Lithium Clay Deposits of the Zeus Property, Eastern Clayton Valley, Nevada

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Abstract

Clay deposits in playa lake/salar environments are now recognized as a significant deposit type for economic concentrations of lithium. Clayton Valley, Nevada, the location of North America's only lithium brine producer, also has paleo-lacustrine lithium clay deposits of significance, including the Zeus property lithium clay deposit in the eastern part of the valley. This study presents new mineralogical studies on the Zeus property lithium clays to help understand their genesis and the potential economic extraction. The Zeus property (owned by Noram Ventures Ltd.) currently has an inferred resource of 17 million tonnes @ 1060 ppm Li (96,500 tonnes Li2CO3 equivalent). Initial XRD and glycolation techniques for two Zeus property bulk samples, one from the surface (relatively oxidized) and the other from ~35 m depth (relatively reduced) indicate that the clay fraction (~50%) includes smectite, illite/muscovite, chlorite, and a significant amount of amorphous matter believed to be poorly crystalline smectite + illite. The non - clay fraction has calcite, quartz and sanidine. Hectorite, sulfates, borates and halides have not been detected (yet). TIMA (Tescan Integrated Mineral Analyzer, using SEM backscatter and X-ray imaging), and petrography will help determine the mode and mineral chemical compositions in more detail, as well as addressing the relative abundance of authigenic vs. transported clay material. Initial indications are that the smectite and illite are authigenic, and formed in and below a playa lake with evolving lithium (and other cation) concentrations. The lithium budget is likely controlled by smectite and illite. Lithium adsorption onto illite and smectite surfaces and crystal edges is dependent on lithium concentration in brine solutions. Smectite adsorbs significantly higher lithium concentrations and has a higher cation exchange capacity than illite. The apparent absence of hectorite may indicate that smectite and illite formed at low temperatures, away from the influence of hydrothermal fluids and hot springs, which are present on the western side of Clayton Valley. Hectorite is relatively refractory and hinders lithium extraction in weak acid solutions. Leaching tests are underway to determine the most effective methods to extract lithium from the clays, and membrane filtration/ion filtration techniques will be tested for lithium solute concentration and purification.

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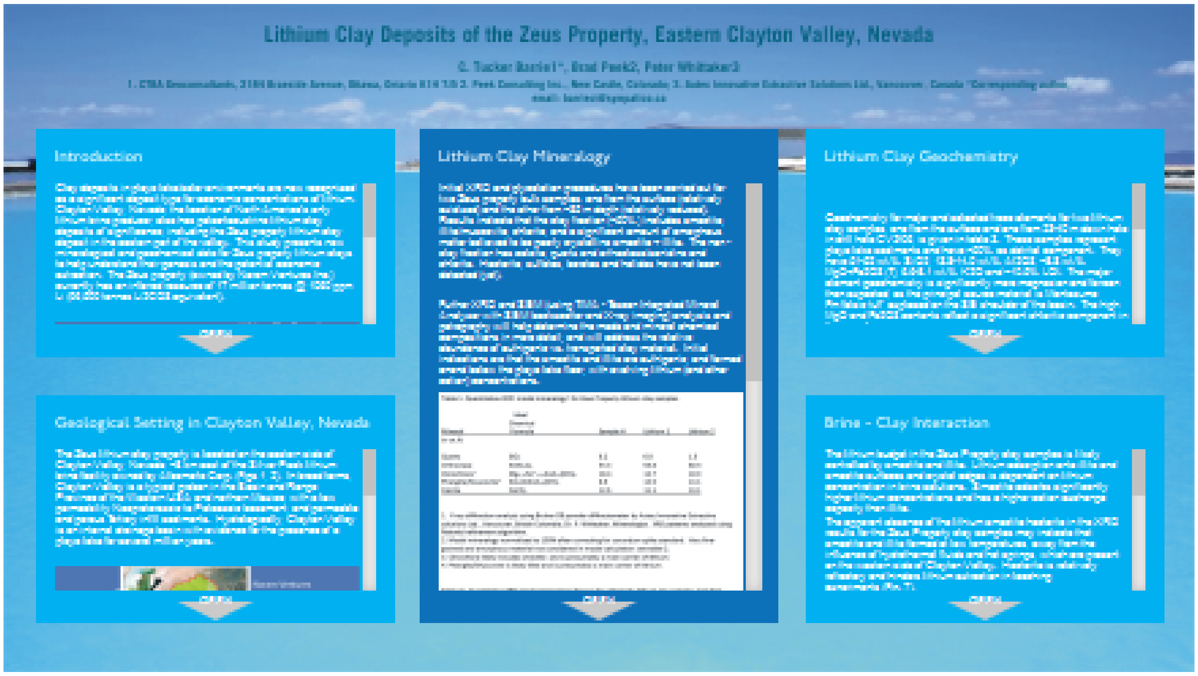

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INTRODUCTION

Clay deposits in playa lake/salar environments are now recognized as a significant deposit type for economic concentrations of lithium. Clayton Valley, Nevada, the location of North America's only lithium brine producer, also has paleo-lacustrine lithium clay deposits of significance, including the Zeus property lithium clay deposit in the eastern part of the valley. This study presents new mineralogical and geochemical data for Zeus property lithium clays to help understand their genesis and the potential economic extraction. The Zeus property (owned by Noram Ventures Inc.) currently has an inferred resource of 17 million tonnes @ 1060 ppm Li (96,500 tonnes Li2CO3 equivalent).

