DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 1998/82

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

Christian Høier

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MINISTRY OF ENVIRONMENT AND ENERGY

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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 Gank-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 55 plugs from Gank-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 55 plugs from Gank-1 taken in the interval 82 - 101 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 cleaning the plugs were dried at 110°C.

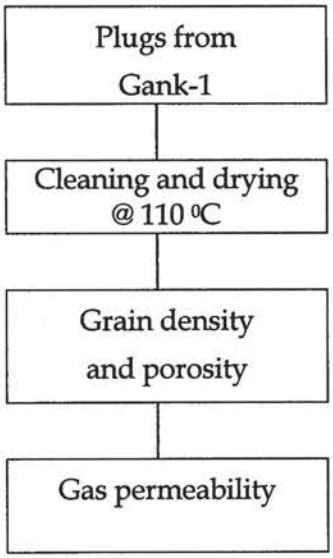
2.2 Grain density and porosity

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 : Gank-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	: GG,MJ
DEPTHS ARE IN METRES		DATE	: 140898
PROGRAM POPE V.5.8		FILE	: GANK98

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.

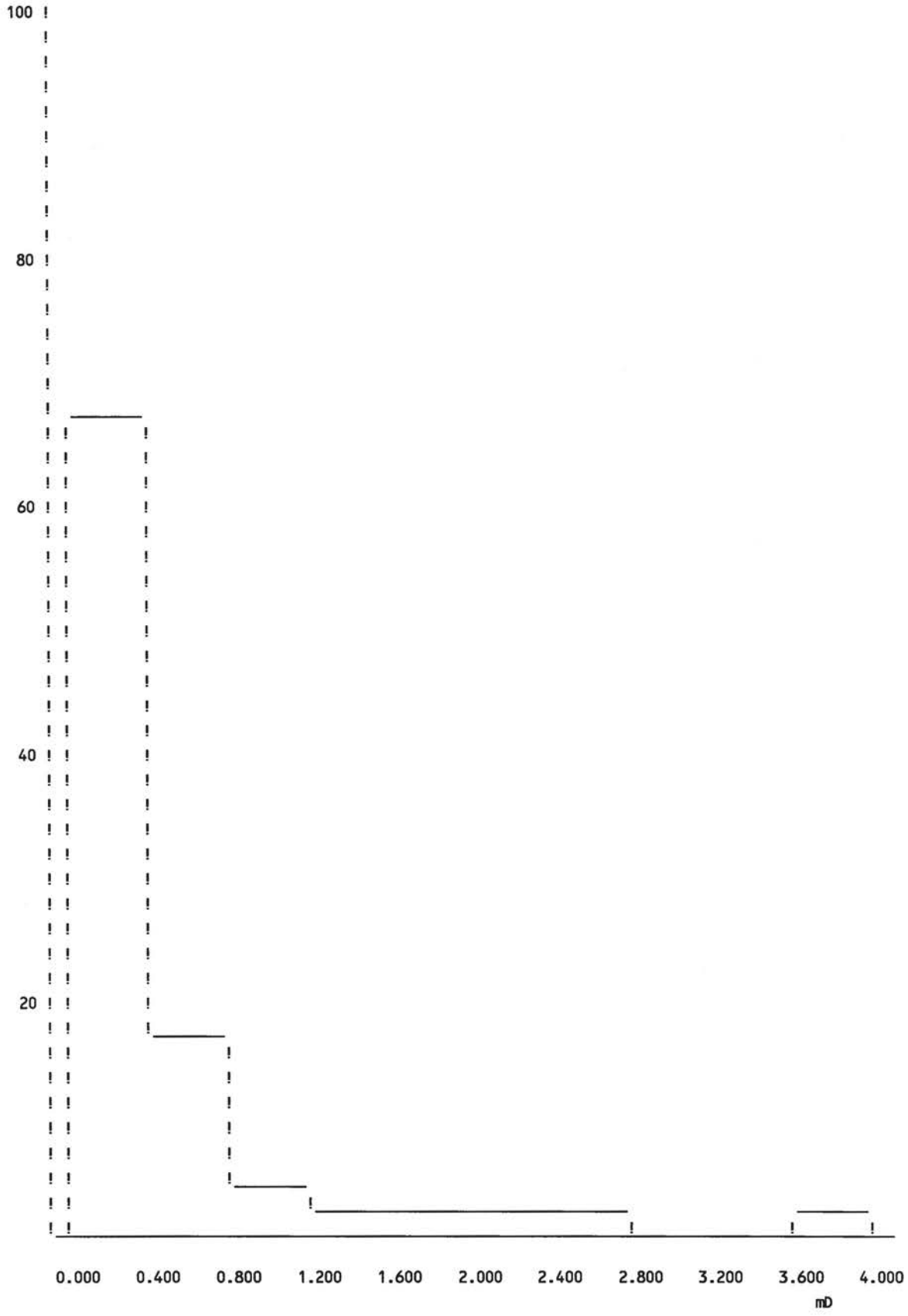
SAMPLE NO.	DEPTH METER	GAS PERM mD	POROSITY %	GRAIN DENS. G/CCM	COMMENT
351	82.83	0.389	8.17	2.506	
352	83.22	0.454	2.96	2.632	
353	83.54	0.682	3.58	2.535	
354	83.85	0.701	2.64	2.625	
355	84.13	0.215	3.05	2.410	
356	84.48	0.107	12.27	2.568	
357	84.78	0.180	3.63	2.451	
358	85.06	0.107	2.96	2.400	
359	85.43	0.265	3.36	2.532	
360	85.75	0.060	5.28	2.460	
361	86.37	0.329	4.64	2.428	
362	86.46	0.404	5.22	2.450	
363	86.75	1.30	5.48	2.448	
364	87.04	1.11	6.46	2.472	
365	87.30	0.227	10.91	2.599	
366	87.66	0.557	8.31	2.622	
367	87.94	0.384	5.27	2.674	
368	88.20	0.134	2.14	2.705	
369	88.46	0.162	2.25	2.705	
370	88.73	0.323	5.47	2.720	
371	88.98	0.246	6.29	2.627	
372	89.24	0.651	6.65	2.604	

