LIU Xiaochun, JAHN Bor-ming, CHENG Hao, LI Sanzhong and QU Wei, 2013. The Tongbai HP Metamorphic Terrane in Central China: Constraints on the Onset and Diachroneity of Continental Subduction. *Acta Geologica Sinica* (English Edition), 87(supp.): 496-498.

The Tongbai HP Metamorphic Terrane in Central China: Constraints on the Onset and Diachroneity of Continental Subduction

LIU Xiaochun[1*], JAHN Bor-ming[2], CHENG Hao[3], LI Sanzhong[4] and QU Wei[1]

1 Institute of Geomechanics, Chinese Academy of Geological Sciences, Beijing 100081, China
2 Department of Geosciences, National Taiwan University, Taipei 10699, Taiwan
3 State Key Laboratory of Marine Geoloy, Tongji University, Shanghai 200092, China
4 *College of Marine Geosciences, Ocean University of China, Qingdao 266100, China*

The Tongbai orogen is located in a key tectonic position linking the Qinling orogen to the west and the Dabie-Sulu orogen to the east. This orogen comprises a Paleozoic accretionary orogenic system in the north and a Permo-Triassic collisional orogenic system in the south; hence it may hold a key to understanding the geological relationships and tectonic evolution of different units in the Qinling-Tongbai-Dabie-Sulu orogenic belt. The Tongbai high-pressure (HP) metamorphic terrane consists of two HP slices (I and II) and a tectonic mélange zone in the north and a blueschist-greenschist zone in the south. We recently undertook petrological and geochronological studies on the two HP slices (Liu et al., 2008, 2010; Cheng et al., 2011; Cui et al., 2012). In conjunction with the available data, we ascertained the framework of the collisional orogenic system in the Tongbai orogen and advocated a diachronous subduction-exhumation model for interpreting the formation and uplifting of the HP/UHP rocks in the orogen.

The HP slice I is represented by the northern and southern eclogite zones occurring on the two sides of the Tongbaishan antiform. It comprises mylonitized granites, quartzofeldspathic gneisses, mica schists, quartzites and marbles with numerous eclogite and garnet amphibolite lenses. Using conventional geothermometers and geobarometers, the peak metamorphic conditions were estimated to be 530-610°C and 1.7-2.0 GPa for the northern zone and 460-560°C and 1.3-1.9 GPa for the southern zone (Liu et al., 2008). These are roughly in agreement with the *P-T* estimates of 490-540°C and 2.1 GPa using the THERMOCALC calculations (Cheng et al., 2011). Taking into account the similarity of rock associations and difference in metamorphic conditions between the two zones, we infer that they may belong to the different portion of the same HP slice. Two zircon U-Pb ages of 255 ± 6 Ma and 257 ± 16 Ma, two garnet-whole rock Lu-Hf isochron ages of 252.3 ± 3.4 Ma and 256.4 ± 2.6 Ma, and one mineral-whole rock Rb-Sr isochron ages of 253 ± 11 Ma were obtained in eclogites from the HP slice I (Liu et al., 2008; Cheng et al., 2011). Since inclusions of garnet, omphacite, amphibole, paragonite, epidote, quartz and rutile were discovered in metamorphic zircon domains, and omphacite occur as inclusions in garnet, the age of ~255 Ma was regarded as the timing of eclogite facies metamorphism. On the other hand, muscovite $^{40}Ar/^{39}Ar$ dating for 3 quartzofeldspathic gneisses and 1 quartzite yielded ages of 238 ± 2 Ma, 238 ± 2 Ma, 234 ± 2 Ma and 217 ± 1 Ma, respectively, whereas reflects the time of muscovite cooling through its closure temperature of ~350ºC.

