Potential for Recovery of Uranium from the Marcellus Shale*

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Abstract

Organic-rich shale has been recognized in the United States as a potentially significant resource of uranium since the early 1950's, with investigations of the Chattanooga oil shale. Processes have been demonstrated to recover oil and uranium by retort, and uranium has been recovered by acid dissolution. The Chattanooga shale is recognized as a major world uranium province, with estimated reserves of 5,000 t of uranium, but there has been no commercial production. Internationally, uranium has been produced from organic-rich shale, in Sweden and Germany. The Marcellus Shale has not been studied as a potential resource of uranium. This paper takes a semi-quantitative look at the potential uranium resource that could be developed because of drilling the Marcellus shale for natural gas. Currently, the cuttings from Marcellus wells are being disposed of in landfills, losing potentially recoverable uranium. It is estimated that a typical horizontal lateral will produce about 178,000 kg (392,423 lbs.) of cuttings. From this volume of cuttings, it is feasible to recover around 4.6 kg (10.1 lbs.) of Uranium. At current prices (US $23/lb.), this amount of Uranium is worth US $232.00 (gross) per well. To date, around 5,900 horizontal Marcellus wells have been drilled. Potentially 27,140 kg (59,833 lbs.) of uranium have been discarded in landfills, a potential unrealized revenue of over US $1.4 MM (gross.) Consistently drilling in the highest zone of gamma ray readings, typically the lower Marcellus, could more than double the amount of uranium recovered. Other high value elements, e.g., cobalt, vanadium and molybdenum, could also be recovered from the Marcellus, increasing the potential revenue stream.

References Cited

Asquith, G., Krygowski, 2004. Basic well log analysis (Second Ed.): AAPG Methods in Exploration Series 16. AAPG, Tulsa, U.S.A., 244 p.

Bruneton, P., Cuney, M, 2016. Geology of Uranium deposits, In: Hore-Lacey, I., ed., Uranium for Nuclear Power - Resources, Mining and Transformation to Fuel, Ch. 2, pp.11-52. Elsevier, Cambridge, U.K., 488 p.

Dahlkamp, F. J, 1993. Uranium Ore Deposits, Springer-Verlag, 460 p.

Doak, J.S., Kravits, M.J., Spartz, M.J. Quinn, P., 2018. Drilling extended laterals in the Marcellus shale. SPE-191783-18ERM-MS, 10 p.

Fortson, L., 2012. Geochemical and spatial investigation of Uranium in the Marcellus shale. M.S Thesis, SUNY, University at Buffalo, Buffalo, NY, U.S.A., 61 p.

Huyck, H. LO., 1990.When is a metalliferous black shale not a black shale, In: Grauch, R. I. and Huyck, H. LO. eds., Metalliferous Black Shale, Ore Deposits—Proceedings, 1989. U.S. Geol. Sur. Circ. 1058, 42-56.

IAEA, 2018. World Distribution of Uranium Deposits (UDEPO), 2016 Edition. IAEA Techdoc-1843. International Atomic Energy Agency, Vienna.

Lecomte, A., et al, 2017. Uranium mineralization in the Alum shale formation (Sweden): Evolution of a U-rich marine black shale from sedimentation to metamorphism. Ore Geology Reviews, 88, 71-98.

Lippmaa, E., Maremäe, A-T. Pilhlak, 2011. Resources, production and processing of Baltoscandian multimetal black shales. Oil Shale, Vol. 28, No. 1, 68-77.

Popova, O., 2017. Marcellus shale play: Geology review. U.S. Energy Information Administration, U.S. DOE, 12p.

Rodgers, M. C.,2016. A lithogeochemical study of the metal contents of the upper Cretaceous oil shales in the Pasquia Hills, East-Central Saskatchewan, In: Summary of Investigation 2016, Volume 2, Saskatchewan Geological Survey, Saskatchewan Ministry Report 2016-4.2, Paper A-1, 17 p.

Spiewak, I. et al, 1982. Chattanooga Shale: An assessment of the resource and technology for the recovery of hydrocarbons and minerals. ORNL/TM-7920, 230 p.

Stuckman, M., Edenborn, H. M., Lopano, C., Hakala, J. A., 2018. Advanced characterization and novel waste management for drill cuttings from Marcellus shale energy development. URTeC: 2883168, 10 p.

Turekian, K. K., Wedepohl, K. H., 1961. Distribution of the elements in some major units of the Earth’s crust. Geol. Soc. America Bull., 175-192.

Wang, G., Carr, T. R., 2012. Methodology of organic-rich shale lithofacies identification and prediction: a case study from Marcellus Shale in the Appalachian basin, In: Black Shale Lithofacies Prediction and Distribution Pattern Analysis of Middle Devonian Marcellus Shale in the Appalachian Basin, Northeastern U.S.A., Ch. I, Ph.D. Dissertation, West Virginia University, WV, U.S.A., 216 p.

Wilson, R. Q., et al., 1954. The recovery of Uranium from the Chattanooga shales. BMI-274, 137 p.

