

Assessing the Potential Helium Resources in Central Kentucky*

J. Richard Bowersox¹

Search and Discovery Article #51573 (2019)**

Posted June 3, 2019

*Adapted from oral presentation given at 2018 AAPG 47th Annual AAPG-SPE Eastern Section Joint Meeting, Pittsburgh, PA, October 7-11, 2018

**Datapages © 2019. Serial rights given by author. For all other rights contact author directly. DOI:10.1306/51573Bowersox2019

¹Kentucky Geological Survey, Lexington, KY, United States (j.r.bowersox@uky.edu)

Abstract

Helium (He) is a rare element essential to medical procedures, such as magnetic resonance imaging, and low temperature physics research. However, the decision to sell Federal helium supplies through the Helium Privatization Act of 1996 may make the United States dependent on foreign sources for its He supply. He is produced in the Earth's crust by radioactive alpha decay of uranium (U) and thorium (Th) isotopes in minerals. Radioactive decay of potassium (K) isotopes, common in crustal rocks, is by gamma decay and does not produce He.

He migrates and accumulates in porous rocks much like oil and natural gas. He concentrations exceeding 1.6 vol.%—three times the minimum concentration required for commercial development in western U.S. helium fields—have been found in oil and gas exploration wells drilled to the Rome Formation, at an average depths > 4500 ft, adjacent to the Kentucky River fault in the Rome Trough, Garrard and Clark Counties, Kentucky. There are, however, no data on He occurrences in the 20-mi gap between those locations.

He generation potential can be estimated by calibration of conventional gamma ray logs (GR) to U and Th concentrations measured by X-ray fluorescence (XRF) analyses of cuttings and core samples from wells in the areas of known He accumulation. These data can then be used as a guide for predicting commercial He accumulations. A spectral gamma ray log (SGR), a logging tool that measures U, Th, and K concentrations in formations penetrated in a wellbore, was run in the Kentucky Geological Survey 1 Hanson Aggregates well, Carter County, Kentucky, and XRF analyses of cuttings from the Conasauga shale and Grenville basement were performed for calibration of SGR and GR log data. SGR log values were a poor match to XRF data, with SGR values of U much lower and Th values higher than XRF values in the Conasauga and SGR measured U values much higher and Th values much lower than XRF values in the Grenville. By calibrating SGR values to XRF measurements, however, calibration of GR log values to U and Th concentrations was possible. Net potential He source rock in the Rome Formation shales was determined using a 108 API units (APIu) cutoff. Average GR values in Rome Formation shales in the Rome Trough at the API unit cutoff increase from about 125 APIu in central Garrard County to more than 200 APIu in southern Clark County. This suggests that the Garrard-Clark counties region has a high likelihood for He generation. Additional XRF analyses of cuttings from the Rome Formation shales will be necessary to confirm this.

If the Garrard-Clark counties region is rich in He, central Kentucky may have a valuable commercial resource. The cost of drilling deeps wells to assess the He distribution, however, has discouraged exploration in the region.

Assessing the Potential Helium Resources in Central Kentucky

Rick Bowersox
Kentucky Geological Survey
University of Kentucky, Lexington, Kentucky

2018 AAPG Eastern Section Meeting
Pittsburgh, Pennsylvania, October 10, 2018

Helium: It's more than balloons

- Helium is a rare element essential to medical procedures, such as magnetic resonance imaging, semiconductor manufacturing, low temperature physics research, and an inert gas heavily used in industry. And balloons, although the helium used in balloons is a small part of the total supply.

The United States is currently the world's biggest supplier, with the bulk of it stored near Amarillo, Texas, in the national helium reserve - which alone accounts for 35% of the world's current supply.



Is it right to waste helium on party balloons?

By Tim Bowler Business reporter, BBC News, 18 November 2013

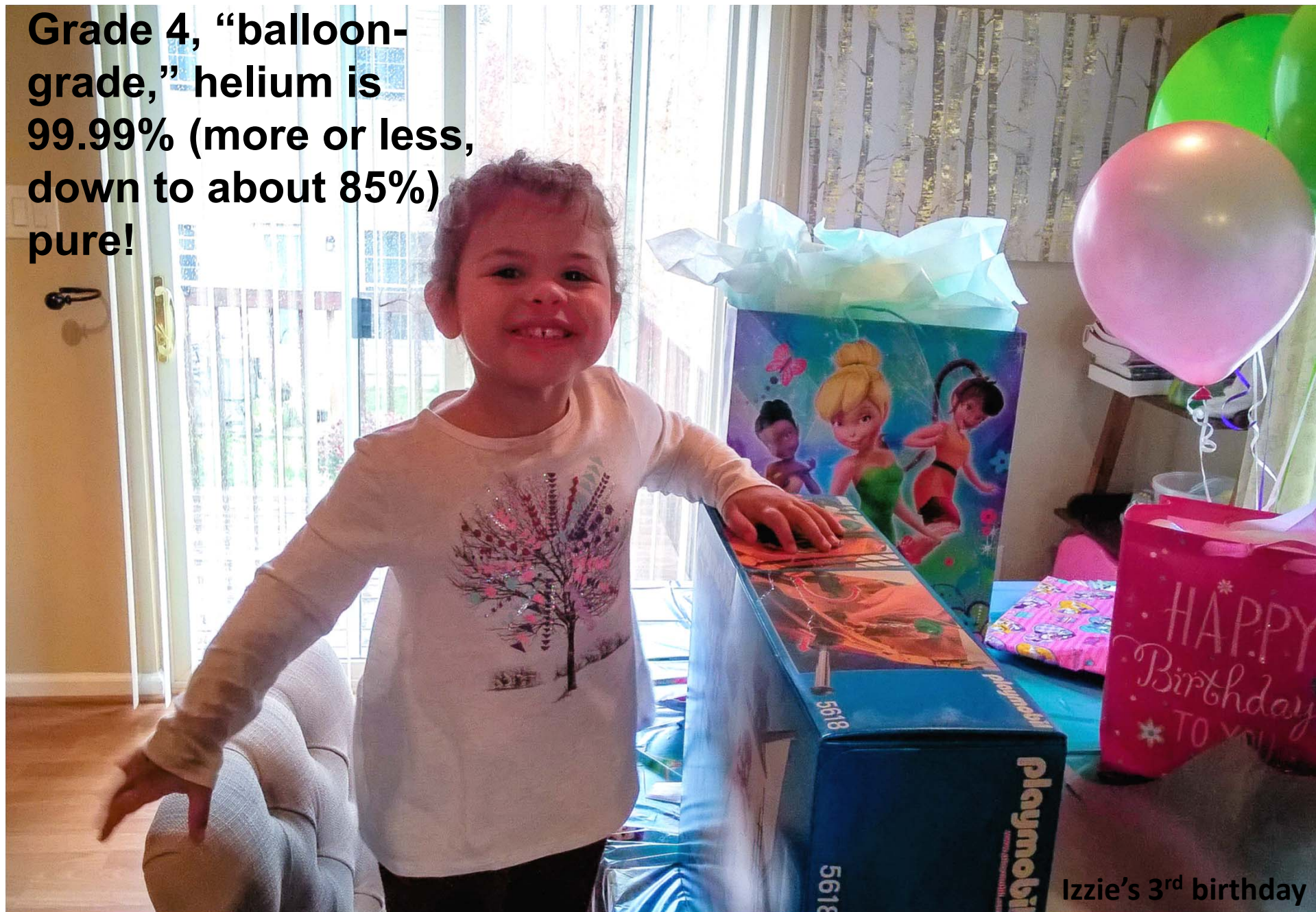
- The decision to sell Federal helium supplies through the Helium Privatization Act of 1996 may make the United States dependent on foreign sources for its helium supply.

