



Recognizing Uranium Source Rocks in the Sedimentary Environment

Steven Sibray¹, Douglas Hallum²

and

Michael D. Campbell³

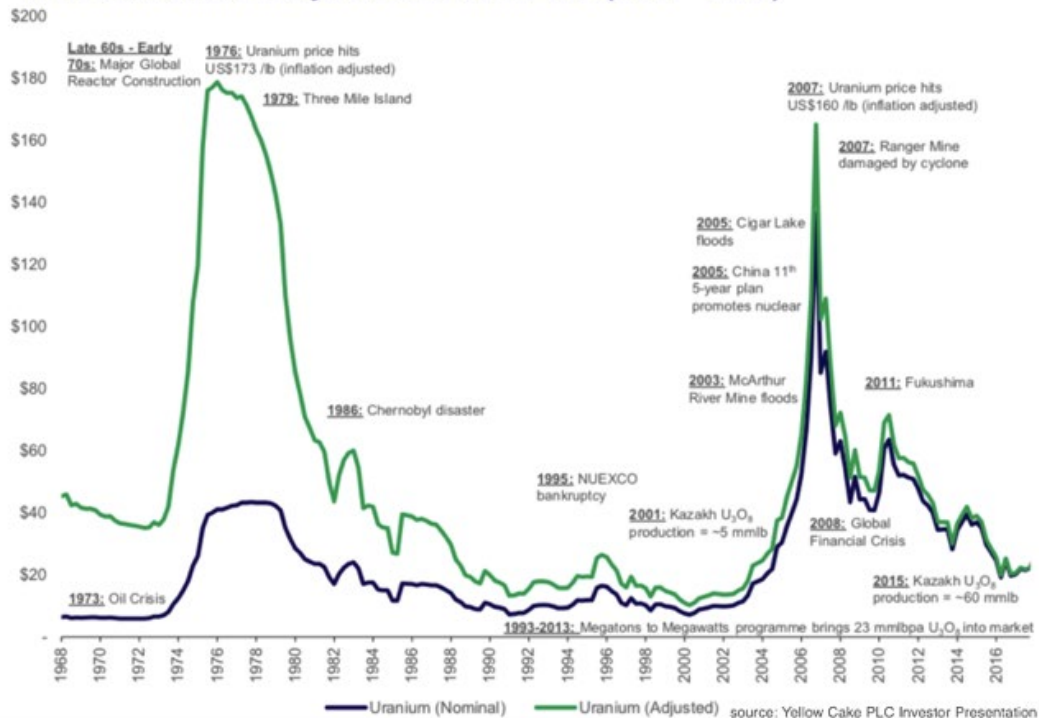
¹ University of Nebraska – Lincoln, NE, and [Vice-Chair \(Academia\), UCOM](#)

² University of Nebraska – Lincoln, NE

³ I2M Consulting LLC, Houston, TX, and [Chairman, UCOM](#)

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Historical Inflation Adjusted Uranium Price (1968 – 2017)





Uranium-ore

Yellowcake
 U_3O_8



Uranium Spot Prices

(dollars per pound of U_3O_8)



