Appendix 6

Mini-Frac Test

MINI-FRAC TESTS AT VCI TRI-STAR NE WELL: 07-25-089-08W4[1]

--- Summary of the tests and analysis results ---

Jefferey Tailleur, Bin Xu and Y. Yuan[2]

BitCan Geosciences & Engineering Inc.
Bay 8, 3200 - 14 Ave NE, Calgary, Alberta T2A 6J4
APEGA Permit of Practice #07814

May 31, 2012

On behalf of Value Creation Inc. (VCI), BitCan conducted 4 mini-frac tests on its' Well: 07-25:

1) Clearwater Shale at 95-97 mTVD,
2) McMurray Shale at 122-122.5 m,
3) McMurray Sand at 140-140.5 m, and
4) McMurray Sand at 154-154.5 m TVD,

The first test at 95-97 mTVD was done on an openhole while the remaining 3 tests were on a cased well. The test locations of well 7-25 are denoted on the well log as shown in Figure 1. Objectives of the tests were to assess the in-situ stress conditions. This report will illustrate how the in-situ minimum stress was estimated as well as include a summary of the results.

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[2] Responsible member under APEGA rules.

1. General test procedure

The mini-/micro-hydraulic fracturing test is regarded in the industry as the most reliable method to assess the in-situ minimum stress. Via controlled well injection, it creates a fracture and propagates it to a sufficient distance from the injection well and into the formation. This ensures the fracture senses the far-field stress condition. The pressure data is analyzed to estimate the fracture closure pressure. The fracture closure pressure can then be equated to the in-situ minimum stress acting perpendicular to the fracture. Our tests employ new advancements and improvements to the mini-/micro-hydraulic fracturing stress test protocol currently used in the petroleum industry. They also contain modifications tailored specifically for use in the oil sands and heavy oil development.

The first test at 95-97 mTVD was performed on an open hole. An isolation packer tool was run into the hole with tubing. The tool straddled the injection zone with a seal at 95.00 and another seal at 97m depth marks, respectively. Fluid was then injected through the tubing and into the isolated interval of 95 to 97 mTVD.

After the above openhole test was completed, the well was cased and cemented. The remaining 3 tests at 122m, 140m and 154m were carried out on the cased well. In each test, an interval of 0.5 m in height was perforated with a phasing of 60° and a density of 20 shot/m. Water was injected bullhead down into the casing. Testing began at the lowest depth on each well and a bridge plug was set between two adjacent perforation intervals.

In all the 4 tests, the injection pressures were monitored on-site via two surface pressure sensors: one close to the pumps and the other at the wellhead. This is valid given the insignificant well friction due to the relatively shallow depth, low injection rates and low-viscosity water being used. The bottomhole pressure is calculated by adding the hydrostatic column to the surface-recorded pressures. For the analysis, the pump pressure has been used. During the shut-in and flow-back, little difference is seen between the pump and wellhead pressure sensors. Multiple injection and shut-in or flow-back cycles were used during each test to verify the data consistency. This is an effective quality-control measure to achieve a better accuracy (Yuan et al., 2011[3]). Figures 2 - 5 plot the recorded pressure and rate history during each of the tests. Multiple injection and shut-in cycles were used during each test.

A flow-back procedure was also used during each test during which, a certain volume of water was manually withdrawn from the injection system (wellbore plus the fracture) during the shut-in period. The fracture is thus able to close quickly and properly due to the manually reduced pressure drop. A plot of BHP vs. cumulative injected volume (called compliance plot), can be used to detect the fracture closure. It is generally agreed that a properly executed and accurately metered flow-back yields better constrained data on the minimum stress. BitCan's mini-frac test system can accurately control and meter the flowed-back volume and rate. Figure 6 illustrates an example compliance plot and its interpreted fracture closure pressure.

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[3] Yuan, Y., Xu, B. and C. Palmgren, 2011, Design of Caprock Integrity in Thermal Stimulation of Shallow Oil-Sands Reservoirs, CSUG/SPE 149371, presented at the Canadian Unconventional Resources Conference held in Calgary, Alberta, Canada, 15–17 November 2011.

2. Analysis of field data and depth profile of the in-situ minimum stress

It is BitCan's practices to place great deal of emphasis on acquiring high quality data during the tests. As shown in Figures 2 to 5, multiple injection/shut-in cycles were used in each test. In all the tests, obvious formation breakdown occurred in the first injection cycle, i.e., a fracture was formed. In the subsequent injection cycles during each test, the pressure declined or stayed relatively flat, signalling the continuous fracture propagation.

For each injection/shut-in cycle, the fracture closure pressure was interpreted by a linear flow (or sqrt(t)) plot. A system compliance plot was also used for the interpretation if the flow-back procedure was used. A good compliance plot, such as the one shown in Figure 6, should have two different slopes. Intersection of these two slopes denotes the fracture closure pressure. The initial slope, corresponding to before the fracture closes, is shallower on the P (pressure) vs.V (flow-back volume) plot while the second slope, reflecting the post-closure system compliance, is steeper.

For each of the 4 tests, the fracture closure pressures, interpreted as described above, are reconciled in Figures 7 to 10 between the different cycles. In general, a consistent closure pressure is seen in each test among the different cycles. Moreover, different interpretation methods, sqrt(t) or compliance plots, all give a similar closure pressure. Combining these methods serves to enhance the interpretation accuracy.

