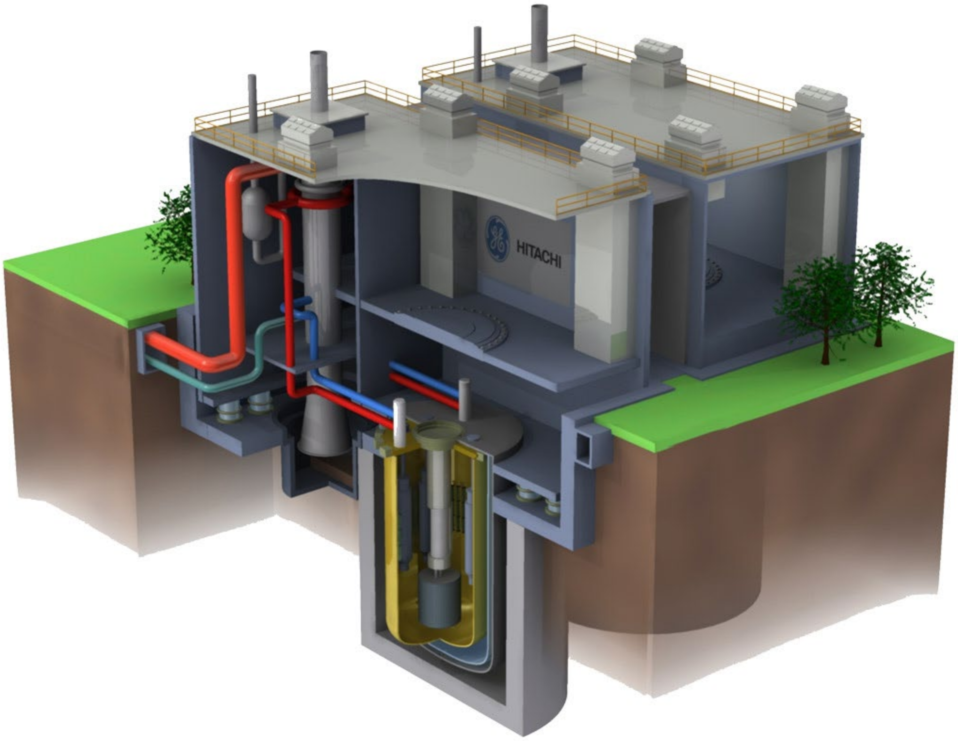
EMD Uranium (Nuclear & REE) Committee

2021 EMD Uranium (Nuclear and REE) Committee Annual Report

June 4, 2021



Small Modular Nuclear Power Plant PRISM Design (SMR)

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UCOM Vice-Chair Reports:

2021 EMD Uranium (Nuclear and REE) Committee Annual Report

Michael D. Campbell, Chairman

Senior Principal and Chief Geologist (Mining) / Chief Hydrogeologist (Environmental), and P.G., P.H., C.P.G., C.P.H., I2M Consulting, LLC, 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: 2010-2011; Fellow SEG; Fellow GSA; Fellow AIG; Fellow and Chartered Geologist GSL; EurGeol; and RM SME Professional Licenses: TX, LA, WY, WA, and AK

June 4, 2021

Vice-Chairs:

- **Henry M. Wise, P.G., C.P.G., (Vice-Chair: Industry),** National Recovery Corporation, La Porte, TX (Founding Member of EMD in 1977, ex-US Steel, Uranium Div.)
- **Steven S. Sibray, P.G., C.P.G., (Vice-Chair: University),** University of Nebraska, Lincoln, NE
- **Robert W. Gregory, P.G., (Vice-Chair: Government),** Wyoming State Geological Survey, Laramie, WY

Advisory Group:

- **Kevin T. Biddle, Ph.D.,** V.P., ExxonMobil Exploration (retired), Houston, TX (Founding Member EMD in 1977)
- **James L. Conca, Ph.D., P.G.,** Senior Scientist, UFA Ventures, Inc., Richland, WA
- **Gerard Fries, Ph.D.,** Orano Mining, KATCO JV, LLP, Nur-Sultan, Kazakhstan
- **Michael A. Jacobs, P.G.,** Manager, D. B. Stevens & Assoc. (Geo-Logic, Inc.), Midland, TX (Founding Member of EMD in 1977, Ex-Tenneco Uranium Inc.)
- **Ali Jaffri, Ph.D.**, Applied Stratigraphix, Westminster, CO
- **Roger W. Lee, Ph.D., P.G.,** Consulting Geochemist, Austin, TX
- **Karl S. Osvald, P.G.,** U.S. BLM, Wyoming State Office Reservoir Management Group, Casper, WY
- **Mark S. Pelizza P.G.,** M. S. Pelizza & Associates, LLC, Plano, TX
- **Arthur R. Renfro, P.G.,** Sr. Geological Consultant, Cheyenne, WY (Founding Member of EMD in 1977, Ex-Teton Exploration Div., United Nuclear Corporation)
- **David Rowlands, Ph.D., P.G.,** Rowlands Geosciences, Houston, TX

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

- **Ruffin I. Rackley**, Senior Geological Consultant, Seattle, WA (Founding Member of EMD in 1977, Secretary-Treasurer: 1977-1979, and Past-President: 1982-1983, Ex-Teton Exploration Div., United Nuclear Corporation)
- **Bruce Rubin**, Senior Geological Consultant, Millers Mills, NY (Founding Member of EMD in 1977, 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.

UCOM COMMITTEE ACTIVITIES

The AAPG Energy Minerals Division's Uranium (Nuclear and Rare Earths) Committee (UCOM) monitors the uranium industry activities and the production of electricity within the nuclear power industry because that drives uranium exploration and development in the United States and overseas.

Input for this Annual Report has been provided by:

Henry M. Wise, P.G., C.P.G. Vice-Chair (Industry) on industry activities in uranium, thorium, and rare-earth exploration and mining;

Steven Sibray, P.G., C.P.G., Vice-Chair (University) on university activities in uranium, thorium, and rare-earth research; and

Robert Gregory, P.G., Vice-Chair (Government) on governmental (State and Federal) activities in uranium, thorium, and rare-earth research.

Special input and reviews are also provided by members of the Advisory Group. A new member has been appointed to the UCOM Advisory Group: Ali Jaffri, Ph.D. of Applied Stratagraphix located in Colorado.

In this year's annual report, we also provide information on current thorium and rare-earth exploration and mining and associated geopolitical activities as part of the UCOM monitoring of "nuclear minerals," thorium and rare-earth elements (REE) activities (a function approved by the UCOM in 2011). Many uranium and thorium deposits include REE in the U.S. and around the world (more).

With the widespread on-set of the Coronavirus in March 2020, the ACE 2020 was cancelled and continued into 2021. The ACE 2021 is scheduled to be held in Denver in the fall and will consists of both in-person and virtual presentations. Most scheduled presentations were held on-line via Zoom, or other teleconferencing or webinar/ PPT formats.

Furthermore, earlier this year, the EMD Executive Committee changed the historical format of future EMD Commodity Committee reports to one-page reports. The UCOM one-page annual report will none-the-less provide a link to this full-scale UCOM Annual Report.

Jay M. McMurray Memorial Grant from AAPG Foundation

UCOM is also pleased to remind the reader that the *Jay McMurray Memorial Grant* is awarded annually to a deserving student(s) whose research involves uranium or nuclear-fuel energy. This grant is made available through the AAPG Grants-In-Aid Program and is endowed by the AAPG Foundation with contributions from his wife, Katherine McMurray, and several colleagues and friends. Students having an interest in applying for the grant should contact the UCOM Chair for further information and guidance. The biography of Mr. McMurray's outstanding contributions to the uranium industry in the U.S. and overseas is available at the AAPG Foundation, 2019.

The recipients of the Grant since 2009 are presented in Table 1. The 2021 recipient has not been announced to date.

