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# Athabasca carbon dioxide storage as gas hydrate: A call for improved current and recent temperature and permafrost data and histories.

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## Summary

Improved Athabasca region subsurface temperature and permafrost data and histories would greatly assist the development of $CO_2$ hydrate storage. The current set of the most reliable data, from high precision temperature logs and gas pool reserve data suggest a complicated current and recent permafrost history throughout Athabasca region that is of great importance for $CO_2$ hydrate storage decision making. The current industrial subsurface temperature data set is flawed, particularly for wells. The opportunity exists to improve the extraction of data from wells by considering these data together with data of other types from other sources. There is a general scientific need to improve this data base, not only for $CO_2$ hydrate storage, but also for other uses.

## Introduction

The Geological Survey of Canada (e.g., Wright et al., 2008) and others (e.g. Zatsepina and Pooladi-Darvish, 2012) investigated unconventional pore space $CO_2$ storage recognizing that $CO_2$ could be efficiently and effectively stored as a gas hydrate (Park et al., 2006). Athabasca region was recognized as the leading Canadian storage opportunity, because of the large regions over which potential $CO_2$ hydrate stability might be achieved. $CO_2$ hydrate storage was also inferred to be favourably located relative to both industrial $CO_2$ point sources (Wright et al., 2008; Cote and Wright, 2013) compared to the nearest available secure aquifer storage opportunities (Jafari and Bachu, 2014).

While conditions suitable for Athabasca $CO_2$ hydrate formation exist, the setting is less than ideally characterized. Natural Athabasca $CO_2$ hydrates have not been identified even though $CO_2$ is a common component of natural gas in the region. The industrial wellbore temperature data set is problematic, in part because it was collected for other purposes, sometimes not too carefully. Current or recent subsurface permafrost extent and its implications for local and regional $CO_2$ hydrate stability with depth and location are essentially poorly to un- described due to these data issues. In addition, details of the lithological variations and geological history in the stratigraphic succession that impact any and all of storage capacity, injection performance and storage complex geomechanics could be improved significantly.

## Theory and/or Method

Previous work identified three main styles of potential Athabasca region $CO_2$ hydrate storage:

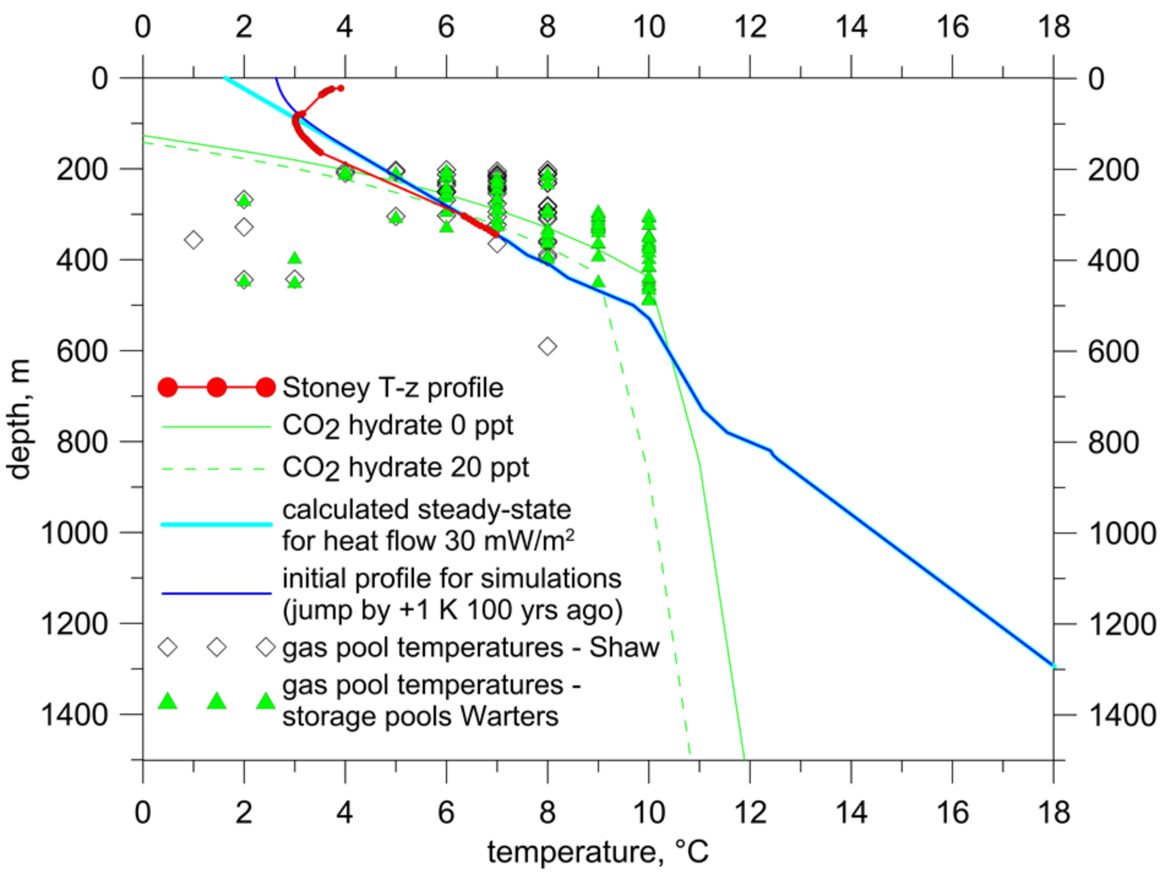
1. In natural gas pools that are currently within the $CO_2$ hydrate stability zone (Shaw, 2004).
2. In natural gas pools that achieve $CO_2$ hydrate stability in response to the injection of the $CO_2$ gas to be stored (Zatsepina and Pooladi-Darvish, 2012).
3. In regional aquifers that are currently within the $CO_2$ hydrate stability zone (Cote and Wright, 2013).

