Pore Throat Controlling Liquid Yield in Shale — Mismatch Between Dry Produced Gas at Surface and Wet Gas or Condensate in the Reservoir*

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Abstract

In the search of liquid rich hydrocarbons in shale, abnormally dry gas has been occasionally encountered and produced in unexpected locations among otherwise wet gas or even condensate wells. In many of these wells, the isojar data, when available has shown compositions much wetter than the isotubes. Our preliminary series of studies integrating geochemistry and core analysis indicate a relationship between very small pore throats and larger hydrocarbon molecules being retained within the reservoir. Series of phase envelopes have been generated for each couplet isotube-isojar as a complement to a carbon isotope analysis and to Pixler plots (slightly modified for shale reservoirs). Our core based integrated work clearly indicates the link between pore throat and retention of larger hydrocarbon molecules. The larger the difference between the isojar and isotube phase envelopes being linked to a larger molecule retention problem. Such a combined sample analysis, after calibration with cores, can be successfully applied to the horizontal legs of any well, delivering a cheap but reliable way of looking at the shale reservoir quality in the absence of cores. As the lithological change is more gradual than in a vertical well, the difference between the phase envelopes of the isojar and isotube is more reliable, making the technique perfectly suited for horizontal wells; the depth match between isotube and isojar is much better in the horizontal part of the well. The same approach can also be used when comparing gas chromatography and blended cuttings gas samples. This comparison involving blended cutting gas is not new and was extensively used in the past in exploration wells as a semi-quantitative indicator of permeability. Applying the approach to shale is just a simple and natural step; it is relatively cheap, especially if blending is done at a later date in the lab and not at the well site. Pore throat apertures are directly linked to rock fabric and to mineralogical composition, the latter two can be addressed by XRF analysis of drill cuttings that gives the elemental composition of the rocks penetrated. To study old wells with no or limited gas composition data, integration between XRF and Phase Envelopes would thus allow extrapolation to areas and wells that may need a closer look.

Pore Throats Controlling Liquid Yield in Shale

Mistmatch between Dry Produced Gas at Surface
and
Wet Gas or Condensate in the Reservoir

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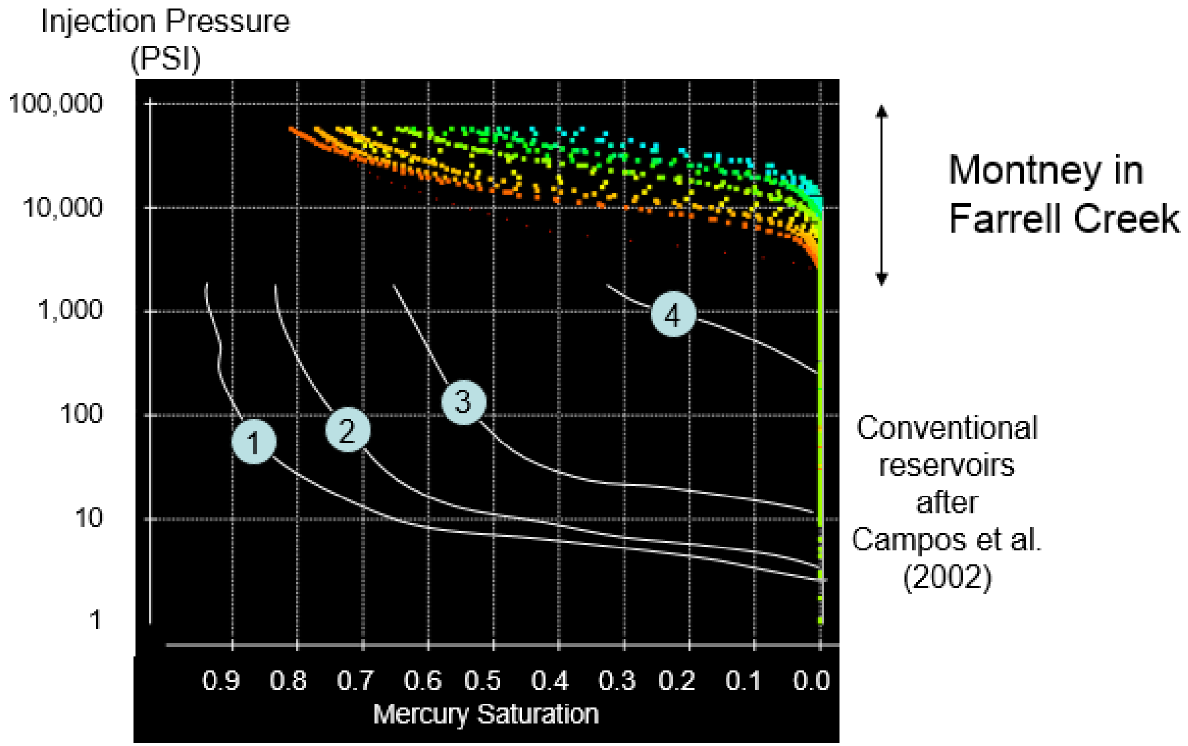
Talk Outline

- The problem:
  - Gas produced versus gas in the reservoir
  - Problem is common in many shale and tight sands
- The data
  - Isojars versus isotubes
- The approach
  - Capillary pressure curves
  - Phase envelopes and Pixler Plots
  - Discrepancies isojars-isotubes
- Conclusions

The importance of pore throat size

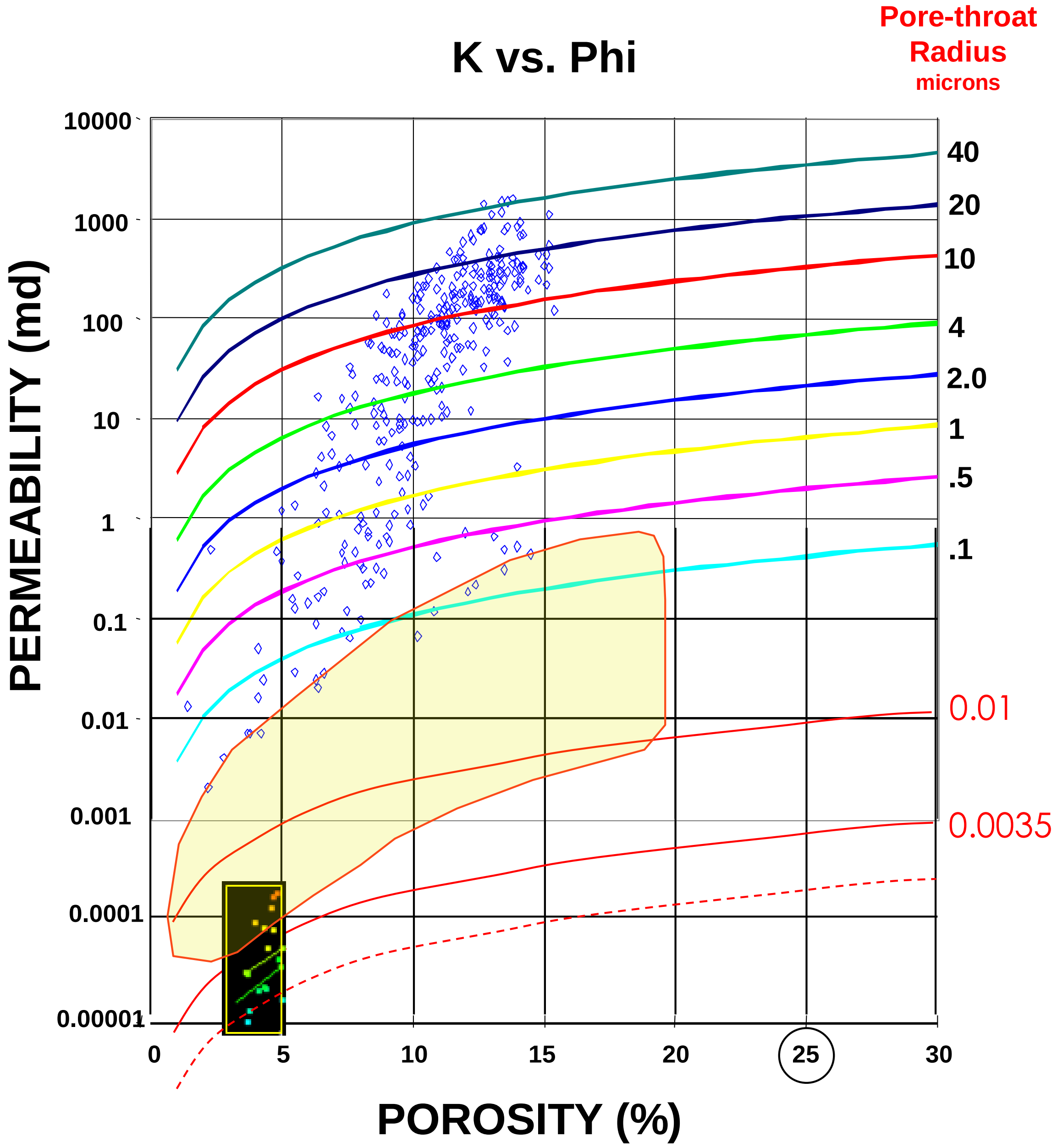
Cap curves of various Petrofacies



1 = Mega 2 = Macro 3 = Meso 4 = Micro

The Farrell Creek Montney samples colored lines at the top of the plot are associated with very high injection pressure compared with conventional reservoirs (white lines). We are dealing with a nanoporous semiconventional system.

