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Kanfenggou UHP Metamorphic Fragment in Eastern Qinling Orogen and Its Relationship to Dabie-Sulu UHP and HP Metamorphic Belts, Central China*

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ABSTRACT: In the Central Orogenic Belt, China, two UHP metamorphic belts are discriminated mainly based on a detailed structural analysis of the Kanfenggou UHP metamorphic fragment exposed in the eastern Qinling orogen, and together with previous regional structural, petrological and geochronological data at the scale of the orogenic domain. The first one corresponds to the South Altun-North Qaidam-North Qinling UHP metamorphic belt. The other is the Dabie-Sulu UHP and HP metamorphic belts. The two UHP metamorphic belts are separated by a series of tectonic slices composed by the Qinling rock group, Danfeng rock group and Liuling or Foziling rock group etc. respectively, and are different in age of the peak UHP metamorphism and geodynamic implications for continental deep subduction and collision. Regional field and petrological relationships suggest that the Kanfenggou UHP metamorphic fragment that contains a large volume of the coesite- and microdiamond-bearing eclogite lenses is compatible with the structures recognized in the South Altun and North Qaidam UHP metamorphic fragments exposed in the western part of China, thereby forming a large UHP metamorphic belt up to 1 000 km long along the orogen strike. This UHP metamorphic belt represents an intercontinental deep subduction and collision belt between the Yangtze and Sino-Korean cratons, occurred during the Paleozoic. On the other hand, the well-constrained Dabie-Sulu UHP and HP metamorphic belts occurred mainly during Triassic time (250—220 Ma), and were produced by the intracontinental deep subduction and collision within the Yangtze craton. The Kanfenggou UHP metamorphic fragment does not appear to link with the Dabie-Sulu UHP and HP metamorphic belts along the orogen. There is no reason to assume the two UHP metamorphic belts as a single giant deep subduction and collision zone in the Central Orogenic Belt situated between the Yangtze and Sino-Korean cratons. Therefore, any dynamic model for the orogen must account for the development of UHP metamorphic rocks belonging to the separate two tectonic belts of different age and tectono-metamorphic history.

KEY WORDS: Kanfenggou, ultrahigh pressure metamorphism, intracontinental collision, intercontinental collision, Central Orogenic Belt, eclogite.

INTRODUCTION

Since coesite-bearing eclogite was discovered in the metamorphic rocks exposed in the Kanfenggou area, near Guanpo, Lushi, Henan Province (Hu et al., 1994), it has attracted a great deal of domestic and international geologist attention. The Kanfenggou fragment, originally called "Ludao-Xiaohemian tectonic block" by Zhang et al. (2001), contains large numbers of eclogite lenses. Recently, microdiamonds occurring as fine-grained inclusions in zircons from both eclogite and its schistic country rocks exposed in the fragment were discovered by Yang et al.

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(2002), again indicating that both the eclogite and associated country rocks experienced ultrahigh pressure (UHP) metamorphism (>(27—40)×10^8 Pa). However, most previous studies have focused on the occurrence of UHP index minerals and the geochronology, no detailed structural analysis of UHP metamorphic rocks has been undertaken to examine the regional tectonic setting for the development of the UHP rocks and their relationship to the Dabie-Sulu UHP and high pressure (HP) metamorphic belts. Knowledge of the tectonic position and structural evolution of the Kanfenggou UHP fragment is generally poorly constrained. Therefore, controversy exists concerning the tectonic history and dynamic significance of metamorphosed, coesite- and microdiamond-bearing continental crust rocks exposed in the northern Qinling orogen (Suo et al., 2002; Yang et al., 2002). The aim of this paper is to describe the petrography, structures and tectonic boundaries of the Kanfenggou UHP metamorphic fragment, and to decipher the relationship between the Kanfenggou UHP metamorphic fragment and the Dabie-Sulu UHP and HP metamorphic belts. It is emphasized that there are, at least, two UHP metamorphic belts of different ages within the Central Orogenic Belt, China. The implications of both UHP metamorphic belts for the dynamic tectonic evolution of the Central Orogenic Belt are briefly discussed.

