TRIASSIC POROSITY TRENDS IN NORTHEASTERN BRITISH COLUMBIA

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ABSTRACT

Interest has increased recently in finding suitable locations for subsurface disposal (sequestration) of carbon dioxide (CO_2) and water incidental to hydrocarbon production. Wireline logs from approximately 600 wells in northeastern British Columbia were evaluated for porosity of Triassic formations with the goal of outlining possible disposal sites. Total porosity for the Doig, Halfway, and Baldonnel Formations was mapped for much of the area with known Triassic sedimentation. Strong northwest trends, roughly coincident with Triassic shorelines, appear for the Halfway Formation. A number of isolated occurrences of porosity (especially wet porosity) have also been outlined for further study. Maps for the Baldonnel and Doig Formations also show potential disposal/sequestration sites within those formations.

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INTRODUCTION

The Triassic Period has so far been the most important geological interval for hydrocarbon production in British Columbia. Its productivity and rapid pace of development over the past five decades have led to exploratory maturity and concomitant decreases in the size and frequency of new discoveries. This project is not aimed at reversing the decline, but it does make use of the wealth of data accumulated in developing this resource to examine an issue related to intense hydrocarbon development: the disposal of production waters and CO_2. If the Triassic has provided BC with many good hydrocarbon reservoirs, it should also be able to provide suitable reservoirs for accepting unwanted gases or fluids; this potential might also extend to the temporary storage of excess gas production.

The maps presented here are intended to illustrate trends in porosity for the major producing formations of the Triassic. Because the maps are regional in extent, it is unlikely that they will do more than help in targeting certain areas for further study of disposal possibilities. Figure 1 places the study area within the context of western Canada.

These maps have not yet been refined to resolve inconsistencies in data. With additional data and critical scrutiny of the output, the maps could evolve to look considerably different. Approximately 600 locations were evaluated in no particular order. These 600 represent only a small portion of the total number of wells with suitable logs available in the area, so more detail would likely add complexity and texture to the contoured trends displayed here. The edges of the maps may eventually be extended to include more area with Triassic sediments. The area mapped represents the most accessible region with likely the greatest need for water disposal and CO_2 sequestration.

Determinations of porosity accurate enough for volumetric calculations were not within the scope of this project. By applying consistent criteria over vast differences in log vintages and quality, a regional picture is presented that shows relative differences in porosity.

The database used to generate the maps in this publication is available upon request. Comments, corrections, or new ideas to improve the product would be appreciated.

METHODOLOGY

To ensure an adequate distribution of well density, approximately two wells per township or NTS block were selected, at diagonally opposite corners wherever possible. Before selection, available logs were previewed and then printed. Recently drilled wells with modern Compensated Neutron Formation Density (CNFD) logs were preferred. Older wells were used if necessary. If no CNFD logs were available, sonic logs were chosen. Some blocks were not sampled at all because they lacked wells with adequate porosity logs. The actual evaluations were done on printed hardcopies of the logs.