Table 1: Recipients of the Jay M. McMurray Memorial Grant from AAPG Foundation

2009	FORMATION OF PRECURSOR CALCIUM PHOSPHATE PHASES DURING CRYSTAL GROWTH OF APATITE AND THEIR ROLE ON THE UPTAKE OF HEAVY METALS AND RADIONUCLIDES	Olaf Borkiewicz	Miami University
2010	PRECIPITATION KINETICS OF AUTUNITE MINERALS: IMPLICATIONS FOR URANIUM IMMOBILIZATION	Denise Levitan	Virginia Tech University
2011	THE FORMATION MECHANISMS OF UNCONFORMITY-RELATED URANIUM DEPOSITS: INSIGHTS FROM NUMERICAL MODELING	Tao Cui	University of Windsor
2012	NOVEL NANOSEISMIC SURVEY TECHNIQUES IN TUNNELS AND MINES	Chiara Mazzoni	University of Strathclyde
2013	(U-TH)/HE AND U-PB DOUBLE DATING CONSTRAINTS ON THE INTERPLAY BETWEEN THRUST DEFORMATION AND BASIN DEVELOPMENT, SEVIERFORELAND BASIN, UTAH	Edgardo Pujols	University of Texas at Austin
2014	ANTHROPOGENICALLY ENHANCED MOBILIZATION OF NATURALLY OCCURRING URANIUM LEADING TO GROUNDWATER CONTAMINATION	Jason Nolan	University of Nebraska - Lincoln
2015	GEOCHEMISTRY AND DIAGENESIS OF GROUNDWATER CALCRETES: IMPLICATIONS FOR CALCRETE-HOSTED URANIUM MINERALIZATION,WESTERN AUSTRALIA	Justin Drummond	Queen's University
2016	GEOCHEMISTRY AND DIAGENESIS OF GROUNDWATER CALCRETES, WESTERN AUSTRALIA: IMPLICATIONS FORCALCRETE-HOSTED URANIUM MINERALIZATION	Justin Drummond	Queen's University
2017	RECONSTRUCTION OF CRETACEOUS PROVENANCES OF ABEOKUTA GROUP OF THE EASTERN DAHOMEY BASIN SOUTHWESTERN NIGERIA BASED ON THE FIRST URANIUM-LEAD DETRITAL ZIRCON GEOCHRONOLOGY	Fadehan Tolulope Abosede	University of Lagos
2018	NOT AWARDED by AAPG FOUNDATION	-	-

2019	GEOCHEMICAL EVALUATION OF THE MISSISSIPPIAN LIMESTONE, ANADARKOSHELF OKLAHOMA	Oyeleye Adeboye	Oklahoma State University
2020	TRACE METAL AND URANIUM ISOTOPE GEOCHEMISTRY OF ORGANIC-RICH SEDIMENTARY DEPOSITS	Michelle Abshire	Oklahoma State University
2021	**TBA**	**TBA**	**TBA**

UCOM Publications and Nuclear Outreach

Until 2018, the EMD co-sponsored Springer Journal: *Natural Resources Research,* which published EMD reports covering the periods: 2017 (here); the 2015 version (here); 2013 version (here); 2011 (here); 2009 (here); and 2007 (here).

With input from older and younger members of EMD, a two-part article has been published in AAPG's *The Explorer*:

Part 1 covers EMD activities from 1968 through mid-2000, with links (here). December Issue.

Part 2 covers the years 2000 through 2018, as published (here), w/links (here). January Issue.

For the original version in manuscript form (Parts 1 and 2), with links, (here).

As a reminder, The AAPG-EMD Memoir 101: *Energy Resources for Human Settlement in the Solar System and Earth's Future in Space* was released in mid-2013 (more). The EMD's Uranium (Nuclear and REE Minerals) Committee and members of I2M Consultants, LLC, contributed the final Chapter entitled: *Nuclear Power and Associated Environmental Issues in the Transition of Exploration and Mining on Earth to the Development of Off-World Natural Resources in the 21st Century* (more). *Forbes.com* has highlighted Memoir 101 emphasizing the coverage of Chapters 8 and 9 (more).

A follow-on paper was prepared by the UCOM Chair: "*Beyond Hydrocarbons .... The Rest of the Story*" (here), which was the basis for an article by the editor of the *World Nuclear News* (here).

James Conca, Ph.D., a member of the UCOM Advisory Group, continues to contribute popular articles to *Forbes.com* on many nuclear and associated energy topics. To review the chronological list of Dr. Conca's contributions to *Forbes.com* to date, see (here). He also has produced a three-part *YouTube* video on "spent" nuclear fuel in 2018 (here).

Also, Ali Jaffri, Ph.D., a new member of the UCOM Advisory Group, presented a webinar entitled: "Sediment-Hosted Uranium Exploration – State of the Science" on November 20, 2020. This was an invited talk hosted by the AAPG Energy Minerals Division, the Wyoming Geological Association, and the Society for Mining, Metallurgy and Exploration.

The UCOM Chairman contributed a presentation for the AAPG Webinar (April 19, 2021): "Pivoting 2021: Thriving Change 7; Energy Industry Supply Chains," entitled: "The U.S. Uranium and REE Supply Chains: A Brief Discussion," *YouTube* version (here). Also, the Chairman served on the panel for the AAPG Webinar (May 26, 2021): "Pivoting 2021: Imaging Technologies & Water Management," and presented a brief synopsis entitled: "Stepping Up to Measuring the Nature of Groundwater Flow Gradients & Groundwater vs Natural Gas …." PDF version (here).

AAPG Energy Minerals Division YouTube Channel (here) offers an increasing array of videos, such as software used in geoscience investigations, commodity committee reports (e.g., on uranium, nuclear power, rare earths, and others to come). The four EMD and Astrogeology Committee sessions held for the 2020 Virtual AAPG Conference are also available. Other videos of interest are carried in the Playlist, e.g., webinars, and other presentations mentioned above.

Selected members of UCOM were interviewed in April for a two-part article in the AAPG *The Explorer* entitled: *"Net-Zero Emissions by 2050? … Not Without Nuclear Power !"* Part 1 – May 1 (here), Part 2 – July 1 (TBA). See Figure 1 (below).

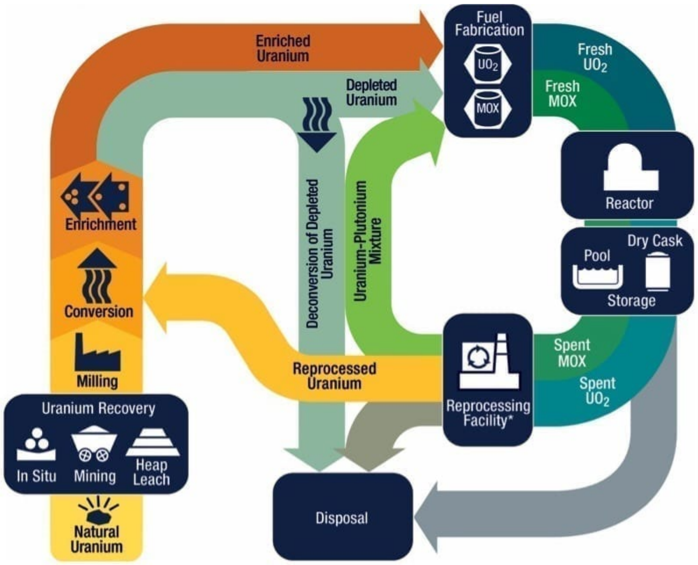


Figure 1 - The Principal Elements of Nuclear Power

UCOM Monitoring and Coverage

UCOM management modified the format of the UCOM report a few years ago to provide greater coverage and more timely information in a more concise reporting format. To accomplish this, the UCOM members continue to examine certain topics as we have in the past, such as the issues behind the current uranium mining industry conditions and activities, and their driving forces, e.g., yellowcake prices, nuclear power plant construction, uranium reserves and world-wide exploration, especially new uranium discoveries.

To support this coverage, the *I2M Web Portal* was upgraded and improved a few years ago, both in response speed and layout, plus it now allows multi-word searches, whereas the previous version only permitted one-word searches (more). The UCOM can now focus on particular issues covered by the *I2M Web Portal* by conducting and presenting search-results that are automatically updated even after we have published the UCOM reports each year so each report is in some parts at least dynamic in nature.

We draw on the *I2M Web Portal* database, which now contains (to May 30, 2021) more than 10,800 abstracts, some enhanced with annotations and with links to current relevant reports and media articles from sources in the U.S. and around the world, (see the Index to all commodity and associated fields covered in the *I2M Web Portal* (here)). The primary emphasis of the *I2M Web Portal* also reflects the interests and objectives of the UCOM as a whole (2017: more) and (2019: more).

UCOM reports began to be simplified and reduced in length in 2018. Continuing in this report, text reductions will be augmented by adding additional links to provide the reader with follow-on reading, should the reader wish to have additional information on the subject. It should be noted here that many links will provide direct Internet sources as well as search results from the *I2M Web Portal* that include summaries, some with comments on the article(s) cited in the text. This provides multiple records of historical development without selection bias.

