Uranium & Nuclear Power are on the Move … Again !

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The AAPG Energy Minerals Division's Uranium (Nuclear and REE) Committee (aka UCOM)

A *YouTube* version of this presentation with naration is also available (here).

2020 AAPG-EMD On-Line Conference: Let's Confront and Tackle the Issues about Energy Resources and Use

November 12, 2020

But First, What is the Role of UCOM Within AAPG ?

- The role of UCOM is to monitor, evaluate, and report on uranium activities in the U.S. and the world for the purpose of advising AAPG members and the general public on an energy source that competes with oil and gas in the generation of electricity for the general public.

- On the basis that uranium exploration and mine development depends on the demands of the nuclear power industry to fuel nuclear reactors to generate electricity, that industry must be monitored to observe the needs for production of uranium from the U. S. and around the world.

- An **annual report** is prepared by **UCOM members** led by the UCOM Chair with input coming from the three Vice-Chairs, the Advisory Group and from Special UCOM Consultants (**more**). UCOM contributes to AAPG and other publications as well (**more**).

- UCOM members also provide input to the **I2M Web Portal** for research purposes (**History**).

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Michael D. Campbell, P.G., P.H., C.P.G., C.P.H., Chairman, I2M Consulting, LLC, Chief Geologist (Mining) / Chief Hydrogeologist (Environmental), Houston, TX (Ex-Teton Exploration Div., United Nuclear Corporation, and Texas Eastern Nuclear, Inc.), Founding Member of EMD in 1977, and Past President of EMD (2010-11), UCOM Chair since 2004.

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- **David Rowlands**, Ph.D., P.G., Rowlands Geosciences, Houston, TX

UCOM **Special Consultants to the Uranium (Nuclear and Rare Earths) Committee:**

- **Ruffin I. Rackley**, Senior Geological Consultant, Seattle, WA (Founding Member of EMD, Secretary-Treasurer: 1977-1979, and President: 1982-1983, Ex-Teton Exploration Div., United Nuclear Corporation)
- **Bruce Rubin**, Senior Geological Consultant, Millers Mills, NY (Founding Member of EMD, Ex-Teton Exploration - United Nuclear Corporation, General Public Utilities, Fuel Div.)
- **M. David Campbell**, P.G., Senior Principal and Senior Project Manager, I2M Consulting, LLC, Houston, TX. (Founder of MarineBio.org and the MarineBio Conservation Society.
- **Robert A. Arrington**, VP, Exploration, Texas Eastern Nuclear, Inc. (retired), College Station, TX (Founding Member of EMD in 1977)

Issues or Reality ?

German Nuclear Power Plant

Does Nuclear Power have a greater role to play in the energy solution in the future?

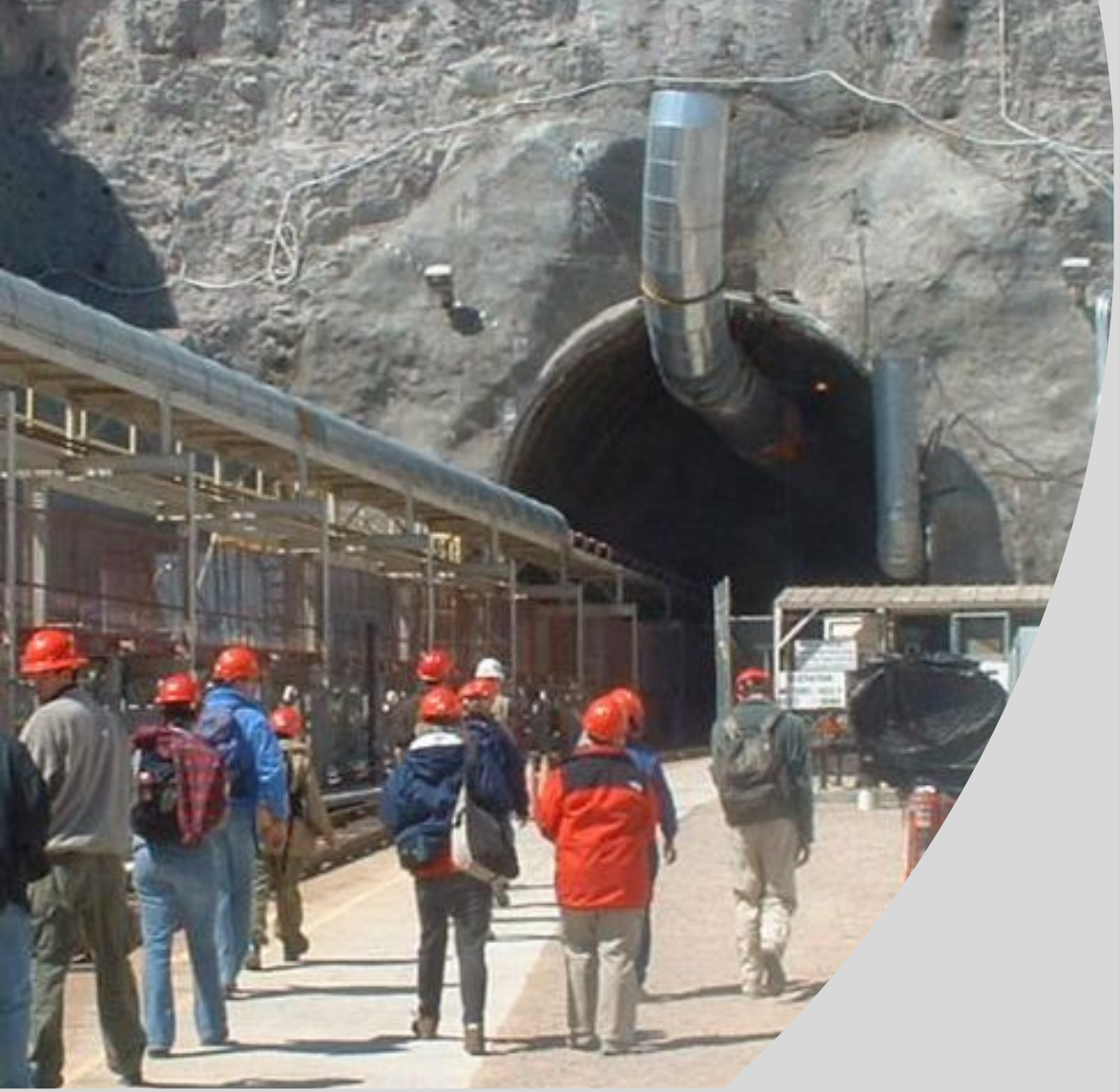
YES !

