Recognizing Uranium Source Rocks in the Sedimentary Environment

Steven Sibray[1], Douglas Hallum[2]

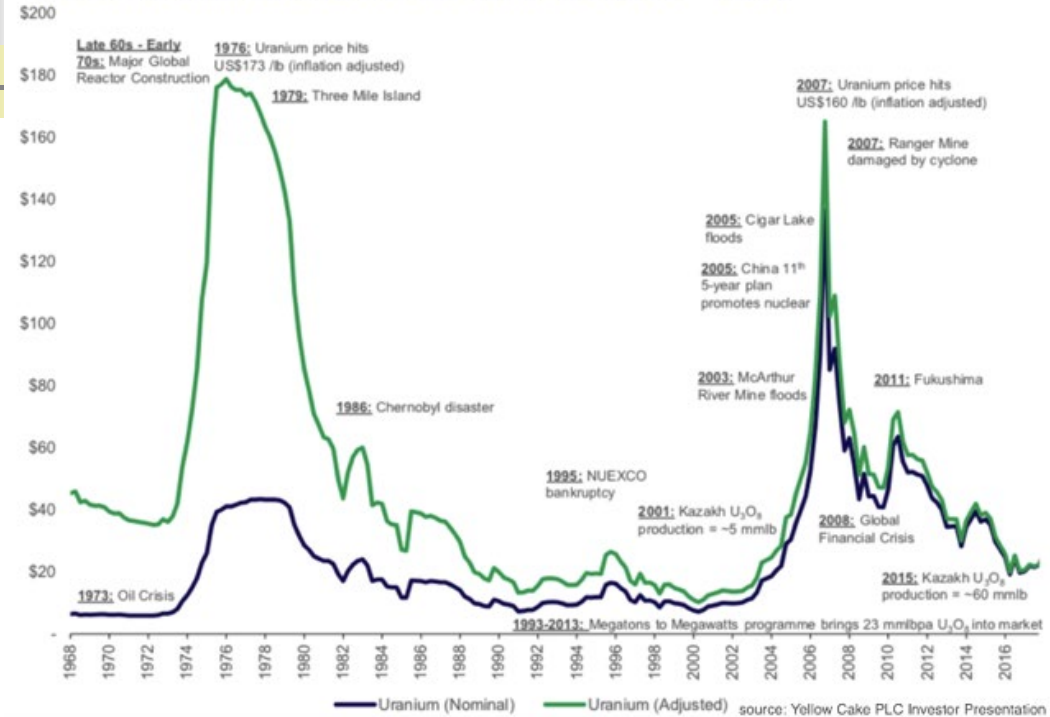
and

Michael D. Campbell[3]

[1] University of Nebraska – Lincoln, NE, and Vice-Chair (Academia), UCOM
[2] University of Nebraska – Lincoln, NE
[3] I2M Consulting LLC, Houston, TX, and Chairman, UCOM

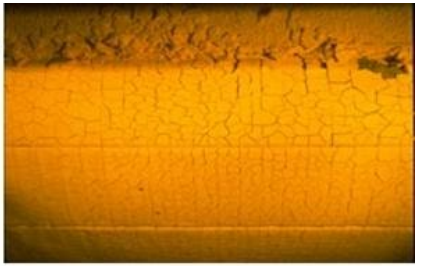
August 28, 2020

Historical Inflation Adjusted Uranium Price (1968 – 2017)



Uranium-ore

Yellowcake
U_3O_8



Uranium Spot Prices

(dollars per pound of U_3O_8)

Price of Yellowcake ($/lb)

35

30

25

Jun 2019

Sept 2019

Dec 2019

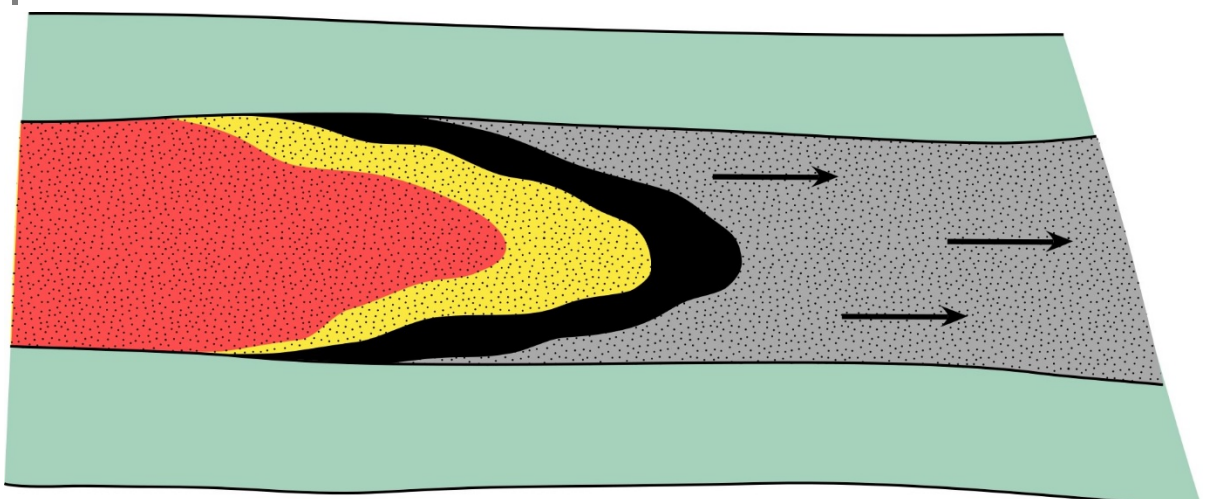
Mar 2020

May 2020

Uranium Exploration Strategies

- Late 1940s and 1950s – Direct Detection (Near Surface).
- Late 1960s and 1970s – Roll Front Model (Pit-300 Ft. Deep; Insitu-1,200 Ft. Deep).
- Uranium Source – Granites, Tuffaceous Sediments, Lignites, Carbonaceous Marine Shales?
- All Tertiary Sandstone Deposits are Roll Fronts (?).
- Significant Sedimentary Deposits are not Roll Fronts.

