Uranium Recovery Realities in the U.S. – A Review

Another Report by the AAPG EMD Uranium Committee

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Presentation Coverage

- ❖ In this presentation, we will be covering a range of topics involving nuclear power. They range from the pros & cons of nuclear power to public concerns, and to exploration, development and production practices and anticipated yellowcake prices.

- ❖ We will discuss past and current uranium recovery methods, such as typical in-situ recovery systems practiced in Wyoming and Texas, have a look at typical well-field layouts, drilling, sampling and geophysical logging, both with the old standard logging methods and the new PFN method, which makes radiological equilibrium studies much easier to do these days than in the past. We also will look at the typical designs of processing plants to produce yellowcake.

- ❖ We will then discuss the typical concerns still expressed by many anti-nuclear groups and by the media serving them, including:

    - various unrealistic expectations they hold,
    - various forms of mis-information they believe, and
    - various half-truths they circulate.

- ❖ With the above as background, we'll summarize current conditions and our expectations on the energy picture over the next 30 years, specifically to generate electricity in the U.S., in terms of both small- and large-scale nuclear plants, and in terms of the future source of nuclear fuel (yellowcake) produced in the U.S. and overseas, and perhaps even from the Moon in the foreseeable future.

Nuclear Power for Electrical Generation Pros and Cons

- **Pros**
  - Excellent for use as base-load electrical generation.
  - Minimal greenhouse-gas emissions during production of electricity to replace coal.
  - Plants very inexpensive to operate (to boil water) in generating electricity.
  - Fuel costs are the lowest of all forms of fuels used to generate electricity.
  - New designs are more efficient with even greater number of safety features.
- **Cons**
  - Expensive to build, amongst the highest of all forms of electrical generation plants, although this expense tends to be offset by the inexpensive fuel costs.
  - Creates high-level waste that must be managed, although high-level waste is a resource that can be reprocessed and storage alternatives are available, and
  - Many Americans are of the opinion that if the U.S. stops using nuclear power, the rest of the world will follow, although the rest of the world is going to expand nuclear use regardless what the U.S. does.

Nuclear Concerns: Safety & Waste Handling

- **Safety**

  Power plants can not explode or melt down.
  - They can not undergo nuclear explosions.
  - Newer plants can operate at lower temperatures, further reducing safety issues.

  Plants have had zero fatalities, except for small Idaho military reactor accident in the 1950's.
  No serious accidents since Three Mile Island incident.
  - Three Mile Island never had a meltdown.
  - Three Mile Island incident resulted in burns to maintenance personnel (burns from hot water) and only minor release of krypton gas to the environment.
  - Chernobyl accident was a bad reactor design operated with poor management; For actual impact, see Cravens and Rhodes (2007), Brand (2009), and IAEA (2004).

  Terrorism (Domestic or Overseas)
  - Built to withstand direct hits from large airplanes and from external explosive devices.

- **Waste Disposal or Storage & Use?**
  - Total high-level waste produced since the 1950's would fill a football field 14 feet deep.
  - Waste stored at 104 plants in the U.S. would occupy a football field 13 barrels high.
  - The Obama administration has withdrawn Yucca Mountain from consideration as a waste disposal site with no proposal for other means of storage, at present. The matter is a political problem, not a technical issue. WIPP Site in New Mexico is suitable and available for high-level waste storage in the existing salt storage caverns.

  Reprocess spent fuel:
  - Only 5% of fissionable material is consumed. Reprocessing of waste would extend current uranium supplies & reduce waste volume.
  - New plant designs burn uranium more efficiently w/Be & Th, thereby reducing waste.

Nuclear Concerns Treated by News Media

- Billions of dollars in subsidies needed for all alternate-energy resources.
- Biodiesel is subsidized $1.00 per gallon.
- Concerns raised even in light of improved public support. In an a recent Reuters article:

“According to a recent survey, 73% of Americans say that it would be "acceptable to build a new reactor within 100 miles of their home." Of course, build it closer, and support erodes rather quickly. Still, with a pro-nuclear U.S. Energy Secretary, and a growing realization that renewable energy is going to struggle in today's energy market. "Aspirations for lower-carbon, or zero-carbon electricity, are unattainable without nuclear in the mix," says global generation expert, Daniel Kruger.

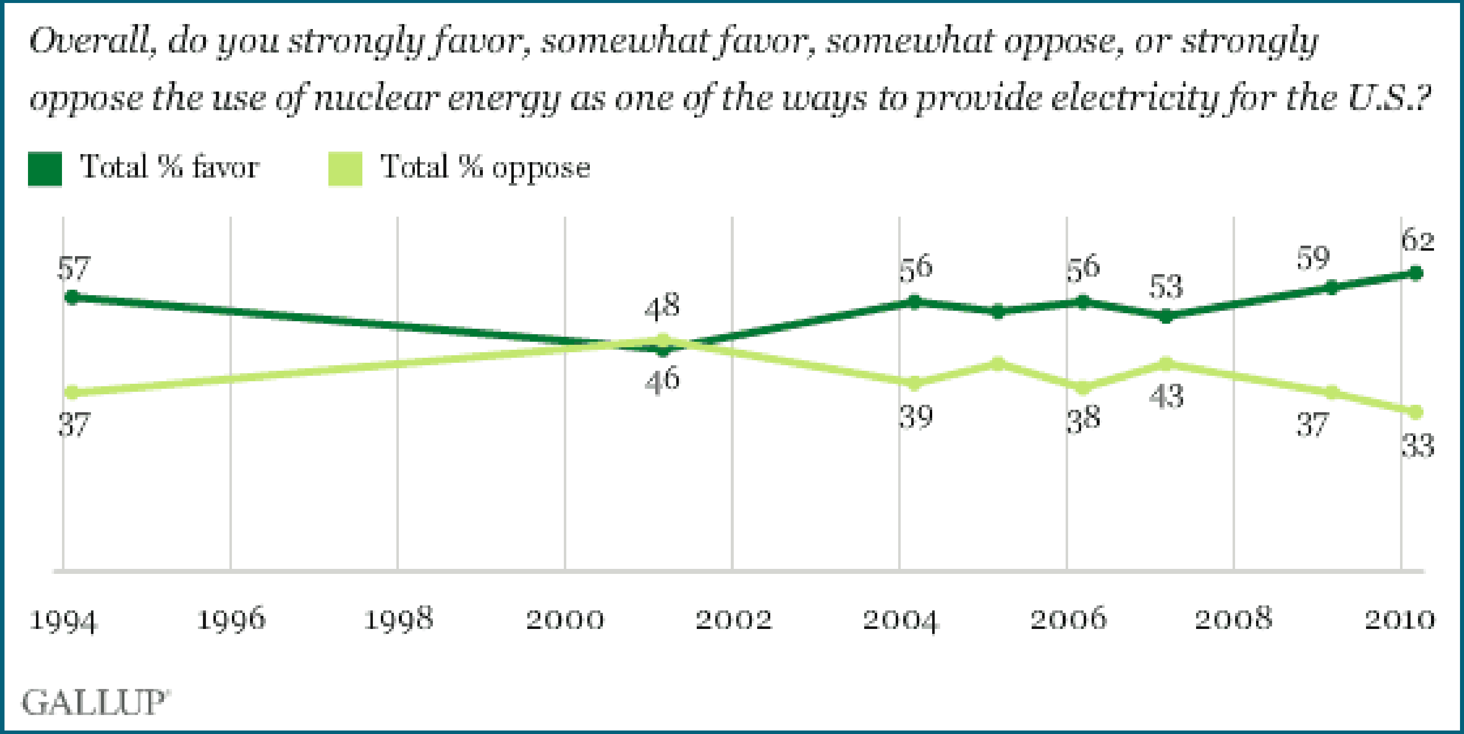
Right now, there are 104 nuclear power plants in the US, which pump out about 20% of the nation's electricity. Obviously, adding another 33 could make huge gains in terms of greenhouse emissions, but are we really ready to confront the disposal of radioactive waste?”

- ✓ There are also studies that demonstrate that those who know the most about nuclear power are more in favor of it as well as studies that show that the closer someone lives to a nuclear reactor the more likely that they will be in favor of nuclear energy, see: MIT (2009)

- ✓ So who says we have to dispose of waste when it could be stored and used one day as a source of nuclear fuel? See recent news items concerning re-processing (Here).

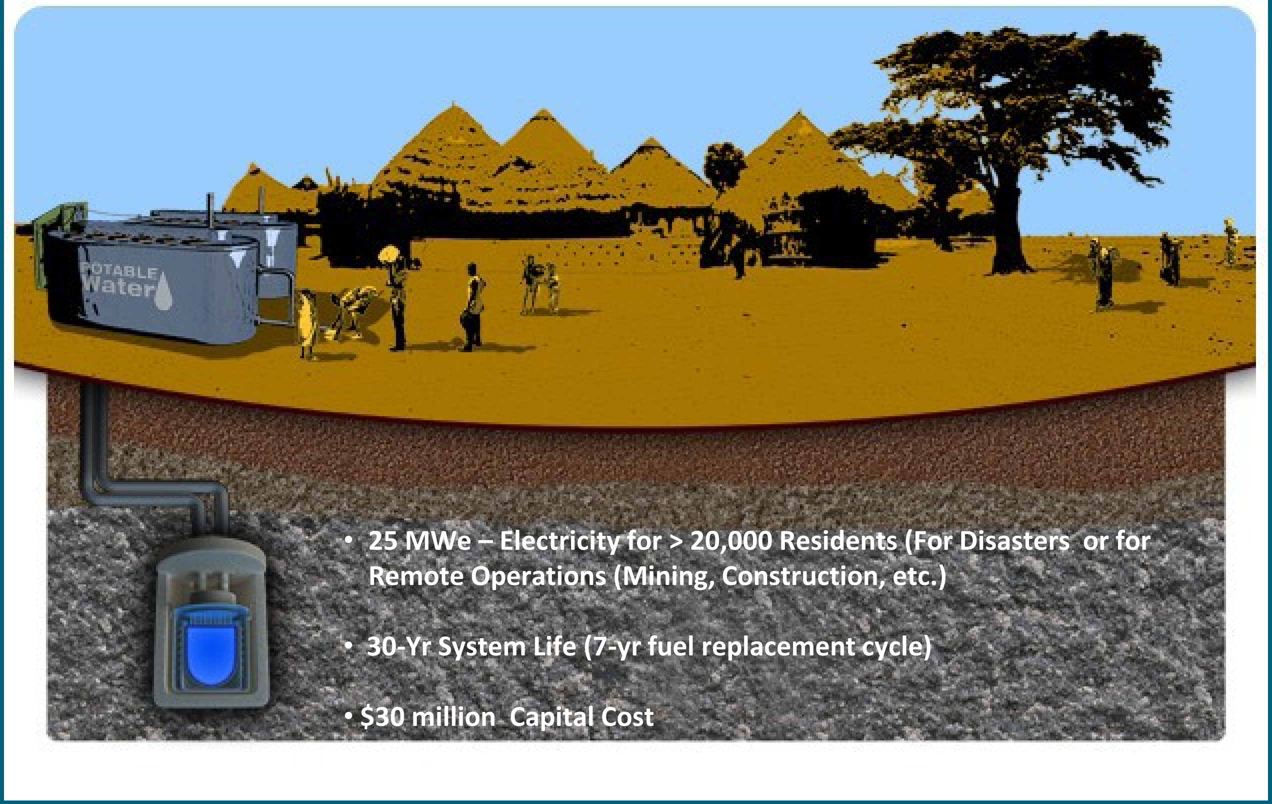
Nuclear Concerns Diminish

Nuclear power continues its rise in popularity. Jones (2010) of Gallup reported that Americans' support for nuclear power has increased to 62%, establishing a new high (see graph below).



Small-Scale Nuclear Plants

Bill Gates has recently endorsed using small-scale nuclear power plants (25,000 MW Units or less), called "nuclear batteries," for cities after disasters such hurricanes or other weather phenomena. Also for use in small communities in remote locations (both on Earth and off-world). Both Terra Power and Hyperion Power are building such units at present.



Courtesy of Hyperion Power Generation, Inc.