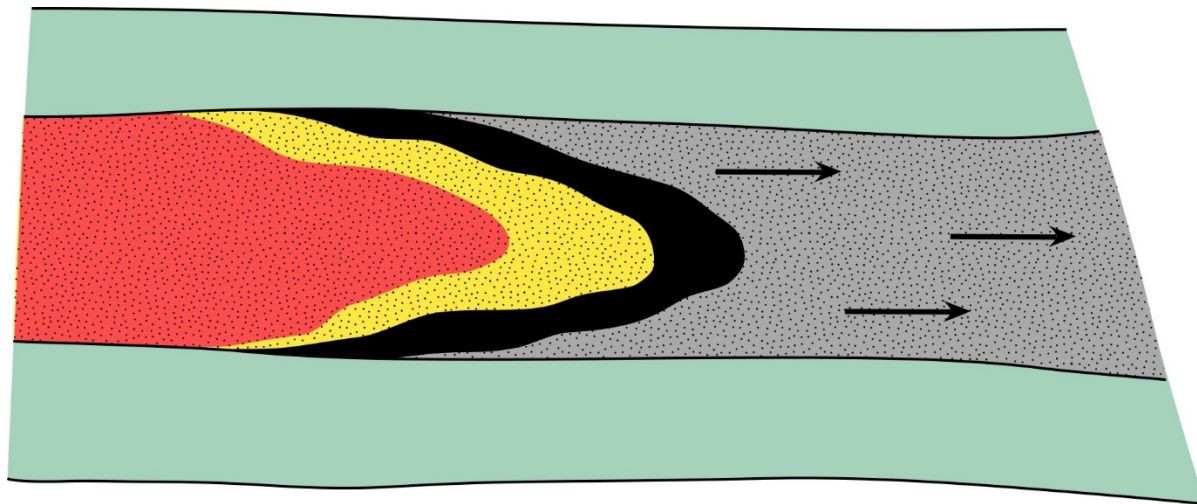


Uranium Exploration Strategies

- 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

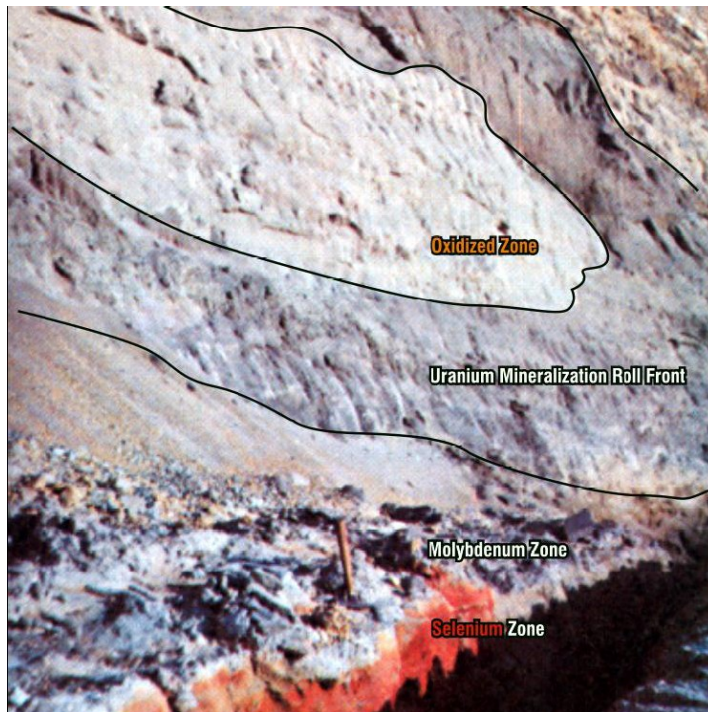
Finch, et al., (1985)

Clay
Uranium ore

Reduced zone, pyrite
Oxidized zone, limonite
Oxidized zone, hematite



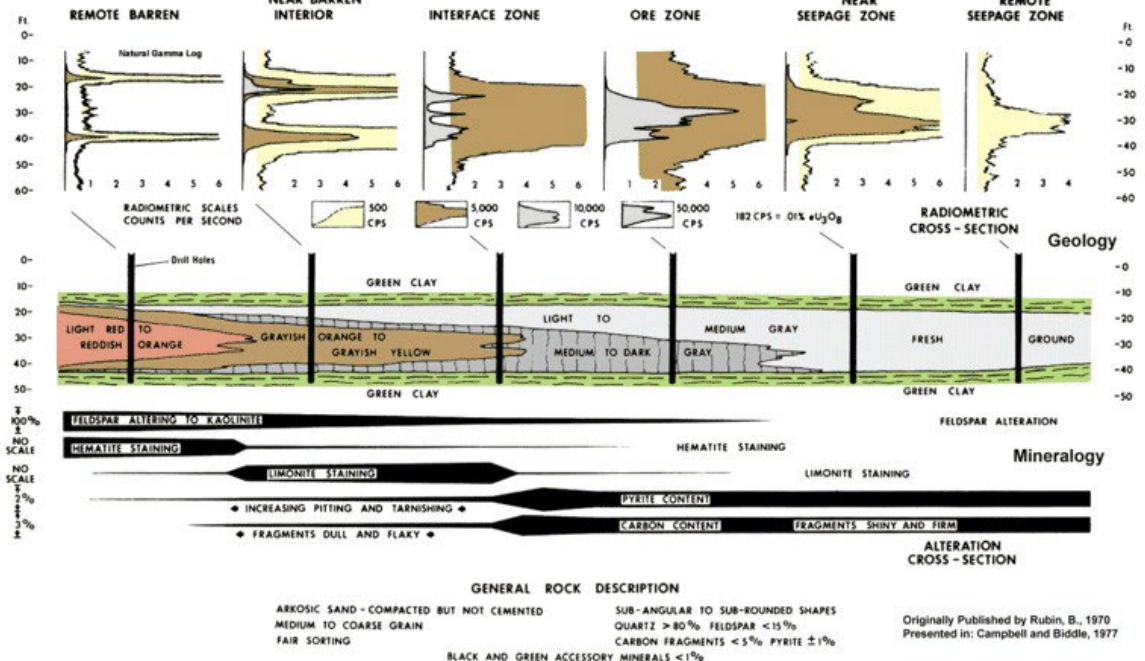
Actual Roll-Front Ore Zone within Oakville Sandstone in an Open Pit Mine Live Oak County, Texas



