Mineral Exploration and Mining

Detecting the Undetectable: Lithium by Portable XRF

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Talk: S3
August

03

Thursday

2017

Bigsky Montana

Lithium by pXRF

- Portable XRF (pXRF) can detect down to Na (Z11).
- **pXRF** cannot detect lithium (Z3) **directly**
- **Lithium** is derived from 2 main sources
  - Lithium-Caesium-Tantalum pegmatites (LCT Pegmatites)
  - Lithium bearing brines associated with salt lakes
- pXRF can detect elements associated with **LCT Pegmatites** (Ga, Rb, Nb, Sn, Cs, Ta & Tl)
- an algorithm based on associated LCT elements is used to estimate the Li content (**Lithium Index**)

Both images are derived from the SAME samples
Laboratory Li, predicted Li from pXRF instrument

A

Predicted Li from pXRF

High
20
30
Low

Which is predicted pXRF Li?

850m

B

Conventional Four Acid

Pioneer RESOURCES LIMITED

200 x 50m grid
n = 207

Why Lithium?

Goldman Sachs has called **Lithium ..**
“the New Gasoline”

Why Lithium?

Goldman Sachs

What if I Told You….. Lithium is the New Gasoline"

Dec 2015

Lithium is now considered a key, strategic energy metal in the clean technology economy that is being fuelled by advances in electric vehicles, energy storage and electronics

U.S. DEPARTMENT OF ENERGY

citi

Energy Storage –

The economic value of energy storage over a 10-year period in the US could reach **$228** billion, **21**% of the **$1** trillion global economic benefit

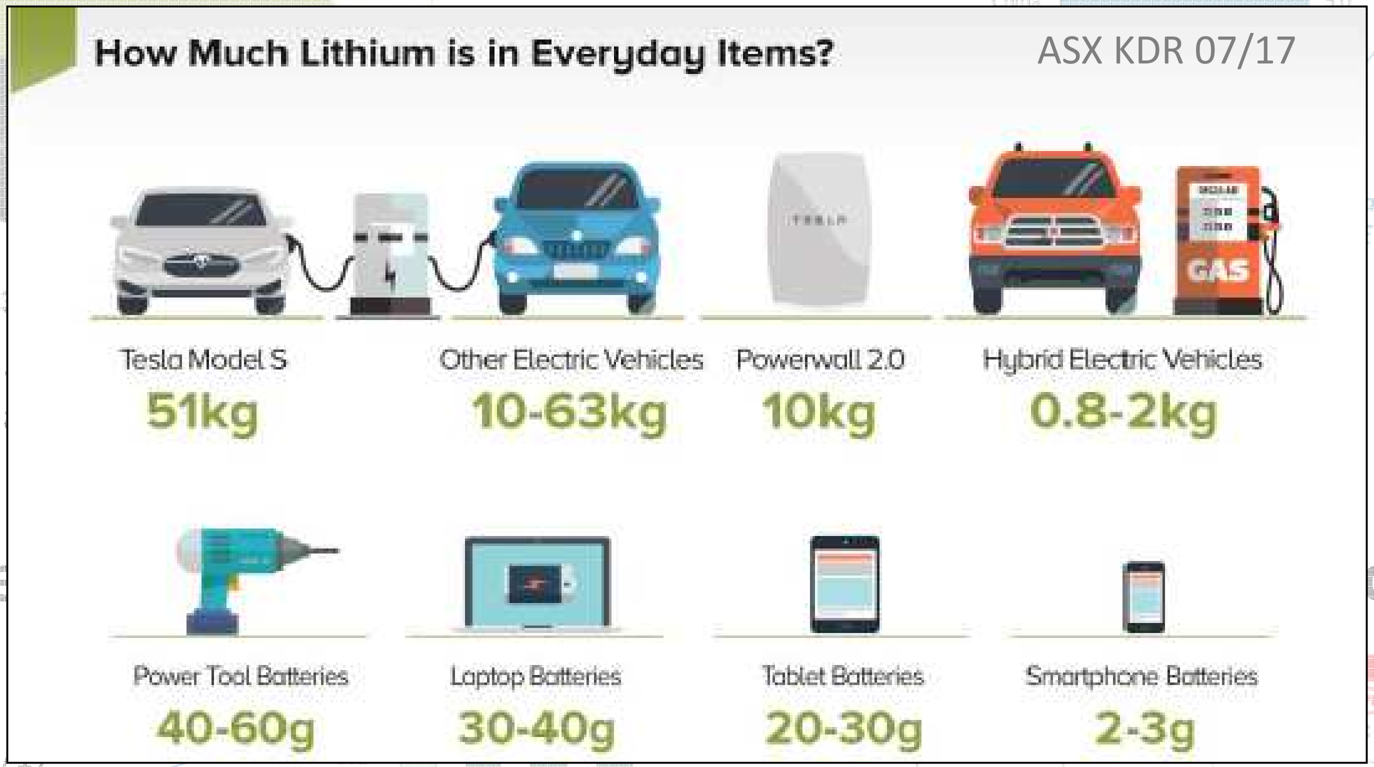
The Economist

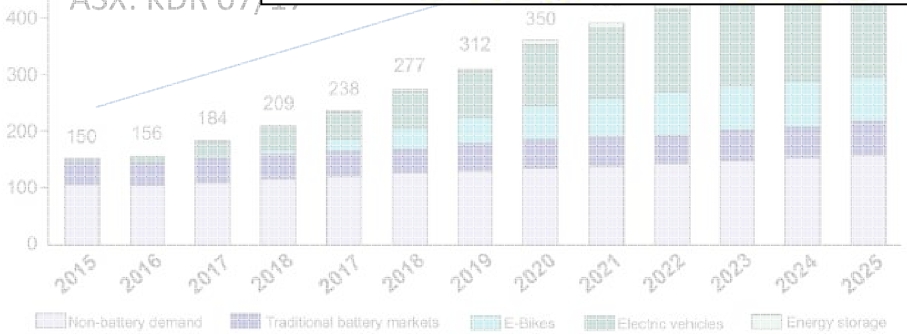
"An Increasingly Precious Metal"