The pore size distribution is a critical factor to the production of liquid rich gas (larger molecular sizes)

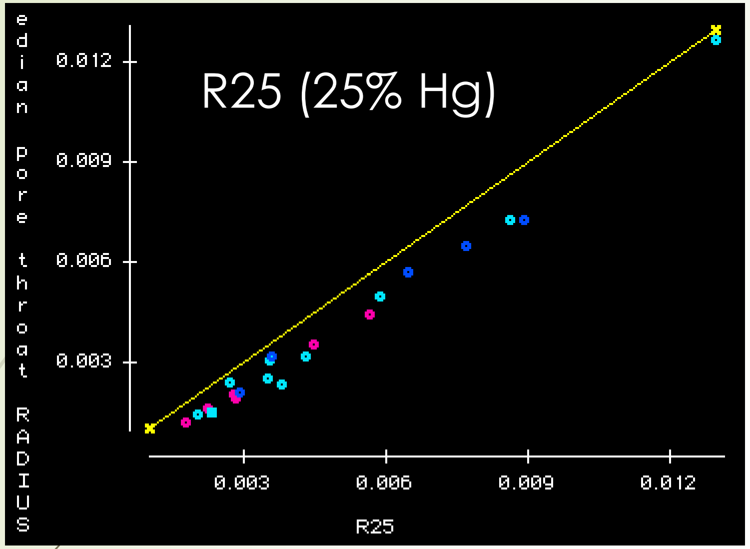


Petrofacies

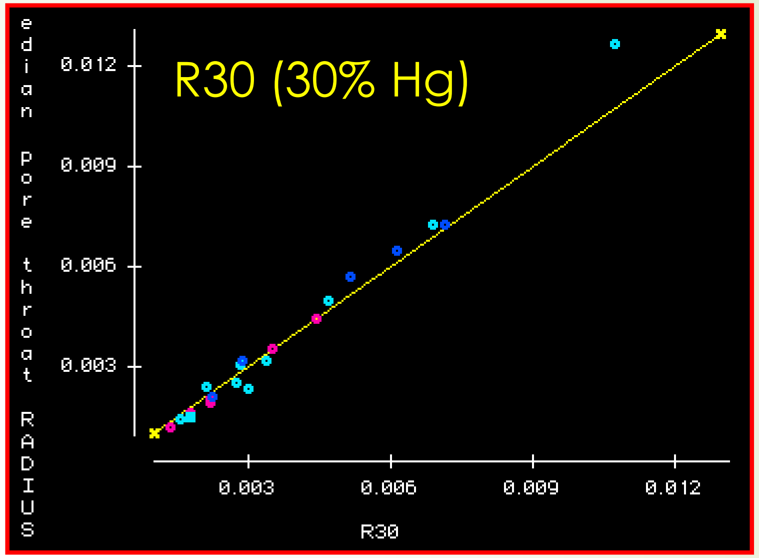
Petrofacies	
Mega	Based on 150+ Cap curves Venezuela (Santa Barbara) **Use 45% Hg**
Macro	
Meso	
Micro	
Nano Tight Sand	Based on 350+ Cap curves **Use 35% Hg**
Nano Hybrid Shale	Farrell Creek Cap curves **Use 30% Hg**
Nano Shale	Typical shale Cap curves **Use 25% Hg**

Modified after Campos, Chatellier et al 2002

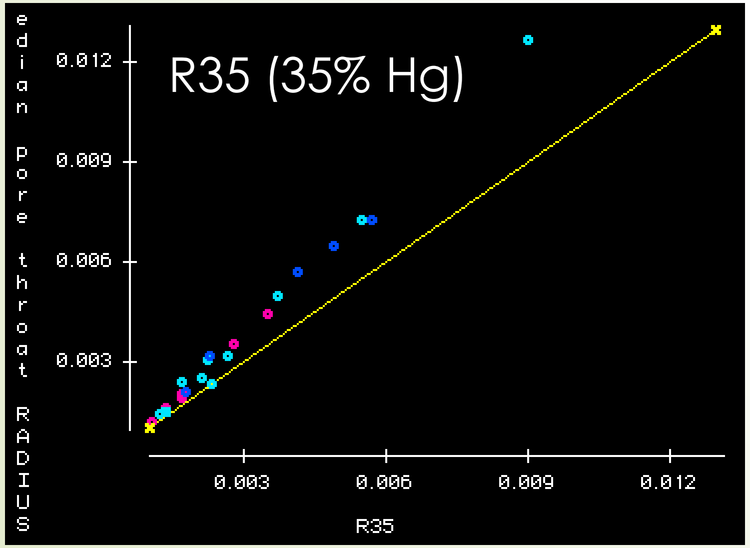
For Montney need to use 30% mercury saturation



Log R25 = 0.204 + 0.531 * Log Ka - 0.350 * Log Φ



Log R30 = 0.215 + 0.547 * Log Ka - 0.420 * Log Φ



Log R35 = 0.255 + 0.565 * Log Ka - 0.523 * Log Φ
(Pittman, 1992)