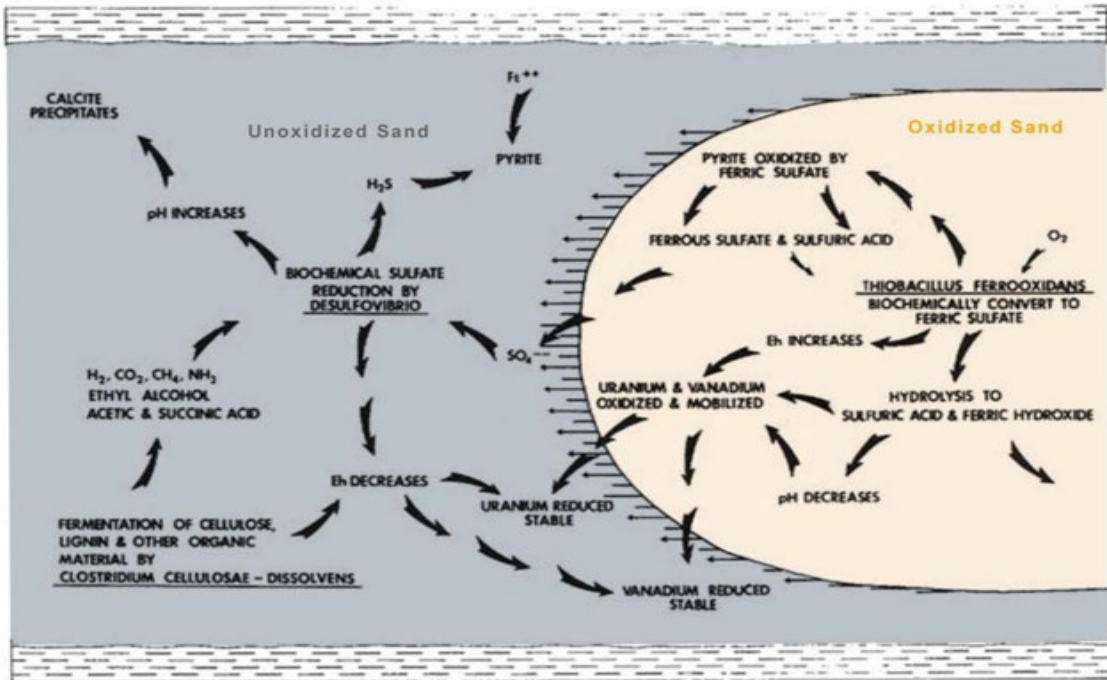
After Dickinson and Duval (1977)

Geophysical, Mineralogical, Geological Relationships in Wyoming Roll Fronts

Uranium Roll-Front Zonation in Wyoming: Borehole Natural Gamma Logs, Geology & Mineralogy



1975 Concept of a Biogeochemical Cell in a Roll-Front

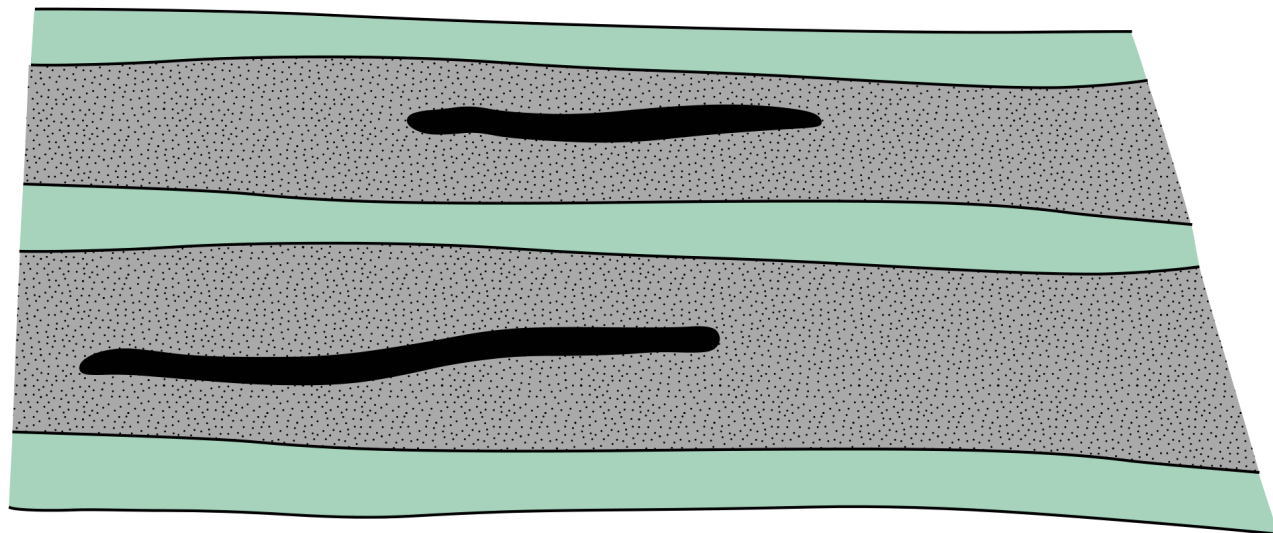


After Rackley, 1975

Rackley, (1968 and 1975)



