

PETROLEUM GEOCHEMISTRY OF WELL 16/1-7



Applied Petroleum Technology AS
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1 INTRODUCTION

This source rock study of well 16/1-7 was commissioned by Torunn Valheim, ExxonMobil, Stavanger. Sixty-four canned cuttings samples were received by APT and 13 of these, in the interval 1770m to 3060m were chosen to undergo the analytical programme requested by ExxonMobil. Table 1 shows the types and numbers of analyses performed.

Table 1. Number of analyses performed

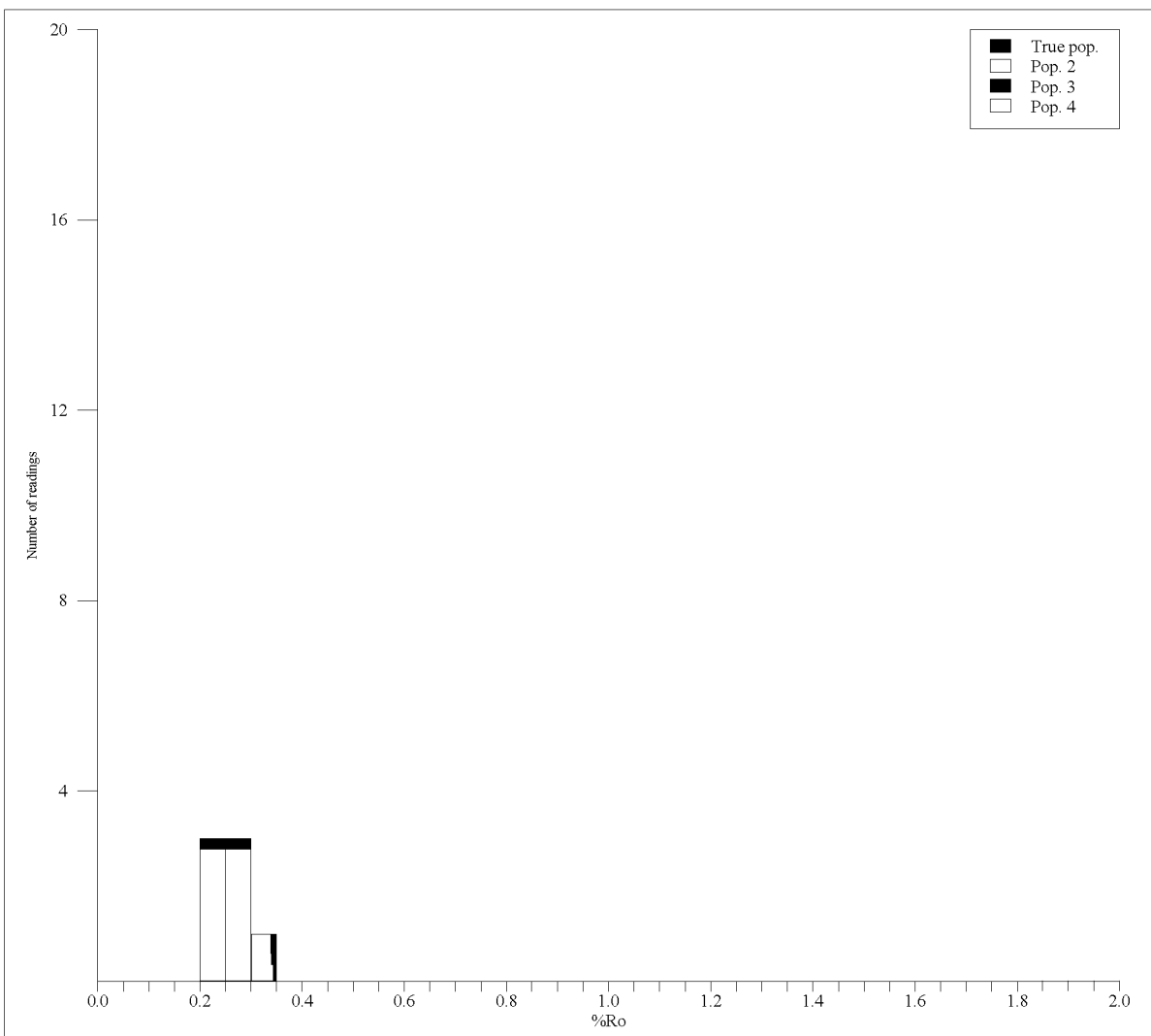
Analysis	Total
Lithology description	13
TOC/Rock-Eval	13
Visual kerogen description	13
Vitrinite reflectance	13
Thermal Extraction GC	2
Pyrolysis GC	13

Table 2. Lithology Description

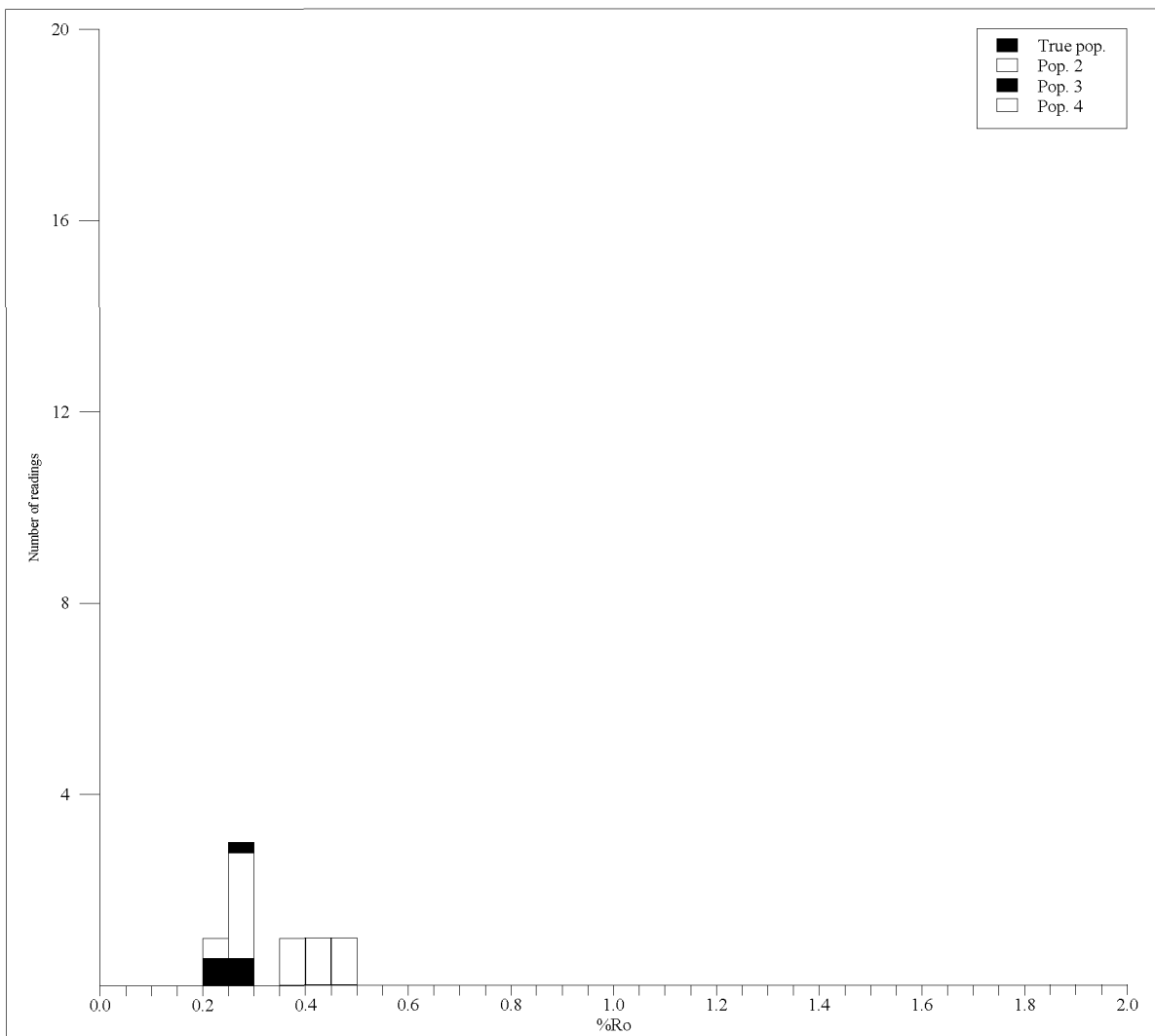
Well	Lower Depth (m)	APT ID	%	Lithology	Attributes
16/1-7	1770	21214	100 %	CLYST	dk gry - dk brn
16/1-7	1860	21217	100 %	CLYST	lt gry
16/1-7	2010	21222	100 %	CLYST	gry - dk brn
16/1-7	2220	21229	100 %	CLYST	gry - dk brn
16/1-7	2400	21235	100 %	CLYST	lt gry - dk gry
16/1-7	2490	21238	100 %	CLYST	calc, lt gry - dk gry
16/1-7	2610	21242A	80%	LST	
16/1-7	2610	21242B	20%	CLYST	lt gry - brn
16/1-7	2760	21247A	80%	CLYST	gry - brn
16/1-7	2760	21247B	20%	LST	
16/1-7	2790	21248A	100%	CLYST	calc, dk gry - dk brn
16/1-7	2790	21248B	trace	LST	
16/1-7	2850	21250	100 %	CLYST	calc, dk gry - dk brn
16/1-7	2940	21253	100 %	CLYST	calc, dk gry - dk brn
16/1-7	2970	21254A	90%	CLYST	lt gry - dk gry, brn
16/1-7	2970	21254B	10%	LST	
16/1-7	3000	21255	100 %	CLYST	lt gry
16/1-7	3060	21257	100 %	CLYST	lt gry - dk gry, brn



