

Overpressure in Shale Gas – When Geochemistry and Engineering Data Meet and Agree

**Jean-Yves Chatellier¹, Kevin Ferworn², Nabila Lazreg Larsen³, Steve Ko³, Pawel Flek¹,
Marianne Molgat¹, and Irene Anderson¹**

¹*Talisman Energy Inc., Calgary, AB, Canada*

²*Geomark, Houston, Texas*

³*Talisman Energy Inc, Pittsburg, Pennsylvania*

A multidisciplinary study has shed a new light on the process of overpressure in shale gas reservoirs. The work consisted of the integration of a large geochemical data set with hydraulic frac and reservoir pressure data from the same wells. Results from this integrated approach suggest that distinct pressure domains exist and that their specific depths and attributes can be easily determined. Whereas various geochemical analyses give conflicting results at first glance, our study shows consistency in the results especially when engineering data is invoked in the analysis.

Diverging gas composition results have been obtained when using varying sampling techniques. Geochemical compositions from chromatography that may be displayed and interpreted in various ways (Fig. 2a) differ from either geochemical compositions measured from iso jars (cuttings) or from isotubes (free gas), the latter exhibiting the highest methane content. In stark contrast, both ethane and propane carbon isotopes give matching and consistent values at similar depths despite the sampling differences (Fig. 2a, pink dots are from isotubes, yellow dots are from iso jars, open circles are from a neighboring well).

Thus three geochemical domains can be defined by their characteristic depth trends in ethane and propane carbon isotopes (Fig. 2a). A shallow domain is characterized by normally increasing isotope values (less negative) with depth. An intermediate domain is characterized by a reverse isotopic compositional trend (more negative with depth). The deeper trend is again normal with increasing isotopic values with depth, however the values are much more negative than in the shallow domain; note that this deeper trend is much more linear when dealing with Ethane isotopes.

Using the geochemistry results as a starting point, frac gradients and reservoir pressure gradients are examined and re-analyzed. This integration exercise has revealed how at least two pressure domains (pressure gradients) are present: a normally pressured domain and an over-pressured one. The traditional way of calculating a pressure gradient (reservoir or frac) is simply dividing the pressure value by the depth (Fig. 1b); however our data sets indicate that individual gradients could be derived for each well (or each geographic/tectonic area) and that their intersection with the normal lithostatic gradient (18.48 kpa/m) is where geochemistry is indicating the onset of overpressure (Fig. 2a).

Over-pressured systems can thus be estimated by geochemistry using any of the following parameters, either independently or in combination: gas composition, gas carbon isotope signatures and Rock-Eval data (Tmax). Each of these tools has its inherent strengths and limitations as do the various methods of collecting data, all of which will be reviewed.

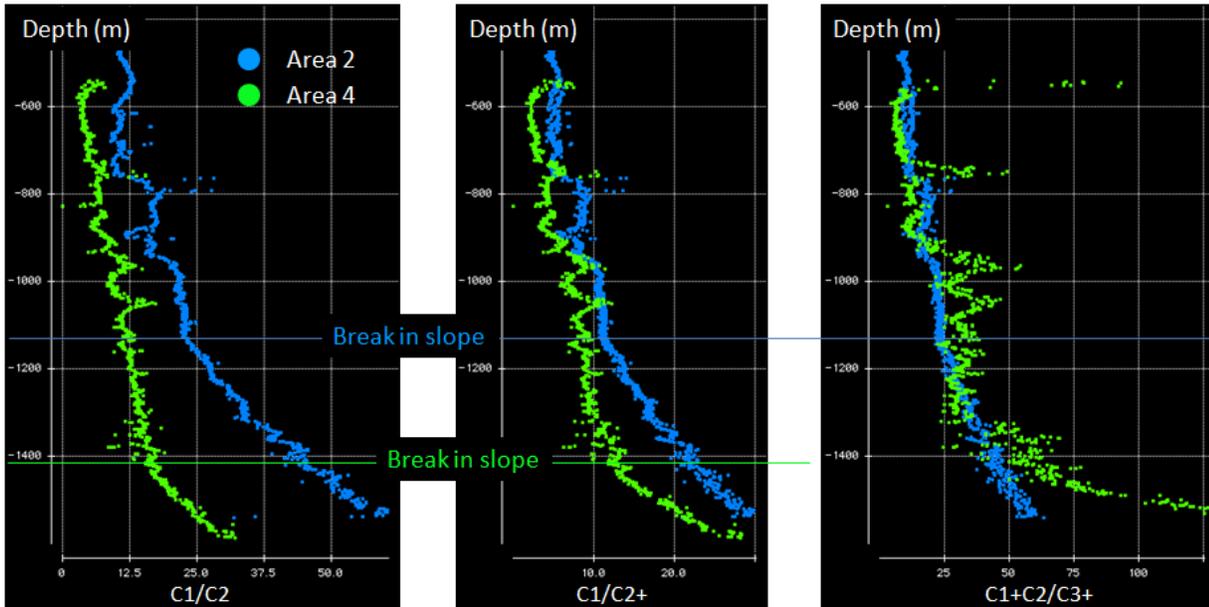
The recognition of two main pressure domains has important implications for well design, loss control management and optimal target depth identification. Furthermore, once the depth of the “normal pressure – overpressure” interface is known (from geochemical analysis in the current well of interest or from neighboring wells) reservoir pressure prediction can be derived from the frac data and vice-versa (Fig. 2a). Figure 2b shows that Tmax is deemed unreliable below a certain depth especially when