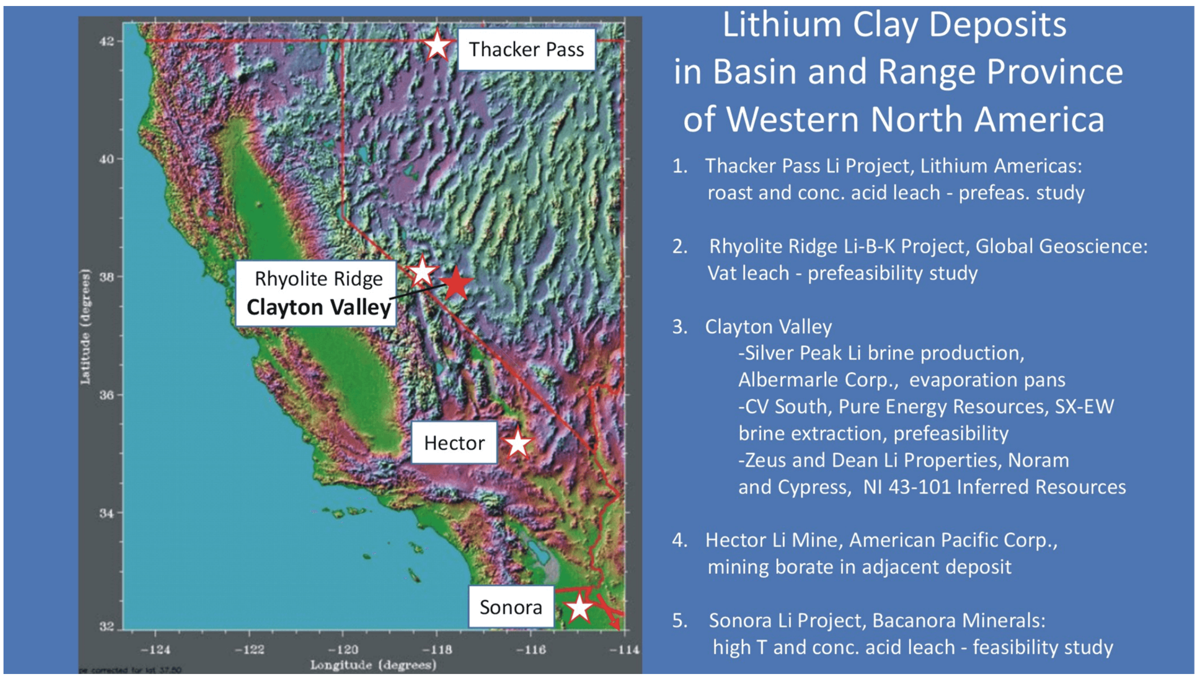


Figure 1. Location of Clayton Valley in the Basin and Range Province of the western USA and Mexico.

GEOLOGICAL SETTING IN CLAYTON VALLEY, NEVADA

The Zeus lithium clay property is located on the eastern side of Clayton Valley, Nevada, ~8 km east of the Silver Peak lithium brine facility owned by Albemarle Corp. (Figs 1, 2). In broad terms, Clayton Valley is a typical graben in the Basin and Range Province of the Western USA and northern Mexico, with a low permeability Neoproterozoic to Paleozoic basement, and permeable and porous Tertiary infill sediments. Hydrologically, Clayton Valley is an internal drainage basin with evidence for the presence of a playa lake for several million years.

