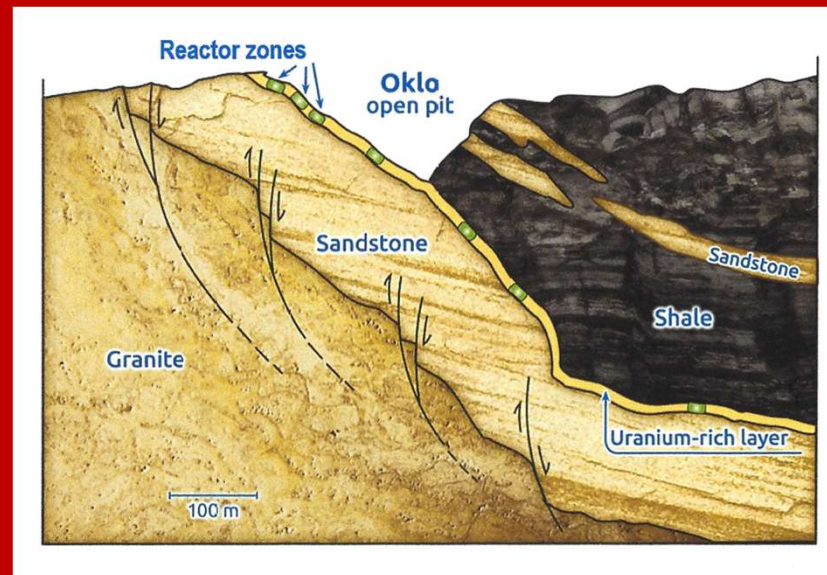


Natural Analogues of Geological Repositories, and WIPP



“At first I saw absolutely nothing. When I was able to open my eyes, I stood still, far more stupefied than astonished.”

—Henry Lawson in “Journey to the Center of the Earth” by Jules Verne.

Natural Analogues

Can natural analogues be used as examples of long-term geological storage of SNP?

The Oklo Mine:
A uranium mine in
The Gabon
Republic.

In circa 1970, U core samples were deficient wrt ^{235}U .



The Oklo Mine

^{235}U is normally 0.72%

Some cores samples contained as little as 0.44% ^{235}U . Why? Was some being stolen?

Follow-up analyses of core samples indicated the presence of more than 30 elements that usually occur as fission products.

In 1972, Francis Perrin

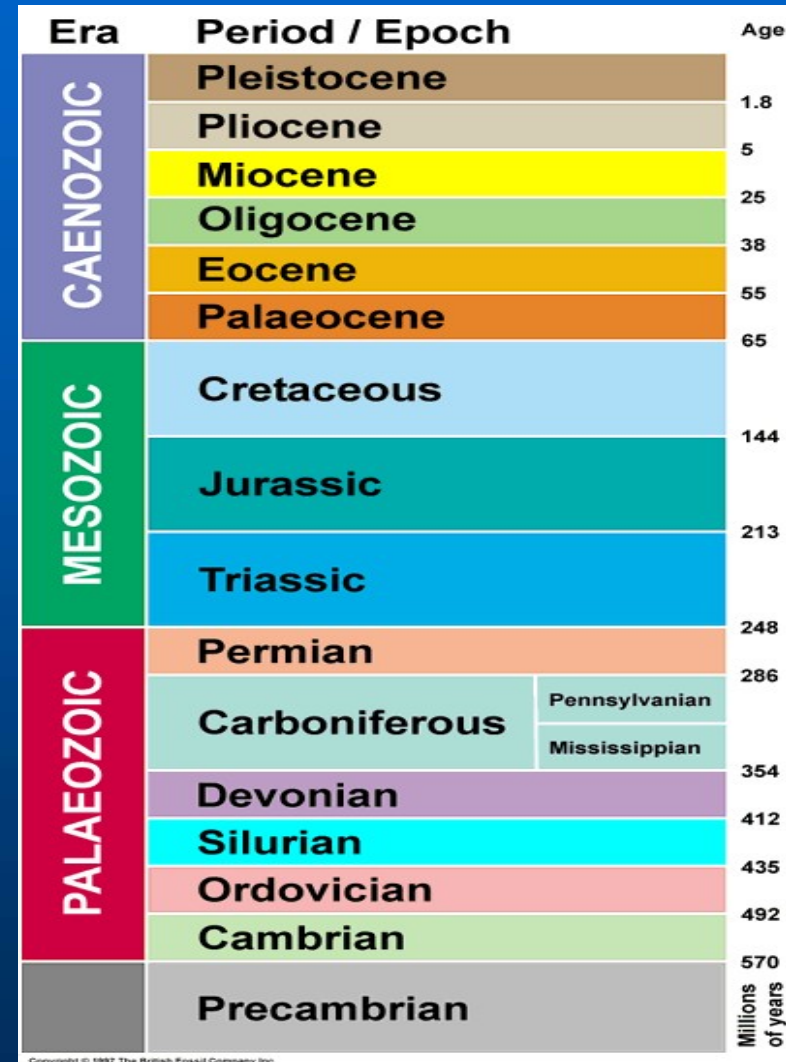
Concluded that, at one time, the Oklo site had yielded a self-sustaining nuclear chain reaction.