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by
R. Scott McCleery

Discussion outline

- Uranium – a little background
- Uranium in the Marcellus
- Marcellus: uranium and trace element -- potential recovery amounts
- Next steps

BACKGROUND

Uranium in nature

- Average uranium concentration: 1.7 to 2.7 ppm in continental crust.
- Typically enriched in silicic magmatic rocks, e.g., granites and rhyolites (10's to 100's ppm) and in high organic carbon, black shales and lignites, and in phosphorites.
- Seawater concentration is typically only 3.3 ppb, and even less in fresh water lakes and rivers

Uranium resources by deposit types

	Type of deposit	Number of deposits	UDEPO resources 2015 (tU)
1	Black shale	48	20,963,792
2	Phosphate	56	14,198,525
3	Lignite-coal	35	7,404,309
4	Sandstone	654	4,365,515
5	Polymetallic ironoxide breccia complex	15	2,432,923
6	Paleo-QPC	88	2,136,950
7	Intrusive	88	1,894,496
8	Proterozoic unconformity	102	1,522,720
9	Metasomatite	78	1,023,986
10	Volcanic-related	136	663,512
11	Metamorphite	111	509,847
12	Granite-related	268	478,482
13	Surficial	77	436,470
14	Carbonate	9	112,057
15	Collapse breccia pipe	17	16,217
	Total	**1,782**	58,159,800

(Source, IAEA TECHDOC-1843, 2016)

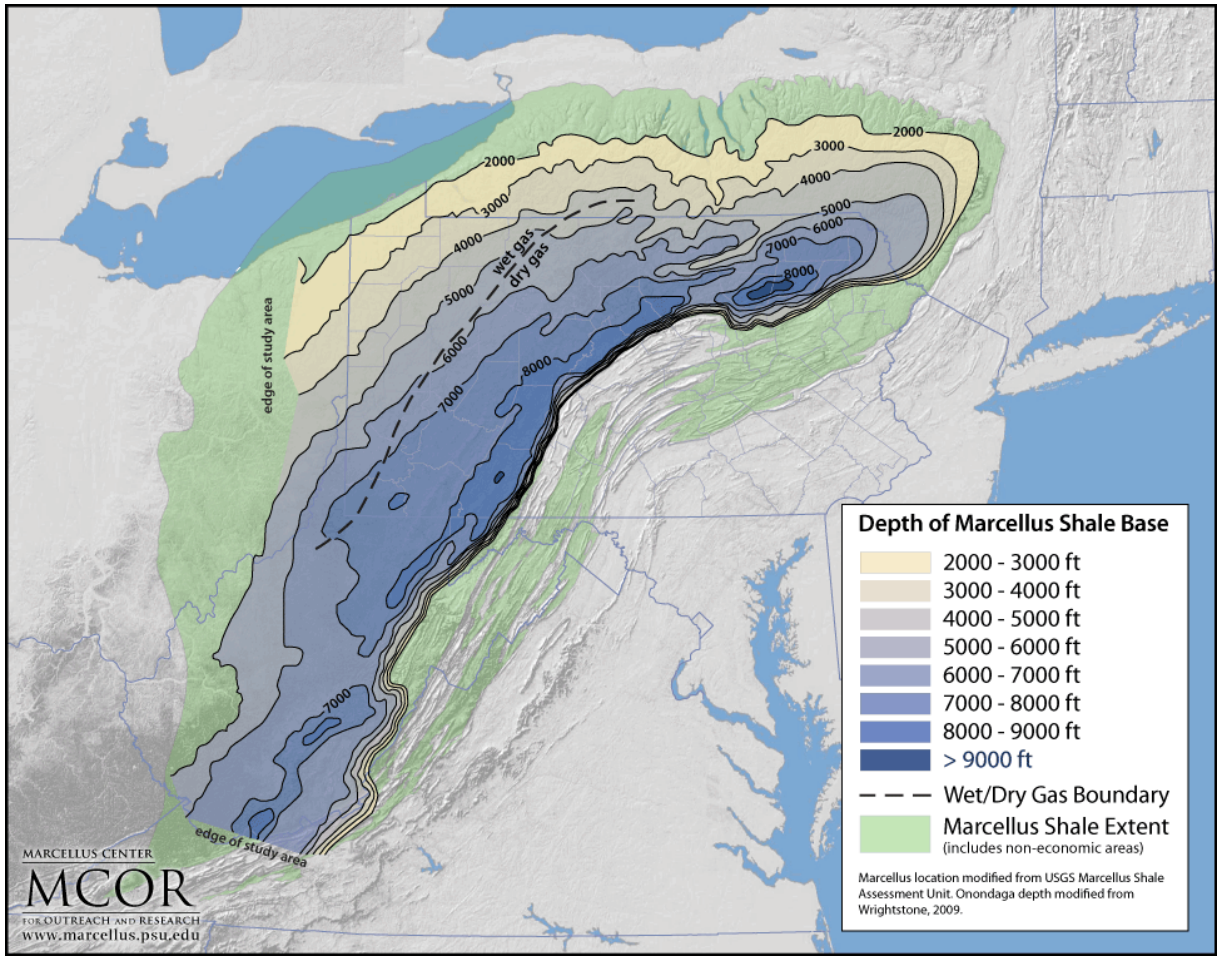
Historical Production of Uranium from Black Shales

Northeast USA	Formation	Geologic resources UDEPO 2014(tU)	Historical production to 2015 (tU)	Grade (ppm U)
Tennessee	Chattanooga	5,000,000	nil	60
Sweden, Norway, Estonia	Alum	1,300,00	300,000	118
Germany	various	200,000	125,000	850

(Sources: Bruneton & Cuney, 2016 & IAEA-TECHDOC-1842, 2018)

