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Review of Preprint egusphere-2026-1596 by Cawood and others

I have completed a thorough review of Preprint egusphere-2026-1596 by Cawood and others entitled “Fault and fracture networks as long-lived conduits for lithium transport". I am very familiar with the geologic setting, structural evolution, and lithium mineralization system in the Clayton Valley region, and I bring expertise in geologic mapping, structural geology, stratigraphy, and U-Pb geochronology. I therefore feel well positioned to evaluate the scientific merit and technical accuracy of this manuscript.

GENERAL COMMENTS:

The manuscript presents new calcite U-Pb geochronologic ages, carbonate clumped-isotope formation temperatures, and lithium concentration data from fault- and fracture-hosted veins, basin-bounding faults, and spring deposits in and around Clayton Valley, a prominent and developing lithium district in southwestern Nevada. The authors interpret these data as evidence that structurally connected fault networks served as long-lived conduits for Li-enriched fluid flow since at least ~15 Ma, predating the emplacement of the ~6 Ma Rhyolite Ridge tuff which has been suggested as a primary Li source reservoir for the Clayton Valley system. The paper addresses a genuinely important and underexplored question: the role of faults and fractures as fluid transport pathways in sediment-hosted Li and Li-brine systems is poorly constrained, and the multi-proxy analytical approach employed here is well suited to the problem. The topic is within scope, and the dataset is novel.

Unfortunately, the manuscript falls well short of supporting its central conclusions, and in its current form I do not recommend it for publication without major revision. My principal concerns are as follows. The paper's most significant interpretive claim – that Li-enriched fluids were circulating along faults prior to 6 Ma, before establishment of the volcanic Li source – is not supported by the data. All fault calcite samples with robustly pre-6 Ma U-Pb ages yield Li concentrations of only 2–21 ppm, at or below average upper continental crust (~35 ± 11 ppm; Teng et al., 2004), providing no geochemical evidence of Li enrichment. Compounding this, the manuscript does not discuss the 2σ uncertainties on U-Pb dates, which are substantial: eight of thirteen dated samples have age uncertainties large enough to overlap the 6.05 Ma age of the Rhyolite Ridge tuff, and cannot be used to argue for pre-source fluid flow. The authors' conclusion that long-lived, pre-volcanic Li transport occurred within the basin is therefore unsupported, and represents a significant overinterpretation of the available data.

The manuscript also contains errors in the representation of average upper continental crust Li content. They cite inconsistent values (~20-30 ppm and 8.5–11.5 ppm in Fig. 3a; ~30 ppm in text) that are neither internally consistent nor traceable to the cited source, which further undermine the interpretive framework. The correct reference value from Teng et al. (2004) renders the statement that "many samples yield Li concentrations that exceed average upper continental crust" incorrect for the majority of the dataset.

Beyond the geochemical interpretations, the petrographic characterization of dated calcite is insufficiently documented to establish that U-Pb ages reflect fault-controlled fluid flow rather than diagenetic, recrystallized, or mixed-generation calcite. CL imaging and textural descriptions linking each sample to its structural position are absent, which is a meaningful gap given current best practices in fault calcite U-Pb geochronology.

The structural figures (Figs. 1, 5, and 8) contain geometric and stratigraphic errors inconsistent with published mapping and structural analyses of the region, including incorrect crustal thickness at Mineral Ridge and Rhyolite Ridge, omission of key SE-dipping fault structures, erroneous detachment timing, and the conspicuous absence of the Rhyolite Ridge tuff from beneath Clayton Valley — despite its documented subsurface occurrence in work by several coauthors. These figures require substantial revision and should be explicitly labeled as conceptual or schematic where appropriate.

More broadly, the discussion is insufficiently developed to support the claims made. The significance of results is overstated and engagement with the existing structural and stratigraphic literature is incomplete. Addressing these issues – particularly the Li content interpretation, age uncertainty treatment, petrographic documentation, and structural figures – would require substantive revision but could yield a much stronger contribution.

