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EVALUATION OF SOURCE ROCK PROPERTIES OF SAMPLES FROM WELL 03/07-06, NORWAY

by

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Sponsor: Norske Shell, Risavika

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1. INTRODUCTION

At the request of EPXT1, Norske Shell, Risavika, Norway, a source rock screening has been carried out on a total of 62 samples from the well 3/7-6 (Spekkhuger-1), Norway. For analysis requests per sample batch reference is made to the following relevant telex order numbers:

2 core samples -	T96436, e-mail of 19-11-96,
9 sidewall samples -	T96439, e-mail of 05-12-96
51 cutting samples -	T96440, e-mail of 11-12-96 (only 51 from the 71 cuttings had residue left, after sample washing)

The following sampled intervals were subjected to source rock analysis:

Depth interval	*Number of samples*	*No. of analyses* TOC	*REV*	*MAC/VR*
2840 - 3426m	12	12	2	1
3442 - 3651m	11	9	4	4
3689 - 4120m	39	39	20	10

The purpose of the investigation was:

1. to detect the presence (or absence) of source rocks in the samples,
2. to determine the quality of the organic matter, as well as its distribution within the mineral matrix,
3. to establish the degree of organic metamorphism (level of maturity).

2. ANALYSIS METHODS

a. The **total organic-carbon (TOC)** content is determined by combustion of the hydrochloric acid treated sample in an automatic Leco equipment. The organic-carbon values are reported in weight percent carbon (1% TOC means 1 g of organic carbon in 100 g of sediment).
By this method the amount of non-carbonate organic carbon is determined. In general a cut-off value of 1.0% organic carbon is used to separate source rocks and non-source rocks. In cutting samples and outcrop samples a cut-off value of 0.5% is maintained because of dilution effects in cutting samples and influence of oxidation in outcrop samples. However, the method cannot distinguish between postmature source rocks that were originally hydrogen-rich or hydrogen-poor. During diagenesis, part of the organic matter in the samples has been released (as CO_2, hydrocarbons, hetero-compounds). As a result of this process the organic-carbon content of a postmature source rock is lower than its original content in the immature stage.

b. The **Rock-Eval II (REV)** is used to calibrate the presence of hydrocarbons (S-1), the hydrocarbon-generation potential (S-2) and the amount of carbon dioxide (S-3) on those samples, of which the organic carbon determination indicated the presence of source-rock potential (Corg. >1.0%). Tmax is the temperature of maximum rate of S-2 hydrocarbon evolution. Hydrogen Index (HI) is a measure of the hydrocarbon generating potential remaining in the kerogen as opposed to that of the whole rock. The Oxygen Index (OI) is the ratio of the released carbon dioxide to organic carbon content and the Production Index (PI) is the ratio of the amount of hydrocarbons released in the first stage of heating to the total amount of hydrocarbons released and cracked during pyrolysis. Source-rock typing by Rock-Eval is based on hydrogen index and oxygen index. These two parameters are plotted in a modified Van Krevelen diagram.

Additional information on type and relative maturity may be obtained from the recorded Tmax. However, the type of source rock also influences Tmax. Therefore, the maturity trend is often obscured by changes in source rock type over longer intervals and maturity determination on Tmax alone can only be a very rough estimate.

c. **Incident-light microscopy** has been used to determine the maceral composition of source rocks by means of microscopy, using incident tungsten light with or without crossed nicols and by means of fluorescence microscopy using incident ultraviolet light. The microscopic classification is based on the different maceral association encountered in different source rocks. Three main source -rock types can be recognised by the following interpretative characteristics:

Type I : algal source rocks (oil prone)

Type II : bacterial source rocks; SOM of algal or land-plant origin (oil prone)

Type III : land-plant containing source rocks (gas prone)

Type IV : containing mainly primary inertinite; sub hydrous (very low hydrogen) Type III rocks

For each selected sample a semi-quantitative maceral description is given in terms of abundant, common, few and rare, indicating a visual estimation of the total organic and inorganic rock content. A visual percentage estimation is also given.