SAMPLE NO.	DEPTH METER	GAS PERM mD	POROSITY %	GRAIN DENS. G/CCM	COMMENT
373	89.43		7.78	2.629	
374	89.74	0.108	4.97	2.676	
375	89.98	0.090	4.36	2.687	
376	90.18	0.174	5.06	2.675	
377	90.69	0.179	4.53	2.675	
378	90.89	0.037	8.62	2.822	
379	91.14	0.342	6.15	2.624	
380	91.83	0.110	4.94	2.660	
381	92.45		11.88	2.629	
382	92.76	0.259	7.78	2.693	
383	93.03	0.067	4.65	2.672	
384	93.35		9.17	2.670	
385	93.66		8.09	2.672	
386	94.07	0.020	5.26	2.654	
387	94.25		7.26	2.623	
388	94.54		8.41	2.651	
389	95.16				
390	95.45		5.78	2.567	
391	95.75				
392	95.85	0.044	4.01	2.618	
393	96.19	0.413	6.24	2.579	
394	96.44	0.363	5.36	2.581	

SAMPLE NO.	DEPTH METER	GAS PERM mD	POROSITY %	GRAIN DENS. G/CCM	COMMENT
395	96.84	1.96	3.28	2.593	
396	96.97	0.286	6.04	2.561	
397	97.32	0.334	8.41	2.573	
398	97.63		13.26	2.552	
399	97.86	0.084	8.28	2.565	
400	98.19	0.088	4.39	2.574	
401	98.50	2.33	5.80	2.562	
402	98.79	3.72	8.37	2.539	
403	99.93	2.64	8.64	2.533	
404	100.30	0.844	8.13	2.547	
405	100.58	0.489	10.10	2.529	