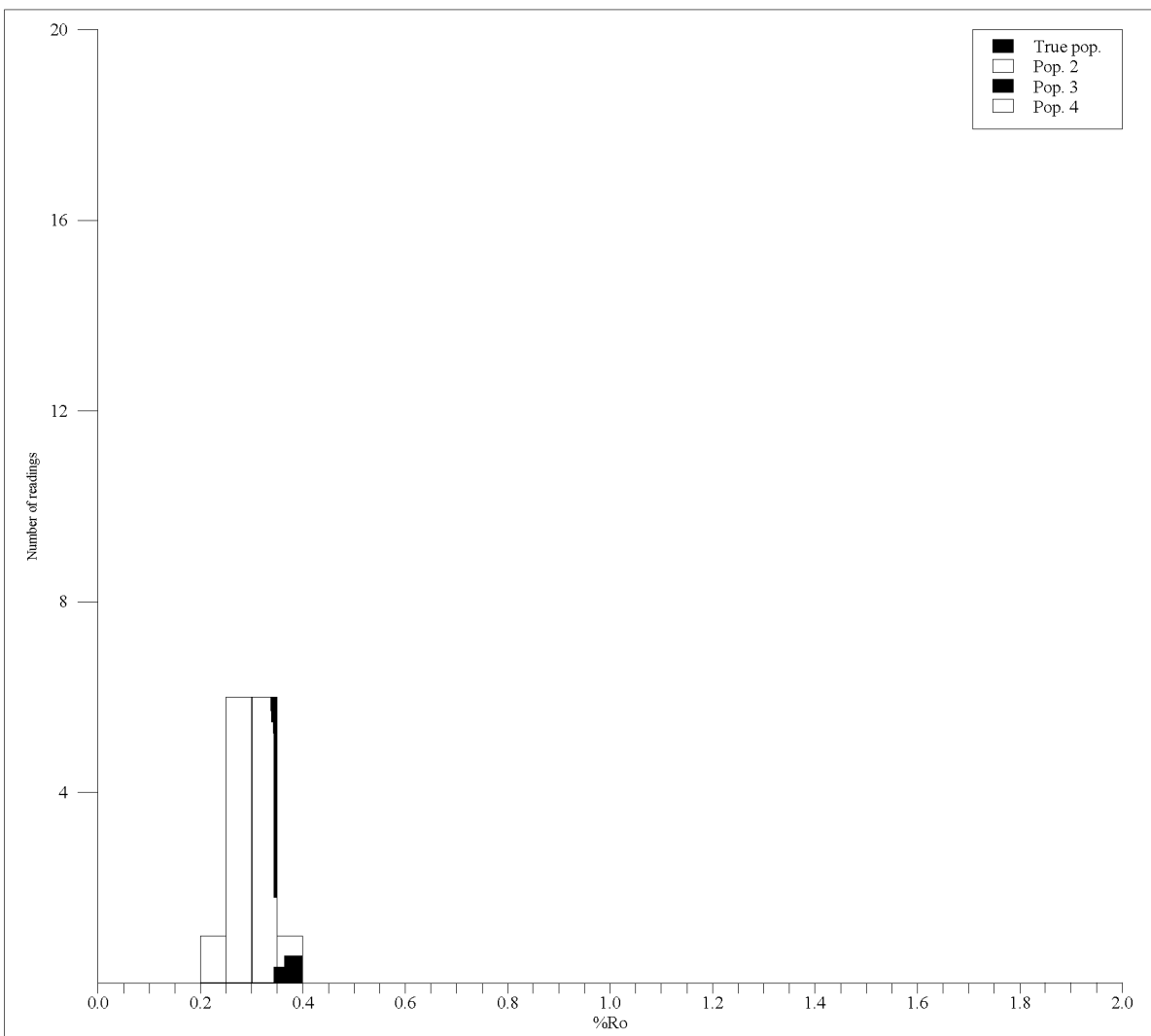
Vitrinite Reflectance Sample Data Sheets



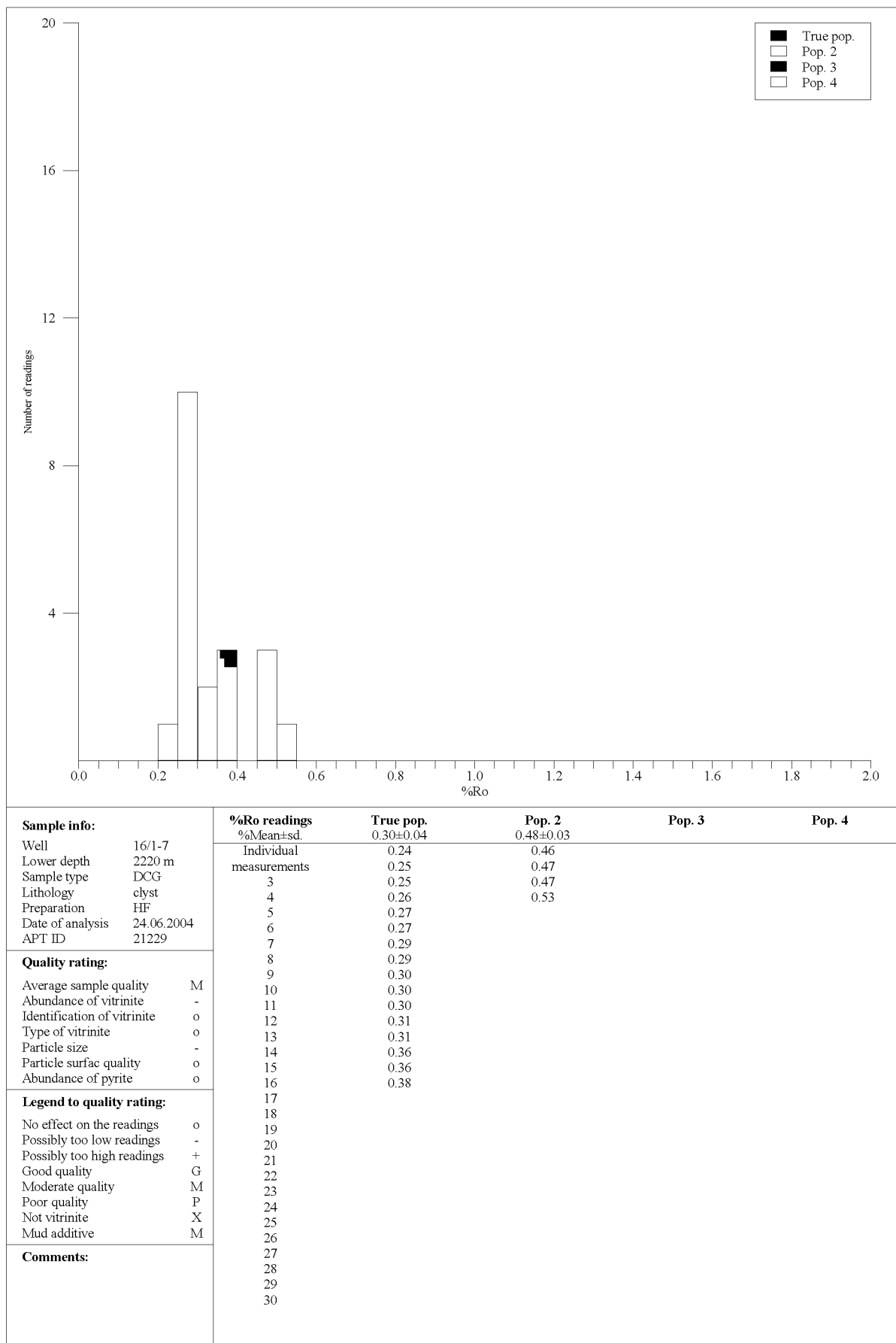
Sample info:		%Ro readings	True pop.	Pop. 2	Pop. 3	Pop. 4
Well	16/1-7	%Mean±sd.	0.26±0.04			
Lower depth	1770 m	Individual	0.21			
Sample type	DCG	measurements	0.22			
Lithology	clst	3	0.22			
Preparation	HF	4	0.25			
Date of analysis	24.06.2004	5	0.27			
APT ID	21214	6	0.29			
		7	0.33			
		8				
		9				
		10				
		11				
		12				
		13				
		14				
		15				
		16				
		17				
		18				
		19				
		20				
		21				
		22				
		23				
		24				
		25				
		26				
		27				
		28				
		29				
		30				
Quality rating:						
Average sample quality	P					
Abundance of vitrinite	-					
Identification of vitrinite	o					
Type of vitrinite	o					
Particle size	-					
Particle surfac quality	-					
Abundance of pyrite	o					
Legend to quality rating:						
No effect on the readings	o					
Possibly too low readings	-					
Possibly too high readings	+					
Good quality	G					
Moderate quality	M					
Poor quality	P					
Not vitrinite	X					
Mud additive	M					
Comments:						

