Preparing for experimental CO_2 injection: Geology of the site

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ABSTRACT

We studied the geological properties of three prospective experimental CO_2 injection zones in the study area in Southern Alberta. The primary target is the Basal Belly River Formation, with secondary targets in the Medicine Hat and Second White Speckled Shale formations, which are at depths of about 285 m, 475 m and 710 m, respectively, below the surface.

We correlated well logs in the immediate area of interest with well logs from a well having a lithology log and from wells with Basal Belly River production. We calibrated the gamma ray logs in the top of the Pakowki Formation so that the average values were consistent in all of the well logs. We then used the gamma ray logs to assess reservoir continuity and sand/shale content in the Belly River Formation above the proposed injection zone and to estimate the sealing properties of this formation.

Based upon our interpretation of the gamma ray logs, it seems probable that the Belly River Formation has sufficient shale content to be a seal in the area of interest.

INTRODUCTION

The Containment and Monitoring Institute (CaMI), which has been established by Carbon Management Canada, is a platform for development and performance validation of technologies intended for measurement, monitoring and containment of subsurface fluids, including carbon dioxide (www.cmcghg.com). CaMI's Field Research Station (FRS#1), which is currently under development, will be a unique opportunity to develop, refine and calibrate monitoring systems and technologies.

The program at FRS#1 is designed to inject small tonnages (up to 1000 tonnes per year) of CO_2 (possibly with small amounts of impurities such as CH_4 or other tracers) into the shallow subsurface (depths <700 m below the surface). The injection targets are water-filled sandstones within Upper Cretaceous clastic reservoir formations, with overlying shales or mixed sand/shale sequences forming the cap rocks.

Site activities will focus on research and technology development as well as training in monitoring technologies. Geophysical, geochemical, geomechanical and geodetic monitoring of the subsurface gas plume (both CO_2 and methane) will be complemented by near-surface hydrogeological studies designed to understand better shallow groundwater systems and near-surface subsurface fluid flow, and to monitor the movement of both CO_2 and CH_4 in an aquifer below the local base of groundwater protection, which is at a depth of about 225 m in the study area near Brooks, Alberta (http://www.cmcghg.com/cami-3/field-research-station-1/).

After an extensive search for a location suitable for experimental injection and monitoring, a site was identified within the Countess Field, near Brooks in Southern Alberta, about 150 km southeast of Calgary (Figure 1). The geological study is centred on

well 07-22-017-16W4M, which is a producing gas well drilled in 1997 by PanCanadian Petroleum and now operated by Cenovus Energy.

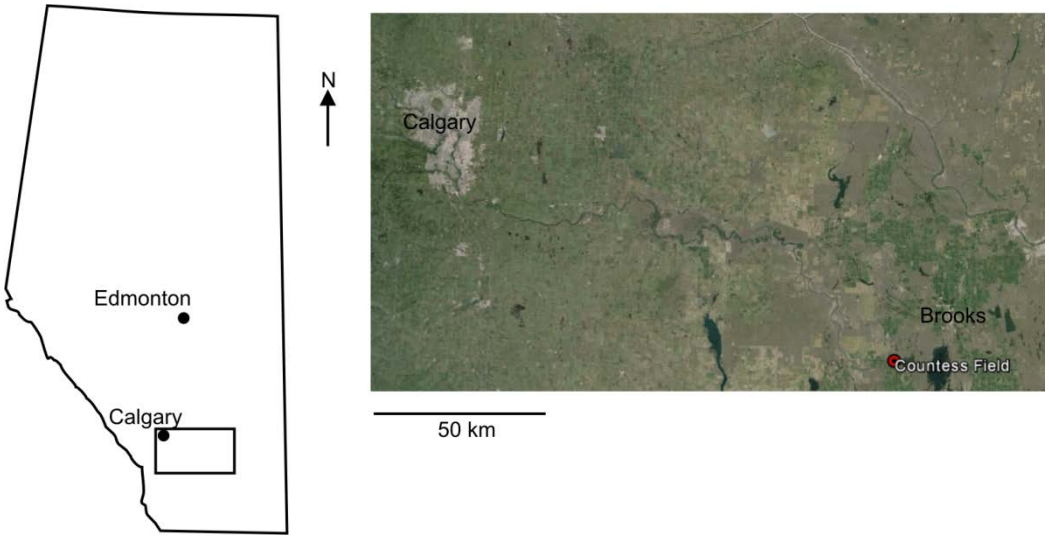

FIG. 1: The location of the study area in the Countess Field in Southern Alberta.

