GeoConvention 2015
GEOSCIENCE
new horizons
Telus Convention Centre • 4-8 May 2015 • Calgary, AB Canada

A Practical Approach to Caprock Analysis For Geologists

Mike Carlson, Applied Reservoir Enterprises Ltd.
Dickson Lee, Peter Cooper and Adam MacDonald, Big Guns Energy Services Inc.
Michelle Uwiera, 3 Phase Terra Consulting Ltd.

Summary

Caprock integrity has become a major issue with failures at Joslyn and Primrose. The AER placed a moratorium on shallow SAGD project approvals in early 214 and issued draft requirements for enhanced applications in June of 2014. The documents are labeled RC-1 through RC-5. The documents will affect all those making SAGD license applications. The AER has said these are for shallow projects and that deeper projects will be dealt with afterwards. While less requirements are likely for the deeper projects, the stage will be largely set in the shallow project environment. Not surprisingly, requirements have become more comprehensive. Having said that, the vast majority of the documents are technically not a surprise.

During the last year the government issued a report in July of 2014 that outlines the underling causes of the Primrose failure. They also took the unusual step of having outside experts produce a commentary on the report. In the covering documents the AER indicated they are of the opinion that such failures are preventable in the future.

Geological description is the foundation of caprock analysis and is therefore of great interest to all geologists, geophysicists and engineers. Caprock needs to be considered early in development.

Introduction

The draft documents outlining the new application requirements have different purposes, that are outlined below:

CODE	TITLE
RC-01	Summary of Conclusions from Reservoir Containment Project
RC-02	Caprock Criteria and Information Requirements
RC-03	Development of the Maximum Operating Pressure Formula
RC-04	Limitations of Geomechanical Models
RC-05	Monitoring Reservoir Containment in Thermal EOR

Major highlights from the documents include:

- Definition of shallow areas and a summary of contents and conclusions in RC-1
- More detailed geological descriptions are required. 3D geophysical interpretations are also now required
- The AER indicates that they do not consider glacial sediments adequate. Although it is true that the sediment are not lithified as much as the Creteaceous sediments, the glacial materials are for the most part re-worked Cretaceous rock and have similar mineralogies. The softer the material (i.e. glacial sediments) the more it can conform to thermal expansion of the pay. From an engineering perspective this is actually an advantage
- Detailed consideration of a number of groundwater settings demonstrate that shallow sediments, which are predominantly (,but not exclusively,) glacial in origin, can have unloading and dessication cracks. There is also increased heterogeneity in Quaternary glacial sediments vs Cretaceous marine sediments. It follows that these two issues most definitely should be dealt with for shallow projects and this means only one thing: more detailed geological description.
- An explanation of the MOP formula is laid out to deal with the potential for fraccing from the well into the caprock by injecting at excessive pressures.
- The limitations of geomechanical models are an accurate representation of the uncertainty inherent in all reservoir models.
- The AER has identified specific requirements for how to set up coupled geomechanical / thermal reservoir models that requires the shoulders of steam chambers be modelled. Single well pair models, located in mid pad, are now not considered acceptable. This should be of major concern to engineeers.The ARE indicated that they had received a number of such models.
- The use of geostatistics is touched on. The requirement for physical integrity suggests a limiting case is more appropriate. Production P50's and P90's do not correspond to caprock needs.
- The geomechanical models (including chamber shoulders) have not explained the failure that occurred at Joslyn. Some scepticism is therefore quite appropriate. It may suggest something else: some fundamental physics are missing. In this case the problem is not related to uncertainty in input. To date, there are still no published models on the Joslyn failure.
- Monitoring is discussed in detail. There has been some very successful monitoring in California, which is not in the public domain which are not discussed.

The increased geological description is laid out in RC-02, and will be of concern to all making applications for SAGD projects. This is the main topic of the paper.

Theory and/or Method

The meat of this paper is thus about detailed logging of the caprock. The techniques used are different than for oil sands pay. They are almost diametrically opposites in strategies:

Issue	**Oil Sands**	**Caprock**
Core handling	Freeze the core to prevent dilation of the sand from evolving solution gas	Keep the core warm, above freezing to prevent core from cracking
Core processing	Slab core for stratigraphic analysis and take pictures	Core kept whole for triaxial testings. Pictures. CT scans, Index tests, & Geotech logging
Core Storage	Most sent to AER core storage center in 0.75 m boxes. Some core is not required by AER	Moisture room with sealed containers and high humidity to preserve physical properties.