If the search result returned a date-arranged list of summaries, the "What's New" result will continue to be updated as new entries are submitted to the database. The reader can also conduct a multi-word search of the database for related or associated topics of interest (more).

As illustrated in the summary of the 2021 UCOM Annual Report Summary, the UCOM focus is also reflected in the *I2M Web Portal* as new information is updated in the database, and covers a range of topics that presents various perspectives to provide balanced coverage of an issue.

The database is therefore dynamic in that new information arrives almost daily in the "What's New" section and covers topics such as:

a) uranium prices (more);

b) **uranium geology** (more);

c) **uranium exploration** (more);

d) **uranium mining and processing** (more);

e) **uranium recovery technology** (more);

f) **nuclear-power economics** (more);

g) **reactor designs** (more); SMRs (more);

h) **operational aspects that drive uranium prices** (more);

i) **historical factors affecting plant shutdowns** (more), and

j) **related environmental and societal issues** involved in such current topics as energy resource selection and climate change (more). The latter have direct and indirect impact on the costs, mining, and utilization of uranium, thorium, and rare-earth resources.

UCOM also monitors, assesses, and reports on the status of thorium and rare-earth exploration (and development) because both are often encountered in some types of hard-rock uranium deposits, and the presence of both impact the economics of recovering uranium and rare earths, often with revenue credit for both.

UCOM coverage also includes summaries of reviews of the current developments in research on:

a) **thorium** (more),

b) **helium-3** (more), and **fusion** research (more), and

c) **nuclear used fuel (waste) storage and handling** (more).

d) **current research developments in the rare earths** (more).

Executive Summary and Conclusions

(Summary presented to the 2021 Annual EMD Zoom Conference (here)).

Based on the UCOM personnel reviews over the past months, we have concluded that:

- A significant rise in uranium prices has been predicted since early 2020, but the major anticipated rise has not yet arrived…."but expected soon."
- Senior U.S. uranium industry personnel indicate that recent activities concerning Section 232 requesting protection of the U.S. uranium mining industry are underway with support in Congress and by President Biden.
- Many uranium companies are beginning to resume drilling properties, especially in Wyoming, Texas, and in Canada (more).
- Numerous discoveries continue to be reported of high-grade uranium deposits in Canada and new low-grade deposits are under development in Argentina and Peru.
- The main Australian uranium mines in South Australia are resuming operations and mines in WA are preparing to resume operations.
- An undeveloped, new uranium "roll front" district has been identified in the eastern Seward Peninsula of Alaska with alkaline source rocks containing high concentrations of uranium, thorium and rare-earth elements occurring around the eastern periphery of the 35-mile diameter basin.
- Many hard-rock uranium deposits also contain associated REEs to the extent that co-production of raw REEs, thorium, and other critical metals are underway for stockpiling, awaiting shipment to processing sites planned in the U.S. and around the world (more).
- Discoveries of a new uranium mineral occurring like calcrete have been made in west Texas, and other uranium mineral formed in the craters as a product of the atomic testing in Nevada.
- There is general agreement that substantial uranium (and thorium) will be available to fuel the U. S., the world's largest fleet of nuclear power plants, which produces more than 30% of the worldwide nuclear generation of clean electricity.
- Some 93 nuclear power plants in the U.S. remain in operation; a few more are scheduled for retirement on the grounds of economics and low-priced natural gas, but two new reactors will be completed soon. President Biden has vowed to maintain the current nuclear plants, and perhaps unshutters some that have been closed prematurely (more).
- Following a 30-year period during which no new reactors were built in the U.S., it is expected that the two reactors will come online soon after 2021; others resulting from 16 license applications made since mid-2007 are proposing to build 24 new nuclear reactors, most of which are of the new small modular reactor (SMR) design.

- The U.S. produced about 4,015 billion (kWh) of electricity at utility-scale facilities in the U.S. in 2019. Currently, about 63% of the U.S. electricity generation is from fossil fuels (coal, natural gas, petroleum, and other gases). About 20% was from uranium providing nuclear energy, and about 17% (and rising) was from renewable energy sources of solar and wind, including hydroelectric power plants.
- The U.S. uranium supply chain is improving with the U.S. government's encouragement of domestic uranium enrichment and fuel fabrication. This will take time to build (more).
- The Governor of Wyoming made a major announcement that TerraPower and Rocky Mountain Power plan to retrofit a Wyoming's existing, but soon to be retired coal-fired power plant, with a nuclear power plant using the new Natrium™ plant design technology (see Wyoming Video Announcement (here).
- Coal production and burning is falling off rapidly; but coal might be useful without burning.
- Uranium production cuts were made in 2019 in the U.S. by the world's largest uranium producers, but uncovered utility demand is expected to reach ~24% by 2021 and 62% by 2025. Hence, production should resume in the foreseeable future as the uranium price continues to rise.
- A number of mines in the U.S. (Texas, Wyoming, South Dakota, etc.) are either on stand-by or are available for rapid development.
- China (planning for 99 reactors by 2030), Russia (7 by 2028), Japan (now upgrading nuclear fleet), and India have aggressive nuclear power plant building programs underway.
- Saudi Arabia, South Korea, and UAE are also building nuclear power plants, some will be incorporating the new SMR designs, and "fast breeder" designs (Russia and India) that consumes most used fuel (waste), and a Russian floating nuclear power plant for use along the coast of Siberia and in the Arctic (using SMR designs).
- The U.S. Navy operates more than 40 ships and submarines with SMR nuclear power plants.
- Fusion research is progressing and even accelerating with new technology development (more).
- Numerous sources of REE have become evident recently, e.g., in coal, fly ash, and in sea-floor deposits (more).
- Research funding by university and industry remains low, but state geological surveys (e.g., Wyoming and New Mexico) and the U.S. Geological Survey. are moving forward with robust research projects on uranium and rare earths.
- The Earth's radiation environment protected by magnetic fields continue to be monitored; and
- More medical applications in the use of radiation have emerged.

- After considerable research, the UCOM has concluded that:
    - Coal-burning power plants should be the primary target for shuttering of operations.
    - The current rush into renewables (wind and solar) should fade as the fundamental failings become apparent in the large-scale projects because of the under-estimating the costs of O&M in their design phases, power intermittency, etc.
    - Geothermal energy will increase in the U.S. but will be limited locally because of line losses from wheeling power state-to-state and potential subsurface environmental issues (generated earthquakes) where competing energy are available.
    - Nuclear power (both large & SMR-scale reactors) will continue to emerge to replace the burning of gas and coal and use of wind & solar energy over the next 20 years.

Nature and Impact of Radiation

Although discussed in past reports, we have updated the information on radiation, whether it relates to that arriving from deep space, mitigated by the strength of our Sun's radiation, or whether it relates to the changing characteristics of the Earth's magnetic fields, which serve to form barriers against solar and deep-space radiations coming into the Earth's atmosphere.

The nature and impact of radiation, perceived and real, have been emphasized over the years by a variety of anti-mining and nuclear-power adversaries. In an attempt to educate AAPG members and the general public, UCOM has been addressing these important issues since the beginning in 2004, reporting within the UCOM on the fear of radiation (e.g., 2005), while continuing to address the issues surrounding human-health issues in greater detail over the past few years (more) and (more).

Because the effects of radiation are difficult to put into perspective by many, and even misinterpreted or exaggerated by agenda-driven adversaries, UCOM portrays radiation in context with our environment on Earth, in the atmosphere, in the orbital reaches, and in deep space (more). And, like coal, there are beneficial uses of radiation in more than one medical field, even quite possibly against the coronavirus.

With respect to other environmental issues involved in uranium exploration and mining, UCOM also monitors, assesses, and reports on matters related to radiation in the environment on Earth. This is based on the fact that one of the principal environmental issues surrounding the expansion of nuclear power as an energy source is fear of radiation, the actual impact of which has been exaggerated in the past in the media, and especially in movies and news reports of the 1970s and 1980s (more).

Also, of specific interest to geoscientists working in field conditions, UCOM reports include the Alerts Program, from the *I2M Web Portal*. The editors monitor and select articles for review on potentially hazardous field conditions. This illustrates that there are real hazards ranging from earthquakes, tsunami, meteorological, natural and human-induced hazards (such as the coronavirus) other than radiation that surrounds us all (Field Alerts: more).

There are other on-going monitoring programs underway at via the *I2M Web Portal*. These include Security Alerts: (more), which cover computer-hacking warning events and cyber-security issues, and media bias monitoring relating to uranium mining and nuclear power in general (more).

