

Husky Energy Inc.

**BULK AND CLAY X-RAY DIFFRACTION ANALYSIS
OF ELEVEN TAR SAND SAMPLES FROM
THE HUSKY PRIMROSE 3-7-69
1AA/03-07-069-04W4M/00 LOCATION**

Work Order A-12250

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X-RAY DIFFRACTION ANALYSIS

Eleven sand or shale samples from Clearwater Formation at the Husky Primrose 3-7-69' 1AA/03-07-069-04W4M/00 location (Table 1) were analyzed by AGAT Laboratories Ltd. for bulk and clay XRD mineralogy.

Table 1 - Sample Information

Sample No.	Depth (m)	Dominant Lithology
1	471.1	Mostly sandstone
2	475.0	Mostly sandstone
3	478.65	Mostly sandstone
4	479.45	Mostly shale
5	481.70	Mostly sandstone
6	486.10	Mostly sandstone
7	488.40	Mostly sandstone
8	489.90	Mostly sandstone
9	492.00	Mostly sandstone
10	492.75	Mostly sandstone
11	494.95	Mostly shale

The clay fraction (less than $3\mu\text{m}$) was separated from the bulk fraction in an ultrasonic bath, using sodium metaphosphate as a deflocculating agent. The separated material was then centrifuged. Weight percentage were measured for both bulk and clay fractions of the samples. Prepared samples were analyzed using X-ray diffraction (XRD) technique. The predominantly sandstone samples will be discussed separate from the predominantly shale samples 4 and 11.

The XRD results for **predominantly sandstone** samples (Table 1) indicate that they consists mainly of quartz (silicon dioxide, SiO_2), with lesser amounts of plagioclase feldspar (sodium calcium aluminum silicate, $\text{Na}[\text{AlSi}_3\text{O}_8] - \text{Ca}[\text{Al}_2\text{Si}_2\text{O}_8]$), potassium feldspar (potassium aluminum silicate, $\text{K}[\text{SiAl}_3\text{O}_8]$), kaolinite (aluminum silicate hydroxide, $\text{Al}_4\text{Si}_4\text{O}_{10}(\text{OH})_8$), illite ($\text{KAl}_2(\text{OH})_2[\text{AlSi}_3(\text{O},\text{OH})_{10}]$) and chlorite (iron, magnesium aluminum silicate, $(\text{Mg},\text{Fe})_5\text{Al}(\text{AlSi}_3)\text{O}_{10}(\text{OH})_9$). Samples 2, 3, 5, 6, 8, 9 and 10 contain trace quantities of mixed-layer (illite – smectite) clays, while sample 7 has minor amounts of smectite ($[(1/2\text{Ca},\text{Na})0.7[\text{Al},\text{Mg},\text{Fe}]_4 [\text{Si},\text{Al}]_8\text{O}_{20}[\text{OH}]4.n\text{H}_2\text{O})$). Smectite and mixed-layer clays are expandable in freshwater.

The XRD results for **predominantly shale** sample 4 (Table 1) consists of illite ($\text{KAl}_2(\text{OH})_2[\text{AlSi}_3(\text{O},\text{OH})_{10}]$), kaolinite (aluminum silicate, $\text{K}[\text{SiAl}_3\text{O}_8]$), quartz (silicon dioxide, SiO_2), with lesser amounts of chlorite (iron, magnesium aluminum silicate, $(\text{Mg},\text{Fe})_5\text{Al}(\text{AlSi}_3)\text{O}_{10}(\text{OH})_9$), mixed – layer (illite – smectite), plus minor plagioclase feldspar (sodium calcium aluminum silicate, $\text{Na}[\text{AlSi}_3\text{O}_8] - \text{Ca}[\text{Al}_2\text{Si}_2\text{O}_8]$) and calcite (calcium feldspar Ca CO_3). In contrast, the XRD results for **predominantly shale** sample 11 (Table 1) consists of smectite ($[(1/2\text{Ca},\text{Na})0.7[\text{Al},\text{Mg},\text{Fe}]_4 [\text{Si},\text{Al}]_8\text{O}_{20}[\text{OH}]4.n\text{H}_2\text{O})$), kaolinite (aluminum silicate, $\text{K}[\text{SiAl}_3\text{O}_8]$), quartz (silicon dioxide, SiO_2), with lesser amounts of chlorite (iron, magnesium aluminum silicate, $(\text{Mg},\text{Fe})_5\text{Al}(\text{AlSi}_3)\text{O}_{10}(\text{OH})_9$), illite ($\text{KAl}_2(\text{OH})_2[\text{AlSi}_3(\text{O},\text{OH})_{10}]$), plagioclase feldspar (sodium calcium aluminum silicate, $\text{Na}[\text{AlSi}_3\text{O}_8] - \text{Ca}[\text{Al}_2\text{Si}_2\text{O}_8]$) and minor potassium feldspar (potassium aluminum silicate, $\text{K}[\text{SiAl}_3\text{O}_8]$).