*French physicist (1901-1992).
Helped establish in 1939 the
possibility of nuclear energy
production of electricity.*

The Oklo Mine

Evidence that, within a U-ore body, a natural reactor became critical, consumed about six tons of fuel during a 600,000 to 5 million-year period, and then the reaction ceased—all in Pre-Cambrian times (about 2 billion years [2 Ga] ago).



The Oklo Mine

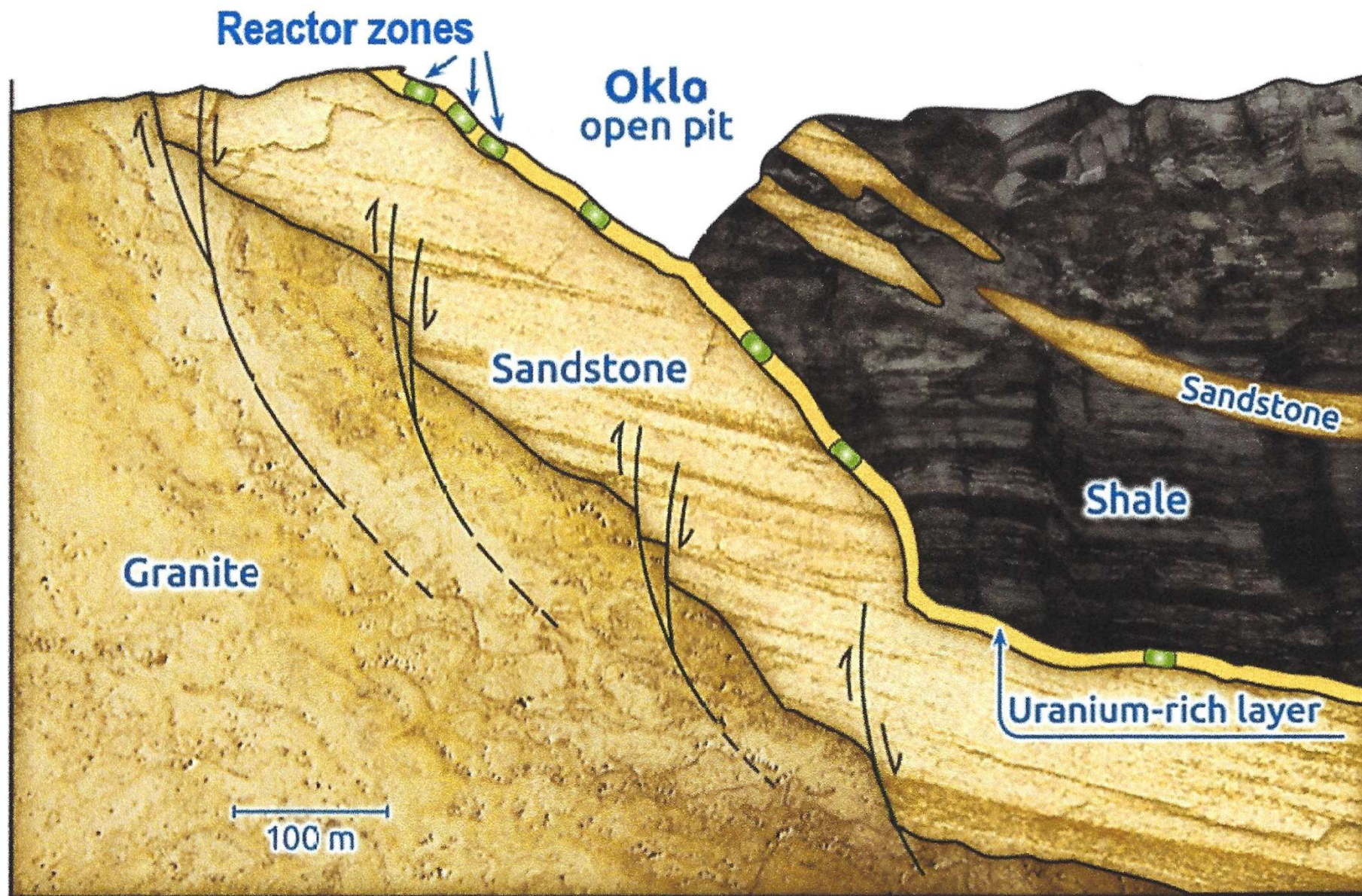
Uranium enrichment? Not needed.
About 17% ^{235}U when the Earth was
formed.

Two billion years ago (2 Ga), there
would have been 3 to 4%
 ^{235}U at Oklo.





The Oklo Mine



**Fossil Reactor 15, located in Oklo.
U oxide remains are visible as the
yellowish rock.**



Migration of fission products and actinides at the Oklo natural reactor sites. From Berzero and D'Alessandro, 1990; Brookins, 1990; Cowan, 1976, and Curtis et al., 1989).