As may be seen from the table everything one learns for oil sands core goes out the window. The handling and processing are so different it suggests two entirely different crews are required.

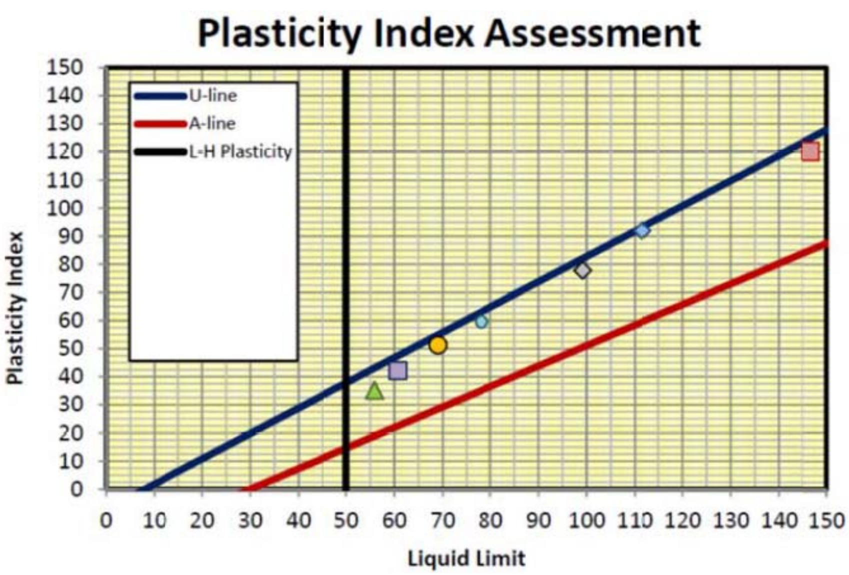
Four things should be explained:

1. Triaxial tesing requires the full core diameter. Larger samples give more representative physical properties. This means that slabbing should not be done. Keeping the whole core allows samples to be picked based on engineering analysis.
2. The logging includes the stratigraphic description. The geomechanical log would be taught in engineering geology. The caprocks in the Athabasca are really soils, they are not lithified. The geomechanical logging is designed to identify diifferences in stiffness (done with fingernail), pocket shear strength and unconfined compressive strength "probe" estimation, and detailed records of the number of core breaks per foot for a Rock Quality Description (RQD) and tracking the orientation and recovery.
3. The moisture room keeps the core solid. It is also possible to take moisture samples right on the drilling rig and check if you're core is OK later on. We've all been to the lab after a core has been in the core storage for a year. The caprock looks like a pile of rubble. No good for testing physical engineering properties.
4. Index properties are the least obvious. Devised by a Swedish Geotechnical engineer (Atterberg) the sample is mixed with water to find out where the clay changes from a plastic solid to a liquid state. The method uses a specially designed cup and requires rolling the clays out, so there is some scientific control. Empirical evidence has been gathered that allows soil friction angles to be estimated. Most importantly, weak zones with different properties can be identifed for a fraction of the cost of a triaxial test. It is greatly reminiscent of making mud pies as a kid. The dirt on one's clothes surely indicates considerable fun can be had.