GEOLOGICAL OVERVIEW

The Central Orogenic Belt between the Yangtze and Sino-Korean cratons has received extensive tectonic investigation in recent years (e. g., Yang et al., 2002; Zhang et al., 2001; Kröner et al., 1993). According to Zhang et al. (2001), the Qinling Orogen, a central segment of the Central Orogenic Belt, from north to south, can be divided into the northern and southern Qinling orogenic belts bounded by the

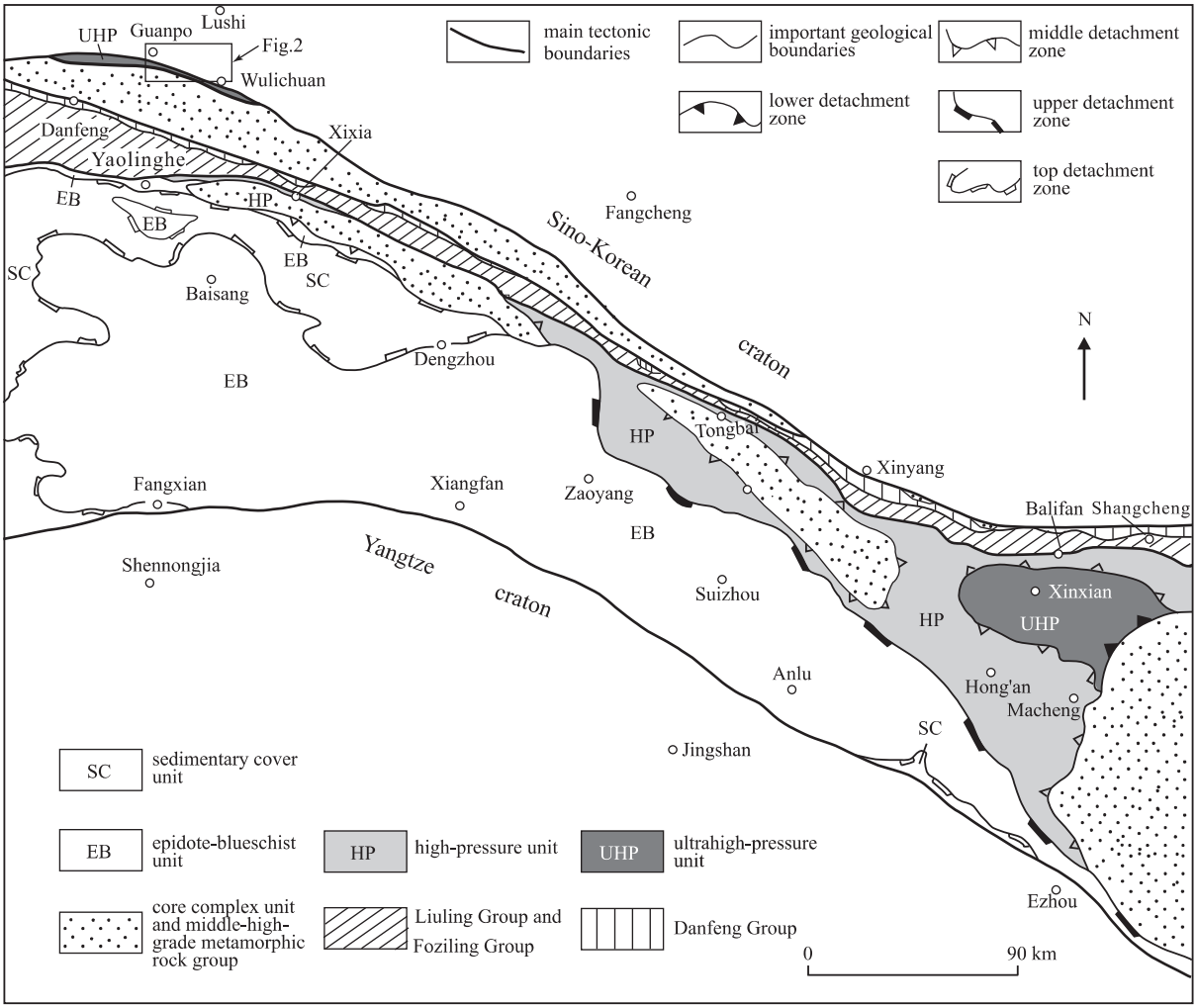

Figure 1. Geological framework of the eastern Qinling-Tongbai-western Dabie Mountains. The rectangle indicates the studied area.