GEOLOGY

The two boreholes drilled at the location 07-22-017-16W4M encountered gas deeper than our target depths, in the Glauconitic sandstone between 1049-1054 m depth KB (266-271 m subsea) and the Bow Island sandstone at 890 m KB (107 m SS).

Wells surrounding 07-22-017-16W4M have encountered gas in many different formations (Figure 2), as seen in Figure 3, which is a map showing the wells in the immediate area of interest around Section 22 with the producing zones annotated. Gas is found in the Milk River, Medicine Hat, Second White Speckled Shale, Bow Island, Mannville and the Sunburst formations. Although the wells in the south of this map produce only from the deepest Cretaceous formations, wells to the south and east of them have shallower production. Figure 3 also shows gas pipelines (red) and oil pipelines (green). There is an oil pipeline running through Section 22 close to the proposed drilling location of the test well, which is 500 m north of well 07-22-17-16W4M.

The primary target for injection at this site is the Basal Belly River sandstones with sands within the Medicine Hat and Second White Speckled Shale formations as secondary targets.

Basal Belly River Formation

The depth of the Basal Belly River Formation over Section 22 is about 285 m below the surface and the unit is 5-7 m thick. The formation is water-wet although well 14-28-017-16W4M is reported to have flowed gas, described as coal bed methane on the well ticket, from a one metre zone at the top of the Basal Belly River. Gas has been encountered in the Basal Belly River in a few wells a few sections away from 07-22-017-16W4M. The nearest gas pool producing from the Basal Belly River is at Eyremore, in T19 R18 W4M, which is about 45 km to the northwest.

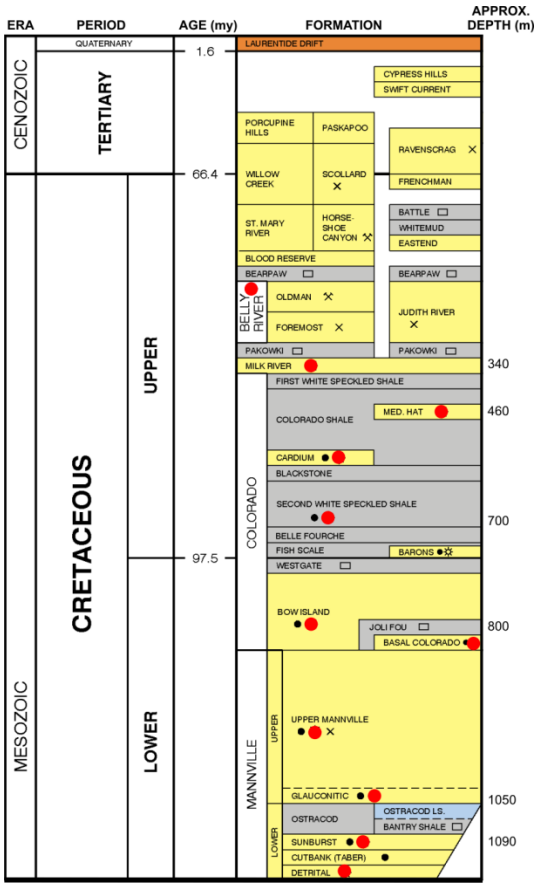

FIG. 2: Stratigraphic chart showing producing formations (after ERCB).