- Nuclear power has the best safety record in the major energy industry (more),
- Nuclear power provides 24/7 back-up to renewables & should provide transition from burning fossil fuels (more),
- Uranium fuel costs to utilities less than 5% of operating costs (more),
- Nuclear Power is climate and business friendly (more).

American Nuclear Power Plant

On Nuclear Power for the Generation of Electricity:

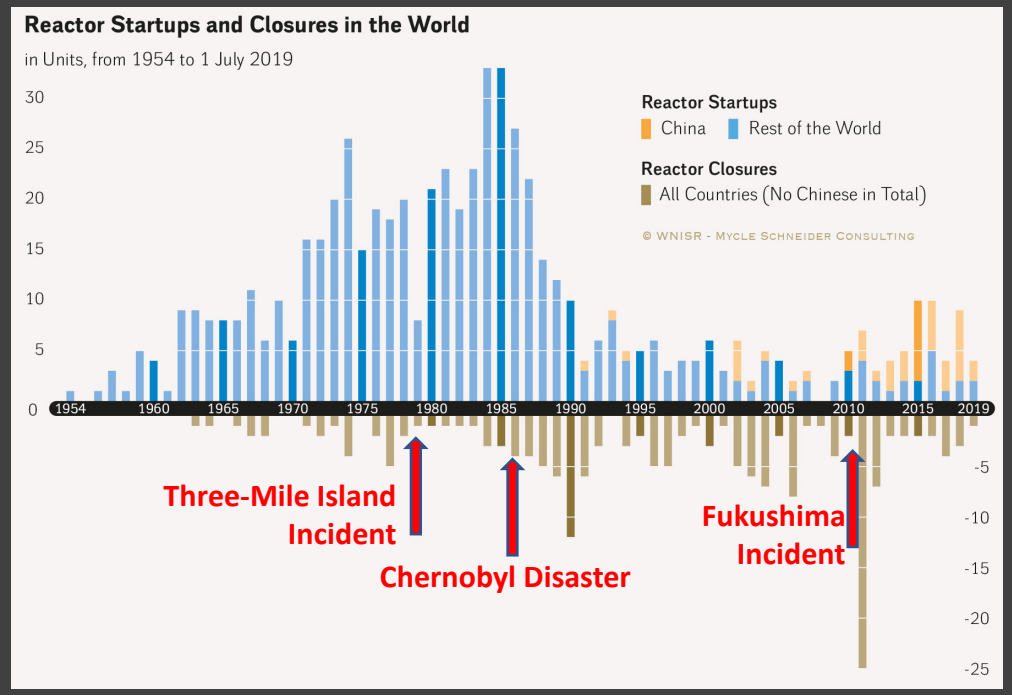
- Nuclear power plants operate by boiling water to turn turbines that generate electricity.
- Heat is generated by the fission that occurs when uranium cells are brought together and controlled by graphite rods.
- The uranium fuel and graphite rods are usually replaced every 5 years or so.
- After years of construction of nuclear power plants, the Hollywood movie "China Syndrome" was released. Only a few days later, the Three- Mile Island incident occurred. This brough massive coverage by the media pandering fear, but no one died, no one was irradiated.
- A few years later, the Chernobyl accident occurred, killing a number of fire fighters and emergency personnel. This was a special case caused by poor reactor design and incompetent management during the time of the Soviet Union and the "Cold War." A number of children contracted thyroid cancer, but 99% were successfully treated, although a few died. The others fully recovered.
- During the next 30 years, the U.S. did not construct one new nuclear power plant, and coal and natural gas provided the bulk of the energy. France, Russia, China and others continued to build new nuclear power plants, with France receiving all power from nuclear power at one stage.
- By 2011, Japan had constructed a large fleet of nuclear power plants, but in that year a large earthquake struck off-shore and sent a tsunami to the Japanese coastline killing 10s of thousands of people. A part of the tsunami broke through one of the protecting walls of a coastline nuclear power plant and flooded the back-up power supply that cooled fuel rods. This resulted in an explosion of hydrogen gas that was set-off by fires in one of the fuel rod storage facilities. Again, no one was hurt or killed at the plant although the media again over played seriousness of the incident.
- The Fukushima incident sent off fears that went around the world, until the actual conditions came out by responsible media. The melt-down of the fuel rods was managed properly. At least one of the reactors was out of service, but the damage was more psychological, than physical. Those people living near the plant left in a panic, and some have not yet returned. But, no one died or was irradiated.
- Shortly after the incident, Japan shut down all of their nuclear power plants for "safety reviews." To date, many of Japan's nuclear power plants are back in service.
- Germany followed by subsequently announcing that they too were shutting down their numerous plants and replacing that power source with 'brown" coal, a lower quality lignite very high in burnable ash, plus natural gas from Russia, and planned to replace them all with renewable energy. Since neither the sun shines very long, nor does the wind blow much in Germany, their "green" activities are creating large increases in electricity costs and increasing use of dirty coal and natural gas.
- The impact of the 2011 incident resulted in a worldwide 60% decrease in the price of yellowcake, the raw fuel which is subsequently refined into pellets suited for loading into nuclear power plants. Also, all of a sudden, too much yellowcake was being produced by mines worldwide because of the shutdowns, but because most of the fuel came from overseas to fuel American nuclear power plants, much of that production declined to preserve future revenues, until the excess fuel had been consumed. This resulted in many years of depressed prices for yellowcake.
- In late 2019, the excess fuel supply was beginning to be consumed, which has prompted the yellowcake "spot" price to increase, but not enough to stimulate re-starts in U.S. uranium mines. Long-term contracts were not yet being sought by the nuclear utilities who buy the fuel as their fuel supplies reach a certain minimum. Recently, the DOD has supported a plan to provide some protection for U.S. mines by creating a Strategic Uranium Reserve, to guarantee uranium price levels .... but this has not yet been consummated.



