AAPG Search and Discovery Article #90172 © CSPG/CSEG/CWLS GeoConvention 2010, Calgary, Alberta, Canada, May 10-14, 2010

Hydraulic Pathways between and within the Scollard and Paskapoo Formations in Alberta: Implications for Pressure Distributions atop the Underpressured Envelope of Central Alberta and Resource Management

Laurence D. Andriashek*
ERCB, Alberta Geological Survey, Edmonton, Alberta
Laurence.Andriashek@ercb.ca

and

Kevin Parks
ERCB, Calgary, Alberta

Introduction

The Cretaceous-Tertiary Scollard Formation of western Alberta is predominantly mudstone with minor siltstone and sandstone plus a regionally extensive series of coal seams, often called the Ardley Coal Zone. The Tertiary Paskapoo Formation is predominantly sandstone at its base but grades upwards into interbedded sandstone, siltstone and mudstone. There is an erosional unconformity between the Scollard and Paskapoo Formation and the top of the Paskapoo Formation is marked by the eroded top of bedrock. The Scollard Formation is economically important for its Ardley coal seams and related coalbed methane resources. The Paskapoo Formation is economically important as a source of industrial and domestic groundwater supply plus a minor amount of natural gas. It is important to understand the degree of hydraulic connectivity between the Scollard coal zones and Paskapoo aquifers to assure that coal and CBM resource development and groundwater protection are compatible.

We are interested in where and how the Scollard-Paskapoo hydrogeological system might have greater or lesser natural tendencies toward hydraulic communication and connectivity. In particular, we focused on two key hydrogeological components: the degree of hydraulic connectivity between the Scollard coals and the Paskapoo Formation; and, the degree of hydraulic connectivity and hydraulic continuity within the Paskapoo Formation itself. The area of study includes all of Alberta underlain by the Paskapoo and Scollard formations, including all areas of the Ardley coal (Figure 1).

Discussion of Findings

Strong local hydraulic connectivity between the Scollard coals and the Paskapoo Formation can occur where Paskapoo sandstone channels have eroded the hydraulically insulating upper Scollard mudstones and rest directly atop the Ardley Coal Zone (Figure 2). Direct sandstone-to-coal contact presumably provides hydraulic connectivity. The evidence for local hydraulic connectivity is the observation that formation pressures and hydraulic heads in the Ardley Coal Zone are similar in magnitude to those measured in the Paskapoo Formation, which relate to depth and position in a gravity-driven regional groundwater-flow system (yellow symbols, figure 3).

Formation pressures in the Scollard Formation, including the Ardley Coal Zone, are strongly subhydrostatic in magnitude (i.e., underpressured) in areas where well evidence indicate channel incisement and connectivity does not exist.This marks the top of the well-known envelope of underpressures in Cretaceous strata of central Alberta, believed by many to be caused poro-elastic dilation in moderately permeable formations due to regional unloading.

The limited data allow us to develop this conceptual model but the probability of connectivity at any given location in the system is presently unknown. Because the presence of overlying Paskapoo channel sandstones cannot be determined from current information, it is impossible to predict the local connectivity of the Scollard coals to the Paskapoo prior to drilling, logging and pressure testing. After drilling, however, the local connectivity can be ascertained with relative certainty. If there is no connectivity, resource development in the Scollard coals would have no probable affect on aquifers in the Paskapoo Formation.

If there is connectivity between the Scollard coals and the Paskapoo Formation at a given location, the probability of effect on groundwater aquifers depends on: the degree of regional interconnectivity of the sandstones in the Paskapoo Formation and, the degree of hydraulic continuity between a site of pressure change in the Scollard and the expression of that change in Paskapoo groundwater over the time scale of a pressure inducement.