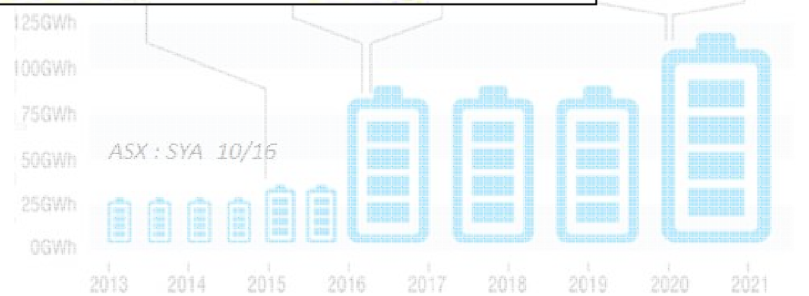
Jan 2016

by 2020 ~20 million EV & hybrid cars

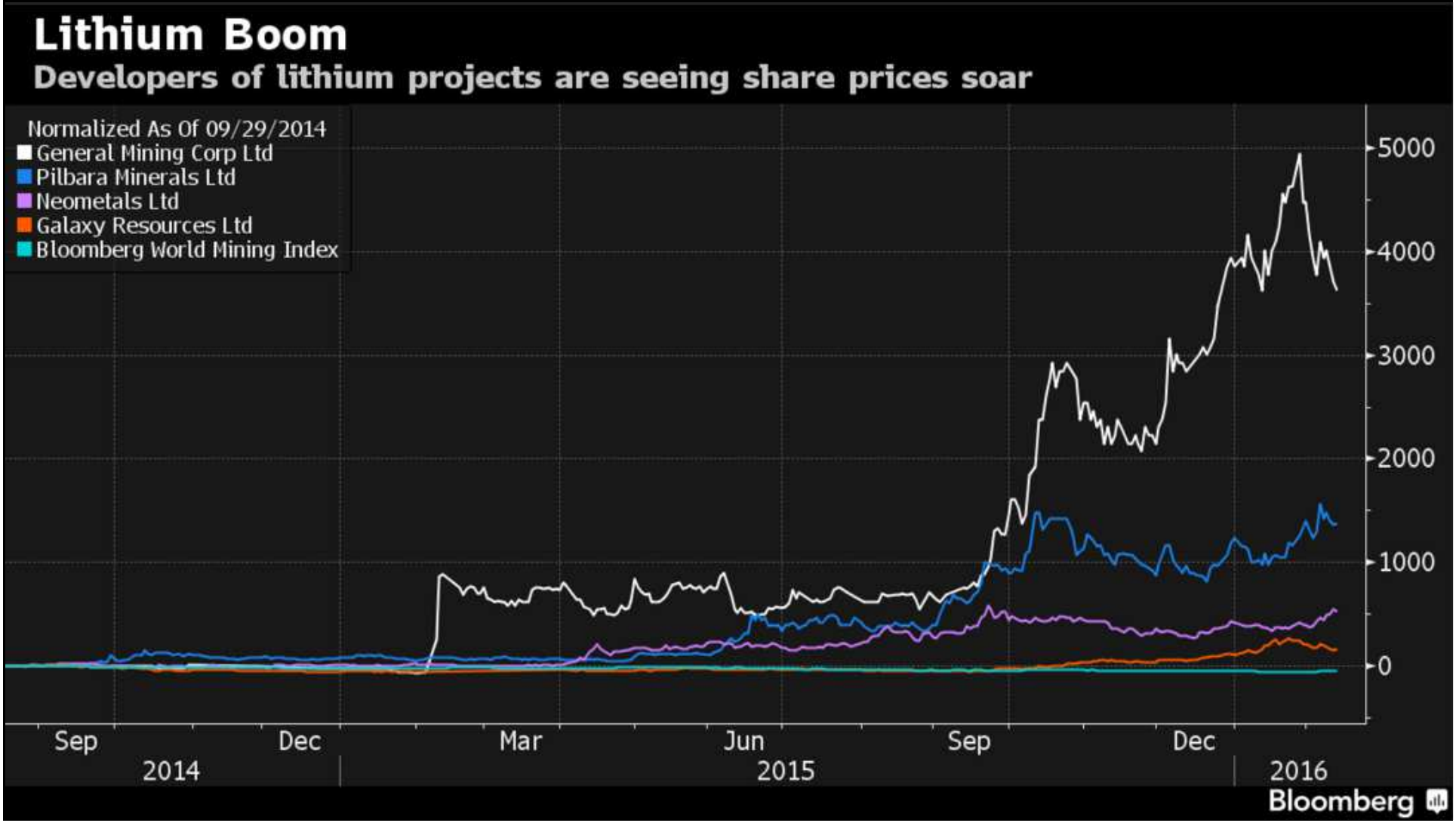
Projected Li Consumption 2025





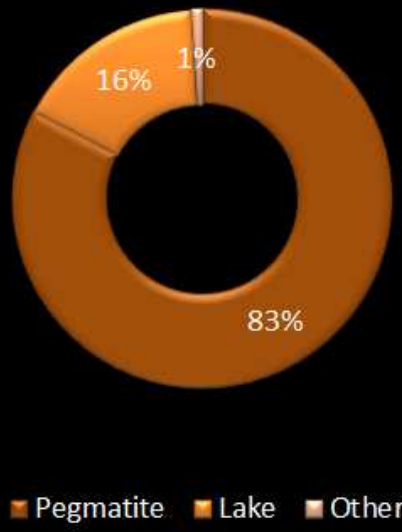


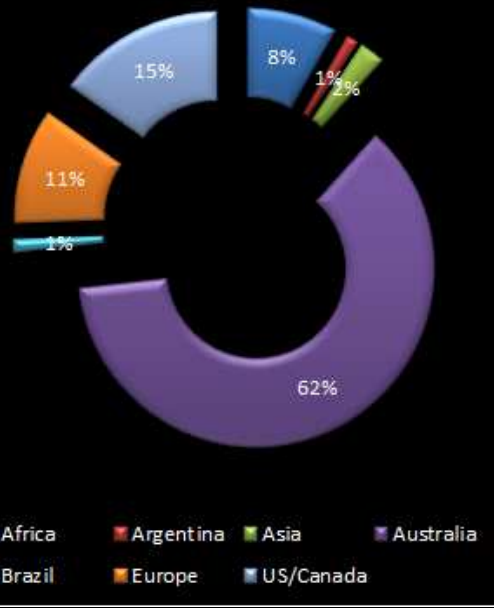
Impact on company value



86 Companies on the ASX have lithium Interests

Pegmatites account for 86% of these companies lithium interests





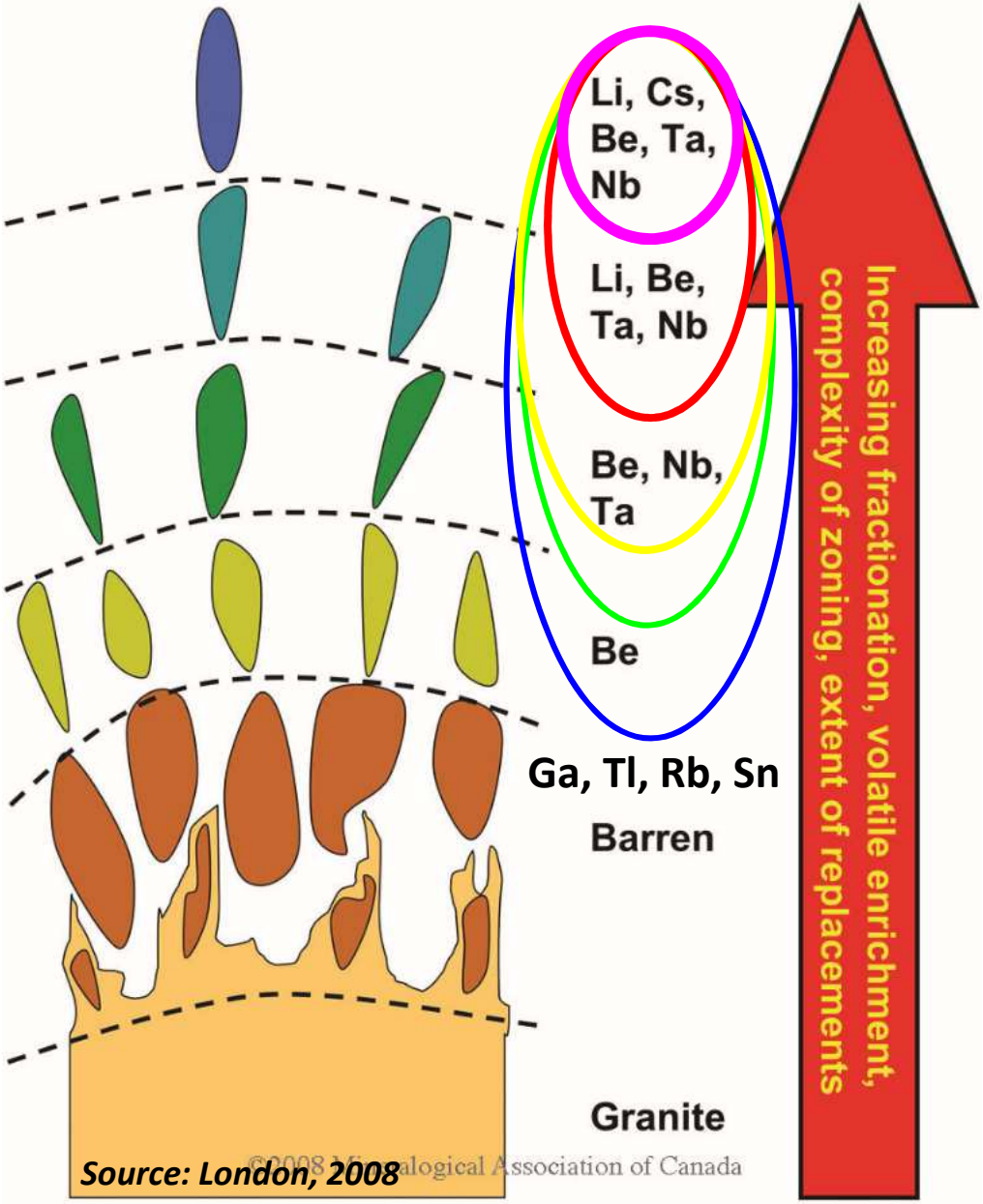
62% of these lithium pegmatites interests are Australian based

LCT Pegmatite Model – element distribution

The element associations provides a potential vector to LCT mineralisation.

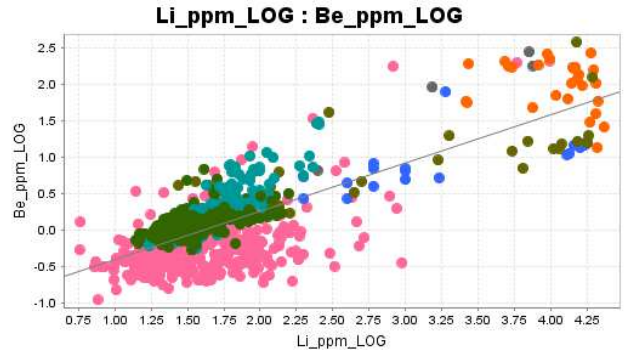
Key LCT Pegmatite Elements

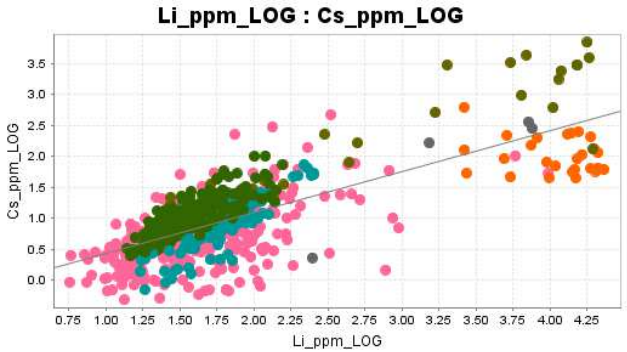
Li, Be, Cs, Ga, Nb, Rb, Sn, Ta, Tl

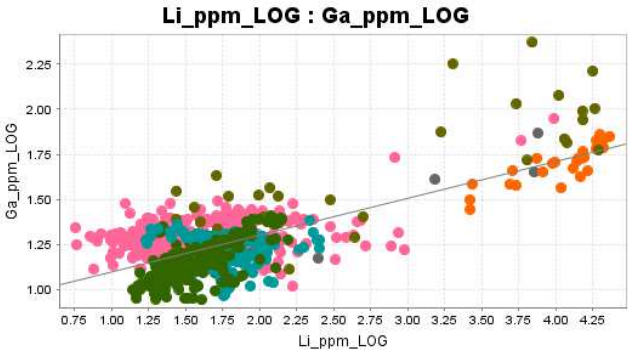


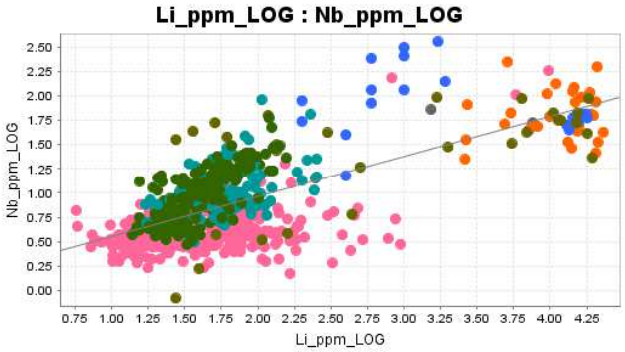
Source: London, 2008

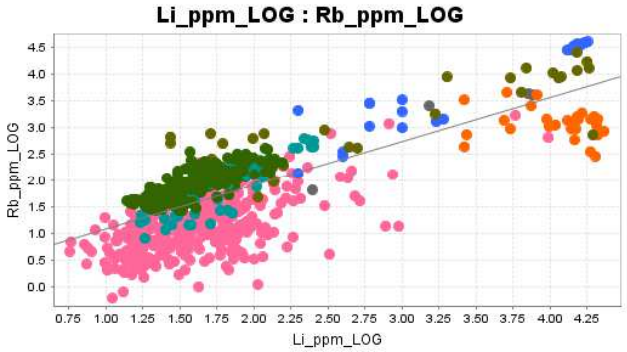
LCT Pegmatite elements

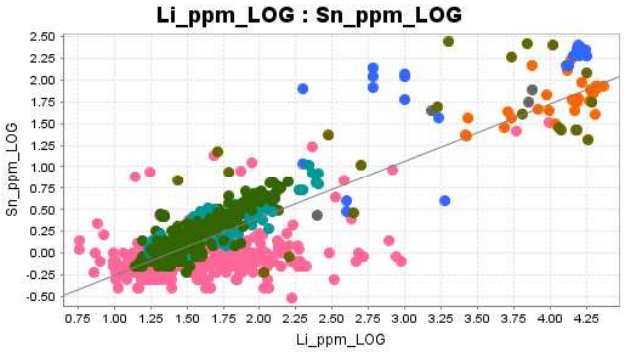


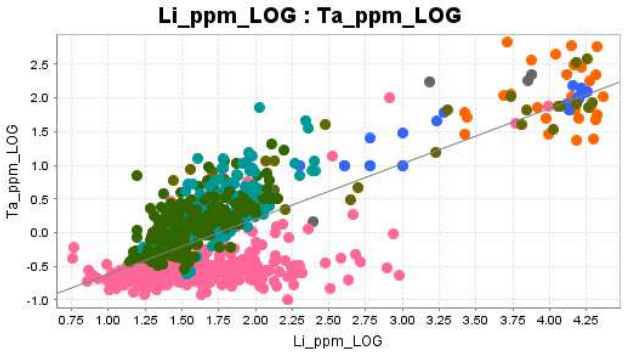


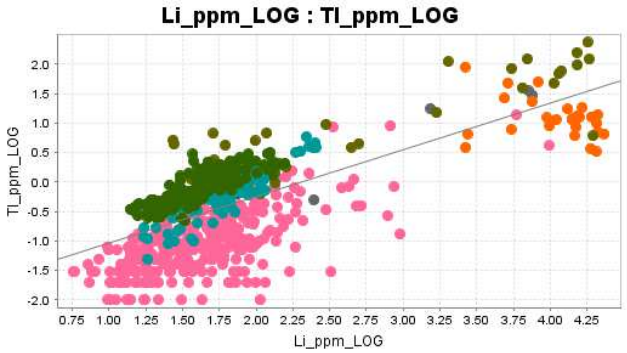










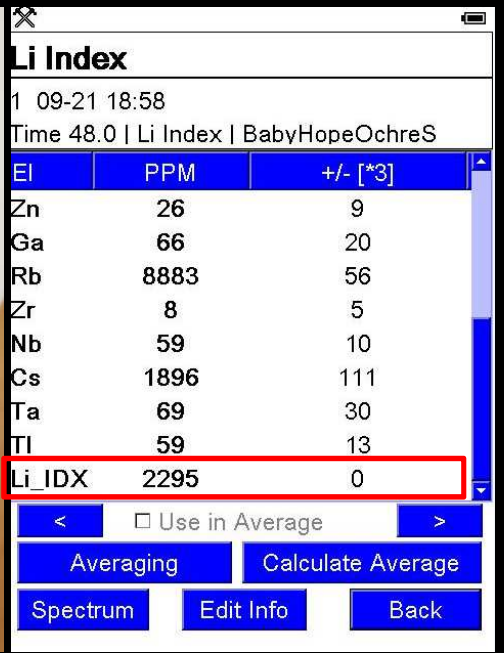


Correlation	Li_ppm_LOG
Li_ppm_LOG	1
Be_ppm_LOG	0.78
Cs_ppm_LOG	0.73
Ga_ppm_LOG	0.72
Nb_ppm_LOG	0.7
Rb_ppm_LOG	0.74
Sn_ppm_LOG	0.84
Ta_ppm_LOG	0.77
Tl_ppm_LOG	0.7

Detecting the undeletable

- pXRF can detect elements associated with **LCT Pegmatites**.
- Derive an algorithm to estimation of the Li content
  - the **Lithium Index**.
- Use EasyCal on Bruker S1 Titan to develop a fundamental calibration “Lithium Index calibration”

LCT elements	Z#	Detectable by pXRF	Detection limit (CAMIRO)
Li	3	NO	n/a
Be	4	NO	n/a
Ga	31	YES	<5
Rb	37	YES	<5
Nb	41	YES	<5
Sn	50	YES	<20
Cs	55	YES	<20
Ta	73	YES	<10
Tl	81	YES	<5