Using R35 (35% SHg)
underestimates
the pore throat size
in Montney

NEED TO USE R30

The important difference between reservoir and surface gas geochemistry

using historical data

- **Isotubes**: Continuous free gas profile

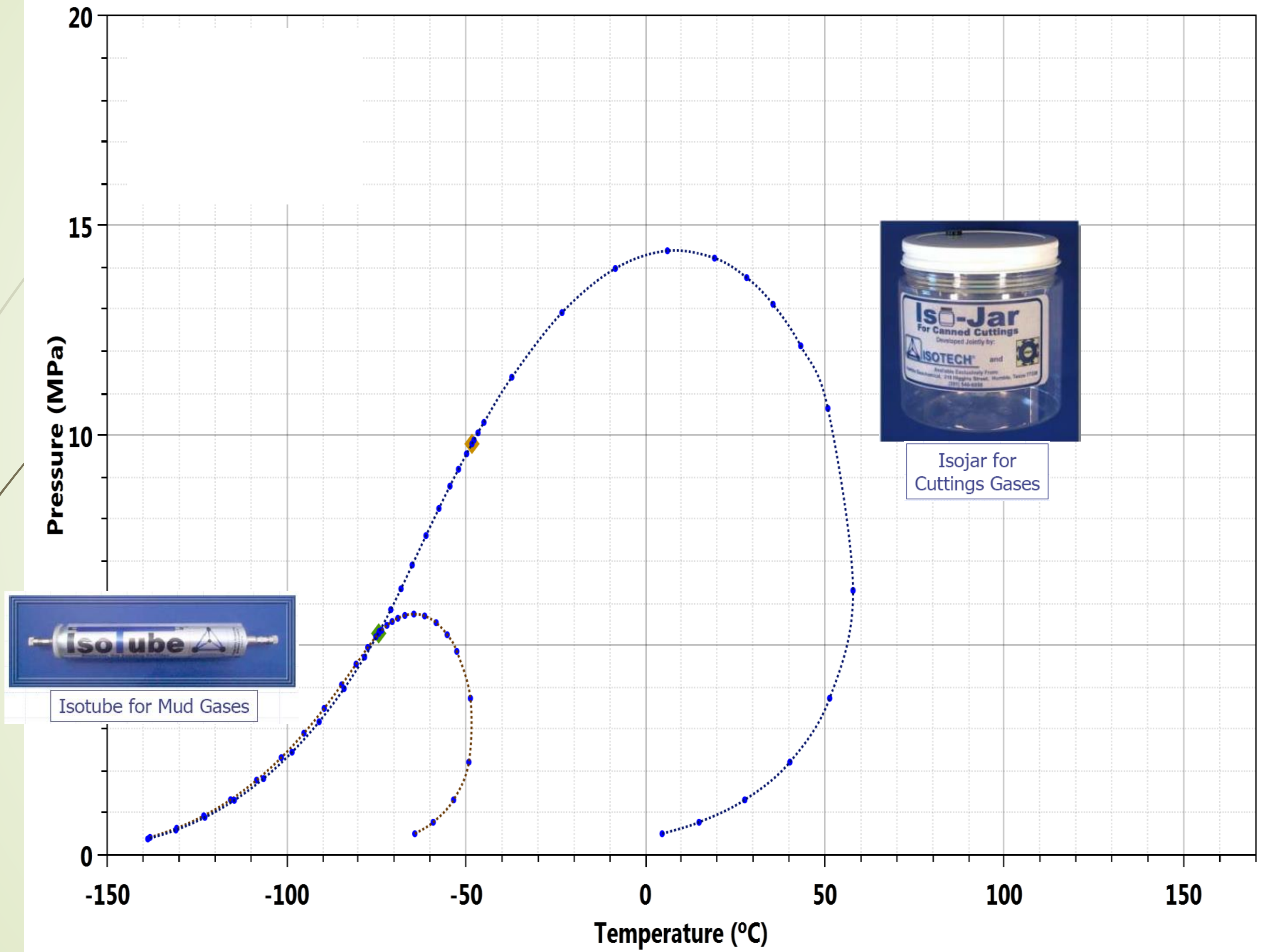
Isotube for Mud Gases

- **Isojars**: Closer to reservoir gas geochemistry

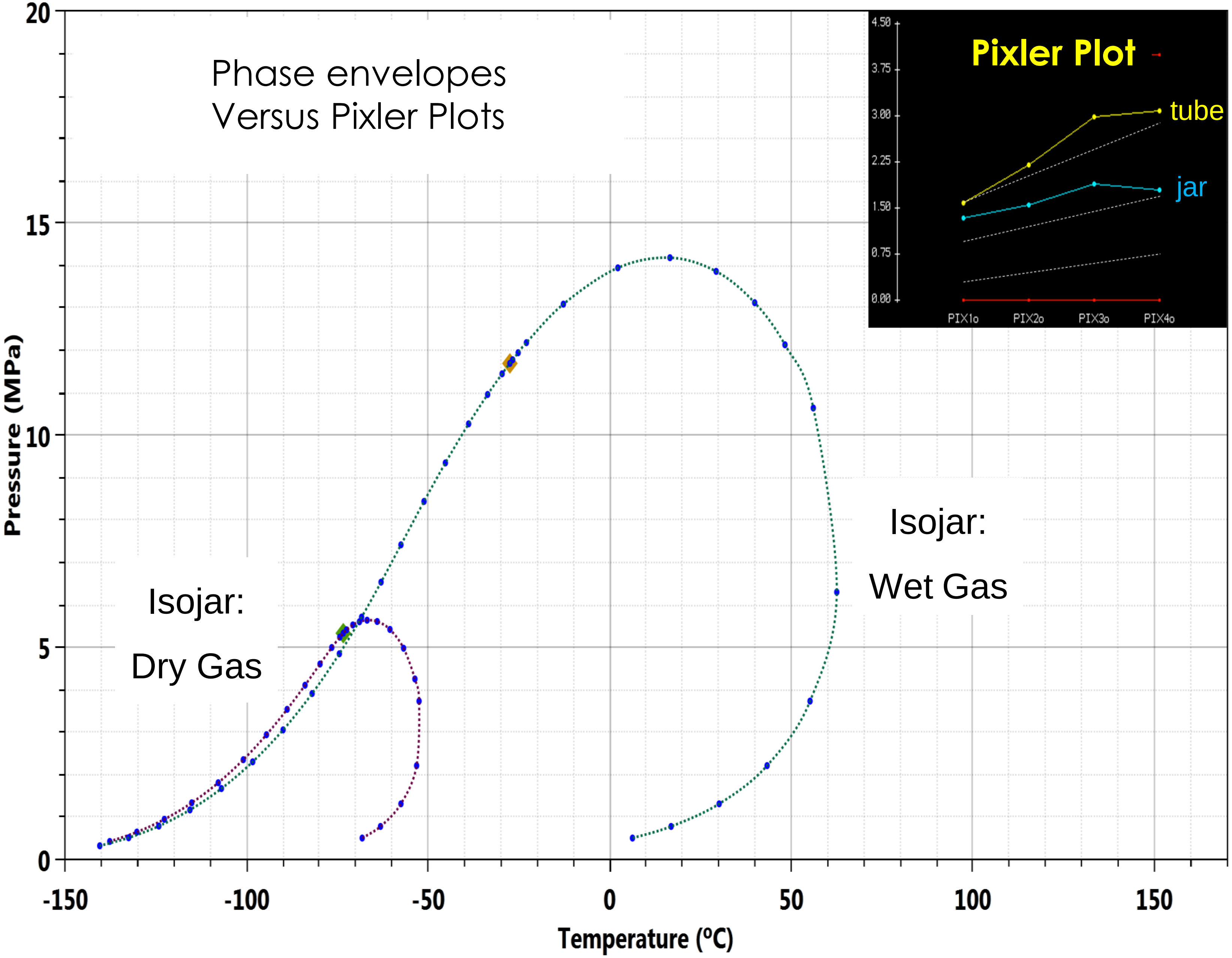
Isojar for Cuttings Gases

- **Difference** Proxy to pore throat size

