DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 1998/81

Rock properties of hyaloclastic rocks. Data from the Marraat-1 core, Nuussuaq, West Greenland (For the Atlantic Margin Group)

Christian Høier

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND
MINISTRY OF ENVIRONMENT AND ENERGY

G E U S

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Contents

1. Introduction

By request of the Atlantic Margin Group (Statoil, Enterprise Oil and Mobil) with Dave Ellis as project manager, GEUS Core Laboratory has carried out conventional core analysis on the well Marraat-1, in the Nuussuaq area, West Greenland.

The analytical programme included the following services:

- Cleaning and drying of plugs
- Grain density and porosity
- Gas permeability

GEUS Core Laboratory received 212 plugs from Marraat-1 in May 1998. Several preliminary data reports have been forwarded to the Atlantic Margin Group during July and August 1998.

2. Sampling and analytical procedure

The laboratory received 212 plugs from Marraat-1 taken in the interval 4 - 63 meter measured depth.

2.1 Cleaning and drying

The plugs were cleaned in Soxhlet extractors for a month. The extracted oil was collected for later analysis.
After drying at 110°C oil was bleeding from the surface of proximally 10 plugs. Presumably the heat must have open some closed pores, or expelled the oil from micro porous parts of the pore system which could not otherwise be reached during the ordinary soxhlet cleaning.

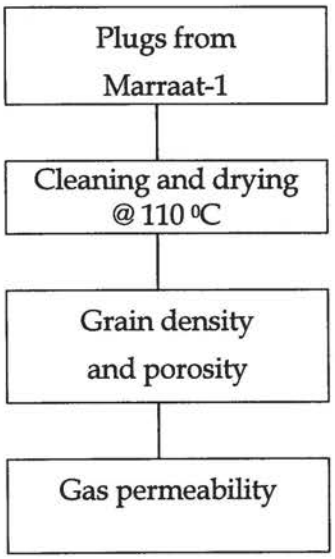
2.2 Grain density and porosity

The porosity was measured over a period of 5 minutes, due to very tight nature of the samples.

2.3 Gas permeability

The permeability was measured using a sleeve pressure of 400 psi.

3. Flow chart of the analytical procedure



4. Analytical methods

The following is a short description of the methods used by the GEUS Core Laboratory. For a more detailed description of methods, instrumentation and principles of calculation the reader is referred to API recommended practice for core analysis procedure (API RP 40, 1960).

4.1 Conventional cleaning and drying

The plugs are drilled and trimmed to a size of 1.5" diameter and 2.5" length. The samples are then placed in a Soxhlet extractor, which continuously soaks and washes the samples with methanol. This process removes water and dissolves salt precipitated in the pore space of the rock. Extraction is terminated when no chloride ions are present in the methanol. Samples containing hydrocarbons are then cleaned in toluene until a clear solution is obtained. Samples are vacuum dried at 90°C or 110°C, or they are humidity dried at 60°C and 40% relative humidity until constant weight occurs, depending on the requirements of the client.

4.2 Gas permeability

The plug is mounted in a Hassler core holder, and a confining pressure of 400 psi is applied to the sleeve. The specific permeability to gas is measured by flowing nitrogen gas through a plug of known dimensions at differential pressures between 0 and 1 bar. No back pressure is applied. The readings of the digital gas permeameter are checked regularly by routine measurement of permeable steel reference plugs.

4.3 He-porosity and grain density

The porosity is measured on cleaned and dried samples. The porosity is determined by subtraction of the measured grain volume and the measured bulk volume. The Helium technique, employing Boyle's Law, is used for grain volume determination, applying a double chambered Helium porosimeter with digital readout, whereas bulk volume is measured by submersion of the plug in a mercury bath using Archimedes principle. Grain density is calculated from the grain volume measurement and the weight of the cleaned and dried sample.

4.4 Precision of analytical data

The table below gives the precision (= reproducibility) at the 68% level of confidence (+/- 1 standard deviation) for routine core analysis measurements performed at the GEUS Core Laboratory.

Measurement	Range, mD	Precision
Grain density		0.003 g/cc
Porosity		0.1 porosity-%
Gas Permeability	0.001-0.01 0.01-0.1 > 0.1	25% 15% 4%

5. Results of conventional core analysis

The results are presented in the following data listing and in frequency plots of:

- Gas permeability
- Porosity
- Grain density

Crossplots of porosity vs. gas permeability are listed in the end

Attached to this report is:

- A core log plotting Depth vs. Grain Density, Porosity and Gas Permeability.