Generalized Roll Front Uranium Deposit



Groundwater flow

Clay

Uranium ore

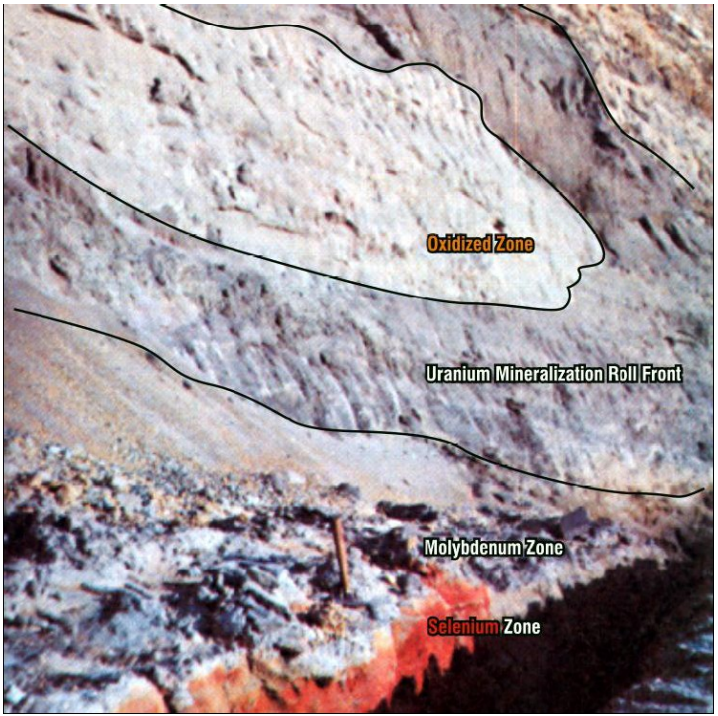
Reduced zone, pyrite

Oxidized zone, limonite

Oxidized zone, hematite

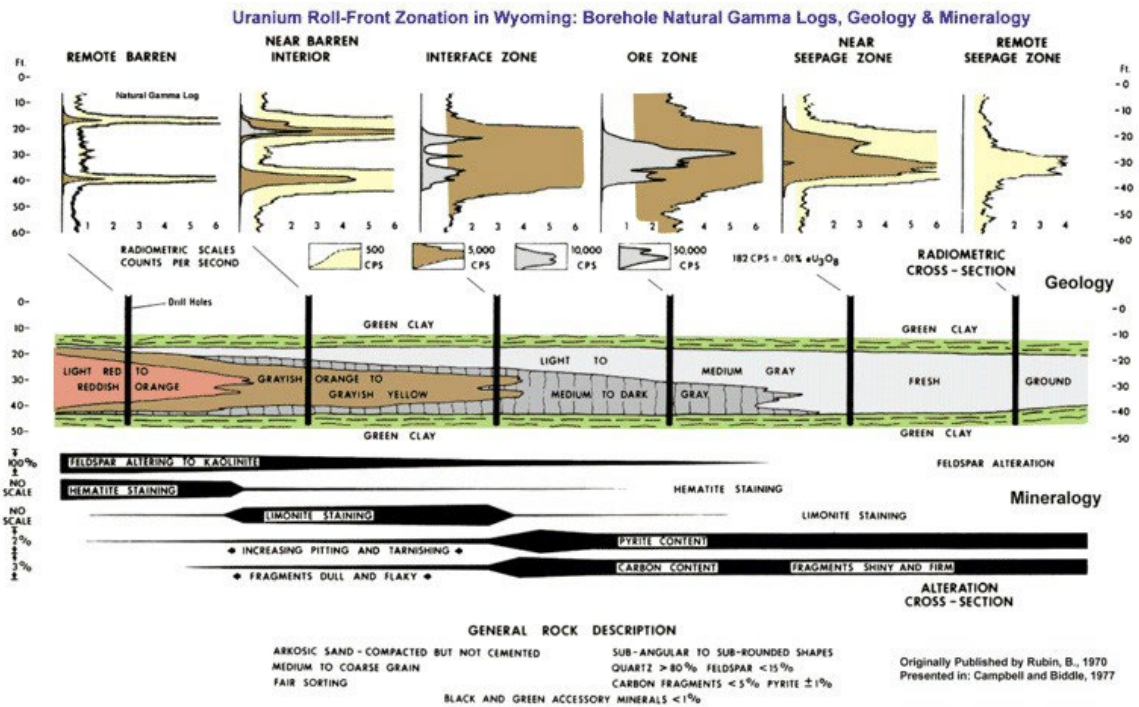
Finch, et al., (1985)

Actual Roll-Front Ore Zone within Oakville Sandstone in an Open Pit Mine Live Oak County, Texas



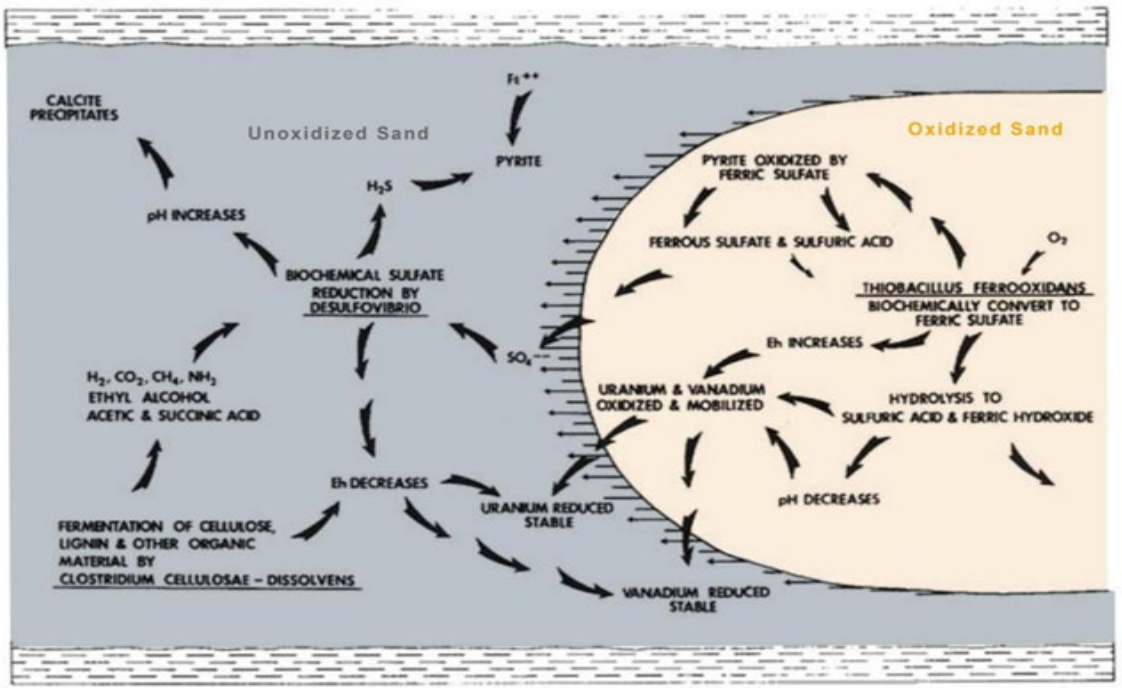
After Dickinson and Duval (1977)