Radionuclide	Observation
Americium	The yields from the reactions may have been limited.
Barium	Behavior of fissiogenic barite masked by naturally occurring barite.
Bismuth	^{209}Bi was derived from the decay of ^{237}Np . Remained with the host UO_2 possibly as a sorbate (half-life of ^{237}Np is 2.12×10^6 years).
Bromide	Assumed to have migrated from the host UO_2
Cadmium	Migrated from the host UO_2 possibly by volatilization.
Indium	^{115}In was likely retained (half-life of 4.4×10^{14} years).
Iodine	Fissiogenic iodine was not retained.
Molybdenum	About 80% of the fissiogenic Mo isotopes had migrated from the host UO_2 but were retained as a sulfide mineral within 1.5 m of the reactor zone in the sandstone gangue (the half-life of ^{100}Mo is 8.5×10^{18} years)
Neodymium	Retained in the host UO_2 . Stable, fissiogenic ^{143}Nd present in greater amounts than background levels.
Neptunium	Assumed to have been retained by sorption and solid solution with UO_2 as inferred by the presence of ^{209}Bi .

Implications about storage

It appeared that many fission products remained in the ore body despite the movement of groundwater through the sandstone.

The presence of ^{99}Ru suggested that ^{99}Tc was once present (half-life of 2.12×10^5 years [212 Ka]).

Stable, deep storage for billions of years.

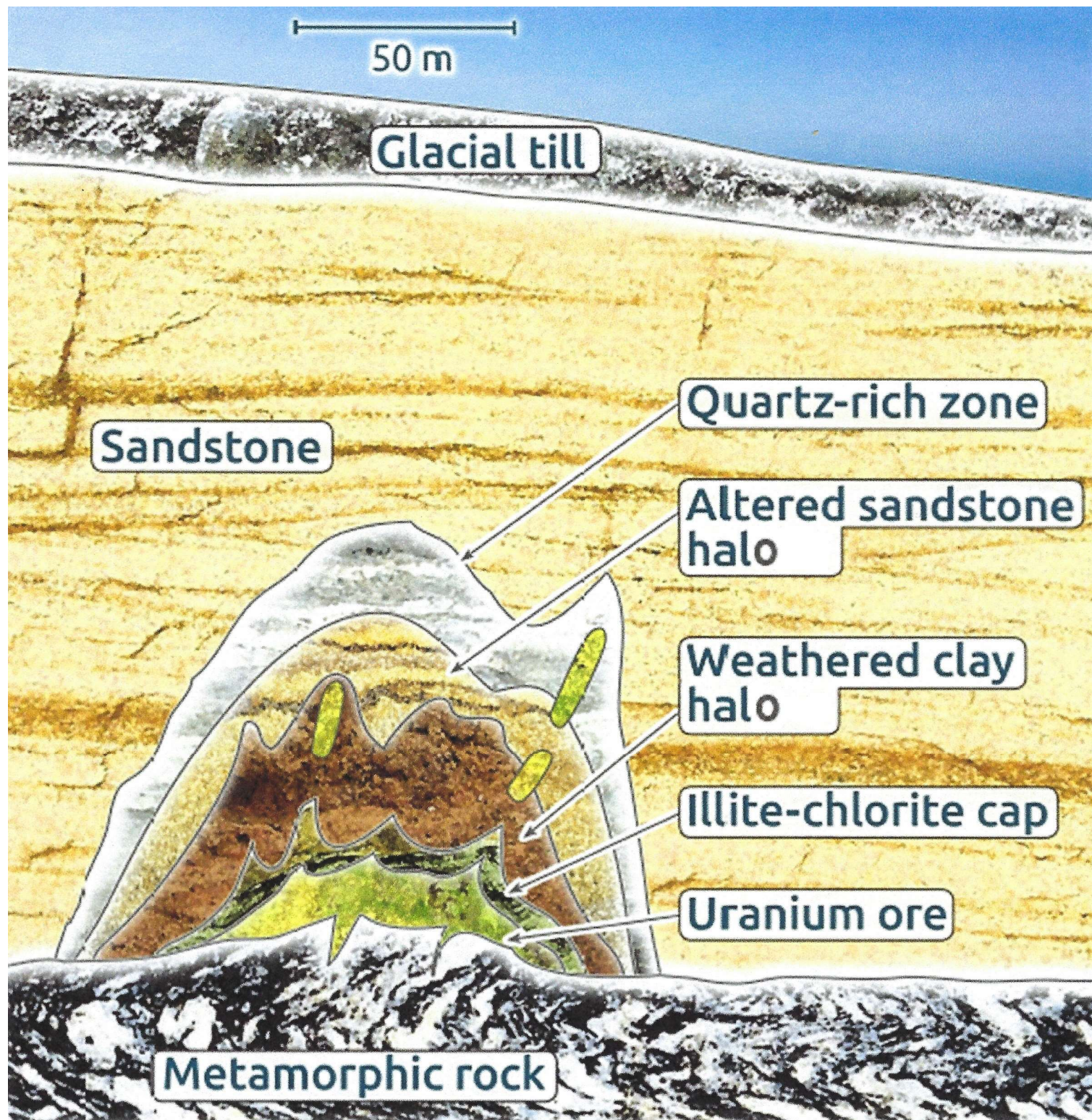
Cigar Lake, Saskatchewan

1.3 billion-year-old (1.3 Ga) U
deposit

About 430 m below land surface.

