ABSTRACT

Detailed stratigraphic examination and extensive sampling of a ~1000-ft-thick surface section of the Devonian-Mississippian Pilot Shale from the central Confusion Range in western Utah demonstrates clear potential for hydrocarbon production. Total organic carbon measurements from dark gray, calcareous and noncalcareous mudrocks, particularly in the lower parts of the formation, range from 1.4 to 2.4 wt.%, and Tmax values fall mostly in the oil potential window (438–449°F). The Pilot could be gas-productive elsewhere as a result of commonly recognized hydrothermal activity in both Nevada and Utah.

Overall, the Pilot Shale in Utah is heterogeneous, as the mudrocks are stratigraphically admixed with calcareous siltstones, micritic to organic limestones, occasional red beds, and fine-grained sandstones. The Pilot is representative of an offshore and locally deep basinal setting influenced by tectonic activity of the Antler orogeny in central Nevada. The Pilot in this locality progressively shallows upward in an oscillatory fashion toward the overlying shelfal Mississippian Joana Limestone. The shallowest deposits in this section consist of distinctive red beds and oncolitic limestones. A near-complete surface gamma-log transect substantiates this overall trend and provides a valuable correlation to a nearby subsurface penetration, and possibly to future wells. Based on both lithologic and biostratigraphic conclusions involving previous conodont work, the lower Pilot is a clear facies equivalent to the Devonian Guilmette Formation and to its formational equivalents elsewhere. The upper Pilot is a lateral equivalent to shallow-water restricted carbonates and clastics, exposed both to the east and south (e.g., Pinyon Peak Limestone, Victoria Peak Quartzite, Fitchville Formation). Parenthetically, the Pilot is exceedingly variable in other sections measured to the west (Nevada), but these sequences also reveal potential for an unconventional hydrocarbon resource.

Overview of the typical Pilot Shale section ("South Slope") through the Joana Limestone, view north, central Confusion Range.

DISCLAIMER

DETAILED STRATIGRAPHY AND HYDROCARBON POTENTIAL OF THE DEVONIAN-MISSISSIPPIAN PILOT SHALE, WESTERN UTAH, U.S.A.

by
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GENERAL GEOLOGIC OVERVIEW

Location of the study site, measured sections, and gamma-ray transects for the Devonian-Mississippian Pilot Shale, central Confusion Range, western Utah.

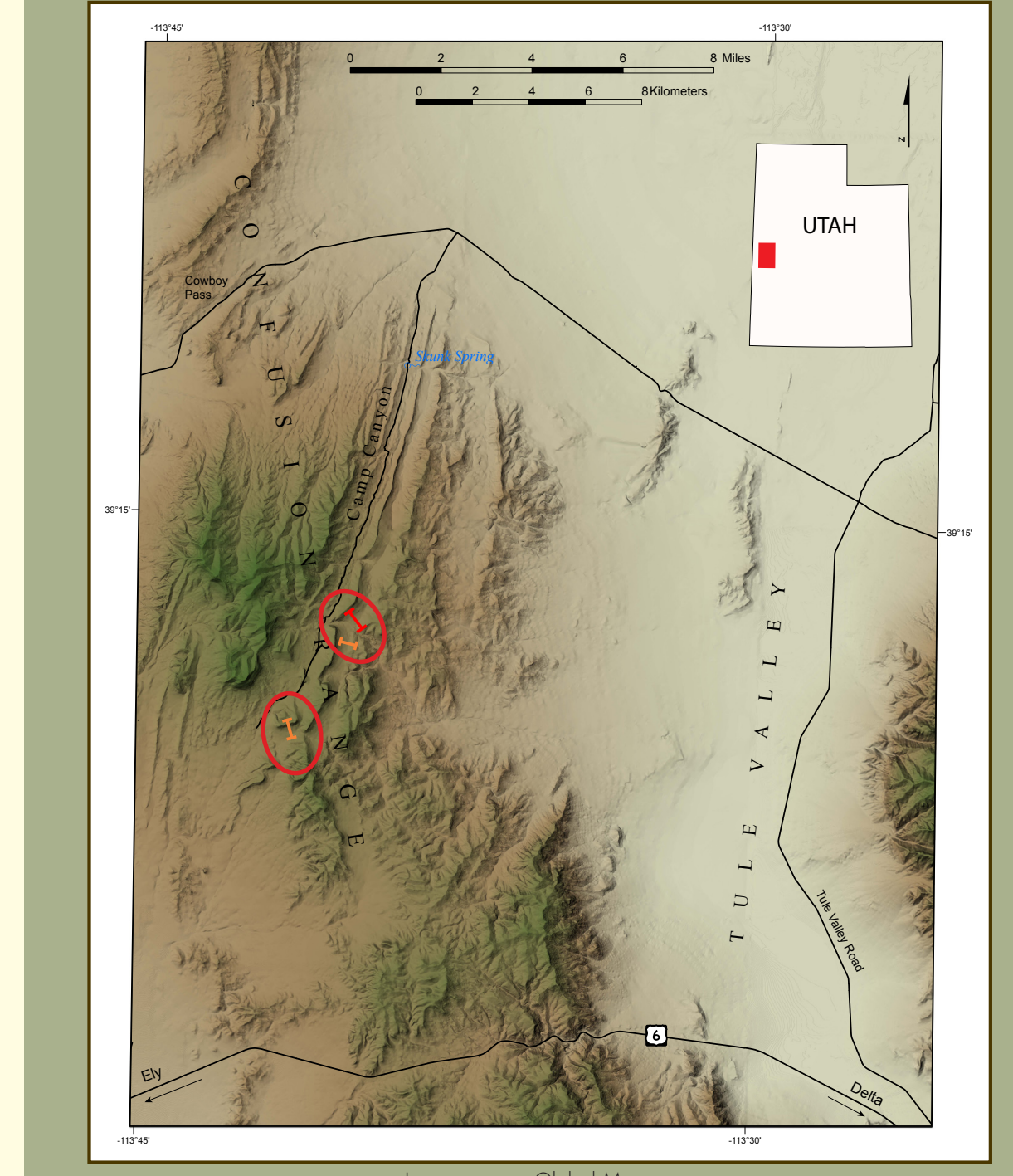


Image source: Global Mapper

Location of the measured section for the Pilot Shale, Cherry Creek Range, east-central Nevada.

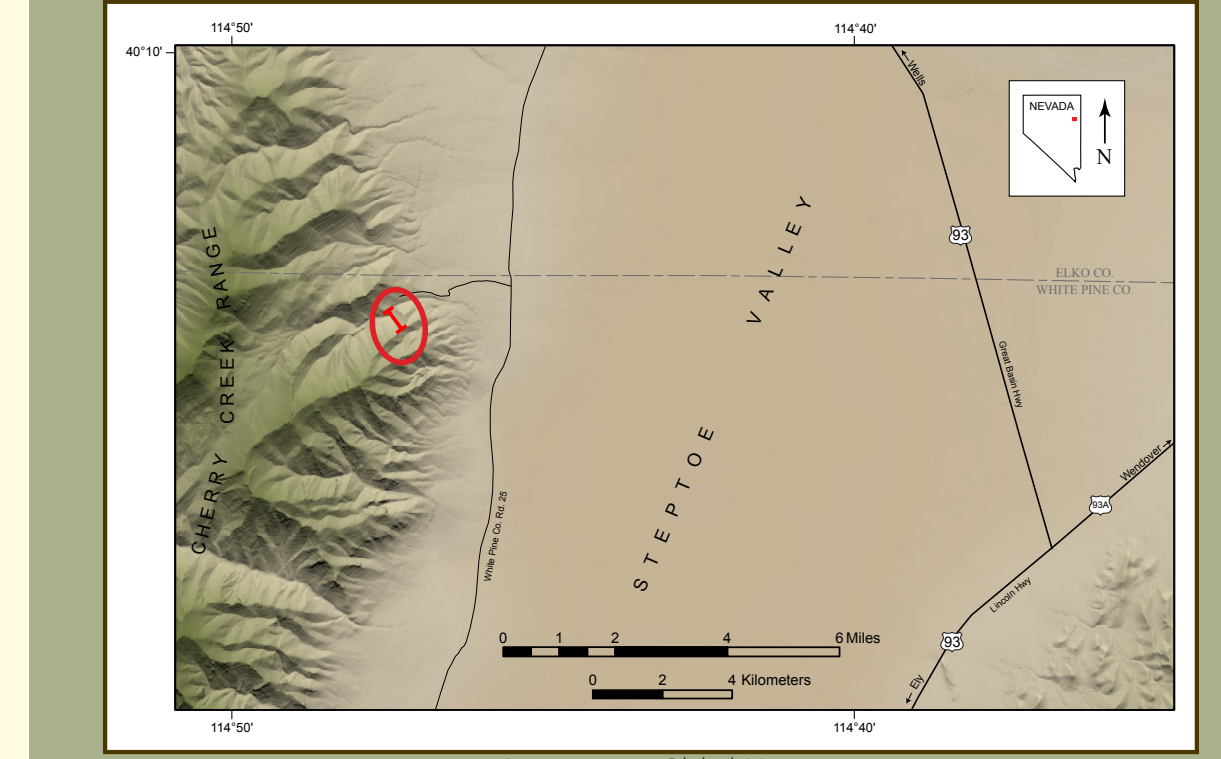
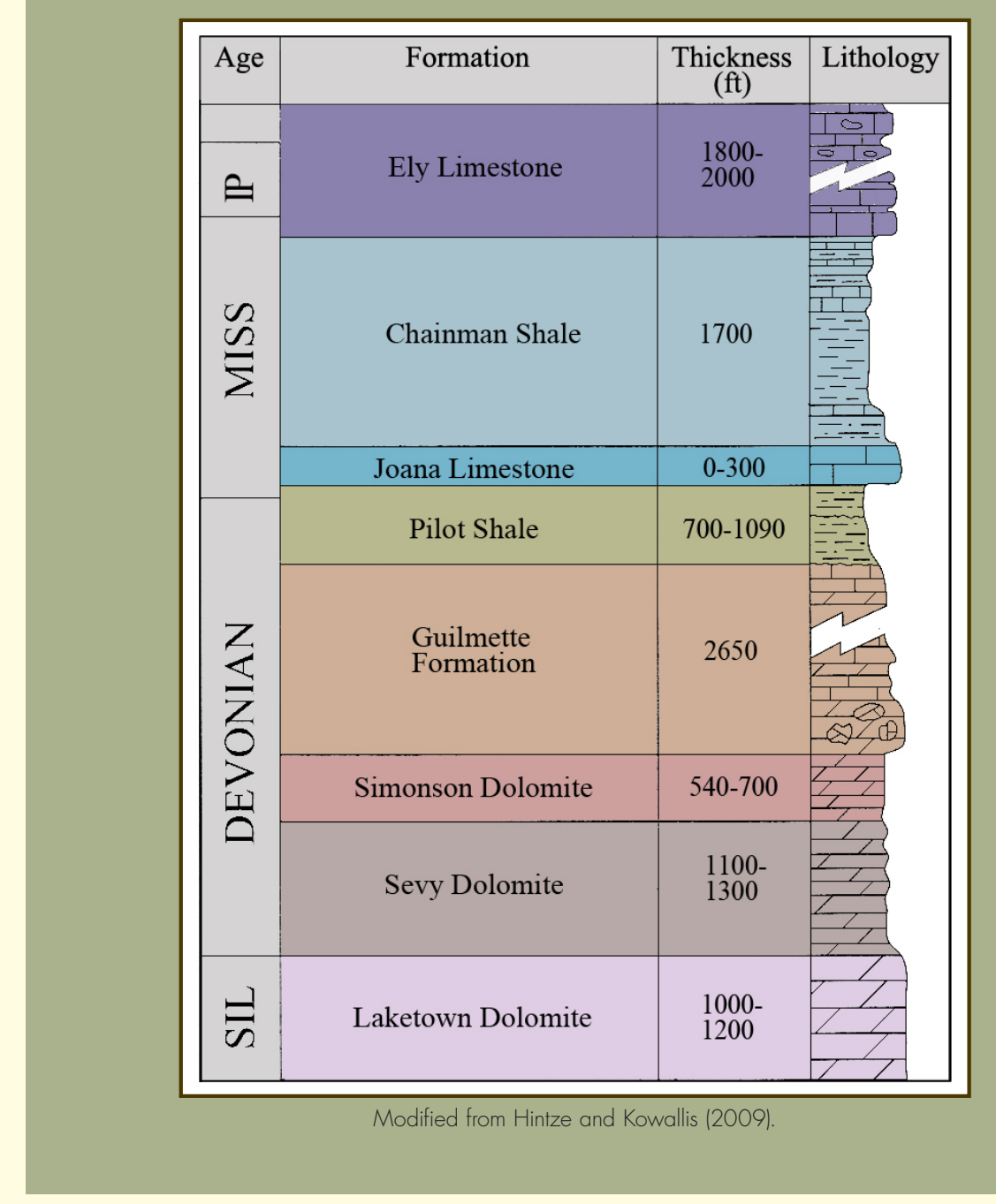