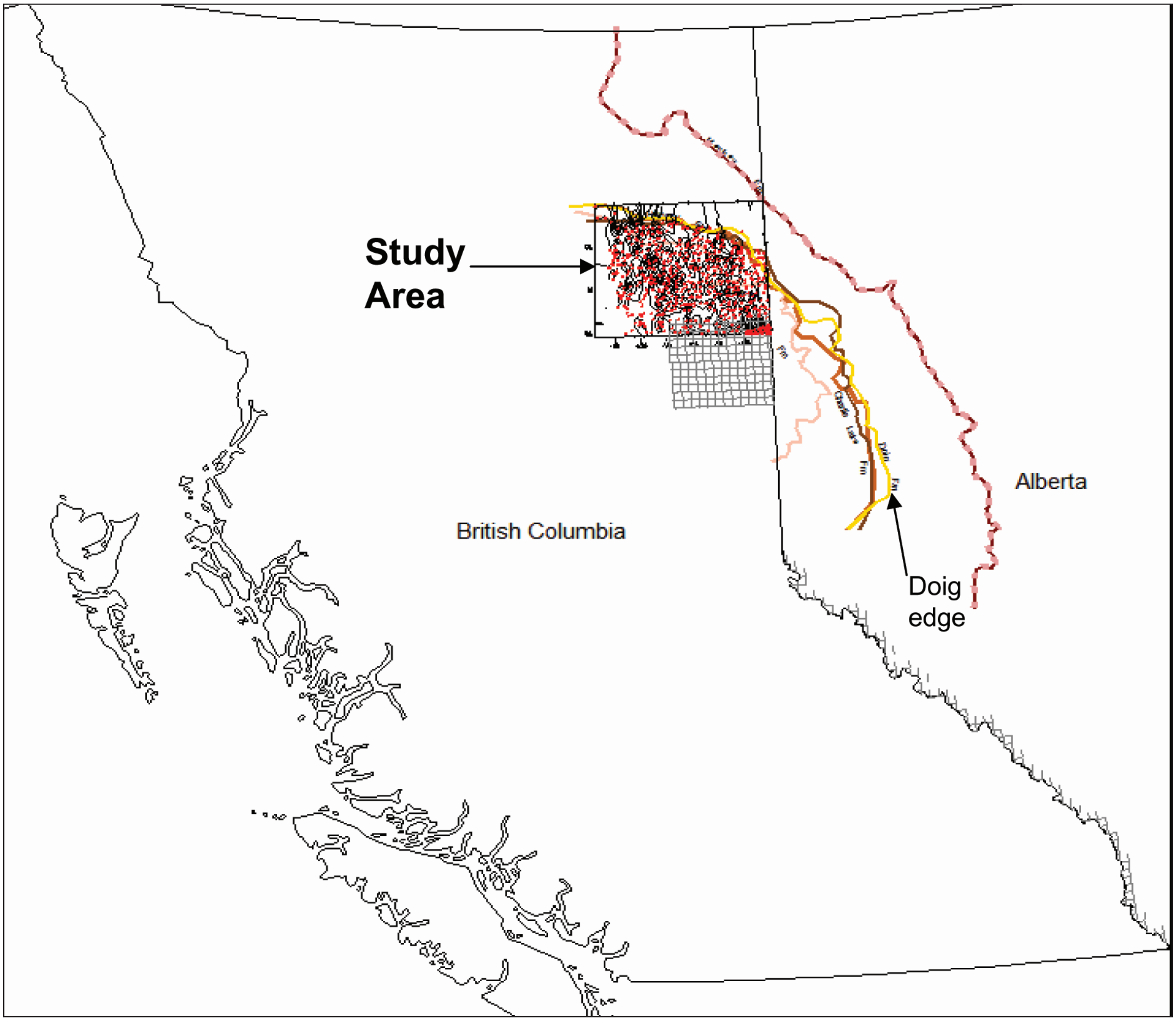

Figure 1: Triassic Porosity Trends in Northeastern British Columbia. The study extends from the northern portion of the township block near Fort St. John to the edge of Doig Formation sedimentation.

The following generally accepted porosity cut-offs were applied for productive Triassic formations in northeastern BC:

Halfway Formation 10%

Charlie Lake Formation 6%

Baldonnel Formation 6%

Doig Formation 6%

Montney Formation 6%

A gamma ray cut-off for shale content was applied for each formation, but especially for Charlie Lake, because otherwise the porosity thickness would be excessively high in many wells, as confirmed by their poor results on drill-stem tests. This cut-off was not applied on a strict numerical basis, but rather by drawing a baseline through the gamma ray curve on a case-by-case basis, depending on the apparent quality of the potential reservoir rock. In most cases, locations with abundant porosity had been tested and/or produced, which was a tip-off that porosity exists. Abandoned locations usually have little or no porosity, except for those that clearly are wet (i.e., have high water saturations).

To eliminate bias, each well location was evaluated independently without knowledge of its geographical location. This was possible because the logs were printed and stacked in essentially random order—one location did not influence the values given to the next because they were usually randomly scattered and not closely offsetting. Mapping and contouring the results were not begun until all 600 wells were evaluated. Contouring was done with Golden Software's Surfer using the kriging technique.