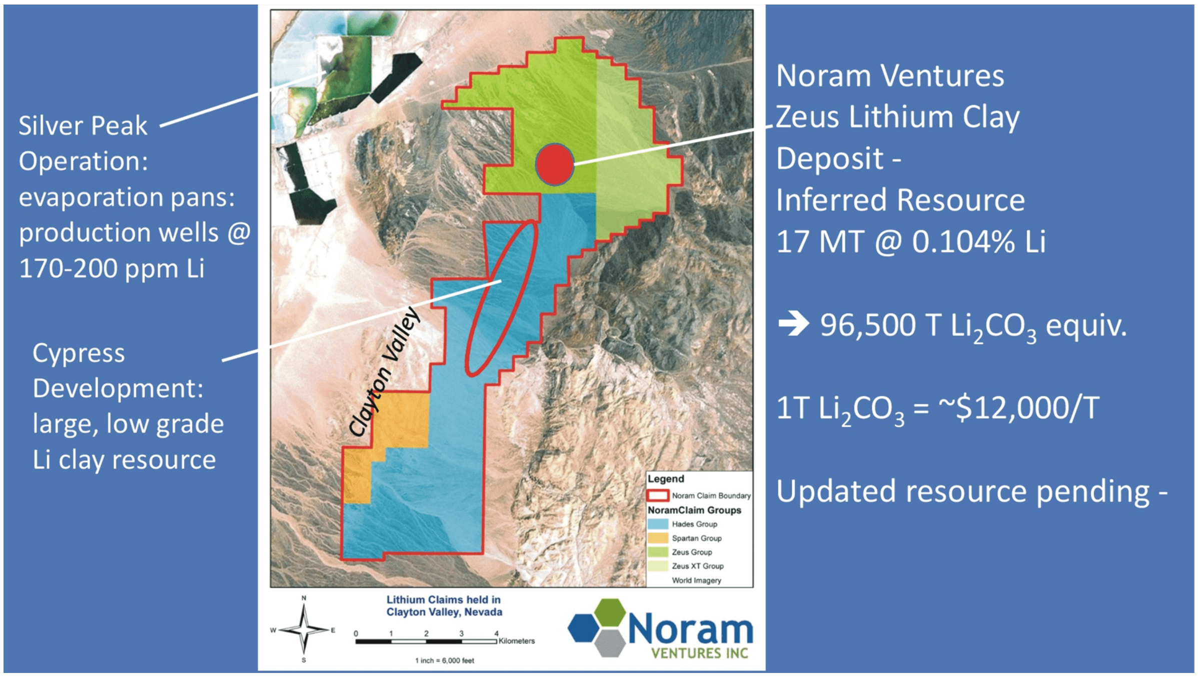
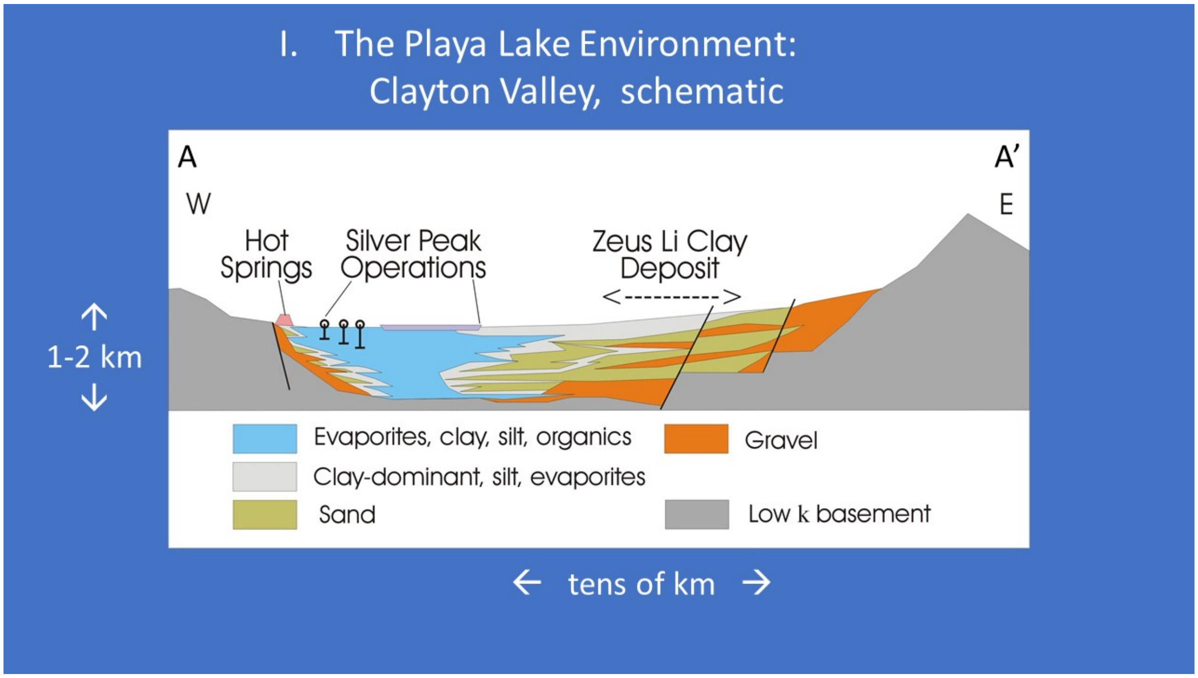


Figure 2. Location of the Zeus lithium clay deposit in eastern Clayton Valley, Nevada.