The HP slice II is represented by the metamorphic enclaves in coarse-grained gneissic granites in the Tongbai Complex. The Tongbai Complex constitutes the core of the Tongbaishan antiform. The metamorphic enclaves, which make up ~20% of the complex, consist of fine-grained dioritic-trondhjemitic gneisses and subordinate amphibolites, paragneisses, calc-silicates and marbles with a few retrograded eclogite lenses. The conventional thermobarometries yielded *P-T* conditions of 660-700°C and 0.80-1.03 GPa for the retrograde amphibolite facie metamorphic stage, whereas the peak metamorphic conditions were inferred to be within the eclogites facies field at <700°C and >1.2 GPa (Liu et al., 2010). Zircon U-Pb geochronology for retrograded eclogites, garnet amphibolites and dioritic-trondhjemitic gneisses reveals a long-term magmatism from 933 to 742 Ma, and metamorphic ages ranging from 232 ± 6 Ma to 220 ± 3 Ma (Liu et al., 2010). The coarse-grained gneissic granites dominating the Tongbai Complex were dated at ~140 Ma. By contrast, $^{40}Ar/^{39}Ar$ thermochronology on hornblende, muscovite from diverse gneisses and amphibolites yielded two age groups at ~135-120 Ma and ~100-90 Ma (Webb

* Corresponding author. E-mail: liuxchqw@yahoo.com.cn

et al., 1999; Cui et al., 2012), implying that the Cretaceous extension of the Tongbai Complex may have involved two episodes of deformation (cooling) and exhumation.

The age of ~255 Ma obtained for the HP slice I marks the oldest date of HP metamorphism in the Tongbai-Dabie-Sulu HP/UHP metamorphic belt. This signifies that the onset of continental subduction and subsequent continent-continent collision were not later than Late Permian. The conclusion is supported by the following two facts. One is that the garnet-whole rock Lu-Hf and Sm-Nd isochron ages of the oceanic-type eclogites from Xiongdian and adjacent area are concentrated to 271-252 Ma (Cheng et al., 2009, 2010a, 2013), which are later than the zircon U-Pb ages of ~315 Ma obtained for the same eclogites (Sun et al., 2002; Cheng et al., 2009; Wu et al., 2009; Liu et al., 2011a). This suggests that these oceanic-type eclogites may have been reworked by continental subduction during the Late Permian. The second is that the muscovite $^{40}Ar/^{39}Ar$ ages obtained for the Nanwan flysch of the Tongbai orogen and the Foziling Group of the Dabie orogen are also clustered at 271-261 Ma (Niu et al., 1994; Faure et al., 2003; Ratschbacher et al., 2006). As generally accepted, these two Devonian flysch sequences represent the hangingwall accretionary complex of the subduction zone (Liu et al., 2013). Considering that the metamorphic ages of 340-310 Ma for the Guishan complex (Liu et al., 2011b) are comparable with those of the Xiongdian eclogites, the oceanic subduction prior to the final collision between the Sino-Korean and Yangtze cratons is inferred to have lasted for ~60 Ma (Fig. 1).

On the other hand, the cooling age (~238 Ma) of the HP slice I is older that the metamorphic age (232-220 Ma) of the HP slice II. This suggests that, when the HP slice II was subducted to deep levels and underwent HP metamorphism, the HP slice I overlain it might have been exhumed to mid- to upper-crustal levels. A muscovite $^{40}Ar/^{39}Ar$ age of 256 ± 1 Ma was obtained for the tectonic mélange zone north of the HP slice I (Huang et al., 2006), suggesting that this epidote-amphibolite facies basement complex of the Yangtze craton represents another medium P/T slice formerly taken its place at a shallow level. This testifies a diachronous (differential) subduction/exhumation model of different HP and UHP slices proposed for the western Dabie (Liu et al., 2004a,b), eastern Dabie (Liu et al., 2007) and Sulu terranes (Liu et al., 2009). Therefore, diachronous subduction and exhumation, or multi-slice or differential subduction and exhumation called respectively by Liu et al. (2007) and Liu et al. (2009), might be a major mechanism for the formation and uplifting of the HP/UHP rocks in the Tongbai-Dabie-Sulu orogen. Furthermore, the HP metamorphism of the Huwan and Hong'an eclogite belts in the western Dabie orogen, which correspond to the HP slice I of the Tongbai orogen, was dated at ~240 Ma (Cheng et al., 2010b; Liu et al., 2012), later than the latter by ~15 Ma. This implies that the HP slice is also

