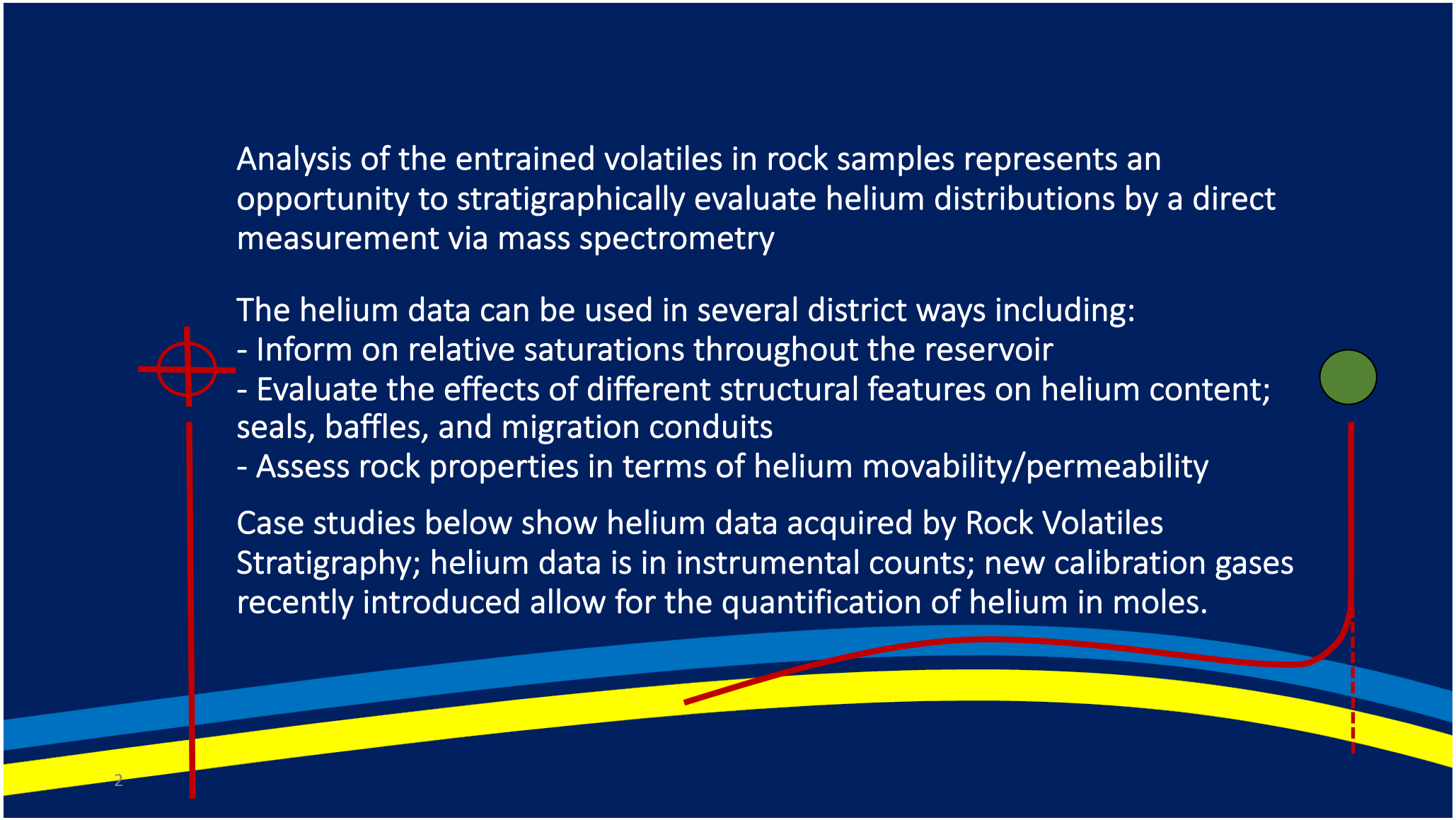
ADVANCED HYDROCARBON STRATIGRAPHY (AHS)

Helium Case Studies

Analysis of the entrained volatiles in rock samples represents an opportunity to stratigraphically evaluate helium distributions by a direct measurement via mass spectrometry

The helium data can be used in several district ways including:
- Inform on relative saturations throughout the reservoir
- Evaluate the effects of different structural features on helium content; seals, baffles, and migration conduits
- Assess rock properties in terms of helium movability/permeability

Case studies below show helium data acquired by Rock Volatiles Stratigraphy; helium data is in instrumental counts; new calibration gases recently introduced allow for the quantification of helium in moles.