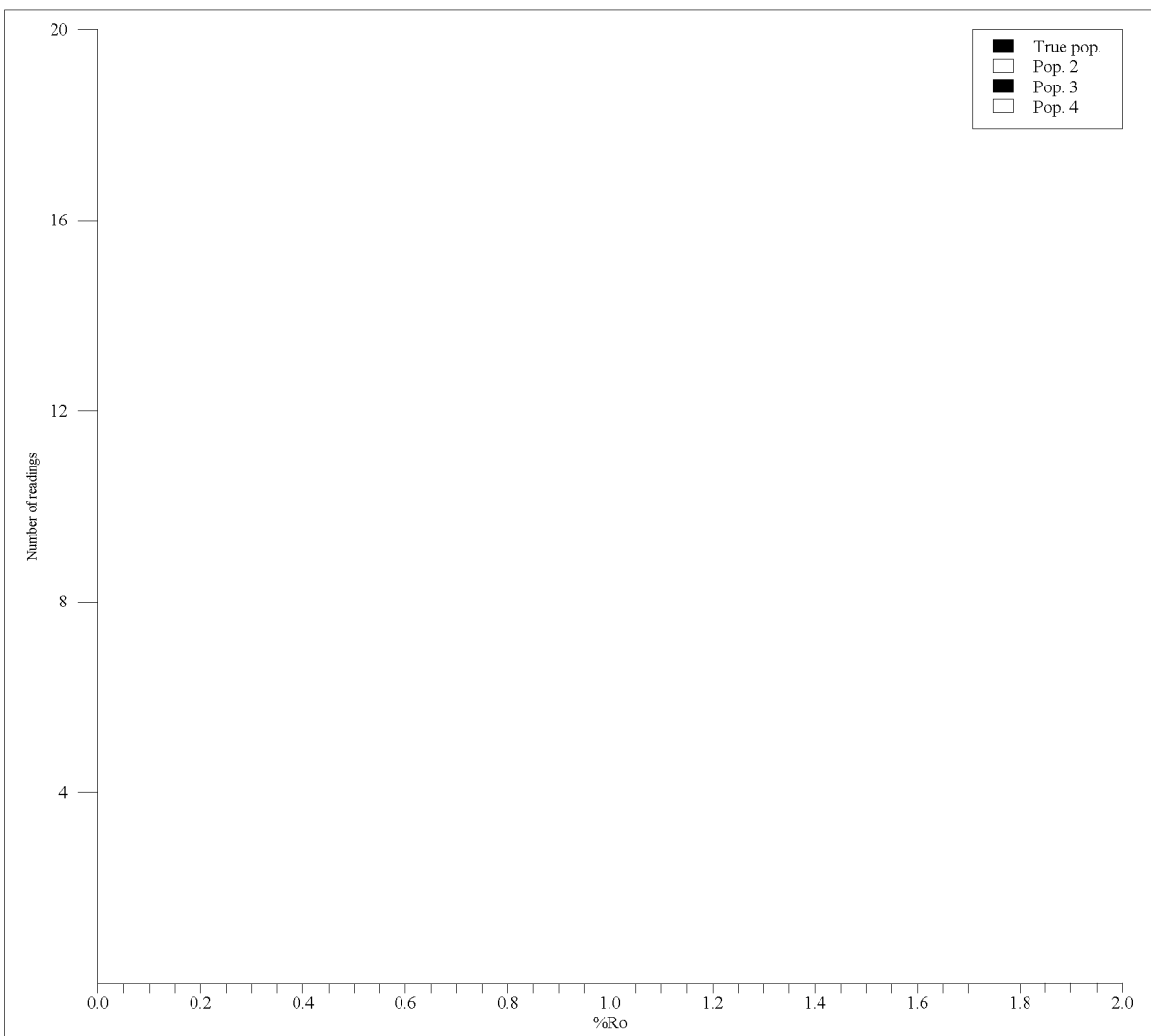


Sample info:	%Ro readings	True pop.	Pop. 2	Pop. 3	Pop. 4
Well 16/1-7	%Mean±sd.	0.25±0.02	0.42±0.05		
Lower depth 1860 m	Individual	0.22	0.36		
Sample type DCG	measurements	0.25	0.43		
Lithology clyst	3	0.25	0.46		
Preparation HF	4	0.26			
Date of analysis 24.06.2004	5				
APT ID 21217	6				
Quality rating:	7				
Average sample quality P	8				
Abundance of vitrinite -	9				
Identification of vitrinite o	10				
Type of vitrinite o	11				
Particle size -	12				
Particle surfac quality -	13				
Abundance of pyrite o	14				
Legend to quality rating:	15				
No effect on the readings o	16				
Possibly too low readings -	17				
Possibly too high readings +	18				
Good quality G	19				
Moderate quality M	20				
Poor quality P	21				
Not vitrinite X	22				
Mud additive M	23				
Comments:	24				
	25				
	26				
	27				
	28				
	29				
	30				

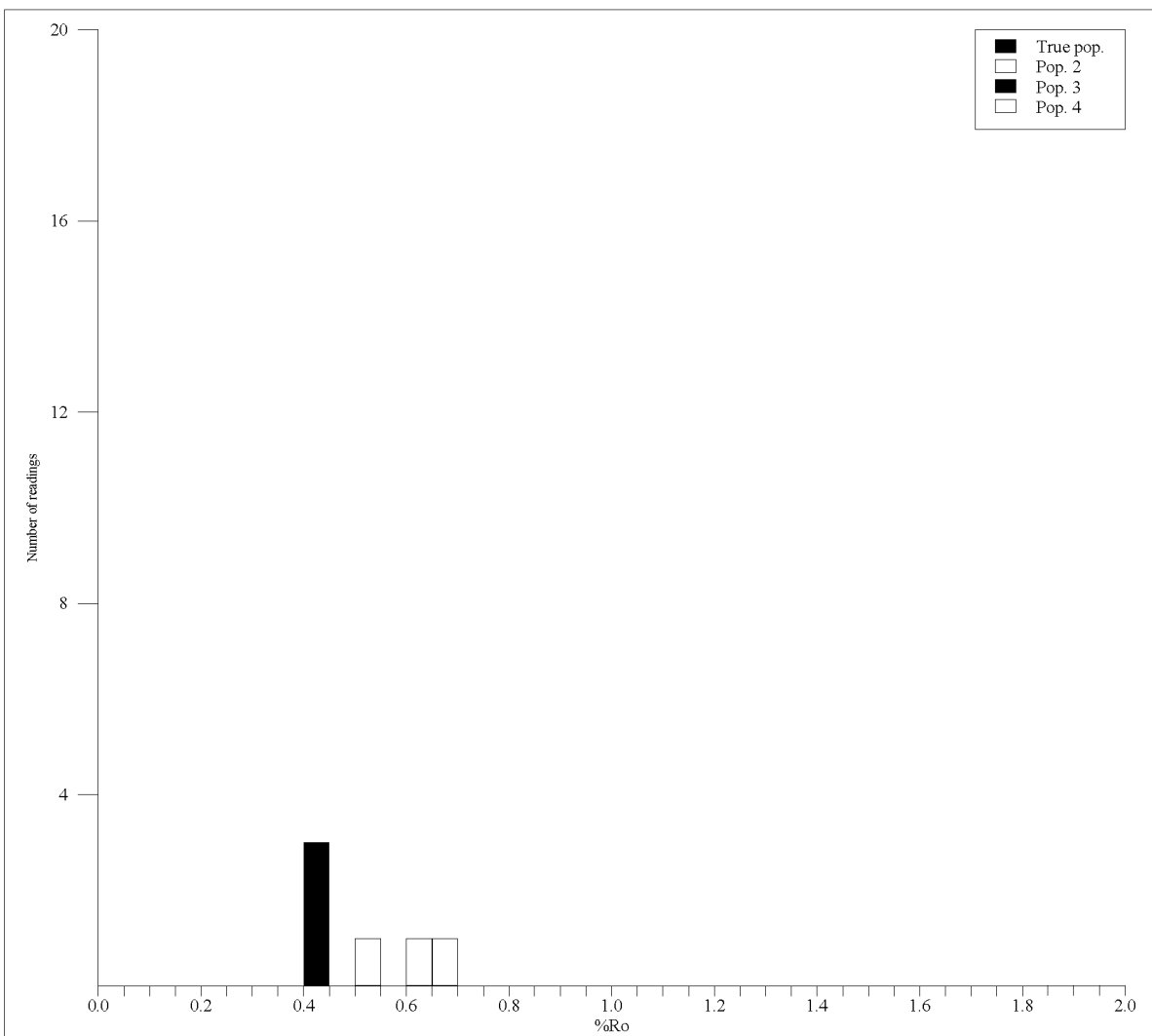


Sample info:		%Ro readings	True pop.	Pop. 2	Pop. 3	Pop. 4
Well	16/1-7	%Mean±sd.	0.30±0.04			
Lower depth	2010 m	Individual	0.24			
Sample type	DCG	measurements	0.25			
Lithology	clyst	3	0.25			
Preparation	HF	4	0.26			
Date of analysis	24.06.2004	5	0.28			
APT ID	21222	6	0.29			
Quality rating:		7	0.30			
Average sample quality	M	8	0.31			
Abundance of vitrinite	-	9	0.32			
Identification of vitrinite	o	10	0.33			
Type of vitrinite	o	11	0.33			
Particle size	-	12	0.34			
Particle surfac quality	-	13	0.34			
Abundance of pyrite	o	14	0.37			
Legend to quality rating:		15				
No effect on the readings	o	16				
Possibly too low readings	-	17				
Possibly too high readings	+	18				
Good quality	G	19				
Moderate quality	M	20				
Poor quality	P	21				
Not vitrinite	X	22				
Mud additive	M	23				
Comments:		24				
		25				
		26				
		27				
		28				
		29				
		30				