Shangdan fault system, and along the orogen, from west to east, it was generally subdivided into the western Qinling orogenic belt and the eastern Qinling orogenic belt (You et al., 1991). The Kanfenggou UHP metamorphic fragment is situated in the northern Qinling orogenic belt, near Guanpo and Wulichuan (Fig. 1 and Fig. 5.3 of Zhang et al., 2001), belonging to the eastern Qinling orogenic belt. It forms a nearly E-W elongated crust slice c. 30 km long and up to 2—5 km wide, which is a possible eastward extension of the South Altun-North Qaidam UHP metamorphic belt recognized in the western part of China (Zhang et al., 2002). Field and petrological relationships indicate that structurally, the Kanfenggou UHP metamorphic fragment lies between the Erlangping rock group of Paleozoic age to the north and the Qinling rock group of Proterozoic age to the south (Fig. 2). Detailed description of the geological setting of the study region can be found in You et al. (1991), Meng and Zhang (2000, 1999), Zhang et al. (2001) and Yang et al. (2002).

KANFENGGOU UHP METAMORPHIC FRAGMENT

As noted above, the Kanfenggou UHP metamorphic fragment is part of the northern Qinling orogenic belt which is mainly composed of a series of fault or ductile shear zone-bounded lithotectonic belts with different structural and metamorphic characteristics. At the map scale, all lithotectonic belts have a sheet-like geometry (Figs. 2, 3). The Shuanghuaishu fault or ductile shear system that is a southward thrusting zone separates the Erlangping rock group with low-grade metamorphic rocks of Paleozoic age in the hanging wall from the Kanfenggou UHP metamorphic fragment in the footwall (Fig. 3). The latter is bordered by the Shanggou ductile shear or mylonite zone up to 500 m thick on the south. The Qinling rock group, south of the Shanggou shear zone, consists mainly of middle-high-grade metamorphic complex including gneiss, amphibolite and marble of Paleoproterozoic age. So far, no typical rock with UHP metamorphic mineral assemblages or remnants has been found in the Qinling complex.

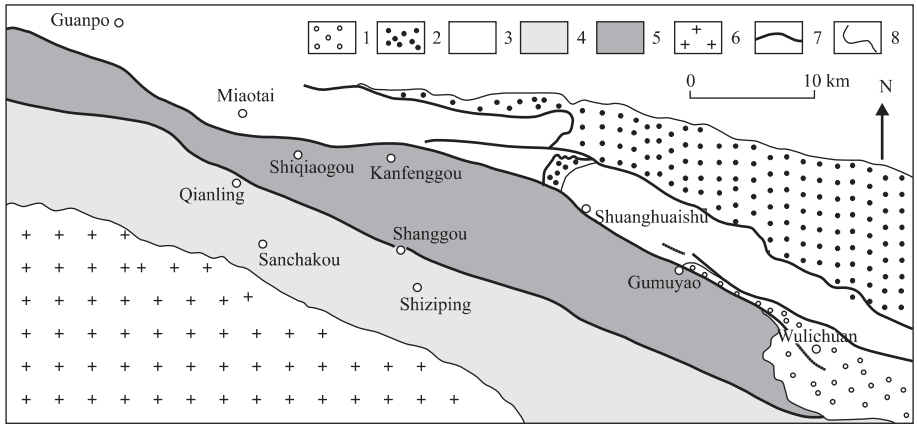

Figure 2. Geological sketch of the Kanfenggou UHP metamorphic fragment and its neighboring area (location in Fig. 1). 1. Late Cretaceous; 2. Late Triassic; 3. Erlangping rock group; 4. Qinling rock group; 5. Kanfenggou UHP fragment; 6. Huichizi intrusive body; 7. main tectonic boundaries; 8. important geological boundaries.