GEOLOGICAL SURVEY OF DENMARK AND GREENLAND

GEUS CORE LABORATORY

CORE ANALYSIS TABULATION

Final report

Compiled by Christian Hoier

WELL : Marraat-1

CORE :

Printed : 3-SEP-98

GENERAL INFORMATION ON THE ANALYSIS

COMPANY	: GEUS/Strat. Afd.	LOCATION	: Grønland
DEPTH INTERVAL :	0.00 - 0.00	CORE NO.'S :	
DEPTHS ARE MEASURED FROM		ANALYSTS	: MJ,GG
DEPTHS ARE IN METRES		DATE	: 030998
PROGRAM POPE V.5.8		FILE	: MARR98

REMARKS :

Plugs have been soxhlet cleaned in methanol and toluene and dried at 110 C. Gas permeability was measured at a confining sleeve pressure of 400 psi. He-porosity was measured unconfined.

SAMPLE NO.	DEPTH METER	GAS PERM mD	POROSITY %	GRAIN DENS. G/CCM	COMMENT
351	4.16	0.030	3.33	2.663	
352	4.49	0.019	0.79	2.643	
353	5.06	0.691	0.43	2.805	
354	5.33	1.66	34.56	2.766	
355	5.56	0.015	0.84	2.831	
356	5.87	0.021	1.61	2.815	
357	6.15	0.016	2.52	2.833	
358	6.49	0.089	3.71	2.809	
359	6.88	0.538	2.98	2.859	
360	7.21	0.023	2.33	2.828	
361	7.18	0.018	2.27	2.821	
362	7.30	0.094	1.99	2.852	
363	7.77	0.418	2.56	2.850	
364	8.11	0.756	4.52	2.843	
365	8.45	0.030	2.41	2.855	
366	8.67	1.17	2.99	2.865	
367	9.26	0.036	3.37	2.846	
368	9.31	0.014	3.36	2.841	
369	9.75	0.022	0.47	2.808	
370	10.10	0.029	2.72	2.835	
371	10.63	0.019	1.57	2.866	
372	11.02	0.100	5.72	2.764	

SAMPLE NO.	DEPTH METER	GAS PERM mD	POROSITY %	GRAIN DENS. G/CCM	COMMENT
373	11.84	0.200	9.88	2.753	
374	12.02	0.227	11.64	2.819	
375	12.14	0.103	9.32	2.807	
376	12.84	0.048	6.69	2.847	
377	13.20	0.042	5.28	2.890	
378	14.08	0.282	13.51	2.799	
379	14.53	0.388	10.62	2.780	
380	14.83	0.122	11.74	2.800	
381	15.30	0.388	14.11	2.821	
382	15.81	0.152	8.95	2.911	
383	16.12		14.73	2.868	
384	16.47	0.395	14.89	2.780	
385	16.75	0.162	12.98	2.822	
386	17.03		11.68	2.928	
387	17.33		13.93	2.896	
388	17.35	0.219	14.35	2.792	
389	17.60	1.43	14.64	2.843	
390	17.95		17.51	2.882	
391	18.28	11.3	17.76	2.810	
392	18.60	0.049	15.10	2.921	
393	18.90				
394	19.49	0.070	9.03	2.924	

SAMPLE NO.	DEPTH METER	GAS PERM mD	POROSITY %	GRAIN DENS. G/CCM	COMMENT
395	19.55	0.044	7.92	2.937	
396	20.11		5.12	2.903	
397	20.36	0.018	3.64	2.924	
398	20.59		3.18	2.881	
399	20.84	0.030	2.72	2.878	
400	21.05	0.027	2.24	2.862	
401	21.15		4.53	2.868	
402	21.42	0.020	1.99	2.850	
403	21.83	0.022	2.88	2.881	
404	22.12	0.046	7.37	2.910	
405	22.43		8.23	2.847	
406	22.83	0.056	9.22	2.824	
407	23.07	0.248	10.24	2.826	
408	23.36	0.051	7.53	2.853	
409	23.64	0.072	8.35	2.886	
410	23.92	0.054	7.09	2.883	
411	24.20	0.017	2.39	2.886	
412	24.86	0.020	2.99	2.848	
413	25.13	0.059	9.70	2.732	
414	25.32	0.033	8.09	2.737	
415	25.70	0.053	9.74	2.892	
416	26.25	0.034	3.46	2.744	

SAMPLE NO.	DEPTH METER	GAS PERM mD	POROSITY %	GRAIN DENS. G/CCM	COMMENT
417	26.53	0.020	1.64	2.714	
418	26.89	0.041	8.16	2.667	
419	27.15	0.038	5.34	2.607	
420	27.44	0.116	13.44	2.653	
421	27.82	0.068	10.66	2.710	
422	28.10	0.046	6.40	2.638	
423	28.40	0.031	3.22	2.552	
424	28.66	0.029	5.70	2.695	
425	29.09	0.048	3.37	2.784	
426	29.55	0.034	6.23	2.795	
427	29.81	0.028	5.48	2.831	
428	30.12	0.050	5.79	2.791	
429	50.46	0.033	10.36	2.809	
430	50.57	0.099	9.41	2.758	
431	50.68	0.121	11.51	2.815	
432	50.94	0.556	13.61	2.792	
433	51.12	0.366	12.27	2.805	
434	51.47	0.091	10.87	2.850	
435	51.80	0.033	8.86	2.899	
436	52.14	0.036	8.25	2.907	
437	52.38	0.038	7.46	2.939	
438	52.78	0.086	9.03	2.938	

