Is the Dongwanzi Complex an Archean Ophiolite?

Kusky et al. (1) reported an ophiolite complex of late Archean age in the Dongwanzi area, North China craton. The recognition of Archean ophiolites is very significant because it suggests that Phanerozoic-style plate tectonic processes can be extrapolated far back to the Archean. To further examine and verify the Dongwanzi ophiolites, we and seven other Chinese and British geologists have made two field trips to the area since the report was published. Detailed field observations suggest that some of the descriptions and interpretations of Kusky et al. on the Dongwanzi ophiolites, although convincing, are not consistent with the practical geological occurrences. We find the so-called Archean Dongwanzi ophiolites questionable for three reasons:

(i) In the Kusky et al. report (1), the Dongwanzi ophiolite complex was considered to be composed of three NE-SW--trending parts, along which large amounts of pillow lavas and sheeted dikes were described to be present. However, these three parts of the complex actually form a composite body of lithologies ranging in age from late Archean to Proterozoic or Mesozoic (Fig. 1). On the 1:200,000 geological map, for example, the central part of the complex is regarded as a Mesozoic ultramafic intrusive into the Mesoproterozoic clastic rocks (the Changcheng-Jixian system), although its precise age needs further dating. They are separated by Mesoproterozoic, unmetamorphosed cover or juxtaposed by faults. In addition, we did not find any convincing pillow lavas and sheeted dikes, as described by Kusky et al. (1). Instead, we found only numerous highly sheared amphibolites and metagabbros in the southern part of the complex and banded felsic gneisses in the northern part.

(ii) Kusky et al. (1) described the mafic-ultramafic accumulates in the Dongwanzi ophiolite complex (Fig. 2) as harzburgites, wehrlites, lherzolites, websterites, and other peridotites, interlayered with olivine-proxene gabbros. Our field observations and thin-section examinations did not verify the existence of these rocks; we found only pyroxenites, hornblendites, and hornblende-pyroxene-gabbros. These rocks are characterized by high Fe and high rare earth element (REE) abundances and contain apatite-bearing V-Ti magnetites that are now being mined by the local populace. V-Ti magnetites are not commonly associated with oceanic mantle rocks, which are normally characterized by high Mg and contain chromites.

(iii) At Dongwanzi village, we found the exact locality of supplemental figure 3 of Kusky et al. (2). In this diagram, Kusky et al. showed gabbros intruded by six sheeted diabase dikes chilled predominantly on their northeast sides. These field observations and thin-section examinations, however, have revealed that the host rock in this location consists not of typical gabbros, as claimed by Kusky et al., but of plagioclase-bearing pyroxenite composed of clinopyroxene (75 to 80%) + magnetite (15 to 20%) + plagioclase (<5%), with a medium-grained plastic texture. Some pyroxenes in the rocks are replaced by porphyroblastic hornblends. Moreover, the mafic dikes are not diabase; they comprise clinopyroxenes, hornblends, magnetites, and minor plagioclases—compositionally similar to the host pyroxenites, except that pyroxenes in the dikes are largely replaced by hornblendes. These mafic dikes commonly have narrow margins that are composed only of hornblendes occurring along a preferred orientation; although they resemble chilled margins, whether they actually represent original chilled margins remains uncertain. Even if the dikes do have chilled margins, that characteristic alone does not indicate a sheeted dike complex, because these so-called chilled margins occur only along the two sides of dikes but never in the host pyroxenites.

The questions raised above lead us to conclude that the so-called Archean Dongwanzi ophiolite complex in the North China craton needs to be further examined before it can be used as a hallmark of Archean plate tectonics.

References and Notes
2. www.sciencemag.org/cgi/content/full/292/5519/1142/DC1
3. We thank B. F. Windley and W. Er-Qi for beneficial discussions.

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Response: Our study (1) was based on...
TECHNICAL COMMENTS

Technical Comments 1: 500,000-scale field observations and our maps were reconnaissance in nature. Zhai et al., by contrast, focus on specific outcrop-scale differences between our maps and alternative interpretations. The 1:200,000 maps referred to by Zhai et al. are unpublished and, because they were considered classified, were not previously available to us.

