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Multidisciplinary approach to identify open fracture systems and assess their impact on hydraulic fracturing and microseismic

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Summary

Until recently, the absence of microseismic events associated with one or several stages of hydraulic fracturing has been an enigma. Our study integrating gas geochemistry and microseismic reveals the link between open fracture networks and absence of microseismic events. Thus gas bimodality seen along a horizontal borehole indicates that one of the gas signature is associated with the shale background gas, the second gas signature is very different and corresponds to gas stored in the open fractures.

The compressibility of the open fracture gas inhibits the generation of any new fractures resulting in linear alignment of a-seismic domain. The latter can be expressed by a-seismic bands or linear termination of microseismic clouds.

Timing of the generation of the open fractures and type of gas filling the open fracture space may not always allow recognition of gas bimodality; nevertheless the compressibility of the gas in the open fractures could still result in damping or annealing any microseismic signature associated with the hydraulic fracturing.

Introduction

During the drilling a horizontal well, only a few data types are recorded. Among these are the gamma ray, the rate of penetration and sometime the gas chromatography. Whereas, for the latter, the breakdown and number of compounds varies with the tool and the service company used, some simple ratios have proved very useful at identifying open fractures in some particular case scenarios.

The main interest of gas chromatography in the search for structural features, compartmentalization or open fracture zones is its dense sampling rate of one sample per meter (sometimes even one every 50 cm).

Geochemical observations and interpretations

The most notable geochemical observation of importance for hydraulic fracturing is the existence of large volumes of rocks exhibiting a very pronounced bimodality in gas compositions. In the example shown on figure 1, bimodality is seen in hydrocarbon ratios such as C4+/C1+ meaning the ratio of heavy hydrocarbons over the total amount of hydrocarbon. A similar bimodality is well expressed by the butane ratio (iC4/nC4). The examples shown are from the Montney shale of the Farrell Creek Area (British Columbia); similar bimodality has been observed in the Lorraine and Utica Shale in Quebec and in the Duvernay shale from Alberta.

The links between bimodality and open fracture systems are several and may include among others image logs, core observations, volumes of gas produced while drilling or even ROP. The link of interest for this presentation relates to the mechanism proposed to explain this bimodality and is addressed with examples from the Farrell Creek Montney shale.

On the figure 1, chromatography along a horizontal borehole exhibits long stretches of drilled lengths with single and fairly constant compositions and other stretches with two completely separate ranges of compositions, what we have called here the gas bimodality. It is important to note that there is a total lack of compositions between the two modes. Similar patterns are found in the neighboring wells from the same pad. The single compositional mode corresponds to the gas composition when the drill bit crushes non-fractured shale its composition is typical of the gas contained in the nano pores from the shale matrix and is directly linked to the maximum maturity level reached by the shale unit during burial. On the other hand, the second compositional mode corresponds to the gas that came from the open fractures and which, in the present case migrated from a deeper shale source (confirmed by methane isotope well profile analysis).

Confirming the proposed mechanism is that wetter gas is present and consistent along the entire horizontal leg of the well whereas the dryer gas being only locally present.

Another observation of possibly higher importance is that the production log indicates that more than 95% of the production comes from the zones with a bimodal gas signature indicating that production preferentially comes from the open fractures.

Microseismic observations and interpretations

For the pad where gas bimodality was observed, each of the wells exhibit an unusual microseismic pattern in that no microseismic events were recorded for a significant number of hydraulic fracs. These absences of microseismic events are only observed in the zones without bimodality, meaning the zones without open fractures.

Coherency cube and ant tracking confirm the link between gas bimodality, microseismic events and structural features of the area (Fig.2).

Similar linear absence or termination of microseismicity has been documented in the Muskwa shale of North-East BC by Ling and Barker (2014).

A perfect link between disciplines and a questionable mechanism

Whereas gas compositions from isojars (cuttings in a jar) are systematically wetter than the produced gas composition from the same interval, the gas composition from the isotubes (free gas collected at the well head) are systematically dryer than the composition of the produced gas.

This is true for all of the wells except for the wells where gas bimodality has been observed. The main puzzle to be addressed is why all of the produced gasses through time are on the same compositional trends as the wells with preexisting open fractures. The link may be in the fact that we created artificial fractures that are mimicking the naturally open fractures.

Future research avenues

Current and future work on the Farrell Creek Montney data set has a three-fold objective:

First, using a reference data set based on produced gas, work has started on comparing isotubes and isojars data dealing with the combined relationships gas composition and isotopic composition, to define a reliable indicator of open fracture density and permeability. Preliminary results are promising.

Second, because the produced gas composition becomes dryer with time; the use of four different compositional ratios or isotopic signature normalized for production volume could be the perfect tool to calculate a realistic stimulated rock volume as a more rapid composition change would indicate a smaller stimulated rock volume. Preliminary results will be discussed outlining the potential of the approach.

Third, gas composition, isotopic composition and water flow back composition are all good indicators of well interference. Work has started on establishing rules and workflows; preliminary results will be presented.

Acknowledgments

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References

Ling, J and Barker, W., 2014, The illumination of natural fractures and faults of the Muskwa shale play in NEBC: a case study, CSPG-CSEG Geoconvention 2013, extended abstract, published in Search and Discovery # #51053.