SAMPLE NO.	DEPTH METER	GAS PERM mD	POROSITY %	GRAIN DENS. G/CCM	COMMENT
439	53.09	0.069	7.93	2.966	
440	53.38	0.062	7.57	2.972	
441	53.76	0.047	6.61	2.957	
442	54.01	0.048	9.47	2.861	
443	54.32	0.105	13.26	2.780	
444	54.70	0.149	11.12	2.855	
445	55.00	0.162	11.48	2.851	
446	55.42	0.116	11.16	2.865	
447	55.75	0.119	10.41	2.877	
448	56.03	0.122	9.89	2.847	
449	56.25	0.115	10.27	2.880	
450	56.60	0.179	11.93	2.808	
451	56.91	0.081	8.20	2.876	
452	57.20	0.058	7.22	2.852	
453	57.33	0.072	7.26	2.866	
454	57.64	0.057	7.57	2.910	
455	57.99	0.023	1.74	2.874	
456	58.33	0.025	2.58	2.893	
457	58.51	0.038	5.40	2.948	
458	58.80	0.028	3.20	2.942	
459	59.11	0.033	4.04	2.940	
460	59.39	0.039	4.14	2.932	

SAMPLE NO.	DEPTH METER	GAS PERM mD	POROSITY %	GRAIN DENS. G/CCM	COMMENT
461	59.69	0.025	2.79	2.901	
462	59.93	0.027	3.51	2.899	
463	60.20	0.027	3.69	2.941	
464	60.49	0.024	2.78	2.935	
465	60.83	0.046	4.45	2.915	
466	61.11	0.031	3.26	2.915	
467	61.38	0.035	3.26	2.857	
468	61.67	0.041	5.52	2.716	
469	62.01	0.068	8.02	2.802	
470	62.30	0.055	8.23	2.824	
471	62.58	0.028	5.84	2.730	
472	62.94	0.063	7.87	2.827	
473	63.27	0.079	8.13	2.832	
474	63.51	0.079	10.65	2.767	
475	63.88	0.059	8.18	2.829	
476	64.17	0.104	7.38	2.832	
477	64.44	0.039	6.44	2.813	
478	64.74	0.032	7.96	2.844	
479	65.03	0.051	6.94	2.833	
480	65.43	0.033	6.68	2.850	
481	65.64	0.032	4.75	2.896	
482	65.96	0.038	5.27	2.905	

SAMPLE NO.	DEPTH METER	GAS PERM mD	POROSITY %	GRAIN DENS. G/CCM	COMMENT
483	66.20	0.025	4.80	2.934	
484	66.45	0.032	3.13	2.934	
485	66.78	0.034	4.88	2.907	
486	67.07	0.046	7.56	2.744	
487	67.36	0.070	7.96	2.785	
488	67.68	0.034	8.73	2.809	
489	67.98	0.056	9.05	2.857	
490	68.18	0.054	9.49	2.808	
491	68.54	0.030	4.70	2.857	
492	68.95	0.034	4.31	2.909	
493	69.12	0.040	5.29	2.897	
494	69.33	0.022	4.47	2.802	
495	69.61	0.065	7.45	2.757	
496	69.86	0.048	6.26	2.808	
497	70.16	0.037	5.95	2.843	
498	70.51	0.032	5.08	2.874	
499	70.88	0.037	5.02	2.873	
500	71.12	0.029	4.34	2.753	
501	71.46	0.067	6.96	2.758	
502	71.75	0.043	8.36	2.773	
503	72.07	0.045	6.86	2.781	
504	72.32	0.376	12.28	2.774	

SAMPLE NO.	DEPTH METER	GAS PERM mD	POROSITY %	GRAIN DENS. G/CCM	COMMENT
505	72.65	0.064	6.93	2.762	
506	72.91	0.040	8.11	2.853	
507	73.21	0.053	6.78	2.883	
508	73.57	0.047	7.08	2.902	
509	73.85	0.027	5.01	2.658	
510	74.10	0.031	7.53	2.799	
511	74.41	0.037	6.48	2.775	
512	74.70	0.029	8.53	2.856	
513	75.05	0.043	8.20	2.811	
514	75.31	0.029	7.19	2.739	
515	75.58	0.037	7.33	2.799	
516	75.83	0.055	7.22	2.807	
517	76.19	0.056	7.91	2.892	
518	76.50	0.050	7.44	2.884	
519	76.77	0.057	7.32	2.829	
520	77.26	0.108	13.38	2.722	
521	77.44	17.6	17.51	2.724	
522	77.74	0.157	13.07	2.714	
523	78.06	0.066	13.15	2.739	
524	78.34	0.096	12.68	2.691	
525	78.69	0.232	14.78	2.744	
526	78.92	0.051	8.43	2.658	

