Uranium in the Grants Mineral Belt – Ore Formation, Mining Techniques, Processing, Economics

Virginia T. McLemore

New Mexico Bureau of Geology and Mineral Resources

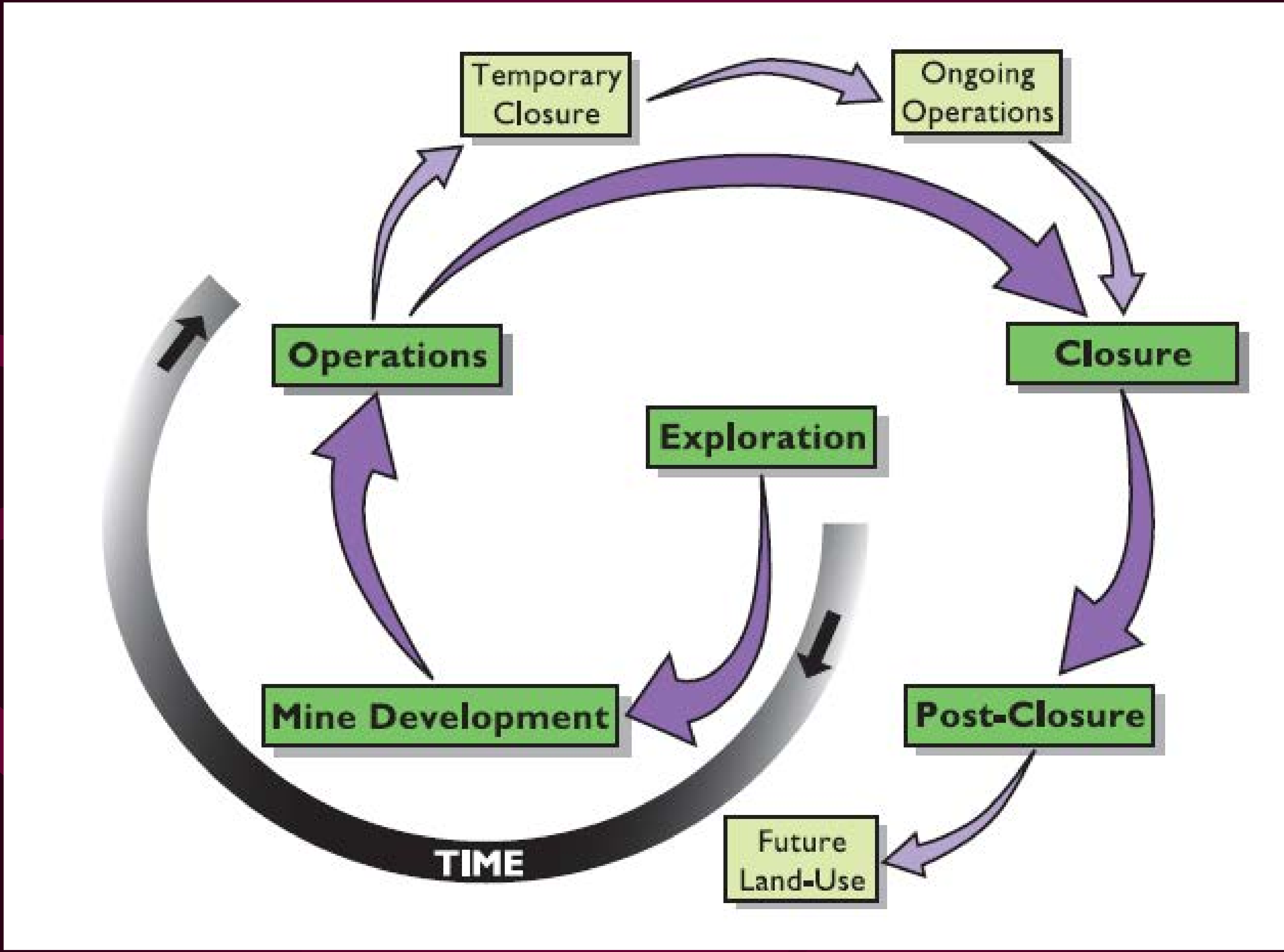
New Mexico Institute of Mining and Technology, Socorro, NM

Outline

- Introduction
- Geologic setting of the Grants district
- Mining and processing
- Reasonable economic potential for development

Introduction

Mine-life cycle



What are the important parameters that characterize uranium deposits?

- Location
- Shape
- Size and grade
- Depth
- Orientation
- Geotectonics
- Mineralogy
- Hydrology
- Boundary conditions

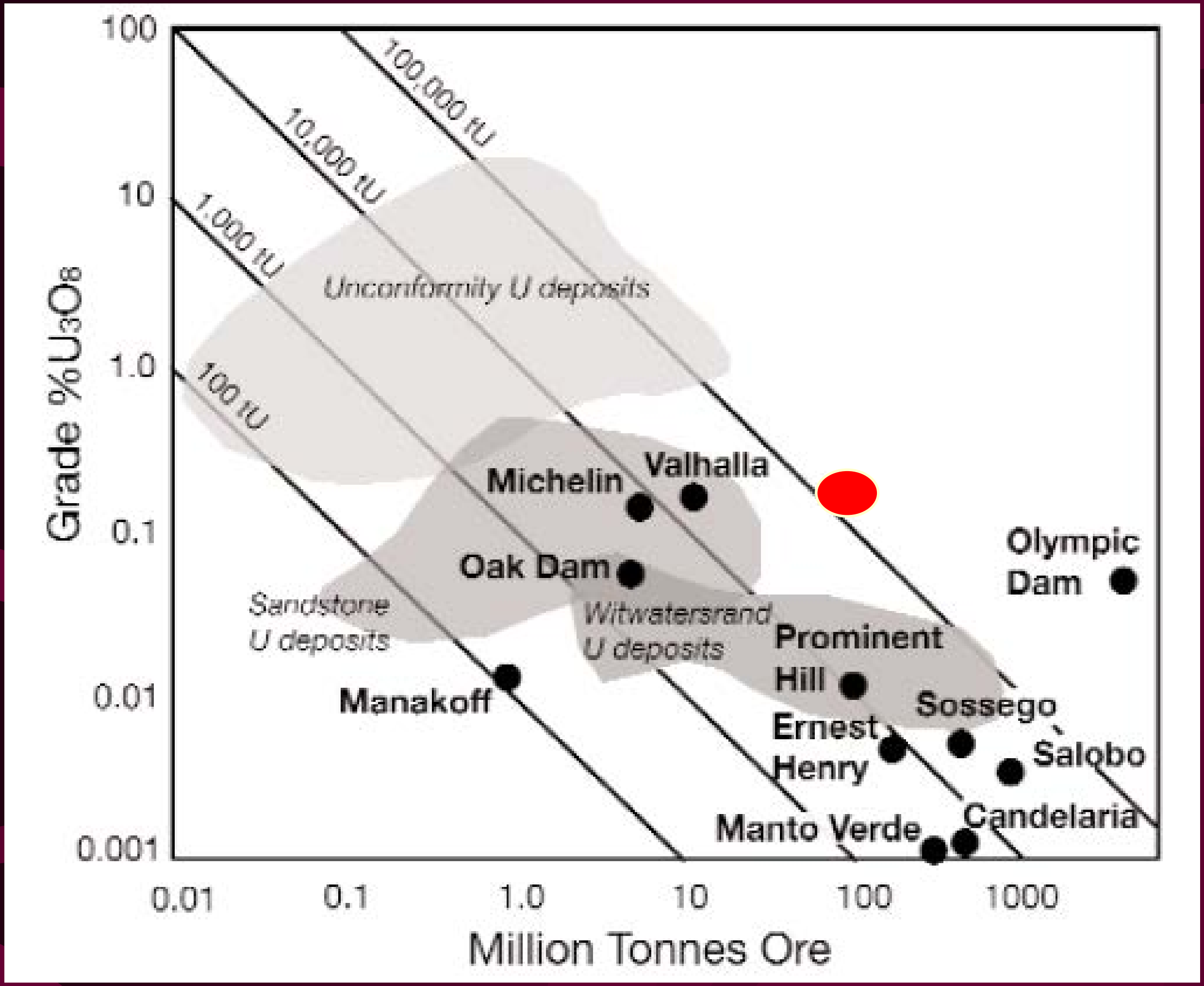
Uranium deposits, like all mineral deposits, are found in specific locations in the world dictated by geologic conditions

Major Uranium Minerals

- Autunite—$Ca(UO_2)(PO_4)_2$ 10-12(H_2O)
- Carnotite—$K_2(UO_2)_2(VO)_4$ 3(H_2O)
- Tyuyamunite—$Ca(UO_2)_2(VO_4)_2$ 5-8H_2O
- Uraninite—UO_2
- Uranophane—$Ca(UO_2)_2SiO_3(OH)_2$ 5(H_2O)

Types of uranium deposits

- Unconformity-related deposits
- **Sandstone deposits**
- Quartz-pebble conglomerate deposits
- Vein deposits
- Hematite breccia complex deposits (IOCG deposits)
- Intrusive deposits
- Phosphorite deposits
- **Collapse breccia pipe deposits**
- Volcanic deposits
- Surficial deposits
- Metasomatite deposits
- Metamorphic deposits
- Lignite
- Black shale deposits
- Other types of deposits
  - **Todilto limestone deposits**



- Iron oxide-Cu-Au (+/- U, REE) deposits (Hematite breccia complex deposits)
- Grants district (V.T. McLemore estimate)

Grade verses tonnage for major types of uranium deposits

Hitzman and Valenta, 2005, *Economic Geology*, v. 100, pp. 1657–1661

Potential critical minerals in Grants district uranium deposits

- Vanadium (produced in past from most deposits)
- Selenium
- Rare earth elements (REE)

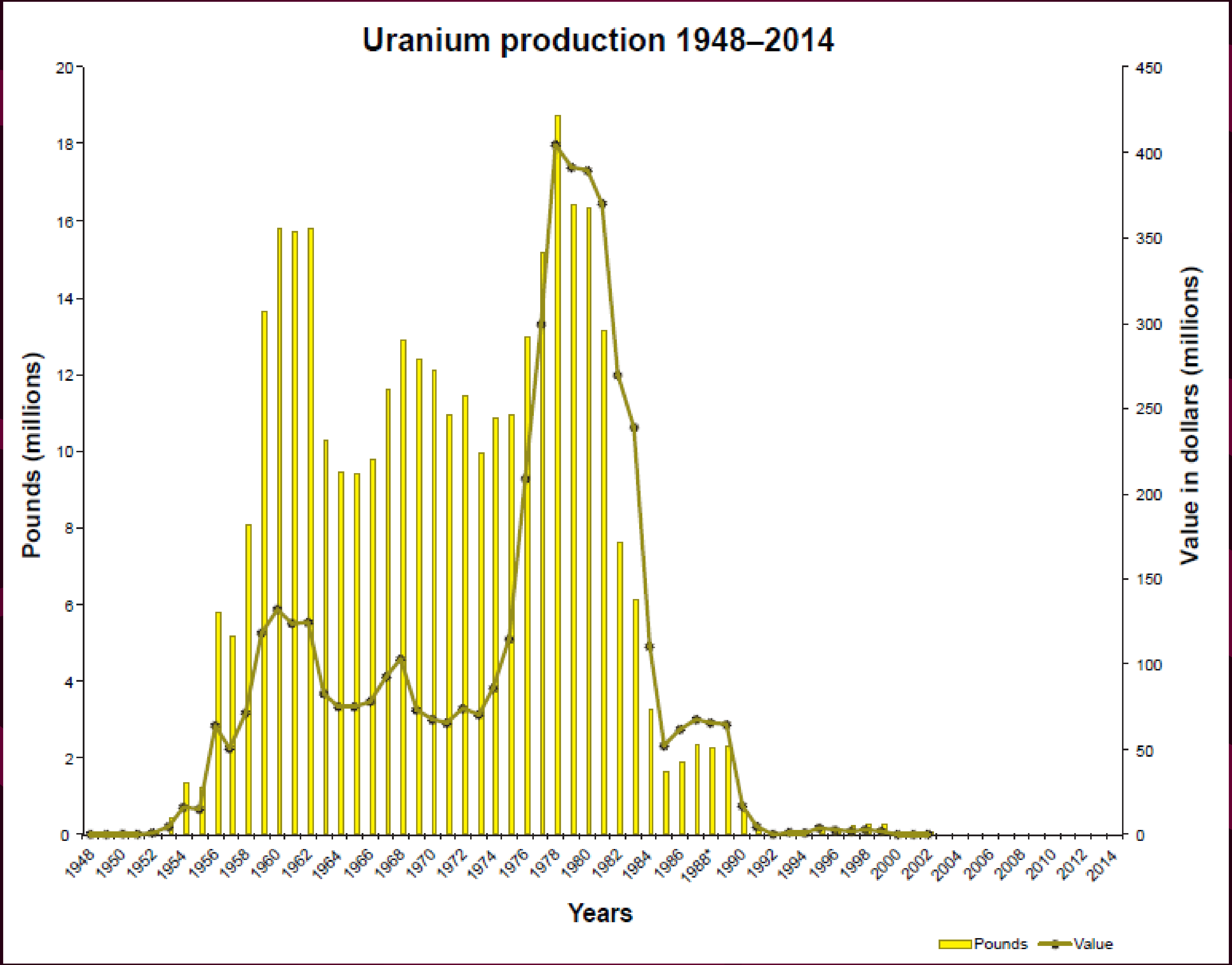

Uranium production 1948–2014
Pounds (millions)
Value in dollars (millions)
Years
Pounds
Value

Table 1. Estimated total production of major commodities in New Mexico, in order of estimated cumulative value (data from USGS, 1902-1927; USBM, 1927-1990; Kelley, 1949; Northrop, 1996; Harrer, 1965; USGS, 1965; Howard, 1967; Harben et al., 2008; Energy Information Administration, 2015; New Mexico Energy, Minerals and Natural Resources Department, 1986-2015). Figures are subject to change as more data are obtained.

Commodity	Years of production	Estimated quantity of production	Estimated cumulative value
Natural Gas	1921-2014	>73 trillion cubic feet	$160 billion
Oil	1922-2014	>6.1 billion barrels	$115 billion
Coal	1882-2013	>1.27 billion short tons	>$21 billion
Copper	1804-2013	>11.5 million tons	>$20.6 billion
Potash	1951-2013	112,054,218 short tons	>$15 billion
Uranium	1948-2002	>347 million pounds	>$4.7 billion
Industrial minerals**	1959-2013	40,276,083 short tons	>$2.6 billion
Aggregates***	1997-2013	>666 short tons	>$2.5 billion
Molybdenum	1951-2013	>176 million pounds	>$852 million
Gold	1931-2013	>3.2 million troy ounces	>$463 million
Zinc	1848-2013	>1.51 million tons	>$337 million
Silver	1903-1991	>118.7 million troy ounces	>$279 million
Lead	1848-2013	>367,000 tons	>$56.7 million
Iron	1883-1992	>6.7 million long tons	>$23 million
Fluorspar	1883-1962	>721,000 tons	$12 million
Manganese	1909-1978	>1.9 million tons	$5 million
Barite	1883-1963	>37,500 tons	>$400,000
Tungsten	1918-1965	113.8 tons (>60% WO_3)	na
Niobium-tantalum	1940-1958	34,000 pounds of concentrates	na

McLemore et al. (2017)

Table 1. Uranium production from 1947–2002 by type of deposit from New Mexico (McLemore and Chenoweth, 1989, 2003; production from 1988–2002 estimated by the authors). Type of deposits refers to Table 2. Total U.S. production from McLemore and Chenoweth (1989) and Energy Information Administration (2010).

Type of deposit	**Production** (lbs U_3O_8)	**Period of production** (Years)	**Production total in NM** (%)
Primary, redistributed, remnant sandstone uranium deposits (Morrison Formation, Grants district)	330,453,000[1]	1951–1988	95.4
Mine water recovery (Morrison Formation, Grants district)	9,635,869	1963–2002	2.4
Tabular sandstone uranium deposits (Morrison Formation, Shiprock district)	493,510	1948–1982	0.1
Other Morrison Formation Sandstone uranium deposits (San Juan Basin)	991	1955–1959	—
Other sandstone uranium deposits (San Juan Basin)	503,279	1952–1970	0.1
Limestone uranium deposits (Todilto Formation[2], redominantly Grants district)	6,671,798	1950–1985	1.9
Other sedimentary rocks with uranium deposits (total NM)	34,889	1952–1970	—
Vein-type uranium deposits (total NM)	226,162	1953–1966	—
Igneous and metamorphic rocks with uranium deposits (total NM)	69	1954–1956	—
Total in New Mexico	348,019,000[1]	1948–2002	100
Total in United States	**927,917,000[1]**	**1947–2002**	**NM is 37.5 of total U.S.**

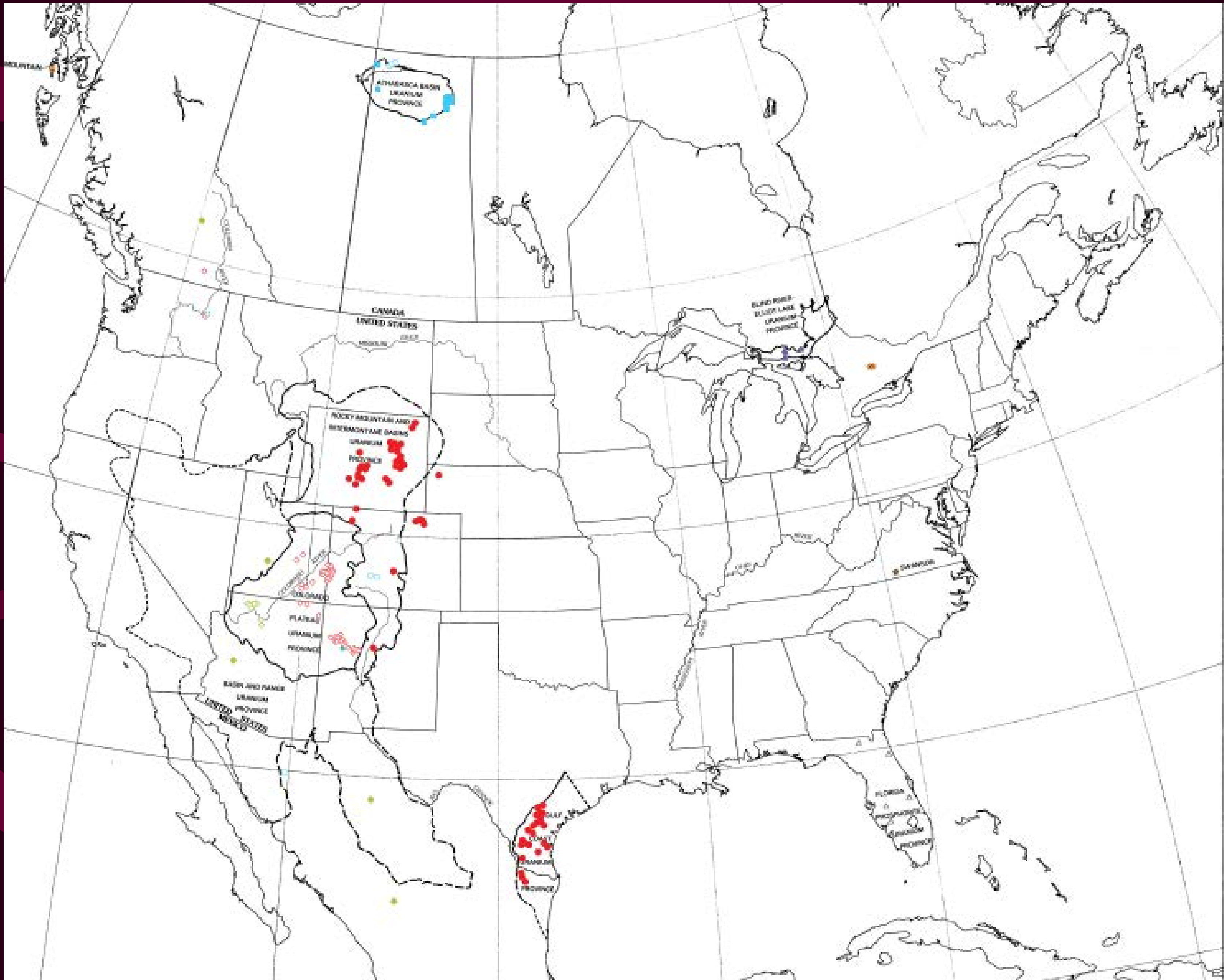
[1]Production rounded to the nearest 1,000 pounds. There has been no uranium production in New Mexico since 2002. [2]Todilto Formation (Cather et al., 2013).