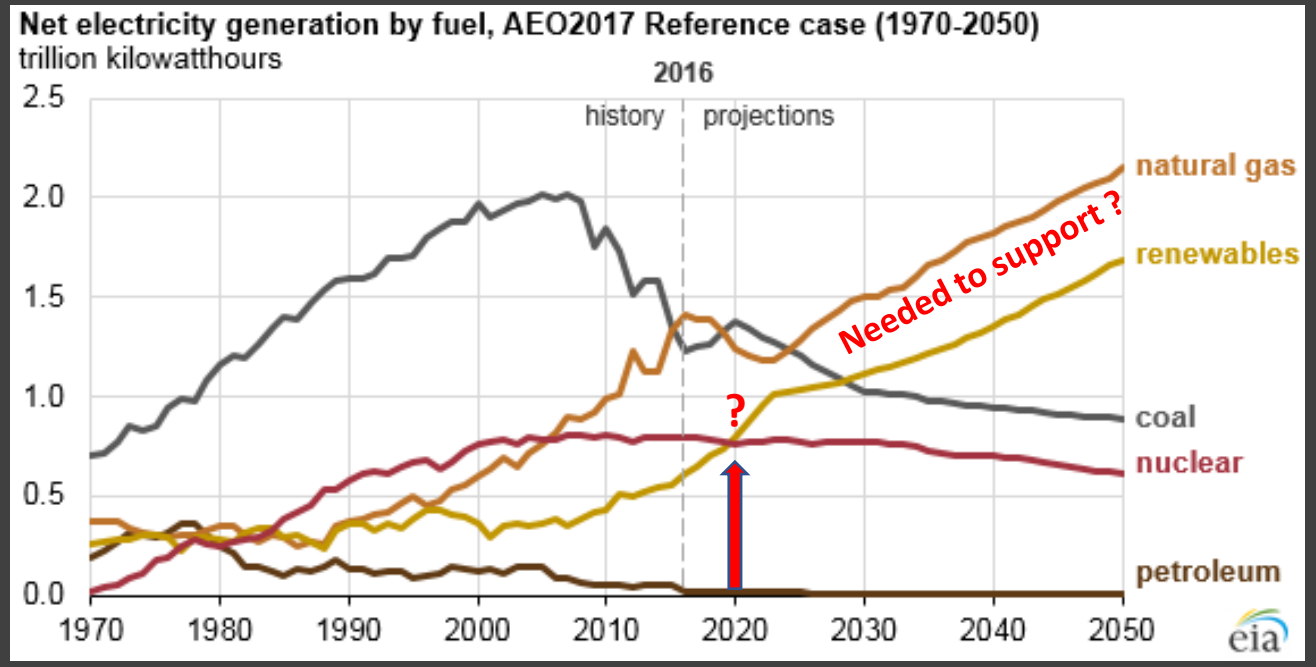
Nuclear waste is being managed safely at the Nuclear Plant Sites, for now, even though the Federal Government & Congress (the Political Left in the past) failed to provide a national storage site, as required by federal law.

- **Yucca Mountain Facility in Nevada cost $ Billions … but (now).**
- **Why not expand the operating Waste Isolation Pilot Plant (WIPP) Facility in New Mexico?**

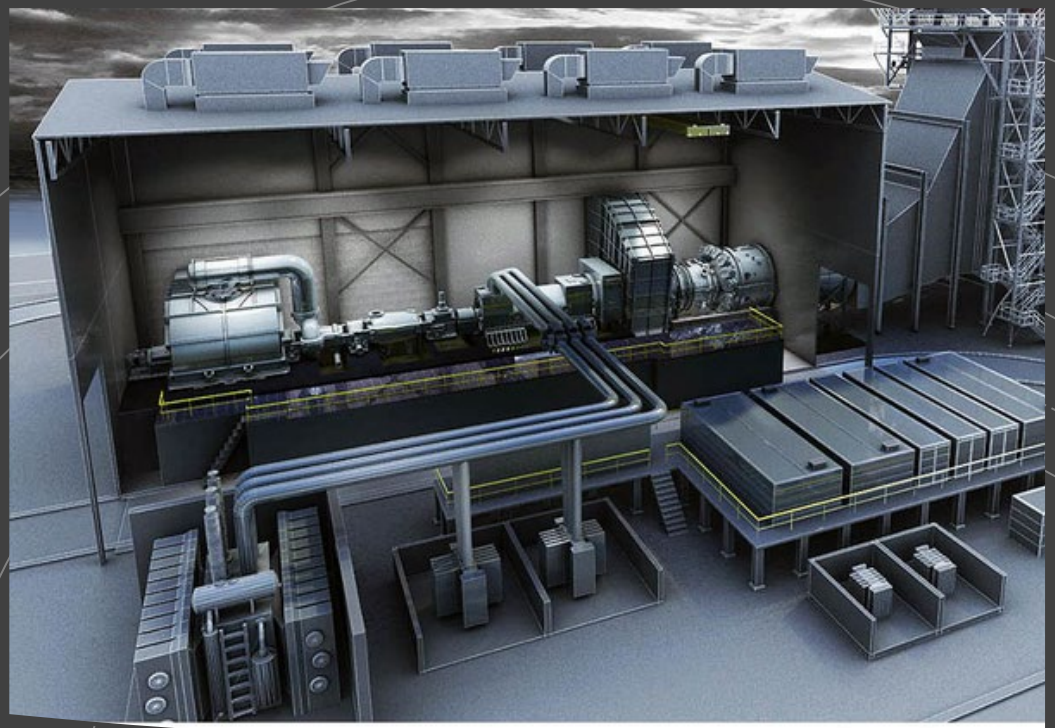
- U.S. generates ~ 2,000 metric tons of used uranium fuel/yr.
- Total waste produced since 1950s = ~83,000 metric tons, which would fit in a football field stacked in containers to a depth of 10 yards (30 feet).



