U Exploration Using Pb Isotopes: Opportunities In Partial Extraction Geochemistry

Graham Carr
(CSIRO)
And
Neil Rutherford
(Rutherford Mineral Resource Consultants)
Introduction

• Research Undertaken in 1990 – collaboration between CSIRO and Neil Rutherford (Surtec)

• Motive: to find a low cost broad scale geochemical exploration technique in the Pine Creek based on stream sediments

• Unreported except to the participants – dramatic downturn in U exploration interest
Contents

1. Why Use Pb Isotopes?
   • Brief theory tutorial
3. Examples from the Pine Creek region of the Northern Territory
Pb Isotopes “101”

Q: Why use Pb isotopes as a surrogate for U?

A: Because:

• Pb isotope ratios are directly dependent on the amount of U in a system and increase with time, and more importantly

• In geochemical explorations samples Pb isotope ratios discriminate between U sources from “normal” rocks and those from U mineralisation.
Pb Isotopes “101”

Why Pb isotopes vary:
- $^{238}\text{U}$ decays to $^{206}\text{Pb}$ ($T^{1/2} = 4.5 \text{ Ga}$)
- $^{232}\text{Th}$ decays to $^{208}\text{Pb}$ ($T^{1/2} = 14 \text{ Ga}$)
- $^{204}\text{Pb}$ has no parent (Invariate)

Therefore:
- If U levels are high, and Th levels are “normal”,
  
  then

  - $^{206}\text{Pb}/^{204}\text{Pb}$ will be high, but $^{208}\text{Pb}/^{204}\text{Pb}$ will be “normal”
Pb Isotopes “101”

Key Messages:

- Pb isotope ratios are sensitive to the U/Th ratios of the source rocks.
- Simply looking for elevated "uranogenic" Pb (\(^{206}\text{Pb}/^{204}\text{Pb}\) ratios) is not a viable exploration technique.
Conventional Pb Isotope Plot – Pine Creek Rocks (Gulson 1979)

Analytical Precision (0.05%)

Two Trends

Derived from $^{232}$Th Decay

Derived from $^{238}$U Decay
Presentation of Results

Analytical Precision

\[ m = \frac{^{208}\text{Pb}/^{204}\text{Pb}(s) - ^{208}\text{Pb}/^{204}\text{Pb}(i)}{^{206}\text{Pb}/^{204}\text{Pb}(s) - ^{206}\text{Pb}/^{204}\text{Pb}(i)} \]

Calculated U/Th of source

\[ \text{U/Th} = \frac{1}{3.35 \times m} \]

Derived from $^{232}\text{Th}$ Decay

- $m = 16.8$, $m^{-1} = 0.06$
- $m = 0.61$, $m^{-1} = 1.63$
- $m = 0.027$, $m^{-1} = 38$
- $m = 0.0002$, $m^{-1} = 582$

Derived from $^{238}\text{U}$ Decay

\[ ^{206}\text{Pb}/^{204}\text{Pb} \]
All Pine Creek Data
(Gulson, 1979)

Background U/Th

Analytical Precision

Zamu Dolerite
Av. Granite
Kombolgie Ss
Av. Sandstone

Threshold (m^{-1} = 2)

Derived from 232Th Decay

Derived from 238U Decay

Anomalous U/Th
All Pine Creek Data
(Gulson, 1979)

Background U/Th

Analytical Precision

m\(^{-1}\) Range <0.2 – 1.6

m\(^{-1}\) Range 2 ~ >1000

Derived from \(^{232}\)Th Decay

Derived from \(^{238}\)U Decay

Anomalous U/Th

\(\frac{^{206}\text{Pb}}{^{204}\text{Pb}}\)

\(\frac{^{208}\text{Pb}}{^{204}\text{Pb}}\)

Graham Carr & Neil Rutherford

IGES 2005

RUTHERFORD
MINERAL RESOURCE CONSULTANTS
ABN: 80 096 525 909
Background Population

Samples containing a component of ore derived-Pb

Sensitivity of “unmixing” background and “ore” signatures in geochemical samples (particularly partial extractions and biota) is dependent on the isotopic contrast between “background” and “ore”
Partial Extraction-Unmixing Ore derived Pb and background Pb

% Pb Derived From U Ore
(Assumes background rocks have \( m^{-1} = 1.5 \))

(\text{Assumes background rocks have } m^{-1} = 1.5)
Partial Extraction - Unmixing Ore derived Pb and background Pb

- For U mineralisation isotopic contrast between "background" and "ore" is very high and we can in theory distinguish a sample leach where only 0.1% of the Pb derives from ore.
Results

1. Soil and vegetation survey over outcropping ore at Koongarra
2. Partial extractions of stream sediments at Caramel mineralisation
3. Partial extractions of streams sediments – recent (secondary) U accumulation
4. Options for analysis
Aqua Regia Leach - Soils over Outcropping Koongarra Deposit

Analytical Precision

\[ \frac{^{208}\text{Pb}}{^{204}\text{Pb}} \]

Koongarra Traverse 1
Koongarra Traverse 2
Koongarra Traverse 2 - Vegetation

\[ \frac{^{206}\text{Pb}}{^{204}\text{Pb}} \]
Caramel

IGES 2005
Graham Carr & Neil Rutherford
Caramel Stream Sediments

Background U/Th

Analytical Precision

HNO₃ Extraction

HCl Extraction

Anomalous U/Th

\( \frac{^{208}\text{Pb}}{^{204}\text{Pb}} \), \( \frac{^{206}\text{Pb}}{^{204}\text{Pb}} \)

IGES 2005
Graham Carr & Neil Rutherford
Nabarlek
Bulk Stream Sed Samples downstream from 800 ppm “recent” U anomaly

Analytical Precision

Threshold m\(^{-1}\) = 2

\( \frac{^{206}\text{Pb}}{^{204}\text{Pb}} \) vs \( \frac{^{208}\text{Pb}}{^{204}\text{Pb}} \)

IGES 2005
Graham Carr & Neil Rutherford
Nabarlek
Bulk Stream Sed Samples downstream from 800 ppm “recent” U anomaly

IGES 2005
Graham Carr & Neil Rutherford