The interpreted in-situ minimum stresses (Smin) at the tested depths are shown in Figure 1. Their specific values are summarized in the following tables:

VCI Tri-Star 07-25-089-08W4						
	TVD, m	Min. stress		Vert. stress		Stress regime
		MPag	kPag/m	MPa	kPa/m	
Clearwater Shale	95-97	1.999	20.82	2.073	21.59	H. frac
McMurray Shale	122-122.5	2.696	22.10	2.660	21.80	H. frac
McMurray Sands	140-140.5	2.870	20.50	3.041	21.72	~H. frac
McMurray Sands	154-154.5	3.136	20.36	3.326	21.60	~H. frac

"Min. stress" at each test interval cited in the above tables is the arithmetic mean of the fracture closure pressures interpreted from each cycle of the corresponding test. It is equivalent to Smin. To be consistent among the tests, the first two cycles for each test are taken out when the mean is calculated. The initial cycles may not have propagated the fracture far away enough from the injection well and thus, the near-wellbore complexities may obscure the interpretations. In a few isolated tests, one or two cycles other than the first 2 cycles are also taken out due to the obvious difficulties for a reliable interpretation. If this happens, this is noted explicitly in Figures 7-10.

"Vert. stress" was calculated independently by integrating the density log of the corresponding well. If the log value falls outside of [2,000, 2,500] kg/m^3, including for the depths without density values, a common 2,500 kg/m^3 is assigned in the calculation.

More details about the stress regime shown in the above tables are described below. When the interpreted in-situ minimum stress, Smin, is smaller than Sv, i.e. "Vert. stress" calculated from the density log, it means a vertical fracture is formed and Smin represents the in-situ minimum horizontal stress, SHmin. In this case, the vertical fracture stress regime, "V. frac", is present.
If Smin differs from Sv by less than 5%, a horizontal fracture stress regime, "H. frac", is assigned. In the latter, the measured fracture closure pressure is close to Sv, i.e., a horizontal fracture is formed. Note that when Smin is similar to Sv, it does not necessarily mean that SHmin is larger than Sv. It is still possible that SHmin is equivalent to Smin and thus, close to Sv. In this case, the preferred fracture direction is not certain between vertical and horizontal directions.

In BitCan's terminologies, if Smin is smaller than Sv by more than 10%, the "V. frac" stress regime is assigned. If Smin is smaller than Sv by 5 to 10% only, a near horizontal fracture stress regime, "~H. frac", is assigned.

In general, the following observations can be drawn from the tests. Discussions are also given for further explanations.

1. All the measured depths are in the horizontal fracture stress regime where the measured in-situ minimum stress (Smin) is approximately equal to the vertical overburden stress (Sv). The latter is independently calculated from the density log.
2. Note that both the McMurray reservoir and its overlying McMurray shale and Clearwater shale are situated in the "H. frac" stress regime. In BitCan's database which compiles about 500 tests in the context of oilsands, the Clearwater shale normally has the "H. frac" stress regime if its depth is shallow such as around 200-300 m and shallower. The present tests agree with the general trend. BitCan's database also shows that the McMurray reservoir is normally in the "V. frac" stress regime if its depth is relatively deep, e.g., deeper than about 200 m. But many tests in shallow McMurray reservoirs point to the "H. frac" stress regime. Our present test also agrees with the latter trend.

