

Section S1: Lithium partitioning

As discussed by Teng et al. (2004), upper continental crust Li abundances are derived largely from silicate- and clay-rich lithologies including shales, granites, crustal composites, and metamorphic rocks, all of which are substantially more favorable hosts for Li than calcite. Published experimental and natural-system studies (Füger et al., 2019; Drake et al., 2023; Branson et al., 2024) consistently report low and variable Li partition coefficients and demonstrate that Li is generally incorporated only weakly into calcite during precipitation. Further, Li incorporation into calcite is strongly dependent on a range of factors, including fluid chemistry, precipitation rate, and pH. As a result, relatively modest Li concentrations in calcite may still be compatible with precipitation from Li-bearing fluids. To address this issue, we compiled Li and Ca concentrations from modern Clayton Valley brines reported by Coffey et al., 2021 (Table S10, reproduced below) and calculated fluid Li/Ca compositions (Fig. S8a, this document).

Sample Type ^a	Li (mg/L)	Na (mg/L)	K (mg/L)	Ca (mg/L)	Mg (mg/L)	SO ₄ (mg/L)	Cl (mg/L)	Alkalinity (mg/L)
Brine	249	44590	5924	358	278	16719	79200	404
Brine	123	24320	2822	456	278	5631	44700	562
Brine	175	33420	3667	582	340	8289	62000	306
Brine	462	73350	9813	455	440	32070	134800	223
Brine	80	17110	1828	446	219	3228	39800	626
Brine	88	17980	2345	323	179	6183	32500	590
Brine	241	51700	5966	543	337	14778	96000	318
Brine	134	30380	3578	387	220	8664	52100	435
Brine	177	32740	4280	394	279	7668	59700	536
Brine	63	13290	1306	865	339	2034	27800	116
Brine	98	19090	2464	260	170	6813	35100	664
Brine	80	16050	1706	491	250	3702	29500	141
Brine	69	20300	1923	370	137	4278	35700	435
Brine	102	91070	2918	589	172	7269	172600	25
Brine	87	21750	1730	363	231	5172	37400	436
Brine	97	24280	2786	215	96	6378	42400	392
Brine	97	20990	2453	185	117	6903	37900	376
Brine	109	27500	2824	133	82	7515	46900	292
Brine	63	18640	1638	235	90	4083	32600	536
Brine	96	34040	2559	379	136	5772	64900	351
Brine	108	35820	3063	265	128	7230	63800	325
Brine	69	15340	1419	564	192	3495	28600	109
Brine	47	9895	962	527	191	2712	18200	120
Brine	59	16390	1535	317	86	2832	30000	434
Brine	56	19010	1639	356	74	2754	34300	426
Brine	53	18120	1450	356	81	2862	32400	436
Brine	85	33250	2416	262	113	6159	60400	283
Brine	49	13410	1017	446	200	2295	60300	313
Brine	162	47100	4280	275	174	10326	76300	200
Brine	68	20670	1700	117	68	4566	29200	348
Brine	77	16730	1899	322	161	5175	26700	518
Brine	89	20540	1826	652	305	2721	35100	261
Brine	133	31320	3493	239	145	10380	48600	350
Brine	280	53640	6507	288	272	18330	88400	209
Brine	293	55890	6602	397	358	18198	93700	187
Brine	199	52140	4970	262	162	13191	85100	215
Brine	100	22600	2129	344	247	6201	36900	425
Brine	124	93720	3182	665	206	7725	159800	21
Brine	80	18740	1679	284	191	3729	29500	518

We then propagated these Li/Ca through experimentally derived calcite-fluid partition coefficients from Füger et al. (2019), Drake et al. (2023), and Branson et al. (2024) to generate predicted calcite Li distributions for comparison with the calcite samples collected in this study. The revised manuscript and supplementary material now include this additional material. Comparisons demonstrate that Li concentrations in our vein calcites are potentially consistent with precipitation from Li-bearing basin fluids, given the low and variable partitioning behavior of Li in calcite.

In particular, only the intermediate partition coefficients from Fuger et al. (2019) produce predicted calcite Li distributions that compare closely with the observed dataset, whereas the remaining published partitioning relationships show only partial overlap. We do not infer that the Fuger et al. (2019) intermediate partition coefficients are uniquely applicable to the Clayton Valley system. Rather, they provide the closest correspondence among the currently available published partitioning relationships. Because Li partitioning is highly sensitive to growth rate and pH (Fuger et al., 2019), and these variables are unconstrained for the natural samples, this comparison should be regarded as a first-order illustration rather than a unique solution. (Fig. S8b, this document). We emphasize that this approach is not intended as a formal paleo-fluid reconstruction and that (i) the chemistry of present-day basin waters compositions may differ from paleo-fluid compositions, (ii) partitioning behavior likely varied among veins as a function of evolving fluid chemistry and precipitation conditions, (iii) this analysis represents a first-order forward-modeling approach designed to evaluate whether the observed calcite Li concentrations are geochemically feasible products of precipitation from Li-bearing basin fluids. We thank the reviewer for raising this important point. We believe that the revised partitioning-based framework provides a substantially more robust and geochemically appropriate basis for interpreting Li concentrations in fracture-hosted calcite. We have nevertheless retained the upper continental crust reference field in revised Fig. 5 to provide broader geochemical context for the measured calcite Li values.