Sincerely,
Michael Darin, PhD, RG
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SPECIFIC COMMENTS:

1) **Inconsistency and unsupported citation for Li reference values for average upper continental crust (UCC) Li reference value**

   The authors report average UCC Li as ~20-30 ppm in the legend of Figure 3a, but depict as a red bar only spanning 8.5–10.5 ppm in the figure, citing Watts (2025) in the caption and on Line 235 This is internally inconsistent and neither value is traceable to Watts (2025), which does not report a UCC Li value; rather, she makes an offhand (and uncited) comparison noting that rhyolitic magmas of the McDermitt volcanic field in Oregon/Nevada have Li contents of "...200–2000 ppm Li (~10X–100X average continental crust)," from which a value of ~20 ppm appears to have been inferred and then inconsistently applied in the current manuscript. **The appropriate citation for average UCC Li is Teng et al. (2004, GCA), who report 35 ± 11 ppm (1σ),** corresponding to a range of ~24–46 ppm. The authors should correct both the figure and text to reflect this value with proper attribution. This is not a minor issue: the inflated baseline used by the authors artificially lowers the threshold for what counts as 'enriched,' and the statement that "many samples yield Li concentrations that exceed avg UCC (~30 ppm)" (Line 235) is demonstrably incorrect under the Teng et al. (2004) value.

Additionally, the authors sometimes conflate these "upper continental crust" values as being "continental crust" values, the latter being lower than the former when averaging over the lower, middle and upper crust. Teng et al (2004), Watts (2025), and most studies typically refer to "upper continental crust" values when comparing to Li enrichment in igneous and sedimentary systems. This should be corrected throughout the paper.

2) Misinterpretation of Li contents in fault calcite

Using the correct UCC baseline of 35 ± 11 ppm (Teng et al., 2004), 20 of 26 fault calcite samples have Li contents below mean UCC (Table 1), and all samples with pre-6 Ma U-Pb dates yield Li of only 2–21 ppm – values which are depleted, or at best unremarkable, relative to average UCC. There is no geochemical basis in these data for concluding that Li-enriched fluids were present in pre-6 Ma fault systems. The only substantially anomalous Li value in fault calcite (460 ppm) derives from a minor fault within Li-enriched lacustrine strata in Cave Spring basin far to the west of Clayton Valley, and is dated at ~6 Ma, consistent with derivation from the Rhyolite Ridge tuff source (6.05 ± 0.08 Ma; Darin et al., 2025) rather than a pre-existing Li reservoir.

3) Age uncertainties undermine the pre-6 Ma fluid flow argument

The manuscript does not discuss 2σ uncertainties on U-Pb dates, which are substantial (ranging from ~20–97% of the reported age). These are only listed in the supplemental table and otherwise ignored in the paper. Of 13 dated samples, 8 have ages spanning 3.9 ± 3.7 to 9.0 ± 3.8 Ma, all of which overlap the 6.05 ± 0.08 Ma age of the Rhyolite Ridge tuff at 2σ and therefore cannot be used to argue for pre-source Li transport. The five remaining dates (15.4 ± 6.4 to 60 ± 19 Ma) that are robustly pre-6 Ma yield Li contents of only 2–11 ppm — the lowest values in the dataset. Taken together, the data show an inverse relationship between age confidence and Li enrichment, which is the opposite of what the authors' interpretation requires.

In light of the above, the authors' main conclusion on Lines 315-319 that "*the presence of lithium-bearing fluids prior to emplacement of major late Miocene silicic volcanic units indicates that lithium transport was already occurring within the basin before establishment of the most commonly cited volcanic source reservoirs*" is not supported. The data are more parsimoniously interpreted as reflecting background crustal fluid flow in pre-6 Ma fault systems, with Li enrichment appearing only in samples that post-date or are contemporaneous with the 6.0-Ma Rhyolite Ridge tuff. The authors should revise their conclusions accordingly and refrain from invoking a long-lived, pre-volcanic Li source unless additional evidence can be brought to bear.