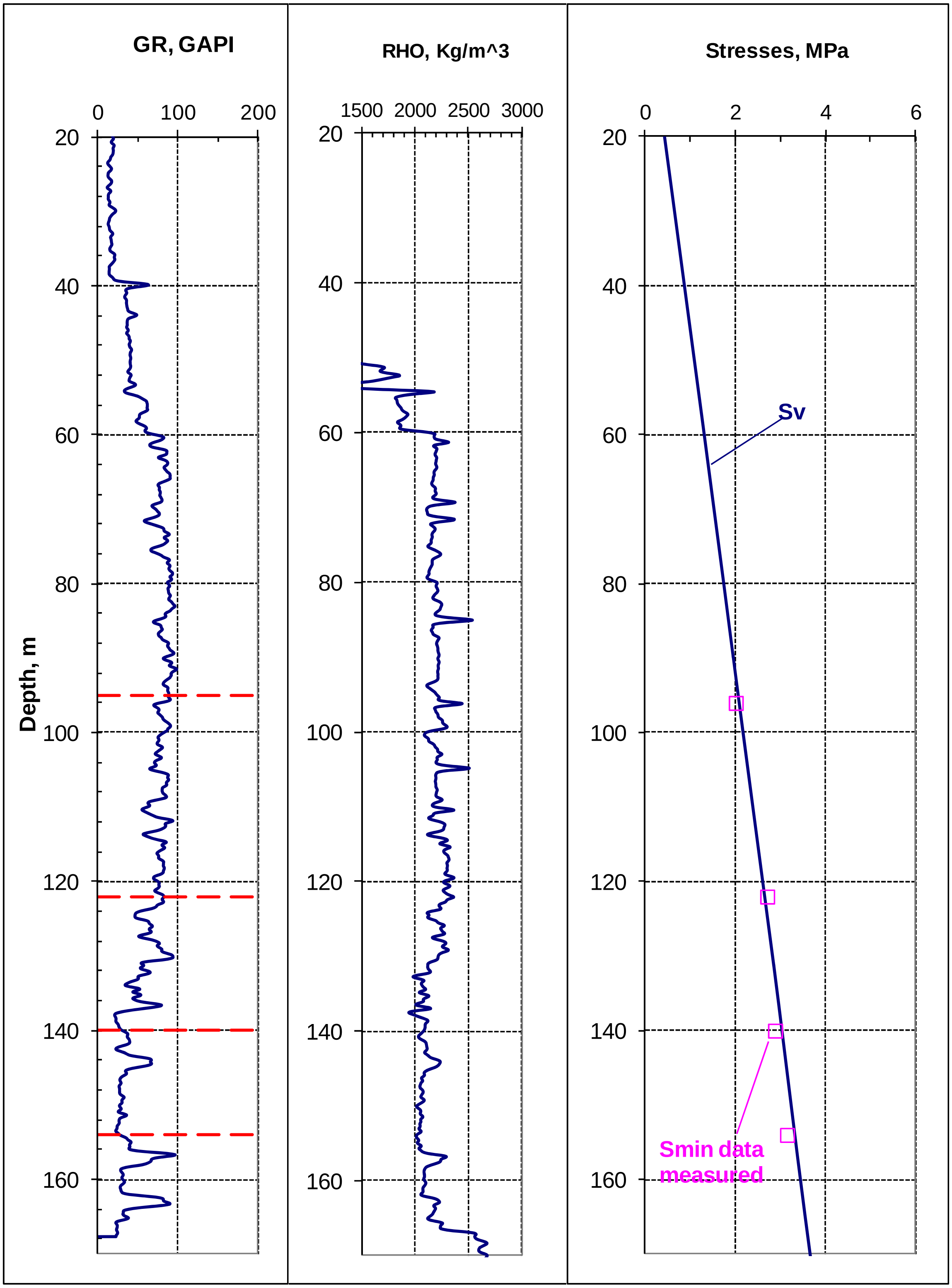


Figure 1: Summary of the in-situ minimum stresses measured from Well 07-25. Red dotted lines on the gamma log denote the mini-frac test intervals. “Sv” denotes the vertical overburden stress calculated from the density log. “Smin” in squares is the interpreted minimum stress from the mini-frac tests.

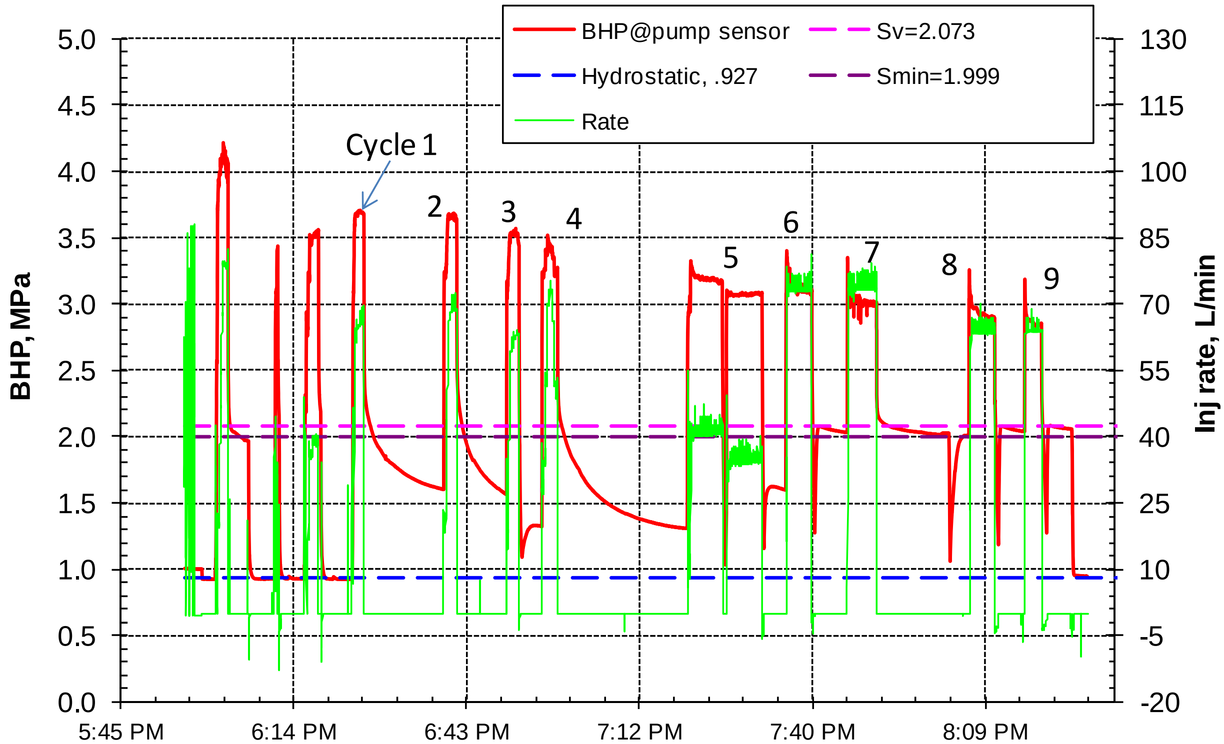


Figure 2: Recorded pressure/rate history during the injection test in the Clearwater at 95-97 m TVD. This was an openhole test. The bottomhole pressures ("BHP") were calculated from a surface pressure sensor at the pump plus the hydraulic head ("Hydrostatic") from the water column weight. The overburden weight ("Sv") was calculated from the density log of the well. "Smin" is the arithmetic mean of fracture closure pressures interpreted from each valid cycle of the test. When Smin is clearly smaller than Sv by more than 10%, it is the in-situ minimum horizontal stress and specially denoted by "SHmin". Similar conventions are used below unless otherwise specified.

