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Notes

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COMMENT

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Yuan et al. (2003) published a deep seismic reflection profile of the Dabie Shan ultrahigh-pressure (UHP) orogen, acquired by the Chinese Geological Survey. The seismic profile provides new insight into the crust structures of the orogen and gives us a better understanding of this specific UHP collisional belt. We welcome the authors' interpretation that the Moho discontinuity at km 150 represents a relic subduction feature and that the Yangtze plate was subducted down to the north beneath the North China plate. They also interpreted a crustal-scale dome structure at the middle-upper crust level across the orogen (km 20–170) and related the doming to the Early Cretaceous extension tectonics. We question the interpretation of an orogen-scale dome. The observed surface geology does not support this interpretation. They interpreted a major top-to-the-south normal fault at km 20–40 (Yuan et al., 2003, their Fig. 2B), which is in conflict with the existing field data. Detailed structural studies by many workers have shown that the high-pressure (HP) belt and the UHP belt are dominated by north-verging structures with south-southeast-dipping foliation and northwest-southeast-stretching lineation, which developed at amphibolite facies metamorphic conditions, and that kinematic indicators suggest top-to-the-northwest sense of motion (e.g., Xu et al., 1996; Hacker et al., 1995, 2000; Faure et al., 1999). The top-to-the-south normal fault is not observed by surface geology work. The interpretation of an Early Cretaceous deformation of the structures is also problematic. The structures were clearly developed at amphibolite facies conditions (see references herein), and $^{40}\text{Ar}/^{39}\text{Ar}$ dating on the muscovite/phengite of various groups from the HP-UHP belts suggests that the white mica cooled down to closure temperature at 180–227 Ma (Hacker et al., 2000), implying that amphibolite facies metamorphism took place in the Late Triassic to Early Jurassic and hence the amphibolite facies deformation took place at the same time, not the Early Cretaceous.

We suggest an alternative interpretation of the seismic profile, which may better fit the surface geology data (Fig. 1). We suggest that

the south-dipping seismic reflections at 0–5 s two-way traveltime (TWTT) interval at km 20–50 (Yuan et al., 2003, their Fig. 2A) represent the blueschist-amphibolite-cold eclogite belt exposed at the surface. The south-dipping seismic reflection is underlain by moderately north-dipping multicycle and high-energy reflections at 5–8 s TWTT. These mid-crust reflections look similar in character to the gently north-dipping reflections under the UHP belt at mid-crust level (Yuan et al., 2003, their Fig. 2A). We interpret the multicycle and high-energy reflections to be stacked lower-crust rocks of the Yangtze plate, which are not exposed on the surface but are overlain by the HP-UHP sheets partially exposed on the surface. The south-dipping fault (Yuan et al., 2003, their Fig. 2B) is a top-to-the-north thrust that juxtaposes the HP and the UHP rocks against the stacked lower crust. Two phases of deformation are envisaged: (1) an early south-directed thrusting of the lower crust of the Yangtze plate and the HP-UHP sheets, which are probably related to the early stage of exhumation, seen as gently north-dipping reflections at mid-crust level (4–8 s TWTT) between km 30 and 100 (Yuan et al. 2003, their Fig. 2A); and (2) a later north-directed thrust of the HP-UHP belts over the stacked lower crust during amphibolite facies metamorphism (as observed by surface geology), which is probably related to the continued northward motion of the Yangtze plate in the Early Jurassic. It is this later phase of deformation that has produced the dominant structures and fabrics exposed at the surface today.

REFERENCES CITED

- Faure, M., Lin, W., Shu, L., Sun, Y., and Scharer, U., 1999, Tectonics of the Dabieshan (eastern China) and possible exhumation mechanism of ultrahigh pressure rocks: *Terra Nova*, v. 11, p. 251–258.
- Hacker, B.R., Ratschbacher, L., Webb, L., and Dong, S., 1995, What brought them up? Exhumation of the Dabieshan ultrahigh-pressure rocks: *Geology*, v. 23, p. 743–746.
- Hacker, B.R., Ratschbacher, L., Webb, L., McWilliams, M.O., Ireland, T., Calvert, A., Dong, S., Wenk, H.-R., and Chateigner, D., 2000, Exhumation of ultrahigh-pressure continental crust in east central China: Late Triassic–Early Jurassic tectonic unroofing: *Journal of Geophysical Research*, v. 105, p. 13,339–13,364.
- Xu, F., Rowley, D.B., and Baker, J., 1996, Refolded syn-ultrahigh-pressure thrust sheets in the southern Dabie complex, China: Field evidence and tectonic implications: *Geology*, v. 24, p. 455–458.

