The Critical Role Portable XRF Played in the Discovery to Delivery of the Rarest Economic Mineral Deposit on Earth - Pollucite at Sinclair, Western Australia.

Dr Nigel Brand\textsuperscript{1,2}, Christabel J Brand\textsuperscript{2} & David J Crook\textsuperscript{3}

\textsuperscript{1}Geochemical Services Pty Ltd, \textsuperscript{2}Portable XRF Services Pty Ltd, \textsuperscript{3}Pioneer Resources Limited
Pollucite in the Sinclair Mine
What is Pollucite?

\[(\text{Cs,Na})_2(\text{Al}_2\text{Si}_4\text{O}_{12})\ 2\text{H}_2\text{O}\]

- A high value mineral due to its high caesium content (\(~29.66\%\ \text{Cs}_2\text{O}\))
- Only forms in extremely fractionated lithium-caesium-tantalum (LCT) pegmatite systems.

Caesium-137 half life of \(~30.17\) years
Host rocks are \(2.7\) Ga
Undergone \(~90M\) half-life cycles
Where do you find Pollucite?

Only 160 occurrences of pollucite known globally
Typically pollucite occurs as grain-size to fist size samples

Source: Mindat.org
Location of Economic Pollucite Deposits?

Only 3 occurrences of economic pollucite known globally
Economic pollucite occurrences range in size 10kT - 100kT
Use of Pollucite

- Pollucite main used is in Cs-formate manufacturing.

- Cs-formate is a drilling fluid used in high temperature / high pressure oil and gas drilling to prevent blowout.

- Cs-formate is LEASED to oil companies during the transition from exploration to production.

Pollucite pricing is not transparent.
Discovery, Delineation, Development of Sinclair and the future....

99 weeks from discovery to development
Detecting
Lithium by pXRF

- Portable XRF (pXRF) can detect down to Na (Z11).
- **pXRF** cannot detect lithium (Z3) **directly**
- 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**)
- Using *EasyCal* on Bruker S1 Titan a fundamental parameter “**Lithium Index**” calibration can be uploaded on **pXRF**
Lithium (calculated)
Both images are derived from the SAME samples
Laboratory Li, predicted Li from pXRF instrument

Which is Li by pXRF?

\[ r^2 = 0.84 \]

"Pioneer considers......to being cost efficient, it ensures very rapid information turn-around". (PIO: ASX 27\textsuperscript{th} July 2016).
DRILLING TO COMMENCE AT PIONEER DOME LITHIUM PROJECT

Perth Western Australia, 23 August 2016: Pioneer Resources Limited ("Company" or "Pioneer", ASX: PIO) is pleased to provide the following exploration update.

The Company advises that drilling is booked to commence on Tuesday 30 August. All regulatory requirements for drilling have been completed, including a Programme of Work approval and a Heritage Protection Survey.
LCT Pegmatite (drilling)

 Changed sampling methodology
LCT Pegmatite (drilling)

RC Drill samples

Oversize discarded
LCT Pegmatite (drilling)

Lithium Index (pXRF)

Caesium (pXRF)

1000
2000

150 ppm
500 ppm
Caesium Discovered .....but who knew?

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Issue with Calibration?

No commercially available high Cs grade certified reference material
Cs – Z:55

Available CRMs for calibrations

All values < 300 ppm

pXRF DL Cs 20 ppm
Custom calibration process

1. Establish settings (kv µa Filter )
   • Qualitative Analysis (look at spectra...)

2. Select Elements,
   • run Samples

3. Measure samples on unit

4. Calibrate
   • Validate

5. Upload onto instrument

Rerun spectra files with new calibration
key elements
Account for ALL elements
Deconvolution
EasyCal (calibration)
Updated custom calibration using Project Samples (4 acid digest)

NOTE:
Only commercially available assay method = four acid with upper detection limit of 500 ppm (lab-1) and 2000 ppm (lab-2); over range through dilution.

No total fusion XRF Cs commercially available (at this stage)
Drilling: Phase 1 (Aug-Sept 2016)
Lithium-Caesium Discovery (pXRF data)

04/10/2016

LITHIUM-CAESIUM DISCOVERY AT PIONEER DOME
(Lithium) 7m at 1.52% Li2O and (High Grade Caesium) 6m at 27.7% Cs2O

Perth, Western Australia, 4 October 2016: Pioneer Resources Limited ("Company" or "Pioneer", ASX: PIO) is pleased to provide the following update regarding its 100% owned Pioneer Dome Lithium Project.

