CANISTER DESORPTION RESULTS FROM WELL DOI-04-1A, FORT YUKON, ALASKA

Chapter B.

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INTRODUCTION

This 2004 coal gas content study was done by reentering a 1994 USGS core hole to sample coal found in Tertiary strata of the Yukon Flats Basin (Ager, 1994). The 1994 well cut a coal at 1253 ft and drilled into it for 28 ft when coring stopped at 1281 ft, still in coal. In 1994, it was noted that gas was bubbling from the core but desorption testing of the coal was not possible at that time. Consequently, the reentry of the 1994 well, now officially named DOI-1A-04, was designed to test the methane content of the Miocene age coal (Ager, 1994). The DOI-1a-04 well (API no. 50-091-20001) is located at latitude 66.55949^{o}N and longitude 145.20616^{o}W. The total depth of the well was 2287 feet. The strata encountered was about 100 ft of River Gravel, followed by Pliocene to Miocene lake beds some 1.5 to 15 million years old (Ager, 1994). Permafrost was encountered in the well from just below the surface to about 300 ft depth. The well cut three major coal beds in two coal zones: the shallowest coal zone has two major coal beds from 1257 to 1315 ft (from gamma log picks) and at 1340 to 1345 ft. The second coal zone was at 1875 to 1920 ft with a major coal bed at 1900 to 1920 ft. The net coal thickness for the major coal beds in the two coal zones was 83 ft. Thin or muddy coals at 1875-1880 ft, 2030 ft, 2039 ft, 2057 ft. and 2067 ft were not sampled for desorption.

TECHNIQUE

Coal desorption followed a modified US Bureau of Mines (USBM) canister desorption method as described by Diamond and Levine (1981), Close and Erwin (1989), Ryan and Dawson (1993), McLennan et al (1994), Mavor and Nelson (1997) and Diamond and Schatzel (1998) as adapted and modified by Barker et al (1991, 2002) for the use of PVC canisters.

A major modification of the USBM technique in this study was the use of zero-headspace canisters (Barker and Dallegge, 2005). Canisters are filled with distilled water instead of helium gas as described in Barker et al. (2002). Distilled water is pre-chilled to about 45 – 50°F in the chilled water tanks to speed up equilibration of the can and coal core to the lost gas temperature.

Also we used a different desorption log form in Barker et al (2002) modified for zero headspace canisters. In zero headspace canisters, it is not necessary to measure internal can temperature for a subsequent headspace correction (Barker and Dallegge, 2005).

All canisters were pressure tested for leaks at 6 PSI over a period of at least 24 hours before use.

Desorption temperature during the lost gas estimate

Lost gas is the unmeasured gas desorbed from coal core from the time it is cut by the drill bit to the time the sample is sealed within the canister. Lost gas is controlled by the coal diffusivity and the length of time required to retrieve a sample. Lost gas is estimated by measuring the apparent rate of gas desorption from the sample sealed in the canister. This rate is used to extrapolate back to time zero, the time of the onset of sample desorption during retrieval.

During the lost gas period, we desorb at ambient mud temperature as discussed further in Barker et al. (2002). This is because mud temperature has been found at DOI-04-1a and wells in several other basins, such as the Maverick basin in Texas; the Nenana and Cook Inlet basins in Alaska to be close to the temperature measured at the center of a freshly opened core face (unpublished USGS data). We imply that because the gas is lost during core retrieval, as pressure decreases, that the mud temperature that the core is bathed in and has equilibrated to, rather than the in-situ coalbed temperature, is the relevant temperature to estimating diffusion of gas out of the coal matrix and therefore, lost gas.

We calculated a formation temperature in the coal zone by using a subsurface temperature of 32°F at the base of the permafrost at about 300 ft and a geothermal gradient range of 1 to 2° F/100 ft. Thus, 950 ft below the base of the permafrost at about 1250 ft, a temperature of 41.5 to 51°F is estimated for the undisturbed equilibrium rock temperature. The drilling operations may warm the mud in the well somewhat above this temperature range. Infrared thermometers were used to check drilling mud, tank and core-face temperature.

Actual mud temperature measurements varied on a roughly diurnal cycle with highs of about 48 to 52° F reached during the day and lows of about 42-45°F reached at night. Depending on the time of the core run, the tank temperatures were adjusted to the mud temperature. Confirmation of the use of mud temperature is made by measuring the temperature at the center of core faces freshly broken open immediately after the core is extruded from the core barrel into the tray. These measurements are typically very close to mud temperature if mud circulation through the well has been maintained for enough time for a thermal stability to be established.

