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
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By

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and

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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)

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

@ Kingsville Dome, 2007
The 1975 Concept of the Biogeochemical Cell in a Roll-Front

After Rackley, 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
• Uranium Mineralization in the Oakville Formation
• Uranium Mineralization in the Goliad Formation
• 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

Reduced Zone
• Typical Well Field and Plant Layout
• Typical Layout of Injection and Production Well Field
• Typical Layout of Injection and Production Well Field
Injection Fluids – Light Acids

- Liquid O₂
- Heat Exchangers
• Permitting Guides

- Background Sampling Water Wells
- Designated Monitoring Wells
- Regional Ground-Water Settings
- Also Use in Exploration Programs
Regional Hydrochemistry: Hydrochemical Facies?
Regional Hydrochemistry: Hydrochemical Facies?

Figure 1. Average annual precipitation for 1951–80 ranged from about 8 to 56 inches.

EXPLANATION

- Older Surface Mines
- Goliad In Situ Mine?
- Kingsville Dome In Situ Mine
- Alta Mesa Dome In Situ Mine

• Monitoring Wells: Monitoring Shallow & Deep Aquifers
• Monitoring Wells: Periphery Sites
Uranium Exploration & Recovery & Health?

- In Texas
- In Colorado
- Numerous Studies:

http://www.mdcampbell.com/PUBMEDSURVEY.pdf
**Human Health & Uranium Recovery**

Table 3. 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’.)

<table>
<thead>
<tr>
<th>Calendar years of death</th>
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<th></th>
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<tr>
<td>Obs</td>
<td>SMR&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Obs</td>
<td>SMR&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Obs</td>
<td>SMR&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td>Karnes County</td>
<td>267</td>
<td>0.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>331</td>
<td>0.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>279</td>
</tr>
<tr>
<td>Control counties</td>
<td>799</td>
<td>0.8&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1102</td>
<td>0.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>818</td>
</tr>
<tr>
<td>RR&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.0</td>
<td>0.9</td>
<td>1.1</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

<sup>a</sup> SMR is the observed number of cancers divided by that expected based on rates within the general population of the United States.

<sup>b</sup> Estimated RR taken as the ratio of the SMR in Karnes County with that in the four control counties.

<sup>c</sup> p < 0.05.

• 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 Mortality in a Texas County with Prior Uranium Mining and Milling Activities, 1950-2001, Journ. Rad. Protection Vol. 23, pp. 247-262.

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

[Diagram showing a timeline with various stages and activities such as Land Acquisition & Drilling Permitting, Reserves Drilling, Coring & Logging, Other Reserves Drilling, Coring & Logging (North & South), Exploration & Production Drilling & Coring, Geological & Geophysical Supervision (Drilling, Coring & Logging) & Mapping, Environmental Background Studies (GW, SW, Radiometric, Aheol., Meteorolog., & Air Quality), Community Relations, TCEQ Meetings, NRC/EPA Meetings, Wildlife, Vegetation, Soil & Socio-Economic Studies, Baseline Report Preparation, Mine Permit Application & Revisions, Permits Revised & Approved, Phase I Installation of Monitoring Wells, Engineering Studies & Design, Development & Construction, Resin Production & Transport.]
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
<table>
<thead>
<tr>
<th>Operation</th>
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<th>County</th>
<th>Regional Aquifer</th>
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<td>Caithness – McBride</td>
<td>G.W.Restored/Plugged/D&amp;D</td>
<td>Duval</td>
<td>Oakville</td>
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<tr>
<td>Chevron – Palangana</td>
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<td>Duval</td>
<td>Goliad</td>
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<td>Cogema – Holiday</td>
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<td>Duval</td>
<td>Catahoula</td>
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<td>Duval</td>
<td>Catahoula</td>
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<tr>
<td>Cogema – O’Hern</td>
<td>G.W.Restored/Plugged/D&amp;D</td>
<td>Duval</td>
<td>Catahoula</td>
</tr>
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<td>Cogema – Cole</td>
<td>G.W.Restored/Plugged/D&amp;D</td>
<td>Duval</td>
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<td>Oakville</td>
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<td>Oakville</td>
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<td>Oakville</td>
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<td>G.W.Restored/Plugged</td>
<td>Live Oak</td>
<td>Goliad</td>
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<td>Everest – Tex-1</td>
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<td>IEC – Pawnee</td>
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<td>Bee</td>
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<td>Oakville</td>
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<td>G.W.Restored/Plugged</td>
<td>Live Oak</td>
<td>Oakville</td>
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<td>Mestena – Alta Mesa</td>
<td>Operation</td>
<td>Brooks</td>
<td>Goliad</td>
</tr>
<tr>
<td>URI – Benavides</td>
<td>G.W.Restored/Plugged/D&amp;D</td>
<td>Duval</td>
<td>Catahoula</td>
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<td>URI – KVD</td>
<td>G.W. Restoration/Operation</td>
<td>Kleberg</td>
<td>Goliad</td>
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<td>Duval</td>
<td>Goliad</td>
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<td>U.S.Steel - Boots</td>
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<td>Oakville</td>
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<td>G.W.Restored/Plugged/D&amp;D</td>
<td>Live Oak</td>
<td>Oakville</td>
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<td>U.S.Steel - Clay West</td>
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<td>Live Oak</td>
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<td>G.W.Restored/Plugged/D&amp;D</td>
<td>Live Oak</td>
<td>Oakville</td>
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</table>
• 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”.
• **Uranium Research**
  - 1970s Technical Literature
  - Company Records
  - NURE Records
  - Find the Missing Generation
• Uranium Field Work
  