We assessed the subsurface distribution of sandstone in the Paskapoo Formation from slice maps derived from gamma-ray logs, using the Battle Formation surface as a datum. We can estimate the degree of regional interconnectivity from sandstone-abundance slice maps using concepts of percolation theory. Percolation concepts suggest that, where regional sandstone abundances are less than 40%, sandstone bodies in the Paskapoo Formation may be locally connected but probably not regionally connected. Where regional sandstone concentrations are greater than 60%, the Paskapoo sandstone bodies probably interconnect at the regional scale as well as the local scale. The threshold marking the change from local-only to local-plus-regional interconnectivity occurs somewhere between 40% and 60% sandstone.

The distribution of natural-gas occurrences in the lower Paskapoo Formation supports this model. Gas occurrences in the Paskapoo Formation with volumes significant enough for commercial production tend to occur where regional sandstone abundances are between 40% and 60% and structurally lower than areas where regional sandstone abundances are less than 40% (figures 4 and 5). Above 60% sandstone, there are few gas occurrences, suggesting that these zones have little capacity to trap natural gas (Figure 6). There are also few gas occurrences when sandstone abundance is below 40%, suggesting minimal regional capacity to allow migration of gas into the Paskapoo sandstones in these zones.

The nature of hydraulic interconnectivity is important in determining hydraulic continuity and therefore the degree of propagation of pressure changes laterally and vertically through the Paskapoo Formation. Hydraulic continuity defines whether a hydraulic or pressure disturbance originating at one point is measurable at a different point. It depends on the distance between the point of origin and the point of observation, the time lag between time of origin and time of observation, and the hydraulic diffusivity of the rock framework between the point of origin and the point of observation.

The hydraulic diffusivity of a sandstone-mudstone system consisting of discrete sandstone bodies encased in mudstone, such as the Paskapoo Formation, will be dominated by sandstone properties where the sandstone is regionally interconnected and by mudstone properties where it is not.

Conclusions

Since we can estimate and map the sandstone abundance and predict regional connectivity using percolation theory, we can identify areas where the sandstone properties will control the regional hydraulic diffusivity and the areas where it will not:

- In areas where sandstone bodies are regionally interconnected, there is likely to be regional hydraulic continuity between most points of origin and most points of observation after 10 or more years of pressure change, wherever those points are located so long as the abundance of sandstone is above 60%.

- Where sandstone bodies do not interconnect regionally, there is not likely to be regional hydraulic continuity between most points of origin and most points of observation after 10 years or more of pressure change, wherever those points are located so long as the abundance of sandstone is below 40%. In these cases, however, there will still be the possibility of local-scale connectivity and hydraulic continuity, which will decrease as the regional sandstone abundance decreases and the points of origin and observation become farther apart.

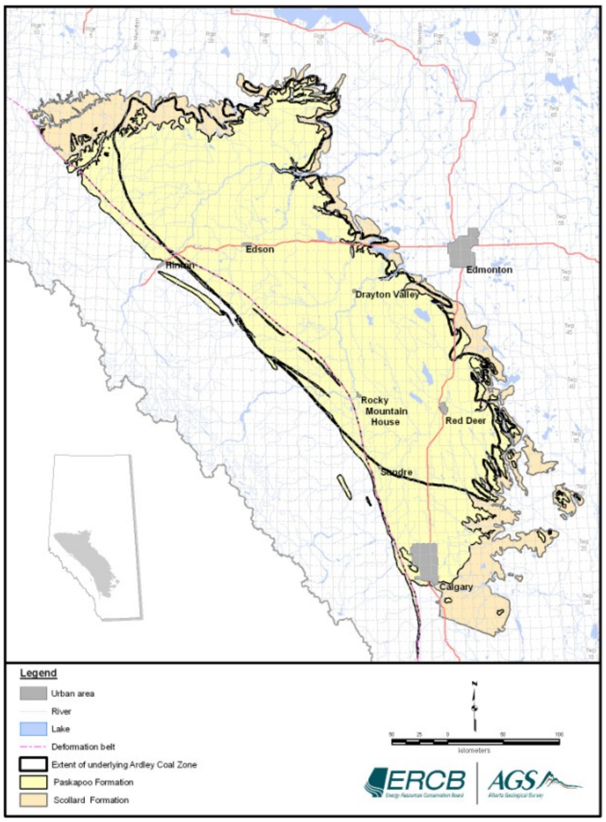

Figure 1. Extent of the Paskapoo and Scollard formations, and the Ardley Coal Zone in Alberta.