Some things about helium you may have never thought of: there is more than one grade of helium.

- **An overview of the different common grades of helium:**
 - **Grade 6 (6.0 helium = 99.9999% purity)**, is about the closest to 100% pure helium that can be processed. It is used in **semiconductor chip manufacturing**, laser cutting, MRI machines, and a carrier gas in gas chromatography.
 - **Grade 5.5 (5.5 helium = 99.9995% purity)** is ultra pure helium gas that is typically considered “**research grade.**” It is also used in chromatography and semiconductor processing, as well as lab research, MRIs, as a shielding gas in welding, a cooling gas for fiber optics, and other industries that require high-purity helium gas.
 - **Grade 5 (5.0 helium = 99.999% purity)** is research grade helium widely used for **gas chromatography and mass spectrometry.**
 - **Grade 4.5 (4.5 helium = 99.995% purity)** is the helium grade most commonly referred to when people say “**industrial grade.**”
 - **Grade 4 ...**

<http://askzephyr.com/what-are-the-different-grades-of-helium-and-what-are-they-used-for/>

Grade 4, “balloon-grade,” helium is 99.99% (more or less, down to about 85%) pure!



Izzie's 3rd birthday

So... Where does helium come from?

He is produced in the Earth's crust by radioactive alpha decay of uranium (U) and thorium (Th) isotopes in minerals. Gamma decay of potassium isotopes, common in crustal rocks, does not produce helium. A tiny fraction of helium is primordial, from the Earth's core.

GENERATION IN MINERALS

A small fraction of the helium in economic accumulations is primordial; most of the helium is generated by radioactive decay of uranium and thorium and their daughter products. Uranium and thorium occur predominantly in mineral grains, not pore water. Thus, helium is generated in minerals. Radioactive decay is independent from temperature and pressure. Uranium and thorium have such long half-lives that generation can be considered linear with time. The total helium generation can be estimated from the uranium and thorium concentration and time:

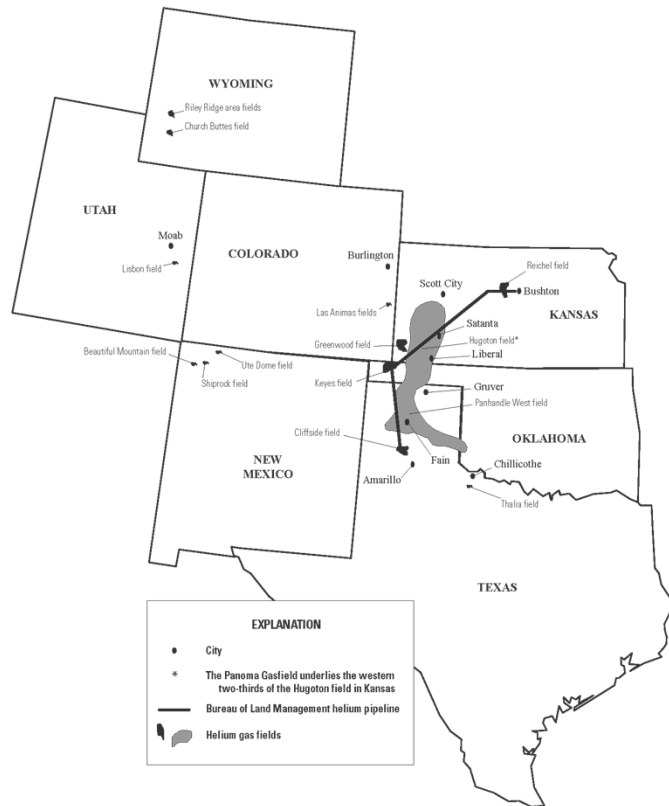
$$\begin{aligned} \text{He (STP cc He/g rk)} &= (1.22\text{E-}13 \cdot \text{ppm U} + 0.292\text{E-}13 \cdot \text{ppm Th}) \cdot T, \text{ y (STP = } 0^{\circ}\text{C, } 0.1 \text{ MPa)} \text{ or} \\ \text{He (mcf/acre-ft)} &= (1.49\text{E-}5 \cdot \text{ppm U} + 3.57\text{E-}6 \cdot \text{ppm Th}) \cdot T, \text{ My (assumes } 2.65 \text{ g/cc density,} \\ &\quad \text{no porosity, and STP = } 60^{\circ} \text{ F and } 1 \text{ atm)} \end{aligned}$$

From Brown (2010)

“Petroleum source rocks are not helium source rocks.”

Brown (2010)

Small amounts of helium is found in almost all natural gas, but there needs to be more than about 0.4% helium in the gas to be commercial



The crude Helium Enrichment Unit in the Cliffside helium storage field, near Amarillo, Texas. Wikipedia, *National Helium Reserve*.