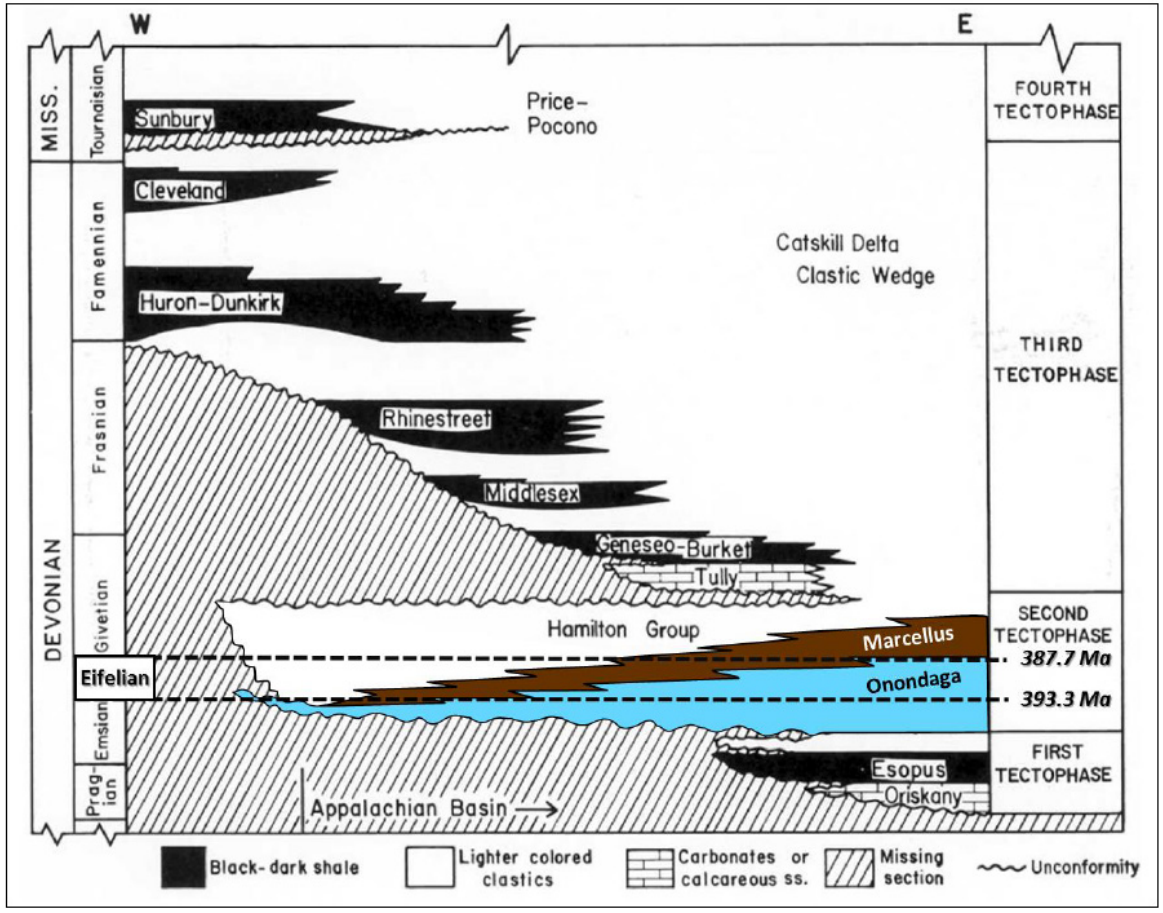
URANIUM IN THE MARCELLUS

Marcellus Shale Extent



Presenter's notes: Crops out on eastern basin and sub-crops to west and north. Marcellus extent ≈ 191,000 mi^2 (500,000 km^2)

Stratigraphy



Upper Lower Devonian to Middle Devonian.
(From Parrish, 2013)

Presenter's notes: Deposition began about 393 ma in latest Lower Devonian (Late Emsian) and finished in Middle Devonian (lower Givetian) circa 388 ma (Parrish, 2013).

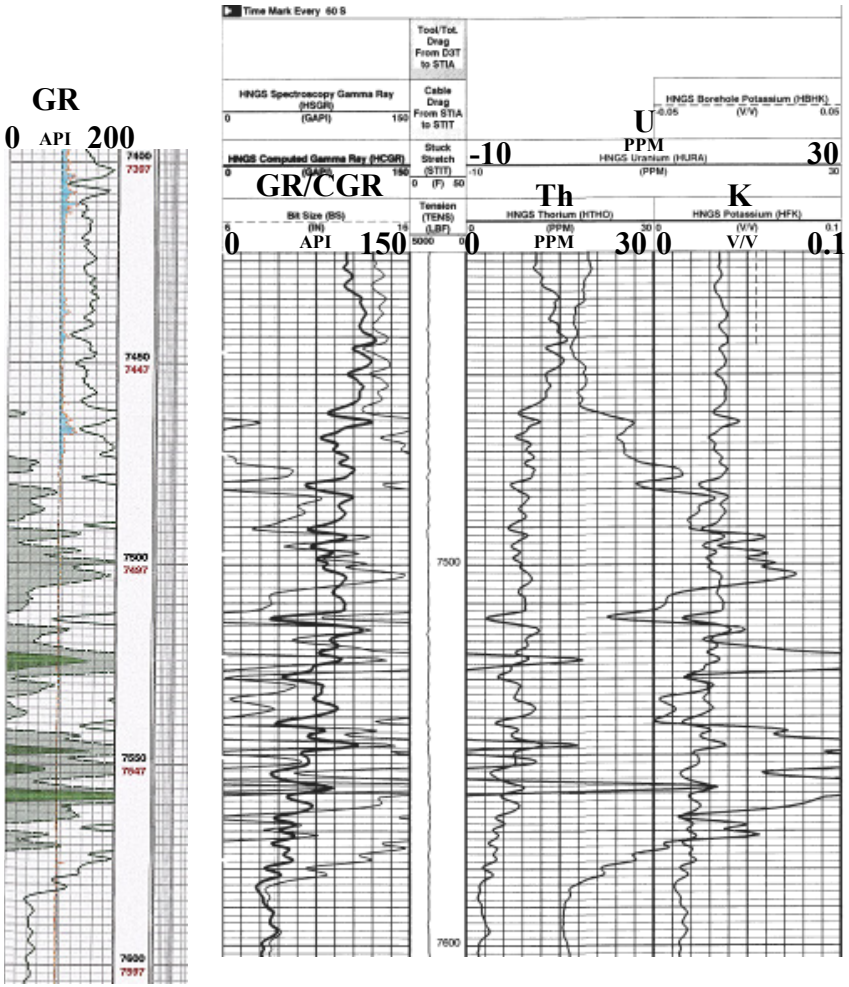
Uranium: Marcellus rock analyses

Source	Uranium (ppm) avg	Uranium (ppm) Range	Measurement Type
Armstrong Well, Taylor Co, WV (unpublished)	29	3 - 74	XRF, 35 samples from core plugs and cuttings
10 samples from WV, NY, VA and PA (Fotson, ,2012)	31	4 - 68	INAA, 6 core & 4 outcrop samples

