Colorado Group, Western Canada Sedimentary Basin: Controls on a Working Biogenic Shale Gas System

Per Kent Pedersen[1], Steve Larter[1], Haiping Huang[1], Dallin Laycock[1], Samantha Taylor[1], Marya Cokar[1], Ian Gates[1], Ron Spencer[1], Nykky Allen[2], Mark Thomas[2], Xuebo Zhao[2], Mohammed Adamu[2], and Andrew Aplin[2]

[1]*Department of Geoscience, University of Calgary, Canada*
[2]*School of Civil Engineering and Geosciences, Newcastle University, UK*

Gas has been produced for more than 100 years from the shale dominated Colorado Group in southern Alberta and Saskatchewan, Canada. These large gas accumulations are laterally extensive with individual gas accumulation fairways often more than tens of miles wide and containing several TCF of gas. Historically productive zones within the thick marine shales of the Colorado Groups are mainly from intervals where the shales are interbedded with thin laminae and thin beds of siltstones and very fine-grained sandstones. Recent sequence stratigraphic studies have shown that production fairways within the shale succession are controlled by complex clinoform architecture which controls the distribution of coarser grained facies. In addition, gas production sweet spots are often found where the clinoforms are detached from proximal shoreline sandstones, and the generated biogenic gas is trapped stratigraphically by the landward onlap of the more sandy deposits onto more shaly deposits of an older clinoform. Detailed examination of thin sections and long, continuous cores indicate substantial evidence of bedload transport of both clay and silt, resulting in textural heterogeneity on a range of scales. Many thin silts and sands exist and may be gas-charged, but because of the low intrinsic permeability of the majority of the mud-rich units, are unlikely to be commercial unless they can be connected by hydraulic fractures.

Produced gases are essentially a mixture of CH_4 and CO_2, with CO_2 contents between 0.5 and 20%. Compositional and isotopic data indicate that the gas is biogenic, and that most or all is generated via hydrogenotrophic methanogenesis involving the reduction of CO_2. Gas generation rates may be invertable from long term production data and ongoing gas generation is assessed as a contributor to net production.

The volumetrics of biogenic gas generation are not well constrained and have been previously estimated from, for example, changes in the O/C ratio of organic matter over the temperature range of biogenic gas generation. Depending on whether the gas is generated via fermentation or CO_2 reduction, the estimates of carbon converted to methane range between 5-10%. These estimates may be minima as they assume – probably wrongly - that no oxygen is derived from H_2O. Comparison of the potentially generated CH_4 to the amount that is actually present shows that perhaps only 10% of the CH_4 potential is retained. This, coupled with isotopic data which suggest that the present gas was generated close to current reservoir temperature, strongly suggests that the Colorado Group biogenic system is both active and very open.

TOC contents of the shales are typically 1-3%, with values up to 10% in some units. The organic matter is a mix of terrestrial and marine, with a higher proportion of marine organic matter in sediments deposited during high stands. Comparisons of measured gas contents (from canisters) with theoretical gas contents based on high pressure gas isotherms suggest that much of the gas through much of the Colorado Group could be present as sorbed gas on organic matter. However, MICP data show that typical pore sizes in the more organic-rich, finer-grained shales are around 10nm, and that permeabilities estimated from the pore size data are in the nanoDarcy range. A high density fracture network in what are rather soft shales is thus required to produce this gas commercially. Sweet spots are thus stratigraphically controlled regions of concentrated silt and sand, and possibly where there are sufficient lenses of coarser grained material to allow fractures to connect together these regions of higher intrinsic permeability and probably higher proportions of free gas. These zones are inherently predictable given sufficiently subtle geological models of shale deposition.