Helping to Understand Compartmentalization and Reservoir Segmentation Using Mass Spectrometer Mud Gas Analysis*

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Abstract

The development of a portable mass spectrometer suitable for drillsite deployments has made possible a new generation of geochemical evaluation that is contributing significantly to better reservoir understanding and in some cases improved completion strategies. The analysis of organic and inorganic compounds in both lateral and vertical wells can yield a useful depiction of heterogeneity by determining segments of compartmentalization related to variability in composition of inorganic and organic compounds, permeability, stratigraphy, and micro-fracturing.

Helping to Understand Compartmentalization and Reservoir Segmentation Using Mass Spectrometer Mud Gas Analysis

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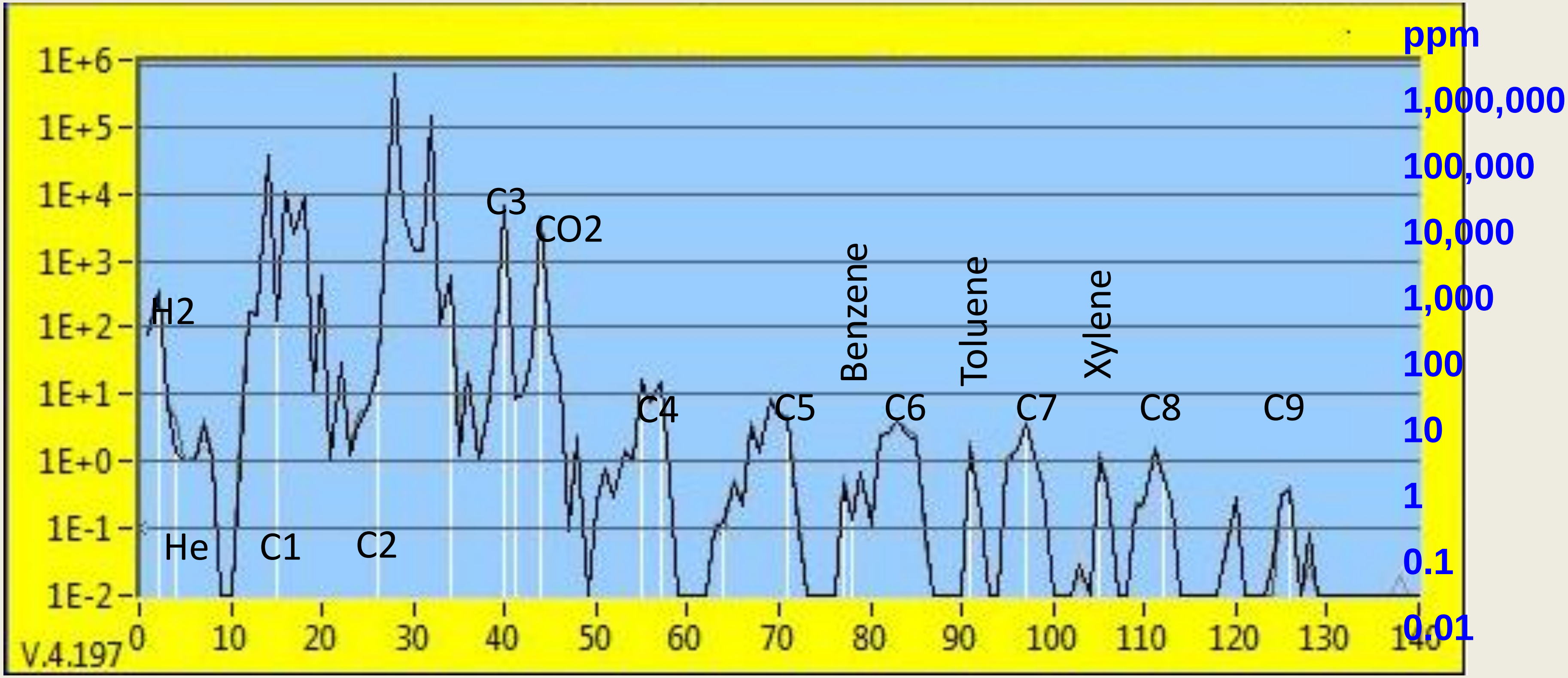


A quadrupole mass spectrometer like the one we use indicates the relative quantities of volatile species within a sample according to their relative "weight", or AMU, as indicated by their mass to charge ratio (m/z). Our usage is such that scale is set to very closely approximate ppm. The range is about 7.5 orders of magnitude which is 2 – 3 times the range of other field devices. LDL is from 3ppm in crowded amu sections down to ppb in cleaner areas. Precision is ppm to ppb and the measurements are linear from a few points off LDL to essentially 100%.

A Little Review:

Pascal's law: (circa 1647 – 1648)

A change in pressure at any point in an enclosed fluid at rest is transmitted undiminished to all points in the fluid.

(Reminder: Fluid means Gas and/or Liquids.)

The compartments we are proposing to help identify are essentially closed, or at least closed enough for the composition ratio treatments discussed herein.

Science text adapted from Wikipedia.org , which just anyone can edit.

Avogadro's law: (circa 1811)

…. For a given mass of an ideal gas, the volume and amount (moles) of the gas are directly proportional if the temperature and pressure are constant.

We can do composition estimates, after all – the temperature and pressure in one of our compartments is at least constant enough for this estimate.

Science text adapted from Wikipedia.org , which just anyone can edit.

Dalton's law: (circa 1801)

(also called Dalton's law of partial pressures) states that the total pressure exerted by the mixture of non-reactive gases is equal to the sum of the partial pressures of individual gases.

In these geologic systems, given that the total pressure is approximately equal, the partial pressure changes (indicated by composition changes) would be indicative of separated compartments.

Science text from Wikipedia.org , which just anyone can edit.