SAMPLE NO.	DEPTH METER	GAS PERM mD	POROSITY %	GRAIN DENS. G/CCM	COMMENT
527	79.19	0.074	10.07	2.682	
528	79.40	0.638	13.56	2.719	
529	79.80	0.107	10.96	2.719	
530	80.09	0.143	11.95	2.739	
531	80.38	0.052	6.60	2.772	
532	80.99	0.043	2.45	2.792	
533	81.28	0.046	3.06	2.815	
534	81.59	0.034	3.09	2.760	
535	81.88	0.146	7.87	2.685	
536	82.04	0.039	7.26	2.614	
537	82.51	0.344	11.85	2.725	
538		0.036	6.06	2.773	
539		0.074	10.51	2.743	
540		0.060	12.36	2.695	
541		0.038	11.03	2.693	
542	84.61	0.090	10.09	2.709	
543	84.82	0.056	8.95	2.657	
544	85.08	0.044	8.85	2.675	
545	85.34	0.097	5.88	2.678	
546	85.69	0.041	6.94	2.615	
547	85.97	0.071	11.69	2.708	
548	86.26	0.117	12.26	2.702	

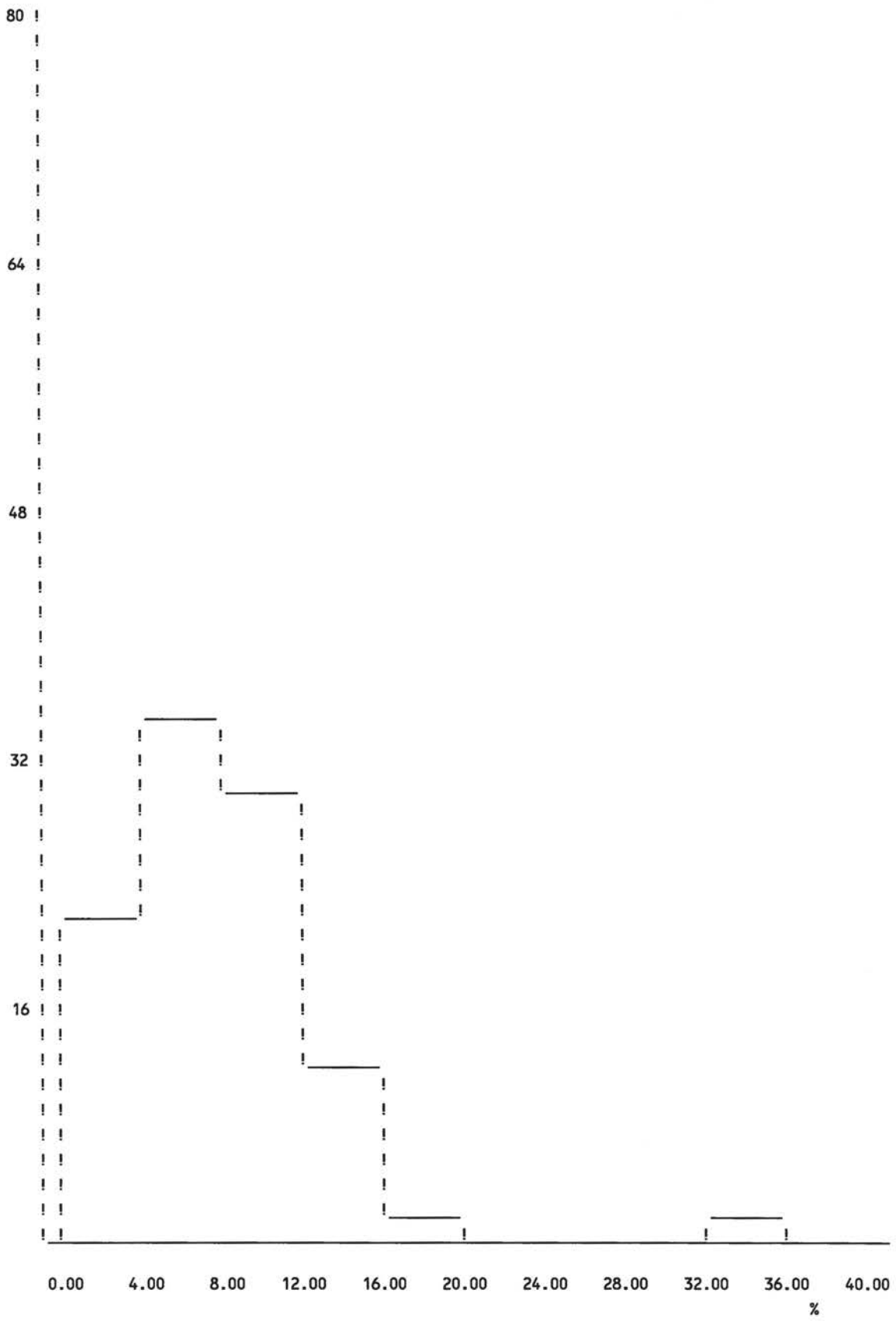
SAMPLE NO.	DEPTH METER	GAS PERM mD	POROSITY %	GRAIN DENS. G/CCM	COMMENT
549	86.53	0.073	8.54	2.703	
550	86.70	0.086	10.45	2.694	
551	87.14	0.033	6.85	2.777	
552	87.42	0.102	7.93	2.725	
553	87.51	0.313	8.68	2.782	
554	87.81	0.028	3.69	2.777	
555	88.09	0.026	3.28	2.838	
556	88.45	0.033	8.13	2.821	
557	88.71	0.173	13.09	2.740	
558	88.91	1.000	15.23	2.757	
559	89.28	0.142	12.62	2.823	
560	89.65	0.158	13.07	2.834	
561	89.88	0.588	11.03	2.815	
562	90.16	1.04	12.35	2.781	