Phase envelopes

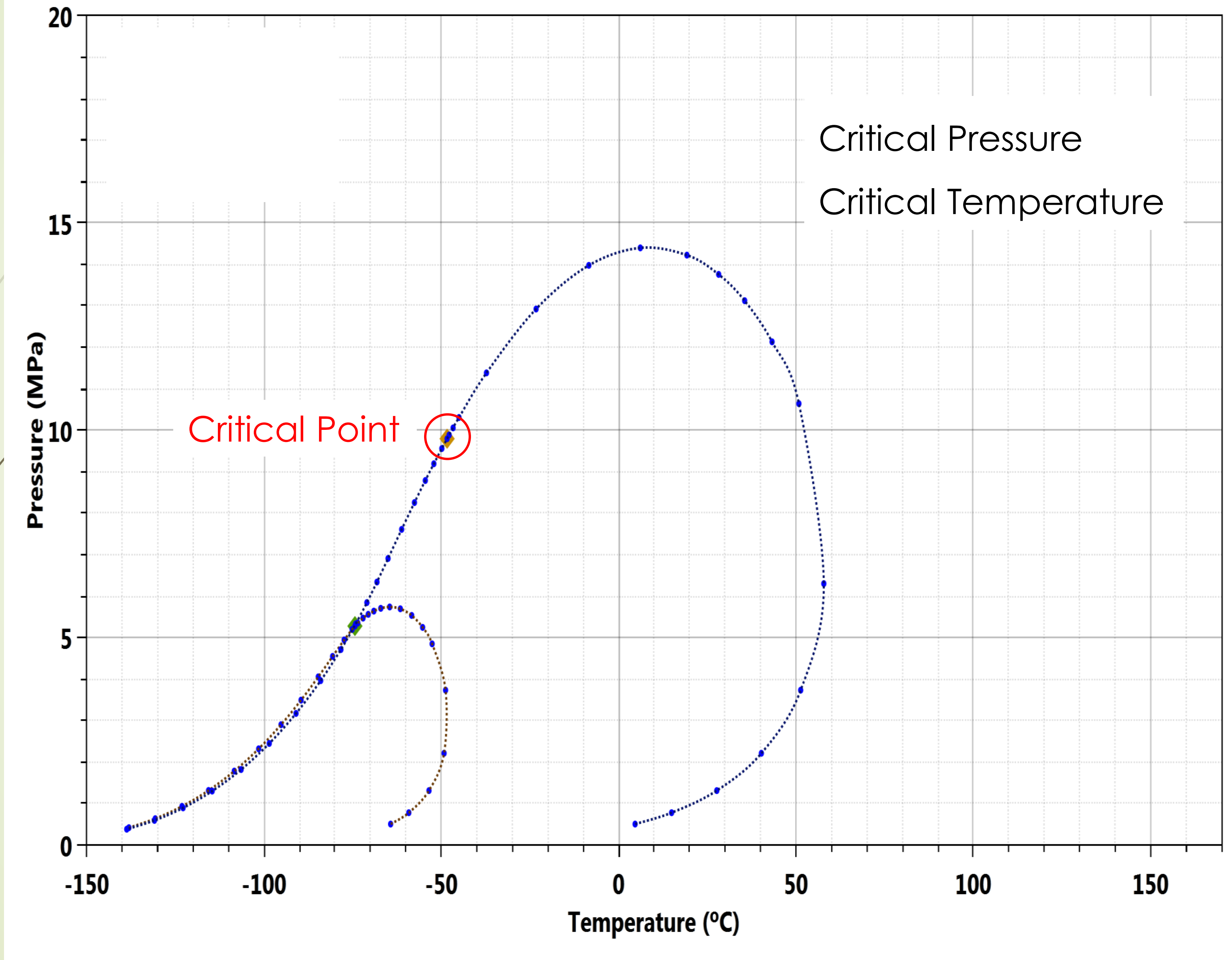


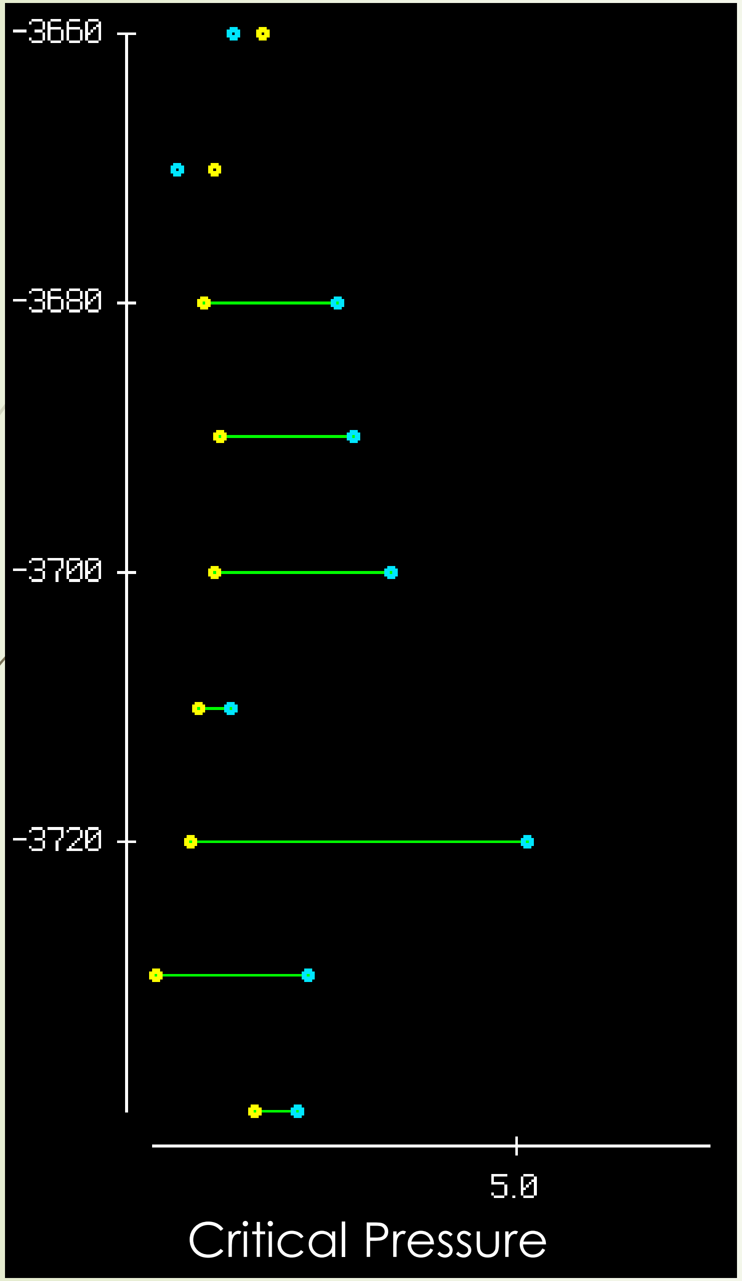
Phase envelopes Versus Pixler Plots



The Critical Points

Phase envelopes

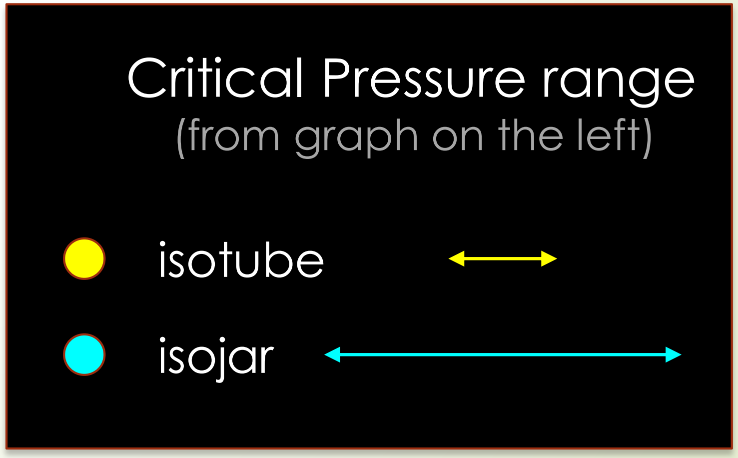


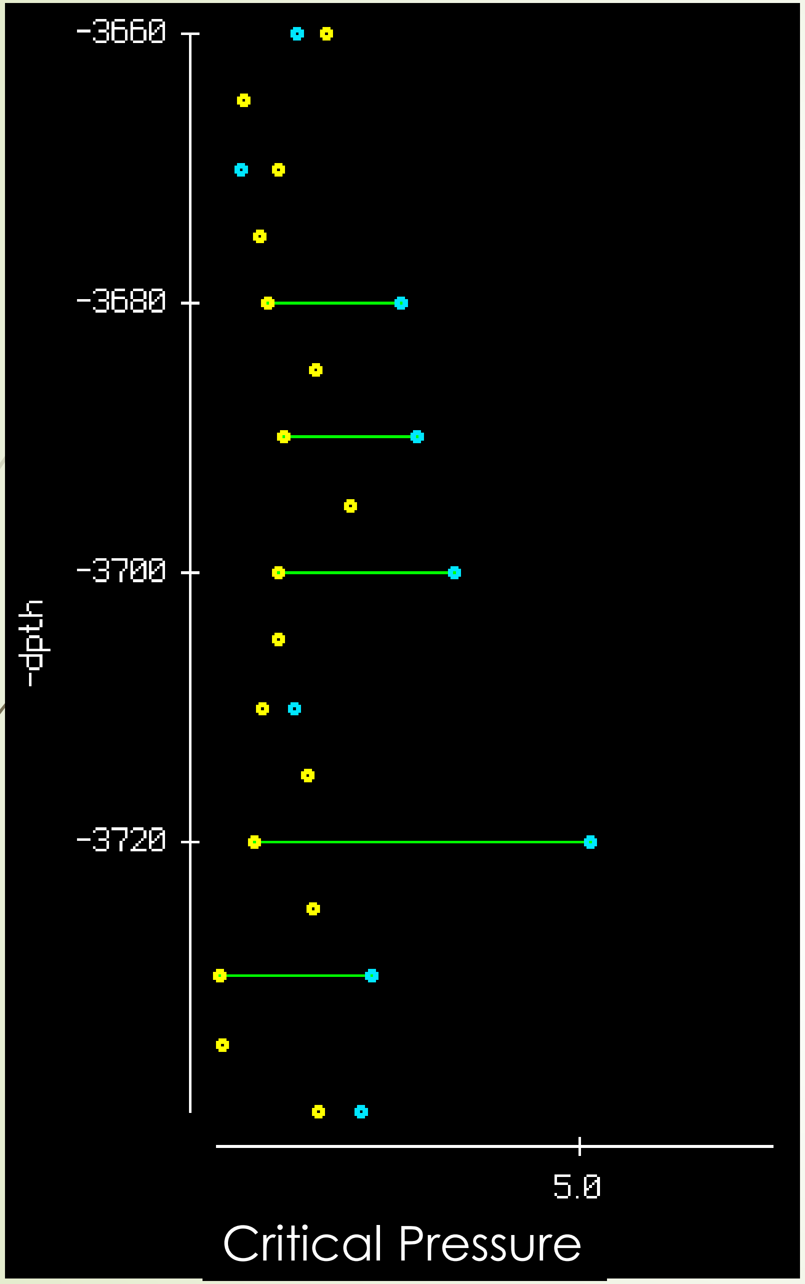


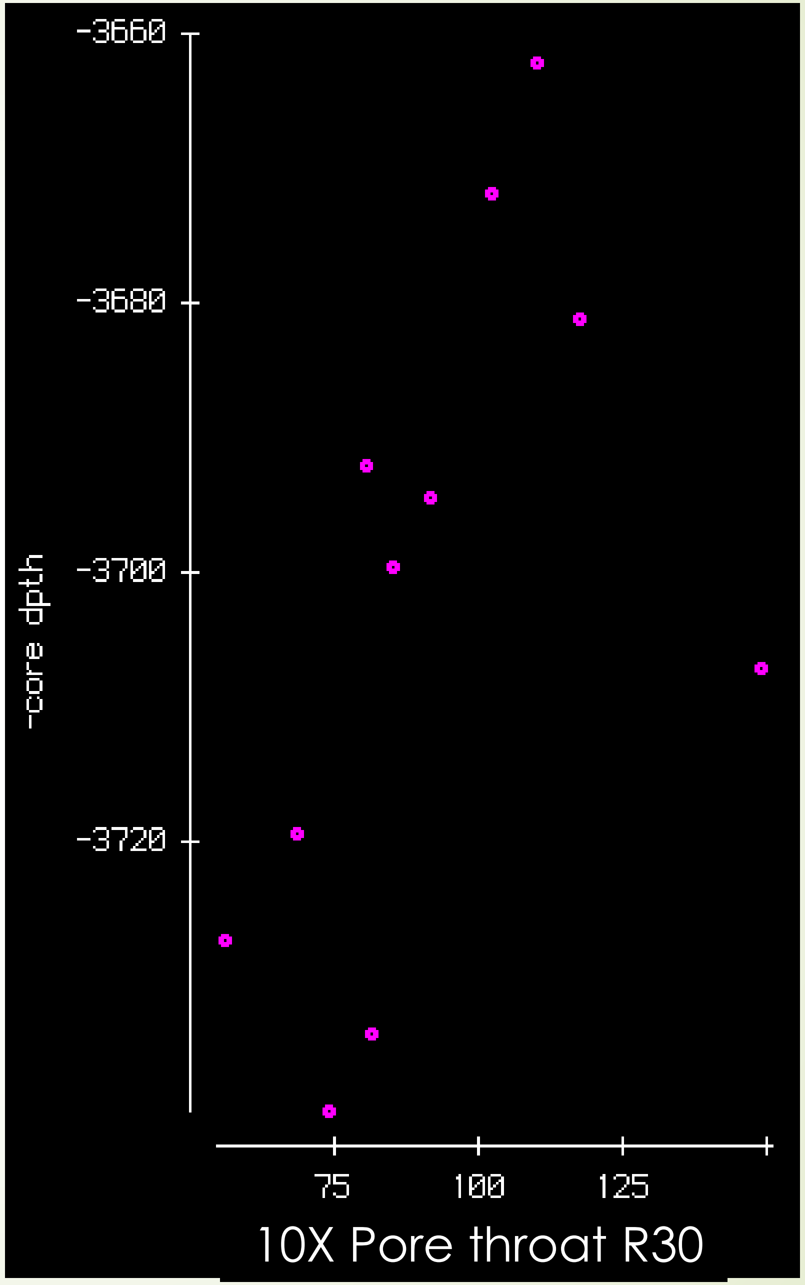
Critical Pressures

The samples here plotted are when both isojars and isotubes have been taken at the same depth; other samples were taken but not plotted