Many holes examined were in poor condition with large and frequent washed-out sections. Under those conditions, the primary porosity tools (density and sonic logs) do not give accurate results—they overstate porosity because the tools are measuring the extra space in the washed-out sections rather than rock properties. For that reason, porosity was not counted for sections that were badly washed out, and therefore porosity is likely understated for some wells. However, this omission can be rationalized for the purpose of this study because rock sections prone to wash-out would probably not be ideal for either CO_2 sequestration or water disposal anyway. Those washed-out sections not included in porosity totals are indicated on the paper logs, which have been retained in files for reference.

More recently drilled wells tended to be less washed out (another reason for choosing them in preference to older wells). The biggest offenders in this respect seemed to be those drilled during the last "big boom" of the late 1970s and early 1980s.

Porosity totals for the Charlie Lake Formation were measured but have not yet been mapped because it would probably not be a viable formation for CO_2 sequestration or water disposal. Porosity for the formation (all members were lumped together) is usually dispersed over a number of thin streaks of marginal quality. It seldom has more than three continuous metres of good porosity. Log presentation also poses a problem because very large sections of Charlie Lake appear to be well above the 6% porosity cut-off. Much of this apparent high porosity for Charlie Lake should probably not be included in the porosity total because it is of marginal quality. Poor drill-stem-test results usually confirm this suspicion. A strict gamma ray cut-off was applied to ensure that only the most viable, effective porosity has been included in the total.

Formation picks were provided by IHS Accumap. Their picks appear to be reliable for the more straightforward picks for the Halfway and Baldonnel Formations. These formations also happen to present the best sequestration potential in the Triassic. The Doig Formation can easily be confused with the base of the Halfway Formation; those locations with good porosity mapped in the Doig Formation could be added to Halfway Formation porosity if so desired by users of this data. Members of the Charlie Lake Formation are difficult to pick, so they were grouped together.

Porosity totals might be greater for formations only partly penetrated, especially for the Doig Formation, where many wells were drilled only deep enough to pick a top.

The Montney Formation was evaluated but not mapped because it is generally very shaley and contains only scattered lenses of cleaner sand and good porosity.

INTERPRETATION

Halfway Formation Porosity

This formation probably presents the best potential for either CO_2 sequestration or water disposal in the Triassic in BC. It has been proven to be a very good oil and gas producer with favourable reservoir qualities of porosity and permeability. It has also been used successfully in a number of places (Janicki 2008) for water disposal. Figure 2 shows that it is widespread in extent but not uniformly porous. Changes in facies from clean sand to relatively dirty or tight sands would aid trapping and isolation of disposed fluids or gases but are not adequate without suitable structure. Where it is porous enough to exceed the cut-off limit (10%), it usually approaches 20% or more for at least a portion of the section. Total thickness of reservoir quality sand ranges from zero to 8 m. Figure 2 shows a northwest-southeast trend of semi-isolated pods of relatively thick porous Halfway Formation sand stretching across the entire mapped area. This conforms roughly with what is generally accepted as the trend of the original Triassic shoreline. Porosity thins to zero at the depositional edge (Cant 1988) to the northeast. A secondary weaker north-south trend appears to splay off the main trend passing through NTS 094A/16, 094H/2, 094H/7, and 094H/10.

A second map for the Halfway Formation (Figure 3) is based upon total porosity-metres where it is clearly wet, as indicated by log responses and/or drill-stem-test results. Low total porosity on this map does not mean the Halfway is non-porous—it just indicates where thick, wet Halfway occurs. The locations with large total thickness values shown on this map should be of interest for either water disposal or CO_2 sequestration because injection into those intervals would not interfere with existing production and wet locations tend to be more isolated than clusters of productive wells—another advantage. Some of the thickest examples of porous Halfway Formation sand often happen to be wet. Many locations with thick sand sections fell only slightly below the cut-off and therefore were mapped with little or no total porosity. Optimistic tweaking of the cut-offs could result in many more metres of porosity for many locations.

