Yujian Wang, Dicheng Zhu, Chengfa Lin, Fangyang Hu, and Jingao Liu, 2021, Quantifying the growth of continental crust through crustal thickness and zircon Hf-O isotopic signatures: A case study from the southern Central Asian Orogenic Belt: GSA Bulletin, https://doi.org/10.1130/B36046.1.

Supplemental Material

Text:

Data sources
Lithology and geochemical characteristics
Calculation parameterization of the net volume of juvenile continental crust

Figure S1 Representative geochemical classification diagrams of the Dananhu-Kanggurtag (orange) and the Aqishan-Yamansu plutons (tiffany blue). The symbols are legends for lithology.

Figure S2 Representative geochemical classification diagrams of the Central Tianshan plutons.

Figure S3 Plots of selected major oxides versus MgO contents and trace element ratios versus SiO_2 contents of the Dananhu-Kanggurtag intrusive rocks. In the plot of FeO^T versus MgO, solid lines depict the olivine composition with Fo contents and the equilibrium melt assuming $K_D^{Fe/Mg}$ ~0.3 (Roeder and Emslie, 1970). In the plots of Al_2O_3 and MnO versus MgO, gray fields, gray dash-dot lines show the composition of olivine and clinopyroxene from the mafic-ultramafic complexes and their average compositions are shown as star symbols. Sample symbols are referred to Figure S1.

Figure S4 Plots of selected major oxides versus MgO contents and trace element ratios versus SiO_2 contents of the Central Tianshan intrusive rocks. Sample symbols are referred to Figure S2.

Figure S5 Binary plots of Zr/Y vs Th/Yb and SiO_2 (wt%) vs K_2O (wt%) for the volcanic lavas from the Dananhu-Kanggurtag belt and Aqishan-Yamansu belt.

Figure S6 Ternary plots of Zr/117-Th-Nb/16 and Ti/100-Zr-Sr/2 for the basaltic lavas from the Dananhu-Kanggurtag belt and Aqishan-Yamansu belt.

Figure S7 N-MORB normalized trace element patters of the Wutongwozi and Gundun basalts from the Dananhu-Kanggurtag belt.

Figure S8 Variable plot of Nb/Yb versus Ba/Nb for the volcanic basalts the Dananhu-Kanggurtag belt and Aqishan-Yamansu belt.

Table S1. Summary of the calibrated crustal thickness using the method by Profeta et al. (2015).

Table S2. Summary of calibrated crustal thickness using method by Mantle and Collins (2008).

DATA SOURCES

The emphasis of this study focuses on investigating the tectonic circumstances and geodynamics of the Eastern Tianshan terrane, determining the mantle-crustal evolution, and then discussing their constraints on the net volume and the growth rate of juvenile continental crust in the Central Asian Orogenic Belt (CAOB). We compiled a published data set, including the whole-rock geochemical, U-Pb ages, and zircon Hf-O isotopic composition of the Late Paleozoic magmatic rocks in the Eastern Tianshan terranes from Li et al. (2002, 2006a), Zhou et al. (2004), He et al. (2005), Li et al. (2006a, 2007), Hou et al. (2006), Li et al. (2006c), Qing (2006), Sun et al. (2006), Sun et al. (2006), Wu et al. (2006, 2008), Xiao et al. (2006), Zhang et al. (2006a, b), Tang et al. (2007, 2008), Chai et al. (2008), Guo et al. (2008), Liu et al. (2008), Xia et al. (2008), Pan (2009), Su et al. (2009), Sun (2009), Wang et al. (2009), Han et al. (2010), Kahaer (2010), Dong et al. (2011), Li et al. (2011), Song et al. (2011), Tang et al. (2011), Wang et al. (2011), Cao (2012), Huang et al. (2012), Jiao et al. (2012), Lei (2012), Qian et al. (2012), Gao and Zhou (2013), Lv (2013), Ren et al. (2013), Rouxianguli and Muhtar (2013), Sun et al. (2013), Yu et al. (2013), Zhang (2013), Mao et al. (2014), Deng et al. (2014, 2015, 2017), Dong et al. (2014), Qi et al. (2014), Su (2014), Xu (2014), Zang (2014), Zhang (2014), Zhou (2014), Dai (2015), Dong (2015, 2019), Ma et al. (2015), Mao et al. (2015, 2016), Wang et al. (2015), Yan (2015), Yu (2015), Zhang et al. (2015a, 2017b), Zhang et al. (2015b), Zheng (2015), Dilibaier (2016), Liu (2016), Mo (2016), Nijat et al. (2016), She et al. (2016), Zhang et al. (2016), Duan et al. (2017), Liu (2017), Teng et al. (2017), Wu et al. (2017), Xiao et al. (2017), Bai et al. (2018), Cui et al. (2018), Du (2018), Du et al. (2018, 2019), Li (2018), Wang et al. (2018a), Wang et al. (2018b), Xiong (2018), You et al. (2018), Zhao et al. (2018), Abulizi (2019), Chen (2019), Guo et al. (2019), Wang et al. (2019), Wang (2019), Wen (2019), Wu (2019), Zhong (2019), Zhou et al. (2019), Pang et al. (2020).

LITHOLOGY AND GEOCHEMICAL CHARACTERISTICS

The lithology and geochemical characteristics of the compiled data set have been investigated here. The Dananhu-Kanggurtag plutons mainly comprise I/S/A-type granites, granodiorites, minor diorites and gabbros, as well as zoned mafic-ultramafic complexes that are distributed mainly at the eastern part of the belt, including lherzolites, websterites and gabbros. The felsic-intermediate plutons commonly exhibit tholeiitic to calc-alkaline and metaluminous-peraluminous features (Fig. S1). The Aqishan-Yamansu plutons comprise I/A-type granites, granodiorites, minor diorites and gabbros. Differently, the felsic-intermediate plutons predominantly exhibit low-K to high-K calc-alkaline and metaluminous features, except for a few albite-altered granites showing extremely low K_2O contents (Fig. S1). The Central Tianshan plutons comprise I/A-type granites, granodiorites, quartz monzonites, syenites, diorites, gabbros, and several mafic-ultramafic complexes that are also located at the eastern part of this belt. The felsic-intermediate plutons display calc-alkaline to shoshonitic and metaluminous-peraluminous features (Fig. S2).

The zoned mafic-ultramafic complexes all have well-determined cumulus textures and differentiation feature from interior to margin due to fractional crystallization. These geological signatures are apparently distinguished from the ultramafic segments of ophiolites. In addition, they are closely associated with Cu-Ni-(Co) sulfide deposits (e.g., Mao et al., 2008; Lightfoot and Evans-Lamswood, 2015; Wang et al., 2018b). Many economic geologists have proposed that these complexes were generated from mantle-derived basaltic melts through fractional crystallization and variable extents of crustal contamination (e.g., Tang et al., 2011, 2012). On the other hand, the zoned mafic-ultramafic complexes all have very small surface area (< 3 km^2: Qin et al., 2011; Lightfoot and Evans-Lamswood, 2015) and are distributed mainly at the eastern parts of the Dananhu-Kanggurtag and the Central Tianshan belts. Geochemically, they appear to show no petrogenetic affinities to the widespread felsic-intermediate plutons. Specifically, plots between major oxides and MgO (Figs. S3-S4) show that the zoned mafic-ultramafic complexes were formed by the effect of fractional crystallization, whereas the felsic-intermediate rocks appear to correlate differently from the descent lines of mafic-ultramafic rocks. For example, Al_2O_3 and MnO contents of the felsic-intermediate plutons of the Dananhu-Kanggurtag belts are too low to be explained by olivine and pyroxene fractionation (Fig. S3). Additionally, although the CaO contents of the felsic-intermediate rocks of the Central Tianshan rocks appear to follow the trend of clinopyroxene fractionation, Al_2O_3 contents do not support this effect (Fig. S4). Trace element ratios with similar partition coefficients, such as Zr/Y, Zr/Nb, Zr/Hf, greatly vary between the felsic-intermediate rocks and mafic-ultramafic complexes. These geochemical features, together with a lack of spatial association, negate any petrogenetic intimacy between the felsic-intermediate rocks and mafic-ultramafic complexes.

The Carboniferous volcanic lavas are distributed in the Dananhu-Kanggurtag and Aqishan-Yamansu belts. Volcanic rocks in Gundun and Wutongwozi strata located at the eastern part of the Dananhu-Kanggurtag belt are strikingly distinguished from the other rocks. The rock types of Gundun and Wutongwozi formations comprise bimodal rhyolites (minor dacites) and basalts and they show tholeiitic to low-K calc-alkaline features (Fig. S5). The basaltic lavas show tholeiitic N-MORB-like features except for a few high-Th subsets (Fig. S6). They are interpreted to be of subduction-related origin rather than relicts of oceanic floor, given the fact of clearly negative Nb-Ta anomalies, significantly positive Pb anomalies, and variable extents of Th-U-Sr enrichment (Fig. S7). In addition, these basalts are plotted in the field of Mariana back-arc basalts with much lower Ba/Nb than the others (Fig. S8). This contradicts with the previously proposed relic oceanic floor origin for these basalts (e.g., He et al., 2005; She et al., 2016). Instead, geochemical evidence indicates that the generation of these basalts was likely related to an intra-arc extension associated with crustal thinning.

Volcanic rocks, mainly located at the center part of the Dananhu-Kanggurtag belt, comprise basalts, andesites, dacites and rhyolites. They show similarly tholeiitic to low-K calc-alkaline features (Fig. S5), but the basalts are plotted in the field of island-arc tholeiitic features (Fig. S6). Given that the Dananhu arc was originally derived from an Early Paleozoic island arc (Ma et al., 1997), the Carboniferous volcanic lavas and intrusive rocks were accretion products of the island arc due to the northward subduction of the North Tianshan ocean underneath the Dananhu island arc.

By contrast, the volcanic lavas at the Aqishan-Yamansu belt, although comprising similar lithology assemblage, display low-K to high-K calc-alkaline features (Fig. S5) and continental arc affinity (Fig. S6). In addition, zircon ε_{Hf} isotope compositions of these rocks vary widely (Fig. 4), indicating a greater crustal input that was most likely derived from the Central Tianshan basement. Hence, an affinity of active continental arc due to the southward subduction of the North Tianshan ocean accounts for the formation of the Aqishan-Yamansu belt.

CALCULATION PARAMETERIZATION OF THE NET VOLUME OF JUVENILE CONTINENTAL CRUST

The average proportion of the mantle-derived component incorporated in the magmatic rocks in the Eastern Tianshan terrane was estimated by isotope mixture modeling (Jahn et al., 2000). We admit that the uncertainty exists in the specific nature and composition of the end-member components and in the mechanism of mixing (i.e., binary mixing vs assimilation-fractional crystallization, hot zone vs mash). However, this provides a first pass but crucial attempt.

On the basis of our study, the three belts were derived from different tectonic settings: (1) the Dananhu-Kanggurtag belt was derived from an accretionary Early Paleozoic island arc and aborted intra-arc; (2) the Aqishan-Yamansu belt was originally an active continental margin; and (3) the Central Tianshan belt was a Precambrian microcontinent. Hence, different from Jahn et al.'s calculation (Jahn et al. 2000), we choose different contaminants for the rocks from different circumstances. Considering there is no available work regarding the composition of sediments from the subducting slab beneath the Eastern Tianshan terrane, we use the sediments from the Australian-New Guinea shelf that are representative for subducting slab material (zircon Hf ~3.8 ppm, ε_{Hf} ~−7: Nebel et al., 2011). Although the sediment from the Australian-New Guinea shelf seems remotely related, we propose it being reasonable because that the granitoids from the CAOB that were influenced by sediment recycling show $\varepsilon_{Hf(t)}$ ranging from −5.0 to −7.0 (Zhang et al., 2017a). We take the metasediments from the Central Tianshan basement (zircon Hf ~3.3 ppm, ε_{Hf} ~−23) as the contaminant for the rocks of the Aqishan-Yamansu and Central Tianshan belts. We apply the depleted mantle (Hf ~0.2 ppm, ε_{Hf} ~16: Salters and Strack, 2004; Nowell et al., 1998) as the radiogenic end-member component for all the rocks. The binary mixing model yields mantle fractions of 0.70–0.99 (avg. 0.95), 0.71–0.99 (avg. 0.97), and 0–0.98 (avg. 0.89) for the Dananhu-Kanggurtag, the Aqishan-Yamansu, and the Central Tianshan magmatic rocks, respectively. The results are similar to previous estimates using whole-rock Nd isotopes (60 – 100%: Jahn et al., 2000; Jahn, 2004) and zircon Hf isotopes (60 – 95%: Tang et al. 2017).

There is notably vertical growth via mantle-derived magma underplating during syn-collisional episode in the Central Tianshan block. Therefore, estimation of the increase of crustal thickness in this unit is easily constrained based on the calibrated crustal thickness, i.e., 21–24 km during ca. 340–310 Ma in the Central Tianshan block. Differently, the amalgamation of the Dananhu-Kanggurtag belt and the Aqishan-Yamansu belt involves both vertical growth and lateral growth. Therefore, the crustal thickness in the two belts are variable, especially the Aqishan-Yamansu belt. The Dananhu-Kanggurtag shows a wide range of 3–21 km during ca. 330–310 Ma. In the Aqishan-Yamansu belt, we assume the differences between the largest crustal thickness and the average crustal thickness during pre-collision stage as the increase of crustal thickness during the syn-collisional episode (i.e., 10–17 km).

The surface area of intrusive and extrusive rocks during syn-collision stage is calculated based on Tang et al. (2017), which reported a total exposed outcrop area of granitic rocks during ca. 330–310 Ma (~11600 km^2) on the Tianshan orogen (including the Eastern Tianshan terrane and Western Tianshan terrane). Based on a global compilation of volumetric volcanic outcrop rates (White et al., 2006), they assumed an intrusive to extrusive ratio of 5:1 (Tang et al., 2017). Hence it yields a total surface area of intrusive and extrusive rocks of the Eastern Tianshan terrane of ~34800 km^2 given a ratio of 1:1 to the Eastern and Western Tianshan terranes. Given the ratio of 2:1:4 to the surface areas of the Dananhu-Kanggurtag, Aqishan-Yamansu, and Central Tianshan belts based on the current surface area, we can calculate the surface areas of magmatic rocks of each belt during syn-collision stage as 9943 km^2, 4971 km^2, and 19886 km^2 to each belt from north to south.

The current surface areas of each belts from north to south are ~24,000 km^2, 12,000 km^2, and 46,000 km^2, respectively.

REFERENCES CITED

Abulizi, R., 2019, Geochemical characteristics and tectonic significance of Late Paleozoic intrusive rocks in Bijigaibulusitai-Daijingquequequ area, southern margin of Mid-Tianshan mountains: Xinjiang, Xinjiang University, 64 p.

Bai, J., Liu, C., Zhang, S., Lu, J., and Sun, J., 2018, Zircon U-Pb geochronology and geochemistry of basalts from the Qi'eshan group in the southern Turpan-Hami basin, East Tianshan: Constraints on closure time of the North Tianshan Ocean: Yanshi Xuebao, v. 34, no. 10, p. 2995–3010.

Cao, R., 2012, The Late Paleozoic tectonomagmatic evolution and metallogenic response in the middle of Qoltag orogenic belt, Eastern Tianshan Mountains [Ph.D. thesis]: Wuhan, China University of Geosciences, 91 p.

Chai, F., Zhang, Z., Mao, J., Dong, L., Zhang, Z., and Wu, H., 2008, Geology, petrology and geochemistry of the Baishiquan Ni-Cu-bearing mafic–ultramafic intrusions in Xinjiang, NW China: Implications for tectonics and genesis of ores: Journal of Asian Earth Sciences, v. 32, no. 2–4, p. 218–235, https://doi.org/10.1016/j.jseaes.2007.10.014.

Chen, Y., 2019, Late Paleozoic tectonic framework and evolution of the southern Central Tianshan: constraints from the granites in Caixiashan, Xinjiang, China [M.S. thesis]: Xinjiang University, 37 p.

Cui, C., Yu, J., Yang, W., Zhang, Y., Cui, Y., and Yu, J., 2018, Geochronology, geochemistry and genersis of Yamansu formation volcanic rocks of southern Aqi mountain in Jueluotage tectonic belt, eastern Tianshan of Xinjiang: Giornale di Geologia, v. 37, no. 1, p. 88–104.

Dai, A., 2015, Study on the geological characteristics and the genesis of Bailing mountain iron deposit in Eastern Tianshan, Xinjiang Province [M.S. thesis]: Chang'an University, 59 p.

Deng, Y., Song, X., Chen, L., Zhou, T., Pirajno, F., Yuan, F., Xie, W., and Zhang, D., 2014, Geochemistry of the Huangshandong Ni–Cu deposit in northwestern China: Implications for the formation of magmatic sulfide mineralization in orogenic belts: Ore Geology Reviews, v. 56, p. 181–198, https://doi.org/10.1016/j.oregeorev.2013.08.012.

Deng, Y., Song, X., Hollings, P., Chen, L., Zhou, T., Yuan, F., Xie, W., Zhang, D., and Zhao, B., 2017, Lithological and geochemical constraints on the magma conduit systems of the Huangshan Ni-Cu sulfide deposit, NW China: Mineralium Deposita, v. 52, no. 6, p. 845–862, https://doi.org/10.1007/s00126-016-0703-7.

Deng, Y., Song, X., Hollings, P., Zhou, T., Yuan, F., Chen, L., and Zhang, D., 2015, Role of asthenosphere and lithosphere in the genesis of the Early Permian Huangshan mafic–ultramafic intrusion in the Northern Tianshan, NW China: Lithos, v. 227, p. 241–254, https://doi.org/10.1016/j.lithos.2015.04.014.

Dilibaier, D., 2016, Genesis of Carboniferous volcanic rocks in the East Tianshan mountains and the multi metal mineralization response [M.S. thesis]: Xinjiang University, 49 p.