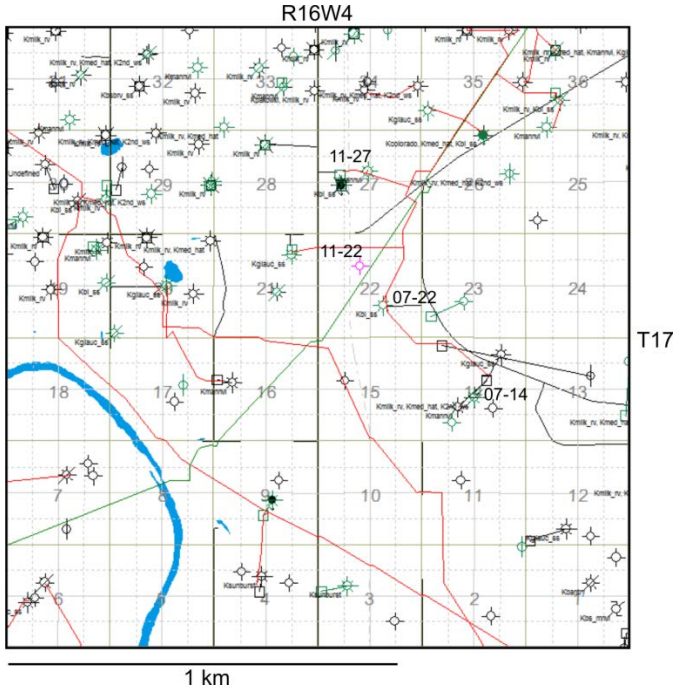

FIG. 3: Wells near Section 22 with producing zones annotated. Red lines denote gas pipelines and green lines denote oil pipelines.

The Belly River Formation is composed of shoreface sands in the basal unit, overlain by coastal plain silts and coals. It is about 200 m thick in the study area (Dawson et al., 1994). The sand content of the Basal Belly River shoreface sands varies quite a lot and in well 07-22-017-16W4M the sands are quite silty.

The Belly River Formation can be divided into the Foremost and Oldman Formations. The Foremost Formation is a fining upwards succession of shallow marine interbedded silts and silty sands, and is overlain by the fluvial Oldman Formation (Dawson et al., 1994; Gordon, 2000). The top of the Foremost Formation may be identified on the gamma ray log by a shift to the right at the base of the Oldman Formation because of a mineralogical change between the Foremost and Oldman formations (Gordon, 2000).

Figure 4 is a cross-section showing the log character of the Basal Belly River in the area of interest. The Basal Belly River sandstone is about 5-6 m thick here.

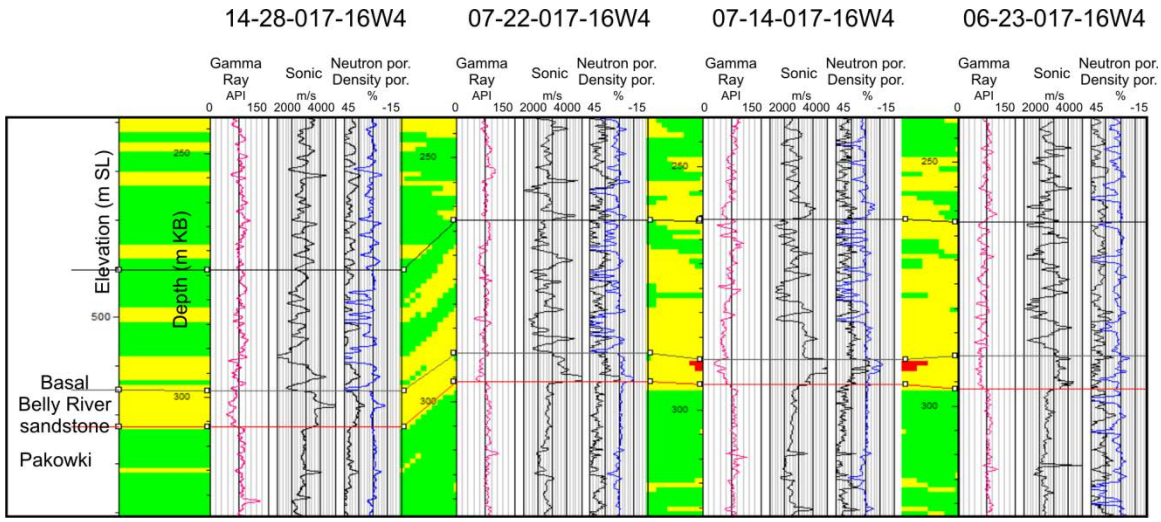

FIG. 4: Cross-section showing the character of the Basal Belly River sandstone around Section 22.