- At End of 2019: 441 Operational Nuclear Reactors World-Wide (Many more to come in Asia). In U.S., 57 plants w/95 reactors in 29 states, which requires ~68 million pounds (34,000 tons) of uranium/yr. from mines to fuel 95 reactors (more). That is about 8,500 bbls of yellowcake from mines.
- New Construction, but is it sufficient to meet the climate needs? In 2020, there are more than 54 reactors under constructions in the world (more). 2 in the U.S.
- New Nuclear Technology may meet the future demand for electricity, SMRs, etc. (more) to respond to climate-change needs (more).
- But EIA projects >> in Renewables + NG ? (more), (more), etc.



- Impact of inherent flaws in the economics of wind and solar projects involving overlooked and under-estimated O&M costs becoming evident (more),
- Wind and Solar energy consumer prices are increasing (more), with gas as grid back-up,
- Wind & Solar Must Have a Back-up Power Grid (Gas or Nuclear?) (more).
- Nuclear energy costs will decline with new technology and SMRs,
- World Nuclear Status (History).



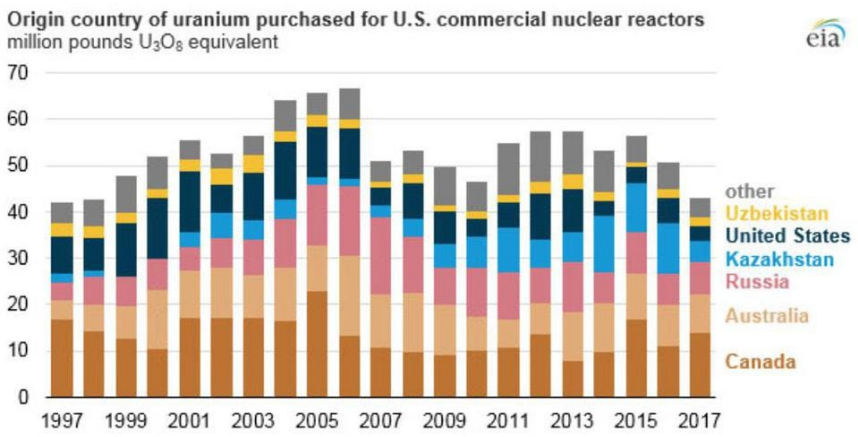
The SMRs Are Coming …….

Characteristics of SMRs

- SMR units built off-site and transported by road/rail,
- Reasonable capital and operating costs,
- Rapid construction and installation,
- Safe to operate and to refuel, and
- Minimal waste handling off-site.

- Small nuclear technology to join the existing technology.
- Small nuclear reactors (SMRs) to add nuclear power to generate electricity for cities, small towns, and in remote areas.
- SMRs can be unitized, where additional 25-75 MW units can be added locally depending power needs.
- History of SMR development by industry (more).

“From where do we get the uranium resources to fuel our 95 nuclear reactors in U.S. ?”



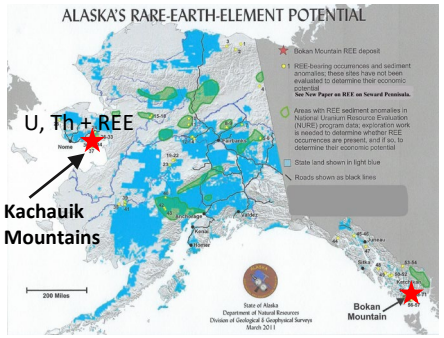
✓ **Uranium Strategic Reserves provided by American Uranium Mining Companies ? Maybe ….**

1. U.S. needs secure source of uranium from within the U.S., if possible (History) and (now).

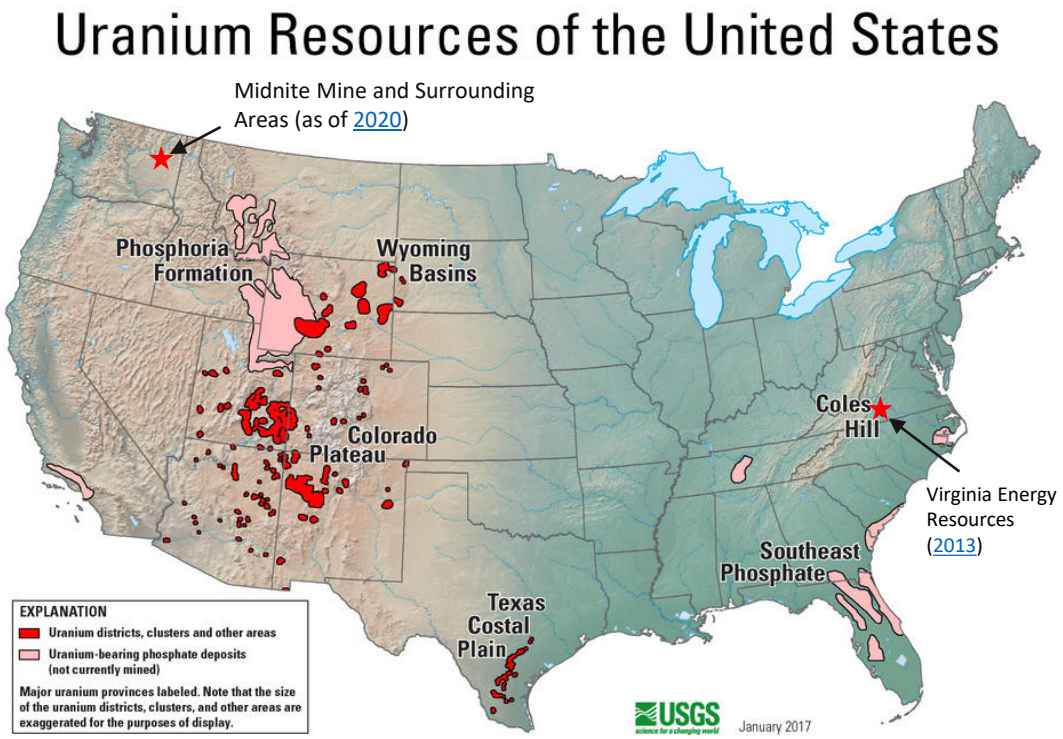
2. What is U.S. Government doing ? (History).