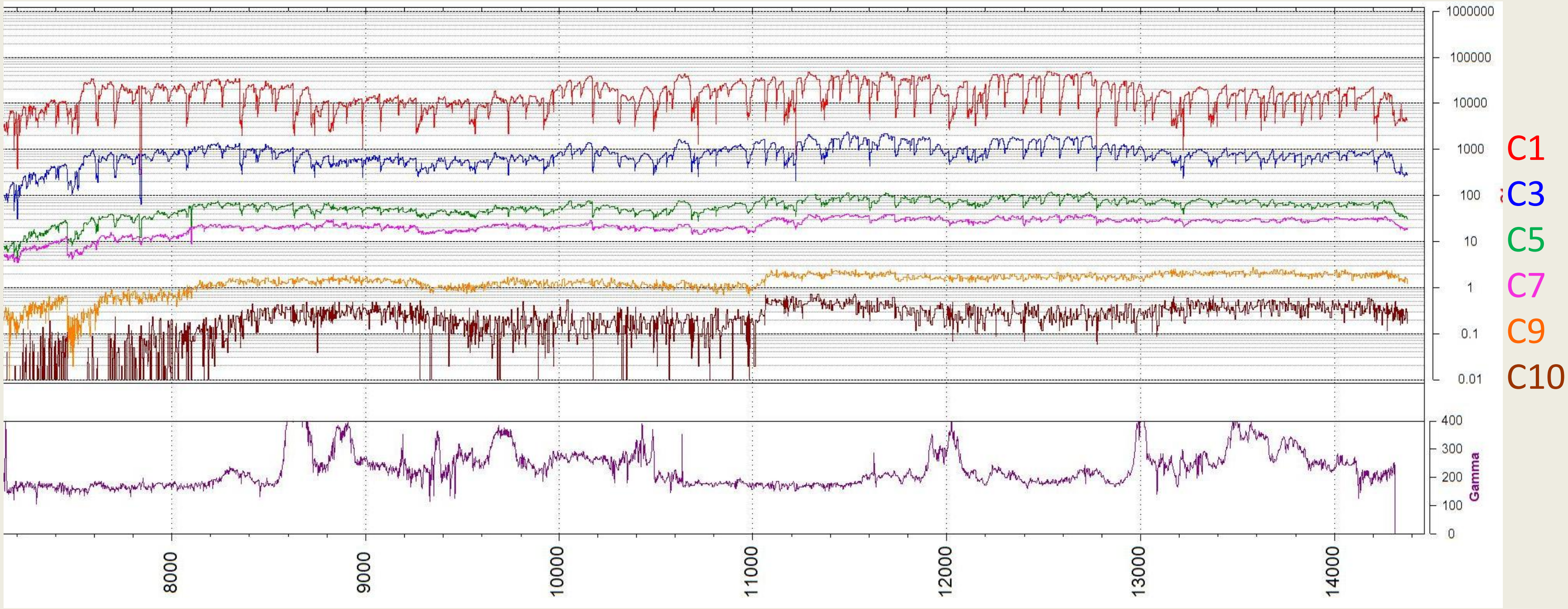
Charles' law: (circca 1787)

… the volume of the gas increases or decreases by the same factor as its temperature

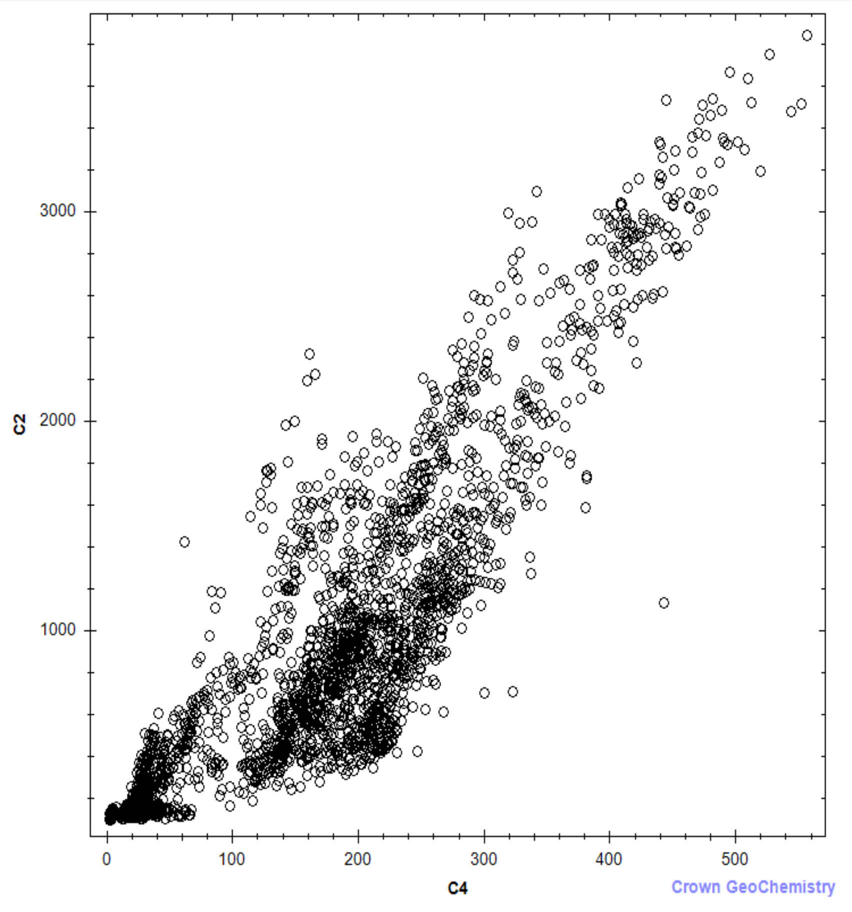
The pressure/volume/temperature thing. Given that our compartmental pressures and temperatures are about constant, our volumes are, indeed, somewhat related to capacity.

And of course Henry's law: (circa 1803)
… the solubility of a gas in a liquid is directly proportional to the partial pressure of the gas above the liquid.

Science text adapted from Wikipedia.org , which just anyone can edit.