Presenter's notes: Armstrong well location shown on map. ICP-OES – Inductively Coupled Plasma Optical Emission Spectrometry; INAA – Instrumental Neutron Activation Analysis.

Typical GR and Spectral GR response

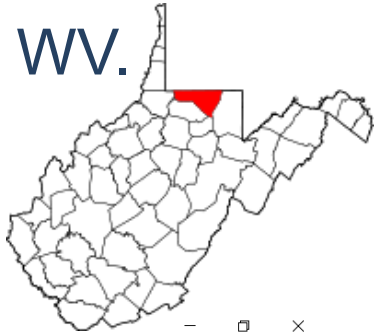
Delmar Light 3H pilot well (4709703662), Upshur Co.



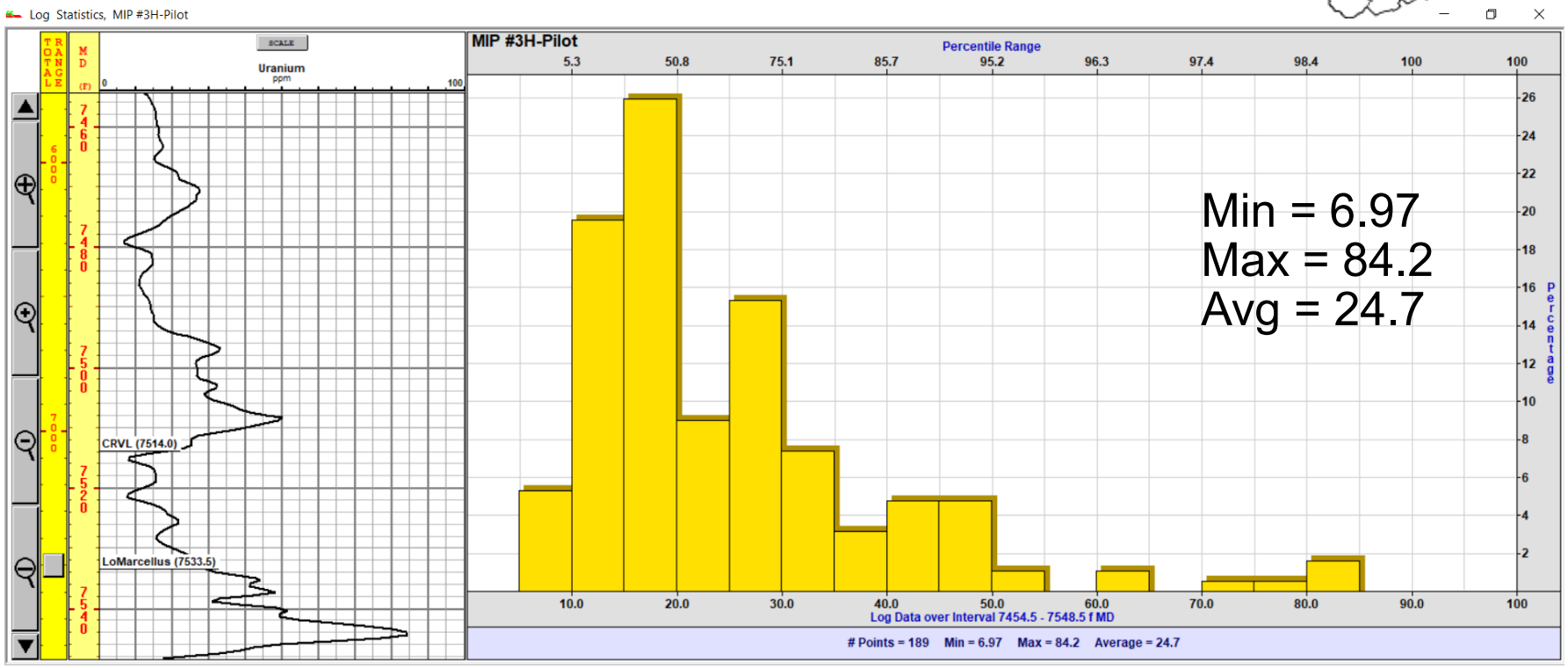
≈57 ppm U

Presenter's notes: Standard GR presentation on the left (0-200 api). The right log is a SGR: Track 2 is the Thorium curve (0-30 ppm) Track 3 is the Potassium curve (0-0.1 v/v) and Uranium curve is in both tracks 2 and 3 (-10 - 30 ppm). A standard GR is made up, chiefly, of the combined radiation from U, Th and K. Logs from the Delmar Light 3H pilot well (4709703662), Upshur Co.

MSEEL (Marcellus Shale Energy and Environmental Laboratory), MIP-3H pilot well in Monongalia, Co., WV.