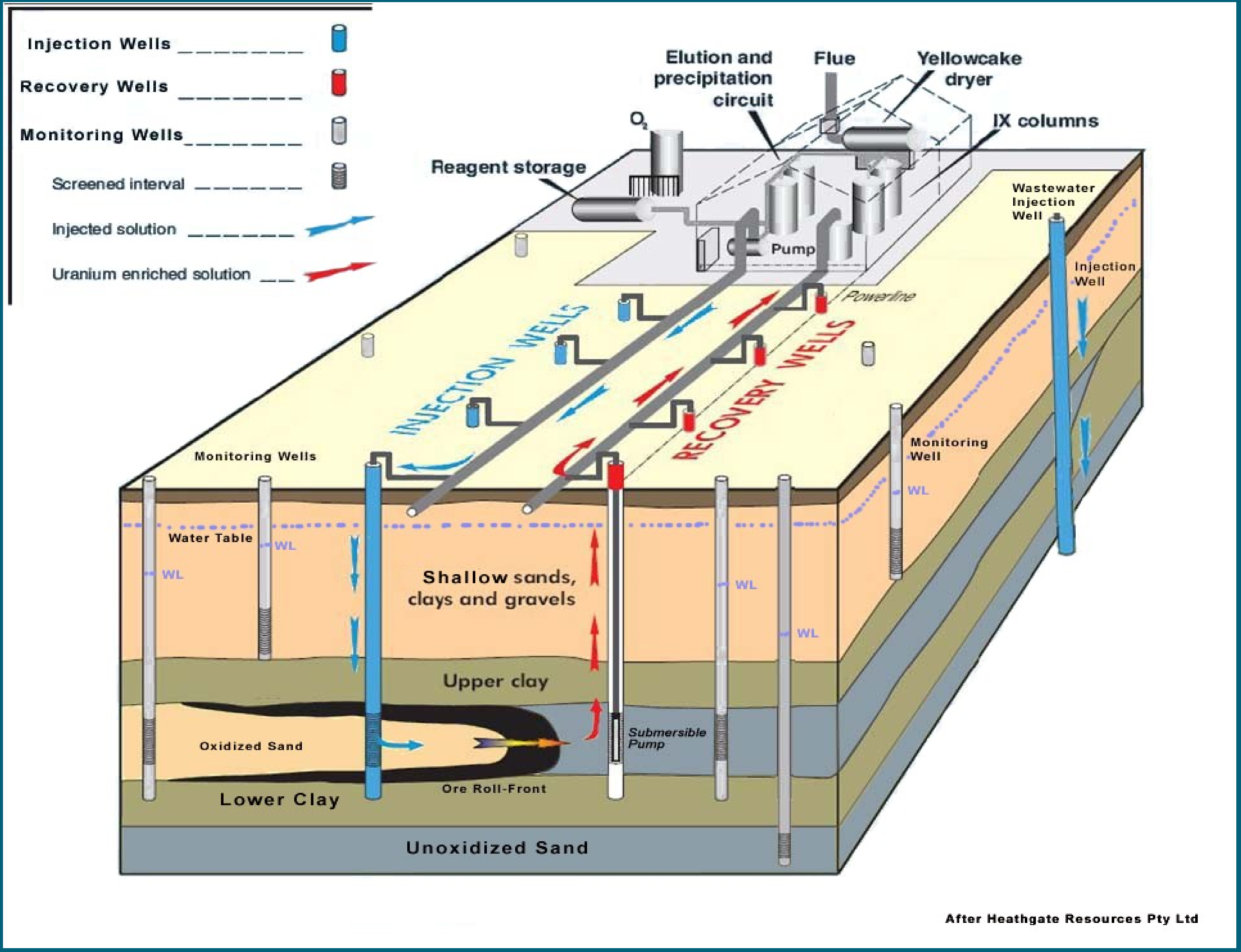
Uranium Recovery Techniques: Past & Present

- **Underground**
  - Problems with radiation exposure to miners who smoke tobacco, etc.
  - What to do with tailings from the old mines? Environmental remediation?
  - Prior to the environmental movement there were insufficient regulations to address health, safety, closure, and remediation concerns.

- **Open Pit Mining of the Past**
  - Fewer problems with radiation exposure to miners
  - Left the ground surface disturbed because of a lack of effective closure.
  - There were insufficient regulations to address health, safety, closure, and remediation concerns during the 1970's and 80's.

- **In-situ Uranium Recovery**
  - Radiation exposure to plant workers very low.
  - No tailings or surface pits to manage.
  - Ground-water remediation of conditions within the original mineralized zone prior to mining required after production is complete, usually about 5 to 7 years of additional operations. This does not involve restoration to regional water-quality levels.

In-Situ Recovery – Typical System, from Extraction to Recovery



In-Situ Recovery – Wyoming Processing

Current Uranium Exploration Operations in Texas: Drill Spacing

Goranson (2008)

Current Uranium Exploration Operations in Texas: Drilling Samples

Goranson (2009)

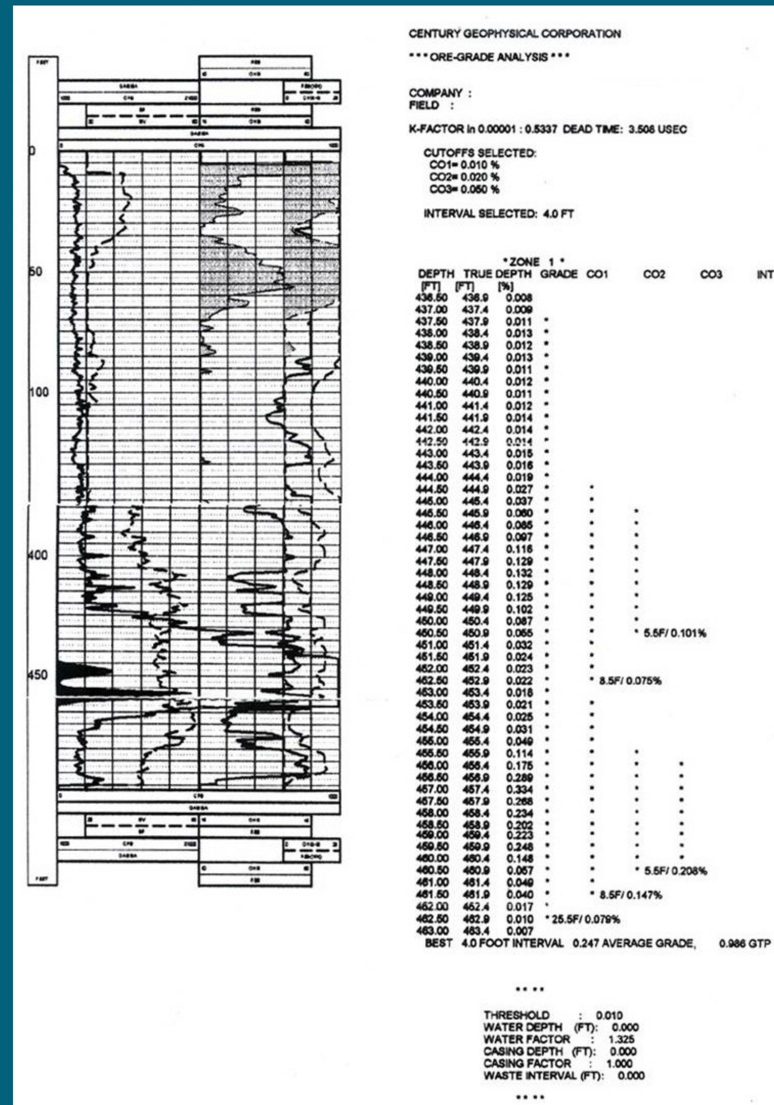
Oxidation, Reduction & Re-Reduction of Sediments

Current Uranium Exploration Operations in Texas: Geophysical Well Logging

- Geophysical logging is conducted soon after drilling to avoid hole caving.
- Once logging is complete, the drill hole is abandoned by filling with cement, installed from bottom to top.

Goranson (2009)

Current Uranium Recovery Operations in Texas: Typical Well Log



CENTURY GEOPHYSICAL CORPORATION

*** ORE-GRADE ANALYSIS ***

COMPANY :
FIELD :

K-FACTOR In 0.00001 : 0.5337 DEAD TIME: 3.508 USEC

CUTOFFS SELECTED:
CO1= 0.010 %
CO2= 0.020 %
CO3= 0.050 %

INTERVAL SELECTED: 4.0 FT

* ZONE 1 *

DEPTH [FT]	TRUE DEPTH [FT]	GRADE [%]	CO1	CO2	CO3	INT
436.50	436.9	0.008				
437.00	437.4	0.009				
437.50	437.9	0.011	*			
438.00	438.4	0.013	*			
438.50	438.9	0.012	*			
439.00	439.4	0.013	*			
439.50	439.9	0.011	*			
440.00	440.4	0.012	*			
440.50	440.9	0.011	*			
441.00	441.4	0.012	*			
441.50	441.9	0.014	*			
442.00	442.4	0.014	*			
442.50	442.9	0.014	*			
443.00	443.4	0.015	*			
443.50	443.9	0.016	*			
444.00	444.4	0.019	*			
444.50	444.9	0.027	*	*		
445.00	445.4	0.037	*	*		
445.50	445.9	0.060	*	*	*	
446.00	446.4	0.085	*	*	*	
446.50	446.9	0.097	*	*	*	
447.00	447.4	0.116	*	*	*	
447.50	447.9	0.129	*	*	*	
448.00	448.4	0.132	*	*	*	
448.50	448.9	0.129	*	*	*	
449.00	449.4	0.125	*	*	*	
449.50	449.9	0.102	*	*	*	
450.00	450.4	0.087	*	*	*	
450.50	450.9	0.065	*	*	* 5.5F/ 0.101%	
451.00	451.4	0.032	*	*		
451.50	451.9	0.024	*	*		
452.00	452.4	0.023	*	*		
452.50	452.9	0.022	*	* 8.5F/ 0.075%		
453.00	453.4	0.018	*			
453.50	453.9	0.021	*	*		
454.00	454.4	0.025	*	*		
454.50	454.9	0.031	*	*		
455.00	455.4	0.049	*	*		
455.50	455.9	0.114	*	*	*	
456.00	456.4	0.175	*	*	*	*
456.50	456.9	0.289	*	*	*	*
457.00	457.4	0.334	*	*	*	*
457.50	457.9	0.268	*	*	*	*
458.00	458.4	0.234	*	*	*	*
458.50	458.9	0.202	*	*	*	*
459.00	459.4	0.223	*	*	*	*
459.50	459.9	0.248	*	*	*	*
460.00	460.4	0.148	*	*	*	*
460.50	460.9	0.067	*	*	* 5.5F/ 0.208%	
461.00	461.4	0.049	*	*		
461.50	461.9	0.040	*	* 8.5F/ 0.147%		
462.00	462.4	0.017	*			
462.50	462.9	0.010	* 25.5F/ 0.079%			
463.00	463.4	0.007				

BEST 4.0 FOOT INTERVAL 0.247 AVERAGE GRADE, 0.986 GTP

** **

THRESHOLD : 0.010
WATER DEPTH (FT): 0.000
WATER FACTOR : 1.325
CASING DEPTH (FT): 0.000
CASING FACTOR : 1.000
WASTE INTERVAL (FT): 0.000