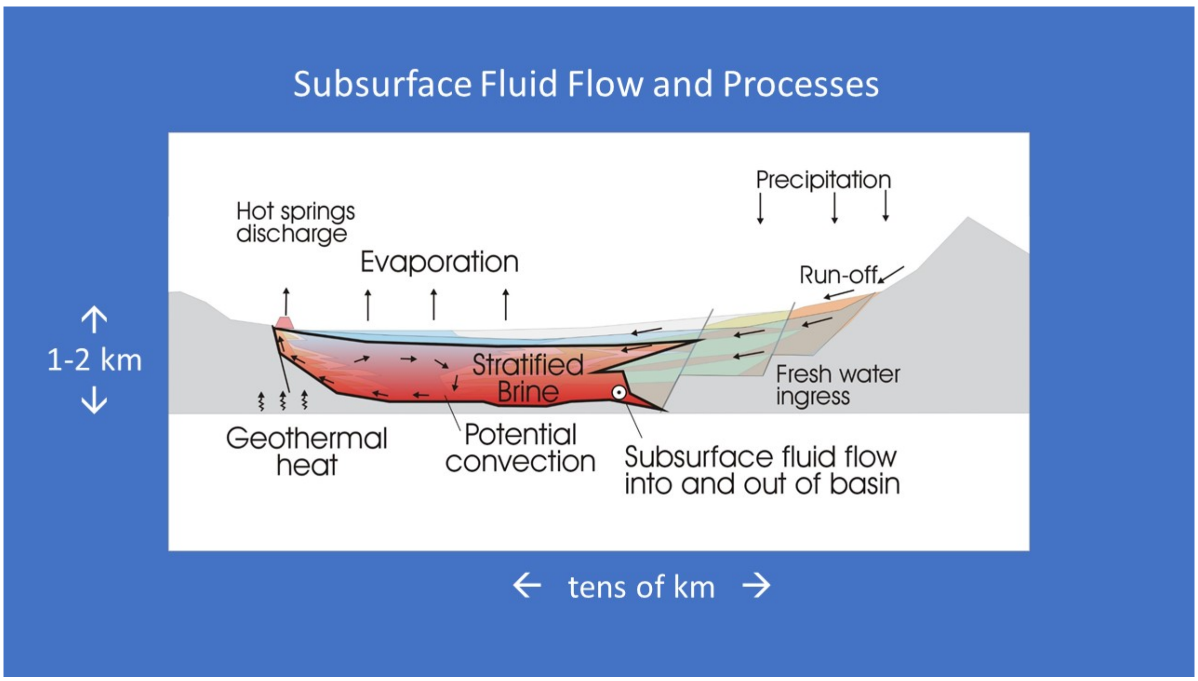


Figure 3. Schematic W-E cross sections across Clayton Valley, including the Zeus lithium clay deposit and the Silver Peak lithium brine operation. a) Lithology and location of hot springs on west side of valley. b) Stratified subsurface brine with possible convection influenced by high geothermal gradient particularly along the western side of the basin where hot spring activity is present. Temperature strongly influences the partitioning of lithium between brine and clays.

LITHIUM CLAY MINERALOGY

Initial XRD and glycolation procedures have been carried out for two Zeus property bulk samples: one from the surface (relatively oxidized) and the other from ~35 m depth (relatively reduced). Results indicate that the clay fraction (~50%) includes smectite, illite/muscovite, chlorite, and a significant amount of amorphous matter believed to be poorly crystalline smectite + illite. The non - clay fraction has calcite, quartz and orthoclase/sanidine and chlorite. Hectorite, sulfates, borates and halides have not been detected (yet).

Further XRD and SEM (using TIMA - Tescan Integrated Mineral Analyzer with SEM backscatter and X-ray imaging) analysis and petrography will help determine the mode and mineral chemical compositions in more detail; and will address the relative abundance of authigenic vs. transported clay material. Initial indications are that the smectite and illite are authigenic, and formed onand below the playa lake floor, with evolving lithium (and other cation) concentrations.

Table 1. Quantitative XRD[1] modal mineralogy[2] for Zeus Property lithium clay samples.

Mineral in wt.%	Ideal Chemical Formula	Sample H	Lithium 1	Lithium 2
Quartz	SiO_2	6.2	6.0	1.5
Orthoclase	$KAlSi_3O_8$	54.3	55.8	60.4
Clinochlore[3]	$Mg_{3.75}Fe^{2+}_{1.25}Si_3O_{12}(OH)_8$	18.4	12.7	10.3
Phengite/Muscovite[4]	$KAl_2(AlSi_3O_{10}(OH)_2$	8.5	14.5	14.1
Calcite	$CaCO_3$	12.5	11.1	13.1

1. X-ray diffraction analysis using Bruker D8 powder diffractometer by Autec Innovative Extractive solutions Ltd., Vancouver, British Colombia; Dr. P. Whittaker, Mineralogist. XRD patterns analyzed using Reitveld refinement algorithm.
2. Modal mineralogy normalized to 100% after correcting for corundum spike standard. Very fine-grained and amorphous material not considered in modal calculation: see table 2.
3. Clinochlore likely includes smectite and is presumably a main carrier of lithium.
4. Phengite/Muscovite is likely illite and is presumably a main carrier of lithium.

Table 2a. Quantitative XRD[1] modal mineralogy[2] for two Zeus Property lithium clay samples, including amorphous material.

Mineral in wt.%	Ideal Chemical Formula	Lithium 1	Lithium 2
Quartz	SiO_2	5.5	1.0
Orthoclase/Sanidine	$KAlSi_3O_8$	28.9	36.0
Chlorite	$Mg_{3.75}Fe^{2+}_{1.25}Si_3O_{12}(OH)_8$	3.3	2.9
Muscovite/Illite	$KAl_2(AlSi_3O_{10}(OH)_2$	18.5	15.9
Calcite	$CaCO_3$	7.9	6.8
Smectite[3]		22	9
Amorphous[4]		14.0	28.4

1. Analyses by X-ray diffraction using a Panalytical X'Pert Pro diffractometer at Actlabs, Ancaster, Ontario; Dr. E. Hrischeva, mineralogist.
2. Modal mineralogy calculated using X'Pert HighScore plus software and PDF4/Minerals ICDD database. and employing the Rietveld method for modal calculation. Crystalline mineral modes recalculated based on known percent of spike corundum and the remainder attributed to amorphous (poorly crystalline) material.
3. Smectite identified on the basis of the broad reflection at ~15 Angstroms that shifted to 17 Angstroms after treatment with ethylene glycol.
4. Amorphous material clay mineralogy for <4 um size fraction estimated in Table 2b.

