies from these complexes (G. Zhao, unpub. Ph.D. thesis, Curtin Univ., 2000). These metamorphic zircons occur as either single grains or overgrowth rims surrounding older magmatic zircon cores, and are structureless, highly luminescent and very low in Th and U contents. These features make them distinctly different from the magmatic zircons that are generally characterized by oscillatory zoning, low luminescence and comparatively high Th and U contents. The metamorphic zircons from different rocks in the zone yield similar concordant $^{207}Pb/^{206}Pb$ ages in the range 1870 to 1800 Ma (Table 1), which are 700 Ma to 150 Ma younger than their magmatic zircon cores (G. Zhao, unpub. Ph.D. thesis, Curtin Univ., 2000). A conclusion from

Table 1. SHRIMP U–Pb zircon ages of the Hengshan, Wutai and Fuping complexes

Rocks	Ages (Ma)	Interpretations	Sources*
Hengshan Complex			
Tonalitic gneiss	2520 ± 15	Crystallization age	(1)
	1872 ± 17	Metamorphic age	
Garnet quartzite	2527 ± 10	Age of source rocks	(1)
	1872 ± 17	Metamorphic age	
Mafic granulite	1827 ± 10	Metamorphic age	(1)
Wutai Complex			
Granitic gneiss	2546 ± 3	Crystallization age	(2)
Granitic gneiss	2531 ± 5	Crystallization age	(2)
Granitic gneiss	2520 ± 9	Crystallization age	(2)
Meta-andesite	2533 ± 8	Protolith age	(2)
Metadacite	2524 ± 8	Protolith age	(2)
Subvolcanics	2516 ± 8	Protolith age	(2)
Monzogranite	2117 ± 18	Crystallization age	(2)
Porphyric granite	2176 ± 12	Crystallization age	(2)
Porphyric granite	2107 ± 15	Crystallization age	(2)
Fuping Complex			
Tonalitic gneiss	2514 ± 11	Crystallization age	(3)
	1805 ± 48	Metamorphic age	
Trondhjemitic gneiss	2499 ± 6	Crystallization age	(3)
	1861 ± 20	Metamorphic age	
Grandodioritic gneiss	2485 ± 9	Crystallization age	(3)
	1824 ± 9	Metamorphic age	
Monzongranitic gneiss	2084 ± 12	Crystallization age	(3)
	1826 ± 18	Metamorphic age	
Granodioritic gneiss	2023 ± 24	Crystallization age	(3)
	1850 ± 11	Metamorphic age	(3)

*(1) S. A. Wilde (unpub. data); (2) Wilde *et al.* (1997); (3) G. Zhao, unpub. Ph.D. thesis, Curtin Univ., 2000

these data is that the main regional metamorphism of the basement rocks in the Central Zone occurred at ~1.85 Ga (Lüliang 'movement'), not at the end of the Archaean, as previously considered by most Chinese geologists. This conclusion is supported by a garnet–clinopyroxene–orthopyroxene Sm–Nd isochron age of 1824 ± 18 Ma and a U–Pb zircon age of 1833 ± 23 Ma from high-pressure granulites in the Central Zone (Guo & Shi, 1996).

7. Assembly of the North China Craton

As discussed above, the Eastern and Western blocks have similar late Archaean lithotectonic assemblages, structural styles and metamorphic *P–T* paths. They are both composed of 2.6–2.5 Ga tonalitic–trondhjemitic–granodioritic gneisses, ultramafic (komatiitic) to mafic igneous rocks, ~2.5 Ga syntectonic granites, with minor amounts of 2.55–2.50 Ga supracrustal rocks. All these rocks underwent regional metamorphism at ~2.5 Ga, shortly after formation. The regional metamorphism is characterized exclusively by isobaric-cooling-type anticlockwise *P–T* paths, and the structural style is dominated by tonalitic–trondhjemitic– granodioritic gneiss domes separated by linear belts of supracrustal rocks. These features do not support a continental collisional model for the formation of the basement rocks in the Eastern and Western blocks. The possible tectonic environments include continental magmatic arc regions, hot spots driven by mantle plumes, or continental rift regions. This question is not further pursued here, although Zhao *et al.* (1998) favoured a mantle plume model to interpret the formation of the basement rocks in the Eastern Block. The key point is that, by the end of Archaean Era, two distinct continental blocks had formed through the interaction of mantle-derived magmas with pre-existing lithosphere in what subsequently became the Eastern and Western blocks.