pXRF Cs > 2%
Delineation
Drilling: Phase 2 (Nov-Dec 2016)
Further High Grade Pollucite

pXRF Cs > 2%

13/12/2016

Pioneer Resources Limited

Perth, Western Australia, 13 December 2016: Pioneer Resources Limited ("Company" or "Pioneer", ASX: PGQ) is pleased to provide a drilling update for its 100%-owned Pioneer Dome Lightfoot Project in the Eastern Goldfields of Western Australia, and notifies of a delay to the drilling programme at Maple Lake, Canada.
Drilling: Phase 3 (January 2017)
Drilling continues to define Sinclair

MINERAL RESOURCE ESTIMATE FOR THE SINCLAIR CAESIUM PROJECT

Australia’s First Caesium Resource: 10,500t grading 17.1% Cs₂O

- Metallurgy Underway - Preliminary Indications for Caesium Formate Production
- Mine Planning Underway – Mining Lease Applied For and Design Work Commences
- January Drill Results Include 3m at 11.5% Cs₂O from 49m in PDR094

Perth, Western Australia: 22 March, 2017: Pioneer Resources Limited (the “Company” or “Pioneer”) (ASX: PIO) is pleased to announce a Mineral Resource Estimate for the Sinclair Caesium Zone, which is within the Company’s 100%-owned Pioneer Dome Lithium-Caesium-Tantalum (“LCT”) Project.
Drilling: Phase 4 (May 2017)
High grade Lithium

20/06/2017

Drilling intersects high grade lithium at Pioneer Dome including:
- PDRC114: 19m at 1.77% Li2O from 39m
- PDRC115: 17m at 1.48% Li2O from 35m
- PDRC116: 20m at 2.48% Li2O from 36m
- PDRC112: 31m at 2.54% Li2O from 47m

Perth, Western Australia, 20 June 2017: Pioneer Resources Limited ("Company" or "Pioneer") is pleased to announce assay results received from the most recent drilling programme at its 100%-held Pioneer Dome Lithium-Cesium-Tantalite ("LCT") Pegmatite Project, near Norseman in WA.
Drilling: Phase 5 (November 2017)
Project Update

17/01/2018

pXRF Cs > 2%
Drilling: Phase 6 (Jan-Feb 2018)
Potassium Feldspar deposit discovered

21/02/2018

Pioneer Resources Limited

Perth, Western Australia: 21 February 2018: Pioneer Resources Limited (the "Company" or "Pioneer") (ASX: PNZ), is pleased to provide the results from 2 diamond core holes drilled within the Company’s 100%-owned Sinclair Zone Caesium Deposit, located within the Pioneer Demo Project approximately 140km south of Kalgoorlie, Western Australia.
Drilling: Phase 7 (Mar-Apr 2018)
Infill drilling of Sinclair

19/04/2018

pXRF Cs > 2%
Drilling: Phase 8 (June-July 2018) Mining Proposal approved

25/07/2018

pXRF Cs > 2%
Drilling: Phase 8 (June-July 2018)  
Mining Proposal approved

25/07/2018
Sinclair Pollucite Ore Shells

200m ~ 220 yds
Fine tuning the matrix matched custom calibration

Fusion XRF vs pXRF (technique comparison)
Fusion XRF vs Fusion XRF (laboratory comparison)
Fusion X vs four acid (method comparison)
Caesium: Fusion XRF vs pXRF

$\text{Cs}_2\text{O}_{\text{pct}} : \text{Cs}_2\text{O}_{\text{pXRF}}$

$\text{DL} \ 0.005 \ % \quad \text{ZoQ} \ 0.05\%$

$\text{CS}_2\text{O}_{\text{PXRF}} = (0.979 \times \text{CS}_2\text{O}_{\text{PCT}})$

$r^2 = 0.99$
Umpire validation: Cs$_2$O analysis

CS$_2$O_ME-XRF15BP = (1.019 * CS$_2$O_PCT)
Within expected analytical error
Cs₂O Fusion vs 4A – method check

Precision between the two methods is excellent
There is an overall positive bias to fusion XRF by ~3% (relative)
Sinclair: pXRF vs fusion XRF

$r^2 = 0.98$
Pollucite

$r^2 = 0.99$
Albite

$r^2 = 1.00$
microcline

$r^2 = 0.99$
Lepidolite

$r^2 = 0.96$
Amblygonite

$r^2 = 0.96$
Lepidolite &

$r^2 = 0.99$
microcline
Development of Sinclair
Grade Control (blast hole) Drilling
Comparison between prepped samples using CTX and sieved (unprepped) samples using Titan S1 pXRF
Cs