The Kanfenggou fragment is mainly composed of metasupracrustal rocks including garnet-bearing phengite-albite-quartz schist, two-mica albite-quartz schist, amphibolite, biotite quartzite and marble, containing a large volume of eclogite or retrograded eclogite lenses. Some detailed petrological work has been carried out by Hu et al. (1996, 1995). They also presented a geological sketch map for the distribution of HP and UHP eclogite locations but did not recognize the full complexity of the structure in the Kanfenggou fragment.

The eclogitic rocks are typically found as meter-scale lenses or pods enveloped by strongly deformed, amphibolite facies quartzofeldspathic schist, and are well exposed at Kanfenggou, Shiqiaogou and Qianling, near Guanpo, Lushi County, Henan Province (Figs. 2, 3). The fresh eclogites with little retrograde alteration are very difficult to be observed in the field, mostly because UHP eclogite facies mineral associations have been largely modified by amphibo-

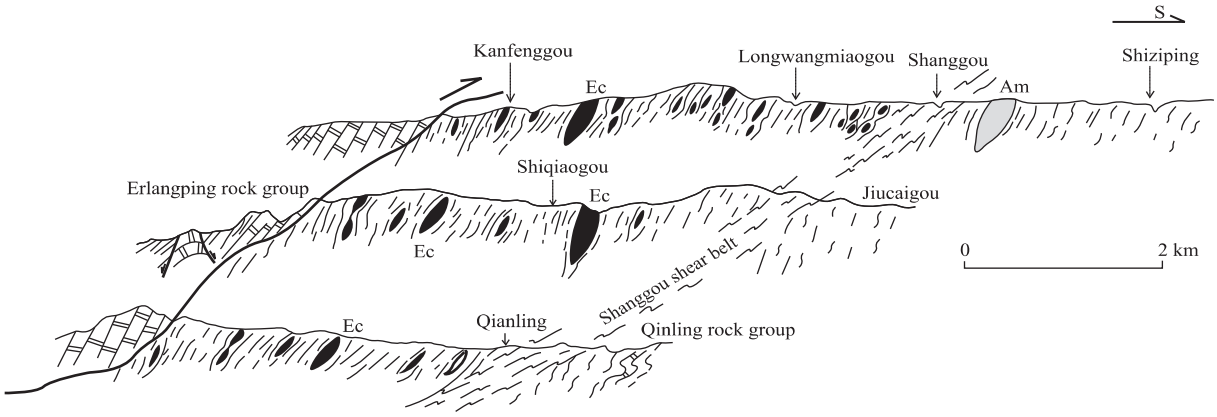

Figure 3. Three exposed cross-sections through the Kanfenggou UHP metamorphic fragment. Ec. eclogite or retrograded eclogite; Am. amphibolite.

lite facies metamorphism. In general, the typical mineral assemblages for the eclogites, situated in the core of the large eclogite or retrograded eclogite lenses, are omphacite+garnet+rutile+amphibole+epidote+phengite+sphene+albite+quartz±coesite or quartz pseudomorphs after coesite (Fig. 4a). They have commonly a dark-colored, massive appearance with a fine-grained and granoblastic texture of straight grain boundaries. Various kinds of symplactites surrounding their host minerals indicating retrograde metamorphism, and fine-grained garnet coronas occurring along boundaries between plagioclase and other phases, reflecting prograde metamorphism were also developed (Zhang and Liou, 1997). Coesite or quartz pseudomorphs after coesite-bearing eclogites have been described from the Kanfenggou fragment (Hu et al., 1996, 1995, 1994). Recently, micro-grains of diamonds occurring as fine-grained inclusions in zircons from the rocks were discovered, for the first time, by Yang et al. (2002), indicating that both eclogites and associated schistic country rocks experienced UHP metamorphism. Field and petrological evidence also suggests that there is a continuous gradation relationship between eclogites or retrograded eclogites and their country rock schists at the outcrop scale, so that this fragment is possibly considered as a UHP metamorphic crust slice as a whole. According to Yang et al. (2002), a (507±38) Ma age can be ascertained for the peak UHP metamorphism of the Kanfenggou fragment. It is thus compatible with the UHP rocks recognized in the South Altun and North Qaidam Mountains (for a review and a discussion of age data, see Yang et al., 2002). This provides further support to the idea that a giant UHP metamorphic belt, the South Altun-North Qaidam-North Qinling UHP metamorphic belt was mainly developed during the Paleozoic (507—400 Ma) in the Central Orogenic Belt. The question of the protoliths of the rocks within the Kanfenggou UHP metamorphic fragment is beyond the scope of the study.