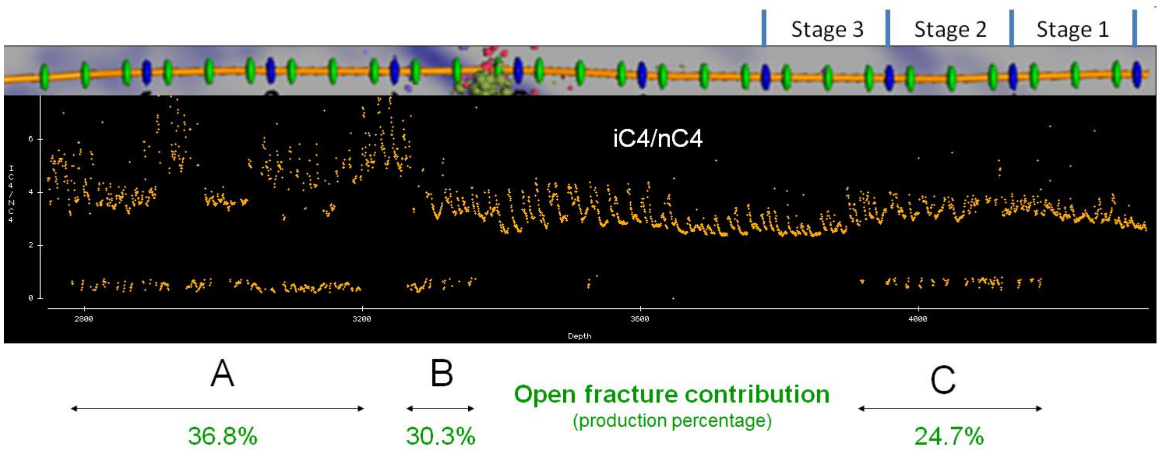

Fig. 1 Identification of open fractures using butane ratios from chromatography in one Montney well in Farrell Creek

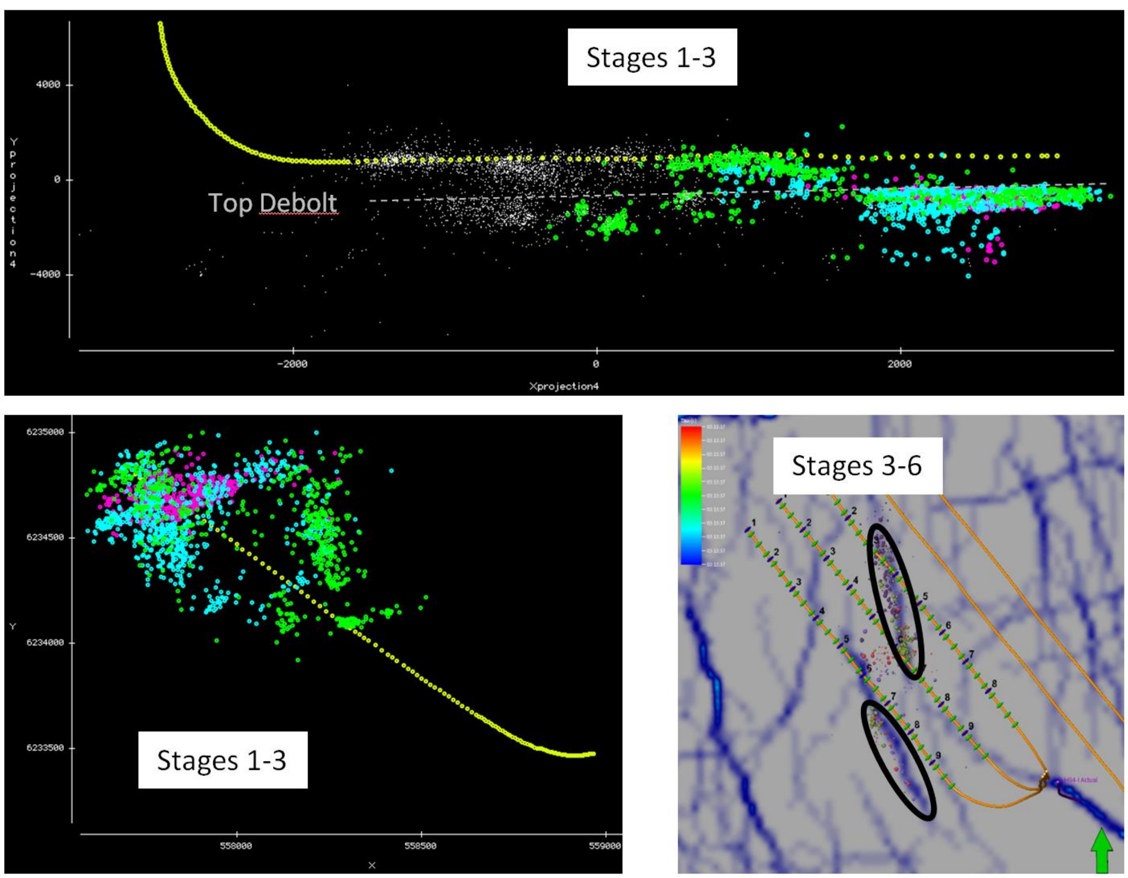

Fig 2 One wellbore profile and maps indicating the absence of microseismic events in the Montney in stages 1 to 3