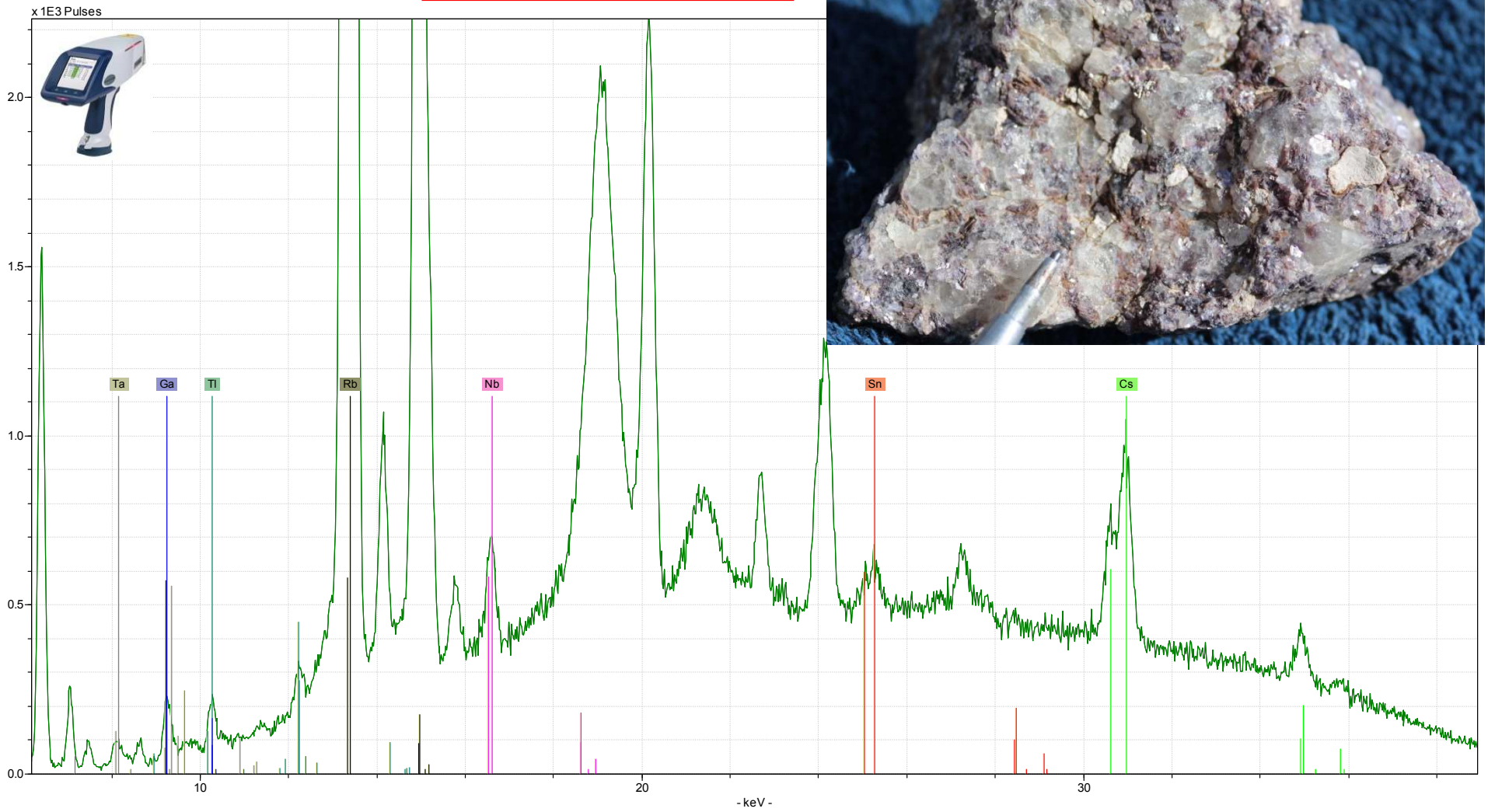


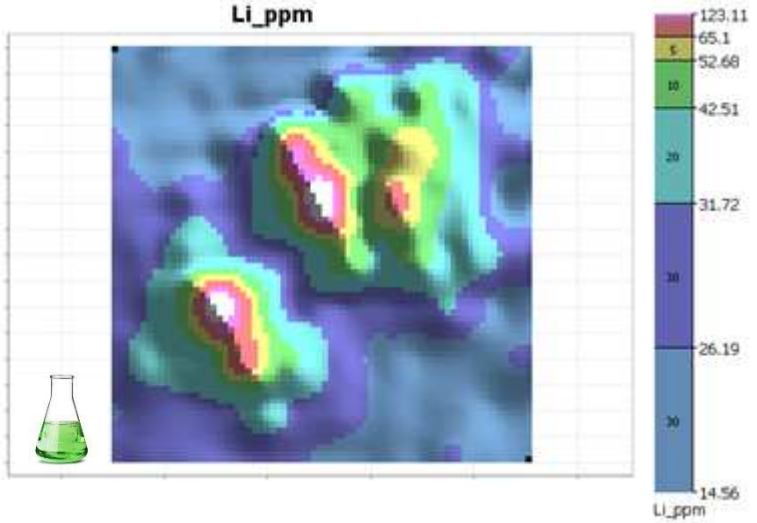
Predicting Li (index)

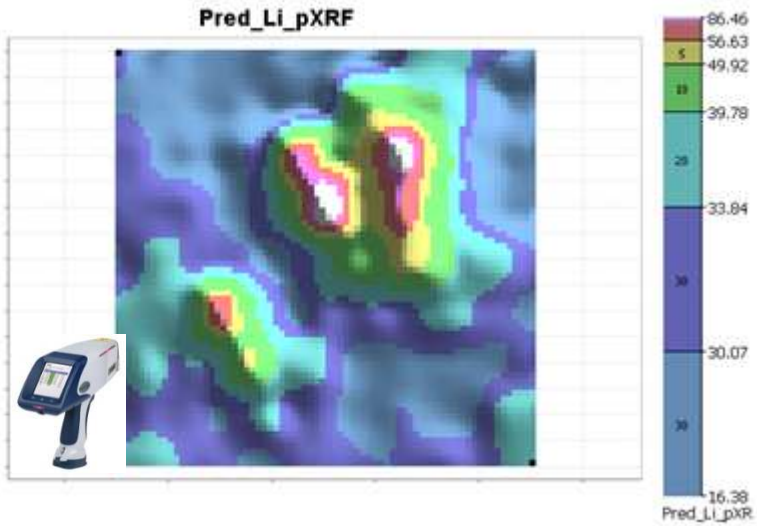
Non blind test

ARC103060

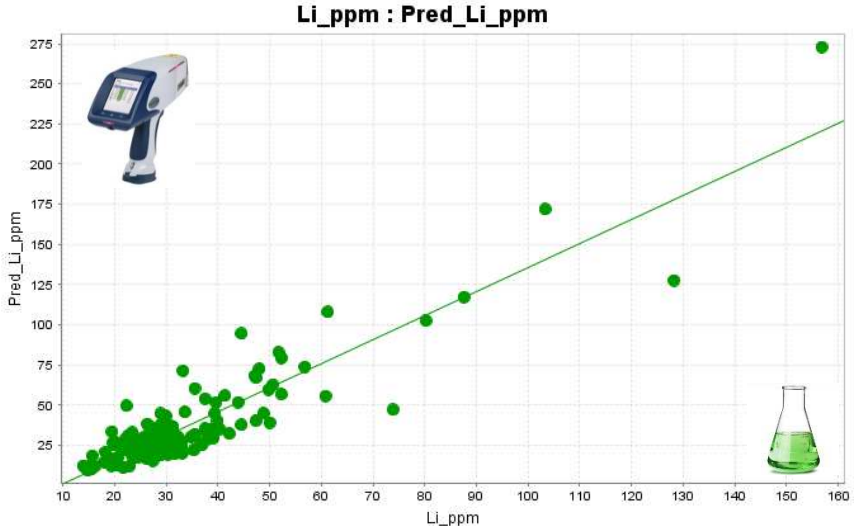
ARC103060	Lab (ppm)	pXRF (ppm)
Cs	2389.51	2459
Ga	65.42	67
Li	11836	Cal: 9040
Nb	56.06	59
Rb	8813.8	8797
Sn	26.5	33
Ta	76.52	90
Tl	77.64	72





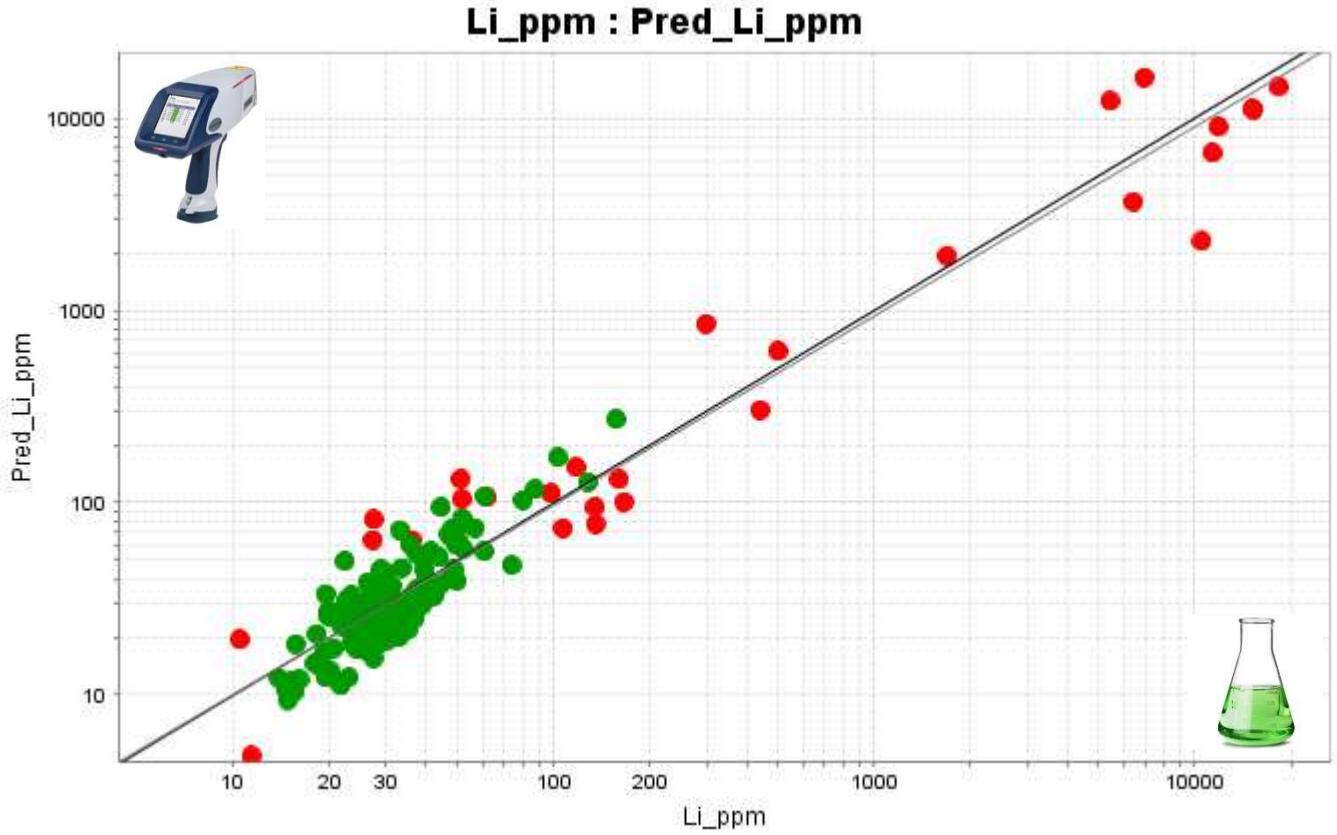


Laboratory assay data (four acid)



Predicting lithium concentration (pXRF data).

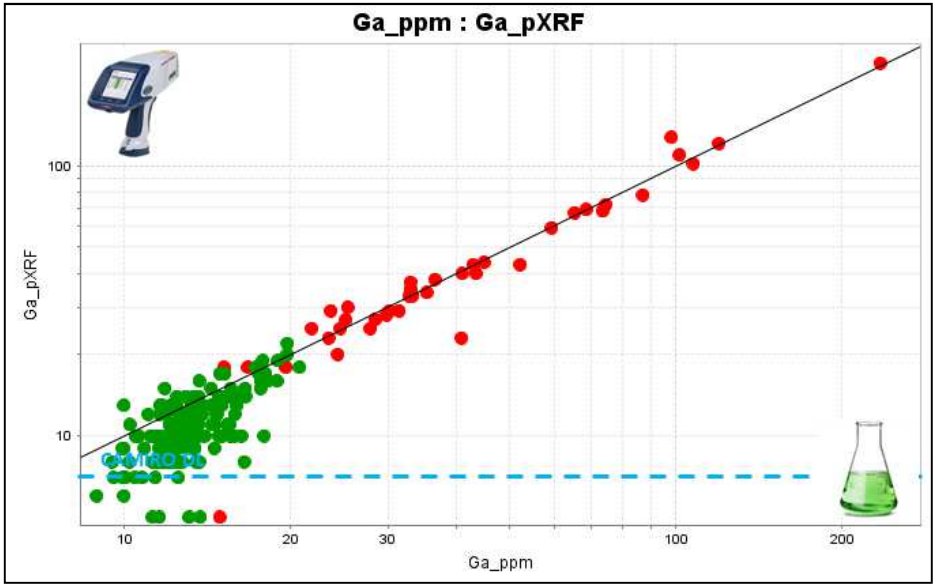
Lithium (calculated)