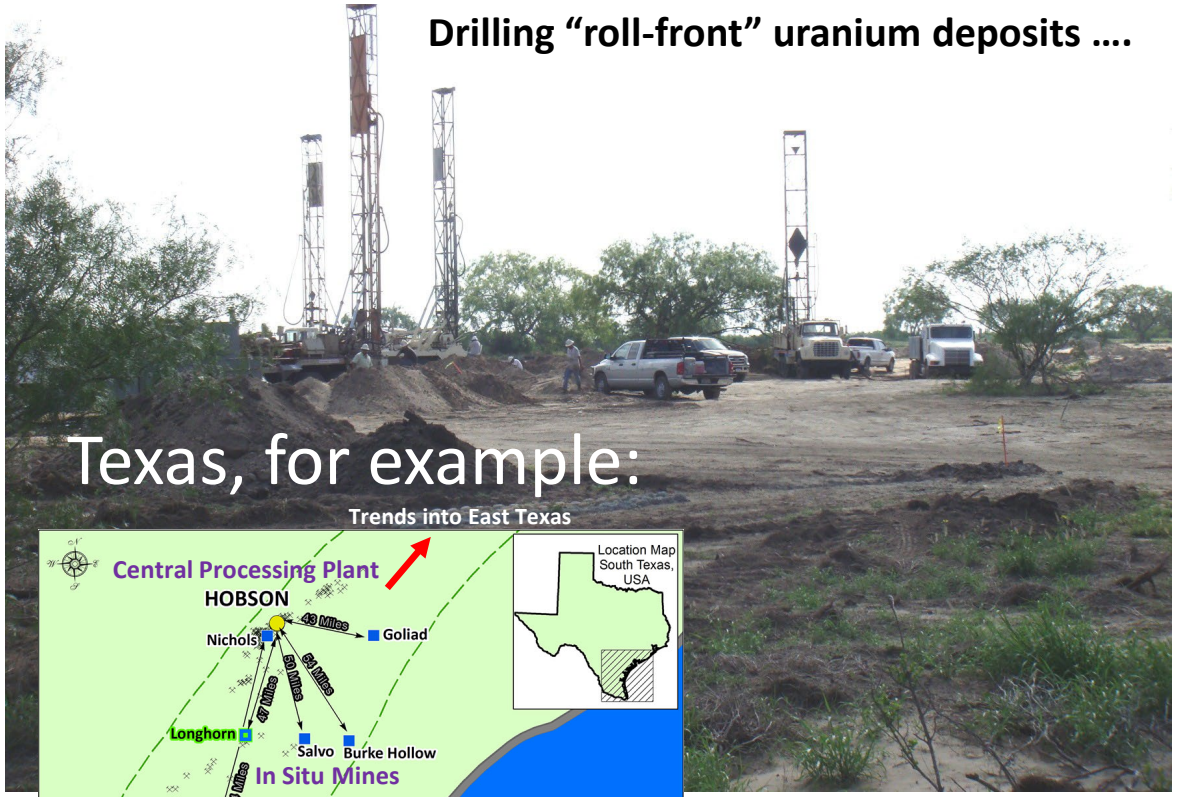
3. Canada and Australia should be our partners in providing uranium, if needed.

4. Where are the uranium deposits in the U.S. ? Known (now) & New (future).



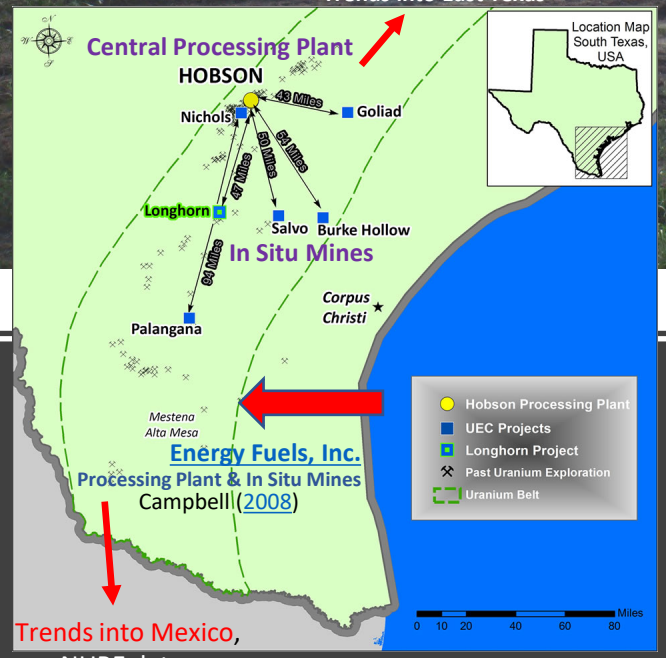
See (more) on Kachauik Prospect.