Vertical Helium Diffusion vs Conductive Pathways

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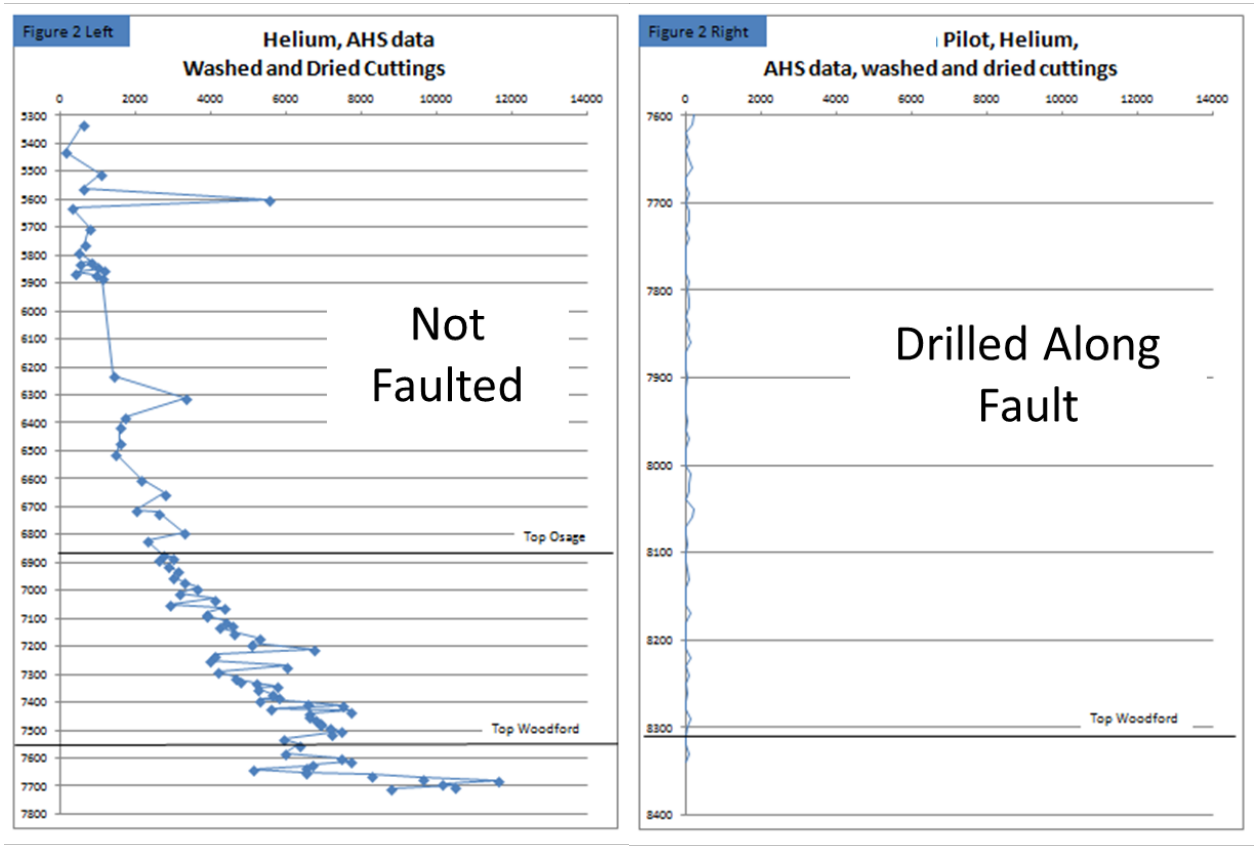
Data comes from analysis of legacy cuttings samples from two vertical wells in the STACK (OK)

Both wells intersect with the hot Woodford which self generates helium through alpha particle emission via radioactive decay.

One well was drilled in unfaulted terrain, the other was drilled along a fault.

The helium in the unfaulted well shows an exponential decay in concentration as it approaches the surface, indicative of a diffusion process with no migration conduits.

The helium in the faulted well is completely missing; fault has acted as a ready migration conduit for escape.