Dong, C., 2015, The Geological-geochemical characteristics and genesis of the Caixiashan Zn-Pb deposit, Eastern Tianshan [M.S. thesis]: Beijing, China University of Geosciences, 81 p.

Dong, G., 2019, Zircon U-Pb dating and geochemistry of the Kudong amphibole gabbro from Central Tianshan in Xinjiang and its tectonic significance [M.S. thesis]: Xinjiang University, 37 p.
Dong, Q., Cong, Y., and Xiao, K., 2014, Geochemical and geological implications of granitic intrusive rocks in Carboniferous to Permian in eastern Tianshan of Xinjiang: Geologica Acta, v. 38, no. 4, p. 517–529.
Dong, Y., Zhang, G., Neubauer, F., Liu, X., Hauzenberger, C., Zhou, D., and Li, W., 2011, Syn- and post-collisional granitoids in the Central Tianshan orogen: Geochemistry, geochronology and implications for tectonic evolution: Gondwana Research, v. 20, no. 2–3, p. 568–581, https://doi.org/10.1016/j.gr.2011.01.013.
Du, L., 2018, Petrogenesis and tectonic setting of Paleozoic felsic intrusions in the Eastern Tianshan [Ph.D. thesis]: Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, 141 p.
Du, L., Long, X., Yuan, C., Zhang, Y., Huang, Z., Sun, M., and Xiao, W., 2018, Petrogenesis of Late Paleozoic diorites and A-type granites in the central Eastern Tianshan, NW China: Response to post-collisional extension triggered by slab breakoff: Lithos, v. 318–319, p. 47–59, https://doi.org/10.1016/j.lithos.2018.08.006.
Du, L., Zhang, Y., Huang, Z., Li, X., Yuan, C., Wu, B., and Long, X., 2019, Devonian to carboniferous tectonic evolution of the Kangguer Ocean in the Eastern Tianshan, NW China: Insights from three episodes of granitoids: Lithos, v. 350–351, 10.1016/j.lithos.2019.105243
Duan, R., Yang, H., Liu, C., Zhang, L., and Tong, X., 2017, Zircon U-Pb and whole rock Rb-Sr dating of Yuanbaoshan gold deposit in Xinjiang and its geological significance: Mineralium Deposita, v. 36, no. 2, p. 449–462.
Guo, F., Jiang, C., Su, C., Xia, M., Xia, Z., and Wei, W., 2008, Tectonic settings of A-type granites of Shaerdelan area, southeastern margin of Junggar block, Xinjiang, western China: Yanshi Xuebao, v. 24, no. 12, p. 2778–2788.
Guo, Y., Zhao, T., Sun, Y., Li, P., and Wang, F., 2019, Zircon U-Pb dating, Hf isotope analysis and its restriction on tectonic environment of the Shuanglong copper deposit in the Eastern Tianshan: Xinjiang Geology, v. 37, no. 2, p. 146–155.
Han, C., Xiao, W., Zhao, G., Ao, S., Zhang, J., Qu, W., and Du, A., 2010, In-situ U-Pb, Hf and Re–Os isotopic analyses of the Xiangshan Ni-Cu-Co deposit in Eastern Tianshan (Xinjiang), Central Asia Orogenic Belt: Constraints on the timing and genesis of the mineralization: Lithos, v. 120, no. 3–4, p. 547–562, https://doi.org/10.1016/j.lithos.2010.09.019.
He, J., Xia, M., and Zhang, X., 2005, Discussion on the structural environment of the Wutongwozi group at Jueluotage region in the East Tianshan: Xinjiang. Xinjiang Geology, v. 23, no. 1, p. 23–27.
Hou, G., Tang, H., and Liu, C., 2006, Geochemical characteristics of the Late Paleozoic volcanics in Jueluotage tectonic belt, eastern Tianshan and its implications: Yanshi Xuebao, v. 22, no. 5, p. 1167–1177.
Huang, X., Qi, L., Gao, J., Liu, Y., and Wang, Y., 2012, Geochemistry of volcanic rocks in the Dikan'er formation of Jueluotage region, eastern Tianshan mountains and its tectonic implications: Acta Petrologica et Mineralogica, v. 31, no. 6, p. 799–817.
Jahn, B.M., 2004, The Central Asian Orogenic Belt and growth of the continental crust in the Phanerozoic, *in* Malpas, J., Fletcher, C.J.N., Ali, J.R., and Aitchison, J.C., eds., Aspects of

the Tectonic Evolution of China: Geological Society, London, Special Publication 226, p. 73–100, https://doi.org/10.1144/GSL.SP.2004.226.01.05.
Jahn, B.M., Wu, F.Y., and Chen, B., 2000, Massive granitoid generation in Central Asia: Nd isotope evidence and implication for continental growth in the Phanerozoic: Episodes, v. 23, p. 82–92, https://doi.org/10.18814/epiiugs/2000/v23i2/001.
Jiao, J.G., Tang, Z.L., and Qian, Z.Z., 2012, The ore genesis and ore-forming process of Tulargen Cu-Ni sulfide deposit in east Tianshan, Xinjiang: Yanshi Xuebao, v. 28, p. 3772–3786.
Kahaer, N., 2010, The tectonic settings and metallogenic characteristics of Eastern Tianshan mountains in Late Paleozoic eracace in Carboniferous [M.S. thesis]: Xinjiang University, 75 p.
Lei, R., 2012, Precambrian and early Paleozoic magmatism, mineralization and tectonic evolution of the Eastern Central Tianshan, NW China [Ph.D. thesis]: Nanjing University, 105 p.
Li, H., 2018, Characteristics and ore bearing characteristics of the volcanic rocks of the Late Carboniferous Tugutu Braque formation in the East Tianshan mountains: [M.S. thesis]: Xinjiang University, 62 p.
Li, J., Qin, K., Xu, X., Sun, H., Cheng, S., Wu, H., and Mo, X., 2007, Geochemistry of Baishiquan Cu-Ni-bearing mafic-ultramafic complex in East Tianshan, Xinjiang: Constraints on ore genesis and tectonic setting: Mineralium Deposita, v. 26, no. 1, p. 43–57.
Li, J., Song, B., Wang, K., Li, Y., Sun, G., and Qi, D., 2006a, Permian mafic-ultramafic complexes on the Southern margin of the Tu-Ha basin, East Tianshan mountains: Geological records of vertical crustal growth in Central Asia: Geoscience Sinica, v. 27, no. 5, p. 424–446.
Li, W., Ren, B., Yang, X., Li, Y., and Chen, Q., 2002, The intermediate-acid intrusive magmatism and its geodynamic significance in Eastern Tianshan region: Northwest Geology, v. 35, no. 4, p. 41–64.
Li, W., Xia, B., Wang, K., Wang, Q., and Wang, H., 2006b, Zircon SHRIMP age and geochemistry of Caizhong granite from East Tianshan, Xinjiang, China: Acta Geologica Sinica, v. 80, no. 1, p. 43–52.
Li, X., Xia, L., Xia, Z., Xu, X., Ma, Z., and Wang, L., 2006c, Petrogenesis of the Carboniferous Qi'eshan group volcanic rocks in the East Tianshan [Earth Science Edition]: Journal of Jilin University, v. 36, no. 3, p. 336–342.
Li, Y., Yang, J., Zhang, J., Li, T., Chen, S., Ren, Y., and Xu, X., 2011, Tectonical significance of the Carboniferous volcanic rocks in eastern Tianshan: Yanshi Xuebao, v. 27, no. 1, p. 193–209.
Lightfoot, P.C., and Evans-Lamswood, D., 2015, Structural controls on the primary distribution of mafic–ultramafic intrusions containing Ni–Cu–Co–(PGE) sulfide mineralization in the roots of large igneous provinces: Ore Geology Reviews, v. 64, p. 354–386, https://doi.org/10.1016/j.oregeorev.2014.07.010.
Liu, B., 2016, The Devonian tectonic evolution of the Hami region, East Tianshan Mt.: Evidence from the geochemistry of igneous rocks [Ph.D. thesis]: Lanzhou University, 68 p.
Liu, S., Wu, C., Gu, L., Zhang, Z., Tang, J., Li, G., Lei, R., and Wang, C., 2008, Geochronology, petrogenesis and tectonic significances of the Baishitouquan pluton in Middle Tianshan, Northwest China: Yanshi Xuebao, v. 24, no. 12, p. 2720–2730.

Liu, W., 2017, The genesis of Aqishan first iran deposit of Jueluotage tectonic belt in the Eastern Tianshan [M.S. thesis]: Beijing, China University of Geosciences, 64 p.
Lv, S., 2013, The petrology and geochemistry characteristics, petrogenesis as well as geological significance of annual granite pluton in the Hancaohu area, East Tianshan mountains of Xinjiang [M.S. thesis]: Chang'an University, 57 p.
Ma, R.S., Shu, L.S., and Sun, J., 1997, Tectonic Evolution and Metallogeny of Eastern Tianshan Mountains: Beijing, Geological Publishing House, 202 p.
Ma, X., Shu, L., and Meert, J.G., 2015, Early Permian slab breakoff in the Chinese Tianshan belt inferred from the post-collisional granitoids: Gondwana Research, v. 27, no. 1, p. 228–243, https://doi.org/10.1016/j.gr.2013.09.018.
Mao, J., Pirajno, F., Zhang, Z., Chai, F., Wu, H., Chen, S., Cheng, L., Yang, J., and Zhang, C., 2008, A review of the Cu–Ni sulphide deposits in the Chinese Tianshan and Altay orogens (Xinjiang Autonomous Region, NW China): Principal characteristics and ore-forming processes: Journal of Asian Earth Sciences, v. 32, no. 2–4, p. 184–203, https://doi.org/10.1016/j.jseaes.2007.10.006.
Mao, Q., Xiao, W., Fang, T., Windley, B.F., Sun, M., Ao, S., Zhang, J., and Huang, X., 2014, Geochronology, geochemistry and petrogenesis of Early Permian alkaline magmatism in the Eastern Tianshan: Implications for tectonics of the Southern Altaids: Lithos, v. 190–191, p. 37–51, https://doi.org/10.1016/j.lithos.2013.11.011.
Mao, Y., Qin, K., Li, C., and Tang, D., 2015, A modified genetic model for the Huangshandong magmatic sulfide deposit in the Central Asian Orogenic Belt, Xinjiang, western China: Mineralium Deposita, v. 50, no. 1, p. 65–82, https://doi.org/10.1007/s00126-014-0524-5.
Mao, Y., Qin, K., Tang, D., Feng, H., and Xue, S., 2016, Crustal contamination and sulfide immiscibility history of the Permian Huangshannan magmatic Ni-Cu sulfide deposit, East Tianshan, NW China: Journal of Asian Earth Sciences, v. 129, p. 22–37, https://doi.org/10.1016/j.jseaes.2016.07.028.
Mantle, G.W., and Collins, W.J., 2008, Quantifying crustal thickness variations in evolving orogens: Correlation between arc basalt composition and Moho depth: Geology, v. 36, no. 1, p. 87–91, https://doi.org/10.1130/G24095A.1.
Mo, Z., 2016, The volcanic architecture and tectonic setting of the Lianshishan in Eastern Tianshan, Aqishan, NW China [M.S. thesis]: Beijing, China University of Geosciences, 59 p.
Nebel, O., Vroon, P.Z., van Westrenen, W., Iizuka, T., and Davies, G.R., 2011, The effect of sediment recycling in subduction zones on the Hf isotope character of new arc crust, Banda arc, Indonesia: Earth and Planetary Science Letters, v. 303, no. 3–4, p. 240–250, https://doi.org/10.1016/j.epsl.2010.12.053.
Nijat, A., Muhtar, Z., and Jia, X., 2016, Geological characteristics of Middle-Late Paleozoic granitoid plutons in the East section of Chinese South Tianshan and its constraints to the closure time of South Tianshan ocean: Geoscience, v. 30, no. 2, p. 263–273.
Nowell, G.M., Kempton, P.D., Noble, S.R., Fitton, J.G., Saunders, A.D., Mahoney, J.J., and Taylor, R.N., 1998, High precision Hf isotope measurements of MORB and OIB by thermal ionisation mass spectrometry: insights into the depleted mantle: Chemical Geology, v. 149, p. 211–233, https://doi.org/10.1016/S0009-2541(98)00036-9.
Pan, S., 2009, Tectonic setting and petrogenesis analysis of Xiaorequanzi formation in Shanshan Xinjiang [M.S. thesis]: Chang'an University, 43 p.

Pang, B., Li, Q., Chen, J., Liu, S., Wang, Z., Chen, Y., and Xiao, B., 2020, Paleozoic intrusive magmatic activity and basement properties of the Dananhu-Tousuquan island arc in the Eastern Tianshan mountains: Northwest Geology, v. 53, no. 2, 10.19751/j.cnki.61–1149/p.2020.02.001.
Profeta, L., Ducea, M.N., Chapman, J.B., Paterson, S.R., Gonzales, S.M.H., Kirsch, M., Petrescu, L., and DeCelles, P.G., 2015, Quantifying crustal thickness over time in magmatic arcs: Scientific Reports, v. 5, no. 1, https://doi.org/10.1038/srep17786.
Qi, W., Muhtar, Z., Nijat, A., Wu, Z., and Fu, X., 2014, Geochemical characteristics of the volcanics from Qi'eshan group in the East Tianshan and its revelation to the tectonic evolution of Paleo-Asian ocean: Arid Land Geography, v. 37, no. 6, p. 1183–1189.
Qian, Z., Zhang, J., Song, T., Duan, J., Jian, C., and Xia, M., 2012, Hf-Nd isotopic characteristics of the Huangshandong mafic-ultramafic intrusion, Eastern Xinjiang, and their geological implications: Northwest Geology, v. 45, no. 4, p. 145–154.
Qin, K., Su, B., Sakyi, P.A., Tang, D., Li, X., Sun, H., Xiao, Q., and Liu, P., 2011, SIMS zircon U-Pb geochronology and Sr-Nd isotopes of Ni-Cu-Bearing Mafic-Ultramafic Intrusions in Eastern Tianshan and Beishan in correlation with flood basalts in Tarim Basin (NW China): Constraints on a ca. 280 Ma mantle plume: American Journal of Science, v. 311, no. 3, p. 237–260, https://doi.org/10.2475/03.2011.03.
Qing, X., 2006, Geochemistry and geological significance of the Xiaodongshan volcanic architecture in the Aqishan area, eastern Tianshan, Xinjiang [M.S. thesis]: China University of Geosciences (Beijing), 52 p.
Ren, M., Wang, Y., Ni, K., and Sun, Y., 2013, Differentiation of magmas in the formation of Permian mafic-ultramafic intrusions in the Dacaotan area, Eastern Tianshan: Implications for Ni-Cu-(PGE) sulfide mineralization potentials: Yanshi Xuebao, v. 29, no. 10, p. 3473–3486.
Roeder, P.L., and Emslie, R.F., 1970, Olivine-liquid equilibrium: Contributions to Mineralogy and Petrology, v. 29, p. 275–289, https://doi.org/10.1007/BF00371276.
Salters, V.J.M., and Stracke, A., 2004, Composition of the depleted mantle: Geochemistry Geophysics Geosystems, v. 5, no. 5, https://doi.org/10.1029/2003GC000597.
She, J., Feng, C., Di, X., and Xu, Y., 2016, Petrochemcial characteristics and significance of Wutongwozi formation in Jueluotage tectonic belt in the East Tianshan: Western Mining Engineering, v. 6, p. 77–81.
Song, X., Xie, W., Deng, Y., Crawford, A.J., Zheng, W., Zhou, G., Deng, G., Cheng, S., and Li, J., 2011, Slab break-off and the formation of Permian mafic–ultramafic intrusions in southern margin of Central Asian Orogenic Belt, Xinjiang, NW China: Lithos, v. 127, no. 1–2, p. 128–143, https://doi.org/10.1016/j.lithos.2011.08.011.
Su, B., 2014, Mafic-ultramafic intrusions in Beishan and Eastern Tianshan at southern CAOB: Petrogenesis, mineralization and tectonic implication [Ph.D. thesis]: Institute of Geology and Geophysics, Chinese Academy of Sciences, 211 p.
Su, C., Jiang, C., Xia, M., Wei, W., and Pan, R., 2009, Geochemistry and zircon SHRIMP U-Pb age of volcanic rocks of Aqishan formation in the eastern area of north Tianshan, China: Yanshi Xuebao, v. 25, no. 4, p. 901–915.
Sun, H., 2009, Ore-forming mechanism in conduit system and ore-bearing property evaluation for mafic-ultramafic complex in Eastern Tianshan, Xinjiang [Ph.D. thesis]: Institute of Geology and Geophysics, Chinese Academy of Sciences, 262 p.