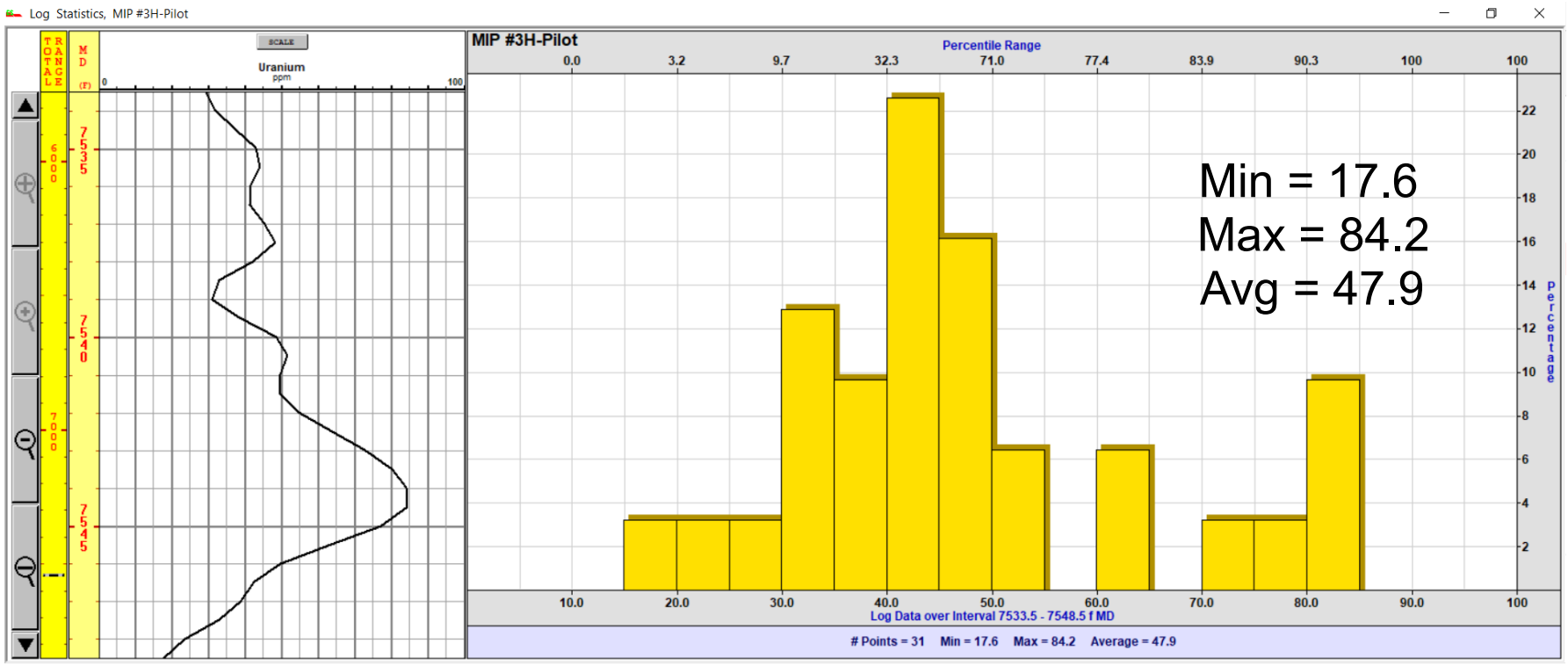
Spectral gamma ray log – uranium curve: Marcellus



Presenter's notes: The pilot well for the MIP-3H horizontal well near Morgantown, WV. Uranium curve over the entire Marcellus interval. Numbers in-line with rock analysis numbers: Armstrong data range 3 -74, avg 29 ppm; Fotson data 4 -68, avg 31.

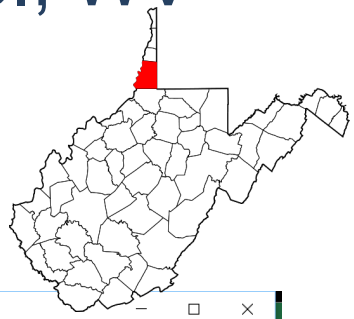
MIP-3H Pilot (continued)

