Multiple Origins and Complex Alteration of Hydrocarbon Gases:
Regional Correlation of Three Mud Gas Depth Profiles across the Western Canada Sedimentary Basin

B.J. Tilley * and K. Muehlenbachs

Department of Earth and Atmospheric Sciences, University of Alberta, 1-26 Earth Sciences Bldg., Edmonton, Alberta T6G 2E3, Canada. E-mail: btilley@ualberta.ca

Abstract

A correlation of carbon isotopic depth profiles from three wells spans a distance of about 200 km across the western part of the Western Canada Sedimentary Basin. Each well penetrates a similar Mississippian to Cretaceous stratigraphic section in the foreland basin, but occurs in a different post-depositional tectonic setting. This study examines the sources, maturities, alteration and connectivity of the gases and illustrates the extent to which molecular and carbon isotope signatures of mud gases can be correlated across this part of the basin. Correlations of overall trends and inflections in isotopic compositions can be made among the three wells but the origin of individual gas packages cannot be assigned to simple processes. Multiple sources, biodegradation, mixing, varying degrees of openness of the system, and possibly late stage thermal cracking have all contributed in varying degrees to the observed carbon isotope signatures.

Keywords

Carbon isotopes, mud gas, gaseous hydrocarbons, Western Canada Sedimentary Basin, alteration of hydrocarbon gases.

Introduction

The molecular and isotopic compositions of mud gases from three wells across the western part of the Western Canada Sedimentary Basin (Figure 1a) have been examined with respect to the regional and local geologic framework. The OJAY well occurs in the easternmost part of the disturbed belt (eastern British Columbia), where two stacked thrust sheets are represented (Figure 1b). The Kakwa well occurs in the undisturbed ‘Deep Basin’ of Alberta, about 100 km east of the OJAY well (Figure 1a). Here, gas generated from abundant Cretaceous coals and reservoired in low porosity-permeability sandstones, created what is known as the ‘Deep Basin Gas Trap’ (Masters, 1984). The Belloy well is located about 150 km updip from the Kakwa well (Figure 1a), where the sedimentary section is significantly thinner in the Peace River Arch area (Figure 1c). The maturity of Lower Cretaceous sediments here is within the lower limits of the oil window at a present depth of 700 to 950 m.

Previous compositional and isotopic study of gases from these wells (Tilley and Muehlenbach, 2003) focused on identifying gas compartments and assessing seals in the three wells. It was found that there were regional seals that were effective in all three wells, and regional seals that had lost integrity only in the Deep Basin well (Figure 2). The objective here is to determine the degree to which the gases can be correlated from well to well and to investigate their origin and alteration histories. The geochemistry of gases from both reservoir and non-reservoir rocks is examined using various models for gas interpretation from the literature.
Results and Discussion

Depth profiles for each of the three wells are shown in a stratigraphic cross section in Figure 2. The gamma ray log and the lithologies are plotted to the far left of each profile along with the stratigraphic boundaries. The carbon isotope analyses for methane (C$_1$), ethane (C$_2$) and propane (C$_3$) for each gas sample are plotted at the depth calculated for that mud gas sample, based on lag depth calculations and monitoring by G-Chem Environmental Ltd. The methane proportion of the total hydrocarbon gas is calculated in per cent and plotted for each gas sample to the right of each isotope profile in Figure 2. For comparison, isotopic values for drill stem test gases from the Gething Formation in the OJAY well and from the Debolt Formation in the Belloy well are plotted on the appropriate isotope profile, at the DST depth, as larger open squares, circles and triangles, for methane, ethane and propane, respectively.

Comparison of the three profiles in Figure 2 shows that there are inter-profile similarities in isotopic trends and inflections at several stratigraphic horizons. Most notable correlations include the inflections in C$_2$ and C$_3$ trends towards lighter isotopic ratios (1) at the top of the Falher Member, (2) in the Wilrich Member, and (3) downward through the Fernie/Nordegg interval in the OJAY and Belloy wells. Within the Gething Formation, a zone of anomalously enriched C$_2$ and C$_3$ isotopic values is a major feature in the OJAY profile. Similar, although more subdued, enrichments are also seen from the Gething Formation in the other two wells.

Near surface biogenic gases, biodegraded thermogenic gases, deeper unaltered thermogenic gases, and mixed gases can all be identified in these wells. Classification of gases by formation, lithology, and the well from which they were recovered, helps to reduce much of the initially-appearing random scatter on various plots of molecular versus isotopic ratios. However, although definite groupings of data do occur, it is evident that the genetic and post-genetic history of these gases is complex and cannot be assigned to a simple process. Within one well there are trends that are consistent with degree of maturation, biodegradation, proportion of biogenic methane or mixing of end members. Comparisons between wells further highlight the unexpected complexity of the system.

References


Figure 1. (a) Locations of three carbon isotope mud gas depth profiles in the western Canada sedimentary basin. (b) Schematic cross section illustrating the structural setting of the OJAY field in the disturbed belt of eastern British Columbia. (Cross section from T. MacRobert, BP Canada Energy Company, pers. comm.). (c) Schematic cross section illustrating the relative positions of the Kakwa and Belloy profiles in the sedimentary basin.
Figure 2. Stratigraphic cross section of three mud gas profiles across the Western Canada Sedimentary Basin.