Nuclear Fuel Exploration, In Situ Recovery, and Environmental Issues

in context with the

National Energy Needs through Year 2040

Texas Commission on Environmental Quality Conference & Trade Fair
Austin, Texas
April 30, 2008

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Version 2.7

- **Purpose of Presentation**

  - ✓ **To Increase Communications between the General Public, Regulatory Agencies (TCEQ, RRC, TDSHS) and the Uranium Industry,**
  - ✓ **Encourage Research by BEG and TWDB on Issues Important to Uranium Industry and to the General Public,**
  - ✓ **Encourage Research on Health and Regulatory issues important to the General Public,**
  - ✓ **Encourage Recruiting Graduates and Professionals Interested in Working in the Uranium Industry, and**
  - ✓ **Encourage Geology Graduates, Academics & Others Working in Natural Resources Development in Texas to Obtain a State License as a Professional Geoscientist.**

- # Coverage of Topics

  - **Introduction to Uranium Exploration & Recovery:**

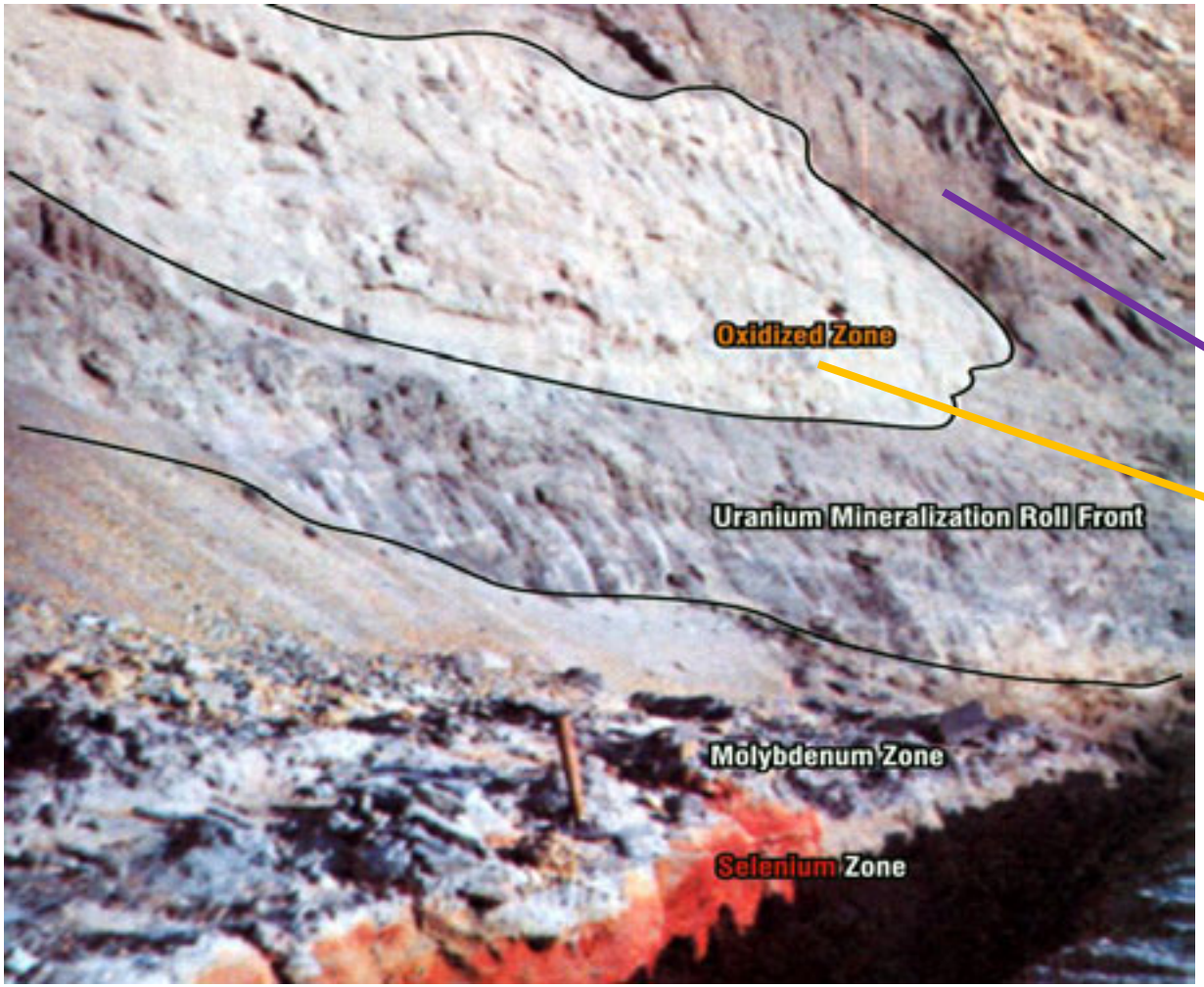
    - **The Old, The Improved, and The Missing**
      - ✓ **Techniques of the 1970s**
      - ✓ **Environmentally Friendly Approach**
      - ✓ **A Missing Generation of Uranium Professionals**
    - **Permitting Guides**
      - ✓ **Background Surveys**
      - ✓ **Surface Water & Ground Water (Water Wells)**
      - ✓ **Regional Hydrogeological Setting**

- # Coverage of Topics

  - **Uranium Exploration & Recovery & Health**
    - ✓ **In Texas**
    - ✓ **In Colorado**
    - ✓ **Numerous Studies**
  - **Community Outreach**
    - ✓ **Project Restoration Histories**
  - **Project Economics & Yellowcake Processing**
  - **Nuclear Power: Present Usage**
  - **Alternative Energy Resources: Solar, Wind & Geothermal Energy**
  - **Predictions: 2008 to 2040**

Geology of Uranium Occurrences in Texas

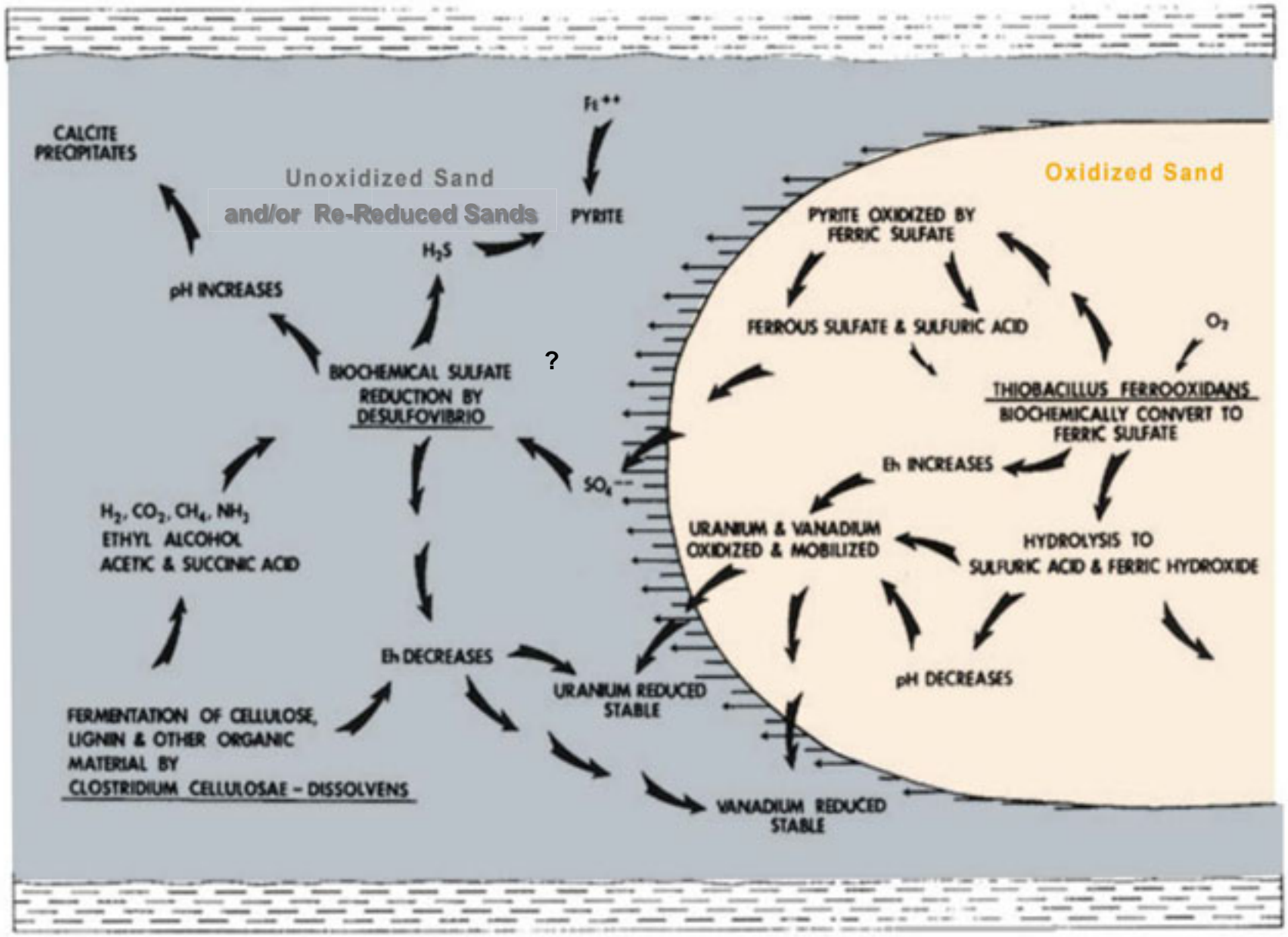
Roll Front in Open Pit Wall, Texas (of 1970s)



@ Kingsville Dome, 2007

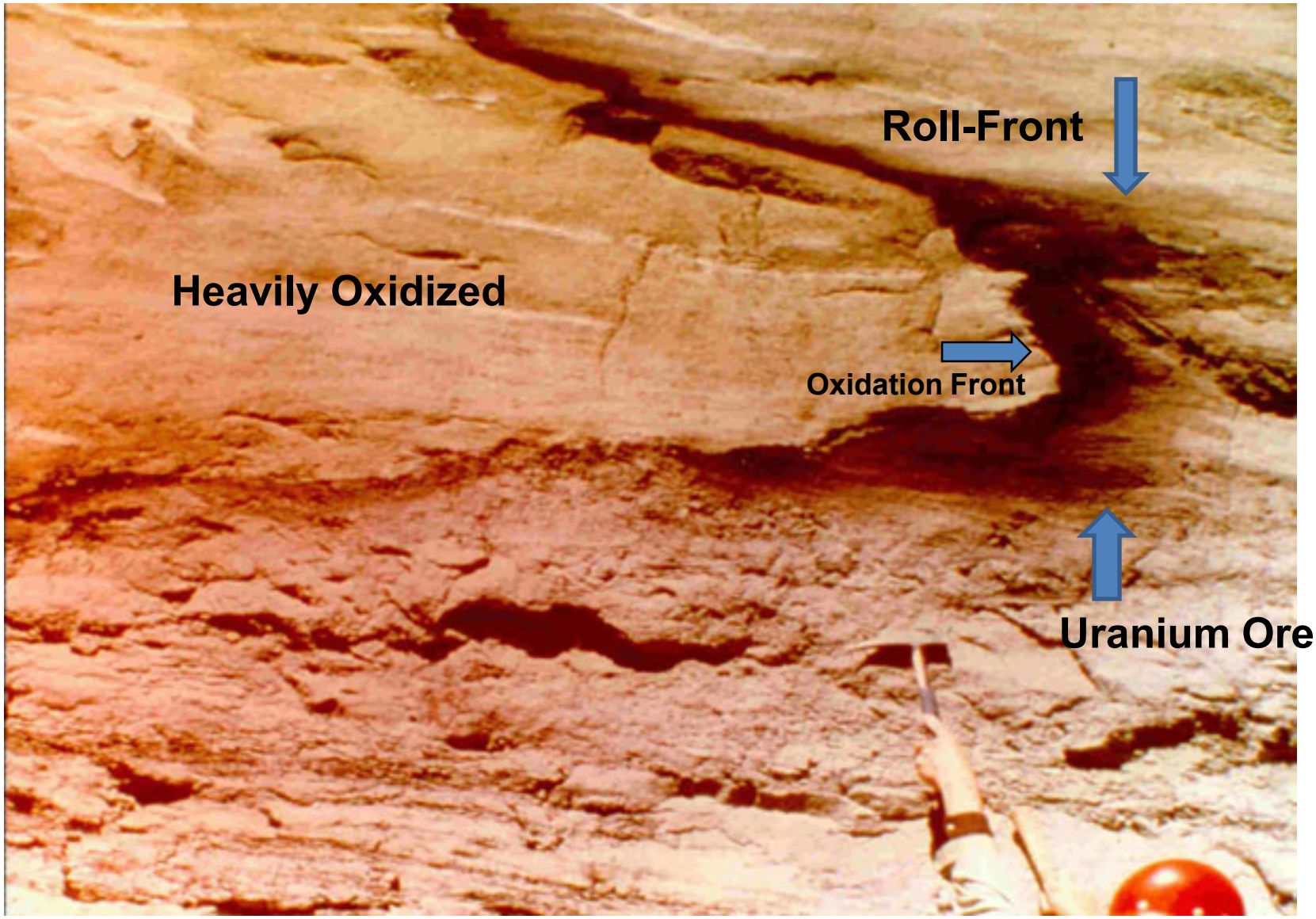
After: Dickinson & Duval, 1977 in *Geology of Alternate Energy Resources,* Published by Houston Geological Society

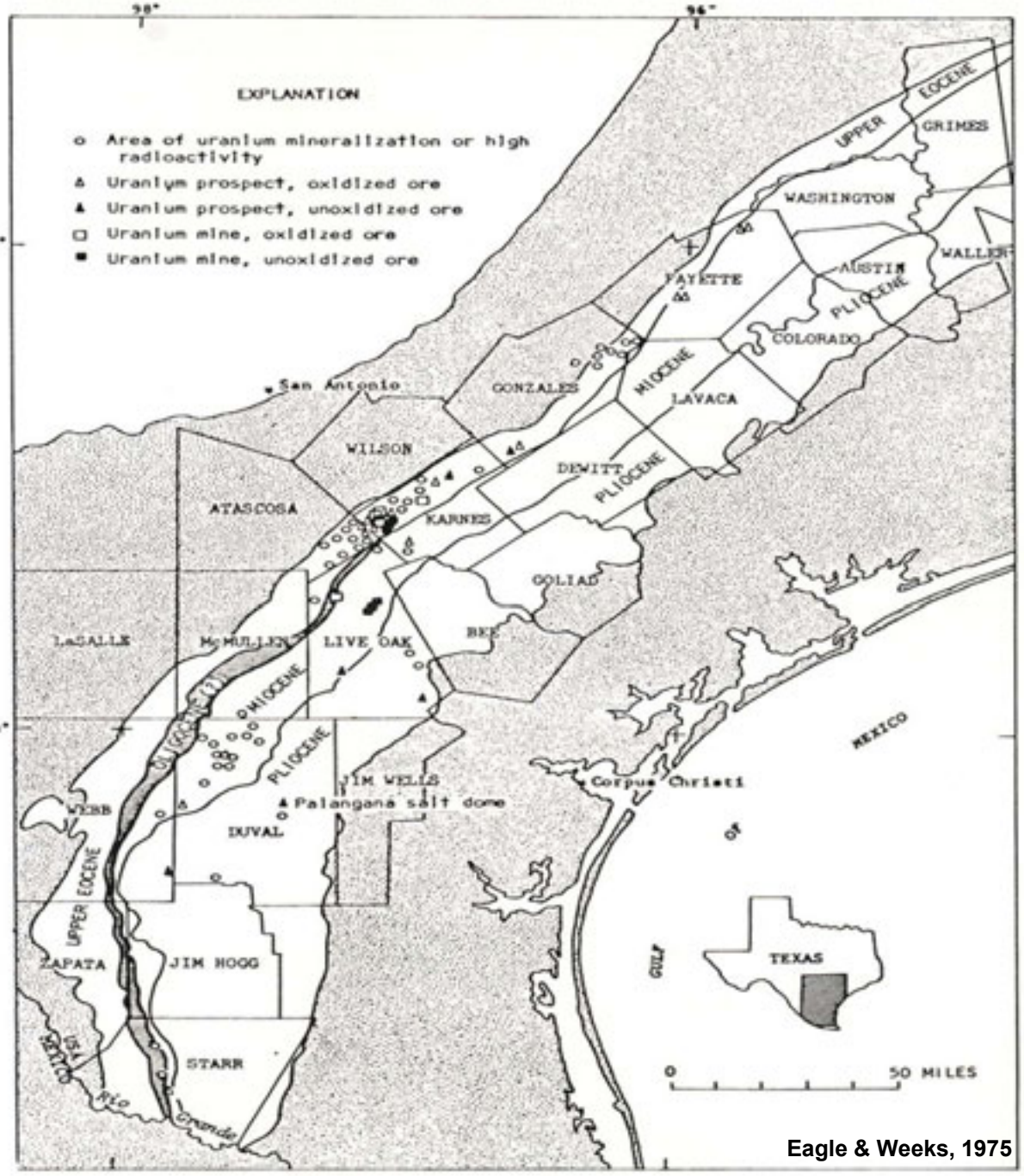
The 1975 Concept of the Biogeochemical Cell in a Roll-Front



After Rackley, 1975

Roll Front in Open Pit Wall, Wyoming (1970s)





Eagle & Weeks, 1975

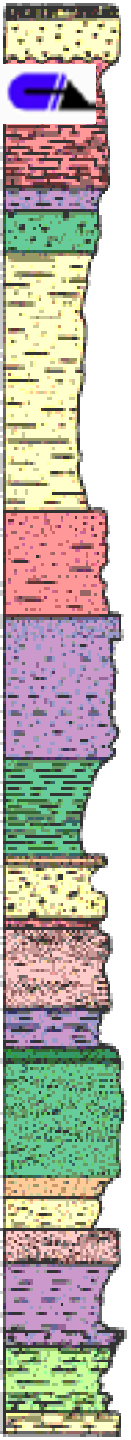
- **Texas Uranium Occurrences Known by the Mid-1970s:**