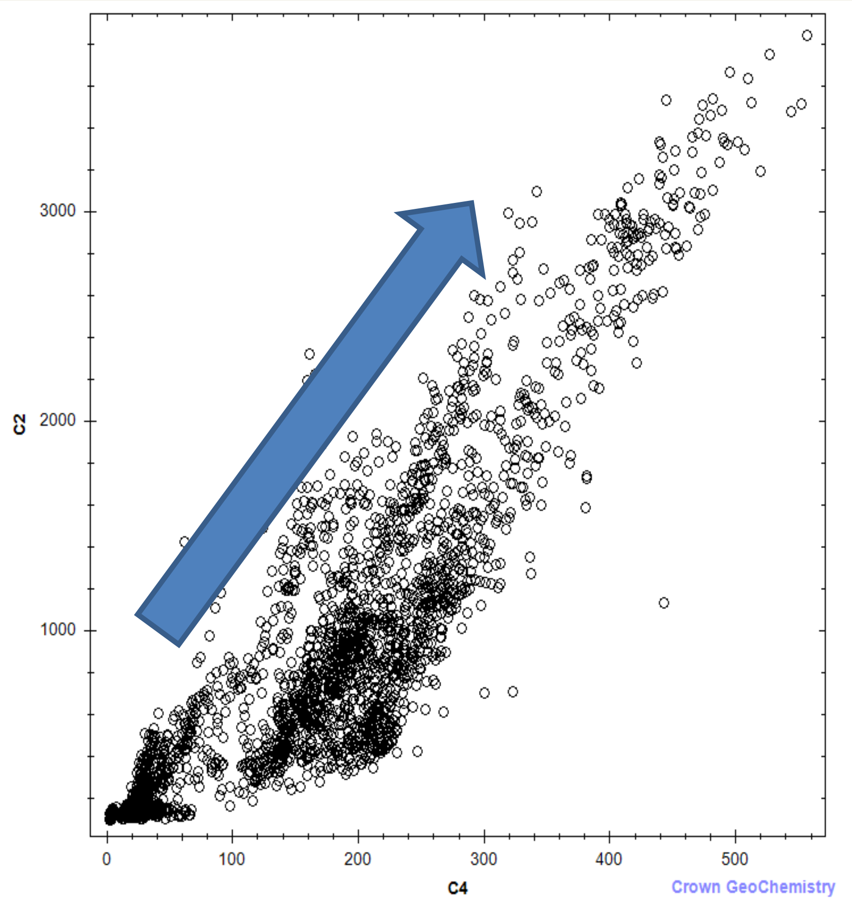


For an actual lateral shale well the mud gas readings look like this in log form. Other than speculation about apparent gas volumes this type of information is not especially easy to use. So let's look at some of this very same data another way.

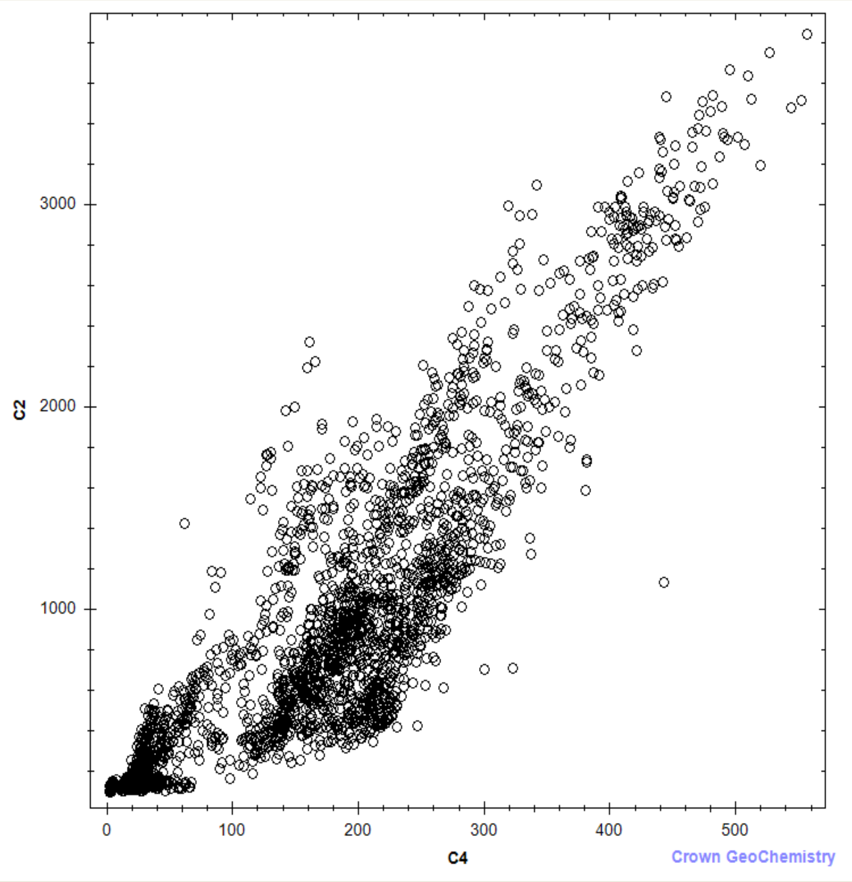


For this same lateral well every foot drilled had a reading for C2 and for C4.

At each depth we go up the C2 axis to that depth's C2 reading and from there over on the C4 axis to that same depth's C4 reading and put a dot.