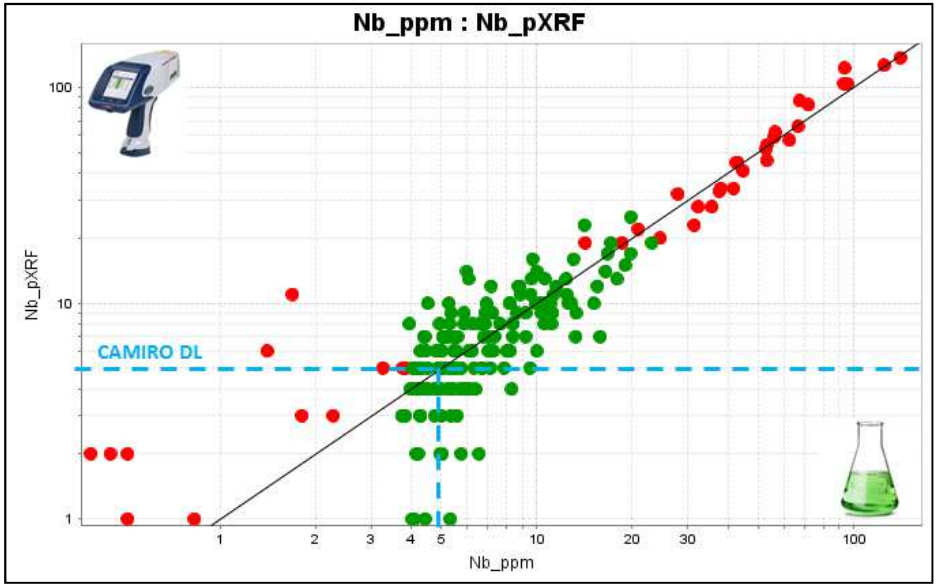


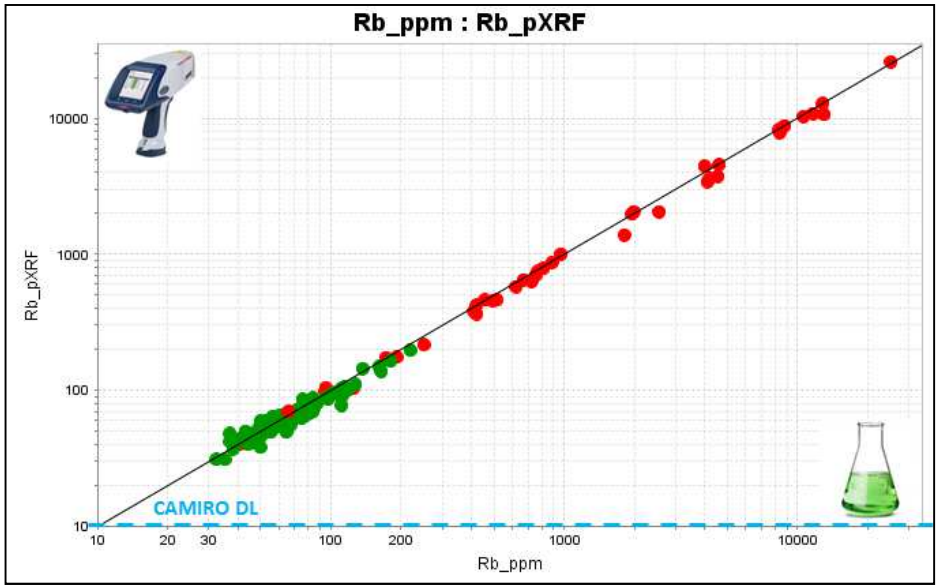
ROCKS

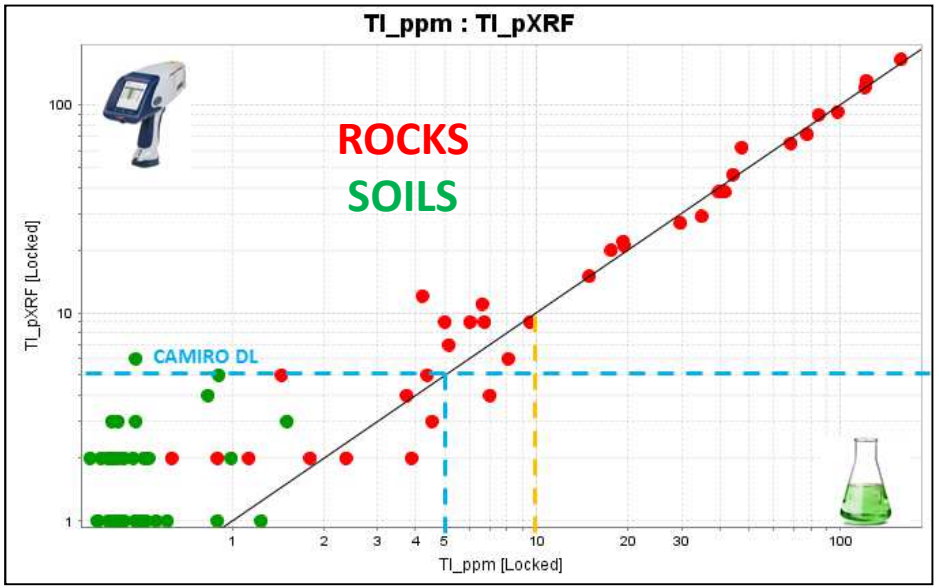
SOILS

Lab vs BpXRF


Ga_ppm : Ga_pXRF
Ga_pXRF
Ga_ppm
CAMIRO DL
100
10
10
20
30
100
200


Nb_ppm : Nb_pXRF
Nb_pXRF
Nb_ppm
CAMIRO DL
100
10
1
1
2
3
4
5
10
20
30
100


Rb_ppm : Rb_pXRF
Rb_pXRF
Rb_ppm
CAMIRO DL
10000
1000
100
10
10
20
30
100
200
1000
10000


Tl_ppm : Tl_pXRF
ROCKS
SOILS
Tl_pXRF [Locked]
Tl_ppm [Locked]
CAMIRO DL
100
10
1
1
2
3
4
5
10
20
30
100

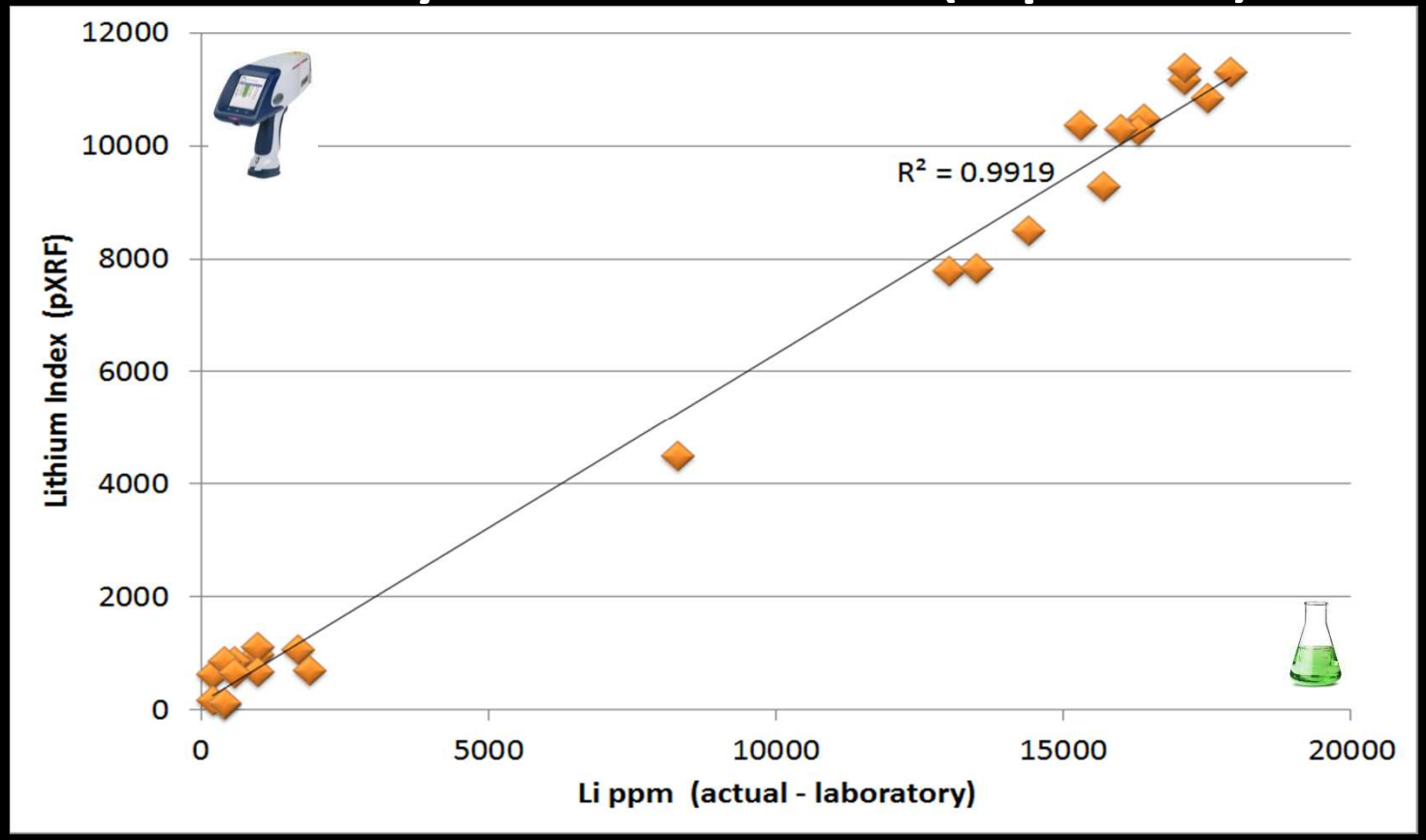
Blind Tests

CASE STUDY 1: Poseidon

- A: Blind pXRF test on rock chip samples from Lake Johnstone
- B: Blind pXRF test on soil samples from Lake Johnston

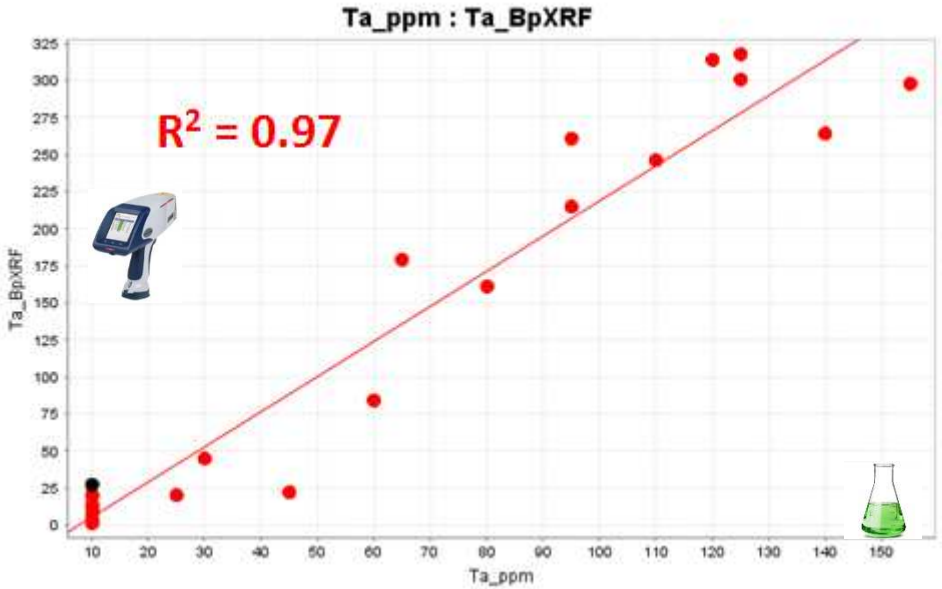
Lake Johnstone

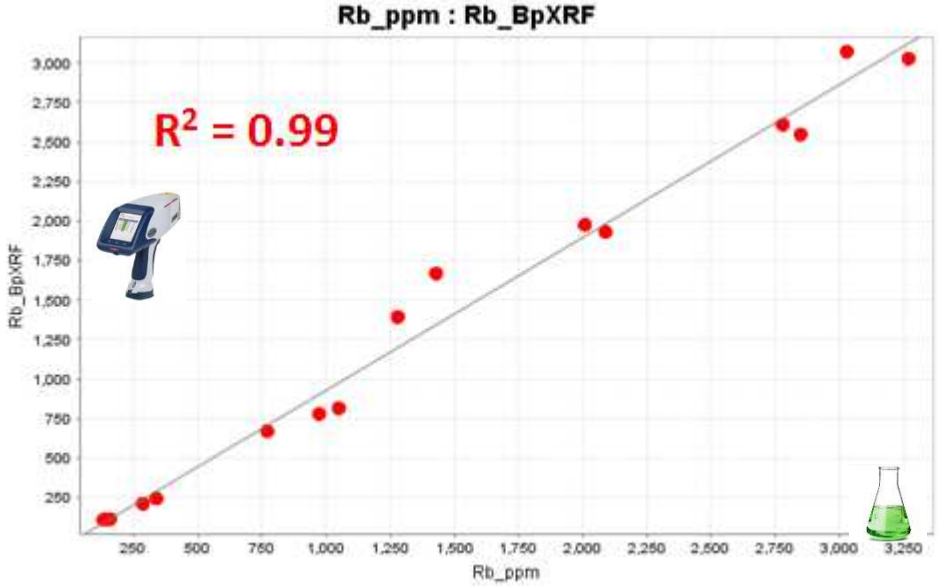
Blind test 1 (rocks)
Li assay vs Li Index (BpXRF)