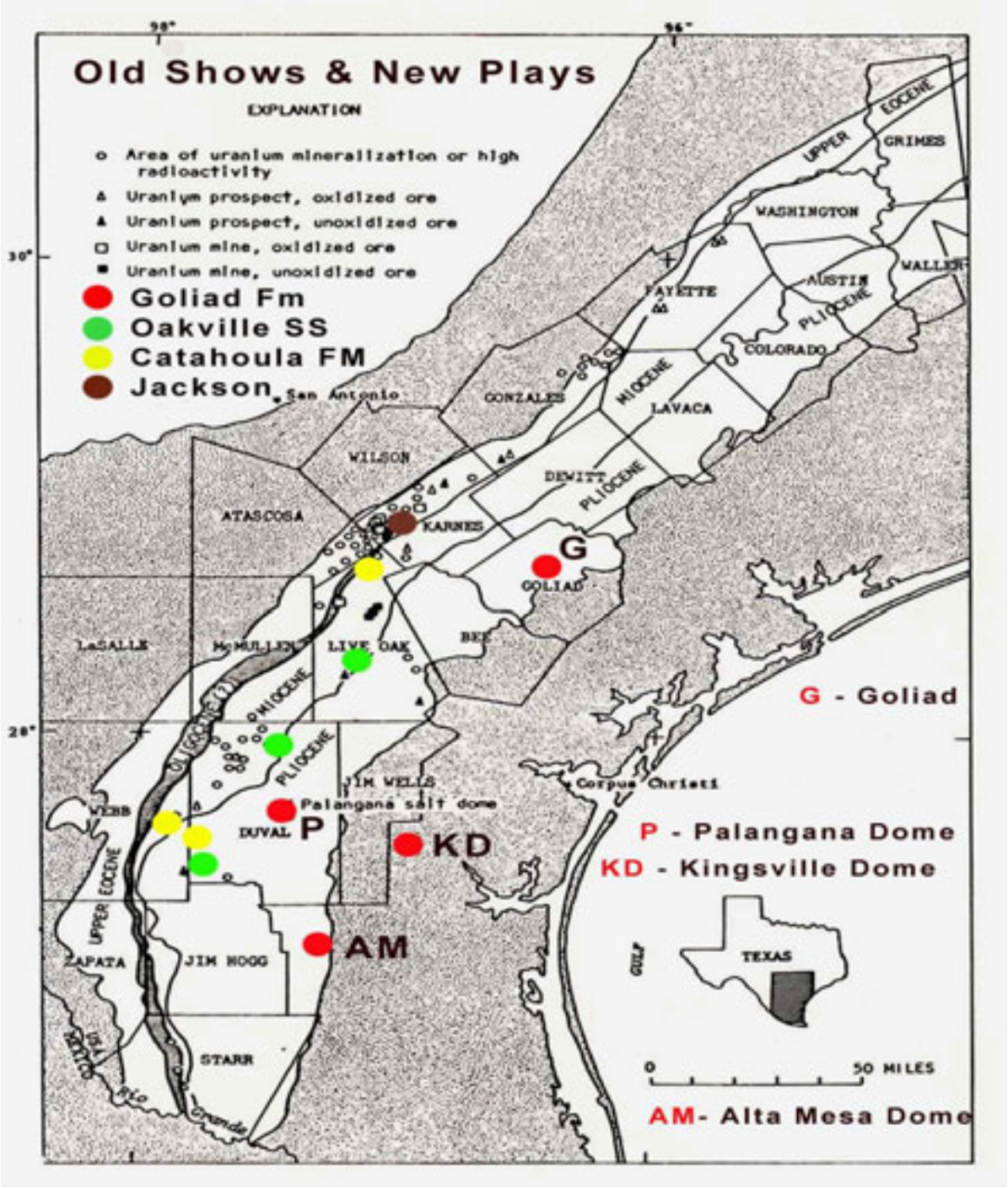
✓ **Outcrops**

✓ **Shallow Ground Water**

✓ **Proximity of Catahoula Tuff**

✓ **Surface Pits**





- **New Occurrences:**

✓ **Deeper**

✓ **Fault Related ?**

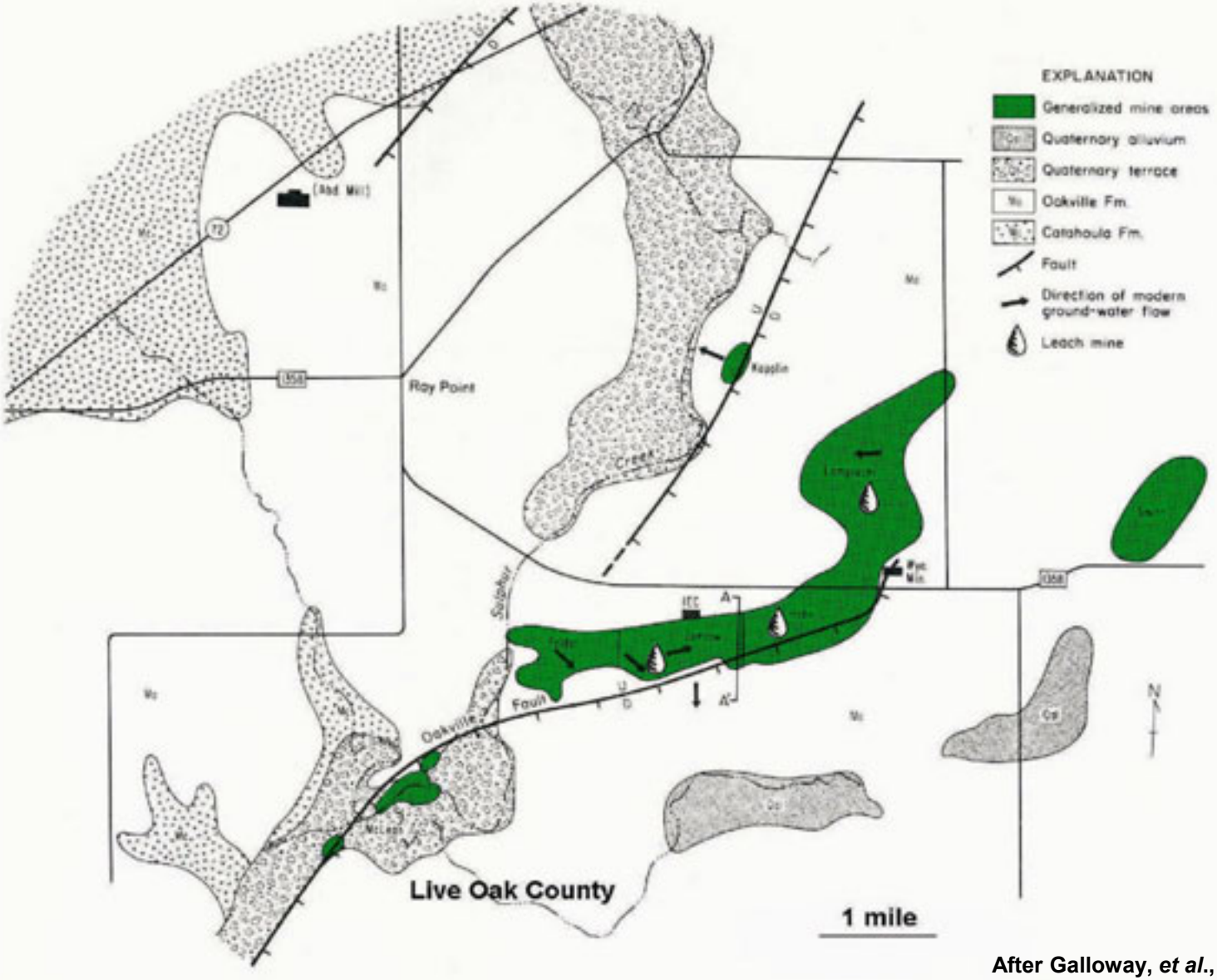
✓ **Salt-Dome Related**

✓ **Other Sources ?**

✓ **Other Reductants**

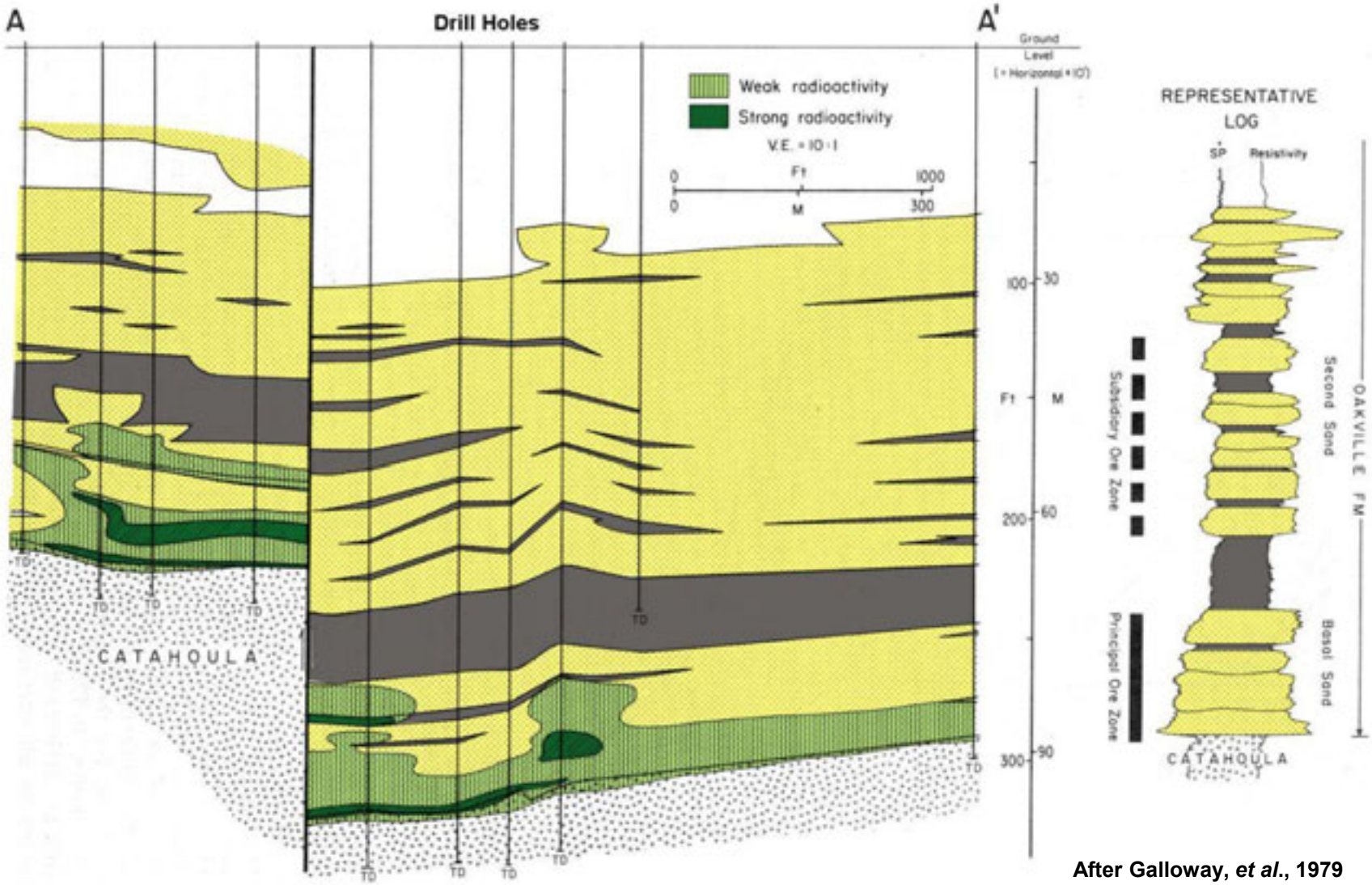
After: Eagle & Weeks, 1975

• Uranium Mineralization in the Oakville Formation



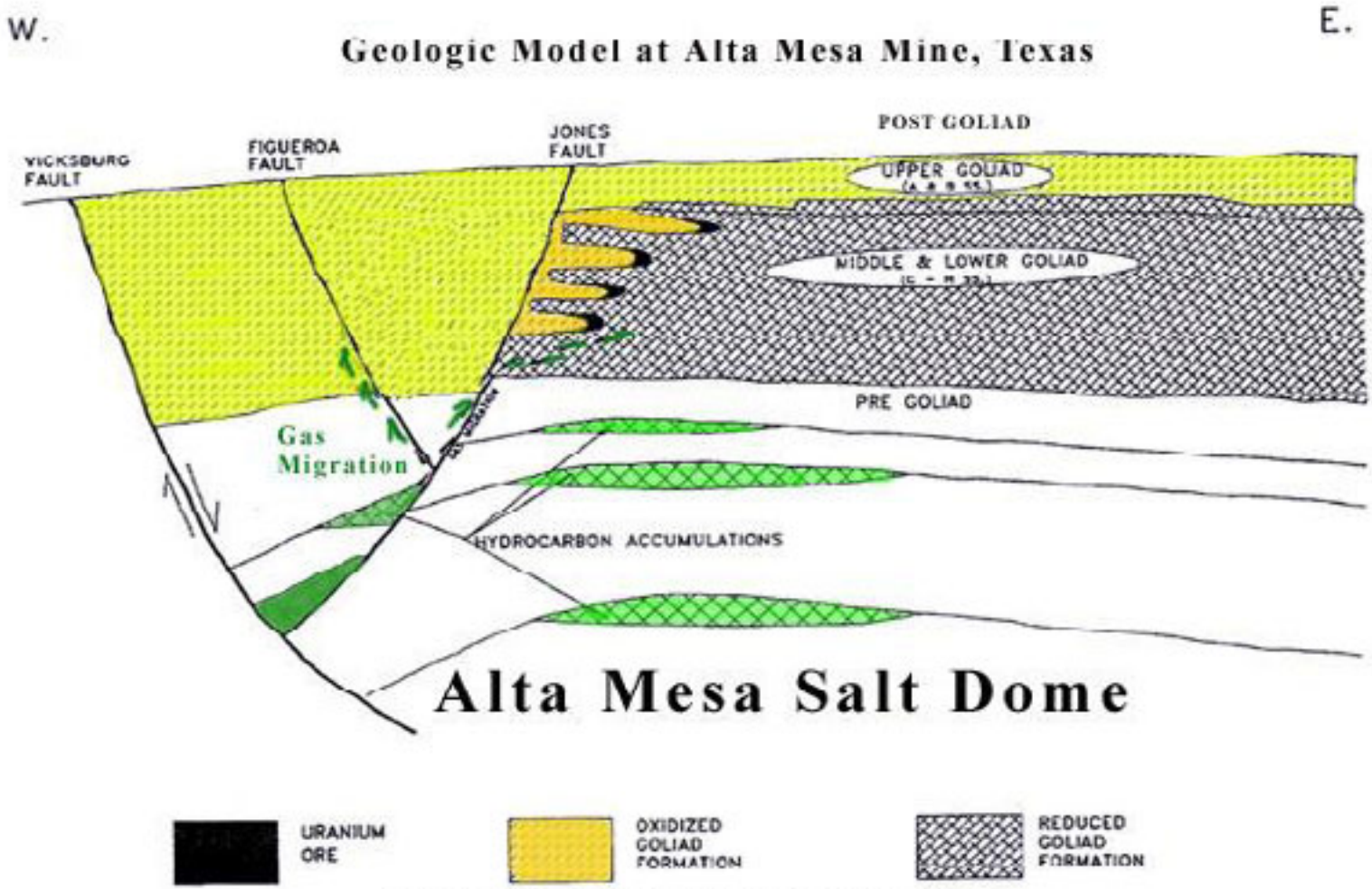
After Galloway, *et al.*, 1979

• Uranium Mineralization in the Oakville Formation

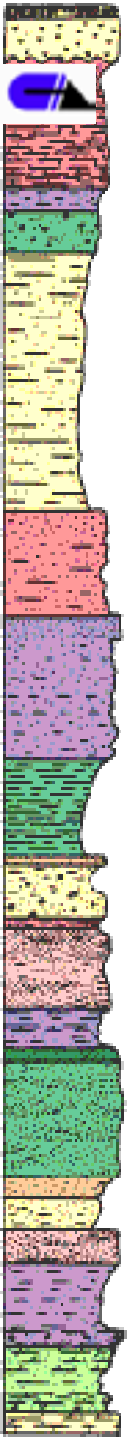


After Galloway, *et al.*, 1979

- **Uranium Mineralization in the Goliad Formation**



From Collins & Talbott, 2007, Proc. U2007.



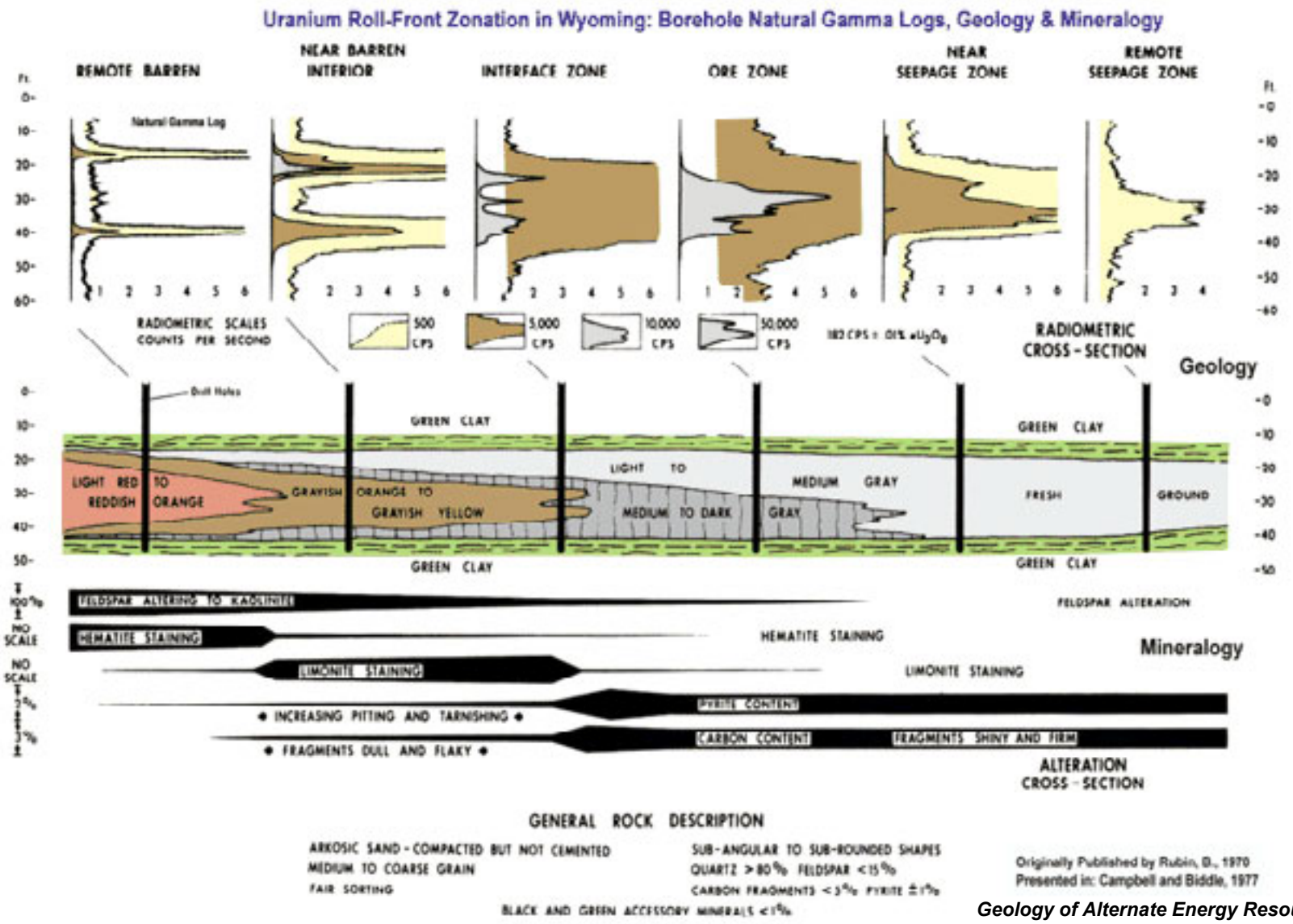
- **Exploration Guides**

Understand Mineralization in 3 Dimensions

- ✓ **Number & Location of Drill Holes**
- ✓ **Number of Core Samples**
- ✓ **Geological Logging**
- ✓ **Geophysical Logging**