The analyses indicates that quartz and both feldspars (plagioclase and potassium) are the primary components of framework sand grains or silts. The clay minerals (kaolinite, illite, chlorite, mixed-layer and smectite) are found as interstitial matrix material and within argillaceous lithoclasts (for example: silty shale, chloritized volcanic rock fragments, altered feldspathic grains and pyllites). The calcite in sample 4 is mostly a diagenetic carbonate cement. Sample 11 with significant amounts of smectite clay is highly

freshwater sensitive. All the other samples except 1 contain minor amounts of mixed-layer clay or smectite (sample 7) and therefore are moderately fresh water sensitive.

Table 1 - Summary of XRD Analysis

Company: Husky Energy Inc.

Work Order No. A12250

Location: Husky Primrose 3-7-69' 1AA/03-07-069-04W4M/00

June, 2006

SAMPLE ID.	TYPE OF ANALYSIS	WEIGHT %	← CLAYS →															Total Clay	
			Qtz	Plag	K-Feld	Cal	Dol	Anhy	Pyr	Hal	Bar	Sider	Kaol	Chl	Ill	ML	Smec		
1 471.1m	BULK FRACTION:	96.68	53	17	7	0	0	0	0	0	0	0	0	13	10	0	0	0	23
	CLAY FRACTION:	3.32	2	2	0	0	0	0	0	0	0	0	0	46	26	20	0	0	92
	BULK & CLAY	100	51	17	7	0	0	0	0	0	0	0	0	14	10	1	0	0	25
2 475m	BULK FRACTION:	97.39	49	24	9	0	0	0	0	0	0	0	0	14	4	0	0	0	18
	CLAY FRACTION:	2.61	4	0	2	0	0	0	0	0	0	0	0	50	10	27	7	0	94
	BULK & CLAY	100	48	24	9	0	0	0	0	0	0	0	0	15	4	1	TR	0	20
3 478.65m	BULK FRACTION:	95.50	43	19	12	0	0	0	0	0	0	0	0	14	4	8	0	0	33
	CLAY FRACTION:	4.50	5	3	0	0	0	0	0	0	0	0	0	33	20	32	8	0	92
	BULK & CLAY	100	41	18	12	0	0	0	0	0	0	0	0	15	12	8	TR	0	35
4 479.45m	BULK FRACTION:	65.47	35	9	0	3	0	0	0	0	0	0	0	25	14	22	0	0	57
	CLAY FRACTION:	34.53	11	0	0	0	0	0	0	0	0	0	0	25	10	40	15	0	90
	BULK & CLAY	100	23	4	0	2	0	0	0	0	0	0	0	25	13	28	5	0	71
5 481.70m	BULK FRACTION:	95.10	38	16	7	0	0	0	0	0	0	0	0	16	11	12	0	0	39
	CLAY FRACTION:	4.90	0	0	0	0	0	0	0	0	0	0	0	48	15	26	10	0	100
	BULK & CLAY	100	37	15	7	0	0	0	0	0	0	0	0	17	11	13	TR	0	41
6 486.1m	BULK FRACTION:	95.37	35	20	10	0	0	0	0	0	0	0	0	19	9	7	0	0	35
	CLAY FRACTION:	4.63	3	3	2	0	0	0	0	0	0	0	0	42	16	28	5	0	91
	BULK & CLAY	100	34	19	10	0	0	0	0	0	0	0	0	20	9	8	TR	0	37
7 488.40m	BULK FRACTION:	95.36	44	20	8	0	0	0	0	0	0	0	0	13	6	9	0	0	29
	CLAY FRACTION:	4.64	1	2	0	0	0	0	0	0	0	0	0	37	13	24	0	25	96
	BULK & CLAY	100	42	18	7	0	0	0	0	0	0	0	0	14	8	10	0	1	33
8 489.9m	BULK FRACTION:	95.96	41	17	7	0	0	0	0	0	0	0	0	18	4	13	0	0	35
	CLAY FRACTION:	4.04	4	1	0	0	0	0	0	0	0	0	0	43	17	18	14	0	95
	BULK & CLAY	100	39	16	7	0	0	0	0	0	0	0	0	19	10	13	TR	0	40