Image source: Global Mapper

Approximate line of sections (red) and transects (orange) indicated within the circles.

Generalized stratigraphic column of the Middle Paleozoic section, central Confusion Range.

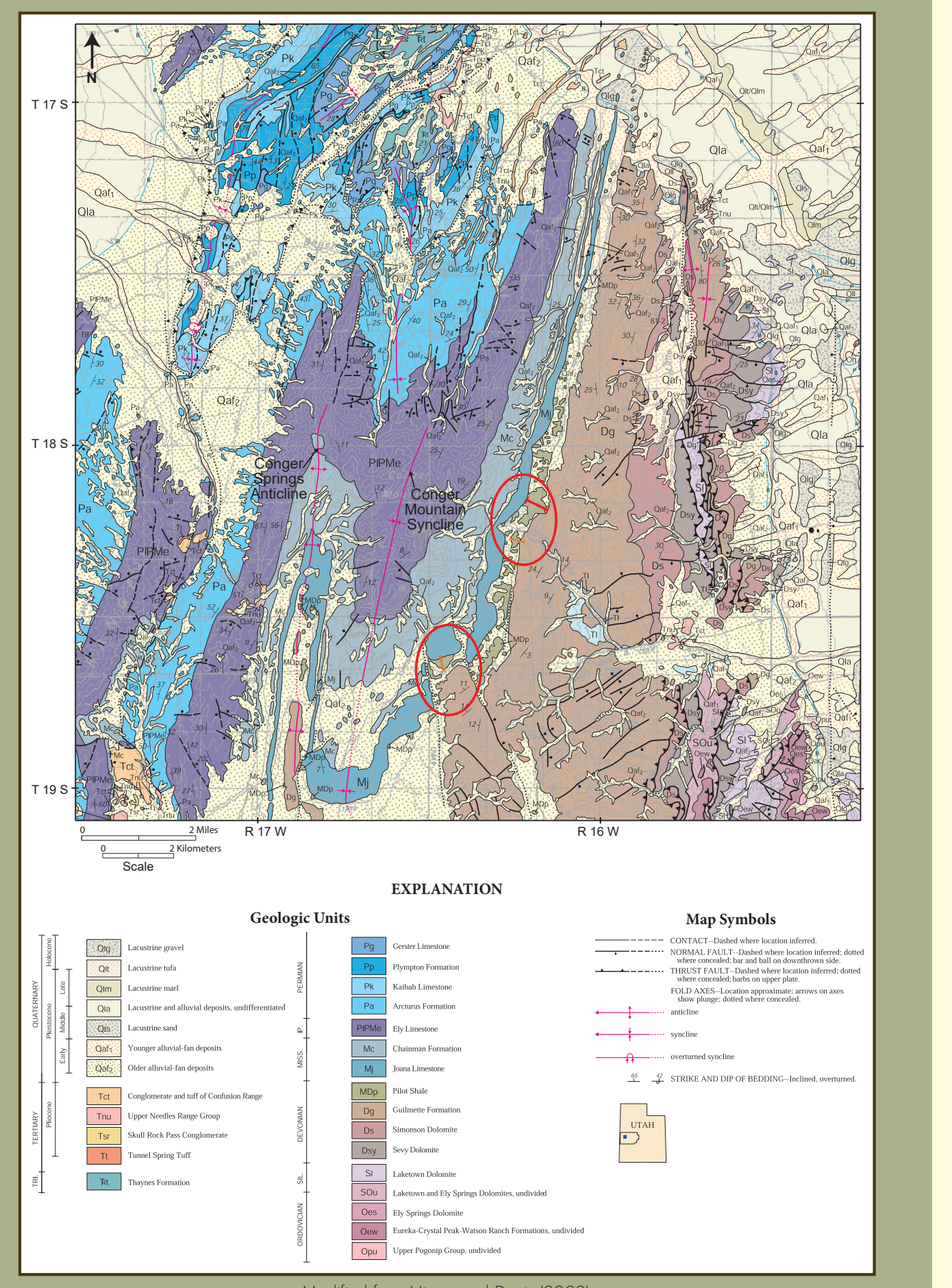


Age	Formation	Thickness (ft)
IP	Ely Limestone	1800-2000
MISS	Chainman Shale	1700
	Joana Limestone	0-300
DEVONIAN	Pilot Shale	700-1090
	Guilmette Formation	2650
	Simonson Dolomite	540-700
	Sevy Dolomite	1100-1300
SIL	Laketown Dolomite	1000-1200

Modified from Hintze and Kowallis (2009).

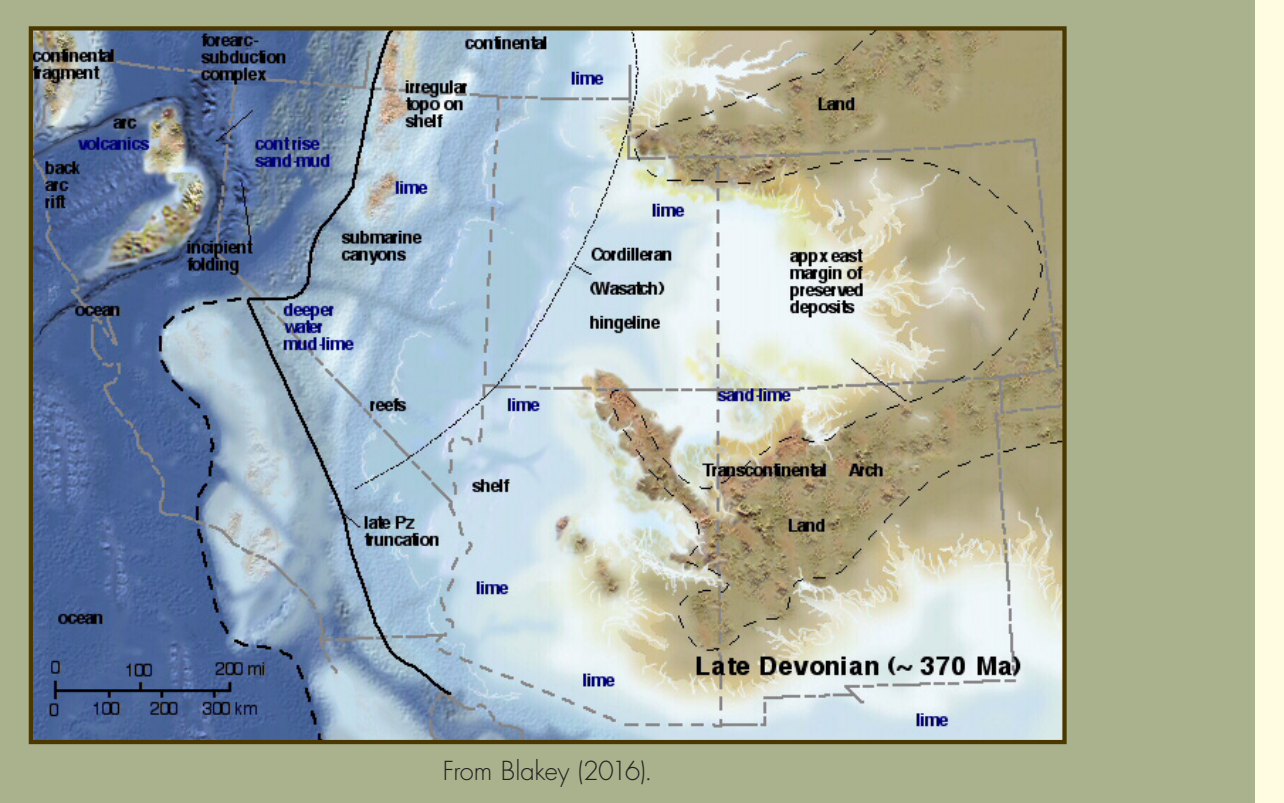
Geologic map of the central Confusion Range, western Millard County, Utah.