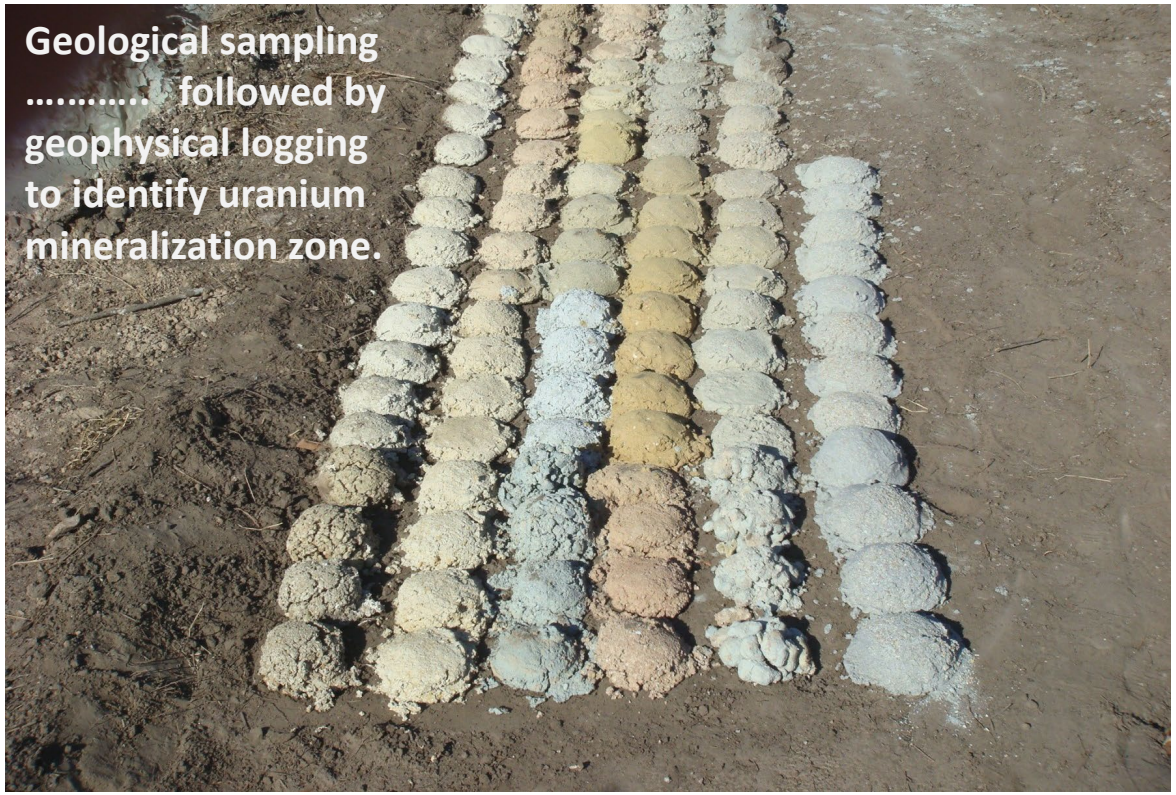




Drilling "roll-front" uranium deposits ….

Texas, for example:





Geological sampling …….. followed by geophysical logging to identify uranium mineralization zone.

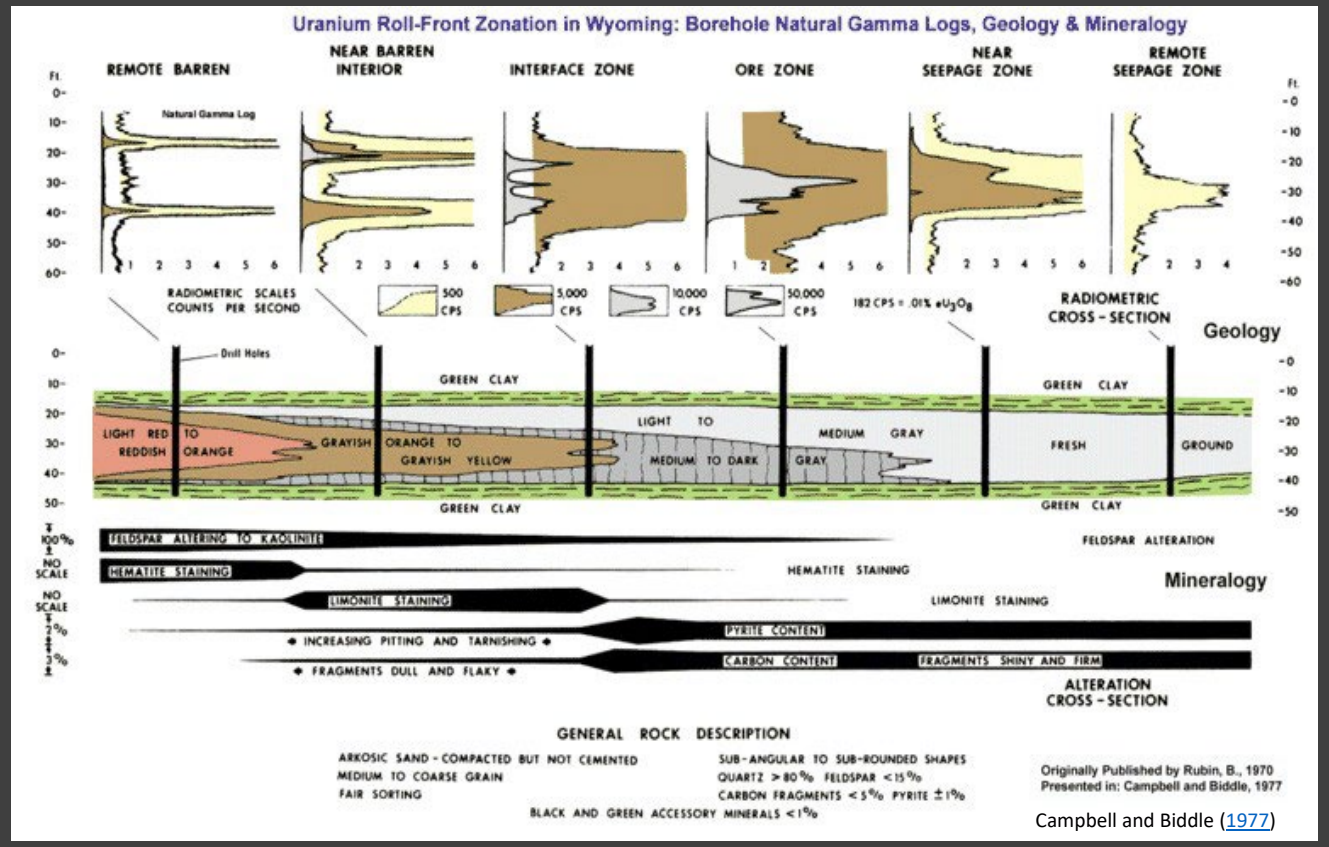
Drilling and Developing American Uranium Resources