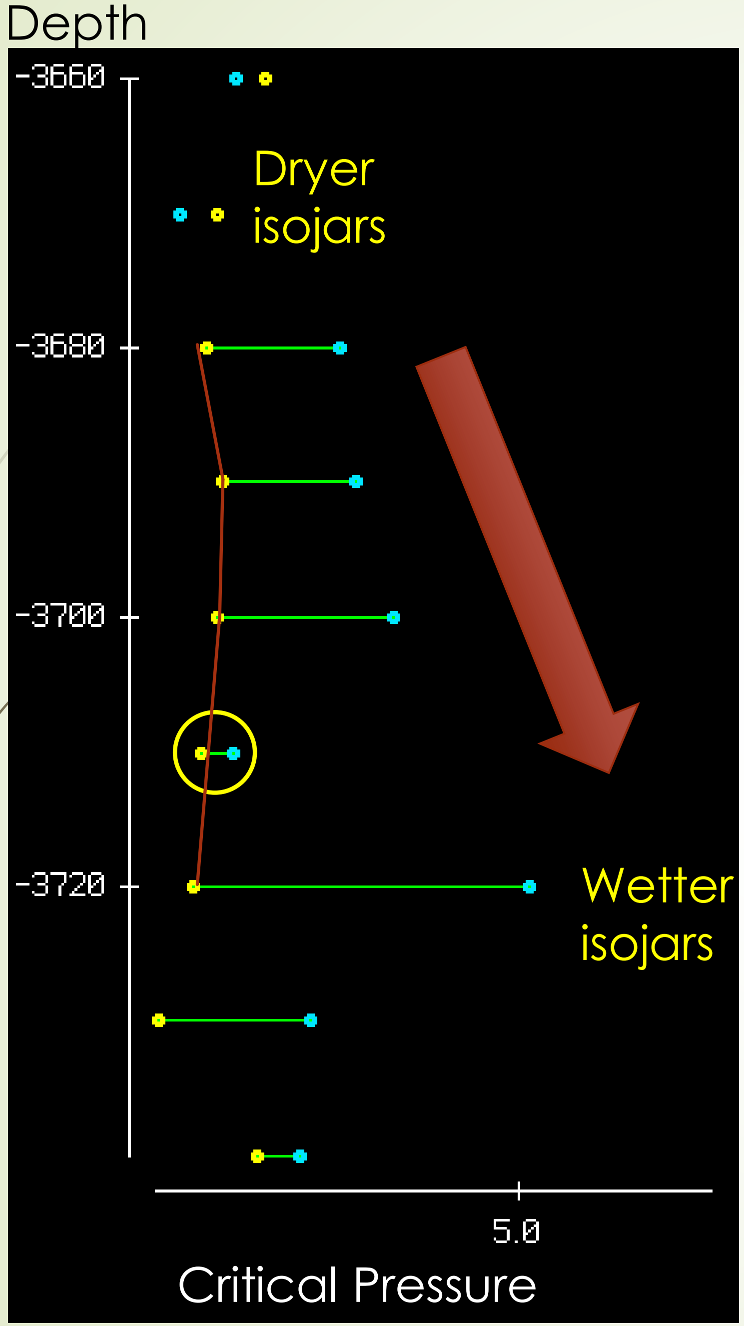
The isotube Critical Pressure has a narrower range than the isojar. The difference between the two is expected to relate to pore throat size

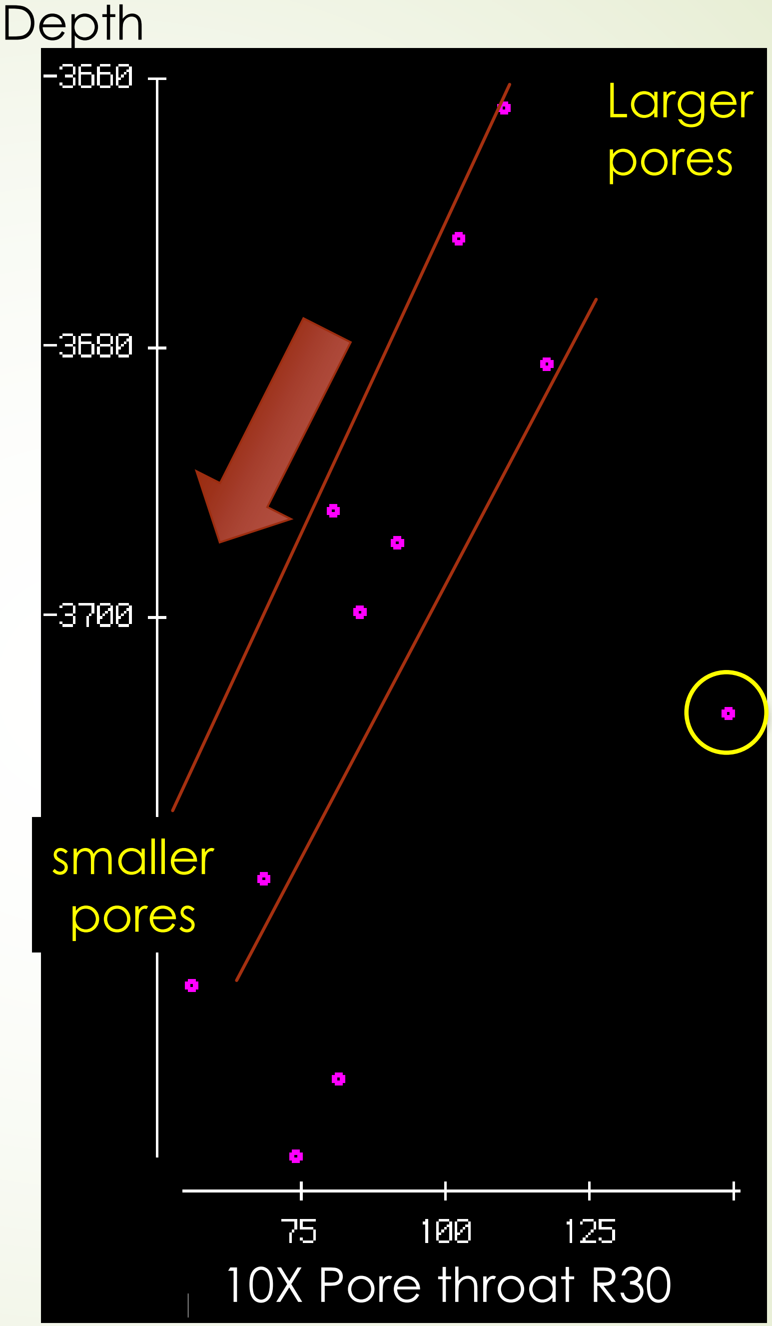






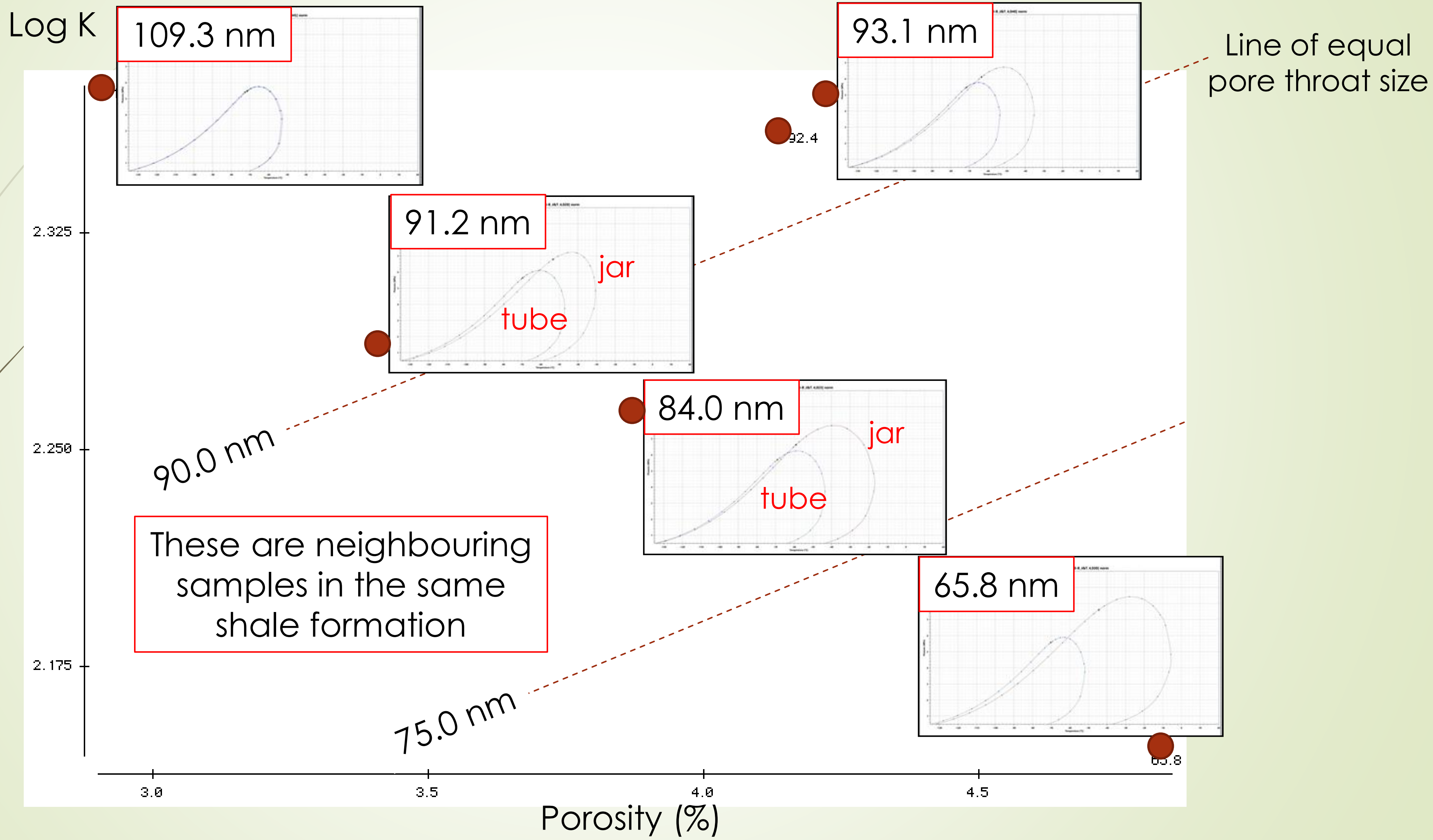
Gas samples and MICP (cap curves) are taken at different depths





Large pore
=
low critical pressure for isojar

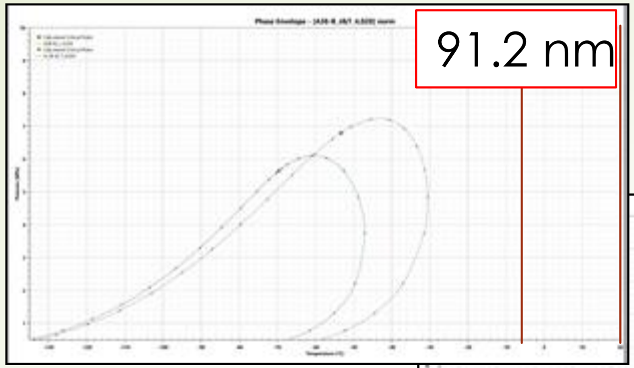
Tighter Pores Linked to Trapped Hydrocarbons