d. The **maturity** of source rocks is determined preferably by measuring the reflectance of vitrinite, the results of which are illustrated by histograms. The maturity is indicated in VR (vitrinite reflectance) or VRE (vitrinite reflectance equivalent) values. Reliable vitrinite reflectance data are of major importance in order to establish the maturity windows for hydrocarbon generation. Very important, therefore, are sample preparation and the identification of the suitable macerals. In RTS, vitrinite reflectance is measured by means of a Leitz Orthoplan microscope equipped with a photometer. This equipment is connected to a computer system. By convention, reflectance of telocollinite is used for maturity determination. Reflectance measurements on desmocollinite generally results in too low values and the results of reflectance measurements on telinite are either too low or too high. In the absence of vitrinite, the maturity or vitrinite reflectance equivalent (VRE) is derived mainly from the state of micrinisation of the SOM (Structureless Organic Matter), fluorescence colours of indigenous liptinites/exsudatinite and reflectance measurements carried out on solid hydrocarbons and graptolites. Fluorescence measurements of liptinites, especially Tasmanites- and Botryococcus-type algae can be used as a maturity tool as well.

Results of Total organic carbon determination and Rock-Eval analyis

Depth/m	*Type*	*TOC*	*S1*	*S2*	*S3*	*Tmax*	*HI*	*OI*	*VR*	*MAC*
2840	C	1.1	0.75	4.76	2.66	405	433	242		
2860	C	1.6	0.62	5.12	1.8	416	320	113		X
2880	C	0.5								
3177	C	0.2								
3243	C	0.1								
3297	C	0.1								
3347	C	1								
3348	C	0.6								
3396	C	0.6								
3408	C	0.6								
3417	C	0.5								
3426	C	0.7								
3442.5	S	2.7	1.06	8.46	1.84	437	313	68		X
3456	C	1								
3468	C	1.3	0.82	5.36	3.04	427	412	234		
3478	C	0.9								
3503	C	0.7								
3543	S	1.3	0.53	2.97	1.1	433	228	85		X
3591	C	1.1	0.78	3.53	2.59	430	321	235		
3639	C	1.3								
3647.78	R								X	X
3650.24	R								X	X
3651	C	1.2	9.61	11.91	7.25	376	993	604		
3689	S	2.2	1.63	6.32	1.79	434	287	81		X
3750	C	2.2								
3756	C	2.2	1.13	4.22	2.47	421	192	112		
3767	S	2.3	1.71	6.54	2.48	438	284	108		X
3777	C	2.5								
3786	C	2.7								
3798	C	2.8	4.11	7.04	4.72	426	251	169		X
3805	S	2.6	1.9	6.14	2.51	433	236	97		X
3816	C	3								
3828	C	3.9	3.5	12.83	2.85	432	329	73		
3837	C	2.8								
3846	C	2.5	2.07	5.97	2.76	431	239	110		
3858	C	2.3								
3867	C	2								
3876	C	1.9								
3888	C	2.2	1.58	4.2	2.51	431	191	114		
3897	C	2.4								
3906	C	2.5	2.21	5.6	2.75	430	224	110		X
3918	C	2								
3927	C	2.2	2.15	5.24	2.43	430	238	110		
3936	C	1.9								
3948	C	2.3								
3958	S	2.3	2.12	6.63	2.19	438	288	95		X
3966	C	2.1								

Table 1

Depth/m	*Type*	*TOC*	*S1*	*S2*	*S3*	*Tmax*	*HI*	*OI*	*VR*	*MAC*
3978	C	2.3	1.82	4.83	2.66	429	210	116		
3987	C	1.8								
3996	C	2.9	2.32	7.44	2.32	434	257	80		
4006.5	S	4.8	4.22	20.32	1.7	442	423	35		X
4017	C	2								
4028	C	0.9								
4038	C	1.7								
4047	C	2.1	2.17	5.78	2.33	431	275	111		
4063.5	S	2.1	2.78	4.9	2.58	438	233	123		X
4068	C	2.2								
4083	C	2.2								
4089	C	3	3.84	7.76	3.57	427	259	119		
4098	C	2.2								
4109.5	S	1.8	1.35	4.59	1.57	441	255	87		X
4120	C	2.3	3.05	5.65	4.44	429	246	193		X

TOC: Total amount of organic carbon (weight percentage)
S1: Amount of free hydrocarbons (mg/g of rock)
S2: Amount of hydrocarbons formed by breakdown of kerogen (mg/g of rock)
S3: Amount of CO_2 evolved during pyrolysis
HI: Hydrogen Index (source rock type)
OI: Oxygen Index
Tmax Relative maturity in degrees Celsius
VR Vitrinite reflectance measurement
MAC Maceral analysis