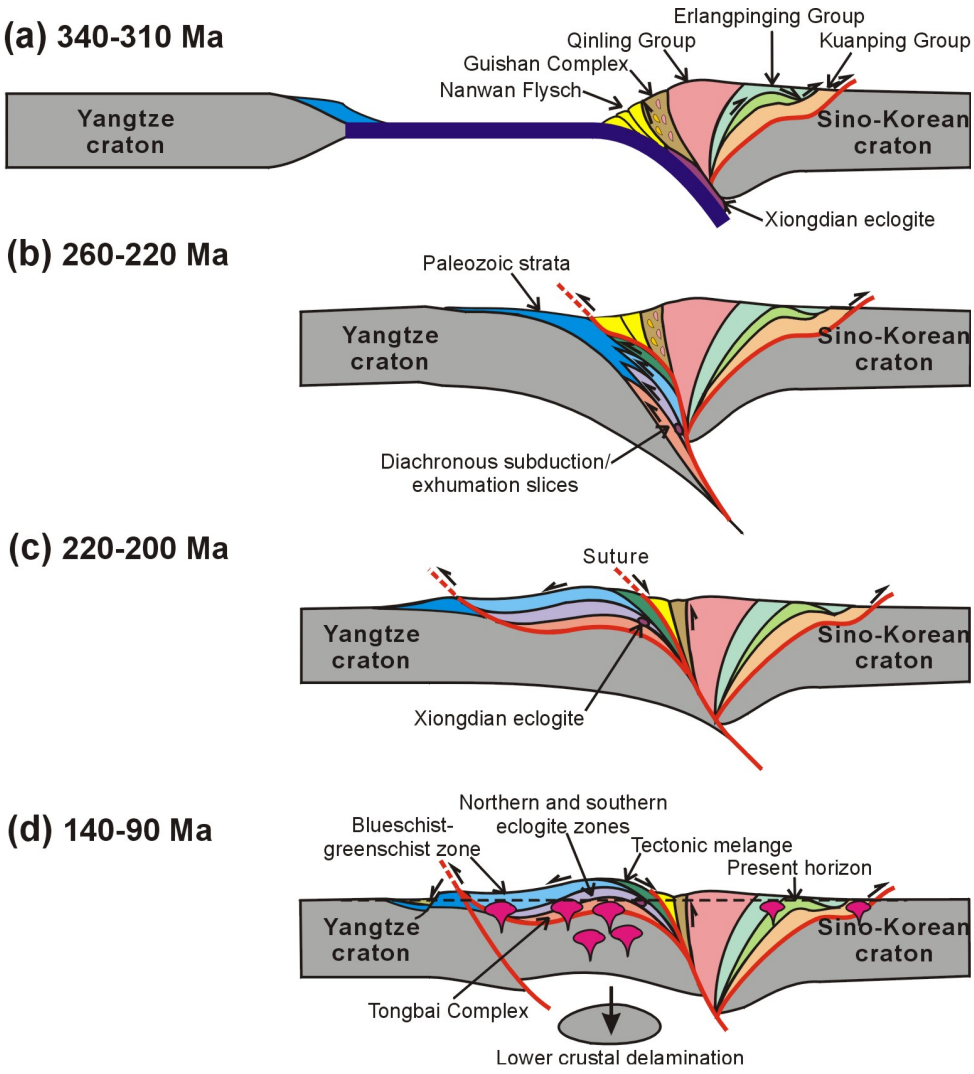

Fig. 1. Tectonic evolution of the Tongbai orogen from oceanic subduction/accretion to continental collision (after Liu et al., 2013)

diachronous along the orogen, mostly as a consequence of the oblique subduction of the Yangtze continental crust.

Acknowledgments

This research was supported by the Chinese '973' Project (2009CB825006) and the Geological Investigation Project of China Geological Survey (1212010711812).