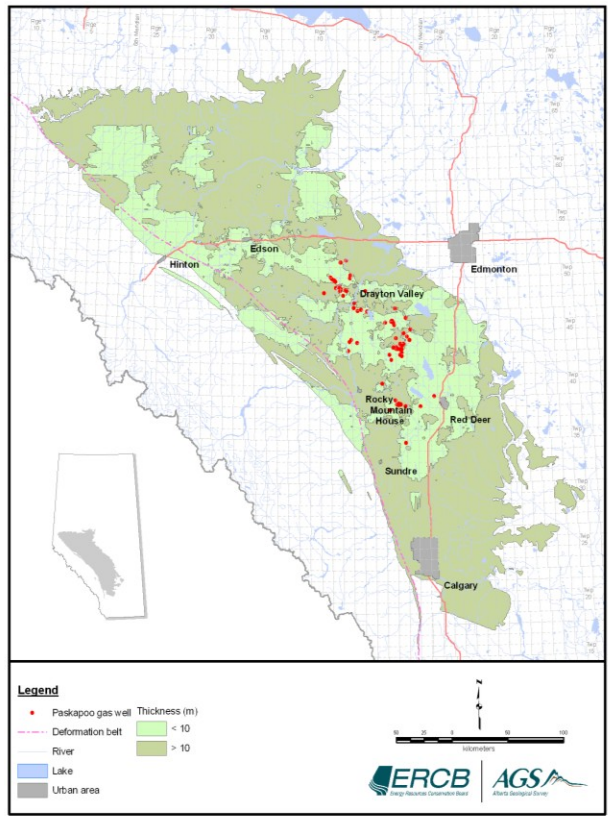

Figure 2. Locations of Paskapoo gas wells relative to thickness of the Scollard Formation above the Ardley Coal Zone.

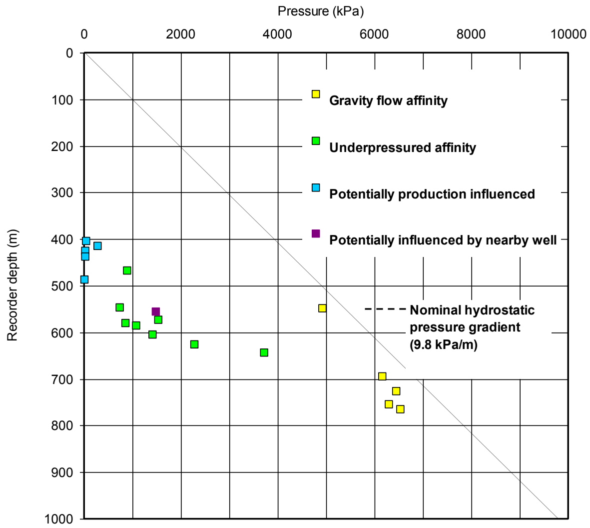

Figure 3. Pressure-depth plot showing normally and underpressured Scollard Formation.