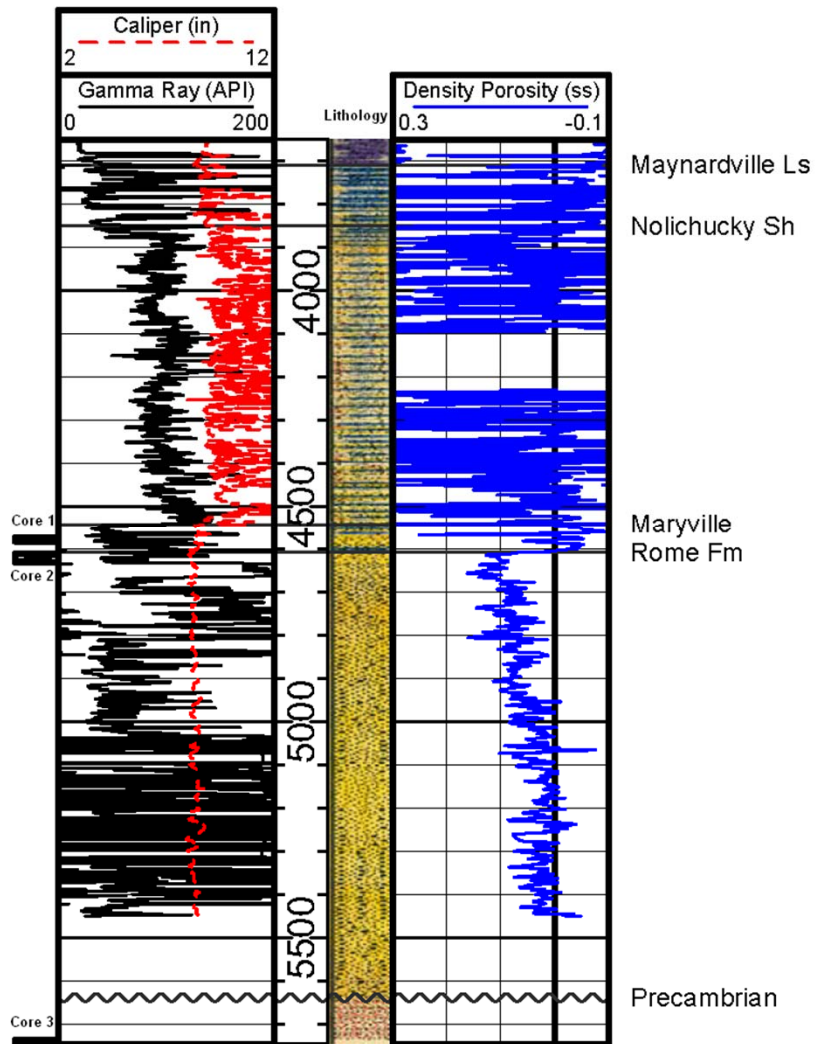
Helium-rich gas fields and helium processing plants in the United States (USGS, 2012).

Federal Helium Program

- **The BLM is responsible for evaluating the nation's helium-bearing gas fields and providing responsible access to Federal land for managed recovery and disposal of helium.**
 - The BLM operates and maintains the Cliffside helium storage reservoir, enrichment plant, and pipeline system near Amarillo, TX, that supplies over 40 percent of domestic demand for helium.
 - The BLM supplies crude helium to private helium refining companies which in turn refine the helium and market it to consumers.
- **The Federal Helium Program is comprised of the following:**
 - Federal Helium Reserve and Pipeline,
 - All other infrastructure owned, leased, or managed under contract by the Secretary of the Interior for the storage, transportation, withdrawal, enrichment, purification, or management of helium.
- **Congress enacted the Helium Stewardship Act of 2013 to replace the Helium Privatization Act of 1996.**
 - Ensures continued access to Federal crude helium; provides for a transition to private ownership of the Federal helium;
 - Sells crude helium at market-driven prices;
 - The Act required the Department of the to sell a portion of the conservation helium stored underground at the Cliffside Field north of Amarillo..

<https://www.blm.gov/programs/energy-and-minerals/helium/federal-helium-program>

Discovery of commercial-grade helium in Kentucky

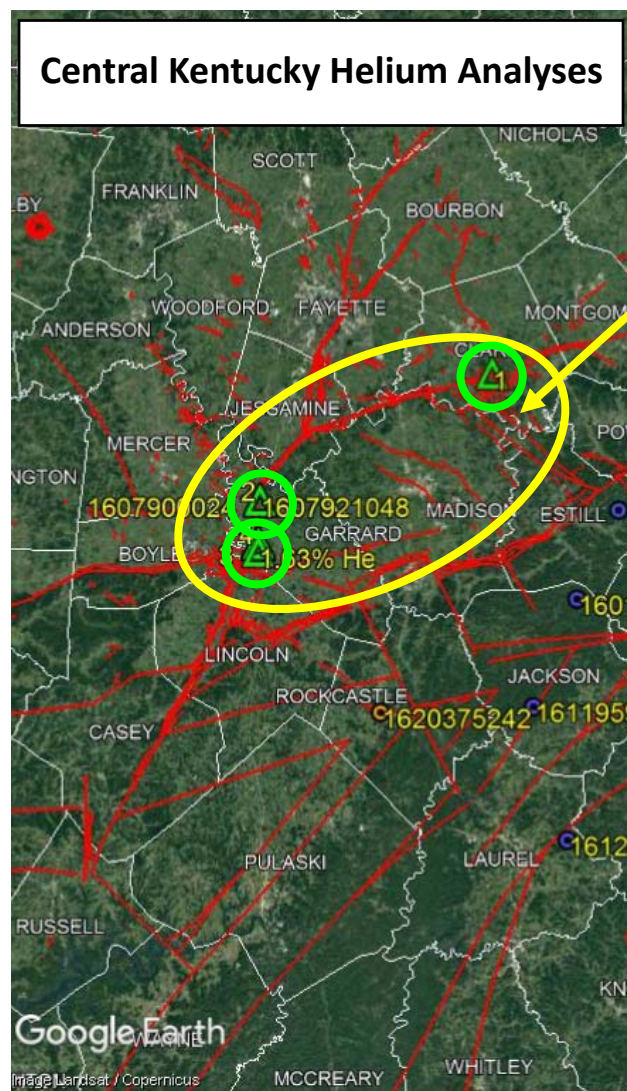


Helium was discovered in Kentucky in the Texaco (now Chevron) 1 Kirby well, Garrard County, in September 1968. Texaco drilled to a TD of 5,745 ft in Precambrian metamorphic basement rock. They cut a 20-ft core in the top of the Cambrian Rome Formation at 4612-4632 ft to evaluate its potential reservoir properties. Three more high-helium wells were subsequently drilled.