Contains about 8% U.

Groundwater saturated since
hydrothermal formation.



Cigar Lake Deposit

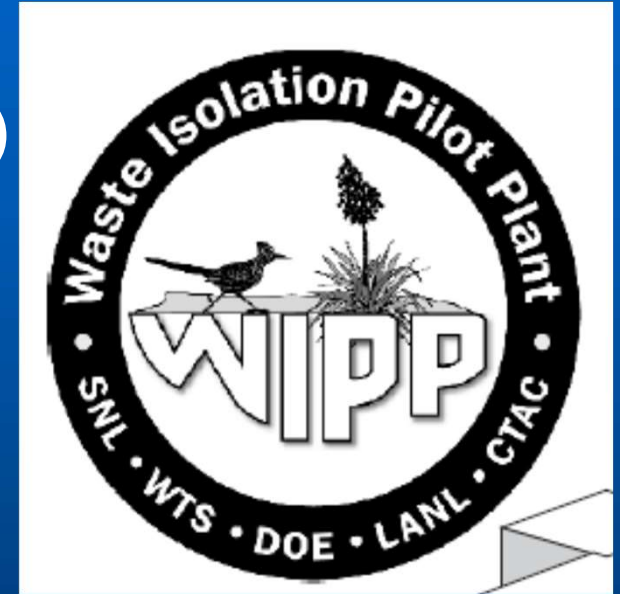
Clay (illite) above the ore.

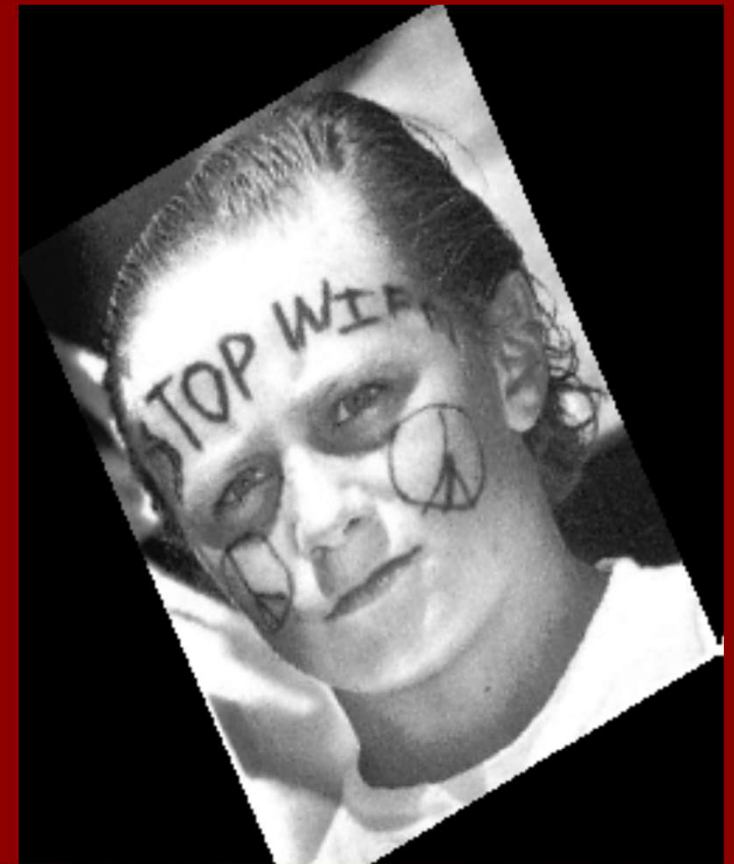
The clay layer provided long-term protection of UO_2 . Groundwater flowed over the deposit and not through it. The clay is a natural barrier.

Only chemical diffusion through the clay. Dissolution of UO_2 limited by its solubility.

Waste Isolation Pilot Plant (WIPP)

Geological repository for
DOE transuranic wastes (TRU)
such as Np, Pu, Am, and Cm.





WIPP

10,240-acre (4,144 ha-) site
near Carlsbad, New Mexico.

Disposal area 2,150 feet deep (655 m).

Waste disposal since 1999.