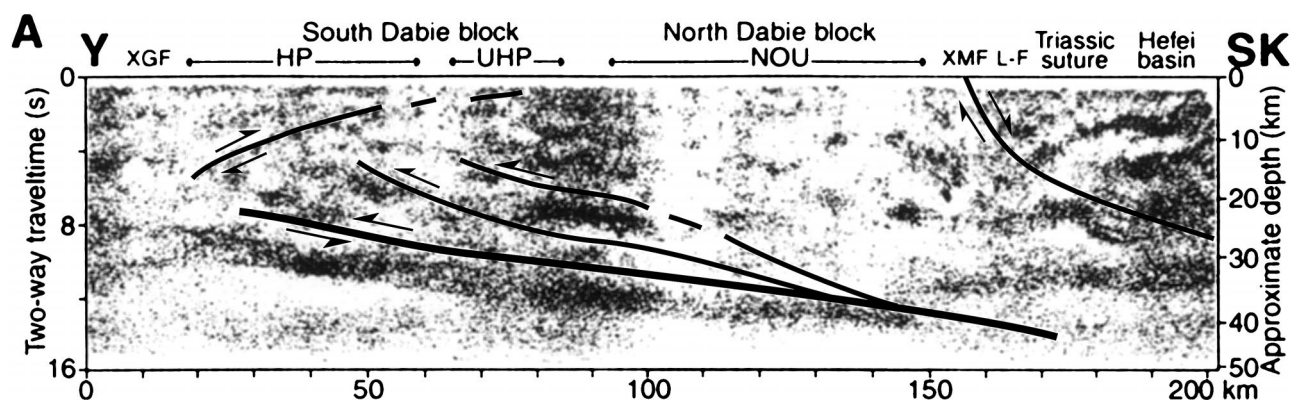


Figure 1. Reinterpreted Figure 2A of Yuan et al. (2003). XGF—Xiangfan-Guangji fault; HP—high-pressure zone; UHP—ultrahigh-pressure eclogite; NOU—Northern orthogneiss unit; XMF—Xiaotian-Mozitang fault; L-F—Luzhengan and Foziling Groups.

Yuan, X.-C., Klemperer, S.L., Teng, W.-B., Liu, L.-X., and Chetwin, E., 2003, Crustal structure and exhumation of the Dabie Shan ultrahigh-pressure orogen, eastern China, from seismic reflection profiling: *Geology*, v. 31, p. 435–438.

REPLY

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We welcome the reinterpretation of our seismic profile (Yuan et al., 2003) as a reminder that any interpretation is just that: an attempt to infer the origins of seismic reflections, based on their geometries and relationships to surface geology. But it is important to recognize the relative importance of different aspects of our interpretation.

We are glad that Zhao and Fang accept our most fundamental interpretation, that the Yangtze plate was subducted down to the north beneath the North China (Sino-Korean) plate, since these authors have previously argued (Zhang et al., 2002) for the opposite polarity (southward subduction of the North China plate) to create the Dabie Shan ultrahigh-pressure (UHP) belt. We are glad they accept our recognition of the Moho offset ("mantle suture") defining the subduction polarity that leads to our most important conclusion, that this archetypal UHP orogen is geometrically indistinguishable from non-UHP orogens, hence that many, if not all, collisional belts may contain cryptic UHP provinces.