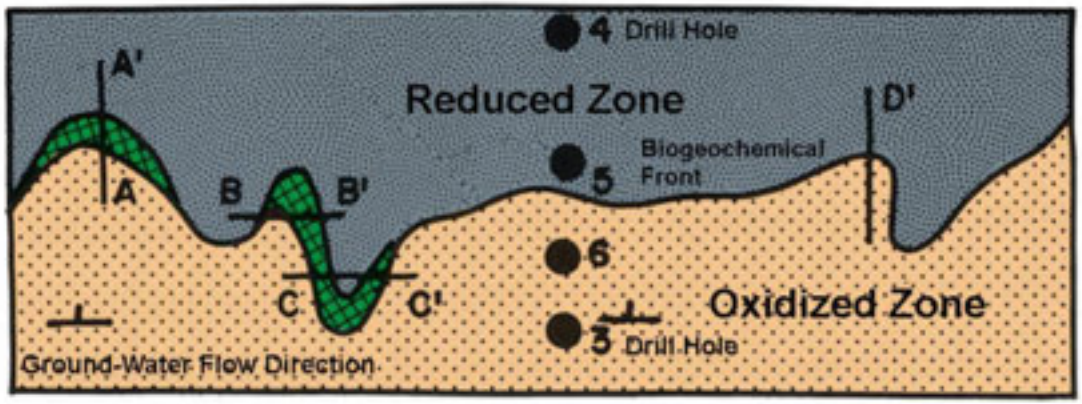
• **Reverse-Circulation Rotary Drilling**

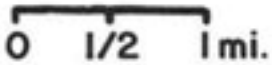
• Exploration Guides

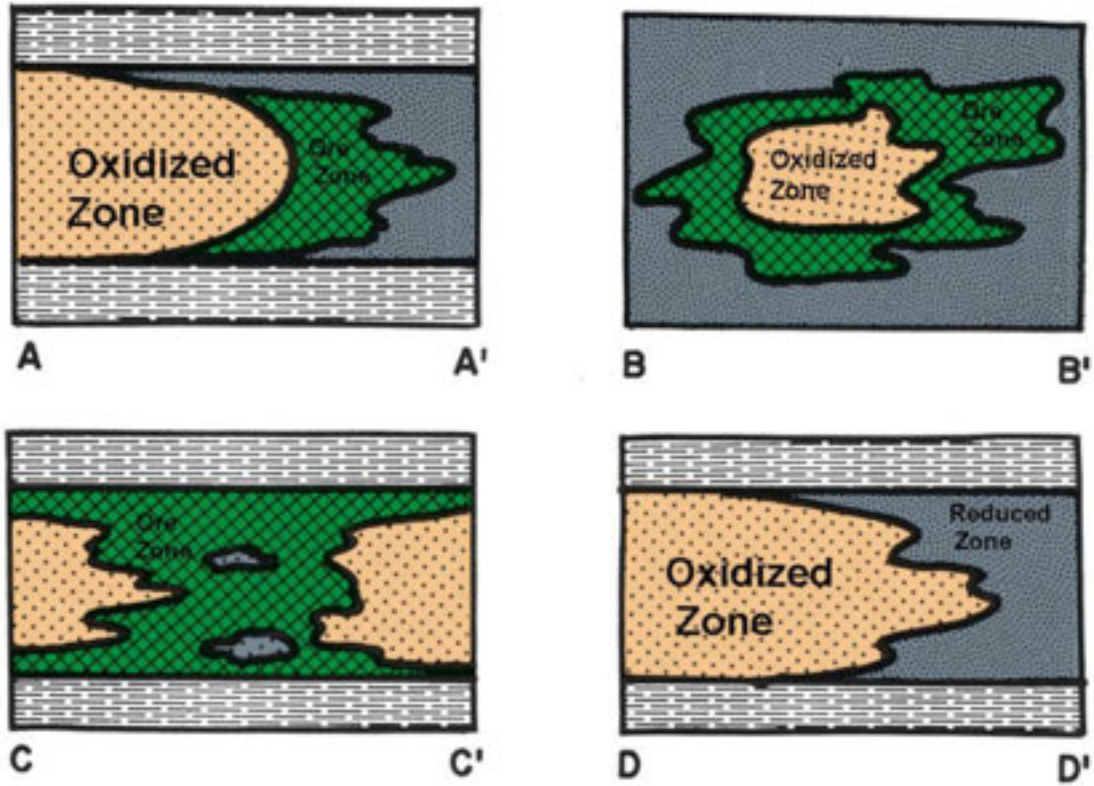


- **Standard Rotary Drilling**

- **Coring Uranium Mineralization**







- **Guide to Locating Oxidized Boundary and Uranium Mineralization:**

✓ **Find Ox-Reduction Boundary**

✓ **Explore Along Boundary**

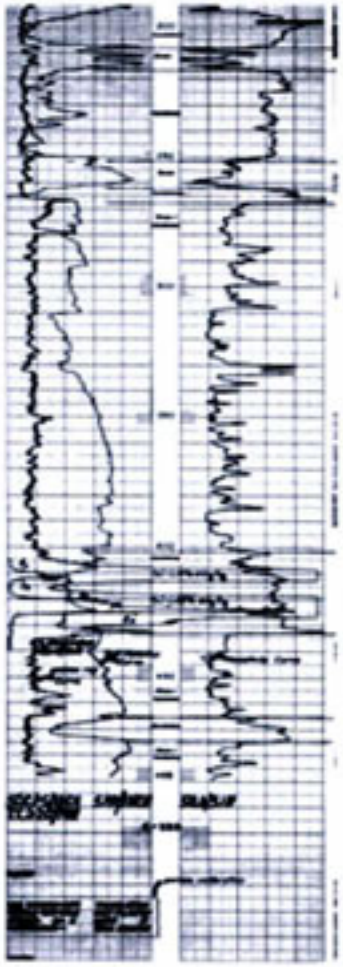
✓ **Step in – Step out Drilling**

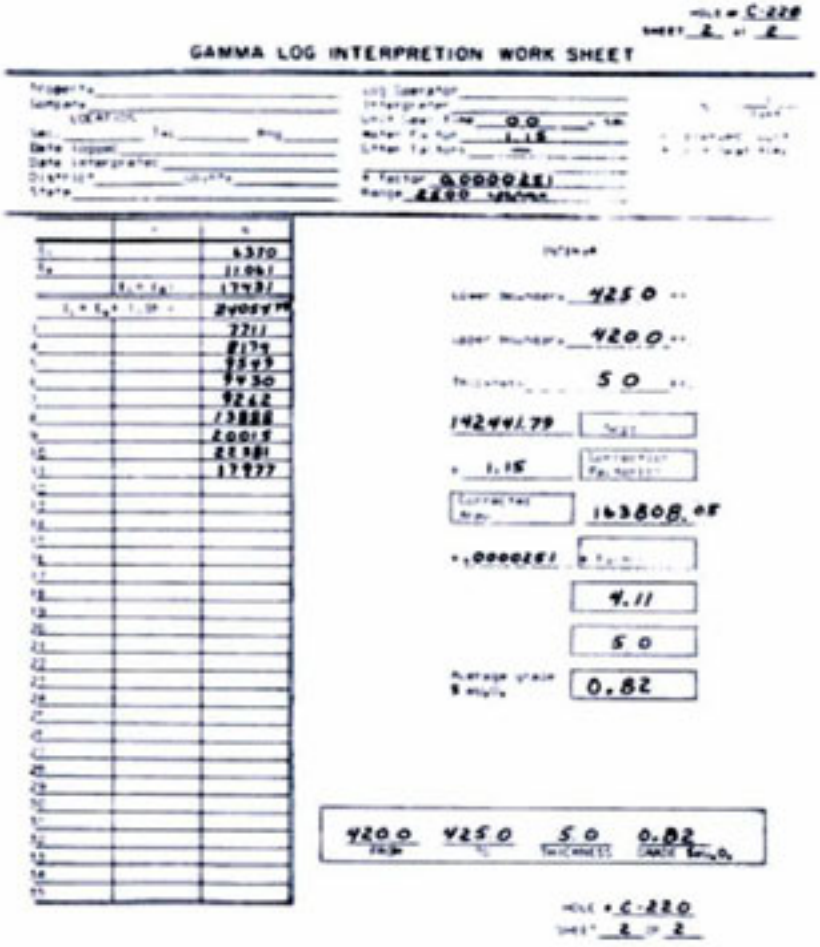
✓ **Develop Character of Local Mineralization**

After Campbell & Biddle, 1977

Geology of Alternate Energy Resources
Houston Geological Society

- **Geophysical Well Logs: Natural Gamma, SP and Resistivity**





From: Century Geophysical Corporation

- **New Equipment:**

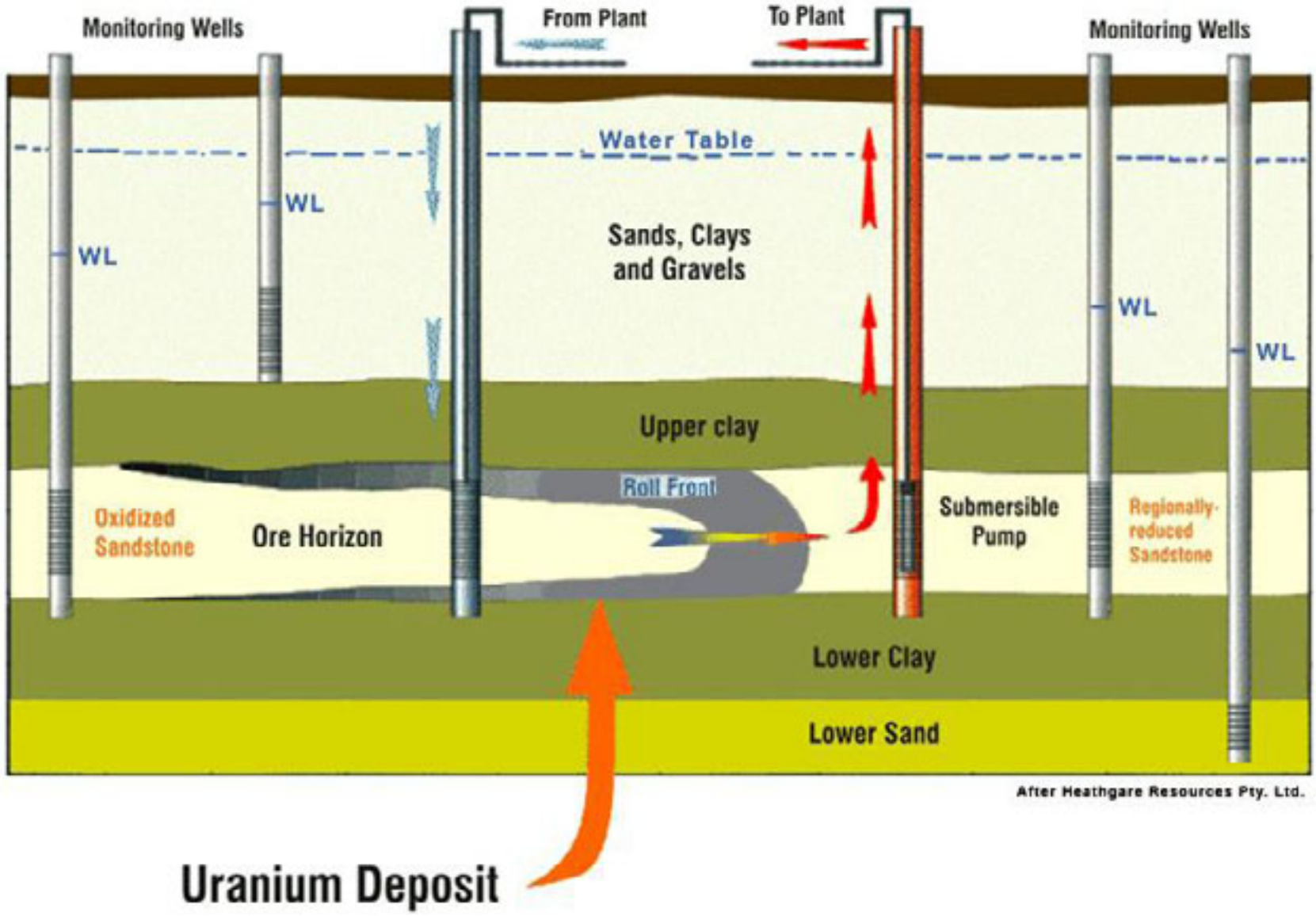
✓ Neutron Logging

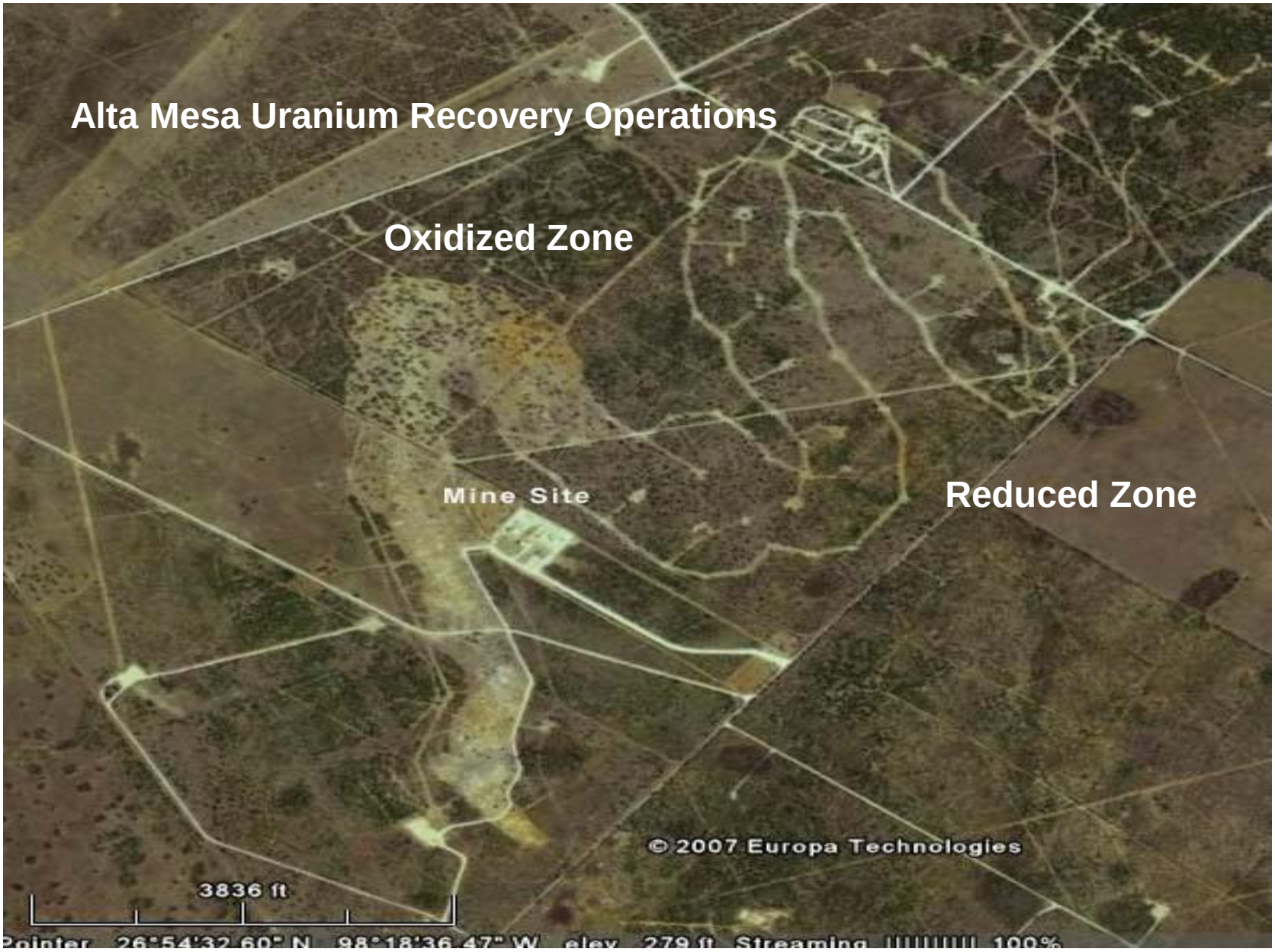
✓ Supports Natural Gamma Logging in Calculating Reserves

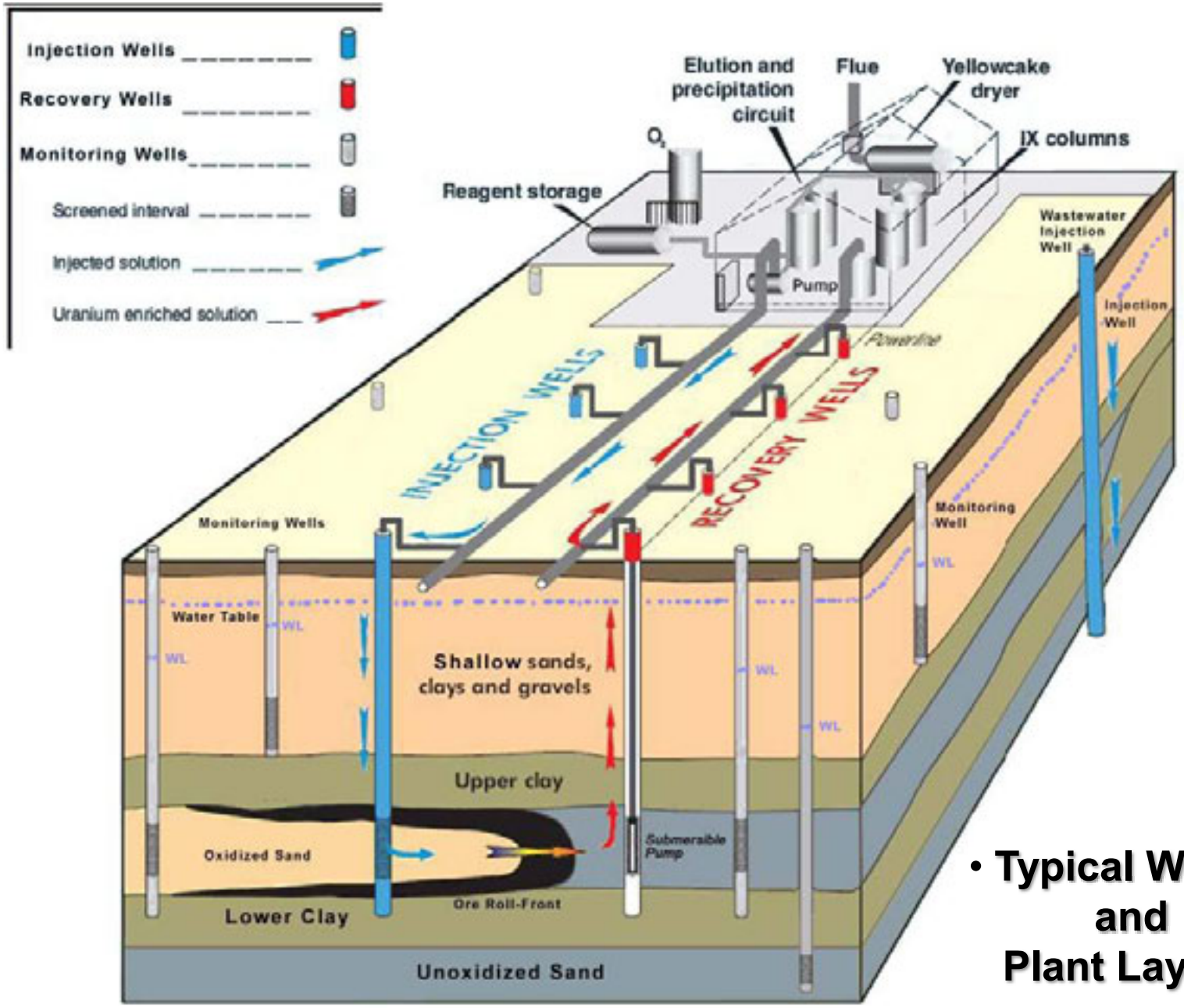
✓ Spectral Logging ?