Historical Perspective

Now that we can look back and separate: a) the clear damage done by our use of atomic weapons to end World War II in Japan from b) the use of nuclear energy for peaceful purposes in harnessing this energy for generating electricity, we also have learned that the actual impact of any nuclear-core meltdown can be managed. For example, no one died or was irradiated as a result of the Three Mile Island incident (more), nor as a result of the damage by the tsunami on the nuclear plants in Japan (more).

The Chernobyl disaster is in a different class. Because of the Soviet Union's expediency used in designing reactors (as a result of "Cold War" competition with the rest of the world), safety issues were largely ignored (more). This resulted in an excessive response to contain the highly radioactive fires of the cores after the explosions. Emergency personnel were rushed into service, which irradiated and killed more than 30 brave emergency responders, such as fire-fighters, paramedics security workers, and no doubt senior party members in charge of local politics, and inflicted thyroid cancer on thousands of children. However, almost 99% of the children were quickly treated and recovered (more). The nuclear industry can now handle such core breaches, learned by the Japanese and the rest of the on-looking world in 2011.

Evacuations were largely safety measures; fear was the main outcome, but no one was irradiated or died managing the core breach caused by the loss of standby power. The other undamaged reactors at the plant site continued in operation (more). The aerial extent of dangerous radiation turned out to be minimal, although the residual fear prevented many nearby residents from returning to their homes. Counseling and education have helped many to understand radiation and to gain a new perspective of radiation that surrounds us all (more). As a result, new safety measures in plant design and in emergency response are being implemented and many of the nuclear power plants in Japan are coming back on-line, driven by the "all-clear" of minimal residual radiation and the high prices of imported natural gas, and by the slow build-up and cost of renewable energy (more). The wastes from the incident are being managed (more).

Germany and Austria remain anti-nuclear, but that resolve is weakening based on the growing perception of nuclear power's actual safety record, having new information on emissions, and being made aware of the new, innovative ways of managing radioactive waste. As will be discussed later in this report, the small, modular reactors (SMRs) will soon be available, which will cut the construction costs considerably from that of previous large-scale nuclear reactors, while maintaining safety, reliability and support of the power grid with minimal interruptions.

Nuclear Power Plants Demand Fuel

Uranium prices and exploration and mining are driven by nuclear-plant demand for fuel for the 96 reactors currently in operation in the U.S. and the 440 reactors worldwide (and for those under construction/planned in the future). Plants also must plan for the storage of their own "used" fuel in the U.S., (which is not all "waste" because some will likely be useful in the future). This is because the U.S. federal government failed to provide the national storage facility mandated by law decades ago while still charging nuclear plants billions of dollars to build Yucca Mountain Facility (the voters of Nevada rejected final approval to begin operating the facility). The government also failed to manage the plants' radioactive used fuel, when alternative storage locations were available, e.g., the WIPP project in New Mexico (more). Plants are currently storing their used fuel on site in dry casks approved by EPA (more), which if they were collected and stored on one site would only require an area the size of an American football field stacking the casks 10-feet high (more).

With 440 nuclear power plants in current operation worldwide, they require some 23 million pounds of yellowcake to be available for processing to fuel pellets to meet the various 3–5-year cycles of the plants. As each new plant construction is announced, an additional 50,000 pounds will be needed 5-10 years in the future to fuel the new plant and then the same every 3 to 5 years hence. This would stimulate new mine production or an expansion of existing mines, should the mines have such capabilities. The world's yearly uranium production (through 2018) has been no more than 120 million pounds (U_3O_8) over the past 10 years (more).

Some mines in Canada, Australia, and perhaps Kazakhstan and elsewhere have significant expansion capabilities, e.g., Cigar Lake, McArthur River in Canada, and Inkai in Kazakhstan. But new, large deposits (some very high grade) have been discovered around the rim of the Athabasca Basin of Saskatchewan and Manitoba, Canada, and in breccia pipe deposits in Arizona (more), and as roll- front deposits in basins elsewhere in the world (i.e., Peru, Uruguay and Paraguay, India, Iran, and Tanzania.

World nuclear power plant requirements for 2020 was indicated at 68,240 tonnes (or 80,472 tonnes of U_3O_8 or 177 million pounds of U_3O_8) (more); any shortfalls were made up from the U_3O_8 held by utilities, dealers, and governments. The White House has recently recognized the value of the U.S. uranium mining industry (more).

The recent move by the White House to provide some protection to the U.S. uranium mining industry is based on the fact that uranium has been purchased by U.S. utilities from potentially unstable sources now that Russia no longer sends the U.S. its outdated nuclear war heads for down-grading and fabrication into nuclear fuel for power plants (see Figure below). The program ended in 2013, about the time Russia began showing signs of instability. Russia has ownership of some uranium production in the U.S. and elsewhere, but it represents a small percentage in the U.S.

If the Biden Administration program results in American-produced uranium replacing the some 14 % of the uranium previously sold by Russia to the U.S., the remaining countries could be considered stable sources for now. With a major expansion of American production in the U.S., 60% of the uranium production currently coming from potentially unstable countries could be replaced with American uranium, and if needed, from Canada and Australia (more).

However, little yellowcake production will be produced in the U.S. until the price of yellowcake approaches the $50.00 to $60.00 level (see Figure 2 for historical and current uranium prices: Note that uranium does not trade on an open market like other commodities. Buyers and sellers negotiate contracts privately. Prices are published by independent market consultants UxC, LLC and TradeTech.)

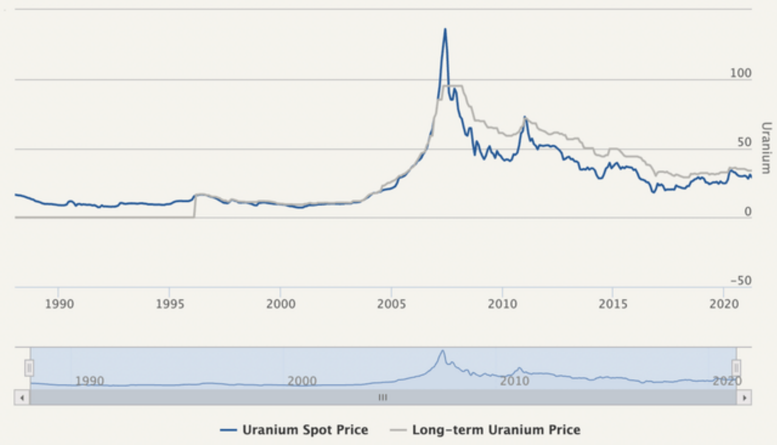


Figure 2 – Uranium Prices (Cameco – 2021)

U. S. Uranium Production

EIA reported that U.S. production of uranium concentrate (U_3O_8) in the first quarter of 2021 could not publicly release the data. Uranium production has declined considerably in recent years, and activity did not reach a threshold where a specific production figure could be published without violating the protections that EIA has committed to provide.

U.S. Uranium In-Situ Recovery Processing Plants in Production/Shuttered (state):

- Lost Creek Project (Wyoming)
- Nichols Ranch In-Situ Recovery (ISR) Project (Wyoming)
- Ross Central Processing Plant (CPP) (Wyoming)
- Smith Ranch-Highland Operation (Wyoming)
- North Butte In-Situ Recovery (ISR) Project

On April 30, 2021, EIA updated the production capacity for the UEC's Hobson ISR Processing Plant to 2,000,000 pounds of uranium concentrate (U_3O_8) per year. We also updated total U.S. production capacity to 27,575,000 pounds of U_3O_8 per year and changed the operating status for

Burke Hollow and the Goliad ISR Uranium Project to *permitted and licensed (and ready to operate).*

Total 2020 U.S. Production from Yellowcake to Electricity

The production of uranium concentrate (yellowcake) is the first step in the nuclear fuel supply chain and production process. The U_3O_8 is then converted into UF_6 to first enable uranium enrichment (to approximately 3-5% U-235, then fuel pellet fabrication, and finally fuel assembly for insertion into the nuclear reactor, which boils water to steam to turn generators to produce electricity in the same way hydroelectric power plants use flowing water to turn generators to produce electricity.

The uranium reserve estimates presented here cannot be compared with the much larger historical data set of uranium reserves published in the July 2010 report *U.S. Uranium Reserves Estimates*. EIA estimated those reserves based on data they collected and data the National Uranium Resource Evaluation (NURE) program developed, which is based on some speculation. The EIA data include about 200 uranium properties that have reserves, collected from 1984 through 2002. The NURE data include about 800 uranium properties with reserves, developed from 1974 through 1983.