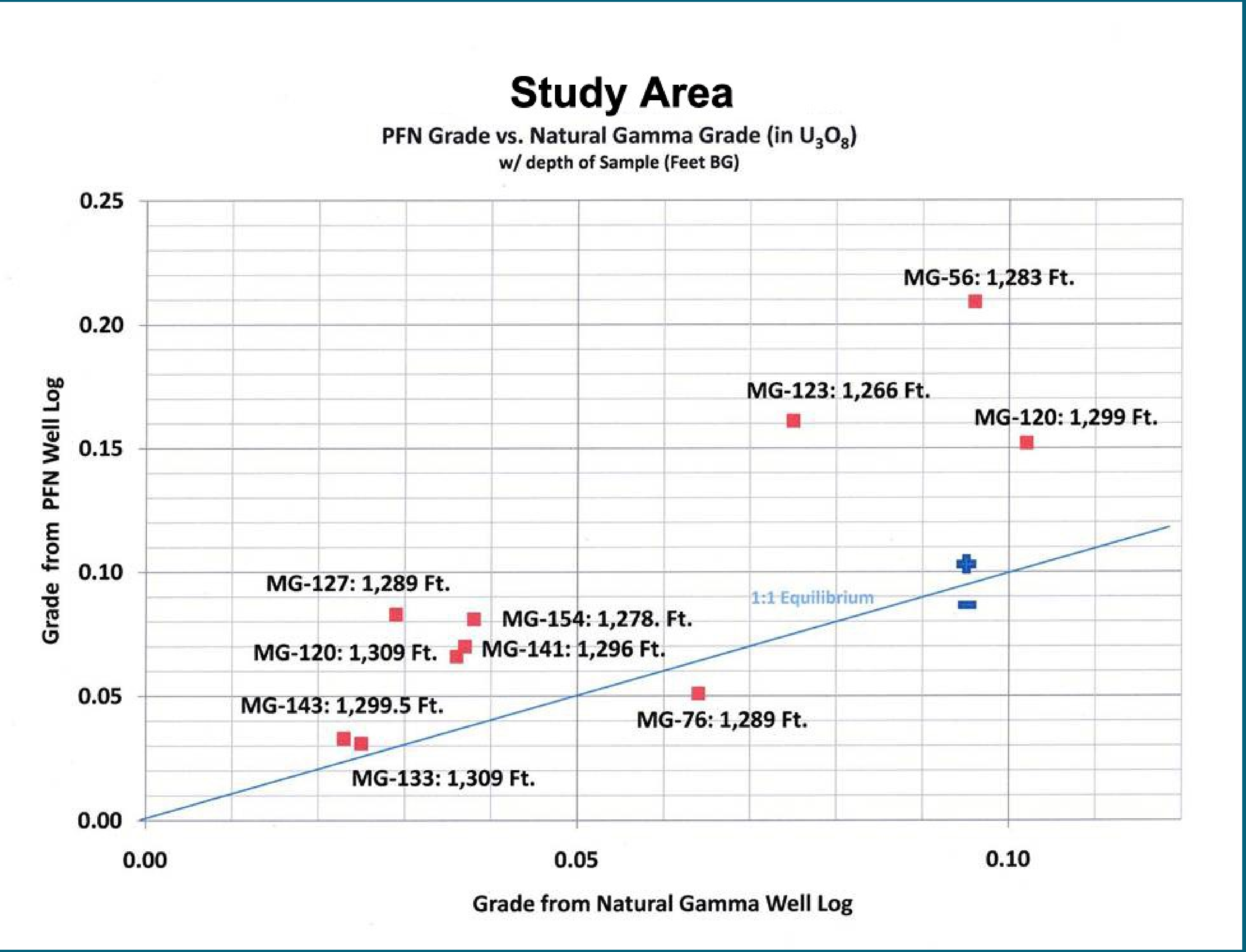
** **

Log vs. Lab

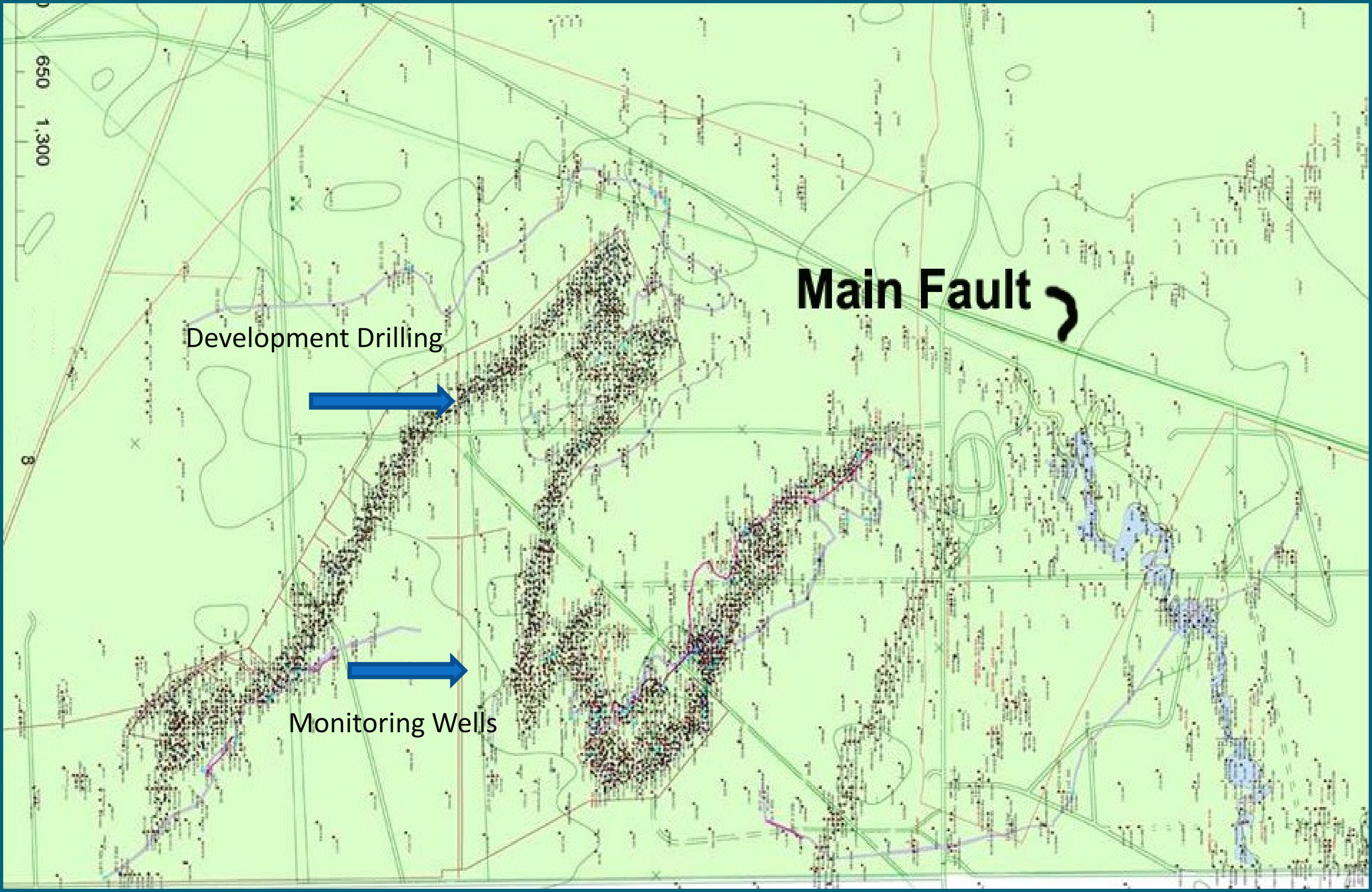
$_{e}U_3O_8$ vs. $_{c}U_3O_8$

The Prompt Fission Neutron (PFN) logging tool overcomes the problem of determining disequilibrium by directly measuring the ^{235}U in the ore zone.

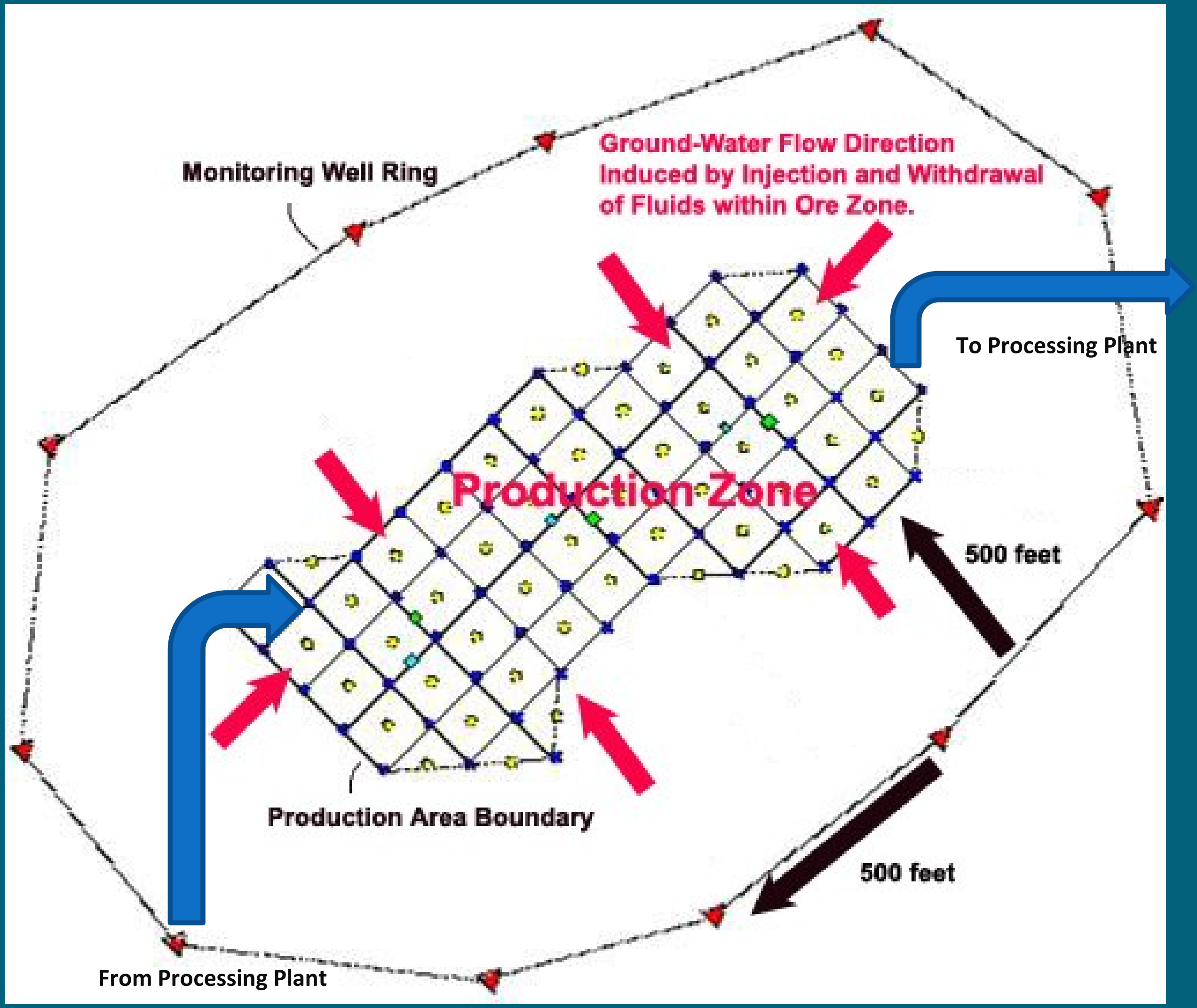
Typical Equilibrium Studies on Uranium Ore in Texas



In-Situ Recovery – Production Trend - Texas



In-Situ Recovery – Wyoming Processing



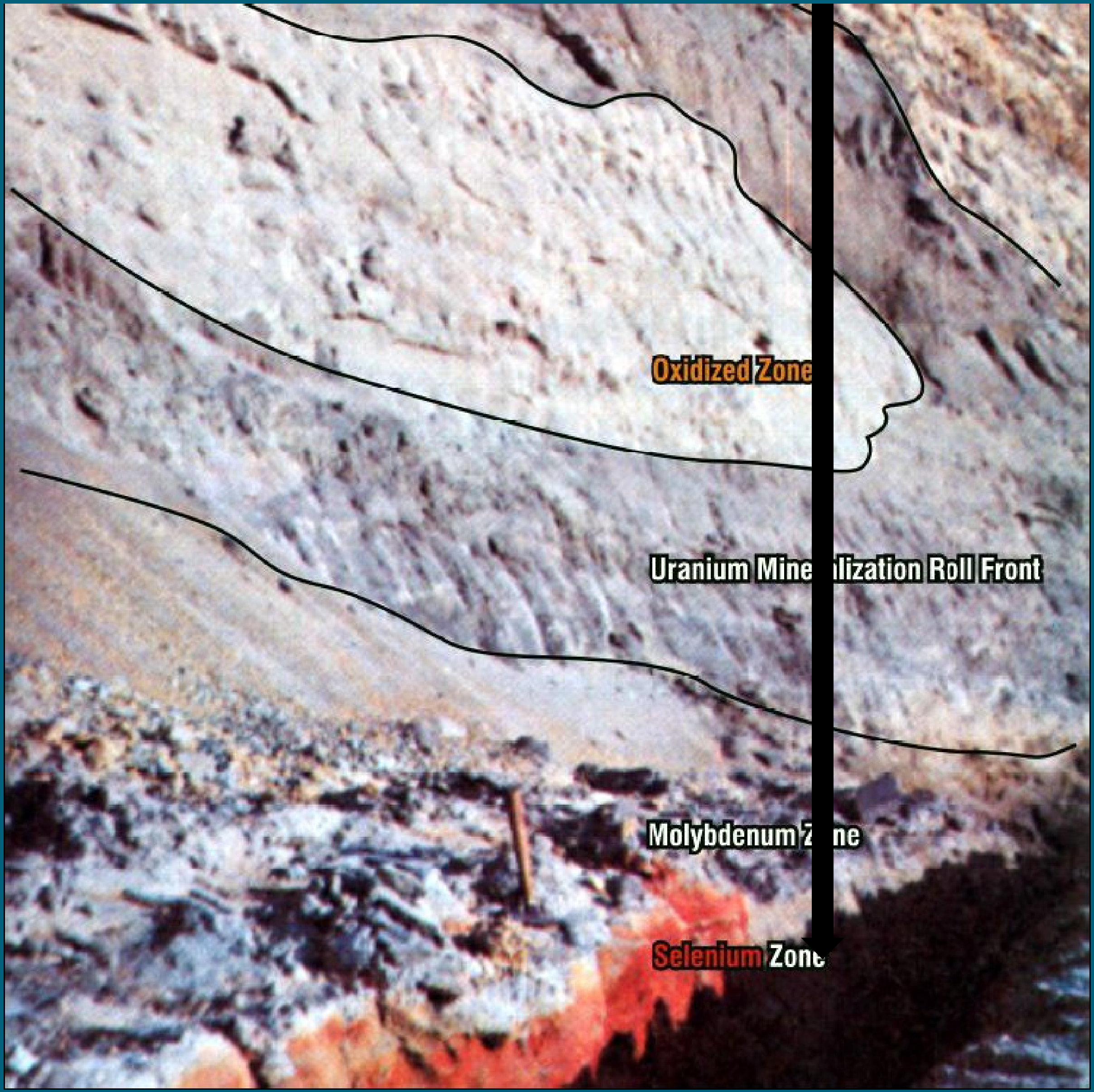
- Ground-water flow is controlled to avoid excursions out of the production zone.
- Once production has been completed, de-oxygenated ground water will be pH-adjusted, and recirculated to precipitate and immobilize indigenous metals.
- Surrounding monitoring wells serve as sentinels as proof that fluids are not escaping from the production zone.