Approximate line of the Pilot Shale measured section and gamma-ray transects in the central Confusion Range study areas indicated by the solid red and orange lines, respectively, within the circles.



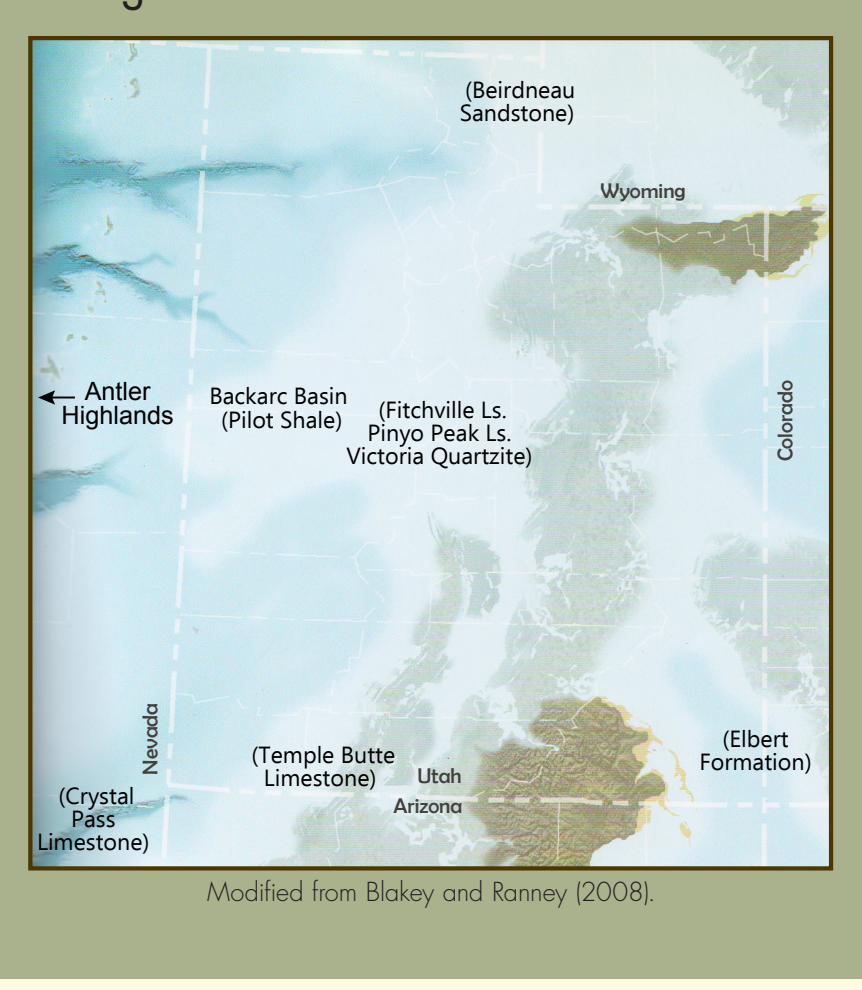
Modified from Hintze and Davis (2002).

Paleogeography of western U.S. during Late Devonian time.



From Blakey (2016).

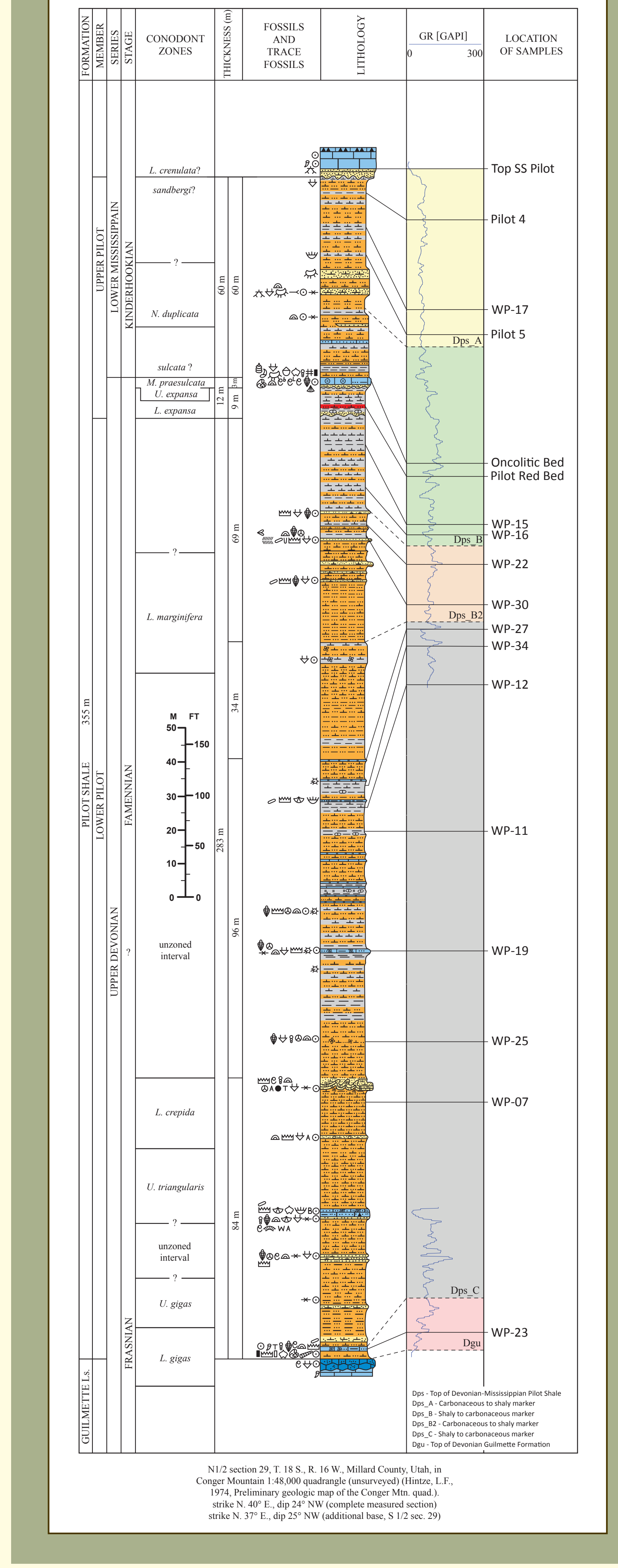
Paleogeography of Utah and eastern Nevada during Late Devonian time.



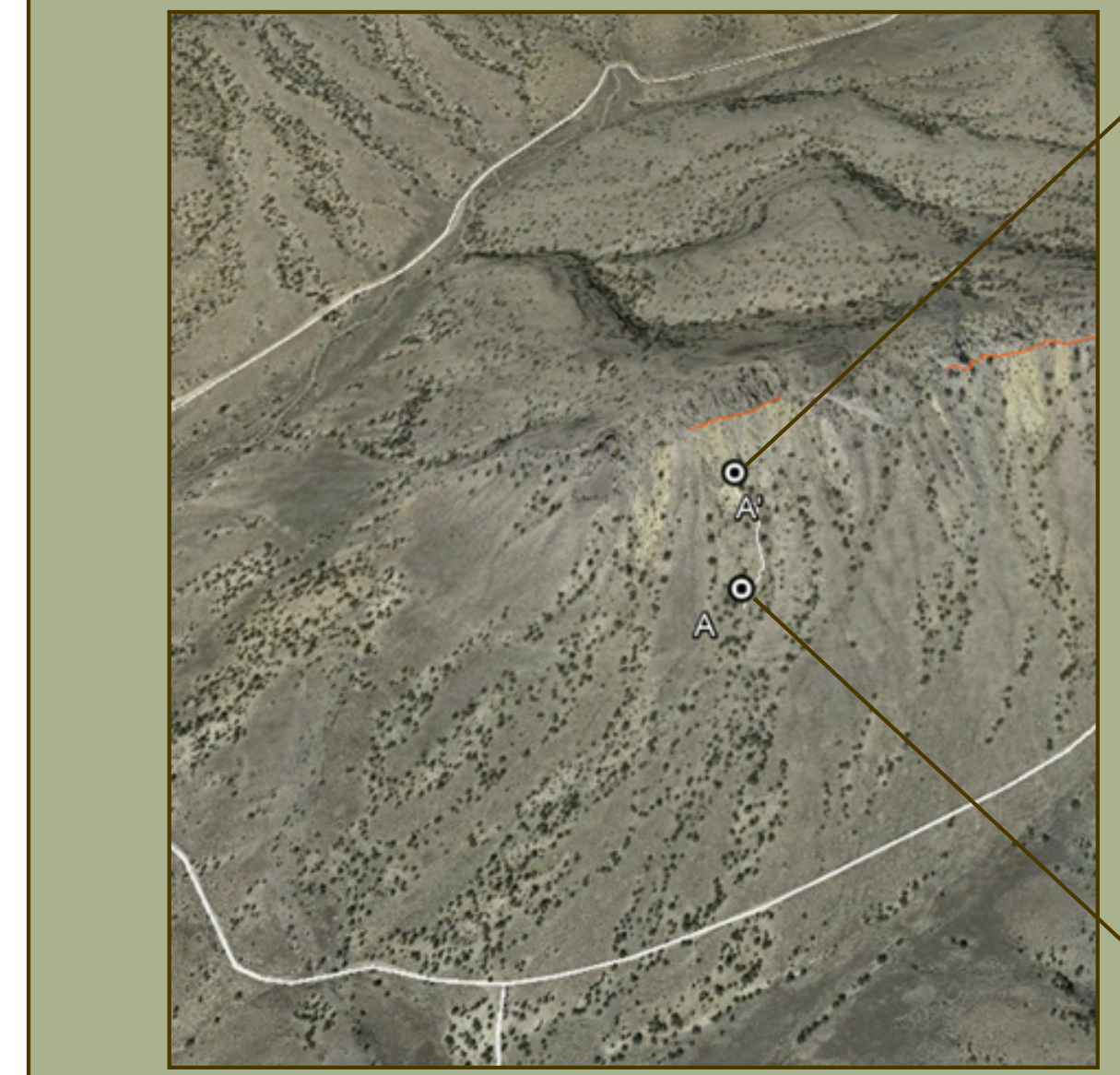
Modified from Blakey and Ranney (2008).

