Geochemical Perspectives Letters

Published by the European Association of Geochemistry

Comment on "^{190}Pt-^{186}Os geochronometer reveals open system behaviour of ^{190}Pt-^{4}He isotope system" by Luguet *et al.* (2019)

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OPEN ACCESS

Comment

https://doi.org/10.7185/geochemlet.2201

Received 15 June 2021 | Accepted 5 December 2021 | Published 17 January 2022

Accurate and precise chronology of ore forming processes is critical for the development of genetic models for ore formation. New methods (^{190}Pt-^{186}Os and ^{190}Pt-^{4}He) have been developed recently for determining the timing and complexity of platinum group metal (PGM) mineralisation (*e.g.*, Coggon *et al.*, 2012; Shukolyukov *et al.*, 2012a, Yakubovich *et al.*, 2015). Although these methods are fraternal, both based on the alpha particle decay of ^{190}Pt, the geochemical behaviour of the daughter products (^{186}Os and ^{4}He) contrasts significantly. The combination of these isotope systems for dating single ore mineral phases offers a great opportunity to resolve the timing of ore formation.

The first combined study of ^{190}Pt-^{186}Os and ^{190}Pt-^{4}He systems in Pt mineralisation - the Kondyor zoned alkaline-ultramafic complex in the Aldan shield, Russia – has generated a controversial result. Mochalov *et al.* (2016) obtained ^{190}Pt-^{4}He ages of multiple individual Pt alloy grains to be 112–129 Ma, that was consistent with regional geology, sequence of mineral formation and independent age estimations. Subsequently Luguet *et al.* (2019) reported a ^{190}Pt-^{186}Os isochron age of 240–250 Ma. This age discrepancy led Luguet *et al.* (2019) to conclude that the ^{190}Pt-^{4}He ages of the Pt grains reflected "open system" behaviour, essentially arguing that the radiogenic ^{4}He generated by Pt decay had diffused out of the grains since their formation. This explanation is extremely difficult to reconcile with the experimental low diffusion rate of radiogenic ^{4}He in Pt-Fe alloys (Shukolyukov *et al.*, 2012a,b), the retention of extremely high concentrations of cosmogenic ^{3}He by Pt-Fe alloys (Yakubovich *et al.*, 2019) and with the theory of helium behaviour in metals in general (Trinkaus and Singh, 2003). Herein we provide an alternative point of view on the discrepancy between ^{190}Pt-^{4}He and ^{190}Pt-^{186}Os systems in Pt alloys of the Kondyor alkaline-ultramafic complex.

There is abundant independent radiometric geochronological age that the Kondyor ultramafic massif and the associated PGM mineralisation has an Early Cretaceous age; Sm-Nd, Rb-Sr, ^{40}Ar-^{39}Ar, baddeleyite U-Pb ages are in the range 120–132 Ma (Table S-1). These ages are essentially consistent within measurement uncertainty. These isotope systems have closure temperatures that range from ~300 °C (biotite Ar-Ar; Harrison *et al.*, 1985) to over 1150 °C (clinopyroxene Sm-Nd; Van Orman *et al.*, 2001), implying that Pt mineralisation was simultaneous with intrusion, and that post-intrusion cooling of the complex was instantaneous, within our ability to resolve it.

Luguet *et al.* (2019) have ignored the evidence for the Cretaceous age of alkaline magmatic complexes, and associated ore deposits, in the Aldan shield region (Yarmolyuk *et al.*, 2019 and references therein). In support of the Early Triassic age of the Kondyor ultramafic complex they remark on the similarity with detrital zircon grains from the Lena river and Mohe-Upper Amur basin. These rivers are 800–1500 km from the Kondyor ultramafic massif, and the detrital zircons are generally accepted to originate in the Angaro-Vitim batholiths and the China craton (Wang *et al.*, 2011; Miller *et al.*, 2013; Guo *et al.*, 2017) rather than the Aldan shield.

The Luguet *et al.* (2019) study failed to put the study material into context. The formation of platinum mineralisation within the Kondyor massif was polycyclic (Mochalov, 2019). Cumulate dunites, the earliest rocks of the massif, underwent syn-magmatic recrystallisation and metasomatic transformation under the influence of ultramafic, mafic, alkaline, and granitoid intrusions. This resulted in the formation of five genetically distinct types of PGMs. The Pt alloys analysed by Luguet *et al.* (2019) belong to the later generations of PGM that were formed due to the recrystallisation and remobilisation of earlier PGM at temperatures not higher than 650–850 °C (see Supplementary Information; Table S-2). This indicates that the PGE chemistry of fluids that were responsible for the formation of these Pt alloys evolved with time. It also indicates that the age of Pt alloys is coeval with the emplacement of Kondyor massif. Thus, there is no evidence for the crystallisation of these Pt alloys in a root of an Early Triassic volcano that was exhumed in Early Cretaceous time, as proposed by Luguet *et al.* (2019).