in Texas, Wyoming, Utah, New Mexico, South Dakota, Nebraska, Colorado, Virginia and Alaska, etc.

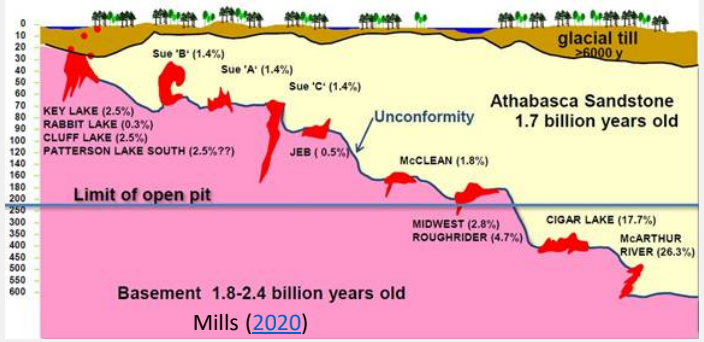
Exploration Methods (more)

Uranium Exploration Methods

Dickinson and Duval (1977)



Campbell and Biddle (1977)

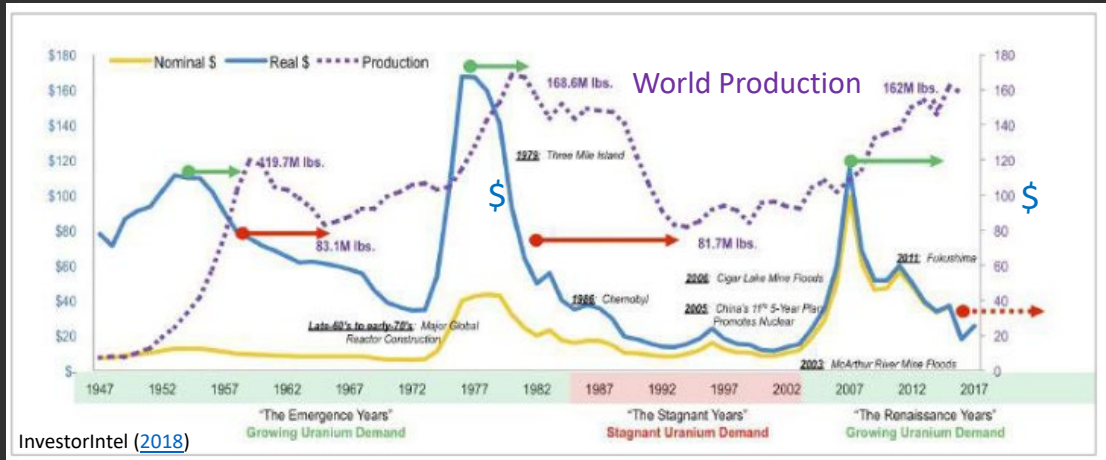


Mills (2020)

Principal Types of Uranium Mineralization

- Roll-Front uranium mineralization exploration methods are well developed (more).
- Exploring for uranium in carbonatites and peralkaline igneous rocks more complicated.
- Exploring for unconformity-related uranium starts with aerial and ground geophysics.

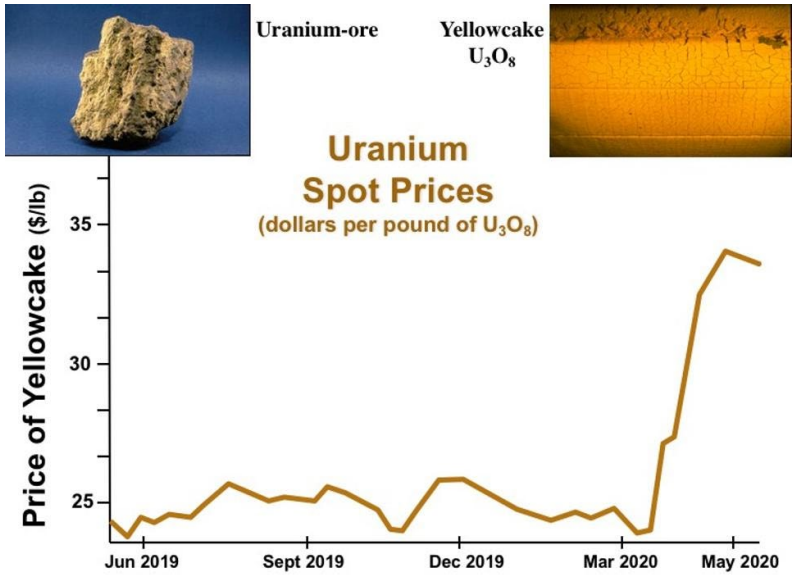
Uranium Price History to Date



InvestorIntel (2018)