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

After Dickinson & Dual (1977)

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

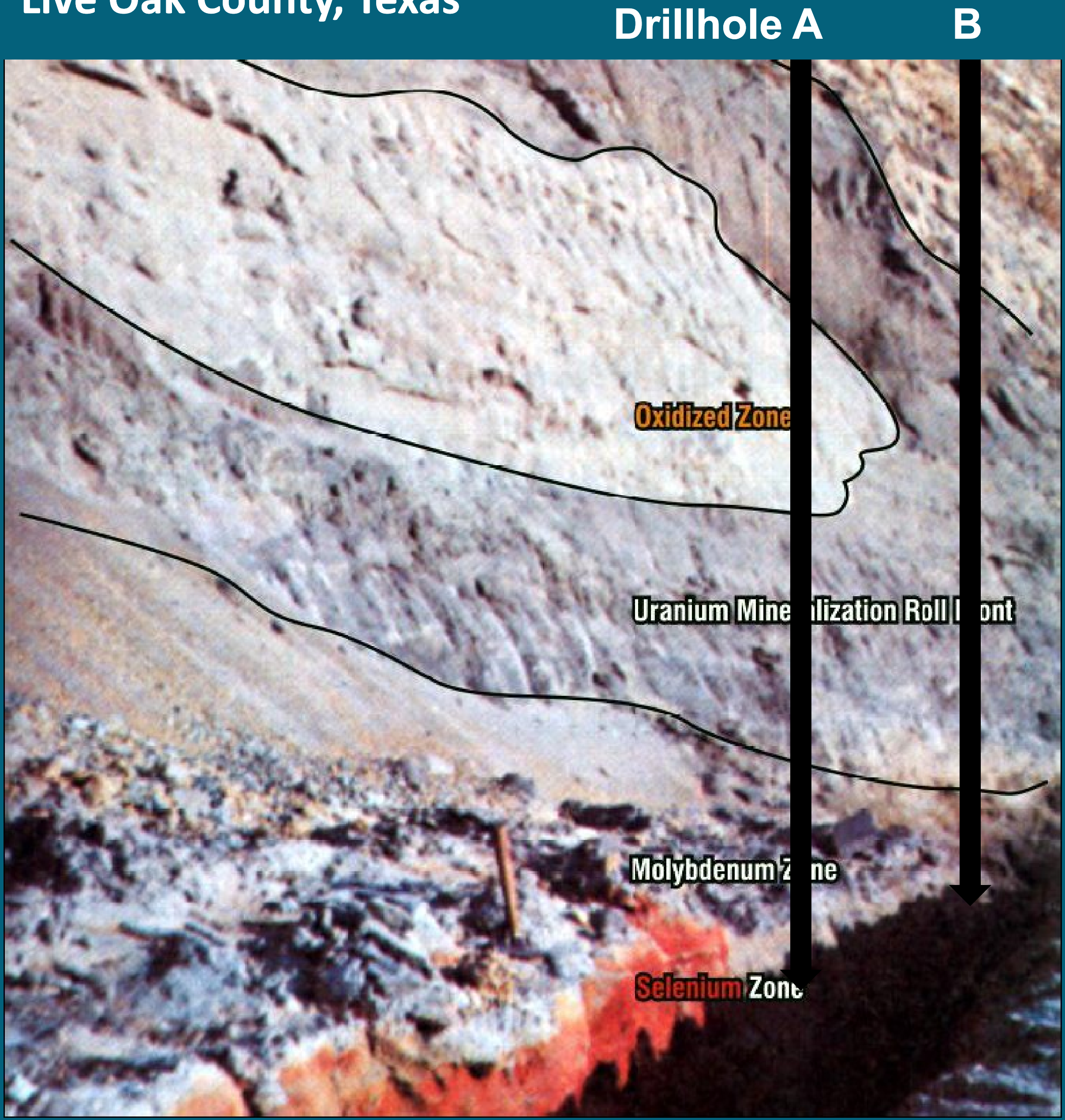
Drillhole A



Hole A is drilled, followed by Hole B.

After Dickinson & Dual (1977)

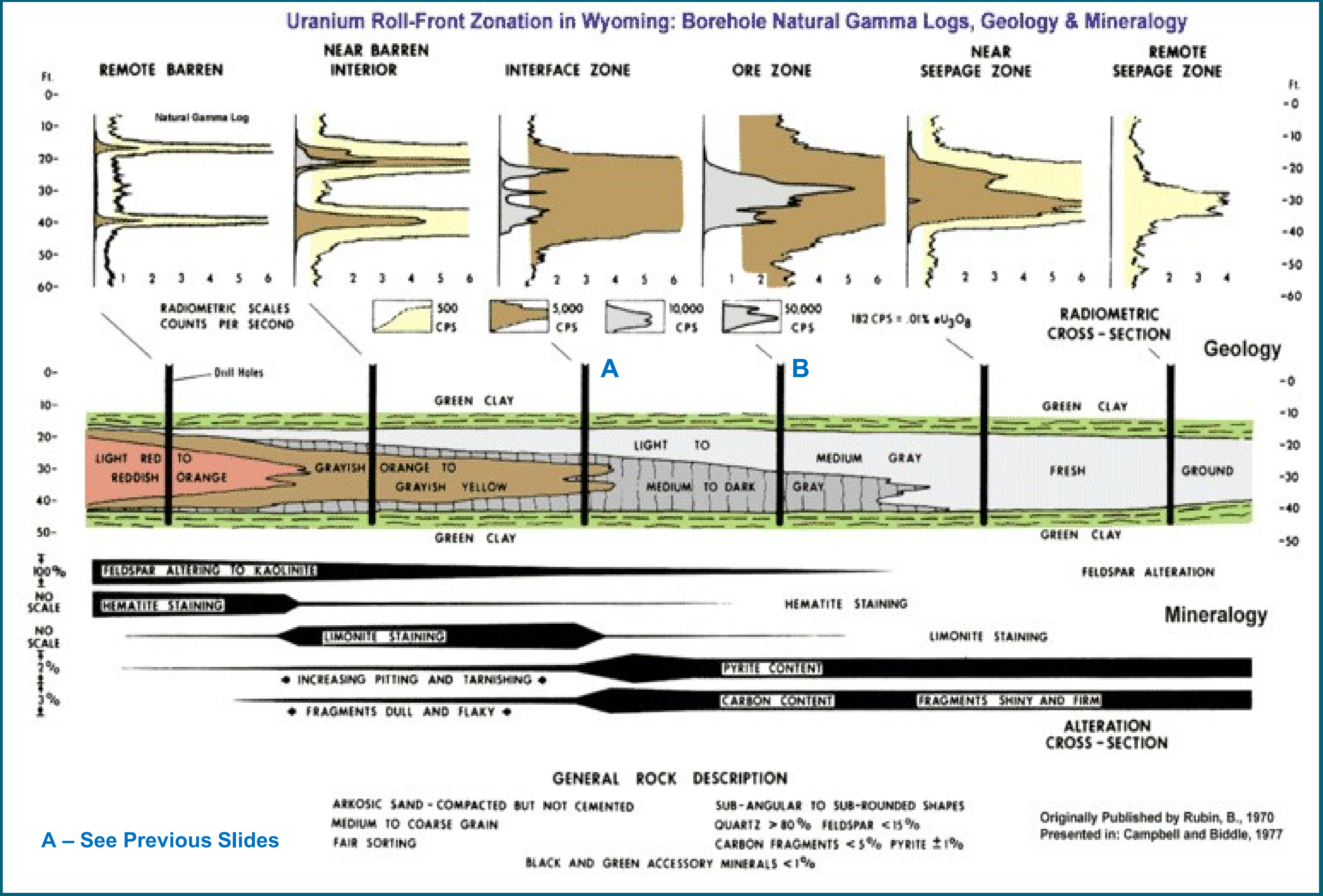
Roll-Front Ore Zone within Oakville Sandstone in an Open Pit Mine Live Oak County, Texas



See Following Slide for location of Drillholes in the Rubin Roll-Front Model.

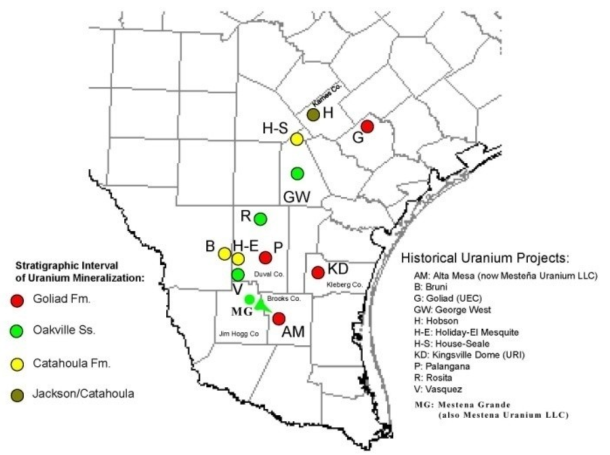
After Dickinson & Dual (1977)

Geophysical, Mineralogical, Geological Relationships in Wyoming Roll Fronts



A – See Previous Slides

Historical & Current Uranium Exploration & Recovery Operations

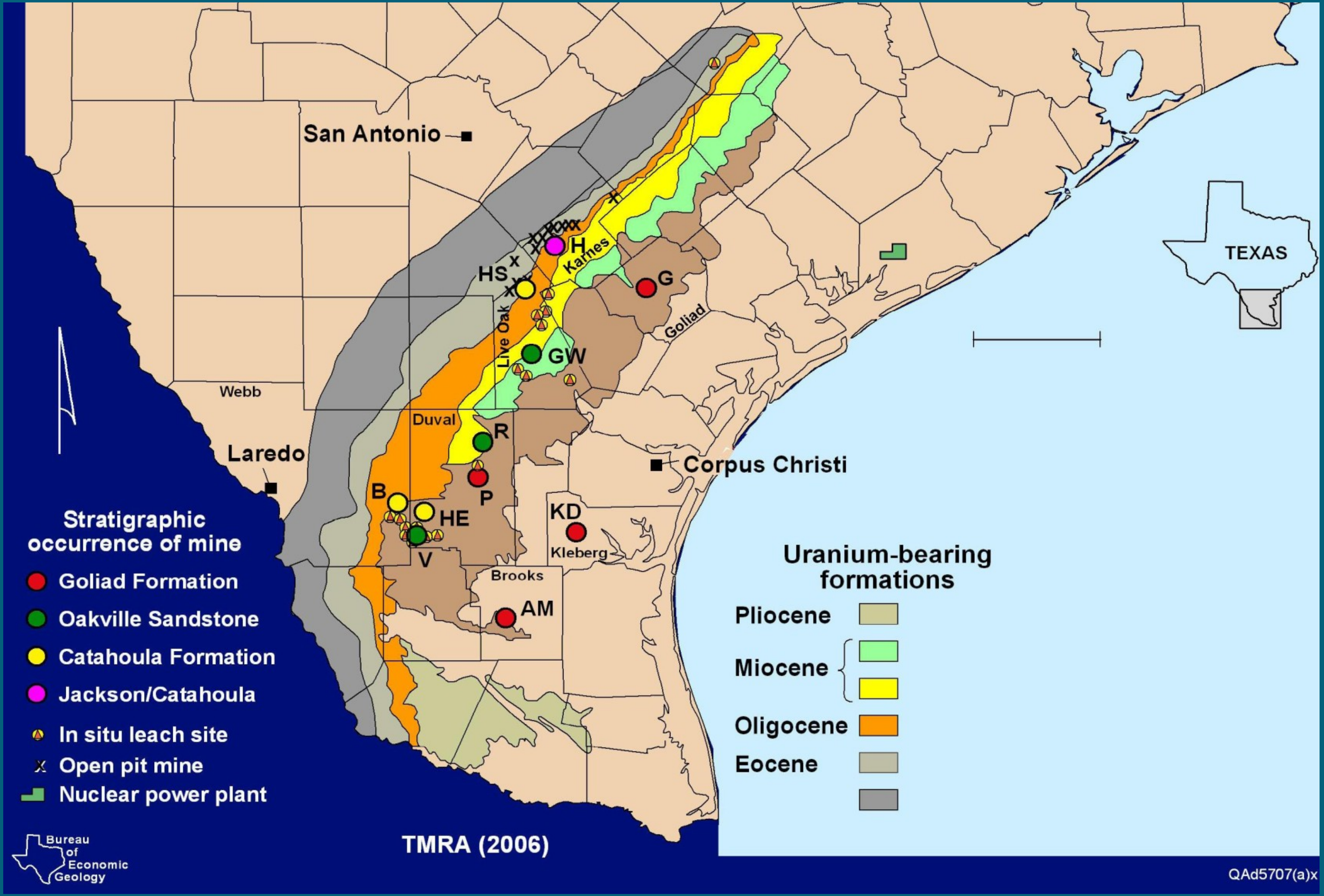


After Campbell and Biddle (1977)