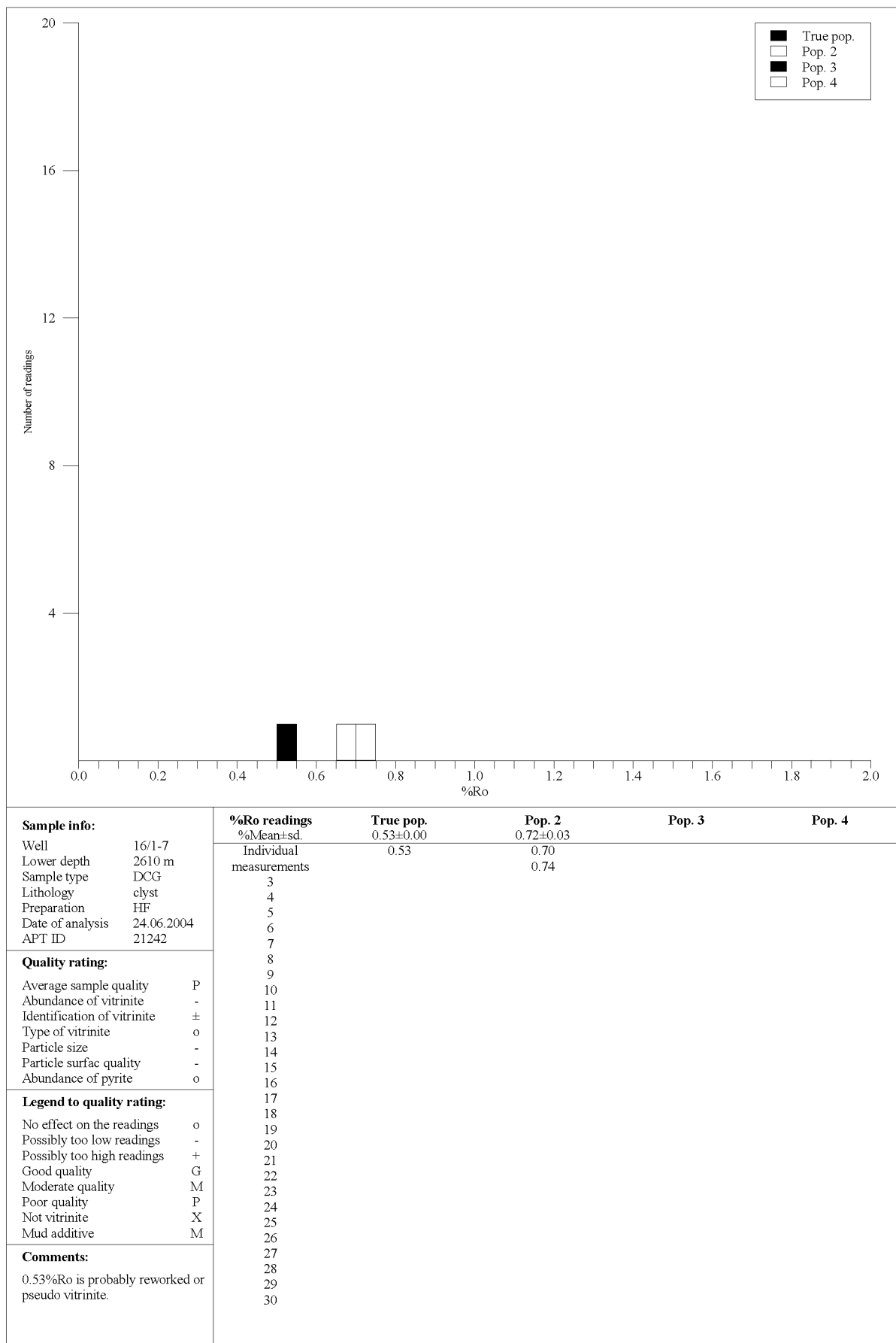


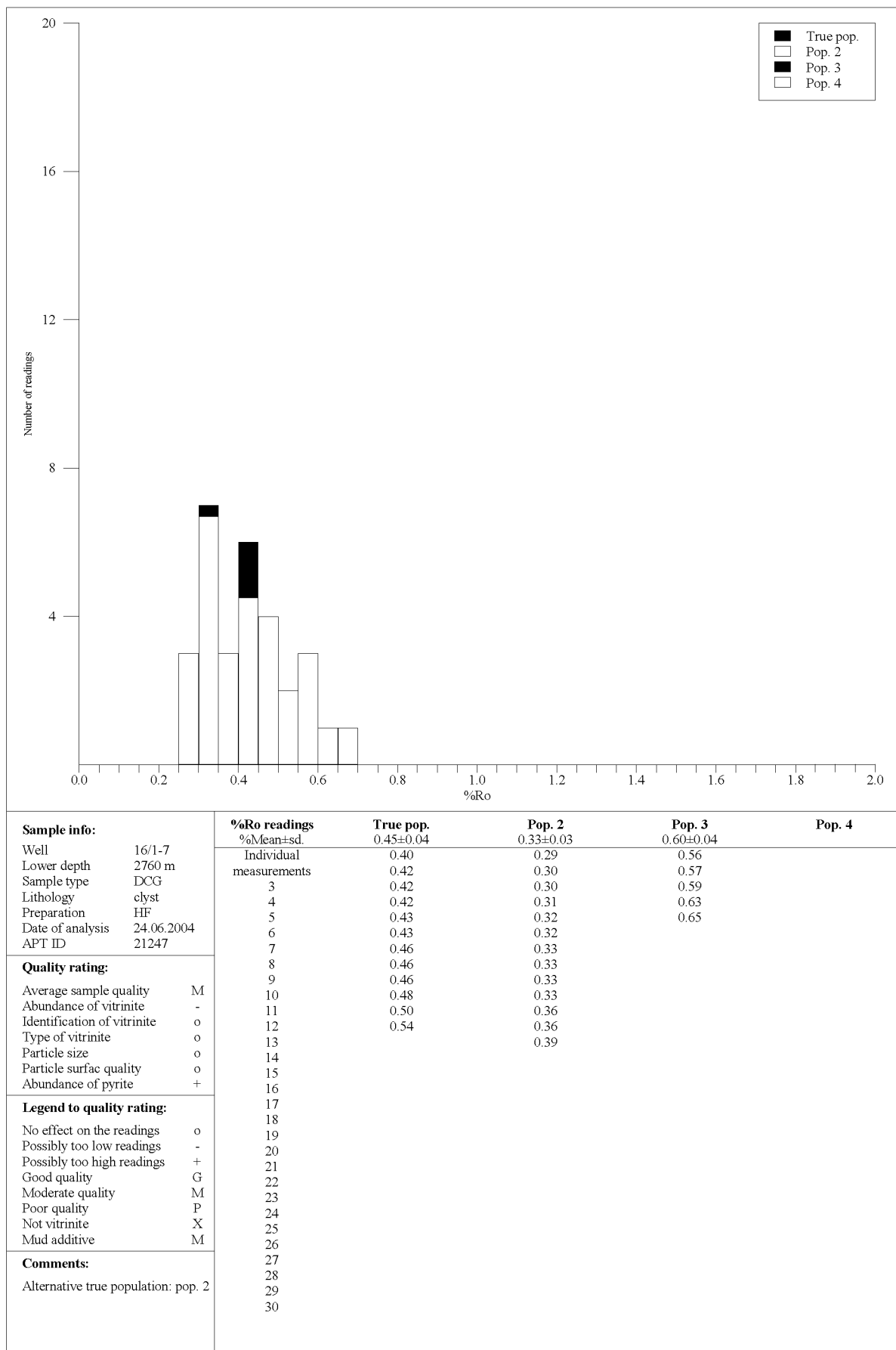


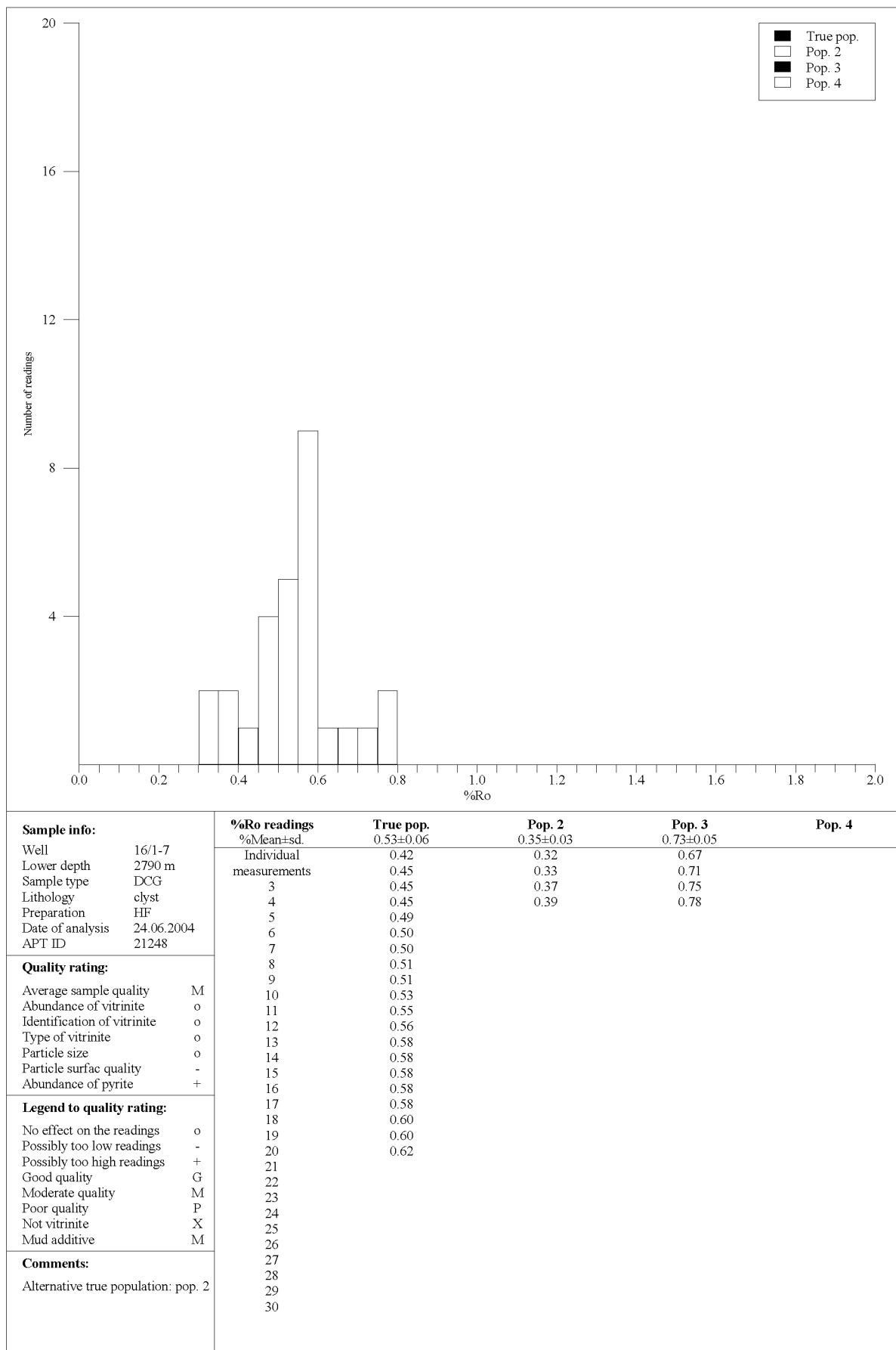
Sample info:	%Ro readings	True pop.	Pop. 2	Pop. 3	Pop. 4
Well: 16/1-7	%Mean±sd.				
Lower depth: 2400 m	Individual				
Sample type: DCG	measurements				
Lithology: clyst	3				
Preparation: HF	4				
Date of analysis: 24.06.2004	5				
APT ID: 21235	6				
	7				
	8				
Quality rating:	9				
Average sample quality: barren	10				
Abundance of vitrinite	11				
Identification of vitrinite	12				
Type of vitrinite	13				
Particle size	14				
Particle surfac quality	15				
Abundance of pyrite	16				
	17				
Legend to quality rating:	18				
No effect on the readings: o	19				
Possibly too low readings: -	20				
Possibly too high readings: +	21				
Good quality: G	22				
Moderate quality: M	23				
Poor quality: P	24				
Not vitrinite: X	25				
Mud additive: M	26				
	27				
Comments:	28				
	29				
	30				