Because of the intensity of retrogressive metamorphism, the pre-existing UHP structures and fabrics were mostly obscured by the post-eclogite deformation and amphibolite facies metamorphism, so that it is difficult to be recognized at the outcrop scale. The present-day observable structures were dominantly produced by heterogeneous shearing under amphibolite facies conditions. Relicts of the UHP metamorphic structures are only observed in some of fresh eclogites from the large eclogite lenses at thin-section scale. The fabric is characterized by a weaker foliation defined by omphacite and phengite shape-preferred orientation. At local and regional scales, as shown in Fig. 3, both the eclogite or retrograded eclogite and the country rock schist exhibit a penetrative continuous foliation dipping 60°—80° to the NEN with a mineral lineation plunging c. 45°—55° to the ENE. Both the foliation and the lineation are defined by amphibole, albite porphyroblast and mica shape-preferred orientation. Furthermore, the amphibolite facies foliation is typically characterized by an anastomosing rheological pattern at different scales, indicating mechanical instabilities and deformation partitioning in a bulk shear environment (Suo et al., 2002; Burg, 1999). It appears that the distributions of eclogite or retrograded eclogite lenses representing lens-shaped domains of low strain are mainly controlled by the efficient strain-regime that has affected these rocks. In addition, some of the amphibolite fa-

cies rocks often show all stages of transformation into mylonites (Fig. 4b), which crosscut the early foliation, and are limited to discrete ductile shear bands around lens-shaped unsheared eclogites. The Kanfenggou UHP metamorphic fragment thus was dismembered into a great number of shear zone-bounded slices, forming a structural pile or stack.

The bounding fault and ductile shear zone or mylonite systems (Fig. 4c) trancate all pre-existing structures or fabrics developed in the Kanfenggou UHP metamorphic fragment (Fig. 3).

POSSIBLE WESTWARD EXTENSION OF DABIE-SULU UHP AND HP METAMORPHIC BELTS

During the past twenty years, there are a wealth of publications about the petrology, geochronology, metamorphic *p-t* paths and tectonic evolution models for the formation and exhumation of the Dabie-Sulu UHP and HP metamorphic rocks (e. g., Suo et al., 2002, 2001; Cheng et al., 2000; Schmid et al., 2000; Hacker et al., 1998; Carswell et al., 1997; Liou et al., 1997; Ames et al., 1996; Eide et al., 1994; Li et al., 1993; Wang and Liou, 1991). However, one problem in working out the tectonic framework and history of these UHP and HP metamorphic rocks is their possible westward extension to the Tongbai Mountains and the eastern Qinling Mountains. A great amount of eclogites or retrograded eclogites widely distributed in the Tongbai Mountains and the regional structural pattern of the metamorphic belt have clearly demonstrated that it is an important part of the Dabie-Sulu UHP and HP metamorphic belts (Suo et al., 2001; Wei et al., 1999). We recently observed the Xiangfanggou fragment that occurs west of the Nanxiang basin. It forms a roughly E-W-trending slice c. 25 km long and 500 m mide. Along the Xixia-Xichuan border region, the outcrops are well exposed (Fig. 1). The fragment consists mainly impure tremolite-bearing marbles and rutile-bearing epidote amphibolites (Fig. 4d). The amphibolite mineral assemblages are amphibole+albite+rutile+titanite/ilmehite+biotite+epidote+chlorite+calcite+quartz±garnet. Some of remnants of retrograde HP metamorphic fabrics are locally preserved in the amphibolites. For example, high-pressure rutile, as original phase or the Ti-bearing phase, is rimmed or partly replaced by titanite. At the same time, some rutiles typically occur as inclusions within ilmenite/titanite, amphibole and epidote in the rocks, indicating that the Xiangfanggou fragment may have undergone HP eclogite facies conditions prior to the epidote-amphibolite facies overprinting. However, extensive recrystallization at epidote-amphibolite facies conditions must have erased most evidence of HP eclogitic assemblages. On the other hand, these facts provide, probably, further evidence for the westward decrease in metamorphic grade from Shandong and Jiangsu provinces to the Dabie-Tongbai-Qinling Mountains (Wang and Liou, 1991).