MEASURED SECTIONS AND GAMMA-RAY TRANSECTS OF THE PILOT SHALE

Central Confusion Range section, Millard County, western Utah. Gamma-ray transect locations to the right.



Oblique Google Earth image, view north, of "South Slope" gamma-ray transect (A–A') of the Pilot Shale, central Confusion Range.



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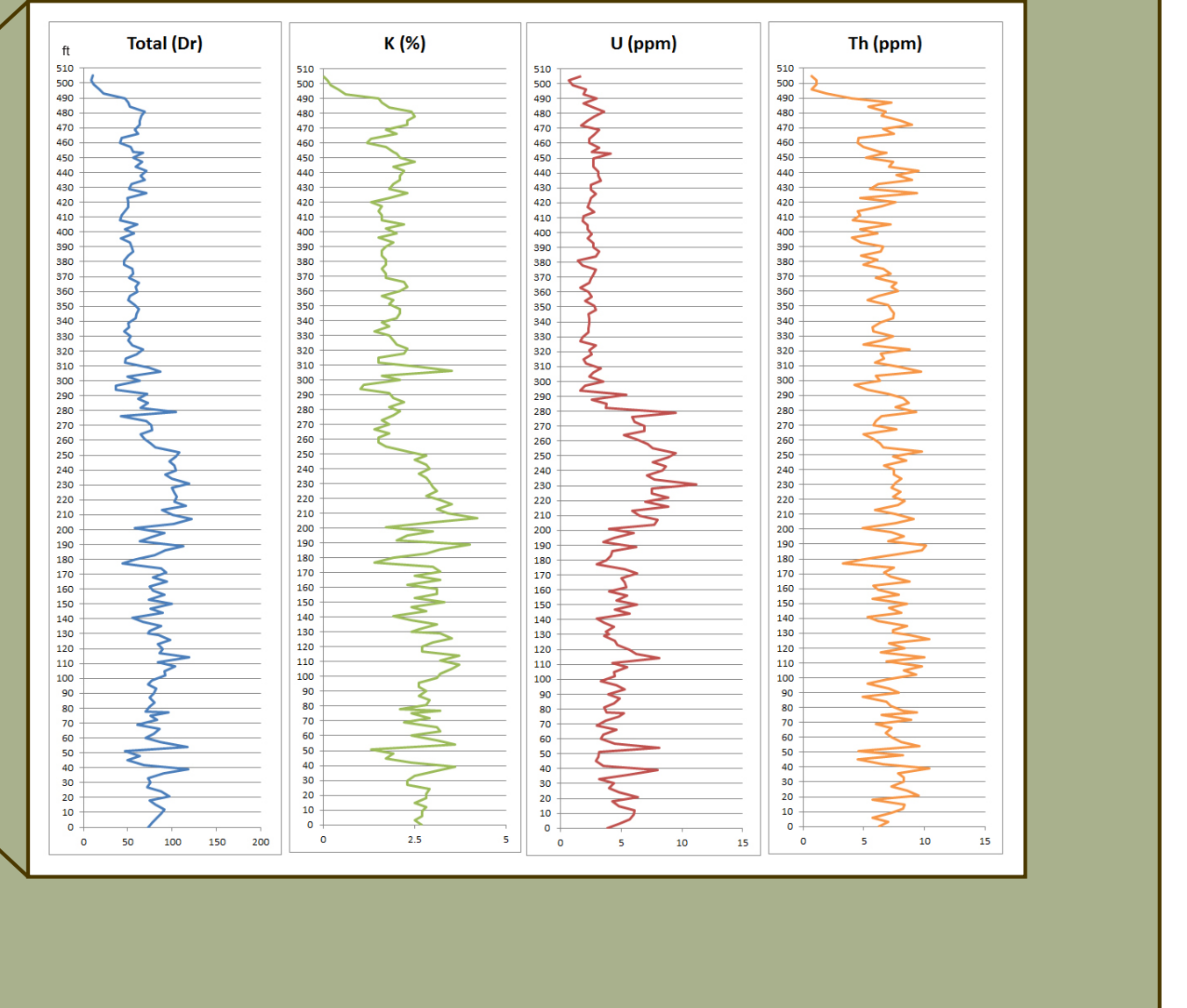
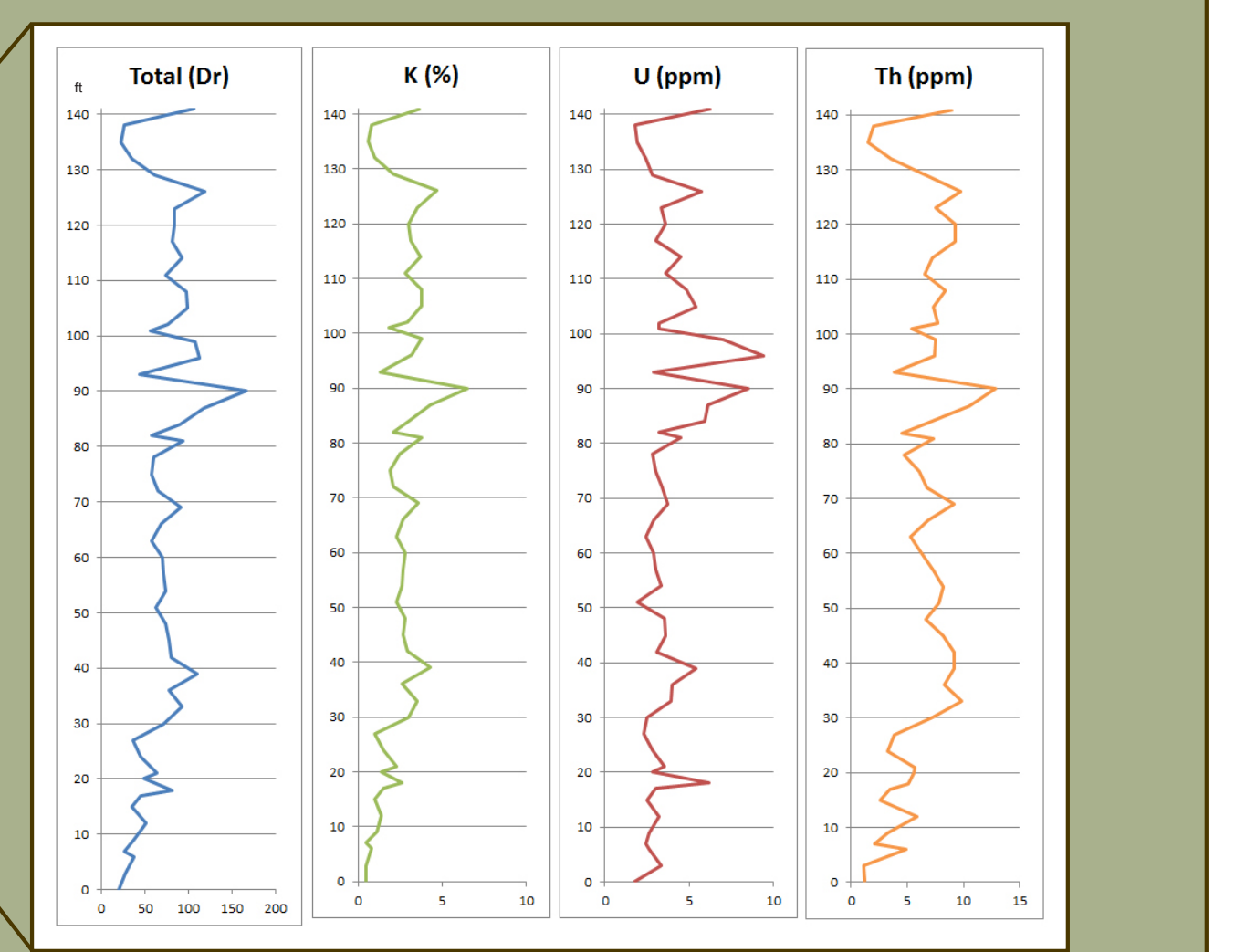
Gamma-ray log of the of "South Slope" transect (correlated to the measured section to the left).



Oblique Google Earth image, view north, of Ledger Canyon/"East Slope" gamma-ray transect (B–B') of the Pilot Shale, central Confusion Range.