Table 1

Maceral Description

Well: NORWAY, 03/07-06

Sample(s)	SOM – LOAD BEARING: dense	SOM – LOAD BEARING: layers	SOM – LOAD BEARING: lenses	SOM: diffuse/intergranular non-LB	Vitrinite VIT-1: layers/lenses telocollinite	Vitrinite VIT-1: detrital telocollinite	Vitrinite VIT-1: layers/lenses telinite	Vitrinite VIT-1: detrital telinite	Vitrinite VIT-2: layers/lenses desmocollinite	Vitrinite VIT-2: detrital desmocollinite	Liptinite: sporinite (micro-)	Liptinite: sporinite (mega-)	Liptinite: cutinite	Liptinite: suberinite	Liptinite: resinite (+fluorinite)	Liptinite: liptodetrinite	Liptinite ALGAE: botryococcus	Liptinite ALGAE: tasmanites	Liptinite ALGAE: other algae	Liptinite ALGAE: microplankton	Liptinite: exsudatinite (fluorescing)	Liptinite: exsudatinite (non-fluorescing)	Inert.: sclerotinite	Inert.: (semi-) fusinite (+inertodetrinite)	Inert.: micrinite	Mineral matter: undefined minerals	Mineral matter: framboidal pyrite	Mineral matter: aggregates / crystals pyrite
2860.00m/C			/	-						-	-					/				/				-			+	/
3442.50m/S		/	/	/						-	-					/	-	-		/				/			+	/
3543.00m/S			/	/						-	-					/	-			/				-		*	+	-
3647.78m/R			/	/						/	/		/		-	+				/				/		*	+	/
3650.24m/R			/	/	+					+	/		/		-	/				/				/		*	+	/
3689.00m/S		-	/	/						-	/		-			/	-	-		/	-			/			+	/
3767.00m/S		-	/	/							/		-			/	-			/	-			/	/		+	/
3798.00m/C			/	/						-						/				-	-			-	/		/	-
3805.00m/S		/	/	/						-	/					+	-			/	-			/	/		+	/
3906.00m/C			-	/							-					/				/	-			-	/		/	/
3958.00m/S			+	/						-	-					/				+	-			/	/		+	/
4006.50m/S		/	+	+						-	/					+				+	-			/	+		+	/
4063.50m/S			/	/						-	-					/				/	-			-	/		/	/
4109.50m/S		-	/	/						-	-					/				/	-			/	/	*	+	/
4120.00m/C			/	/						-	-					-				-	-			/	/		/	/

LEGEND
- Rare
/ Few
+ Common
* Abundant
? Unknown

Figure 2a

Visual volume percentage estimation

Well: NORWAY, 03/07-06

Sample(s)	Organic matter – SOM – LOAD BEARING – dense	SOM – LOAD BEARING – layers	SOM – LOAD BEARING – lenses	SOM – diffuse/intergranular non-LB	Vitrinite – VIT-1 – layers/lenses telocollinite	VIT-1 – detrital telocollinite	VIT-1 – layers/lenses telinite	VIT-1 – detrital telinite	Vitrinite – VIT-2 – layers/lenses desmocollinite	VIT-2 – detrital desmocollinite	Liptinite – sporinite (micro-)	sporinite (mega-)	cutinite	suberinite	resinite (+fluorinite)	liptodetrinite	ALGAE – botryococcus	ALGAE – tasmanites	ALGAE – other algae	ALGAE – microplankton	exsudatinite (fluorescing)	exsudatinite (non-fluorescing)	Inert. – sclerotinite	(semi-) fusinite (+inertodetrinite)	micrinite	Mineral matter – undefined minerals	framboidal pyrite	aggregates / crystals pyrite
2860.00m/C			1	<1						<1	<1					1				1				<1		92	4	1
3442.50m/S		1	2	1						<1	<1					2	<1	<1		2				1		84	6	1
3543.00m/S			1	1						<1	<1					1	<1			1				<1		93	3	<1
3647.78m/R			1	2						2	1		2		<1	3				1				1		83	3	1
3650.24m/R			1	1	4					5	1		2		<1	2				1				1		78	3	1
3689.00m/S		<1	1	1						<1	1		<1			2	<1	<1		1	R			1		88	4	1
3767.00m/S		<1	2	2							1		<1			2	<1			2	R			1	F	86	3	1
3798.00m/C			1	1						<1						1				<1	R			<1	F	96	1	<1
3805.00m/S		1	2	1						<1	2					3	<1			2	R			1	F	77	10	1
3906.00m/C			<1	1							<1					1				1	R			<1	F	94	2	1
3958.00m/S			3	2						<1	<1					2				3	R			1	F	80	8	1
4006.50m/S		2	3	4						<1	1					5				3	R			1	C	74	6	1
4063.50m/S			1	1						<1	<1					1				1	R			<1	F	93	2	1
4109.50m/S		<1	2	2						<1	<1					1				2	R			1	F	87	4	1
4120.00m/C			1	1						<1	<1					<1				<1	R			1	F	94	2	1

