

LA-UR-22-21608

Approved for public release; distribution is unlimited.

Title: Utility of Sr and Nd isotope signatures in U ores and UOCs

Author(s): Inglis, Jeremy David

Intended for: JAEA - NSDD PA-13 U ORE/UOC JSA Technical Meeting – Feb28th 2022

Issued: 2022-02-24



Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by Triad National Security, LLC for the National Nuclear Security Administration of U.S. Department of Energy under contract 89233218CNA000001. By approving this article, the publisher recognizes that the U.S. Government retains nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy. Los Alamos National Laboratory strongly supports academic freedom and a researcher's right to publish; as an institution, however, the Laboratory does not endorse the viewpoint of a publication or guarantee its technical correctness.

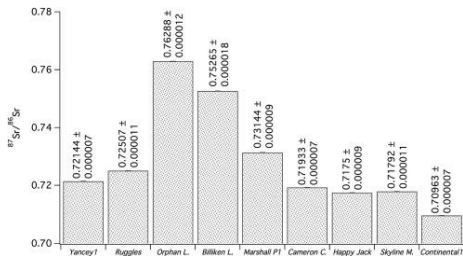


Utility of Sr and Nd isotope signatures in U ores and UOCs

Jeremy D Inglis

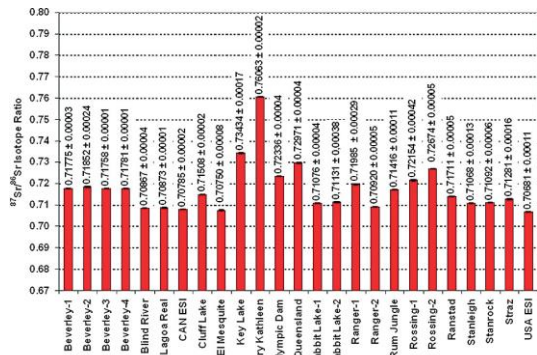
JAEA - NSDD PA-13 U ORE/UOC JSA Technical
Meeting – Feb28th 2022

Sr Isotope Signatures:



$^{87}\text{Sr}/^{86}\text{Sr}$ isotope signature of North American ore deposits (Balboni et al. 2016)

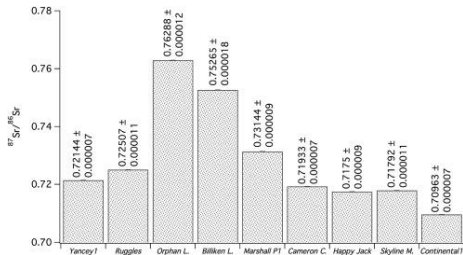
Individual ‘raw’ uranium ore deposits can have widely different Sr concentrations and $^{87}\text{Sr}/^{86}\text{Sr}$ ratios.



$^{87}\text{Sr}/^{86}\text{Sr}$ isotope signature of global UOCs (Varga et al. 2009)

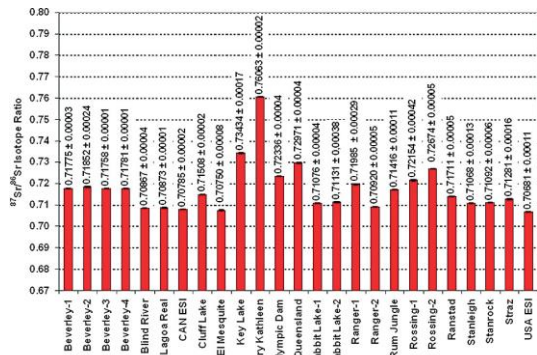
Uranium ore concentrates can also exhibit large variations Sr concentration and $^{87}\text{Sr}/^{86}\text{Sr}$ ratio.

Sr Isotope Signatures:



$^{87}\text{Sr}/^{86}\text{Sr}$ isotope signature of North American ore deposits (Balboni et al. 2016)