Table 2b. Relative proportions of clay minerals in the < 4 um size fraction[1].

Mineral in wt.%	Lithium 1	Lithium 2
Smectite	53	36
Illite	45	62
Chlorite	2	2 .

1. See footnotes 3 and 4 for Table 2a.

LITHIUM CLAY GEOCHEMISTRY

Geochemistry for major and selected trace elements for two lithium clay samples, one from the surface and one from 23-40 m down hole in drill hole CVZ-06, is given in table 3. These samples represent playa lake sediments and have >50% as detrital component. They have 51-52 wt.% SiO2, 13.8-14.0 wt.% Al2O3, ~8.8 wt.% MgO+Fe2O3 (T), 6.6-8.1 wt.% K2O and ~10.5% LOI. The major element geochemistry is significantly more magnesian and ferroan than expected, as the principal source material is Montezuma Fm felsic tuff explosed on the SE shoulder of the basin. The high MgO and Fe2O3 contents reflect a significant chloritic component in the samples.

The two samples have lithium contents of 980 ppm Li and 1290 ppm Li. They also have high Rb and Cs contents, which may prove to be economically important. The relatively high, ppm level Ag content likely reflects a detrital component derived from Au-Ag vein mineralization in Paleozoic basement rocks at higher elevations to the east.

Table 3. Zeus Property geochemistry[1] for surface and downhole samples.

	SAMPLE 1[2]	SAMPLE 2[3]
in wt.%		
SiO2	52.09	51.44
Al2O3	13.95	13.79
Fe2O3(T)	4.68	4.67
MnO	0.09	0.10
MgO	4.22	4.20
CaO	5.98	6.10
Na2O	1.68	1.02
K2O	6.64	8.07
TiO2	0.56	0.53
P2O5	0.09	0.09
LOI	10.65	10.48
Total	100.60	100.50
in ppm		
Li	980	1290
Ba	582	580
Sr	2638	2239

Y	20	19
Sc	11	10
Zr	172	166
Be	3	3
V	100	99
B	1220	1150
Rb	338	295
Ag	0.87	0.11
Cs	70.3	53
S	800	2800
Sr	741	2024

1. Analyses by ICP on fused samples with aqua regia digestion, except lithium by ICP-OES (not fused) and boron by neutron activation (not fused); at Actlabs, Ancaster, Ontario.
For Rb, Ag, Cs, S and Sr analyses by ME-MS61 at ALS Global, Vancouver, British Colombia.
2. Surface sample taken near CVS-06 drill collar; Rb, Ag, Cs, S and Sr average of top 3 meters of drill hole CVZ-06 (n=3).
3. Down hole sample from 23-40 m depth in drill hole CVZ06.

The lithium, rubidium, potassium and sodium contents in the Zeus lithium clay deposit are shown in cross-section in figures 4 and 5. There is consistent enrichment in the unconsolidated playa lake clays near surface across the deposit.

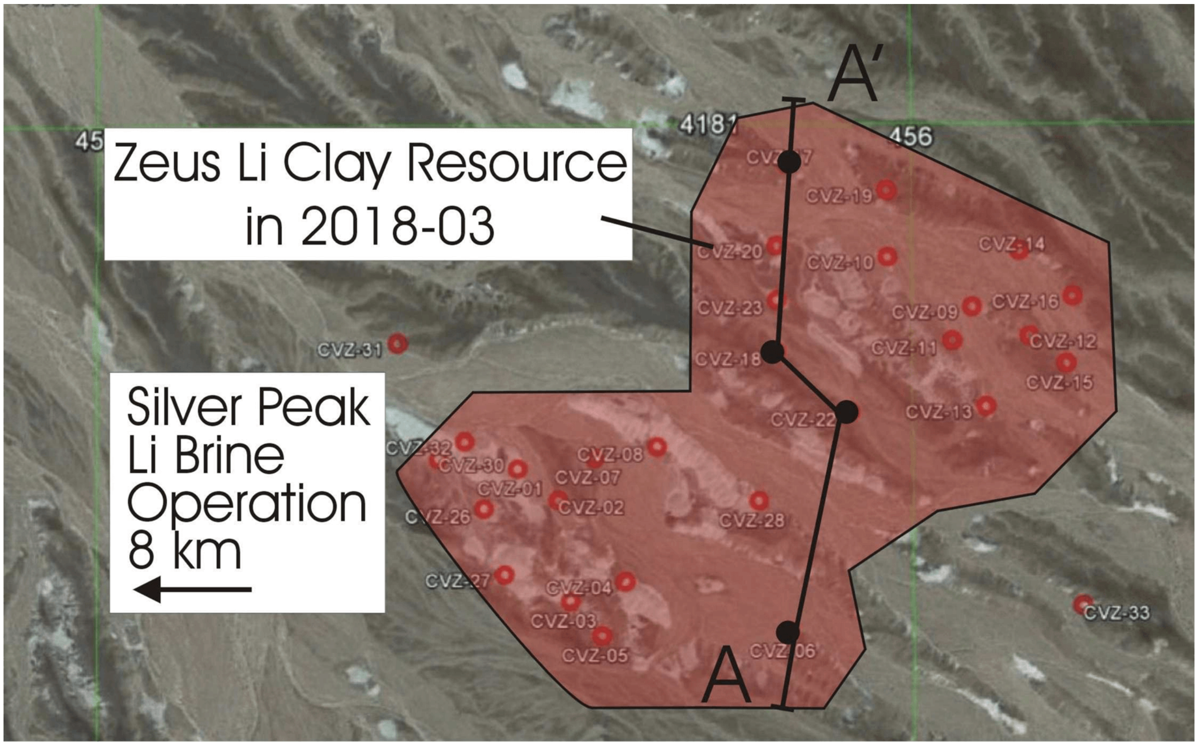


Figure 4. Outline of initial lithium clay resource on Google map image, and S-N cross-section A-A' shown in figures 5 and 6.

