Elevated $^{208,207,206}Pb/^{204}Pb$ by volatile degassing from impact melts

B.S. KAMBER*[1], R. SCHOENBERG[2], D.T. MURPHY[1], H.ST.C. O'NEILL[3], J.R. REIMINK[4]

[1]Queensland University of Technology, Brisbane, Australia: balz.kamber@qut.edu.au
[2]Eberhard-Karls University of Tuebingen, Germany
[3]Australian National University, Canberra, Australia
[4]The Pennsylvania State University, U.S.A.

It has long been known[1] that early Archaean galena has two distinct Pb-isotope flavours: one from a source with superchondritic $^{208}Pb/^{206}Pb$ and a high $^{207,206}Pb/^{204}Pb$, the other of a composition conformable with 'normal' isotope evolution models. The source of the former is conventionally interpreted as late Hadean crust with high time-integrated $^{232}Th/^{238}U$ and $^{238}U/^{204}Pb$[1,2]. Here we propose an alternative explanation: non-conformable Pb could reflect isotope fractionation during volatile loss from impact melts.

Rayleigh distillation of light isotopes into the gaseous phase with moderate fractionation factors ($\alpha \sim 0.9996$) reproduces trajectories of galena with high $^{208,207,206}Pb/^{204}Pb$, provided impact melts lost ~99% of their Pb. Notably, the sequence of element volatilisation from silicate melts may differ markedly from that seen in the condensation of solar gas, and can separate metals with similar nebular condensation temperatures (i.e. Pb-Zn)[3]. Extensive loss of Pb from melts can cause measurably heavier isotope ratios despite the high atomic mass of Pb. Pronounced volatile Pb-loss is supported by lack of common Pb in angrites[4] and Pb depletion of the Sudbury impact basin[5]. Preferential loss of light Pb-isotopes also explains why no galena data plot at lower $^{208,207,206}Pb/^{204}Pb$ than conformable Pb. Early Archaean Pb-isotopes may therefore not require Hadean silicate Earth differentiation, and Pb isotopes could be decoupled from ^{142}Nd or ^{182}W anomalies, which track ancient differentiation.

The $^{206}Pb/^{204}Pb$ ratios of non-conformable galena favour Pb-loss from Eo- and Palaeoarchaean over earlier Hadean impact melts but similar processes have conceivably operated during Hadean collisional erosion on targets and bolides[6].

Volatility-induced fractionation from impact melts may explain Pb-isotope and volatile element ratio differences (e.g. Zn/Cs) between silicate Earth reservoirs and the Moon.

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