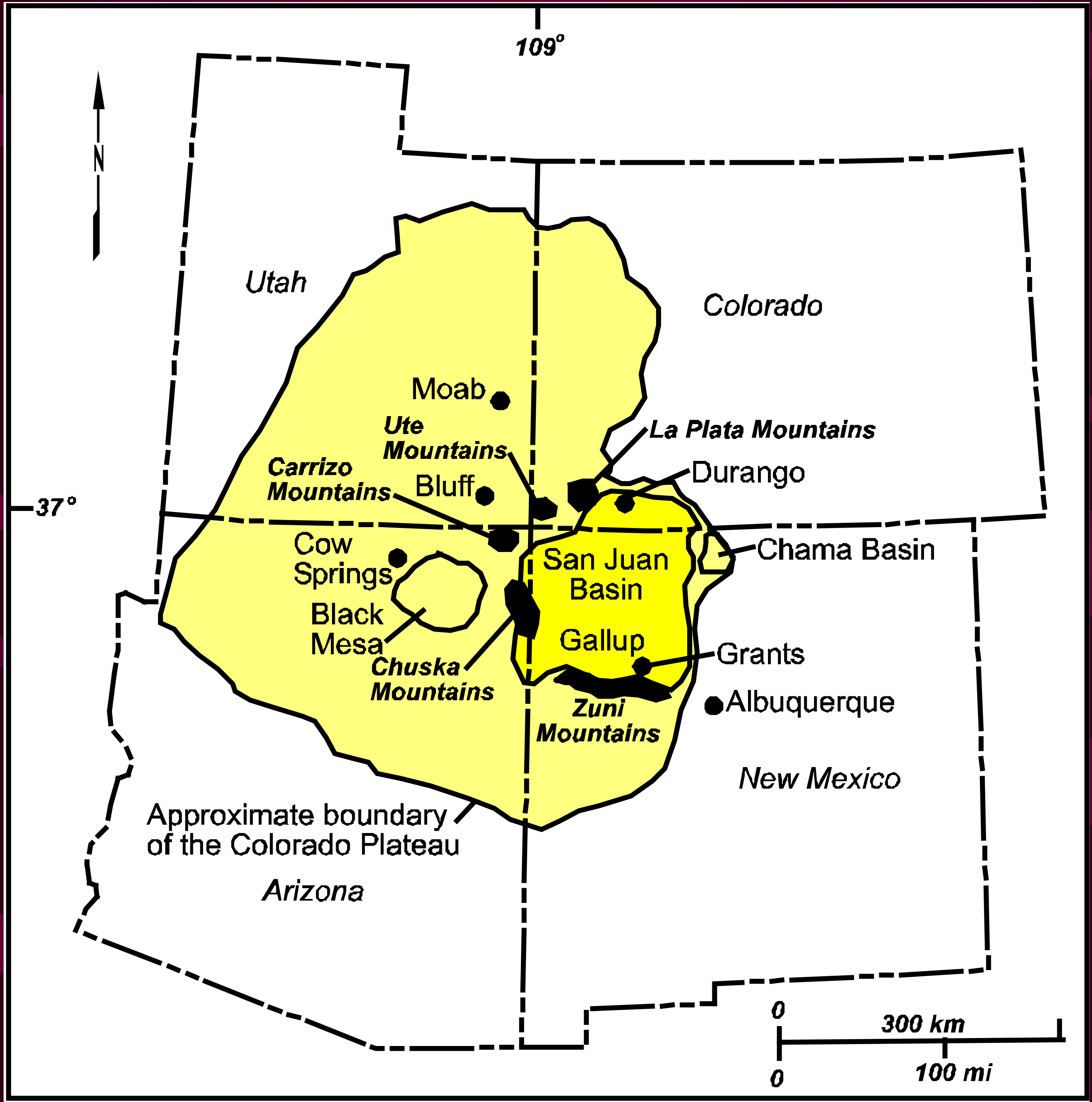
McLemore and Chenoweth (2017)

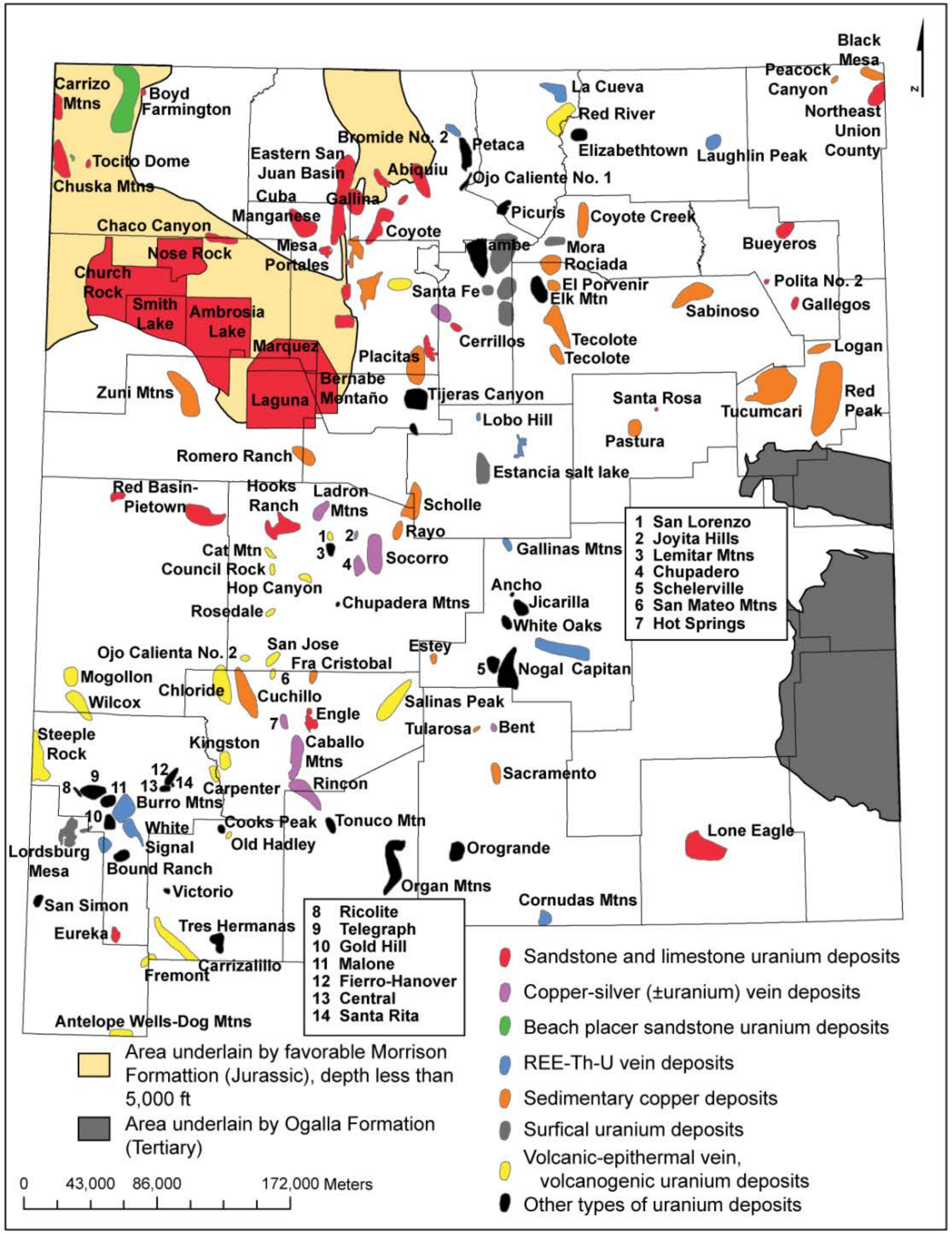
Grants district

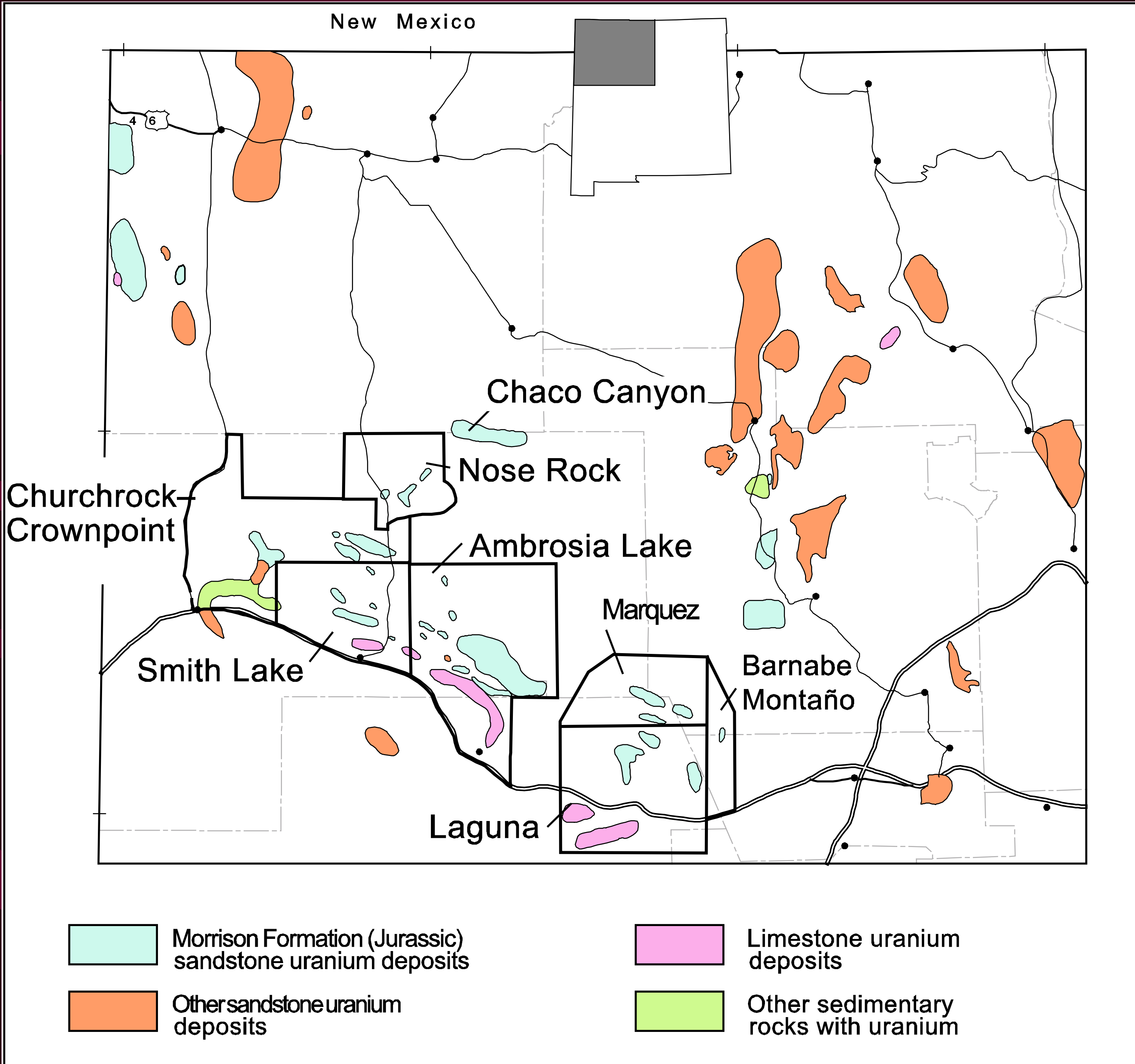
- ~340 million lbs of U_3O_8 have been produced 1948-2002
- ~409 million lbs of U_3O_8 historic resources have been reported by various companies
- Probably another ~200 million lbs of U_3O_8 remain to be discovered
- The district contained more than 900 million lbs U_3O_8

GEOLOGIC SETTING OF THE GRANTS DISTRICT

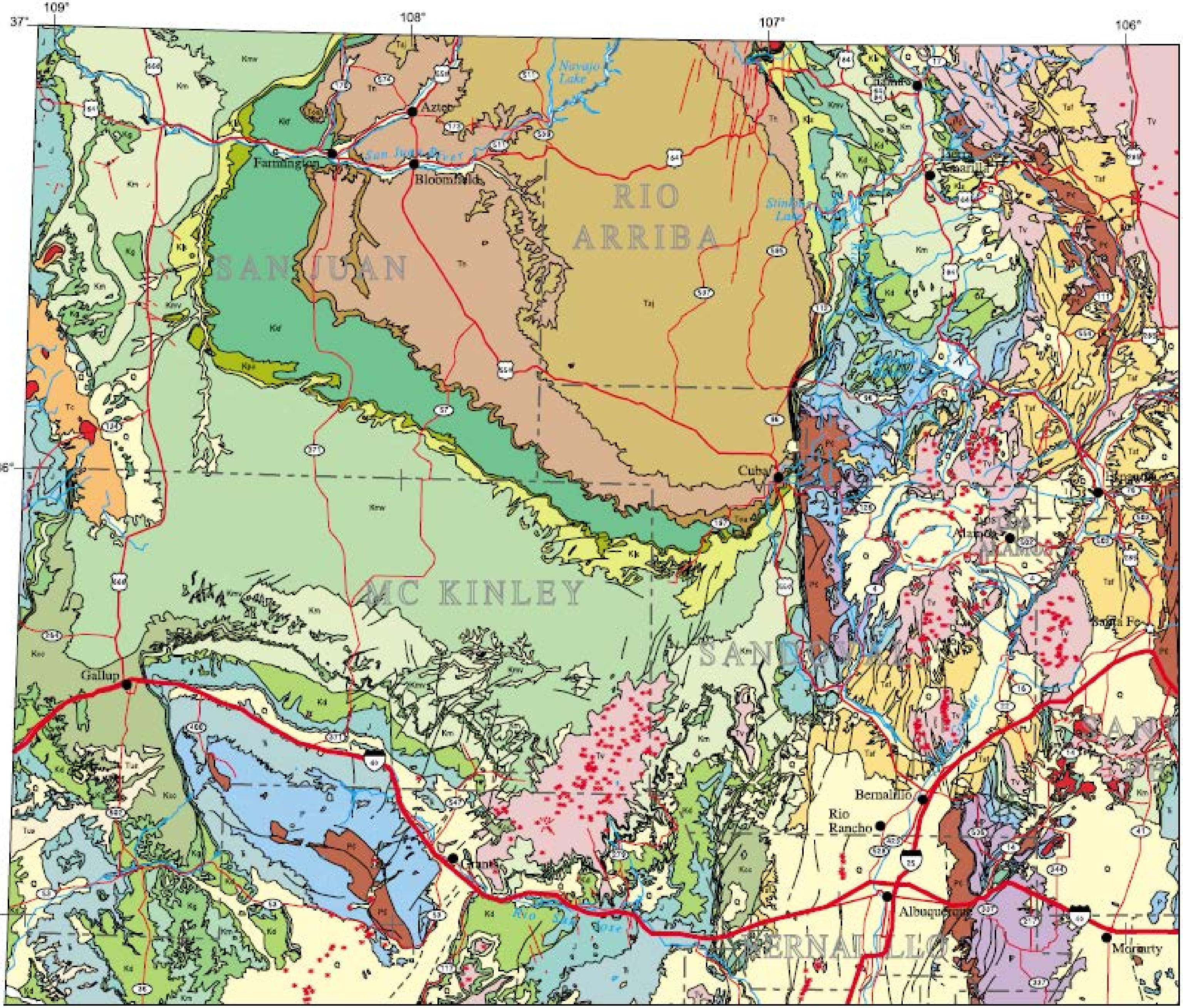

ATHABASCA BASIN URANIUM PROVINCE
CANADA
UNITED STATES
BLIND RIVER-ELLIOT LAKE URANIUM PROVINCE
ROCKY MOUNTAIN AND INTERMONTANE BASINS URANIUM PROVINCE
COLORADO PLATEAU URANIUM PROVINCE
BASIN AND RANGE URANIUM PROVINCE
UNITED STATES
MEXICO
GULF COAST URANIUM PROVINCE
FLORIDA PHOSPHORITE URANIUM PROVINCE


109°
37°
N
Utah
Colorado
Moab
Ute Mountains
La Plata Mountains
Carrizo Mountains
Bluff
Durango
Cow Springs
San Juan Basin
Chama Basin
Black Mesa
Gallup
Grants
Chuska Mountains
Albuquerque
Zuni Mountains
New Mexico
Approximate boundary of the Colorado Plateau
Arizona
0
300 km
0
100 mi


Black Mesa
Peacock Canyon
Northeast Union County
Carrizo Mtns
Boyd Farmington
La Cueva
Red River
Elizabethtown
Laughlin Peak
Bromide No. 2
Petaca
Eastern San Juan Basin
Abiquiu
Ojo Caliente No. 1
Tocito Dome
Chuska Mtns
Cuba
Gallina
Manganese
Picuris
Coyote Creek
Coyote
Chaco Canyon
Mesa Portales
Nose Rock
Nambe
Mora
Rociada
Bueyeros
Church Rock
Santa Fe
El Porvenir
Elk Mtn
Polita No. 2
Gallegos
Smith Lake
Ambrosia Lake
Sabinoso
Cerrillos
Tecolote
Tecolote
Logan
Marquez
Placitas
Bernabe
Montaño
Laguna
Zuni Mtns
Tijeras Canyon
Santa Rosa
Tucumcari
Red Peak
Lobo Hill
Pastura
Romero Ranch
Estancia salt lake
Red Basin-Pietown
Hooks Ranch
Ladron Mtns
Scholle
Rayo
Socorro
Cat Mtn
Council Rock
Hop Canyon
Rosedale
Chupadera Mtns
Gallinas Mtns
Ancho
Jicarilla
White Oaks
1 San Lorenzo
2 Joyita Hills
3 Lemitar Mtns
4 Chupadero
5 Schelerville
6 San Mateo Mtns
7 Hot Springs
Ojo Calienta No. 2
San Jose
Fra Cristobal
Estey
Nogal
Capitan
Mogollon
Wilcox
Chloride
Cuchillo
Salinas Peak
Engle
Tularosa
Bent
Steeple Rock
Kingston
Caballo Mtns
Sacramento
Burro Mtns
Carpenter
Rincon
White Signal
Cooks Peak
Tonuco Mtn
Lordsburg Mesa
Old Hadley
Orogrande
Lone Eagle
Bound Ranch
Victorio
Organ Mtns
Cornudas Mtns
San Simon
Tres Hermanas
Eureka
Carrizalillo
Fremont
Antelope Wells-Dog Mtns
8 Ricolite
9 Telegraph
10 Gold Hill
11 Malone
12 Fierro-Hanover
13 Central
14 Santa Rita
Sandstone and limestone uranium deposits
Copper-silver (±uranium) vein deposits
Beach placer sandstone uranium deposits
REE-Th-U vein deposits
Sedimentary copper deposits
Surfical uranium deposits
Volcanic-epithermal vein, volcanogenic uranium deposits
Other types of uranium deposits
Area underlain by favorable Morrison Formattion (Jurassic), depth less than 5,000 ft
Area underlain by Ogalla Formation (Tertiary)
0 43,000 86,000 172,000 Meters
N



New Mexico
4
6
Chaco Canyon
Nose Rock
Churchrock-Crownpoint
Ambrosia Lake
Marquez
Barnabe Montaño
Smith Lake
Laguna
Morrison Formation (Jurassic) sandstone uranium deposits
Other sandstone uranium deposits
Limestone uranium deposits
Other sedimentary rocks with uranium


109°
108°
107°
106°
37°
36°
35°
SAN JUAN
RIO ARRIBA
MC KINLEY
SANDOVAL
BERNALILLO
LOS ALAMOS
Navajo Lake
Aztec
Farmington
Bloomfield
San Juan River
Chama
Tierra Amarilla
Cuba
Gallup
Grants
Bernalillo
Rio Rancho
Albuquerque
Santa Fe
Moriarty
Los Alamos
Rio San Jose