Geophysical, Mineralogical, Geological Relationships in Wyoming Roll Fronts



Rubin (1970)
Modified by Campbell and Biddle (1977)

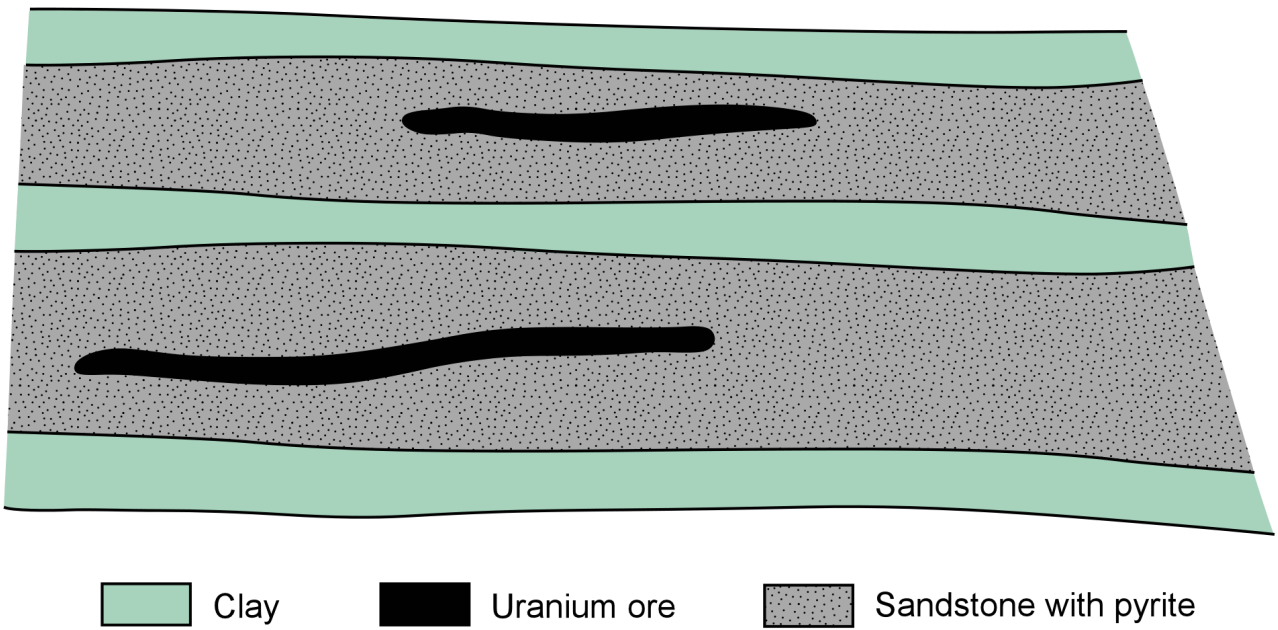
1975 Concept of a Biogeochemical Cell in a Roll-Front



After Rackley, 1975

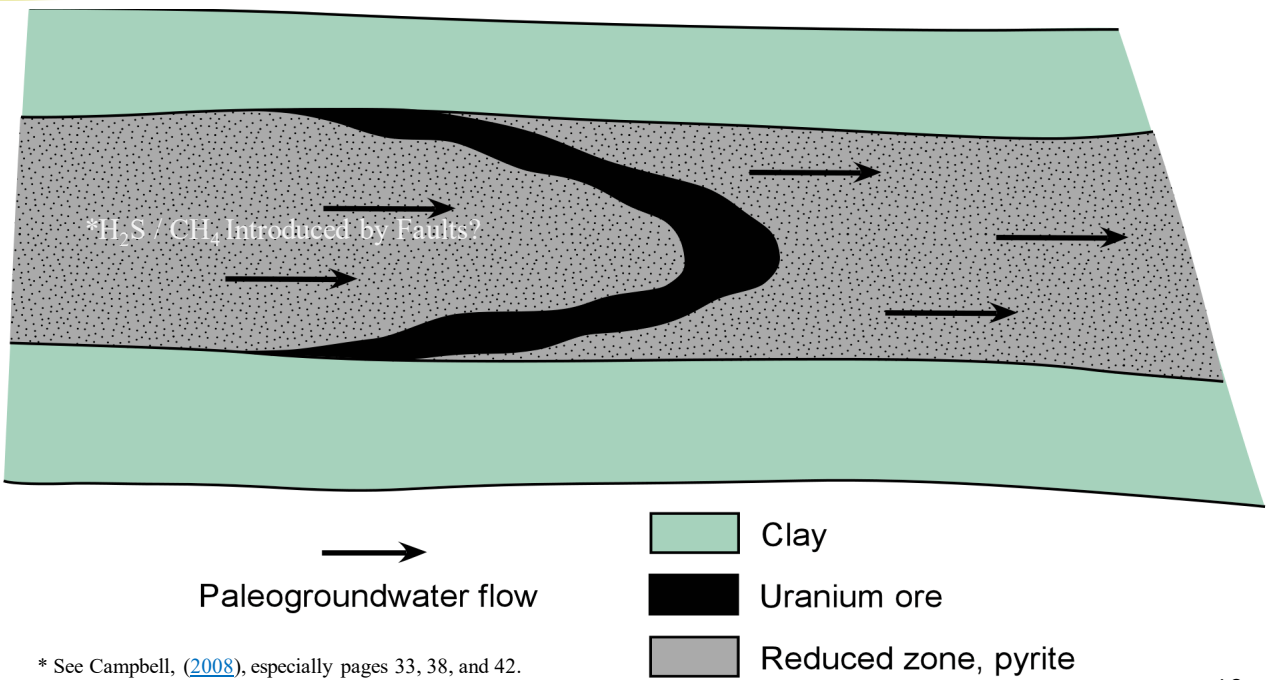
Rackley, (1968 and 1975)