Table 1(Contd.) - Summary of XRD Analysis

Company: Husky Energy Inc

Work Order No. A12250

Location: Husky Primrose 3-7-69' 1AA/03-07-069-04W4M/00

June, 2006

SAMPLE ID.	TYPE OF ANALYSIS	WEIGHT %	← CLAYS →															Total Clay	
			Qtz	Plag	K-Feld	Cal	Dol	Anhy	Pyr	Hal	Bar	Sider	Kaol	Chl	Ill	ML	Smec		
9 492.0m	BULK FRACTION:	95.20	28	28	5	0	0	0	0	0	0	0	0	21	9	9	0	0	39
	CLAY FRACTION:	4.80	2	0	1	0	0	0	0	0	0	0	0	51	25	17	4	0	97
	BULK & CLAY	100	27	27	5	0	0	0	0	0	0	0	0	22	10	9	TR	0	41
10 492.75m	BULK FRACTION:	96.41	44	14	7	0	0	0	0	0	0	0	0	20	8	7	0	0	35
	CLAY FRACTION:	3.59	2	1	0	0	0	0	0	0	0	0	0	31	13	47	5	0	97
	BULK & CLAY	100	43	13	7	0	0	0	0	0	0	0	0	20	9	8	TR	0	37
11 494.95m	BULK FRACTION:	80.05	27	12	5	0	0	0	0	0	0	0	0	25	14	6	0	12	56
	CLAY FRACTION:	19.95	3	0	1	0	0	0	0	0	0	0	0	11	6	19	0	59	96
	BULK & CLAY	100	22	9	4	0	0	0	0	0	0	0	0	22	12	8	0	22	65

XRD LEGEND

- XRD Analysis is semi-quantitative (approx. 10% at best) and identifies only crystalline substances; amorphous (non-crystalline) substances will not be detected.
- Bulk Fraction – greater than 3 microns size fraction.
- Clay Fraction – less than 3 micron size fraction.
- Bulk and Clay – mathematical recalculation including the bulk and clay fraction representing the whole sample.
- Total Clay – sum of the clay minerals (may include authigenic and matrix clays plus clays in rock fragments).

ABBREVIATIONS

Amp - Amphiboles	Dol - Dolomite	Marc - Marcasite	Pr - Pure (95 – 100%)
Ana - Analcime	Gyp - Gypsum	ML* - Illite-Smectite	NPr - Near Pure (90 – 95%)
Anh - Anhydrite	Hal - Halite	Plag - Plagioclase Feldspar	Abnt - Abundant (60 – 90%)
Ank - Ankerite	Hem - Hematite	Pyr - Pyrite	Com - Common (30 – 60%)
Apa - Apatite	Ill - Illite	Qtz - Quartz	Mnr - Minor (10 – 30%)
Bar - Barite	Kaol - Kaolinite	Sid - Siderite	Rre - Rare (1 – 10%)
Cal - Calcite	K-feld - Potassic Feldspar	Sm - Smectite (montmorillonite)	Tr - Trace; detectable,
Chl - Chlorite	Jaro - Jarosite	ML** - Corrensite (chlorite-smectite)	but not measurable (0 – 1%)
	Mack - Mackinawite	Unk - Unknown mineral	

NOTE: Not all these minerals are present in this sample suite

APPENDIX

BULK & CLAY PROCEDURES

1. Crush dry rock sample until grains disintegrate completely.
2. Weigh empty beaker and put sample in it. Weigh again “total weight”. (≈ 3 g of sample).
3. Add 50 mL of distilled water, plus a few drops of Sodium Metaphosphate.
4. Put in ultrasonic bath for 2 (two) hours.
5. Stir sample and pour out top portion into test tube.
6. Centrifuge for 5 minutes at 600 rpm.
7. Pour out top portion into another test tube for the clay fraction ($< 3\mu\text{m}$) sample.
8. Recombine the coarser residue in the first test tube with the residue in the beaker and weight this “bulk sample” (after drying completely). Subtract this weight from the “total weight” to get the clay fraction weight.
9. Centrifuge the “clay fines” in the second test tube for 20 minutes at maximum rpms.
10. Pour out most of the water then shake test tube using Vortex Mixer.
11. Pipette onto a glass slide.
12. Put the slide on the hot plate (low) until dry then run sample in XRD.
13. Then put slide in a glycol vapour bath overnight (glycolated clay); Smectite will swell and be recognized.
14. If chlorite suspected, then treat the remaining sample in the test tube with diluted HCl and leave overnight (acidized clay). If chlorite was present in the sample this test causes it to disappear.
15. Run the “clay fraction” slide from 2-38 degrees.
16. Grind the “bulk sample” and spread the powder on an aluminum holder then run from 4-58 degrees.