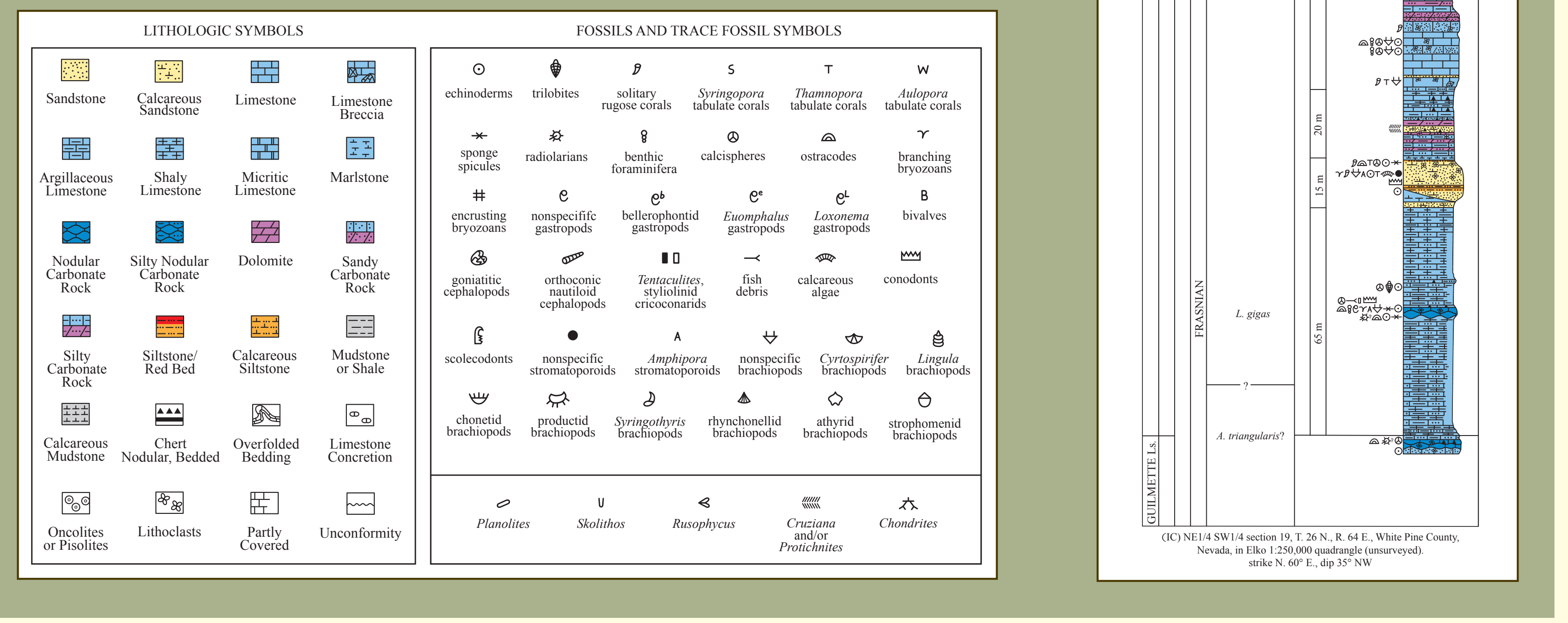
© Google 2017

Gamma-ray log of the Ledger Canyon/"East Slope" transect (correlated to the measured section to the left).

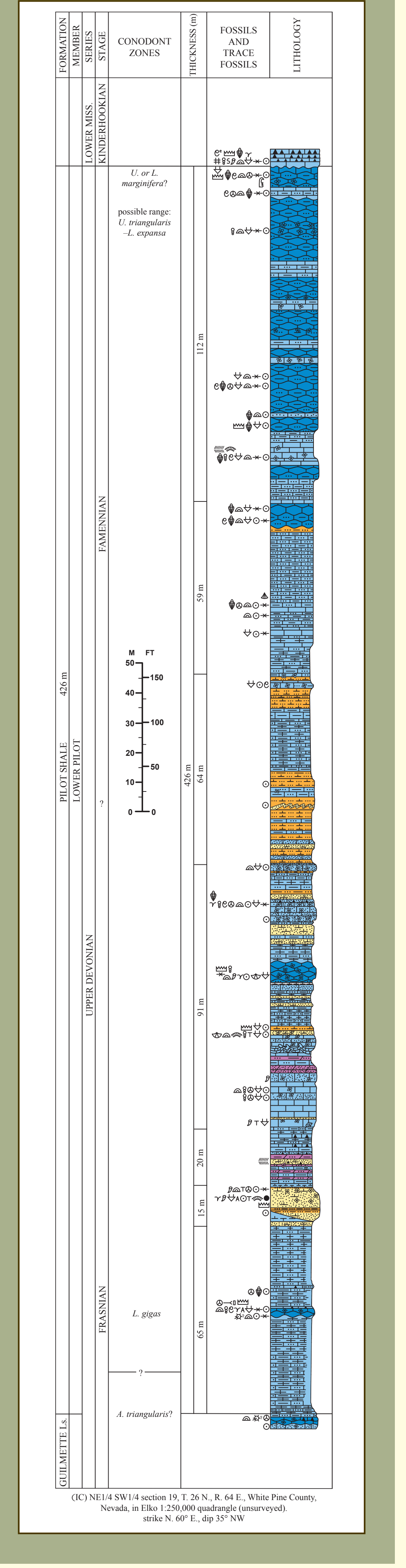


See study area and geologic maps for location of gamma-ray transects.

Explanation for measured sections.



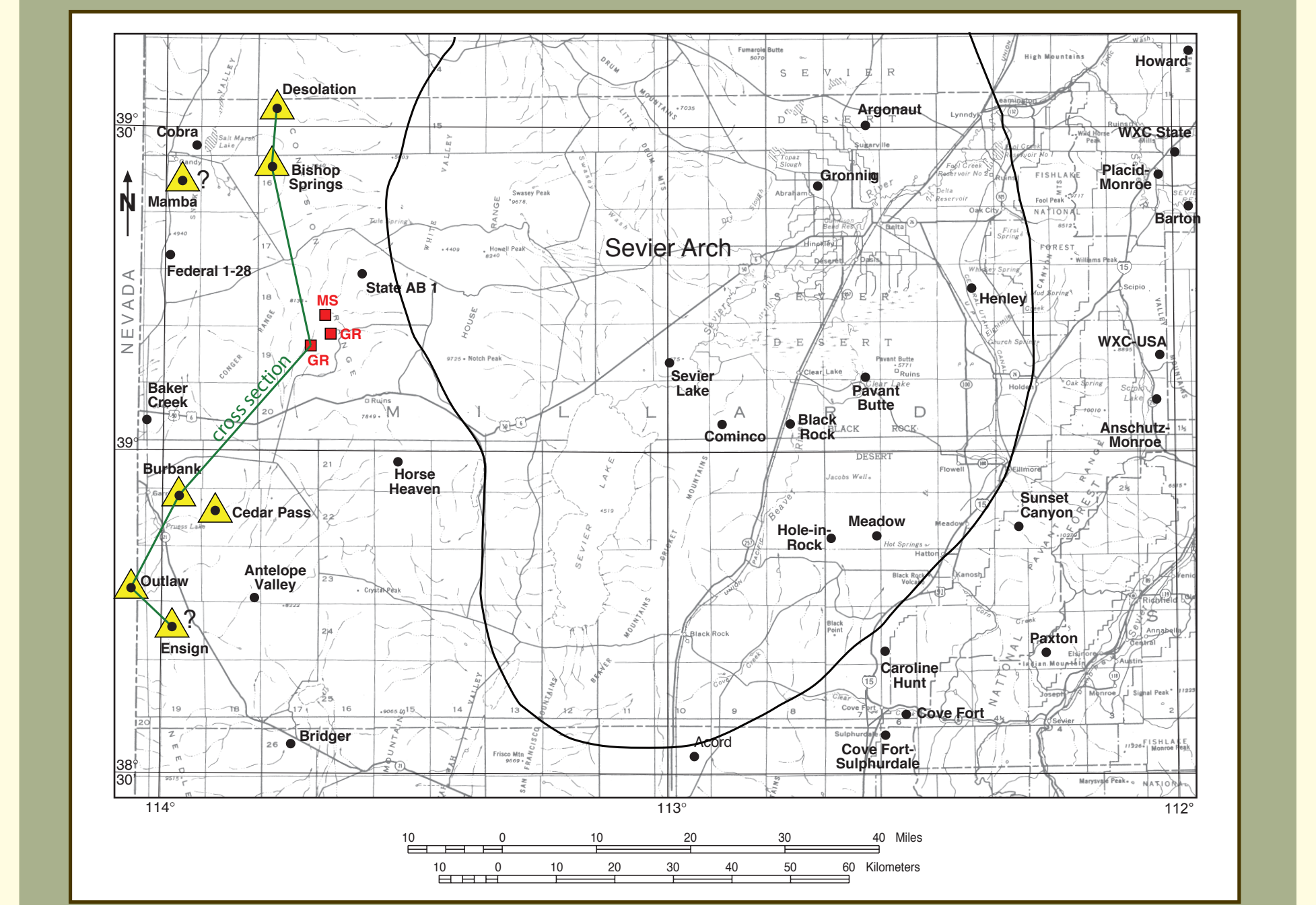
Cherry Creek Range section, White Pine County, east-central Nevada.