LEGEND
R Rare
F Few
C Common
A Abundant
? Unknown

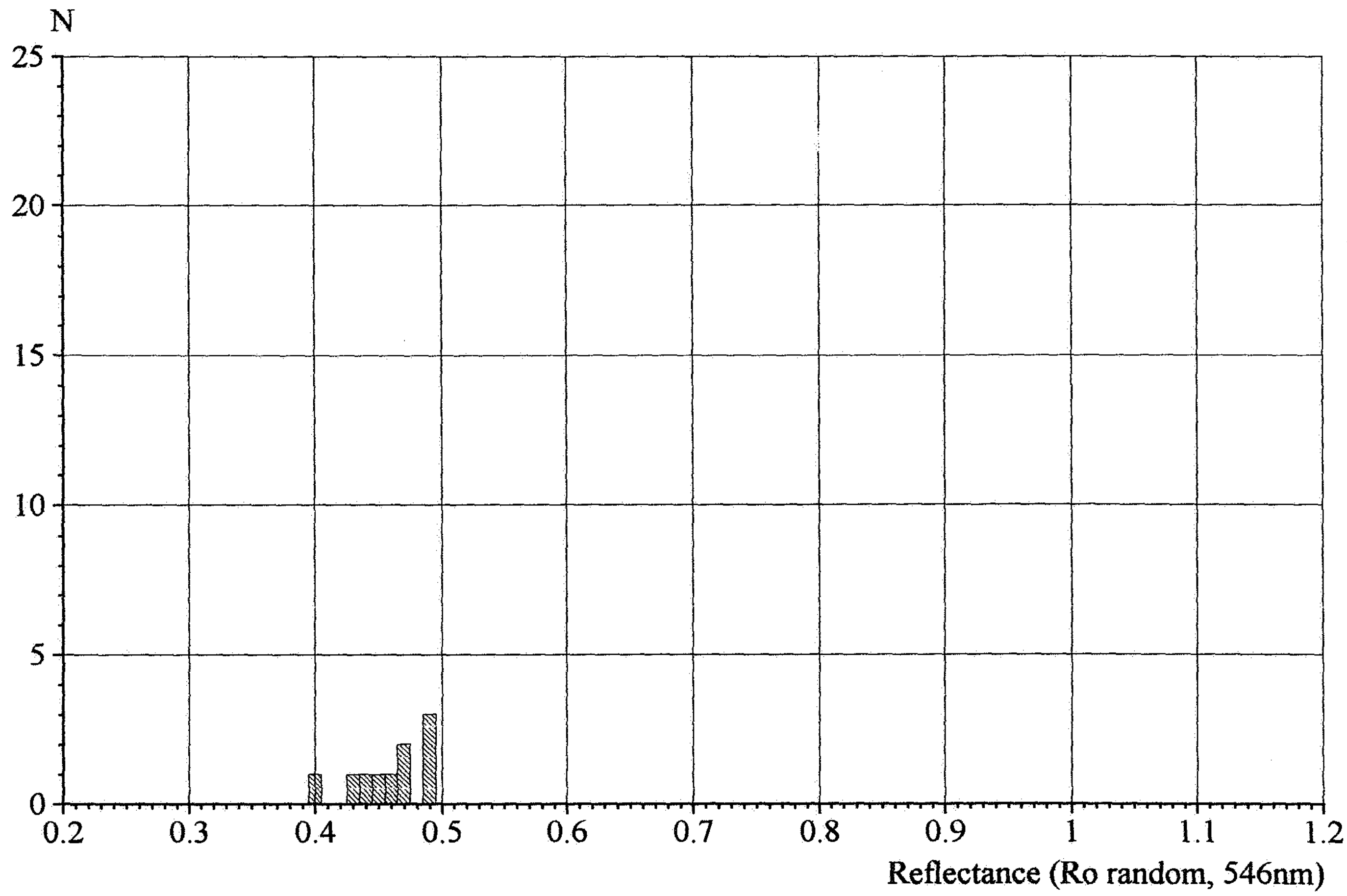
Depth	Sample Type	Comment
2860.00m (s 186041)	C	Sample slightly oxidised Sample partly oxidised WHITE-LT YELLOW FLUORESCING LIPTIITES -> IMMATURE
3442.50m (s 186091)	S	Vitrinite grades into (semi-) fusinite LIGHT YELLOW FLUORESCENCE -> IMMATURE
3543.00m (s 186092)	S	Vitrinite grades into (semi-) fusinite LIGHT YELLOW - YELLOW FLUORESCENCE -> (JUST)MATURE Light yellow fluorescence -> immature
3647.78m (s 185422)	R	Allochthonous vitrinite; rare glauconite White - yellow fluorescing liptinites
3650.24m (s 185423)	R	Allochthonous Telocollinite / Desmocollinite White - yellow fluorescing liptinites
3689.00m (s 186093)	S	Sample partly oxidised Vitrinite grades into (semi-) fusinite LIGHT YELLOW FLUORESCENCE
3767.00m (s 186094)	S	SOM partly micrinised Sample partly oxidised LIGHT YELLOW - YELLOW FLUORESCENCE -> (JUST)MATURE RARE ACRITARCHS
3798.00m (s 186063)	C	SOM partly micrinised Sample partly oxidised Contaminated COMMON BIT-METAMORPHISM LIGHT YELLOW - YELLOW FLUORESCENCE -> (JUST)MATURE