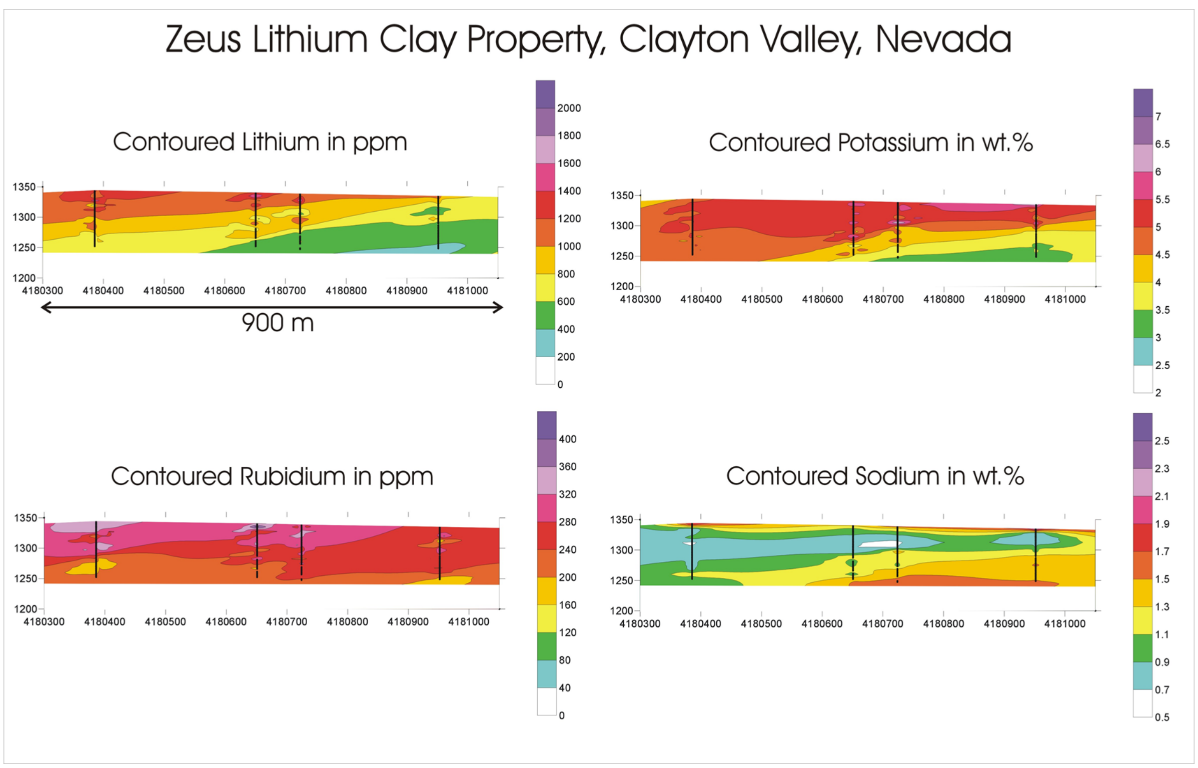


Figure 5. Contoured values for Li, Rb, K and Na for South - North cross-section across Zeus lithium deposit. See figure 4 for cross-section location. The clay-rich playa lake facies strata dip gently to the SSE, and are underlain by a more clastic-rich unit informally known as sandy blue mudstone.

In figure 6, numerous elements are plotted down hole for drill hole CVZ-05 in the center of the of the Zeus lithium clay deposit as presently outlined. A more clastic-rich sandy mudstone unit underlies the playa lake clay-rich sediments near surface, and partly accounts for the broad upward-trending enrichment in alkalis which are associated with clay minerals, and possibly with residual salts (e.g., near-surface sodium enrichment).