REGIONAL WELL CORRELATIONS

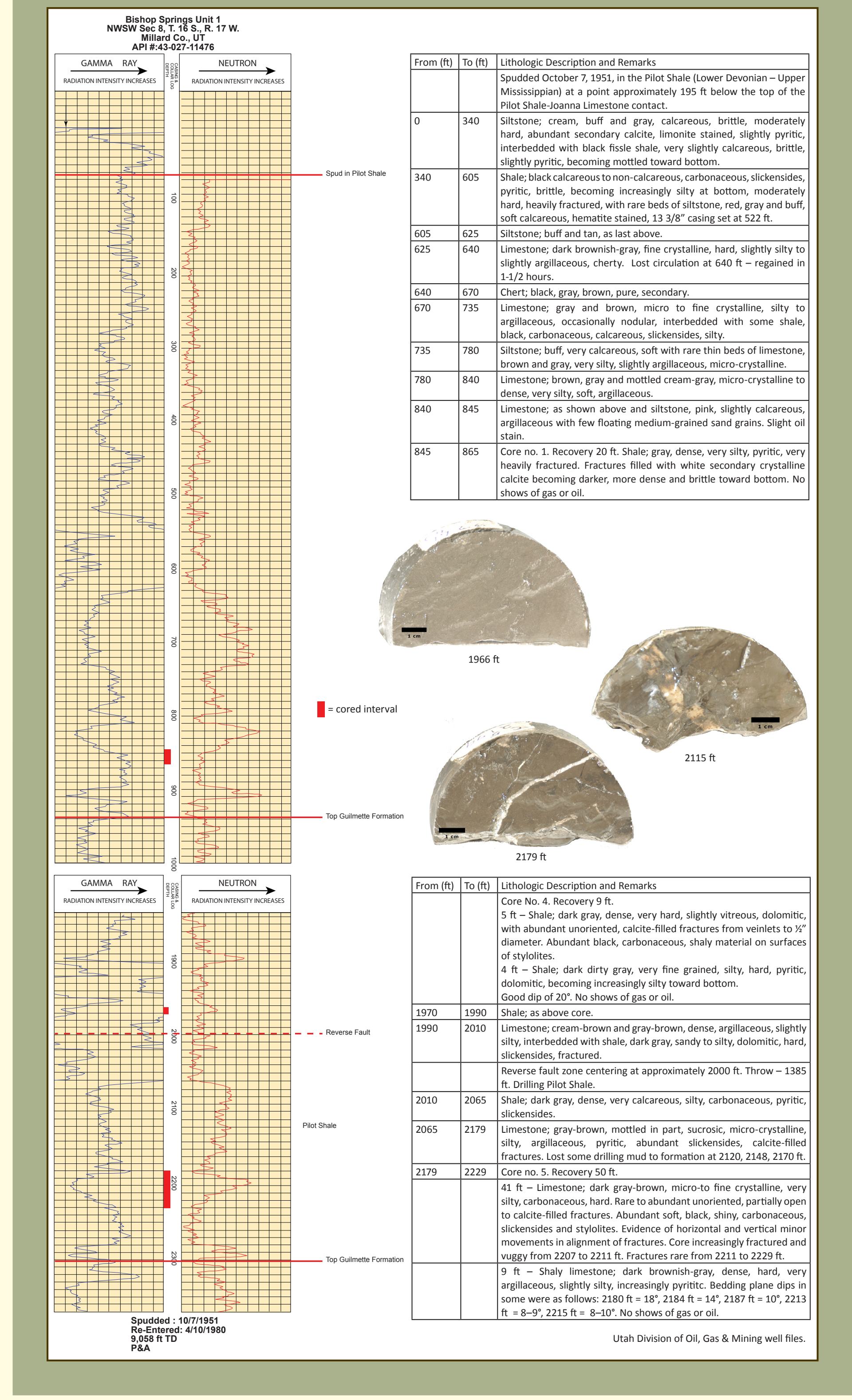
Location of selected deep exploration wells in and adjacent to Millard County, western Utah.

Wells penetrating the Pilot Shale are identified with a yellow highlighted triangle; the Confusion Range measured section (MS) and gamma-ray transects (GR) are also shown. Also shown is the Sevier arch, a broad structural culmination formed during the Late Cretaceous Sevier orogeny. Lower Ordovician rocks are overlain by Tertiary volcanics on the arch in this area; all younger sedimentary rocks are missing. Cross section shown below.



From Hintze and Davis (2003).

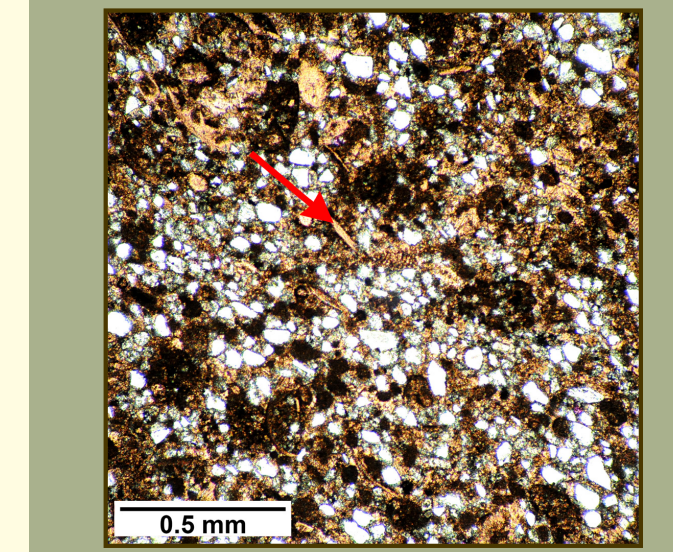
Wireline log and lithologic core chip description of the Pilot Shale, Bishop Springs Unit 1 well.



From (ft)	To (ft)	Lithologic Description and Remarks
		Spudded October 7, 1951, in the Pilot Shale (Lower Devonian – Upper Mississippian) at a point approximately 195 ft below the top of the Pilot Shale-Joanna Limestone contact.
0	340	Siltstone; cream, buff and gray, calcareous, brittle, moderately hard, abundant secondary calcite, limonite stained, slightly pyritic, interbedded with black fissle shale, very slightly calcareous, brittle, slightly pyritic, becoming mottled toward bottom.
340	605	Shale; black calcareous to non-calcareous, carbonaceous, slickensides, pyritic, brittle, becoming increasingly silty at bottom, moderately [illegible]

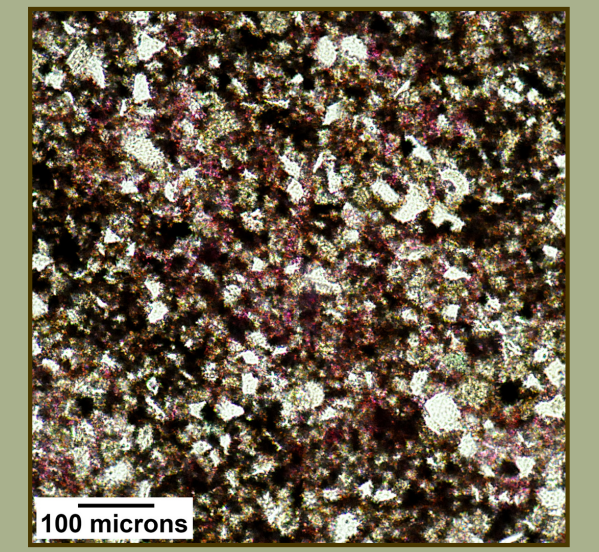
PILOT SHALE PETROGRAPHY

Sample WP-11



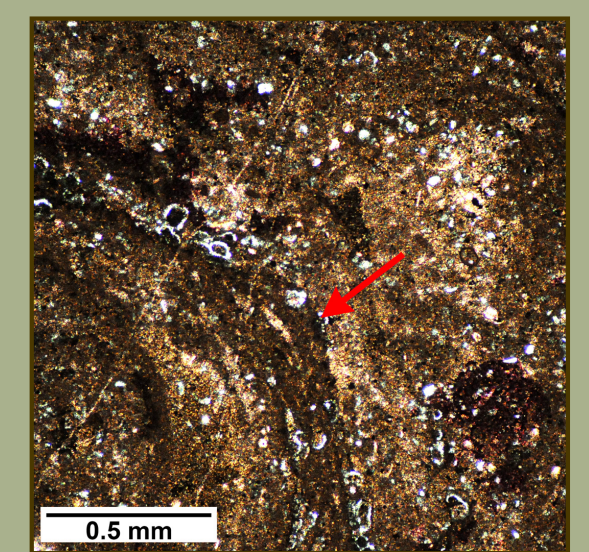
Low magnification view of calcareous siltstone, typical of many samples taken from the Pilot Shale. A mixture of poorly sorted silt, reworked fossil fragments (arrow), and calcite cement (bronze) is typical. Porosity is generally poor due to the pervasive cementation. Plane polarized light (40X).

Sample WP-07



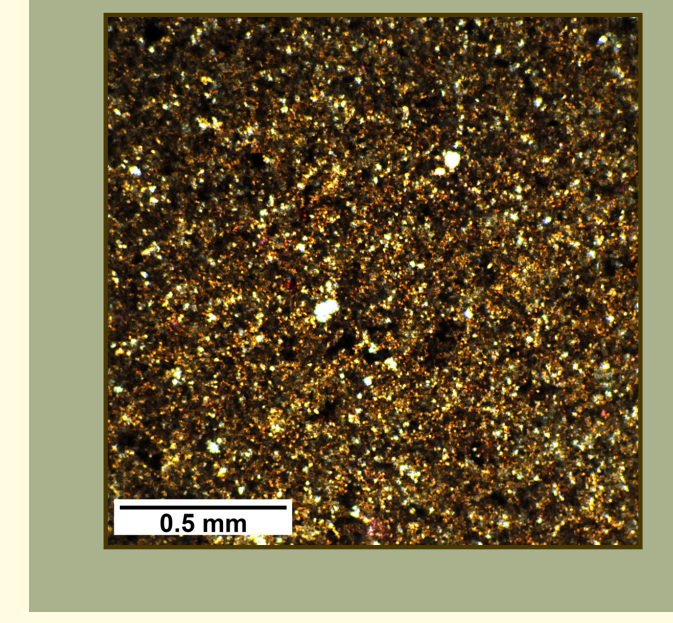
Close-up view clearly separates the three major constituents with quartz/feldspar being poorly sorted and somewhat angular although well-rounded quartz grains are seen elsewhere. Porosity (faint magenta) consists of intercrystalline voids inspired by incomplete dolomite cementation, interparticle void space among the siliciclastics, and microporosity likely present in clays as well as in organic material. Plane polarized light (100X).