3805.00m (s 186095)	S	SOM partly micrinised Laminated (algal) SOM partly bacterially transformed Fossil remains LIGHT YELLOW - YELLOW FLUORESCENCE -> (JUST)MATURE
3906.00m (s 186073)	C	SOM partly micrinised Contaminated ABUNDANT BIT-METAMORPHISM LIGHT YELLOW - YELLOW FLUORESCENCE
3958.00m (s 186096)	S	SOM partly micrinised Sample partly oxidised Vitrinite shows oxidation features Vitrinite grades into (semi-) fusinite Laminated (algal) SOM partly bacterially transformed (LIGHT)YELLOW - YELLOW FLUORESCENCE -> MATURE
4006.50m (s 186097)	S	SOM partly micrinised SOM micrinised Sample slightly oxidised Pyrite shows oxidation features Laminated (algal) SOM partly bacterially transformed YELLOW FLUORESCENCE -> MATURE
4063.50m (s 186098)	S	SOM partly micrinised Sample oxidised YELLOW FLUORESCENCE -> MATURE
4109.50m (s 186099)	S	SOM partly micrinised Sample partly oxidised Vitrinite grades into (semi-) fusinite YELLOW FLUORESCENCE -> MATURE
4120.00m (s 186090)	C	Sample oxidised Vitrinite shows oxidation features Contaminated COMMON BIT-METAMORPHISM YELLOW FLUORESCENCE