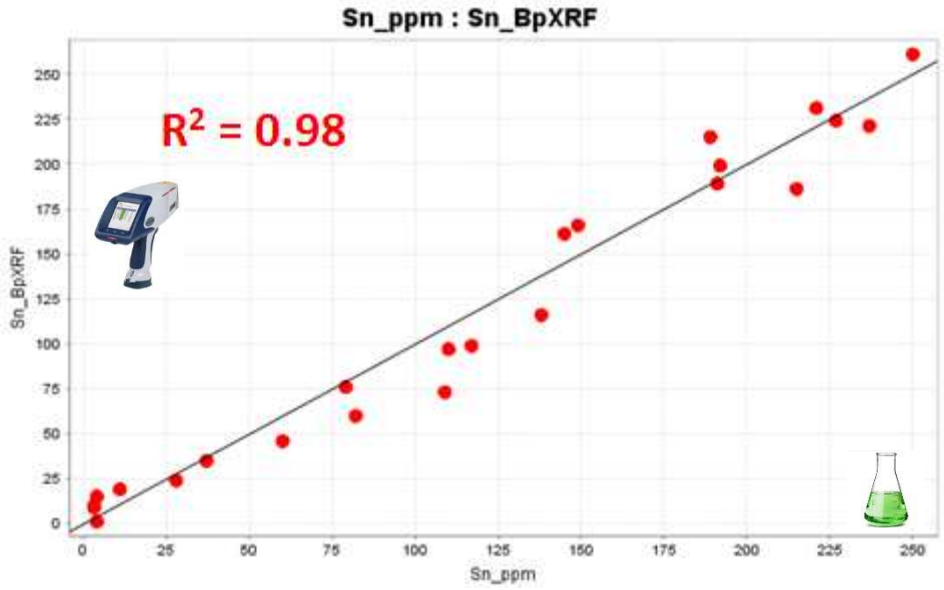


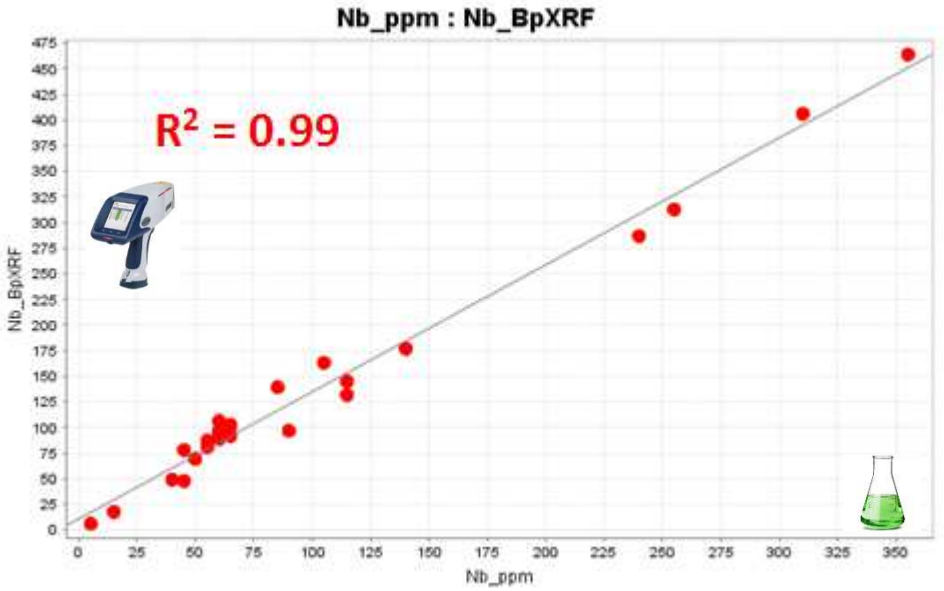
"This is an exceptional outcome giving Poseidon confidence to apply cost effect and rapid analysis techniques on site" (POS: ASX 21st July 2016).

Lab vs BpXRF


Ta_ppm : Ta_BpXRF
R² = 0.97
Ta_BpXRF
Ta_ppm


Rb_ppm : Rb_BpXRF
R² = 0.99
Rb_BpXRF
Rb_ppm

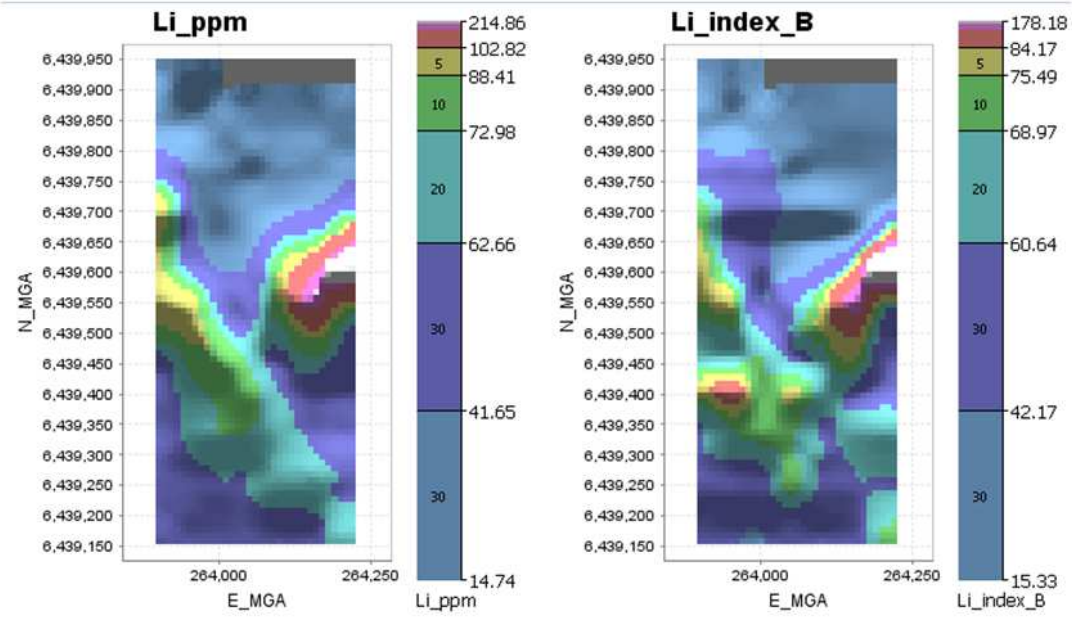

Sn_ppm : Sn_BpXRF
R² = 0.98
Sn_BpXRF
Sn_ppm


Nb_ppm : Nb_BpXRF
R² = 0.99
Nb_BpXRF
Nb_ppm

CASE STUDY 1: Soils

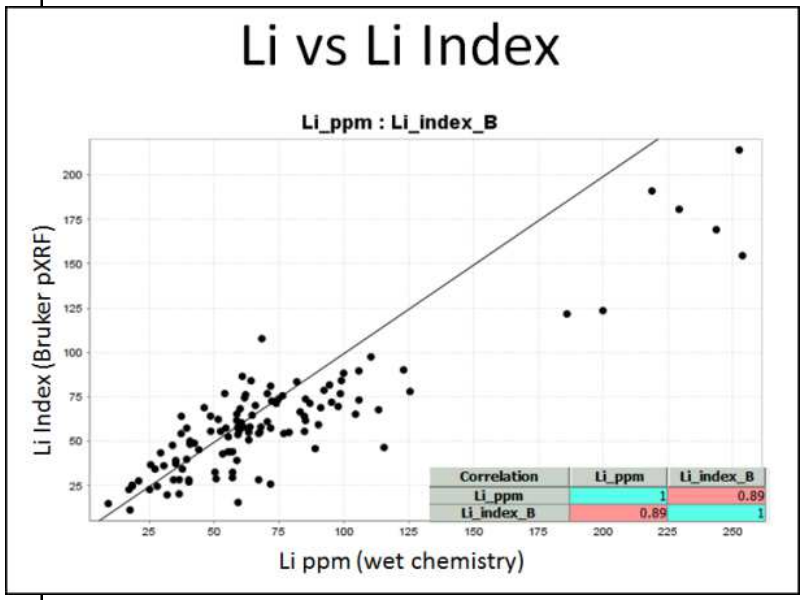
LITHIUM TARGETS GENERATED AT LAKE JOHNSTON (ASX:POS 12/10/2016)

Lithium images



Li ppm (wet chemistry) Li Index (Bruker pXRF)

Based on the initial samples that were dispatched to Intertek (n = 116)

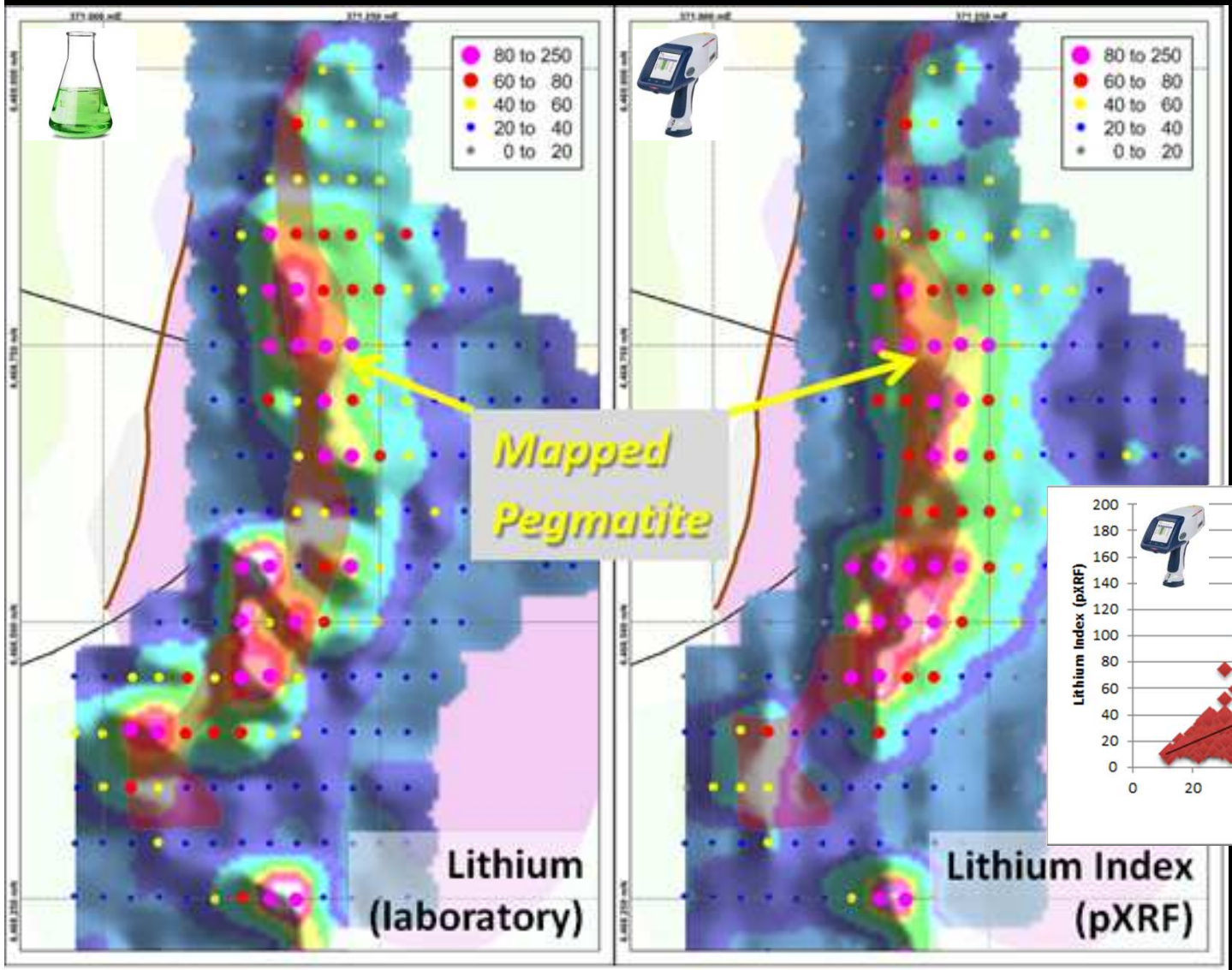


CASE STUDY 2: Pioneer Resources

- Blind test conducted on - 250um soil samples collected over an LCT Pegmatite prospect (PEG008)

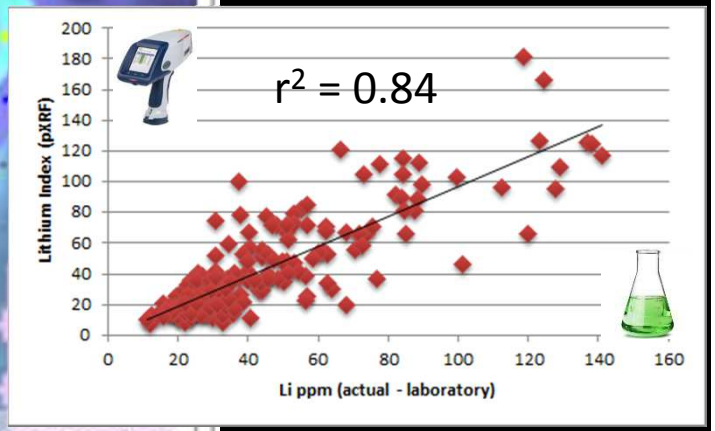
- Blind test conducted on – drill samples from LCT Pegmatite (PEG008)

CASE STUDY 3 (soils)
Li assay vs Li –index (BpXRF)



Pioneer RESOURCES LIMITED

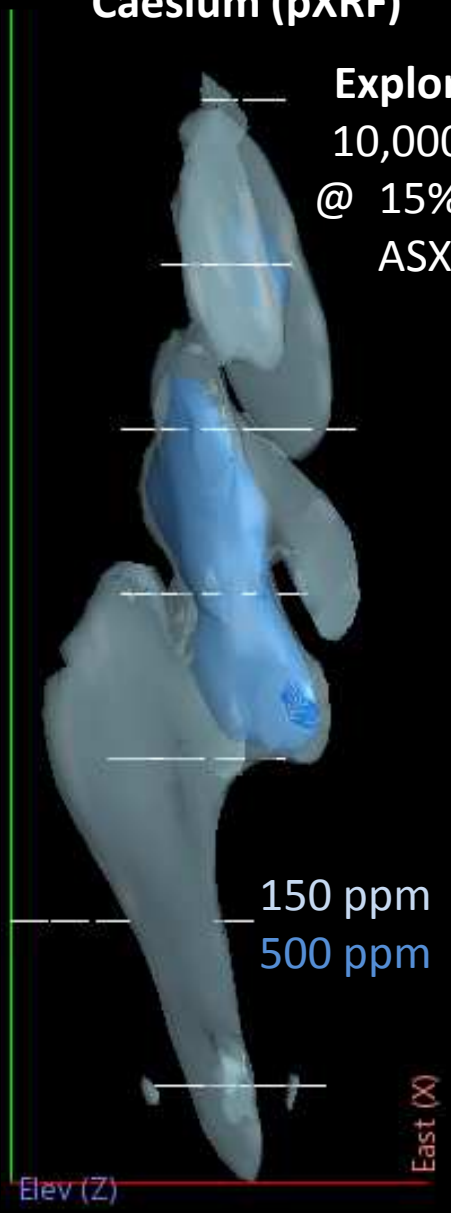
"Pioneer considers…… to being cost efficient, it ensures very rapid information turn-around". (PIO: ASX 27th July 2016).