Log and core photos are from Core of the Month, <https://www.uky.edu/KGS/rocksmineral/core-month-10-2018.php>

Helium analyses $\geq 0.2\%$ in central Kentucky wells

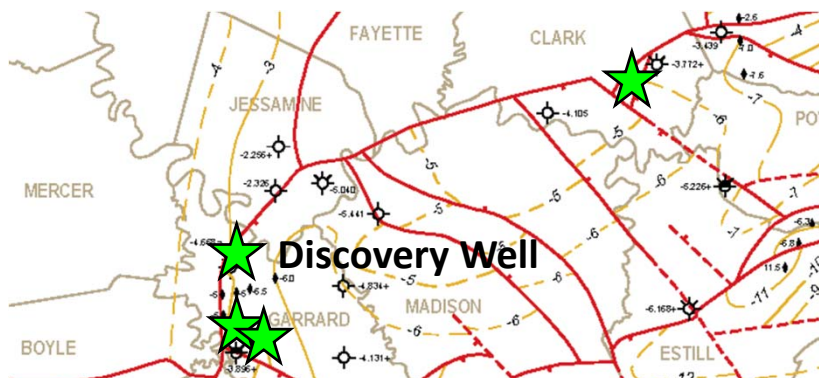


API Number	Well Name	County	He (%)	Source
1607900024	Texaco 1 Kirby	Garrard	1.92	USBM IC 9129 (1987)
1607900024	Texaco 1 Kirby	Garrard	1.81	USBM IC 9129 (1987)
1607900024	Texaco 1 Kirby	Garrard	1.69	USBM IC 9129 (1987)
1607900024	Texaco 1 Kirby	Garrard	1.24	USBM IC 9129 (1987)
1604900033	Triana 1 E. Thomas	Clark	1.81	KGS
1607900041	Hoy 1 Burdette	Garrard	1.63	KGS
1607900028	Widener 1 Burdette	Garrard	1.32	USBM IC 9129 (1987)
1602500140	Ashland 82 Evans	Breathitt	0.80	USGS
1620300005	Hunt's Natural Resources 1 Livesay	Rockcastle	0.60	USBM IC 9225 (1988)
1620300005	Hunt's Natural Resources 1 Livesay	Rockcastle	0.60	USBM IC 9225 (1988)
na	Hoenig 1A Blanton	Magoffin	0.47	USBM IC 9129 (1987)
1601300012	Wiser Oil 8 Greasy Brush Coal	Bell	0.43	USBM IC 9129 (1987)
1602500043	Ashland 93 Evans	Breathitt	0.41	USGS
1611900636	Kentucky-West Virginia Gas 6858 Francis	Knott	0.40	USBM IC 9129 (1987)
1602500128	Ashland 100 Evans	Breathitt	0.37	USGS
1619300851	Kentucky-West Virginia Gas 7309 Claiborne	Perry	0.35	USBM IC 9129 (1987)
1619300361	Kepco K343-7296 Couch	Perry	0.34	USBM IC 9129 (1987)
1602500058	Ashland Exploration 55 Evans	Breathitt	0.34	USBM IC 9167 (1988)
161930023	Kentucky-West Virginia Gas 1382 Eversole	Perry	0.32	USBM IC 9129 (1987)
na	Kentucky-West Virginia Gas 5756 Sizemore	Magoffin	0.31	USBM IC 9129 (1987)
1615303597	Kentucky-West Virginia Gas 5799 Minix	Magoffin	0.30	USBM IC 9129 (1987)
1613100062	Wiser Oil 1B Huber	Leslie	0.27	USBM IC 9129 (1987)
na	Inland Gas 272 Davis	Johnson	0.26	USBM IC 9129 (1987)
1619300501	Kentucky-West Virginia Gas 6856 Brasher	Perry	0.26	USBM IC 9129 (1987)
1615302580	Inland Gas 305 Hoyer	Magoffin	0.25	USBM IC 9129 (1987)
1613100398	Kentucky-West Virginia Gas 7323 William Cress	Leslie	0.24	USBM IC 9129 (1987)
1619504273	United Fuel Gas 9027 Kentland Coal & Coke #147	Pike	0.23	USBM IC 9129 (1987)
1612701761	Kentucky-West Virginia Gas 1213 Moore	Lawrence	0.23	USBM IC 9129 (1987)
1607100426	Kentucky-West Virginia Gas 6835 Hamilton	Floyd	0.23	USBM IC 9129 (1987)
1613100293	United Fuel Gas 1 Fordson Coal	Leslie	0.22	USBM IC 9129 (1987)
1602500508	Ashland 116A Evans	Breathitt	0.22	USGS
1615302709	Compton 1 Rowe	Magoffin	0.21	USBM IC 9129 (1987)
1612500064	Oliver Jenkins 1 Lucas	Laurel	0.20	USBM IC 9129 (1987)
na	Crest Oil 1 T.M. Cordle	Lawrence	0.20	USBM IC 9129 (1987)
1612700517	Kentucky-West Virginia Gas 1124 Moore	Lawrence	0.20	USBM IC 9129 (1987)
1612906437	Bretange 2P Beach	Lee	0.20	KGS

**Noncommercial
Helium Analyses**

Helium resources in central Kentucky

- What do we know about the potential helium resources in central Kentucky?
 - Helium is present in a cluster of wells in Garrard County and one well in Clark County, about 20 mi to the northeast.
 - All four discovery wells, and later follow-on wells in Garrard County, were drilled close to the Lexington/Kentucky River faults that are bounding faults of the Rome Trough.
 - Helium is trapped in the Cambrian Rome Formation sandstones that are interbedded with shales and overlie Precambrian metamorphic basement rocks.