After desorption during the lost gas period was nearly completed, tank temperature was allowed to rise to room temperature to prepare the canisters for transport from the drill site to the Laboratory.

Analysis of desorption data

The spreadsheet used for correction of the data to STP and preparation of a lost gas estimate uses a spreadsheet described in Barker et al (2002). The data from this analysis are presented in Appendix 1.

CORING OPERATIONS

The 2004 reentry well, DOI-04-1A was spudded on August 21, 2004 by drilling out a cement and completion bentonite plug in an existing 120 ft of casing left from the 1994 USGS well. The drillers expected that the new well would soon divert away from the strata disturbed by the 1994 well and enable us to core the entire coal rather than missing the first 28 feet that had been cored in 1994. Open-hole drilling was used to reach the core point at 1200 ft.

Upper Coal zone

The core point at 1200 ft is some 53 ft above the upper coal zone, the open-hole drill string was tripped out of the well to put in the slim-hole diamond wireline coring system. Tripping in the core string proceeded normally until the core string was dropped early in the morning of August 25. Drill string recovery operations ("fishing") ensued and the string was recovered to the surface during the evening of August 25. Given the depth of top of the lost core string and its known length, it appears that the core string had accessed the existing 1994 hole and the core bit had settled to within 4 feet of the original 1994 core well TD at 1281 ft.

When the core string was recovered, the base of the core string was plugged with about 12-15 inches of what appeared to be solid coal rather than coal cuttings. This coal plug was interpreted as further evidence that the base of the drill string had penetrated the coal at the base of the existing 1994 hole. Given the evidence, the decision was made to ream out the hole to within a few feet of the original 1994 TD and start coring from there. Monitoring of drill cuttings during reaming confirmed that a thick section of coal was now found above the base of the well. Adding the 12 to 15 inches of coal found in the base of the recovered drill string to the original 28 feet cored in 1994, means that approximately the first 30 feet of the coal seam were not cored in DOI-04-1a. However, as the coal was reamed in preparation for coring, we recovered three drill cuttings samples from the interval 1251 – 1281 ft and placed them in canisters for desorption (canister sample cuttings-1, 2, 3 in table 1).

The first core run, intentionally cut short to test the coring system and recovery, was retrieved at about 19:30 on August 26, 2004 and consisted of 18 inches of brown coal (lignite) that were placed in canisters 104-1 and 104-2. To assure we had enough desorption data, we placed all coal core in canisters for the first ten feet of recovered coal. After we had about 10 canisters filled with coal, we started desorbing every other foot of coal. Some coal core was lost during coring and core retrieval as well. Among the other vagaries of coring in general, the recovery problems are thought to be caused by sticky clay partings in the coal zone that clogged the carbide core catcher leading to some core slipping out of the core barrel during retrieval. In some cases, the lost coal cores were recovered on the next core run and placed in canisters (see can 104-9 spreadsheet notes) since

they should have retained their gas by staying at the hydrostatic pressure at the bottom of the well. Coring in mostly coal continued to about 1345 ft when the last approximately 4 ft thick coal was recovered from the coal zone. Thus, the major Fort Yukon coal zone lies from about 1257 to 1345 ft (drillers depths corrected using gamma log picks).

Lower Coal Zone

A lower coal zone was intersected at about 1900 ft (driller depths are herein corrected to gamma log depths) and was inadvertently drilled into for about 10 ft before the open hole drilling was stopped. Coal cuttings were recovered from 1905 – 1910 ft in placed in canisters 104-31 and 104-32. Coring commenced at 1909 ft and continued to 1919 ft. A total of 10 ft of coal core was recovered and all of this core was placed in canisters 104-33 to 104-42.

RESULTS

Desorption

The upper coal zone cores gas contents average 13.1 scf/ton with a standard deviation of 3.5 scf/ton for 21 samples. The lower coal zone cores gas contents average 19.1 scf/ton with a standard deviation of 4.0 scf/ton for 10 samples. The

Coalbed Saturation from Isotherms.

Methane adsorption isotherms are measured by reintroducing methane to a coal and measuring the equilibrium gas content at a given pressure and at a constant temperature. The resulting curves (Figs. 1 and 2) can be used with measured gas content from canister desorption (Table 1) to estimate several parameters of which two, degree of saturation and the reduction in reservoir pressure needed to saturate the coal, are significant in resource assessment.