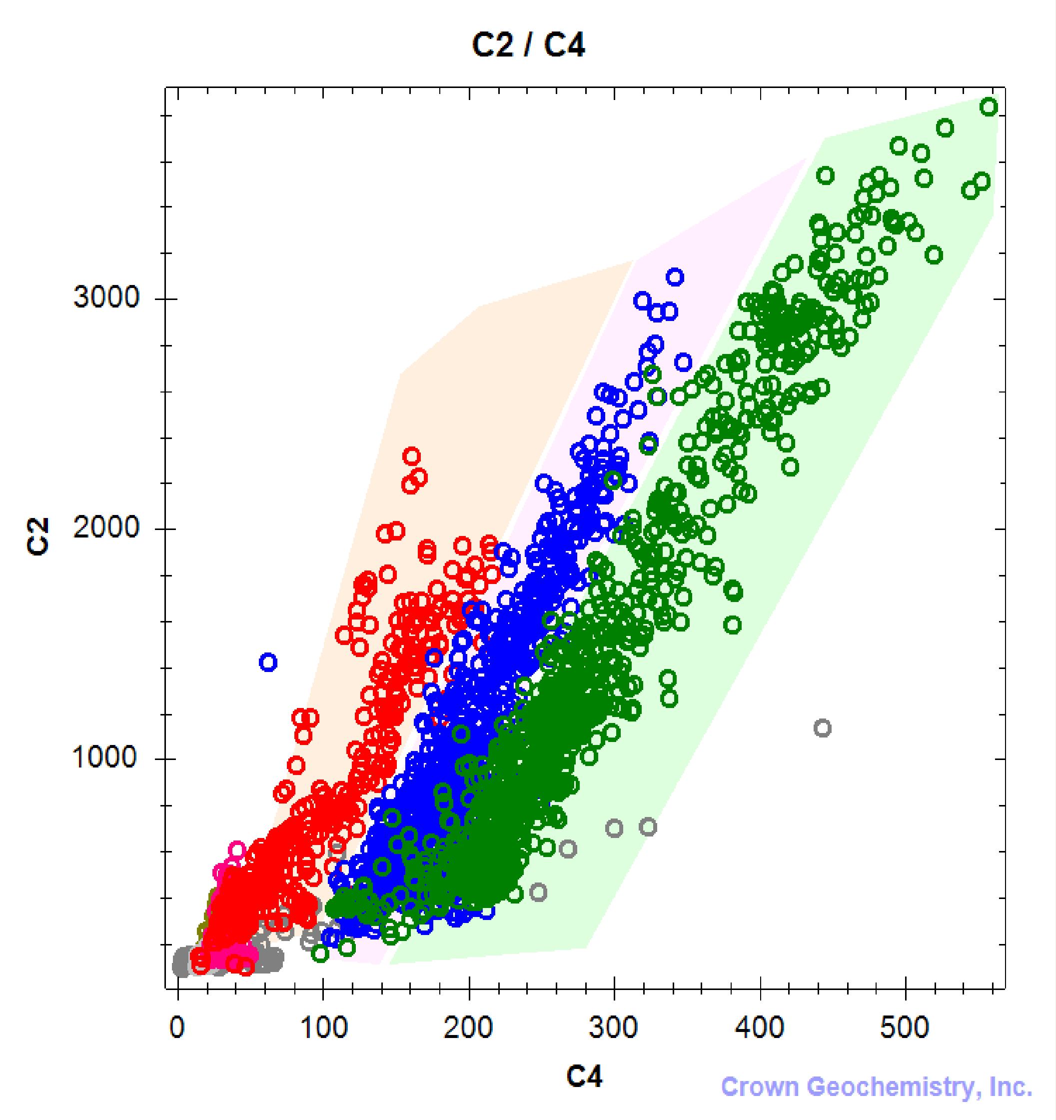


More of well gas volume alone would simply result in more of each component at the same ratio to each other, given the gas laws mentioned earlier.



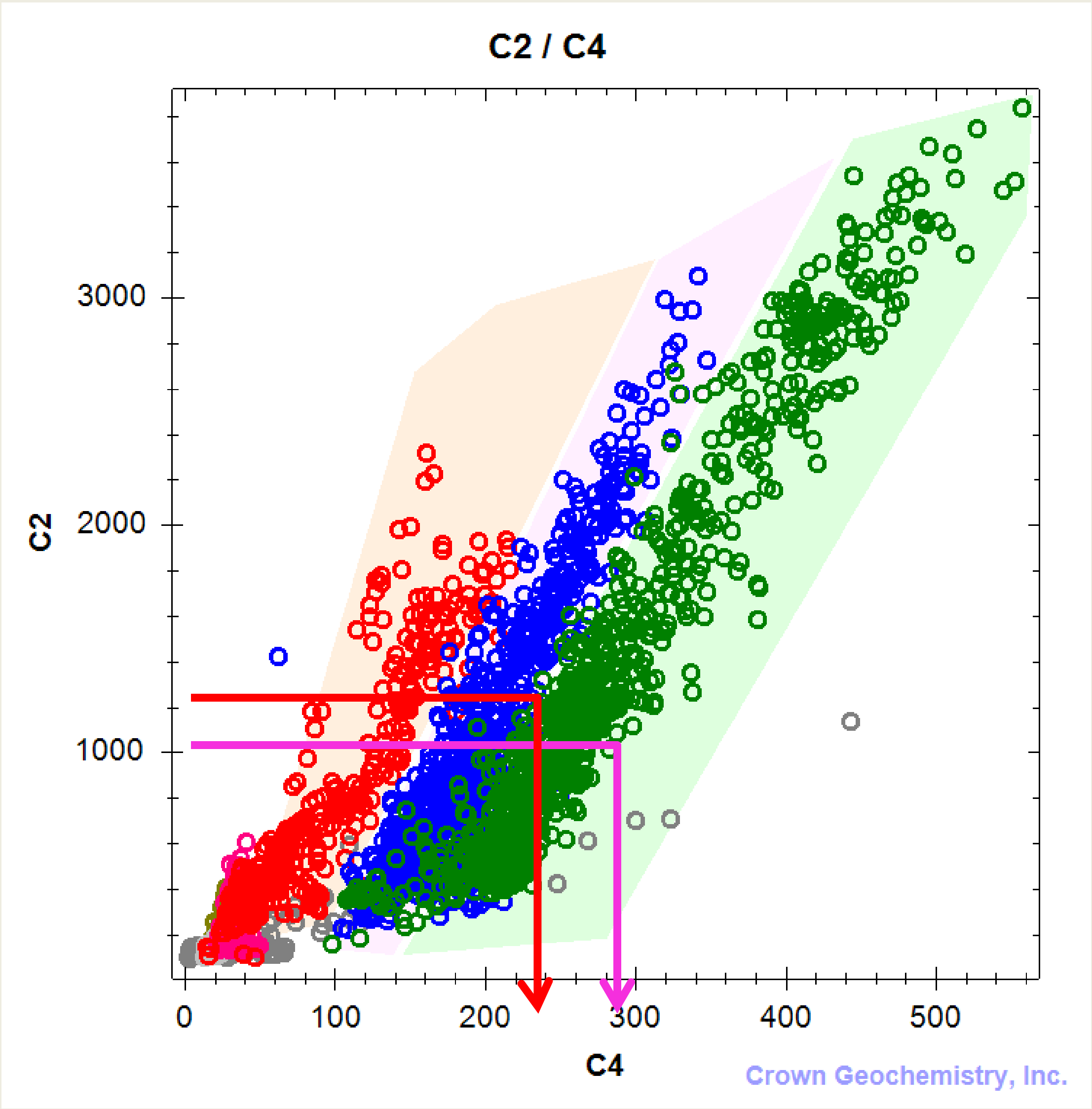
For this data set there appear to be at least three distinct data groupings and their composition ratios are slightly different.