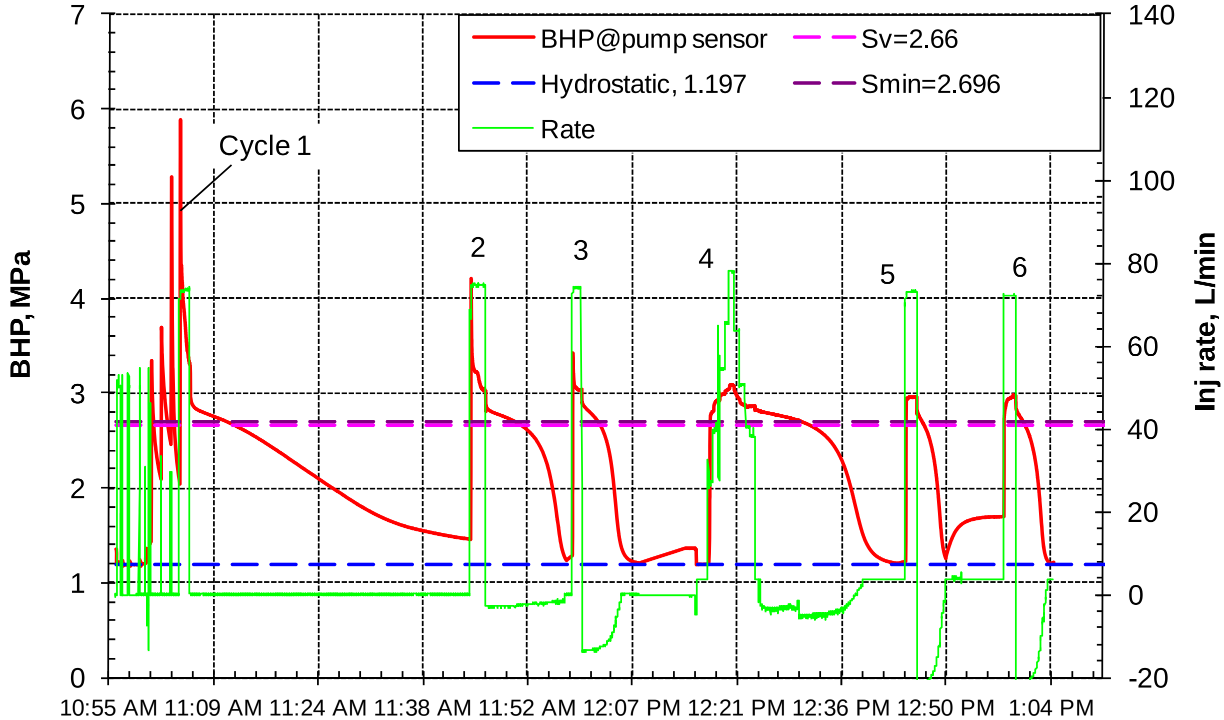


Figure 3: Pressure/rate history, McMurray Shale at 122-122.5 m TVD.

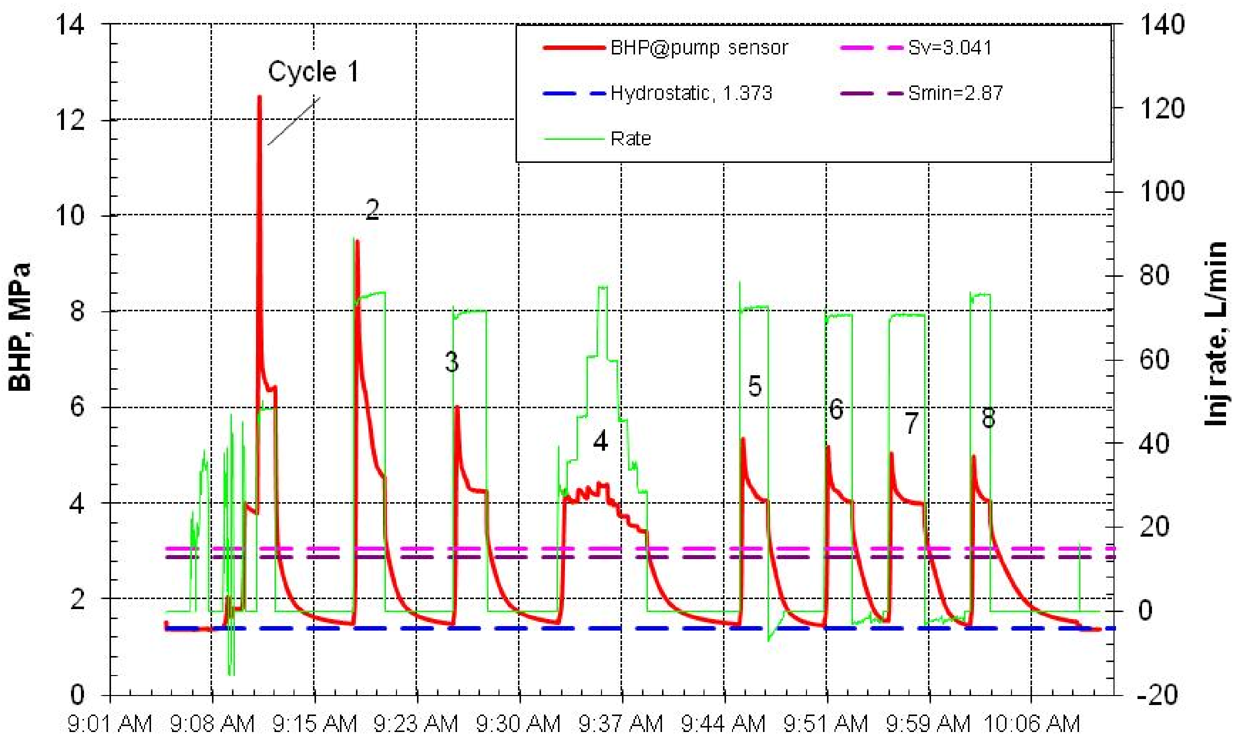


Figure 4: Pressure/rate history, McMurray Sands at 140-140.5 m TVD.