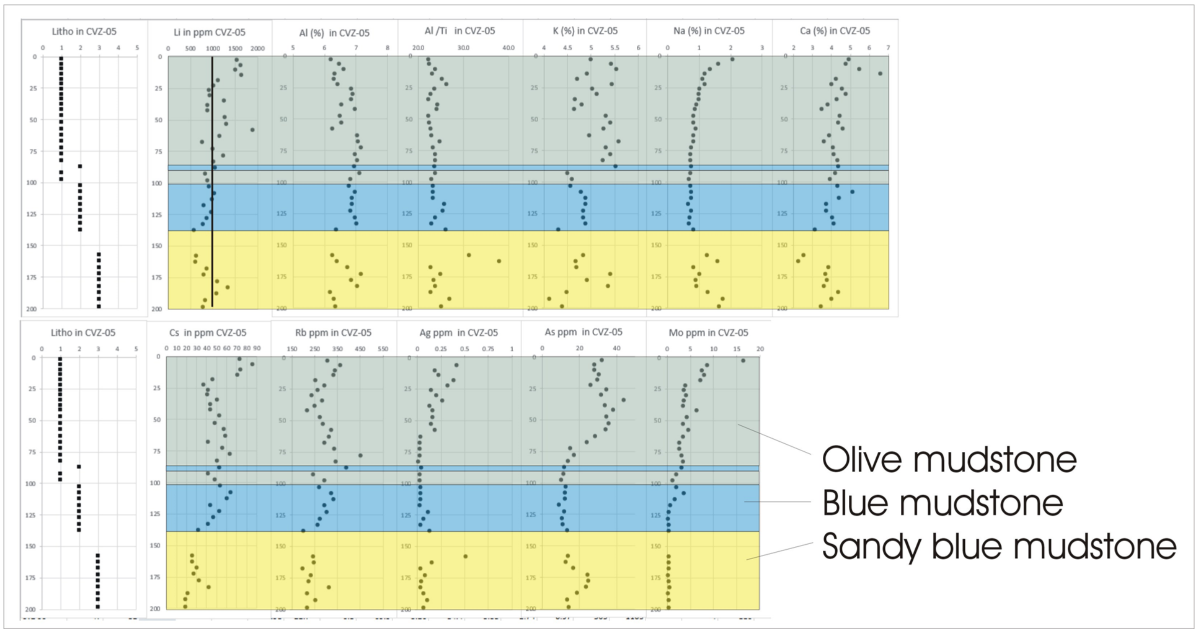


Figure 6. Downhole elemental plots for drill hole CVZ-05, with Li, Al, Al/Ti, K, Na, Ca, Cs Rb, Ag, As and Mo. 1000 ppm Li content is marked for reference. Note strong enrichment in Na and Cs near the surface.

BRINE - CLAY INTERACTION

The lithium budget in the Zeus Property clay samples is likely controlled by smectite and illite. Lithium adsorption onto illite and smectite surfaces and crystal edges is dependent on lithium concentration in brine solutions. Smectite adsorbs significantly higher lithium concentrations and has a higher cation exchange capacity than illite.

The apparent absence of the lithium smectite hectorite in the XRD results for the Zeus Property clay samples may indicate that smectite and illite formed at low temperatures, away from the influence of hydrothermal fluids and hot springs, which are present on the western side of Clayton Valley. Hectorite is relatively refractory and hinders lithium extraction in leaching experiments (Fig. 7).

Leaching tests are underway to determine the most effective methods to extract lithium from the Zeus Property clay samples. Initial results indicate that >80% of the lithium can be leached in 2M H2SO4 solution at 80 degrees Celsius (Fig. 8). Other leaching experiments are planned using NaOH solutions, which is effective at selectively leaching lithium while leaving magnesium behind. Membrane filtration, ion filtration ans solvent extraction techniques may also be considered for lithium solute concentration and purification.

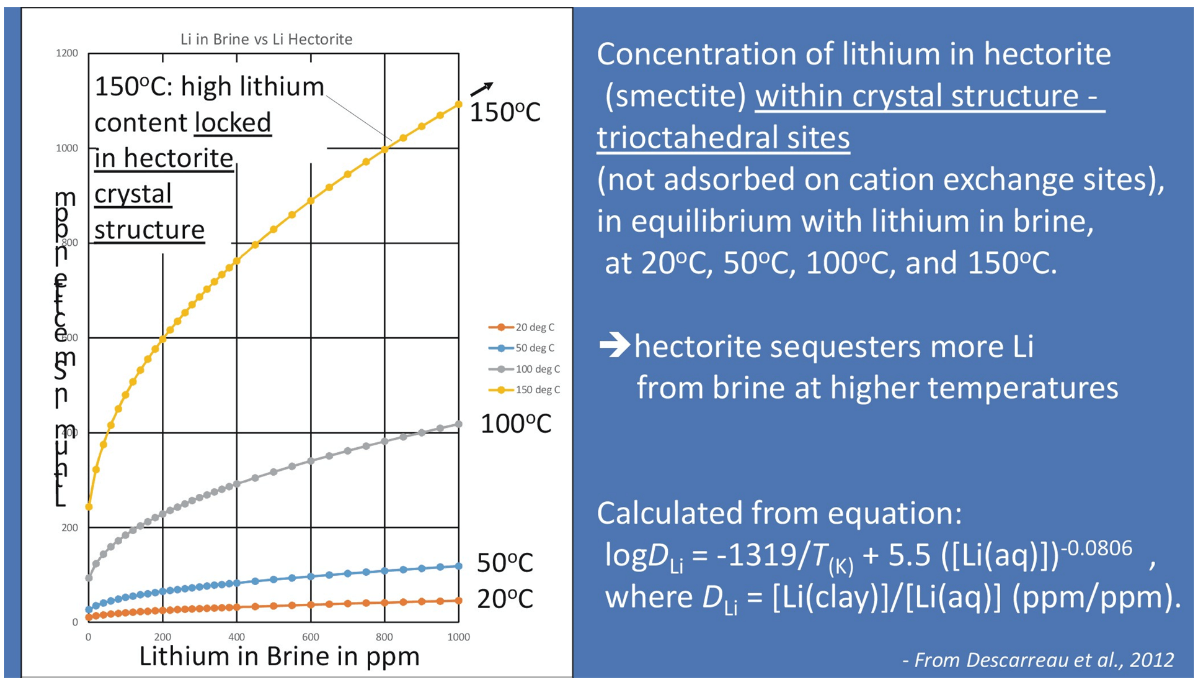


Figure 7. Concentration of lithium in hectorite trioctahedral sites in equilibrium with brine at varying temperatures, based on data and equations in Descarreau et al., 2012.