4) Lack of Petrographic Context for Geochronological Interpretations

The authors state on Line 140 that "*analyses included petrographic characterization and screening for uranium content prior to dating,*" but no petrographic results are reported for the dated calcite samples. They go on to interpret that, "*Vein calcite precipitation ages…span ~15.4 to 3.9 Ma, indicating that fluid flow and associated mineralization along faults and fractures persisted over multi-Myr timescales.*" (Lines 248-250). This is a significant gap, because the credibility of the U-Pb ages as records of fault-controlled fluid flow is inseparable from textural and structural context.

The authors frame their U-Pb ages as dating calcite precipitation and fluid flow rather than fault activity per se, which is appropriate. However, petrographic documentation remains essential to establish that the dated material is in fact primary fault- or fracture-hosted vein calcite rather than: (1) diagenetic calcite that predates faulting and was simply exposed within the fault zone, which would provide only a maximum age on fluid flow along that structure; or (2) recrystallized calcite whose U-Pb system was partially reset by a later, unrelated fluid event, which could produce apparent ages that do not correspond to any discrete geological episode. The claim that fault-controlled fluid flow 'persisted over multi-Myr timescales' also requires that the spread of ages reflects multiple discrete precipitation events rather than open-system isotopic disturbance producing an artificially dispersed isochron array — a distinction that cannot be evaluated without CL imaging and textural data.

At minimum, the authors should provide, for each dated sample: (1) the structural position of the calcite (fault core, damage zone, breccia cement, fracture vein, etc.); (2) calcite texture and morphology (fibrous, elongate-blocky, sparry, etc.); and (3) cathodoluminescence (CL) imaging results, or an explicit statement that CL was not performed with justification for why primary, single-generation calcite can nonetheless be assumed. CL imaging is effectively standard practice in fault calcite U-Pb studies (e.g., Nuriel et al., 2017, EPSL; Roberts and Holdsworth, 2022, JSG) because it is the primary means of identifying mixed-generation ablation and recrystallization textures, either of which can yield geologically meaningless apparent ages.

The 460 ppm Li outlier from faults cutting Li-enriched strata is a case in point: without petrographic context, it cannot be determined whether this calcite precipitated from migrating Li-enriched fluids (supporting the authors' interpretation) or incorporated Li diagenetically from the enclosing host stratigraphy. The authors are encouraged to expand their petrographic documentation to the level needed to support their interpretations, ideally in a supplementary table accompanied by representative photomicrographs in plane-polarized light and CL for each sample setting, which are lacking.

5) Structural interpretations are inconsistent with published studies

The cross-sectional figures (Figs. 1d, 5, and 8) contain structural interpretations that are inconsistent with published mapping and structural analyses of the Clayton Valley region, and the evolutionary diagrams in Fig. 8 omit or misrepresent key geological features central to the paper's argument. These issues suggest insufficient engagement with the background literature and require substantial revision:

- Crustal geometry at Mineral Ridge and Rhyolite Ridge: The Cambrian section at Mineral Ridge is known to be dramatically attenuated, as documented in detail by Diamond and Ingersoll (2002, IGR), and the expected crustal thickness at Rhyolite Ridge is therefore well under 2 km. The cross sections as drawn depict thicknesses of 10–12 km in this position, which is inconsistent with the published structural framework by more than an order of magnitude. The authors should revise the crustal geometry in all relevant panels to reflect published constraints, with explicit reference to Diamond and Ingersoll (2002) and the more recent detailed geologic mapping and structural analyses of Ogilvie et al. (2023, NBMG OFR) and Darin et al. (2025, Economic Geology), neither of which appears to have been incorporated into the figures on the western panel margins.