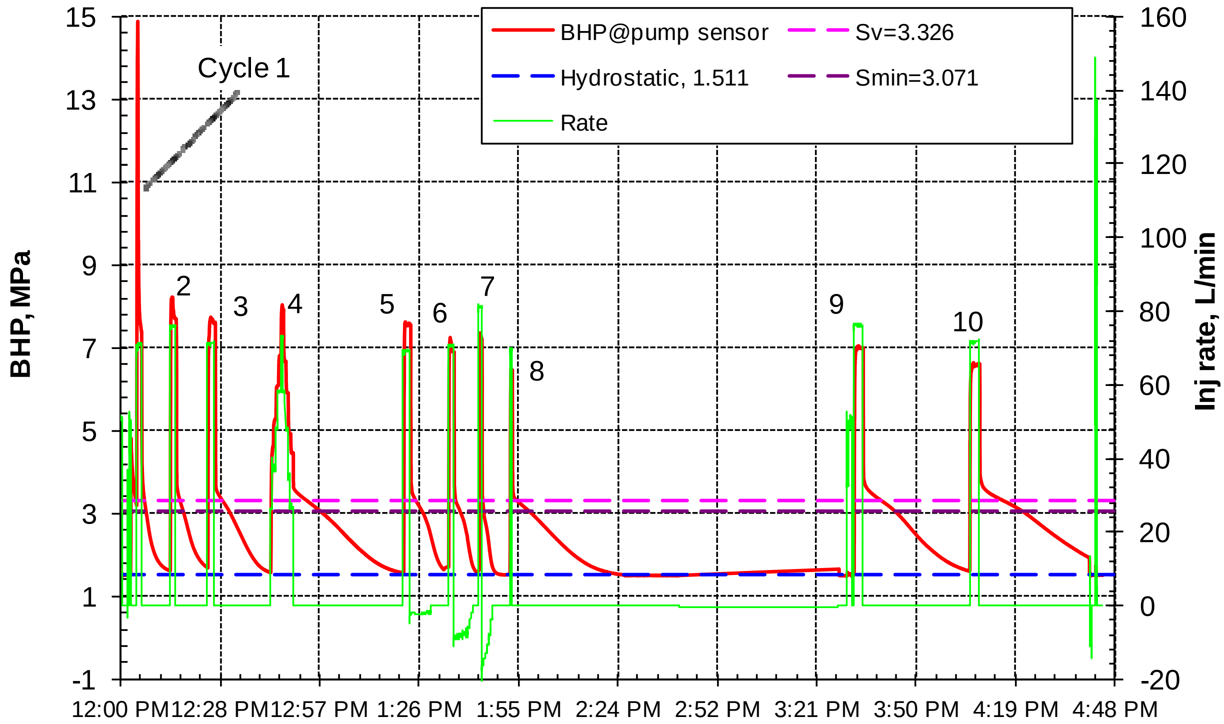


Figure 5: Pressure/rate history, McMurray Sands at 154-154.5 m TVD.

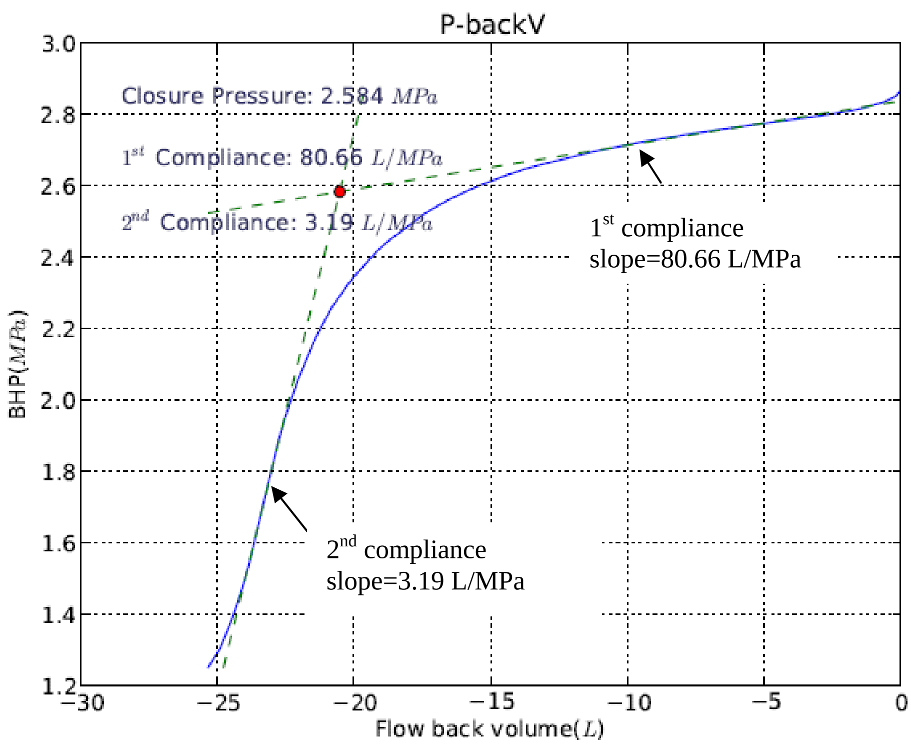
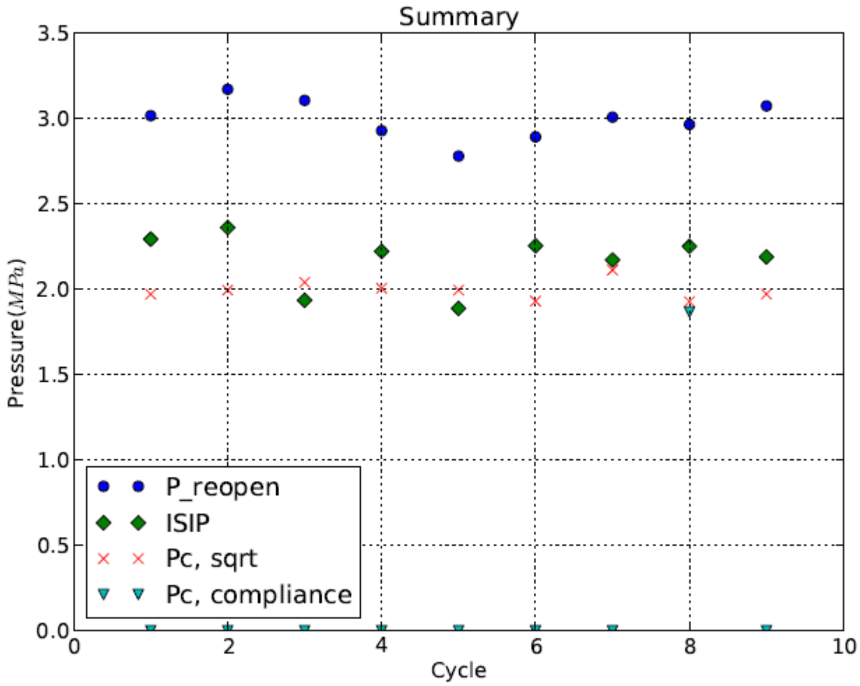