Typical Tabular Uranium Type Deposit

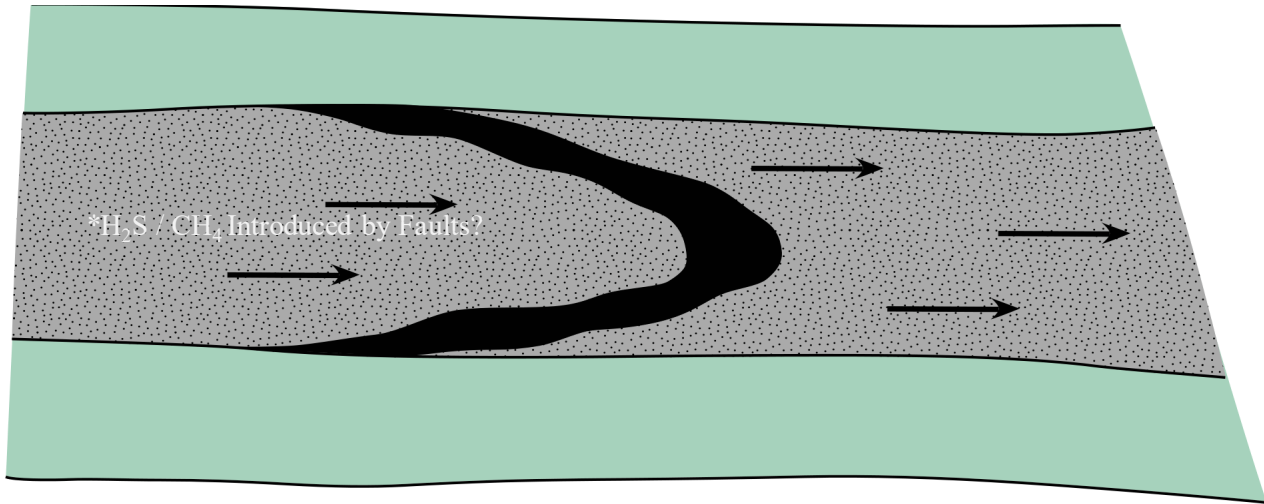


 Clay




 Uranium ore

 Sandstone with pyrite

Typical Reduced Roll Front (Re-Reduced?)



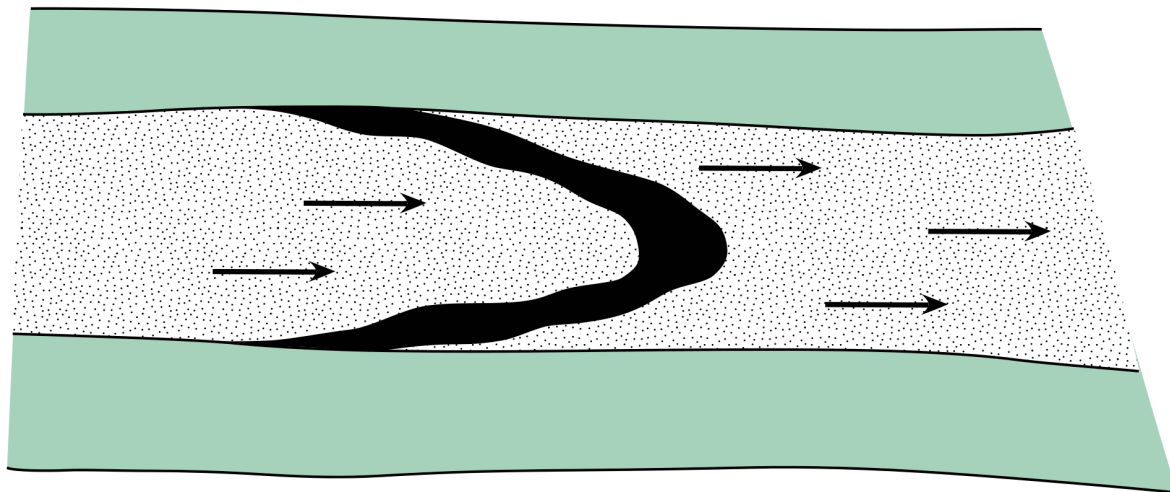
→
Paleogroundwater flow

-  Clay
-  Uranium ore
-  Reduced zone, pyrite




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



Typical Roll Front Without Fe Minerals



→
Paleogroundwater flow

-  Clay
-  Uranium ore
-  Fe minerals absent

(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 + H₂O = Clay + SiO₂ + U⁺⁶ (in solution)