✓ Additional Logging Equipment?

- **In-Situ Recovery of Uranium**




Alta Mesa Uranium Recovery Operations
Oxidized Zone
Mine Site
Reduced Zone
© 2007 Europa Technologies
3836 ft



- **Typical Well Field and Plant Layout**

After Heathgate Resources Pty Ltd

- **Typical Layout of Injection and Production Well Field**

• Typical Layout of Injection and Production Well Field

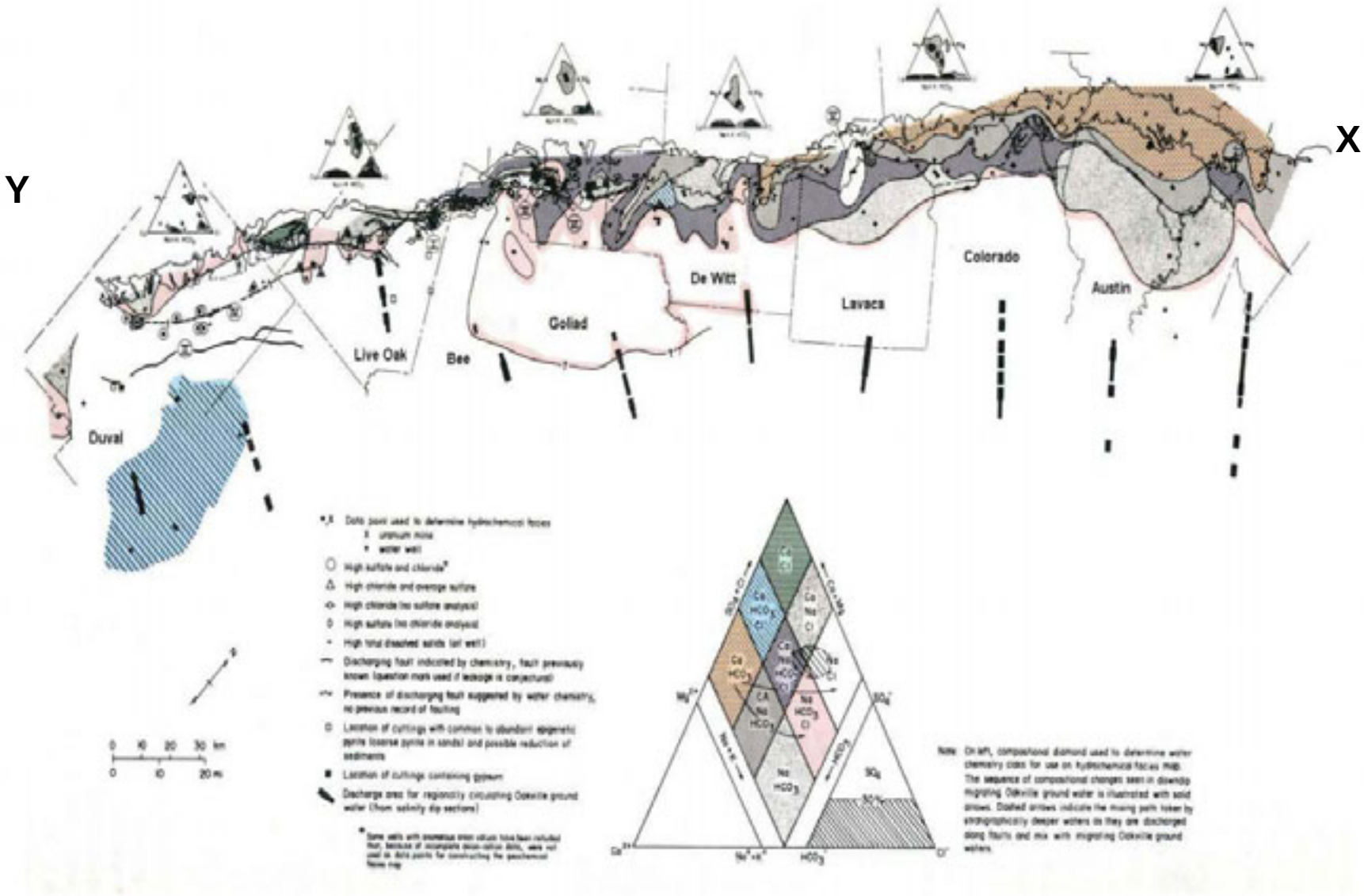

Oxidized ?
Reduced ?
Plant Site
Image © 2007 DigitalGlobe
1253 ft
Pointer 27°25'01.76" N 97°46'42.80" W elev 36 ft Streaming 100%

• Injection Fluids – Light Acids

- **Permitting Guides**

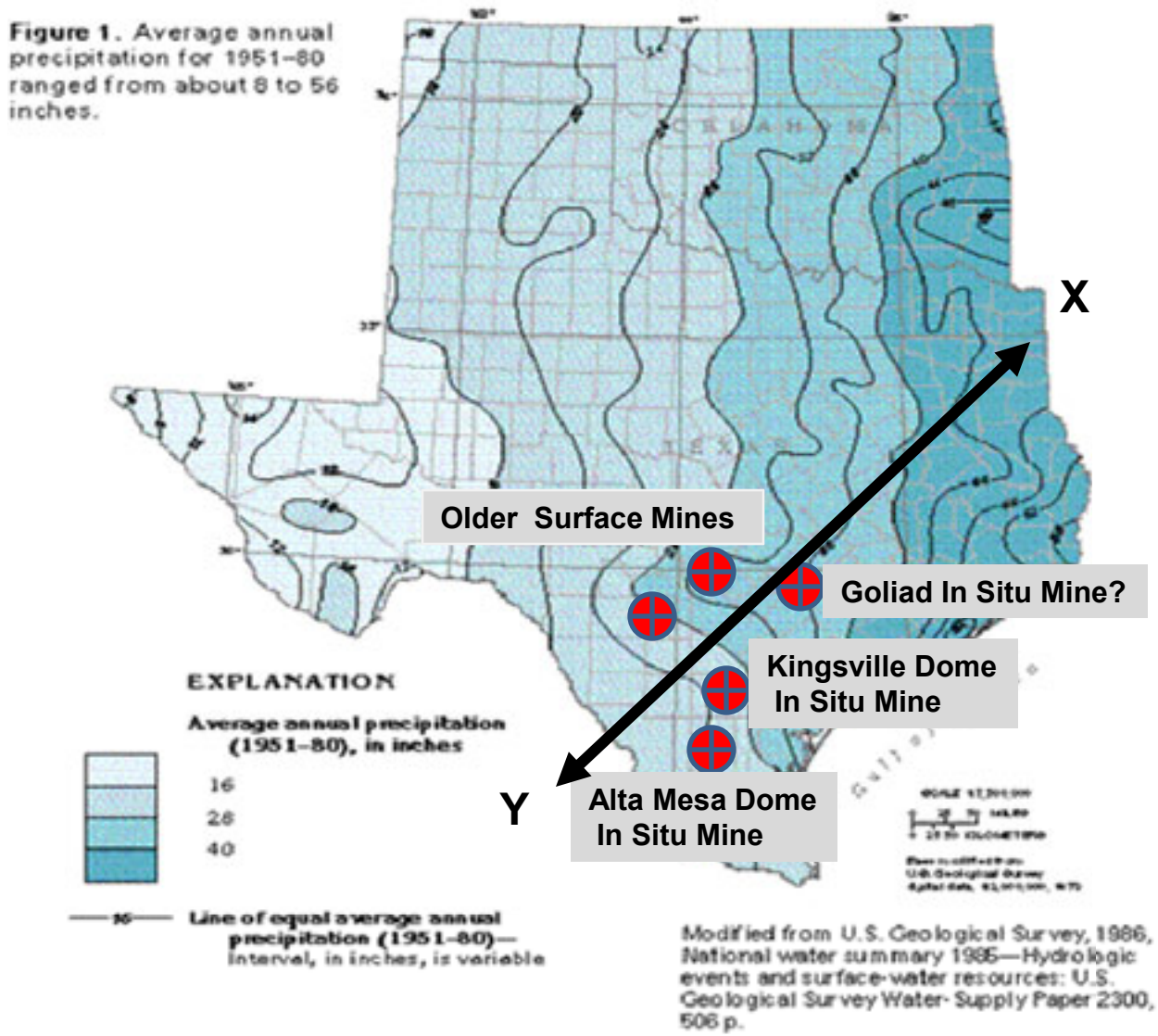
  - ✓ **Background Sampling Water Wells**
  - ✓ **Designated Monitoring Wells**
  - ✓ **Regional Ground-Water Settings**
  - ✓ **Also Use in Exploration Programs**

- **Regional Hydrochemistry: Hydrochemical Facies?**



After Smith, *et al*., 1982

- **Regional Hydrochemistry: Hydrochemical Facies?**



- **Monitoring Wells:**

Monitoring Shallow & Deep Aquifers

- **Monitoring Wells: Periphery Sites**

- **Uranium Exploration & Recovery <u>&</u> Health?**

  - ✓ **In Texas**
  - ✓ **In Colorado**
  - ✓ **Numerous Studies:**

http://www.mdcampbell.com/PUBMEDSURVEY.pdf

- **Human Health & Uranium Recovery**

Table 3.[d] Mortality due to all types of cancer, all ages and sexes combined over four time periods, 1950–2001, in Karnes County and in the four control counties. ('Obs' stands for 'Observed'.)

	Calendar years of death									
	1950–64		1965–79		1980–89		1990–2001		All	
	Obs	SMR[a]	Obs	SMR[a]	Obs	SMR[a]	Obs	SMR[a]	Obs	SMR[a]
Karnes County	267	0.9[c]	331	0.9[c]	279	0.9	346	0.9[c]	1223	0.88[c]
Control counties	799	0.8[c]	1102	0.9[c]	818	0.8[c]	1138	0.9[c]	3857	0.88[c]
RR[b]	1.0		0.9		1.1		1.0		1.0	

[a] SMR is the observed number of cancers divided by that expected based on rates within the general population of the United States.

[b] Estimated RR taken as the ratio of the SMR in Karnes County with that in the four control counties.

[c] $p < 0.05$.

d After Boice, *et al.*, 2003, Cancer Mortality in a Texas County with Prior Uranum Mining and Milling Activities, 1950-2001, *Journ.Radiological Protection*, Vol.23, pp. 247-262.

• Human Health & Uranium Recovery

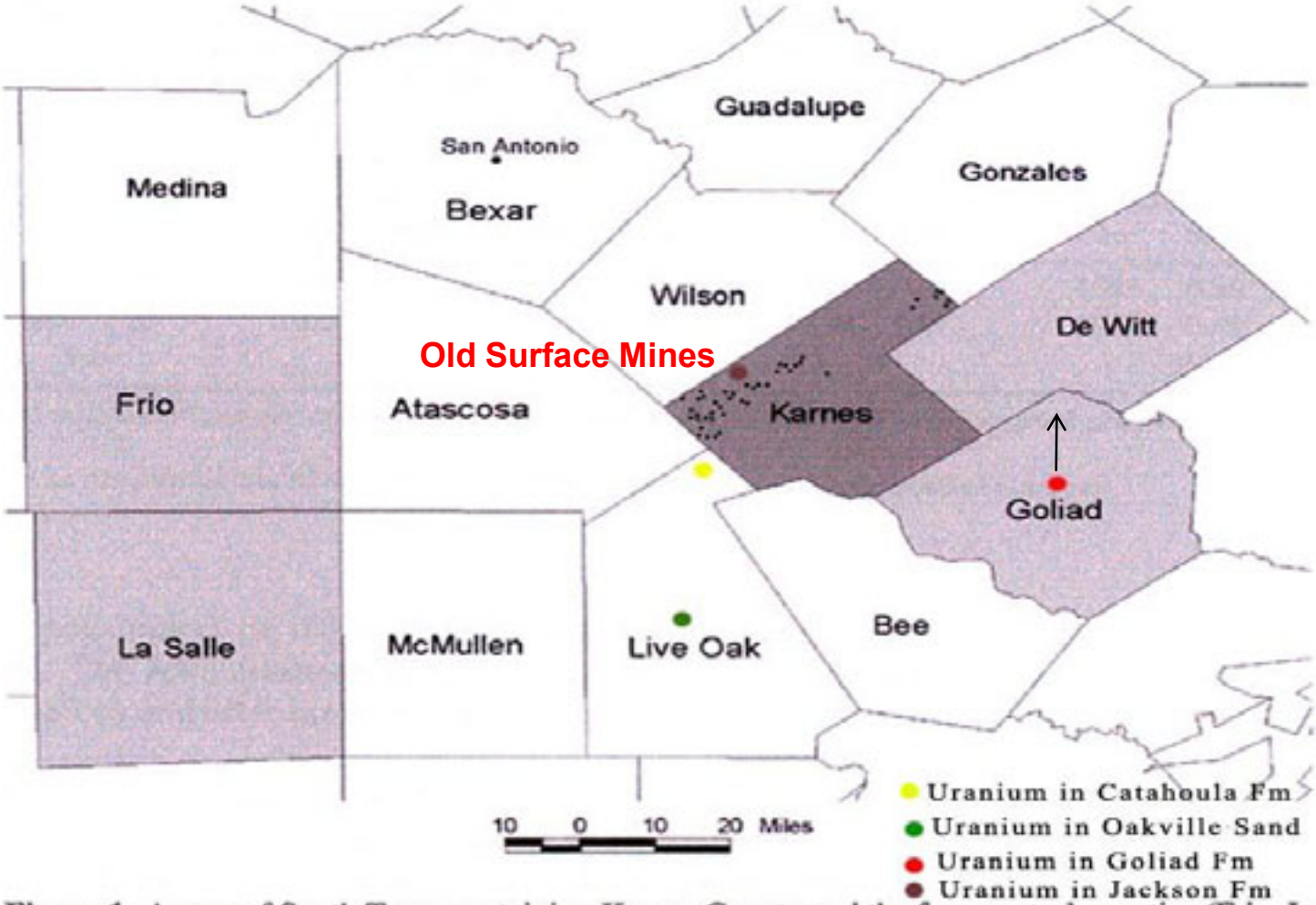
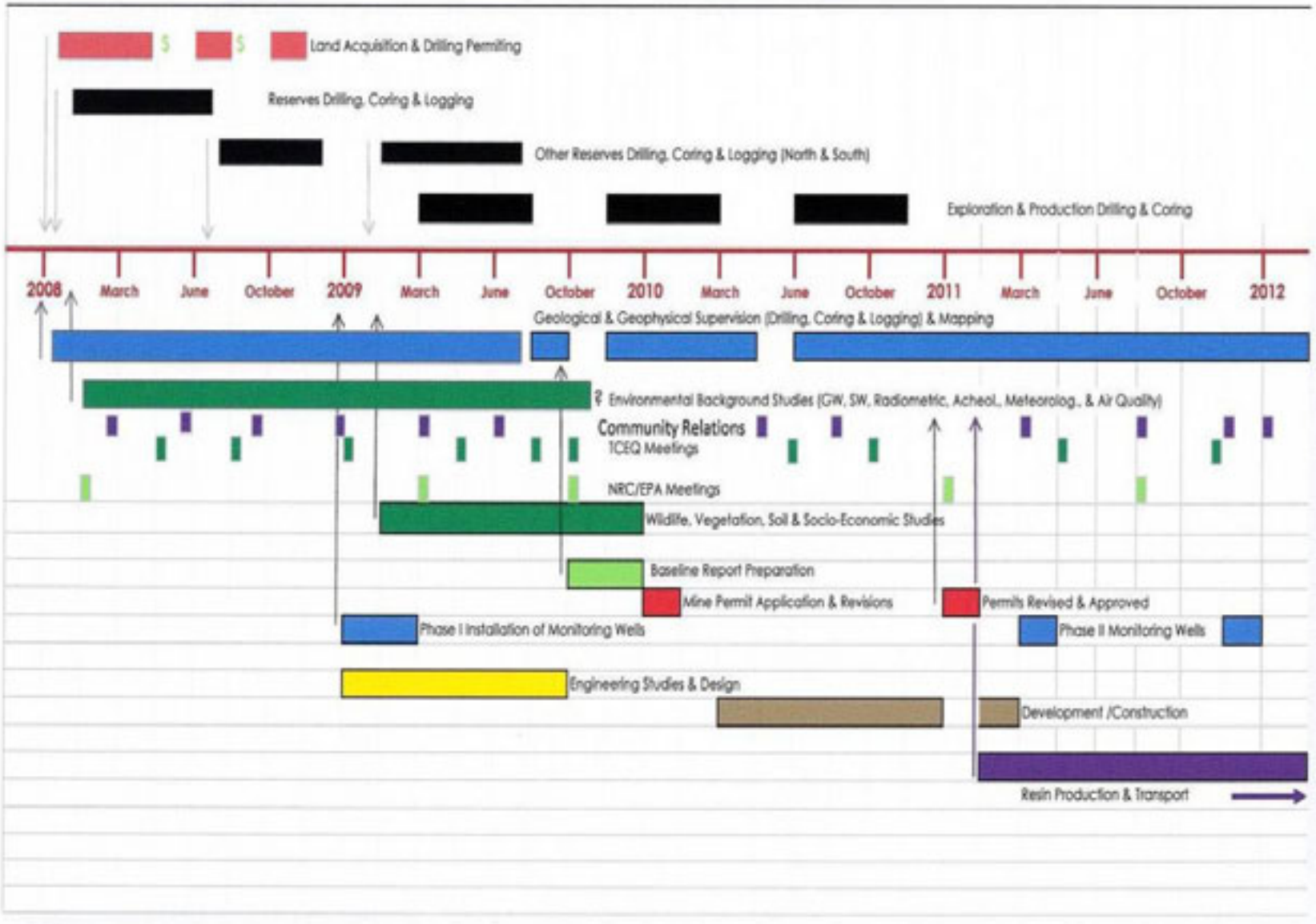


Figure 1. A map of South Texas containing Karnes County and the four control counties (Frio, La Salle, DeWitt and Goliad). The dots in Karnes County represent the prior location of 43 mines and 3 mills (Railroad Commission of Texas, Surface Mining and Reclamation Division map).