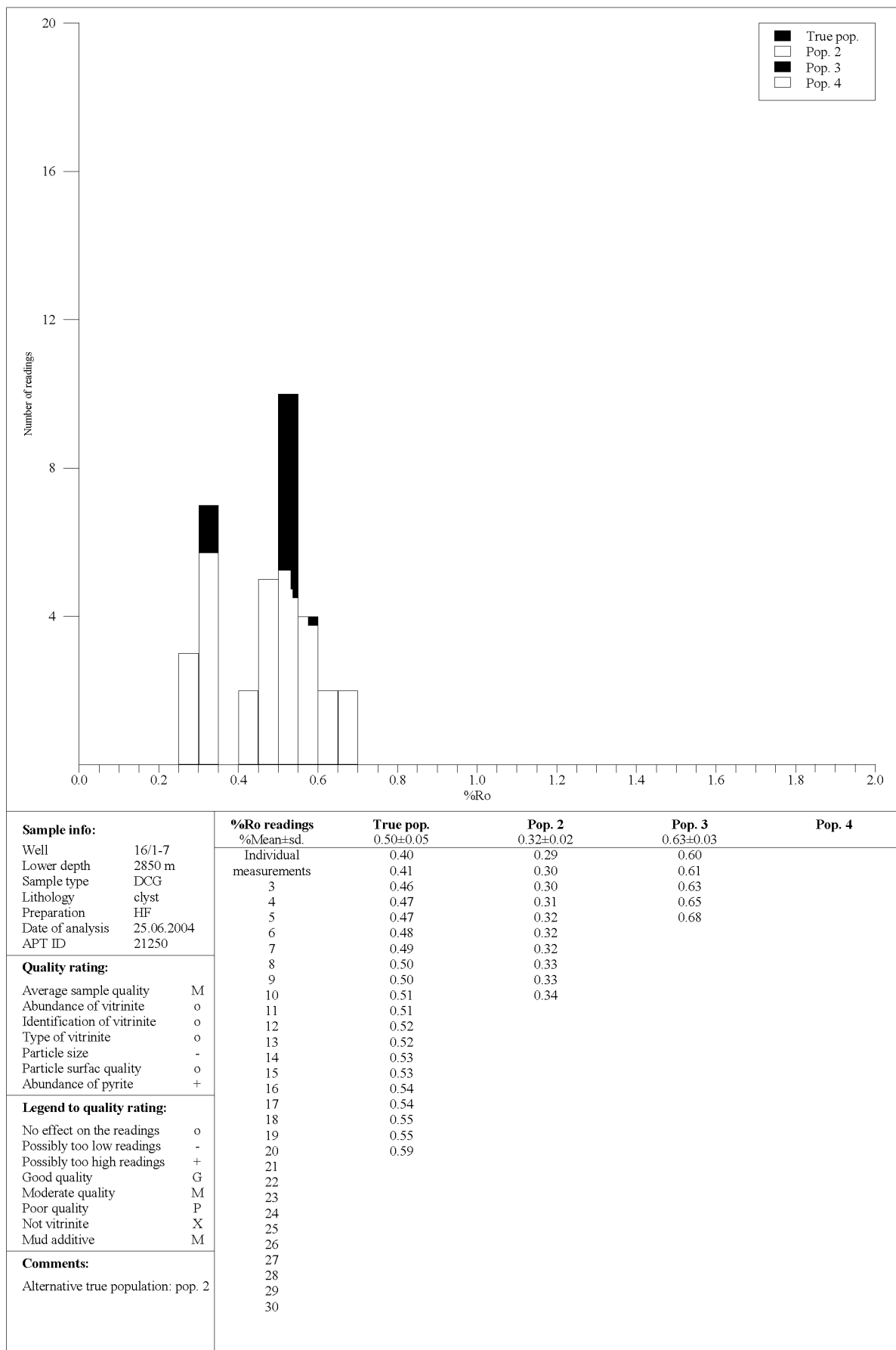


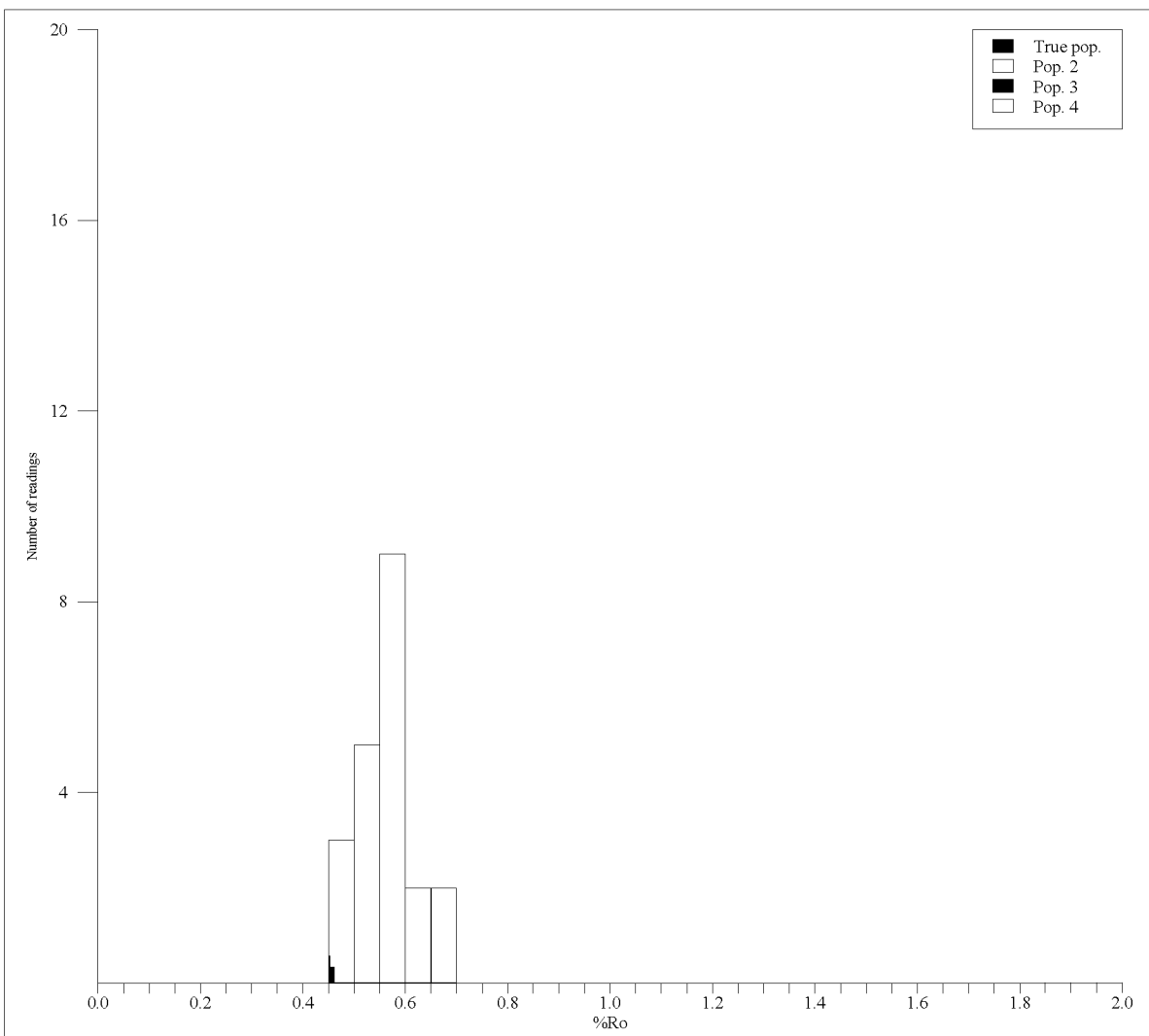
Sample info:	%Ro readings	True pop.	Pop. 2	Pop. 3	Pop. 4
Well	16/1-7	%Mean±sd.	0.40±0.01	0.61±0.10	
Lower depth	2490 m	Individual	0.40	0.50	
Sample type	DCG	measurements	0.40	0.63	
Lithology	clst	3	0.41	0.69	
Preparation	HF	4			
Date of analysis	24.06.2004	5			
APT ID	21238	6			
		7			
Quality rating:		8			
Average sample quality	P	9			
Abundance of vitrinite	-	10			
Identification of vitrinite	±	11			
Type of vitrinite	o	12			
Particle size	-	13			
Particle surfac quality	-	14			
Abundance of pyrite	o	15			
		16			
Legend to quality rating:		17			
No effect on the readings	o	18			
Possibly too low readings	-	19			
Possibly too high readings	+	20			
Good quality	G	21			
Moderate quality	M	22			
Poor quality	P	23			
Not vitrinite	X	24			
Mud additive	M	25			
		26			
Comments:		27			
		28			
		29			
		30			