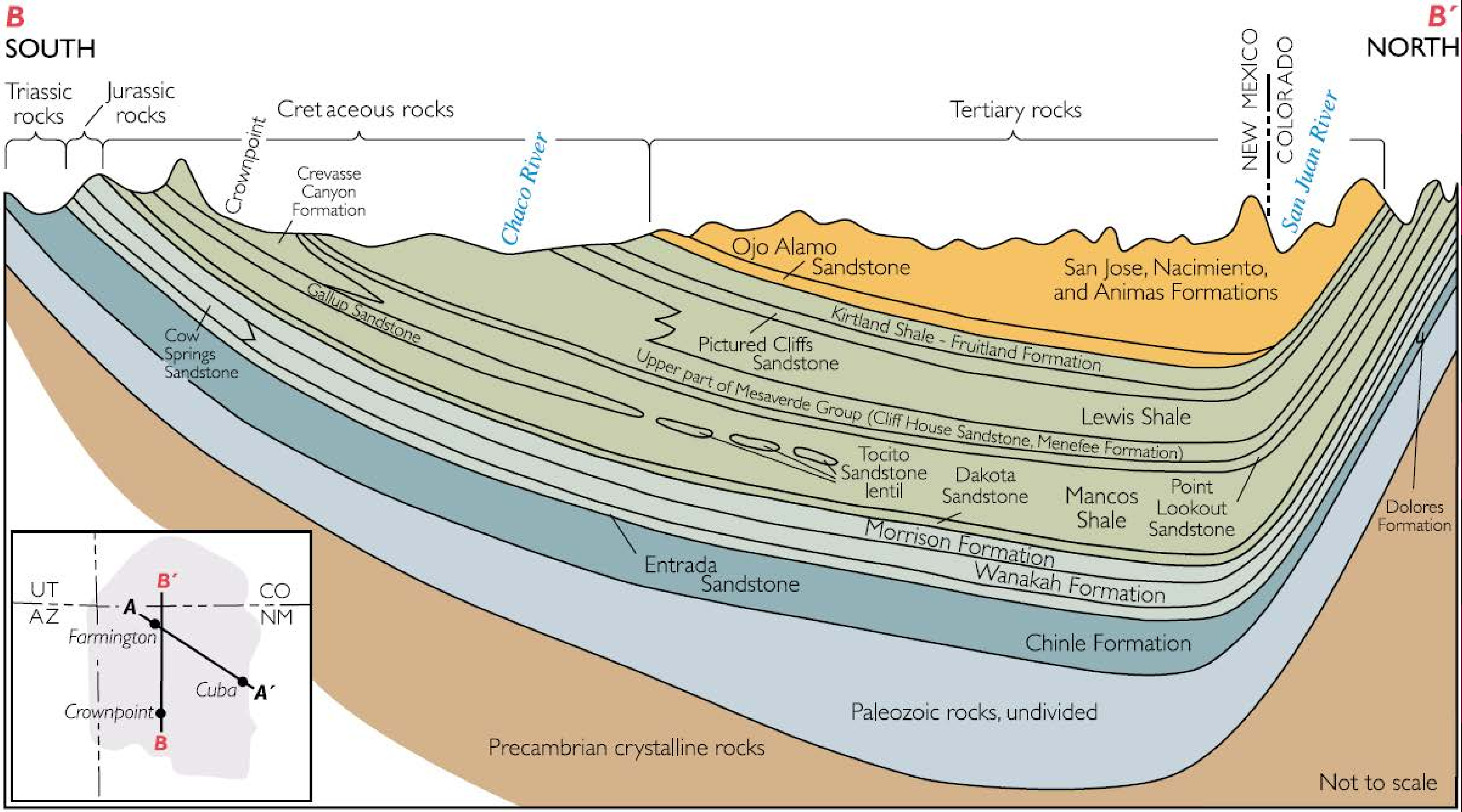
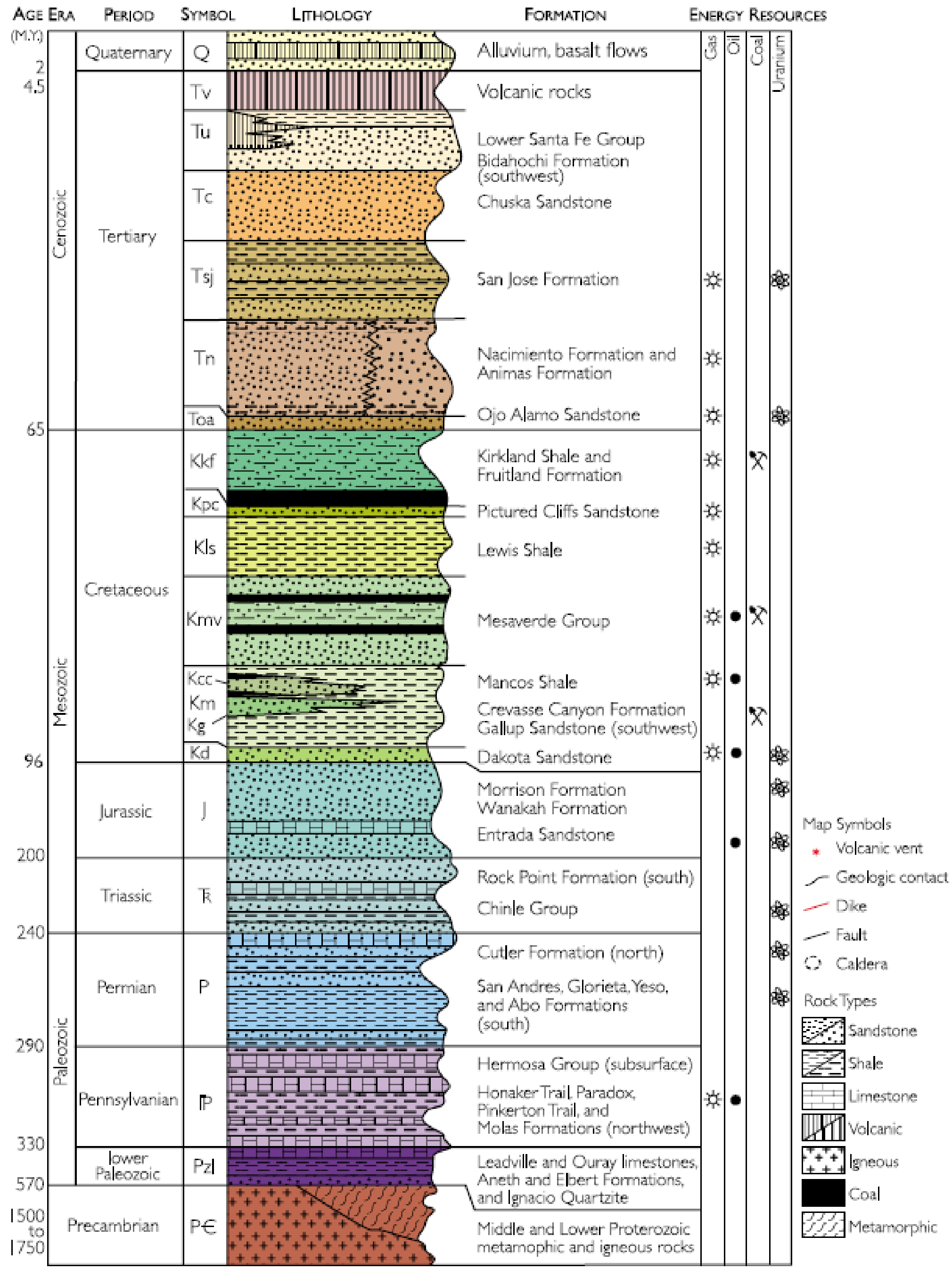
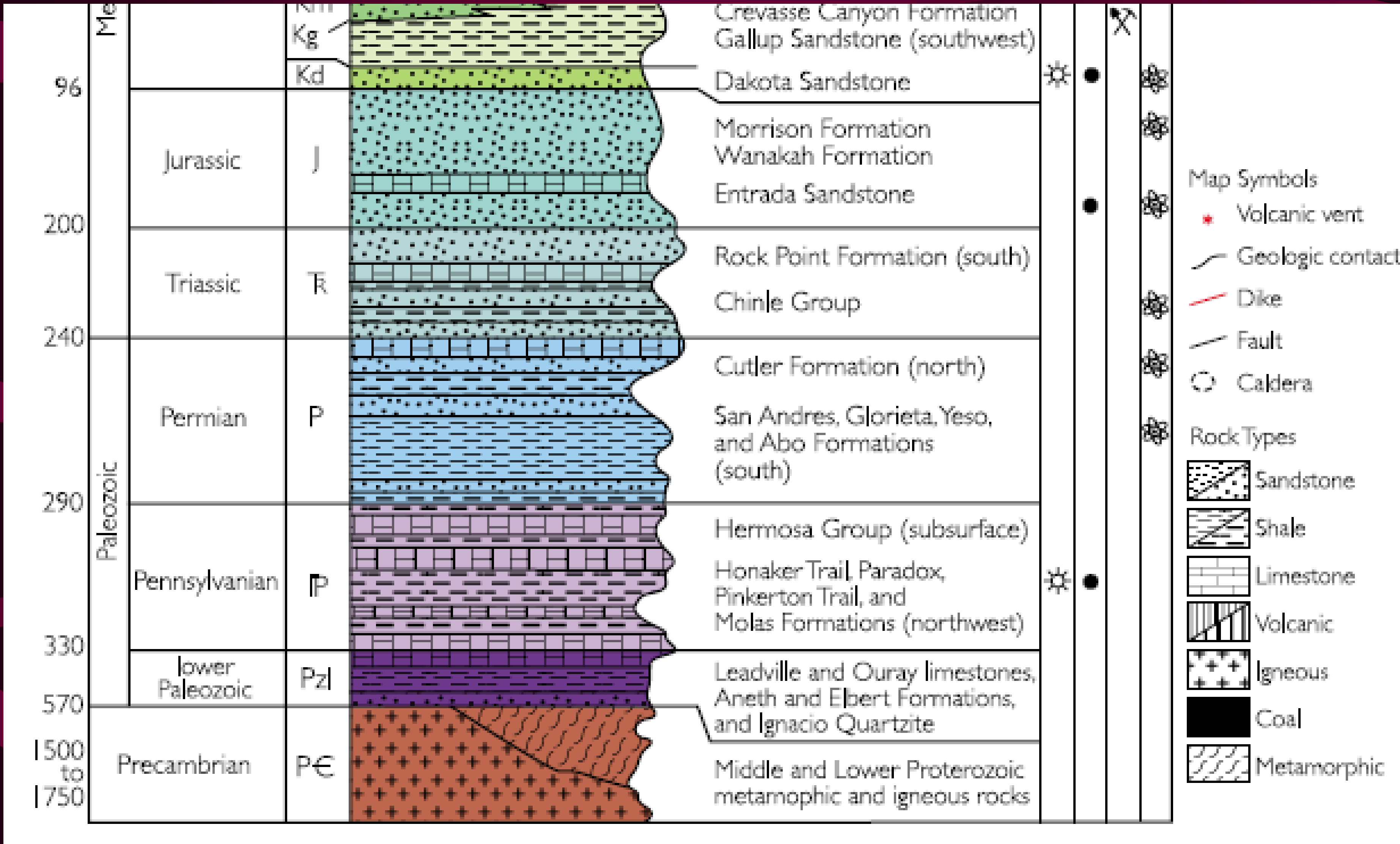


FIGURE 3 Diagrammatic southwest-northeast cross section of San Juan Basin, from Craigg, 2001 (p.12).


Age (M.Y.)
Era
Period
Symbol
Lithology
Formation
Energy Resources
Gas
Oil
Coal
Uranium
Cenozoic
Mesozoic
Paleozoic
Quaternary
Tertiary
Cretaceous
Jurassic
Triassic
Permian
Pennsylvanian
lower Paleozoic
Precambrian
2
4.5
65
96
200
240
290
330
570
1500 to 1750
Q
Tv
Tu
Tc
Tsj
Tn
Toa
Kkf
Kpc
Kls
Kmv
Kcc
Km
Kg
Kd
J
Ѣ
P
ⱣP
Pzl
P€
Alluvium, basalt flows
Volcanic rocks
Lower Santa Fe Group
Bidahochi Formation (southwest)
Chuska Sandstone
San Jose Formation
Nacimiento Formation and Animas Formation
Ojo Alamo Sandstone
Kirkland Shale and Fruitland Formation
Pictured Cliffs Sandstone
Lewis Shale
Mesaverde Group
Mancos Shale
Crevasse Canyon Formation
Gallup Sandstone (southwest)
Dakota Sandstone
Morrison Formation
Wanakah Formation
Entrada Sandstone
Rock Point Formation (south)
Chinle Group
Cutler Formation (north)
San Andres, Glorieta, Yeso, and Abo Formations (south)
Hermosa Group (subsurface)
Honaker Trail, Paradox, Pinkerton Trail, and Molas Formations (northwest)
Leadville and Ouray limestones, Aneth and Elbert Formations, and Ignacio Quartzite
Middle and Lower Proterozoic metamorphic and igneous rocks
Map Symbols
Volcanic vent
Geologic contact
Dike
Fault
Caldera
Rock Types
Sandstone
Shale
Limestone
Volcanic
Igneous
Coal
Metamorphic



Me
Kg
Kd
Crevasse Canyon Formation
Gallup Sandstone (southwest)
Dakota Sandstone
96
Jurassic
J
Morrison Formation
Wanakah Formation
Entrada Sandstone
200
Triassic
Ћ
Rock Point Formation (south)
Chinle Group
240
Permian
P
Cutler Formation (north)
San Andres, Glorieta, Yeso, and Abo Formations (south)
290
Paleozoic
Pennsylvanian
ⅡP
Hermosa Group (subsurface)
Honaker Trail, Paradox, Pinkerton Trail, and Molas Formations (northwest)
330
lower Paleozoic
Pzl
Leadville and Ouray limestones, Aneth and Elbert Formations, and Ignacio Quartzite
570
1500 to 1750
Precambrian
P€
Middle and Lower Proterozoic metamophic and igneous rocks
Map Symbols
Volcanic vent
Geologic contact
Dike
Fault
Caldera
Rock Types
Sandstone
Shale
Limestone
Volcanic
Igneous
Coal
Metamorphic

Description of the Grants uranium deposits

Tabular

- Less than 2.5 m thick
- Grades exceed 0.2% U_3O_8
- Sharp boundaries
- Locally offset by Laramide (Late Cretaceous)-Tertiary faults
- Black to dark gray because of the associated humate
- Also called primary, trend, prefault, black banded, channel, blanket ore


6
3

Redistributed

- 3-46 m thick
- Grades less than 0.2% U_3O_8
- Commonly localized by faults
- Form roll front geometries locally
- Diffuse ore to waste boundaries
- Dark, brownish gray to light gray
- Also called postfault, stack, secondary, roll front ore

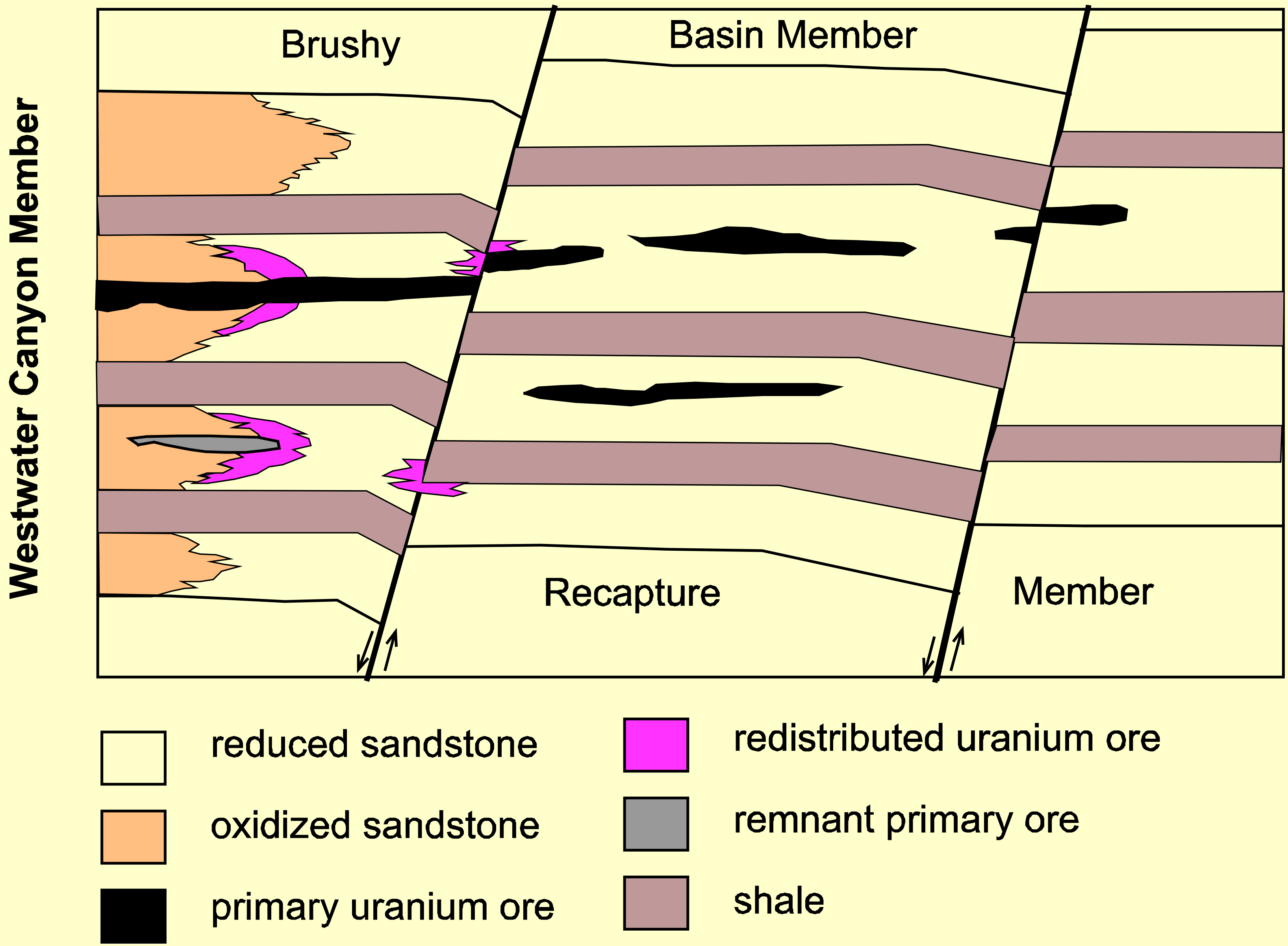
Redistributed or roll-type uranium deposits

Open pit mine in Wyoming, Power Resources, Inc.

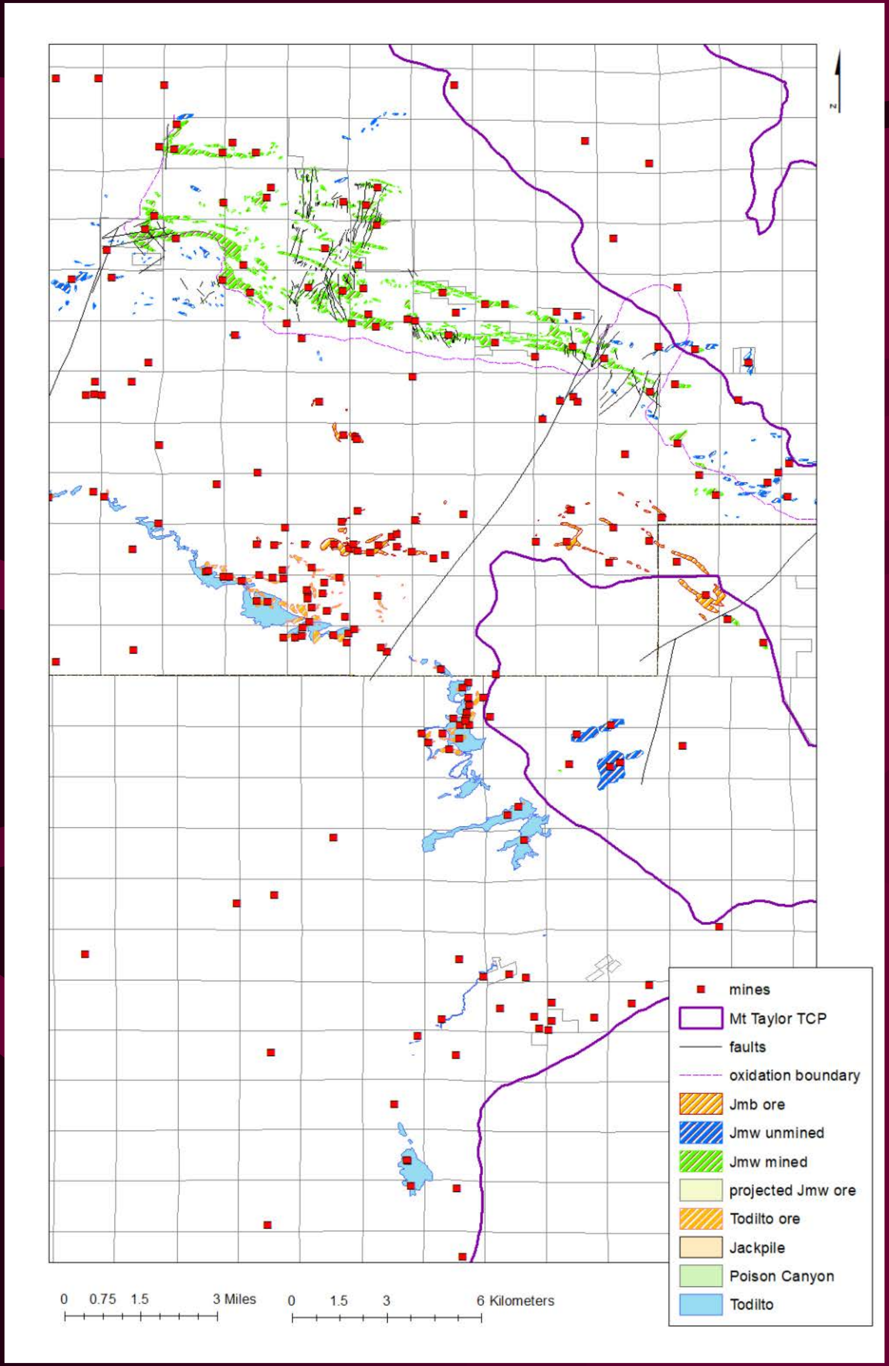
http://www.wma-minelife.com/uranium/mining/rllfrnt1.html

Remnant-primary sandstone uranium deposits

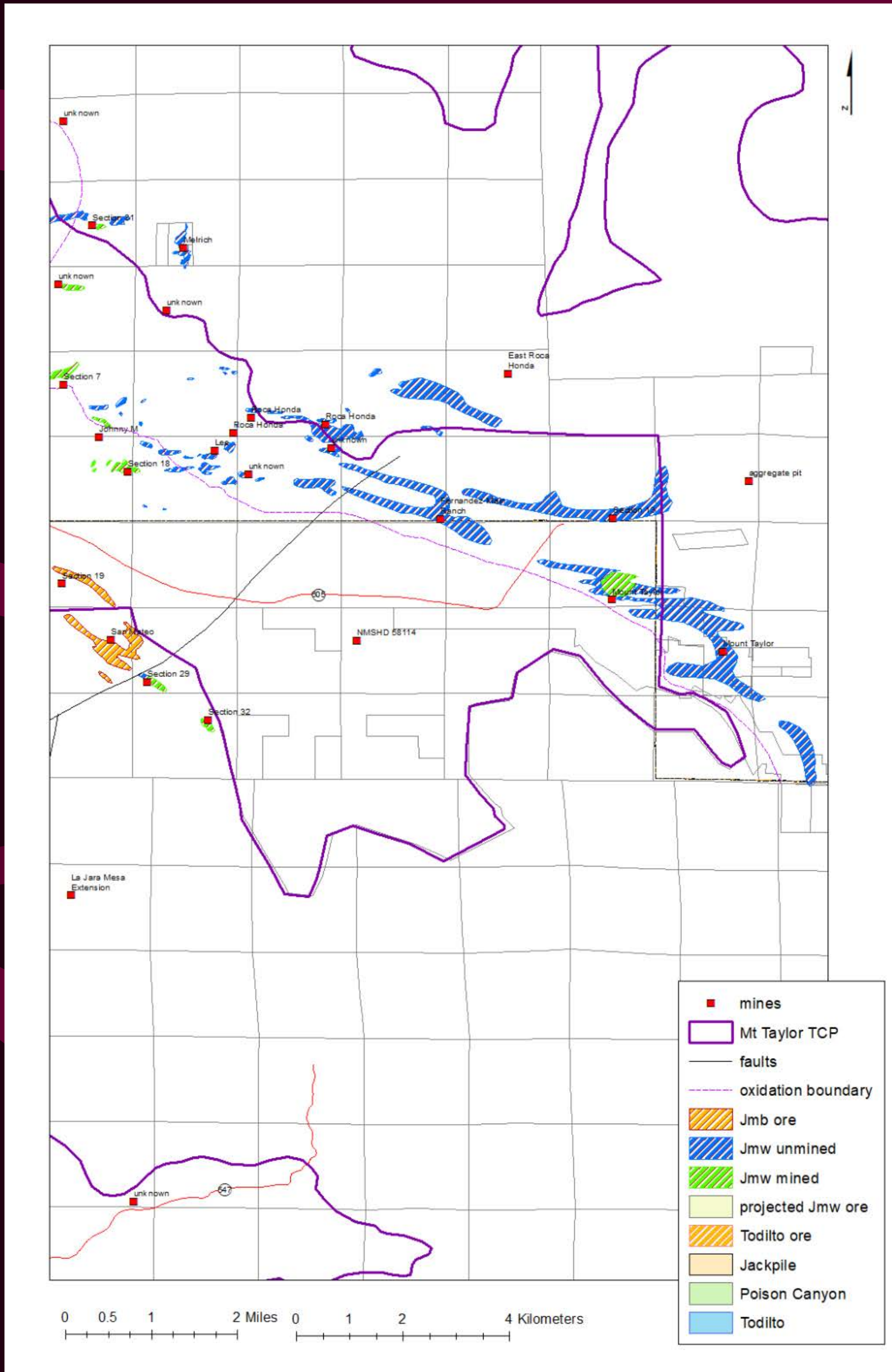
- Surrounded by oxidized sandstone
- Where the sandstone host surrounding the primary deposits was impermeable and the oxidizing waters could not dissolve the deposit, remnant-primary sandstone uranium deposits remain
- Also called ghost ore bodies


Brushy
Basin Member
Westwater Canyon Member
Recapture
Member
reduced sandstone
oxidized sandstone
primary uranium ore
redistributed uranium ore
remnant primary ore
shale

Ambrosia Lake area



Mt. Taylor area



HOW DID THE DEPOSITS FORM?