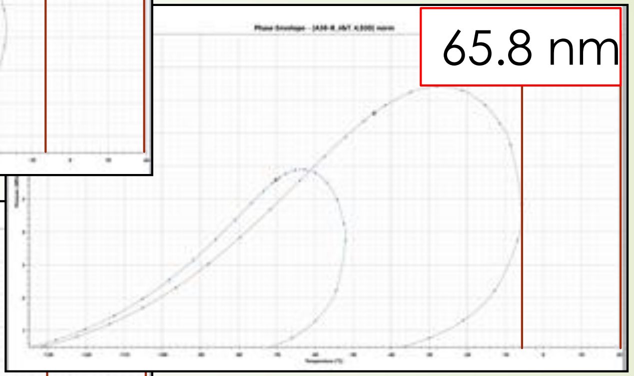


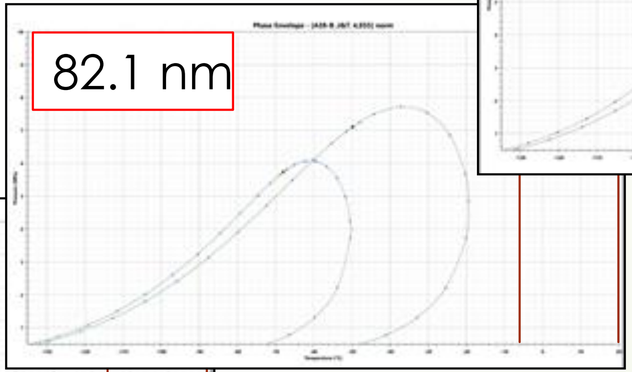
Rapid change in pore throat size

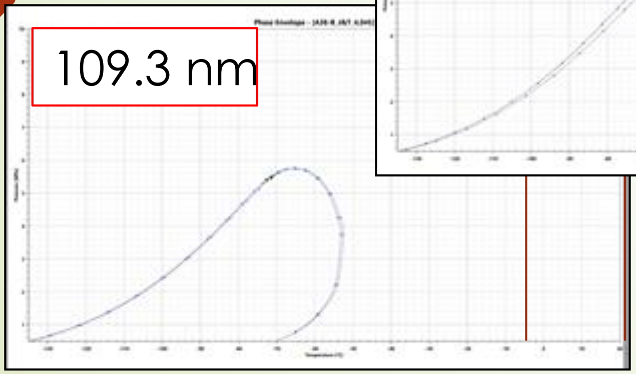
Hydrocarbon wetness of the isojars is seemingly linked to pore throat size:
Smaller pore throat
= wetter gas

5m







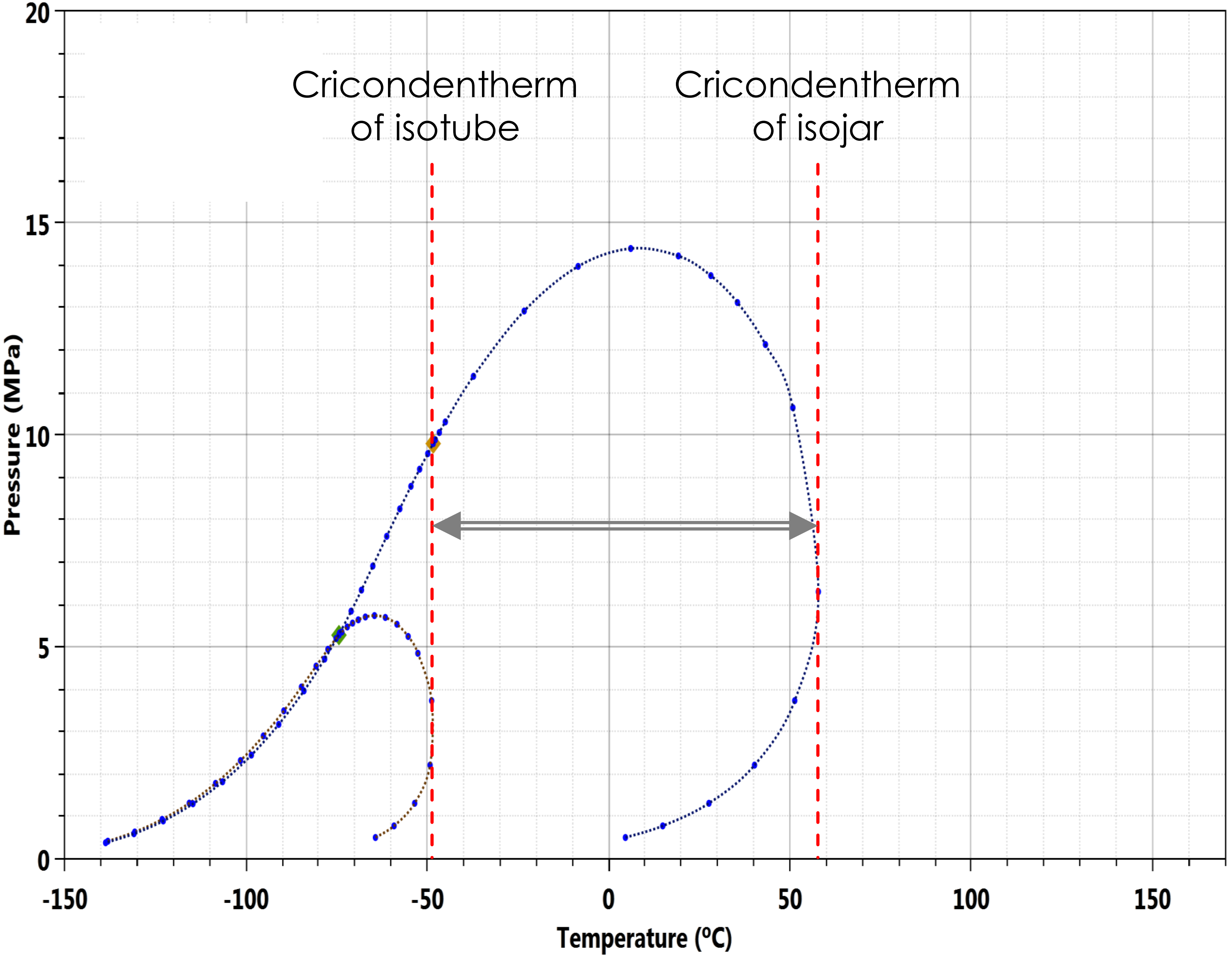


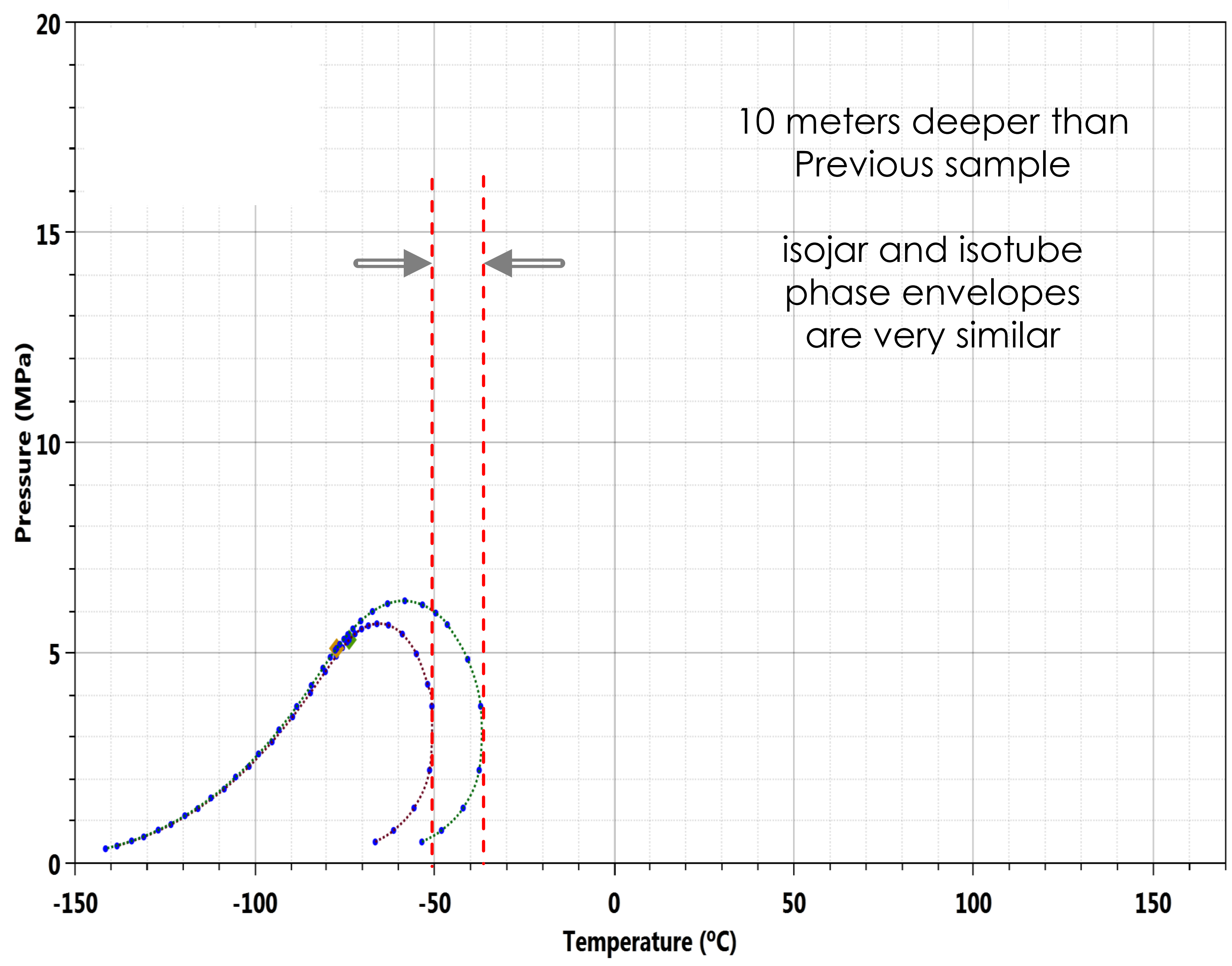
Pore throat is based on 30% Hg cap curve

