Reply to Comment on “\(^{190}\text{Pt}-^{186}\text{Os}\) geochronometer reveals open system behaviour of \(^{190}\text{Pt}\text{-}^{4}\text{He isotope system}\)” by Yakubovich et al. (2022)

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Luguet et al. (2019) applied the Re-Os and Pt-Os chronometers to date the Pt mineralisation of the Kondyor Zoned Ultramafic Complex (ZUC) and suggested this to be ~250-240 Ma and related to the subduction of the Mongol-Okhotsk (MO) ocean seafloor under the Siberian craton. The discrepancy with the Early Cretaceous \(^{190}\text{Pt}\text{-}^{4}\text{He isochronal ages\) of Mochalov et al. (2016) led Luguet et al. (2019) to conclude that the \(^{190}\text{Pt}\text{-}^{4}\text{He chronometer was not robust due to the complex history of the Kondyor Pt mineralisation, thus not providing a meaningful insight into the mineralisation age. Yakubovich et al. (2022) challenge these interpretations. There is however little controversy when the current Pt-Os (Luguet et al., 2019) and Pt-Os (Mochalov et al., 2016) isotopic systems are considered together with regional geological history.

(1) Nekrasov et al. (2005) identified, within the chromitites of the Kondyor ZUC dunite core, an early high temperature (HT) Pt alloy suite associated with chromites containing up to 64 wt. % of \(\text{Cr}_2\text{O}_3\) and a late suite of Pt alloys associated with chromites containing up to 54 wt. % \(\text{Cr}_2\text{O}_3\). The chromites from the schlieren of \(^{190}\text{Pt}\text{-}^{188}\text{Os\) ratio of the Pt alloys range from 0.06 to 19.89 (Table S-2 of Luguet et al., 2019) rules out native osmium occurring as nanometric exsolution lamellae within the Pt alloys (Fig. 1 of Luguet et al., 2019) rules out native osmium being primary, and undeniably argues for a sub-solidus origin. Osmium exsolution lamellae observed in Pt alloys from the Uralian Alaskan-type ZUC (Garutti et al., 2002; Zaccarini et al., 2019) and from the Kondyor ZUC (Luguet et al., 2019; Malitch et al., 2020) likely reflect the low fS2 of a given magmatic system, where Os partitions into the Pt alloy structure unable to form Os sulfides (Garutti et al., 2002). The large range of Pt-Os of the Pt alloys reflect variable proportions of Os exsolution lamellae (Luguet et al., 2019) and the “heterogeneous” \(\text{Os}\text{-}^{186}\text{Os}\) is simply due to the ingrowth of \(^{186}\text{Os\) over ca. 250 Myr. This is the basic implication of an isochron and a model age!

(2) Figure 1 of Yakubovich et al. (2022) only demonstrates that the \(^{189}\text{Os}\text{-}^{186}\text{Os\) ratio does not show a normal distribution, defining compositional clusters between Os-poor Pt alloys and increasingly Os-rich Pt alloys. The subsequent “mineralogical classification” undertaken by Luguet et al. (2022) is erroneous and arbitrary. These authors argue that the Os-richest Pt alloys of Luguet et al. (2019) are native osmium. The Os-richest Pt alloy analysed by Luguet et al. (2019) has a \(^{190}\text{Pt}\text{-}^{188}\text{Os\) of 0.064, corresponding to Pt/Os ~60 - clearly not native osmium. It is also puzzling that two grains classified as “Os” by Yakubovich et al. (2022) have \(^{190}\text{Pt}\text{-}^{188}\text{Os\) overlapping with their own “Pt + Os” group. These “Os” grains appear to be classified as such to fortuitously yield a 116 Ma Pt-Os isochron, similar to the Pt-He age. In contrast, the internal isochrons of the \(^{190}\text{Pt}\text{-}^{188}\text{Os\) compositional clusters yield ages (see Fig. 1, this reply) in agreement with the model age of the Os-poorest Pt alloy and the isochronal age calculated on the whole dataset (Luguet et al., 2019).

(3) According to Yakubovich et al. (2022), native osmium, which we did not analyse, formed prior to the Pt alloys, implying a primary heterogeneity in \(^{188}\text{Os}\text{-}^{186}\text{Os\) and systematic Pt-Os variations among the Pt alloys. The sole observation that native osmium occurs as nanometric exsolution lamellae within the Pt alloys (Fig. 1 of Luguet et al., 2019) rules out native osmium being primary, and undeniably argues for a sub-solidus origin. Osmium exsolution lamellae observed in Pt alloys from the Uralian Alaskan-type ZUC (Garutti et al., 2002; Zaccarini et al., 2019) and from the Kondyor ZUC (Luguet et al., 2019; Malitch et al., 2020) likely reflect the low fS2 of a given magmatic system, where Os partitions into the Pt alloy structure unable to form Os sulfides (Garutti et al., 2002). The large range of Pt-Os of the Pt alloys reflect variable proportions of Os exsolution lamellae (Luguet et al., 2019) and the “heterogeneous” \(\text{Os}\text{-}^{186}\text{Os\) is simply due to the ingrowth of \(^{186}\text{Os\) over ca. 250 Myr. This is the basic implication of an isochron and a model age!

(4) Magmatic ca. 250 Ma ages are reported all along the MO suture, from Mongolia to the Okhotsk Ocean, resulting from the bivergent subduction of the MO ocean under Siberia in the north and Amuria in the south. Of particular interest are those obtained in plutonic and volcanic rocks from the northern side of the MO suture (Sotnikov et al., 2005; Gladkochub et al., 2010; Donskaya et al., 2013), especially from the Dzhugdzhur-Stanovoi magmatic belt (Sal’nikova et al., 2006) and the Dzhagdy Transect (Sorokin et al., 2020), located on the far east of the MO suture, regionally close to the Kondyor ZUC.

(5) Contrary to the proposal of Yakubovich et al. (2022), it is impossible to disturb and age the Pt-Os ages during or consequent to a younger event having overprinted the Kondyor ZUC, due to the very low abundance of \(^{190}\text{Pt\) (0.0136 %; Böhle et al., 2001) and the long half-life of the \(^{190}\text{Pt\) decay (~469 Gyr; Begemann et al., 2001). We maintain that the Pt-He ages record a younger event than the Pt-Os ages, possibly

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190Pt–186Os isotopic system fingerprints an earlier redistribution of by Malitch reflecting poor He retention in Kondyor Pt alloys. Shukolyukov 188Os isochrons of the Kondyor Pt alloys (global and compositional Normal probability plot of the190Pt/188Os composi-
tion of the Kondyor Pt alloys analysed by Luguet et al. (2019). Geochemical Perspectives Letters

Finally, we highlight the conclusion of Yakubovich et al. (2022) [190Pt–He age reflects the mineralisation itself, while the 190Pt–186Os isotopic system fingerprints an earlier redistri-
bution of PGE"], which ultimately asserts that the Pt-Os records an earlier event (i.e. the Pt mineralisation of Kondyor ZUC) than the Pt-He system. By agreeing with Luguet et al. (2019), Yakubovich et al. (2022) signal that they do not understand the implication of their own assertion, rendering their comment to Luguet et al. (2019) obsolete.

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Additional Information

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