Figure 2c

Reflectance histogram

Country	*Norway*	Sample type	*Core*
Well	*03/07-06*	Sample/Order	*S185422/01*
Depth	*3647.78 m*	Analyst	*KMR*
Reference	*Derrick floor*	Date	*21-11-1996*

	Mean	Std	Min	Max	Mode	Measurements
Desmocollinite	*0.46*	*0.03*	*0.4*	*0.49*	*0.49*	*10*



Comment:

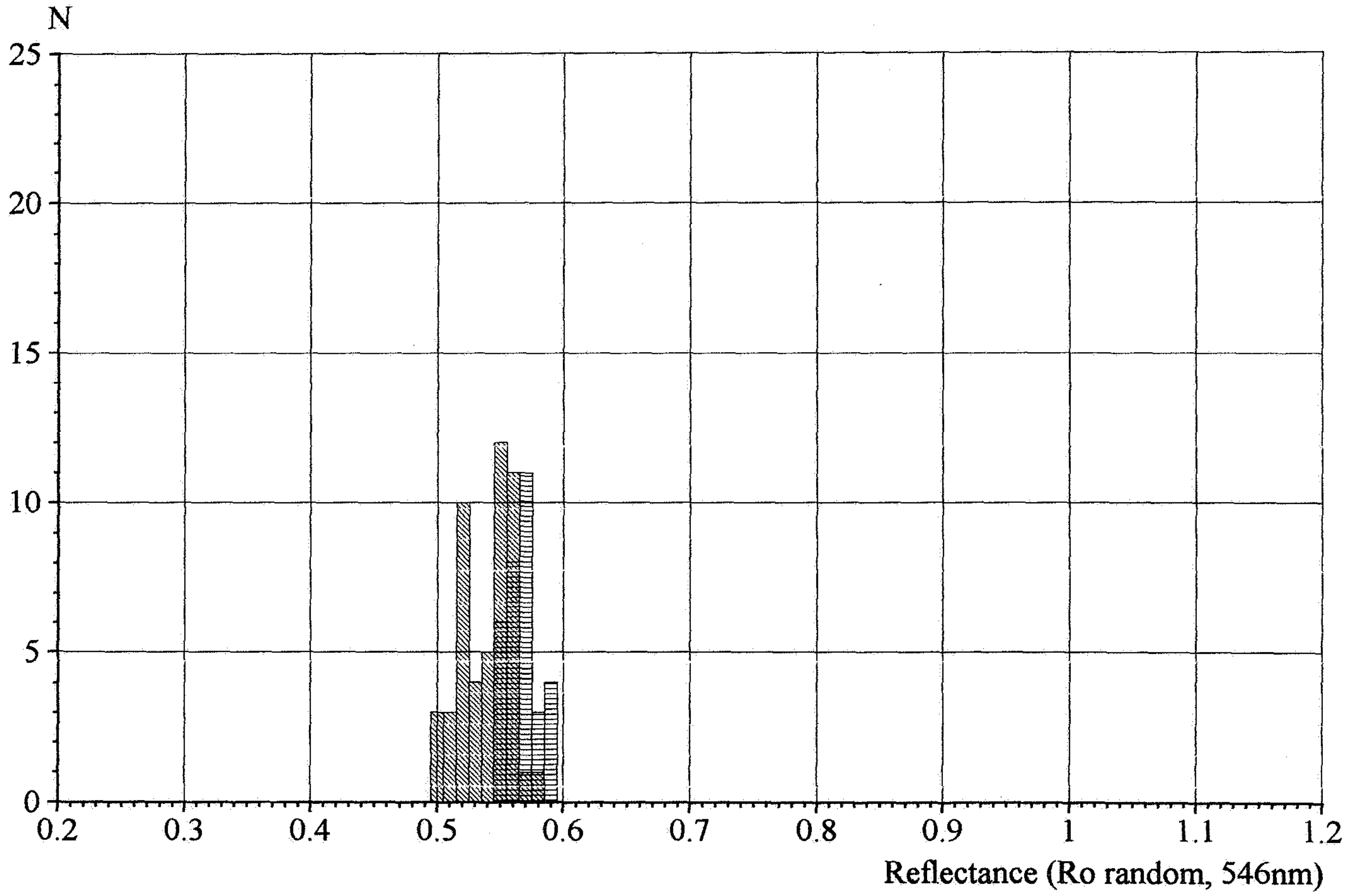
Small detrital desmocollinite with strongly suppressed reflectance

Figure 5

Reflectance histogram

Country	*Norway*	Sample type	*Core*
Well	*03/07-06*	Sample/Order	*S185423/01*
Depth	*3650.24 m*	Analyst	*KMR*
Reference	*Derrick floor*	Date	*21-11-1996*

	Mean	Std	Min	Max	Mode	Measurements
Telocollinite/Desmocollinite	*0.57*	*0.01*	*0.55*	*0.59*	*0.57*	*32*
Telocollinite/Desmocollinite	*0.54*	*0.02*	*0.5*	*0.58*	*0.55*	*50*



Comment:

Pop. 1: single layer of Telocollinite / Desmocollinite, slightly fluorescing and contaning few mineral matter and abundant framboidal pyrite.
Pop. 2: a.a., but smaller fragments distributed as lenses in the mineral matrix.
Reflectance suppressed -> VRE is probably around 0.60%.

Figure 6