The primary uranium deposits are associated with humates. Therefore we need to understand the origin of the humates as well as the uranium.

Origin of humates

- Organic matter, not petroleum derived
  - Plant debris incorporated into the alluvial fans at the time of deposition
  - Plant material associated with the overlying lacustrine units
  - Dakota and pre-Dakota swamps
- Locally it is detrital (L-Bar deposits)
- At most places, were deposited just after the sandstones were emplaced but before the uranium

There is no consensus on details of the origin of the Morrison primary sandstone uranium deposits

- Alteration of volcanic detritus and shales within the Morrison Formation (Lacustrine-humate model)
- Ground water derived from a volcanic highland to the southwest
- Combination of the above

Possible episodes of uranium mineralization

- During and soon after deposition of the host sandstones (i.e. Jurassic)
- During pre-Dakota erosional interval (Late Jurassic to early Cretaceous)
- During the present erosional cycle (which started in late Miocene or early Pliocene)

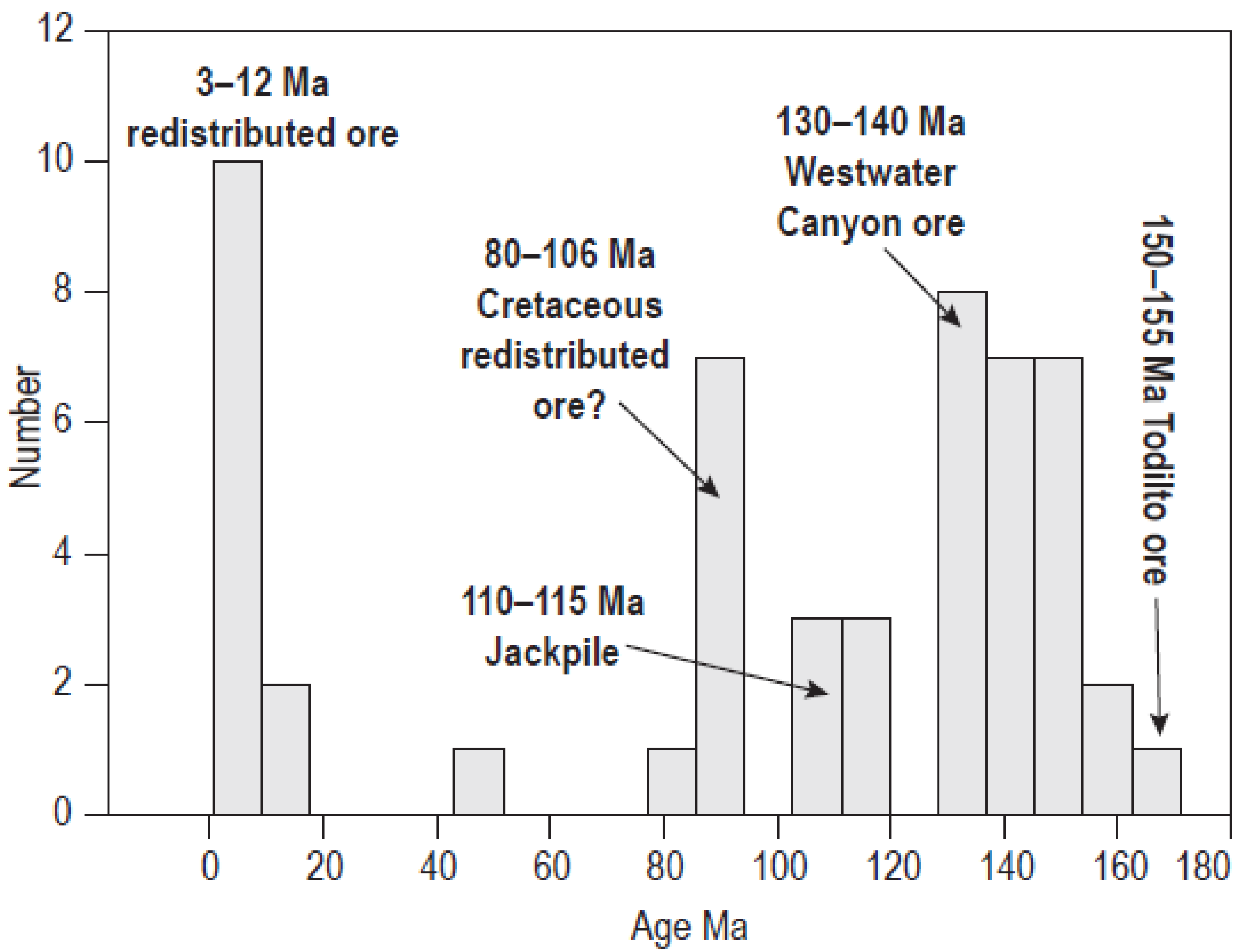


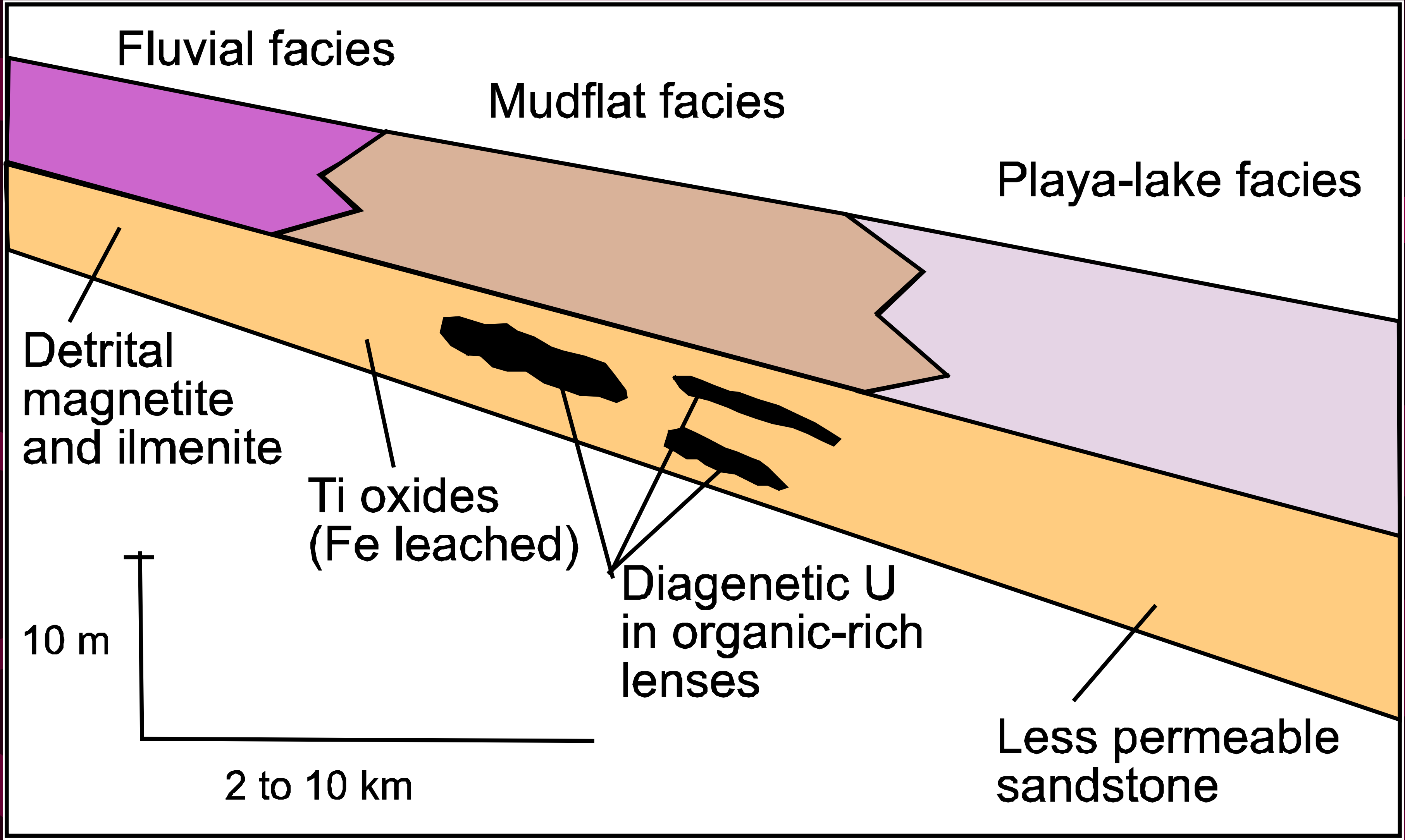
Figure 15. Age determinations of Grants district mineralization (McLemore, 2011). Includes Pb/U, K/Ar, Rb/Sr, and fission track dates from Miller and Kulp (1963), Nash and Kerr (1966), Nash (1968), Berglof (1970, 1989), Brookins et al. (1977), Brookins (1980), Ludwig et al. (1982), Hooper (1983) and is summarized by Wilks and Chapin (1997).

AGE

from McLemore (2011)

Lacustrine-humate model

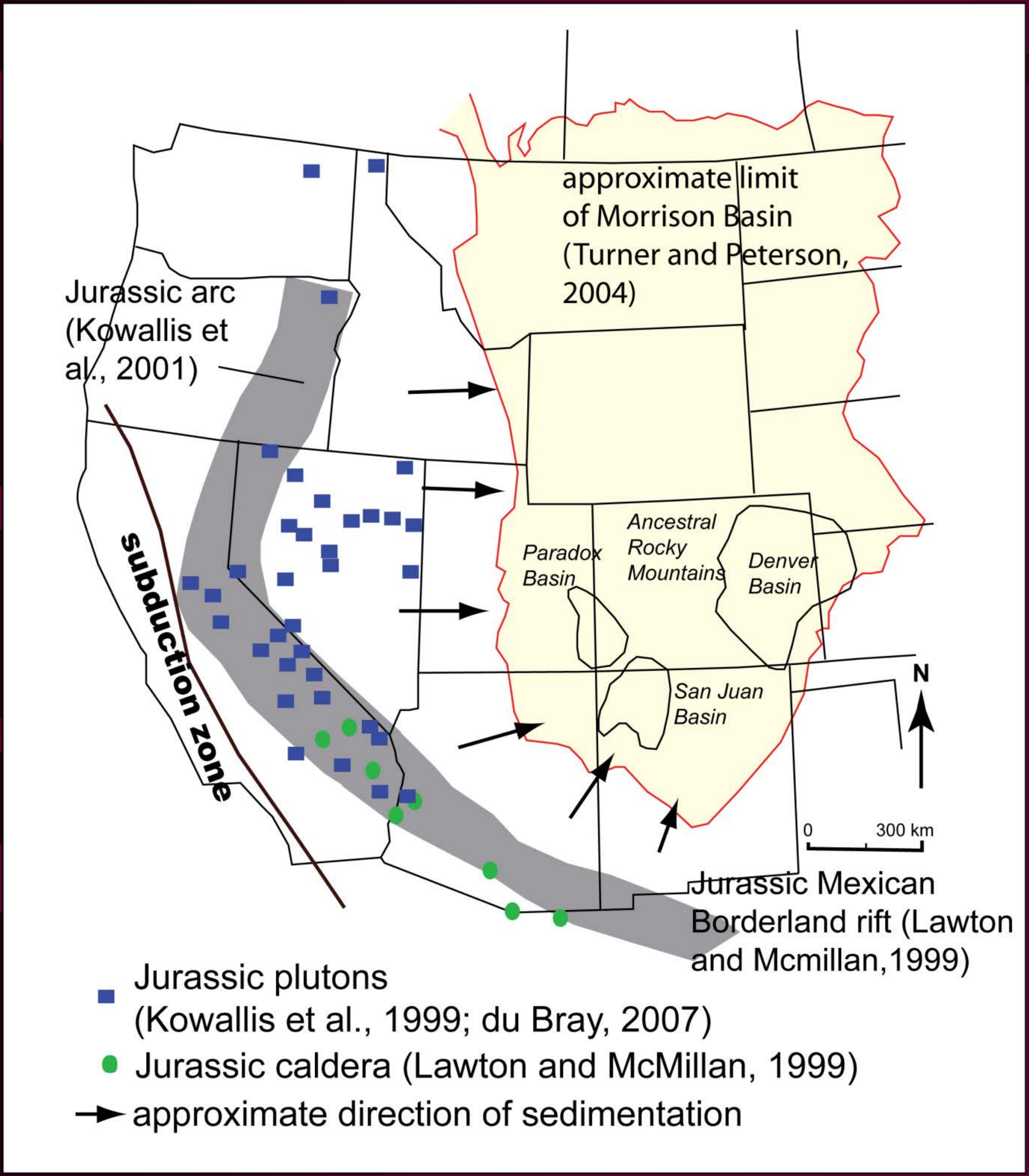
- Ground water was expelled by compaction from lacustrine muds formed by a large playa lake
- Humate or secondary organic material precipitated as a result of flocculation into tabular bodies
- During or after precipitation of the humate bodies, uranium was precipitated from ground water



from Turner-Peterson and Fishman (1986)

Brine-interface model

- Uranium and humate were deposited during diagenesis by reduction at the interface of meteoric fresh water and basinal brines
- Uranium precipitated in the presence of humates at a gravitationally stable interface between relatively dilute, shallow meteoric water and saline brines that migrated up dip from deeper in the basin
- Ground-water flow was impeded by upthrown blocks of Precambrian crust and forced upwards
- These zones of upwelling are closely associated with uranium-vanadium deposits

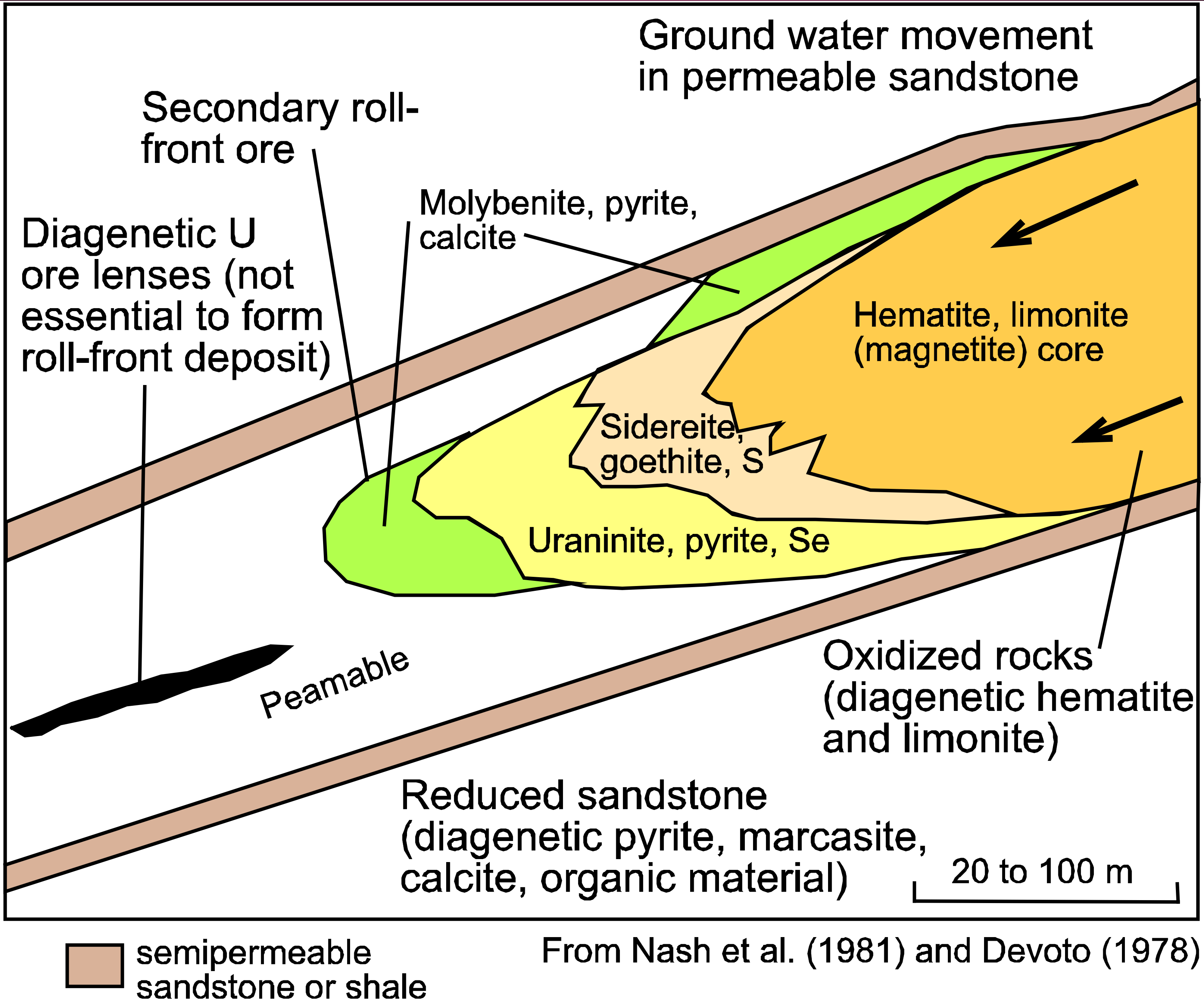


POTENTIAL SOURCE

from McLemore (2011)

Redistributed uranium deposits

- After formation of the primary sandstone uranium deposits, oxidizing ground waters migrated through the uranium deposits and remobilized some of the primary sandstone uranium deposits
- Uranium was reprecipitated ahead of the oxidizing waters forming redistributed or roll front sandstone uranium deposits
- Evidence suggests that more than one oxidation front occurred in places (Cretaceous and a Tertiary oxidation front)


Ground water movement in permeable sandstone
Secondary roll-front ore
Molybenite, pyrite, calcite
Diagenetic U ore lenses (not essential to form roll-front deposit)
Hematite, limonite (magnetite) core
Sidereite, goethite, S
Uraninite, pyrite, Se
Peamable
Oxidized rocks (diagenetic hematite and limonite)
Reduced sandstone (diagenetic pyrite, marcasite, calcite, organic material)
20 to 100 m
semipermeable sandstone or shale
From Nash et al. (1981) and Devoto (1978)

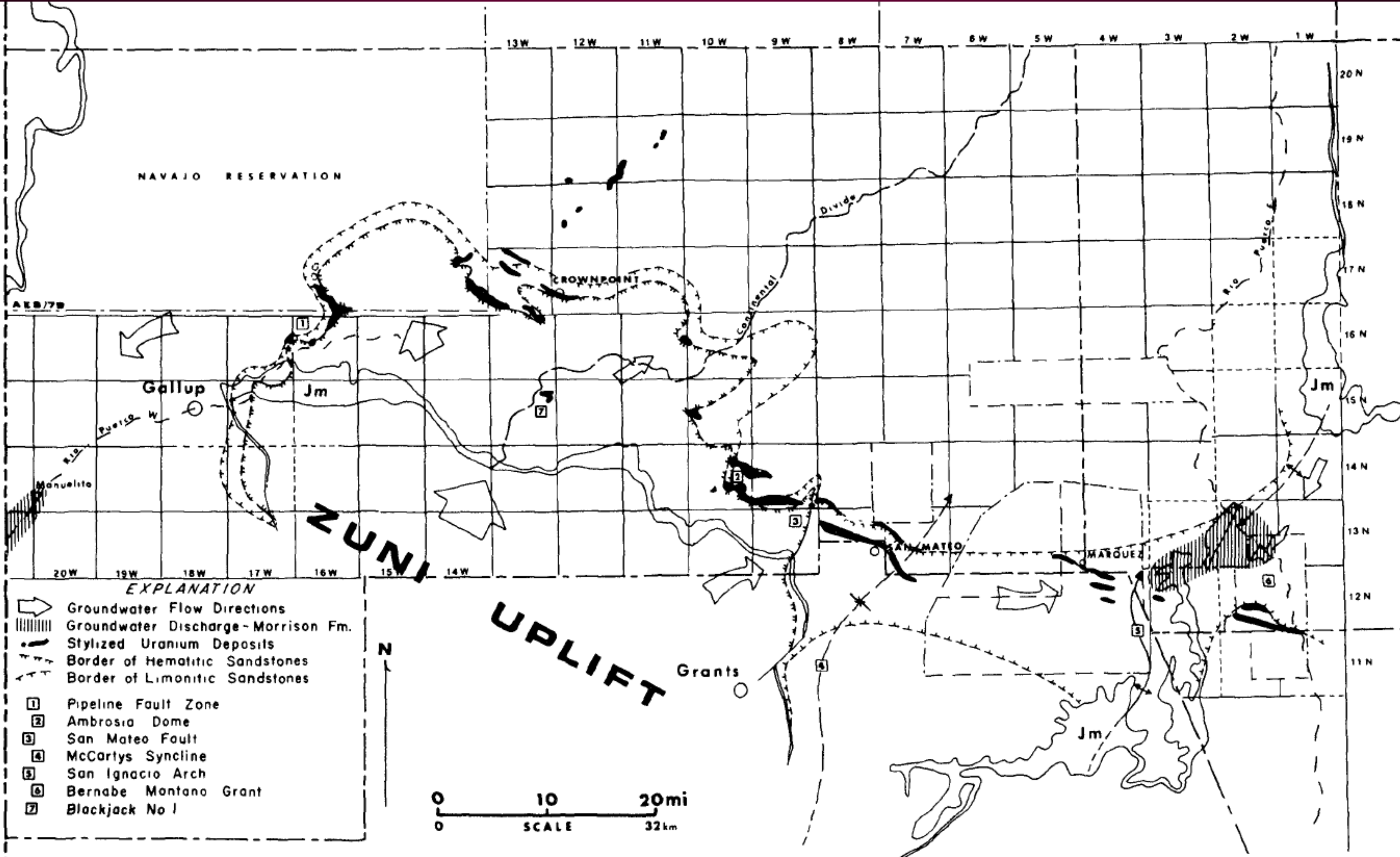


FIGURE 4. Map showing distribution of Tertiary-Quaternary oxidation in sandstone of Westwater Canyon Member, Morrison Formation. See Saucier (11), from which this figure is taken, for full discussion of details shown on map.

