LETTER

REPLY TO BADA: Acidity and fluid composition on the Tagish Lake parent body

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A comment from Bada (1) attempts to flag multiple issues with our recent study (2). We appreciate the opportunity to respond, as Bada raises some interesting points, but many of his comments appear to overinterpret our results in a manner well beyond the scope of our original study. We believe Bada's comments (1) can be broadly grouped into two key points for discussion: 1) the calculation used to yield the racemization timeline and 2) issues with our final conclusion. We address the points separately as follows:

1) Given the racemization timeline calculations were a significant tangent from the key dataset generated by our study, we could not include full details within the three-page scope of the Brief Reports format. We incorporated a number of variables previously reported in the literature, notably an alteration temperature of 80 °C (an upper temperature limit calculated by ref. 3), and a pH value of 9, as modeled by ref. 4 and further confirmed by the atom probe tomography data presented in our study (2), as noted by Bada ["The alkaline pH was deduced from their investigation of the mineralogy of the meteorite" (2)]. Using those conditions, we conducted the calculation for aspartic acid using the formulas in refs. 5 and 6, with D/L ratios from ref. 7 and *k* value (for aspartic acid at a constant pH of 9) from ref. 8. Bada (1) also questions the occurrence of Fe in the alteration fluid. Given the aqueous alteration on the Tagish Lake parent body resulted in the formation of framboidal magnetite ($Fe^{2+}Fe^{3+}{}_2O_4$), we believe it is fair to assume that the solution contained Fe. Thus, our reference to ref. 9 provides a useful insight into the potential implications of alkaline fluids on amino acid synthesis in such a system, which we simply highlight would occur faster than at a neutral pH.
2) Bada concludes that his comments negate a key finding of our paper ("low abundances of amino acids in Tagish Lake cannot be ascribed to fluid chemistry") (1). However, this comment appears to be anchored on the preceding discussion around the detection of ammonia and hydrogen cyanide in other carbonaceous chondrites, such as Murchison (10). We fail to see how such observations influence the possibility for Strecker synthesis on the Tagish Lake parent body as samples such as Murchison would have been sourced from unique, potentially very disparate, planetary sources. Furthermore, we struggle to understand Bada's (1) ultimate concerns with our conclusions, when the author himself notes that our study constrained the alkaline pH of the alteration fluid before highlighting the importance of alkaline conditions for amino acid racemization [aspartic acid racemization occurring at a rate a factor of 10 higher than at neutral pH conditions (8)]. Thus, despite a suitable aqueous environment, amino acids did not form on the Tagish Lake parent body to the same extent as they did in Murchison. This would indicate that the chemistry and pH of the fluid is not the limiting factor for the formation of amino acids, something our study provided evidence for (2).

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The authors declare no competing interest.

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