- Post-6 Ma basin fill and the Li-brine system: The summary evolutionary diagrams in Fig. 8a and 8b do not adequately represent the post-6 Ma basin fill in Clayton Valley that hosts the prolific Li-brine system and related sediment-hosted Li deposits documented at depth (e.g., Gagnon et al., 2023). If the thin green layer in those panels is intended to represent these strata, this needs to be stated explicitly and the stratigraphic thickness and geometry should reflect published subsurface constraints. More critically, the figures appear to imply stratigraphic connectivity between the Cave Spring Basin at Rhyolite Ridge (Darin et al., 2025) and Clayton Valley proper. If this connectivity is central to the paper's fluid-flow model, it must be discussed explicitly in the text and supported with substantiating evidence; the reviewers are not aware of published data establishing this connection, and it cannot be conveyed schematically without justification.
- Mineral Ridge/Silver Peak detachment timing: Fig. 8 depicts activity on the Mineral Ridge detachment extending to 3–0 Ma, which is inconsistent with the timing constraints that suggest detachment slip ceased by ~6-4 Ma (e.g., Oldow et al., 1994, Geol; Diamond and Ingersoll, 2002, IGR; Darin et al., 2025). The authors should either revise the figure to reflect the established deformation history of this structure or provide explicit citations and reasoning for departing from the published record.

General recommendation: The structural figures as presented read as largely schematic, and several of the interpretations they convey are not defended in the text. Given that the fault network geometry is foundational to the paper's fluid-flow model, the authors are strongly encouraged to revise the cross sections to conform to published mapping and structural data, clearly distinguish between constrained geometry and schematic inference, and provide explicit discussion of any structural interpretations – particularly subsurface connectivity – that go beyond what has been documented in prior work.

6) Issues with geologic map and legend in Figure 1

Figure 1 requires substantial revision on several grounds. The depiction of metamorphic core complexes is incomplete, omitting those in the Weepah Hills to the north of Clayton Valley (see Darin et al., 2025, Fig. 1b). The legend in Fig. 1c does not correspond to the geologic map in Fig. 1b or the cross section in Fig. 1d — many more map units are shown on the map than are included in the legend, several colored polygons appear to overlap along the western map edge, and key features lack labels; all of these issues must be corrected. The cross section in Fig. 1d should be explicitly labeled a 'conceptual' or 'schematic' diagram, as it is not geometrically restored or scaled. Its northwestern end requires revision to honor the first-order structural relationships documented by Ogilvie et al. (2023) and Darin et al. (2025), particularly the Cambrian section thickness and the major SE-dipping fault structures, both of which are misrepresented as currently drawn. Finally, the 6 Ma Rhyolite Ridge tuff is conspicuously absent from beneath Clayton Valley in the cross section, despite its documented subsurface occurrence in work by several coauthors of this manuscript (Gagnon et al., 2023, GSAB) and its regional correlation by Darin et al. (2025); given its central role in the paper's Li-sourcing argument, it must be included.

TECHNICAL CORRECTIONS:

- Line 97: capitalize "Late Miocene"; this sub-epoch is now formally recognized by the International Commission on Stratigraphy (ICS) International Chronostratigraphic Chart v.2024/12
- Line 97: change "west-dipping" to "mostly west-dipping"; some major structures in Rhyolite Ridge area are east-dipping (Darin et al., 2025)
- Line 99: Because you include Rhyolite Ridge (RR) here and that study spans nearly half the cross-section in Fig. 1d, you should consider citing Darin et al (2025) again here. That paper documented this well at RR, and you are talking regionally here not in specific about CV. Or if you actually intend to refer to CV in specific, then make this explicit before describing the stratigraphy and structure in this sentence.
- Lines 119–120: "*Sampling of fault- and fracture-hosted calcite veins deliberately targeted relatively late-stage brittle structures interpreted to be related to Basin and Range extension*." – How exactly were early (pre-Basin and Range) structures differentiated. By what criteria? Dip angle?
- Line 242-243: "*basement-hosted calcite veins generally contain low to moderate lithium concentrations (commonly <10 ppm, rarely exceeding ~30 ppm*." According to Table 1, none of these samples have Li content >30 ppm ,and only 2 of 26 fault/vein samples in the dataset overlap average UCC values; see prior comments above.
- Figure 2c-f: it is very difficult to tell from these photos where exactly the calcite samples come from and their textural context. Consider arrows or other labels to indicate sample location on each panel.