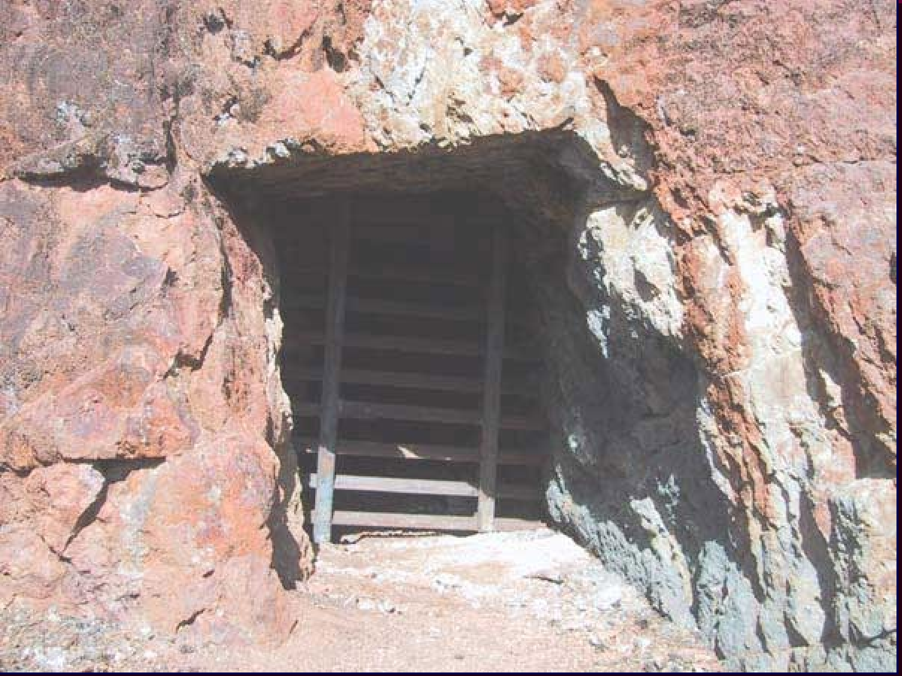
MINING

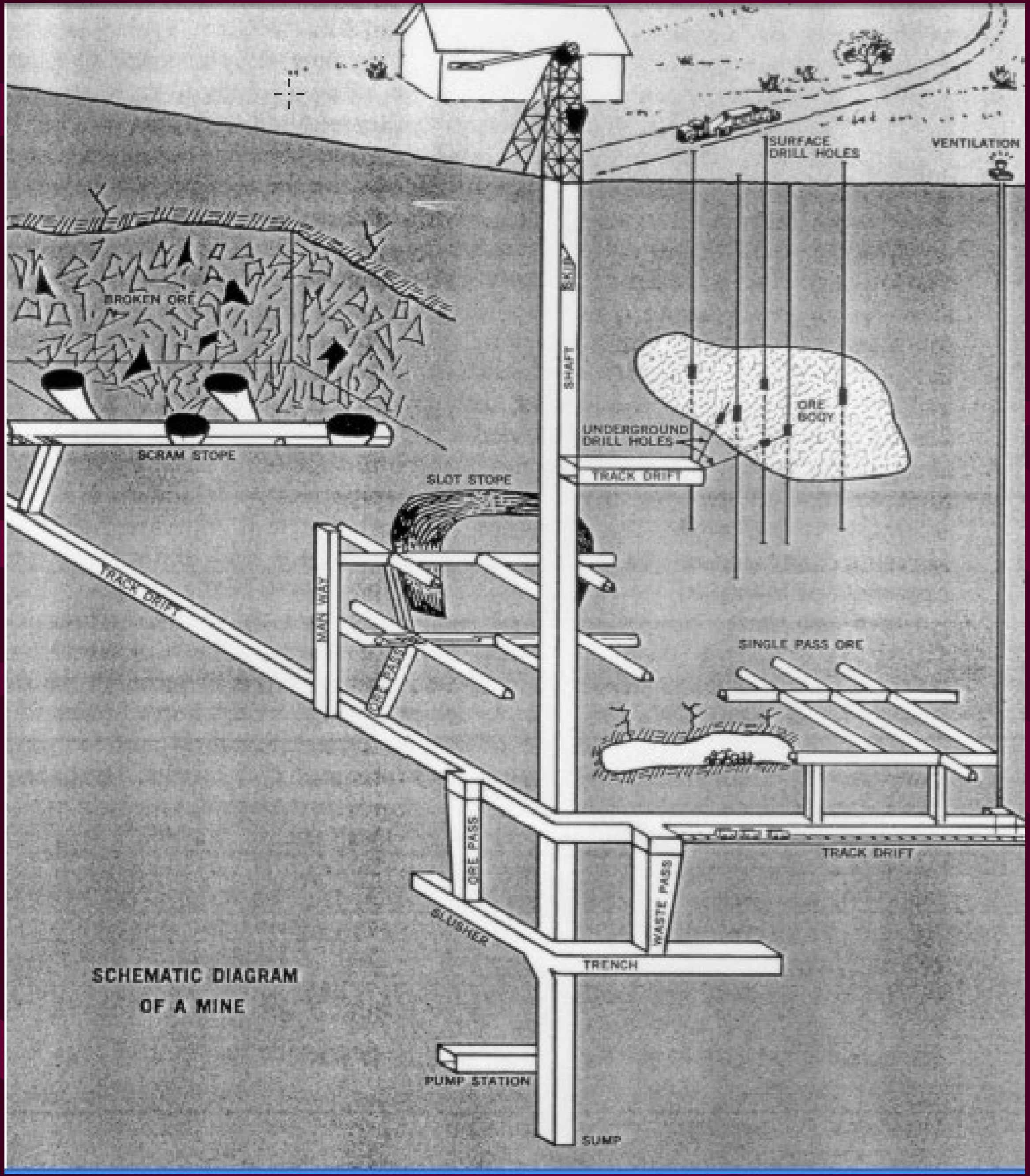
- Open pit
- Underground
- Heap leaching
- In situ leaching or recovery

Sweetwater mine, Wy

OPEN PIT MINES

Underground Mining





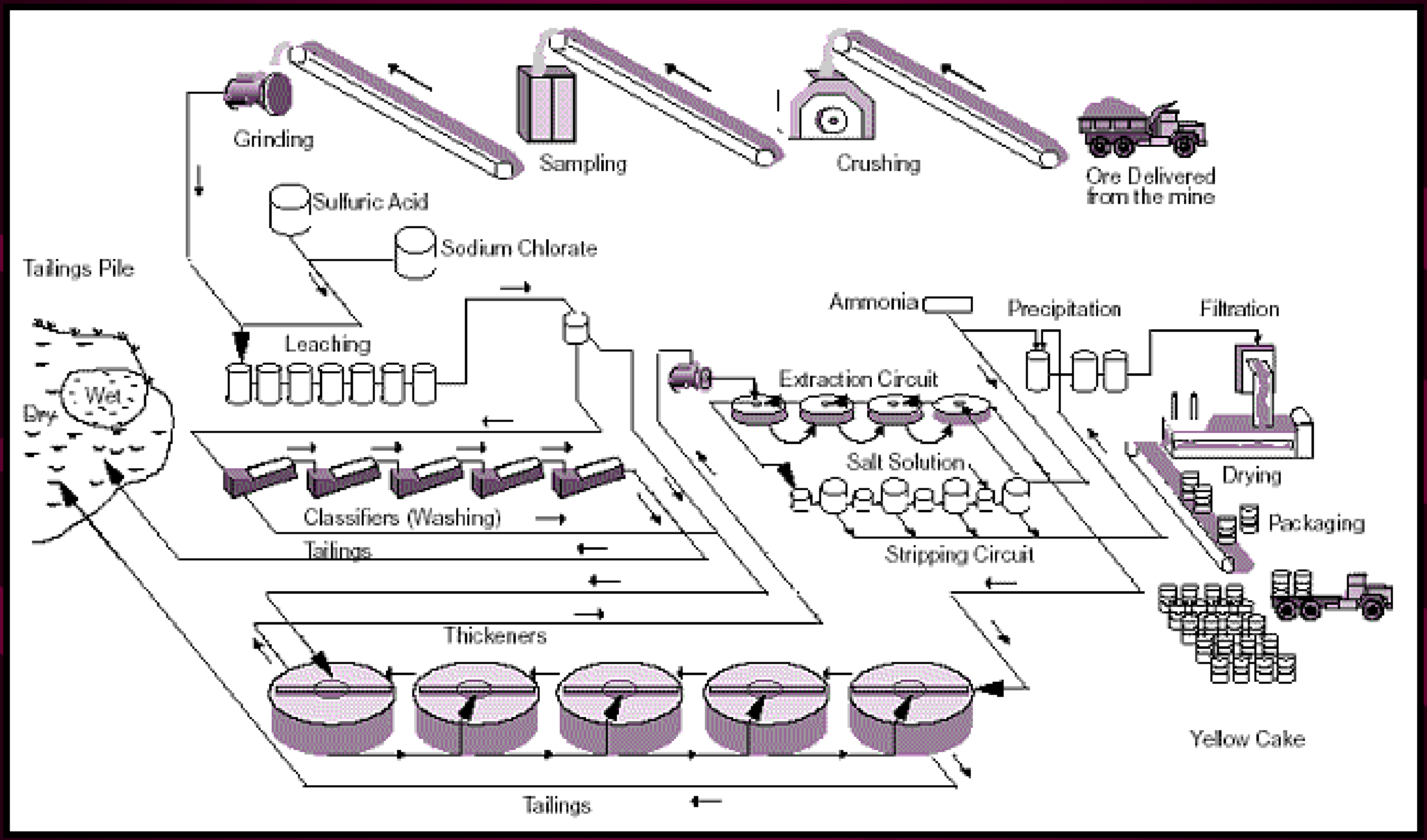
SURFACE DRILL HOLES
VENTILATION
BROKEN ORE
SHAFT
ORE BODY
UNDERGROUND DRILL HOLES
SCRAM STOPE
TRACK DRIFT
SLOT STOPE
TRACK DRIFT
MAN WAY
SINGLE PASS ORE
TRACK DRIFT
ORE PASS
WASTE PASS
SLUSHER
TRENCH
SCHEMATIC DIAGRAM
OF A MINE
PUMP STATION
SUMP

IAEA TE_1174

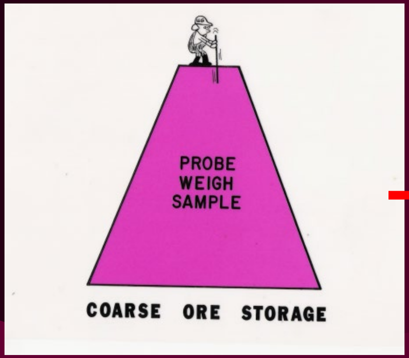
Methods of uranium processing

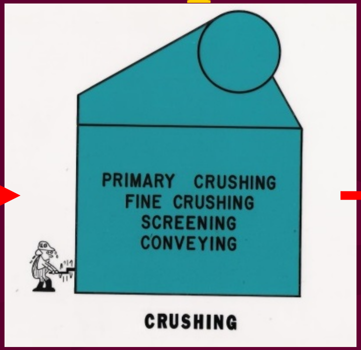
- Conventional mining and milling
  - Higher grade deposits
  - Mineralogy and lithology determine if it is acid or alkaline leach
  - No mills in NM, although there are plans underway for at least 1 mill in the Grants district
- In situ recovery
  - Typically roll front deposits
  - Mineralogy and chemistry important
  - Mo and V interferes with recovery of U
- Heap leaching

Conventional Uranium Mill Unit Processes



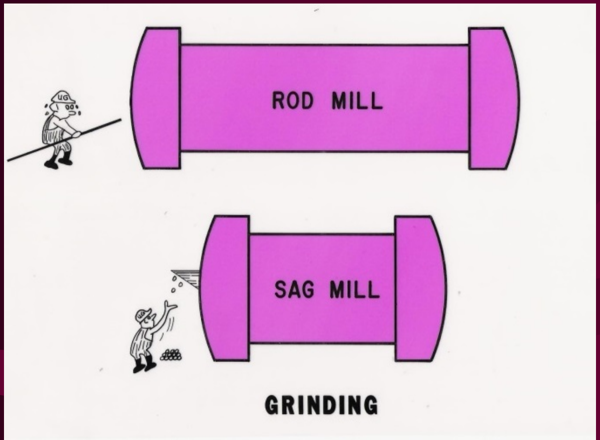
Rock Crushing, Sampling, Stockpiling





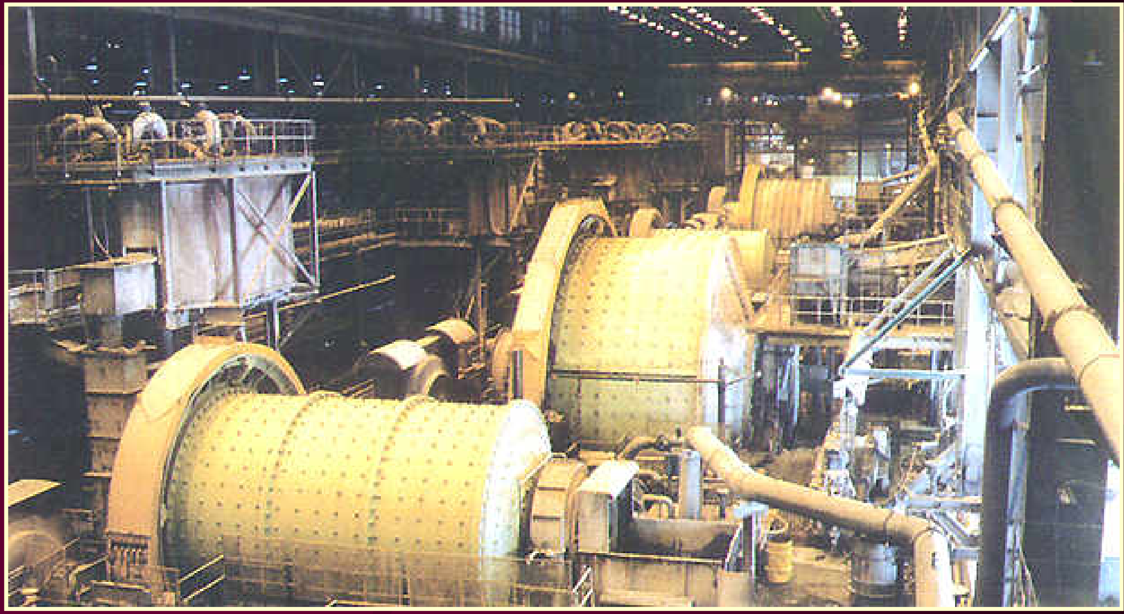
- Trucks are weighed
- Ore is sampled
- Ore is crushed to < ¼" size in series of crushers
- Crushed ore is stockpiled

Grinding

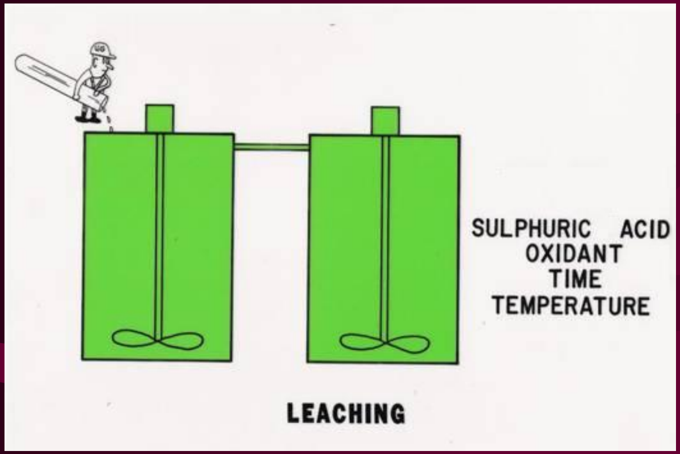


- Rod Mills
- Ball Mills
- Semi-Autogenous Grinding (SAG) Mills
- Water is added to make pulp

- Grinders in Operating Mill
- Ball Mill in foreground
- SAG Mills in background



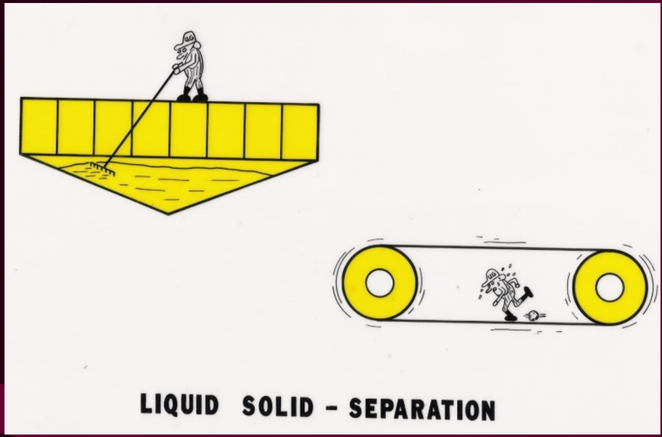
Leaching Process



- Acid Leaching System
- Sulfuric Acid Leach
- Acid, Heat and Oxidant (sodium chlorate) applied

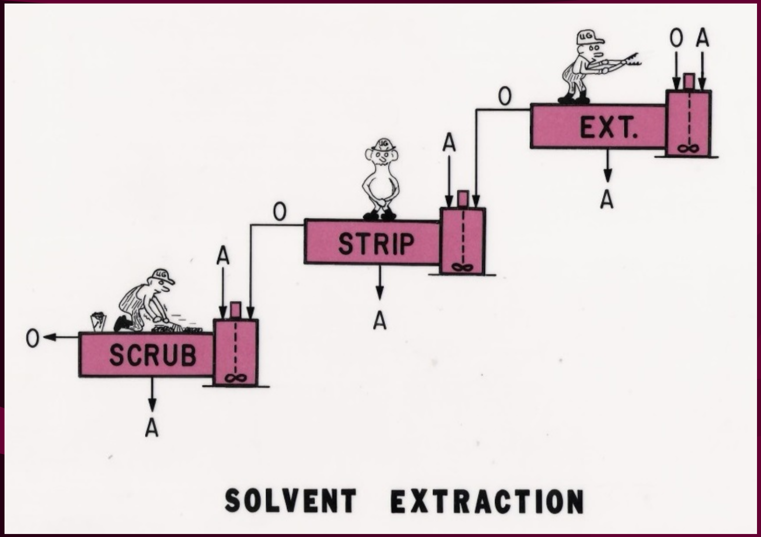
- 50% solids/ 50% water is mixed w/ Acid to ~22% solids
- Uranium is "leached" into solution

Classifiers/Settling Tanks



- Solids are washed of the Uranium
- Solids advance to thickeners to separate “tailings”
- < 1% of Soluble Uranium remains in tailings
- 99% of Uranium is now in the “pregnant” liquor

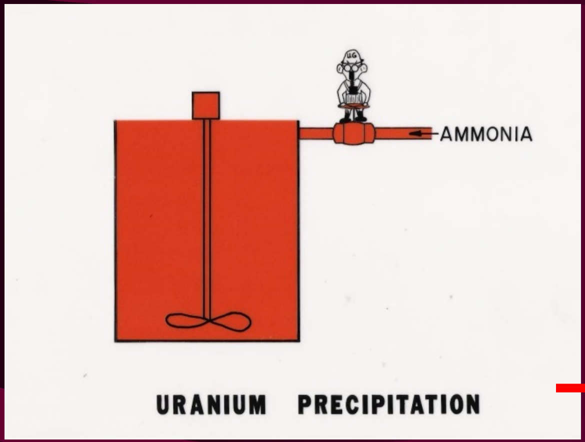
Solvent Extraction



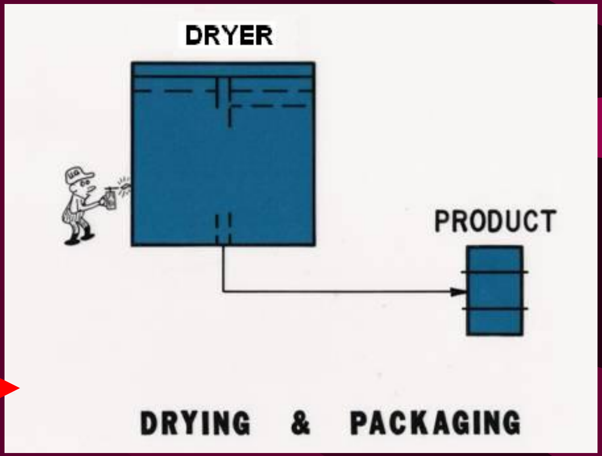
- Dissolved Uranium is chemically extracted from "pregnant" liquor
- Selective removal of Uranium from solution
- Uranium is concentrated 4x

- Mixer-Settler mixes Ur-acid solution w/ kerosene
- U transferred to Solvent phase
- Raffinate – barren aqueous solution, free of Uranium
- Stripping concentrates U 40x