Figure 1 shows the Pt-Os data sample 1265 obtained by Luguet *et al.* (2019; Table S-2, part 2). There is significant variation in ^{190}Pt/^{188}Os and ^{186}Os/^{188}Os ratios. Based on ^{190}Pt/^{188}Os ratio the samples studied by Luguet *et al.* (2019) fall into several mineral types; native osmium (Os, Os^{+}), aggregates and crypto-aggregates of native osmium with isoferroplatinum (Pt + Os) and isoferroplatinum (Pt, Pt^{+}) (Fig. 1b). The regression line in ^{190}Pt/^{188}Os and ^{186}Os/^{188}Os space for each of these mineral types have different and distinct slopes (Fig. 1a). Ontogeny of the minerals show that native osmium crystallised before the Pt alloys

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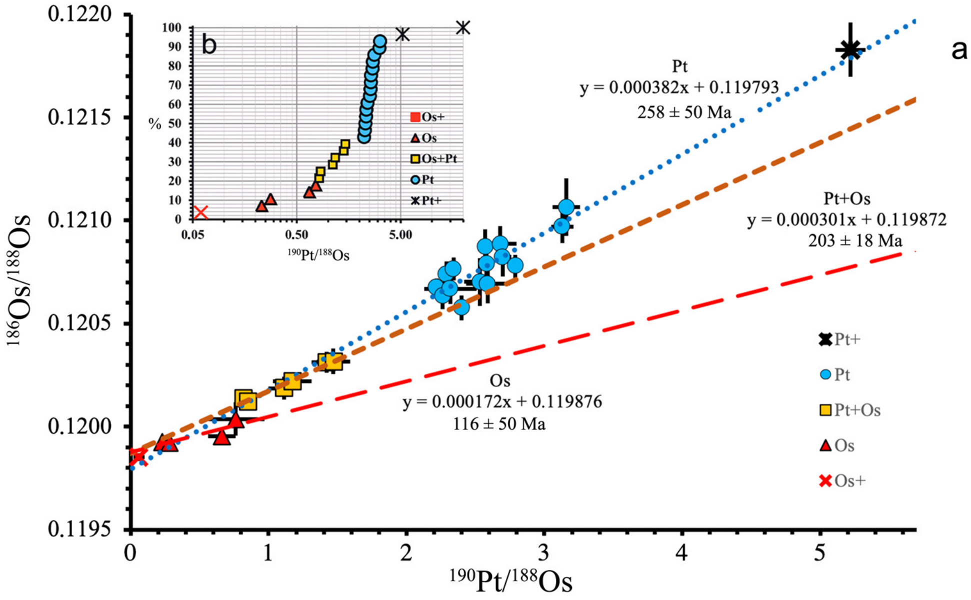

Figure 1 $^{186}Os/^{188}Os$ *vs.* $^{190}Pt/^{188}Os$ and $^{190}Pt/^{188}Os$ probability plot based on the data provided by Luguet *et al.* (2019) (Table S-2, part 2). The original plot (Fig. 1b in Luguet *et al.*, 2019) is modified by constructing independent regression lines for various mineral types, distinguished by their $^{190}Pt/^{188}Os$ ratios. Error bars correspond to 1 s.e. Point D-S2 is not shown on the $^{190}Pt/^{188}Os$–$^{186}Os/^{188}Os$ plot, as it is off scale. Os^{+} and Pt^{+} indicate native osmium and isoferroplatinum, that have significantly different $^{190}Pt/^{188}Os$ ratios and were excluded from the construction of regression lines in $^{190}Pt/^{188}Os$–$^{186}Os/^{188}Os$ coordinates. Ages are calculated in IsoplotR software from a regression line (Vermeesch, 2018).

(see Fig. 1 in Luguet *et al.*, 2019). This implies heterogeneity in primary $^{186}Os/^{188}Os$ composition, which is accompanied by systematic differences in the $^{190}Pt/^{188}Os$ ratio (Fig. 1b). Thus, the regression line in $^{190}Pt/^{188}Os$ and $^{186}Os/^{188}Os$ space through all the data (Fig. 2b in Luguet *et al.*, 2019) is not an isochron, and therefore provides no age information. The obvious disturbance of ^{187}Re-^{187}Os isotope system within the same grains (Fig. 2a in Luguet *et al.*, 2019) directly confirms this.

In summary, the data provided by Luguet *et al.* (2019) do not show any evidence for open ^{190}Pt-^{4}He system behaviour. Nor does it provide any support for an Early Triassic age of the Kondyor massif. The discrepancy between ^{190}Pt-^{4}He and ^{190}Pt-^{186}Os ages of the Pt alloys of the Kondyor massif reflect contrasting geochemical behaviour of daughter isotopes during the polycyclic formation of platinum mineralisation. ^{190}Pt-^{4}He age reflects the age of mineral formation itself, while the ^{190}Pt-^{186}Os isotope system fingerprints earlier redistribution of PGE. Luguet *et al.* (2019) have established a number of remarkable features of the behaviour of the Pt and Os isotopes in PGM grains. If such phenomena are present in other ore occurrences in the other ultramafic massifs (mantle, island arc, shield) they will surely provide a number of significant additions to the mineralogy of the PGE and geochemistry of HSE in general.

Acknowledgements

The authors are grateful to A.V. Ivanov and A.B. Kotov for valuable discussion. This research was supported by RTD of IPGG RAS (FMUW-2022-0004; FMUW-2022-0003) and SUERC.

Editor: Cin-Ty Lee

Additional Information

Supplementary Information accompanies this letter at https://www.geochemicalperspectivesletters.org/article2201.

Cite this letter as: Yakubovich, O.V., Mochalov, A.G., Savatenkov, V.M., Stuart, F.M. (2022) Comment on "^{190}Pt-^{186}Os geochronometer reveals open system behaviour of ^{190}Pt-^{4}He isotope system" by Luguet *et al.* (2019). *Geochem. Persp. Let.* 20, 19–21. https://doi.org/10.7185/geochemlet.2201

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