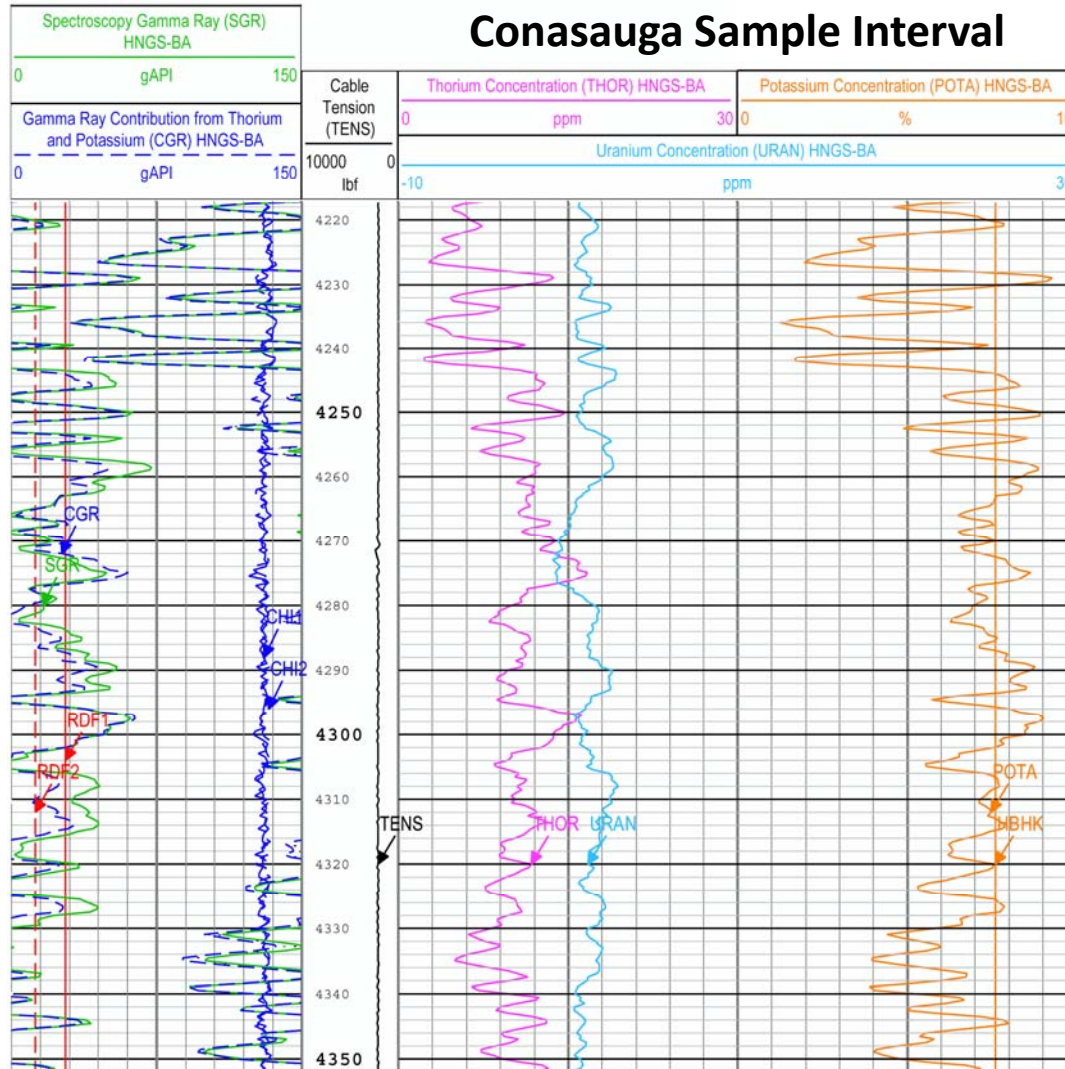
Structural contours on top of central Kentucky Precambrian basement. Green stars are discovery wells with tested high helium-content . From Drahovzal and Noger (1995).



Evaluating potential helium resources in central Kentucky

- Helium is generated in a source rock, and it migrates, is trapped, and accumulates in porous rocks much like oil and natural gas.
- Although the “source rock” and resource generation methodology is different, in the end evaluation of helium resources proceed much like a petroleum resource evaluation.
 - U, Th, and U+Th content of the Conasauga and Grenville section in the KGS 1 Hanson Aggregates well, Carter County, measured by the spectral gamma ray log were correlated to the total gamma ray response.
 - The U and Th concentrations of “source rock” measured by the spectral gamma ray log were normalized to those measured by XRF from cuttings and core.
 - A gamma ray cutoff was calculated for the total gamma ray log corresponding to about 120 API units. Net “source rock” shale in the Rome was then counted for each well in the evaluation area and an iso-gamma ray map constructed and “net pay” rock volume calculated.

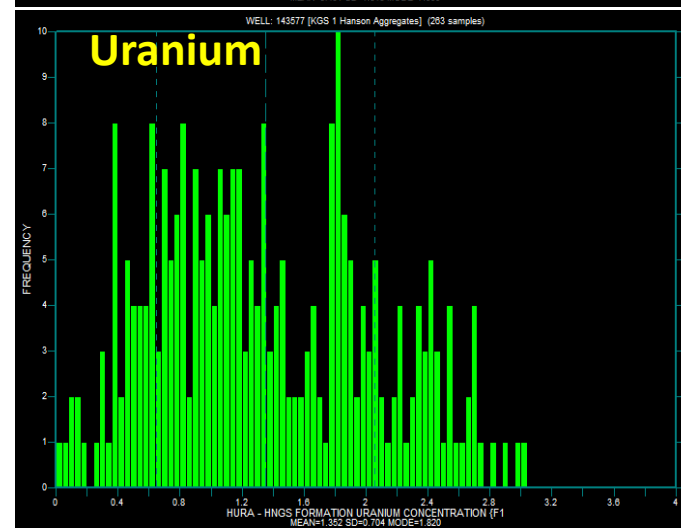
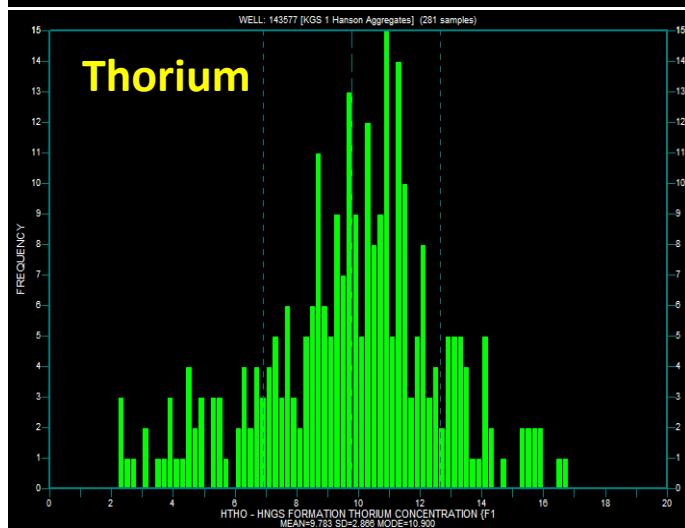
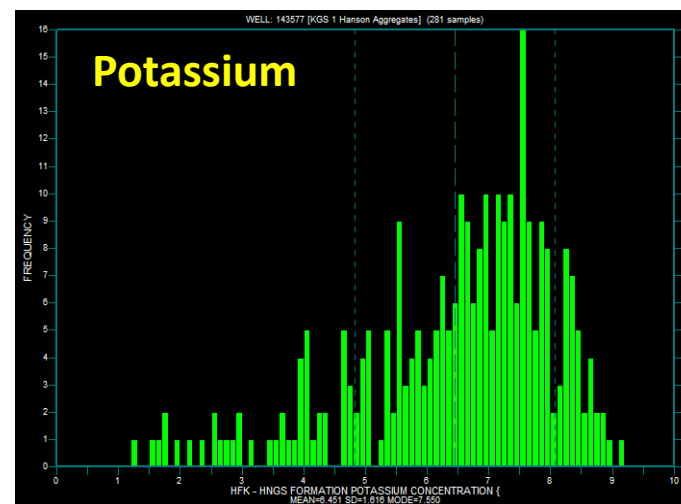
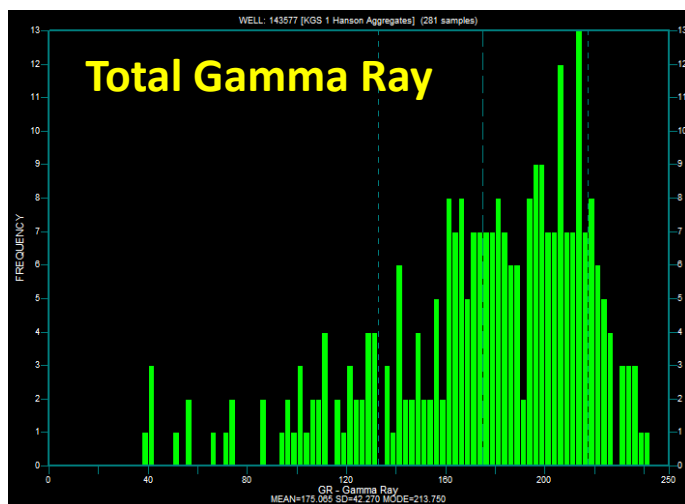
KGS 1 Hanson Aggregates Spectral Gamma Ray Log