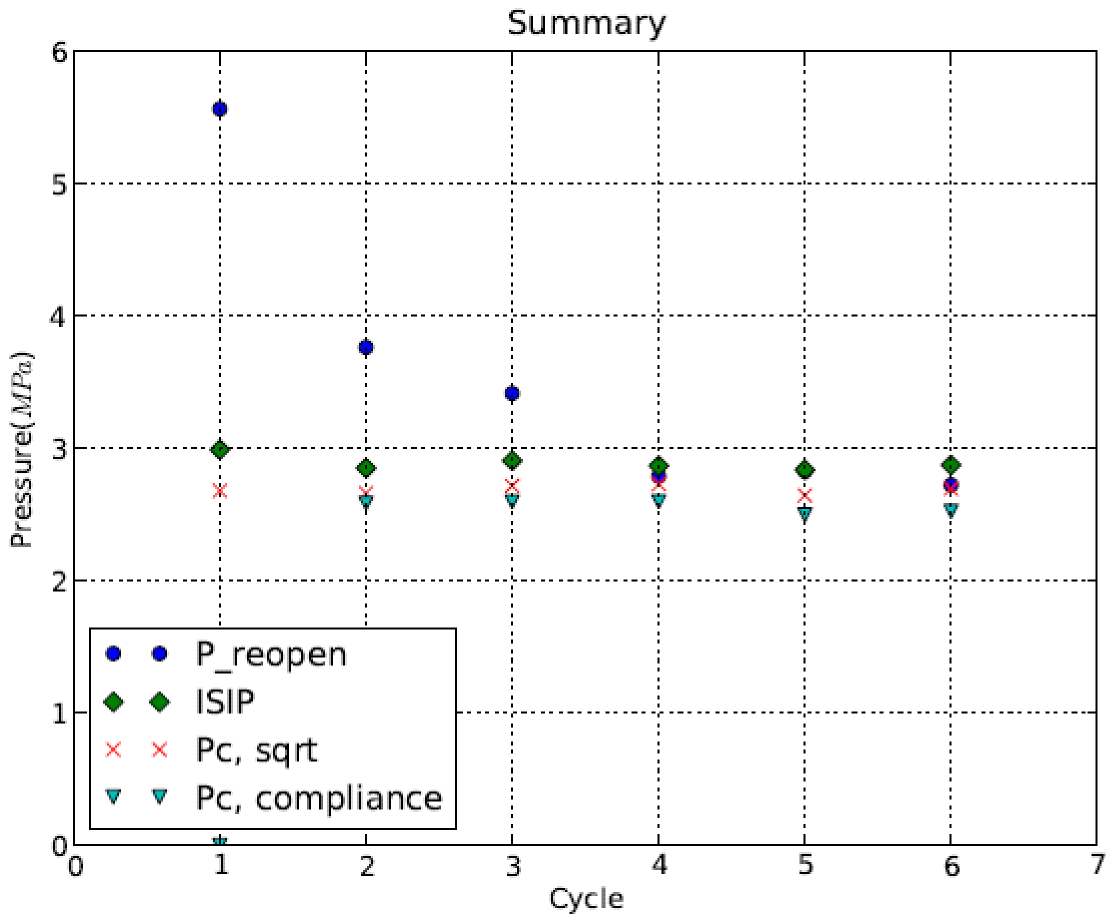
Figure 6: Fracture closure pressure interpreted from the compliance plot for Cycle #2 in the McMurray shale test at 122-122.5 m. The negative volume on the x-axis denotes the flow-back volume.