Sun, H., Qin, K., Li, J., Xu, X., San, J., Ding, K., and Hui, W., 2006, Petrographic and geochemical characteristics of the Tulargen Cu-Ni-Co sulfide deposit, East Tianshan, Xinjiang, and its tectonic setting: Geology in China, v. 33, no. 3, p. 606–617.
Sun, T., Qian, Z., Li, C., Xia, M., and Yang, S., 2013, Petrogenesis and economic potential of the Erhongwa mafic–ultramafic intrusion in the Central Asian Orogenic Belt, NW China: Constraints from olivine chemistry, U–Pb age and Hf isotopes of zircons, and whole-rock Sr–Nd–Pb isotopes: Lithos, v. 182–183, p. 185–199, https://doi.org/10.1016/j.lithos.2013.10.004.
Tang, D., Qin, K., Li, C., Qi, L., Su, B., and Qu, W., 2011, Zircon dating, Hf–Sr–Nd–Os isotopes and PGE geochemistry of the Tianyu sulfide-bearing mafic–ultramafic intrusion in the Central Asian Orogenic Belt, NW China: Lithos, v. 126, no. 1–2, p. 84–98, https://doi.org/10.1016/j.lithos.2011.06.007.
Tang, D., Qin, K., Sun, H., Su, B., and Xiao, Q., 2012, The role of crustal contamination in the formation of Ni–Cu sulfide deposits in Eastern Tianshan, Xinjiang, Northwest China: Evidence from trace element geochemistry, Re-Os, Sr-Nd, zircon Hf–O, and sulfur isotopes: Journal of Asian Earth Sciences, v. 49, p. 145–160, https://doi.org/10.1016/j.jseaes.2011.11.014.
Tang, J., Gu, L., Zhang, Z., Wu, C., San, J., Wang, C., Liu, S., and Li, G., 2008, Peraluminous granite in Huangshan-Jingerquan area of eastern Tianshan: Geochemistry, mineralogy and geochronology: Yanshi Xuebao, v. 24, no. 5, p. 921–946.
Tang, J., Gu, L., Zhang, Z., Wu, C., San, J., Wang, C., Liu, S., and Zhang, G., 2007, Characteristics, age and origin of the Xianshuiquan gneissose granite in eastern Tianshan: Yanshi Xuebao, v. 23, no. 8, p. 1803–1820.
Tang, G.J., Chung, S.L., Hawkesworth, C.J., Cawood, P.A., Wang, Q., Wyman, D.A., Xu, Y.G., Zhao, Z.H., 2017, Short episodes of crust generation during protracted accretionary processes: Evidence from Central Asian Orogenic Belt, NW China: Earth and Planetary Science Letter, v. 464, 142–154.
Tang, G.J., Chung, S.L., Hawkesworth, C.J., Cawood, P.A., Wang, Q., Wyman, D.A., Xu, Y.G., Zhao, Z.H., 2017, Short episodes of crust generation during protracted accretionary processes: Evidence from Central Asian Orogenic Belt, NW China: Earth and Planetary Science Letter, v. 464, 142–154.
Wang P., Zhu, Z., Zhao, T. and Zhao, H., 2011, Volcanic rock petrochemical characteristics and tectonic sigificance of the Xiaorequanzi formation, Quiletage, Jueluotage area of Xinjiang: Xinjiang Geology, v. 29, no. 4, p. 372–376.
Wang, C., Chen, B., Ma, X., and Yan, X., 2015, Petrogenesis of Early and Late Paleozoic plutons in Sanchakou area of East Tianshan and their implications for evolution of Kangur suture zone: Journal of Earth Science and Environment, v. 37, no. 5, p. 52–70.
Wang, J., Wang, X., Deng, M., and Sun, T., 2018a, LA-ICP-MS zircon U-Pb age of the Sidingheishan granitic pluton from east Tianshan, Xinjiang, China, and its geological implications: Contributions to Geology and Mineral Resources Research, v. 33, no. 3, p. 365–374.
Wang, Q., Zhang, J., Wang, S., Yu, L., and Xiao, B., 2019, Petrogenesis and tectonic setting of the quartz porphyry in Mazhuangshan gold deposit, Eastern Tianshan orogen: Evidence from geochemistry, zircon U-Pb geochronology and Sr-Nd-Hf isotopes: Yanshi Xuebao, v. 35, no. 5, p. 1503–1518.

Wang, X., 2019, Geochemistry of Aqishan granite in Jueluotage orogenic belt and its tectonic significance [M.S. thesis]: Xinjiang University, 42 p.
Wang, Y., Lv, X., and Liu, Y., 2018b, Petrogenesis and Ni-Cu-Co Sulfide Formation of Mafic Enclaves in Tulaergen Mafic-Ultramafic Intrusive Rocks, Eastern Tianshan, Northwest China: Implications for Liquid Immiscibility and Hydrothermal Remobilization of Platinum-Group Elements: Economic Geology and the Bulletin of the Society of Economic Geologists, v. 113, no. 8, p. 1795–1816, https://doi.org/10.5382/econgeo.2018.4613.
Wang, Y., Wang, J., Wang, L., and Long, L., 2009, Characteristics of two mafic-ultramafic rock series in the Xiangshan Cu-Ni-(V) Ti-Fe ore district, Xinjiang: Yanshi Xuebao, v. 25, no. 4, p. 888–900.
Wen, D., 2019, Petrogenesis and tectonic implications of the Late Paleozoic granites from the Xingxingxia area of the Central Tianshan [M.S. thesis]: Chinese Academy of Geological Sciences, 82 p.
White, S.M., Crisp, J.A., and Spera, F.J., 2006, Long-term volumetric eruption rates and magma budgets: Geochemistry Geophysics Geosystems, v. 7, Q03010, https://doi.org/10.1029/2005GC001002.
Wu, B., 2019, Late Paleozoic magmatism and crustal growth in the Aqishan-Yamansu belt of Eastern Tianshan [M.S. thesis]: Northwest University, 100 p.
Wu, C., Liao, Q., Li, Q., and Yang, Z., 2008, The Late Carboniferous volcanic arc rocks in Jueluotage area, Eastern Tianshan, China: Geological Science and Technology Information, v. 27, no. 6, p. 29–36.
Wu, C., Zhang, Z., Khin, Z., Fernando, D.P., Tang, J., Zheng, Y., Wang, C., and San, J., 2006, Geochronology, geochemistry and tectonic significances of the Hongyuntan granitoids in the Qoltag area, Eastern Tianshan: Yanshi Xuebao, v. 22, no. 5, p. 1121–1134.
Wu, Y., Zhou, K., Li, N., and Chen, Y., 2017, Zircon U–Pb dating and Sr–Nd–Pb–Hf isotopes of the ore–associated porphyry at the giant Donggebi Mo deposit, Eastern Tianshan, NW China: Ore Geology Reviews, v. 81, p. 794–807, https://doi.org/10.1016/j.oregeorev.2016.02.007.
Xia, M., Jiang, C., Qian, Z., Sun, T., Xia, Z., and Lu, R., 2008, Geochemistry and petrogenesis for Hulu intrusion in East Tianshan, Xinjiang: Yanshi Xuebao, v. 24, no. 12, p. 2749–2760.
Xiao, B., Chen, H., Hollings, P., Han, J., Wang, Y., Yang, J., and Cai, K., 2017, Magmatic evolution of the Tuwu–Yandong porphyry Cu belt, NW China: Constraints from geochronology, geochemistry and Sr–Nd–Hf isotopes: Gondwana Research, v. 43, p. 74–91, https://doi.org/10.1016/j.gr.2015.09.003.
Xiao, W., Han, C., Yuan, C., Chen, H., Sun, M., Lin, S., Li, Z., Mao, Q., Zhang, J., Sun, S., and Li, J., 2006, Unique Carboniferous-Permian tectonic-metallogenic framework of Northern Xinjiang (NW China): Constraints for the tectonics of the southern Paleoasian Domain: Yanshi Xuebao, v. 22, no. 5, p. 1062–1076.
Xiong, W., 2018, Geochemical characteristics and tectonic environment of magmatic rocks in the area of Hami Dananhu of Xinjiang [M.S. thesis]: Lanzhou University, 54 p.
Xu, L., 2014, The petrogenesis of magmatic rocks in the Shaquanzi Fe(-Cu) deposit area, Eastern Tianshan, Xinjiang [M.S. thesis]: Xinjiang University, 59 p.
Yan, Y., 2015, Study on characteristics and mineralization mechanism of Carboniferous volcanic rocks of Chilongfeng iron deposit in the Eastern Tianshan, Xinjiang [M.S. thesis]: Chang'an University, 59 p.

You, M., Li, H., and Wang, Y., 2018, Magma evolution of Huangshannan mafic-ultramafic intrusion in East Tianshan region: Indication from mineralogy and Sr, Nd isotopic characteristics: Yanshi Xuebao, v. 34, no. 11, p. 3422–3432.
Yu, J., Meng, Y., Li, J., Guo, L., and Wang, J., 2013, Geochemical characteristics and tectonic significance of granitoid rock in Alatage, Eastern Tianshan [Earth Science Edition]: Journal of Jilin University, v. 43, no. 3, p. 765–775.
Yu, N., 2015, Geochemical characteristics and tectonic environment of Carboniferous volcanic rock in the Yamansu volcanic arc of East Tianshan mountains [M.S. thesis]: Xinjiang University, 43 p.
Zang, Y., 2014, Geological characteristics and tectonic evolution of Yuhai porphyry copper deposit in Eastern Tianshan [M.S. thesis]: Chang'an University, 62 p.
Zhang, C., Liu, L., Santosh, M., Luo, Q., and Zhang, X., 2017a, Sediment recycling and crustal growth in the Central Asian Orogenic Belt: Evidence from Sr-Nd-Hf isotopes and trace elements in granitoids of the Chinese Altay: Gondwana Research, v. 47, p. 142–160, https://doi.org/10.1016/j.gr.2016.08.009.
Zhang, F., Wang, Y., and Liu, J., 2016, Petrogenesis of Late Carboniferous granitoids in the Chihu area of Eastern Tianshan, Northwest China, and tectonic implications: geochronological, geochemical, and zircon Hf-O isotopic constraints: International Geology Review, v. 58, no. 8, p. 949–966, https://doi.org/10.1080/00206814.2015.1136800.
Zhang, L., Wan, B., Li, W., and Tang, H., 2006a, Geochemistry and tectonic setting of copper-bearing porphyries on the southern margin of Tuha basin, Xinjiang: Yanshi Xuebao, v. 22, no. 1, p. 225–235.
Zhang, L., Xiao, W., Qin, K., and Zhang, Q., 2006b, The adakite connection of the Tuwu–Yandong copper porphyry belt, eastern Tianshan, NW China: trace element and Sr-Nd-Pb isotope geochemistry: Mineralium Deposita, v. 41, no. 2, p. 188–200, https://doi.org/10.1007/s00126-006-0058-6.
Zhang, R., 2013, Geochemical characteristics and petrogenesis of the Erhongwa mafic-ultramafic intrusion, Xinjiang [M.S. thesis]: Chang'an University, 48 p.
Zhang, T., 2014, The petrogenesis and tectonic setting of the Late Carboniferous volcanic rocks from Jueluotage area, Eastern Tianshan, NW China [M.S. thesis]: Chang'an University, 71 p.
Zhang, X., Zhao, G., Eizenhöfer, P.R., Sun, M., Han, Y., Hou, W., Liu, D., Wang, B., Liu, Q., and Xu, B., 2015a, Latest Carboniferous closure of the Junggar Ocean constrained by geochemical and zircon U–Pb–Hf isotopic data of granitic gneisses from the Central Tianshan block, NW China: Lithos, v. 238, p. 26–36, https://doi.org/10.1016/j.lithos.2015.09.012.
Zhang, X., Zhao, G., Sun, M., Han, Y., and Liu, Q., 2017b, Triassic magmatic reactivation in Eastern Tianshan, NW China: Evidence from geochemistry and zircon U-Pb-Hf isotopes of granites: Journal of Asian Earth Sciences, v. 145, p. 446–459, https://doi.org/10.1016/j.jseaes.2017.06.022.
Zhang, Y., Yuan, C., Sun, M., Long, X., Xia, X., Wang, X., and Huang, Z., 2015b, Permian doleritic dikes in the Beishan Orogenic Belt, NW China: Asthenosphere–lithosphere interaction in response to slab break-off: Lithos, v. 233, p. 174–192, https://doi.org/10.1016/j.lithos.2015.04.001.
Zhao, B., Deng, Y., Zhou, T., Yuan, F., Zhang, D., Deng, G., Li, W., and Li, Y., 2018, Petrogenesis of the Baixintan Ni-Cu sulfide-bearing mafic-ultramafic intrusion, East

Tianshan: Evidence from geochronology, petrochemistry and Sr-Nd isotope: Yanshi Xuebao, v. 34, no. 9, p. 2733–2753.

Zheng, R., 2015, Geological characteristics and genesis of Hongyuntan iron deposits in the Eastern Tianshan, Xinjiang [M.S. thesis]: Beijing, China University of Geosciences, 102 p.

Zhong, L., 2019, Paleozoic accretionary orogeny and crustal evolution of the western segment of Chinese Central Tianshan [Ph.D. thesis]: Nanjing University, 210 p.

Zhou, G., Wang, Y., Shi, Y., Xie, H., Li, D., and Guo, B., 2019, Geochronology and geochemistry of mafic intrusions in the Kalatag area, eastern Tianshan: Yanshi Xuebao, v. 35, no. 10, p. 3189–3212.

Zhou, H., 2014, Study on the Late Paleozoic intrusive rocks in the Xingxingxia region - Reconstructing the structural facies and tectonic eovlution during the Late Paleozoic [M.S. thesis]: Northwest University, 101 p.

Zhou, M., Lesher, C.M., Yang, Z., Li, J., and Sun, M., 2004, Geochemistry and petrogenesis of 270 Ma Ni–Cu–(PGE) sulfide-bearing mafic intrusions in the Huangshan district, Eastern Xinjiang, Northwest China: implications for the tectonic evolution of the Central Asian orogenic belt: Chemical Geology, v. 209, no. 3–4, p. 233–257, https://doi.org/10.1016/j.chemgeo.2004.05.005.

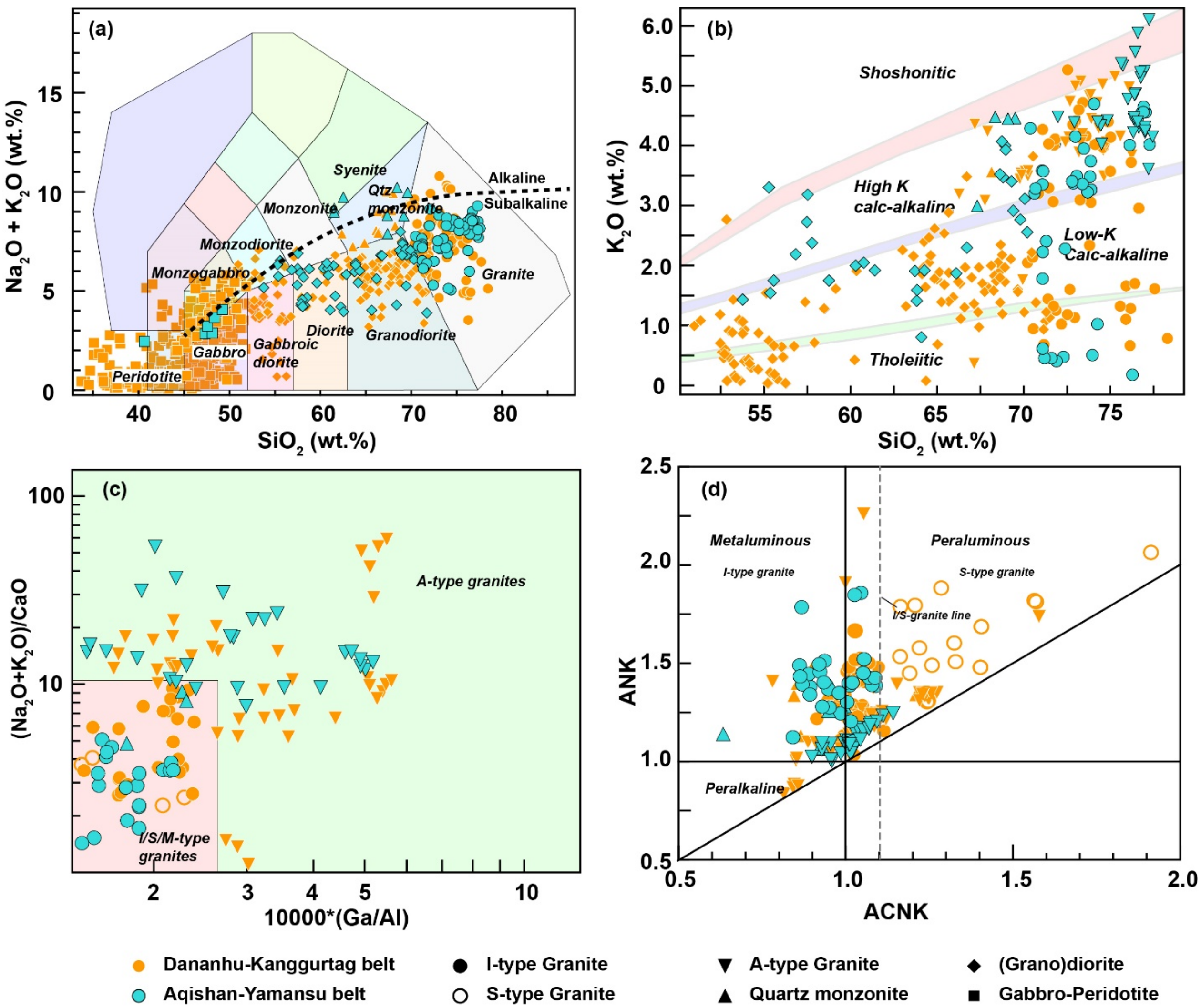


Figure S1 Representative geochemical classification diagrams of the Dananhu-Kanggurtag (orange) and the Aqishan-Yamansu plutons (tiffany blue). The symbols are legends for lithology.