Typical Tabular Uranium Type Deposit



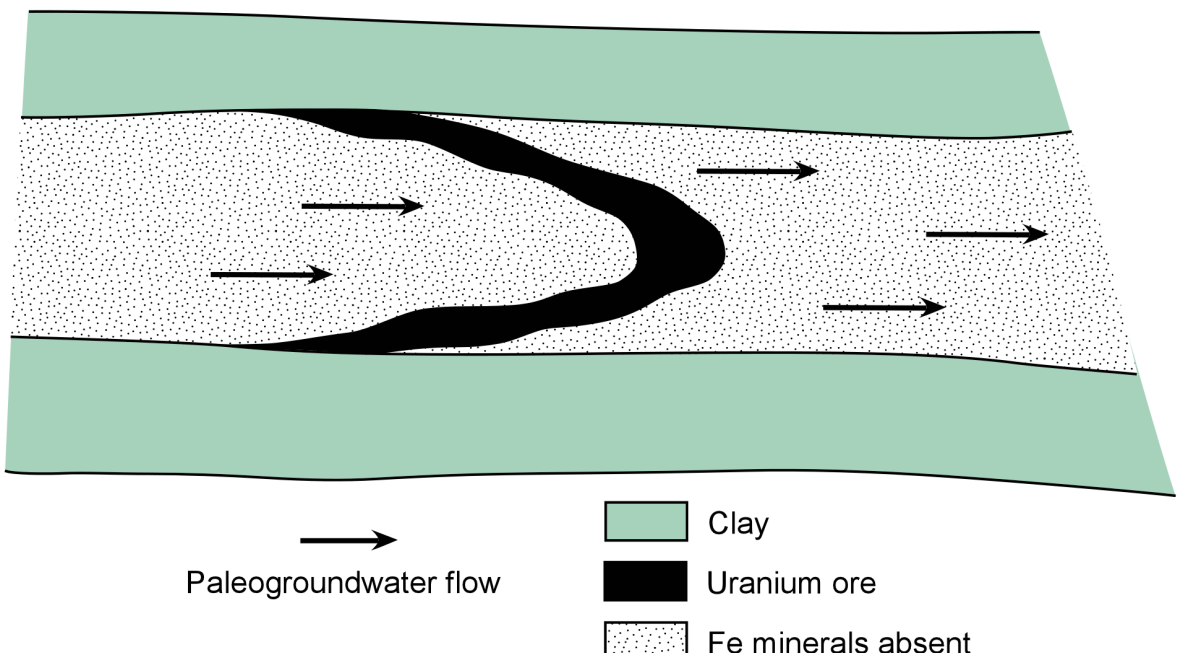
Sandford (1992)

Typical Reduced Roll Front (Re-Reduced?)



* See Campbell, (2008), especially pages 33, 38, and 42.

Typical Roll Front Without Fe Minerals



(Fe not involved in biochemical activity in U ↓ from solution?)

Miscellaneous Sedimentary U Deposits

- Carbonates – Todilto Limestone, Grants, N.M.
- Breccia Pipes – Northern Arizona
- Mixed Types – Unconformity, Hydrothermal –

Exploring for the Unconventional Deposits

- Non-Roll Front Sedimentary U Deposits
- Understanding Uranium Systems
- Analogy – Petroleum Systems (Role of H_2S and CH_4)
- Source – Migration – Trap – Faulting
- Need to Identify Other Sources of Uranium for Frontier Exploration Areas (Lignite?)
- Incorporate Paleohydrogeology

Arkosic Sediments – U Source

- Investigate Granite Source
- Some Granites More "Leachable" than Others
- Uranium in Allanite vs Zircon & Monazite
- Research U/Pb systematics & U/TH Ratio
- Potential Granite Sources – Wyoming, Colorado Plateau – not Texas (Volcanics/ in Lignites?)
- Australian Paleo-Valley Roll Front / Calcrete-Type
- Canadian Unconformity Mineralization

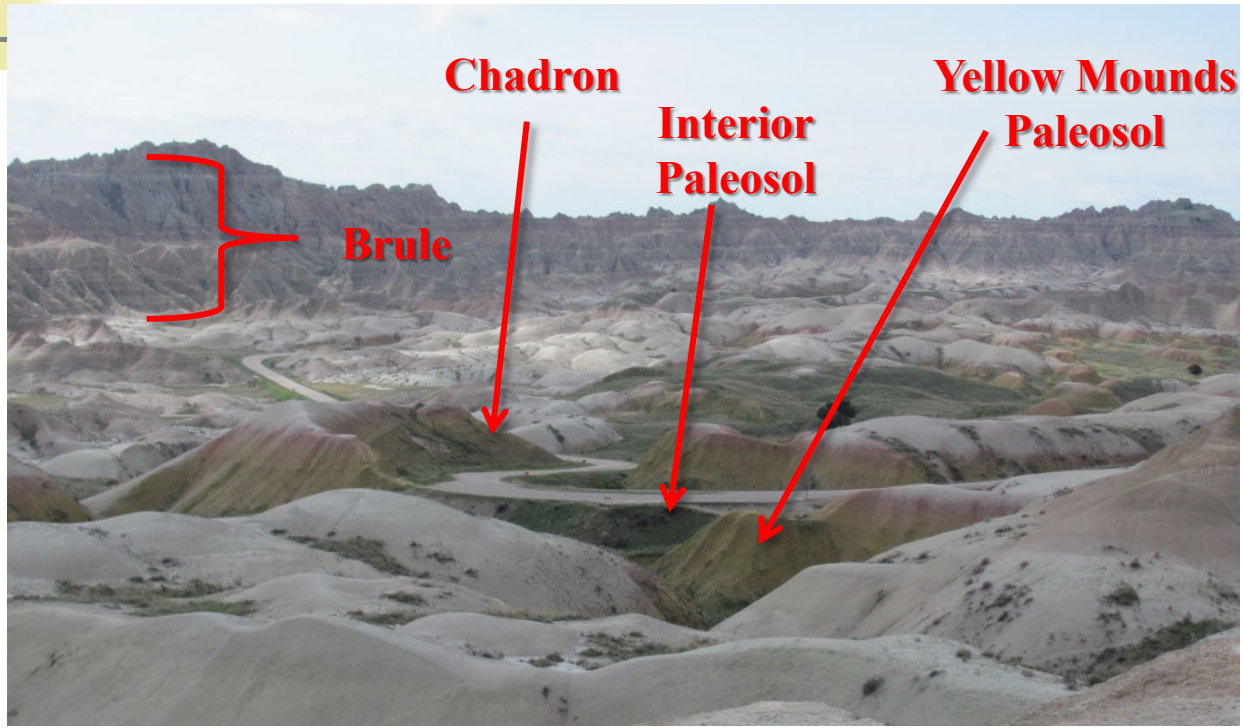
Tuffaceous Sediments – U Source

Volcanic Glass + H_2O = Clay + SiO_2 + U^{+6} (in solution)