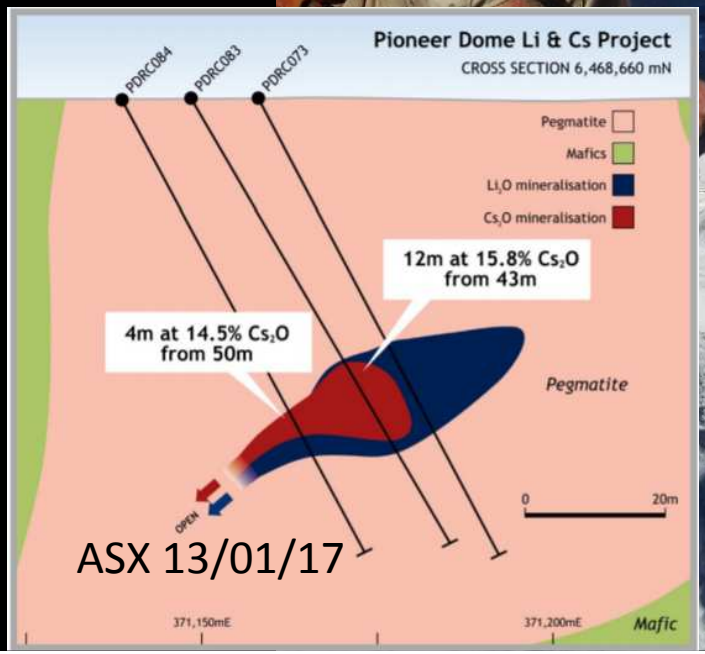
LCT Pegmatite (drilling)

Lithium Index (pXRF)

Caesium (pXRF)



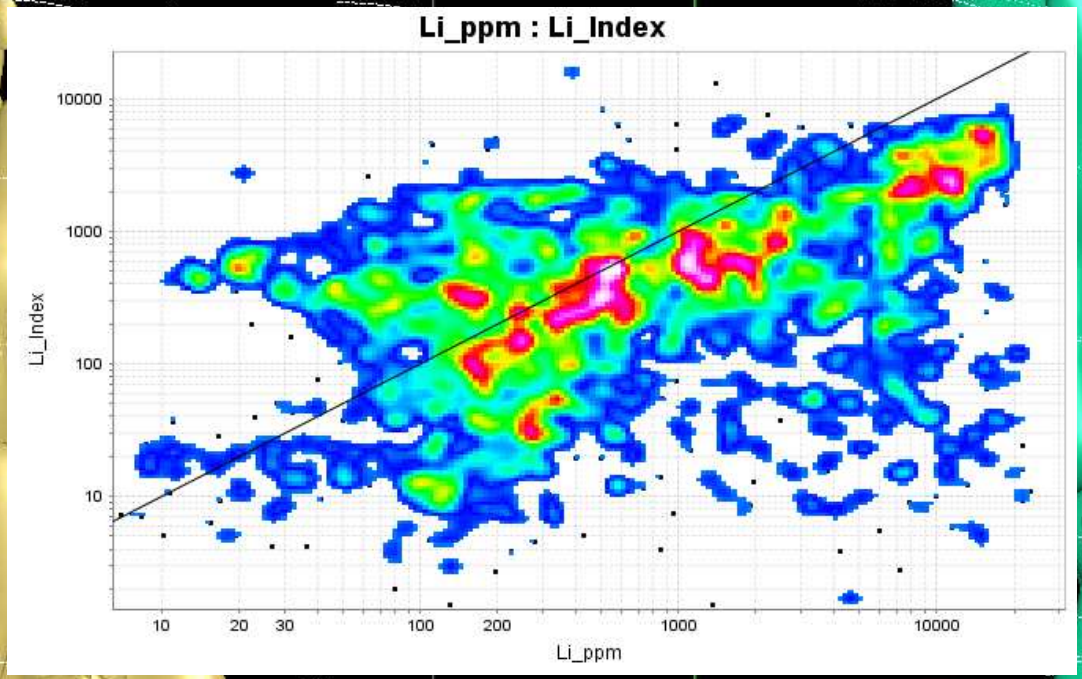
Exploration target
10,000t to 15,000t
@ 15% to 25% Cs_2O
ASX 13/01/17

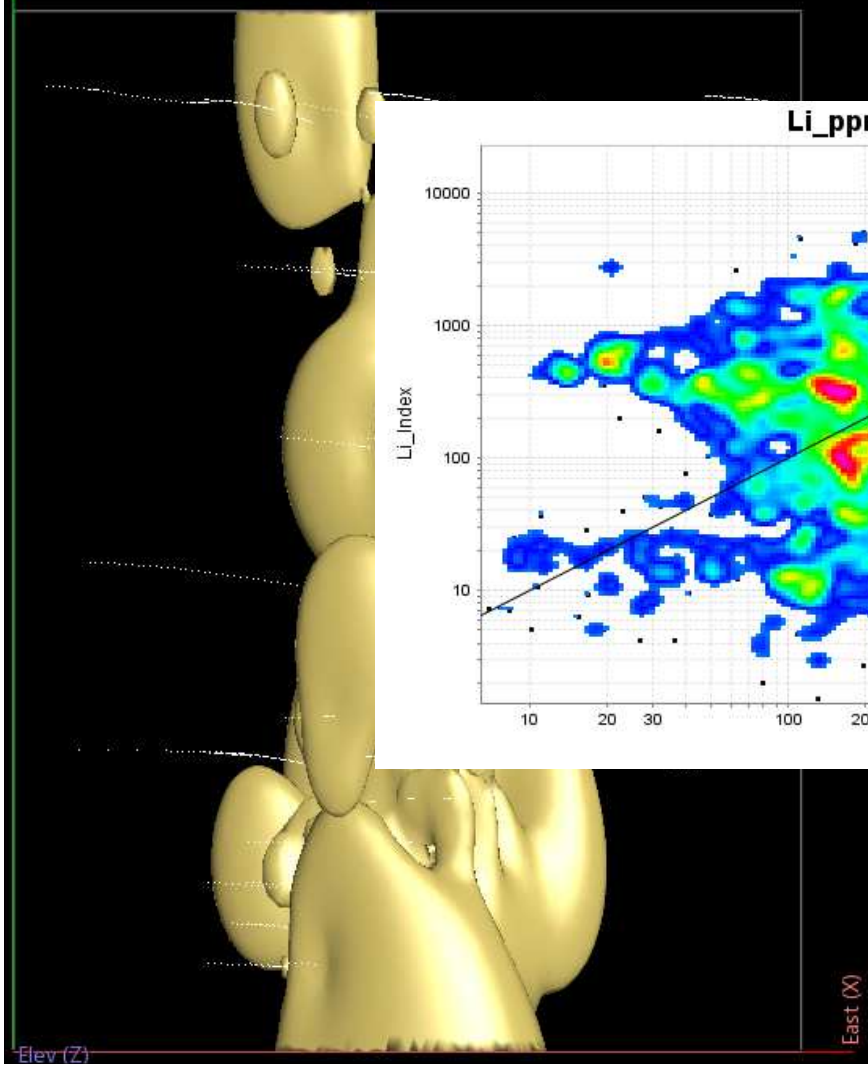


ASX 13/01/17

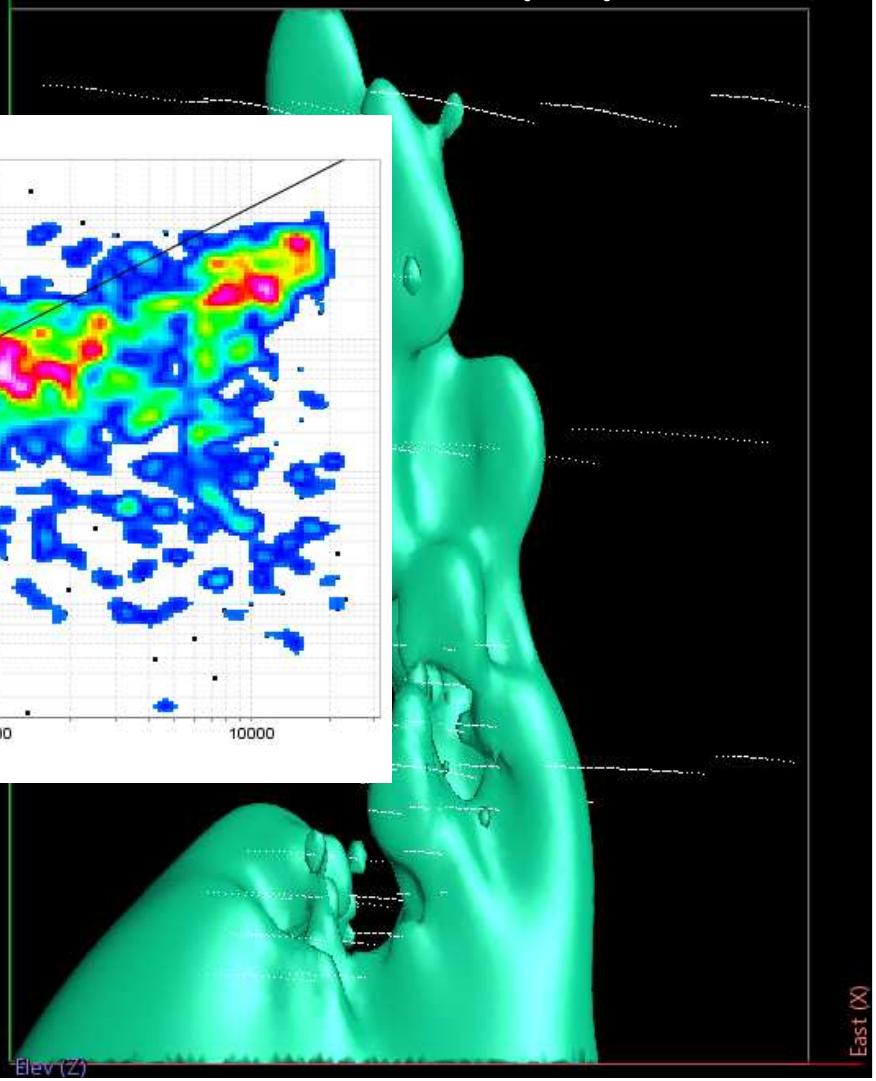
LCT Pegmatite (drilling)

Lithium Index (pXRF)





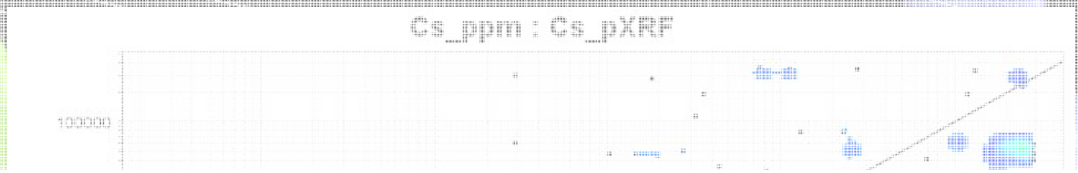
Lithium (Lab)



LCT Pegmatite (drilling)

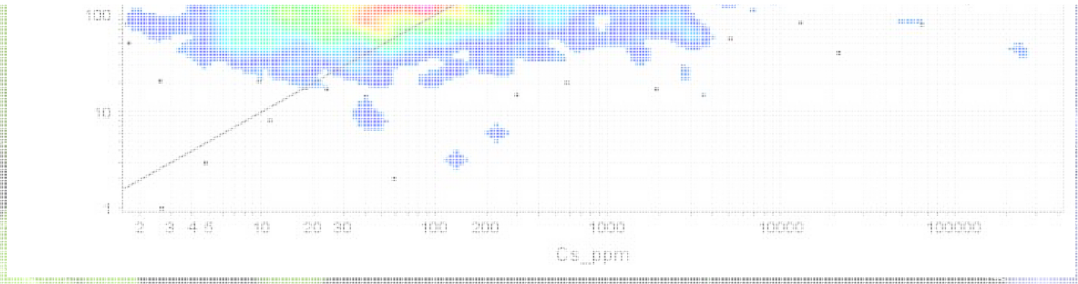
Caesium (pXRF)

Caesium (Lab)