Lower Marcellus, only

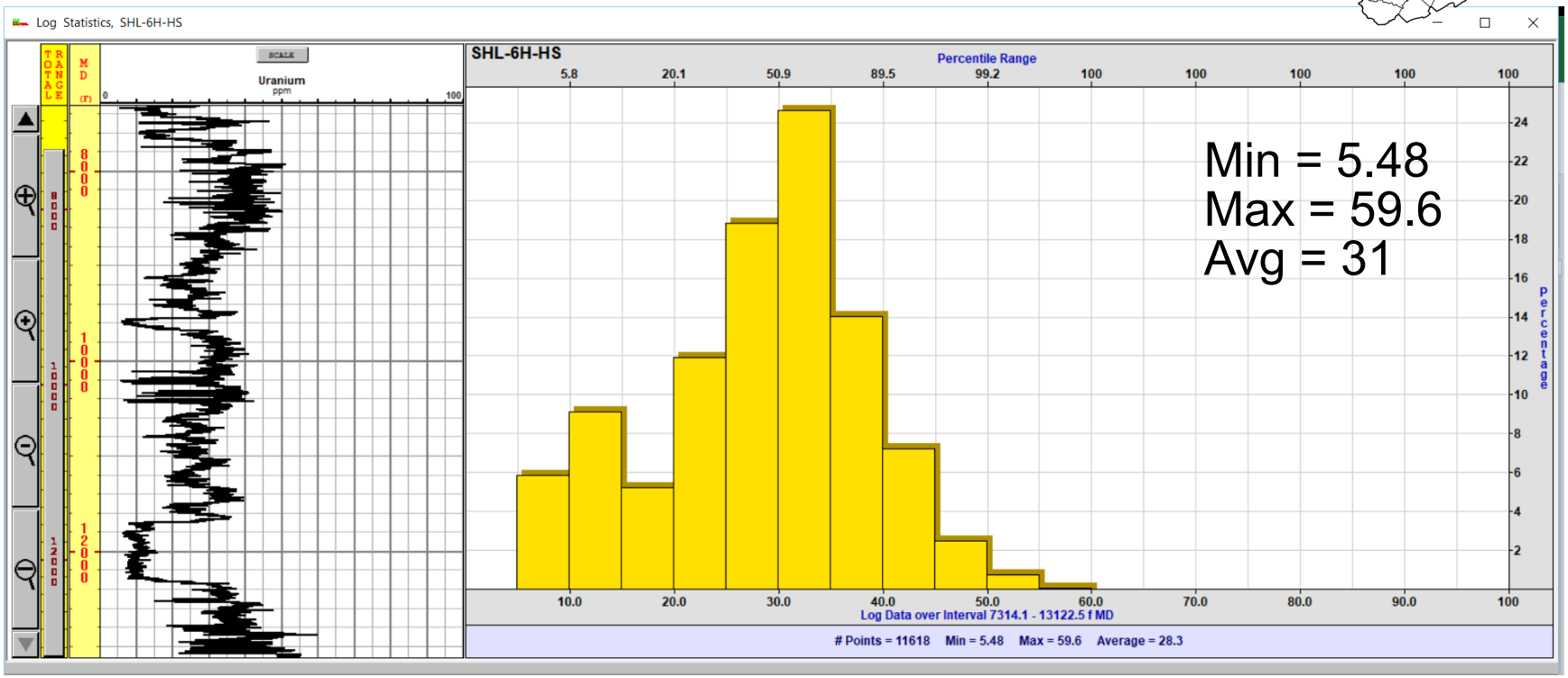


Presenter's notes: MIP-3H in Monongalia, Co., WV. The pilot well for the MIP-3H horizontal well. Uranium curve over the lower Marcellus, only.

Nobel Energy Inc. SHL 6H HS, Marshall Co., WV



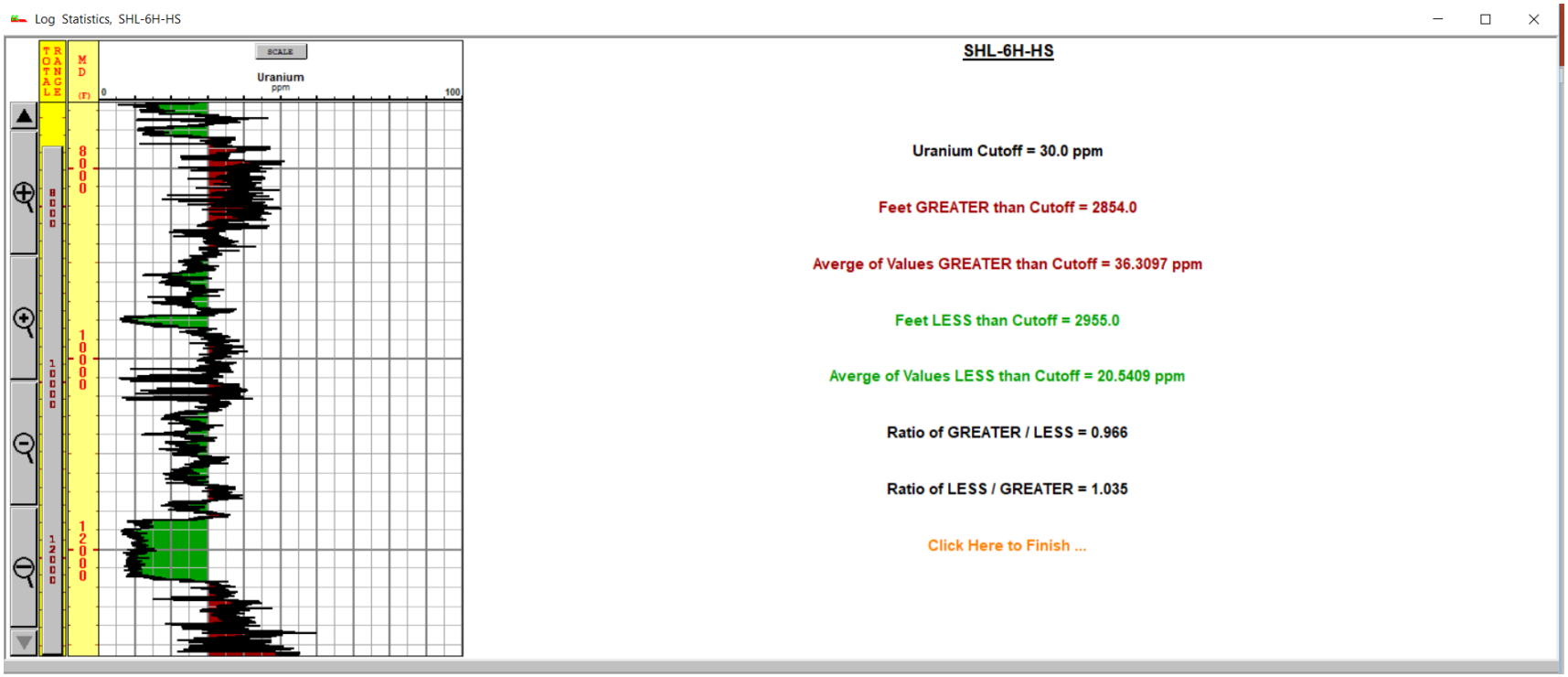
Digital Spectralog Gamma Ray – run in horizontal lateral



Presenter's notes: Log is MD. Armstrong data range 3 -74, avg 29 ppm; Fotson data 4 -68, avg 31.