In addition, following specific natural $CH_4$ hydrate and free gas occurrences, it may be possible to manufacture a gas hydrate "trap", below which gas-phase $CO_2$ storage can augment the $CO_2$ hydrate storage volume.

These alternative opportunities complicate the decision making process regarding the choice of location for a "proof of principle" experiment that would demonstrate the ability to and technologies for the manufacturing $CO_2$ hydrate storage. The characterization and analysis of the hydrate storage opportunity is complicated additionally by the uncertainties in the ultimate storage potential and relative costs of each of the three storage styles, in large part due ultimately to the unreliability of the industrial subsurface temperature data set. Finally, the style of $CO_2$ hydrate storage that could be best suited to efficient industrial storage may not be the most practical choice of storage for a "proof-of-principle" experiment.

## Examples

Zatsepina and Pooladi-Darvish (2012) indicate that the rate of $CO_2$ hydrate formation that would occur in gas pools that are not currently in the $CO_2$ hydrate stability zone is probably too slow for a practical "proof-of-principle" experiment, despite the attractive features of this type of storage for actual applications. This type of storage also requires the simultaneous presence of water, gas and hydrate phases. The geomechanical suitability of gas pool caprocks are not currently demonstrated to ensure this stability, although the regional integrity of steam chambers in SAGD operations suggests this may not be a significant risk generally. The exact situation at any storage operation will have to be determined locally.




Currently, better opportunties for a $CO_2$ hydrate "proof-of-principle" test appear to occur in natural gas pools and regional aquifers that are already within the $CO_2$ hydrate stability zone. Such regions are inferred to have had distinctive subsurface permafrost and temperature histories such that the subsurface is currently variably in and outside of the $CO_2$ hydrate stability zone. Gas pool temperature variations vary widely between about 200-500 m depth and this suggests that permafrost history controls fundamentally where gas pools and aquifers lie with respect to the $CO_2$ hydrate stability zone currently (Figure 1).

The red line (Figure 1) represents a current high resolution temperature profile at Stony Lake, within the regional municipality of Wood Buffalo. It indicates that a $CO_2$ hydrate stability zone almost 300 m thick occurs currently in a region where previous work attributed no significant $CO_2$ hydrate stability potential. In addition, there a several gas pools with temperatures typically <3$^oC$, that suggest both the presence of current or recent subsurface permafrost to depths of ~130 m, that results in a current $CO_2$ hydrate stability zone that is more than 1000 m thick.

The Alberta Geological Survey is currently mapping indications for surface permafrost in Athabasca region, but the extent and variations of current or recent subsurface permafrost is essentially unknown. To what degree it will be possible to use a variety of data types, surficial indicators, well Tower Reports, seismic shot hole drillers' logs, or other survey or construction data to infer the distribution, depth and history of Athabasca permafrost and current temperatures remains an important, but uncertain enterprise.

It may be possible to conduct proof-of-principle $CO_2$ hydrate storage experiments at currently identified sites within the $CO_2$ hydrate stability zone. However, the planning, development and implementation of $CO_2$ hydrate storage will require an improved model of the subsurface temperature and permafrost history throughout Athabasca region. To this end it is desirable, as a community of geoscience and engineering practice, to develop methods that ensure all types of activities and surveys maximize the collection and dissemination of public shallow subsurface Athabasca temperature and permafrost data sets that are in everyone's best interest to collect. Such data sets will have benefits that could inform, construction, transportation, and wildlife management activities.

## Conclusions

1. Current Athabasca region subsurface temperature and permafrost data is flawed and incomplete.
2. The development of Athabasca $CO_2$ hydrate storage opportunities, among other users, would be assisted greatly by an improved understanding of the regional and local temperature and permafrost history.
3. Diverse existing data sets may contribute to an improved use of the existing industrial temperature data set.
4. Efforts should be made to coordinate the collection of new and reliable data incidental to current and on-going activities of may types that will, once accumulated, improve our understanding generally and specifically about currrent and recent Athabasca subsurface temperatures and permafrost histories.
5. This is a general scientific opportunity that should be conducted voluntarily and publically through a mechanism yet to be established.

### References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