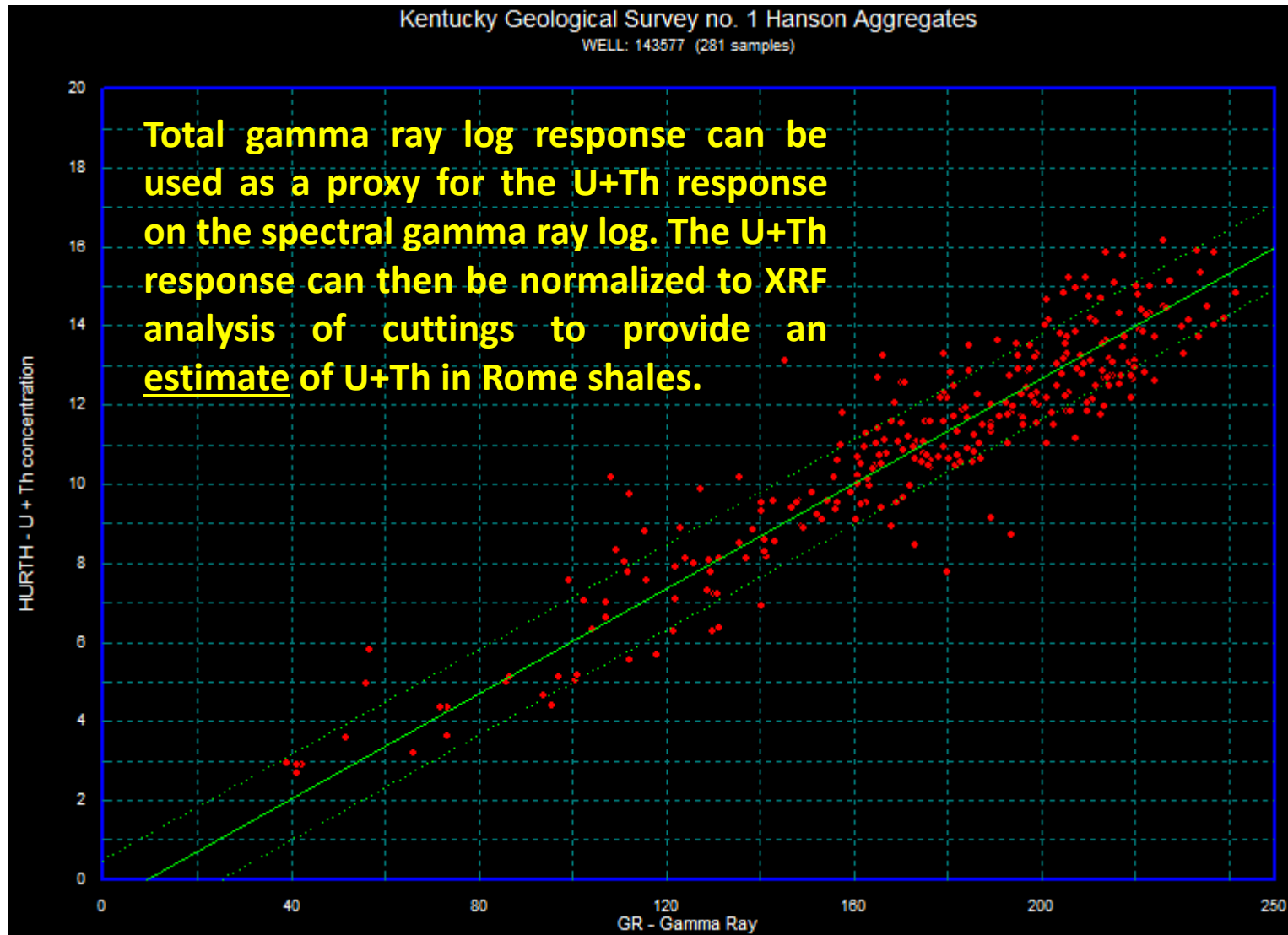
**XRF analysis 4220-4360 ft
vs Spectral Gamma Ray log**

**The Spectral Gamma Ray log
consistently shows less uranium
and more thorium than XRF
analysis of Conasauga cuttings.**

Potassium is abundant in the Conasauga-basement section, and is the largest contributor to total gamma ray log response, whereas uranium has the lowest contribution.



Total U+Th gamma ray response vs total gamma ray



Helium generation test case

Typical Generation Rates (Figure Below)

Helium generation in typical (average) rocks are shown as a function of time of generation (below). Hot shales have by far the greatest generation potential, with a generation rate about 8 times higher than average shale. Typical sandstones and carbonates have less generation potential than average shales. Average shales have the generation potential of average granites. These calculations are approximate because they are based on average rock compositions and assumed bulk density.