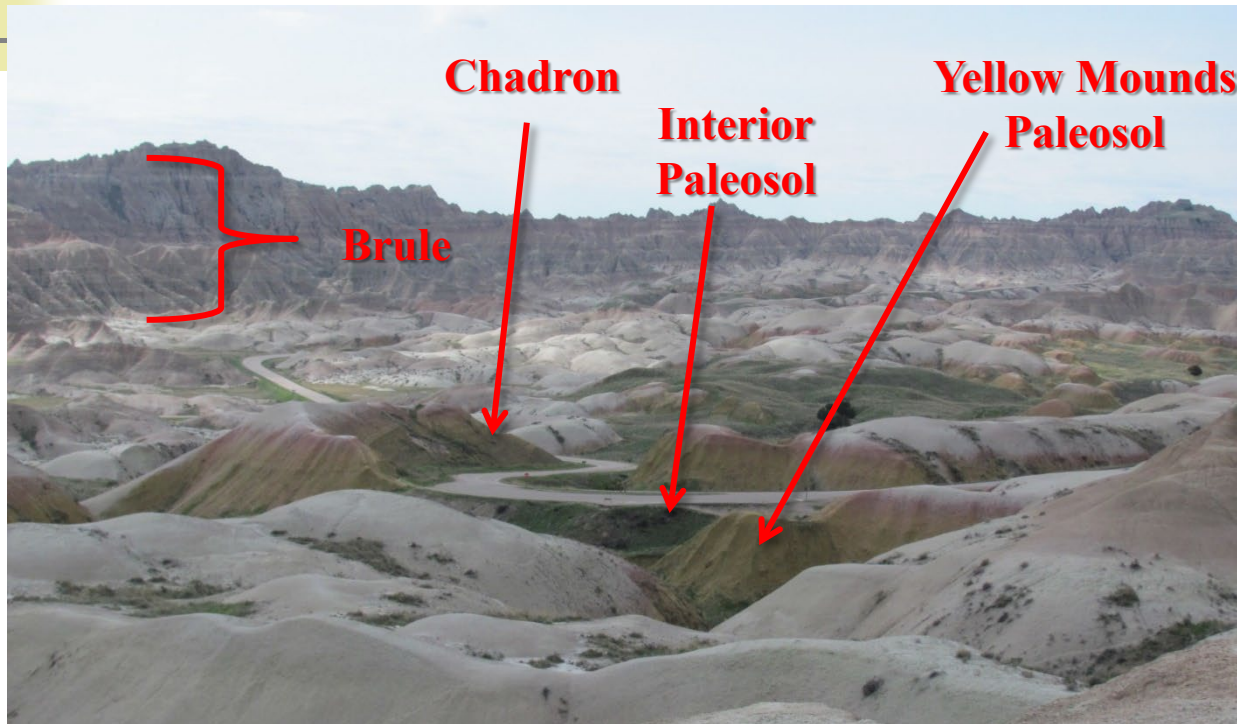


Volcaniclastics as U - Source

- 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.



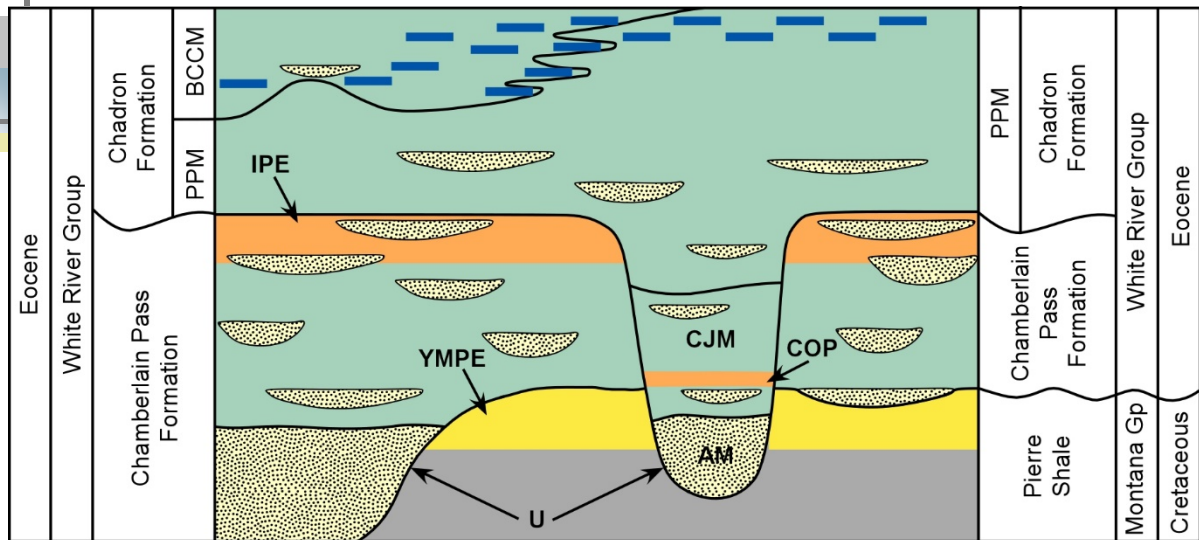


Yellow Mounds Paleosol Sioux Co. NE



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](#))



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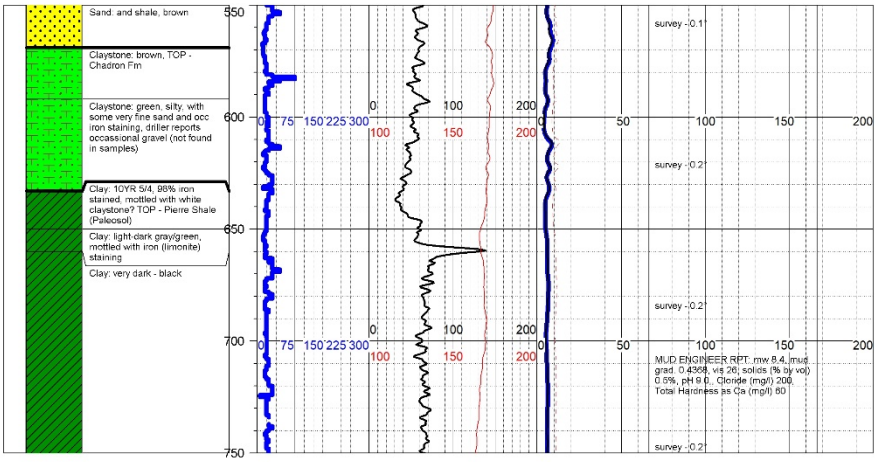
402 W State Farm Rd, North Platte, NE 69101