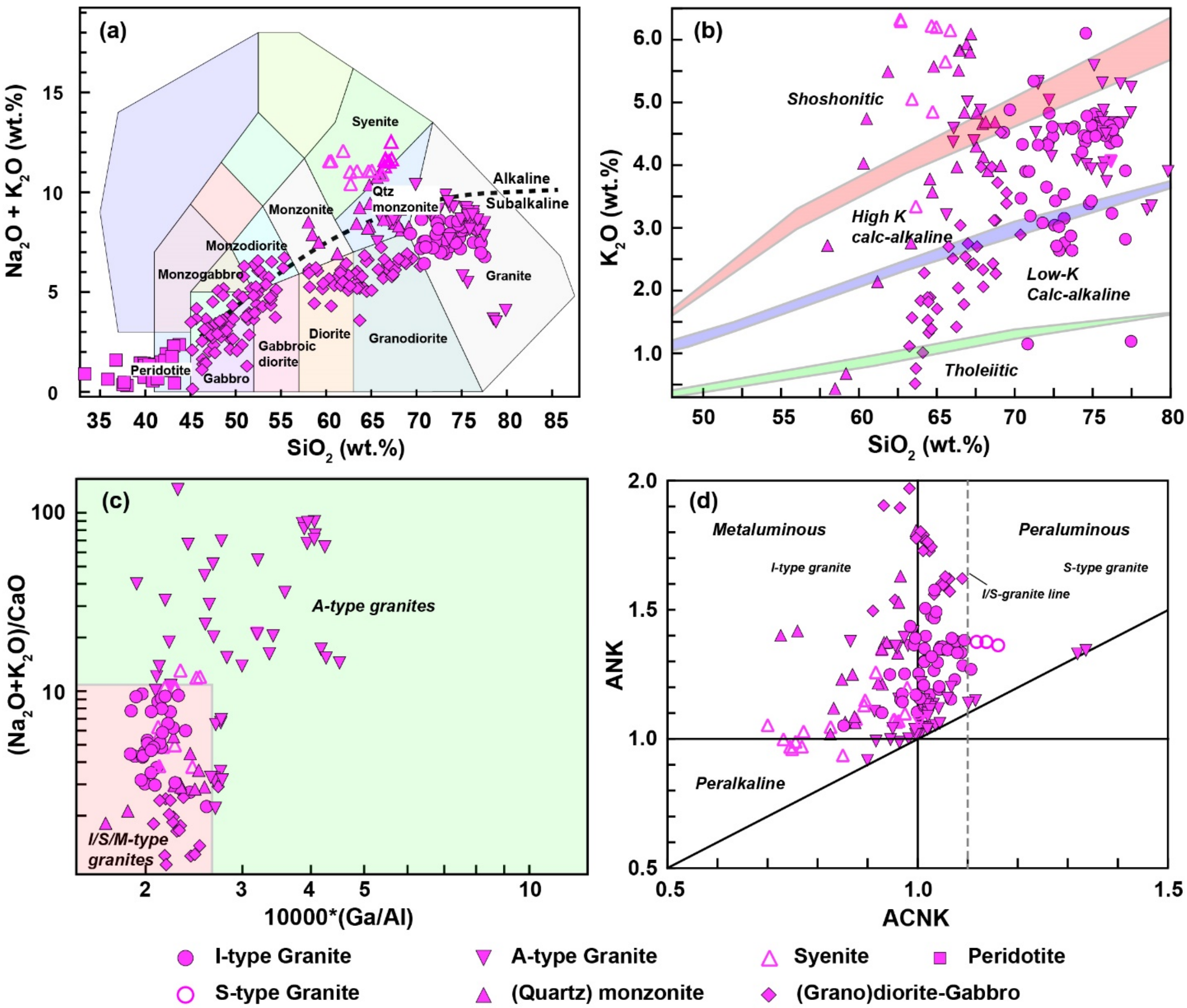


Figure S2 Representative geochemical classification diagrams of the Central Tianshan plutons.

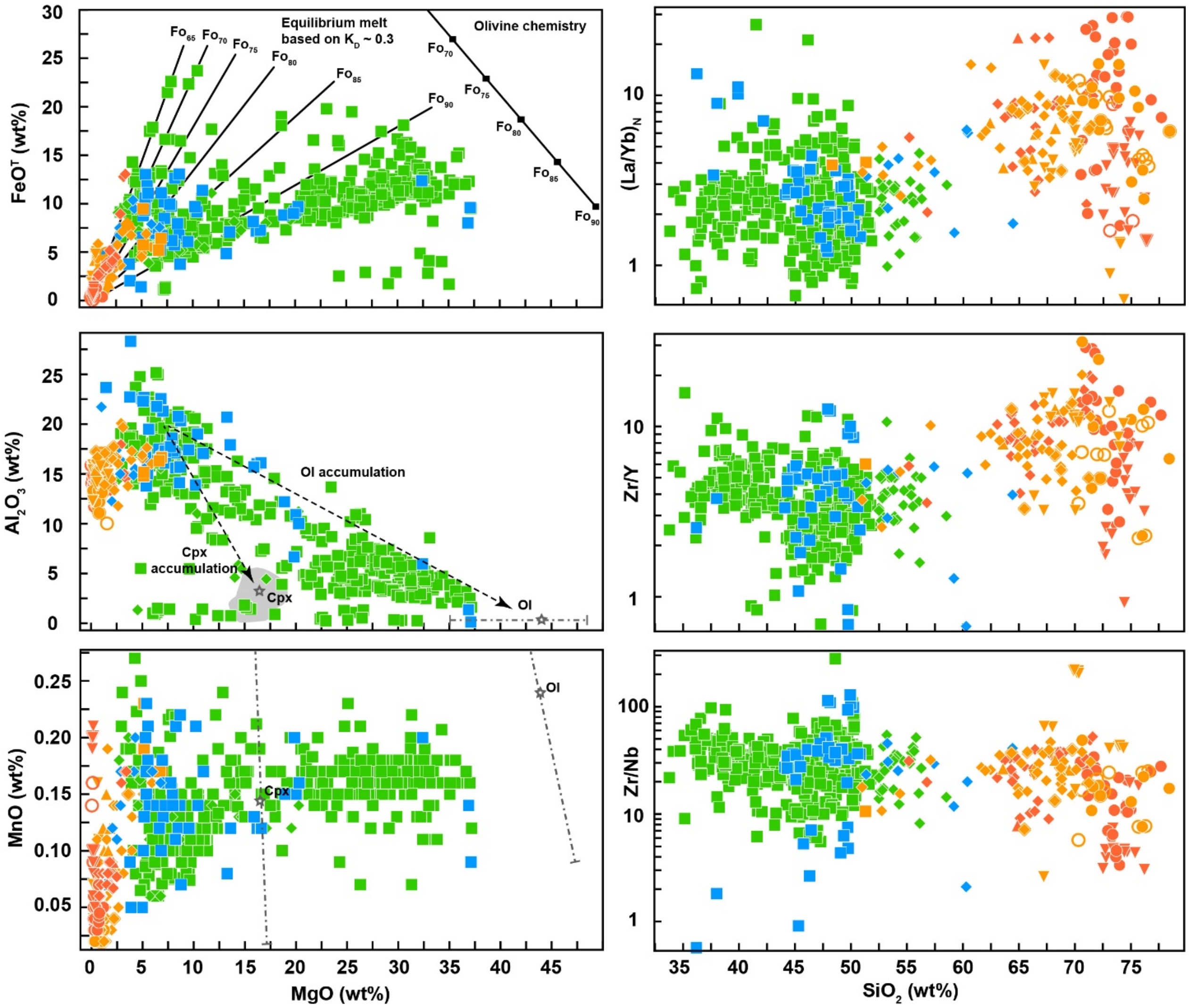


Figure S3 Plots of selected major oxides versus MgO contents and trace element ratios versus SiO_2 contents of the Dananhu-Kanggurtag intrusive rocks. In the plot of FeO^T versus MgO, solid lines depict the olivine composition with Fo contents and the equilibrium melt assuming $K_D^{Fe/Mg}$ ~ 0.3 (Roeder and Emslie, 1970). In the plots of Al_2O_3 and MnO versus MgO, grey fields, grey dash-dot lines show the composition of olivine and clinopyroxene from the mafic-ultramafic complexes and their average compositions are shown as star symbols. Sample symbols are referred to Figure S1.

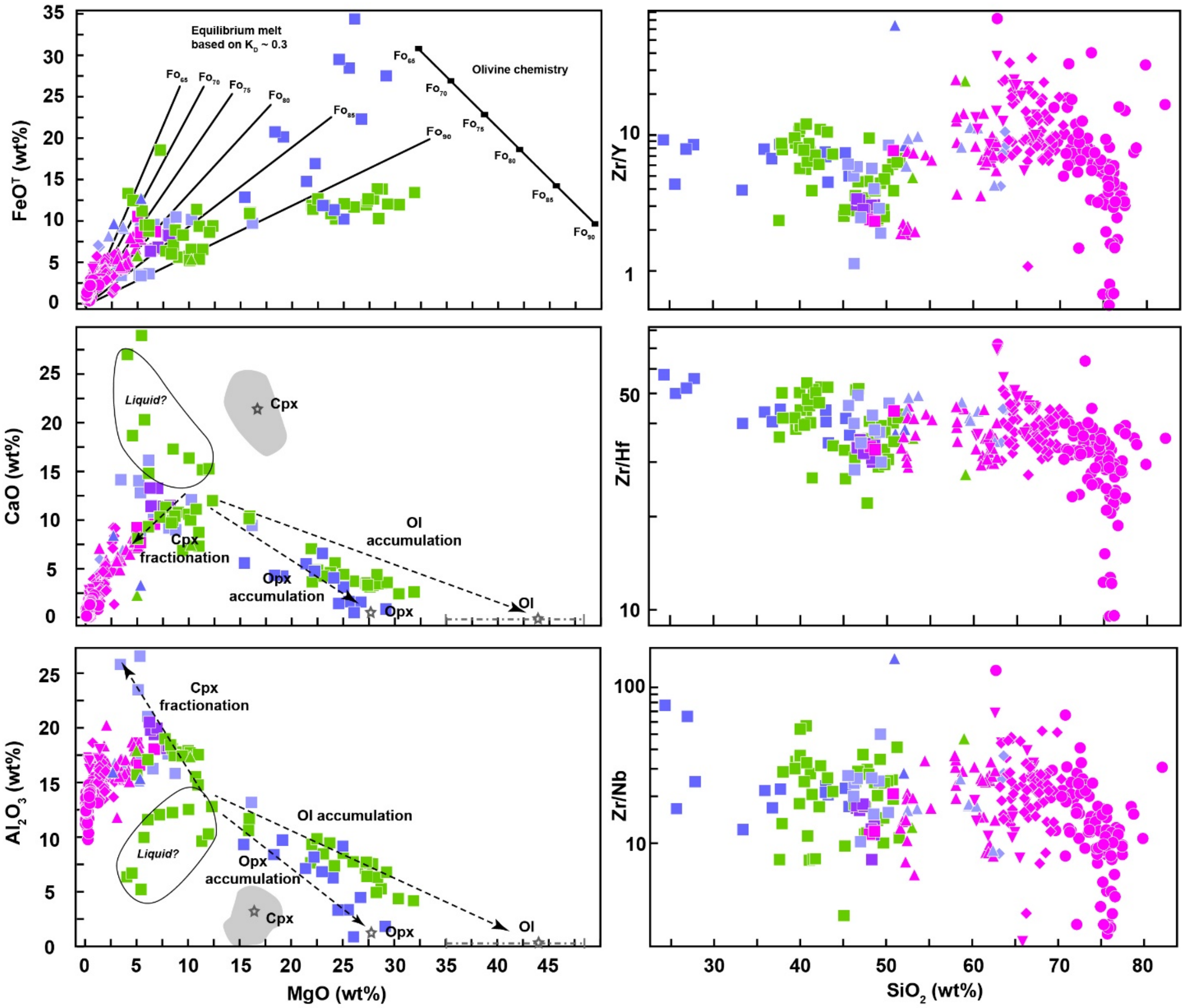


Figure S4 Plots of selected major oxides versus MgO contents and trace element ratios versus SiO_2 contents of the Central Tianshan intrusive rocks. Sample symbols are referred to Figure S2.

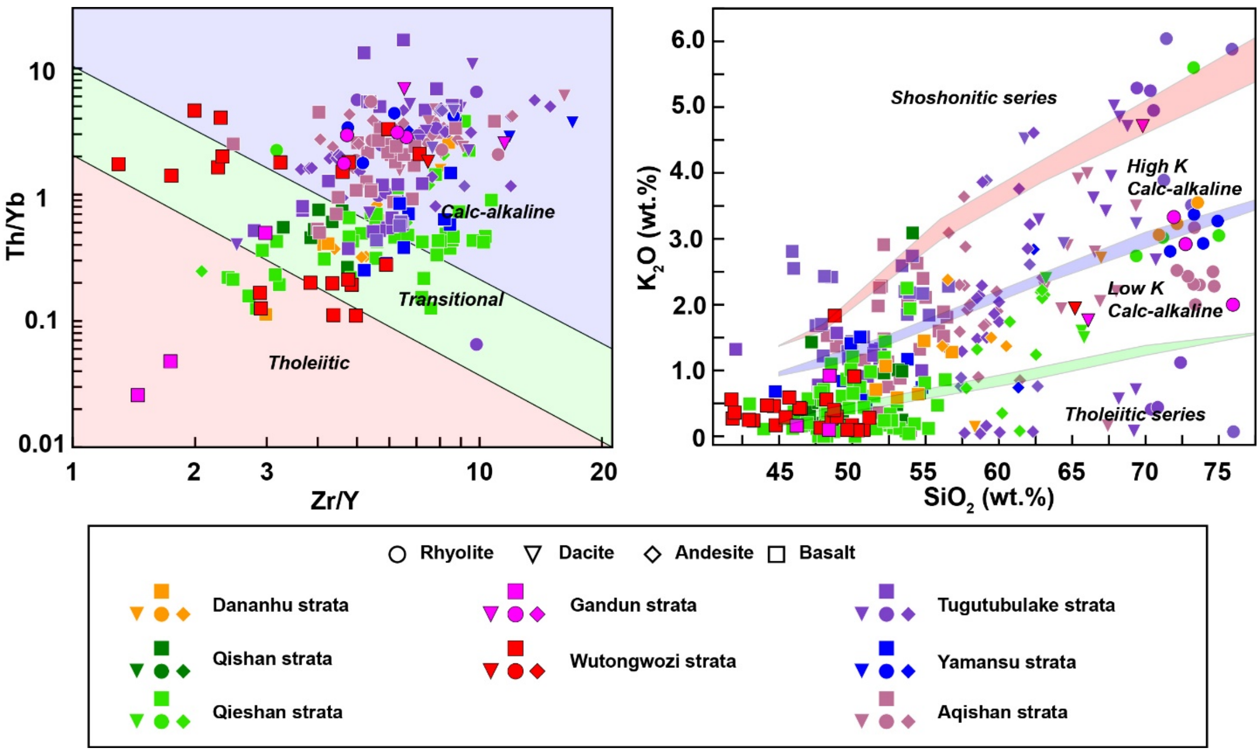


Figure S5 Binary plots of Zr/Y vs Th/Yb and SiO_2 (wt.%) vs K_2O (wt.%) for the volcanic lavas from the Dananhu-Kanggurtag belt and Aqishan-Yamansu belt.

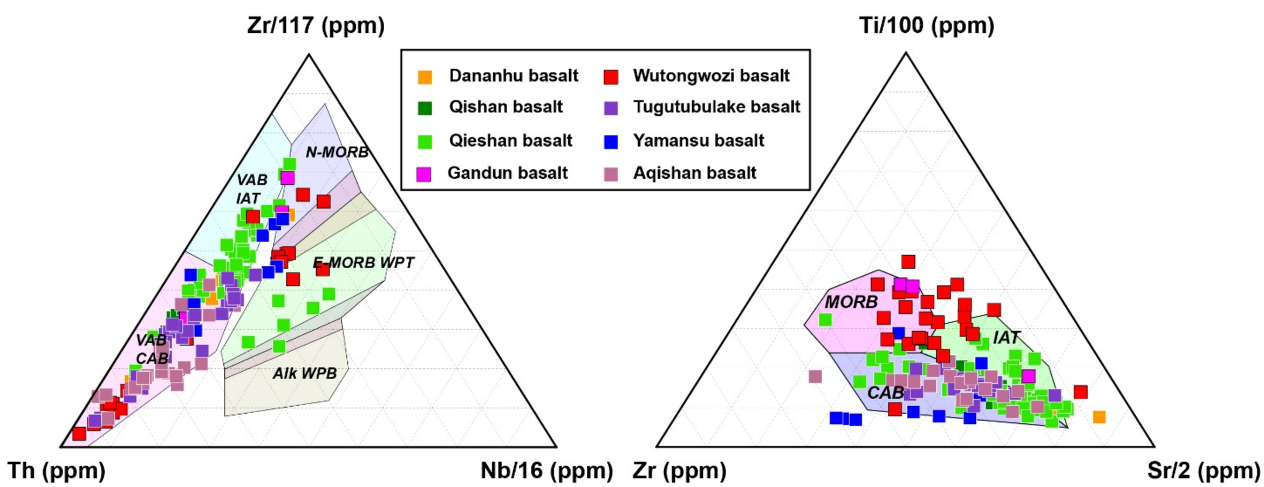


Figure S6 Ternary plots of Zr/117-Th-Nb/16 and Ti/100-Zr-Sr/2 for the basaltic lavas from the Dananhu-Kanggurtag belt and Aqishan-Yamansu belt.