Characteristic Pressures and Compliances

Cycle #	P_reopen (MPa)	ISIP (MPa)	Pc, sqrt (MPa)	Pc, compliance (MPa)	Cb, inj (L/MPa)	Cf, back (L/MPa)	Cb, back (L/MPa)
1	3.018	2.295	1.971	0.000	1.09	0.00	0.00
2	3.173	2.363	1.996	0.000	0.64	0.00	0.00
3	3.108	1.936	2.041	0.000	0.65	0.00	0.00
4	2.930	2.222	2.007	0.000	0.73	0.00	0.00
5	2.781	1.889	1.996	0.000	0.69	0.00	0.00
6	2.894	2.255	1.931	0.000	0.50	0.00	0.00
7	3.009	2.172	2.114	0.000	0.00	0.00	0.00
8	2.966	2.252	1.929	1.867	0.36	2.52	1.29
9	3.075	2.190	1.973	0.000	0.97	0.00	0.00

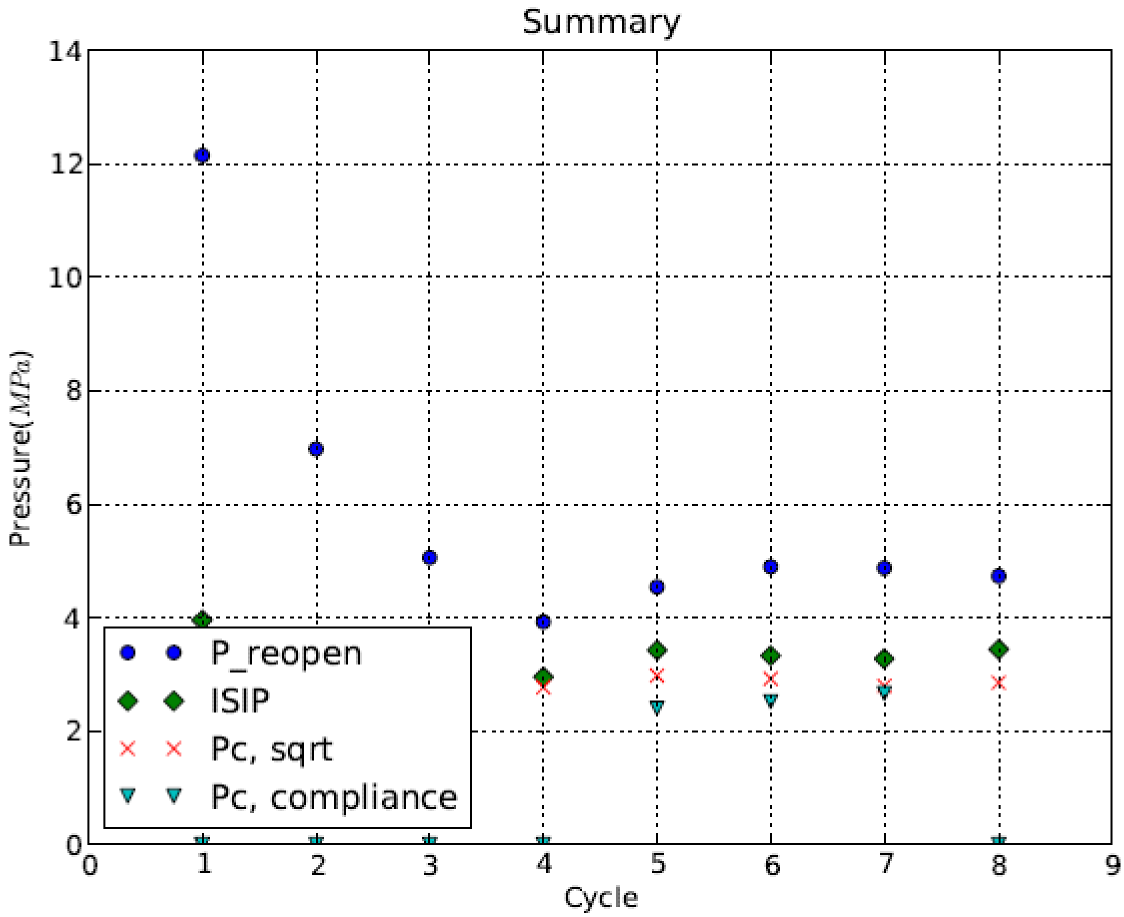
Figure 7: Various characteristic pressures interpreted from the test at 95-97 m TVD (Clearwater). “P_reopen” denotes the fracture reopening pressure where the fracture starts to re-open during the subsequent injection. In the first cycle, P_reopen corresponds to the breakdown pressure when the fracture was formed. “ISIP” is the Instantaneous Shut-In Pressure. “Pc, sqrt” refers to the fracture closure pressure extracted by the sqrt(dt)-plot. “Pc, compliance” is the fracture closure pressure extracted by the compliance plot from the flow-back tests. “Cb, inj (Cf, back or Cb, back)” refers to the initial system compliance during the injection (the system compliance before or after the fracture closure during the flowback). Fracture closure pressure reported in the text for the test is the arithmetic mean of Pc,sqrt interpreted from each cycle with the results for the initial two cycles dropped out. All pressures are downhole values equivalent to the BHP plotted in Figure 2, which have been converted from surface pump pressures using the density of water for hydrostatic head. Similar conventions hold for all the plots below unless otherwise specified.