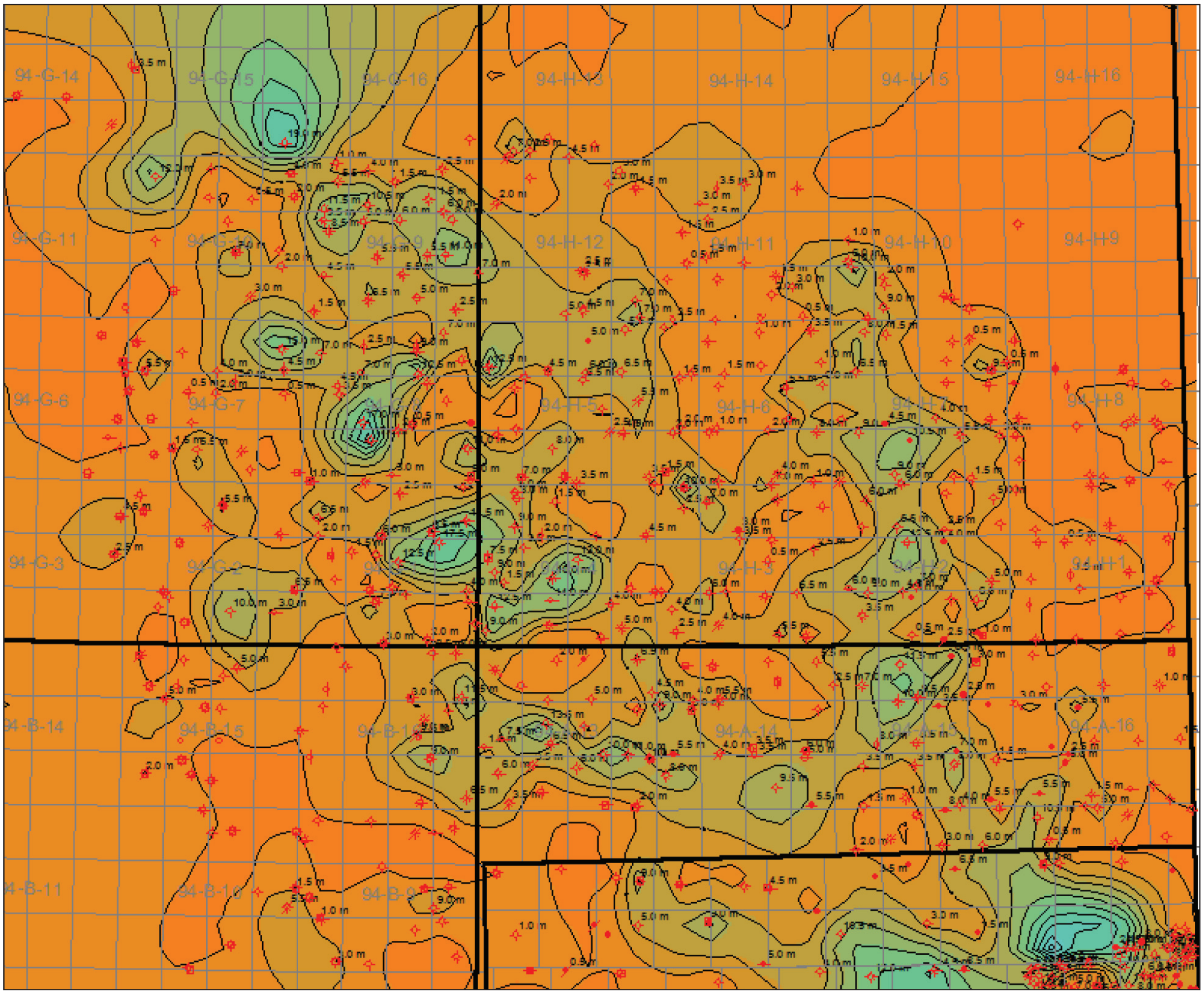

Figure 2: Halfway Formation Porosity (contour interval 2 m). Green represents thick porosity. Orange and brown represent low totals. Porosity cut-off is 10%.

