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Comment on "Formation of abnormally high density H_2S fluid in sedimentary basins" by Liu *et al.*, 2025

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Comment

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Liu *et al.* (2025) recently reported high density H_2S in fluid inclusions from the Ediacaran Doushantuo Formation, South China. Based on this novel finding, they proposed: (i) widespread Mississippi Valley-Type (MVT) lead-zinc ore deposits within the Doushantuo Formation, (ii) a "calcite purification model" to explain the presence of H_2S-rich fluid inclusions, and (iii) a hydrothermal origin for methane-derived authigenic calcite (MDAC) nodules.

While the results presented in this study are intriguing and potentially significant, the proposed conceptual model appears inconsistent with several key geological observations. This comment is intended to encourage further discussion and clarification of the issues outlined below.

MVT Lead-Zinc Ore Deposits. The authors interpret the presence of H_2S-rich fluid inclusions and MDAC nodules in the context of extensive MVT lead-zinc ore deposits within the Doushantuo Formation (Liu *et al.*, 2025). However, despite decades of intensive investigation (Ader *et al.*, 2009; Li *et al.*, 2010; Jiang *et al.*, 2011; Macouin *et al.*, 2012; Cui *et al.*, 2016, 2017, 2022; Shi *et al.*, 2022), no enrichment of lead-zinc minerals—such as galena, sphalerite, pyrite, or chalcopyrite—has been documented at the studied Yangjiaping, Zhongling, Caojunba, and Nanbeizhan sections. In the absence of direct geological evidence for lead-zinc mineralisation at these locations, the claim of widespread MVT lead-zinc ore deposits is perhaps misleading.

Calcite Purification Model. The authors propose a "calcite purification model" to explain the association between MDAC and H_2S-rich fluid inclusions. In this model, the progressive precipitation of authigenic calcite consumes the alkalinity generated by thermogenic sulfate reduction (TSR), thereby driving diagenetic fluids increasingly enriched, and eventually saturated, in H_2S (Liu *et al.*, 2025).

It is important to note that the process described above is not self-sustaining. H_2S-rich fluids are stable only under highly acidic conditions, which would promote rapid dissolution of calcite, rather than being continuously enriched by calcite precipitation. In other words, the formation of authigenic calcite cannot progressively enrich diagenetic fluids in H_2S, as a pH equilibrium would eventually be reached due to the concurrent dissolution of carbonates—including both MDAC and the dolostone host rock in the case of Doushantuo—in such acidic conditions. Therefore, to form large scale MVT deposits, the source of sulfide must be external; otherwise, internal generation of sulfide (*e.g.*, TSR) within the host carbonates would be neutralised by carbonate dissolution, which buffers acidity.

Additionally, the authors' calcite purification model also appears inconsistent with published petrographic observations. In this model, authigenic calcite precipitates prior to quartz mineralisation during nodule growth, with quartz forming in the centre of the nodules (see Fig. 4 in Liu *et al.*, 2025). However, previous studies have shown that the MDAC nodules in the upper Doushantuo Formation are typically lined by a thin quartz rim, with quartz crystals growing centripetally inward (Cui *et al.*, 2016, 2017; Shi *et al.*, 2022), suggesting that quartz likely formed before or concurrently with MDAC. Similar petrographic patterns have also been observed elsewhere (see Xiao *et al.*, 2010; Wang *et al.*, 2020). We suggest that any conceptual model for these authigenic features should align with the existing petrographic observations.

Complex Diagenetic and Burial Histories. The homogenisation temperatures of fluid inclusions measured by Liu *et al.* (2025) are not totally unexpected, as similar or even higher values have been reported using various methods (Table 1). Notably, a burial temperature of ~241 °C has been estimated for the South China region (Wang *et al.*, 2017). While each geothermometer carries its own assumptions and uncertainties, the collective implication is clear: the Ediacaran strata in South China have undergone a complex history of diagenesis and deep burial.

Disentangling the influence of each individual process during deposition, diagenesis, and deep burial remains a challenging, yet critical, task when evaluating the veracity and significance of these sedimentary fabrics. On the one hand, the meticulous work of Liu *et al.* (2025) offers valuable new data and interpretations, and is therefore truly commendable; on the other hand, perhaps more work is warranted to fully understand these enigmatic textures and geochemical signatures.

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Table 1 Published temperature estimates for the Ediacaran Doushantuo (DST) Formation based on various analytical approaches. Sources are listed in chronological order: 1) Bristow *et al.* (2011); 2) Loyd *et al.* (2015); 3) Wang *et al.* (2017); 4) Zhou *et al.* (2017); 5) Shi *et al.* (2023); 6) Liu *et al.* (2025). MDAC, methane-derived authigenic calcite.

Methods	Published temperatures	Samples and position	Sources
Clumped isotope temperature	86–156 °C	Dolomite veins* in basal DST	#1
Clumped isotope temperature	129–189 °C	White calcite spar in basal DST	#1
Clumped isotope temperature	275–476 °C	Black MDAC* in basal DST	#1
Clumped isotope temperature	34–164 °C	Carbonate matrix in upper DST	#2
Raman spectroscopy	~200–300 °C	Carbonaceous materials in basal DST	#3
Geothermal calculation	~241 °C	DST	#3
Homogenisation temperatures of fluid inclusions	160–220 °C	Quartz cements in basal DST	#4
Clumped isotope temperature	182–212 °C	MDAC in basal DST	#5
Homogenisation temperatures of fluid inclusions	138–160 °C	Calcite cements in upper DST	#6
Homogenisation temperatures of fluid inclusions	113–158 °C	Quartz cements in upper DST	#6

* See also Cui *et al.* (2024) for a critical reassessment of dolomite veins and MDAC cements within cap dolostones of the basal Doushantuo Formation.

Additional Information

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