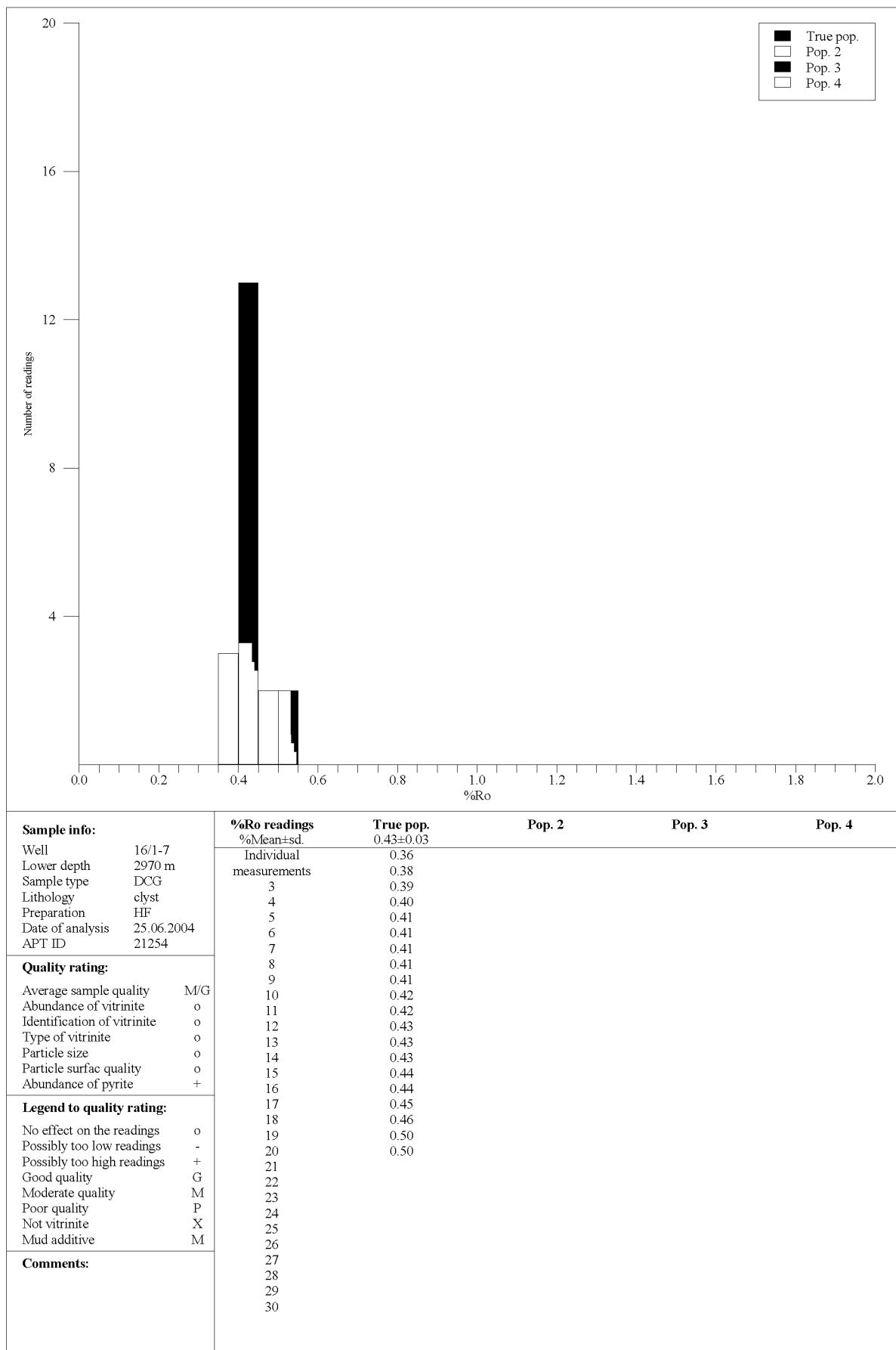


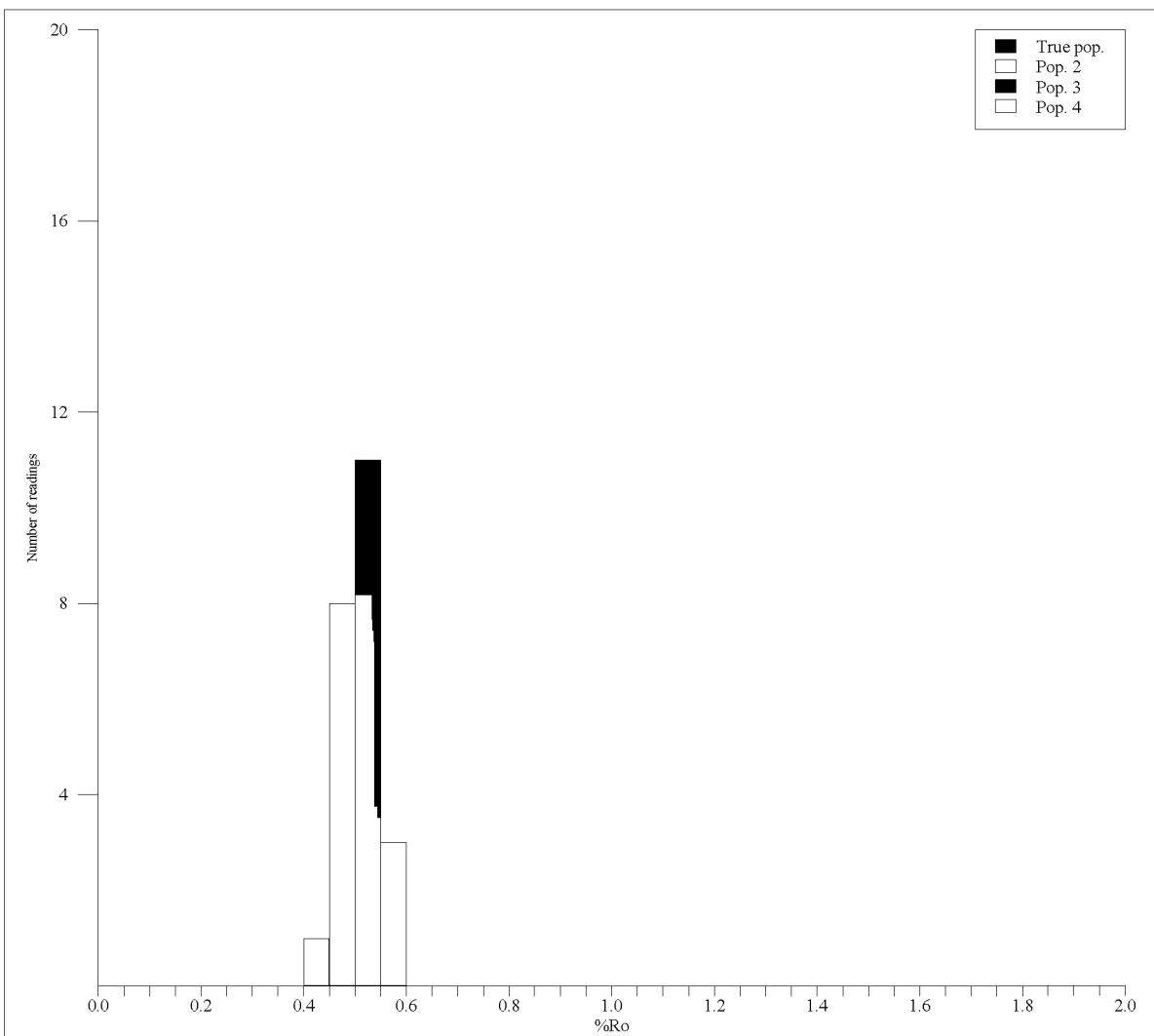






Sample info:	%Ro readings	True pop.	Pop. 2	Pop. 3	Pop. 4
Well: 16/1-7	%Mean±sd.	0.56±0.06			
Lower depth: 2940 m	Individual measurements	0.46			
Sample type: DCG	3	0.47			
Lithology: clyst	4	0.49			
Preparation: HF	5	0.50			
Date of analysis: 25.06.2004	6	0.51			
APT ID: 21253	7	0.51			
	8	0.52			
Quality rating:	9	0.53			
Average sample quality: M	10	0.55			
Abundance of vitrinite: o	11	0.55			
Identification of vitrinite: o	12	0.56			
Type of vitrinite: o	13	0.56			
Particle size: -	14	0.56			
Particle surfac quality: o	15	0.58			
Abundance of pyrite: +	16	0.58			
	17	0.59			
	18	0.59			
	19	0.62			
Legend to quality rating:	20	0.63			
No effect on the readings: o	21	0.67			
Possibly too low readings: -	22	0.68			
Possibly too high readings: +	23				
Good quality: G	24				
Moderate quality: M	25				
Poor quality: P	26				
Not vitrinite: X	27				
Mud additive: M	28				
	29				
	30				
Comments:					





Sample info:		%Ro readings	True pop.	Pop. 2	Pop. 3	Pop. 4
Well	16/1-7	%Mean±sd.	0.51±0.04			
Lower depth	3060 m	Individual	0.41			
Sample type	DCG	measurements	0.45			
Lithology	clyst	3	0.46			
Preparation	HF	4	0.46			
Date of analysis	25.06.2004	5	0.47			
APT ID	21257	6	0.48			
Quality rating:		7	0.49			
Average sample quality	G	8	0.49			
Abundance of vitrinite	o	9	0.49			
Identification of vitrinite	o	10	0.50			
Type of vitrinite	o	11	0.50			
Particle size	o	12	0.51			
Particle surfac quality	o	13	0.51			
Abundance of pyrite	o	14	0.53			
Legend to quality rating:		15	0.53			
No effect on the readings	o	16	0.53			
Possibly too low readings	-	17	0.53			
Possibly too high readings	+	18	0.53			
Good quality	G	19	0.54			
Moderate quality	M	20	0.54			
Poor quality	P	21	0.55			
Not vitrinite	X	22	0.56			
Mud additive	M	23	0.57			
Comments:		24				
		25				
		26				
		27				
		28				
		29				
		30				

Table 3. TOC and Rock-Eval data

Well	Lower Depth	APT ID	S1 (mg/g)	S2 (mg/g)	S3 (mg/g)	Tmax (°C)	PP (mg/g)	PI (wt ratio)	HI (mg HC/g TOC)	OI (mg CO ₂ /g TOC)	TOC (%)
16/1-7	1770	21214	6.94	5.02	1.35	309	11.96	0.58	335	90	1.50
16/1-7	1860	21217	18.68	8.07	1.32	320	26.75	0.70	301	49	2.68
16/1-7	2010	21222	15.24	7.52	1.56	307	22.76	0.67	279	58	2.70
16/1-7	2220	21229	31.56	9.81	1.65	426	41.37	0.76	212	36	4.63
16/1-7	2400	21235	32.17	7.89	1.16	261	40.06	0.80	198	29	3.98
16/1-7	2490	21238	37.95	7.61	1.21	432	45.56	0.83	171	27	4.45
16/1-7	2610	21242B	41.80	5.31	1.28	436	47.11	0.89	124	30	4.30
16/1-7	2760	21247A	34.86	37.36	1.03	423	72.21	0.48	385	11	9.71