Medicine Hat Formation

The Santonian Medicine Hat Formation (Warren, 1985), which occurs in southeastern Alberta and southwestern Saskatchewan below the First White Speckled Shale, consists of at least three upward-coarsening, very fine-grained sandstone and siltstone successions, 3 to 11 m thick, deposited in a shallow-marine shelf setting (Gilboy, 1987; Hankel et al., 1989). The formation is up to 60 m thick. The Medicine Hat forms a shallow-gas reservoir and is the largest and oldest gas field in Canada, containing locally derived biogenic gas (Leckie et al., 1994). Figure 5 is a cross-section showing sand-prone zones in the Medicine Hat Formation. Gas was encountered in two 1 m thick sandstones in well 07-14-017-16W4M (red dots).

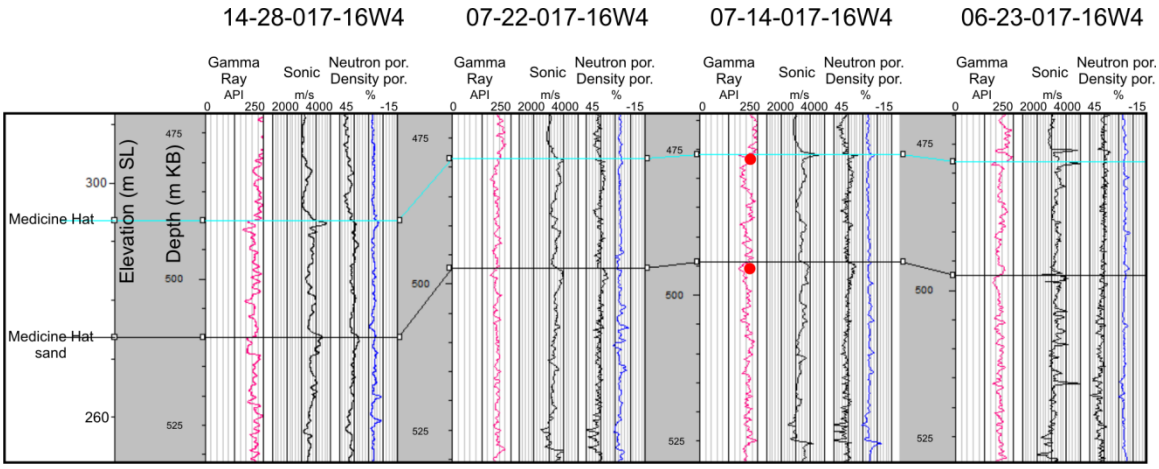

FIG. 5: Cross-section showing the character of the Medicine Hat Formation around Section 22. Gas was encountered in two 1 m thick sandstones in well 07-14-017-16W4M, as indicated by the red dots.

Second White Speckled Shale

This predominantly marine mudstone unit contains some fine-grained distal marine shoreface sands. A few wells have flowed gas from thin sand zones but their neutron porosity–density signatures do not exhibit crossover. Well 102/7-14-017-16W4M has 2 m of net pay in the Second White Speckled Shale at 712 m KB (69 m subsea), where there is a decrease in the gamma ray reading and increase in sonic velocity (Figure 6).