Helium and HC Resource Distribution, Risks, and Extent of Risk

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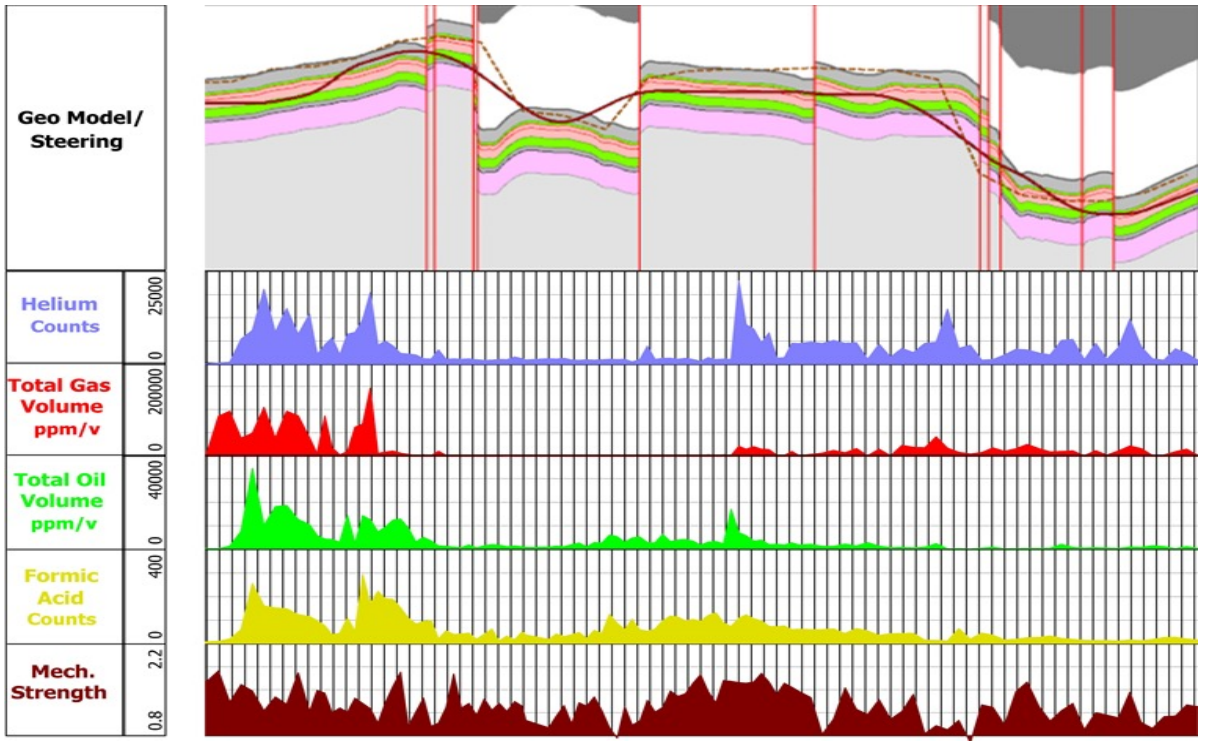
Sealed at well cuttings samples were used to evaluate a 2-mile Woodford lateral in the Arkoma (OK).

Faults control the resource concentration acting as communication pathways. Helium and gas are depleted hundreds of feet proximal to some faults. Large quantities of liquid HC and diagenetic compounds (acids) are present; their distributions are influenced by the faults too.

Reduced mechanical strength occurs at faults possibly leading to borehole stability issues.

Analysis allows for a meaningful assessment of the saturations of helium and other resources along the length of the borehole while assessing the risks different structural features present and how close to those features the resource loss begins to occur.



Structurally Complex Gas Well, Helium Accumulation under Anticline (Marcellus, PA)