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:

Lithology	Depth (feet)	Penetration Rate	API Gamma	Res (Shallow)	
		(feet/hour)	0.0	200.0	0.0
	0		SP	0	200
	100			0.0	200.0





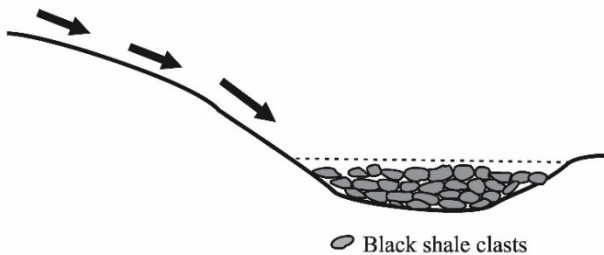


Uranium in Bauxite - Puzzling

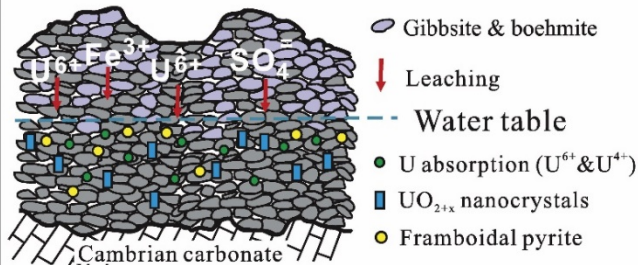
- [Yanfeng bauxite deposit](#), China
- Paleo-karstic deposit
- U average: 35 ppm, 18-62.4 ppm
- Geochemical Study – Th/U and REE
- Intense Weathering
- Parent Material – Black Shale - Lower Cambrian

Genesis of Black Shale Uranium

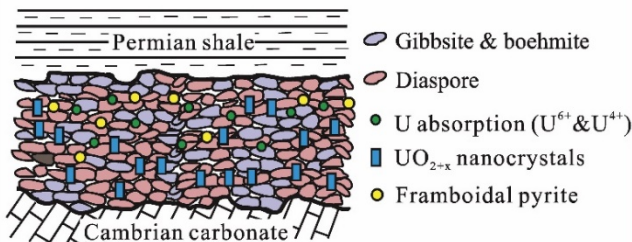
a) Transport of black shale from distant sources & deposition in karstic depressions



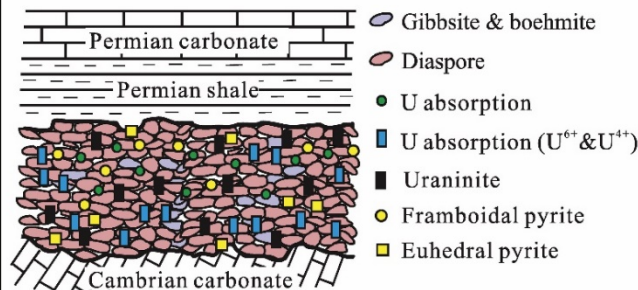
b) In-situ weathering of black shale clasts: local U mobilization and fixation (absorption & UO_{2+x} nanocrystals)



c) Early diagenesis: further fixation of U in bauxites (UO_{2+x} nanocrystals)



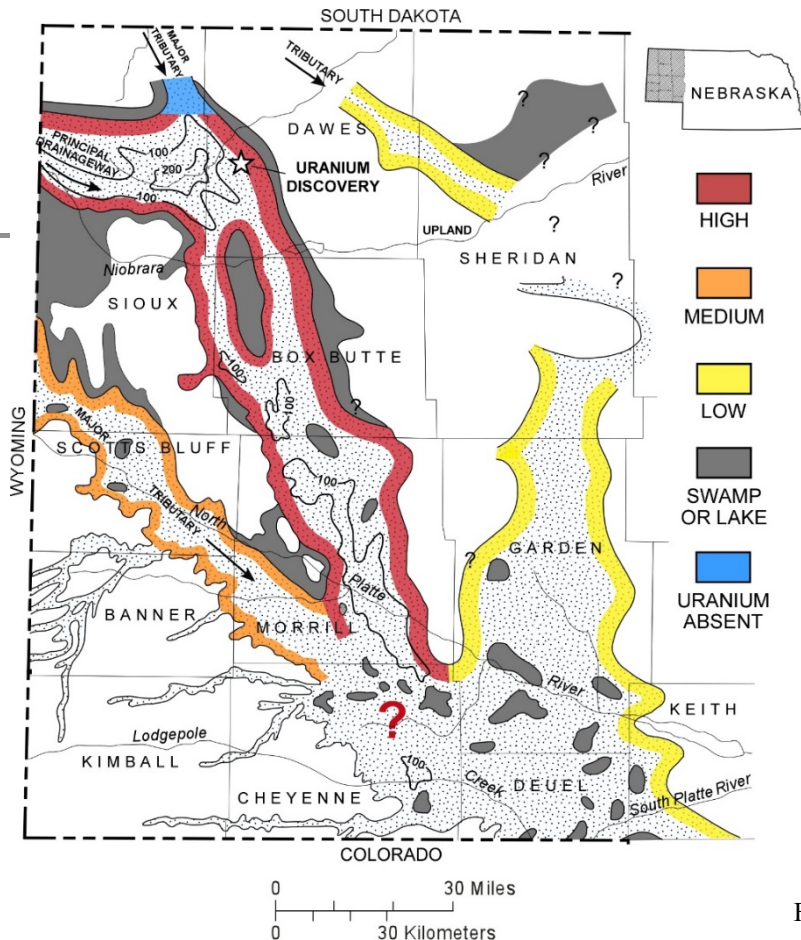
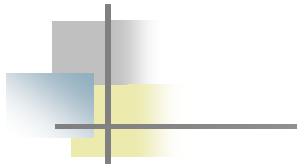
d) Burial diagenesis: formation of micro-scale uraninite