CS_CTX = (0.9692 * CS__XRF)

\[
\text{Cs_CTX : Cs__xrf}
\]

\[
R^2 = 0.83
\]

\[
\begin{array}{|c|c|c|}
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\text{N} & \text{Cs_CTX} & \text{Cs__xrf} \\
\hline
\text{Count Numeric} & 427 & 384 \\
\text{Minimum} & 0.0010 & 0.0001 \\
\text{Maximum} & 29.14 & 27.89 \\
\text{Mean} & 1.13 & 0.97 \\
\text{Standard Deviation} & 4.09 & 3.57 \\
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Cs: Probable Sample Switched

Cs_CTX : Cs_xrf

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Delineation (grade control data)
In-pit grade verification
In-pit grade verification
In-pit grade verification

To Stockpile
Pollucite Stockpile
Stockpile Crushing Grade Control
Primary stockpile Grade Control
collected using 4 trenching shovels, combined then
riffle split, every 15 minutes

Split

Oversize discarded

Pulverised to -75um

Sieved

Site Lab

Screen
Stockpile Crushing Grade Control

Poor sample vs sample reproducibility - good “group” comparison – overall unacceptable

<table>
<thead>
<tr>
<th>Rill2</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>RSD</th>
<th>Sdev</th>
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</thead>
<tbody>
<tr>
<td>Cs_screen</td>
<td>7.32</td>
<td>20.58</td>
<td>11.76</td>
<td>24.07</td>
<td>2.83</td>
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<tr>
<td>Cs_lab</td>
<td>8.89</td>
<td>15.50</td>
<td>11.37</td>
<td>12.87</td>
<td>1.46</td>
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</tbody>
</table>

Sinclair Stockpile - Rill2

n = 34, mean screen 11.76% Cs, mean lab = 11.37%Cs

R² = -0.157
Primary stockpile Grade Control
collected using 4 trenching shovels, combined then riffle split, every 15 minutes

Split

Pulverised to -75um

results ~4 hours

Site Lab

results ~4 week

Commercial Lab
Stockpile – Crushing Lab check

Conundrum due to contaminated pXRF cups being reused resulting in an increase in Cs and reduction of Al -
The contained caesium, being 1,640 tonnes, has outperformed the start-up Resource Estimate of 1,047 tonnes by an increase of 593 tonnes or 57%.
Mining Completed
Shipment control
Shipment Grade Control

collected using spear, combined then riffle split

Site Lab

Commercial Lab

Pulverised to -75um

Split

Split

Pioneer

CABOT

TOYOTA

Bruker

Intertek

Commercial Lab

Site Lab
Shipment Grade control
Shipments Commence

**SINCLAIR MINE: SHIPMENTS OF POLLUCITE COMMENCE**

Perth, Western Australia: 1 February 2019: Pioneer Resources Limited (ASX:PIO) ("Pioneer" or "the Company") is pleased to provide a further update in relation to the sale to pollucite ore to Cabot Speciality Fluids Ltd ("CabotSF") under the binding offtake and funding agreement between the parties (refer ASX release 20 June 2018).
FIRST POLLUCITE ARRIVES IN CANADA

REVISED SHIPMENT AND PAYMENT SCHEDULE SET OUT

Perth, Western Australia: 17 April 2019: Pioneer Resources Limited ("Pioneer" or the "Company") (ASX: PIO) is pleased to provide an update for its 100%-owned Sinclair mining operation, Australia’s first mine to extract the caesium mineral, pollucite, located 40km north of Norseman, Western Australia.
## Summary

<table>
<thead>
<tr>
<th>Stage</th>
<th>Instrument</th>
<th>Calibration</th>
<th>Validation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discovery</td>
<td></td>
<td>Lithium Index calibration</td>
<td></td>
</tr>
<tr>
<td>Delineation</td>
<td></td>
<td>Matrix matched Cs custom calibration v1</td>
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<tr>
<td>R&amp;D</td>
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<td>Matrix matched Cs custom calibration v2</td>
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<tr>
<td>Development</td>
<td></td>
<td>Matrix matched Cs custom calibration &amp; Lithium Index calibration</td>
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</tr>
<tr>
<td>Delivery</td>
<td></td>
<td>Matrix matched Cs custom calibration</td>
<td></td>
</tr>
</tbody>
</table>
Discovery, Delineation, Development of Sinclair and the future....

- 27/07/2016: Confirms LCT Pegmatites
- 17/10/2016: Sinclair Discovery
- 12/06/2019: Spodumene Discovered
- 31/7 to 04/08 2017: Mining Commences
- 19/04/2018: Continuity confirmed
- 05/09 2019: Mining Completed

99 weeks from discovery to development

Sources: TRADINGECONOMICS.COM | OTC
Acknowledgements

• Denver X-Ray
• PIO
• pXRFs
• Bruker
HISTORY MAKING
First time Sodium measured in the field on a pXRF in AIR
13\textsuperscript{th} July 2018, Kalgoorlie