After Boice, 2003, Cancer Motality in a Texas County with Prior Uranium Mining and Milling Activities, 1950-2001, *Journ. Rad. Protection* Vol. 23, pp. 247-262.

TYPICAL EXPLORATION & DEVELOPMENT PLANNING
Uranium Recovery Company: 2008 - 2012



- **Environmental Issues & New Perspectives**

Re-Writing & Updating Regulations:

Texas Railroad Commission Uranium
Exploration Area Permits

Texas Dept. of State Health Services
ISR for Plant,

Texas Commission on Environmental Quality

1. **UIC Aquifer Exemption & Class III Permits,**
2. **Production Area Authorization (PAA) for Recovery Operations &**
3. **Class I UIC Nonhazardous Well Permit for Wastewater Disposal**

- **Environmental Issues & New Perspectives**

Regulations (Cont'd)

Texas Commission Environmental Quality

4. Clean-ups of Releases & Spills in Well Field and Pipelines.

Texas Parks & Wildlife & Texas Historical Office

U.S. Army Corp of Engineers

U.S. Environmental Protection Agency

Drinking Water Aquifer Exemptions

U. S. Mine Safety and Health Administration

Recovery & Processing Operations Safety

- **Environmental Issues & Perspectives**

New Perspectives: Not "Cookie-Cutter Functions"

A. "While the aquifer may contain suitable drinking water quality, the area of the aquifer containing uranium mineralization was naturally contaminated by biogeochemical processes long before humans could drill water wells into the aquifer."

B. "Baseline environmental studies are essential to provide reasonable in-situ recovery closure guidelines."

- **Environmental Issues & Perspectives**

New Perspectives:

Baseline Studies Involve:

1. Physical Characteristics, such as: topography, geology, hydrology/hydrogeology, soils, air quality, radiological background, weather/climate information, etc.

2. Biological Characteristics, such as: flora and fauna (terrestrial and aquatic), endangered species (if present), radiological sampling of biota, and

3. Socio-Economic Characteristics, such as: analyses of local populations, employment, resources such as agriculture, fishing, tourism, archeology, and historical information.

• Environmental Issues & Perspectives

Issues to be Anticipated:

- ✓ Type of Solutions Used in In-Situ Recovery of Uranium?
- ✓ What is a Reasonable Clean-Up Goal?
- ✓ What to do about Abandoned Wells?
- ✓ Best way to Dispose of Wastewaters?
- ✓ Company Employees Trained in Handling Radioactive Materials?
- ✓ Have all Water Wells been Sampled in Immediate Area?

"A Strong Community-Relations Program should be an Integral Part of Management's Function"

Community Outreach

- Talk with Community about Technical Issues
- Rumors & Falsehoods
- Conflicting Agendas
- Positive Features of Uranium Development
- Combating Media Bias Program:

  http://www.mdcampbell.com/CAReviewszz/careviews.htm

• Environmental Issues & New Perspectives

ISL URANIUM RECOVERY RECLAMATION STATUS - 2007			
Operation	Status	County	Regional Aquifer
Caithness – McBride	G.W.Restored/Plugged/D&D	Duval	Oakville
Chevron – Palangana	G.W.Restored/Plugged/D&D	Duval	Goliad
Cogema – Holiday	G.W.Restored/Plugged	Duval	Catahoula
Cogema – El Mesquite	G.W.Restored/Plugged	Duval	Catahoula
Cogema - O'Hern	G.W.Restored/Plugged/D&D	Duval	Catahoula
Cogema – Cole	G.W.Restored/Plugged/D&D	Duval	Catahoula
Conoco- Trevino	G.W.Restored/Plugged/D&D	Duval	Oakville
Everest – Hobson	G.W.Restored/Plugged/D&D	Karnes	Oakville
Everest – Las Palmas	G.W.Restored/Plugged/D&D	Duval	Oakville
Everest – Mt Lucas	G.W.Restored/Plugged	Live Oak	Goliad
Everest – Tex-1	G.W.Restored/Plugged/D&D	Karnes	Oakville
IEC – Pawnee	G.W.Restored/Plugged/D&D	Bee	Oakville
IEC – Zamzow	G.W.Restored/Plugged/D&D	Live Oak	Oakville
IEC – Lamprecht	G.W.Restored/Plugged	Live Oak	Oakville
Mestena – Alta Mesa	Operation	Brooks	Goliad
URI – Benavides	G.W.Restored/Plugged/D&D	Duval	Catahoula
URI – KVD	G.W. Restoration/Operation	Kleberg	Goliad
URI – Longoria	G.W.Restored/Plugged/D&D	Duval	Catahoula
URI – Rosita	G.W.Restored/Operation	Duval	Goliad
URI – Vasquez	Operation	Duval	Goliad
U.S.Steel - Boots	G.W.Restored/Plugged/D&D	Live Oak	Oakville
U.S.Steel - Burns	G.W.Restored/Plugged/D&D	Live Oak	Oakville
U.S.Steel - Clay West	G.W.Restored/Plugged/D&D	Live Oak	Oakville
U.S.Steel - Mosier	G.W.Restored/Plugged/D&D	Live Oak	Oakville

Pelizza, 2007

• Uranium Production & Economics

- ✓ **Like Oil & Gas, Guided by the Sale Price of Yellowcake,**
- ✓ **Controlled by Recovery Efficiencies,**
- ✓ **Affected by Plant Operations, and**
- ✓ **Affected by Delivery Options Available at the Mill.**

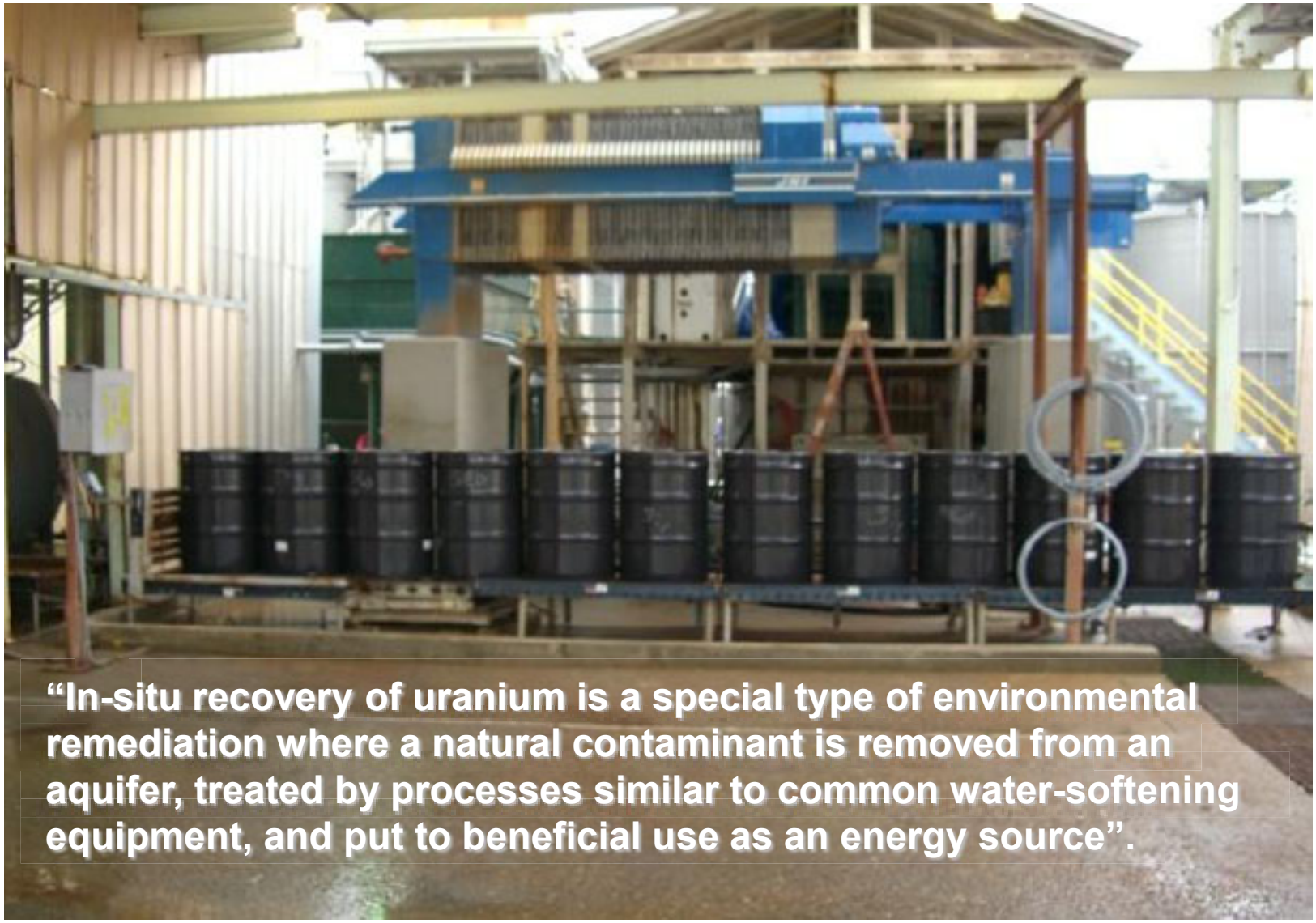
• Yellowcake Product

Approximately 880 pounds of yellowcake / BBL

At Market Price of $100 / #

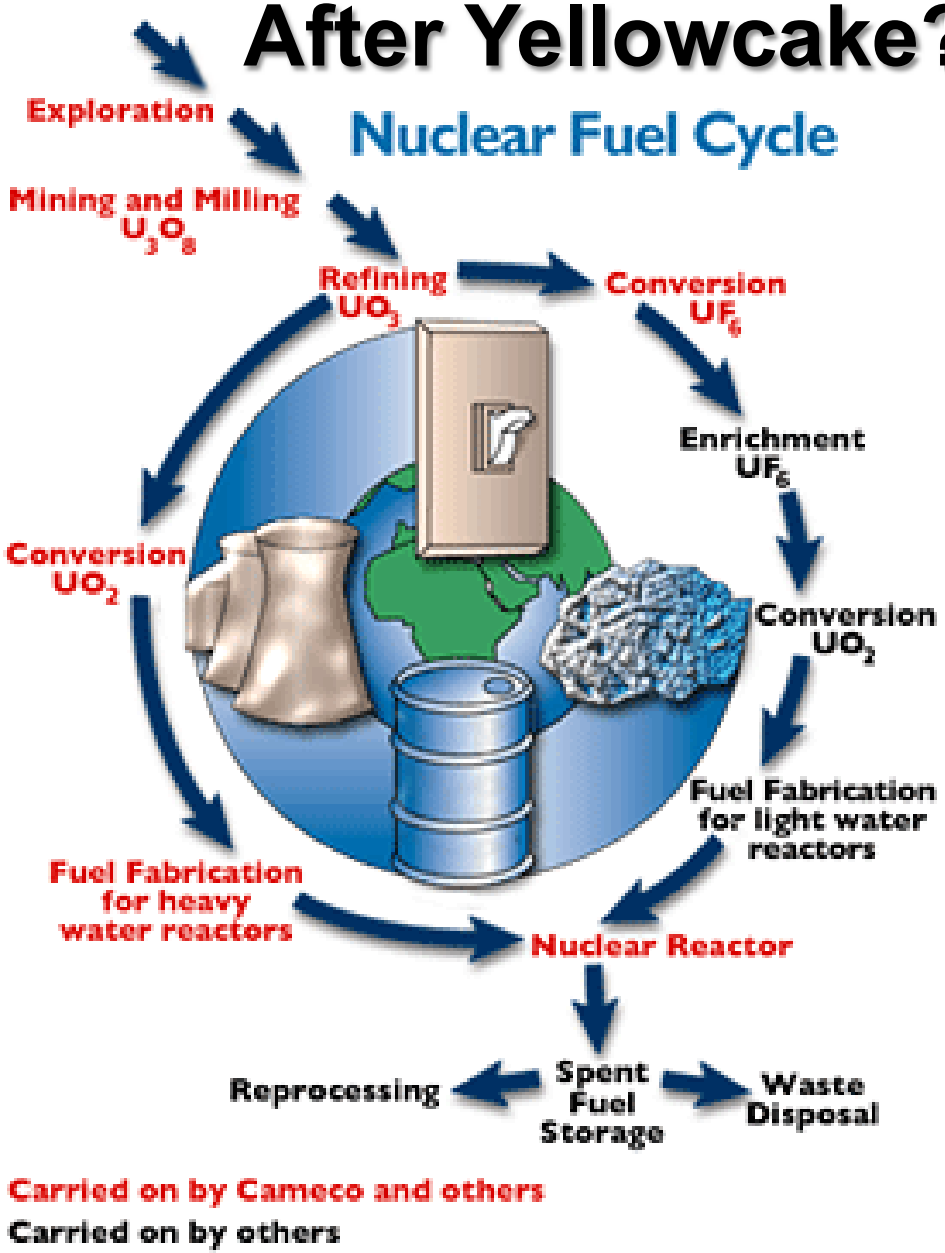
$88,000 / BBL

- **Month's Production of Yellowcake?**



"In-situ recovery of uranium is a special type of environmental remediation where a natural contaminant is removed from an aquifer, treated by processes similar to common water-softening equipment, and put to beneficial use as an energy source".

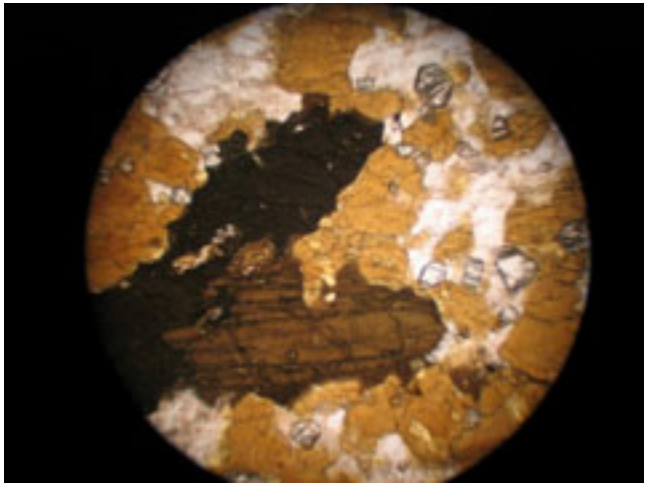
After Yellowcake?



Cameco, 2007

Surface-Sediment Analysis

- **Uranium Research**
  - 1970s Technical Literature
  - Company Records
  - NURE Records
  - Find the Missing Generation



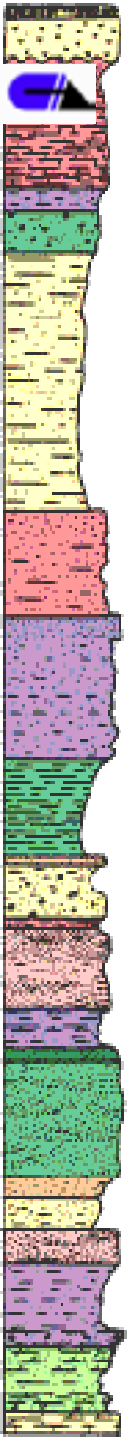
Thin-Section Analysis

• Uranium Field Work

✓ Conducting Outcrop Analysis

✓ Conducting Field Reconnaissance

✓ Sampling Environmental Monitoring Wells



Anti-Nuclear Power?