% OF SAMPLES

DISTRIBUTION OF GAS PERMEABILITY
N = 203

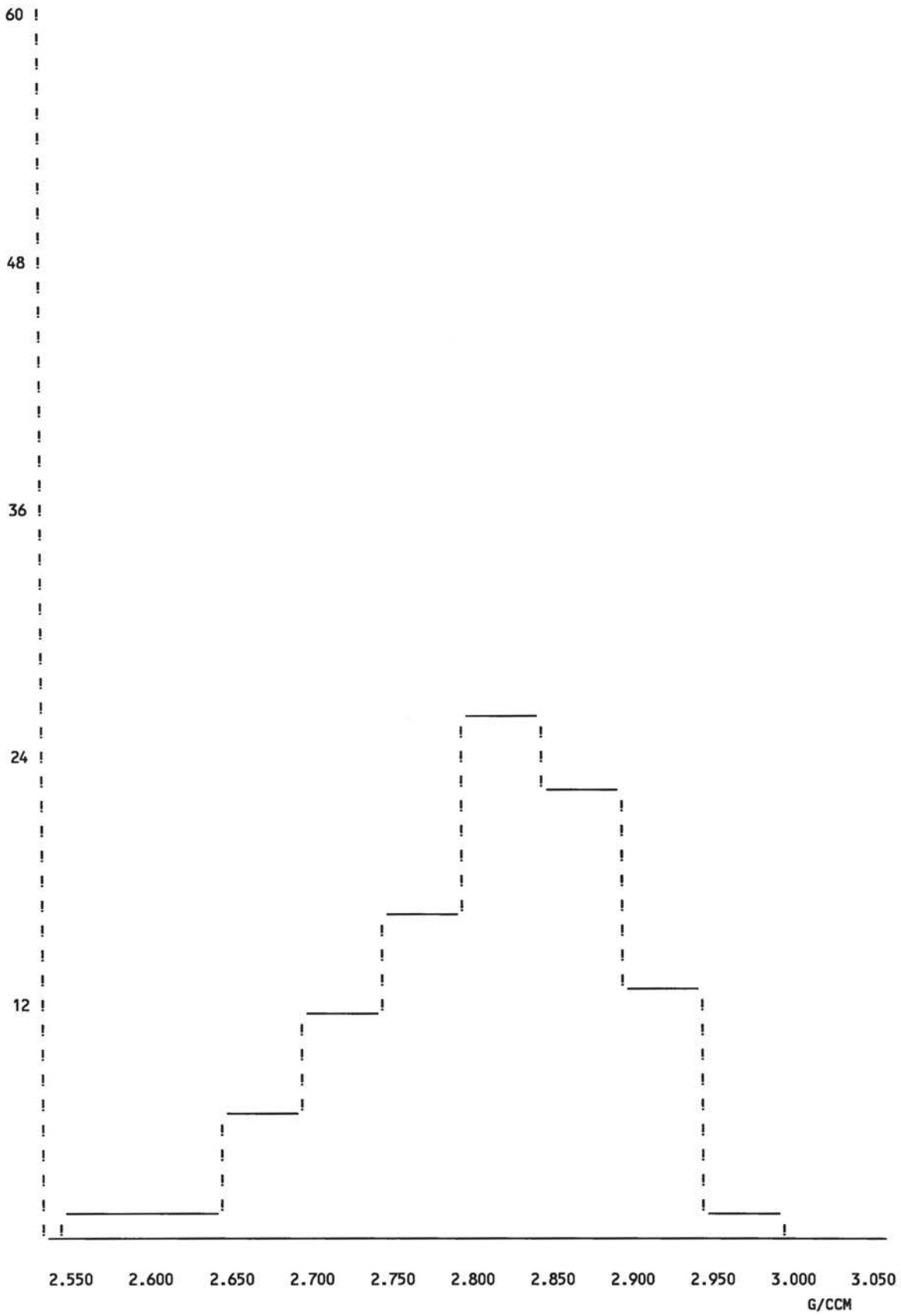
% OF SAMPLES

DISTRIBUTION OF POROSITY
N = 211



% OF SAMPLES

DISTRIBUTION OF GRAIN DENSITY
N = 211



STATISTICAL INFORMATION ON THE POROSITY - GAS PERMEABILITY RELATIONSHIP
CALCULATED ONLY FROM SAMPLES WITH NON-ZERO PERMEABILITY.