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 $\approx 800,000$ 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?

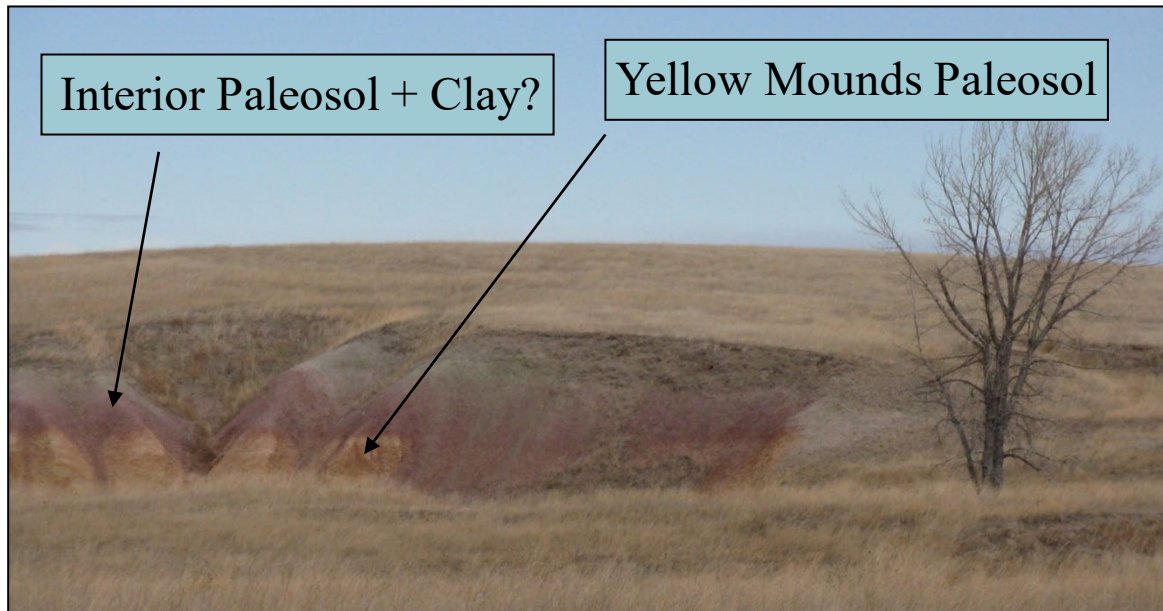


Why Uranium Absent in Other Northern Tributary (Yellow)?

- 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.