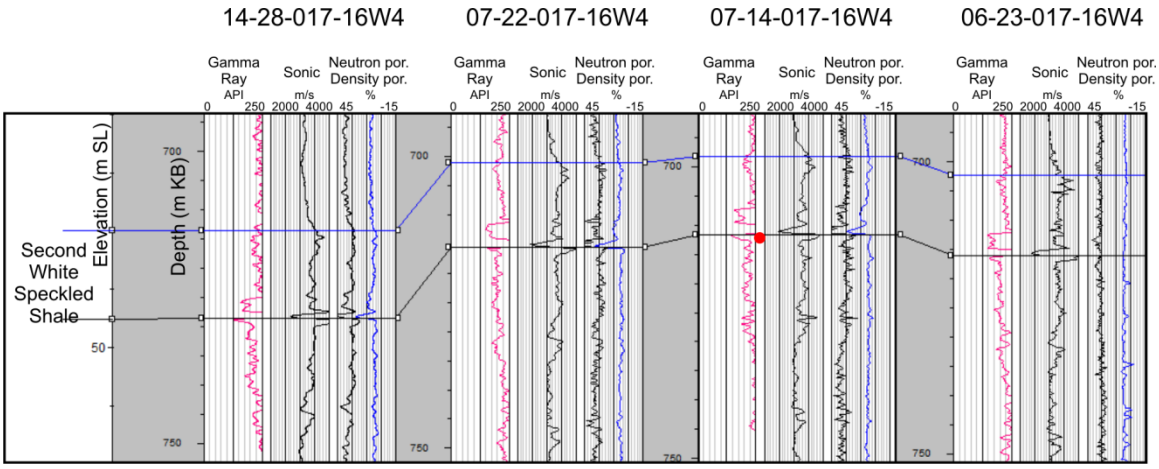

FIG. 6: Cross-section showing the character of the Second White Speckled Shale around Section 22. The thin sand unit shows up as a sharp spike on the gamma ray and sonic logs. Gas was encountered in well 07-14-017-16W4M in a 2 m sand (red dot).

Sealing capabilities of the Belly River Formation

Of critical interest in this study area is the capability of the Belly River Formation to form a barrier to migration of injected CO_2 from the Basal Belly River sandstone. The sand/shale ration in a formation may be estimated from the gamma ray logs if those logs are reliable. We wanted to calibrate the gamma ray logs by tying one to a lithology log. None of the lithology logs for wells in this area covers the Belly River Formation so we correlated well 07-22-17-16W4M to the nearest well with a lithology log, 16-25-017-18W4M, which is 15 km to the west (Figure 7). The wells in the cross-section (Figure 8) are flattened on the top of the Basal Belly River and have been calibrated so that the average gamma ray values in the uppermost Pakowki Formation are equivalent. The Pakowki is predominantly fine-grained, being composed of mudstones and siltstones deposited during a marine transgression (Rosenthal et al., 1984).

The colour background shows the lithology based upon the gamma ray values. It was designed to match the lithology log as well as possible in the Belly River section and is divided into the three basic types: sand, silty sand and silt/shale. There are also coals (black) in the lithology log. This correlation implies that the Belly River Formation in Section 22-017-016W4M might be slightly sandier than in Section 25-017-18W4M.

The well correlations were expanded further to include wells from a producing pool, Eyremore, in T19R18W4M, to compare the shale content of the Belly River Formation where it must be a seal to the shale content in Section 22-017-16W4M. The cross-section (Figure 9) is flattened on a correlation approximately at the top of the Foremost Formation. The lithology in the section overlying the Basal Belly River appears to be similar in wells 13-09-019-18W4M and 11-22-017-16W4M in terms of sand/shale content. Since this lithology must be a seal at Eyremore for the Basal Belly River to be a producing gas reservoir, it would appear probable, based upon the gamma ray colour coding, that it is also a seal at Countess. We estimate that the Belly River section above the target injection formation is composed of about 40% silty sand and 60% silt/shale in Section 22. There also appear to be several shale units that are at least 10 m thick. In comparison, well 15-05-019-18W4M has about 37% silty sand and 63% silt/shale in the same interval.

SUMMARY

We studied the geological properties of three prospective experimental CO_2 injection zones: the Basal Belly River sands at a depth of about 285 m and thin sands within the Medicine Hat and Second White Speckled Shale formations at depths of about 475 m and 710 m, respectively, below the surface.