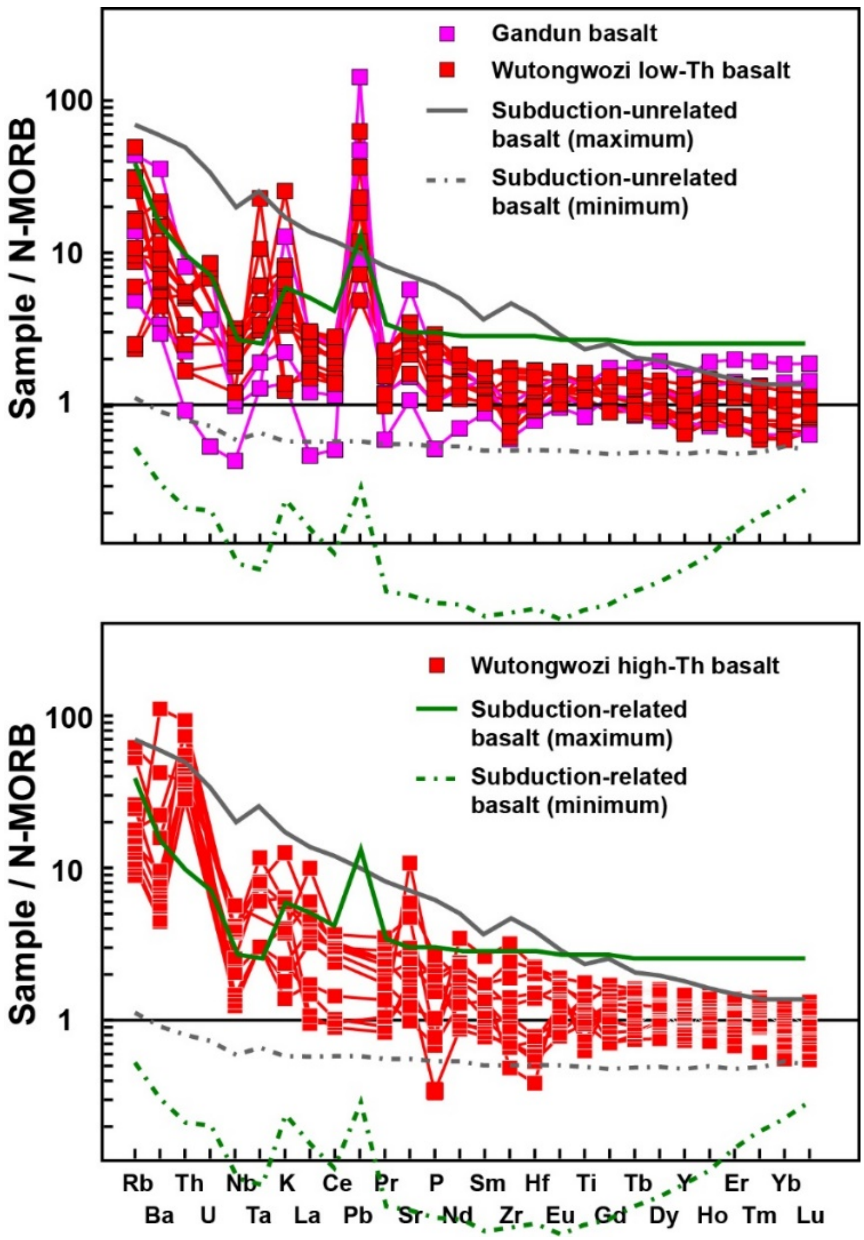


Figure S7 N-MORB normalized trace element patters of the Wutongwozi and Gundun basalts from the Dananhu-Kanggurtag belt.

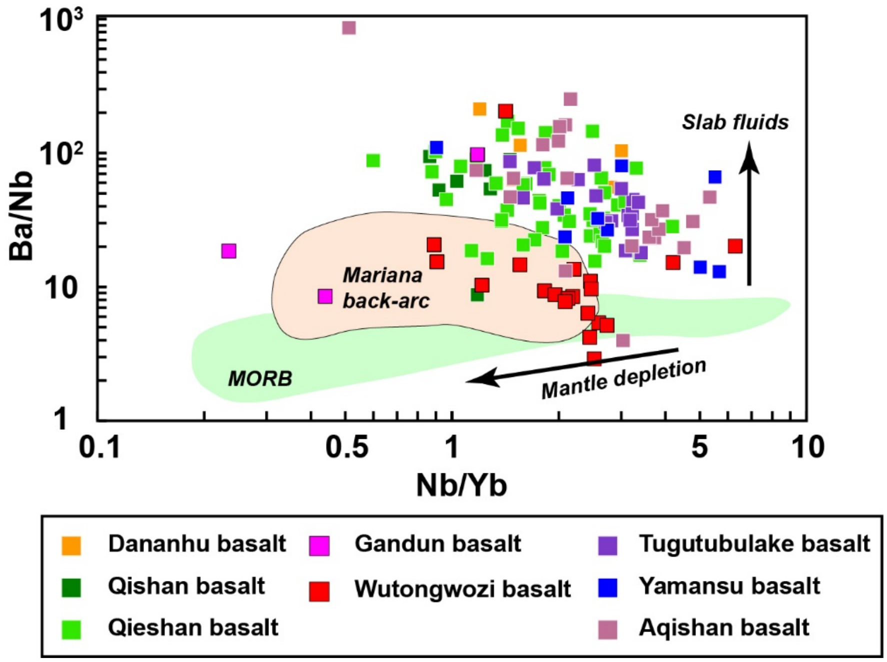


Figure S8 Variable plot of Nb/Yb versus Ba/Nb for the volcanic basalts the Dananhu-Kanggurtag belt and Aqishan-Yamansu belt.

Color version of figures in the main text

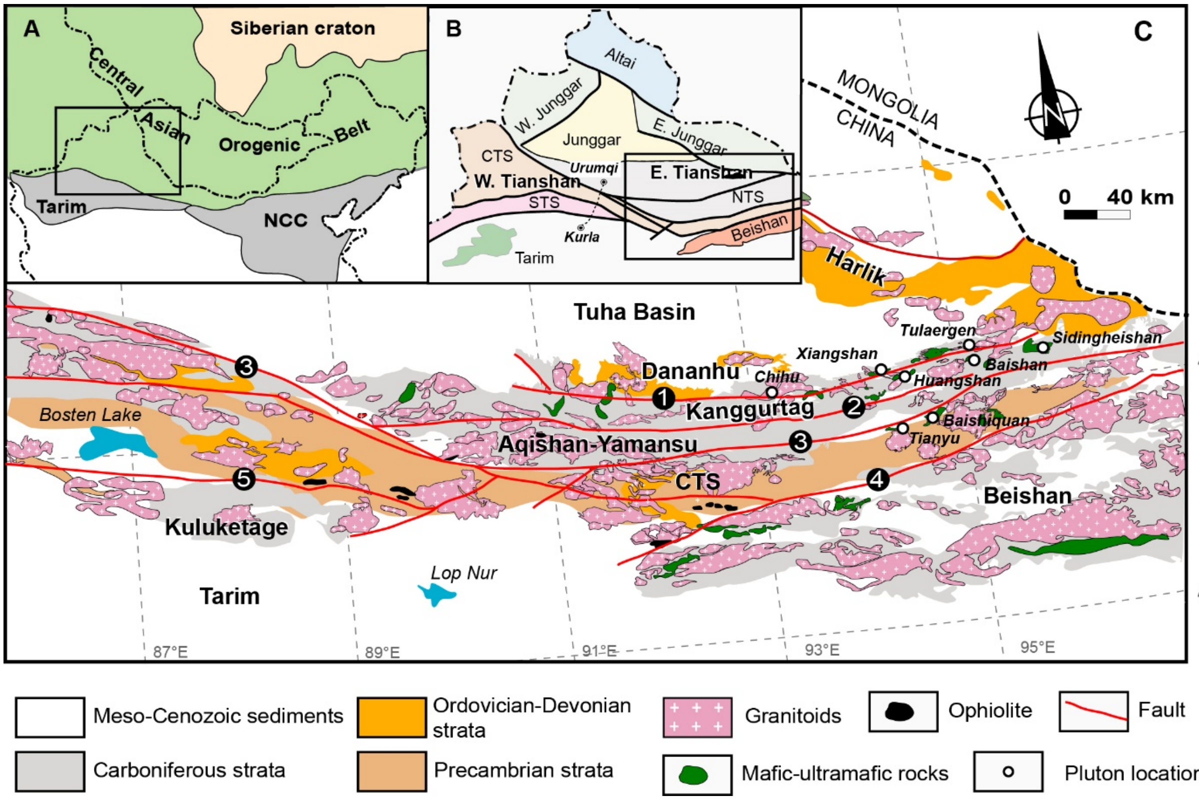


Figure 1

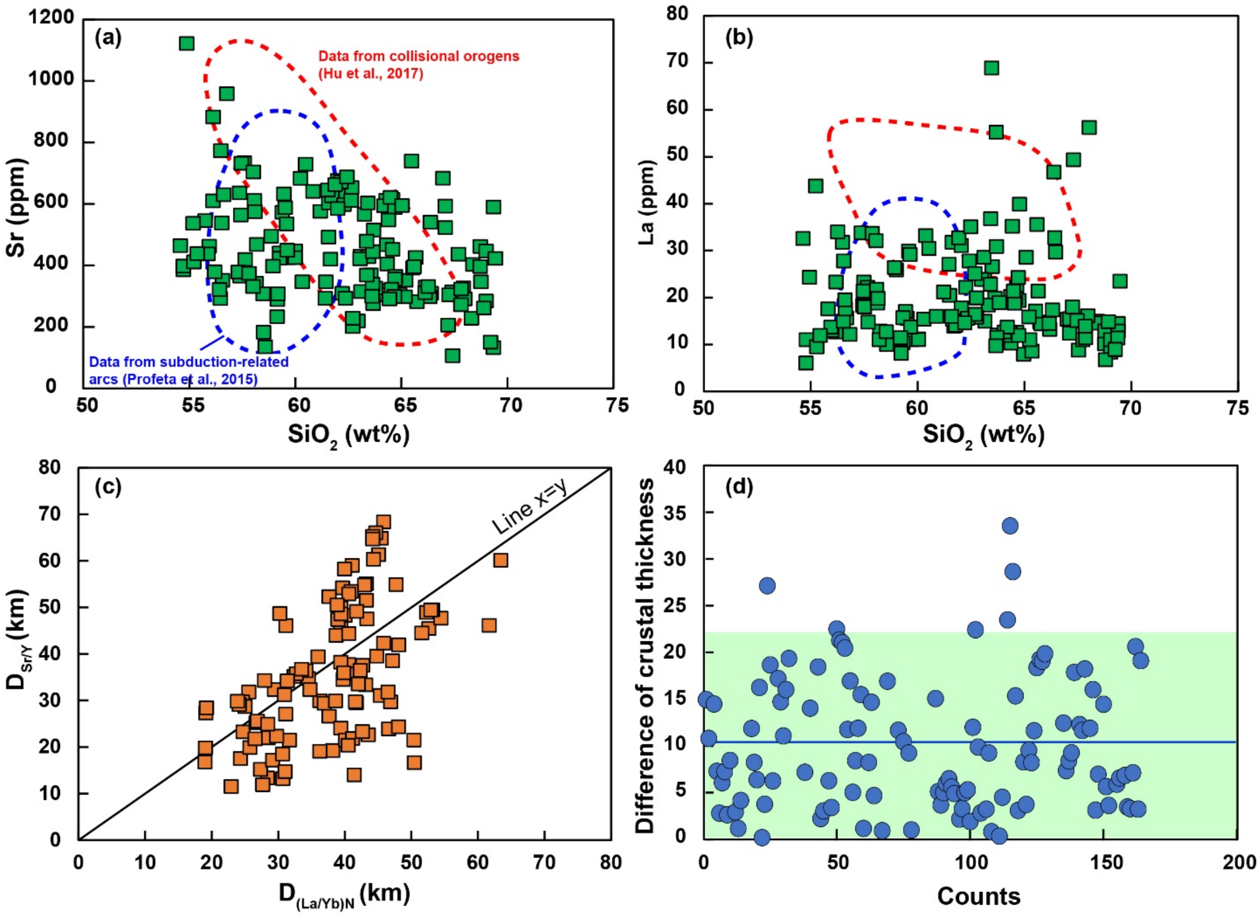

(a)
Data from collisional orogens
(Hu et al., 2017)
Data from subduction-related
arcs (Profeta et al., 2015)
Sr (ppm)
SiO2 (wt%)
(b)
La (ppm)
SiO2 (wt%)
(c)
Line x=y
DSr/Y (km)
D(La/Yb)N (km)
(d)
Difference of crustal thickness
Counts

Figure 2

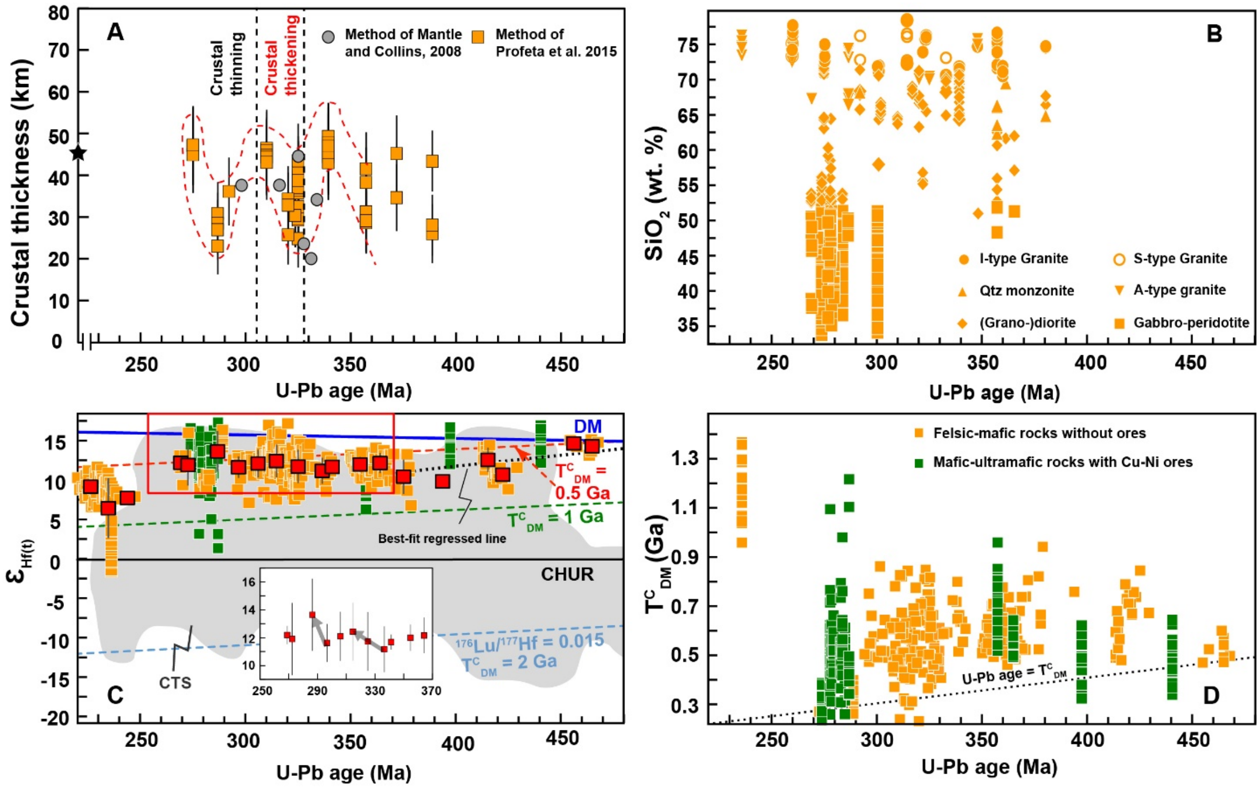


Figure 3

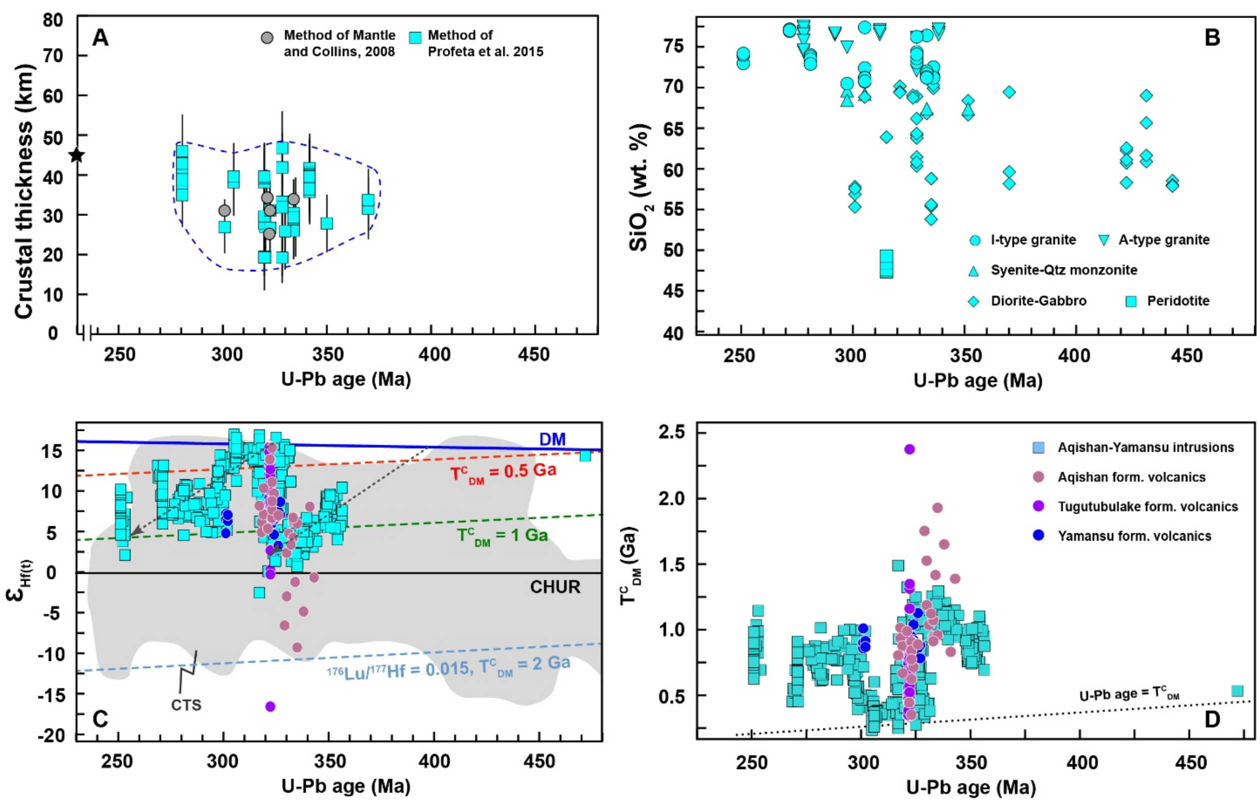
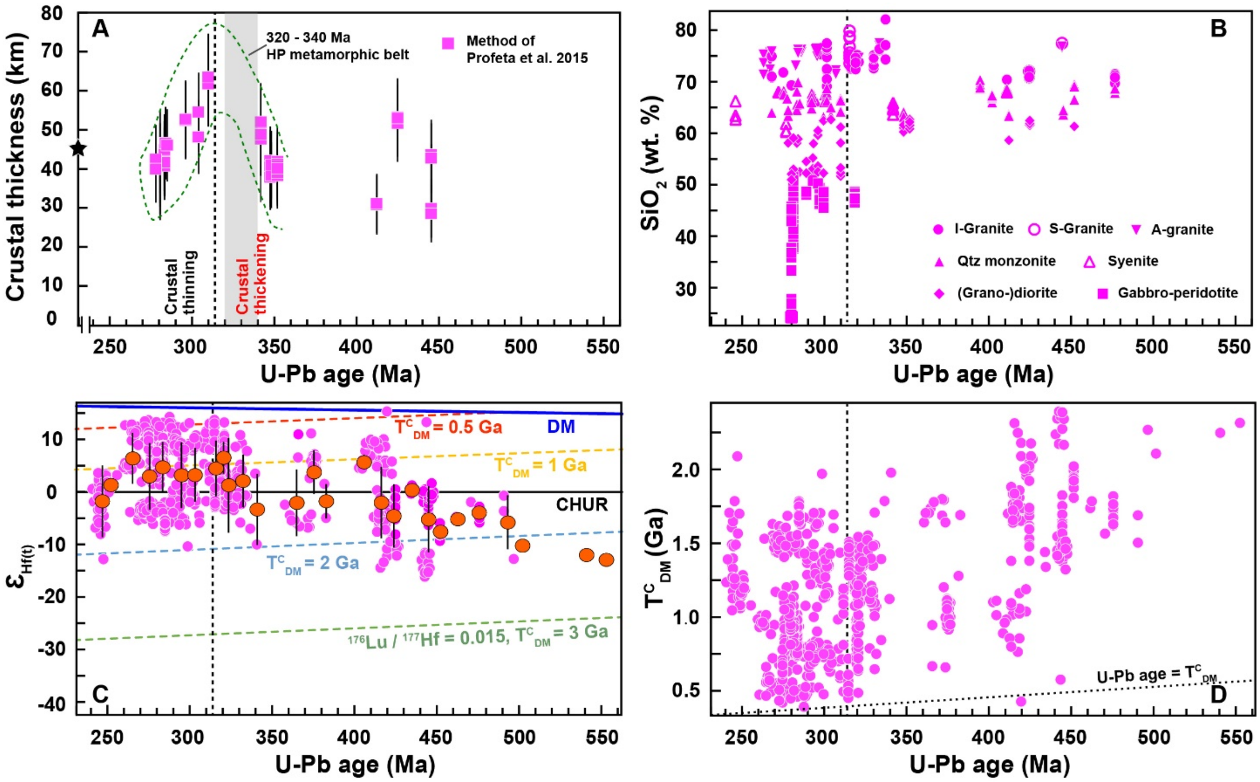