Precipitation and Drying



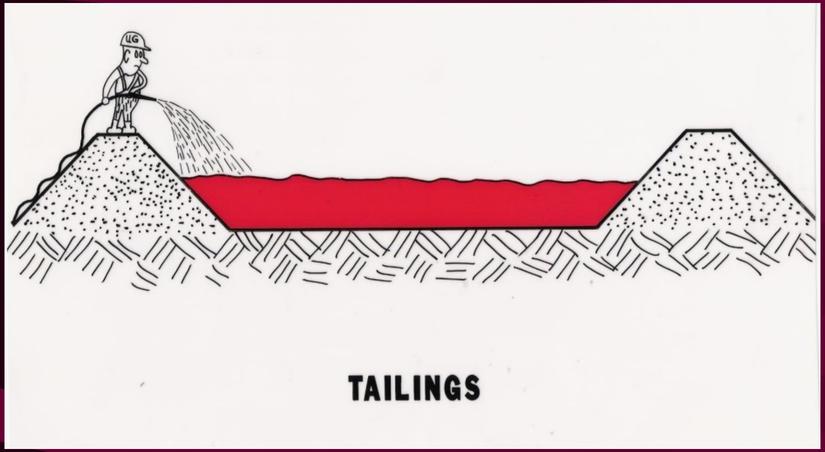
- U “falls out” of solution
- Settles to bottom of Precipitation Tanks



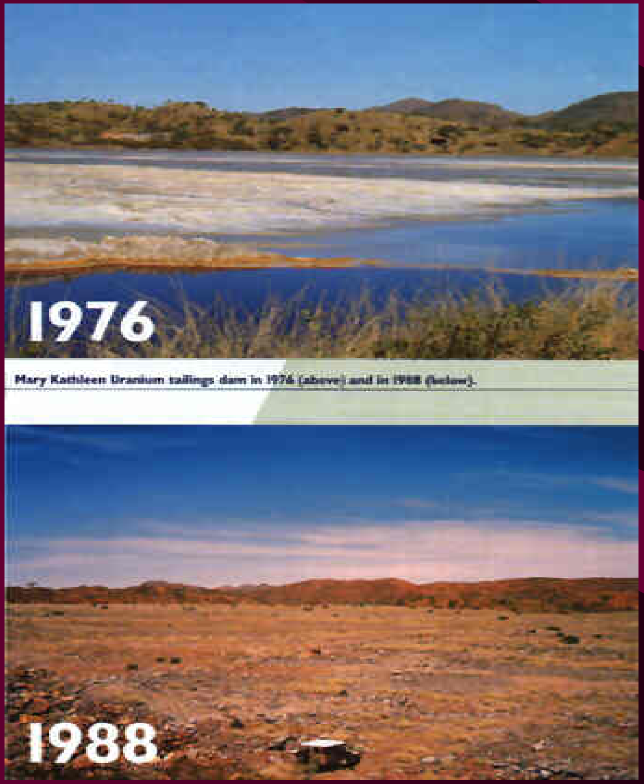
- U is now a solid
- Dewatering via Centrifuge or Filter Press

- Final Drying step produces Yellow Cake
- Drying Temp ~1200 degrees F

Tailings Ponds

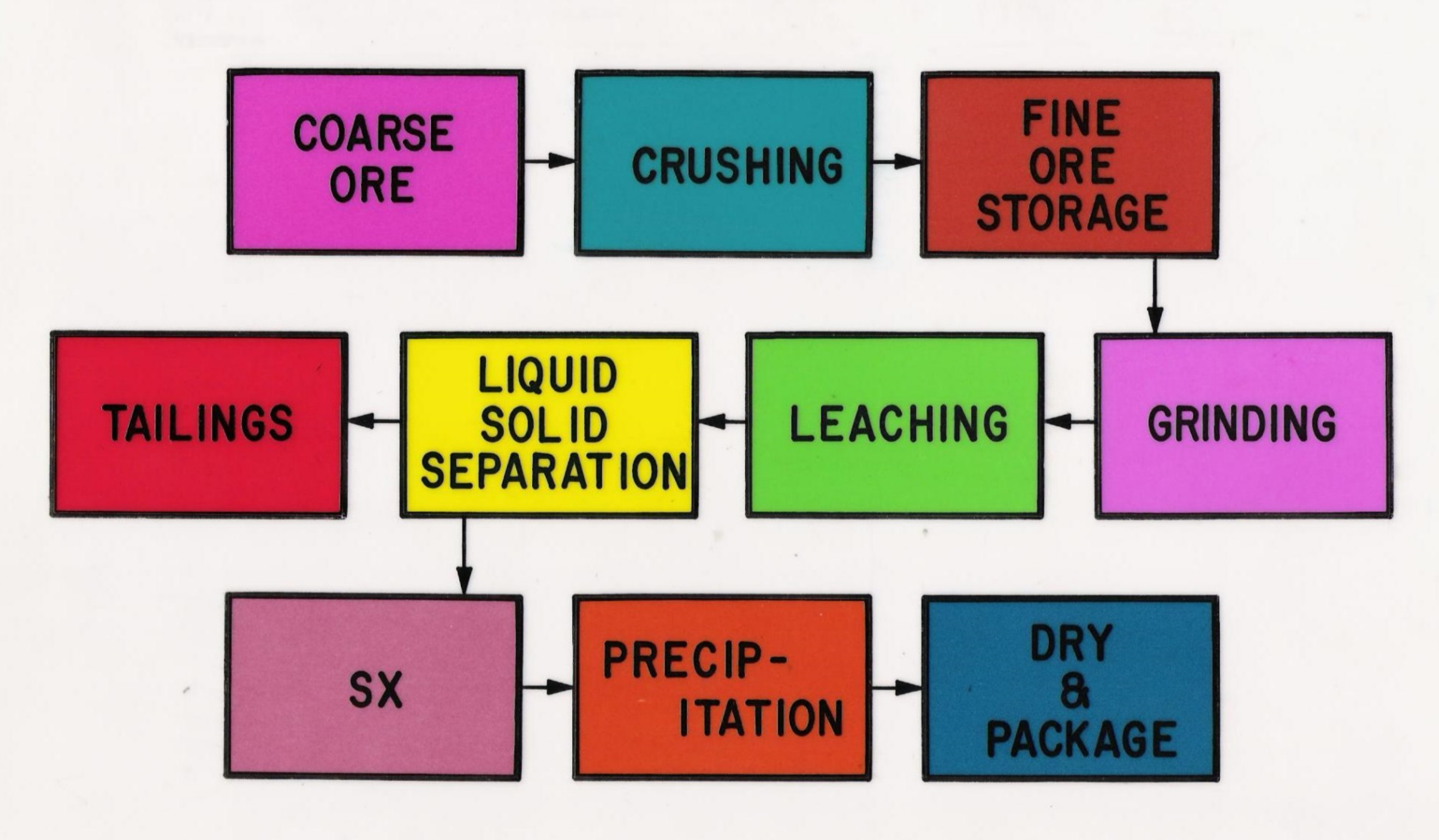


- Solids and liquid wastes are disposed in lined ponds
- Water is recycled
- Solids allowed to dry



- Dried solid “tails” are Capped w/ ~13’ of clay, rock and topsoil
- Capped pond is re-vegetated
- Extensive environmental monitoring
- Heavily regulated, financially bonded - ensures protection of environment

Mill Process Summary



A Conventional Mill

White Mesa Uranium Mill, Blanding Utah

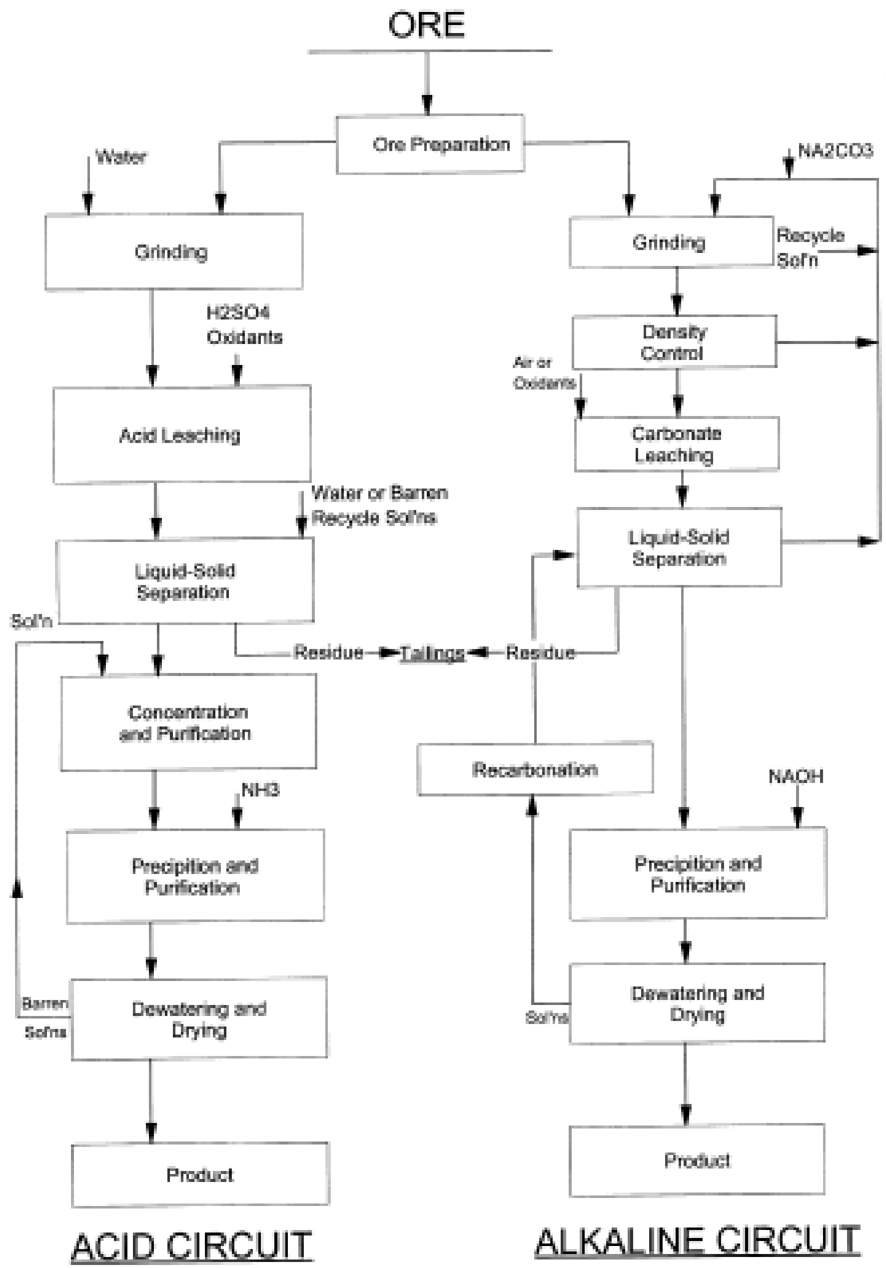


FIG. 4. Mill processing flowsheet.

IAEA TE_1174

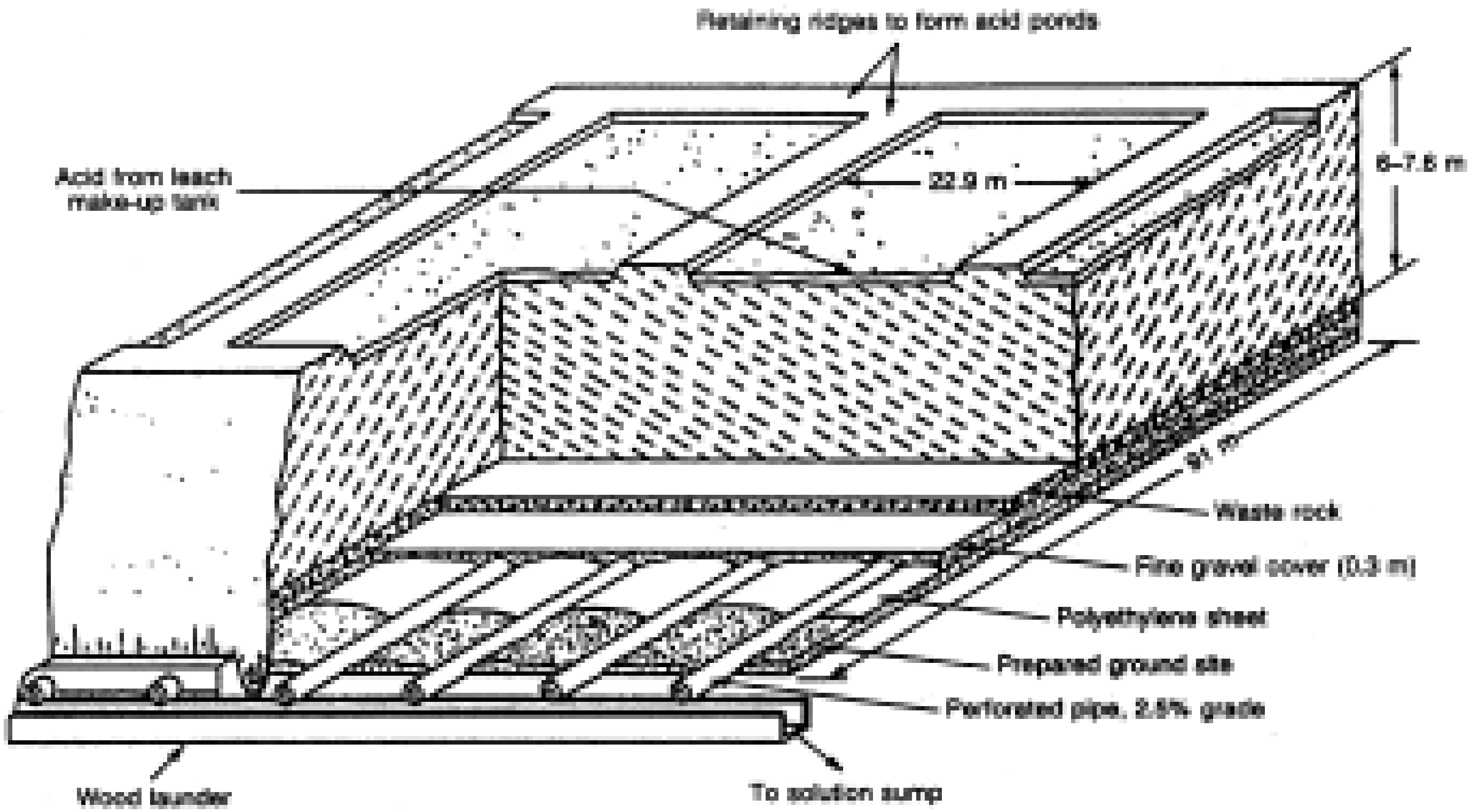


FIG. 5. Heap leaching pad construction.

Heap Leaching

Past ISR in New Mexico

- Mobil at Crownpoint
- UNC-Teton at Section 23
- Grace Nuclear at Hook’s Ranch
- Section 13 north of Seboyeta and Church Rock
- Anaconda at Windwhip, part of the Jackpile Paguate mine)
- Mine water recovery from Ambrosia Lake and other mines

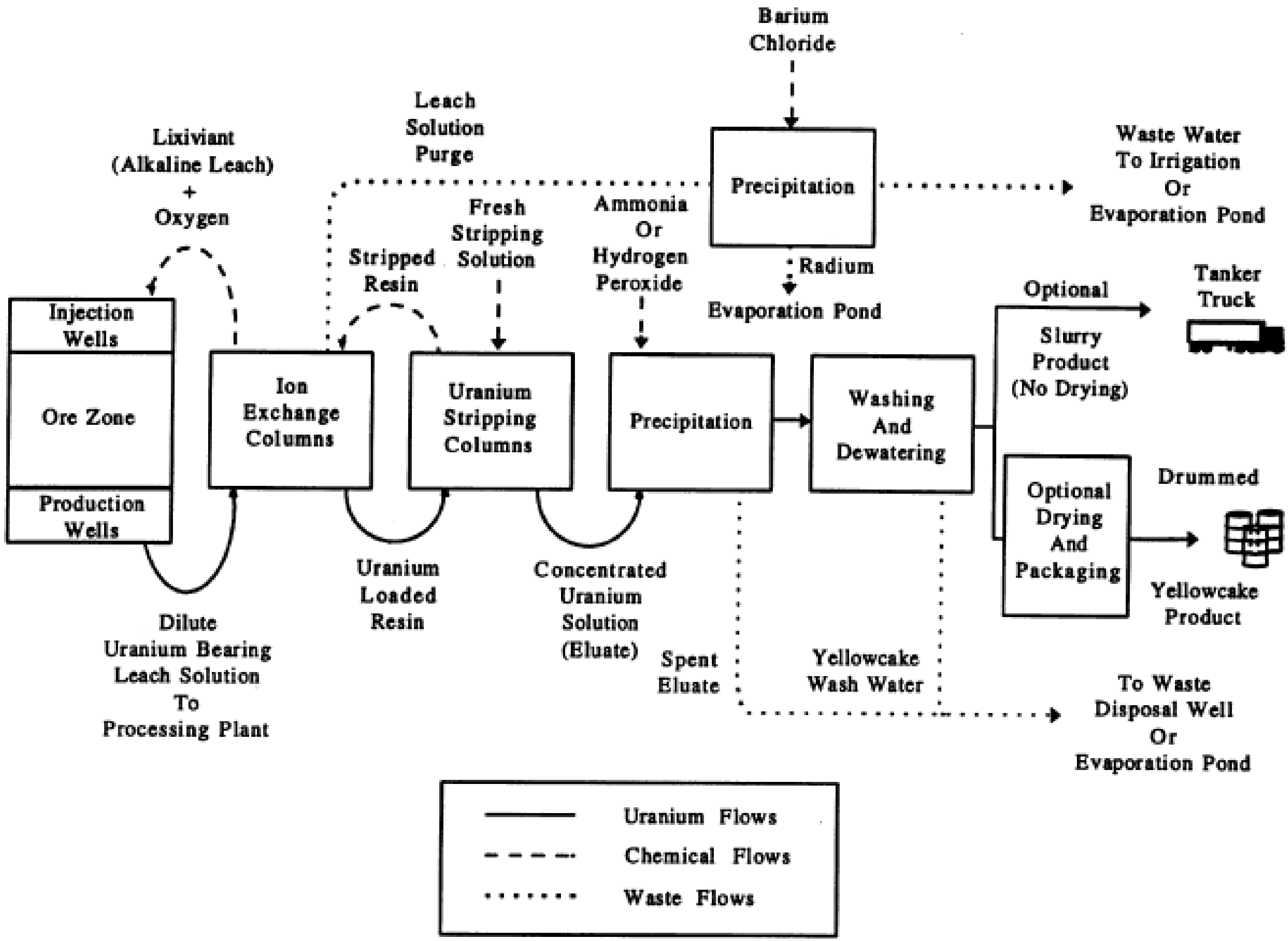
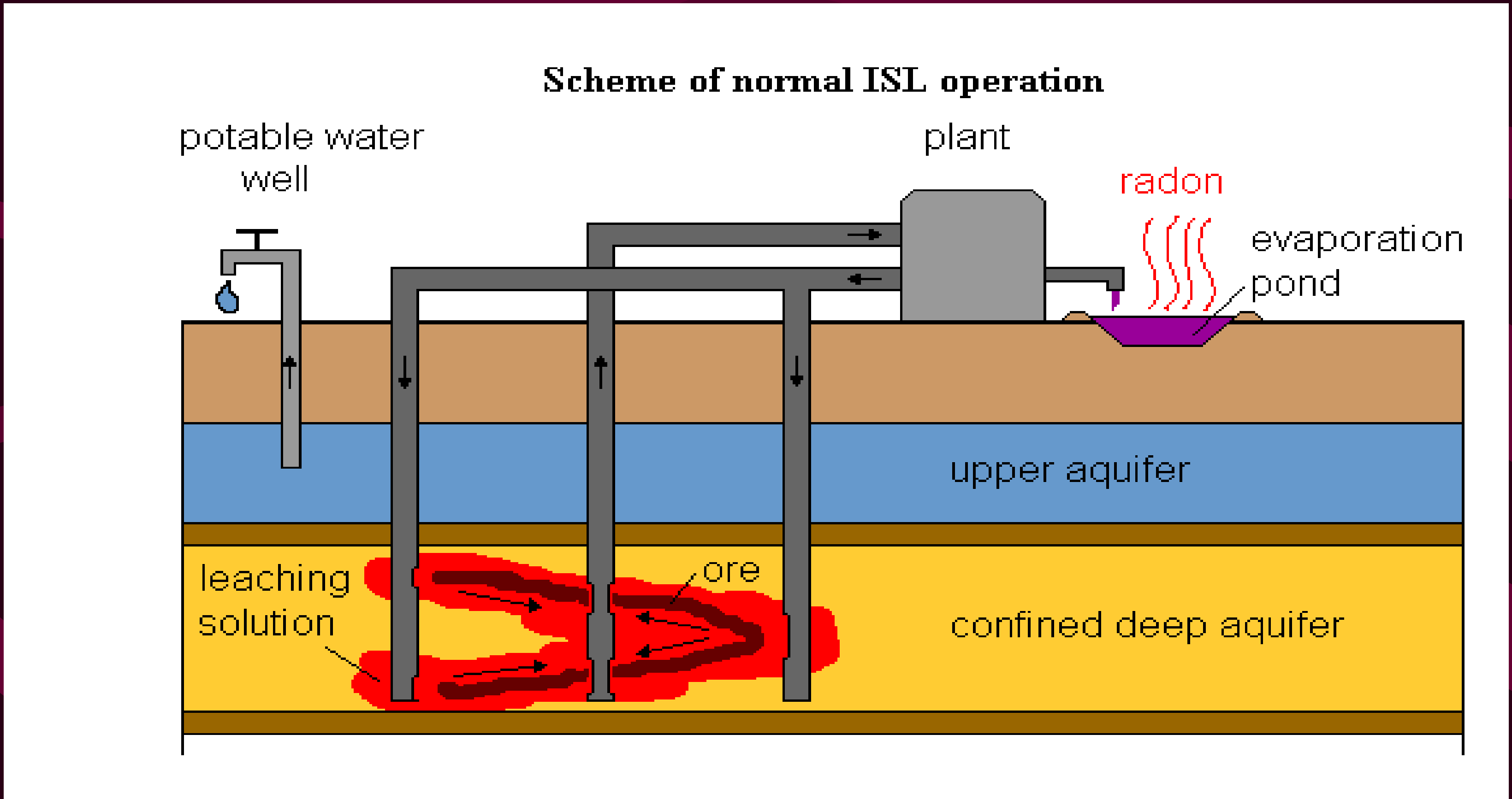


FIG. 23. Process flow diagram for a typical uranium in situ leaching mining facility.

