NOVEL GEOCHEMICAL TECHNIQUES INTEGRATED IN EXPLORATION FOR URANIUM DEPOSITS AT DEPTH

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Forward looking statement:

(1) These results reflect industry-university collaborations.

(2) The focus will be on unconformity-type U deposits, but the approach is applicable to all types of U deposits.

(3) The approach is also equally applicable to most other types of metal deposits as well.
Exploration geochemistry targets:

1. **Primary dispersion**—alteration coeval with mineralization
2. **Secondary dispersion**—migration of elements post mineralization

- **Primary dispersion elements** include Ce, U, Co, Ni, S, K (and others)
- **Secondary dispersion elements** include Pb*, V, As, Co, Ni, U, some REEs, alkalis, Zn, S, Bi, Ba, He

*Components from above (common Pb*, As, Cu, Zn, Ni etc)*

*Mineralized zones*

(modified from Cameron et al., 2004)
Uranium is unique geochemically because:

(1) It produces a variety of products with distinctly different geochemical attributes that can be used to indicate a U-rich source including He, Rn, Ra, Pb, Th, U

(2) Unlike Au, U has two major isotopes (and intermediate ones) that can be used to fingerprint a U-rich source

Novel techniques discussed in this talk include:

- Mineralogy
- U isotopes
- Pb isotopes
- Organic gases

Geochemical techniques are only effective with geologic and geophysical techniques, to which they can add mutual value!
Primary dispersion in unconformity-related uranium deposits

- Chlorite Zone
- Outer Illite-Chlorite Alteration Zone ± Late Carbonate-Quartz Chlorite Veinlets
- Inner Chlorite Zone
- Clay & Hematite
- Pyritic Alteration
- Intense Fracturing
- Illitic (Cigar Lake) or Kaolinitic (Key Lake) Alteration
- Paleoregolith
- Inner Illite ± Chlorite Dravite, Hematite Zone
- Outer Illite-Chlorite Alteration Zone ± Late Carbonate-Quartz Chlorite Veinlets
- Sandstone-hosted
- Basement-hosted

After Thomas, 2007
Primary dispersion in sandstone-hosted uranium deposits

Grants Uranium Region--distribution of facies and diagenetic alteration in the Westwater Canyon Member and overlying Brushy Basin Member (Hansley, 1986; Turner-Peterson and Fishmann, 1986)
The Athabasca example—fluid temperatures and alteration from primary dispersion of mineralizing fluids
VR-01—far from mineralization—few temps above 250°C and not prospective
ZK85-01 near mineralization—temps >250ºC in Mfa/MFb
Halliday Lake Exploration Example—primary dispersion from drill core
Primary dispersion of fluids
$\delta^{238}U$ for uranium ore minerals from various deposits

$\delta^{238}U$ (‰) for uranium ore minerals from various deposits, with $^{238}U/^{235}U$ ratio, indicating $^{235}U$ remains in fluid and indicates better oxidizing environments.

- Calculated in fluid environments
- Related to $^{238}U/^{235}U$ ratio

Bar chart showing $\delta^{238}U$ values for different ore types and environments.
Models for U isotopes U-deposits

Fluids react with reductants (high $\delta^{238}U$) and $^{235}U$ stays in fluid—precipitates as reduction efficiency increases or further downstream (low $\delta^{238}U$)
$\delta^{238}\text{U}$ values vs. average grade for uranium ores from Athabasca and Kombolgie basins unconformity-related deposits
Uranium isotopes—primary dispersion recorded in clays from Cigar (red & blue), McArthur (green) and Outer Ring
Weak Acid Leach (WAL) extraction of elements can be used to indicate which elements are mobile—example from Cigar Lake.
Use of Pb isotopes and mobile elements in detecting deposits

Radiogenic Pb is produced by decay of U --this Pb migrates to grain edges and into pore spaces and fluids and gases.

Gases such as H₂S, CO₂, HCl etc. passing through the ore zone mobilize the radiogenic Pb.

Clays & Fe-Mn-oxides effectively trap Pb complexes in permeable zones or along fractures.

Pb-complexes

Early Proterozoic Metasedimentary Rocks

Sheared Graphitic Metapelitite

Archean Gneisses and Granitoids

Regolith

Middle Proterozoic Sandstone

Overburden

Silicified Zone

Hematite Zone

Illite Zone

Pb-complexes
Weak Acid Leach (WAL) indicates that mobile components moved through the sandstone and fractures all the way to the surface.
How large are these secondary dispersion haloes?

Holk et al., 2003
Model ages of the Pb extracted with WAL from the sandstone in mineralized areas are younger than the basin, whereas barren areas are older.
Cigar Lake West—evidence for secondary dispersion

Samples collected:
350 from each A1, A2, B, C soil horizons; 650 vegetation; 220 tree cores; 270 drill core samples—deposit at 460m
Those elements in surface samples that reliably indicate mineralization or faults that transect the mineralization include Pb isotopes, U, Pb, Ni, Co, Zn, Mn, Tl and C & N isotopes—minimal relation to topography.
Organic compounds released from A2, C clays and drill core from Cigar

Bioactive—occurs in both core and surface clays where there are anomalies
Gases are being used, but we are getting smarter on how to sample and use them—example from gases collected in drill holes at Centennial.
How far down can we “see” deposits at depth?
Recent results in the use of geochemistry in detecting deep uranium deposits:

(1) Map element distributions in and around deposits to assess the total chemical environment associated with the deposit,

(2) Use element tracing with isotopic compositions in surface media to detect specific components from uranium deposits at depth,

(3) Capitalize on element mobility across the geosphere-biosphere interface to enhance exploration using select media

(4) Geochemical data from drill core or surface media can enhance target identification when integrated with geophysical data.