The structural styles and isothermal-decompression-type clockwise *P–T* paths of late Archaean to Palaeoproterozoic basement rocks in the Central Zone and the Palaeoproterozoic khondalites from the Western Block reflect tectonothermal processes characterized by initial crustal thickening, subsequent nearly isothermal exhumation and final cooling. This sequence of tectonic events is consistent with a continent–continent collisional environment (cf. Harley, 1992; Windley, 1992). Considering the spatial and timing relationships between the Central Zone and the Eastern and Western blocks, this collisional event is most likely related to the amalgamation of the Eastern and Western blocks in the late Palaeoproterozoic Era. Geological and geochemical studies indicate that the basement rocks in the Central Zone represent late Archaean to Palaeoproterozoic active continental magmatic arc regions (Sun, Armstrong & Lambert, 1992; Wang *et al.* 1996). The Palaeoproterozoic khondalite series in the Western Block represents stable continental-margin deposits around the margins of the Western Block (Lu & Jin, 1993). These data lead to the following tectonic scenario for the amalgamation of the North China Craton (Fig. 3).

In the late Archaean to Palaeoproterozoic Era, the Eastern Block had an active-type continental margin on its western side at which continental magmatic arcs and intra-arc basins developed, whereas the Western Block had a passive-type continental margin on its eastern side along which stable continental margin sediments were deposited, forming the protoliths of the khondalitic rocks. Intervening between the two blocks was an ocean, which was undergoing subduction beneath the western margin of the Eastern Block (Fig. 3a). At ~1.85 Ga, the ocean between the two blocks disappeared through subduction, and collision between the Eastern and Western blocks occurred. During collision, the Palaeoproterozoic sedimentary rocks along the passive continental margin of the Western Block were thrust over the active-type continental margin of the Eastern Block (Fig. 3b), because of their relatively low density. This may explain the tectonic relationship showing that some Palaeoproterozoic khondalites were thrust over the granulite-facies terrains in the Central Zone. The collision caused crustal-scale folding, thrusting and thickening, and resulted in medium- to high-pressure granulite-facies metamorphism in the lower crust and greenschist- to amphibolite-facies metamorphism in the upper crust (Fig. 3c). Following peak metamorphism, the thickened crust underwent exhumation and accompanying decompression, which resulted in the development of asymmetric folds and widespread symplectic textures in the rocks (Fig. 3d). Finally, retrogressive metamorphism took place when the crust was exhumed to shallow levels (Fig. 3e). These tectonic processes led to the final assembly of the North China Craton at ~1.85 Ga.

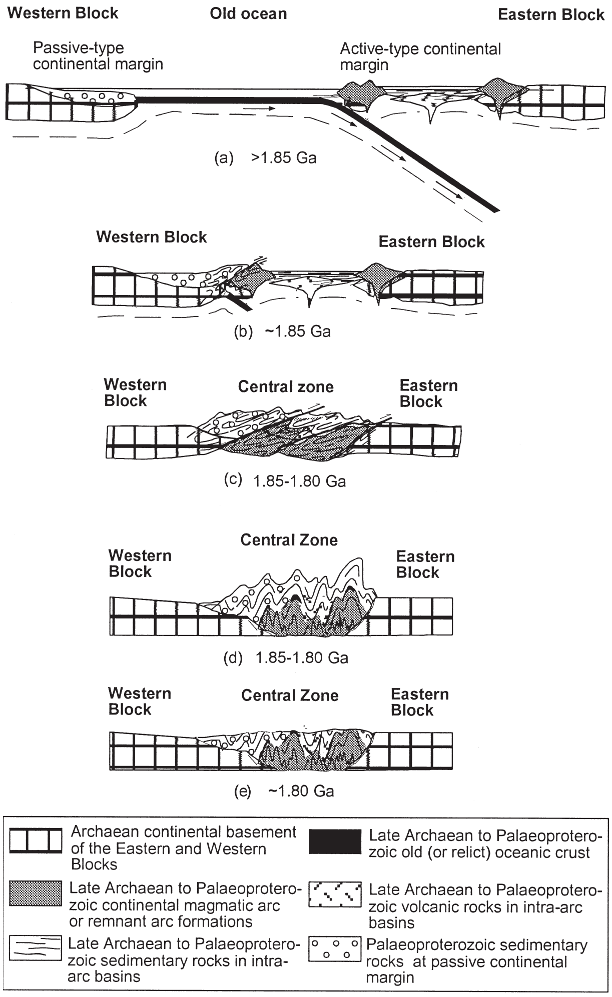

Figure 3. A series of schematic sections showing the proposed tectonothermal evolution and Palaeoproterozoic amalgamation of the North China Craton along the Central Zone.

Acknowledgments. I am indebted to A. Kröner and K. C. Condie for their critical and helpful comments that led to substantial improvements of this paper. This work was partly supported by a RGC Grant (HKU7115/00P) to M. Sun. This is Tectonics Special Research Centre Publication No. 122.