In situ recovery

IAEA TE_1174

In situ Recovery



http://www.wise-uranium.org/uisl.html

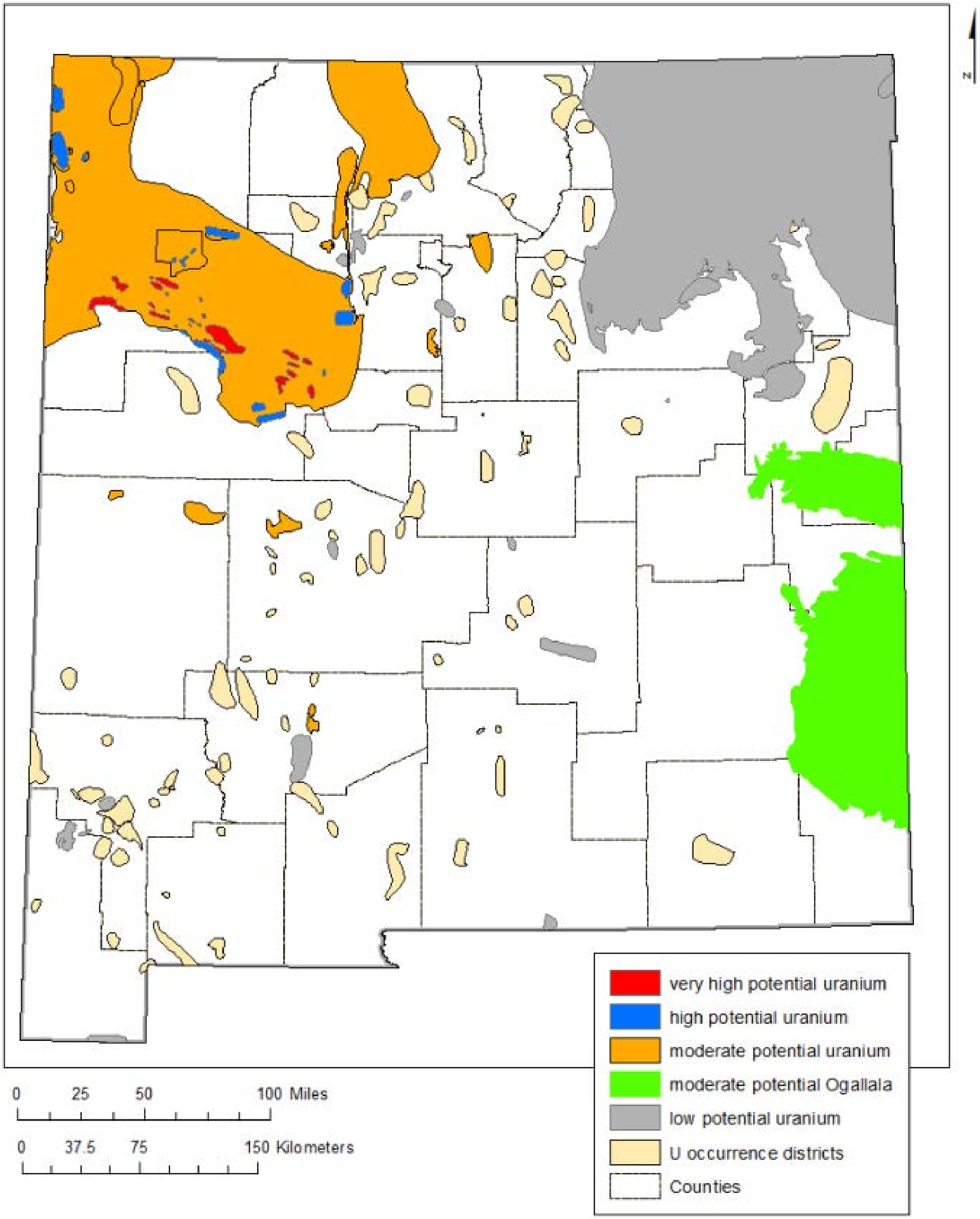
South Texas


MC-II FLOW ANALYZER
NuFlo
MC-II FLOW ANALYZER
NuFlo
MC-II FLOW ANALYZER
NuFlo

South Texas

South Texas

Uranium Potential in New Mexico



very high potential uranium
high potential uranium
moderate potential uranium
moderate potential Ogallala
low potential uranium
U occurrence districts
Counties
0 25 50 100 Miles
0 37.5 75 150 Kilometers
N

Historical Production from the Morrison Formation

- 340 million lbs of U_3O_8 from 1948-2001
- Accounting for 97% of the total uranium production in New Mexico
- More than 30% of the total uranium production in the United States
- 7th largest district in total uranium production in the world

New Mexico is

2nd in uranium reserves 15 million tons ore at 0.277% U_3O_8 (84 million lbs U_3O_8) at $30/lb

U.S. Forward-Cost Uranium Reserves by State, December 31, 2003

State(s)	$30 per pound			$50 per pound		
	Ore (million tons)	Grade[a] (percent U_3O_8)	U_3O_8 (million pounds)	Ore (million tons)	Grade[a] (percent U_3O_8)	U_3O_8 (million pounds)
Wyoming	41	0.129	106	238	0.076	363
New Mexico	15	0.280	84	102	0.167	341
Arizona, Colorado, Utah	8	0.281	45	45	0.138	123
Texas	4	0.077	6	18	0.063	23
Other[b]	6	0.199	24	21	0.094	40
Total	**74**	**0.178**	**265**	**424**	**0.105**	**890**

[a]Weighted average percent U_3O_8 per ton of ore.

[b]Includes California, Idaho, Nebraska, Nevada, North Dakota, Oregon, South Dakota, and Washington.

Notes: Uranium reserves that could be recovered as a byproduct of phosphate and copper mining are not included in this table. Reserves values in forward-cost categories are cumulative: that is, the quantity at each level of forward-cost includes all reserves at the lower costs. Totals may not equal sum of components because of independent rounding.

Sources: Estimated by Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, based on industry conferences; U.S. Department of Energy, Grand Junction Office, files; and Energy Information Administration, Form EIA-858, "Uranium Industry Annual Survey," Schedule A, Uranium Raw Material Activities (1984-2002) and Form EIA-851A, "Domestic Uranium Production Report" (2003).

http://www.eia.doe.gov/cneaf/nuclear/page/reserves/ures.html

Why did uranium production cease in New Mexico?

- Three Mile Island produced a public perception in the U.S. that nuclear power was dangerous.
- At the same time, NM uranium deposits in production were decreasing in grade by nearly half.
- Significant changes were beginning to occur that would increase the cost of mine and mill reclamation as well as future permitting in the U.S.
- More attractive, larger, higher grade uranium deposits in Canada and Australia were discovered.
- Large coal deposits were found throughout the U.S. that could meet the nation’s energy needs.

There is sufficient uranium reserves to meet the current reactor demand.

In order for NM deposits to once again be economic—

- Must build new reactors to increase demand.

- Wait for reserves at other localities to be depleted by production.

- Decrease cost of production/increase price.

- Mine closure plans must be approved before mining can begin.

Importance of sandstone uranium deposits in the Grants district

- Major mining companies abandoned the districts after the last cycle leaving advanced uranium projects.
- Inexpensive property acquisition costs includes $$ millions of exploration and development expenditures.
- Availability of data and technical expertise.
- Recent advances in in situ leaching makes sandstone uranium deposits attractive economically.

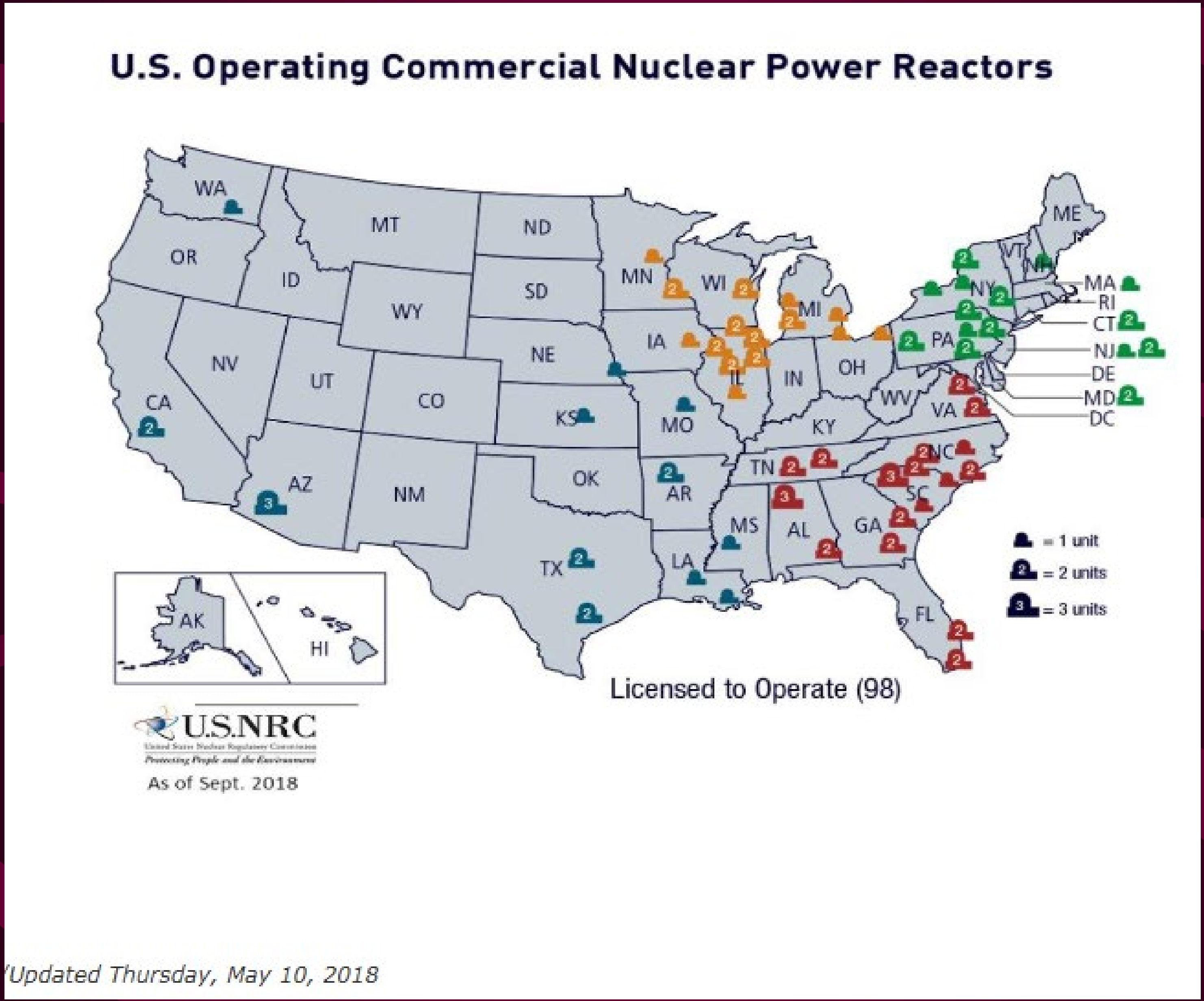
Comments

- None of the uranium mills remain in the Grants region.
- Current plans by some companies are to mine uranium by in situ recovery.
- Any conventional mining of uranium will require shipping to an existing mill in Utah or licensing and building a new mill in New Mexico.
- The Navajo Nation has declared that no uranium production will occur in Indian Country.

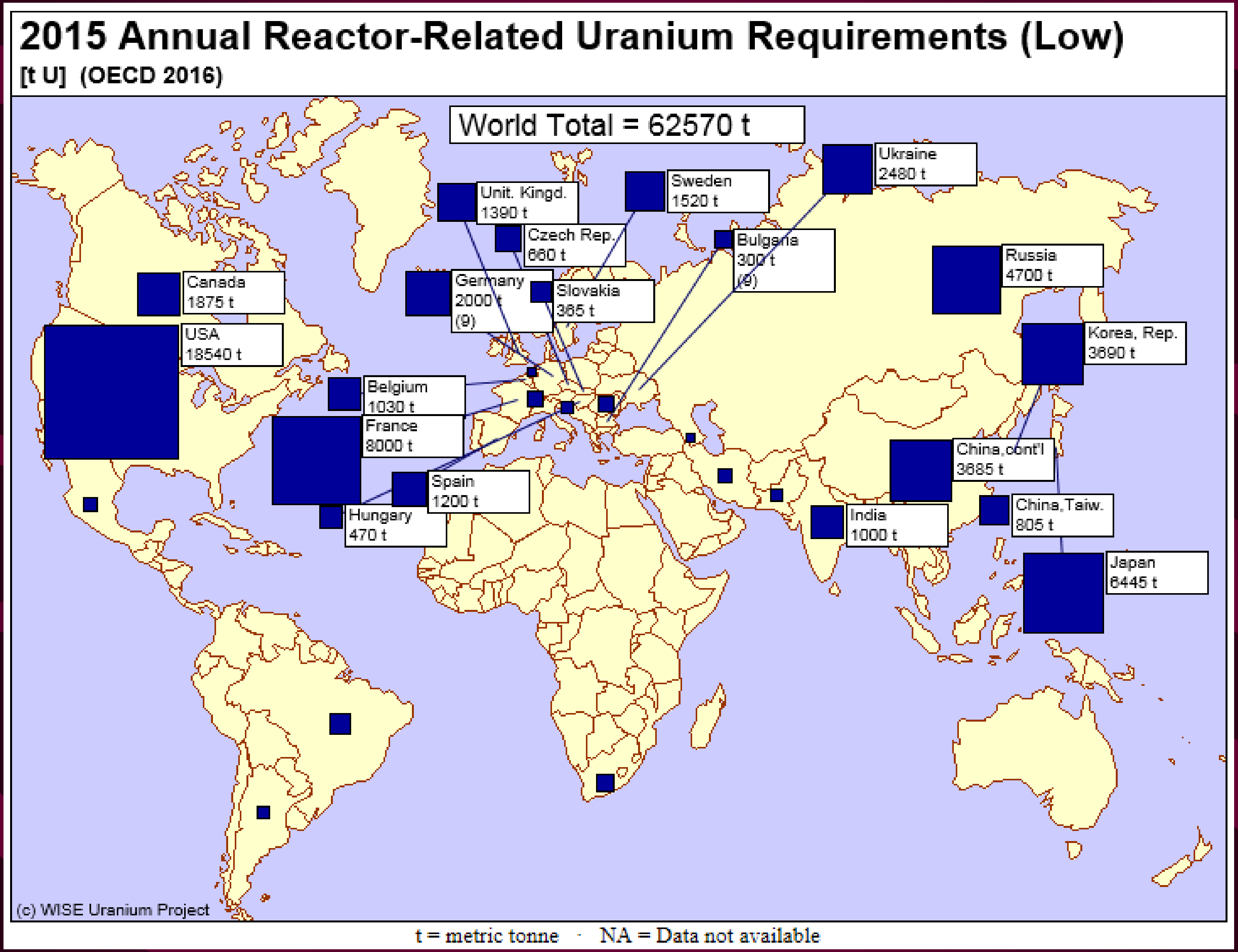
Reasonable economic potential for development

NUCLEAR POWER PLANTS

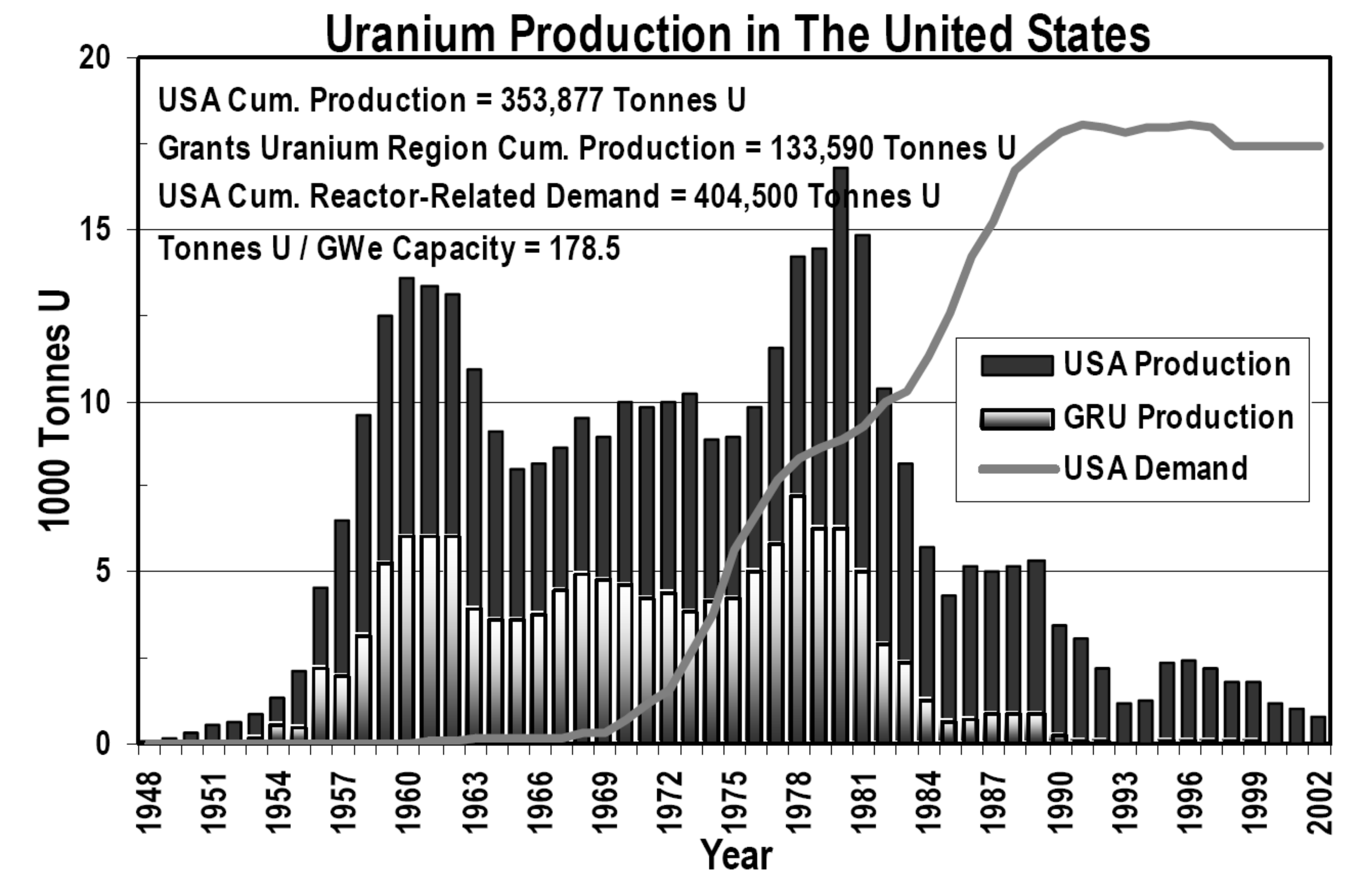
https://www.theguardian.com/environment/interactive/2012/mar/08/nuclear-power-plants-world-map



https://www.nrc.gov/reactors/operating/map-power-reactors.html

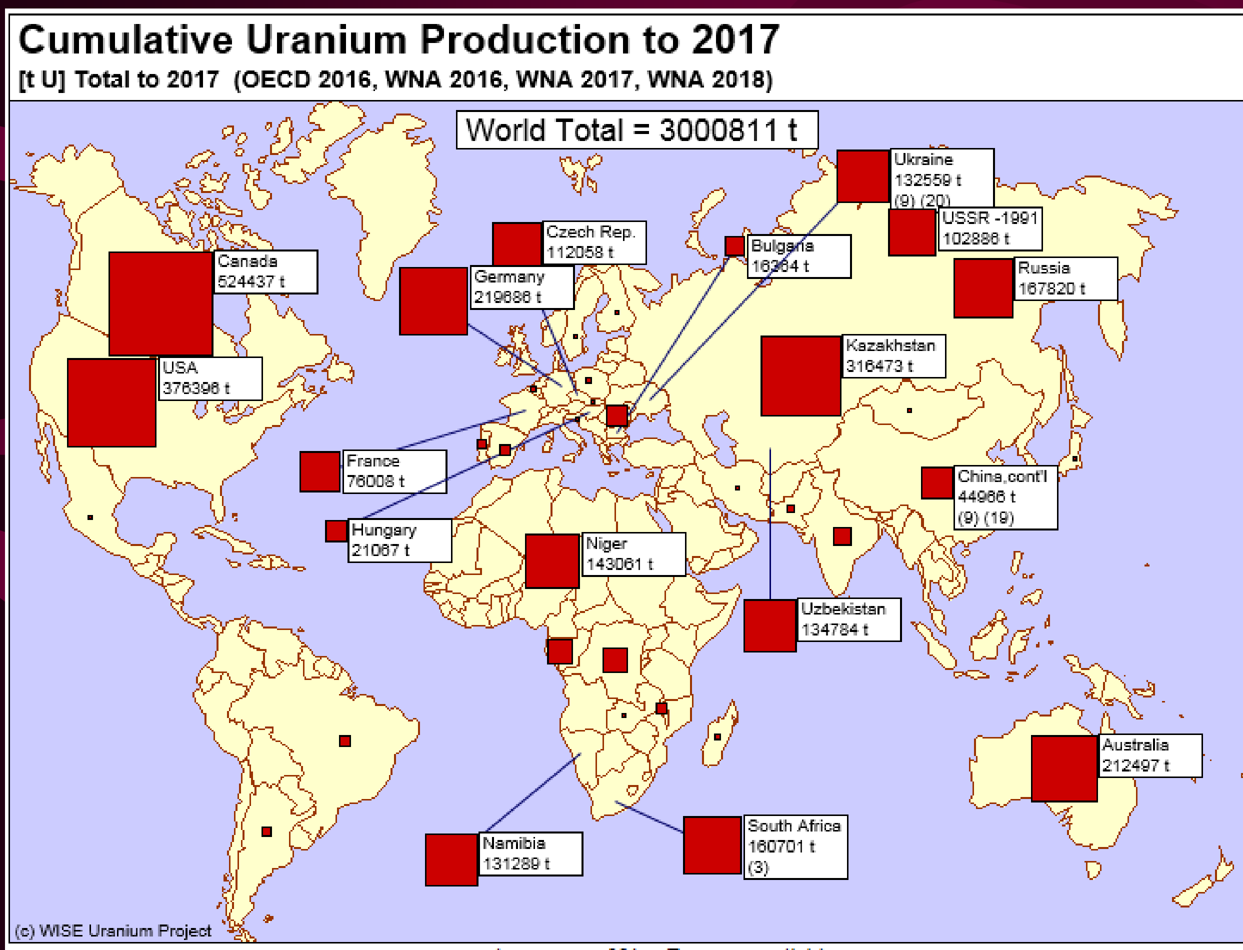


http://www.wise-uranium.org/umaps.html



Pelizza and McCarn (2002)