Since our initial report, we have spent several months in the field remapping the entire area. Our new, more detailed maps and laboratory analyses naturally require some modification of the initial reconnaissance maps and interpretations. Based on our new results, we now exclude the northwestern belt from the Dongwanzi ophiolite, recognize that the pillow lava section is thinner than previously estimated, and recognize that the pillow lavas are structurally detached from lower parts of the ophiolite. We have also determined that the central belt (CB) includes Mesozoic intrusive components (2). Despite these newly recognized complexities, the two senior authors of the original study maintain that there is sufficient evidence that the southeastern belt and perhaps parts of the central belt may contain remnants of an Archean ophiolite. In addition, we now have data that suggest that many of the structurally complex mafic and ultramafic bodies in the Zunhua structural belt, including parts of the northwestern belt, may have an ophiolitic origin.

Zhai et al. claim that the CB both represents a Mesozoic intrusion into the Mesoproterozoic Changcheng system and has been faulted against the Mesoproterozoic sedimentary sequence. We initially reported that the CB was cut by Mesozoic diorite [supplemental figure 1 in (1)], and now recognize that at least some of the gabbro and pyroxenite is Mesozoic as well (2). However, parts of the central belt are probably Archean: unlike the Changcheng system, these rocks have been strongly metamorphosed (amphibolite grade), and it is difficult for a younger intrusive to be more strongly deformed and metamorphosed than the rocks into which it supposedly intrudes. Additionally, there is no contact metamorphism of the overlying Changcheng system—only a faulted contact at the base of the Changcheng. Finally, the northeastern end of the CB is intruded by Archean TTG gneiss that contains many mafic and ultramafic inclusions from the CB.

The CB is indeed complex, however. The possibly older rock units in the CB, which may be part of a dismembered and metamorphosed Archean ophiolite suite, include serpentinitized harzburgite with disseminated chromite, pyroxenite, cumulate ultramafics, olivine-gabbro, hornblende-gabbro, leucogabbro, mafic dikes, sheeted dikes, and rodingite. The cpx-pyroxenite is strongly sheared and dynamically recrystallized. Malachite, pyrite, and epidote are identified within fractures of the metagabbro of CB, possibly associated with oceanic fluid circulation, which is also identified within pillow lava near Shangyin. The CB is cut by at least four deformed dike swarms—three mafic dike swarms (including pyroxenite dikes, sheared gabbroic dikes, and diabase dikes), followed by one plagioclase-granite swarm dated at ~300 Ma (2). Mesozoic diorite and gabbro (2) also cuts the CB, and one undeformed mafic dike swarm also intrudes the Mesoproterozoic sequence.

Because Zhai et al. could not find pillow lavas or sheeted dikes, they conclude that these features do not exist at Dongwanzi. We have mapped pillow lavas from several locations in and around Dongwanzi, as illustrated here (Fig. 1, A to C) and in our original study. Whereas Zhai et al. report that some of the rocks that we labeled as gabbro are actually pyroxenites, the unit they sampled is one we mapped as “pyroxenite/olivine-pyroxene-gabbro” [supplemental figure 1 in (1)]. The petrographic observations depend on which parts of the layered gabbro/pyroxenite are sampled, however, and the unit cannot be fully described by sampling roadside outcrops alone. We described significant mineralogical variations in this unit, and whether the particular sample is cpx-gabbro or plag-pyroxenite depends on small variations in plagioclase content and on whether one samples the dark or the light layers [supplemental figure 2A in (1)]. Zhai et al. suggest that the rocks contain magnetite but not chromite; again, this depends on where and how comprehensively the rocks are sampled. We recognize both mag-

Fig. 1. (A to C) Pillow lavas from Dongwanzi ophiolite and Zunhua structural belt that (A) are easy to recognize, (B) show budding, and (C) are difficult to recognize. (D) Nodular and orbicular chromite; scale bar is 1 cm. (E) Field samples showing nodular and orbicular chromite in serpentinitized dunite matrix. (F) Photomicrograph showing chromite nodule (0.9 mm across) in serpentinitized dunite matrix. (G) Photomicrograph of a harzburgite from southwest of Shangyin that shows orthopyroxene (OPX), chromite (CMT), and olivine (OL) crystals (field of view is 3.2 mm horizontally). (H) Flat REE plots of pillow lavas and metabasites from Dongwanzi ophiolite and nearby belts.
Tectonic Comments

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References
2. R. D. Tucker, personal communication.

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