References

Bai, J. & Dai, F. Y. 1998. Archaean crust of China. In *Precambrian Crustal Evolution of China* (eds X. Y. Ma and J. Bai), pp. 15–86. Beijing: Springer Geological Publishing House.

Guo, J. H. & Shi, X. 1996. Geochronology and important geological events. In *Granulites and Lower Continental Crust in the North China Craton* (ed. M. G. Zhai), pp. 21–54. Beijing: Seismological Press.

Harley, S. L. 1992. Proterozoic granulite terranes. In *Proterozoic crustal evolution* (K. C. Condie), pp. 301–60. Amsterdam, New York, Tokyo: Elsevier.

Hoffman, P. F. 1989. Speculations on Laurentia's first gigayear (2.0 to 1.0 Ga). *Geology* **17**, 135–8.

Huang, J. Q. 1977. The basic outline of China tectonics. *Acta Geologica Sinica* **52**, 117–35 (in Chinese).

Kröner, A., Cui, W. Y., Wang, W. Y., Wang, C. Q. & Nemchin, A. 1998. Single zircon ages from high-grade rocks of the Jianping Complex, Liaoning Province, NE China. *Journal of Asian Earth Sciences* **16**, 519–32.

Li, J. H. & Qian, Q. L. 1991. A study on Longquanguan shear zone in northern part of Taihang Mountain. *Shanxi Geology* **6**, 17-29 (in Chinese).

Liu, D. Y., Nutman, A. P., Compston, W., Wu, J. S. & Shen, Q. H. 1992. Remnants of 3800 crust in the Chinese Part of the Sino-Korean craton. *Geology* **20**, 339–42.

Liu, S. W., Shen, Q. H. & Geng, Y. S. 1996. Metamorphic evolution and Gibbs analysis of two types of mafic granulites in Northwestern Hebei. *Acta Petrologica Sinica* **12**, 261–75.

Lu, L. Z. & Jin, S. Q. 1993. P–T–t paths and tectonic history of an early Precambrian granulite facies terrane, Jining district, southeastern Inner Mongolia, China. *Journal of Metamorphic Geology* **11**, 483–98.

Sun, M., Armstrong, R. L. & Lambert, R. St. J. 1992. Petrochemistry and Sr, Pb and Nd isotopic geochemistry of Early Precambrian rocks, Wutaishan and Taihangshan areas, China. *Precambrian Research* **56**, 1–31.

Van Kranendonk, M. J., St-Onge, M. R. & Henderson, J. R. 1993. Palaeoproterozoic tectonic assembly of North Laurentia through multiple indentations. *Precambrian Research* **63**, 325–47.

Wang, K. Y., Li, J. L., Hao, J., Li, J. H. & Zhou, S. P. 1996. The Wutaishan mountain belt within the Shanxi Province, Northern China: a record of Late Archaean collision tectonics. *Precambrian Research* **78**, 95–103.

Wilde, S. A., Cawood, P., Wang, K. Y. & Nemchin, A. 1997. The relationship and timing of granitoid evolution with respect to felsic volcanism in the Wutai Complex, North China craton. Proceedings of the 30th IGC. *Precambrian Geology and Metamorphic Petrology* **17**, 75–88.

Windley, B. 1992. Proterozoic collisional and accretionary orogens. In *Proterozoic crustal evolution* (ed K. C. Condie), pp. 419–46. Amsterdam, New York, Tokyo: Elsevier.

Wu, C. H. & Zhong, C. T. 1998. Palaeoproterozoic SW–NE collision model for the central North China Craton. *Progress in Precambrian Research* **21**, 28–50 (in Chinese).

Zhai, M. G., Guo, J. H. & Yan, Y. H. 1992. Discovery and preliminary study of Archaean high-pressure granulites in the North China. *Science in China* **12**, 1325–30.

Zhai, M. G., Guo, J. H. Li, Y. G. & Yan, Y. H. 1995. Discovery of Archaean retrograded eclogites in the North China Craton and their tectonic implications. *Science in China* **40**, 1590–4.

Zhao, G. C., Wilde, S. A., Cawood, P. A. & Lu, L. Z. 1998. Thermal evolution of Archaean basement rocks from the eastern part of the North China Craton and its bearing on tectonic setting. *International Geology Review* **40**, 706–21.

Zhao, G. C., Wilde, S. A., Cawood, P. A. & Lu, L. Z. 1999. Tectonothermal history of the basement rocks in the western zone of the North China Craton and its tectonic implications. *Tectonophysics* **310**, 223–40.

Zhao, G. C., Cawood, P. A., Wilde, S. A., Sun, M. & Lu, L. Z. 2000. Metamorphism of basement rocks in the Central Zone of the North China Craton: implications for the Paleoproterozoic crutal evolution. *Precambrian Research* **103**, 55–88.