All of the isotubes have very similar composition and similar phase envelopes

Cricondentherms and Cricondenbars

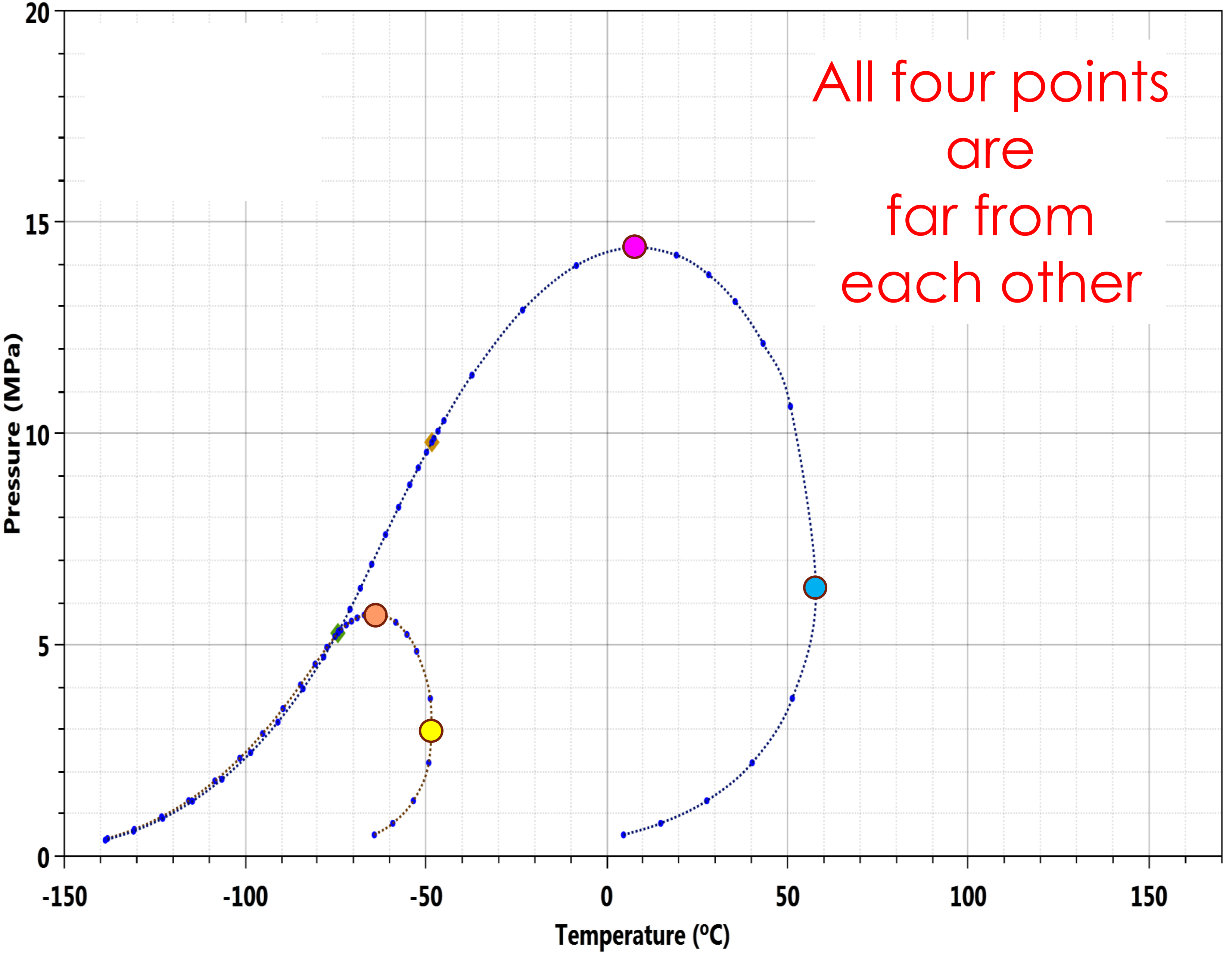
Cricondentherms

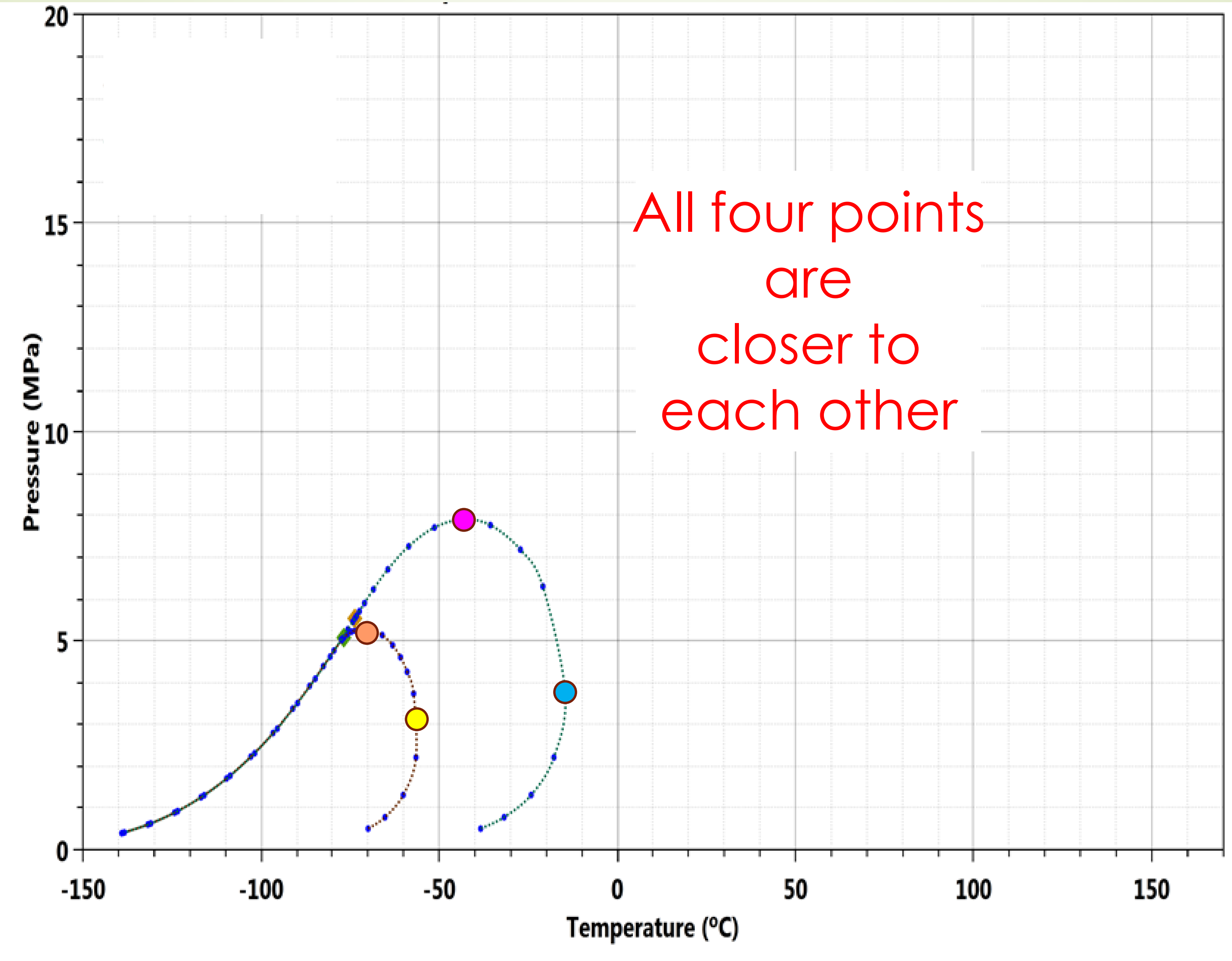




20
15
10
5
0
Pressure (MPa)
-150
-100
-50
0
50
100
150
Temperature (°C)
10 meters deeper than
Previous sample
isojar and isotube
phase envelopes
are very similar