Characteristic Pressures and Compliances

Cycle #	P_reopen (MPa)	ISIP (MPa)	Pc, sqrt (MPa)	Pc, compliance (MPa)	Cb, inj (L/MPa)	Cf, back (L/MPa)	Cb, back (L/MPa)
1	5.568	2.991	2.679	0.000	1.25	0.00	0.00
2	3.766	2.851	2.661	2.584	1.24	80.66	3.19
3	3.417	2.908	2.717	2.595	1.75	163.84	6.95
4	2.790	2.869	2.729	2.597	1.96	168.60	12.12
5	2.828	2.839	2.644	2.497	2.36	154.53	10.04
6	2.724	2.875	2.695	2.522	1.83	175.78	9.44

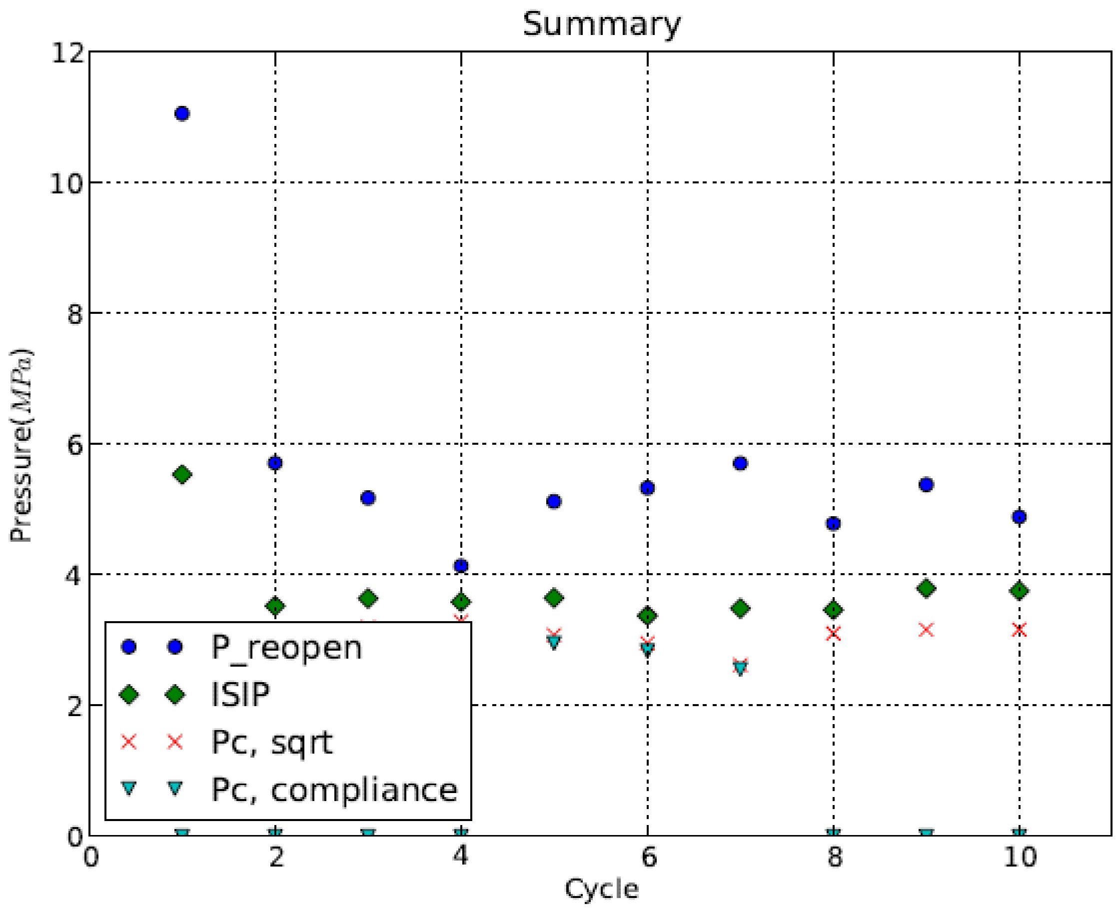
Figure 8: Various characteristic pressures interpreted from the test in the McMurray Shales at 122 m.



Characteristic Pressures and Compliances

Cycle #	P_reopen (MPa)	ISIP (MPa)	Pc, sqrt (MPa)	Pc, compliance (MPa)	Cb, inj (L/MPa)	Cf, back (L/MPa)	Cb, back (L/MPa)
1	12.154	3.956	2.276	0.000	0.79	0.00	0.00
2	6.972	3.225	2.797	0.000	1.18	0.00	0.00
3	5.053	3.066	2.908	0.000	1.76	0.00	0.00
4	3.926	2.951	2.769	0.000	2.28	0.00	0.00
5	4.542	3.425	2.976	2.401	1.66	3.54	2.39
6	4.891	3.329	2.921	2.515	1.79	2.17	1.95
7	4.870	3.274	2.794	2.658	1.97	2.05	1.93
8	4.731	3.442	2.852	0.000	1.97	0.00	0.00

Figure 9: Various characteristic pressures interpreted from the McMurray Oilsands test at 140 m.



Characteristic Pressures and Compliances

Cycle #	P_reopen (MPa)	ISIP (MPa)	Pc, sqrt (MPa)	Pc, compliance (MPa)	Cb, inj (L/MPa)	Cf, back (L/MPa)	Cb, back (L/MPa)
1	11.059	5.533	3.077	0.000	1.09	0.00	0.00
2	5.712	3.529	3.107	0.000	1.11	0.00	0.00
3	5.178	3.640	3.202	0.000	1.27	0.00	0.00
4	4.137	3.589	3.291	0.000	2.11	0.00	0.00
5	5.125	3.645	3.077	2.952	1.42	16.82	6.01
6	5.329	3.379	2.954	2.833	1.58	45.78	12.86
7	5.706	3.488	2.621	2.554	1.55	37.02	12.74
8	4.785	3.468	3.102	0.000	1.67	0.00	0.00
9	5.379	3.794	3.161	0.000	1.94	0.00	0.00
10	4.887	3.753	3.162	0.000	1.90	0.00	0.00

Figure 10: Various characteristic pressures interpreted from the McMurray Oilsands test at 154 m.