NUMBER OF SAMPLES : 203

SINGLE-SAMPLE STATISTICS:

POROSITY:

MEAN POROSITY	:	7.63	%
VARIANCE ON POROSITY	:	17.32	%**2

PERMEABILITY:

GEOMETRIC AVERAGE	:	0.07	mD
ARITHMETRIC AVERAGE	:	0.26	mD
HARMONIC AVERAGE	:	0.05	mD

STATISTICS CALCULATED FROM LINEAR REGRESSION OF PERMEABILITY ON POROSITY:

MODEL: LOG10(PERMEABILITY) = INTERCEPT + SLOPE*POROSITY + RESIDUAL

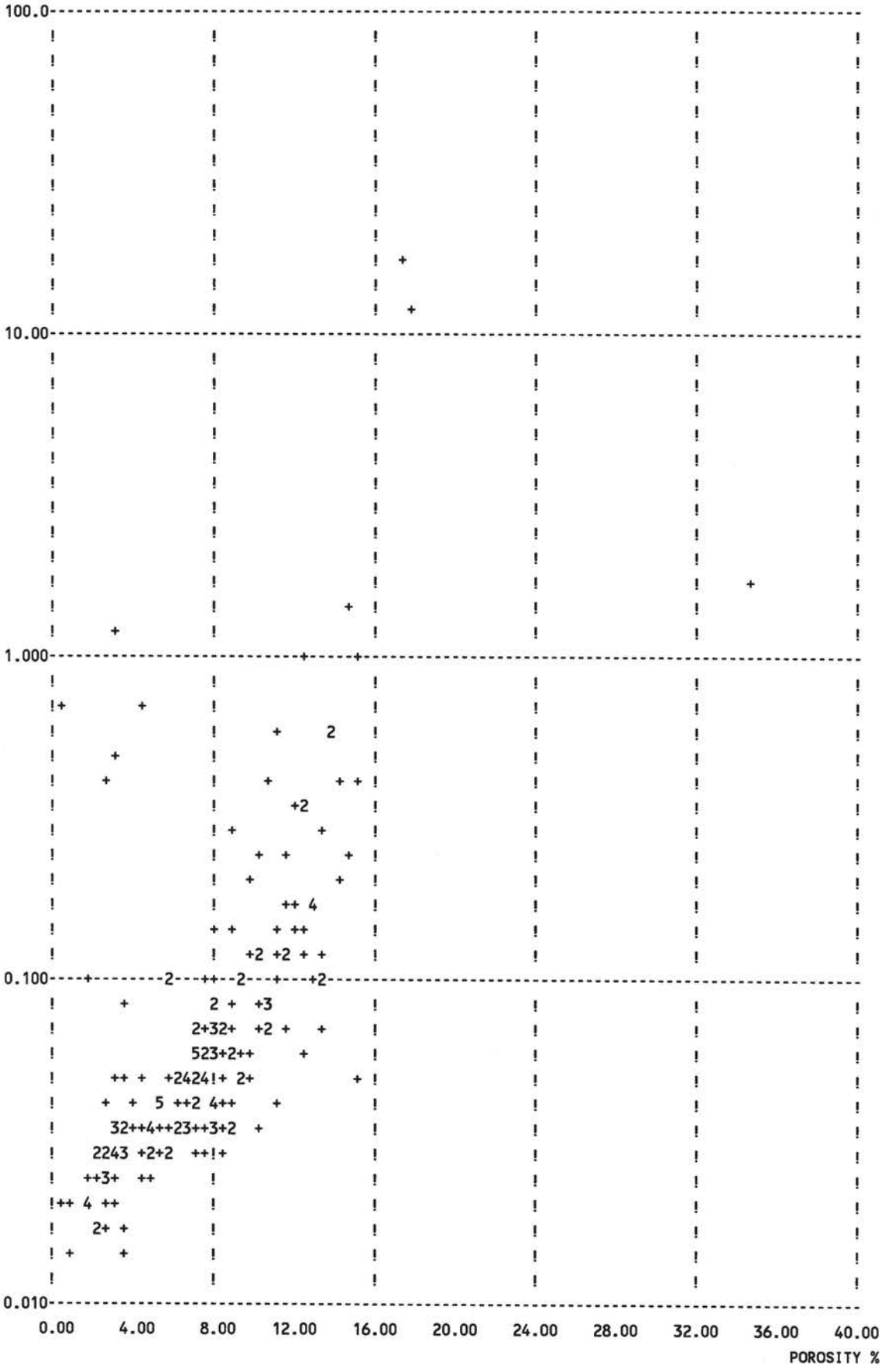
DEGREES OF FREEDOM	:	201	
COEFFICIENT OF DETERMINATION	:	0.441	
STANDARD ERROR ON THE REGRESSION	:	0.355	log(mD)
ESTIMATED INTERCEPT	:	-1.747	log(mD)
ESTIMATED STANDARD ERROR ON INTERCEPT	:	0.052	log(mD)
ESTIMATED SLOPE	:	0.07566	log(mD)/%
ESTIMATED STANDARD ERROR ON SLOPE	:	0.00601	log(mD)/%