Zhao and Fang take issue with a less-important aspect of our paper, our interpretation of south-dipping reflection fabrics in the southern Dabie Shan as representing a south-dipping normal fault or shear zone. In contrast, they interpret these and other reflections as a south-dipping, north-directed thrust fault. Zhao and Fang state that kinematic indicators in the high-pressure (HP) and UHP belt (km 20–80 in their Fig. 1) show top-to-northwest sense of motion (Hacker et al., 1995, 2000), and they infer this to represent northwest-directed thrusting, in contrast to Hacker et al. (2000) and Ratschbacher et al. (2000) who map these top-to-northwest structures as extensional faults rotated into their present geometry by later up-doming. Zhao and Fang then extrapolate the surface top-to-northwest structures to depth and interpret the origin of reflections as deep as 15 km as northwest-directed thrust

zones. This aspect of their interpretation may lack internal consistency, because Zhao and Fang show the northward-directed thrust as cutting off a series of south-directed thrusts and shears in the middle and lower crust. In their interpretation, the northward-directed thrust sheet must carry northward rocks that contain top-to-the-southeast indicators, so equally at odds with the exposed geology, unless this early phase has been entirely obliterated and overprinted by younger structures. Thus the Zhao and Fang interpretation shows structures of two different ages, lower-crustal Triassic south-directed thrusts that are overprinted in the upper crust by Early Jurassic north-directed thrusts.

Readers of our paper will recall that our interpretation (Yuan et al., 2003, Fig. 2B) similarly includes elements of different ages. It is important to note that we suggest the south-dipping reflections may represent a structure active during Cretaceous exhumation of the UHP belt, following Ratschbacher et al. (2000) in recognizing that a major part of the exhumation of the Dabie Shan took place in the Cretaceous (see also Xu et al., 2002). We also note that there is outcrop evidence of top-to-south normal shear zones along the boundary between the Northern orthogneiss unit (Yuan et al., 2003, Fig. 2) and the UHP belt (Hacker et al., 1995; Ratschbacher et al., 2000; Suo et al., 2000), though there is remaining disagreement on the magnitude and importance of these shear zones.

In our paper (Yuan et al., 2003) we took no position on whether the south-dipping reflective structures might have had an earlier contractional history. Thus the "alternative interpretation" of Zhao and Fang is not in conflict with our interpretation; it merely suggests a richer and more complex history for some of the shallow reflections along our profile.

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REFERENCES CITED

- Hacker, B.R., Ratschbacher, L., Webb, L., and Dong, S.-W., 1995, What brought them up? Exhumation of the Dabie Shan ultrahigh-pressure rocks: *Geology*, v. 23, p. 743–746.
- Hacker, B.R., Ratschbacher, L., Webb, L., McWilliams, M.O., Ireland, T., Calvert, A., Dong, S.-W., Wenk, H.-R., and Chateigner, D., 2000, Exhumation of ultrahigh-pressure continental crust in east-central China: Late Triassic–Early Jurassic unroofing: *Journal of Geophysical Research*, v. 105, p. 13,339–13,364.
- Ratschbacher, L., Hacker, B.R., Webb, L., McWilliams, M.O., Ireland, T., Dong, S.-W., Calvert, A., Chateigner, D., and Wenk, H.-R., 2000, Exhumation of ultrahigh-pressure continental crust in east-central China: Cretaceous and Cenozoic unroofing and the Tan-Lu fault: *Journal of Geophysical Research*, v. 105, p. 13,303–13,338.
- Suo, S., Zhong, Z., and You, Z., 2000, Extensional deformation of post ultrahigh-pressure metamorphism and exhumation process of ultrahigh-pressure metamorphic rocks in the Dabie massif, China: *Science in China (Scientia Sinica)*, ser. D, v. 43, p. 225–236.
- Xu, C., Zhou, Z., and Ma, C., 2002, Geochronological constraints on 140–85 Ma thermal doming extension in the Dabie orogen, central China: *Science in China (Scientia Sinica)*, ser. D, v. 45, p. 801–817.
- Yuan, X.-C., Klemperer, S.L., Teng, W.-B., Liu, L.-X., and Chetwin, E., 2003, Crustal structure and exhumation of the Dabie Shan ultrahigh-pressure orogen, eastern China, from seismic reflection profiling: *Geology*, v. 31, p. 435–438.
- Zhang, Z.-Y., Fang, A.-M., and Yu, L.-J., 2002, UHP ductile shear complex at Yangkou, Sulu UHP metamorphic belt, central China: Implication for continent subduction and exhumation: *Proceedings of International Workshop on Geophysics and Structure Geology of UHPM Terranes*, Institute of Geology and Geophysics and Chinese Academy of Sciences, Beijing, Sept. 20–21, 2002, p. 46–49.

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