We correlated well logs in the immediate area of interest with well logs from a well having a lithology log and from wells with Basal Belly River production. We calibrated the gamma ray logs in the top of the Pakowki Formation so that the average values were equivalent in all of the well logs. We then used the calibrated gamma ray logs to assess reservoir continuity and sand/shale content in the Belly River Formation above the proposed injection zone and to estimate the sealing properties of this formation.

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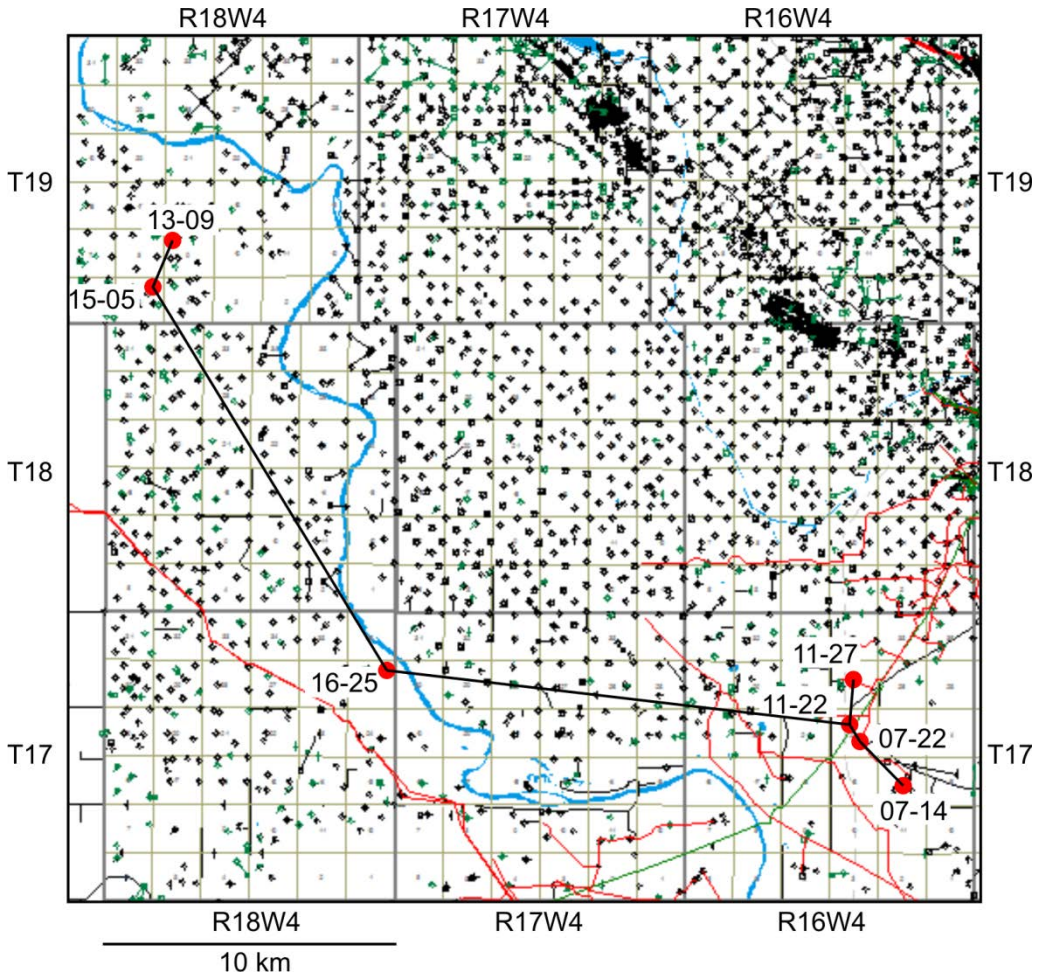

FIG. 7: Wells beyond the immediate area of interest used to correlate gamma ray logs to determine lithology and estimate sand/shale ratios.