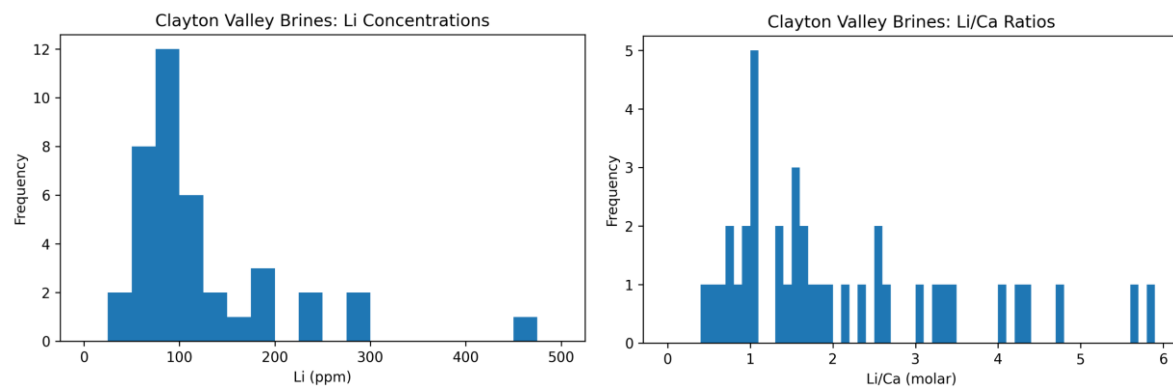


Figure S3. Histograms showing lithium concentrations and Li/Ca ratios for Clayton Valley brines compiled from Coffey et al. (2021). (Left) Distribution of Li concentrations (ppm) in sampled basin brines. (Right) Distribution of molar Li/Ca ratios for the same brine dataset. These data were used as input fluid compositions for forward modeling of calcite Li concentrations using experimentally derived calcite-fluid partition coefficients.

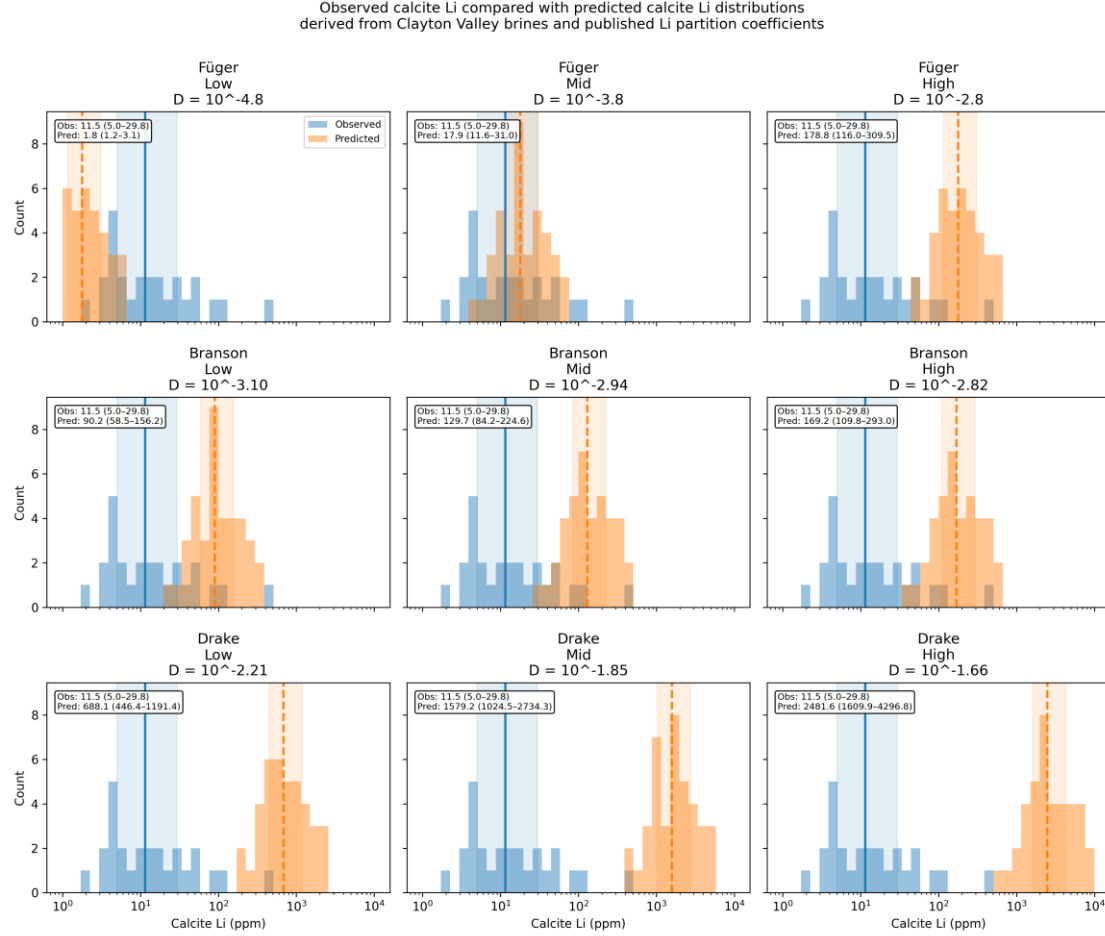


Figure S4. Comparison between observed calcite Li concentrations and predicted calcite Li distributions generated from Clayton Valley brine compositions and published calcite-fluid Li partition coefficients. Blue histograms show measured calcite Li concentrations from this study. Orange histograms show predicted calcite Li distributions generated by propagating measured Clayton Valley brine Li/Ca ratios through experimentally derived partition coefficients reported by Füger et al. (2019), Branson et al. (2024), and Drake et al. (2023). Columns show low, intermediate (“mid”), and high partition coefficient scenarios for each study. Solid vertical lines show medians and shaded fields show interquartile ranges (IQRs) for observed and predicted datasets. These calculations are intended as first-order forward-modeling tests of whether the observed calcite Li concentrations are compatible with precipitation from Li-bearing basin fluids, rather than formal paleo-fluid reconstructions.