Baldonnel Formation Porosity

The northwest-southeast trend for porosity-metres (Figure 4) for the Baldonnel Formation is generally consistent with the ancient Triassic shoreline, which advanced and retreated over a low-relief slope. The trend is muted and irregular in comparison to the Halfway because erosion removed the top rock units in many locations towards the northeastern limits of deposition. The upper units tend to be the most porous. In many locations, the Baldonnel section has too little matrix porosity to be counted. The Baldonnel often appears to be fractured; therefore porosity that was included in the totals might not be just matrix porosity. Even where clearly enhanced by fracturing, measured porosity is often just above cut-off.

Fracture porosity is probably not ideal for containing waste water or CO_2 because fractures could cause wastes to flow in unpredictable paths. The increase in pressure introduced by injecting waste streams could enlarge and extend existing fractures into and beyond the formations intended to seal them in place.

The best sites to consider for disposal into the Baldonnel Formation appear to lie west and north of the Siphon and Boundary Lake Fields, respectively. Another potential area of interest lies near the Birley Field in NTS Block 094H/3. The Boundary Lake Field itself appears to be of relatively little interest, but it would be problematic for disposal because it is known to be dissected by many normal faults, which could act as conduits into overlying formations.

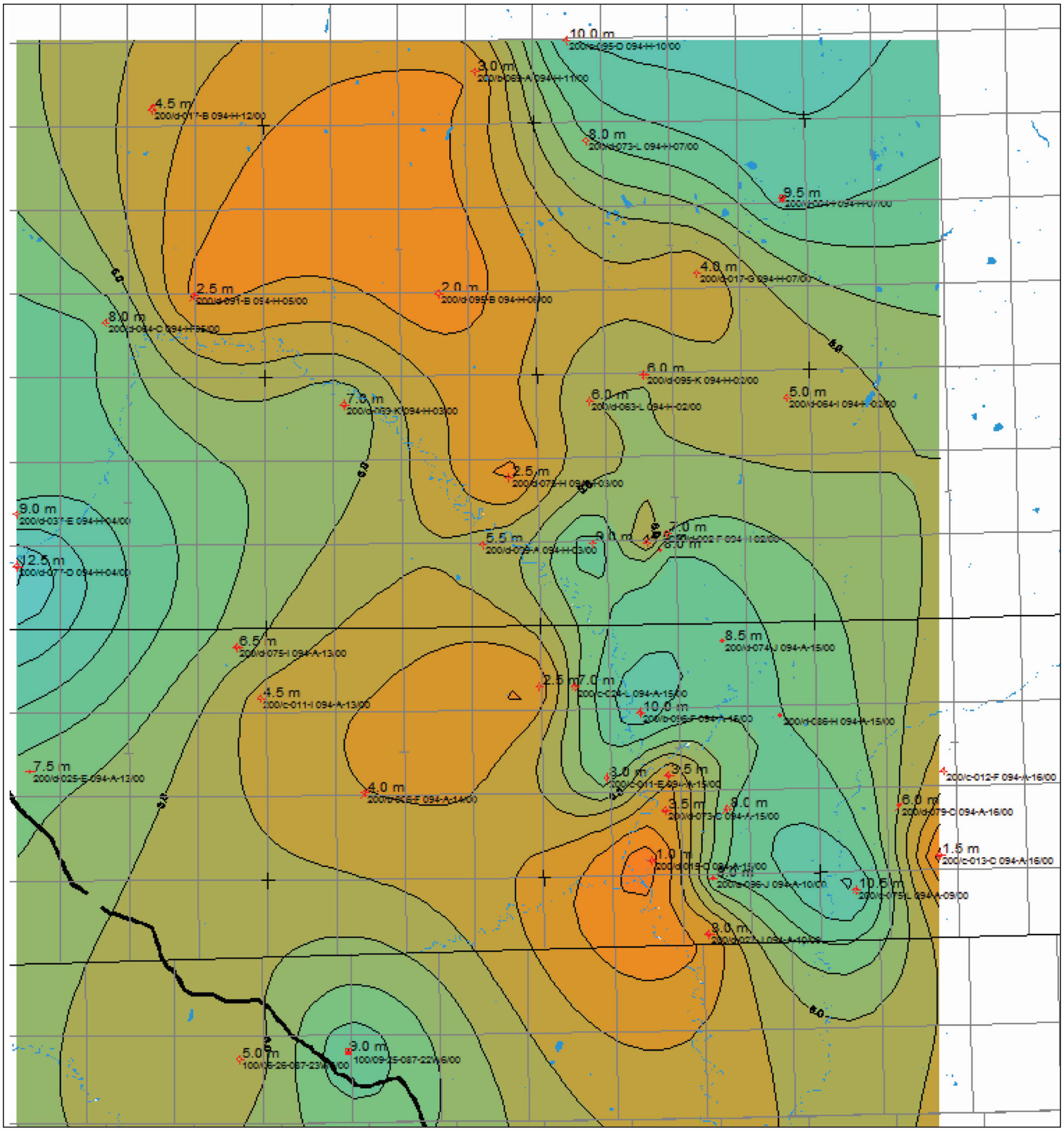

Figure 3: Wet Halfway Formation Porosity (contour interval 2 m). A strong northwest trend of thick, wet and porous Halfway occurs to the north of the township block. Isolated occurrences, such as the 9 m in 9-25-87-22W6, might be of greatest value for water disposal or CO_2 sequestration.

Doig Formation Porosity

The Doig Formation can easily be confused with the Halfway (as discussed above), so porosity-metres might not be valid in all cases. Despite that possibility, the Doig Formation, or the rock that occurs at the stratigraphic level picked as Doig in these wells, shows some promise because the thickest porosity-metres appear to be isolated in scattered, discrete pods. This would be favourable because good porosity in one or several wells would tend to be surrounded by wells with little or no Doig porosity. There would be less chance, therefore, of injected wastes interfering with current production or escaping into uphole formations.

No clear trend is discernable for the Doig Formation, at least for the area covered (Figure 5). This lack of a trend might be an indication of poorly defined stratigraphic picks; on the other hand, it might simply indicate that the natural