Fear

Weapon of War,
Hollywood
&
Press Media

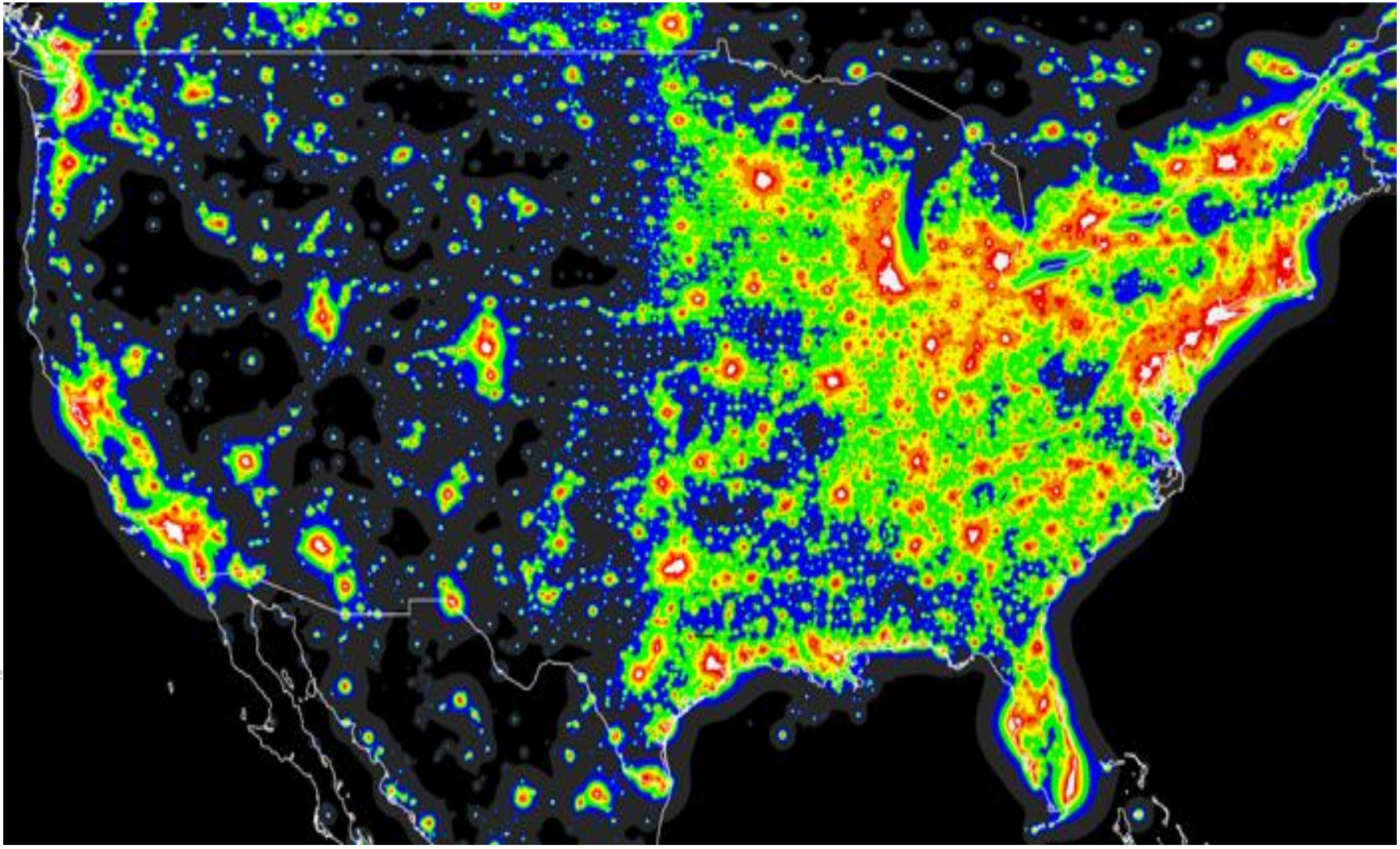
Assessment

Safety Record,
Economic Advantage, Jobs,
Technology, Management

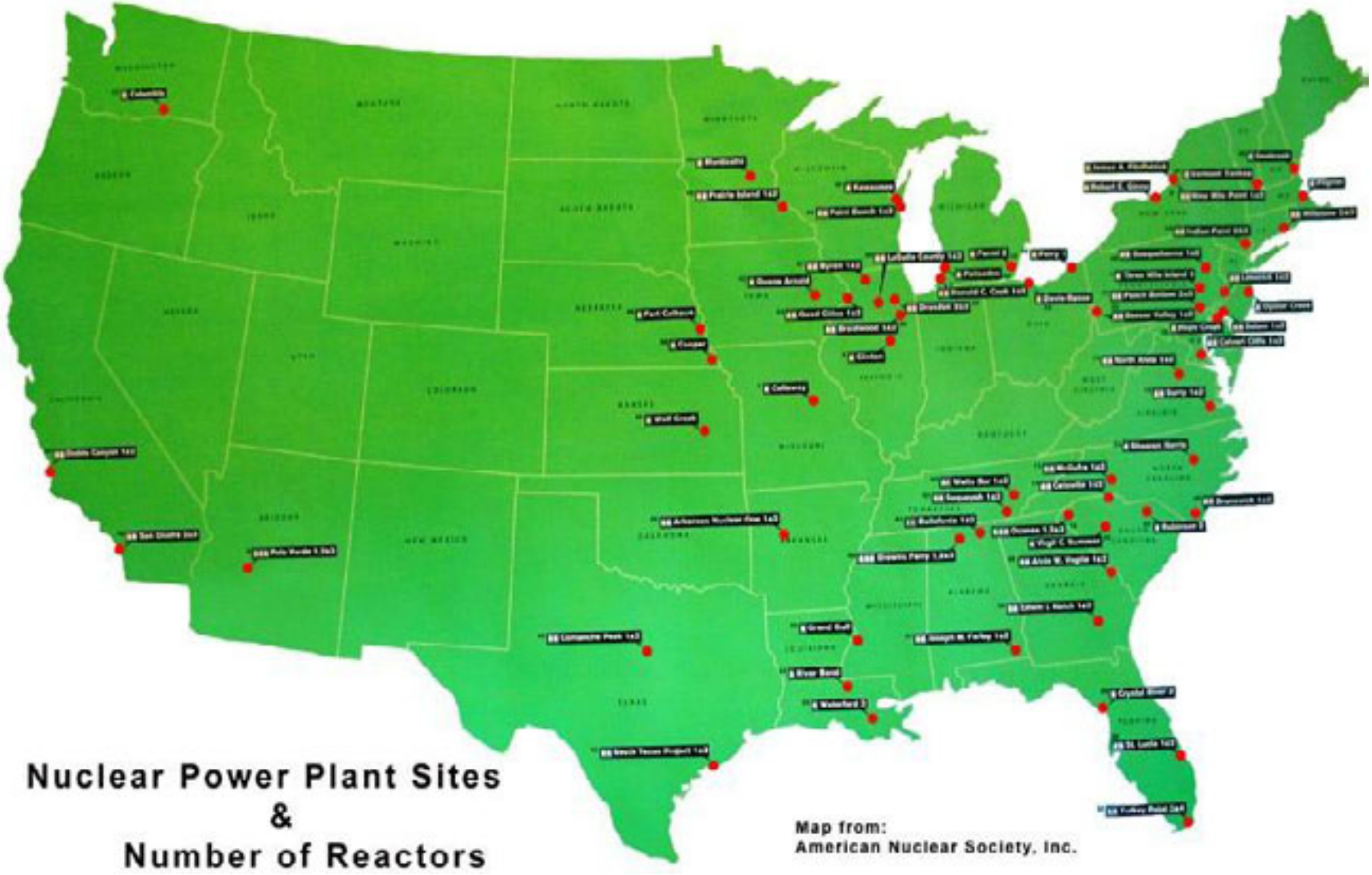
Risk

Comparative Analysis
w/ Other Types of Risk:
NIMBY - Industry, Local, etc.

The U.S. Power Grid: Night Lights Tell the Story



The U.S. Nuclear Power Plant Sites



What about Nuclear Waste Management?

Fear

Exposure?
Drinking Water?
Hollywood
&
Press Media

Assessment

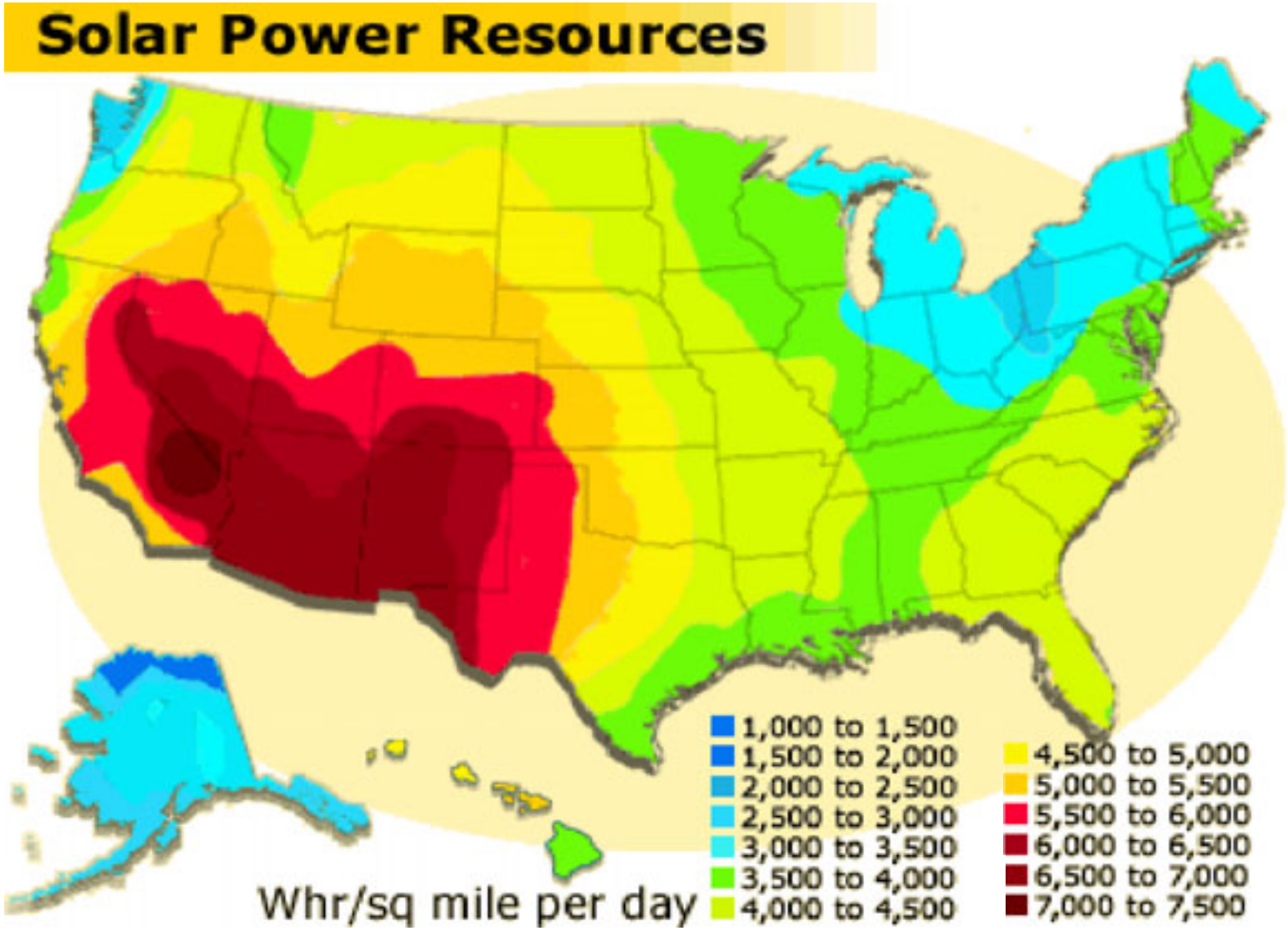
Safety Record, Good Science
New Technology, Improved Management

Risk

Comparative Analysis
w/ Other Types of Risk:
NIMBY - Industry, Local, &
w/ International Solutions.

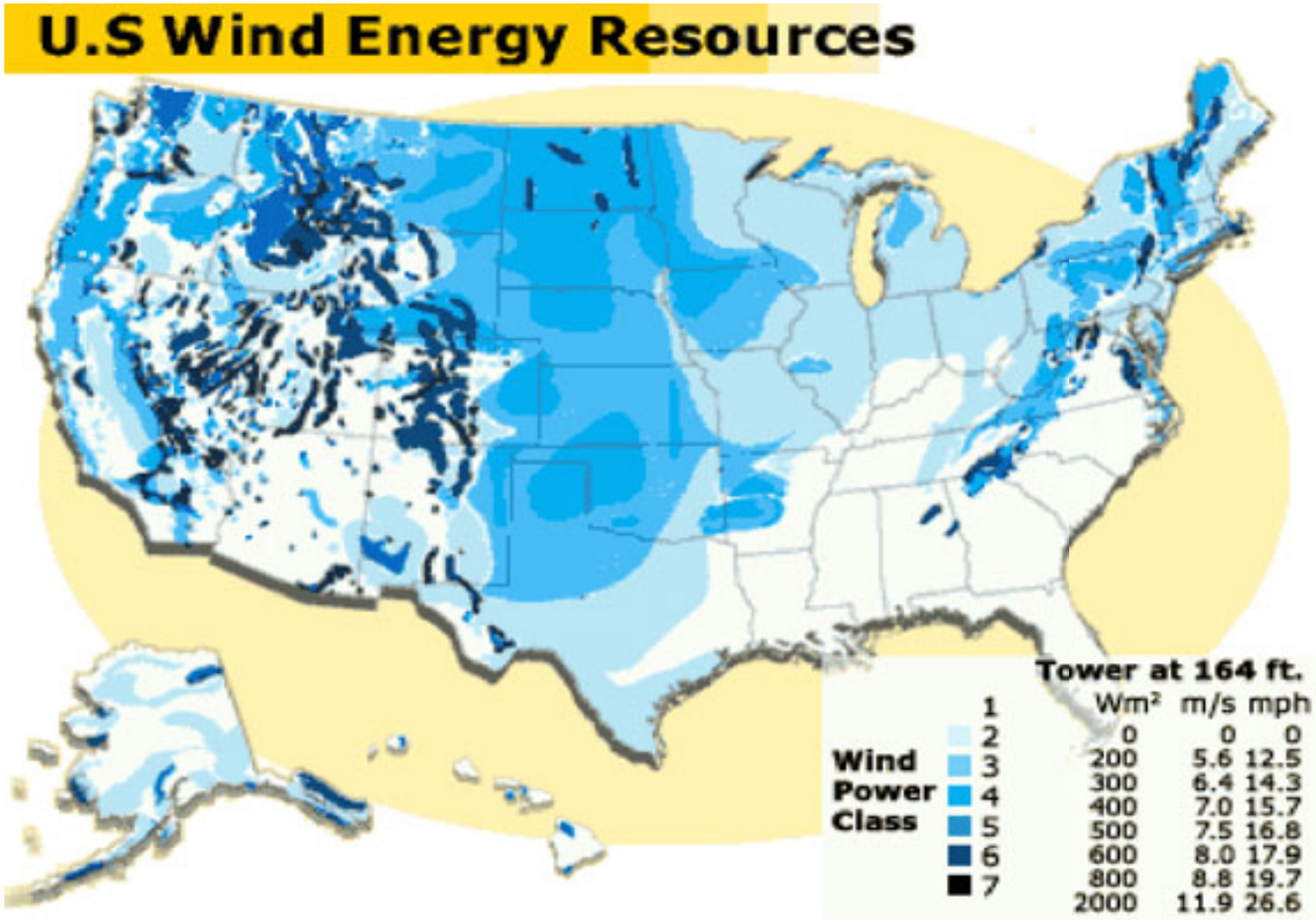
…And there are always disagreements….

But What about Solar Power?

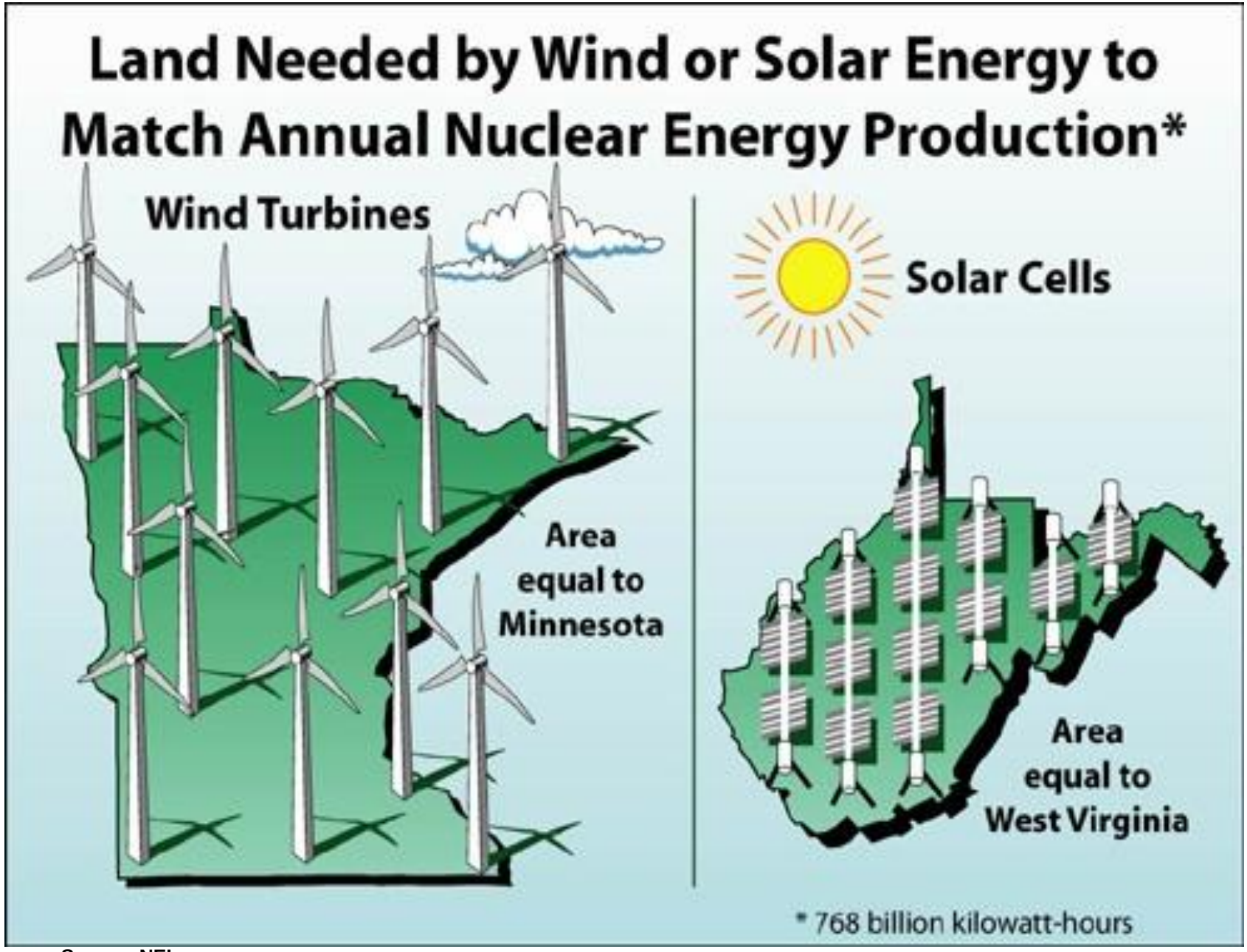


Source: NEI

But What about Wind Power?

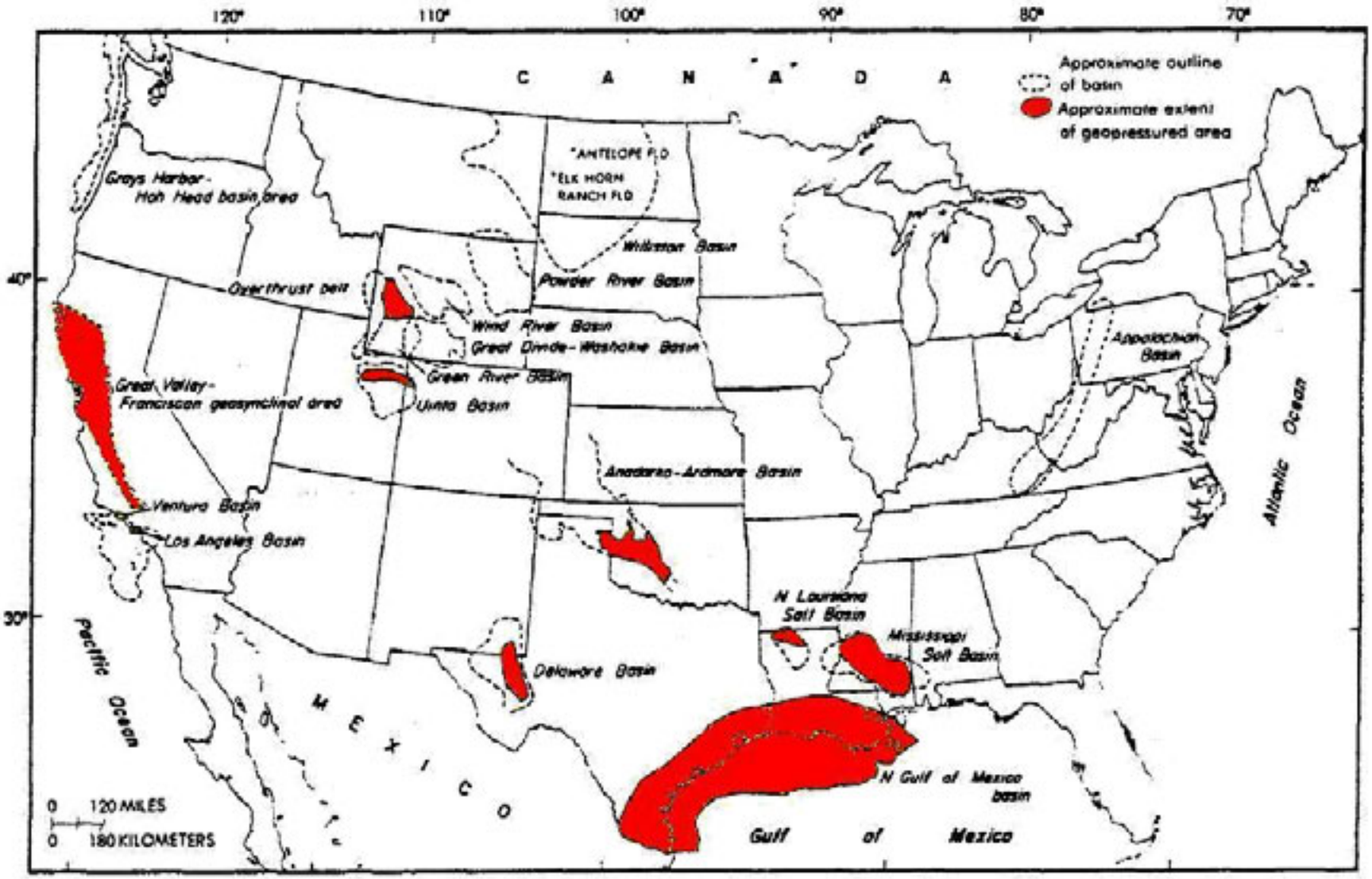


Source: NEI


Land Needed by Wind or Solar Energy to Match Annual Nuclear Energy Production*
Wind Turbines
Area equal to Minnesota
Solar Cells
Area equal to West Virginia
* 768 billion kilowatt-hours