Figure 4



A
Crustal thickness (km)
320 - 340 Ma
HP metamorphic belt
Method of
Profeta et al. 2015
Crustal thinning
Crustal thickening
U-Pb age (Ma)
B
SiO2 (wt. %)
I-Granite
S-Granite
A-granite
Qtz monzonite
Syenite
(Grano-)diorite
Gabbro-peridotite
U-Pb age (Ma)
C
εHf(t)
TCDM = 0.5 Ga
DM
TCDM = 1 Ga
CHUR
TCDM = 2 Ga
176Lu / 177Hf = 0.015, TCDM = 3 Ga
U-Pb age (Ma)
D
TCDM (Ga)
U-Pb age = TCDM
U-Pb age (Ma)

Figure 5

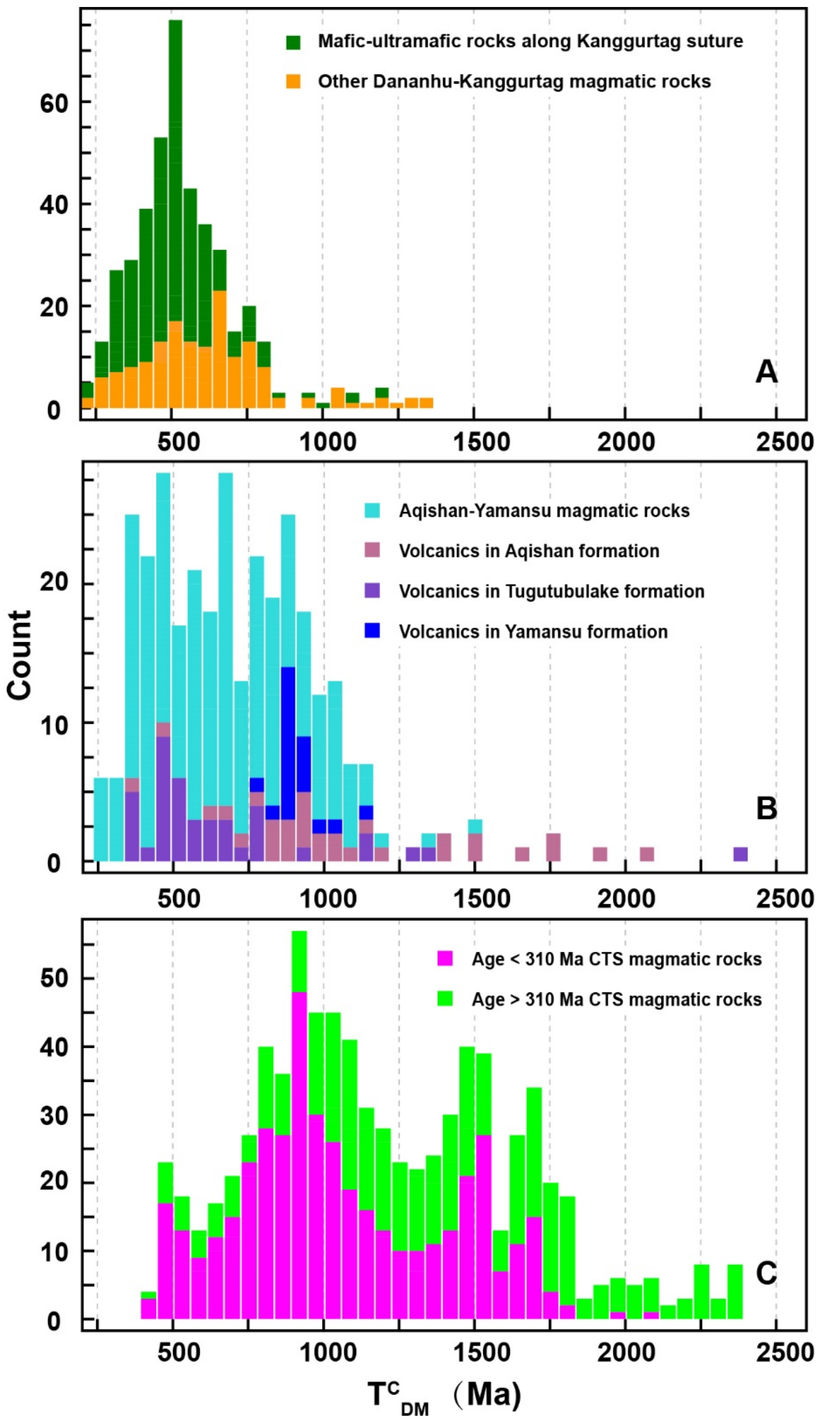

Mafic-ultramafic rocks along Kanggurtag suture
Other Dananhu-Kanggurtag magmatic rocks
A
Aqishan-Yamansu magmatic rocks
Volcanics in Aqishan formation
Volcanics in Tugutubulake formation
Volcanics in Yamansu formation
B
Count
Age < 310 Ma CTS magmatic rocks
Age > 310 Ma CTS magmatic rocks
C
T^C_DM (Ma)

Figure 6

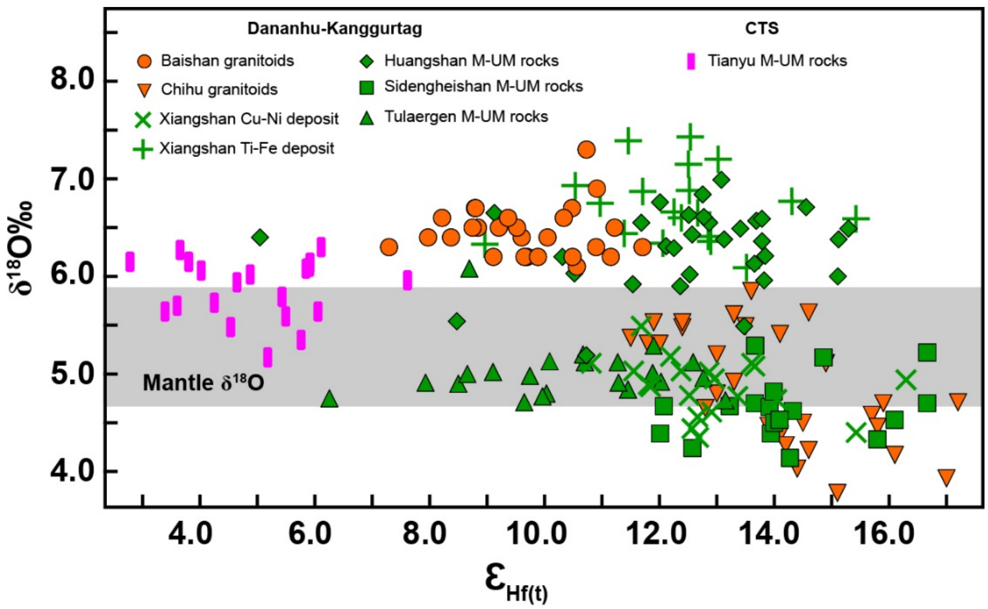

Dananhu-Kanggurtag
CTS
Baishan granitoids
Chihu granitoids
Xiangshan Cu-Ni deposit
Xiangshan Ti-Fe deposit
Huangshan M-UM rocks
Sidengheishan M-UM rocks
Tulaergen M-UM rocks
Tianyu M-UM rocks
Mantle $\delta^{18}O$
$\delta^{18}O$‰
$\varepsilon_{Hf(t)}$
8.0
7.0
6.0
5.0
4.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0

Figure 7

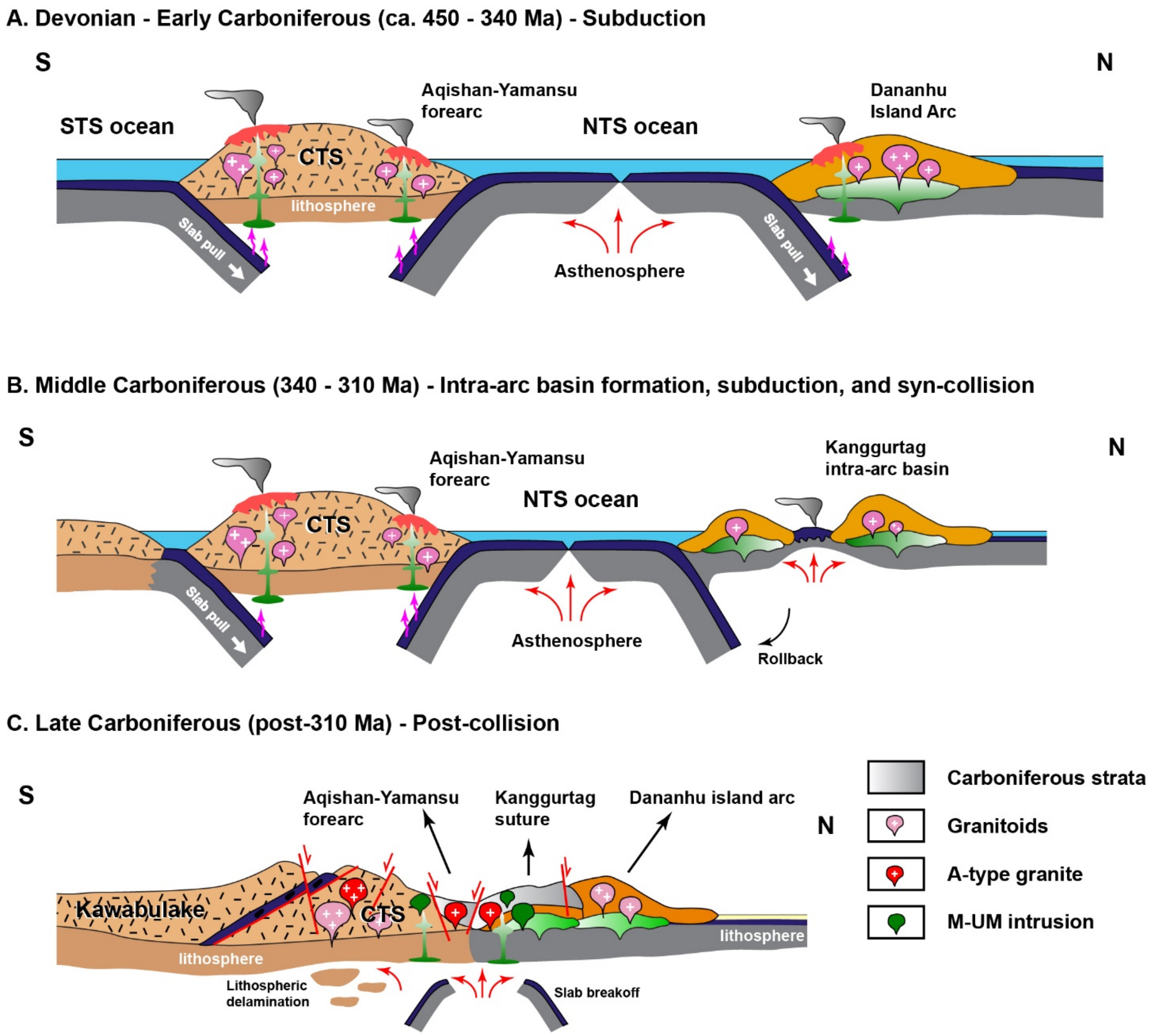

A. Devonian - Early Carboniferous (ca. 450 - 340 Ma) - Subduction
S
N
STS ocean
CTS
lithosphere
Slab pull
Aqishan-Yamansu
forearc
NTS ocean
Asthenosphere
Dananhu
Island Arc
Slab pull
B. Middle Carboniferous (340 - 310 Ma) - Intra-arc basin formation, subduction, and syn-collision
S
N
CTS
Slab pull
Aqishan-Yamansu
forearc
NTS ocean
Asthenosphere
Kanggurtag
intra-arc basin
Rollback
C. Late Carboniferous (post-310 Ma) - Post-collision
S
N
Kawabulake
CTS
lithosphere
Lithospheric
delamination
Aqishan-Yamansu
forearc
Kanggurtag
suture
Dananhu island arc
lithosphere
Slab breakoff
Carboniferous strata
Granitoids
A-type granite
M-UM intrusion

Figure 8

Table S1 Summary of the calibrated crustal thickness using the method by Profeta et al. (2015)