- Production to 2017
- Canada 524,437 tU
- USA 376,396 tU
- Kazakhstan 316,473 tU



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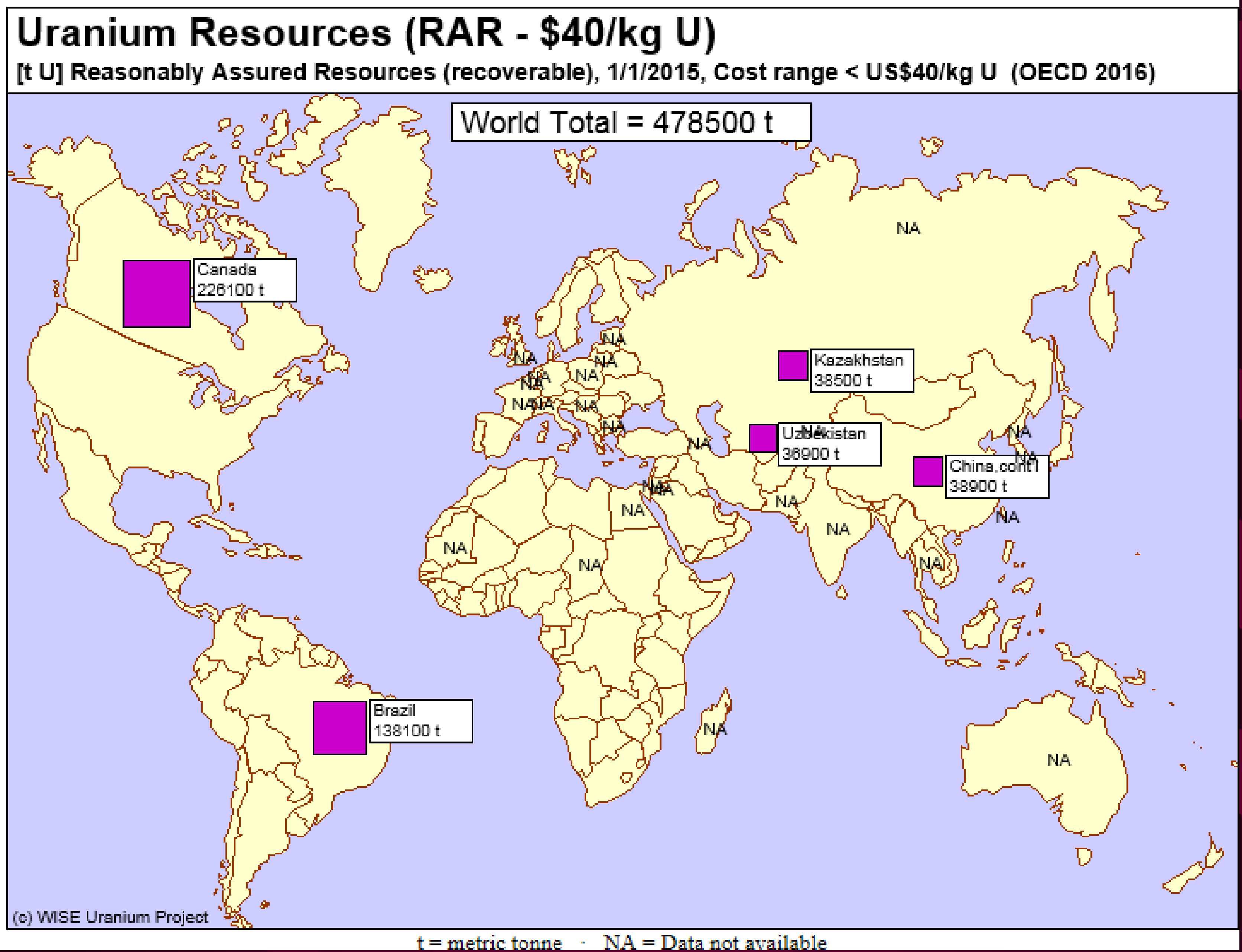

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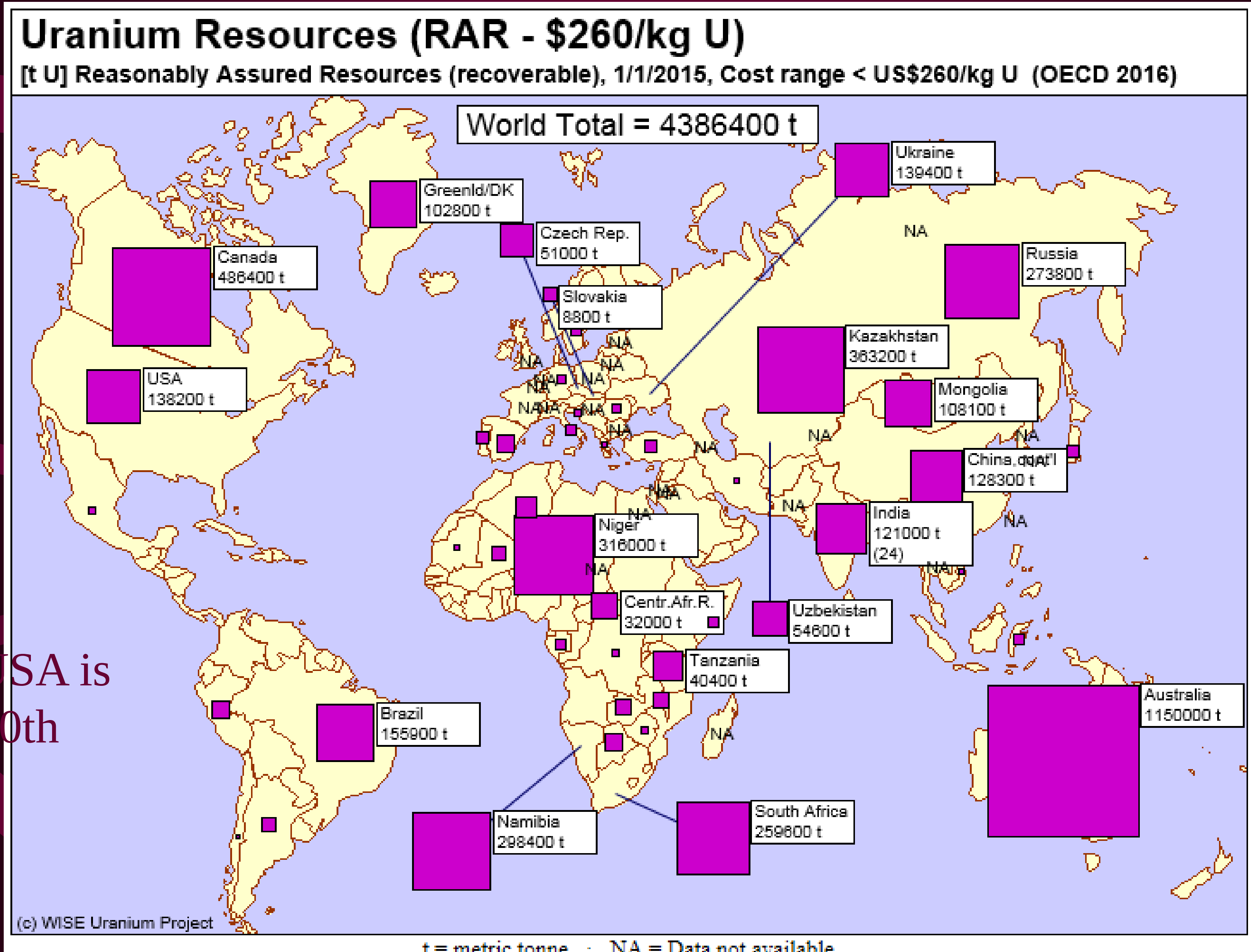
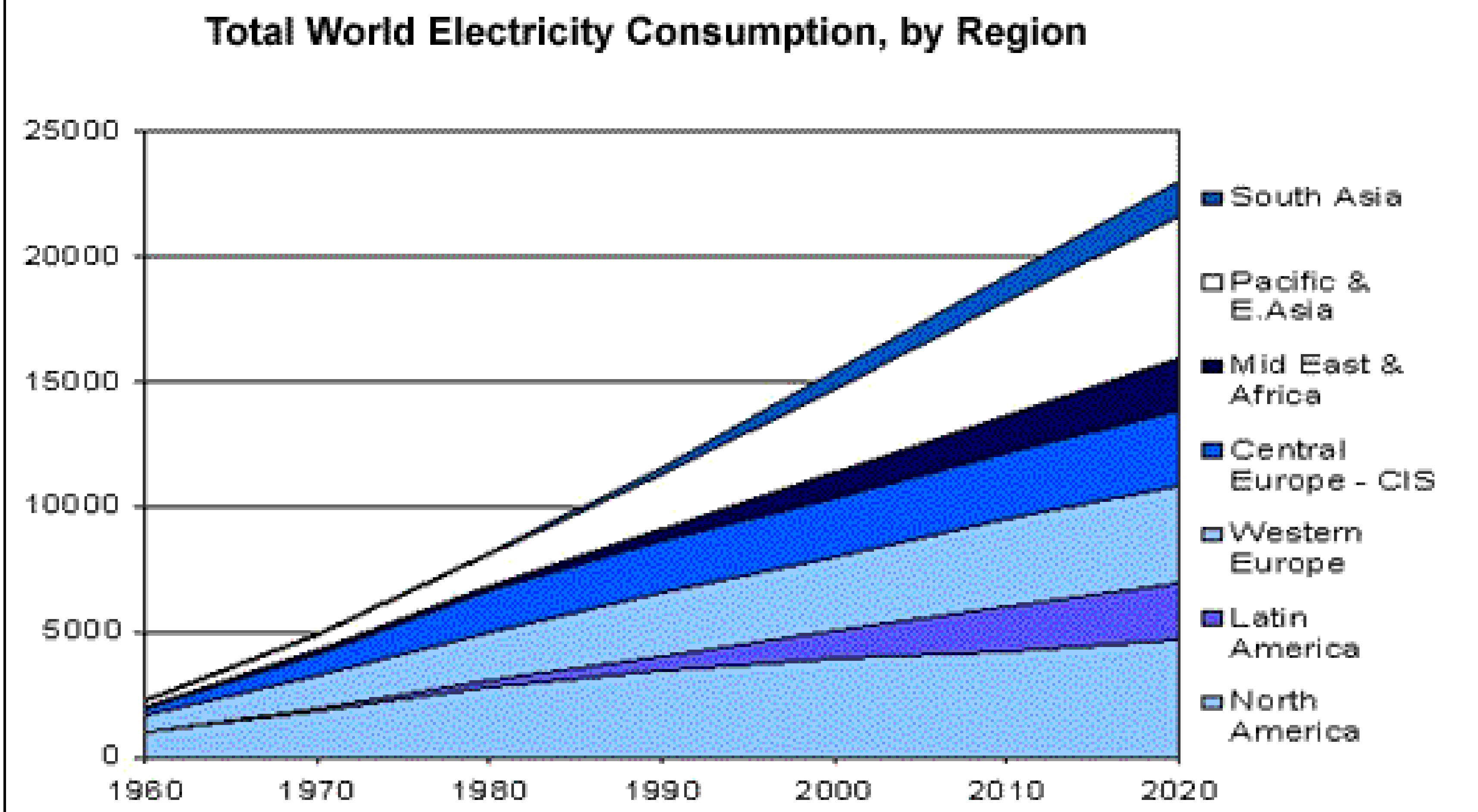


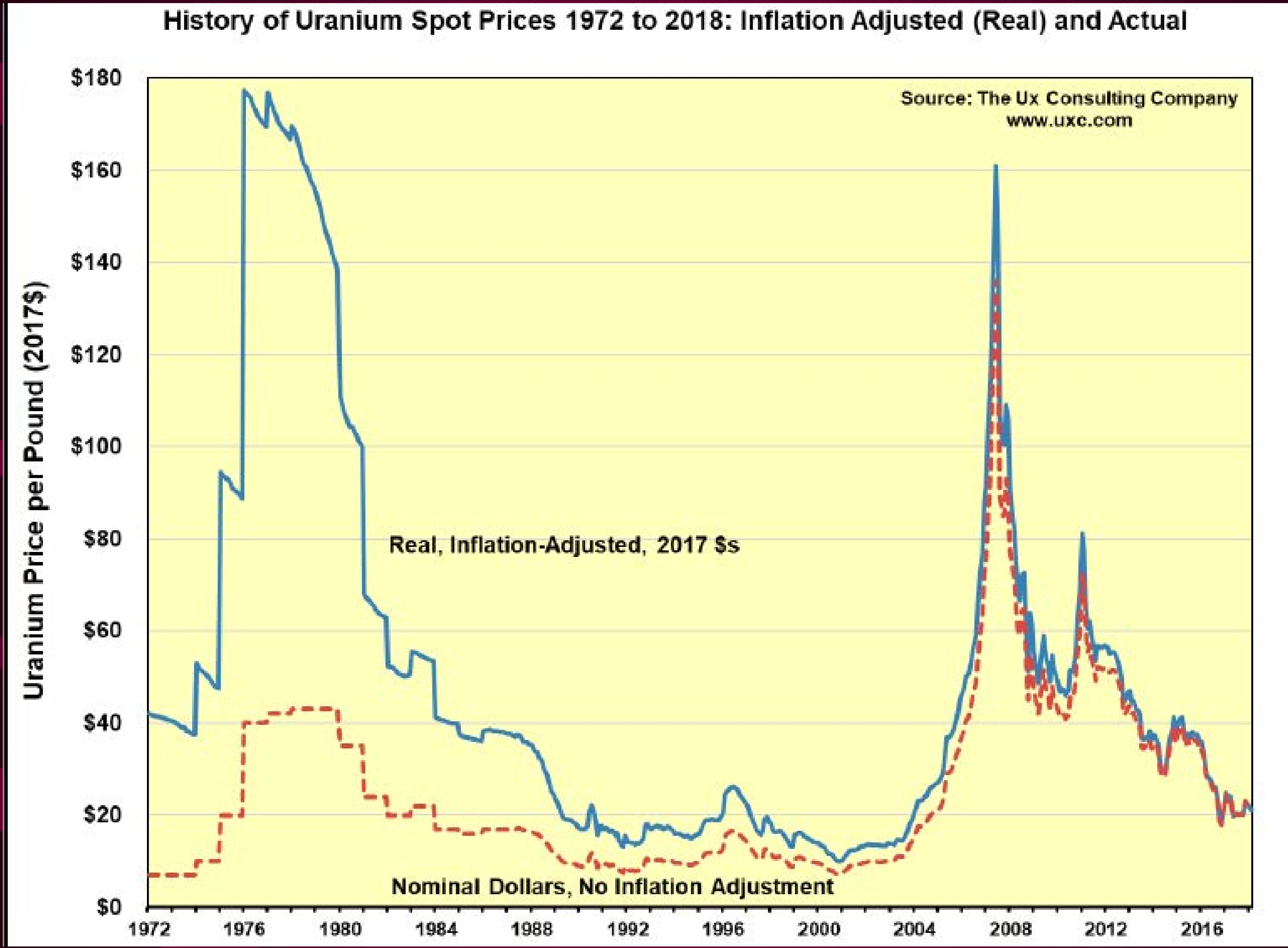
USA is 10th

http://www.wise-uranium.org/umaps.html



Source: World Energy Council 1993. Projection to 2020 is Reference Case (total: 13.4 Gtoe, compared with Modified Reference 16.0 Gtoe. High Growth 17.2 Gtoe and Ecologically-driven 11.3 Gtoe cases

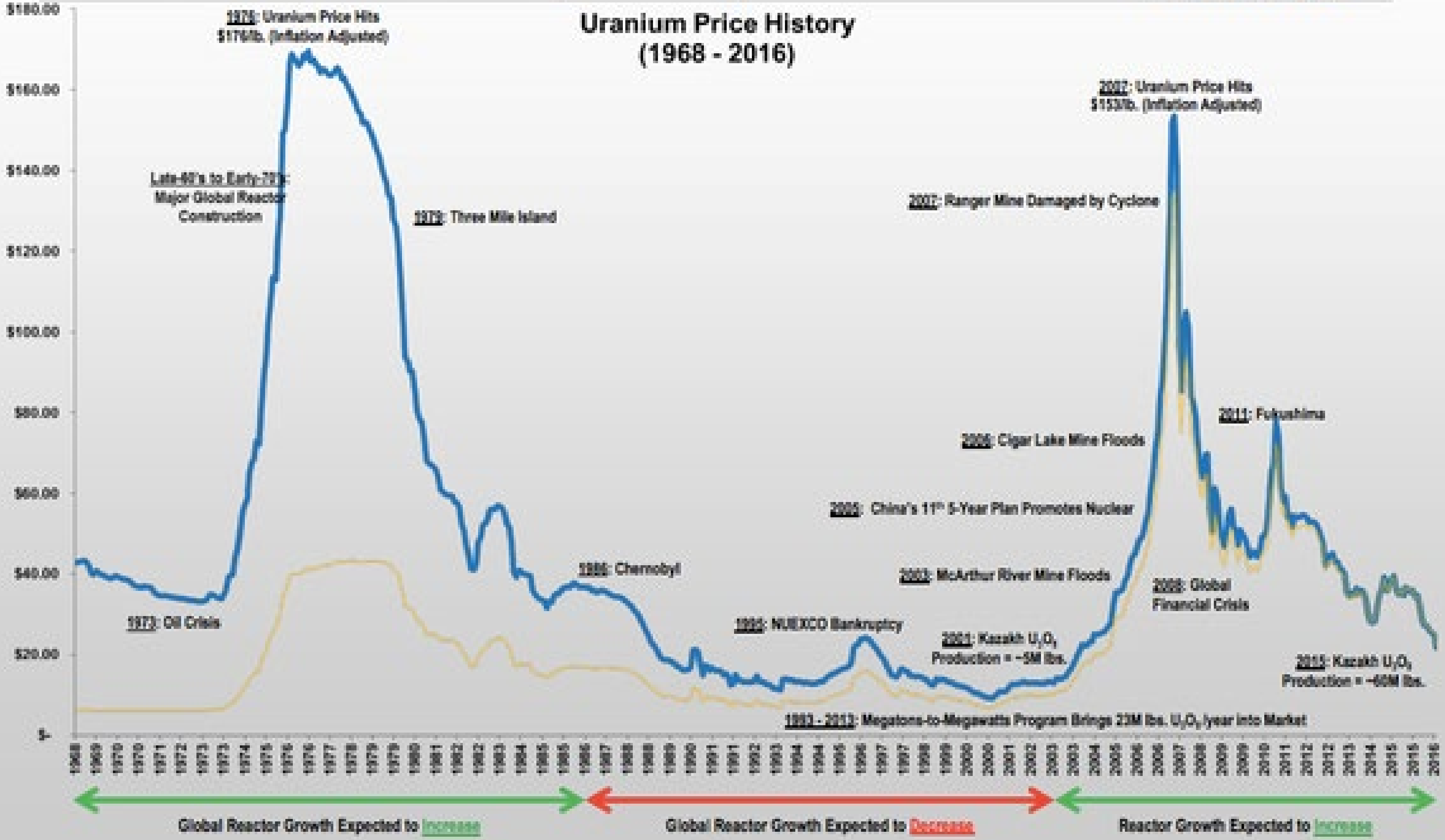
http://www.world-nuclear.org/opinion/opinion6.html



Some analysts suggest uranium prices could exceed $40/lb U_3O_8 by 2020

Uranium Price History

Events & Macroeconomic Factors (1968 – 2016)



Future of Nuclear Power

- Renewable energy is becoming more important throughout the world and is competitive with nuclear energy, because of the subsidies
- But must have a sustainable baseload that does not create CO_2 emissions=nuclear
- Small nuclear reactors could be a game changer
- Thorium reactors could be a game changer
- Assumption that U.S. Navy will continue to operate nuclear power
- Plenty of uranium resources in world

Future of uranium mining in Grants district

- Higher cost reserves than elsewhere in world
- Most Grants deposits must be mined by conventional methods, not in situ recovery, unless the technology changes=requires a mill
- Heap leaching is a possibility, if it could be permitted
- A lot of public opposition to mining in the Grants district

Summary

- Sandstone uranium deposits have played a major role in historical uranium production
- Although other types of uranium deposits are higher in grade and larger in tonnage, sandstone uranium deposits will in the future become a significant player
  - As in-situ leaching technologies improve cutting production costs
  - As demand for uranium increases world-wide increasing the price of uranium
  - Probably in the long-term >10 yrs in NM

FUTURE WORK

- Refine our estimates of uranium resources/reserves potential in the state
- Continue detailed mineralogy studies (XRD and electron microprobe)
- Define the origin of distribution of primary verses redistributed deposits in the San Juan Basin
- Geochemical characteristics of naturally-occurring groundwater that oxidized, remobilized, and redeposited primary tabular uranium deposits in the Grants district
- Study of clay species in the mineralized zones, and their impacts on porosity and permeability characteristics during uranium extraction and mobility