Uranium Occurrences

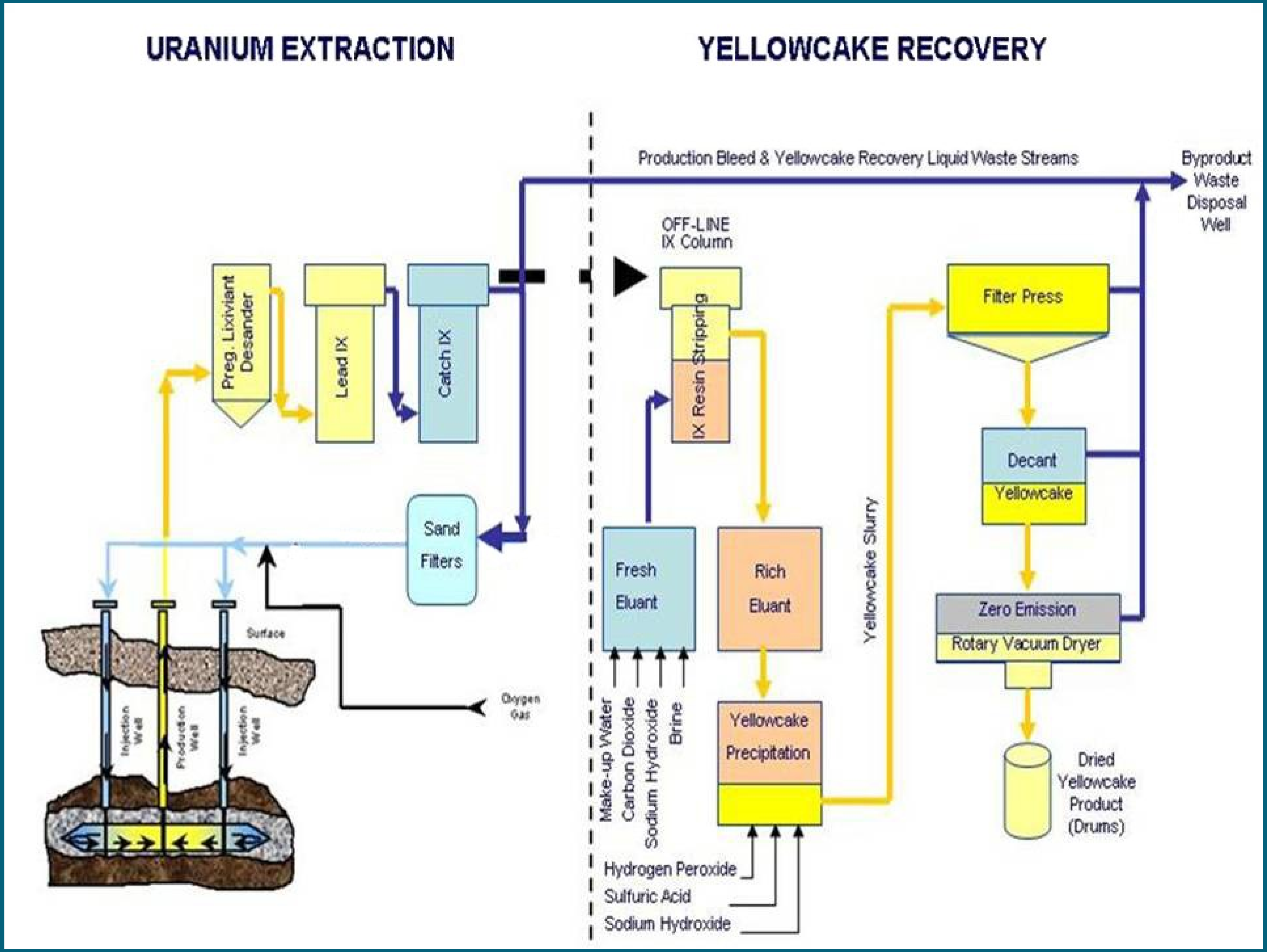
System	Series	Group	Geologic Unit	Description
QUATERNARY	Holocene		Flood-plain alluvium	Sand, gravel, silt, clay.
QUATERNARY	Holocene		Fluvial terrace deposits	Sand, gravel, silt, clay.
QUATERNARY	Pleistocene		Pleistocene Deweyville Formation, Beaumont Clay, Montgomery Formation, Bentley Formation, and Pliocene (?) Willis Sand.	Sand, gravel, silt, clay.
TERTIARY	Pliocene		**Goliad Formation**	Fine to coarse sand and conglomerate; calcareous clay; basal medium to coarse sandstone. Strongly calichified.
TERTIARY	Miocene		Fleming Formation	Calcareous clay and sand.
TERTIARY	Miocene		**Oakville Sandstone**	Calcareous, crossbedded, coarse sand. Some clay and silt and reworked sand and clay pebbles near base.
TERTIARY	Oligocene		Catahoula (Gueydan Formation of some authors): Chusa Tuff	Calcareous tuff; bentonitic clay; some gravel and varicolored sand near base. Soledad in Duval County, grades into sand lenses in northern Duval and adjacent counties.
TERTIARY	Oligocene		Catahoula (Gueydan Formation of some authors): Soledad Conglomerate	
TERTIARY	Oligocene		Catahoula (Gueydan Formation of some authors): Fant Tuff	
TERTIARY	Oligocene		Frio Clay (Southwest of Karnes County)	Light-gray to green clay; local sand-filled channels.
TERTIARY	Eocene	Jackson	Whitsett Formation: Fashing Clay	Chiefly clay; some lignite, sand, *Corbicula* coquina, oysters.
TERTIARY	Eocene	Jackson	Whitsett Formation: Tordilla Sandstone, Calliham Sandstone west of Karnes County.	Very fine sand.
TERTIARY	Eocene	Jackson	Whitsett Formation: Dubose Clay	Silt, sand, clay, lignite.
TERTIARY	Eocene	Jackson	Whitsett Formation: Deweesville Sandstone	Mostly fine sand; some carbonaceous silt and clay.
TERTIARY	Eocene	Jackson	Whitsett Formation: Conquista Clay	Carbonaceous clay.
TERTIARY	Eocene	Jackson	Whitsett Formation: Dilworth Sandstone	Fine sand, abundant *Ophiomorpha*.

Historical & Current Uranium Exploration & Recovery Operations in Texas

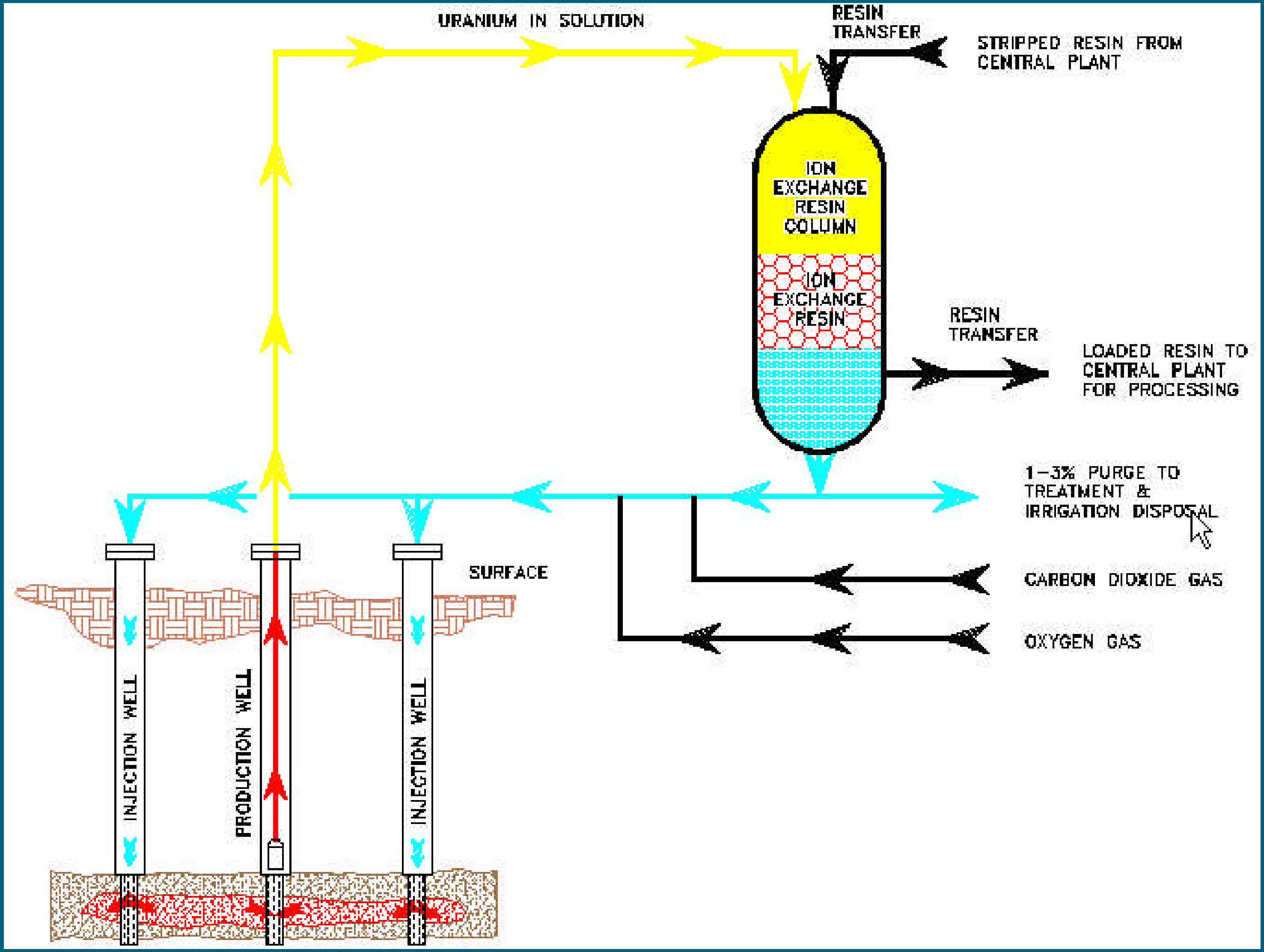


Ambrose (2007)

In-Situ Recovery – From Extraction to Recovery - Texas

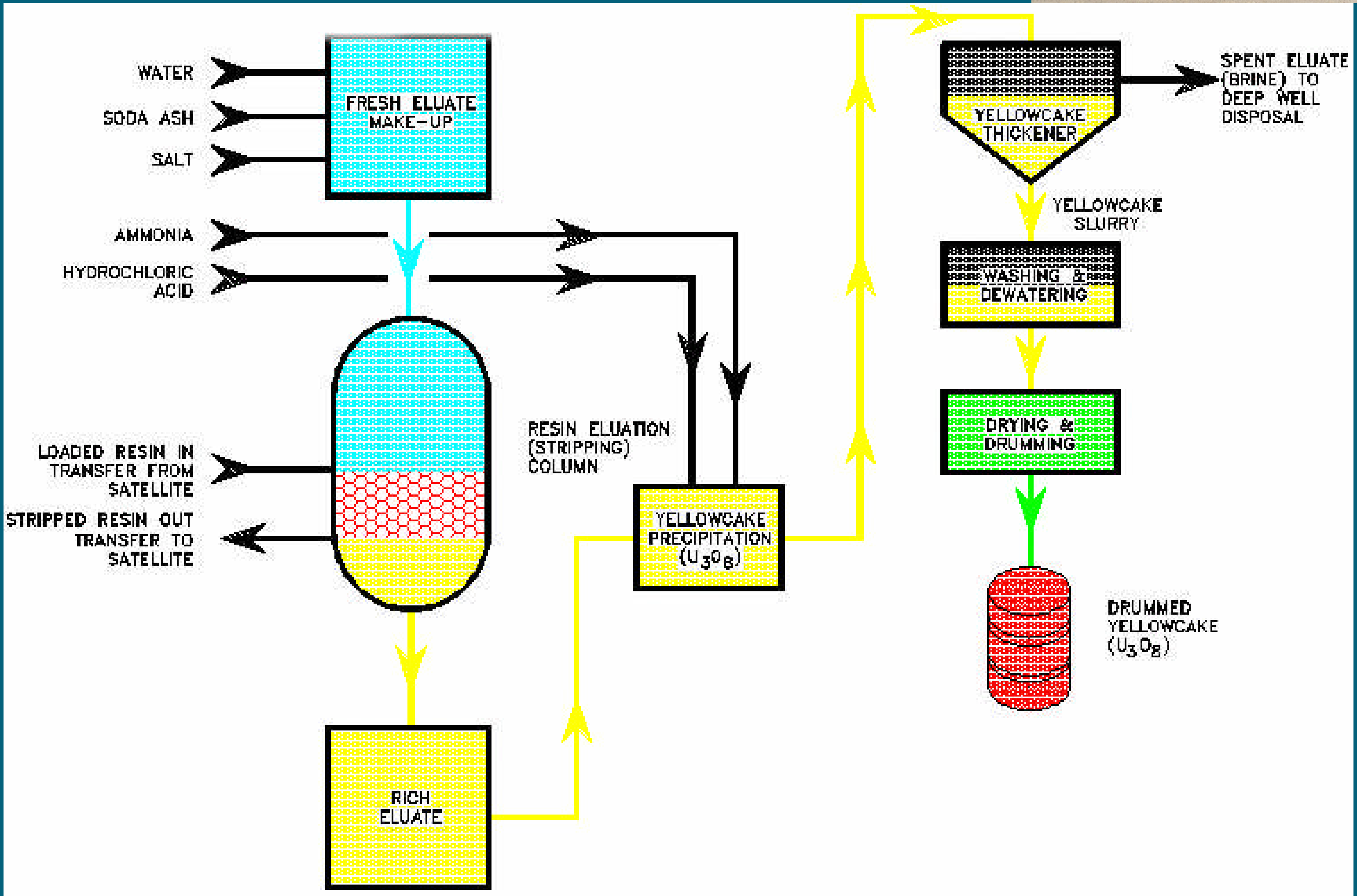


In-Situ Recovery – Wyoming Processing – Satellite Fields



In-Situ Recovery – Wyoming Processing

From satellite fields to Central Processing Plant



In-Situ Recovery – Yellowcake Production - Texas

Typical Plant Production: 1-2 million lbs/year

Yellowcake Value

1 Barrel = ~ 800 lbs U_3O_8

@ $40.00/lb = $32,000.