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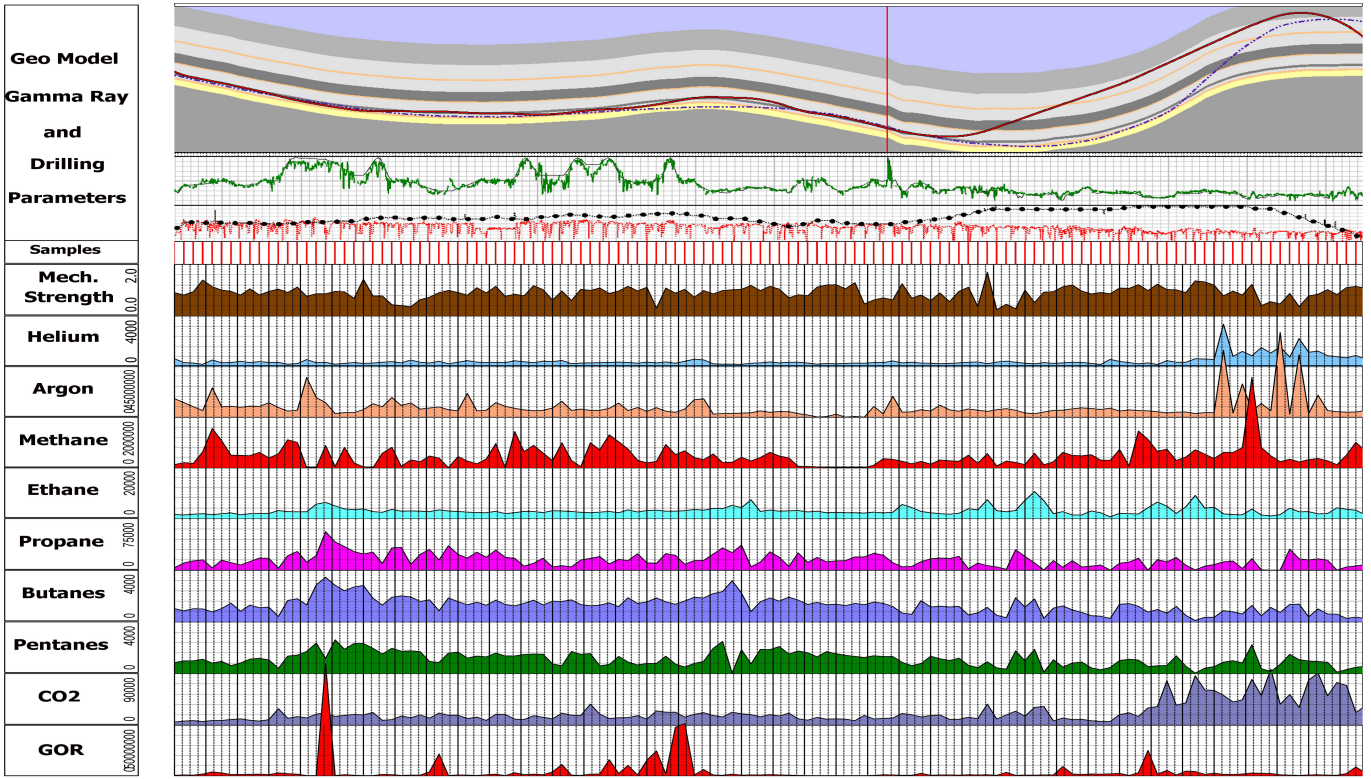
Sealed at well cuttings samples were collected on a dry gas Marcellus lateral.

Methane and argon are depleted several hundred feet prior to the fault; larger molecules like ethane and CO2 are not effected by the fault

High GOR response features pick out natural fractures and contain resource compositions equivalent to offset production

Both observations suggest that the pore throats are sized between methane and ethane

Helium is low throughout the borehole suggesting loss via fault; but significant accumulation of helium and other gases is observed below anticline.



Helium Accumulates Below Biogenic Tar Mat Seal; Arkoma, OK

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Legacy cuttings from an Arkoma gas well with overpressure; economics were prohibitive for intermediate casing

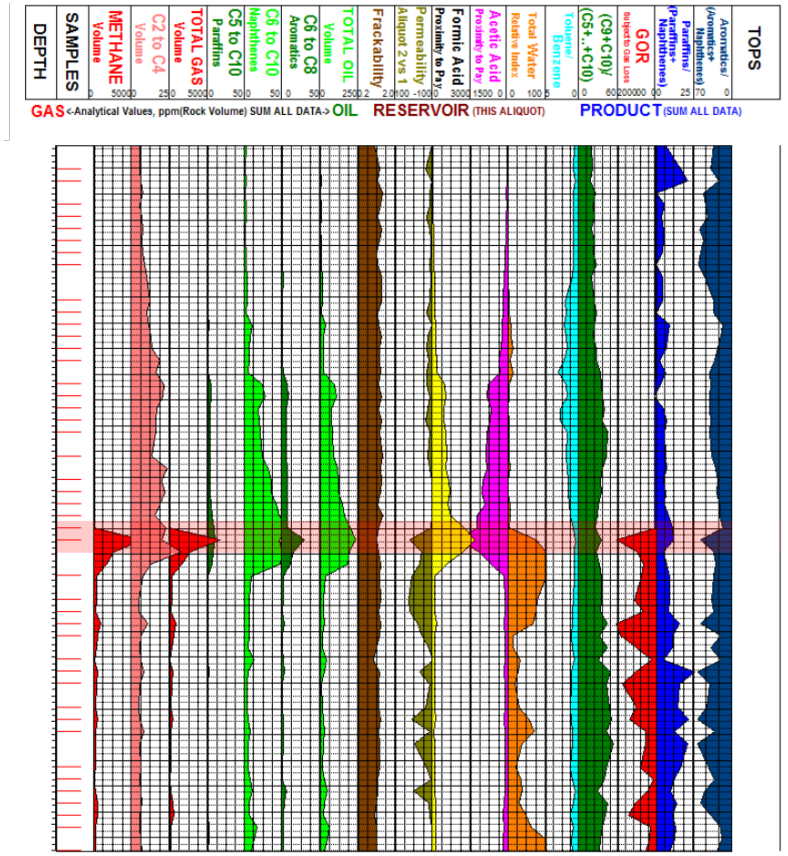
Volatiles analysis identified same depth of overpressure as mud log (red highlight; determined it was due to biological activity)