Although the data collected on the Form EIA-851A survey covers a much smaller set of properties than the earlier EIA data and NURE data, EIA personnel now conclude (2020) that within its scope the Form EIA-851A data provide more reliable estimates of the uranium recoverable at each forward cost than the estimates derived from 1974 through 2002.

In particular, the Form EIA- 851A data are more reliable because the NURE data have not been comprehensively updated in many years and are no longer considered a current data source for such purposes, although very useful in frontier and trend exploration projects by the uranium industry in the past and future.

Value of World-Wide Uranium Supplies

Uranium occurrences are common in a number of areas in the U.S. Some are located in remote areas and some occur within known aquifers below populated areas (see pages 14-19). Aside from the very large, undeveloped uranium deposit in Virginia, the top uranium mines and new discoveries are in Canada, Australia, Kazakhstan, South America and others, there will be no shortage of fuel supplies from producing and future mines for many decades (more).

With a plethora of sources available, uranium production may be controlled for the purpose of supporting production costs in the U.S. and elsewhere. As indicated to date, 35 countries account for U_3O_8 resources in the ground (equivalent to about 10 billion pounds U_3O_8), which would provide utilities with fuel for some 100 years based on a worldwide consumption rate of 50 million pounds U_3O_8/year over a 3-year fuel cycle for 450 reactors (more).

Nuclear power is now expected to expand in the coming years (as the large-scale solar and wind projects' operation and maintenance costs drive up electricity costs), the number of reactors are expected by some experts to rise from the current 450 to 1,400 operational reactors by 2050. By 2075, large fusion power plants will likely be on the rise to supply the all-electric power grid worldwide. Both fission and fusion plants will likely co-exist over the next 100 years as fusion is perfected as the principal power source on Earth but also for use off-world as new fusion-powered ships begin to be capable of approaching light speed.

Based on recent discoveries in Canada alone, its percent of acknowledged world reserves will increase considerably. One condition that could develop is a long-term over supply of uranium to be produced from a plethora of high- and low-grade deposits that would keep prices even below $50.00/ pound, less than what is required for some of the in-situ mines in the U.S. to operate economically. Some grades reported in Canadian deposits are so high that the beginning of robotic mining could well be in the offing. This could raise the cost to mine and transport such high-grade ore in the beginning, but costs would decrease as the technology settles in (more).

Substantial investment money is coming into the new Canadian uranium discoveries to support the development of these high-grade deposits (more), including the Chinese who are buying into mines in Canada (more), in Greenland, and in Namibia (more); mine development is also available with Russian funding (more). The projected demand in the foreseeable future to fuel the expanding fleet of nuclear power plants in the U.S. and worldwide will likely rise significantly if Chinese and Indian construction come to pass, fuel needs will rise significantly over the next 10 years and beyond as will the uranium price.

Drilling within uranium prospects is very active in Africa, and South America, in China, and in Australia and Asia; although the latter has substantial uranium potential, it is still suffering from political fatigue in all uranium states, although discussions are currently under way about encouraging nuclear power to replace coal and some new renewables with increasingly expensive electricity costs (Western Australia, Northern Territory, Queensland, and even South Australia) (more). The emphasis on nuclear power by China is reflected by numerous frontier uranium exploration projects being conducted by Chinese geologists.

FUEL COMPETITION

Updated citations on topical issues:

1. Coal vs. Nuclear Power and Natural Gas (here)
2. Renewable Energy vs. Nuclear Power (here)
3. Industry Bias: Google Search Results: (here)
4. Academic Bias: Google Search Results: (here)

Thorium Activities Summary

Thorium-Based Reactors continue development in the U.S., but especially in China and India (more). The WNA presented a 2017 status review of thorium resources and engineering experts opine on reactor development to date.

Updated citations topical issues related to thorium research:

1. I2M Web Portal: Search Results: Thorium (more)
2. University Research: Google Search: Thorium (more)
3. Industry Research: Google Search: Thorium (more)

Rare Earth Activities Summary

1. I2M Web Portal: Search Results “Rare Earth” REE (more)
2. University Research: Google Search Results (more)

3. Industry Research: Google Search Results (more)

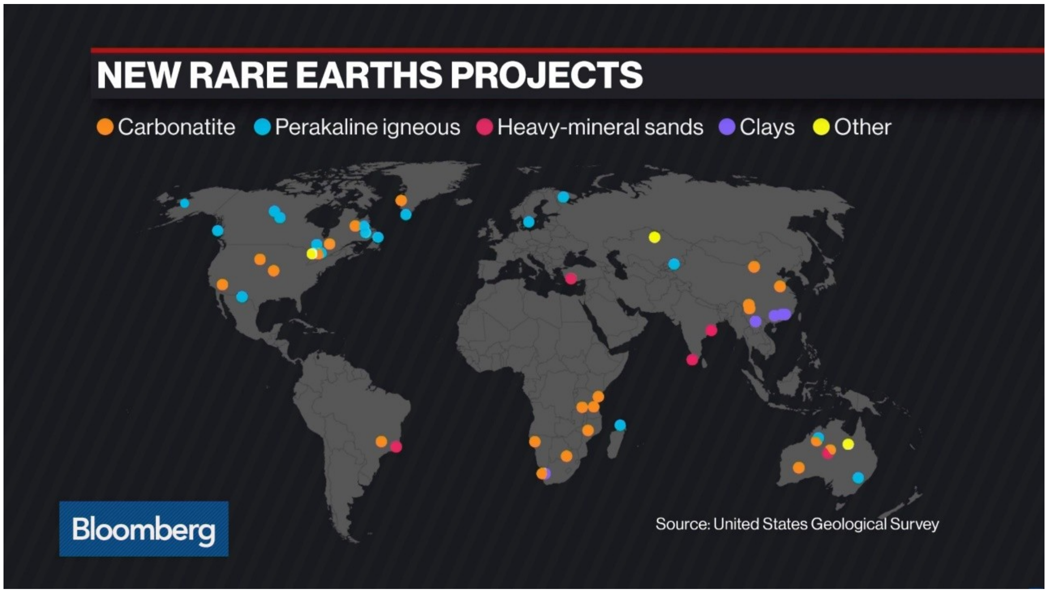


Figure 3 – Types of REE Occurrences in the World

ADVERSARIES of URANIUM MINING and NUCLEAR POWER DEVELOPMENT

1. Industry Media Bias (more)
2. Academic Bias (more)

II. URANIUM and RARE EARTH UNIVERSITY RESEARCH

Steven S. Sibray, P.G., C.P.G., (Vice-Chair: University), University of Nebraska, Lincoln, NE

Interest in uranium and thorium research has decreased since the Fukushima Daiichi nuclear accident in 2011 with very few grants and new sources for funding. Interest in Rare Earth Elements [REE] research has also decreased somewhat due weak market conditions. Lack of career opportunities in the uranium mining might also be a factor in the apparent absence of student interest in pursuing research related to uranium exploration. Although there have been significant recent increases in the spot price of uranium in late 2020, it has not been enough to offset the extreme pessimism concerning the future of the uranium mining industry among geology students looking at future employment in mineral exploration.

The Society of Economic Geologists Foundation (SEGF) and the SEG Canada Foundation (SEGCF) have listed Student Research Grant awards for 2020. These grants assist students with field and laboratory expenses for thesis research on mineral deposits as required for graduate degrees at accredited universities. Grants are awarded on a competitive basis and are available to students worldwide. Of the 30 SEG grants awarded, one was granted for the study of uranium, and another was for the study of a niobium bearing carbonatite in Brazil, a potential source of REE. Of the 13 SEGCF grants awarded, one was for the study of REE vein mineralization in Canada. The two SEG grants were from the Hugh E. McKinstry Fund which was named after the late Dr. McKinstry who was a former president of SEG and a professor of economic geology at Harvard University.

Thomas Jones	US$2,700	University of Witwatersrand (South Africa)	Ph.D.	Structural of the South-Central Zone, Damara Orogenic Belt, Namibia, and its implications for uranium mineralization.
David Benoit	US$3,300	Université du Québec à Montréal (Canada)	B.Sc.	Exploration for rare earth vein mineralization in the Centra l Gneiss Belt of the Grenville Province, Maniwaki, Quebec.
Felipe V. Ruiz	US$4,800	University of Chile (Chile)	Ph.D.	The origin of one of the world's largest niobium resources: The Catalão II carbonatite complex, Central Brazil.