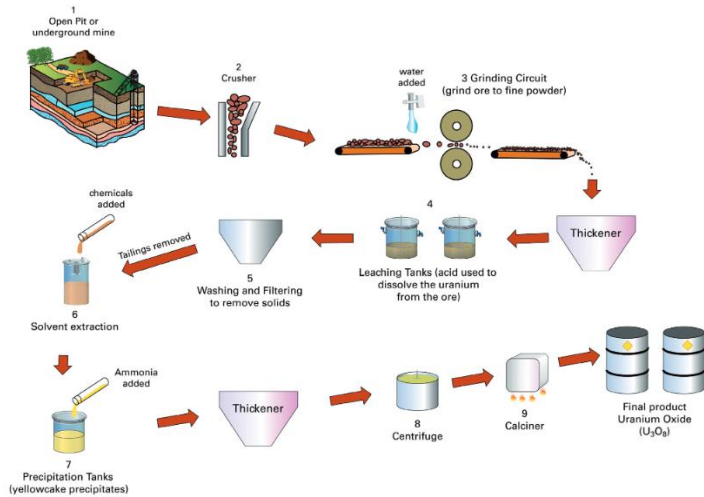
Individual 'raw' uranium ore deposits can have widely different Sr concentrations and $^{87}\text{Sr}/^{86}\text{Sr}$ ratios.



$^{87}\text{Sr}/^{86}\text{Sr}$ isotope signature of global UOCs (Varga et al. 2009)

Uranium ore concentrates can also exhibit large variations Sr concentration and $^{87}\text{Sr}/^{86}\text{Sr}$ ratio.

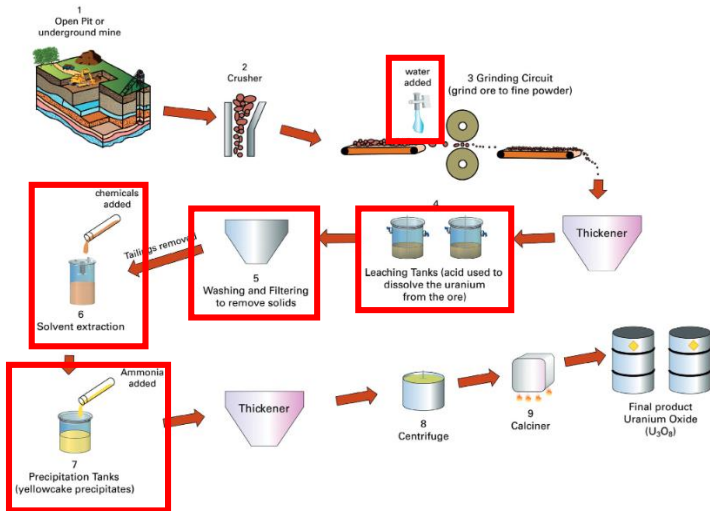
Significance of Extraction process on isotope signature



Uranium extraction process has several stages that may dilute isotope signature of the original ore by the addition of chemicals and reagents with distinct isotopic ratios:

- Washing
- Solvent extraction
- Leaching

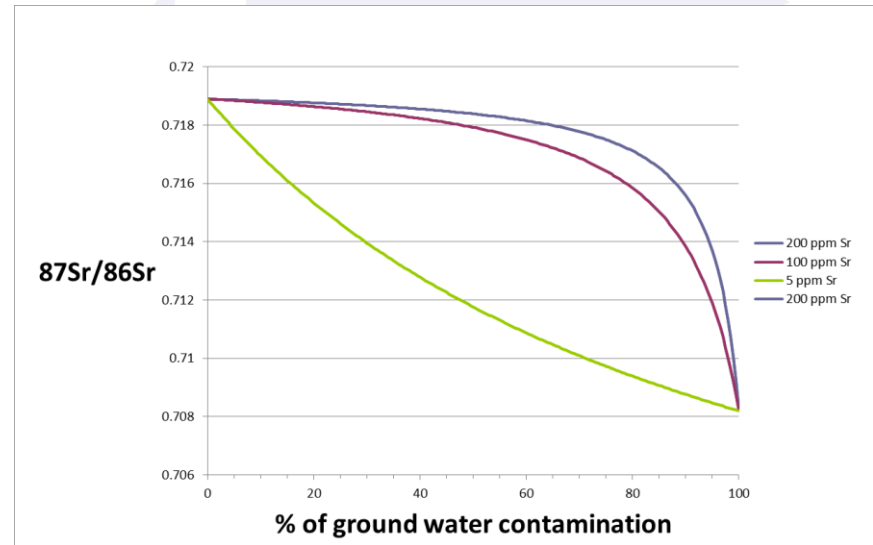
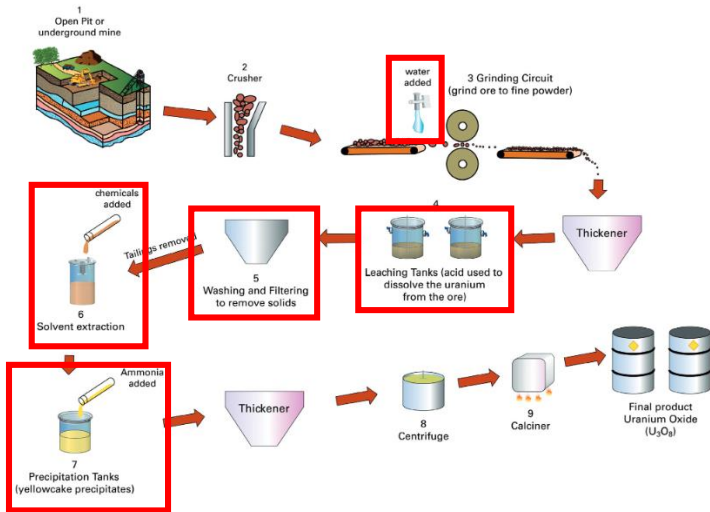
Significance of Extraction process on isotope signature