Longitude	Latitude	Sample No.	Location	Area	Data source	Age (Ma)	error	Rb/Sr	Sr/Y	$D_{Sr/Y}$	La/Yb_N	$D_{La/YbN}$	2SD	Diff.
89.733657	42.242795	LI-10	Xiaorequanzi	Dananhu	Pan, 2009	325	3.2	0.18	34.44	46.28	4.25	31.22	7.63	15.06
89.733657	42.242795	LI-11	Xiaorequanzi	Dananhu	Pan, 2009	325	3.2	0.12	16.92	26.84	5.77	37.73	8.33	10.90
89.733657	42.242795	LI-24	Xiaorequanzi	Dananhu	Pan, 2009	325	3.2	0.15	50.10	63.66	8.90	46.93	9.33	
89.733657	42.242795	LI-45	Xiaorequanzi	Dananhu	Pan, 2009	325	3.2	0.08	41.70	54.33	6.35	39.76	8.55	14.58
89.733657	42.242795	Ll-8	Xiaorequanzi	Dananhu	Pan, 2009	325	3.2	0.09	34.96	46.86	6.26	39.47	8.52	7.38
89.733657	42.242795	LI-9	Xiaorequanzi	Dananhu	Pan, 2009	325	3.2	0.09	24.63	35.39	4.51	32.46	7.77	2.93
89.733657	42.242795	LI-22	Xiaorequanzi	Dananhu	Pan, 2009	325	3.2	0.10	19.93	30.17	5.41	36.34	8.19	6.17
89.733657	42.242795	LI-23	Xiaorequanzi	Dananhu	Pan, 2009	325	3.2	0.16	19.46	29.66	5.58	37.01	8.26	7.35
89.733657	42.242795	LI-33	Xiaorequanzi	Dananhu	Pan, 2009	325	3.2	0.10	26.92	37.93	6.62	40.66	8.65	2.73
89.733657	42.242795	2	Xiaorequanzi	Dananhu	Wang P. et al., 2011	325	3.2	0.03	22.09	32.57	3.92	29.52	7.45	3.05
89.733657	42.242795	3	Xiaorequanzi	Dananhu	Wang P. et al., 2011	325	3.2	0.11	13.92	23.50	3.14	24.79	6.94	1.29
89.733657	42.242795	4	Xiaorequanzi	Dananhu	Wang P. et al., 2011	325	3.2	0.05	35.71	47.69	7.54	43.41	8.95	4.28
93.131147	42.461619	XT404-11-1	Dananhu	Dananhu	Liu, 2016	388.8	1.7	0.05	37.34	49.50	5.79	37.81	8.34	11.69
93.131147	42.461619	XT404-11-2	Dananhu	Dananhu	Liu, 2016	388.8	1.7	0.17	22.03	32.51	7.49	43.28	8.93	10.78
93.131147	42.461619	XT102-4-1	Dananhu	Dananhu	Liu, 2016	388.8	1.7	0.08	36.73	48.83	3.33	26.00	7.07	22.83
93.131147	42.461619	XT404-22-1	Dananhu	Dananhu	Liu, 2016	388.8	1.7	0.06	42.53	55.26	7.50	43.31	8.93	11.96
93.131147	42.461619	XT404-29-2	Dananhu	Dananhu	Liu, 2016	388.8	1.7	0.05	17.59	27.57	2.42	19.22	6.34	8.35
93.131147	42.461619	XT501-11-1	Dananhu	Dananhu	Liu, 2016	388.8	1.7	0.06	23.86	34.53	3.66	28.03	7.29	6.50
93.301025	42.558667	D-8	Dananhu	Dananhu	Xiong, 2015	371.8	7	0.09	48.13	61.48	8.18	45.14	9.13	16.33
93.301025	42.558667	D-4	Dananhu	Dananhu	Xiong, 2015	371.8	7	0.09	24.21	34.92	4.99	34.62	8.00	0.30
91.607358	42.399662	14	Kezilkalasayi	Dananhu	Kahaer, 2010	357.3	6.2	0.10	17.37	27.33	4.25	31.21	7.63	3.89
91.607358	42.399662	17	Kezilkalasayi	Dananhu	Kahaer, 2010	357.3	6.2	0.12	5.65	14.33	6.89	41.50	8.74	27.18
91.607358	42.399662	18	Kezilkalasayi	Dananhu	Kahaer, 2010	357.3	6.2	0.19	10.33	19.52	5.92	38.26	8.39	18.74
91.607358	42.399662	19	Kezilkalasayi	Dananhu	Kahaer, 2010	357.3	6.2	0.16	12.76	22.21	3.76	28.58	7.35	6.37
91.787433	42.558656	09SF10	Shaerhu	Dananhu	Mao et al., 2014	286.7	2.1	0.20	4.88	13.47	4.16	30.77	7.59	17.30
91.787433	42.558656	09SF11	Shaerhu	Dananhu	Mao et al., 2014	286.7	2.1	0.19	5.06	13.66	3.74	28.48	7.34	14.81
91.787433	42.558656	09SF13	Shaerhu	Dananhu	Mao et al., 2014	286.7	2.1	0.16	3.41	11.84	2.89	23.01	6.75	
92.556557	42.304583	YD13-114	Tuwu-	Dananhu	Xiao et al., 2017	339.3	2.2	0.14	47.23	60.48	7.89	44.39	9.05	16.09
92.556557	42.304583	Btw38	Tuwu-	Dananhu	Xiao et al., 2017	339.3	2.2	0.07	51.27	64.96	8.33	45.53	9.17	19.42
92.556557	42.304583	T-4f	Tuwu-	Dananhu	Xiao et al., 2017	339.3	2.2				8.07	44.85	9.10	
92.556557	42.304583	R-2	Tuwu-	Dananhu	Xiao et al., 2017	339.3	2.2				8.91	46.97	9.33	
92.556557	42.304583	YD-6	Tuwu-	Dananhu	Xiao et al., 2017	339.3	2.2	0.11	42.36	55.07	9.26	47.79	9.42	7.28
92.556557	42.304583	RY-2	Tuwu-	Dananhu	Xiao et al., 2017	339.3	2.2				8.91	46.97	9.33	
92.556557	42.304583	YD13-145	Tuwu-	Dananhu	Xiao et al., 2017	323.6	2.5	0.05	36.77	48.86	4.08	30.33	7.54	18.53
92.947828	42.445485	CH001-16	Chihu	Dananhu	Zhang et al., 2016	320.2	2.4	0.12	25.73	36.61	4.90	34.25	7.96	2.36
92.947828	42.445485	CH001-14	Chihu	Dananhu	Zhang et al., 2016	320.2	2.4	0.14	25.14	35.96	4.58	32.80	7.80	3.16
92.947828	42.445485	CH001-15	Chihu	Dananhu	Zhang et al., 2016	320.2	2.4	0.15	21.63	32.06	3.28	25.69	7.04	6.38
92.947828	42.445485	CH-21	Chihu	Dananhu	Zhang et al., 2016	320.2	2.4	0.12	23.57	34.21	5.20	35.51	8.10	1.30
92.947828	42.445485	CHOO 1-6	Chihu	Dananhu	Zhang et al., 2016	320.2	2.4	0.10	21.18	31.56	6.33	39.68	8.54	8.12
92.947828	42.445485	CHOO 1-5	Chihu	Dananhu	Zhang et al., 2016	314.5	2.5	0.09	32.51	44.13	6.52	40.32	8.61	3.82
92.947828	42.445485	CHOO 1-4	Chihu	Dananhu	Zhang et al., 2016	314.5	2.5	0.07	28.12	39.26	7.11	42.17	8.81	2.91
92.947828	42.445485	Bchl4	Chihu	Dananhu	Li et al., 2002	292.1	3.5	0.11	28.42	39.60	5.34	36.08	8.16	3.52
92.291522	42.184332	X3ET240	Kanggurtag	Kanggurtag	Du et al., 2019	360	3	0.20	18.66	28.76	3.62	27.81	7.27	0.95
92.291522	42.184332	X3ET241	Kanggurtag	Kanggurtag	Du et al., 2019	360	3	0.11	30.90	42.35	5.43	36.45	8.20	
92.291522	42.184332	X3ET242	Kanggurtag	Kanggurtag	Du et al., 2019	360	3	0.18	10.81	20.04	3.42	26.60	7.14	6.56
92.291522	42.184332	X3ET243	Kanggurtag	Kanggurtag	Du et al., 2019	360	3	0.11	26.00	36.91	3.66	28.03	7.29	8.88
92.291522	42.184332	X3ET244	Kanggurtag	Kanggurtag	Du et al., 2019	360	3	0.07	10.88	20.13	2.29	18.07	6.22	2.06
92.291522	42.184332	X3ET216	Kanggurtag	Kanggurtag	Du et al., 2019	310	2	0.06	54.42	68.46	8.47	45.90	9.21	22.56
92.291522	42.184332	X3ET217	Kanggurtag	Kanggurtag	Du et al., 2019	310	2	0.05	52.31	66.11	8.02	44.73	9.09	21.38
92.291522	42.184332	X3ET218	Kanggurtag	Kanggurtag	Du et al., 2019	310	2	0.05	51.65	65.38	7.85	44.27	9.04	21.12

92.291522	42.184332	X3ET219	Kanggurtag	Kanggurtag	Du et al., 2019	310	2	0.06	51.13	64.80	7.85	44.27	9.04	20.54
92.291522	42.184332	X3ET221	Kanggurtag	Kanggurtag	Du et al., 2019	310	2	0.07	42.21	54.91	7.41	43.05	8.91	
94.951324	42.592765	HG-02	Hancaohu	Kanggurtag	Lv, 2013	275	2.9	0.19	28.54	39.73	8.07	44.86	9.10	5.14
94.951324	42.592765	HG-03	Hancaohu	Kanggurtag	Lv, 2013	275	2.9	0.20	27.62	38.71	9.02	47.22	9.36	8.51
90.943557	41.945755	XI40709-1	Aqishan	Yamansu	Mo, 2016	334	2	0.17	6.68	15.47	3.56	27.44	7.23	11.97
90.943557	41.945755	X150714-8	Aqishan	Yamansu	Liu, 2017	350	2	0.05	3.72	12.18	3.61	27.75	7.26	15.57
90.943557	41.945755	X140914-5	Aqishan	Yamansu	Qing, 2006	302.4		0.17	15.70	25.48	3.45	26.76	7.15	1.28
90.943557	41.945755	15-58	Aqishan	Yamansu	Su et al., 2009	341.7	2.7	0.05	36.39	48.44	6.46	40.11	8.59	8.33
90.943557	41.945755	15-15	Aqishan	Yamansu	Su et al., 2009	341.7	2.7	0.05	40.02	52.47	5.77	37.73	8.33	14.74
90.943557	41.945755	15-52/2	Aqishan	Yamansu	Su et al., 2009	341.7	2.7	0.11	25.06	35.87	6.62	40.66	8.65	4.79
90.943557	41.945755	15--6	Aqishan	Yamansu	Su et al., 2009	341.7	2.7	0.12	27.36	38.42	6.26	39.47	8.52	1.05
90.943557	41.945755	15-21	Aqishan	Yamansu	Su et al., 2009	341.7	2.7	0.19	10.19	19.36	5.41	36.34	8.19	
93.449775	42.081553	YM-1	Yamansu	Yamansu	Cao, 2012	334		0.12	5.42	14.06	4.25	31.21	7.63	17.15
93.449775	42.081553	YM-2	Yamansu	Yamansu	Cao, 2012	334		0.06	4.66	13.23	3.44	26.69	7.15	13.46
92.318643	41.983444	DK-4	Tugutubulake	Yamansu	Cao, 2012	320	1.2	0.05	8.49	17.48	3.87	29.25	7.42	11.77
92.009022	41.926211	07Y-1235	Tugutubulake	Yamansu	Li et al., 2011	320	1.2	0.05	37.86	50.07	6.28	39.52	8.53	
92.009022	41.926211	D041-2YQ	Tugutubulake	Yamansu	Yan, 2015	320.5	1.2	0.16	18.56	28.65	2.43	19.30	6.35	9.35
92.009022	41.926211	D295-2YQ	Tugutubulake	Yamansu	Yan, 2015	320.5	1.2	0.09	16.01	25.82	3.48	26.94	7.17	1.12
91.127457	41.968209	N-13-RS-3	Tugutubulake	Yamansu	Dilimulati, 2016	314	4.2	0.06	4.66	13.22	3.44	26.71	7.15	13.49
91.127457	41.968209	N-13-RS-4	Tugutubulake	Yamansu	Dilimulati, 2016	314	4.2	0.04	6.42	15.17	4.65	33.12	7.84	17.95
91.127457	41.968209	N-6-RS4	Tugutubulake	Yamansu	Yu, 2015	314	4.2	0.17	14.65	24.31	6.26	39.46	8.52	
91.127457	41.968209	N-13-RS-2	Tugutubulake	Yamansu	Dilimulati, 2016	314	4.2	0.12	5.42	14.06	4.24	31.16	7.63	17.09
91.127457	41.968209	N-13-RS-3	Tugutubulake	Yamansu	Dilimulati, 2016	314	4.2	0.06	4.66	13.22	3.44	26.71	7.15	13.49
91.127457	41.968209	HLF-4	Tugutubulake	Yamansu	Li, 2018	305.3	2.4	0.17	14.65	24.31	6.26	39.46	8.52	15.15
91.127457	41.968209	16CXS-5	Tugutubulake	Yamansu	Wu, 2019	330	3	0.12	19.74	29.96	3.13	24.73	6.93	5.23
91.127457	41.968209	16CXS-6	Tugutubulake	Yamansu	Wu, 2019	330	3	0.15	18.81	28.92	3.19	25.11	6.98	3.81
91.127457	41.968209	16CXS-7	Tugutubulake	Yamansu	Wu, 2019	330	3	0.16	19.19	29.35	3.06	24.23	6.88	5.12
91.127457	41.968209	16CXS-8	Tugutubulake	Yamansu	Wu, 2019	330	3	0.09	19.81	30.04	3.02	23.95	6.85	6.09
91.127457	41.968209	16CXS-12	Tugutubulake	Yamansu	Wu, 2019	330	3	0.18	10.88	20.13	3.30	25.82	7.05	5.69
89.990045	42.073961	L2-8	Haerjiawu	Yamansu	Teng et al., 2017	280.60	1.8	0.08	26.77	37.77	7.31	42.77	8.88	5.00
89.990045	42.073961	L2-12-1	Haerjiawu	Yamansu	Teng et al., 2017	280.60	1.8	0.10	22.10	32.58	5.04	34.86	8.03	2.28
89.990045	42.073961	L2-12-2	Haerjiawu	Yamansu	Teng et al., 2017	280.60	1.8	0.10	31.05	42.51	8.48	45.91	9.21	
89.990045	42.073961	L2-14	Haerjiawu	Yamansu	Teng et al., 2017	280.60	1.8	0.13	24.02	34.71	6.37	39.83	8.56	5.12
89.990045	42.073961	L2-16	Haerjiawu	Yamansu	Teng et al., 2017	280.60	1.8	0.12	32.54	44.16	6.06	38.77	8.45	5.40
91.065856	41.959365	HYT-134	Hongyuntan	Yamansu	Zheng, 2015	328.5	9.3	0.11	8.14	17.08	2.40	19.10	6.33	2.02
91.065856	41.959365	X333	Hongyuntan	Yamansu	Wu et al., 2006	328.50	9.3	0.17	19.51	29.71	6.99	41.80	8.77	12.09
91.065856	41.959365	X334	Hongyuntan	Yamansu	Wu et al., 2006	328.50	9.3	0.21	14.51	24.16	8.78	46.66	9.30	22.49
91.065856	41.959365	X353	Hongyuntan	Yamansu	Wu et al., 2006	328.50	9.3	0.21	12.37	21.78	4.36	31.77	7.69	9.99
91.249325	41.927862	DO2O/2YQ	Bailingshan	Yamansu	Dai, 2015	305.3	2.4	0.05	16.70	26.59	2.48	19.72	6.40	6.87
91.249325	41.927862	DO21/3YQ	Bailingshan	Yamansu	Dai, 2015	305.3	2.4	0.15	12.03	21.40	3.37	26.29	7.10	4.89
95.88306	42.644398	X460	Xianshuiquan	Yamansu	Tang et al., 2007	369.9	5.6	0.12	23.76	34.42	4.30	31.46	7.66	2.96
95.88306	42.644398	X462	Xianshuiquan	Yamansu	Tang et al., 2007	369.9	5.6	0.06	26.02	36.93	4.75	33.59	7.89	3.34
94.650655	42.249212	B0036-60	Tugutubulake	Yamansu	Huang et al., 2012	320	1.2	0.23	6.73	15.52	4.56	32.73	7.80	17.21
94.650655	42.249212	D041/2YQ	Tugutubulake	Yamansu	Huang et al., 2012	320	1.2	0.16	18.56	28.65	2.43	19.30	6.35	9.35
85.232863	42.920664		Bijigaibulutai	CTS	Abulizi, 2019	341.8	2.1	0.20	14.90	24.59	9.41	48.13	9.45	23.53
85.232863	42.920664		Bijigaibulutai	CTS	Abulizi, 2019	341.8	2.1	0.15	8.00	16.93	10.52	50.51	9.71	
85.232863	42.920664		Bijigaibulutai	CTS	Abulizi, 2019	341.8	2.1	0.17	12.37	21.78	10.51	50.47	9.71	28.69
85.668008	42.806362		Yikaibulusitai	CTS	Abulizi, 2019	309.9	5.1	0.12	34.47	46.31	17.84	61.74	10.92	15.44
85.668008	42.806362		Yikaibulusitai	CTS	Abulizi, 2019	309.9	5.1	0.13	47.04	60.27	19.38	63.49	11.11	3.23
85.668008	42.806362		Yikaibulusitai	CTS	Abulizi, 2019	309.9	5.1	0.14	25.71	36.59	8.05	44.79	9.09	
87.0103	42.70681	753-3	Central	CTS	Ma et al., 2015	283.3	3.1	0.13	23.02	33.60	7.47	43.22	8.93	9.62
87.0103	42.70681	753-5	Central	CTS	Ma et al., 2015	283.3	3.1	0.15	23.19	33.79	7.08	42.09	8.80	8.30
87.0103	42.70681	753-6	Central	CTS	Ma et al., 2015	283.3	3.1	0.20	19.74	29.97	6.95	41.68	8.76	11.72
92.249453	41.564342		Alatage	CTS	Mao et al., 2014	347.5	5.9	0.15	12.35	21.75	6.49	40.21	8.60	18.46

92.249453	41.564342		Alatage	CTS	Mao et al., 2014	347.5	5.9	0.18	12.67	22.11	6.81	41.26	8.71	19.15
92.249453	41.564342		Alatage	CTS	Mao et al., 2014	347.5	5.9	0.18	11.34	20.64	6.60	40.58	8.64	19.94
91.421435	41.664366	C-123	Caixiashan	CTS	Dong, 2015	351.9	3.5	0.05	35.58	47.54	6.14	39.04	8.48	8.51
93.9614	41.85445	X12-30-3	Xingxingxia	CTS	Wen, 2019	284.00	1	0.15	21.62	32.04	8.75	46.58	9.29	14.53
94.896772	41.893806	XX01-2	Xingxingxia	CTS	Zhou, 2014	278	3	0.06	25.78	36.67	7.19	42.41	8.84	5.74
94.896772	41.893806	XX17-1	Xingxingxia	CTS	Zhou, 2014	278	3	0.19	25.34	36.18	6.40	39.93	8.57	3.75
94.896772	41.893806	XX17-4	Xingxingxia	CTS	Zhou, 2014	278	3	0.08	42.53	55.26	9.68	48.72	9.52	
95.008861	41.944433	XX07-2	Xingxingxia	CTS	Zhou, 2014	304	3	0.10	30.30	41.68	25.90	69.67	11.77	
95.008861	41.944433	XX07-3	Xingxingxia	CTS	Zhou, 2014	304	3	0.09	30.70	42.13	9.42	48.15	9.46	6.02
95.008861	41.944433	XX07-5	Xingxingxia	CTS	Zhou, 2014	304	3	0.11	35.84	47.84	12.70	54.50	10.14	
95.1283	41.79000	XJ-35	Xingxingxia	CTS	Lei, 2012	424.9	5.8	0.13	33.02	44.70	11.09	51.63	9.83	6.93
95.1283	41.79000	XJ-38	Xingxingxia	CTS	Lei, 2012	424.9	5.8	0.14	37.47	49.65	11.96	53.23	10.00	3.58
95.1283	41.79000	XJ-39	Xingxingxia	CTS	Lei, 2012	424.9	5.8	0.10	37.42	49.58	11.82	52.98	9.98	3.40
94.714798	41.776337	XJ477	Tianhudong	CTS	Lei, 2012	445.3	4.6	0.09	13.13	22.62	3.99	29.85	7.49	
94.714798	41.776337	XJ478	Tianhudong	CTS	Lei, 2012	445.3	4.6	0.12	13.39	22.92	7.61	43.60	8.97	20.69
94.714798	41.776337	XJ480	Tianhudong	CTS	Lei, 2012	445.3	4.6	0.13	13.97	23.56	7.31	42.74	8.87	19.18

Note: The values in red are discarded numbers that do not pass the Thompson Tau test.