The degree of saturation for the Upper coal zone is calculated to be 31%. The reduction of reservoir pressure to saturate the coal bed with methane is 435 psi. The degree of saturation for the Lower coal zone is calculated to be 41%. The reduction of reservoir pressure to saturate the coal bed with methane is 600 psi This is a relatively low degree of saturation in both coal zones. The low saturation is reflected in the relatively high reduction in reservoir pressure required to saturate the coals in either coal zone. Because a coal bed must reach saturation for desorption to occur, the large indicated pressure reduction required to reach saturation suggests that a large volume of water would have to be pumped out of the coal beds before gas production by desorption would occur. Based on this analysis, the cost for pumping out the coalbed water and disposing of the produced water would appear to be a major factor in determining if gas production is cost effective at Fort Yukon.

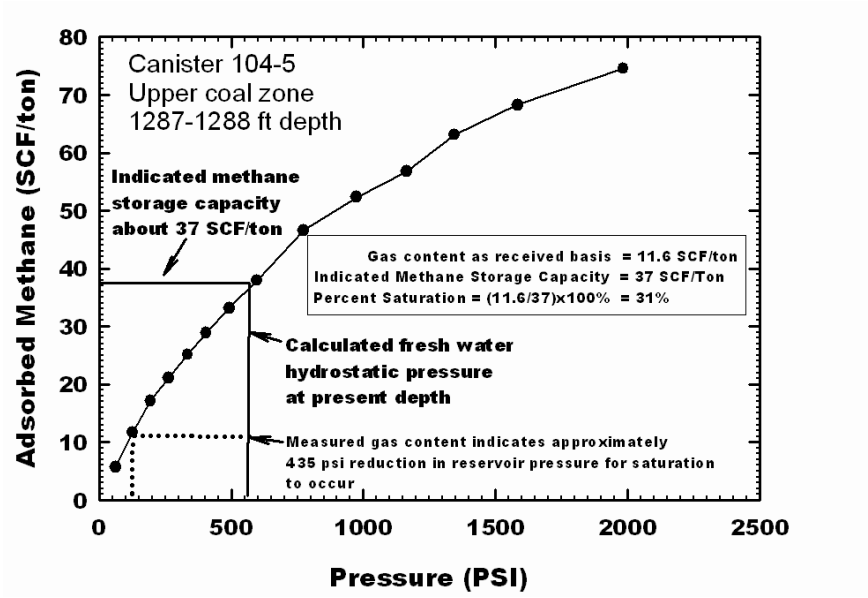

Figure 1. Methane adsorption isotherm for Canister 104-5 at 1287 to 1288 ft depth in the upper coal zone, DOI-04-1a well, Fort Yukon, AK. Isotherm conditions were: 15°C, coal at equilibrium moisture. Absorbed methane values reported on an as received basis. Coal zone pressures calculated using a fresh water hydrostatic gradient projected to the sample depth.

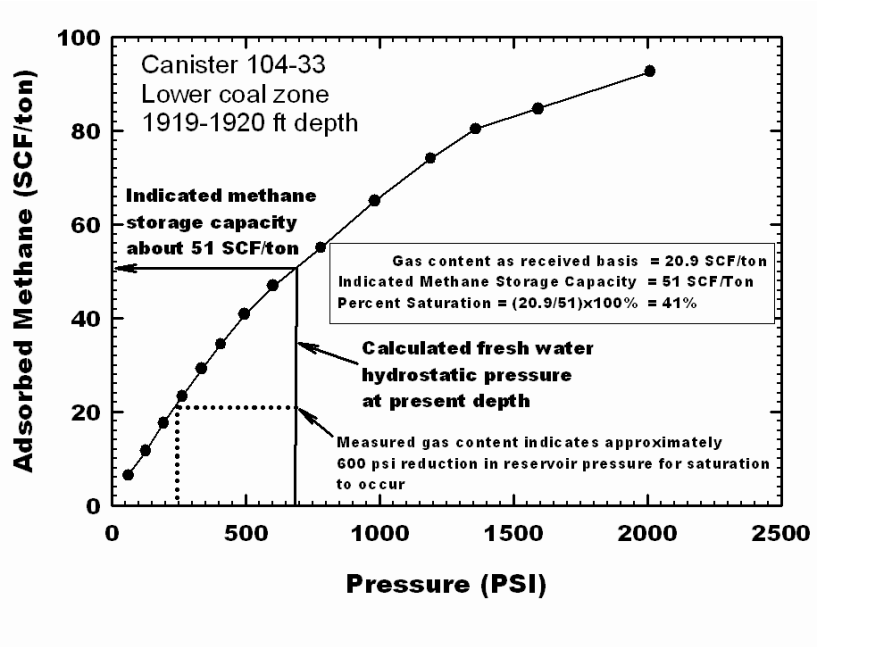

Figure 2. Methane adsorption isotherm for Canister 104-33 at 1919 to 1920 ft depth in the lower coal zone, DOI-04-1a well, Fort Yukon, AK. Isotherm conditions were: 15°C, coal at equilibrium moisture. Absorbed methane values

reported on an as received basis. Coal zone pressures calculated using a fresh water hydrostatic gradient projected to the sample depth.