Colorado School of Mines

There are no uranium research projects currently at Colorado School of Mines [CSM]. There is one REE research project: “Partitioning of REEs between minerals and fluids” by PhD student Joseph Caleb Chappell. This was conducted under guidance of Dr. Alexander Gysi.

New Mexico Institute of Mining and Technology

Dr. Virginia McLemore at New Mexico Institute of Mining and Technology has been very active in uranium and REE research and has provided a list of publications and abstracts published in 2020.

McLemore, V.T., Smith, A., Riggins, A.M., Dunbar, N., Rämö, O.T., and Heizler, M.T., 2020, “REE-bearing Cambrian-Ordovician episyenites and carbonatites in southern and central New Mexico, USA,” *in* Koutz, F.R. and Pinnell, W.M., eds. *Vision for Discovery: Geology and Ore Deposits in the Great Basin*: Geological Society of Nevada, 2020 Symposium Proceedings, p. 411-428.

McLemore, V.T., Frey, B., Hayek, E.E., Hettiarachchi, E., Brown, R., Chavez, O., Paul, S., and Das, M., 2020, "The Jackpile-Paguate Uranium Mine, Grants Uranium District: Changes in Perspectives from Production to Superfund Site," *in* Frey, B.A., Kelley, S.A., Zeigler, K.E., McLemore, V.T., Goff., F, and Ulmer-Scholle, D.S., eds., *The Geology of the Mount Taylor Area: New Mexico*, Geological Society, Special Publication 14, p. 77-88,
URL: https://nmgs.nmt.edu/publications/special/14/ .

McLemore, V.T., 2020, **"**Critical Minerals in New Mexico; Work Needed to Realize Resources," *Mining Engineering*, v. 72, no. 2, pp. 31, URL:
https://me.smenet.org/abstract.cfm?preview=1&articleID=9501&page=31

McLemore, V.T., 2020, "Uranium Deposits in the Poison Canyon Trend, Ambrosia Lake Subdistrict, Grants Uranium District, McKinley and Cibola Counties, New Mexico," *in* Frey, B.A., Kelley, S.A., Zeigler, K.E., McLemore, V.T., Goff., F, and Ulmer-Scholle, D.S., eds., *The Geology of the Mount Taylor Area: New Mexico*, Geological Society, Special Publication 14, p. 53-64, URL: https://nmgs.nmt.edu/publications/special/14/ .

University of Regina [Canada]

Dr. Guoxiang Chi has coauthored an introduction to a special issue of *Ore Geology Reviews* in 2021, "*Diversity of Uranium Deposits in China – An introduction to the Special Issue*." China possesses about 30% of the nuclear power plants under construction which will put demands on uranium resources in the future. China is ranked only #10 in terms of uranium reserves worldwide. This has resulted in the publication of many research papers on the geology of uranium deposits in China. The abstract can be accessed here: https://doi.org/10.1016/j.oregeorev.2020.103944

Ore Geology Reviews

A few noteworthy research papers on uranium deposits were published in *Ore Geology Reviews* during 2020. One paper describing the petrology and mineralogy of a sandstone-hosted deposit in the Ordos Basin China noted that sulfuric acid could not be used as an oxidizing agent where carbonate cements [presumably calcium carbonate] where present because calcium sulfate would precipitate and plug up pore space and reduce permeability.

Xuebin Su, Zhengbang Liu, Yixuan Yao, Zhiming Du, 2020, "Petrology, Mineralogy, and Ore Leaching of Sandstone-Hosted Uranium Deposits in the Ordos Basin, North China," *Ore Geology Reviews*, Volume 127, 2020, 103768, ISSN 0169-1368,
https://doi.org/10.1016/j.oregeorev.2020.103768.

Other interesting uranium papers published in *Ore Geology Reviews* include the following:

Fengjun Nie, Zhaobin Yan, Zhibing Feng, Mangen Li, Fei Xia, Chengyong Zhang, Yanguo Wang, Jianxin Yang, Shihu Kang, Kefeng Shen, Genetic models and exploration implication of the paleochannel sandstone-type uranium deposits in the Erlian Basin, North China – A review and comparative study, Ore Geology Reviews, Volume 127, 2020, 103821, ISSN 0169-1368, https://doi.org/10.1016/j.oregeorev.2020.103821.

Junmin Jia, Hui Rong, Yangquan Jiao, Liqun Wu, Yan Wang, Hongliang Li, Minqiang Cao, Mineralogy and geochemistry of carbonate cement in sandstone and implications for mineralization of the Qianjiadian sandstone-hosted uranium deposit, southern Songliao Basin, China, Ore Geology Reviews, Volume 123, 2020, 103590, ISSN 0169-1368. https://doi.org/10.1016/j.oregeorev.2020.103590.

Mineralium Deposita

One noteworthy paper published in *Mineralium Deposita* investigated trace element signature in hematite and goethite associated with uranium deposits in the Kiggavik-Andrew Lake structural trend [KALST]. The trace elements indicated the source of uranium was thought to basement rocks. This is the same conclusion than the recent research cited in last year's report concerning the nearby Athabasca Basin where Guoxiang Chi et al, 2019, found uranium-rich fluid inclusions derived from the sandstones throughout the basin.

The *Mineral Deposita* paper is cited here:

Makvandi, S., Huang, X., Beaudoin, G. *et al.,* 2021 "Trace Element Signatures in Hematite and Goethite Associated with the Kiggavik–Andrew Lake Structural Trend Uranium Deposits (Nunavut, Canada)," *Miner Deposita,* Vol. 56**,** pp. 509–535 (2021).

The paper on the Athabasca Basin fluid inclusions is cited here:

Chi G, Chu H, Petts D, Jackson S, Williams-Jones A.E., 2019, "Uranium-Rich Diagenetic Fluids Provide the Key to Unconformity Related Uranium in the Athabasca Basin," *Sci Rep.,* Vol. 9:5530. https://doi.org/10.1038/s41598-019-42032-0

Carbonatite REE Papers

A very good overview of REE bearing carbonatite deposits was published in Minerals:

Wang, Z.-Y.; Fan, H.-R.; Zhou, L.; Yang, K.-F.; She, H.-D., 2020,"Carbonatite-Related REE Deposits: An Overview," *Minerals*, Vol. 10, pp. 965. https://doi.org/10.3390/min10110965

Two papers on the world's largest REE deposit [Bayan Obo] were published in the *Journal of Geochemical Exploration*:

Pei Ni, Jin Zhou, Zhe Chi, Jun-Yi Pan, Su-Ning Li, Jun-Ying Ding, Liang Han, 2020, "Carbonatite Dyke and Related REE Mineralization in the Bayan Obo REE Ore Field, North China: Evidence from Geochemistry, CO Isotopes and Rb Sr Dating," *Journal of Geochemical Exploration*, Vol. 215, pp. 106560, ISSN 0375-6742, https://doi.org/10.1016/j.gexplo.2020.106560.

Jian Zhou, Xueqiu Wang, Lanshi Nie, Jennifer M. McKinley, Hanliang Liu, Bimin Zhang, Zhixuan Han, 2020, "Geochemical Background and Dispersion Pattern of the World's Largest REE Deposit of Bayan Obo, China," *Journal of Geochemical Exploration*, Vol. 215, pp.106545, ISSN 0375-6742, https://doi.org/10.1016/j.gexplo.2020.106545 .

III. Uranium-Related State/Federal Government Research

Robert W. Gregory, P.G., (Vice-Chair: Government), Wyoming State Geological Survey, Laramie, WY

USGS

The U.S. Geological Survey recently shifted their primary focus to critical minerals, drawing personnel resources away from their uranium efforts. However, Dr. Susan Hall maintains her diligent focus into a number of areas of important uranium research efforts. She provides the following summary:

Appalachian Highlands Assessment: A genetic model developed for the Coles Hill deposit in Virginia concluded that uranium formed during high heat flow that accompanied tectonic extension during the Triassic and along a regional shear zone that developed in the Carboniferous. These new understandings will help assess the potential for other metasomatite-type uranium deposits in the southeastern United States. Several publications are in press or review that summarize this work (more).