A few positions deeper to the overpressure is an oil/water contact of a previously unknown oil column, oil is undergoing severe biodegradation (<20 API) depleting paraffins and producing organic acids

Organic acids are being converted to gaseous methane, CO2, CO, and H2; one volume of liquid acids produces ~400 volumes of gaseous species

If oxygen/meteoric water source can be identified wells can be diverted and drilled without encountering overpressure

Identification of unknown oil column offers new exploration possibilities



Mechanism of Helium Accumulation and Overpressure; Arkoma, OK

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How do you have helium accumulate and have a biogenic overpressure at the base of an oil column?

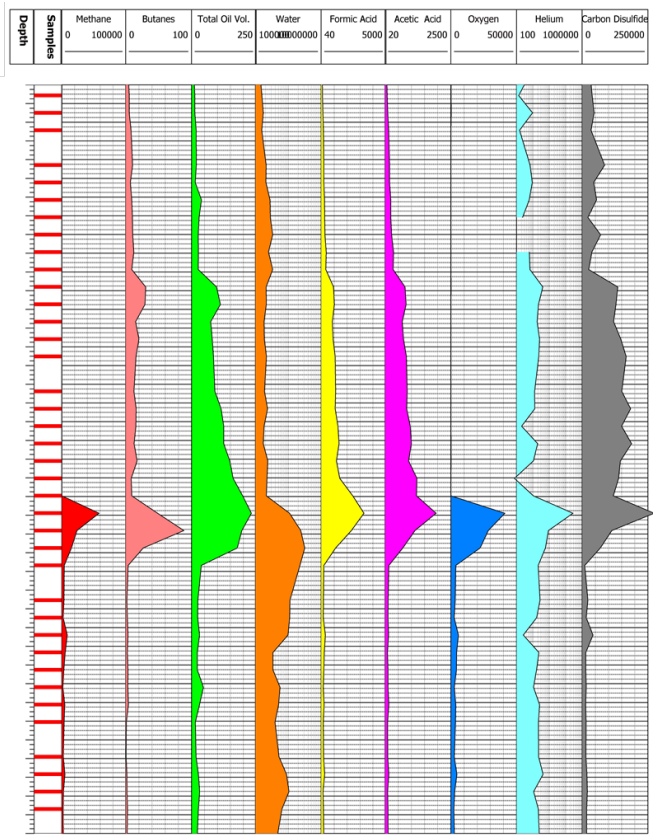
From the sampled depth where the high methane is observed to the base of the oil column(3 samples deeper) is a transition zone with increasing water content

High organic acids and O_2 in transition zone, active biological zone; butane is a major target of subsurface metabolism, lack of synchronization with methane further speaks to active biological processes especially at the top of the transition zone

High helium (100-1000 times above baseline levels) is observed at same depth as high methane, strong evidence the presence of a feature preventing vertical migration, very strong/tight sealing/baffling feature

Highest CS_2 is observed at the top of the transition zone, high values of CS_2 combined with oil composition are consistent with tar mat formation based on work in know tar mats in Alaska

Helium accumulation and overpressure in transition zone are because of a strong overlying tar mat seal at the top of the transition zone



First Known Helium Analysis of Any 60+ Year Old Cores: AHS Analysis of Purdy B & F Wells, Keyes Helium Field, Ok

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We know of no previous successful analyses of Helium in 60+ year old core by any lab.

To determine the feasibility of using legacy core and cuttings for Helium exploration, AHS working with the OKGS, used 60+ year old core samples from 2 Helium wells, Purdy F and Purdy B, from the Keyes Helium Field in the Oklahoma Panhandle. 36 core samples and 13 blanks were analyzed.

AHS's gentle mass spectrometry analyses clearly detects above background levels of He in these old unpreserved cores.

Additional research to optimize the detection and mapping of Helium resources from legacy core and cuttings materials is ongoing.