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Table 1A. Summary of Canister Desorption Results, Upper Coal Zone

Canister Number	Depth Interval From gamma ray log (drillers depth)		Canister Sample Lithology	Raw coal mass	Lost Gas Estimate	Total Raw Gas Content
Upper Coal Zone	Top	Bottom				(as-received basis)
	(feet)	(feet)	% coal	(g)		(scf/ton)
CORE						
104-1	(1283)	(1284)	100	1056	60	14.1
104-2	(1284)	(1284.5)	50	490	40	13.5
104-3	(1285)	(1286)	100	907	85	10.8
104-4	(1286)	(1287)	100	905	80	9.8
104-5	(1287)	(1288)	100	951	80	11.6
104-6	(1288)	(1289)	100	1009	115	21.1
104-7	(1289)	(1290)	100	1149	85	7.0
104-8	(1290)	(1290.7)	70	471	85	14.5
104-9	(1295)	(1296)	100	961	85	13.4
104-10	(1304.5)	(1305.5)	100	1087	110	13.8
104-11	(1306.5)	(1307.5)	100	1193	95	12.1
104-12	(1308.5)	(1309.5)	100	1115	130	13.6
104-13	(1310.5)	(1311.5)	100	1132	130	13.9
104-14	(1312.5)	(1313.5)	100	842	80	11.0
104-15	(1315)	(1316)	100	1038	80	12.9
104-16	(1319)	(1320)	100	1171	85	8.6
104-17	(1324)	(1325)	100	1518	100	9.0
104-18	(1339.7)	(1340.7)	100	1082	100	18.7
104-19	1342 (1343)	1343 (1344)	100	749	100	19.5
104-20	1343 (1346)	1344 (1347)	100	1028	110	15.2
104-21	1344 (1349.25)	1345 (1350.25)	100	1098	100	10.9
Statistics:				Sample	Mean	13.1
				Standard	Deviation	3.5
CUTTINGS						
Cuttings-1	1265*	1270*	80	575	45	7.7
Cuttings-2	1270*	1275*	80	609	20	4.6
Cuttings-3	1275*	1280*	80	886	20	2.0
Statistics:				Sample	Mean	4.8
				Standard	Deviation	2.9

* = depth interval estimated from lag time. These cuttings were not screened and the coal fines lose their gas quickly thought to lead to the spuriously low raw gas content.

Table 1B. Summary of Canister Desorption Results, Lower Coal Zone

Canister Number	Depth Interval From gamma ray log (drillers depth)		Canister Sample Lithology*	Raw coal mass		Lost Gas Estimate	Total Raw Gas
Lower Coal Zone	Top	Bottom					Content (as-received basis)
	(feet)	(feet)	% coal	(g)			(cc/g)
CORE							
104-33	1909 (1919)	1910 (1920)	n.r. 100?	1006		120	20.9
104-34	1910 (1920)	1911 (1921)	n.r. 100?	1037		100	22.5
104-35	1911 (1921)	1912 (1922.1)	n.r. 100?	1105		100	19.4
104-36	1912 (1922.1)	1913 (1923.1)	n.r. 100?	994		120	20.4
104-37	1913 (1923.1)	1914 (1924.1)	n.r. 100?	996		120	20.9
104-38	1914 (1924.1)	1915 (1925.0)	n.r. 100?	1239		120	12.8
104-39	1915 (1925.0)	1916 (1926.0)	n.r. 100?	1118		120	17.8
104-40	1916 (1926.0)	1917 (1927.0)	n.r. 100?	1115		125	21.7
104-41	1917 (1927.0)	1918 (1928.0)	n.r. 100?	993		85	23.1
104-42	1918 (1928.0)	1919 (1929.0)	n.r. 100?	1233		85	11.2
						Mean	19.1
						Standard Deviation	4.0

Abbrevations = n.r. = not reported.
*Lithology about 100% coal from gamma log interpretation

Appendix 1. Desorption and coal analysis summary

See online version of this open file report at www.usgs.gov for file link.

Appendix 2. Raw and corrected desorption data with lost gas estimate

See online version of this open file report at www.usgs.gov for file links.

Appendix 3. Rock-Eval Pyrolysis Raw data

See online version of this open file report at www.usgs.gov for file link.