Colorado Plateau Sandstone-hosted Uranium Assessment: In 2020, USGS began a regional study of uranium occurrences on the Colorado Plateau. Field studies evaluated twelve uranium districts mostly in the northern portion of the Plateau, and field work will continue in the southern portion of the Plateau in 2021. A regional grade-and-tonnage model for uranium deposits on the Plateau is in development, mostly by volunteers drawing on records from the National Archives. Many uranium deposits in the Plateau were explored by evaluating "bleached" sandstones. To explore the causes and impacts of bleaching, targeted research is in progress focused on the chemical and petrologic changes caused by a modern hydrocarbon seep that is actively bleaching local sandstones. For additional information on uranium occurrences on the Colorado Plateau, see: Jaffri, 2020; Silvan, et al., 2020; Campbell, et al., 2020; and (more).

USGS EarthMRI project: USGS identified over 60 high-priority uranium focus areas in the conterminous United States that are "prospective" for concealed uranium deposits. This work has been compiled into publications that are in review (more).

International Uranium Supply: Because U.S. utilities are so heavily reliant on international uranium supply, USGS has initiated a project to identify the major vulnerabilities to this international supply. Analysis of secular changes in production and demand and the accuracy of past projections of both is in progress. The goal is to identify the most important drivers for expansion or contraction of world supply. The vulnerability of the U.S. uranium supply has been discussed in some detail (Campbell, et al., 2020, Campbell, 2021), and (more).

WYOMING

In a major announcement on June 2, 2021, Governor Mark Gordon, along with U.S. Secretary of Energy Jennifer Granholm, U.S. Senator John Barrasso, TerraPower Founder Bill Gates, with President and CEO Chris Levesque, and Rocky Mountain Power President and CEO Gary Hoogeveen announced plans to retrofit on of Wyoming’s existing (but soon to be retired) coal-fired power plants to a nuclear power plant using the Natrium^{TM} plant design technology (Wyoming Video Announcement (here).

The proposed project includes a 345 MW sodium-cooled fast reactor and molten salt-based storage technology. No details on the timeline for the project or which plant will converted have yet been announced. More information about the technology can be found on TerraPower’s website (here).

The WSGS continues to collaborate with the USGS on its EarthMRI efforts. The central Laramie Range is currently being evaluated for critical minerals, along with mapping projects on the King Mountain and Ragged Top Mountain quadrangles. The CLR project will continue in 2021, while additional focus areas are also being proposed in other areas in Wyoming.

The WSGS has not been able to engage in uranium-related research over the past year other than some preliminary data gathering relating to uranium, vanadium, and critical mineral occurrences and trends in select roll-front deposits. For additional information on uranium in Wyoming, see (here).

The projected budget shortfalls for the 2020–2021 production years have diverted efforts of many of the WSGS staff to provide the Wyoming state legislature with the data required to make difficult budget decisions. Due to Covid-19's effect on Wyoming's economy, particularly to the oil and gas industry, Wyoming state government was faced with unprecedented budget deficit forecasts. As a result, Wyoming, has had to undergo a number of massive budget cuts. Along with numerous agencies around Wyoming, some of those budget cuts have also affected the Wyoming State Geological Survey. Consequently, the uranium geologist position (currently held by the writer) will no longer be a part of the WSGS as of July 1, 2021.

Ambient Radiation and Other Potential Hazards from Space

As included in previous UCOM Annual reports, we present discussions of the radiation occurring offworld in space and of that coming into our atmosphere, some of which making it to the Earth's surface. This is for the purpose of informing and emphasizing to AAPG members and the general public that radiation is not only emitted by naturally occurring radioactive minerals containing uranium, radium, and thorium (that emit alpha, beta, and gamma radiation), but also by energy sources produced in our Sun (emerging as sunlight but also as coronal mass ejections (CMEs) containing various types of radiation) and from other stars in our galaxy and beyond as gamma rays (from GRBs), ultraviolet and infrared rays, some X-rays, high-speed neutrinos and neutrons, and other particles. Some of the latter strike Earth's surface and all of the life exposed, including humans. However, humans and life in general have evolved and have generally dealt with this radiation, with some periods in geologic history of high radiation causing gene mutations as part of evolving, some life surviving, some extinguished. The well-known major decrease (called bottleneck) in the human population suggested in ice cores and sediment analyses dated around 70,000 years ago may have been caused by a CME or GRB (more).

Although the Earth's magnetic shield and atmosphere normally block some of the radiation, some reach the Earth with humans responding by avoiding excessive exposure, or by applying sun-block ointments, etc. As we begin to explore offworld, astronauts also will need to be shielded while spending time on the ISS conducting research, and while exploring for life and for minerals of economic interest (uranium, helium-3, thorium, and REE) on the Moon, and on nearby asteroids, the moons of Jupiter (e.g., Europa, etc.), the moons of Saturn (Enceladus) (Titan), and other sites within our solar system.

To investigate how much gamma and neutron radiation reaches humans on Earth, approximately once a week, Spaceweather.com and the students of Earth to Sky Calculus have been releasing space-weather balloons to the stratosphere over California and other states. These balloons are equipped with radiation sensors that detect cosmic rays, a form of space weather.

Cosmic rays can seed clouds, trigger lightning, and penetrate commercial airplanes. Furthermore, there are studies (#1, #2, #3, #4) linking cosmic rays with cardiac arrhythmias and sudden cardiac death in the general population. Our latest measurements show that cosmic rays are intensifying, with an increase of more than 18% since 2014 (see Figure 4):

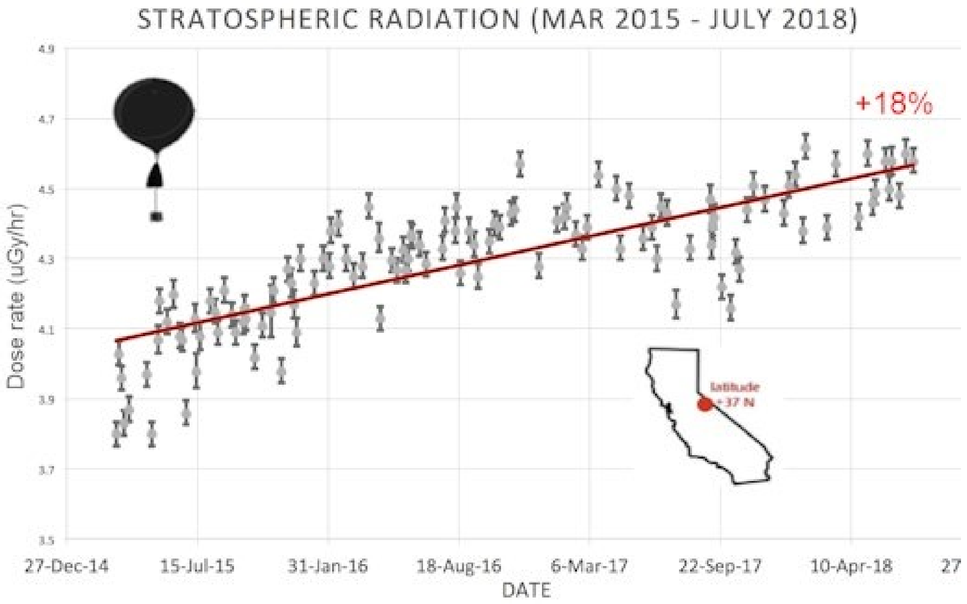


Figure 4 - (Spaceweather)

The data points in the graph above correspond to the peak of the Reneger-Pfotzer maximum, which lies about 67,000 feet above central California. When cosmic rays enter the Earth's atmosphere, they produce a spray of secondary particles that is most intense at the entrance to the stratosphere. Physicists Eric Reneger and Georg Pfotzer discovered the maximum using balloons in the 1930s and it is what is measured (see plot: more).

On route to the stratosphere, their sensors also pass through aviation altitudes (see Figure 5) In the plot below, dose rates are expressed as multiples of sea level. For instance, they observed that boarding a plane that flies at an altitude of 25,000 feet exposes passengers to dose rates ~10x higher than sea level (more). At 40,000 feet, the multiplier is closer to 50x. The radiation sensors onboard their helium balloons detect X-rays and gamma-rays in the energy range 10 keV to 20 MeV. These energies span the range of medical X-ray machines and airport security scanners (more).

Cosmic rays are intensifying because of the Sun’s reduced output. Solar storm clouds such as coronal mass ejections (CMEs) sweep aside cosmic rays when they pass by Earth. During Solar Maximum, CMEs are abundant and cosmic rays are held at bay. Now, however, the solar cycle is swinging toward Solar Minimum, allowing cosmic rays to return. Another reason could be the weakening of Earth's magnetic field, which surrounds Earth and helps to protect us from deep-space cosmic and other radiation (more) .