The Xiangfanggou fragment also has a sheet-like geometry, in which the E-W trending foliation dips to the north between 40° and 50° (Fig. 5). On the foliation plane, a nearly NE-SW-trending stretching lineation can be observed. Structurally, thus it may have been connected to the Tongbai HP metamorphic belt (Suo et al., 2001), indicating that the Dabie-Sulu UHP and HP metamorphic belts cross the Nanxiang basin and extend into the eastern Qinling Mountains. Detailed structural and petrological analysis of the Xiangfanggou HP fragment will be presented elsewhere. It is necessary for us to indicate here that structures and rock assemblages of the Xiangfanggou fragment are similar to those of the Samgot unit situated in the Imjingang belt of the Korean peninsula, the eastern end of the Dabie-Sulu UHP and HP metamorphic belts (Ree et al., 1996).

TECTONIC INTERPRETATION AND CONCLUSIONS

According to Yang et al. (2002), 507 Ma, 500 Ma and 495 Ma ages can be ascertained for the peak metamorphism in the Kanfenggou UHP fragment, South Altun UHP fragment and North Qaidam UHP fragment, respectively. The ages of the peak metamorphism in the Dabie-Sulu UHP and HP metamorphic belts have been basically determined to be 250 to 220 Ma by a variety of chronological methods in different laboratories (Suo et al., 2003; Hacker et al., 1998; Ames et al., 1996; Chavagnac and Jahn, 1996; Eide et al., 1994; Li et al., 1993). On the other hand, the South Altun-North Qaidam-North Qinling UHP metamorphic belt occurs north of the Shangdan fault system, while the Dabie-Sulu UHP and HP metamorphic belts crop out south of the Shangdan fault system. The Qinling rock group, the Danfeng rock group and the Liuling Group or Foziling Group low-grade metamorphic rocks lie between these two UHP belts (Fig. 1), which reflect different tectonic settings in the regional tectonic framework in