ACKNOWLEDGEMENTS

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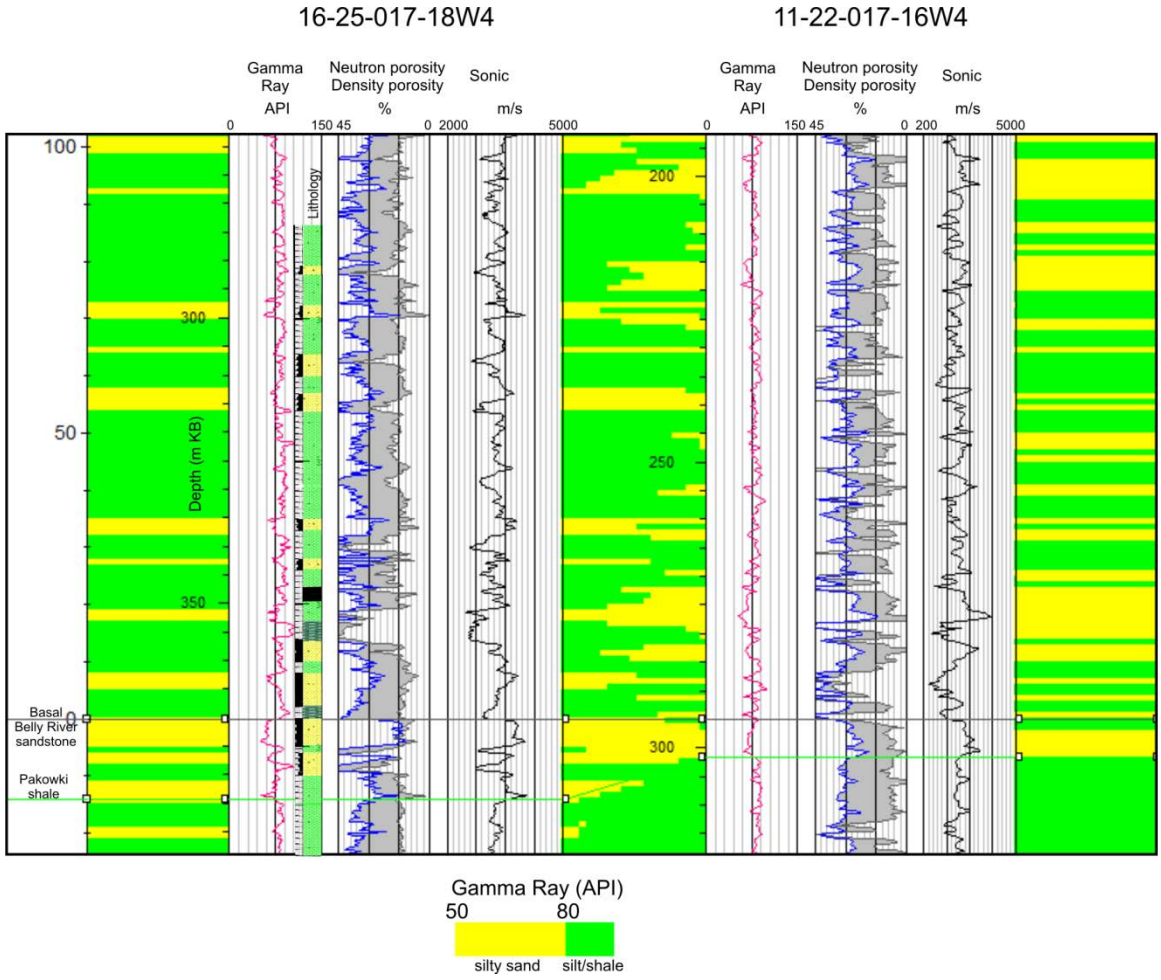

FIG. 8: Correlation of gamma ray logs from well 11-22-017-16W4M with well 16-25-017-018W4M, which has a lithology log. The logs are flattened on the top of the Basal Belly River.