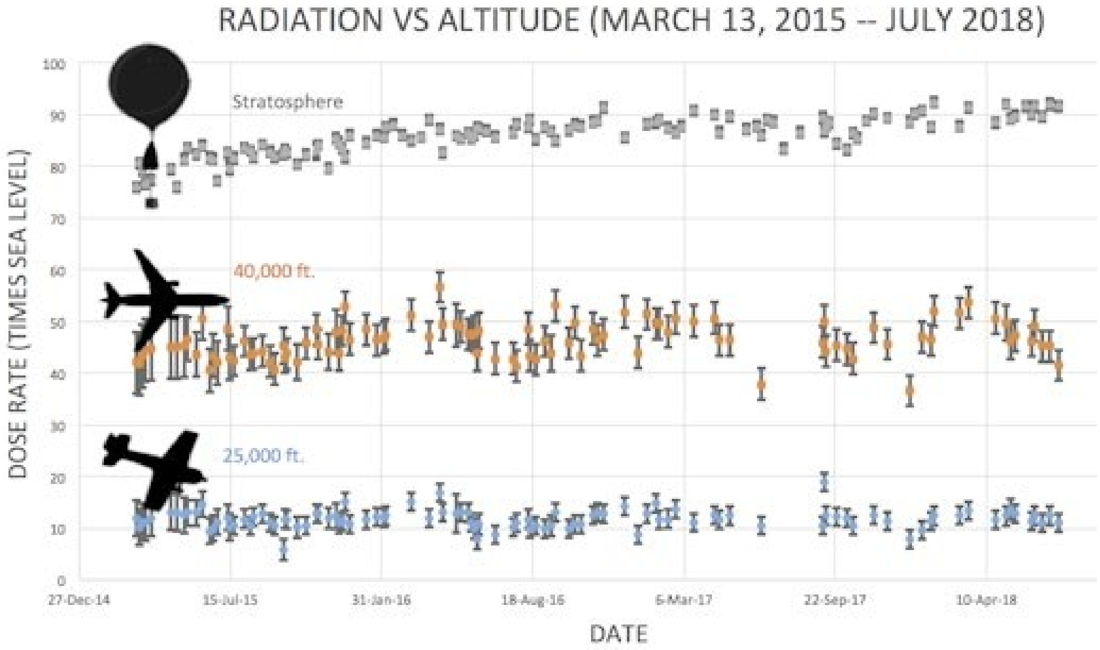


Figure 5 (Spaceweather)

For a dynamic viewing of the northern lights (*Aurora Borealis* aka Earth’s magnetic field in action*)*), see Figure 6, which illustrates a coronal mass ejection (CME) from the Sun, which, but for the magnetic shield, the Earth would be devoid of life as we know it (more).

There continues to be widespread discussions by geologists, geophysics and astronomers regarding the pending magnetic pole reversal and the migration of the north pole from northern Canada toward Russia (more).

Figure 6

Coronal Mass Ejection (CME) Heading for Earth and the Earth's Defense

Also, red lightning has only recently been confirmed in detail above distant thunderheads as momentary flashes, and Smith (2019) caught a group over two big storms in Kansas (see Figure 7 below). These atmospheric phenomena are termed "sprites" and constitute an exotic form of electricity that appears to shoot up from major storm clouds, instead of down like ordinary lightning

Figure 7

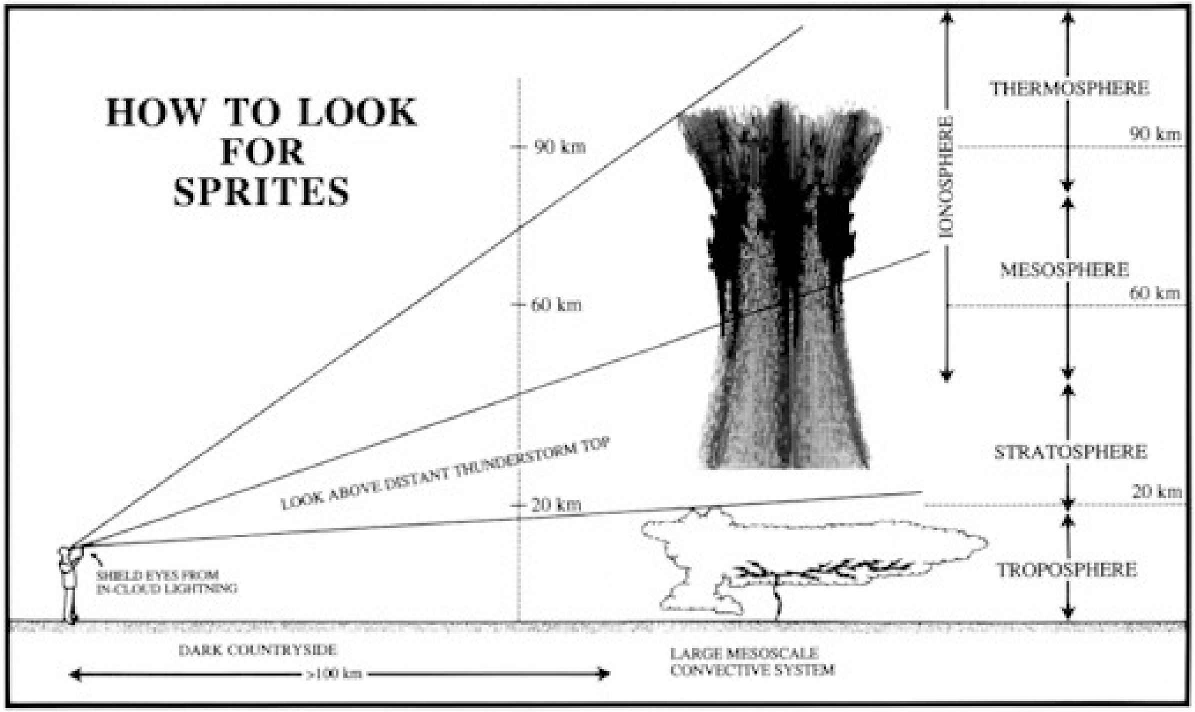
Observable Sprites over Kansas in 2019 (Smith, 2019).

Although sprites have been reported for at least a century, many scientists did not believe they existed until after 1989 when sprites were accidentally photographed by researchers from the University of Minnesota and confirmed by video cameras onboard the space shuttle (more).

Smith (2019) has been observing and photographing sprites for years in the stormy U.S. Great Plains around Oklahoma and Kansas. Here are two examples of clusters he caught simultaneously with direct visual observation and camera. The jellyfish shapes he observed had a fiery orange/red color, likely reflecting ionized nitrogen and/or a form of oxygen (ozone?) in the upper atmosphere. The underlying physics of sprites are still not fully understood.

Some models hold that cosmic rays help them get started by creating conductive paths in the atmosphere. If cosmic rays do indeed spark sprites, Tony Phillips (2019) suggests that they could be explained because cosmic rays are nearing a Space Age high. See Figure 8 viewing sprites.

Figure 8



More examples of sprites may now be found at Smith (2019).

Monitoring for Hazardous Asteroid/Comet Arrivals

After years of prodding by astronomers and others, U.S. government and NASA, JPL, etc. are finally beginning to support and implement a well-funded and meaningful program to monitor asteroids and comets within the orbital reaches of Earth, and to determine what to do if one comes our way (more). CNEOS is NASA's center for computing asteroid and comet orbits and their odds of Earth impact (more). Also see the updates (here). The modeled response did not turn-out well for Earth (more),

Human Hazards in Zero Gravity and Orbital and Deep-Space Radiation

Recent medical reports on astronauts returning from long stays in zero gravity on the ISS show that serious damage occurs to brains (more) and tissues (more). This will require rotation and shielding in ships built for space travel and advanced robotics to minimize exposure to astronauts (more). Exposure in near-zero gravity while on bases on the Moon, Mars, Europa, Titan, etc. is currently under intense research. With China forging ahead in the 2nd Space Race, their experiences will no doubt be closely monitored by the U.S., Europe, Japan, Israel, India, and other space-faring nations (more).

Research into all types of known ionizing and other radiation will allow the radiation issues surrounding uranium mining, nuclear power plant operations, and the associated nuclear waste to be placed into the proper perspective of managing any risks involved.

In closing, remember that the I2M Web Portal references and search results cited in this and previous UCOM reports are continuously updated in the I2M Web Portal as new information is entered into the I2M database. However, some references go directly to the Internet source without comment or assimilation.

Historical and Reading List of Links (See 2020 UCOM Annual Report (here).

To see the Archive of previous UCOM Reports, see (here).

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