Oncolitic Bed



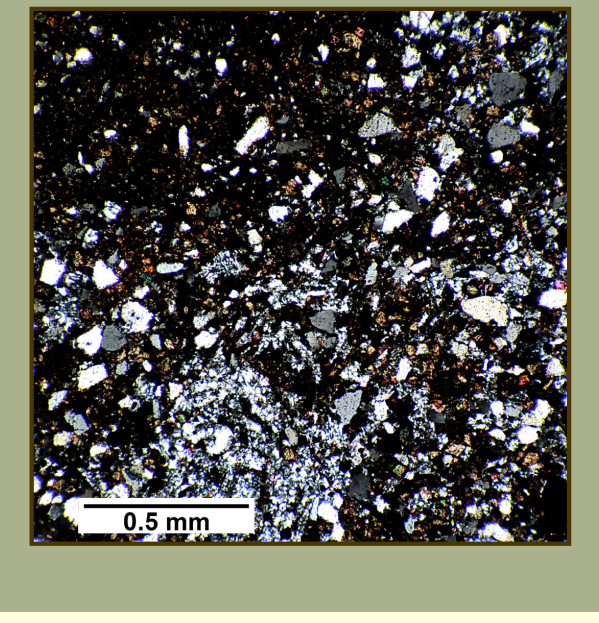
Abundant oncoids (arrow) in a dark gray limestone are common to this stratigraphic interval, most likely attributable to a comparative lowstand at this moment of time. A distinct red bed is in stratigraphic vicinity, seen best on field photographs associated with this presentation. Note the numerous bulbous encrusting forams (white) viewed in this specimen. Plane polarized light (40X).

Sample WP-17



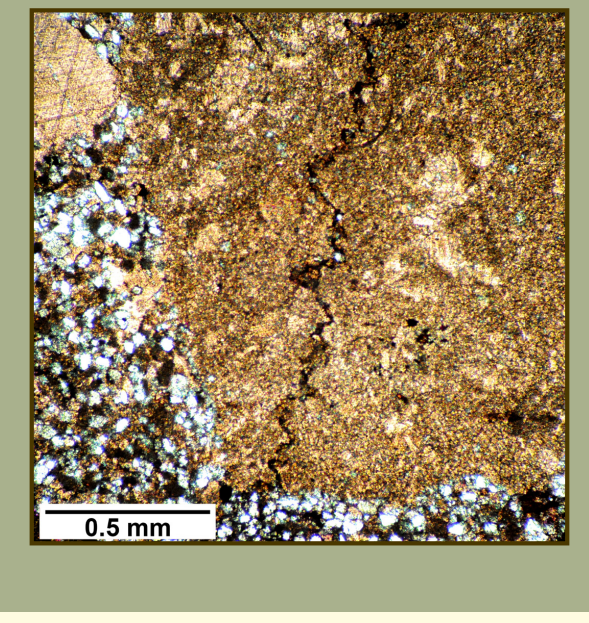
Low magnification view of a black (in field) phosphatic mudrock containing small amounts of detrital silt, organic matter, and microporous void space. The relative occurrence of this facies in the sections measured is admittedly unknown, but log responses in any drilled well could be informative. Plane polarized light (40X).

Sample WP-34



In some cases, true sand-size particles of quartz, feldspar, and chert (salt and pepper) are admixed with finer-grained materials, reinforcing the concept of a mixed or multi-sourced provenance. Nonetheless, dolomite, organic material (black), and some porosity are still evident in this relatively coarse grained material. Plane polarized light (40X).

Sample WP-23



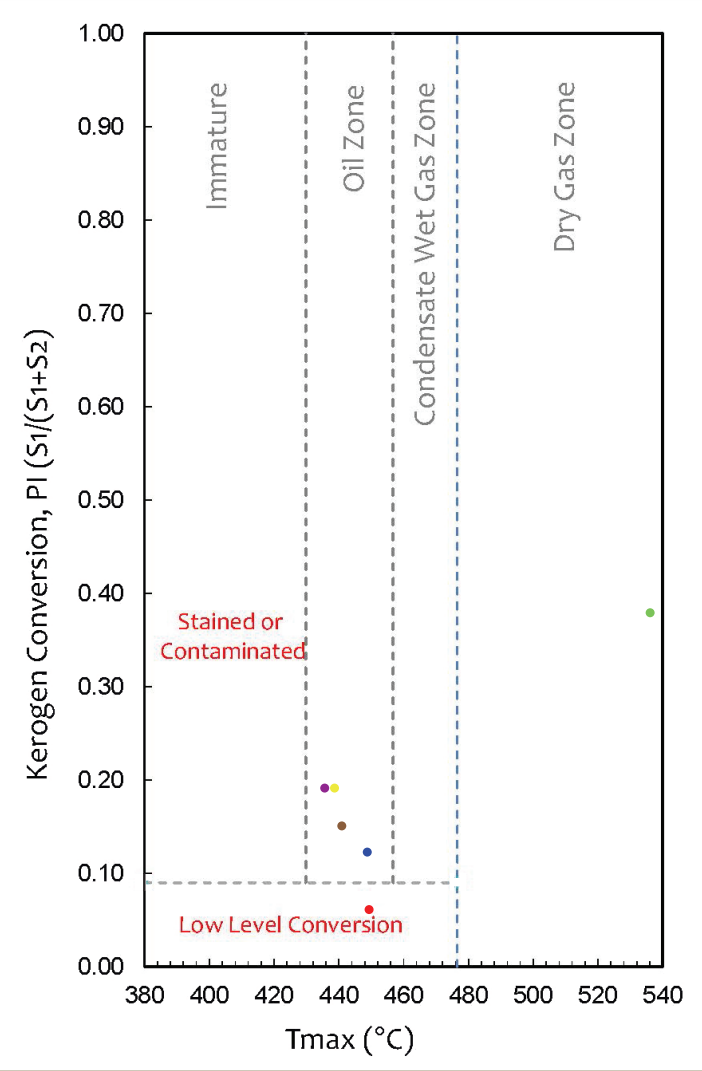
Reworked limestone fragments (bronze) are seen periodically in this location. Such rounded clasts, as seen here, likely reflect the erosion of shelfal materials as the silt brusquely descended into the relatively deep basin. Associated stratigraphic work outside of the Confusion Range strongly suggests correlation to more shallow deposits elsewhere. These shallow formations were clearly eroded when the Pilot Shale was deposited. Plane polarized light (40X).

GEOCHEMISTRY

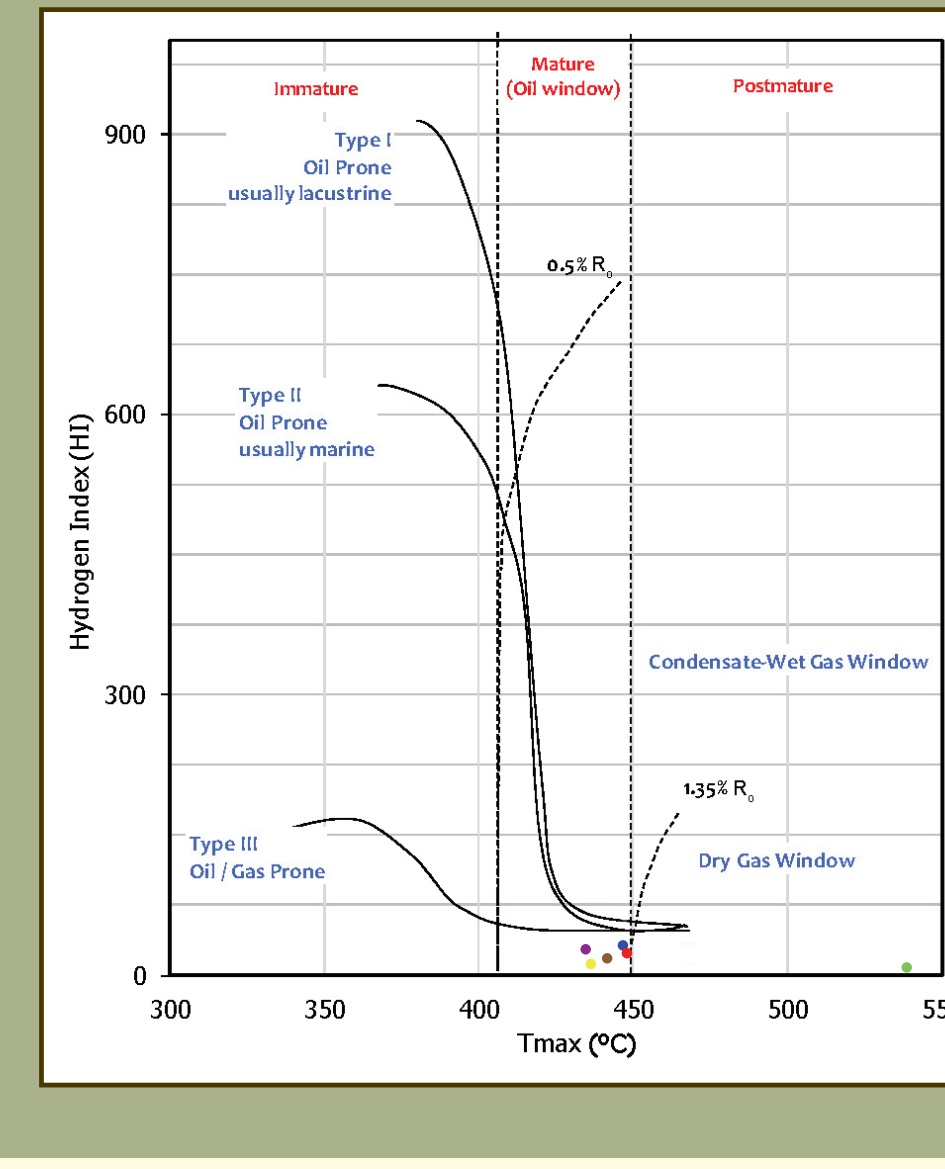
Sample ID	Weight (mg)	S1[1]	S2[2]	S3[3]	PI[4]	Tmax[5] (°C)	S3CO[6]	GOC[7] (wt.%)	NGOC[8] (wt.%)	TOC[9] (wt.%)	OSI[10]	HI[11]	OI[12]
WP-15 ●	47.9	0.05	0.31	0.69	0.15	444	0.30	0.07	1.56	1.63	3	19	42
WP-16 ●	56.4	0.05	0.23	0.32	0.19	438	0.32	0.05	1.68	1.73	3	13	18
WP-17 ●	45.4	0.03	0.05	0.83	0.37	539	0.32	0.05	1.31	1.36	2	3	61
WP-22 ●	46.9	0.10	0.63	1.01	0.13	448	0.30	0.11	2.27	2.38	4	26	42
WP-27 ●	46.4	0.03	0.45	1.17	0.07	449	0.41	0.10	1.83	1.92	1	23	60
WP-30 ●	48.0	0.03	0.13	0.84	0.19	436	0.24	0.05	0.56	0.61	5	21	137