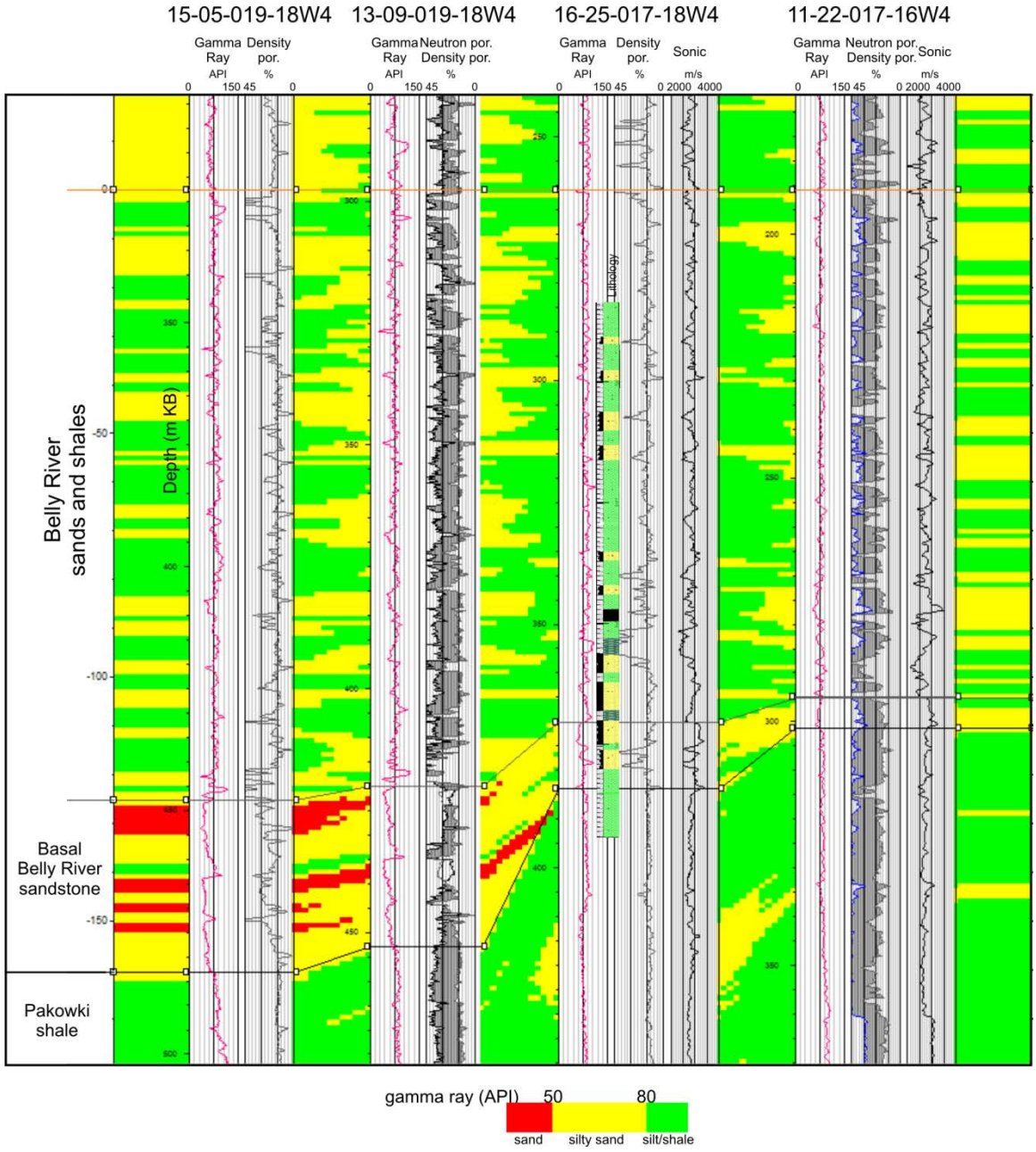

FIG. 9: Correlation of gamma ray logs from well 11-22-017-16W4M with well 16-25-017-18W4M, which has a lithology log, and wells 15-05-019-18W4M and13-09-019-18W4M, which are producing from a thick Basal Belly River sandstone. The logs are flattened on an event in the Belly River Formation, approximately at the top of the Foremost Formation. We estimate that the Belly River section above the target injection formation is composed of about 40% silty sand and 60% silt/shale in Section 22, compared to about 37% silty sand and 63% silt/shale in well 15-05-019-18W4M.