Let's look at this in more detail …



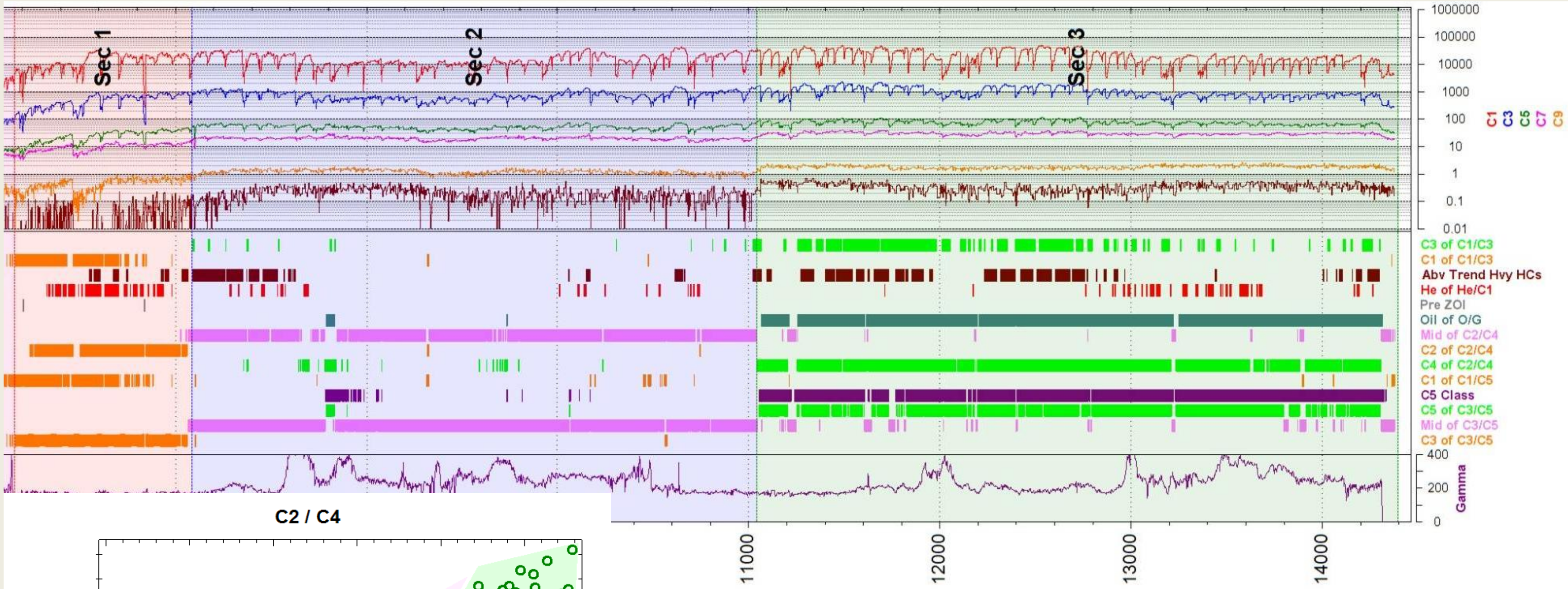
These same data points are here sorted into depth grouped ranges colour-coded as:

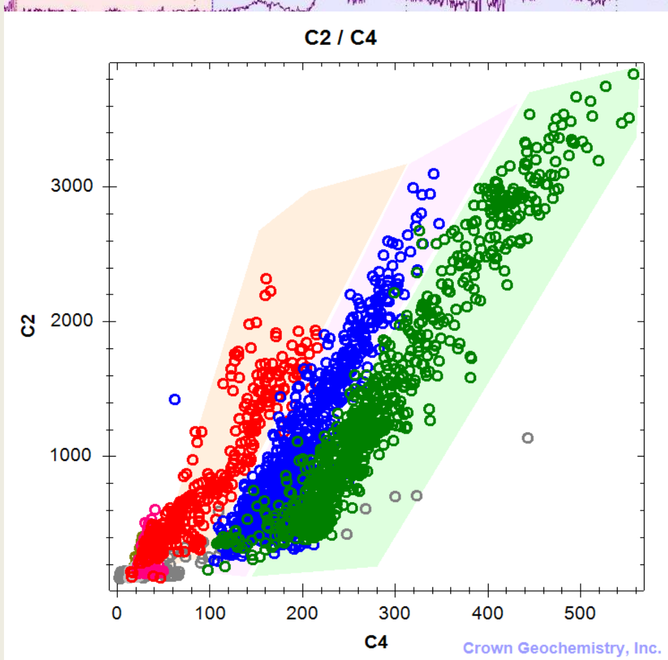
- From start of section to depth2 as red
- From depth2 to depth3 as blue
- From depth3 to T.D. as green



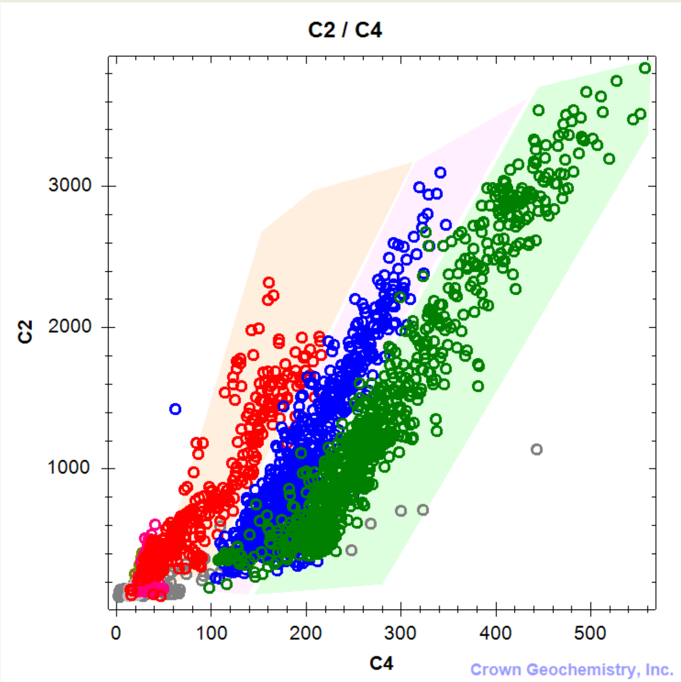
Seems there is more C2 per C4 in the blue group than in the green group.

If these were in the same compartment, then they would be at the same ratio to each other if those guys back in the 1800's were right.