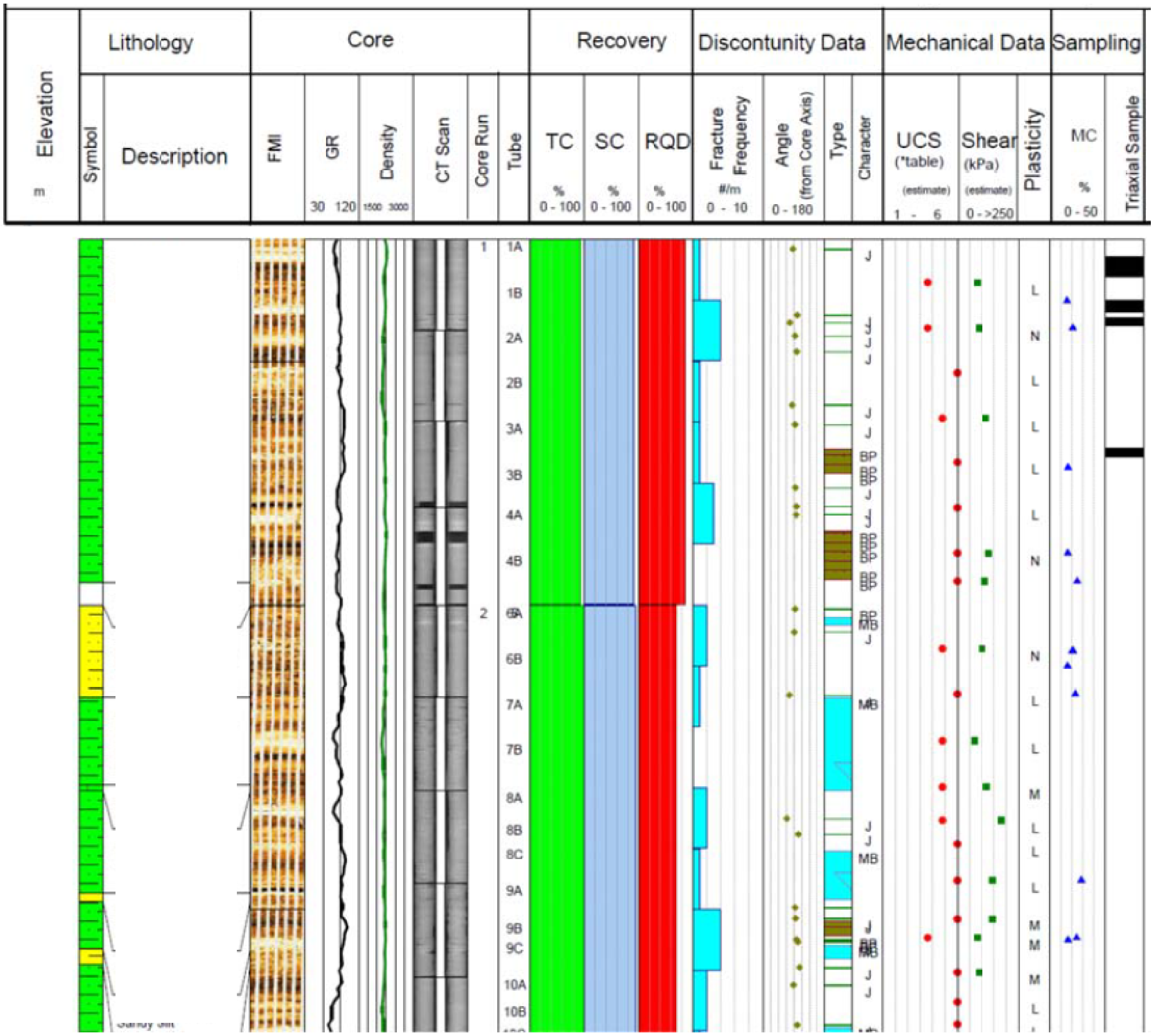
The real key to this is to be able to evaluate the entire caprock interval with indicator tests that are relatively inexpensive. Critical areas are then reserved for the more expensive triaxial testing.

Examples

Atterberg Limit test results are shown on a diagram, such as the one shown below:



Geomechanical logs are correlated to traditional gamma-ray logs. They include lithological description, FMI images, soil density from open hole logs, recovery estimates, RQD, orientations and the type of breaks identified (with codes), and the results of index tests. An example is shown below:



Conclusions

The AER is requiring more detailed description for thermal project licensing. Good description needs to include geotechnical engineering elements as well as traditional geological elements. The core handling for caprock core is very different than for oil sands (reservoir) core, which suggests two different teams. A different storage strategy is required for caprock core than for oil sands core.

Acknowledgements

The authors would like to thank Big Guns Energy Services Inc. for permission to describe this process.