@ $60.00/lb = $48,000.

@ $80.00/lb = $64,000.

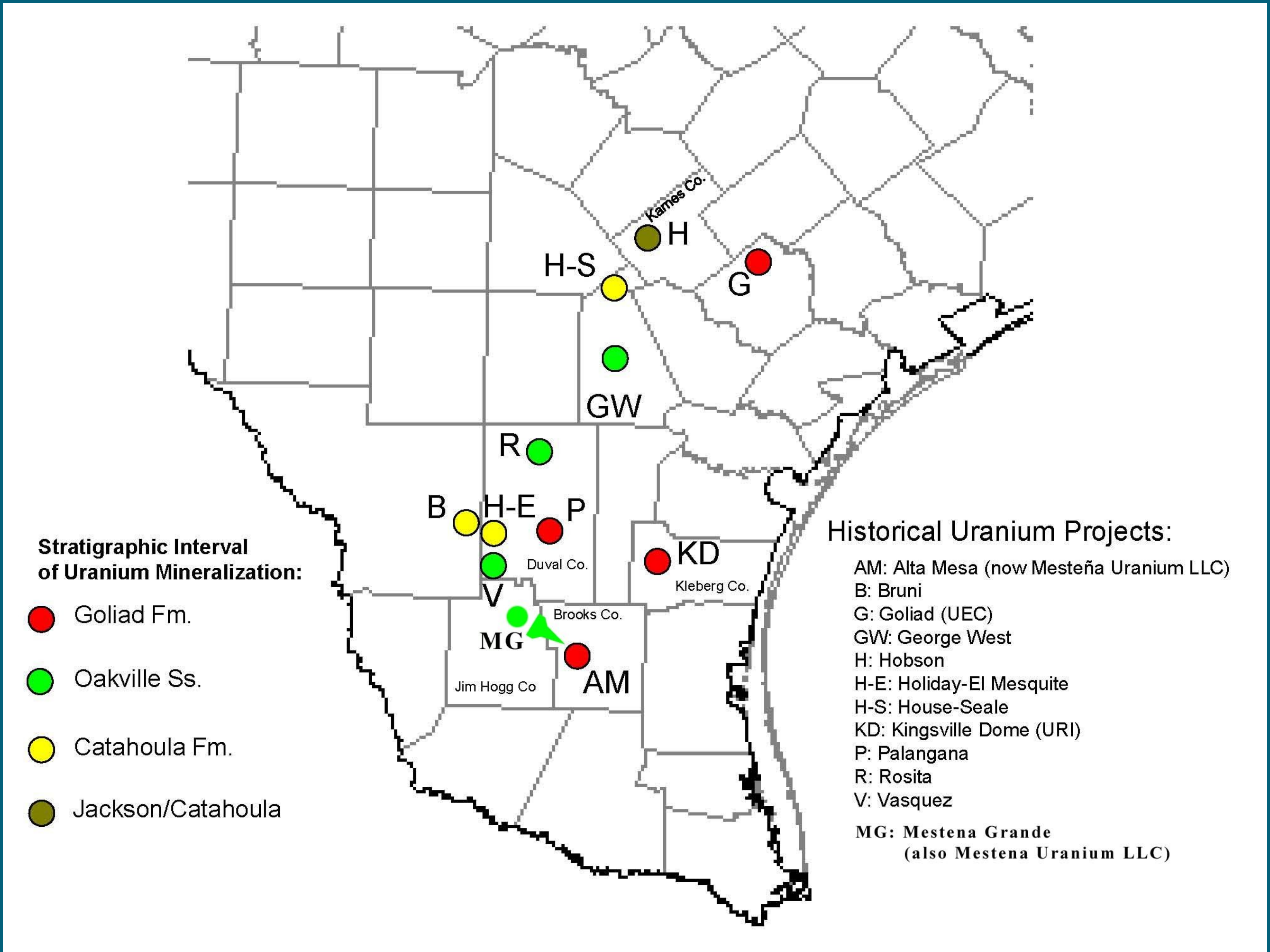
In-Situ Recovery – Processing Plant and Offices - Texas

Goranson (2008)

In-Situ Recovery – Yellowcake Price History & Projections

Historical Spot Price of U_3O_8 (after UXC.com) and Projected Price, see C&A News Release)

Historical & Current Uranium Exploration & Recovery Operations in Texas



Typical Concerns by Environmental Advocacy Groups & Associated Media

- *"Previous mines didn't close using the original cleanup levels, amended levels were used."*
  - True, but in the 1970's these levels were the drinking water standards.
  - While uranium roll-front deposits naturally occur in drinking-water aquifers, the ground water within such mineralized areas exceed those standards. Therefore, drinking-water standards could never be reached.
  - Even after mining, 20 to 40% of the deposit remains in the aquifer as a natural contaminant forever keeping the area of the deposit from meeting drinking-water standards. This is why the hydrochemistry of the ground water within and surrounding the deposit was and is used as baseline to determine if the surrounding ground water has been disturbed.
  - New rules and regulations require cleanup standards be derived from baseline studies, i.e., from sampling the ground water (from water wells) surrounding and within the site.

- *"There are health risks living around a uranium mine."*
  - There are no reported incidents of health problems from people living near any ISR mine. See Boice, *et al*., (2003), and U.S. National Institutes of Health (2008).

- *"Mines release radiation into the air."*
  - True, but only underground mines (of which Texas has none) show releases based on monitoring. No radiation has ever been detected in the air outside of uranium processing plants in Texas.
  - Radiation emanating from uranium and its daughter products extends only a short-distance, and personnel within the processing plant (where yellowcake is produced) carry radiation badges that are checked daily by the plant-safety staff.

Typical Unrealistic Expectations by Environmental Advocacy Groups

- *"Living around uranium mines show increased cancer rates."*
  - Not substantiated in any current in-situ recovery operation in the U.S.
  - Increased cancer rates have been attributed to smokers who worked in underground mines only during the 1950's and 60's in New Mexico & Colorado.
  - Study made in Karnes County, where mining was conducted using shallow open pits, have indicated no unusual increase of cancer rate. See Boice, *et al*., (2003), and U.S. National Institutes of Health (2008)

- *"Groups want aquifer baseline studies prior to any exploration drilling."*
  - Good idea, but would you advertise to everyone the area of exploration interest? Also, depending on the area, there may not be an adequate spread of water wells in the stratigraphic interval of interest, which would require the drilling of holes to gain the necessary data.

- *"In-situ Recovery operations should never be performed in drinking water aquifers."*
  - Roll-front uranium deposits typically occur in drinking water aquifers, but the ground water within a uranium deposit, regardless of depth, should never be considered as drinking water.
  - Restoration can start within a production zone that has been depleted while production continues in a nearby production unit (concurrent restoration). Most uranium recovery operations conduct concurrent restoration. In fact, both the National Radiation Commission (NRC) and the Wyoming Department of Environmental Quality (WDEQ) are now requiring concurrent restoration.

Typical Mis-Information Held by Environmental Advocacy Groups

- *"Uranium mining needs to be done in remote areas, far away from people's drinking water"*
  - Nice aspiration, but uranium is recovered where it's found, not where it isn't.
  - Uranium should be recovered to remove a "natural contaminant" if located in sparsely populated areas where development is anticipated.

- *"Exploration for uranium pollutes surface-water & ground-water supplies."*
  - There's never been any reports of this in Texas or elsewhere in U.S. The drilling mud is designed to prevent fluids from flowing into or out of the boring.
  - Exploration drilling activities do not inject any fluids into the aquifer, see Campbell and Gray (1975). Drilling mud is used to remove drill cuttings, fill the boring, and keep it from caving until geophysical logging has been completed.
  - Studies by mud companies have demonstrated that the mud cake controls the drilling fluid within the bore hole. Also, operators plug or grout the holes to assure that there will not be communication of fluids between aquifers.

- *"Recovering uranium from a drinking water aquifer is illegal."*
  - This stems from a misunderstanding on the part of Environmental Advocacy Groups about injecting fluids into a drinking water aquifer and what constitutes the boundaries of a drinking water aquifer.
  - In most locations, ground-water quality decreases with depth and is relatively consistent horizontally. However, in the case of areas with roll-front uranium deposits, the ground-water quality also varies horizontally.
  - The area in and around the mineralization is not part of the drinking water aquifer because the water quality in and around the deposit exceeds the drinking water-quality standards and has for millions of years.

Typical Mis-Information Held by Environmental Advocacy Groups

- *“Mining activities will destroy the aquifer by pumping all available water and causing pollution.”*
  - ISR wells typically pump an average of 10-15 gal/minute, 30-50 gal/minute in large operations, and return 99% of that to the aquifer during mining activities.
- “No ISR mine ever remediated the mined area to it’s original condition. They all had to amend their permits.”
  - While this is true, it’s also misleading because all of these mines were opened in the 1970’s, at a time of little to no environmental regulations.
  - No baseline aquifer studies were conducted and so the original cleanup standards for the mines were set as the EPA drinking water standards.
  - Since the mined area was never drinking water quality to begin with, these cleanup standards were unreasonable. However, this fact never gets emphasized.
- *“Most aquifers have lower quality water with depth.”*
  - Areas of mineralization have horizontal changes in ground-water quality.
  - In the Gulf Coast of Texas, ground water generally becomes more saline with depth due to the age of the ground water, trapped brines associated with oil and gas occurrences and the proximity to the Gulf of Mexico.
  - The older the ground water (or the longer the ground water flows in the aquifer), the more the ground water (containing greater TDS) becomes even more saline.

Typical Mis-Information Held by Environmental Advocacy Groups

- *"Small local news media almost always portrays uranium companies in a negative light."*
  - Recent coverage of the trial in Goliad, Texas on whether a new uranium mine will be permitted to open provide coverage of those portions of the trial presented by the anti-mining group, but provide little or no coverage of the mining company's defense. See Example News (Here).

- *"Mining companies generally don't care about the environment or health and safety of the workers."*
  - This statement assumes that there are no environmental or health and safety laws and regulations. It is based on practices that occurred 40 to 60 years ago, prior to modern environmental and health and safety laws and regulations.
  - In addition, what company would want to be responsible for causing injuries to their employees? Pragmatically, constantly having to replace sick or injured employees are expensive and time-consuming.
  - Most people working in the industry are insulted by this irresponsible statement.

- *"The news media almost always portrays anti-nuclear advocates in a positive light."*
  - The news media appears in most instances to have an agenda to advance wind and solar power to the detriment of all other forms of energy. This is yet another indication of the news media's bias towards all forms of energy that aren't "green" or "green enough".

- *"The news media often portrays governmental agencies as good only when they obstruct mining or nuclear energy and side with environmental advocacy groups."*
  - This is yet another indication of the news media's bias towards all forms of energy that aren't "green" or "green enough".

Typical Mis-Information Held by Environmental Advocacy Groups

- *"The news media makes no distinction between the three forms of mining."*
  - They are constantly quoting problems with underground & open-pit uranium mining from the 1950's to 1970's as evidence that these problems continue, and that ISR will have the same problems. This despite the fact that this period of time was prior to the enactment of environmental legislation even though ISR is a vastly different technique that keeps mining personnel from being exposed to any harmful effects of direct exposure to the ore deposit's natural radiation in the subsurface.

- *"The government has a vested interest in allowing exploration and mining permits because that is how the governmental agencies are funded."*
  - TCEQ budget comes from the State Budget.
  - Permits typically cost $100. All permit fees go to the State of Texas.
  - U.S.G.S. Studies are generally neutral in their investigations. However, Hall (2009) of the USGS in Denver did an in depth study of aquifer restoration of in-situ operations using data as far back as the 1970s. She fully expected to find multiple problems when she started but her final conclusion was that the companies had been successful in eliminating all excursions.
  - The mineralized zone that occurs within an aquifer is typically 60-80% removed, so returning the aquifer to it's original condition is impossible. Immobilization of soluble metals is part of restoration, including residual uranium and other metals.
  - The NRC regulates uranium mining in other states and is a fee-recovery agency, i.e. they bill the regulated companies for the time the NRC spends on their applications. However, similar to Texas, the payments go to the U.S. Treasury's General Fund, not to the NRC, which operates on a budget approved by Congress but will not undertake work that it has not budgeted.