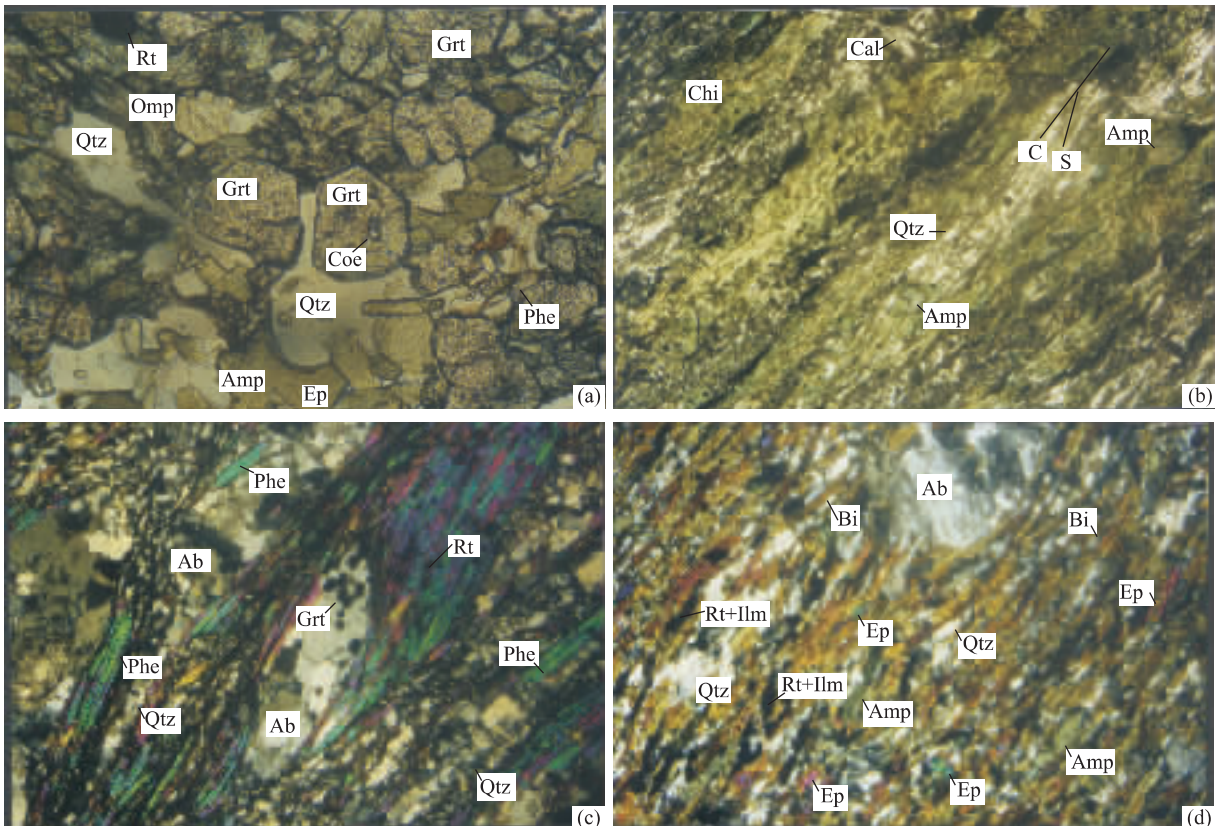

Figure 4. (a) Retrograded coesite-bearing massive eclogite of granoblastic texture with straight grain boundaries (sample K-r-1) from Kanfenggou. Plane light, width of view≈1.3 mm; (b) S-C mylonite of the retrograded eclogite (sample Sh-r-1) from Shiqiaogou. Plane light, width of view≈5 mm; (c) Strongly mylonitized garnet-bearing phengite-albite-quartz schist (sample D-r-3_2) from the Shanggou shear zone. Crossed polars, width of view≈5 mm; (d) Deformed rutile-bearing epidote amphibolite (sample Q-r-7_1) from the Xiangfanggou fragment. Crossed polars, width of view≈5 mm. Grt. garnet; Omp. omphacite; Rt. rutile; Ab. albite; Phe. phengite; Qtz. quartz; Coe. coesite; Ep. epidote; Am. amphibole; Cal. calcite; Chi. chilorite; Ilm. ilmenite.

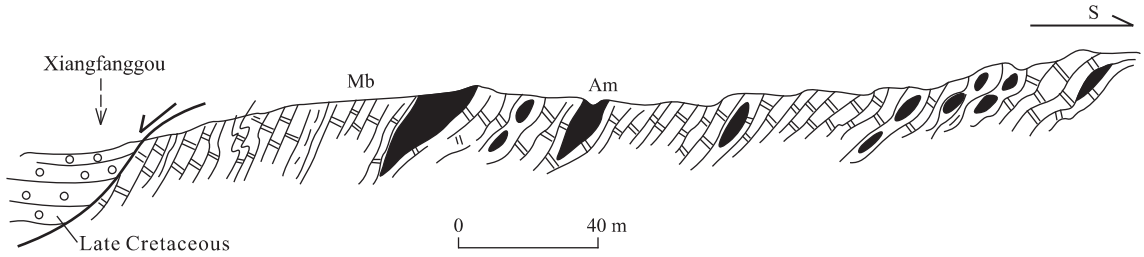

Figure 5. Schematic cross-section showing marble interlayered with rutile-bearing amphibolite at the Xiangfanggou locality, Xixia, Henan Province. Am. rutile-bearing amphibolite; Mb. tremolite-bearing marble.

the Central Orogenic Belt. The eastern end of the Kanfenggou UHP metamorphic fragment does not appear to link with the Dabie-Sulu UHP and HP metamorphic belts along strike although the possible eastward extension to the region is buried beneath Late Cretaceous sediments (Fig. 2). Conversely, the features previously recognized as shown in Fig. 6 in the Dabie Mountains can be observed in the Tongbai Mountains (Suo et al., 2001) and the eastern Qinling Mountains. Consequently, the Kanfenggou UHP metamorphic fragment is not a bridge between the two UHP metamorphic belts. There is no reason to view the two UHP metamorphic belts as a single giant deep subduction and collision belt in the Central