References

1. Uweira-Gartner, Carlson, Walters and Palmgren; "Geomechanical Simulation of Caprock Performance for a Proposed, Low Pressure, Steam Assisted Gravity Drainage Project", CSUG/SPE 148886; Canadian Unconventional Resources Conference held in Calgary, Alberta, Canada, 15–17 November 2011.
2. Uwiera-Gartner, M.M.E., Carlson, M. R., and Palmgren, C.T.S.; "Evaluation of the Clearwater Formation caprock for a proposed, low pressure, steam-assisted gravity-drainage pilot project in Northeast Alberta", SPE Annual Technical Conference and Exhibition held in Denver, Colorado, USA, 30 October–2 November, 2011.
3. Hein, and Fairgrieve; "Joslyn Creek SAGD: Geologic Factors Related to a Surface Steam Release Incident, Athabasca Oil Sands Area", 2011 CSPG / CSEG / CWLS convention.
4. Total E&P Canada Ltd., Surface Steam Release of May 18th, 2006, Joslyn Creek SAGD Thermal Operation, ERCB Staff Review and Analysis, February 11th, 2010.
5. Total Canada, Summary of investigations into the Joslyn May 18th, 2006 Steam Release, TEPC/GSR/2007.006, December 2007.
6. Chhina, H.S., Luhning, R.W., Bilak, R.A. and Best, D.A., "A horizontal fracture test in the Athabasca Oil Sands", CIM Paper No. 87-38-55, Preprint, Annual Technical Meeting of the CIM, June 7-10, 1987.
7. H. Loseth, L. Wensaas, B. Arntsen, N. Hanken, C. Basire and K. Graue, "11000 m long gas blow-out pipes", P524 EAGE 63rd Conference & Technical Exhibition — Amsterdam, The Netherlands, 11 - 15 June 2001
8. ERCB Investigation Report, MEG Energy Corp. Steam Pipeline Failure, License No. P 46441, Line No. 001, May 5th, 2007", September 2nd, 2008.
9. Gale, J., Tiselj, I., "Water hammer in elastic pipes", International Conference, Nuclear Energy for New Europe, Kranjska Gora, Slovenia, Sept. 9-12, 2002.
10. Giot, Prof. Michel, "Two-Phase flow water hammer transients and induced loads on materials and structures of nuclear power plants (WAHAloads)", European Consortium, UCL/TERM Batiment Simon Stevin, 2, Place du Levant, B-1348, Louvain-la-Neuve, Belgique.
11. Progress Report on Research Activities in 2003, KFKI Atomic Energy Research Institute, Budapest 114, POB 49, H-1525 Hungary.
12. NUREG/CR-6519: Screening Reactor Steam/Water Piping Systems for Water Hammer, P. Griffiths, MIT, Sept. 1997.
13. Bjorge, R.W., Initiation of Water Hammer in Horizontal or Nearly-horizontal Pipes Containing Steam and Subcooled Water, Ph.D. Dissertation, MIT, January 1983.
14. Carlson, M.R. (Mike); "And now for something completely different: condensation induced water hammer and steam assisted gravity drainage in the Athabasca oil sands", NURETH14-600, The 14th International Topical Meeting on Nuclear Reactor Thermalhydraulics, NURETH-14 Toronto, Ontario, Canada, September 25-30, 2011. Kerntechnik 77 (2012), Carl Hanser Verlag, Munchen.
15. Carlson, M.R. (Mike); "Detailed Consideration of the Proposed Joslyn Failure Mechanism", CETI, April-May 2012.
16. Carlson, M.R. (Mike); "A discussion about condensation induced water hammer and caprock integrity"; Society of Petroleum Engineers, Edmonton Section, Dinner presentation, January 10th, 2012.
17. Carlson, M.R. (Mike); "What every SAGD operator and engineer should know about potential failure by condensation-induced water hammer", Journal of Canadian Heavy Oil Association, September 2010.
18. Edmunds, N.R. and Good, W.K.; "The nature and control of geyser phenomena in thermal production risers", JCPT 96-04-04, April 1996, Volume 34 No. 4.
19. Carlson, M.R. (Mike); SPE-156962-PP "An Analysis of the Caprock Failure at Joslyn", presented at the SPE Heavy Oil Conference held in Calgary, Alberta, Canada 12-14th June 2012.