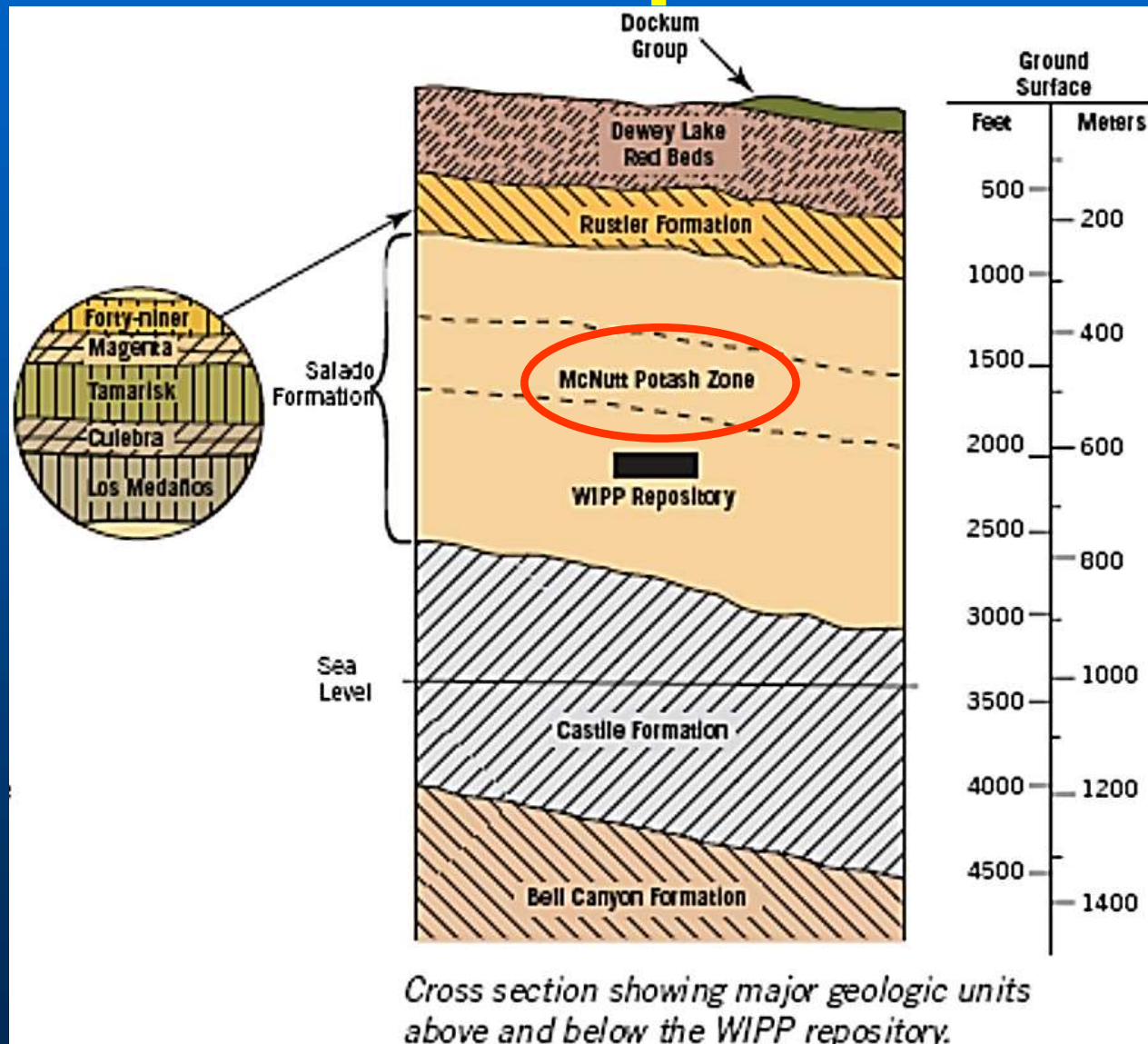
DOE/defense/legacy-related wastes only.

High-level waste and spent nuclear fuel are
not allowed.