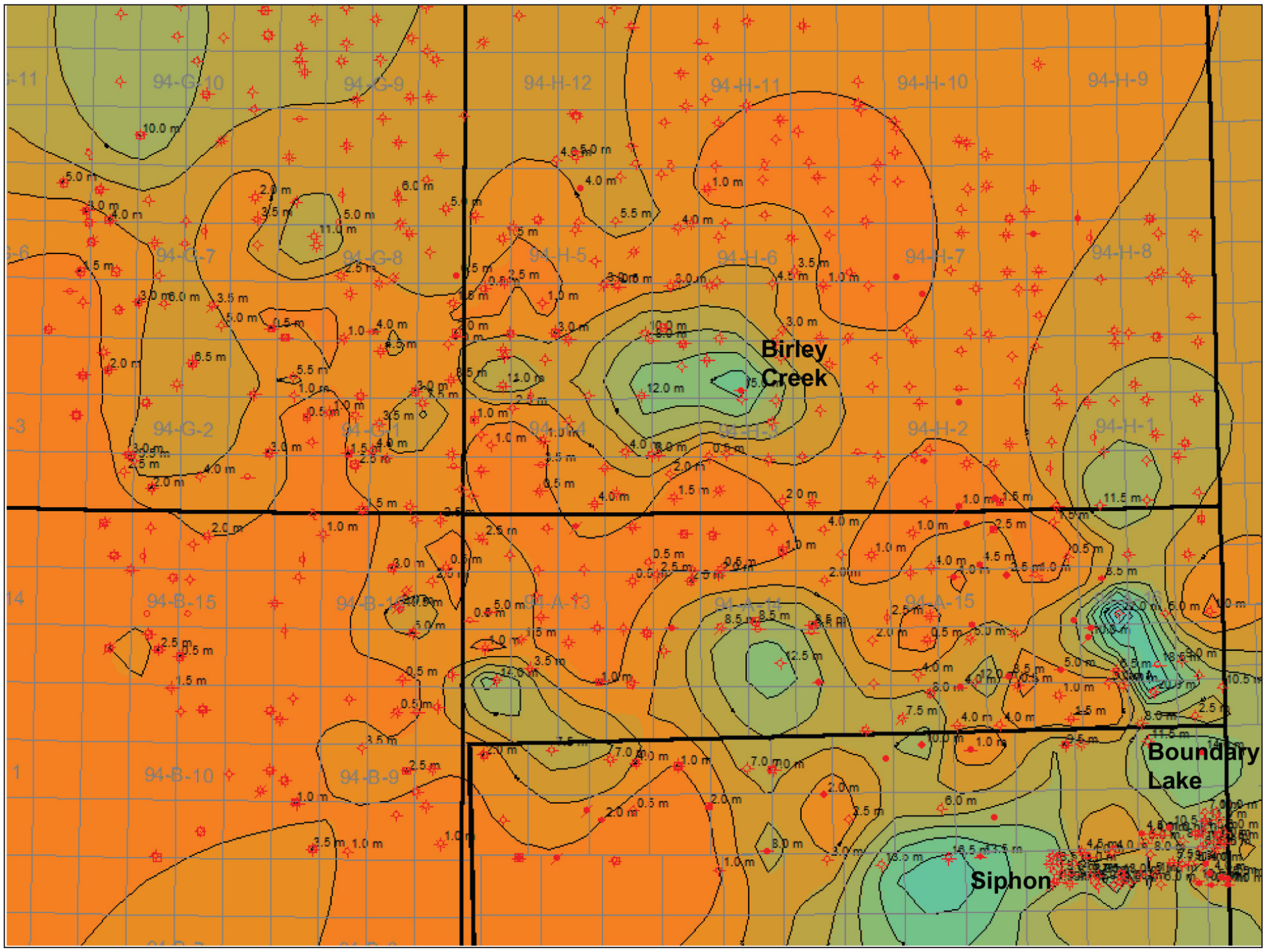

Figure 4: Baldonnel Formation Porosity (contour interval 2 m). Green represents the thickest accumulations of porous Baldonnel. The best sites to consider for disposal into the Baldonnel Formation appear to lie west and north of the Siphon and Boundary Lake Fields, respectively.

tendency of the Doig Formation is to be less clean and porous than the overlying Halfway Formation and that porosity, when it occurs, requires special geological conditions. This apparent randomness of porosity might be advantageous when considering disposal sites because isolation is beneficial in containing wastes.

While most of the Doig Formation appears to have low porosity, in a few places it does have among the thickest occurrences of any of the Triassic formations considered. The northeast trend (some might break this trend into two isolated pods) in NTS Block 094A/14 and the north-westernmost portion of the township block shows very good porosity totals of up to 29 m. Several isolated but relatively thick pods of up to 15 m and surrounded by low porosity occur to the northwest.