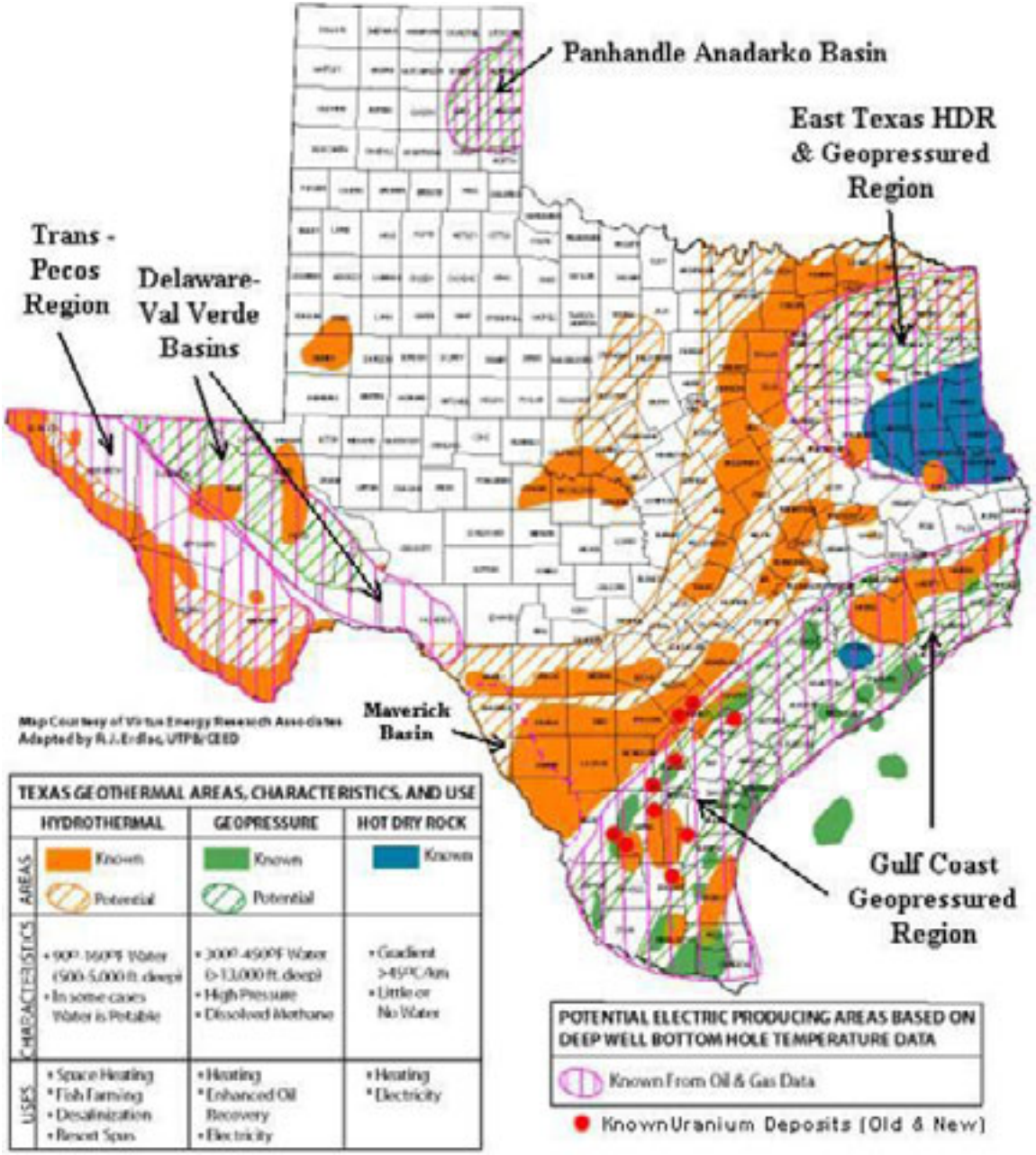
Source: NEI

What about Geopressured Geothermal Resources?



After Erdlac, 2007

Geothermal Resources in Texas



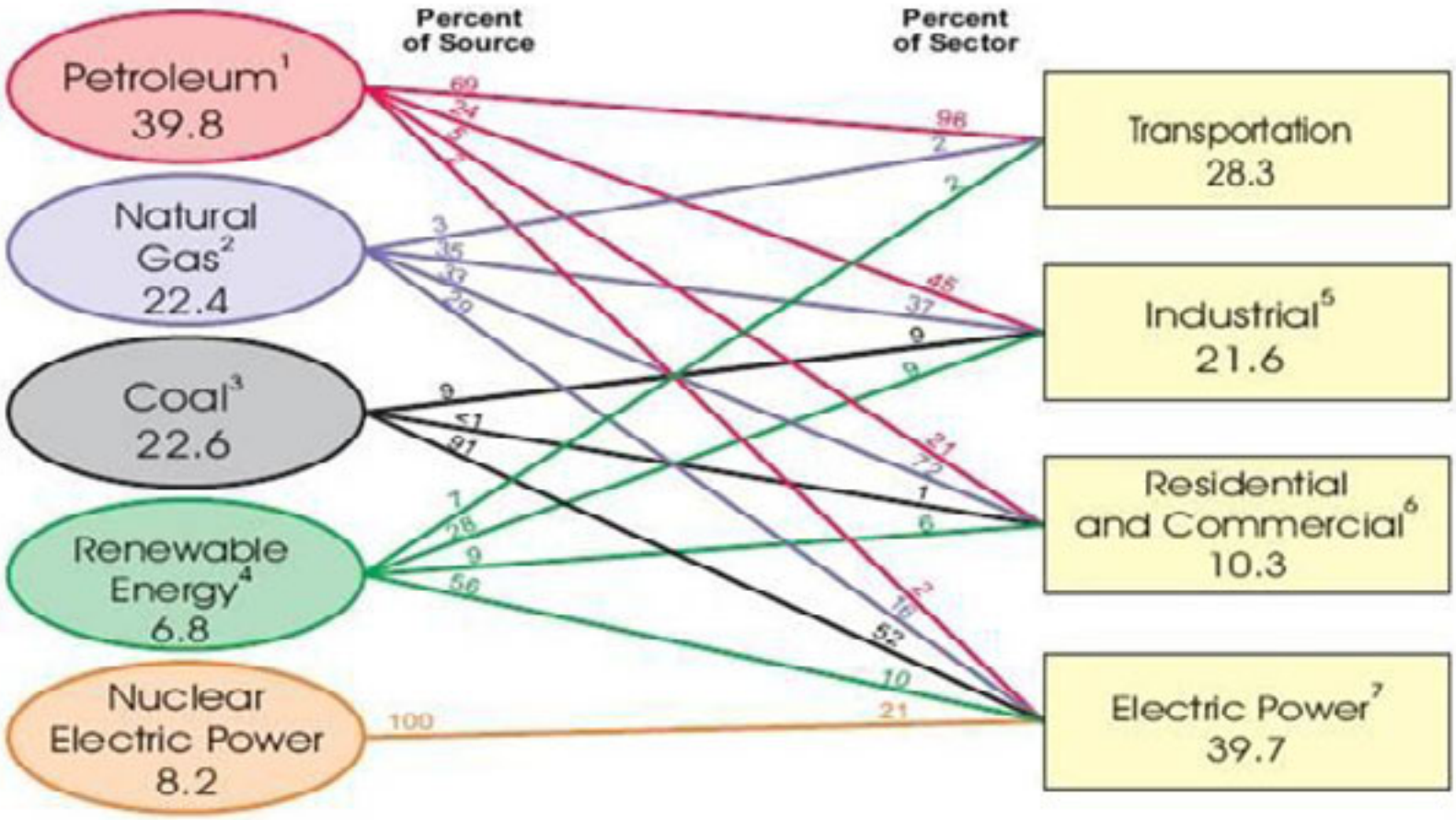
After Erdlac, 2007

What about New Sources of Power?

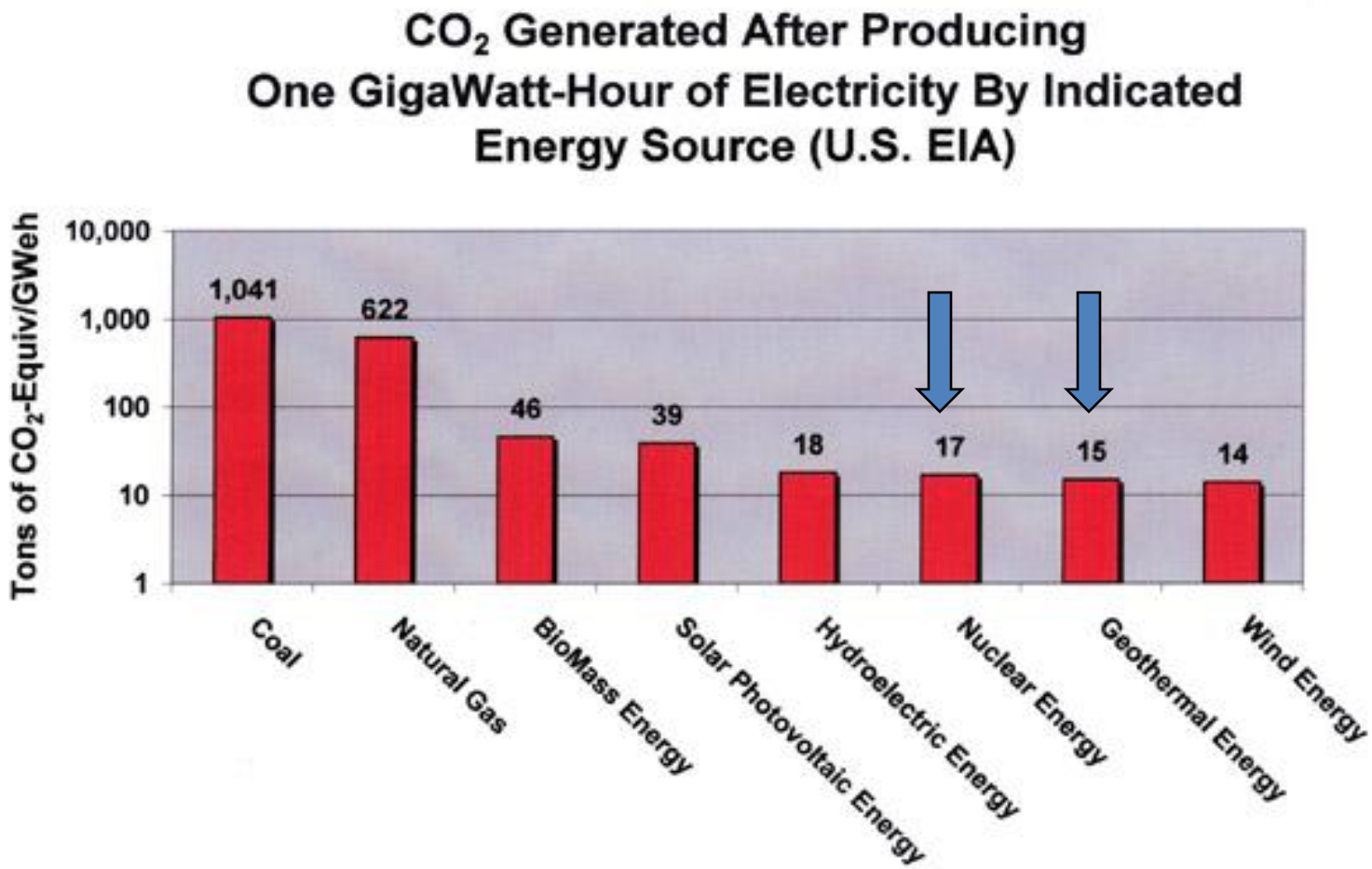
What about the Economics ?

Comparing Power Technologies	
Technology	Expected Capacity Factor (%)
Coal	71
Nuclear	90
Geothermal	86 - 95
Wind	25 - 40
Solar	24 - 33
Natual Gas Combustion Turbine	30 - 35
Hydropower	30 - 35
Biomass	83

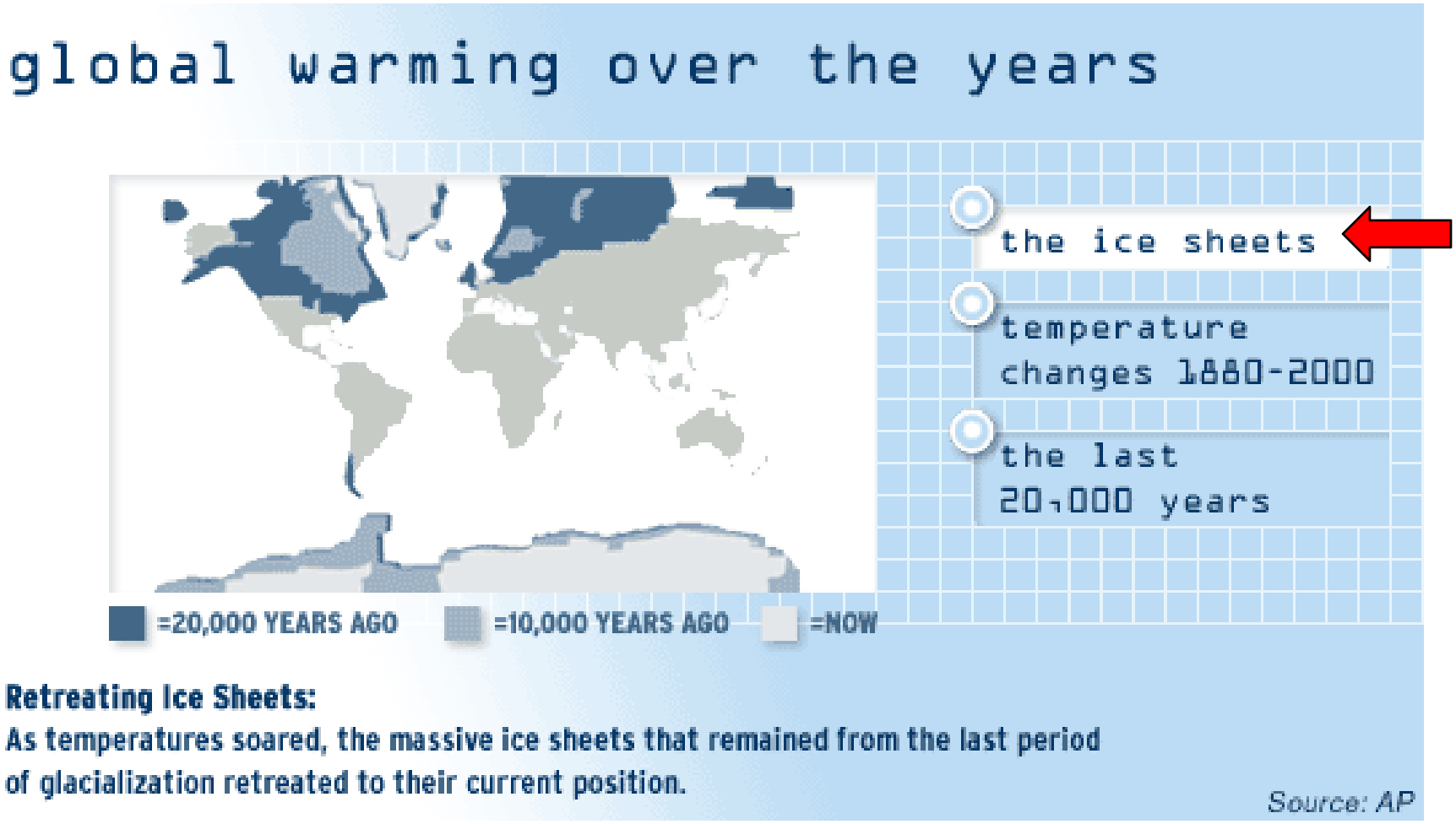
What about Present Usage Energy Resources?



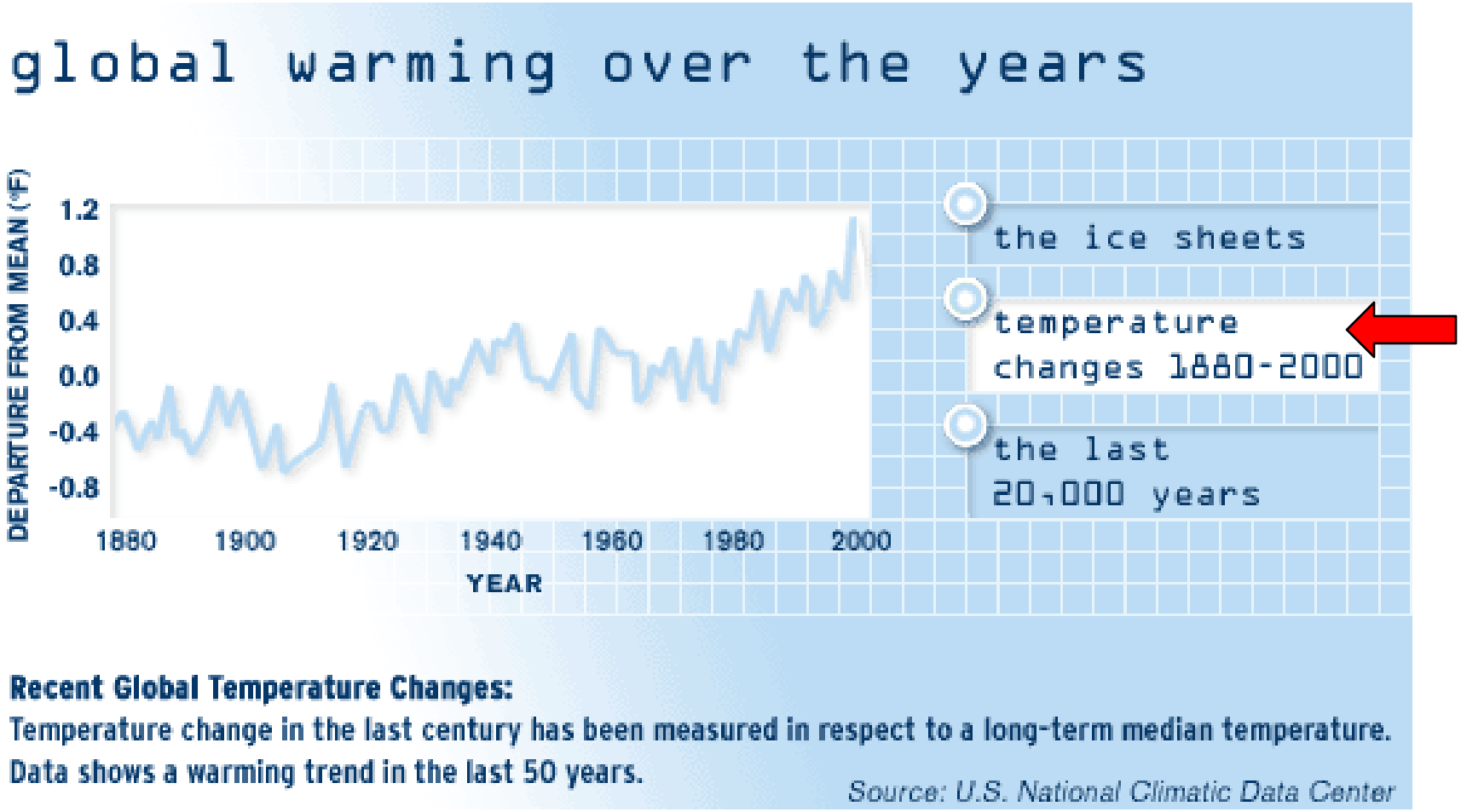
What about Produced CO_2 ?