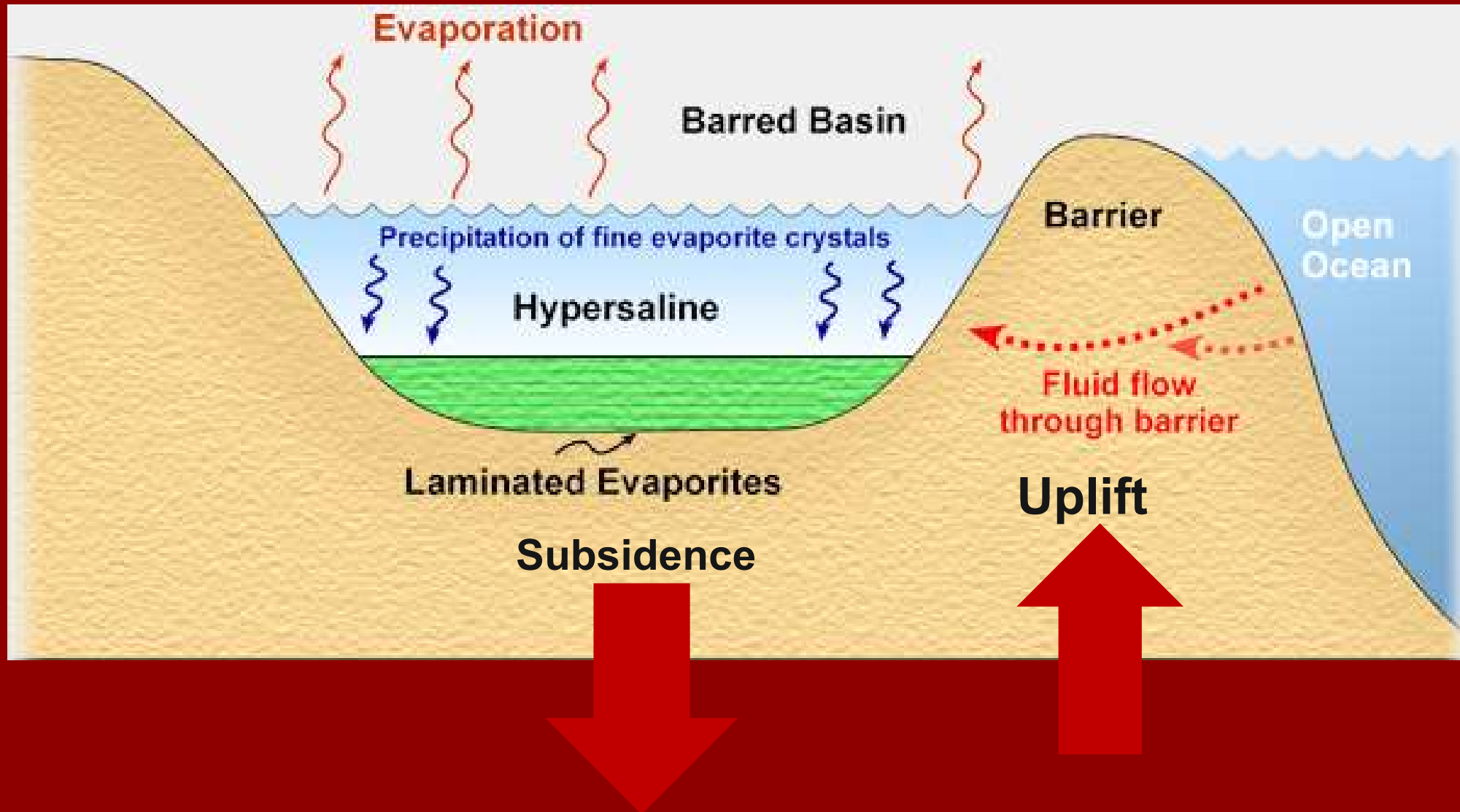
<http://www.wipp.energy.gov/> (2:34)