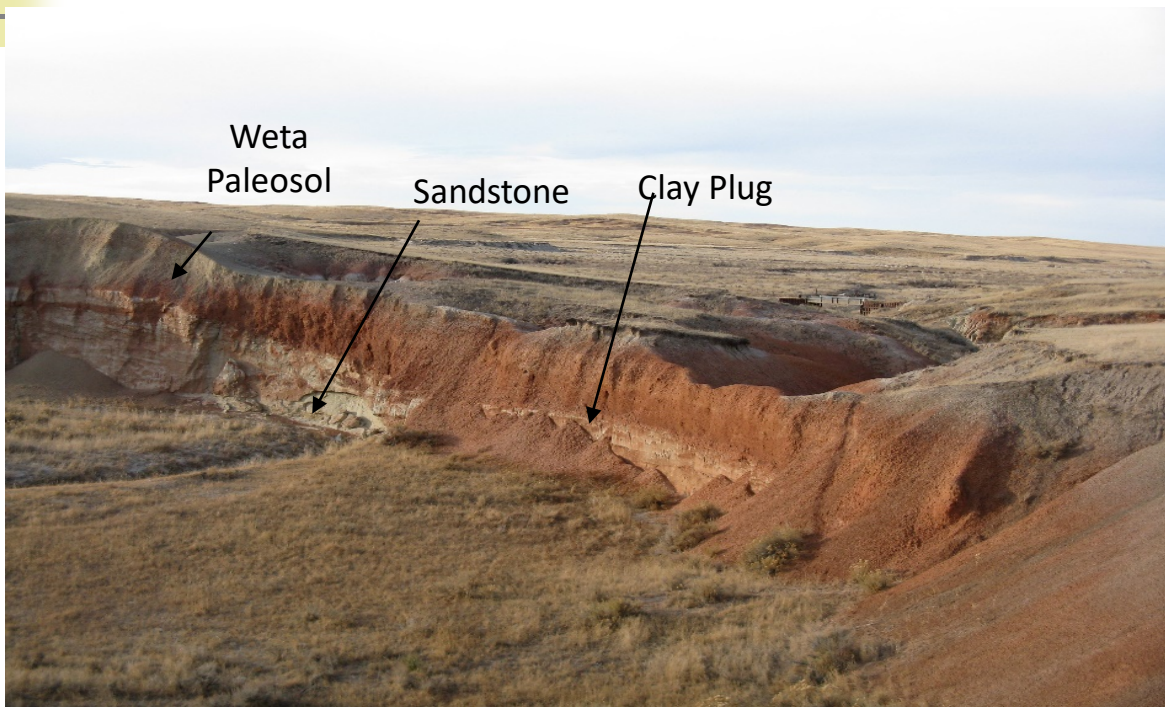
Yellow Mounds and Interior Paleosols – Sioux Co., NE



From Sibray, ([2010](#))



Chamberlain Pass Fm. Sioux C. NE





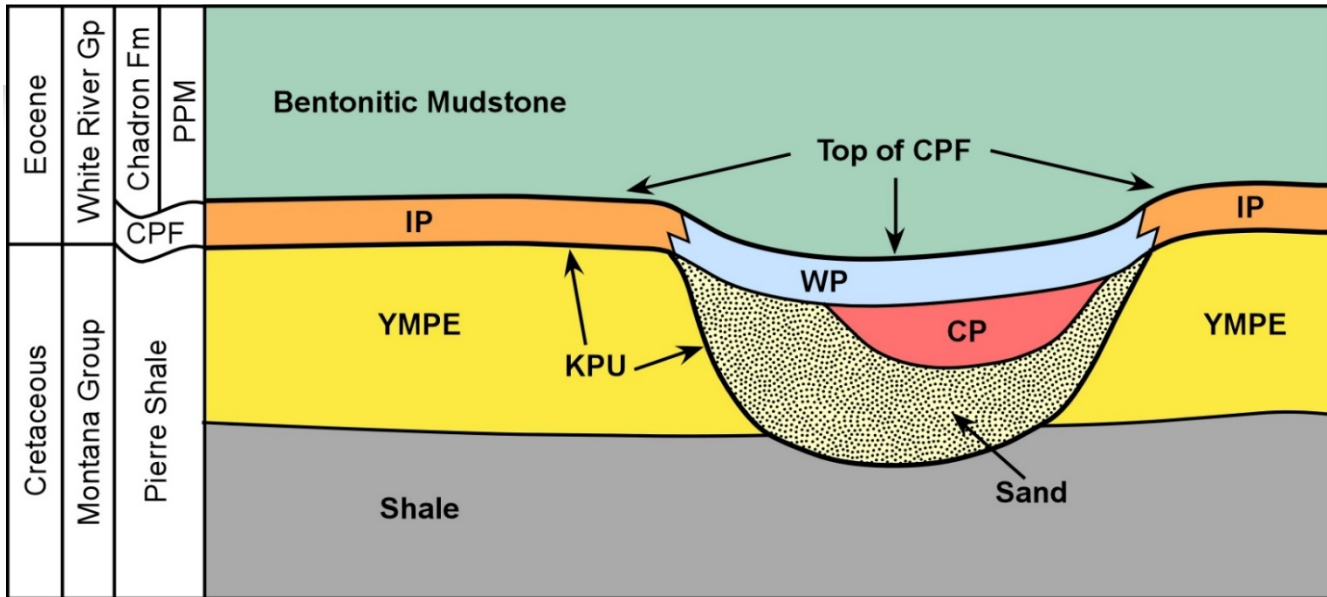
Basal Sands of Chamberlain Pass Fm. (Cemented by Mn Oxides)



From Sibray, ([2010](#))



Cretaceous / Paleogene Unconformity



CPF - Chamberlain Pass Formation

* IP - Interior Paleosol

WP - Weta Paleosol

PPM - Peanut Peak Member

YMPE - Yellow Mounds Paleosol

CP - Clay Plug

From Sibray, (2010)

KPU - Cretaceous Paleogene Unconformity

*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

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7. **“Uranium in South Texas”:**

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8. **”UCOM 2020 Annual Report”:**

<http://www.i2massociates.com/downloads/EMDUraniumNuclearMineralsandREECCommitteeAnnualReport-2020.pdf>



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- Nebraska Public Power District [NPPD]
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Questions????