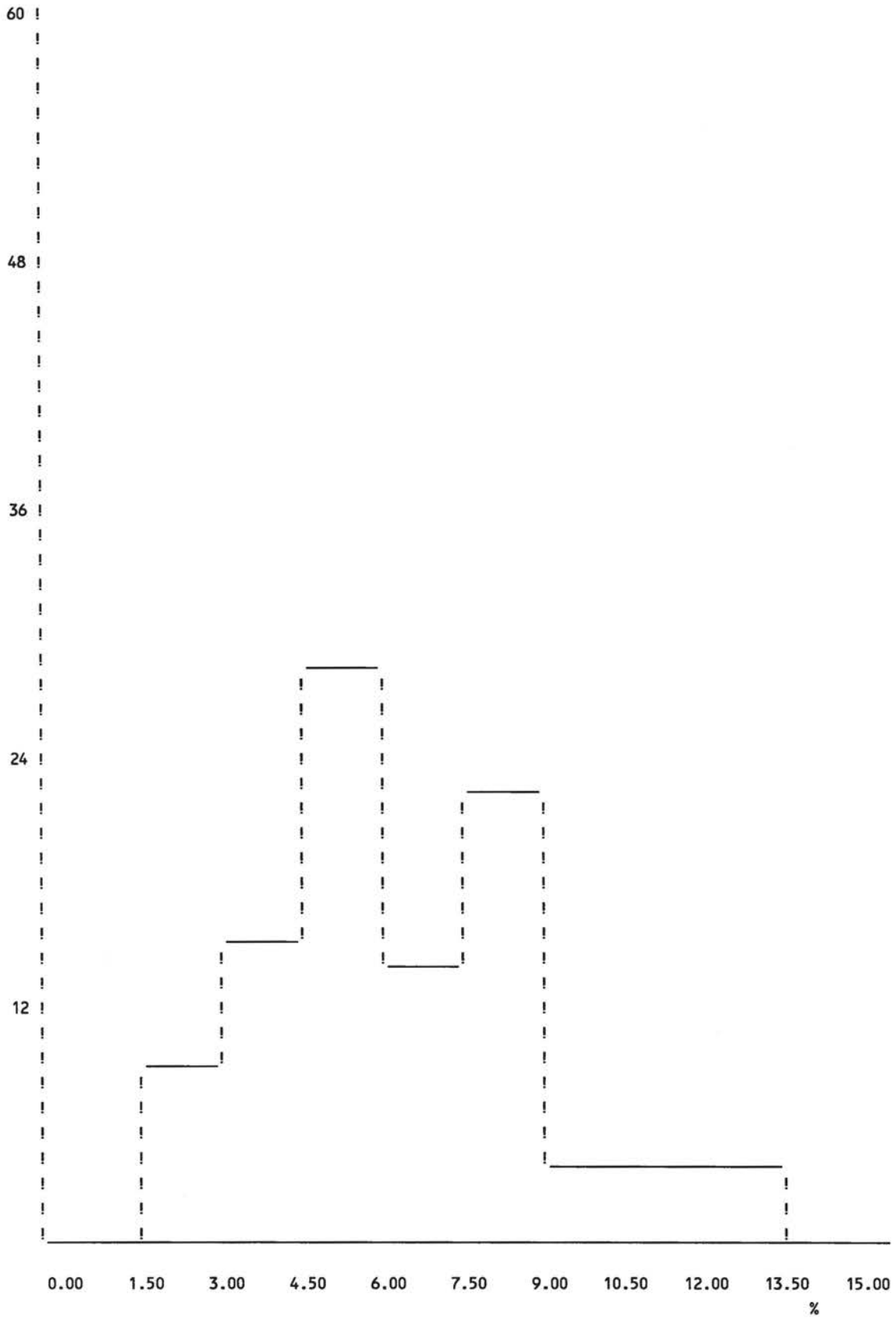
% OF SAMPLES

DISTRIBUTION OF GAS PERMEABILITY
N = 45



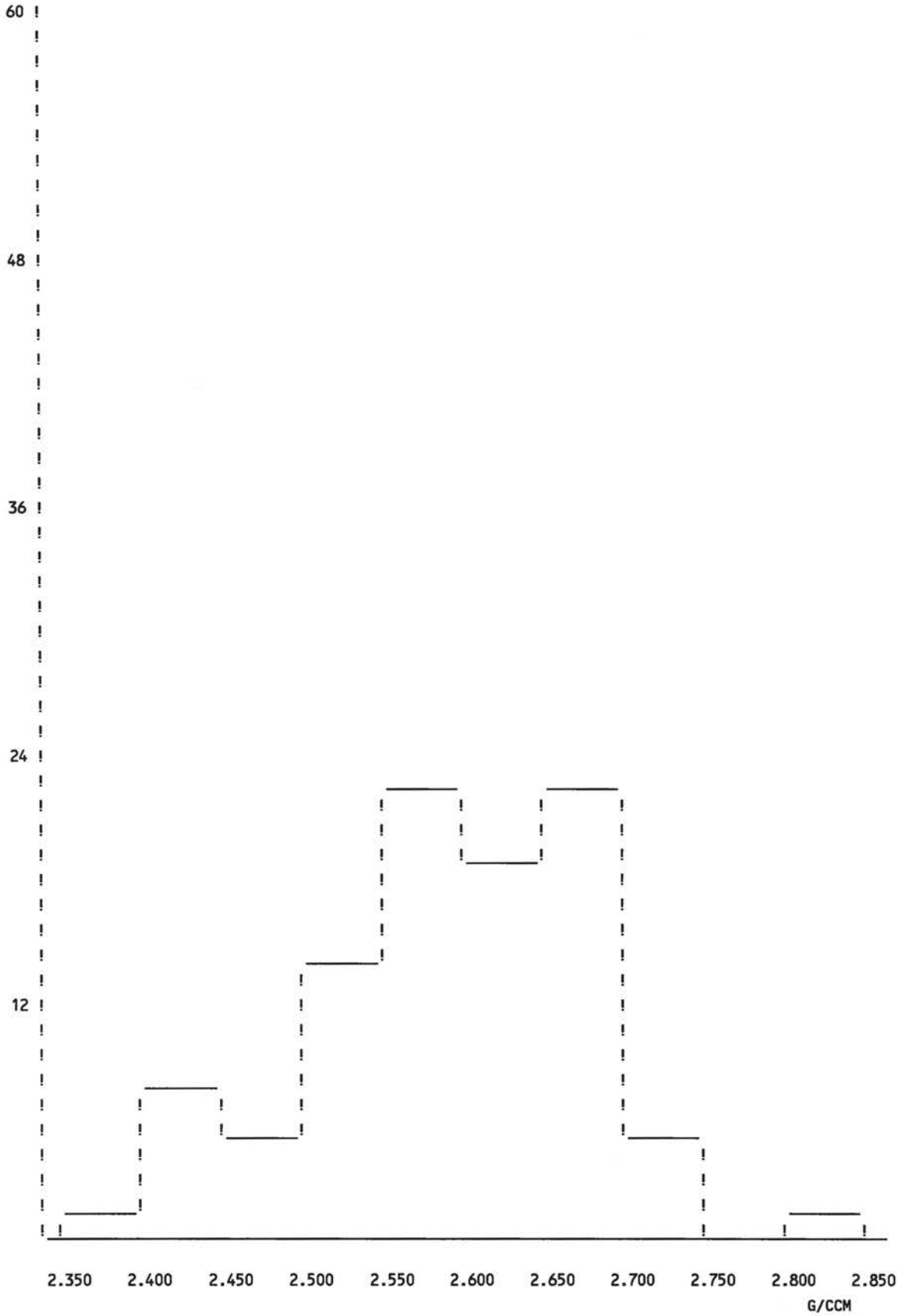
% OF SAMPLES

DISTRIBUTION OF POROSITY
N = 53



% OF SAMPLES

DISTRIBUTION OF GRAIN DENSITY
N = 53



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

NUMBER OF SAMPLES : 45

SINGLE-SAMPLE STATISTICS:

POROSITY:

MEAN POROSITY	:	5.79	%
VARIANCE ON POROSITY	:	5.50	%**2

PERMEABILITY:

GEOMETRIC AVERAGE	:	0.28	mD
ARITHMETRIC AVERAGE	:	0.53	mD
HARMONIC AVERAGE	:	0.15	mD

STATISTICS CALCULATED FROM LINEAR REGRESSION OF PERMEABILITY ON POROSITY:

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

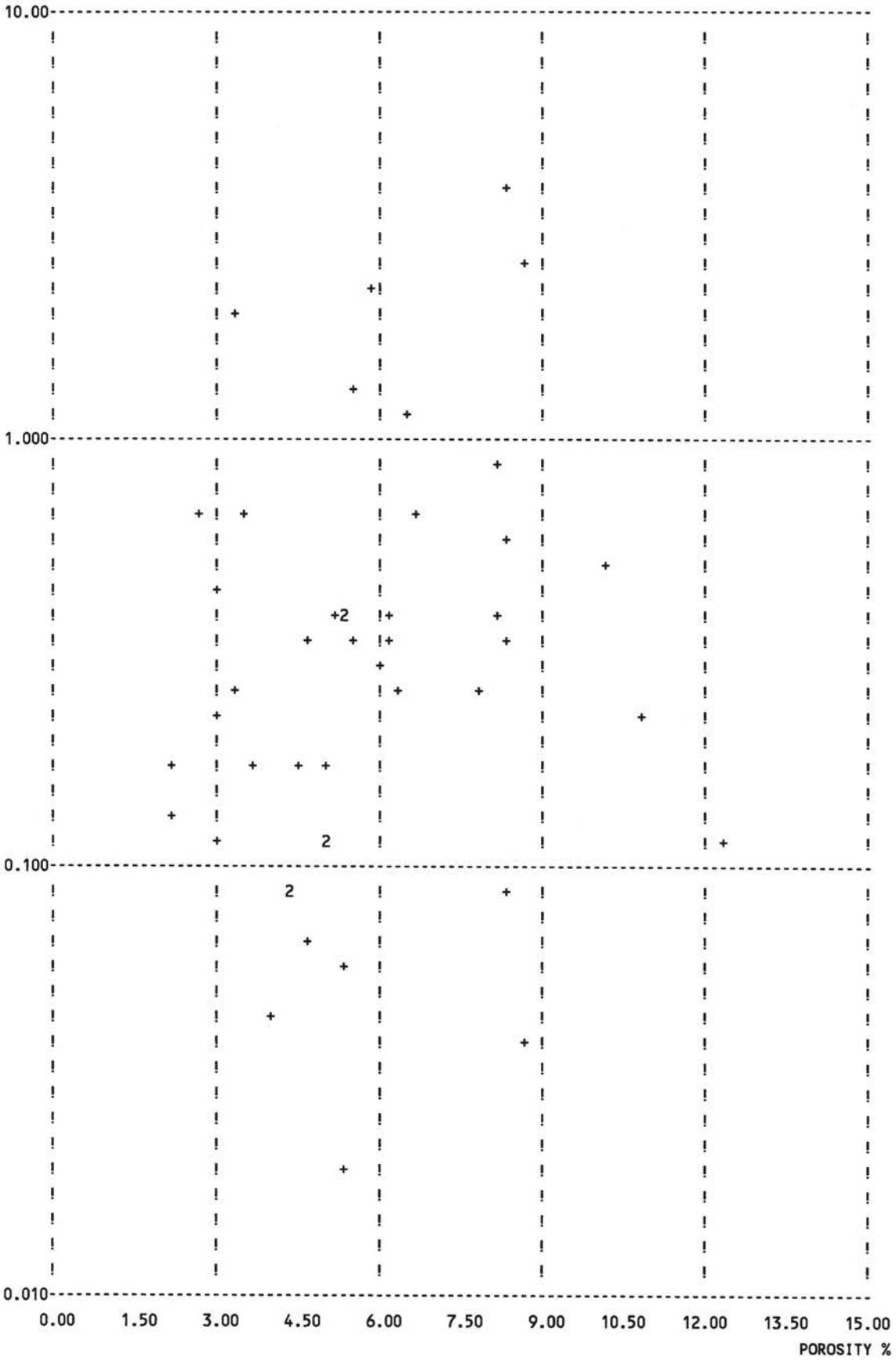
DEGREES OF FREEDOM	:	43	
COEFFICIENT OF DETERMINATION	:	0.019	
STANDARD ERROR ON THE REGRESSION	:	0.499	log(mD)
ESTIMATED INTERCEPT	:	-0.729	log(mD)
ESTIMATED STANDARD ERROR ON INTERCEPT	:	0.200	log(mD)
ESTIMATED SLOPE	:	0.02949	log(mD)/%
ESTIMATED STANDARD ERROR ON SLOPE	:	0.03209	log(mD)/%