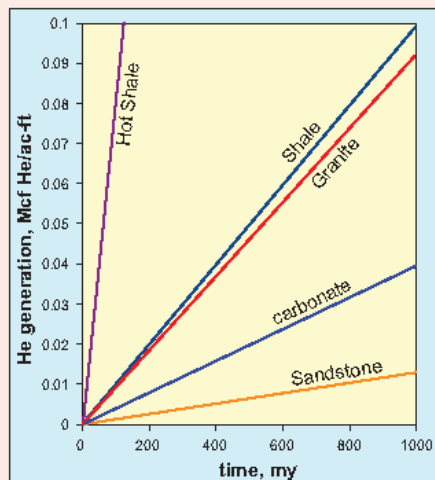
Rates of generation are low. It therefore takes significant geological time to generate significant helium per volume of rock. This means that (1) source rock volume must be large, and (2) there must be some concentration mechanism that allows dispersed helium generation to be concentrated.

Helium generation is trivial compared to gas generation. For example, a shale with minimum petroleum source rock potential ($S_2^0 = 2 \text{ mg HC/g rk}$) generates approximately 377 scf of hydrocarbon gas per ac-ft, over three thousand times greater than helium generation in typical shales after a billion years. Any rock generating hydrocarbon gases would dilute helium to sub-economic levels. Petroleum source rocks are not helium source rocks.

Average Rock Concentrations, wt. ppm

Rock	ppm U	ppm Th
granite	3	13
shale	3.7	12
sandstone	0.45	1.7
limestone	2.2	1.7
Hot Shale	50	12

Concentrations from Turekian and Wedepohl (1961), except for the hot shale, which is an unpublished Woodford analysis from spectral GR log.

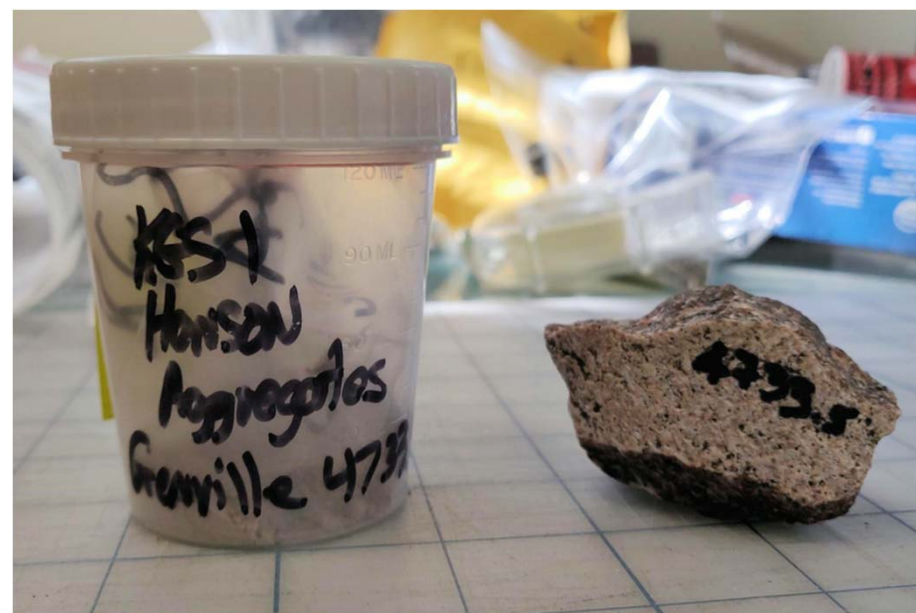


Implications:

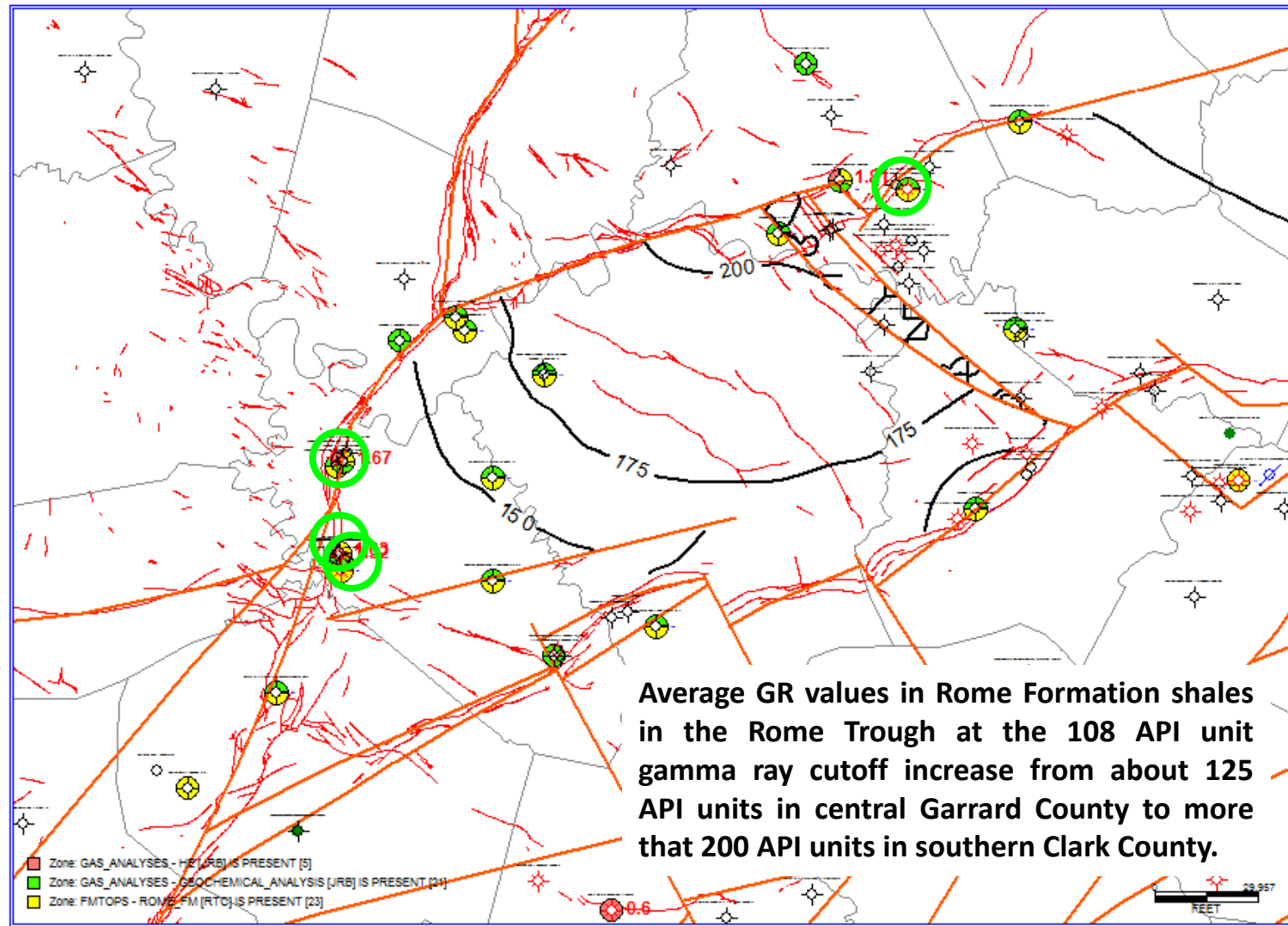
- Sedimentary rocks have similar source potential to basement rocks. Both are "lean" source rocks. A large rock volume and relatively long geological time is required to generate potentially economic amounts of helium.
- Thermally mature petroleum source rocks cannot be helium source rocks.