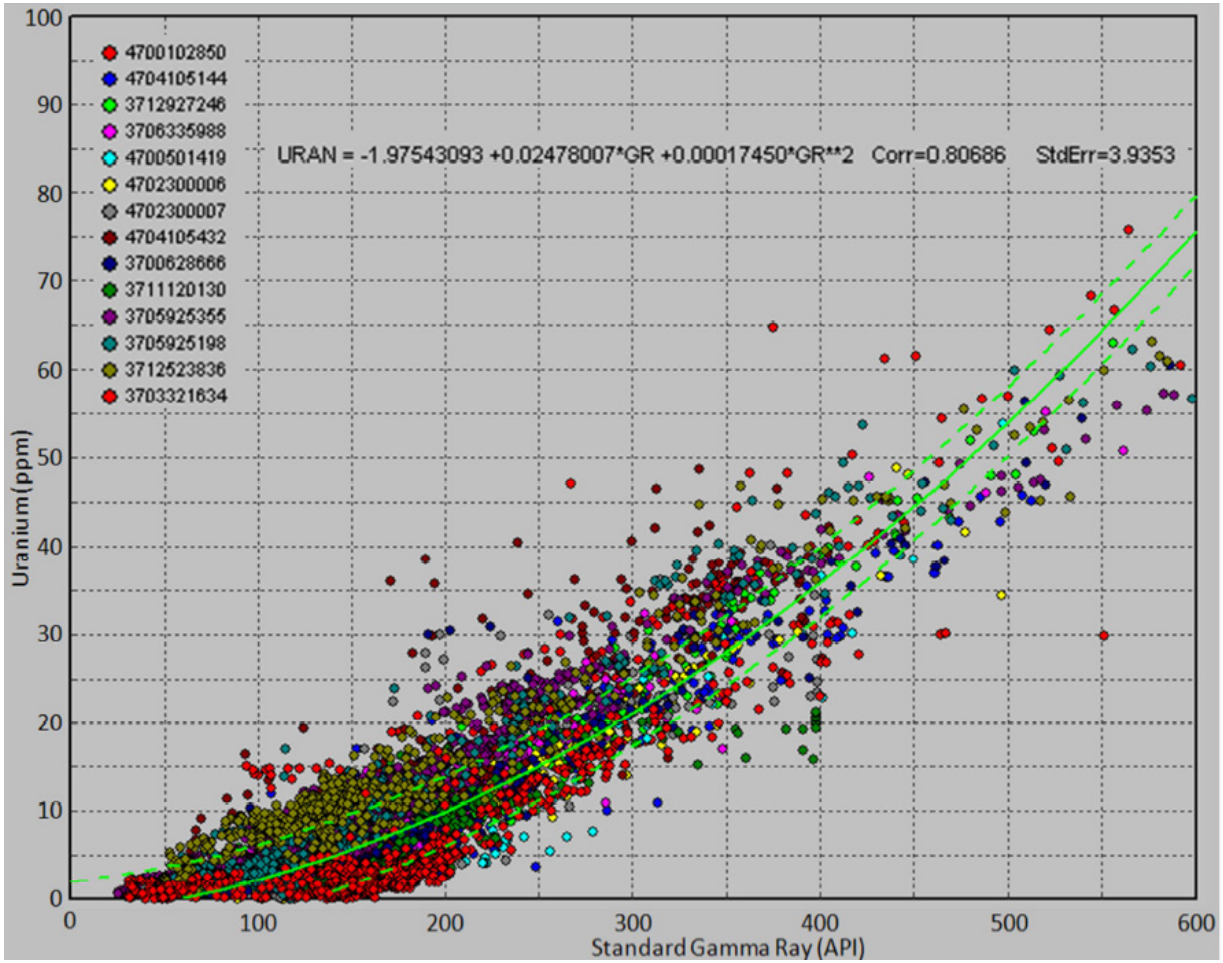
Nobel Energy Inc. SHL 6H HS, Marshall Co., WV

Continued…



Presenter's notes: Based on a cutoff of 30 ppm, which is approx. the P50 of the previous figure. Outcrop petrophysical work by Walker-Milani (2011) indicated average 30 ppm, maximum 77 ppm for the organic rich lower Marcellus.

Calculated relationship between standard GR and uranium content



(From Wang and Carr, 2012)

Presenter's notes: Using spectral gamma ray and PNS logs, which measure uranium a relationship was developed to predict uranium concentration from a standard GR log.

Uranium and other economic elements

POTENTIAL RECOVERY

Estimated Uranium Recovery per Lateral

- Typ. Lateral length = 5,900 ft or 179,832 cm
- Typ. Hole size = 8.75 in or 22.225 cm (radius = 11.1125 cm)
- Volume = 69,765,500 cm^3 ($\pi r^2 h$)
- Avg. Marcellus density = 2.55 g/ cm^3
- Mass of cutting (Vol. x density) = 177,973,501.5 g = 178,000 kg (392,423 lbs)
- Uranium @ 32ppm = 178,000 x 0.000032 = 5.70 kg
- Assuming 80% recovery = 4.56 kg (10.1 lb)
- Value per lateral = $23 /lb x 10.1 lbs = *$230 per lateral*