compared with the vitrinite data that show a linear trend of increasing values with depth. The depth of onset of overpressure predicted from hydraulic frac data is in the depth range below which Tmax is unreliable; in some wells the Tmax data seem to mimic the isotope reversal behavior associated with overpressure; however the hypothetical link between the two phenomena needs to be investigated.

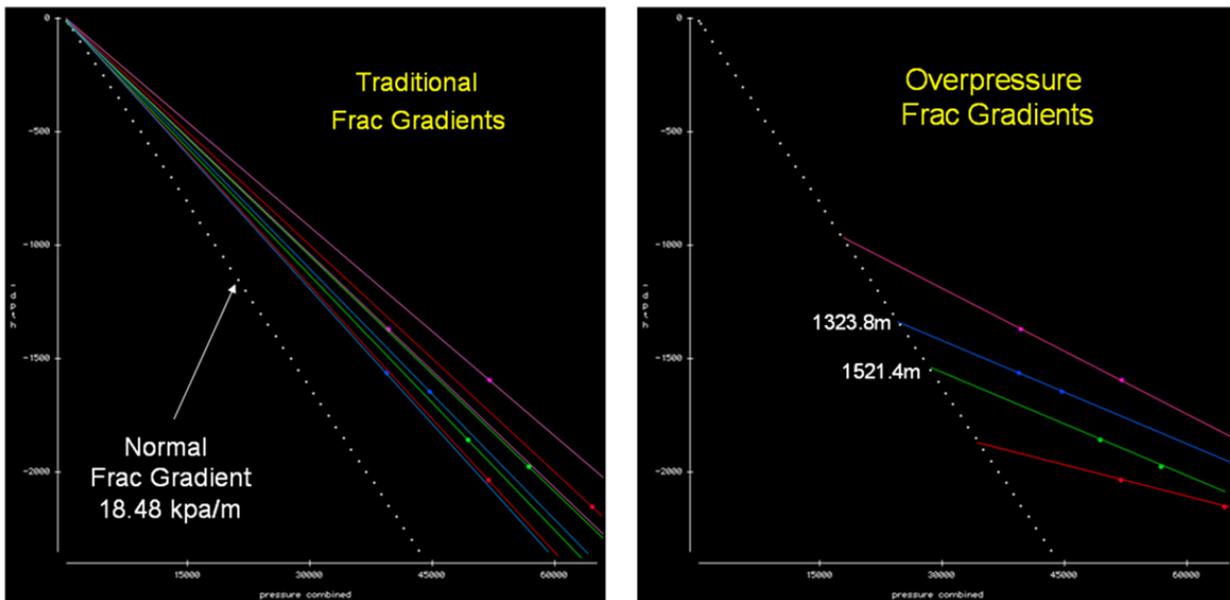
The data from various basins is consistently indicating the high probability that overpressure and a possible associated increase in temperature are linked to secondary cracking (isotope reversal), process that results in the presence of a “reservoir” filled with dry gas.

Our multidisciplinary integration has given a new angle for further study of the isotope reversal phenomena and of the overpressure mechanism. Our data analysis has thus outlined a few questions that have to be addressed:

- 1) Could the isotope reversal be equated to a stability field for propane and ethane and thus, could the linear trend associated with the isotope reversal be understood as the gradual change from propane or ethane into methane?
- 2) Can the change from propane or ethane into methane create over-pressuring and what would be the underlying mechanism? Could the two extra atoms of hydrogen needed to go from ethane to methane be taken from some remaining interstitial water?
- 3) The Rock-Eval problem associated with the S2 pick suppression seems to coincide with the overpressure domain; what would be the link with the isotope reversal?