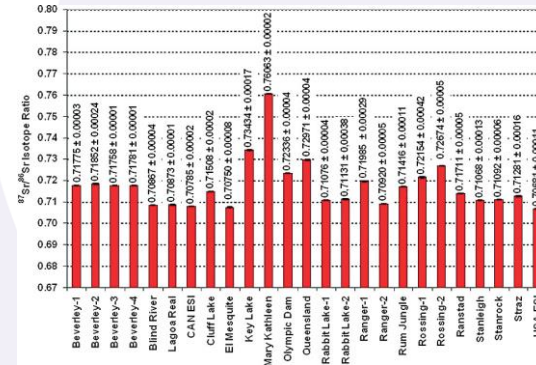
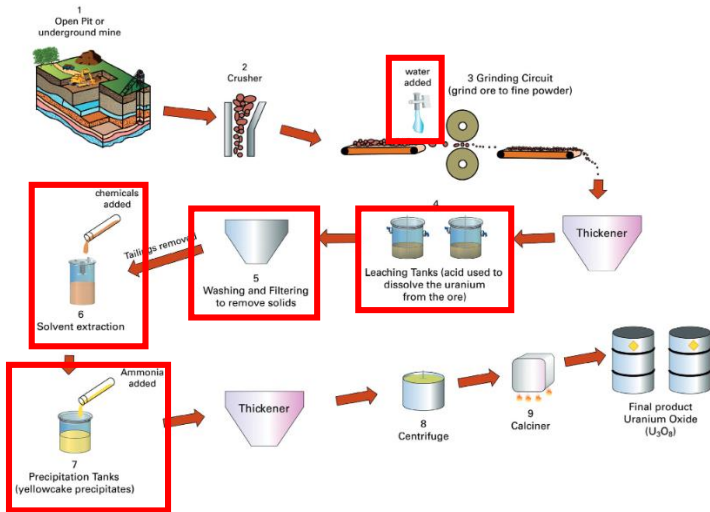
Uranium extraction process has several stages that may dilute isotope signature of the original ore by the addition of chemicals and reagents with distinct isotopic ratios:

- Washing
- Solvent extraction
- Leaching

Significance of Extraction process on isotope signature



Significance of Extraction process on isotope signature



UOC Sr isotope values likely a combination:

- Ores being processed
- Extraction methods and Sr values of reagents

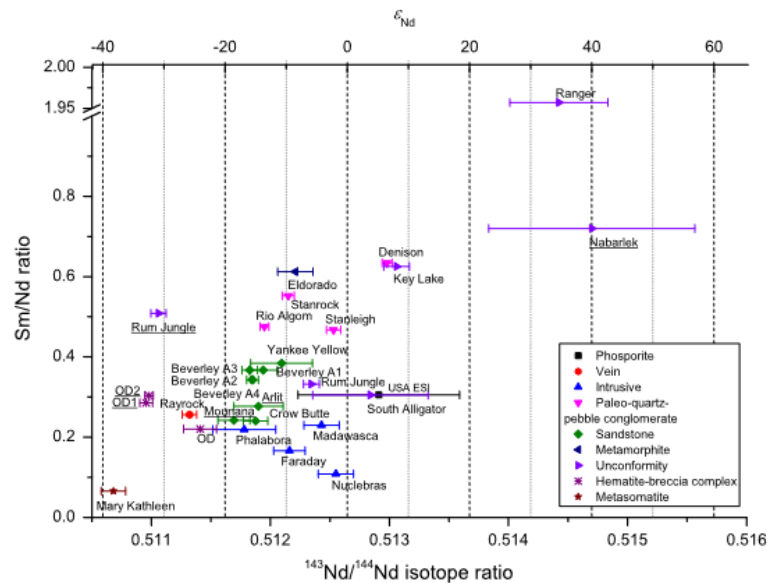
Nd isotope signatures

¹⁴⁴ Sm 3.07	¹⁴⁵ Sm	¹⁴⁶ Sm	¹⁴⁷ Sm 14.99	¹⁴⁸ Sm 11.24	¹⁴⁹ Sm 13.28	¹⁵⁰ Sm 7.38	¹⁵¹ Sm	¹⁵² Sm 26.75	¹⁵³ Sm	¹⁵⁴ Sm 22.75	
	¹⁴⁴ Pm	¹⁴⁵ Pm	¹⁴⁶ Pm	¹⁴⁷ Pm	¹⁴⁸ Pm	¹⁴⁹ Pm	¹⁵⁰ Pm	¹⁵¹ Pm	¹⁵² Pm	¹⁵³ Pm	15
¹⁴² Nd 27.2	¹⁴³ Nd 12.2	¹⁴⁴ Nd 23.8	¹⁴⁵ Nd 8.3	¹⁴⁶ Nd 17.2	¹⁴⁷ Nd	¹⁴⁸ Nd 5.7	¹⁴⁹ Nd	¹⁵⁰ Nd 5.6	¹⁵¹ Nd	¹⁵² Nd	15
			¹⁴⁴ Pr	¹⁴⁵ Pr	¹⁴⁶ Pr	¹⁴⁷ Pr	¹⁴⁸ Pr	¹⁴⁹ Pr	¹⁵⁰ Pr	¹⁵¹ Pr	15

Nd has the potential to be used as an isotopic fingerprint for ores and UOCs

- Less mobile than Sr
- The $^{143}\text{Nd}/^{144}\text{Nd}$ composition of Nd increases as a function of time because of the decay of ^{147}Sm
- The $^{143}\text{Nd}/^{144}\text{Nd}$ of a rock (ore) is determined by:
 - The initial $^{143}\text{Nd}/^{144}\text{Nd}$ ratio
 - The $^{147}\text{Sm}/^{144}\text{Nd}$ ratio
 - The age

Nd isotope signatures

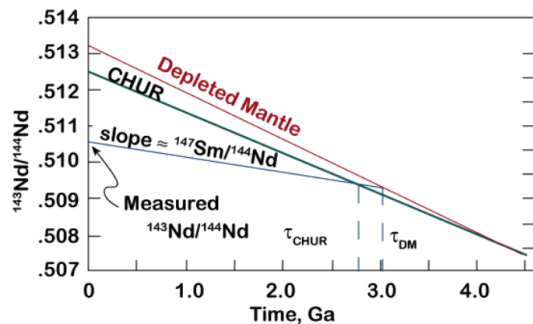


Nd isotope composition of global ore deposits (Krajko et al. 2014)

Nd has the potential to be used as an isotopic fingerprint for ores and UOCs

- Less mobile than Sr
- The $^{143}\text{Nd}/^{144}\text{Nd}$ composition of Nd increases as a function of time because of the decay of ^{147}Sm
- The $^{143}\text{Nd}/^{144}\text{Nd}$ of a rock (ore) is determined by:
 - The initial $^{143}\text{Nd}/^{144}\text{Nd}$ ratio
 - The $^{147}\text{Sm}/^{144}\text{Nd}$ ratio
 - The age

Nd isotope signatures



In some instances the model age will match age of ore (e.g. juvenile rocks)

Sm-Nd isotope analysis can yield model ages (point to the last geological fractionation event)

Basic idea is that there is a large fractionation event during melting to form rocks, subsequent crustal processing produces little change Sm/Nd ratio

We can project back along the slope defined by the ${}^{147}\text{Sm}/{}^{144}\text{Nd}$ to the point of intersection with mantle evolution curve

Is it possible to use Sm-Nd model ages to differentiate some ore deposits?

- May work for some ore deposits (i.e. granite / pegmatite hosted ores)
- Requires some big assumptions:
 - One geological fractionation
 - No subsequent fractionation of Sm and Nd during ore formation or processing
 - No mixing of different geological reservoirs
 - Unreasonable T_{DM} ages point to modern Sm-Nd fractionation away from geological values?