Volcaniclastics as U - Source

- Potential Source – Wyoming, Colorado Plateau & Texas
- Rhyolitic glass high in U and easily leached
- Pedogenesis Important (Walton A.W., et al. 1981)
- High Th/U – U leached (Zielinski R.A., 1983)
- Source Rock – Paleosol with High Th/U (Sibray, S.S., 2010)

White River Group
Badlands National Park, S.D.

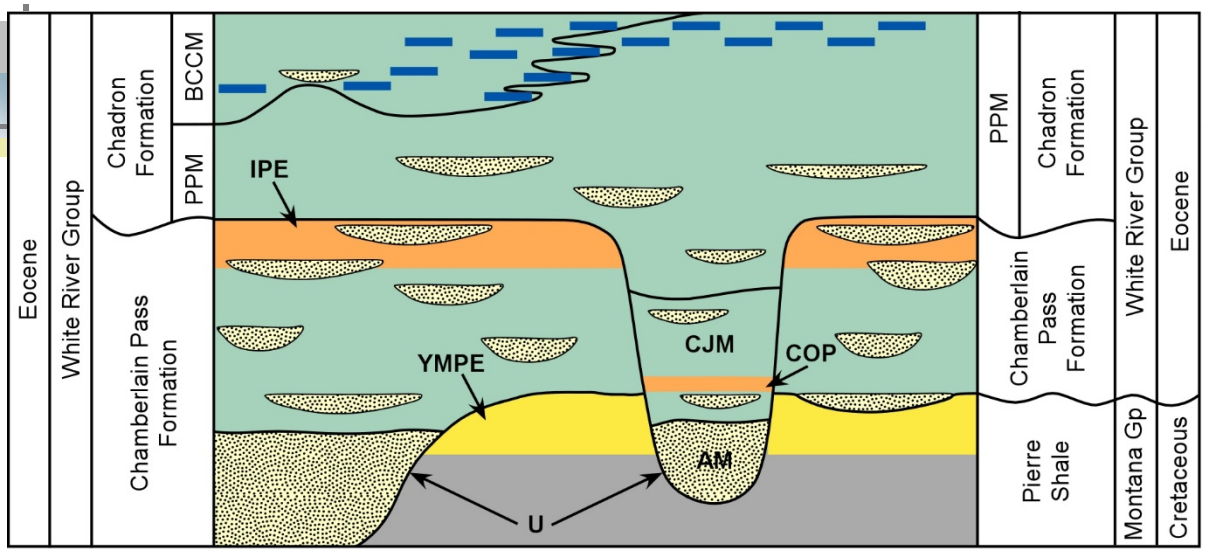


From Sibray, (2010)

Yellow Mounds Paleosol Sioux Co. NE

From Sibray, (2010)

Paleosol as Possible Uranium Source



Lacustrine limestone

Sand

Mudstone

Shale

Possible Uranium Source - Paleosol

Yellow Mounds Paleosol Equivalent

BCCM - Big Cottonwood Creek Member
PPM - Peanut Peak Member
CJM - Crazy Johnson Member
AM - Ahearn Member
IPE - Interior Paleosol Equivalent
YMPE - Yellow Mounds Paleosol Equivalent
COP - Chadron Oxidizing Paleosol
U - Potential Uranium Deposits

From Sibray, (2010)

Basal Chadron Fm – South Dakota

From Sibray, (2010)

Basal Sand Chamberlain Pass Fm Sioux Co. NE

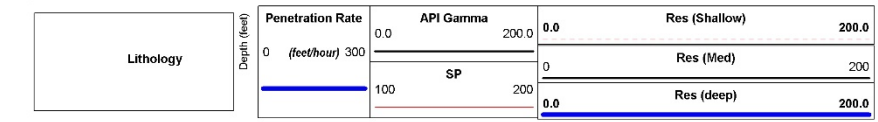
From Sibray, (2010)

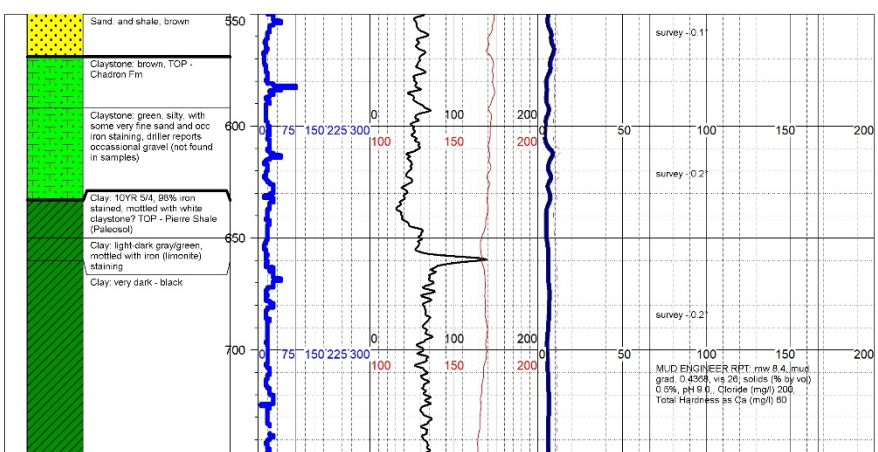
CONSERVATION AND SURVEY DIVISION
School of Natural Resources
Phone: 308-696-6743
402 W State Farm Rd, North Platte, NE 69101