From Brown (2010)

Interval	Grenville Gneiss				Source
	U _{Log} (ppm)	Th _{Log} (ppm)	U _{XRF} (ppm)	Th _{XRF} (ppm)	
4720-4740	5.75	11.51	< 2	23	Cuttings
4740-4760	5.21	11.41	3	23	Cuttings
4760-4780	5.77	10.44	< 2	23	Cuttings
4780-4800	6.15	6.74	< 2	24	Cuttings
4800-4820	6.15	8.25	< 2	22	Cuttings
Average	5.81	9.67	< 2	23	
4733.5	7.1	13.4	2	3	Core



Iso-gamma ray map net feet of “pay rock” for the evaluation area at a 108 API units gamma ray cutoff



Estimating helium generated in the Rome Trough evaluation area since 500 Ma (upper Cambrian)

Using the equations from Brown (2010; slide 6), the estimated volume of helium generated was calculated assuming a conservative 50 ft of Precambrian Grenville and 100 ft Rome Formation shale “source rock.” is 2.4 Bcf of helium.

KGS 1 Hanson Aggregates helium generation model

Grenville Core	XRF ppm	He generated in 500 Myr	0.02 mcf/Ac-ft of source rock
U	2.0	Prospective area	465,500 acre fault block in the Rome
Th	3.0	Source rock thickness	50 ft source rock in the Grenville
		471 MMcfg He generated	

Conasauga	XRF ppm	He generated in 500 Myr	0.04 mcf/Ac-ft of source rock
U	4.1	Prospective area	465,500 acre fault block in the Rome
Th	6.0	Source rock thickness	100 ft source rock in the Conasauga
		1,920 MMcfg He generated	
Total		<u>2,392 MMcfg He generated</u>	

Estimated reservoir volume in the Rome Formation, assuming 90 ft of sand averaging 10% porosity (from the Hoy Energy 1 John King, Garrard County), is 4.2 million acre-ft.

So, why develop helium resources in Kentucky?



Distances to Eastern markets from helium sources: Amarillo, 1600 mi; Garrard County, 600 mi.

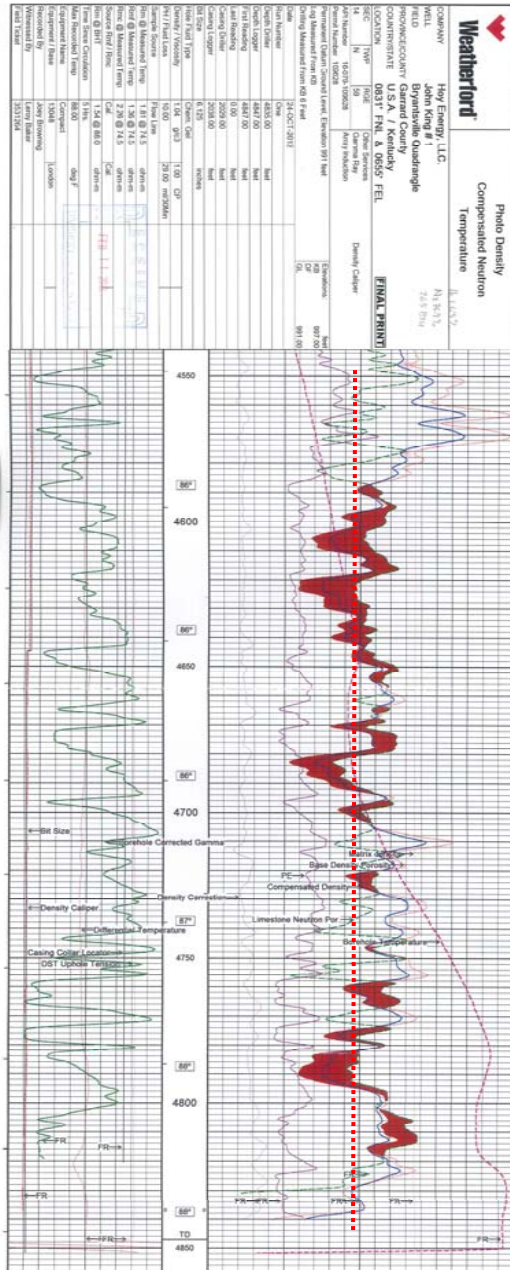
- Benefits to a Developer
 - Proximity to eastern US markets
 - Industry-friendly state government
 - Comparatively low tax rates
- Benefits to Kentucky
 - New resource base
 - Jobs near coal-impacted counties
 - Landowner royalties
 - Taxes
- Disincentives
 - No local infrastructure
 - Unknown resource size
 - Development costs



Conclusions

If the Garrard-Clark Counties region is as rich in helium as it appears, central Kentucky may have a valuable commercial resource. The cost of drilling deeps wells to assess an otherwise iffy resource, however, appears to have discouraged exploration in the region.

Helium-bearing interval in Rome Formation sands (red shaded intervals, left), in Hoy Energy 1 John King, Garrard County, Kentucky (KGS record number 143296). The red dashed lined is 10% density porosity. The total helium-bearing interval in the well is 97 ft $\geq$ 10% porosity.





Kentucky Geological Survey

For more information contact Rick Bowersox at office phone (859) 323-0536, or email to j.r.bowersox@uky.edu.

see blue.™



Kentucky
Geological Survey