Typical Half-Truths Held by Environmental Advocacy Groups

- “Homeowner reported a change in their drinking water from their well.”
  - Water turned red & muddy after exploration drilling occurred 1,250 feet from the well.
  - Water was sampled and analyses were performed, but the results were never reported.
  - The Texas Railroad Commission investigated and found the exploration drilling had nothing to do with it. Source of red water: iron bacteria and poor water-well maintenance by owner.

- *“The government doesn’t protect individual’s interests.”*
  - This statement assumes there are no environmental or health and safety laws and rules. It usually is presented by people who live in the area of the uranium mineralization but don’t own prospective mineral leases.
  - The nuclear industry, including uranium mining, is one of the most regulated industry in the US and in the world. The environmental and safety regulations are geared to protect human health and the environment.

- “Local Experts who worked in a mine or served on Groundwater Conservation Boards are often presented by the news media as experts, but are practicing geology and/or hydrogeology in public with no training or experience in the fields.”
  - Discussions took place with personnel of local Ground Water Districts who have little or incorrect understanding of ground-water flow.
  - Local meetings were held where individuals who spoke on technical issues relating to uranium exploration or uranium recovery but were unqualified to do so.

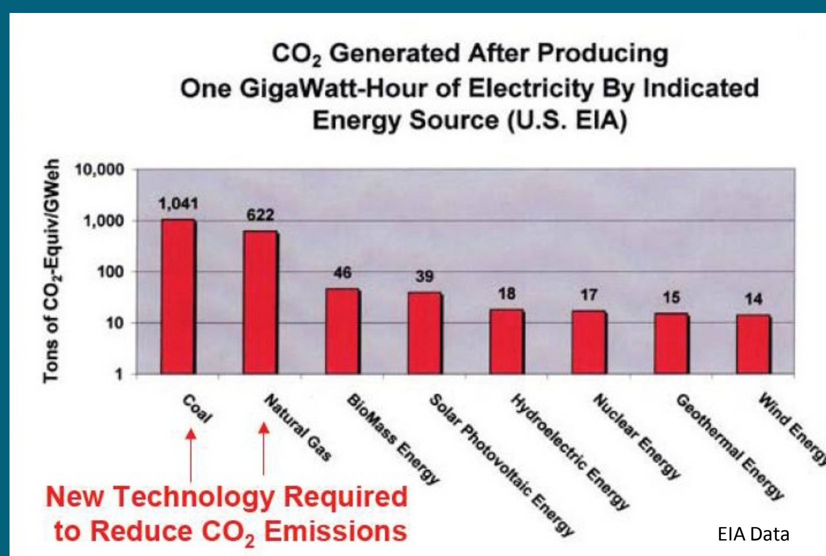
- *“Uranium produced in the U.S. gets exported overseas.”*
  - We don’t produce enough uranium to run our own power plants in the U.S. at present; why export it?

Typical Half-Truths Held by Environmental Advocacy Groups

- *"Nuclear Power isn't really carbon-free."*
    - Minor compared to conventional energy sources, i.e., coal, oil & gas, etc.
    - The uranium processing plant is similar to a home-water softener, exchanges occur onto resins which are flushed and replaced from time to time, and the yellowcake must be dried before shipment, both requiring energy.

- "Some water-resource academics in Australia, for example, while criticizing the development of uranium resources, make claims that environmental costs are not being fully assessed, such as energy/water/chemicals consumption, greenhouse gas emissions, and social issues, claiming that 'significant gaps remain in complete sustainability reporting and accounting."

    - Mudd and Diesendorf (2008) make such claims without providing adequate data to support their views, while making negative innuendos concerning the development of uranium in Australia and elsewhere. They ignore the same considerations for solar, wind, biomass, and conventional energy resources.



EIA studies illustrate current understanding of CO_2 production.

Community Outreach Programs

❖ **Company personnel should talk with community about technical issues:**

✓ Talk issues, dispel rumors & falsehoods and provide supporting information concerning:

1) the unlikely occurrence of ground-water contamination by exploration drilling and in-situ recovery operations, and

2) the need for local owners to provide regular maintenance by a Certified Water Well Contractor on their water wells to avoid or eliminate iron, manganese, and sulfate-reducing bacteria from fouling their wells, i.e. red water, etc., a condition that is entirely unrelated to nearby uranium drilling or development activities.

✓ Explore or identify conflicting agendi, such as:

1) envy of nearby land owners who do not have uranium below their lands,

2) fear expressed by local real-estate agents that property values may fall because of the presence of uranium exploration & development activities in the area, and

3) opposition of local residents to nuclear power development in general.

✓ Point out positive features of uranium development & recovery, like oil & gas, i.e., local employment & spending, community funding (schools, etc.).

✓ Combat media bias program with objections to treatment by local and national news media, e.g. http://mdcampbell.com/CAReviewszz/I2MAReviews.htm

Community Outreach Programs

❖ Basic Technical Facts About Uranium Recovery Projects:

✓ In one sense, in-situ recovery of uranium is both a natural resource development project (like oil and gas production) and a natural contaminant remediation project (like in other industrial environmental projects involving industry wastes).

✓ Although uranium ore is a natural energy resource, it is also a bacterial waste product that was formed within the bio-geochemical cell of the mineralizing roll-front, and required millions of years to form.

✓ A properly conducted assessment would show that the aquifer containing the uranium mineralization contains both suitable (away from the mineralized zone) and unsuitable drinking water quality (within the mineralized zone), which has been the case for millions of years before uranium recovery was even contemplated.

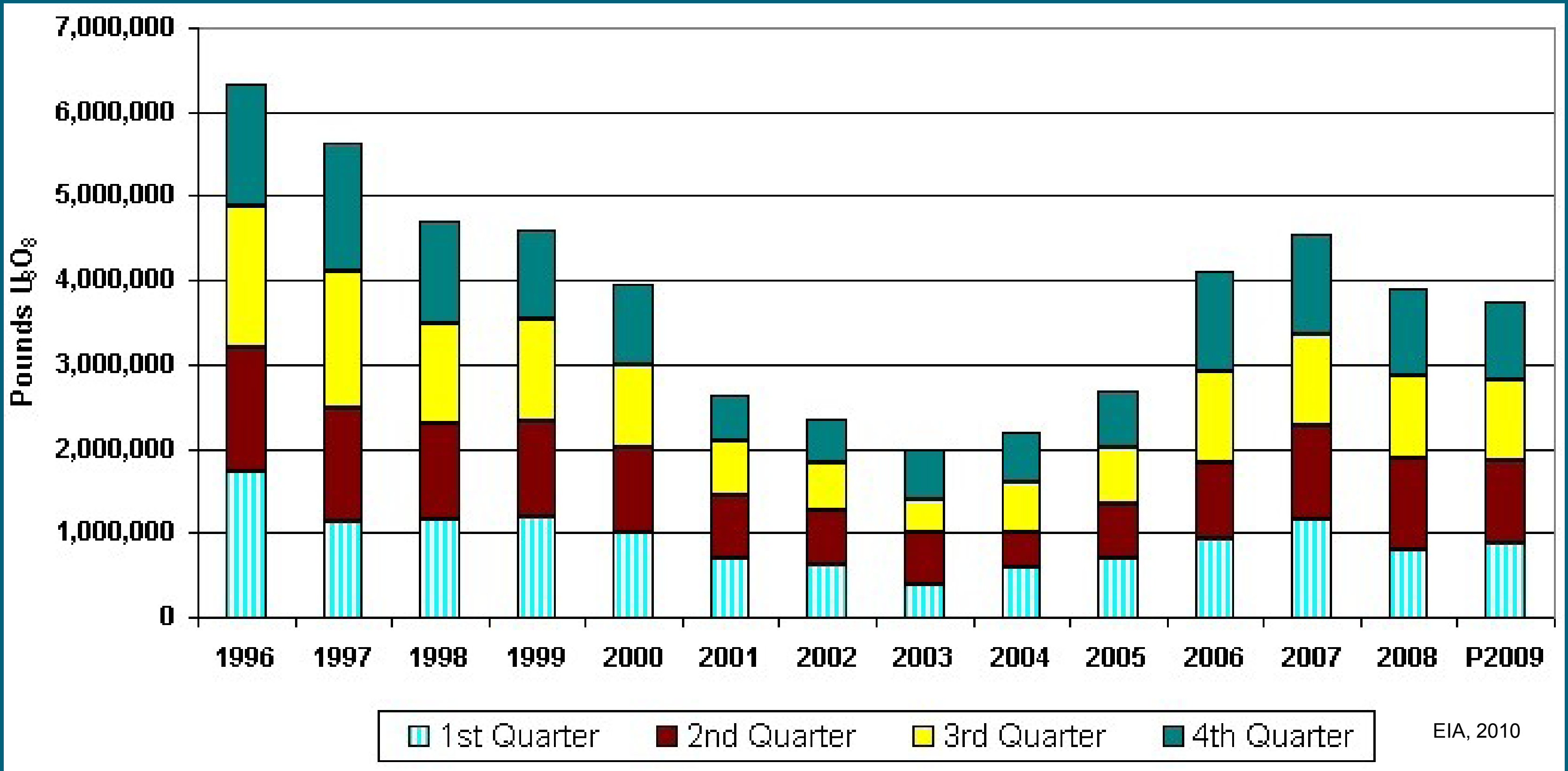
✓ The process of in-situ recovery of uranium involves dissolving the solid uranium minerals found in a few aquifers in Texas (and in New Mexico, Colorado, Wyoming, Kazakhstan and other regions in the world) with oxygen so that the uranium in solution can be pumped to the processing plant to be converted back into a solid to form yellowcake. The processing is similar to a home water softener. Older mining methods excavated the ore from open pits and from underground mines.

✓ After the recovery process has been completed, the conditions within the depleted ore zone are returned to the original reducing conditions causing the remaining fluids to drop any mineralization in solution to re-form back to solid minerals that become stationary in the depleted ore zone. Hence, no migration of uranium, molybdenum, selenium, etc.

Current Conditions/Expectations of the U.S. Nuclear Industry:

- 4 million lbs / year U_3O_8 (Yellowcake) Recovered in U.S. (2009).
- 25 million lbs / year U_3O_8 from Decommissioned Nuclear Weapons Program ends in 2013.
- 29 million lbs / year U_3O_8 Current Capacity in U.S. (per EIA and Nuclear Regulatory Commission (NRC) data)
- 104 Nuclear Power Plants in U.S. (441 Plants in World as of 2010)
- 52 million lbs / year U_3O_8 Required to Load 104 U.S. Reactors in U.S. (3-5 Year Fuel Cycle) – BeO & other modifications would increase Fuel Burn Life and Reduce Load Requirements.
- 900 million lbs U_3O_8 Resources in U.S.? Assume 50% will become available as the yellowcake price increases above $80.00 over the next 10 years and beyond.
- About 33 Permit Applications for new plants in various stages of the application process in the U.S. 50 new Applications anticipated by 2013. Twenty new plants to come on line by 2020 and about 10 plants over next 10 years, depending upon infrastructure development & support.
- Available Waste Storage Site: WIPP site in New Mexico is presently licensed for defense transuranic nuclear waste including significant reprocessed spent fuel waste from old defense reactors. The site would be ideal for storing all nuclear waste at modest cost, at a cost of ten times less than cost projections for Yucca Mountain. Space is already set aside, and the infrastructure and work force are in place. Selection is a political problem, not technical.
- Globally (including U.S.) there are 441 plants in operation, 52 plants under construction, 143 planned and more than 340 proposed. NEI projects 1,000 to 1,200 reactors globally by 2030.