Log: 01-NPPD-2017

Well Screens

Total Depth:	3552' measured depth
Location:	Sutherland, NE
Latitude:	N41° 04' 24.44"
Longitude:	W101° 08' 8.03"
Hole Diameter:	
Elevation (Ground Surface):	3140' (3148' @ KB)
Drilling Date:	9/19/2017 - 11/2/2017
Drilled By:	Hydro Resources
Lithology Logged By:	Driller/Hallum/Hemenway
Geophysical Log Operator:	






N.P.
NEBRASKA WATER SURVEY
CI-NPPD-2017
SWNW 29-13N-33W
LINCOLN CO
630'-640'
Hubco, INC.
HUTCHINSON, KS 67504-1286
N.P.
NEBRASKA WATER SURVEY
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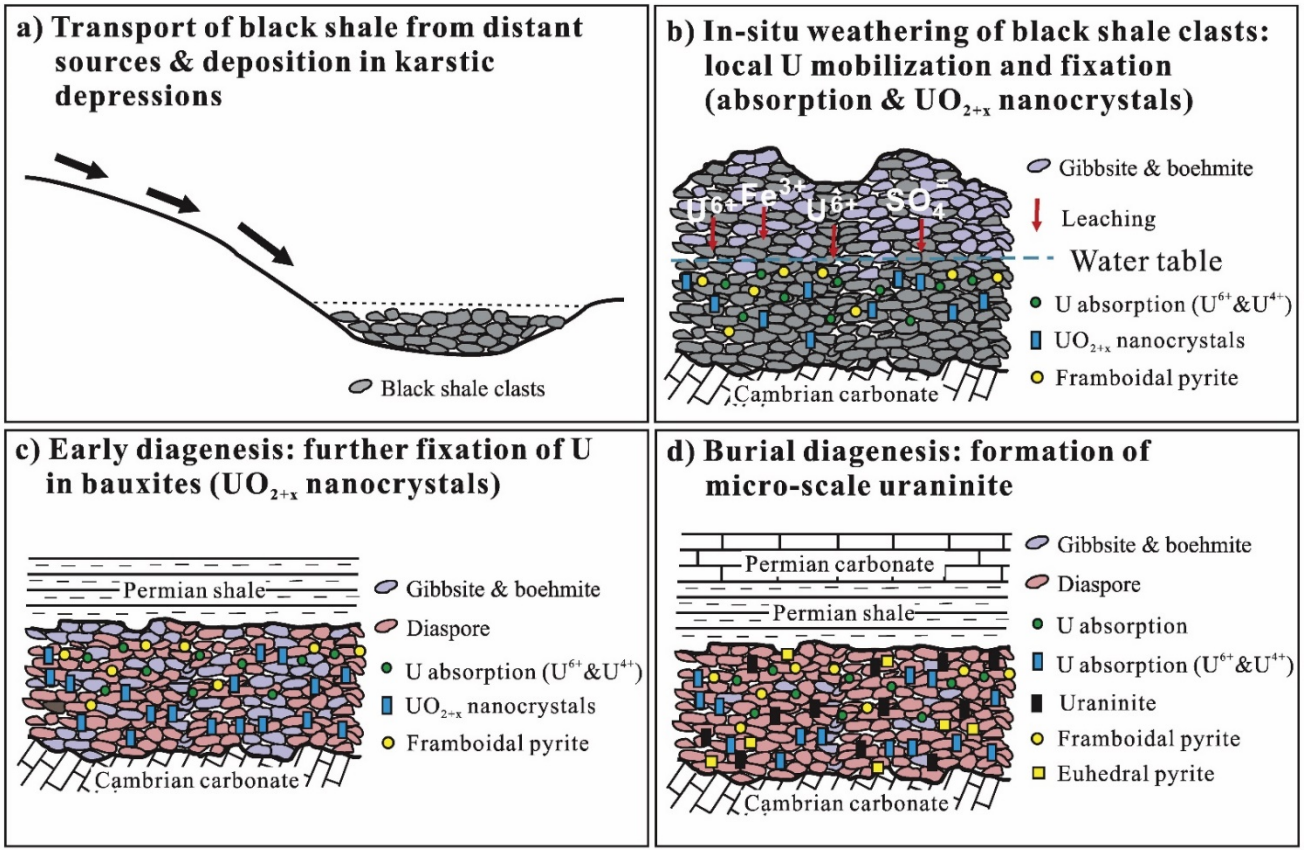
HUTCHINSON, KS 67504-1286

Uranium in Bauxite - Puzzling

- Yanfeng bauxite deposit, China
- Paleo-karstic deposit
- U average: 35 ppm, 18-62.4 ppm
- Geochemical Study – Th/U and REE
- Intense Weathering
- Parent Material – Black Shale - Lower Cambrian