16/1-7	2790	21248	32.03	23.21	0.87	425	55.24	0.58	328	12	7.08
16/1-7	2850	21250	29.96	14.55	0.60	428	44.51	0.67	248	10	5.86
16/1-7	2940	21253	30.15	12.35	0.75	428	42.50	0.71	206	13	5.99
16/1-7	2970	21254A	35.54	23.30	0.43	430	58.84	0.60	258	5	9.04
16/1-7	3060	21257	31.36	9.46	0.58	432	40.82	0.77	179	11	5.27

Table 4. Visual Kerogen Description

Well	Lower Depth	APT ID	FA(%)	HA(%)	AL(%)	HE(%)	WO(%)	CO(%)	SCI
16/1-7	1770	21214	0	80	10	10	0	0	3-4
16/1-7	1860	21217	0	75	15	10	0	0	3-4
16/1-7	2010	21222	0	70	20	10	0	0	3-4
16/1-7	2220	21229	0	60	20	15	0	5	3-5
16/1-7	2400	21235	0	80	10	5	0	5	3-5
16/1-7	2490	21238	0	80	5	10	0	5	3-5
16/1-7	2610	21242	80	5	5	5	0	5	4-5
16/1-7	2760	21247	20	30	40	10	0	0	4-6
16/1-7	2790	21248	5	30	50	10	0	5	4-6
16/1-7	2850	21250	0	50	30	10	5	5	5-7
16/1-7	2940	21253	0	55	10	20	10	5	5-7
16/1-7	2970	21254	0	50	20	10	10	10	5-7
16/1-7	3060	21257	0	40	20	10	20	10	5-7

Table 5. Vitrinite Reflectance

Well	Lower Depth	APT ID	Sample prep.	%Lithology	%Ro	Std. dev.	No. of measurements	Quality rating	Overall quality	Comment
16/1-7	1770	21214	HF	clyst	0.26	0.04	7	-00--0	P	
16/1-7	1860	21217	HF	clyst	0.25	0.02	4	-00--0	P	
16/1-7	2010	21222	HF	clyst	0.30	0.04	14	-00--0	M	
16/1-7	2220	21229	HF	clyst	0.30	0.04	16	-00-00	M	
16/1-7	2400	21235	HF	clyst	barren					
16/1-7	2490	21238	HF	clyst	0.40	0.01	3	-±0--0	P	
16/1-7	2610	21242	HF	clyst	0.53	0.00	1	-±0--0	P	See data sheet
16/1-7	2760	21247	HF	clyst	0.45	0.04	12	-0000+	M	
16/1-7	2790	21248	HF	clyst	0.53	0.06	20	0000+	M	
16/1-7	2850	21250	HF	clyst	0.50	0.05	20	000-0+	M	
16/1-7	2940	21253	HF	clyst	0.56	0.06	21	000-0+	M	
16/1-7	2970	21254	HF	clyst	0.43	0.03	20	00000+	M/G	
16/1-7	3060	21257	HF	clyst	0.51	0.04	23	000000	G	

Legend to Vitrinite reflectance data

Lithology code		Sample quality		Sample preparation	
sst	Sandstone	G	Good	HF	Sample treatment with hydrofluoric acid prior to analysis
slst	Siltstone	M	Moderate		
clyst	Claystone	P	Poor	Bulk	Sample treated as bulk rock
sh	Shale	st	Hydrocarbon staining		
lst	Limestone				
coal	Coal				

Sample description and measurement evaluation (perfect sample characterised as: 000000)

Sign order	Parameter	Sign	Sign legend:
1	Abundance of vitrinite	-0	- May give too low vitrinite reflectance sample value
2	Identification of vitrinite	-0+	o Reliable vitrinite reflectance sample value
3	Type of vitrinite	-0+	+ May give too high vitrinite reflectance sample value
4	Vitrinite fragment size	-0	
5	Vitrinite surface quality	-0	
6	Abundance of pyrite	0+	

Table 6. Pyrolysis GC (peak area)