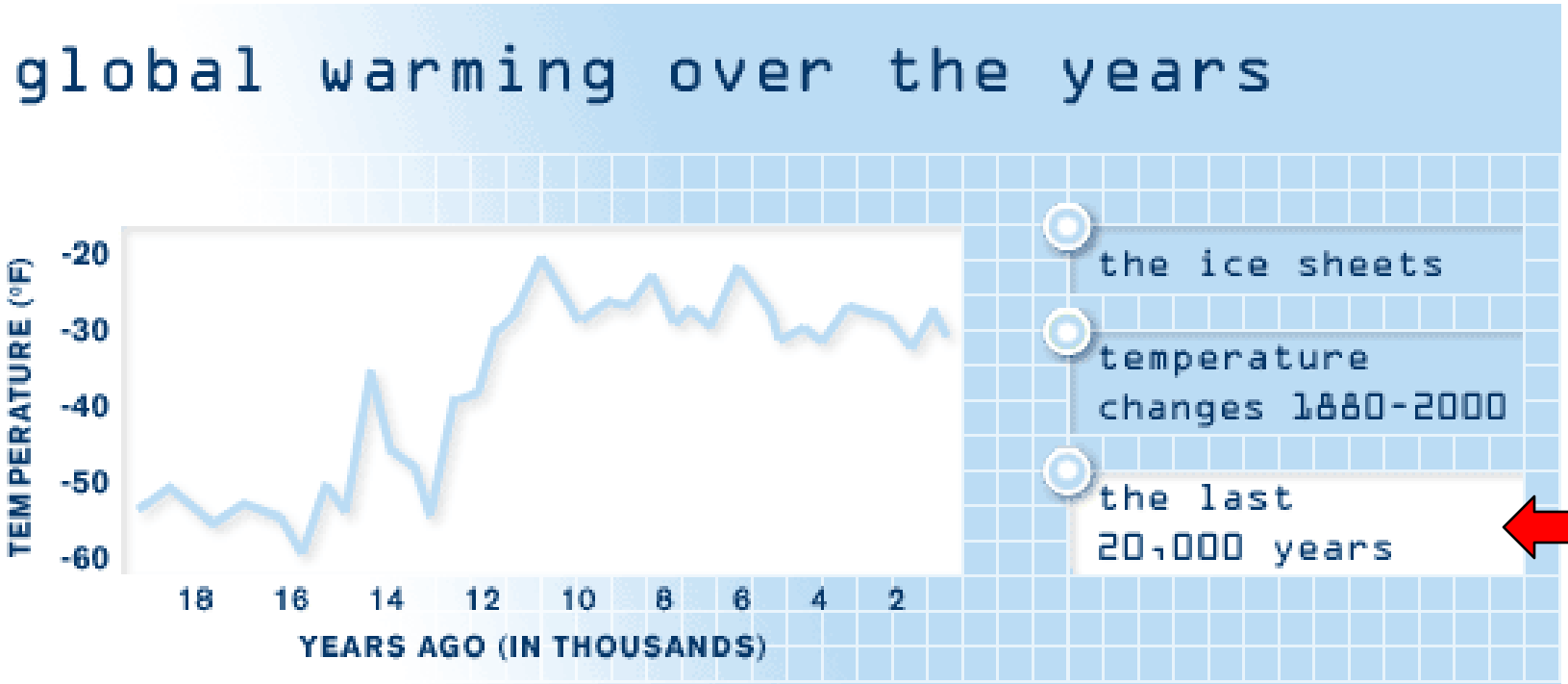
...And there are always disagreements....



...And there are always disagreements....



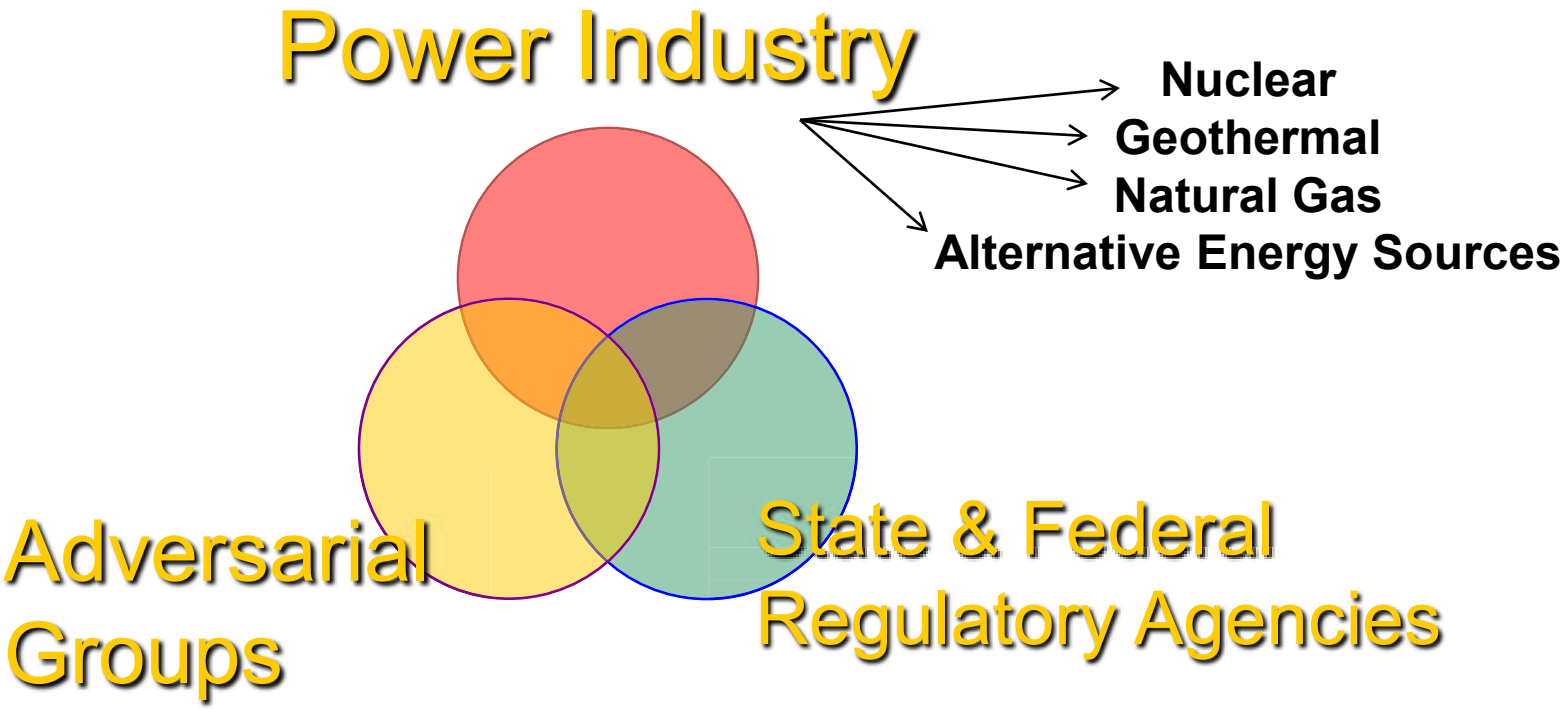
...And there are always disagreements....



Average Temperature in Greenland:
By studying deep samples of ice taken from Greenland and other areas, researchers have been able to understand historical climate changes throughout the years. This graph shows the average temperature in Greenland during the last 20,000 years.

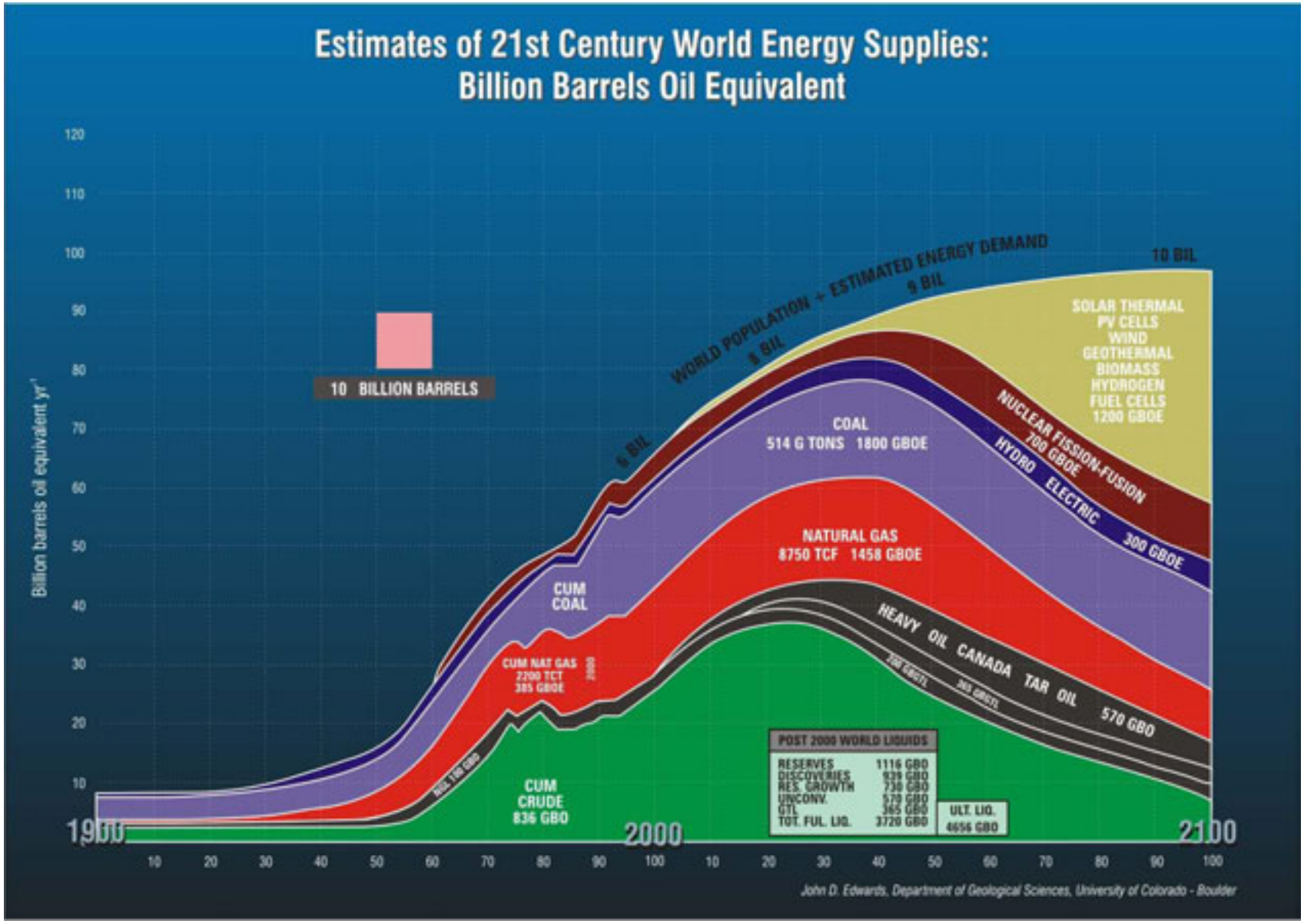
Source: AP

- **Checks and Balances**

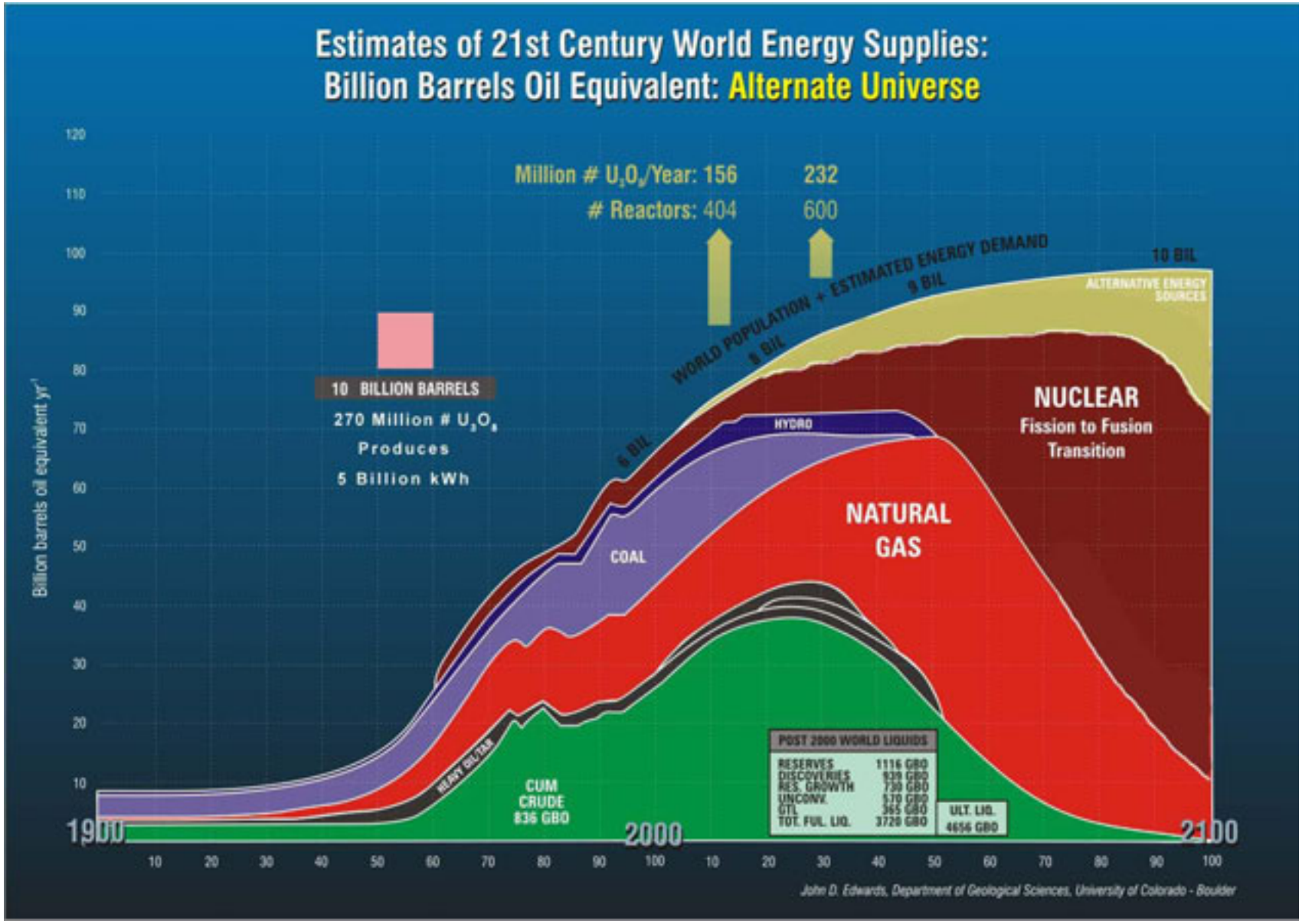


We are in this together; united we stand, divided we fall…

Today's Paradyme



An Alternate Universe



Our Predictions: 2008 to 2040*?

*** Will Change as Technical Breakthroughs Impact Our Predictions**

1) **Transition Over 30 years from Using Coal to Nuclear Power to Supply the U.S. Power Grid,**

2) **Remote Favorable Areas for Solar and Wind Will Be Permitted into Periphery of U.S. Power Grid,**

3) **Natural Gas to Remain Important for Years to Come,**

4) **Geothermal May Increase by 10% of Power Needs or Better in Texas and Western U.S.**

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Note: For an online version of this presentation (with links), see: http://www.mdcampbell.com (C&A NEWS).

Biographies

•**Michael D. Campbell, P.G., P.H.,** serves as Managing Partner for the firm, M. D. Campbell and Associates, L.P. in Houston, Texas. He has a strong professional history in major international engineering and uranium mining companies such as CONOCO Mining, Teton Exploration, Div. United Nuclear Corporation, and Texas Eastern Nuclear, Inc. during the 1970s and 1980s, and such as Law Engineering, DuPont, and others in environmental projects from the 1980s to the present. Mr. Campbell has over 40 years of mining, minerals and environmental project experience and has published three technical books on uranium and other natural resources, and numerous associated reports, technical papers, and presentations in the U.S. and overseas. Mr. Campbell is a graduate of The Ohio State University with a Bachelors Degree in geology and hydrogeology, a Masters Degree from Rice University in geology and geophysics, and was elected a Fellow in the Geological Society of America. He was a Founding Member in 1977 of the Energy Minerals Division of AAPG and presently serves as Chairman of the Uranium Committee. He is a Licensed Professional Geoscientist in Texas and in other states. For additional information, see his CV at: http://www.mdcampbell.com/mdcCV.asp.

** **Henry M. Wise, P.G**., has more than 30 years of professional experience in geological, uranium exploration and development and environmental remediation. His experience includes the exploration and in-situ recovery of roll-front uranium deposits in South Texas where he was responsible for the delineation and production at the Pawilk Mine for U.S. Steel. He also has substantial experience in ground-water remediation projects in Texas. Mr. Wise is a graduate of Boston University and obtained as Master's Degree from the University of Texas at El Paso in geology. He was a Founding Member in 1977 of the Energy Minerals Division of AAPG and is a member of the Uranium Committee. He is a Licensed Professional Geoscientist in Texas.

*** **Jeffery D. King, P.G.** received his Bachelor's Degree in Geology from Western Washington University and has over 25 years of technical and managerial experience in the natural-resource field. Mr. King has extensive management experience, has managed the operations of a mining company and large-scale redevelopment projects, and he has developed successful regulatory- and landowner-negotiation and public-relations programs. He also has conducted or directly managed many aspects of site permitting and financial and technical evaluations of mining properties for a major mining company. In the 1990s, Mr. King worked for the DuPont Company directing environmental projects in Washington, Oregon, Alaska and British Columbia, Canada. Over the years, he has founded three successful companies. The most recent is Pacific Environmental and Redevelopment Corporation, located in Seattle, Washington, to focus on large-scale projects involving the redevelopment of formerly environmentally challenged properties. He is licensed as a Professional Geologist in the State of Washington.