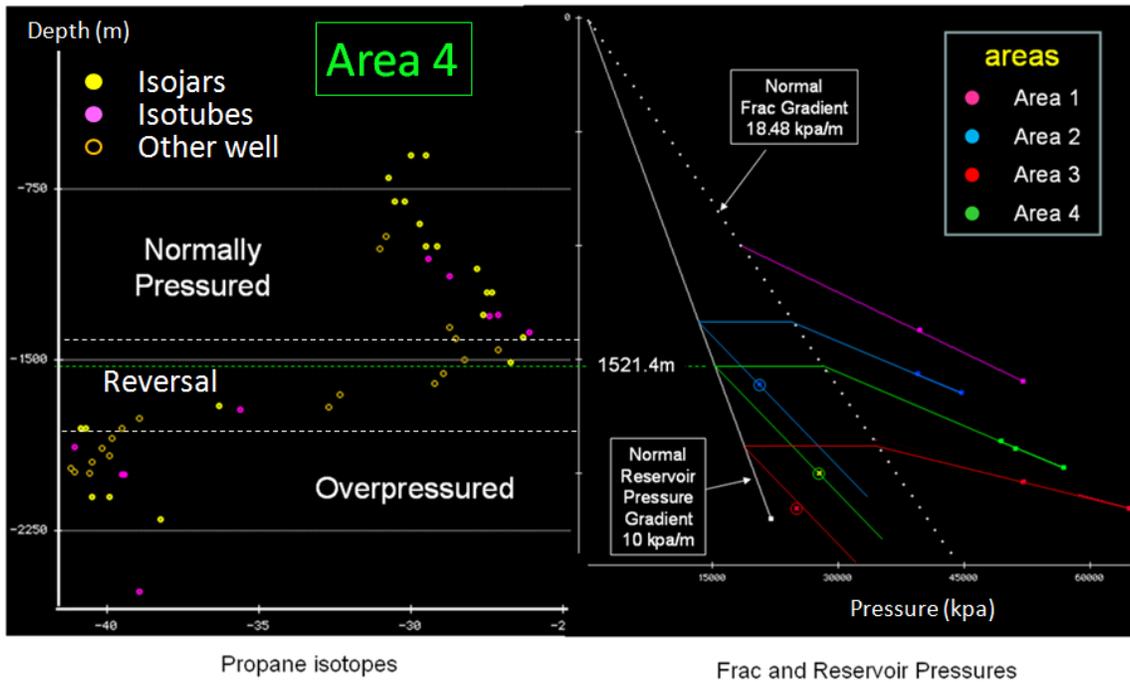


a) Three ways of viewing gas compositions – note the similar depth of the breaks in slope – what do they mean and why are they different from carbon isotopes breaks in slope (see fig 2a)

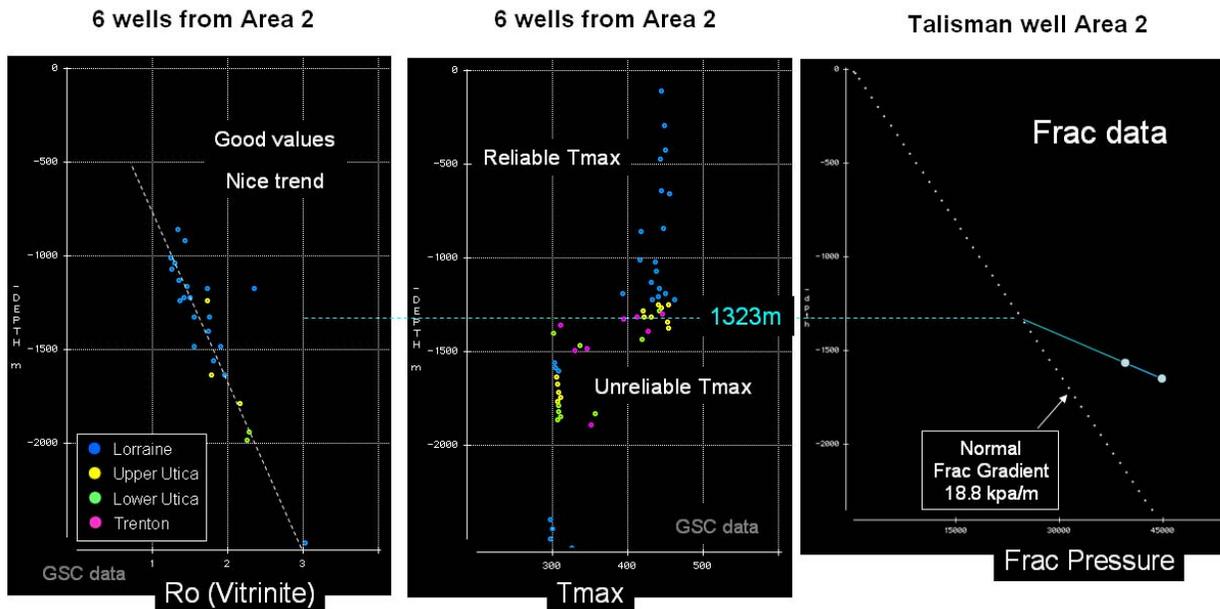


b) Two ways of looking at gradients – but which one is correct?

Fig. 1 Data displayed and interpreted differently, is one interpretation better than the other?



a) Overpressure identification from isotopes, frac pressure or reservoir pressure (long term monitoring)



b) Problem with Tmax possibly linked to overpressure regime

Fig. 2 Multidisciplinary approach helps define upper envelope of the overpressure domain