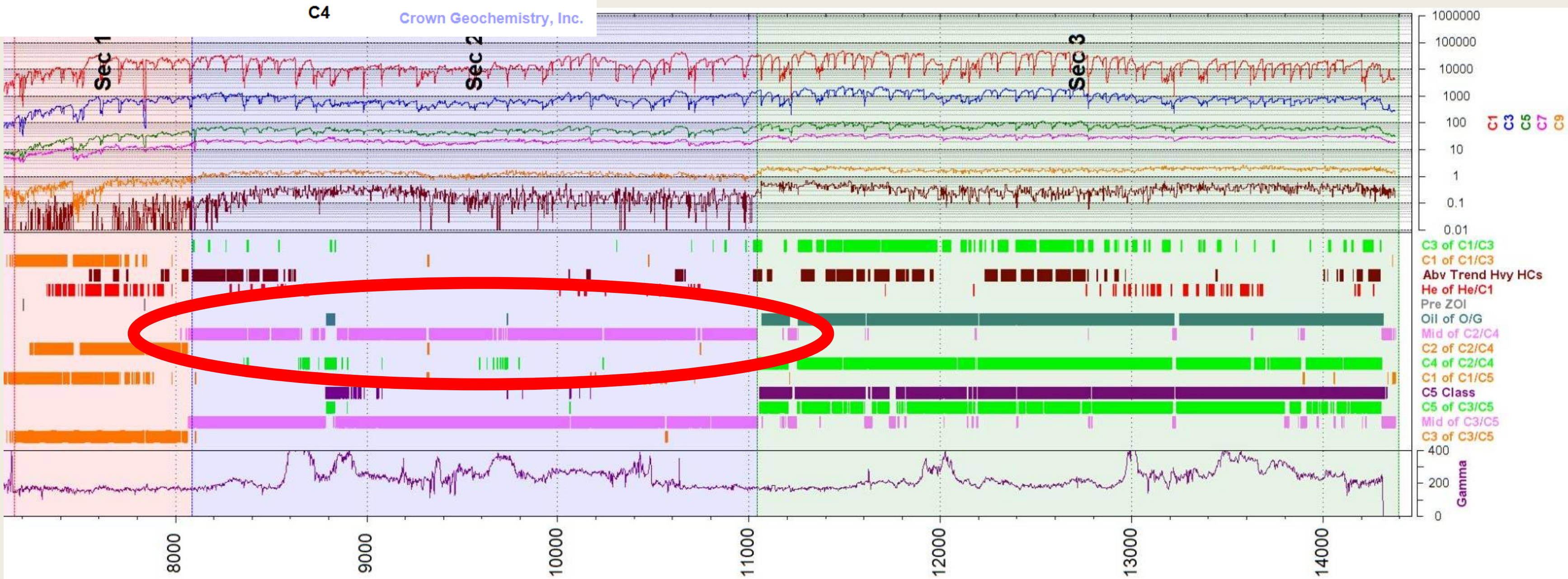


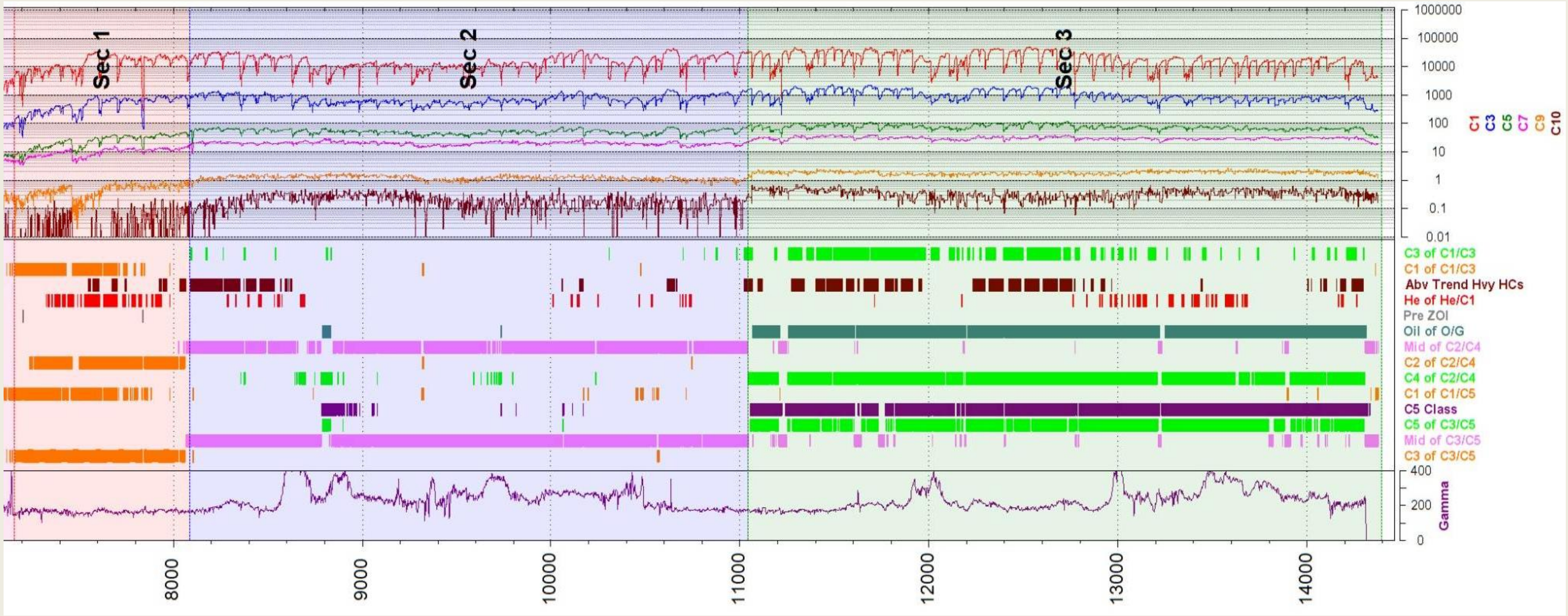


The blue data points from the cross plot chart were made to be blue by selecting a depth range and choosing blue as the color for that range as in Sec 2 above.



These same data points (made blue by choice to indicate data from the depth range of Sec 2) are here wrapped in a pink filled polygon, albeit a faint pink. Any data points falling within that pink polygon on the x-plot have pink hash marks in the DNA-looking display. See the red-circled inset.