MINERAL RESOURCE ESTIMATE FOR THE SINCLAIR CAESIUM PROJECT

Australia's First Caesium Resource: 10,500t grading 17.1% Cs_2O



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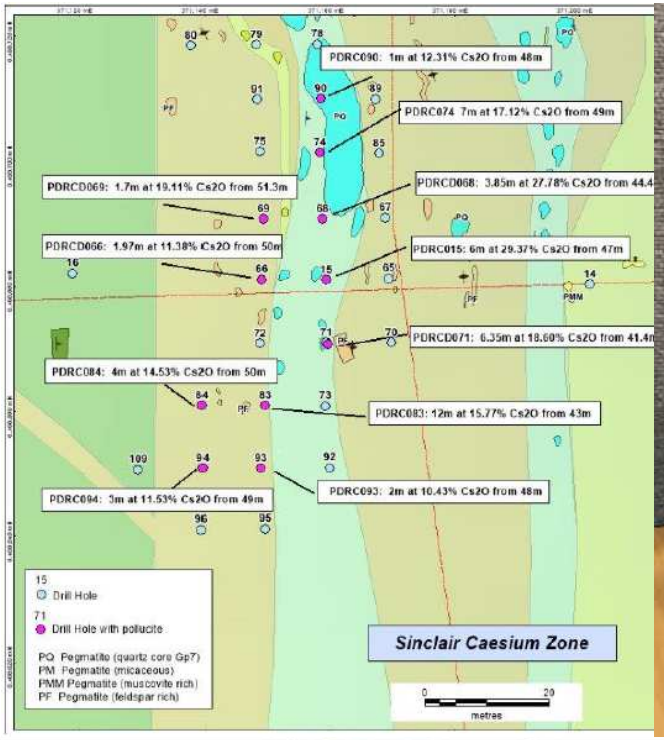

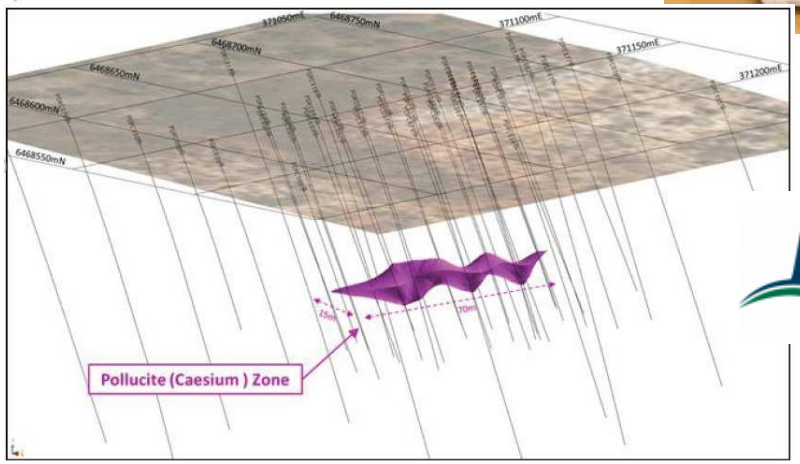

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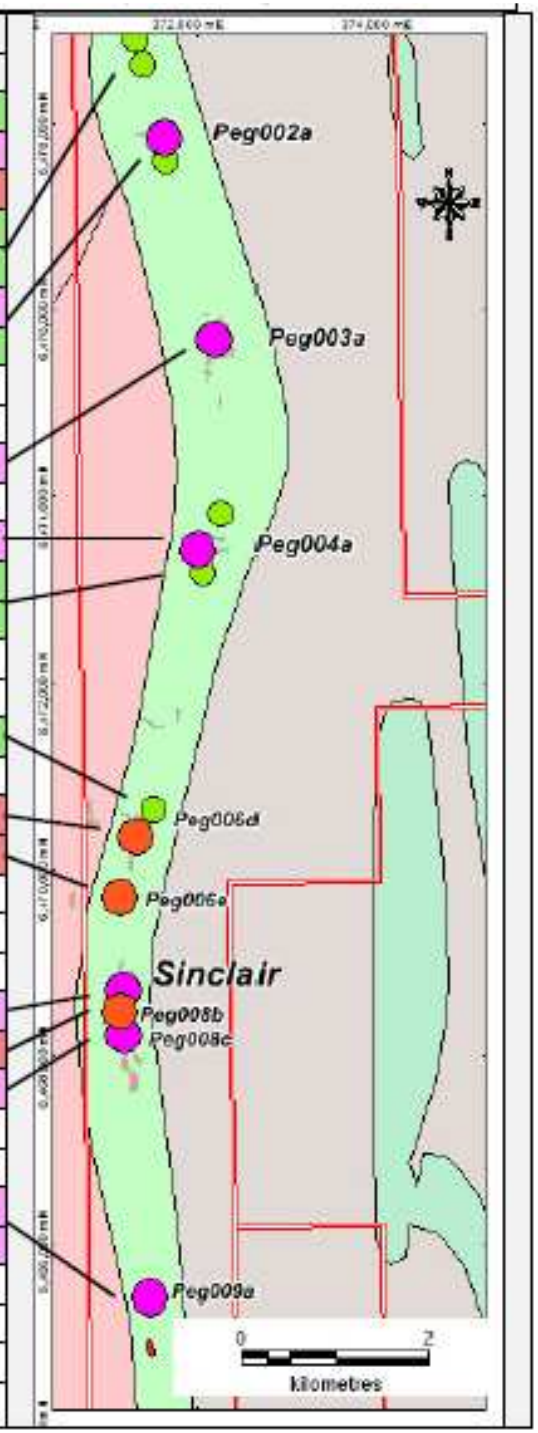
ASX 22/03/17

Pioneer Dome Status

Pegmatite Group	Regional Soils		Sub-Prospect	Infill Soils		Brand
	pXRF	Lab		pXRF	Lab	BGR
PEG001	Complete	36%	PEG001e	NO	n/a	Rank 3
PEG002	Complete	40%	PEG001a	Partial	NO	Rank 5
			PEG001b	NO	n/a	Rank 4
			PEG001c	NO	n/a	Rank 3
			PEG001d	NO	n/a	Rank 3
			PEG002a	NO	n/a	Rank 5
			PEG002b	NO	n/a	Rank 3
			PEG002c	YES	NO	Rank 2
			PEG002d	NO	n/a	Rank 2
PEG003	Complete	23%	PEG003a	Partial	NO	Rank 5
			PEG003b	Partial	NO	Rank 2
PEG004	Complete	40%	PEG004a	YES	YES	Rank 5
			PEG004b	NO	n/a	Rank 3
			PEG004c	YES	YES	Rank 3
PEG006	Complete	32%	PEG005a	YES	NO	Rank 1
			PEG006a	YES	YES	Rank 2
			PEG006b	YES	YES	Rank 3
			PEG006c	YES	YES	Rank 2
			PEG006d	YES	YES	Rank 4
			PEG006e	NO	n/a	Rank 4
			PEG006f	NO	n/a	Rank 2
			PEG006g	NO	n/a	Rank 2
PEG007	Complete	100%	PEG007a	YES	YES	Rank 1
PEG008	Complete	55%	Sinclair	YES	YES	Rank 5
			PEG008b	NO	n/a	Rank 4
			PEG008c	Partial	YES	Rank 5
			PEG008d	NO	n/a	Rank 2
			PEG008e	NO	n/a	Rank 2
PEG009	Complete	0%	PEG009a_E	YES	YES	Rank 5
			PEG009a_W	YES	YES	Rank 5
PEG010	Complete	16%	PEG010	NO	n/a	
			PEG012	YES	YES	Rank 0
PEG013	Complete	0%	PEGB81	YES	NO	Rank 0
			PEGB81	YES	NO	Rank 0

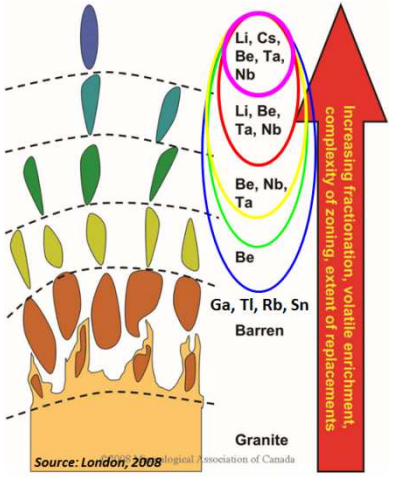


ASX:PIO 31/01/17

7200 samples completed

Rank LCT pegmatite targets based on model

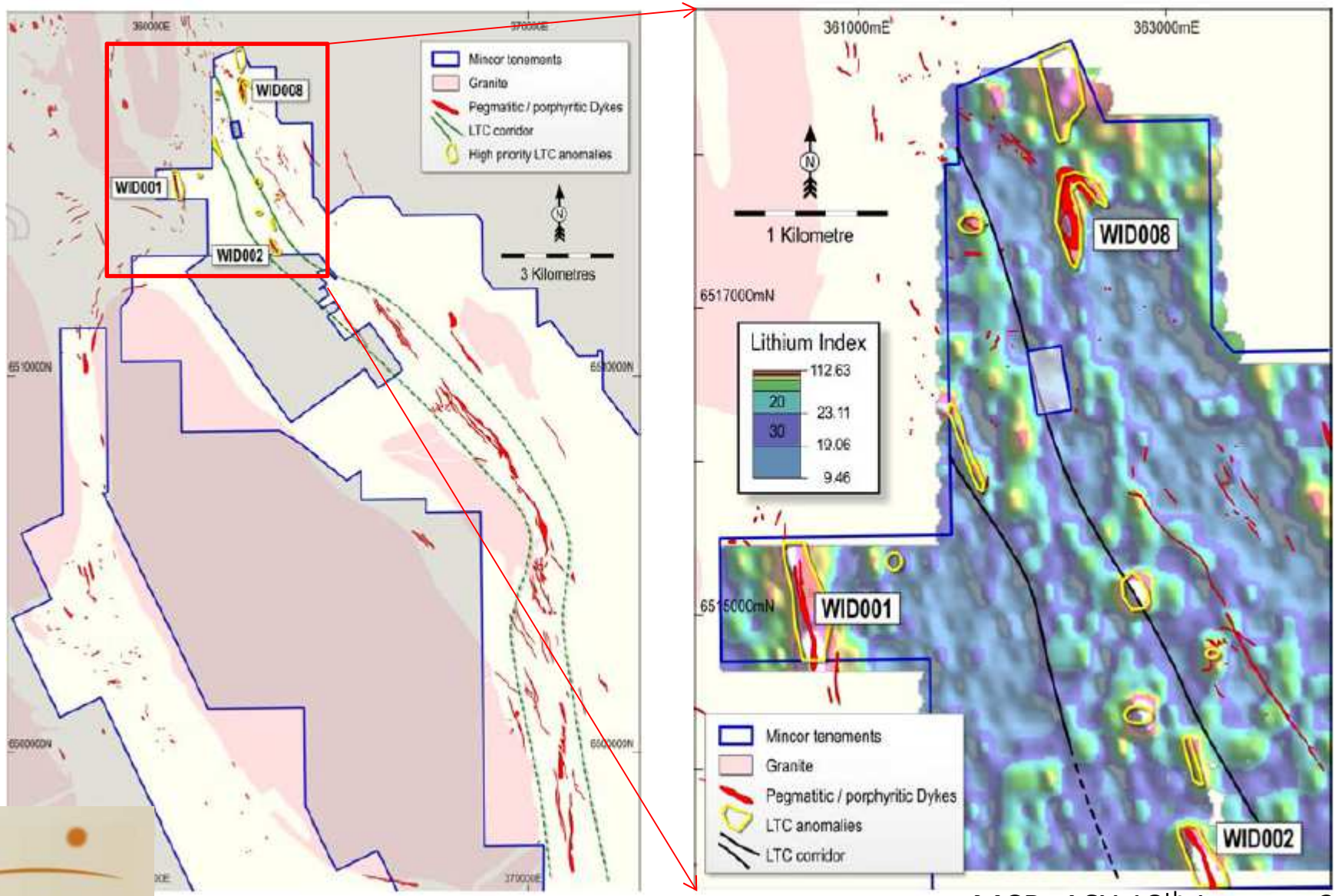
Confirm with wet chemistry



CASE STUDY 3: Mincor Resources

- Blind test conducted on - 250um soil samples collected over an unknown Pegmatite corridor.