Key words: HP/UHP, diachroneity, continental subduction, Tongbai

References

Cheng, H., King, R.L., Nakamura, E., Vervoort, J.D., Zheng, Y. F., Ota, T., Wu, Y.B., Kobayashi, K., Zhou, Z.Y., 2009. Transitional time of oceanic to continental subduction in the Dabie orogen: constraints from U-Pb, Lu-Hf, Sm-Nd and Ar-Ar multichronometric dating. *Lithos*, 110: 327-342.

Cheng, H., DuFrane, S.A., Vervoort, J.D., Nakamura, E., Zheng, Y.F., Zhou, Z.Y., 2010a. Protracted oceanic subduction prior to continental subduction: new Lu–Hf and Sm–Nd geochronology of oceanic-type high-pressure eclogite in the western Dabie orogen. *American Mineralogist*, 95: 1214-1223.

Cheng, H., DuFrane, S.A., Vervoort, J.D., Nakamura, E., Li, Q. L., Zhou, Z.Y., 2010b. The Triassic age for oceanic eclogites in the Dabie orogen: entrainment of oceanic fragments in the continental subduction. *Lithos*, 117: 82-98.

Cheng, H. Zhang, C., Vervoort, J.D., Wu, Y.B., Zheng, Y.F., Zheng, S., Zhou, Z.Y., 2011. New Lu-Hf geochronology constraints the onset of continental subduction in the Dabie orogen. *Lithos*, 121: 41-54.

Cheng, H., Zhang, Z., Vervoort, J.D., Zhou, Z.Y., 2013. New Lu-Hf and Sm-Nd geochronology constraints the subduction of oceanic crust during the Carboniferous-Permian in the Dabie orogen. *Journal of Asian Earth Sciences*, 63: 139-150.

Cui, J.J., Liu, X.C., Dong, S.W., Hu, J.M., 2012. U-Pb and $^{40}Ar/^{39}Ar$ geochronology of the Tongbai complex, central China: implications for Cretaceous exhumation and lateral extrusion of the Tongbai-Dabie HP/UHP terrane. *Journal of Asian Earth Sciences*, 47: 155-170.

Faure, M., Lin, W., Schärer, U., Shu, L., Sun, Y., Arnaud, N., 2003. Continental subduction and exhumation of the UHP rocks. Structural and geochronological insights from the Dabieshan (East China). *Lithos*, 70: 213-241.

Huang, S.Y., Xu, B., Wang, C.Q., Zhan, S., Deng, R.J., 2006. Geometry, Kinematics and evolution of the Tongbai orogenic belt. *Science in China (Series D)*, 49: 828-838.

Liu, X.C., Jahn, B.-M., Liu, D.Y., Dong, S.W., Li, S.Z., 2004a. SHRIMP U-Pb zircon dating of a metagabbro and eclogites from western Dabieshan (Hong'an block), China, and its tectonic implications. *Tectonophysics*, 394: 171-192.

Liu, X.C., Wei, C.J., Li, S.Z., Dong, S.W., Liu, J.M., 2004b. Thermobaric structure of a traverse across western Dabieshan: implications for collision tectonics between the Sino-Korean and Yangtze cratons. *Journal of Metamorphic Geology*, 22: 361-379.

Liu, Y.C., Li, S.G., Xu, S.T., 2007. Zircon SHRIMP U-Pb dating for gneisses in northern Dabie high T/P metamorphic zone, central China: implications for decoupling within subducted continental crust. *Lithos*, 96: 170-185.

Liu, X.C., Jahn, B.-M., Dong, S.W., Lou, Y.X., Cui, J.J., 2008. High-pressure metamorphic rocks from Tongbaishan, central China: U-Pb and $^{40}Ar/^{39}Ar$ age constraints on the provenance of protoliths and timing of metamorphism. *Lithos*, 105: 301-318.