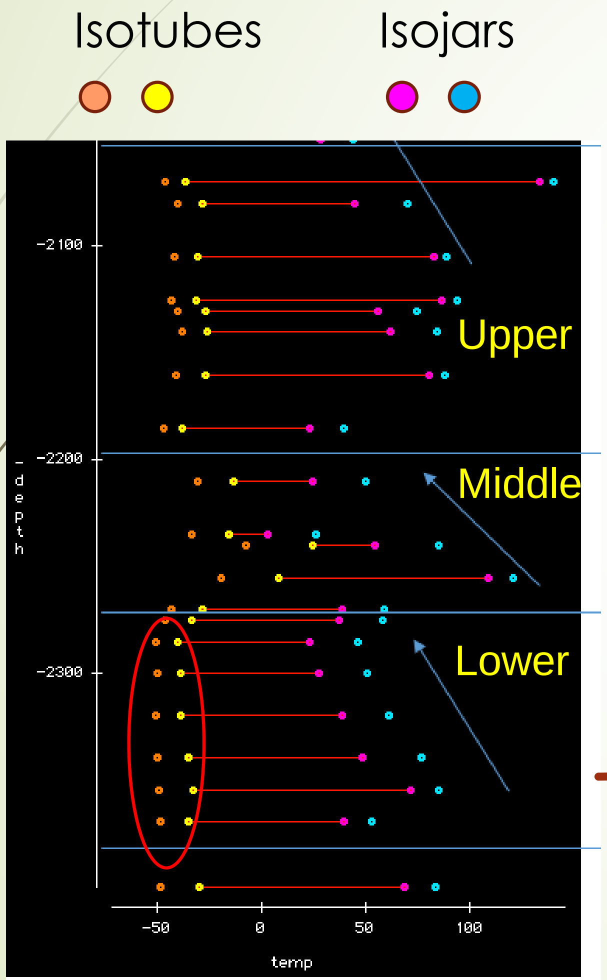
Cricondentherm



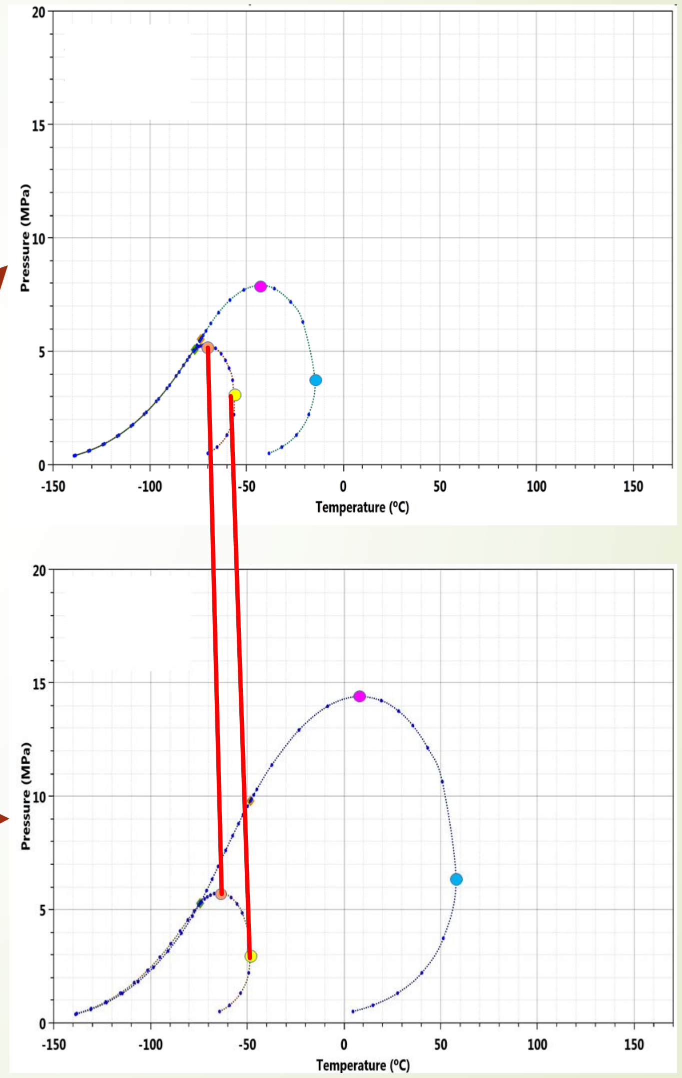

All four points are closer to each other
Pressure (MPa)
Temperature (°C)
20
15
10
5
0
-150
-100
-50
0
50
100
150

Learning from a 300 metre thick Montney

Isotubes



PVT Cricontemperatures

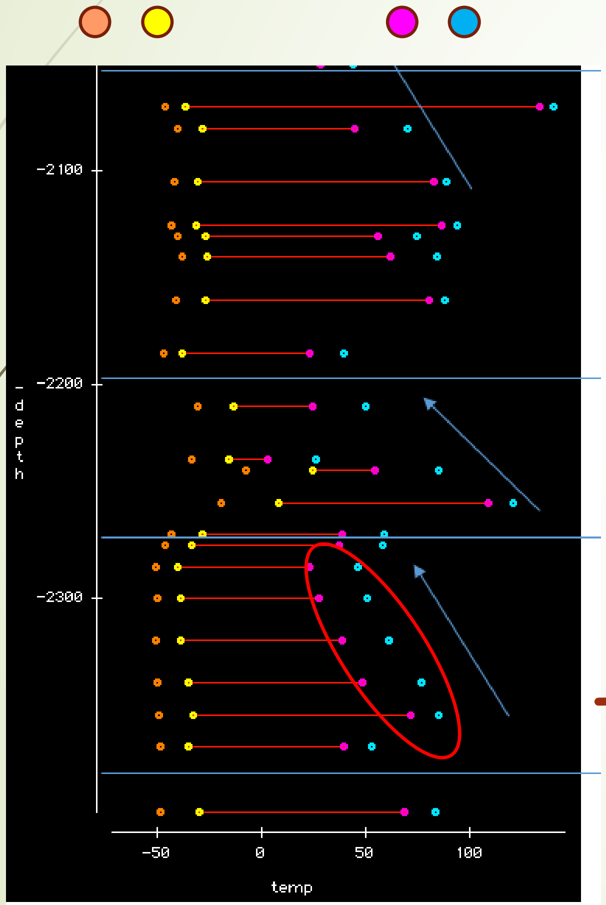


Extremely similar gas compositions as seen by the isotubes in Lower Montney

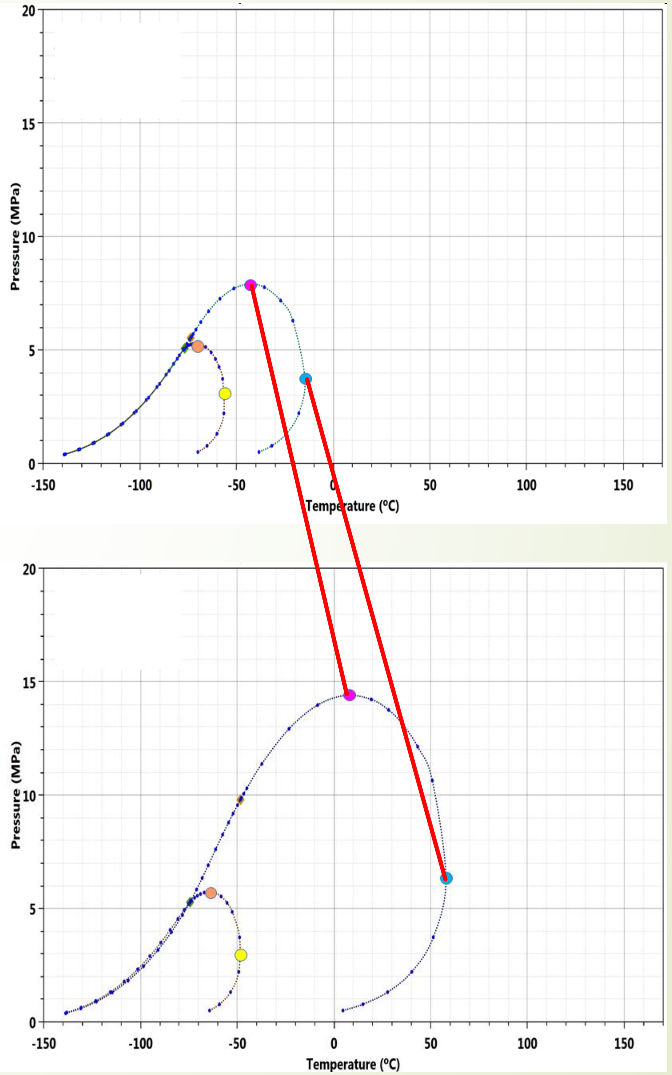
Learning from a 300 metre thick Montney

Isojars

Isotubes Isojars



PVT Cricontemperatures



Gradual change
in
gas compositions
seen by
the isojars
in Lower Montney

Observations are
in agreement
with a coarsening
upward sequence
associated
with increasing
pore throat sizes
upward

Solving the isojar problem

In the jar, gas is released through time from the cuttings

Time of sampling may vary and

In some cases that may introduce large differences

Blending the cuttings

That will take away the time dependency

New approach to pore throat size

and hydrocarbon pore blocking

- **Chromatograph**: Continuous free gas profile
- **Blended cutting gas**: Real reservoir gas geochemistry
- **Difference** Best proxy for pore throat size

Workflow for pore throat size assessment

Free gas sample → Gas Chromatograph or isotube → Phase envelope

Difference = pore throat

Cutting gas sample → Blended cuttings gas chromatography → Phase envelope

Workflow for “pore blocking phase” assessment

Identification of Pore throat restriction → Identification of Mineral phase blocking → Montney Case → Proxy to Bitumen plugging

Difference Between jars and chromatograph → XRF on blended cuttings → Silica cement using Si/Zr; Carbonate cement Using Ca/Mn → if no cement Problem = bitumen

Can be done on complete horizontal wells very cheaply

Because you have the XRF on the cuttings you also have the **brittleness**

Conclusions

- Vital need to integrate different aspects of the pore system
- Understand pore throat size restriction
  - Mineral phase restrictions (quartz or carbonate cement)
  - Bitumen restriction
- Solution proposed
  - Gas chromatography with blended cutting gas and XRF
  - Phase envelope analysis of collected gas
- This is Cheap, Fast, Reliable and can be very Useful