Burial in Permian-Age Salt Deposits

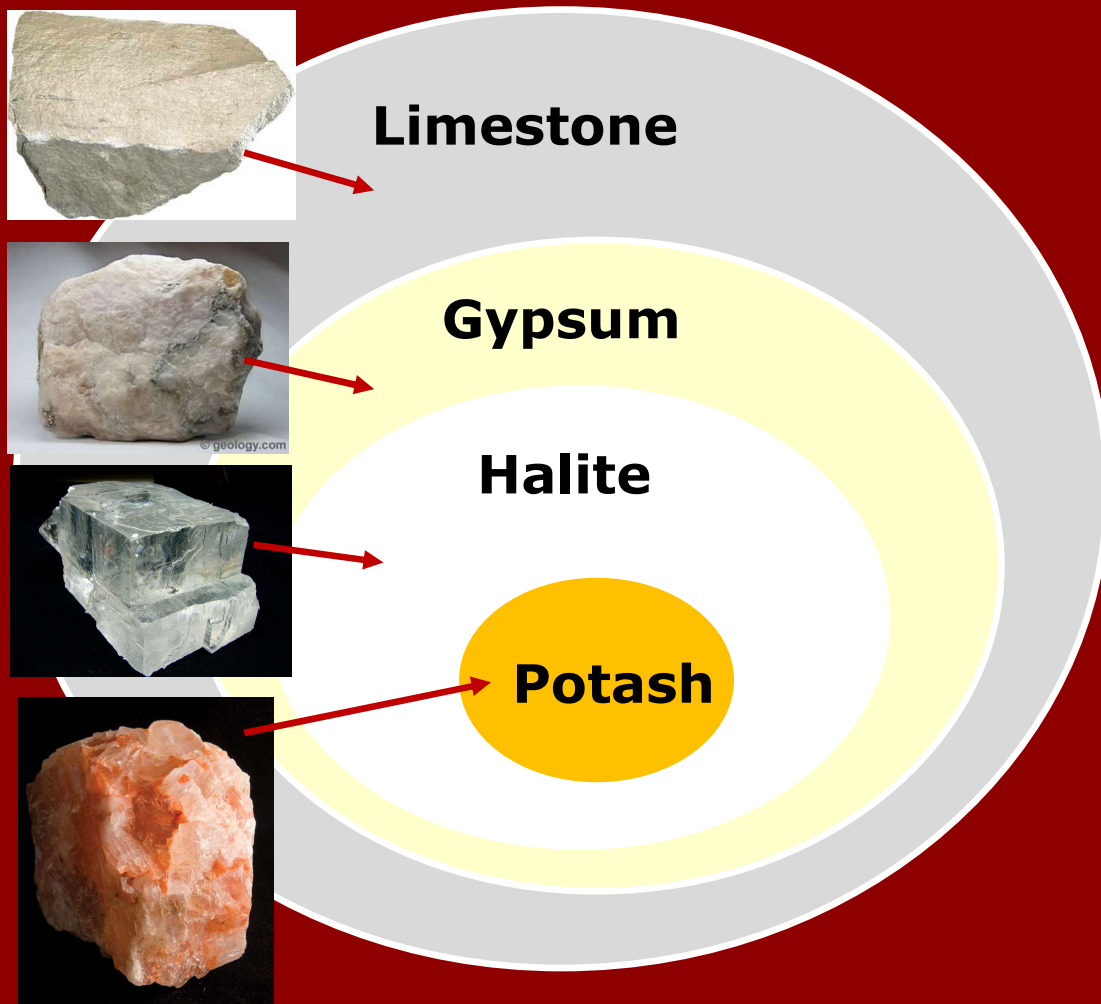


Origin of Halite (Salt)

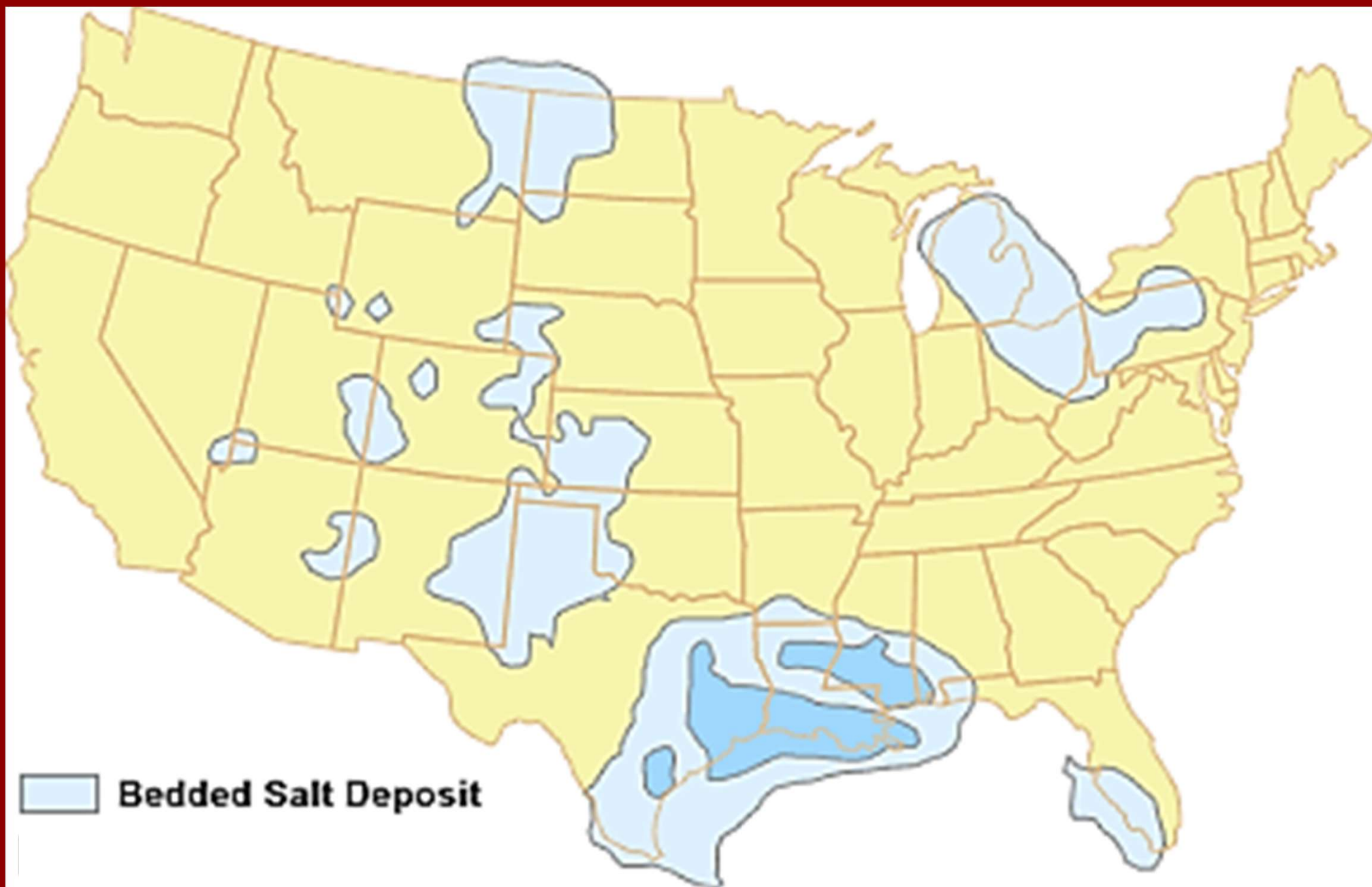


Origin of Halite (Salt)

Evaporites: Minerals that precipitate from sea water as the water evaporates.