Well	Lower Depth	APT ID	%C1(UCM)	%C2-C5 (UCM)	%C6-C14 (UCM)	%C15+ (UCM)	%C1 (X-UCM)	%C2-C5 (X-UCM)	%C6-C14 (X-UCM)	%C15+ (X-UCM)	C1	C2-C5	C6-C14	C15+	C6-C14 (UCM)	C15+ (UCM)
16/1-7	1770	21214	1.7	29.9	59.1	9.3	1.8	32.7	59.3	6.1	9.53E+5	1.69E+7	3.06E+7	3.14E+6	3.33E+7	5.25E+6
16/1-7	1860	21217	1.5	22.6	56.7	19.2	1.8	27.4	59.0	11.8	8.18E+5	1.23E+7	2.64E+7	5.31E+6	3.08E+7	1.04E+7
16/1-7	2010	21222	3.4	25.5	55.1	16.0	4.0	29.6	56.6	9.8	2.37E+6	1.77E+7	3.39E+7	5.89E+6	3.84E+7	1.12E+7
16/1-7	2220	21229	2.8	17.6	46.2	33.4	3.9	24.8	52.2	19.1	2.70E+6	1.70E+7	3.58E+7	1.31E+7	4.46E+7	3.23E+7
16/1-7	2400	21235	2.2	19.5	49.0	29.4	2.8	24.6	53.5	19.1	1.19E+6	1.06E+7	2.30E+7	8.22E+6	2.66E+7	1.59E+7
16/1-7	2490	21238	2.3	19.2	46.9	31.6	2.9	24.1	51.1	21.9	1.84E+6	1.56E+7	3.29E+7	1.41E+7	3.81E+7	2.56E+7
16/1-7	2610	21242B	2.1	22.0	47.5	28.4	2.7	27.6	52.5	17.2	1.39E+6	1.43E+7	2.72E+7	8.89E+6	3.09E+7	1.85E+7
16/1-7	2760	21247A	2.9	11.2	34.6	51.3	5.8	22.5	50.0	21.7	2.15E+6	8.37E+6	1.86E+7	8.10E+6	2.59E+7	3.84E+7
16/1-7	2790	21248A	2.4	11.3	36.1	50.2	4.9	22.8	54.2	18.1	2.71E+6	1.27E+7	3.01E+7	1.01E+7	4.05E+7	5.64E+7
16/1-7	2850	21250	2.9	13.3	38.0	45.8	5.0	23.1	51.4	20.6	2.39E+6	1.11E+7	2.47E+7	9.89E+6	3.17E+7	3.81E+7
16/1-7	2940	21253	3.7	14.7	38.4	43.2	6.2	24.3	49.9	19.6	3.19E+6	1.26E+7	2.59E+7	1.02E+7	3.30E+7	3.71E+7
16/1-7	2970	21254A	5.8	13.6	32.3	48.2	10.1	23.7	43.2	22.9	4.29E+6	1.00E+7	1.83E+7	9.71E+6	2.38E+7	3.54E+7
16/1-7	3060	21257	5.4	14.0	33.7	46.9	8.6	22.4	43.5	25.5	4.67E+6	1.22E+7	2.37E+7	1.39E+7	2.93E+7	4.06E+7

Table 6. continued, Pyrolysis GC (peak area)

Well	Lower Depth	APT ID	n-Heptene	Tol	n-Octene	mp-Xyl	Weight (mg)
16/1-7	1770	21214	2.97E+5	1.45E+6	8.59E+4	6.16E+5	14.7
16/1-7	1860	21217	3.83E+5	1.31E+6	2.52E+5	3.81E+5	7.0
16/1-7	2010	21222	4.00E+5	1.70E+6	2.42E+5	5.96E+5	9.9
16/1-7	2220	21229	6.74E+5	1.43E+6	5.39E+5	5.14E+5	8.1
16/1-7	2400	21235	4.41E+5	1.13E+6	3.37E+5	2.62E+5	8.2
16/1-7	2490	21238	6.65E+5	1.66E+6	5.45E+5	3.43E+5	9.6
16/1-7	2610	21242B	6.10E+5	9.07E+5	4.70E+5	2.73E+5	10.4
16/1-7	2760	21247A	4.33E+5	4.66E+5	3.30E+5	3.39E+5	2.7
16/1-7	2790	21248A	6.62E+5	6.23E+5	5.06E+5	4.87E+5	4.2
16/1-7	2850	21250	5.32E+5	5.70E+5	4.11E+5	4.01E+5	4.6
16/1-7	2940	21253	5.23E+5	8.09E+5	4.00E+5	4.85E+5	5.9
16/1-7	2970	21254A	3.36E+5	7.34E+5	2.66E+5	4.93E+5	3.1
16/1-7	3060	21257	4.65E+5	9.40E+5	3.54E+5	4.28E+5	8.9

Table 7. Thermal Extraction GC (peak area)

Well	Lower Depth	APT ID	nC6	nC7	nC8	nC9	nC10	nC11	nC12	nC13	nC14	nC15	nC16	nC17	nC18	nC19
16/1-7	3000	21255	2.39E+4	1.40E+4	1.67E+4	1.19E+4	2.01E+4	2.76E+5	2.93E+6	9.02E+6	9.83E+6	1.84E+7	1.29E+7	1.03E+7	6.86E+6	4.81E+6
16/1-7	3060	21257	4.28E+4	2.48E+4	1.15E+4	1.98E+4	1.97E+4	8.87E+4	1.10E+6	5.87E+6	8.24E+6	1.58E+7	1.28E+7	9.85E+6	7.17E+6	4.91E+6

Table 7 continued, Thermal Extraction GC (peak area)

Well	Lower Depth	APT ID	nC20	nC21	nC22	nC23	nC24	nC25	nC26	nC27	nC28	nC29
16/1-7	3000	21255	3.19E+6	1.95E+6	1.12E+6	5.59E+5	2.46E+5	7.82E+4	2.65E+4	1.61E+4	8.54E+3	6.00E+3
16/1-7	3060	21257	3.26E+6	1.98E+6	1.12E+6	5.72E+5	2.60E+5	9.50E+4	4.17E+4	2.96E+4	1.89E+4	1.71E+4

Experimental Procedures

All procedures follow NIGOGA, 4th Edition. Below are brief descriptions of procedures/analytical conditions.

Sample preparation

Cuttings samples are washed in water to remove mud. When oil based mud is used, soap (Zalo) is added to the sample and the sample is washed thoroughly in warm water to remove mud and soap.

TOC and Rock-Eval

A Rock-Eval 6 instrument is used. The analysis is performed in two steps, pyrolysis and oxidation, when TOC is measured. Jet-Rock 1 was run as every tenth sample and checked against the acceptable range given in NIGOGA.

Temperature programme

Pyrolysis: 300 °C (3 min.) - 25 °C/min. - 650 °C (0 min.)

Oxidation: 400 °C (3 min.) - 25 °C/min. - 850 °C (5 min.)

Vitrinite reflectance analysis

The samples are prepared either as “whole rock” or are treated with hydrochloric and hydrofluoric acid prior to further preparation. The aim of the acid treatment is to avoid soft and expanding mineral phases in order to ensure good polishing quality. The whole rock or the kerogen resulting from the acid treatment is embedded in an epoxy resin to make briquettes, ground flat and polished using 0.25 micron diamond paste and magnesium oxide as the two final steps.

The analytical equipment used is a Zeiss MPM 03 photometer microscope equipped with an Epiplan-Neofluar 40/0.90 oil objective. The sensitive measuring spot is kept constant for all measurements at about 2.5 micron in diameter. The measurements are made through a green band pass filter (546 nm) and in oil immersion (refractive index 1.515 at 18 °C). The readings are made without a polarizer and using a stationary stage. This procedure is called measurement of random reflectance (%Rm). The photometer is calibrated daily against a standard of known reflectance (%Rm = 0.588) and routinely (daily) checked against two other standards of significant different reflectances (%Rm = 0.879 and 1.696). A deviation from these values of less than ± 0.01 and ± 0.02 respectively is considered acceptable. The calibration is routinely checked during the course of measurements at least every hour, and a deviation of less than ± 0.005 is considered acceptable.

For each sample at least 20 points are measured if possible, and quality ratings are given to various important aspects, which may affect the measurements. These aspects are abundance of vitrinite, uncertainties in the identification of indigenous vitrinite, type of vitrinite, particle size, particle surface quality and abundance of pyrite.

Visual kerogen analysis

The samples are treated with hydrochloric and hydrofluoric acid to isolate the kerogen. The residual material for kerogen description is embedded on a cover glass, dried and finally mounted on an object glass using the preserving glue Entellan. The analytical equipment being used is a Zeiss MPM 03 photometer microscope equipped with a Neofluar 40/0.75 and a

Neofluar 10/0.30 objective. UV light excitation and transmittent white light is used to make a visual classification of the kerogen.

PyGC

A HP5890 II instrument with an MSSV injector and an FID is used. The column is a HP-1, length 50 m, i.d. 0.25 mm, film thickness 0.50 μm .

The pyrolysis oven is preheated to 300 °C. The sample tube is placed in the injector system and then broken. The temperature is then increased to 600 °C at a rate of 25 °C/min. The pyrolysis products are collected in the cold trap for fourteen minutes before being released into the GC column, whereupon the following temperature programme is run:

Initial temperature: 40 °C (10 min. from breaking of sample tube) – heating rate: 5 °C/min. – final hold temperature: 300 °C (23 min.)