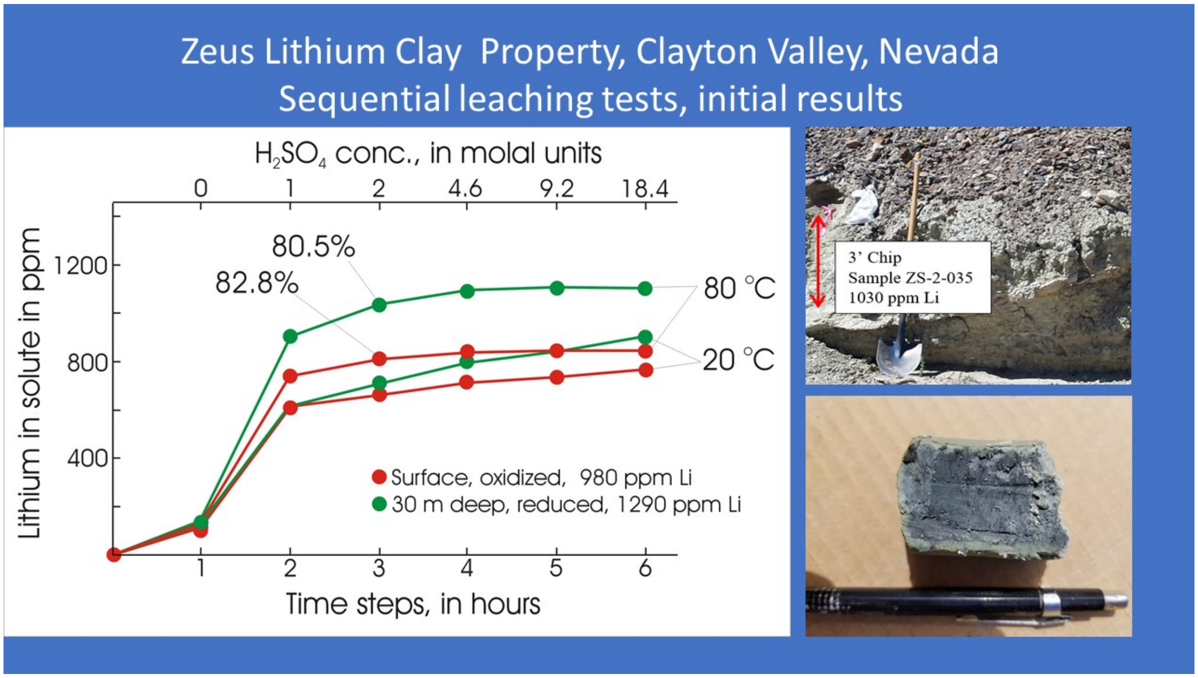


Figure 8. Initial leach tests for Zeus Property lithium clay samples from surface and from 23-40 m depth in drill hole CVZ-06. Greater than 80% lithium is extracted from both samples in 2M H2SO4 solution at 80 degrees Celsius.

Discussion

In time, there will be numerous other lithium clay deposits discovered and delineated with potential to be economically viable. At present, the most pressing issue from an economic standpoint is about cost-effective lithium extraction. This study demonstrates that low pH leaching at low to moderate temperatures may yield 80+% of lithium from the Zeus property clays, but with high magnesium contents as well which requires extra steps for magnesium removal before purification. High pH leaching, as has been tested recently by Enertopia Corp. for lithium clays from a nearby property in eastern Clayton Valley, may yield a leachate with low magnesium contents but appears to yield only ~25% of the contained lithium. Much higher yields can be derived by roasting in the presence of sodium sulphate (e..g., Bacanora Lithium - Sonora Project, Mexico), and subsequent leaching; however the energy costs are higher than for the aforementioned options.

Further research is necessary to determine the most economical of these (and other) options for the Zeus Propertery lithium clays.

Acknowledgements

We acknowledge Noram Ventures Ltd. of Vancouver, British Colombia for permission to present this poster.

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ABSTRACT

Clay deposits in playa lake/salar environments are now recognized as a significant deposit type for economic concentrations of lithium. Clayton Valley, Nevada, the location of North America's only lithium brine producer, also has paleo-lacustrine lithium clay deposits of significance, including the Zeus property lithium clay deposit in the eastern part of the valley. This study presents new mineralogical studies on the Zeus property lithium clays to help understand their genesis and the potential economic extraction. The Zeus property (owned by Noram Ventures Ltd.) currently has an inferred resource of 17 million tonnes @ 1060 ppm Li (96,500 tonnes Li2CO3 equivalent).

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