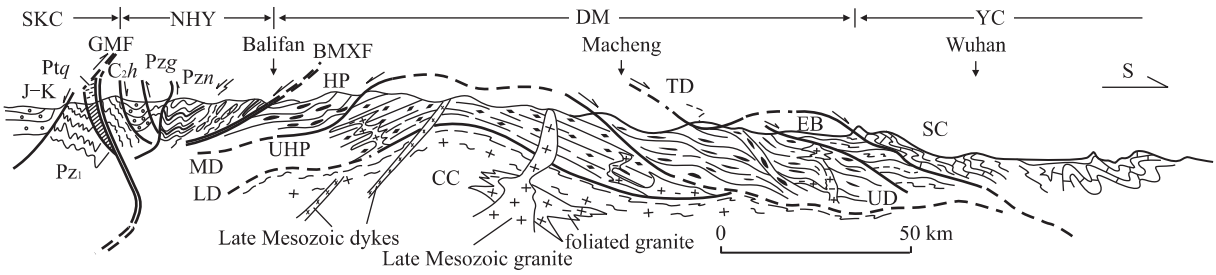

Figure 6. Synthetic S-N section across the entire Dabie Mountains, showing major lithotectonic divisions and main tectonic boundaries of the Dabie-Sulu UHP and HP metamorphic belts. SKC. Sino-Korean craton; NHY. Northern-Huaiyang tectonic belt; DM. Dabie massif; YC. Yangtze craton; CC. core complex unit; UHP. ultrahigh-pressure unit; HP. high-pressure unit; EB. epidote-blueschist unit; SC. sedimentary cover; LD. lower detachment zone; MD. middle detachment zone; UD. upper detachment zone. TD. top detachment zone; GMF. Guishan-Meishan fault; BMXF. Balifan-Mozitan-Xiaotian fault; Pt*q*. Qinling rock group; Pz_1. Lower Paleozoic; Pz*g*. Guishan Formation; Pz*n*. Nanwan Formation; C_2h. Huyoufang Formation; J-K. Jurassic-Cretaceous (modified from Suo et al. (2003)).

Orogenic Belt.

The two UHP metamorphic belts noted above are a first-order feature of the Central Orogenic Belt that had a long complex history. Regional structural and petrological relations at the scale of the orogenic domain, and also taking into account data described in the literature (e. g., Zhang et al., 2001; Meng and Zhang, 2000, 1999; Yin and Nie, 1993; Mattauer et al., 1985), suggest that in Paleozoic time, northward subduction of the Yangtze craton to depths of about 100 km or more beneath the Sino-Korean craton and collision of the two cratons took place to form UHP metamorphic assemblages, whereas in Triassic time, the Dabie-Sulu UHP and HP metamorphic belts may have been formed in a north-dipping subduction and collision belt which lies within the Yangtze craton. The former is considered as the intercontinental deep subduction and collision, while the latter as the intracontinetal subduction and collision. Additionally, the differences between both UHP metamorphic belts in regional structure, rock association and exhumation process are also apparent. Further study is necessary to verify the interpretation.

The following tentative conclusions can be drawn: (1) The Kanfenggou fragment is a UHP metamorphic crustal slice that is an important part of the South Altun-North Qaidam-North Qinling UHP metamorphic belt of Paleozoic age. However, it can not be connected with the Dabie-Sulu UHP and HP metamorphic belts. (2) The Dabie-Sulu UHP and HP metamorphic belts of Triassic age possibly cross the Nanxiang basin and extend into the eastern Qinling Mountains. (3) There are, at least, two UHP metamorphic belts of different ages of the peak metamorphism and tectonic setting in the Central Orogenic Belt, China. They represent the intercontinental and intracontinental deep subduction and collision or suture belts, respectively. The Kanfenggou UHP metamorphic fragment is not a bridge between both UHP metamorphic belts. Any dynamic model for the Central Orogenic Belt must account for the development of the two separate UHP metamorphic belts.

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