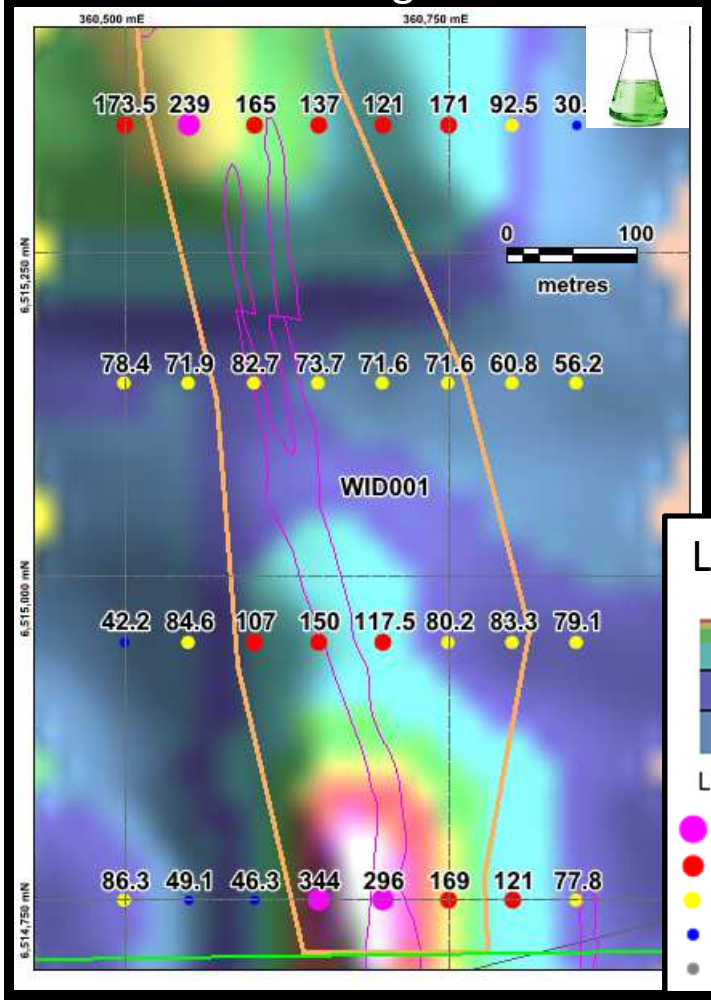
LCT Pegmatite Corridor: Widgie

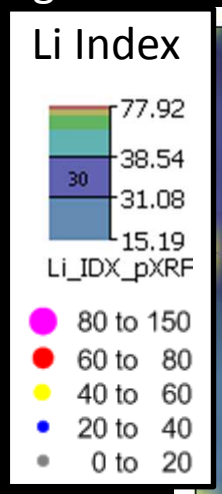


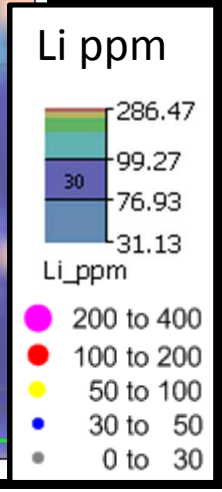
MCR: ASX 18th January 2017

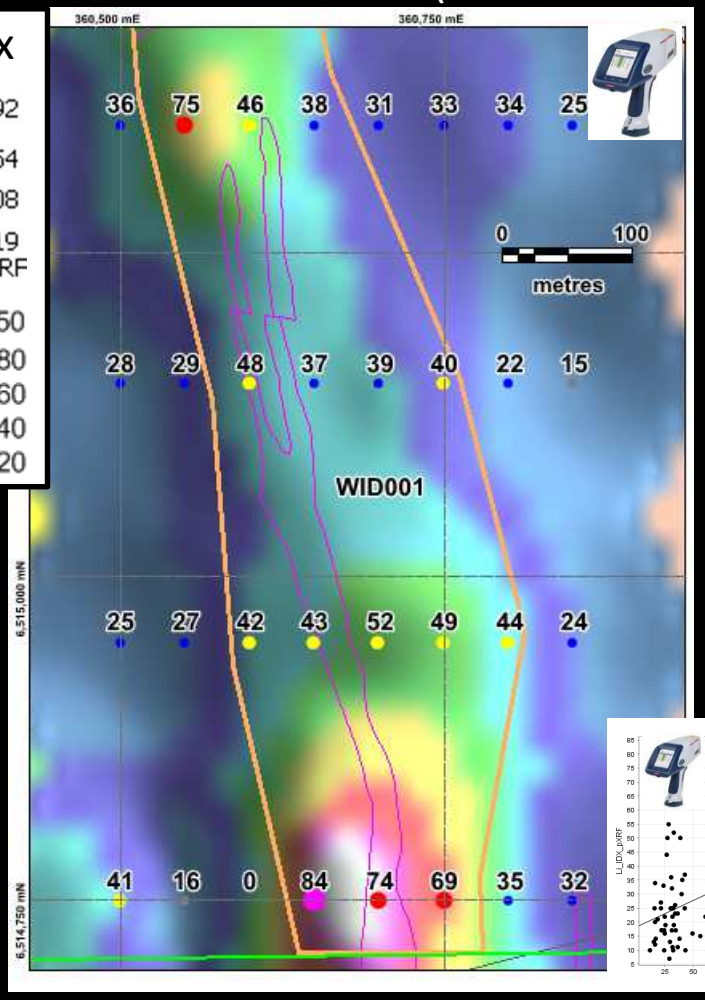
Blind Test 3 (soils)
Li assay vs Li –index (BpXRF)

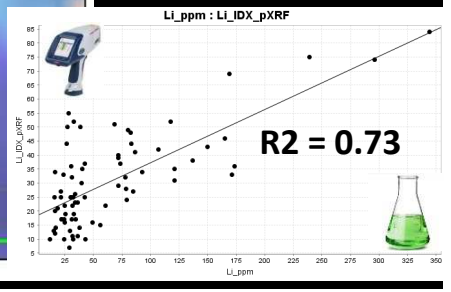
"The results from initial soil programs have identified multiple LCT Pegmatite bodies…..the results confirm the interpretation of a major LCT corridor of significant strike length on Mincor's tenements". (MCR: ASX 18th January 2017).











Summary

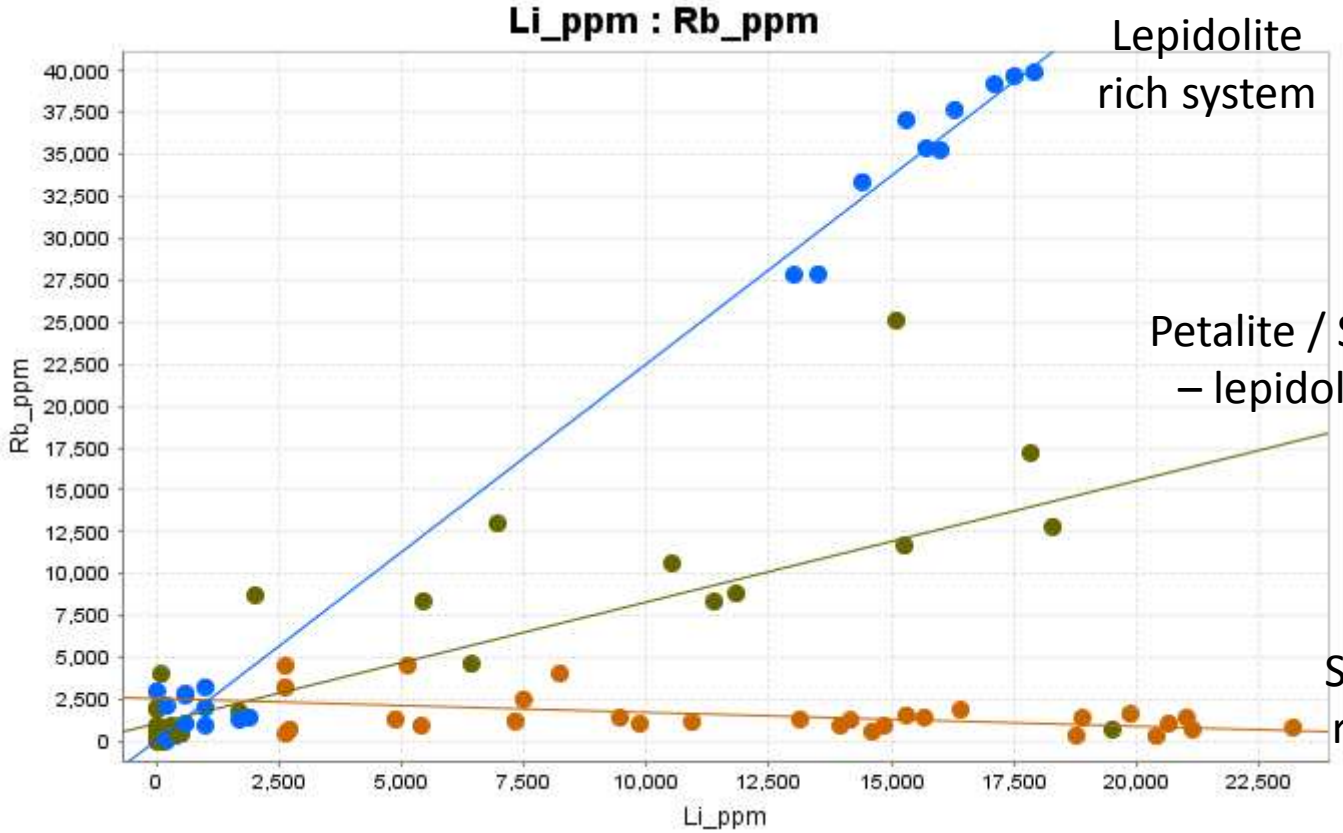
- BpXRF provides “fit for purpose” data on elements associated with LCT Pegmaites (Ga, Rb, Nb, Sn, Cs, Ta, Tl) and can satisfactorily predict Lithium concentrations.
  - Implication: significant saving during exploration and exploitation of LCT pegmatite systems.

LCT elements	Z#	Detectable by pXRF	Appropriate for rocks	BRUKER pXRF
Li	3	NO	Calculated	Calculated
Be	4	NO	NO	NO
Ga	31	YES: Kα	YES	Yes
Rb	37	YES: Kα	YES	Yes
Nb	41	YES: Kα	YES	Yes
Sn	50	YES: Kα	YES	Yes
Cs	55	YES: Kα	YES	Yes
Ta	73	YES: Lα	YES	Yes
Tl	81	YES: Lα	YES	Yes

Word of Caution

Minerals have a fundamental bearing on the element response of an LCT Systems

Li Systems: Rock data only

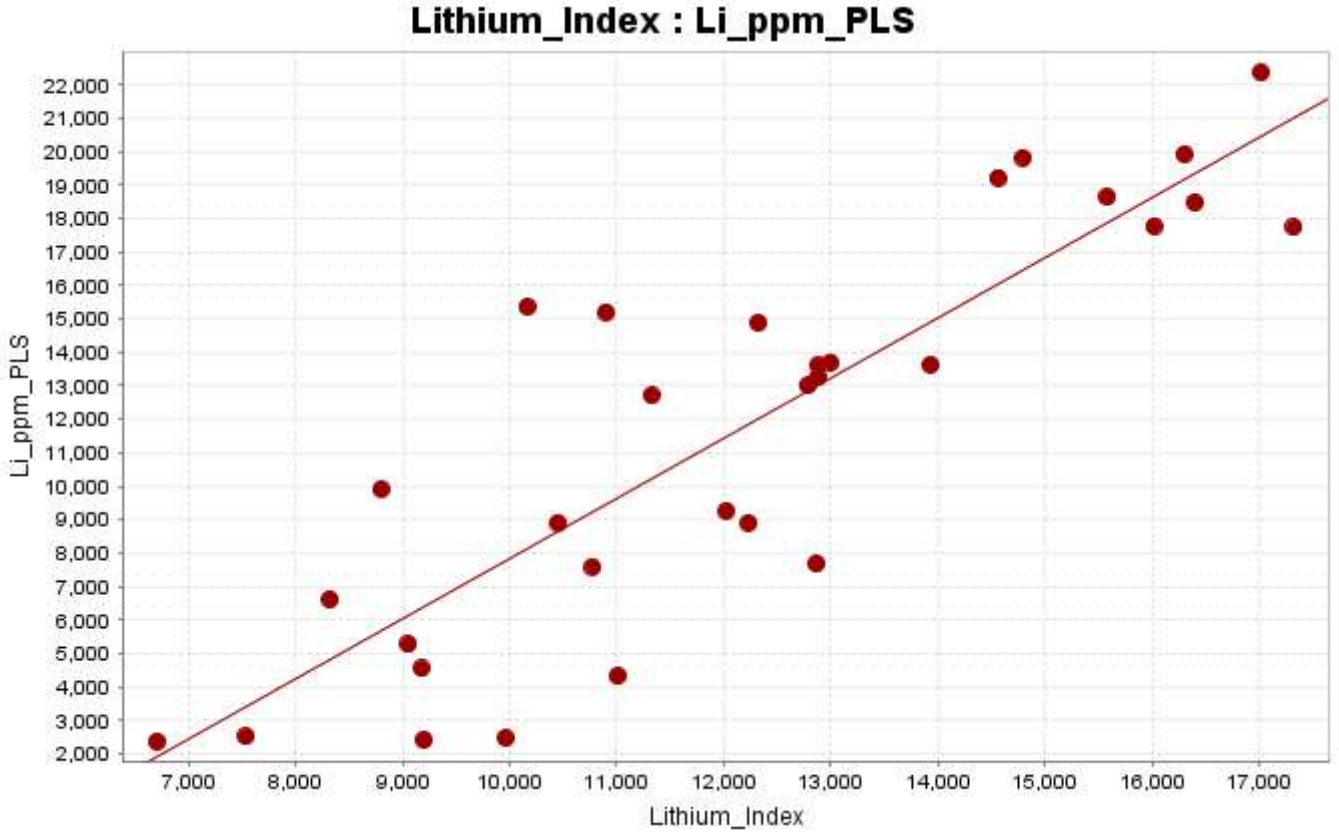


Lepidolite rich system

Petalite / Spodumene – lepidolite system

Spodumene rich system

Li (ppm) vs “Lithium Spodumene Index”



The pXRF “Lithium Index” provides an adequate field guide for a lithium value and is considered “fit for purpose” yet requiring additional field trial.

Acknowledgements

Bruker: Providing training on **EasyCal** and calibration support

Bruker Authorised Application Centre (Perth)
Undertaken the “Lithium Index Calibration”

Pioneer, Poseidon, and Mincor for permission to publish their data

Numerous unnamed public & private companies who have assisted along the way