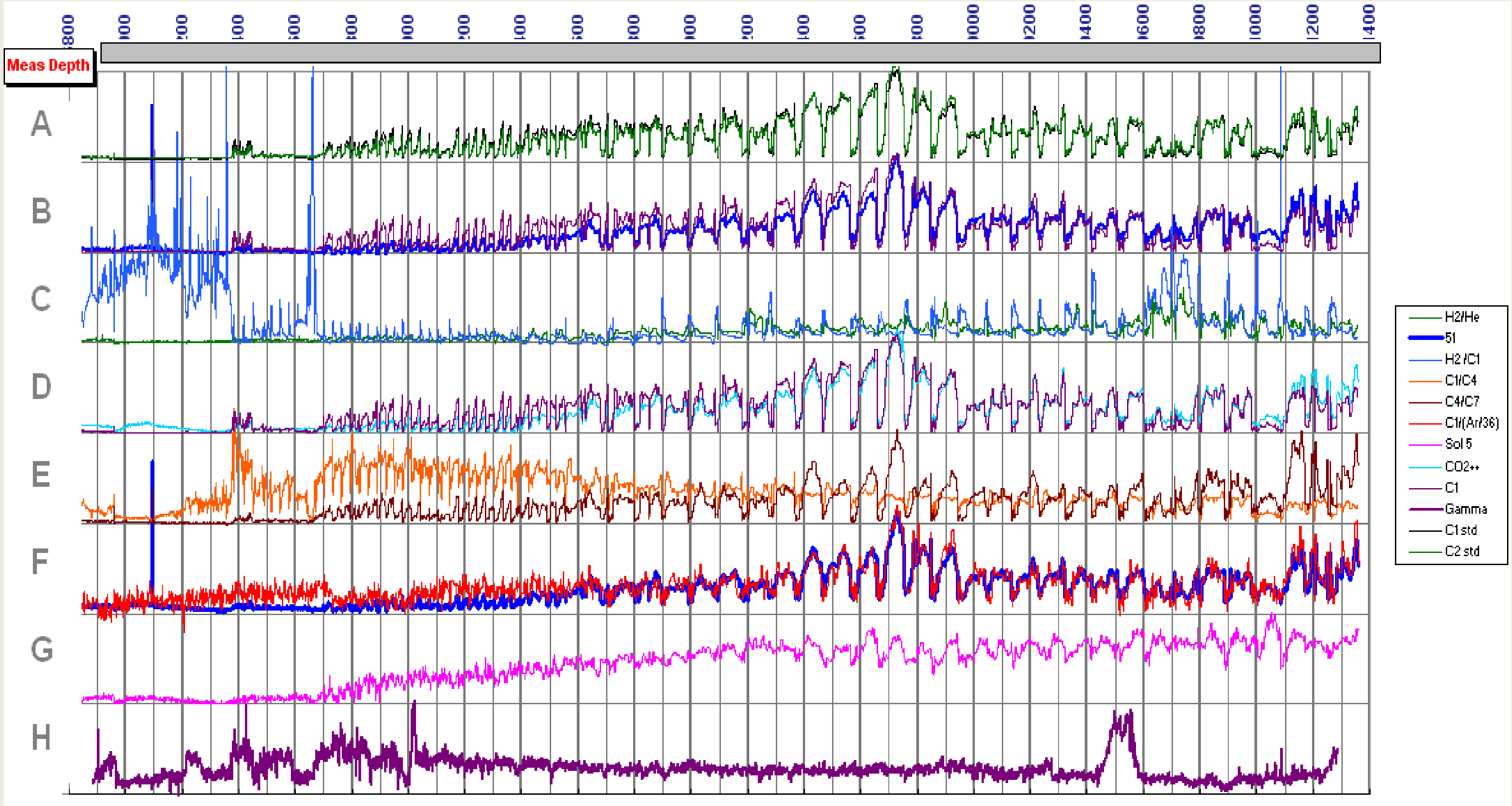
So, instead of trying to look at curve data visually we have tested a number of x-plots, chosen analytic conditions, and displayed these as “DNA”. This type of analysis is not all that we do with gas data; we make smaller footage range x-plots for instance, but this is an essential part of our flow compartments analysis.

What they knew at the end of the 18th century that still applies today is that gas physics laws, like the ones we covered earlier in the talk, unlike the speed limit, are not optional. They can't be broken by geologists for convenience.

If I release helium into a container the size of an office room in one corner, the helium pressure to nitrogen in the farthest corner will very quickly and very effectively equilibrate.

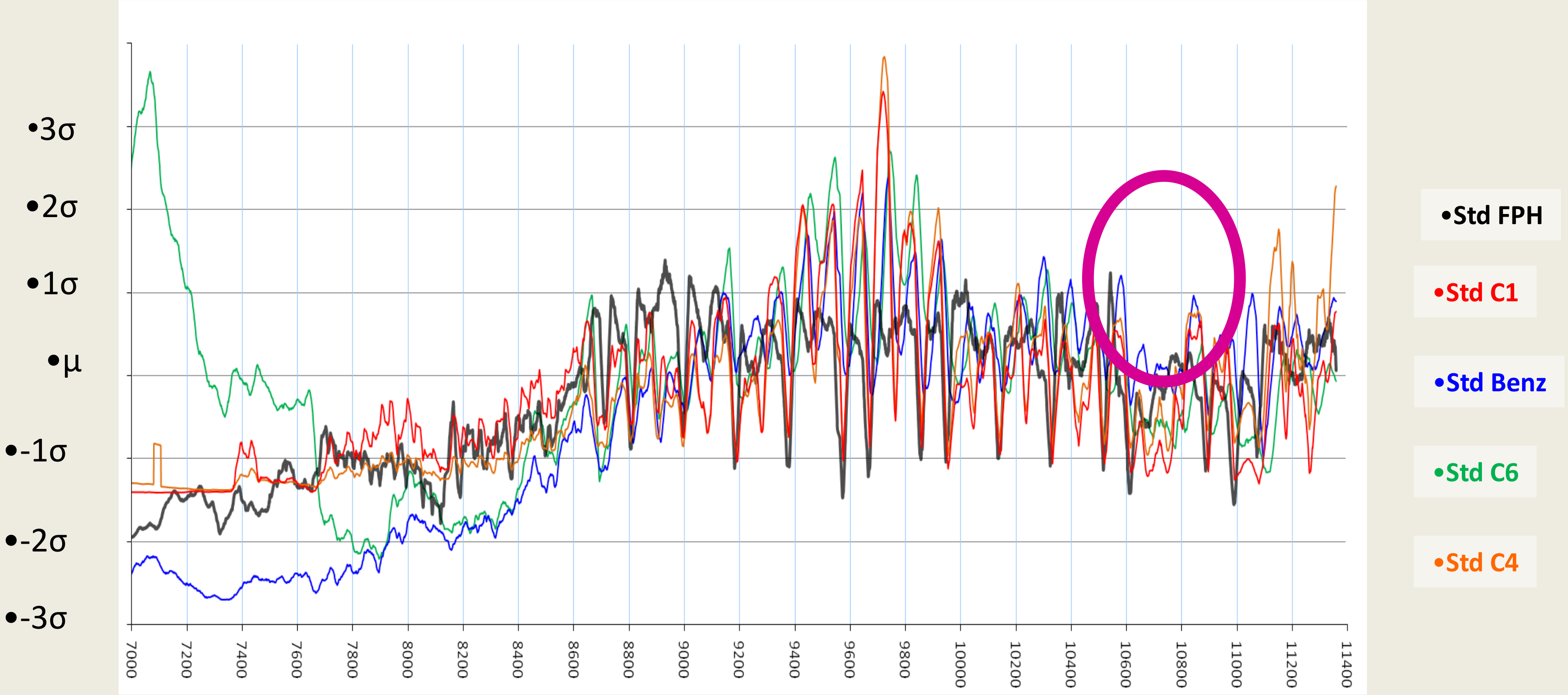
If a drill bit then penetrates the “room” the gas being circulated back up, if at different component ratios, would indicate that the bit had gotten in to a new room and where it had done so. How tall or wide the “room” might be would not be predictable, but how far over to the other side could be if we drilled that far.