Genesis of Black Shale Uranium

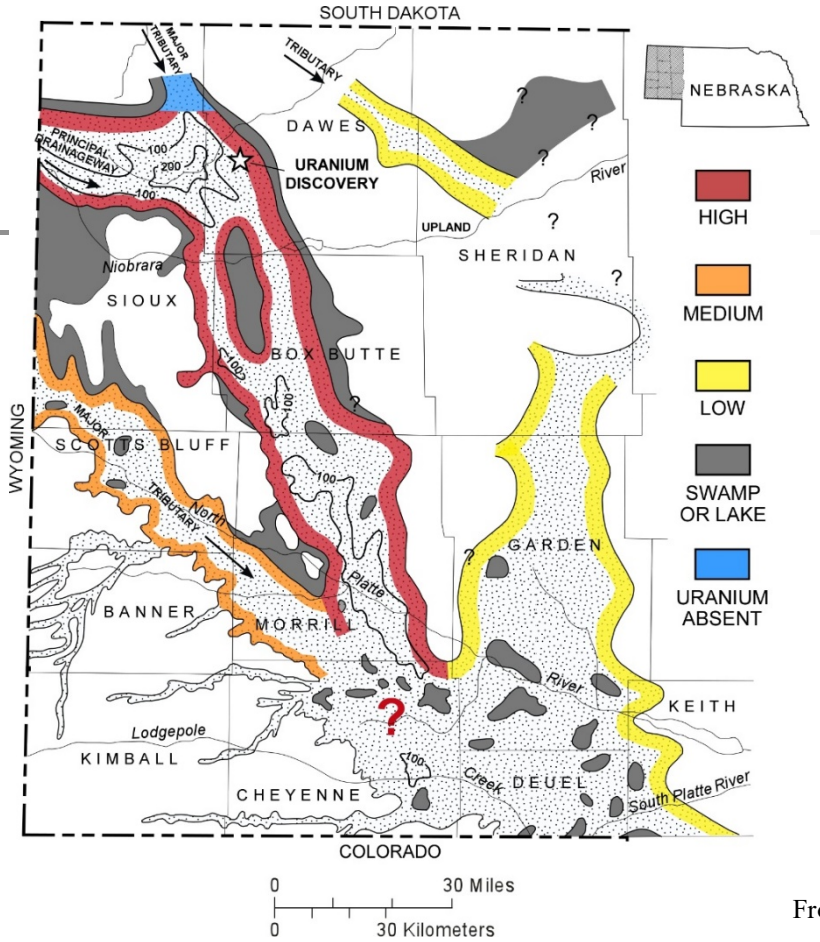


Long, et al., (2017)

Crow Butte Deposit Dawes Co. Nebraska

- Discovery Announced – January 13, 1981
- $U_3O_8 \geq 25$ Million Lbs. $\geq 0.25\%$
- Production – Started 1991
- Produces ≈ 800,000 Lbs./Year
- Total Production = 18 Million Lbs.
- Basal White River Group – Chamberlain Pass?

Uranium Potential of Fluvial Boundaries



From Sibray, (2010)

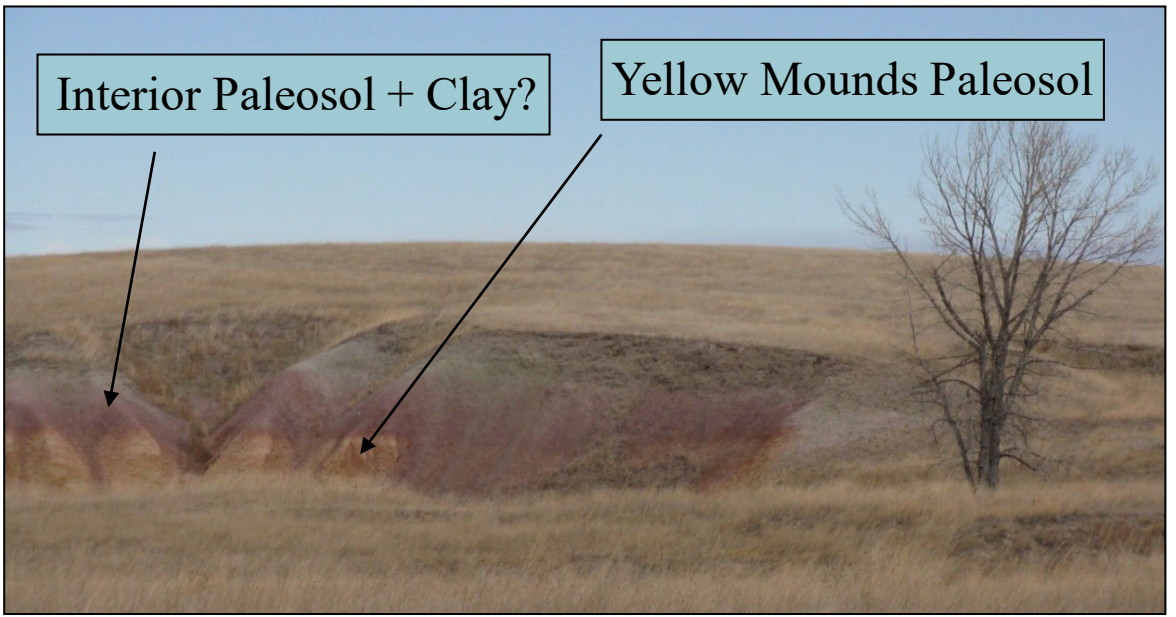
Why Uranium Absent in Northern (Blue) Tributary?

- Chadron Fm. Contains Bentonitic Clay
- Uranium Released From Clay - Limited Migration?
- Lack of Granitic Source?
- Lack of Rhyolitic Source in Interior Paleosol?
- Lack of Lignite Source in Fluvial Sediments?

Why Uranium Absent in Other Northern Tributary (Yellow)?

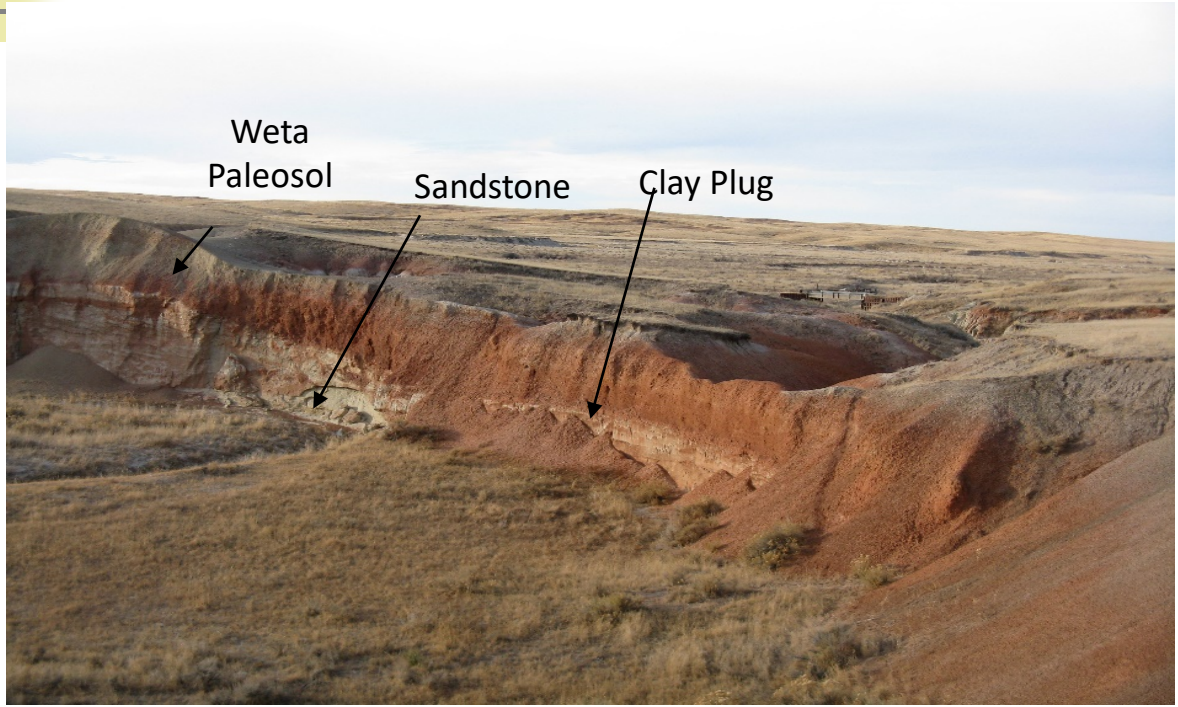
- Uranium Migrated Through but No Accumulation.
- Reported Radiation Damage in Quartz using Cathodoluminescence Microscopy (Leibold, 2013).
  - Found Damage in Ore Zone but Not Upgradient.
  - Lack of Radiation Damage in Upgradient Core Suggests It Never Hosted Ore.
- Roll Front - Moves Periodically (?) and Only Forms under Favorable HydroBioGeochemical Conditions.