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 : Gank-1 PAGE :17

GAS PERMEABILITY CORE :

mD (Log)



Well: Gank-1

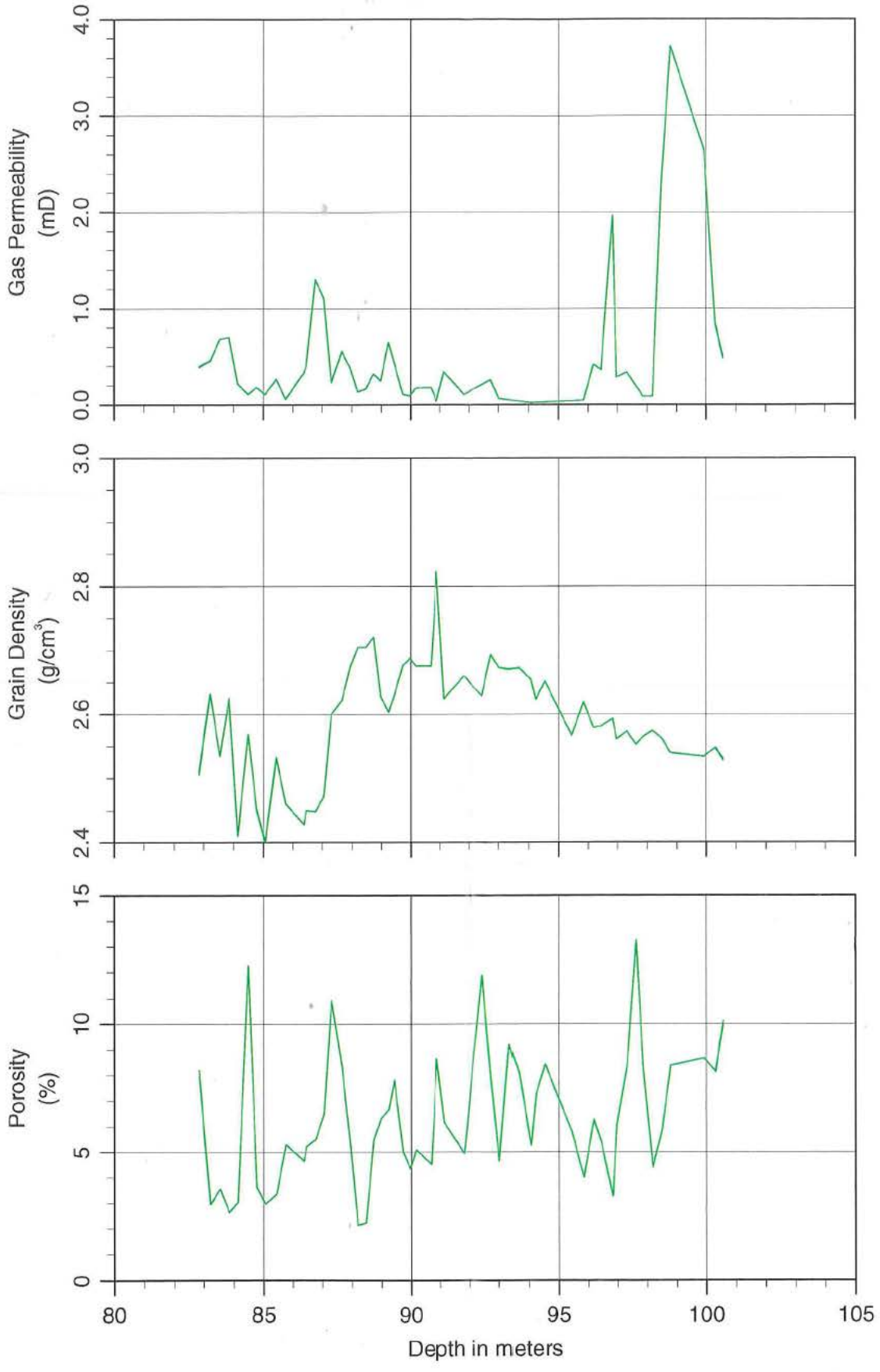
Core log

Depth vs.
Gas Permeability
Grain Density
Porosity

Scale 1:200

Legend

Core



GEUS Core Analysis Laboratory, 3-SEP-98