From: **Multiplot Lateral Analysis guide**



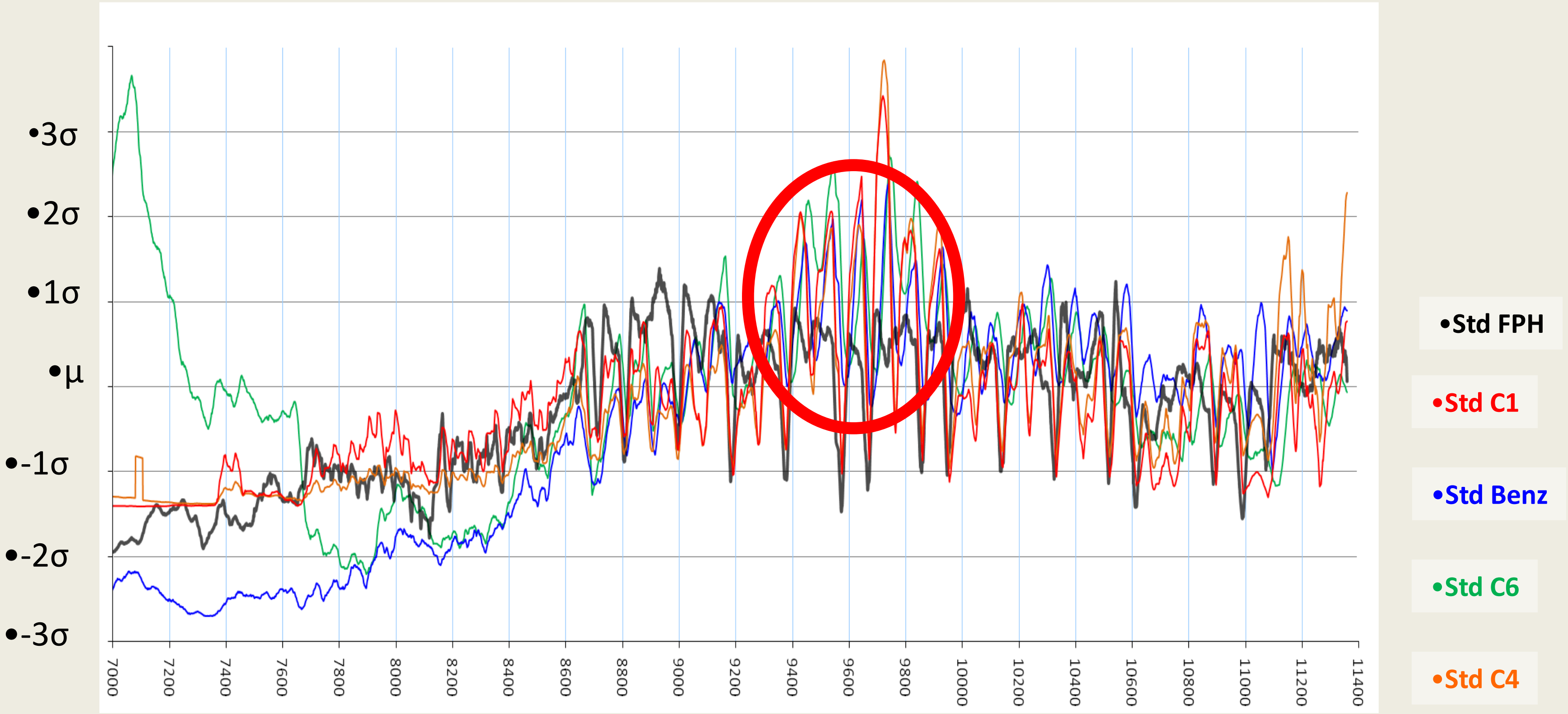
This particular well happens to have very good gas data (collected with the patented new Gas Cannibal ™ gas extractor from F.I.T. Inc.). This lateral has only mild stratigraphic variation helping isolate interpretation techniques. Certainly things may be learned using this type of linear graph in conjunction with other available analysis; for instance, the eye falls to the high apparent volumes toward the middle of and low values toward the toe of this lateral.

From: Std 2   **Standardized Data Lateral Analysis**



But here is the same data in Std Dev form. This circled inset highlights that toe portion of the data where the HC apparent volume drops very low. But so does ROP and the data for different produced HCs drops about the same as ROP does. This is nothing but reduced drilling rate, thus dropping the gas amounts as a rate arriving at the surface.

Also from: Std 2 **Standardized Data Lateral Analysis**



This circled inset highlights a portion of the data where the HCs remarkably out-perform ROP-predicted volumes. The HCs that are part of this anomaly are ALL of the HCs, and to about the same degree. This perhaps would not be the case if this were not a source rock shale. This footage section is suggestive of secondary porosity such as microfracturing.

Read that “SWEET SPOT” if you like.

Any Questions?