Yellow Mounds and Interior Paleosols – Sioux Co., NE



From Sibray, (2010)

Chamberlain Pass Fm. Sioux C. NE

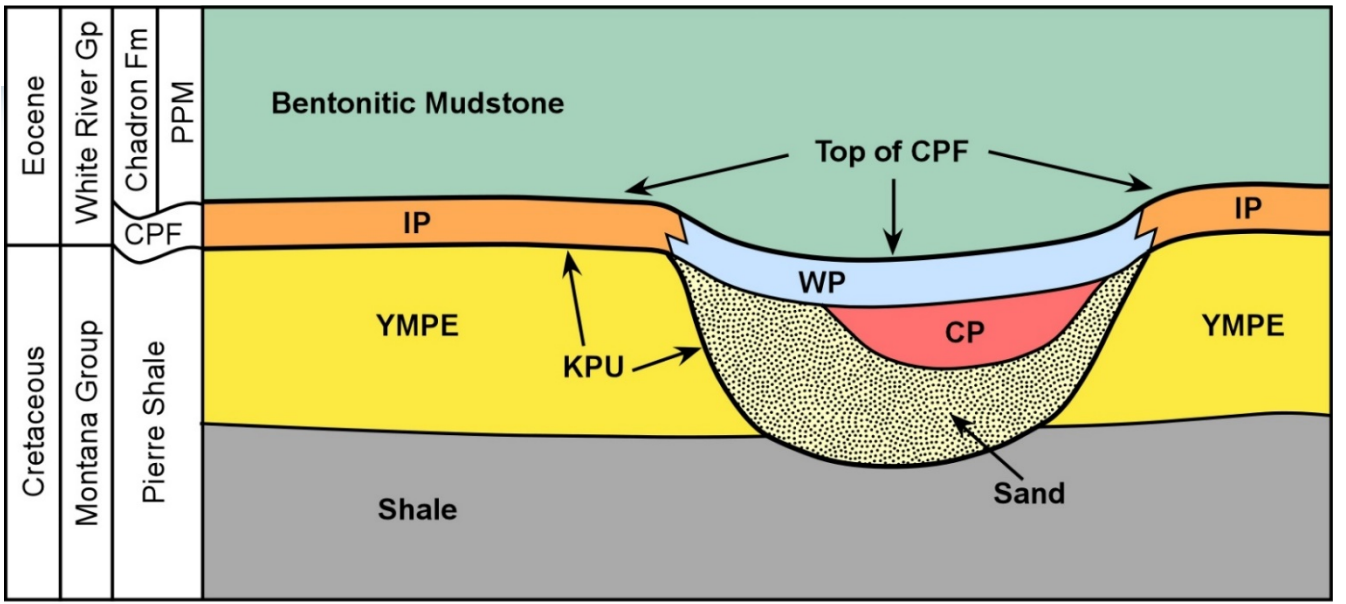


From Sibray, (2010)

Basal Sands of Chamberlain Pass Fm. (Cemented by Mn Oxides)

From Sibray, (2010)

Cretaceous / Paleogene Unconformity



CPF - Chamberlain Pass Formation

PPM - Peanut Peak Member

From Sibray, (2010)

* IP - Interior Paleosol

YMPE - Yellow Mounds Paleosol

KPU - Cretaceous Paleogene Unconformity

WP - Weta Paleosol

CP - Clay Plug

*Note: IP Containing Atmospheric Fallout of Ash from Meteor Impact in Wyoming and/or Mexico?
See: Wise and Campbell (2018), pp. 128-131.

GeoChemical/Petrographic Study – WRG Paleosols

- Th/U Ratios Relatively Constant:
  - Volcanic Source? and or
  - Meteor Impact Source?
- Th – Not Mobile During Weathering
- Th/U – Higher In Source Rock?
- REE in Paleosols – Source? minor fractionation
- REE can characterize parent material in Paleosols.
- Morrison Fm. and Chinle Group Deposits

Conclusions

- Yellow Mounds Paleosol – depleted in Uranium
- Eocene Oxidizing Paleosols – Uranium Source?
- Geochemistry + Paleopedology Define Source Rocks Exploration for Unconventional Sedimentary Uranium Deposits.

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Supporting References

Search Results from the I2M Web Portal and Other Sources:

"Search Terms:"

1. "**Uranium Exploration**":
http://web.i2massociates.com/search_resource.php?search_value=%22Uranium+Exploration%22&sort=date#page=1

2. **"Nebraska" Uranium**: https://www.dmr.nd.gov/ndgs/mineral/uranium.asp and
http://web.i2massociates.com/search_resource.php?search_value=Nebraska&sort=date#page=1

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4. **"Unconformity" – Related Uranium Deposits:**
http://web.i2massociates.com/search_resource.php?search_value=Unconformity#page=1

5. **"Allanite" – Research:**
http://web.i2massociates.com/search_resource.php?search_value=Allanite#page=1

6. **"Allanite in Alaska":**
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8. **"UCOM 2020 Annual Report":**
http://www.i2massociates.com/downloads/EMDUraniumNuclearMineralsandREECommitteeAnnualReport-2020.pdf

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- Nebraska Department of Environmental and Energy [NDEE]
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Questions????