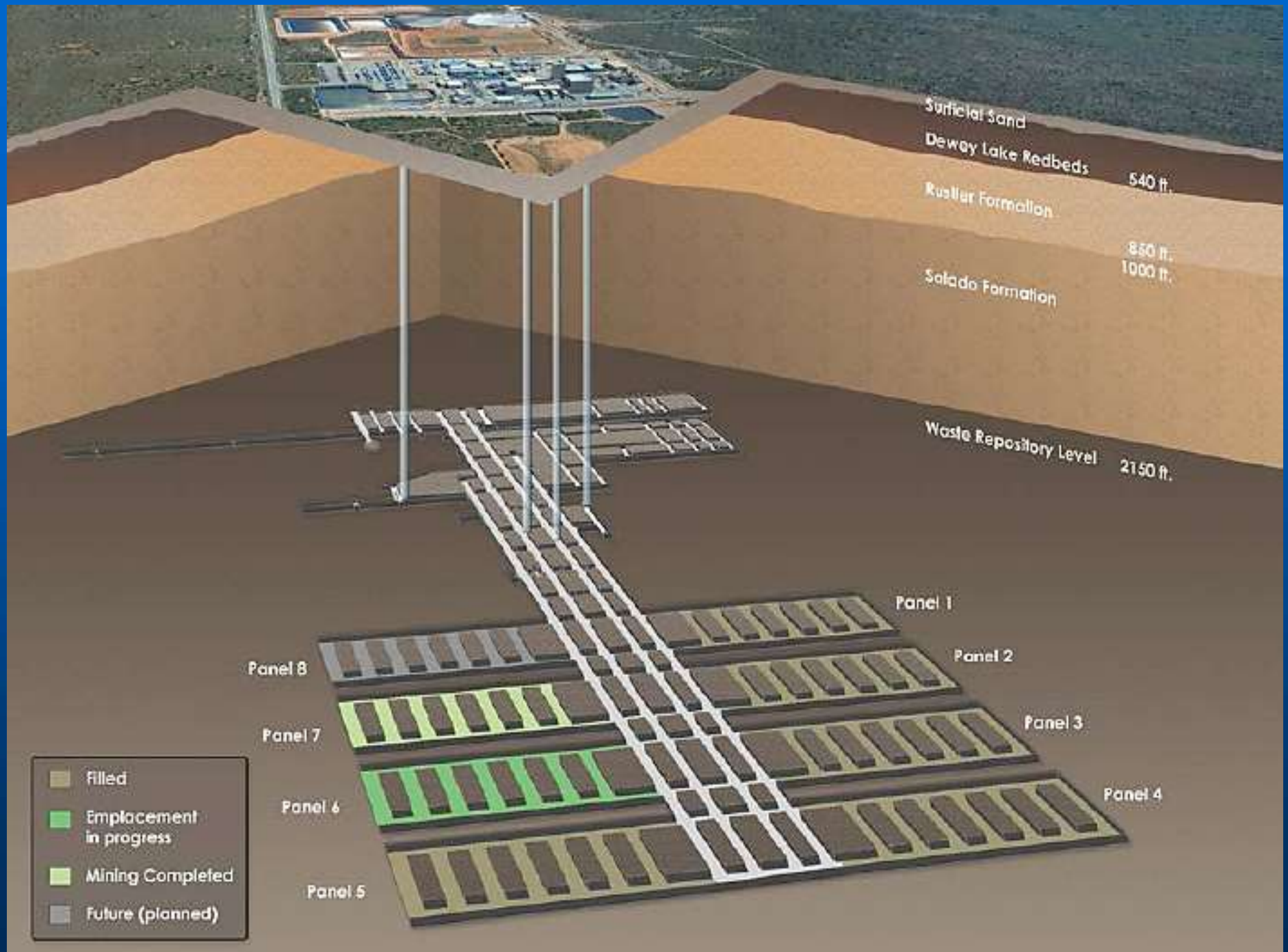
By geological processes, a structural basin holding sea water can be isolated from the sea. As the water evaporates, minerals form. Carbonates then gypsum because they are less soluble than halite or potash (potassium carbonate or hydroxide)













<http://www.youtube.com/watch?v=3bo36aKc8EY> (6:52)

Good Public Relations

“Visitors to Carlsbad, New Mexico are encouraged to visit the WIPP Experience Exhibit. Friendly staff are available to answer questions about this one-of-a-kind facility. Free 250-million-year-old (250 Ma) rock salt samples are available for all visitors.”

Class Assignment 7

**Speciation and Solubility of Uranium,
Cesium, and Strontium.**

Not in the textbook.

Rubric:

The assignment is worth 20 points.

**There are 10 questions. Each is worth 2
points.**

Questions?