Table S2 Summary of calibrated crustal thickness using method by Mantle and Collins (2008).

Sample No.	Location	Area	Data source	Age	Age error	SiO_2	MgO	Y	Ce	Ce/Y	$D_{Ce/Y}$
WT-1	Wutongwozi	Kanggurtag	Cao, 2012			42.95	5.41	26.6	20.1	0.76	**16.50**
WT-2	Wutongwozi	Kanggurtag	Cao, 2012			41.84	4	27.6	20.4	0.74	**16.10**
WT-3	Wutongwozi	Kanggurtag	Cao, 2012			44.18	5.54	26.5	19.6	0.74	**16.11**
WT-4	Wutongwozi	Kanggurtag	Cao, 2012			41.76	4.62	19	17	0.89	**19.55**
WT-6	Wutongwozi	Kanggurtag	Cao, 2012			41.97	4.96	29.7	21	0.71	**15.30**
LILYQ28	Wutongwozi	Kanggurtag	He, et al., 2005			50.76	6.92	29	10.8	0.37	**3.73**
LILYQ33	Wutongwozi	Kanggurtag	He, et al., 2005			47.84	7.38	22.7	18	0.79	**17.37**
LIX-YQ12	Wutongwozi	Kanggurtag	He, et al., 2005			44.78	6.25	20.6	22.6	1.10	**23.23**
D7566	Wutongwozi	Kanggurtag	She, et al., 2016	Early Carboniferous (?)		50.13	5.93	28.4	24.3	0.86	**18.74**
D7565	Wutongwozi	Kanggurtag	She, et al., 2016			46.48	6.46	21.8	20.5	0.94	**20.45**
D1928	Wutongwozi	Kanggurtag	She, et al., 2016			46.4	7.54	30	22.3	0.74	**16.20**
D7567	Wutongwozi	Kanggurtag	She, et al., 2016			48.6	8.79	30.4	22.5	0.74	**16.13**
12HM- 37	Wutongwozi	Kanggurtag	Zhang, 2014			45.7	3.57	38	14.9	0.39	**4.66**
12HM- 38	Wutongwozi	Kanggurtag	Zhang, 2014			48.74	3.78	32.2	17.2	0.53	**10.24**
12HM- 40	Wutongwozi	Kanggurtag	Zhang, 2014			43.25	5.1	23.3	14.9	0.64	**13.49**
12HM- 41	Wutongwozi	Kanggurtag	Zhang, 2014			48.8	2.17	29.1	14.5	0.50	**8.98**
07 Y- 1141	Gandun	Kanggurtag	Li et al., 2011			48.44	5.92	21.5	18.1	0.84	**18.45**
	Qishanzu	Dananhu	Xiong, 2015	331.2		47.22	5.92	35.9	36.24	1.01	21.73
	Qishanzu	Dananhu	Xiong, 2015	331.2		47.72	8.81	27	21.16	0.78	17.16
	Qishanzu	Dananhu	Xiong, 2015	331.2		49.35	6.91	23.69	21.43	0.90	19.75
	Qishanzu	Dananhu	Xiong, 2015	331.2		53.39	4.24	44.82	41.9	0.93	20.34
	Qishanzu	Dananhu	Xiong, 2015	331.2		52.16	6.5	27.56	28.59	**1.04**	**22.22**
	Qishanzu	Dananhu	Xiong, 2015	331.2		48.5	5.67	33.15	29.92	0.90	19.71
LI-38	Xiaorequanzi	Dananhu	Pan, 2009	325	3.2	50.29	4.54	11.37	33.94	2.99	41.30
L1-47	Xiaorequanzi	Dananhu	Pan, 2009	325	3.2	49.45	4.04	12.12	37.95	**3.13**	**42.16**
LI-60	Xiaorequanzi	Dananhu	Pan, 2009	325	3.2	51.95	3	11.57	24.5	2.12	35.10
7	Xiaorequanzi	Dananhu	Wang et al., 2011	325	3.2	50.78	4.55	25.2	36.5	1.45	28.25
8	Xiaorequanzi	Dananhu	Wang et al., 2011	325	3.2	49.51	6.93	18.97	25.4	1.34	26.83
9	Xiaorequanzi	Dananhu	Wang et al., 2011	325	3.2	49.65	5	14.1	34.9	2.48	37.92
10	Xiaorequanzi	Dananhu	Wang et al., 2011	325	3.2	49.15	5.32	14.14	253	17.89	73.62
13HM-23	Qieshan	Dananhu	Zhang, 2014	299.4	7.7	53.12	4.48	26.3	33.6	1.28	25.98
13HM-24	Qieshan	Dananhu	Zhang, 2014	299.4	7.7	48.16	6.39	17.6	26.5	1.51	28.95
13HM-25	Qieshan	Dananhu	Zhang, 2014	299.4	7.7	48.29	6.11	17.3	26.2	1.51	29.05
13HM-26	Qieshan	Dananhu	Zhang, 2014	299.4	7.7	47.02	4.93	25.5	47.3	1.85	32.71
13HM-27	Qieshan	Dananhu	Zhang, 2014	299.4	7.7	49.38	4.48	24.5	44.6	1.82	32.37
13HM-28	Qieshan	Dananhu	Zhang, 2014	299.4	7.7	48.69	4.75	25.3	41.8	1.65	30.62
13HM-29	Qieshan	Dananhu	Zhang, 2014	299.4	7.7	49.62	6.41	20.7	50.6	**2.44**	**37.69**
13HM-31	Qieshan	Dananhu	Zhang, 2014	299.4	7.7	47.32	7.94	22.7	23	1.01	21.80

13HM-32	Qieshan	Dananhu	Zhang, 2014	299.4	7.7	49.31	6.15	20.9	38.7	1.85	32.68
13HM-33	Qieshan	Dananhu	Zhang, 2014	299.4	7.7	51.48	4.81	23.5	41.7	1.77	31.91
13HM-34	Qieshan	Dananhu	Zhang, 2014	299.4	7.7	48.56	6.46	20.9	36.1	1.73	31.42
13HM-35	Qieshan	Dananhu	Zhang, 2014	299.4	7.7	48.05	6.01	19.3	36.6	1.90	33.11
13HM-36	Qieshan	Dananhu	Zhang, 2014	299.4	7.7	47.1	6.58	7.98	27.2	3.41	43.69
13HM-37	Qieshan	Dananhu	Zhang, 2014	299.4	7.7	48.01	5.76	23.2	37.5	1.62	30.23
13HM-38	Qieshan	Dananhu	Zhang, 2014	299.4	7.7	46.54	7.31	11.2	22	1.96	33.75
13HM-39	Qieshan	Dananhu	Zhang, 2014	299.4	7.7	47.55	7.94	21.9	20.2	0.92	20.10
13HM-40	Qieshan	Dananhu	Zhang, 2014	299.4	7.7	46.32	7.24	20.6	19.2	0.93	20.29
13HM-45	Qieshan	Dananhu	Zhang, 2014	299.4	7.7	48.72	5.62	16.5	19.6	1.19	24.67
13HM-45-1	Qieshan	Dananhu	Zhang, 2014	299.4	7.7	52.4	5.06	16.8	19.4	1.15	24.16
TW1h	Qieshan	Dananhu	Bai et al., 2018	314	3.5	49.62	6.41	20.7	50.6	**2.44**	**37.69**
TW2h	Qieshan	Dananhu	Bai et al., 2018	314	3.5	49.31	6.15	20.9	38.7	1.85	32.68
TW4h	Qieshan	Dananhu	Bai et al., 2018	314	3.5	48.56	6.46	20.9	36.1	1.73	31.42
SL-1h	Qieshan	Dananhu	Bai et al., 2018	314	3.5	48.05	6.01	19.3	36.6	1.90	33.11
SL-3h	Qieshan	Dananhu	Bai et al., 2018	314	3.5	47.55	7.94	21.9	20.2	0.92	20.10
SL-6h	Qieshan	Dananhu	Bai et al., 2018	314	3.5	48.72	5.62	16.5	19.6	1.19	24.67
NH-lh	Qieshan	Dananhu	Bai et al., 2018	316	2.3	52.4	5.06	16.8	19.4	1.15	24.16
NH-2h	Qieshan	Dananhu	Bai et al., 2018	316	2.3	48.16	6.39	17.6	26.5	1.51	28.95
NH-3h	Qieshan	Dananhu	Bai et al., 2018	316	2.3	48.29	6.11	17.3	26.2	1.51	29.05
TW-4	Qieshan	Dananhu	Hou et al., 2006	334		46.97	5.98	23.2	34.7	1.50	28.83
TW-4-1	Qieshan	Dananhu	Hou et al., 2006	334		46.01	5.2	24.4	36.8	1.51	28.98
TW-5	Qieshan	Dananhu	Hou et al., 2006	334		48.18	7.57	27.6	18.8	0.68	14.63
TW-7	Qieshan	Dananhu	Hou et al., 2006	334		50.65	4.71	16	18	1.13	23.68
TW-8	Qieshan	Dananhu	Hou et al., 2006	334		50.8	4.02	17.2	42	**2.44**	**37.67**
Bb-158 - 1	Qieshan	Dananhu	Li et al., 2006	322.6	2	50.52	4.46	23	39.2	1.70	31.18
Bb-160-2	Qieshan	Dananhu	Li et al., 2006	322.6	2	48.73	4.87	17	30.1	1.77	31.87
Bb - 162	Qieshan	Dananhu	Li et al., 2006	322.6	2	50.19	5.17	21	50.8	**2.42**	**37.50**
Bb - 165-1	Qieshan	Dananhu	Li et al., 2006	322.6	2	47.7	6.56	22	20.2	0.92	20.02
Bb-165 -2	Qieshan	Dananhu	Li et al., 2006	322.6	2	48.26	6.68	22	17.8	0.81	17.73
Bb- 172	Qieshan	Dananhu	Li et al., 2006	322.6	2	48.06	7.53	20	23.8	1.19	24.70
YD13-7-1	Qieshan	Dananhu	Xiao et al., 2017	322.6	2	49.6	6.42	16.70	33.3	1.99	34.02
YD13-7-2	Qieshan	Dananhu	Xiao et al., 2017	322.6	2	50.1	6.38	17.30	32.3	1.87	32.83
Bb-158-1[g]	Qieshan	Dananhu	Xiao et al., 2017	322.6	2	50.5	4.46	23.00	39.2	1.70	31.18
Bb-162[g]	Qieshan	Dananhu	Xiao et al., 2017	322.6	2	50.2	5.17	21.00	50.8	2.42	37.50
Bb-165-1[g]	Qieshan	Dananhu	Xiao et al., 2017	322.6	2	47.7	6.56	22.00	20.2	0.92	20.02
Bb-165-2[g]	Qieshan	Dananhu	Xiao et al., 2017	322.6	2	48.3	6.68	22.00	17.8	0.81	17.73
Bb-172[g]	Qieshan	Dananhu	Xiao et al., 2017	322.6	2	48.1	7.53	20.00	23.8	1.19	24.70
ZK198-391[c]	Qieshan	Dananhu	Xiao et al., 2017	322.6	2	49.9	6.81	22.40	33.0	1.47	28.55
TW206-2[e]	Qieshan	Dananhu	Xiao et al., 2017	322.6	2	50.0	7.51	19.40	28.9	1.49	28.75
TW8-1[b]	Qieshan	Dananhu	Xiao et al., 2017	322.6	2	43.0	9.86	25.50	29.3	1.15	24.07

TW8-2[b]	Qieshan	Dananhu	Xiao et al., 2017	322.6	2	45.9	8.02	26.20	40.6	1.55	29.47
TW8-3[b]	Qieshan	Dananhu	Xiao et al., 2017	322.6	2	48.4	6.82	24.00	46.8	1.95	33.61
TW9-3[b]	Qieshan	Dananhu	Xiao et al., 2017	322.6	2	47.6	8.34	28.00	23.7	0.85	18.55
TW10-5[b]	Qieshan	Dananhu	Xiao et al., 2017	322.6	2	46.9	7.18	27.30	50.8	1.86	32.77
TW10-7[b]	Qieshan	Dananhu	Xiao et al., 2017	322.6	2	44.0	10.19	27.40	23.0	0.84	18.40
TW11-6[b]	Qieshan	Dananhu	Xiao et al., 2017	322.6	2	48.0	8.59	21.80	47.1	2.16	35.46
JX-22	Yamansu	Aqishan-Yamansu	Hou et al., 2006	334		49.9	3.93	49.6	107	2.16	35.44
JX-24	Yamansu	Aqishan-Yamansu	Hou et al., 2006	334		49.37	397	63	138	**2.19**	**35.71**
YM-8	Yamansu	Aqishan-Yamansu	Hou et al., 2006	334		44.75	7.15	39	37.6	0.96	20.90
YM-14	Yamansu	Aqishan-Yamansu	Hou et al., 2006	334		48.4	6.15	29.5	28.2	0.96	20.75
YM-16	Yamansu	Aqishan-Yamansu	Hou et al., 2006	334		50.93	5.58	25.8	32.3	1.25	25.61
YM-17	Yamansu	Aqishan-Yamansu	Hou et al., 2006	334		50.53	4.23	29.4	88.4	3.01	41.43
YM-19	Yamansu	Aqishan-Yamansu	Hou et al., 2006	334		51.95	4.7	24.7	49.8	2.02	34.22
SQZ13-91	Tugutubulake	Aqishan-Yamansu	Xu, 2014	322.7	1.7	48.6	9.6	23.6	25.4	**1.08**	**22.89**
SQZ13-92	Tugutubulake	Aqishan-Yamansu	Xu, 2014	322.7	1.7	48.1	9.5	24.5	26.1	1.07	22.70
SQZ13-93	Tugutubulake	Aqishan-Yamansu	Xu, 2014	322.7	1.7	47.9	10.5	23.4	24	1.03	22.02
SQZ13-94	Tugutubulake	Aqishan-Yamansu	Xu, 2014	322.7	1.7	45.9	7.47	25.1	26.1	1.04	22.26
SQZ13-95	Tugutubulake	Aqishan-Yamansu	Xu, 2014	322.7	1.7	46	7.08	25.8	27.2	1.05	22.51
D207/2YQ	Tugutubulake	Aqishan-Yamansu	Yan, 2015	320.5	1.2	50.91	6.66	22.90	29.8	1.30	26.31
07Y-1184	Tugutubulake	Aqishan-Yamansu	Yan, 2015	320.5	1.2	50.78	5.72	32.4	56.4	1.74	31.56
07Y-1185	Tugutubulake	Aqishan-Yamansu	Yan, 2015	320.5	1.2	48.33	2.93	28.9	49.7	1.72	31.35
HF00-08-2	Tugutubulake	Aqishan-Yamansu	Yan, 2015	320.5	1.2	48.94	4.87	26.07	46.1	**1.77**	**31.85**
HF00-08-1	Tugutubulake	Aqishan-Yamansu	Yan, 2015	320.5	1.2	42.05	3.06	25.72	40.34	1.57	29.68
Boo-36-51	Tugutubulake	Aqishan-Yamansu	Yan, 2015	320.5	1.2	47.68	5.32	27.95	35.59	1.27	25.92
07 Y-1184	Tugutubulake	Aqishan-Yamansu	Li et al., 2011	320	1.2	50.78	5.72	32.4	56.4	1.74	31.56
07 Y-1185	Tugutubulake	Aqishan-Yamansu	Li et al., 2011	320	1.2	48.33	2.93	28.9	49.7	1.72	31.35
07Y-1199	Tugutubulake	Aqishan-Yamansu	Li et al., 2011	320	1.2	49.96	7.04	25.6	45.2	1.77	31.82
07Y-1203	Tugutubulake	Aqishan-Yamansu	Li et al., 2011	320	1.2	49.68	6.87	27	53.9	**2.00**	**34.04**
07Y-1247	Tugutubulake	Aqishan-Yamansu	Li et al., 2011	320	1.2	49.74	9.82	17.1	24.4	1.43	27.98
SQZ0902	Tugutubulake-shaquanzi	Aqishan-Yamansu	Huang et al., 2012	320	1.2	48.15	8.18	24.6	35.8	1.46	28.33
SQZO9O6	Tugutubulake-shaquanzi	Aqishan-Yamansu	Huang et al., 2012	320	1.2	48.01	7.41	24.4	37.5	1.54	29.32
SQZO9O9	Tugutubulake-shaquanzi	Aqishan-Yamansu	Huang et al., 2012	320	1.2	47.53	7.37	23.7	36.2	1.53	29.20
HF0008-2	Tugutubulake-shaquanzi	Aqishan-Yamansu	Huang et al., 2012	320	1.2	48.94	4.87	26.07	46.1	1.77	31.85
H FOOD 8-1	Tugutubulake	Aqishan-Yamansu	Wu et al., 2008	305.3	2.4	42.05	3.06	25.72	40.34	1.57	29.68
BOO 36-51	Tugutubulake	Aqishan-Yamansu	Wu et al., 2008	305.3	2.4	47.68	5.32	27.95	35.59	1.27	25.92
HF0008-2	Tugutubulake	Aqishan-Yamansu	Wu et al., 2008	305.3	2.4	48.94	4.87	26.07	46.1	**1.77**	**31.85**
CHS-1	Tugutubulake	Aqishan-Yamansu	Li, 2018	305.3	2.4	42.05	3.06	25.72	40.34	1.57	29.68
CHS-2	Tugutubulake	Aqishan-Yamansu	Li, 2018	305.3	2.4	47.68	5.32	27.95	35.59	1.27	25.92
CHS-3	Tugutubulake	Aqishan-Yamansu	Li, 2018	305.3	2.4	48.94	4.87	26.07	46.1	1.77	31.85

Note: the numbers in red are selected values that has maximum Ce/Y ratio. The numbers in bold denote very thin crustal thickness, but do not show in Figures 2-4 due to lack of precise ages.