Liu, F.L., Gerdes, A., Xue, H.M., 2009. Differential subduction and exhumation of crustal slices in the Sulu HP-UHP metamorphic terrane: insights from mineral inclusions, trace elements, U-Pb and Lu-Hf isotope analyses of zircon in orthogneiss. *Journal of Metamorphic Geology*, 27: 805-825.

Liu, X.C., Jahn, B.-M., Cui, J.J., Li, S.Z, Wu, Y.B., Li, X.H., 2010. Triassic retrograded eclogites and Cretaceous gneissic granites in the Tongbai Complex, central China: implications for the architecture of the HP/UHP Tongbai-Dabie-Sulu collision zone. *Lithos*, 119: 211-237.

Liu, X.C., Wu, Y.B., Gao, S., Wang, J., Peng, M., Gong, H.J., Liu, Y.S., Yuan, H.L., 2011a. Zircon U-Pb and Hf evidence for coupled subduction of oceanic and continental crust during the Carboniferous in the Huwan shear zone, western Dabie orogen, central China. *Journal of Metamorphic Geology*, 29: 233-249.

Liu, X.C., Jahn, B.-M., Hu, J., Li, S.Z., Liu, X., Song, B., 2011b. Metamorphic patterns and SHRIMP zircon ages of medium-to-high grade rocks from the Tongbai orogen, central China: implications for multiple accretion/collision processes prior to terminal continental collision. *Journal of Metamorphic Geology*, 29: 979-1002.

Liu, X.C., Wu, Y.B., Gao, S., Peng, M., Wang, J., Wang, H., Gong, H.J., Yuan, H.L., 2012. Triassic high-pressure metamorphism in the Huwan shear zone: Tracking the initial subduction of continental crust in the whole Dabie orogen. *Lithos*, 136-139: 60-72.

Liu, X.C., Jahn, B.-M., Li, S.Z., Liu, Y.S., 2013. U-Pb zircon age and geochemical constraints on tectonic evolution of the Paleozoic accretionary orogenic system in the Tongbai orogen, central China. *Tectonophysics*, doi.org/10.1016/j. tecto.2013.04.003.

Niu, B.G., Fu, Y.L., Liu, Z.G., Ren, J.S., Chen, W., 1994. Main tectonothermal events and $^{40}Ar/^{39}Ar$ dating of the Tongbai-Dabie Mts. *Acta Geoscientia Sinica*, 15: 20-34.

Ratschbacher, L., Franz, L., Enkelmann, E., Jonckheere, R., Pörschke, A., Hacker, B.R., Dong, S.W., Zhang, Y.Q., 2006. The Sino-Korean-Yangtze suture, the Huwan detachment, and the Paleozoic-Tertiary exhumation of (ultra)high-pressure rocks along the Tongbai-Xinxian-Dabie Mountains. In: Hacker, B.R., McClelland, W.C., Liou, J.G. (Eds.), Ultrahigh-pressure Metamorphism: Deep Continental Subduction. *Geological Society of America Special Paper*, 403: 45-75.

Sun, W.D., Williams, I.S., Li, S.G., 2002. Carboniferous and Triassic eclogites in the western Dabie Mountains, east-central China: evidence for protracted convergence of the North and South China Blocks. *Journal of Metamorphic Geology*, 20: 873-886.

Webb, L.E., Hacker, B.R., Ratschbacher, L., McWilliams, M.O., Dong, S.W., 1999. Thermochronologic constraints on deformation and cooling history of high- and ultrahigh-pressure rocks in the Qinling-Dabie orogen, eastern China. *Tectonics*, 18: 621-638.

Wu, Y.B., Hanchar, J.M., Gao, S., Sylvester, P.J., Tubrett, M., Qiu, H.N., Wijbrans, J.R., Brouwer, F.M., Yang, S.H., Yang, Q.J., Liu Y.S., Yuan, H.L., 2009. Age and nature of eclogites in the Huwan shear zone, and the multi-stage evolution of the Qinling-Dabie-Sulu orogen, central China. *Earth and Planetary Science Letters*, 277: 345-354.