[1] S1 = amount of free hydrocarbons in the sample (mg HC/g rock)
[2] S2 = amount of hydrocarbons generated by pyrolitic degradation of kerogen (mg HC/g rock)
[3] S3 = amount of CO_2 (mg CO_2/g rock) produced during pyrolysis of kerogen
[4] PI = production index (S1/S1+S2)
[5] Tmax = temperature (°C) of maximum release of hydrocarbons from cracking of kerogen during pyrolysis
[6] S3CO = amount of CO (mgCO/g rock) produced during pyrolysis of kerogen
[7] GOC = generative organic carbon
[8] NGOC = non-generative organic carbon
[9] TOC = total organic carbon (wt.%)
[10] OSI = oil saturation index (S1 x 100/TOC)
[11] HI = hydrogen index (S2/TOC x100)
[12] OI = oxygen index (S1 x100/TOC)

Total organic carbon and programmed pyrolysis data of Pilot Shale from the samples collected in the Confusion Range sections.



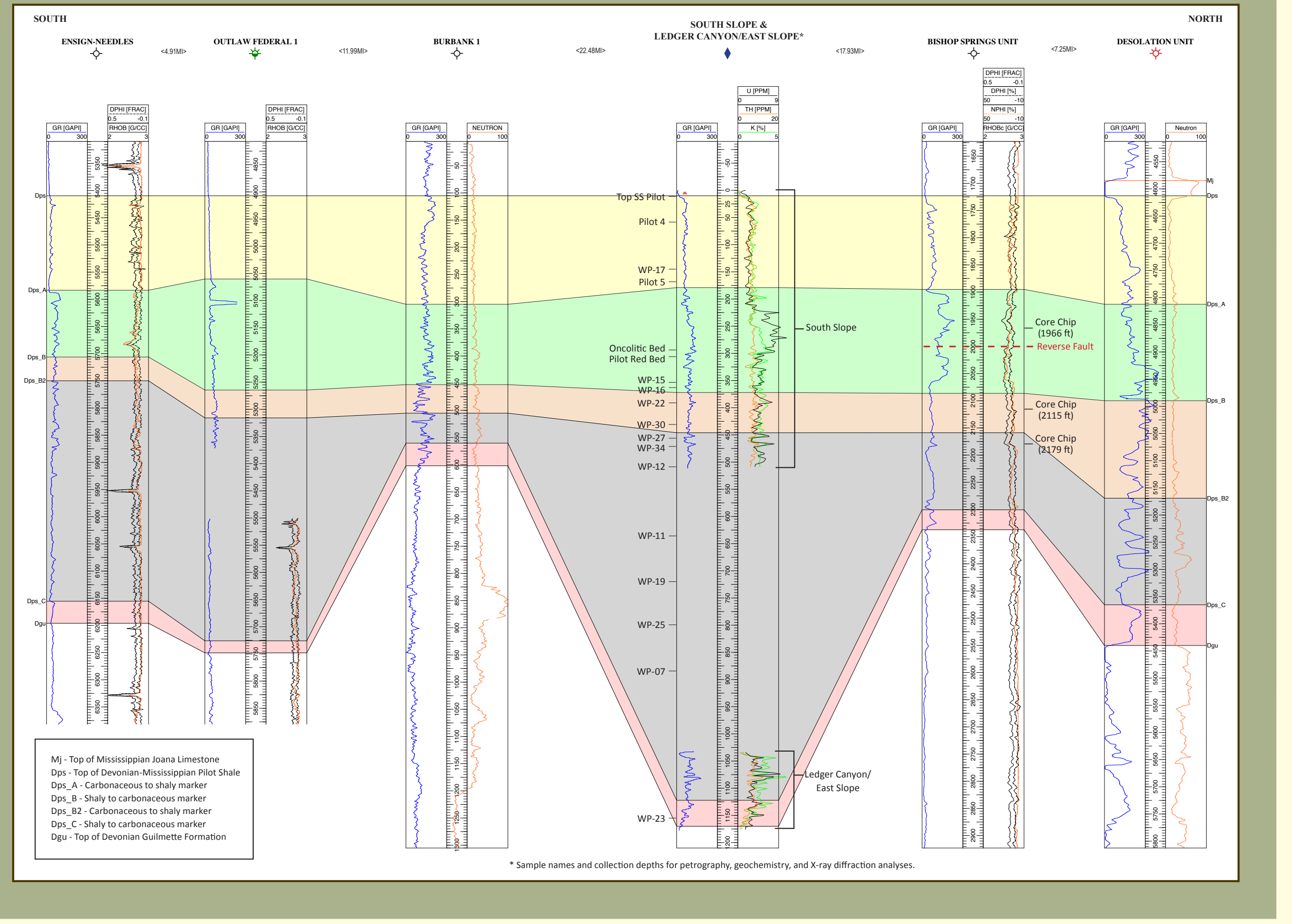
Production index (PI) vs. Tmax suggests that oil is possible in the Pilot Shale.



Hydrogen index (HI) vs. Tmax suggests the possibility of oil production.

Surface versus subsurface correlation.

Line of cross section shown on well location map above left.



X-RAY DIFFRACTION (XRD) ANALYSIS

Sample	Depth (ft)	Qtz (wt%)	Cal (wt%)	Dol (wt%)	Alb (wt%)	Orth (wt%)	Feld (wt%)	Sum of Feldspar Group* (wt%)	Mica (wt%)	Musc (wt%)	Kaol (wt%)	Mont (wt%)	Verm (wt%)	Gyp (wt%)	Chl (wt%)	Tita (wt%)	Total
Top SS Pilot	10	8.2	1.8	14.5		68.0		68.0		7.4							99.9
Pilot 4	58	23.0	0.8	62.0	0.7			Tr		13.9							100.4
Pilot 5	168	32.0	8.4	41.0		0.4	0.3	Tr		13.5	2.9	0.7				0.2	99.1
Pilot Red Bed	305	89.0	0.0	5.7			Tr	Tr	4.5		0.6						99.8
WP-16	362	24.0	2.0	54.0		8.7	1.6	10.3		9.7			Tr				100.1
WP-22	390	26.0	0.0	32.3			4.2	4.2		30.3	6.8		0.3	Tr			99.9
WP-12	508	37.0	28.7	20.0				0.0	1.1	11.4	2.1						100.3
WP-19	718	13.4	66.0	14.0			0.7	Tr		2.0	1.4		1.3		0.6		99.4
WP-25	798	2.7	1.1	43.0			9.0	9.0	40.0	1.9	1.8	0.8					100.3
WP-07	883	23.0	0.8	68.0	0.7			Tr		6.9		1.1					100.5

Notes:
* Column is summary of the albite, orthoclase, and feldspar categories.

Abbreviations: Qtz = quartz, Cal = calcite, Dol = dolomite, Alb = albite, Orth = orthoclase, Feld = feldspar (undifferientiated), Mica = mica (undifferientiated), Musc = muscovite, Kaol = kaolonite, Mont = montmorillonite, Verm = vermiculite, Gyp = gypsum, Chl = chloride, Tita = titanite, Tr = trace

MAJOR CONCLUSIONS

Panel III

- Surface work in the central Confusion Range of western Utah has revealed an overall shallowing upward sequence within the Devonian-Mississippian Pilot Shale, although this trend is clearly oscillatory. A single red bed, an oncolitic limestone, and sand-enriched units are all located in the uppermost 300 ft. A prominent lowstand initiated the red bed, oncolitic limestone, and surfaces of erosion and occurs below the contact with the overlying Joana Limestone (Mississippian).

- Not surprisingly, the most organic-rich intervals are found in the lower part of the ~1170-ft section where organic-rich siltstones, mudrocks, and deep-water limestones are present.

- Extreme stratigraphic variability should be expected in the Pilot Shale, as exhibited by additional work both in Utah and in Nevada, and by the extensive literature on the Devonian of the western U.S. in particular. Conodont work done here and elsewhere provides additional evidence for this lithostratigraphic conclusion.

- Surface gamma-ray logging of this section has at least allowed correlation to other nearby wells in spite of some obvious compositional variability. One major purpose of this study involved achieving some success with surface-to-log correlation for future exploratory efforts.

- Porosity from surface samples is especially observable in the organic-rich dolomitic siltstones (or silty dolomites), and true calcareous siltstones appear well cemented by calcite and have low porosity as a result. A single sample of organic phosphate also exhibits intercrystalline voids. Permeability in all cases should be modest because of the relatively small pore sizes associated with fine-grained mineralogical constituents and textural details.

- Organic geochemistry is favorable for hydrocarbon production in spite of apparent siliciclastic abundance. TOC values in selected samples are generally in the 1–2% range, and Tmax measurements indicate propensity for liquid hydrocarbon potential.

Ledger Canyon/“East Slope,” Central Confusion Range

ACKNOWLEDGMENTS

Bereskin & Associates

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