UxC (2020)

- The financial health of the U.S. uranium industry depends on a reasonable price for yellowcake to fuel nuclear utilities (History).
- A Yellowcake price in the range of ±$50-$60/ pound is needed for U.S. in situ mines, whereas many high-grade (underground) / open-pit mining operations need less to make a reasonable profit (more).
- Overseas government support of mining introduces advantages not available to private industry in the U.S.
- Opposition by some media and groups to the use of nuclear power and uranium mining is funded by all competing energy sources (History).
- Russia does not own 20% of U.S. uranium reserves (more).
- Russian company (Uranium One, Inc) has widespread interests in nuclear power and owns significant supplies within Russia and in Kazakhstan, Tanzania, & Mozambique. (History).
- Russian company does own operating mines in Wyoming, (i.e., Christensen Ranch / Irigaray mines) & exploration properties in Colorado, Utah and Texas.



Conca (2020)

Conclusions:

- **Uranium will be needed to fuel nuclear power plants until fusion power arrives, followed by a long transition period from fission to fusion power plants …… 50 years or so.**
- **Uranium resource occurrences are widespread in the world (more). But to power fusion plants, ^{3}He resources are available on the Moon (more).**
- **The economics of developing any particular deposit depends on price of yellowcake, cost to produce, and local, state, and federal support of nuclear power, e.g., Germany, Japan.**
- **The U.S. uranium industry could supply most of the fuel needs of the American nuclear utility industry, with supporting supplies to come from Canada and Australia, and other friendly countries, if necessary.**
- **Employment in the geoscience fields will increase, e.g., Nuclear, Mining, Geothermal, Environmental, and NASA & Aerospace Industry for Off-World Exploration … (more).**
- **Employment links: (AIPG, US), (UK), (Canada), and (Australia). Buckle-up !**

UCOM monitors uranium, thorium, and associated rare-earth exploration & development in a variety of ways:
See UCOM website (here), and the I2M Web Portal (here).
Also see 2020 ACE Presentation by UCOM members on REE (here).

Selected References (Others by Link):

1. Campbell, M. D., and K. Biddle, 1977, "Frontier Uranium Exploration in the South-Central U.S.: Chapter 1" in *Geology of Alternate Energy Resources in the South-Central United States*, (M. D. Campbell (ed)), published by Houston Geological Society, pp. 3-44. see: http://www.mdcampbell.com/CamBidd77.pdf

2. Campbell, et al., 2014, "Coal, Just Not for Burning," AIPG Journal: *The Professional Geologist*, pp. 21-25; URL: http://i2massociates.com/downloads/CampbellJustNotforBurning-July19-2014Col.pdf

3. Campbell, et al., 2017, "An Update: Nuclear Power and Uranium Markets, Ownership and Uranium One (Russian Government) and Other Ownership of Uranium Resources in the World," URL: http://www.i2massociates.com/downloads/JGG-1-009.pdf

4. Campbell, et al., 2020, UCOM Annual Report, URL: EMDUraniumNuclearMineralsandREECommitteeAnnualReport-2020.pdf

5. Conca, J. R., 2019, "Nuclear Power - Where's The Uranium Coming From?" URL: https://www.forbes.com/sites/jamesconca/2019/05/28/nuclear-power-wheres-the-uranium-coming-from/#2192214a7b9f

6. Conca, J. R., 2020," How The Uranium Market Will Evolve For The Post-Pandemic Energy World," *Forbes.com, May 22, URL*: https://www.forbes.com/sites/jamesconca/2020/05/22/where-do-we-stand-on-uranium-in-the-post-pandemic-energy-world/#26795f857dd7

7. Dickinson, K. A., and J. S. Duval, 1977, "South Texas Uranium: Geologic Controls, Exploration Techniques, and Potential: Chapter 2: Trend Areas and Exploration Techniques Utilization," in *Geology of Alternate Energy Resources in the South-Central United States* (M. D. Campbell (ed)), Houston Geological Society, pp. 45-66. See: http://www.mdcampbell.com/DickDuvl77.pdf

8. EMD, 2017, "AAPG's Energy Minerals Division's 2017 Unconventional (and Alternative) Energy Resources Review Paper Released," For UCOM contribution in review article, see URL: https://i2massociates.com/downloads/EMDNRR2017.pdf (see PDF pages: 35-50).

9. EMD and AAPG Astrogeology Committee, 2013, "Energy Resources for Human Settlement in the Solar System and Earth's Future in Space," AAPG-Astrogeology, / EMD Memoir 10, URL: http://www.i2massociates.com/downloads/Memoir101-T0fC2016.pdf, UCOM personnel contributed Chapter 9 of the Memoir 101.

10. Mills, R., 2020, "Ahead of the Herd Blog,"URL:https://aheadoftheherd.com/Newsletter/2014/The-Makings-of-a-Discovery.htm

11. Rubin, B., 1970, Uranium Roll-Front Zonation in the Southern Powder River Basin, Wyoming: *Wyoming Geological Society Earth Science Bull.*, Vol. 3, No. 4, December, pp. 5-12, URL: http://mdcampbell.com/RubinWGA70.pdf

12. Rackley, R. I., 1975, "The Environment of Wyoming Tertiary Uranium Deposits:" *AAPG Bulletin*, v. 56, n. 4, pp. 755-774.

13. Rackley, R. I., P. N. Shockey, and M. P. Dahill, 1968, "Concepts and Methods of Uranium Exploration, Wyoming Geological Assoc. Guidebook," pp. 115- 124, see: http://www.i2massociates.com/downloads/Rackley1968.pdf

14. **Note:** see another 2020 ACE presentation by UCOM members: "Recognizing Uranium Source Rocks in the Sedimentary Environment," URL: https://i2massociates.com/downloads/AAPGConfSept-Oct.pdf

Questions of Issues or Reality?

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