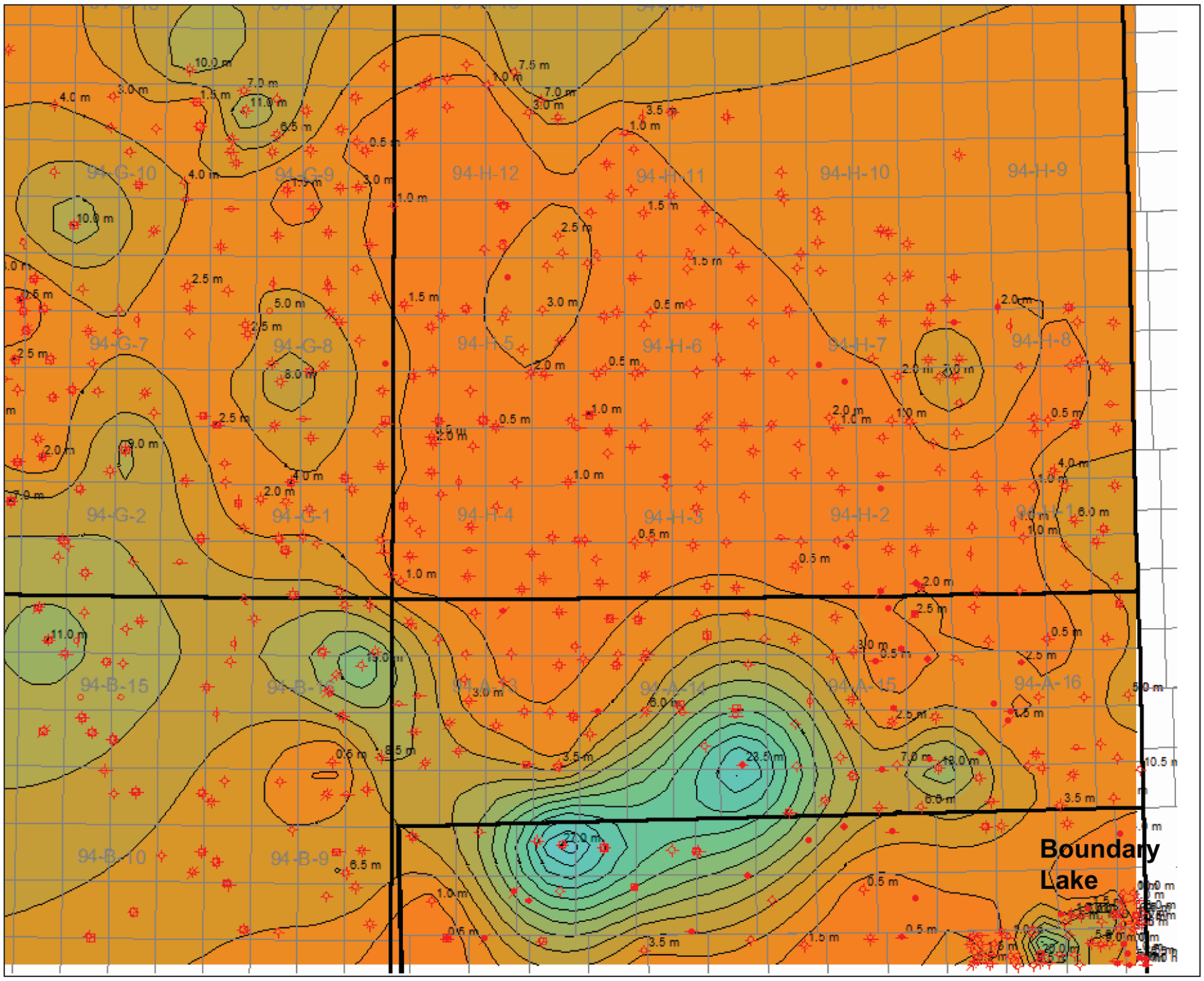

Figure 5: Doig Formation Porosity (contour interval 2 m) . Thick Doig porosity, highlighted in green, occurs at the northwest edge of the township block. Another small but thick occurrence is present in the Boundary Lake Field. An overall strong trend does not appear to be present.

CONCLUSIONS

This project attempts to identify potential sites for disposal of produced waters or CO_2 in northeastern British Columbia by mapping porosity of Triassic formations. Roughly 600 evenly distributed locations were selected for evaluation of Triassic porosity. Maps showing porosity-metres for the Halfway, Baldonnel, and Doig Formations were drawn. More work will be done to refine the mapping presented here.

Overall, the Halfway has the greatest number of potential disposal sites because many locations have good sections of continuous porosity. A number of locations with wet Halfway were segregated and mapped separately. The trends of thick porosity shown by this map should receive special consideration because wet locations tend to be more isolated and disposal into those areas would not be disruptive to production.

The Baldonnel Formation has generally less-favourable characteristics for waste disposal, but some porous trends are present, and it does have a local history of accepting significant volumes of produced waters.

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