  ✓ Conducting Outcrop Analysis
  ✓ Conducting Field Reconnaissance
  ✓ Sampling Environmental Monitoring Wells
Assessment

Safety Record, Economic Advantage, Jobs, Technology, Management

Risk

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

Fear

Weapon of War, Hollywood & Press Media

Anti-Nuclear Power?
The U.S. Power Grid: Night Lights Tell the Story
The U.S. Nuclear Power Plant Sites
What about Nuclear Waste Management?

Fear

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

Assessment
Safety Record, Good Science New Technology, Improved Management
...And there are always disagreements....
But What about Solar Power?

Solar Power Resources

Source: NEI
But What about Wind Power?

Source: NEI
Land Needed by Wind or Solar Energy to Match Annual Nuclear Energy Production*

Wind Turbines

Solar Cells

Area equal to Minnesota

Area equal to West Virginia

* 768 billion kilowatt-hours

Source: NEI
What about Geopressured Geothermal Resources?

After Erdlac, 2007
Geothermal Resources in Texas

Map courtesy of Virtual Energy Research Associates. Adapted by R.L. Erdlacs, UTEP/CEED.

Potential electric producing areas based on deep well bottom hole temperature data.

- Known from oil & gas data
- Known uranium deposits (Old & New)

After Erdlacs, 2007
What about New Sources of Power?
What about the Economics?

<table>
<thead>
<tr>
<th>Technology</th>
<th>Expected Capacity Factor (%)</th>
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</thead>
<tbody>
<tr>
<td>Coal</td>
<td>71</td>
</tr>
<tr>
<td><strong>Nuclear</strong></td>
<td>90</td>
</tr>
<tr>
<td>Geothermal</td>
<td>86 - 95</td>
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<tr>
<td>Wind</td>
<td>25 - 40</td>
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<tr>
<td>Solar</td>
<td>24 - 33</td>
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<tr>
<td>Natural Gas Combustion</td>
<td>30 - 35</td>
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<tr>
<td>Turbine</td>
<td></td>
</tr>
<tr>
<td>Hydropower</td>
<td>30 - 35</td>
</tr>
<tr>
<td><strong>Biomass</strong></td>
<td>83</td>
</tr>
</tbody>
</table>
What about Present Usage Energy Resources?

- **Petroleum**: 39.8%
  - Transportation: 28.3%
- **Natural Gas**: 22.4%
  - Industrial: 21.6%
- **Coal**: 22.6%
  - Residential and Commercial: 10.3%
- **Renewable Energy**: 6.8%
  - Electric Power: 39.7%
- **Nuclear Electric Power**: 8.2%
What about Produced CO$_2$?
...And there are always disagreements....

global warming over the years

Retreating Ice Sheets:
As temperatures soared, the massive ice sheets that remained from the last period of glacialization retreated to their current position.

Source: AP
...And there are always disagreements.

**Recent Global Temperature Changes:**
Temperature change in the last century has been measured in respect to a long-term median temperature. Data shows a warming trend in the last 50 years.

*Source: U.S. National Climatic Data Center*
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
We are in this together; united we stand, divided we fall...
Today’s Paradyme

Estimates of 21st Century World Energy Supplies: Billion Barrels Oil Equivalent

- Solar Thermal
- PV Cells
- Nuclear Fission-Fusion
- Hydro
- Electric
- Natural Gas
- Heavy Oil
- Canada Tar Oil
- Coal
- 514 G Tons 1800 GBOE
- CUM Nat Gas 2760 TCF 1458 GBOE
- CUM Crude 836 GBOE

World Population + Estimated Energy Demand

10 BILLION BARRELS
An Alternate Universe

Estimates of 21st Century World Energy Supplies:
Billion Barrels Oil Equivalent: Alternate Universe

Million # U₂O₅/Year: 156
# Reactors: 404

232
600

WORLD POPULATION + ESTIMATED ENERGY DEMAND

10 BIL

NUCLEAR
Fission to Fusion Transition

270 Million # U₂O₅
Produces
5 Billion kWh

COAL

NATURAL GAS

10 BILLION BARRELS

Cum Crude 836 GBO

POST 2000 WORLD LIQUIDS
RESERVES 1116 GBO
DISCOVERIES 538 GBO
RES. GROWTH 730 GBO
UNCONV. 579 GBO
GTL 360 GBO
ULT. U.D. 4656 GBO

TOT. FUL. LIQ. 3726 GBO

John D. Edwards, Department of Geological Sciences, University of Colorado - Boulder
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.
Selected References


Selected References (Continued)


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](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.