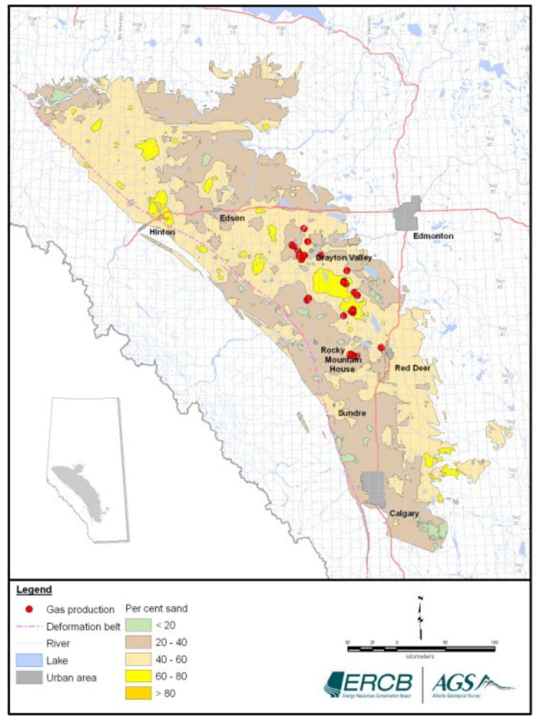

Figure 4. Vertically averaged gamma-ray–derived sandstone abundance, slice from 100 to 150 m above the Battle Formation.

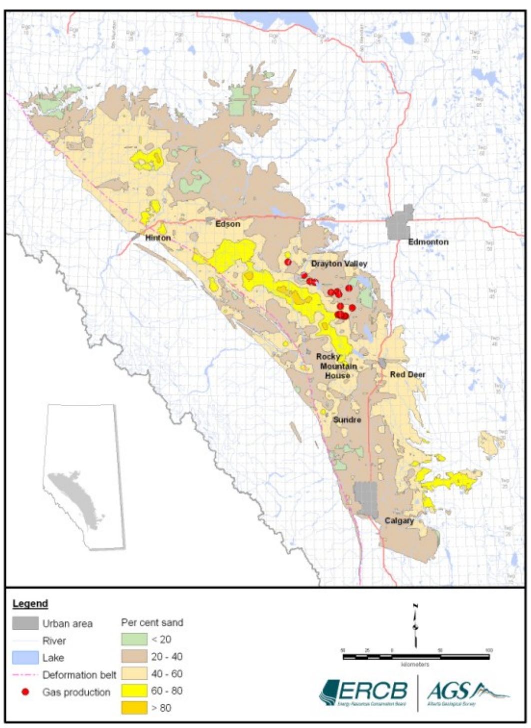

Figure 5. Vertically averaged gamma-ray–derived sandstone abundance, slice from 150 to 200 m above the Battle Formation.

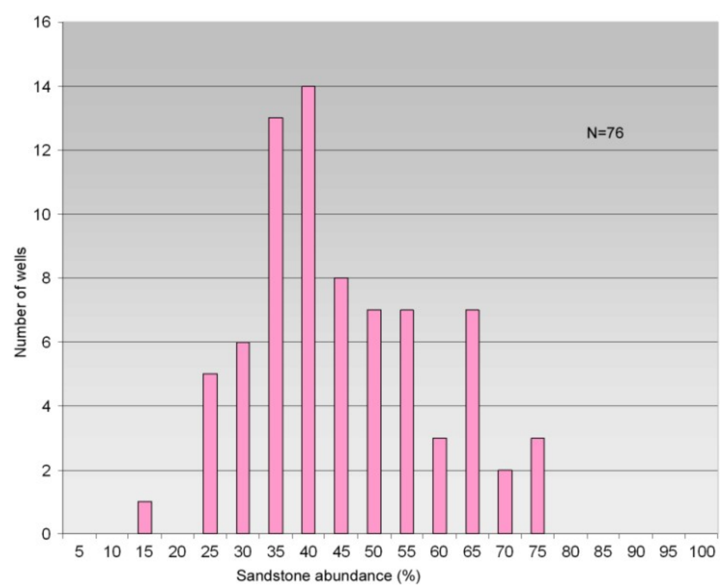

Figure 6. Histogram showing sandstone abundance of the 50 m slice in which the Paskapoo gas well was completed. Most wells are completed in intervals where sandstone abundance ranges between 35% and 65%.