PLEASE REMARK THAT THE REGRESSION STATISTICS PERTAIN TO LOG PERMEABILITY VALUES.
THE COEFFICIENT OF DETERMINATION GIVES THE FRACTION AF THE TOTAL VARIATION SQUARED
WHICH IS EXPLAINED BY THE MODEL.
THE STANDARD ERROR ON THE REGRESSION GIVES THE MEAN 1 SIGMA ERROR ON THE LOG
PERMEABILITY ESTIMATES.

CROSSPLOT OF POROSITY VS. GAS PERMEABILITY WELL : Marraat-1 PAGE :24

GAS PERMEABILITY CORE :

mD (Log)



Well: Marraat-1

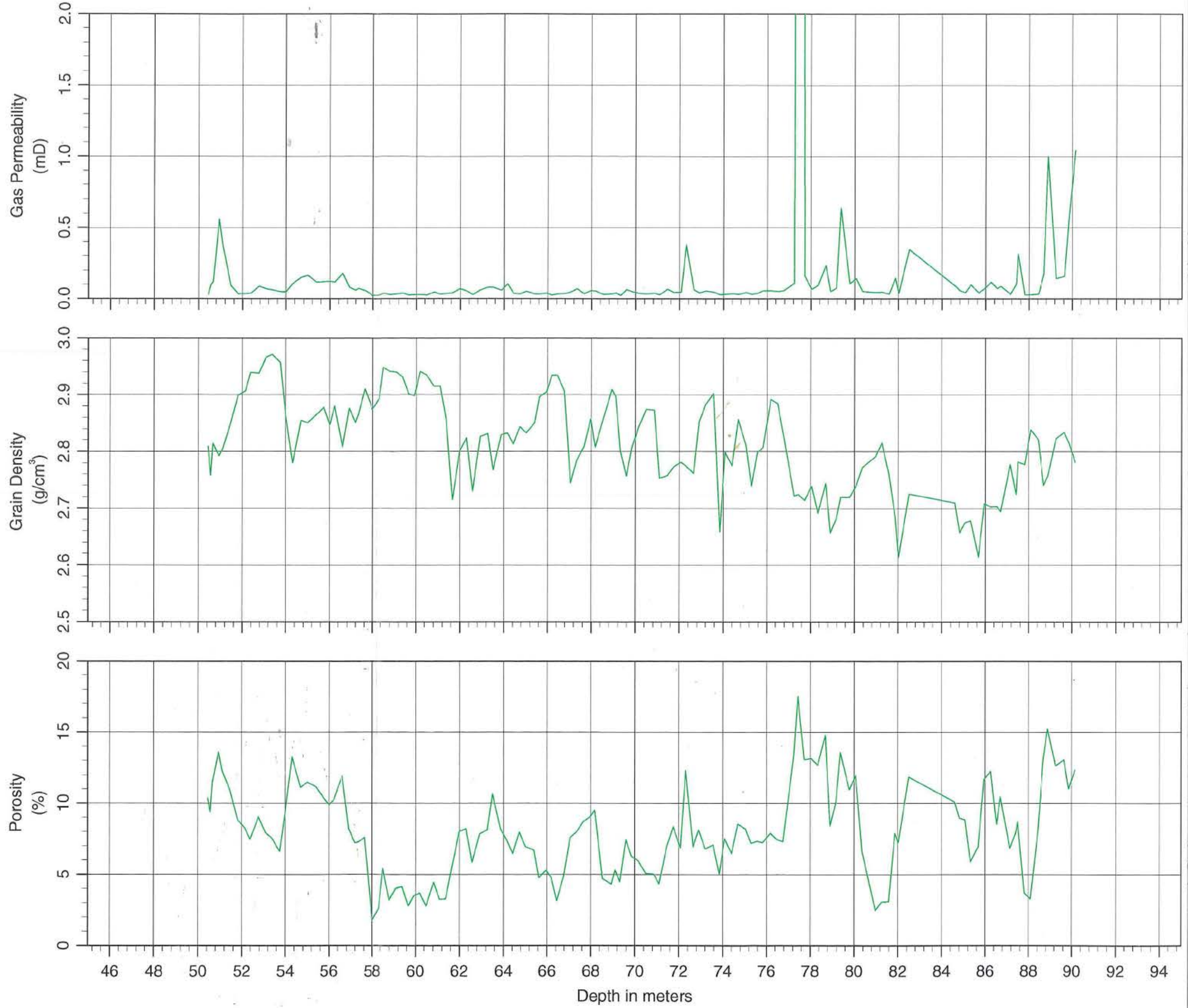
Core log 2

Depth vs.
Gas Permeability
Grain Density
Porosity

Scale 1:200

Legend

Core



GEUS Core Analysis Laboratory, 3-SEP-98

Well: Marraat-1

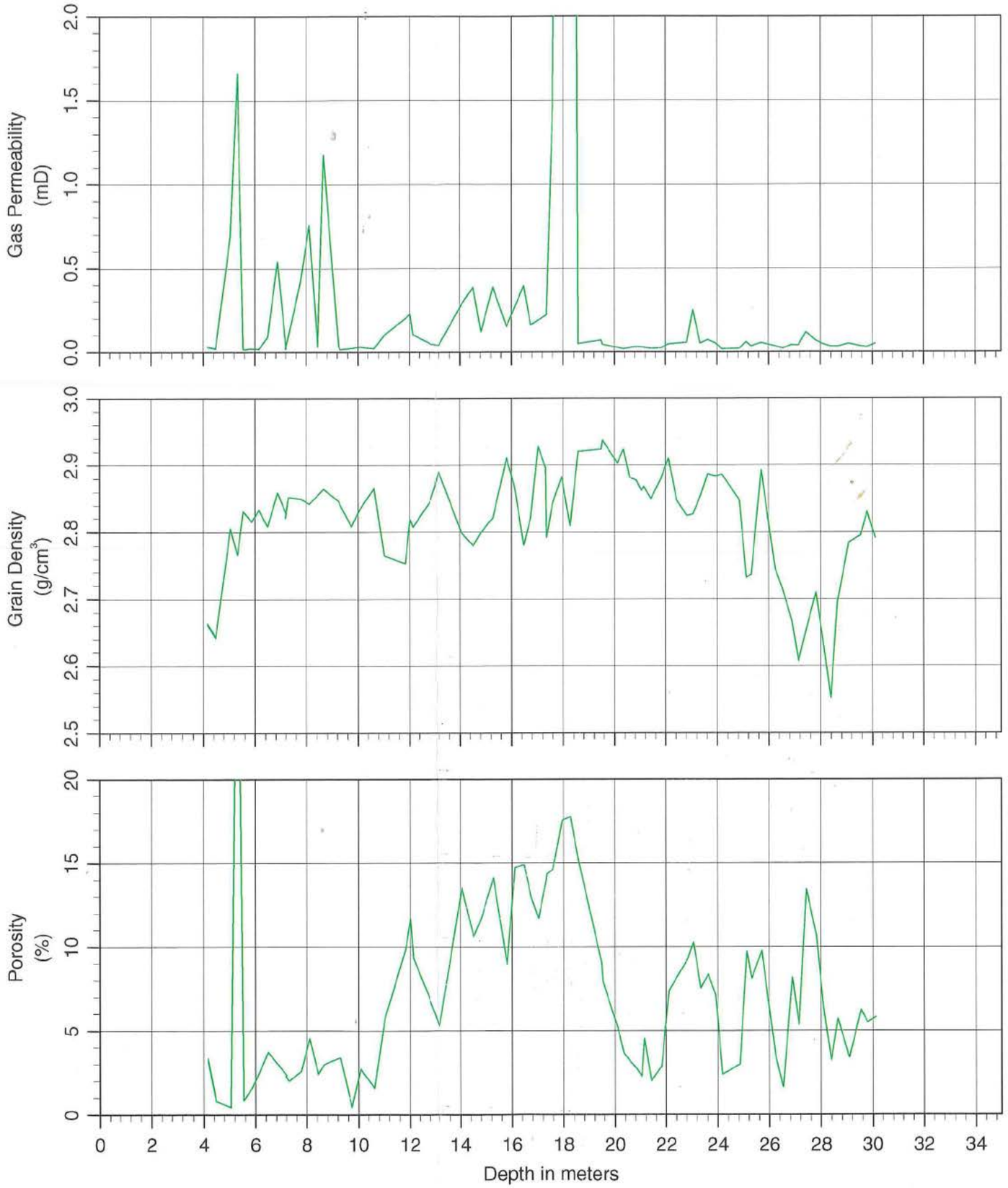
Core log 1

Depth vs.
- Gas Permeability
- Grain Density
- Porosity

Scale 1:200

Legend

Core



GEUS Core Analysis Laboratory, 3-SEP-98