Historical / Current Production of the U.S. Uranium Mining Industry

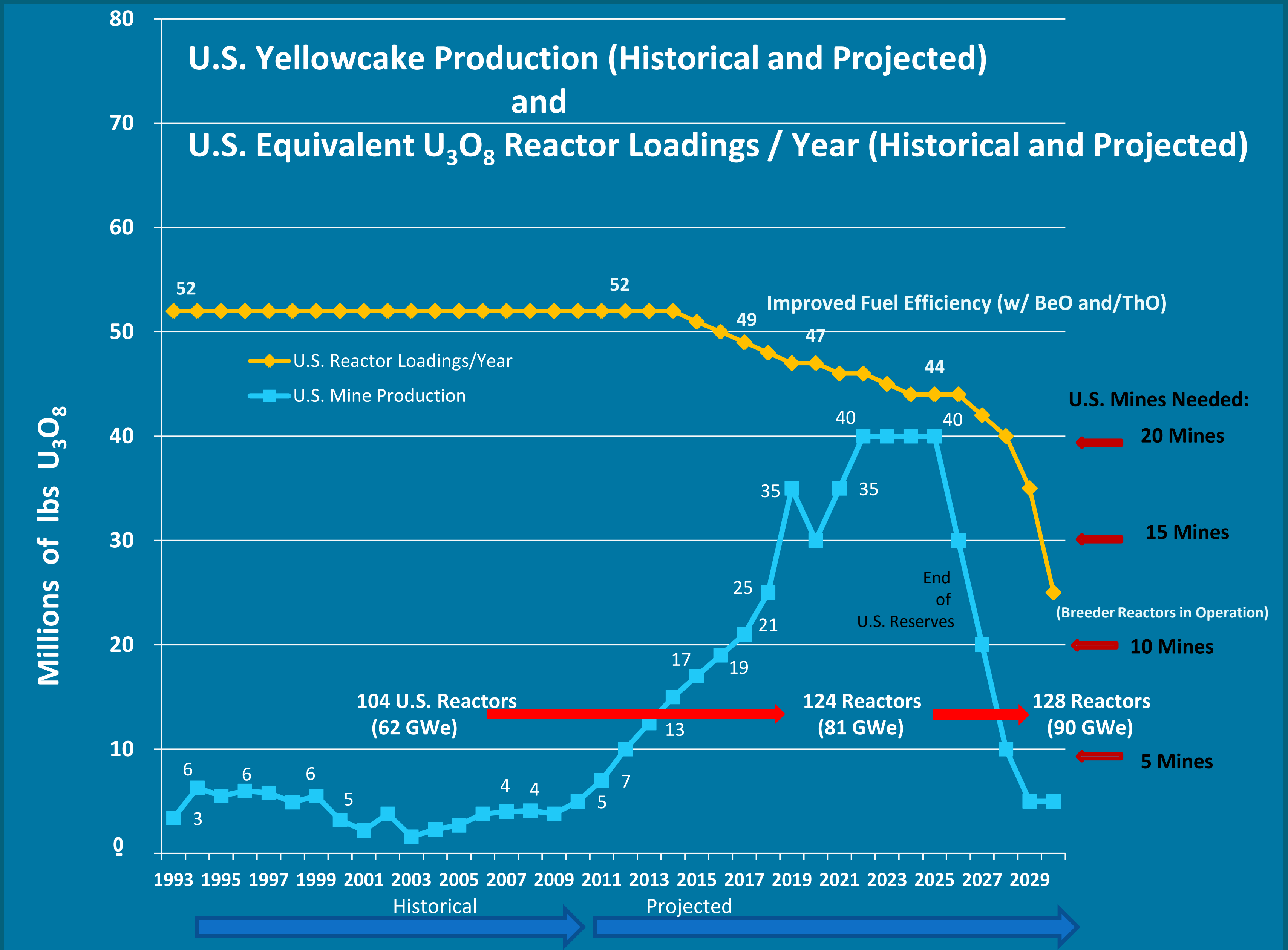


- 4 Mines Operating Today in U.S. = About 4 million lbs/year U_3O_8
- U.S. will need about 20 Mines in production to meet 2021 Requirements….???

Current Conditions / Expectations of the U.S. Nuclear Industry

- Estimated U.S. Resources: ~ 900 million lbs. Assume 50% as Reserves: Through 2025 years?
- After about 2025, additional yellowcake production must come from the overseas sources (i.e., high-grade deposits in Canada, Australia, Gabon, Argentina, and from lower-grade deposits in Kazakhstan, Niger, Zambia , Columbia, Guyana, and/or from
- Re-processing of nuclear waste with Type IV Reactors (Breeder Reactors) by 2030 or before.
- Public will support nuclear development because coal mining and use are no longer acceptable in view of current climate-change issues. Current technology will be phased out over coming 15 years. Domestic natural gas will likely contribute to the U.S. for decades to come.
- A new energy-and-climate bill emerges in Congress: $54 billion in federal-loan guarantees for new nuclear projects. Plus 10% tax credit for nuclear construction costs and use of tax-exempt bonds for joint ventures for advanced nuclear facilities.
- The World Nuclear Association (WNA) projects possible world expansion of nuclear generating capability from current base of 387 GWe (441 plants rated @ 880 MWe (Ave) to at least 1,100 GWe (rated @ 1,000 MWe (Ave) for about 1,000 plants) by 2030.
- A summary of the current uranium production and projected increases (driven by the anticipated increase in yellowcake price over the next few years) and the fuel needs to load U.S. reactors are projected in the following figure.
- The type of reactors and some of their features are presented in the table that follows.

Historical / Expectations of the U.S. Uranium Mining Industry

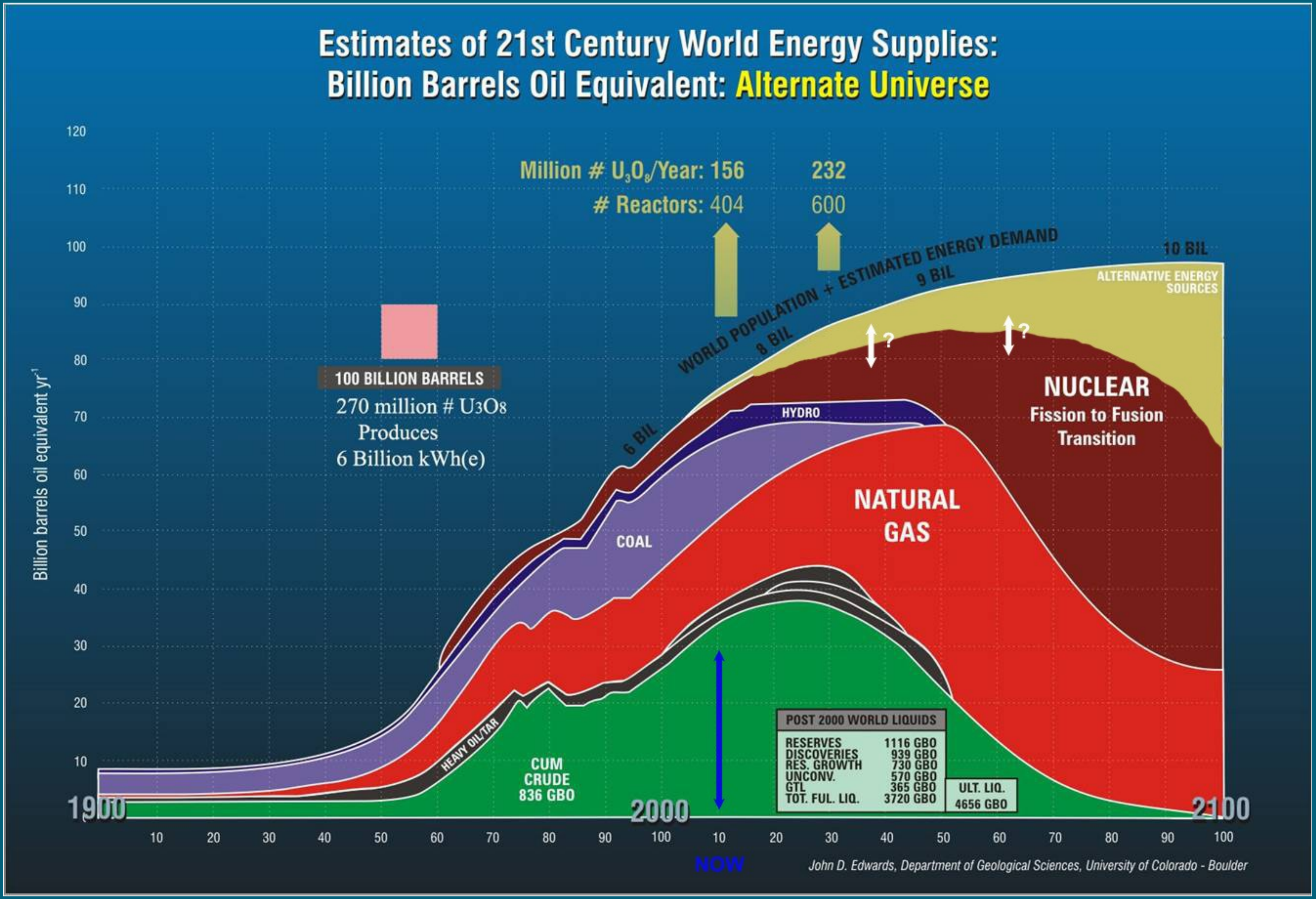


Current Conditions / Reactor Types of the World Nuclear Industry

Reactor Type	Main Countries	Number	GWe	Fuel	Coolant	Moderator
Pressurized Water Reactor (PWR)	US, France, Japan, Russia, China	**265**	**251.6**	enriched UO_2	**water**	**water**
Boiling Water Reactor (BWR)	US, Japan, Sweden	**94**	**86.4**	enriched UO_2	**water**	**water**
Pressurized Heavy-Water Reactor 'CANDU' (PHWR)	Canada	**44**	**24.3**	natural UO_2	**heavy water**	**heavy water**
Gas-Cooled Reactor | (AGR & Magnox)	UK	**18**	**10.8**	natural U (metal), enriched UO_2	**CO_2**	**graphite**
Light -Water Graphite Reactor (RBMK)	Russia	**12**	**12.3**	enriched UO_2	**water**	**graphite**
Fast -Neutron Reactor (FBR)	Japan, France, Russia	**4**	**1.0**	PuO_2 and UO_2	**liquid sodium**	**none**
Other	Russia	**4**	**0.05**	enriched UO_2	**water**	**graphite**
	TOTALs:	**441**	**386.5**			

NEI, 2010

Where is the Energy Coming From in the Future?



After Campbell and Campbell (2005)

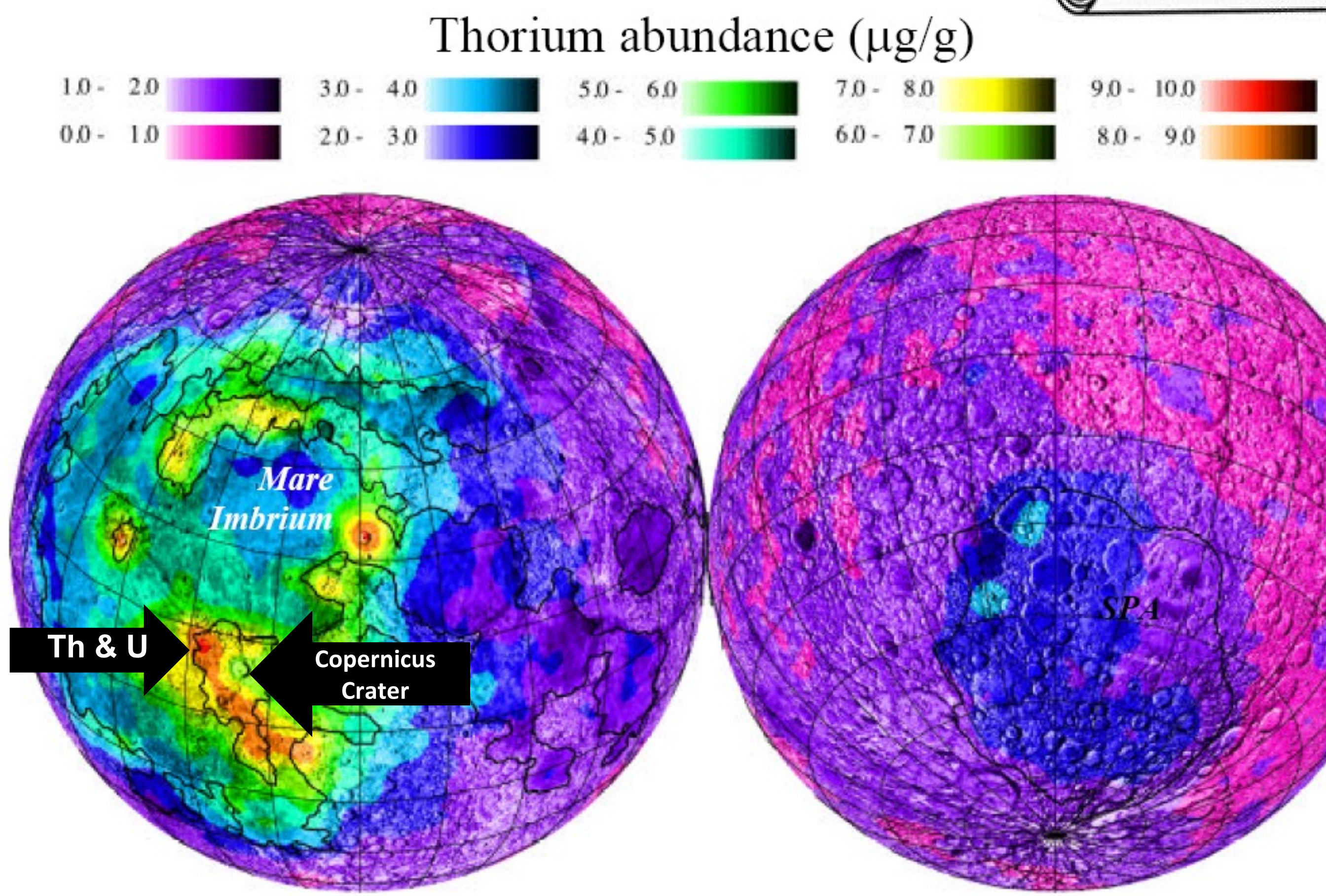
Generation of Electricity: Both Small- and Large-Scale Nuclear Energy Plants

Do We Need to Look Elsewhere Too?

China, India, Japan, Russia are turning to the Moon!!!

WHY?
Uranium has been discovered.
Rare Earths, Helium-3, Water, etc.

We think the 2nd Space Race may well be afoot….



(After Elphic, *et al.* (2000); Campbell, *et al.* (2009); Yamashita (2009); and Campbell and Ambrose (2010))

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For Abstract & Biographies of the authors of this presentation, see: http://www.hgs.org/en/cev/1158

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