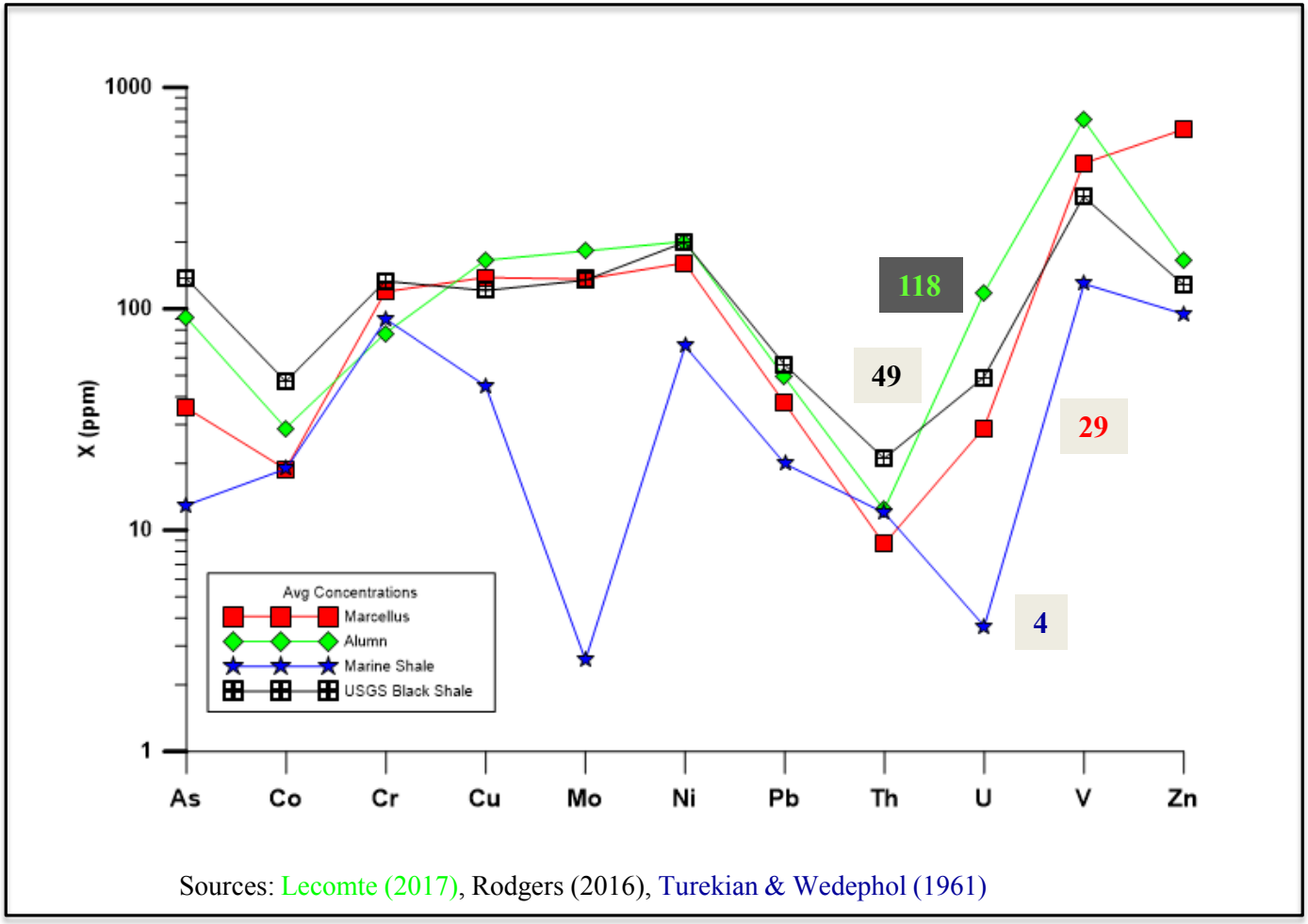
Historical Uranium Prices

Source: The Ux Consulting Company, LLC. http://www.uxc.com/.

Basin-Wide Uranium Loss Estimate

- Estimated no. Marcellus horizontal wells, WV & PA: ≈5,900
- 5,900 x 4.6 kg (U/recoverable) = 27,410 kg U (59,833 lb)
- 59,833 lb x $23 /lb = *$1.4 MM uranium lost to landfills*

Marcellus elements vs other shales



Sources: Lecomte (2017), Rodgers (2016), Turekian & Wedephol (1961)

Presenter's notes: Three organic rich shales and one non-organic rich marine shale. Significant deference between normal marine shale and organic rich shales for heavy metals, like Mo and U due to their strong affinity for the porphyrin ring, organic structure. Alum shale is Middle Cambrian to Early Ordovician.

Other Economic Elements

Element	Raw recovery % (acid leaching)	HYTORT spent shale recovery %
Aluminum	39	77
Iron	21	99
Cobalt	**35**	**100**
Chromium	55	84
Copper	28	88
Manganese	59	92
Molybdenum	**30**	**98**
Nickle	35	97
Uranium	78	82
Vanadium	**32**	**96**
Zinc	76	94
Rare Earths	**44**	**75**

(After Lippmaa et al, 2011)

Element	Marcellus ppm	Per Well Recovery	Price $/lb	Value
Cobalt (Co)	21.6	8.5 lb	29.6	$252
Molybdenum (Mo) (oxide price)	136.9	53.7 lb	11.79	$633
Scandium (Sc) (oxide price)	13.9	5.45 lb	489.34	$2,667
Vanadium	456.2	179.0 lb	18.5	$3,312

Price 5-Sep-18, infomine.com
Price 9-May-18, Mineralprices.com
Price 6-Sep-18, vanadiumprice.com

Presenter's notes: HYTORT - produces shale oil by hydrogenation; oil shale is processed at controlled heating rates in a high-pressure hydrogen environment, which allows a carbon conversion rate of around 80%.

Economic Summary

Potential Value:

U	$230
Co	$252
Mo	$613
Sc	$2,667
V	$3,312
Sum	$7,074 per lateral

Potential loss:

U only → $1.4 MM

U + 4 → $42 MM

Based on 5,900 wells

NEXT STEPS

Next steps

- Acquire and analyze additional rock data
- Demonstrate extraction volumes
- Develop economic model

Acknowledgements

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Thank you!