

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

Christian Høier



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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 Gane-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 104 plugs from Gane-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 104 plugs from Gane-1 taken in the intervals 4 – 11 , 144 – 165 and 455 – 465 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.

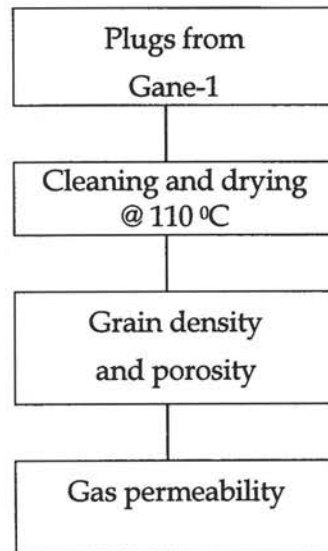
2.2 Grain density and porosity

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	25%
	0.01-0.1	15%
	> 0.1	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 : Gane-1

CORE :

Printed : 3-SEP-98

GENERAL INFORMATION ON THE ANALYSIS

LOCATION : Grønland
CORE NO.'S :
ANALYSTS : GG,MJ
DATE : 030998
FILE : GANE98

! 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.

THE GEOLOGICAL SURVEY OF DENMARK AND GREENLAND IS FULLY RESPONSIBLE FOR THE ANALYTICAL RESULTS IN THE PRESENT REPORT. THE SURVEY, HOWEVER, BEARS NO RESPONSIBILITY OF DECISIONS AND INTERPRETATIONS BASED ON THE DATA PRESENTED.

SAMPLE NO.	DEPTH METER	GAS PERM mD	POROSITY %	GRAIN DENS. G/CCM	COMMENT
1051	3.79	0.150	6.34	2.741	
1052	4.05	0.094	3.82	2.735	
1053	4.31	0.023	2.80	2.774	
1054	4.73	0.181	5.94	2.704	
1055	4.99	0.181	5.30	2.722	
1056	5.29	0.063	4.19	2.720	
1057	5.70	0.155	4.12	2.727	
1058	5.89	0.069	6.17	2.754	
1059	6.71	0.083	4.48	2.748	
1060	6.98	0.079	5.55	2.751	
1061	8.56		2.76	2.851	
1062	8.88	0.146	4.72	2.720	
1063	9.22	0.695	12.82	2.670	
1064	9.55	0.138	6.08	2.750	
1065	9.85	0.241	8.28	2.766	
1066	10.18	0.260	6.57	2.743	
1067	144.46	0.019	1.51	2.853	
1068	144.63	0.213	15.71	2.569	
1069	145.01	0.059	18.67	2.627	
1070	145.35		20.65	2.616	
1071	145.47	0.068	17.69	2.622	
1072	145.64		16.11	2.588	

SAMPLE NO.	DEPTH METER	GAS PERM mD	POROSITY %	GRAIN DENS. G/CCM	COMMENT
1073	146.03		16.78	2.589	
1074	146.49	0.287	6.16	2.471	
1075	146.77	5.16	6.59	2.533	
1076	147.11		2.49	2.791	
1077	147.61	0.814	5.34	2.568	
1078	148.12	0.027	3.73	2.712	
1079	148.52	0.377	3.05	2.641	
1080	148.84	0.710	4.20	2.641	
1081	149.21	0.380	2.79	2.672	
1082	149.52	0.769	3.56	2.671	
1083	149.83	1.63	9.73	2.639	
1084	150.15	2.22	13.00	2.605	
1085	150.46	0.070	6.08	2.546	
1086	150.77	0.110	5.29	2.585	
1087	151.07	0.068	5.27	2.632	
1088	151.41	0.228	8.23	2.507	
1089	151.71	0.152	5.62	2.602	
1090	152.14	0.058	3.46	2.654	
1091	152.27	0.119	5.24	2.614	
1092	152.60	0.859	7.81	2.612	
1093	152.87	1.25	7.96	2.629	
1094	153.23	0.727	6.93	2.617	

SAMPLE NO.	DEPTH METER	GAS PERM mD	POROSITY %	GRAIN DENS. G/CCM	COMMENT
1095	153.47	0.392	6.29	2.622	
1096	153.78	1.10	7.22	2.619	
1097	154.06	0.044	5.99	2.702	
1098	157.46	1.21	7.05	2.667	
1099	157.77	1.33	7.22	2.601	
1100	158.07	1.27	8.84	2.622	
1101	158.35	2.44	9.26	2.645	
1102	158.56	4.76	9.99	2.636	
1103	158.90	0.680	6.55	2.695	
1104	159.13	0.599	6.32	2.642	
1105	159.39	0.332	6.48	2.705	
1106	159.66	0.286	6.59	2.685	
1107	159.97	0.049	2.34	2.840	
1108	160.24	0.185	4.84	2.769	
1109	160.60	0.052	3.89	2.736	
1110	160.86	0.051	2.91	2.713	
1111	161.20	2.92	7.85	2.704	
1112	161.52	0.550	6.95	2.719	
1113	161.88	1.14	7.84	2.631	
1114	162.32	0.442	5.95	2.677	
1115	162.57	0.067	3.32	2.762	
1116	162.99	0.066	3.50	2.780	

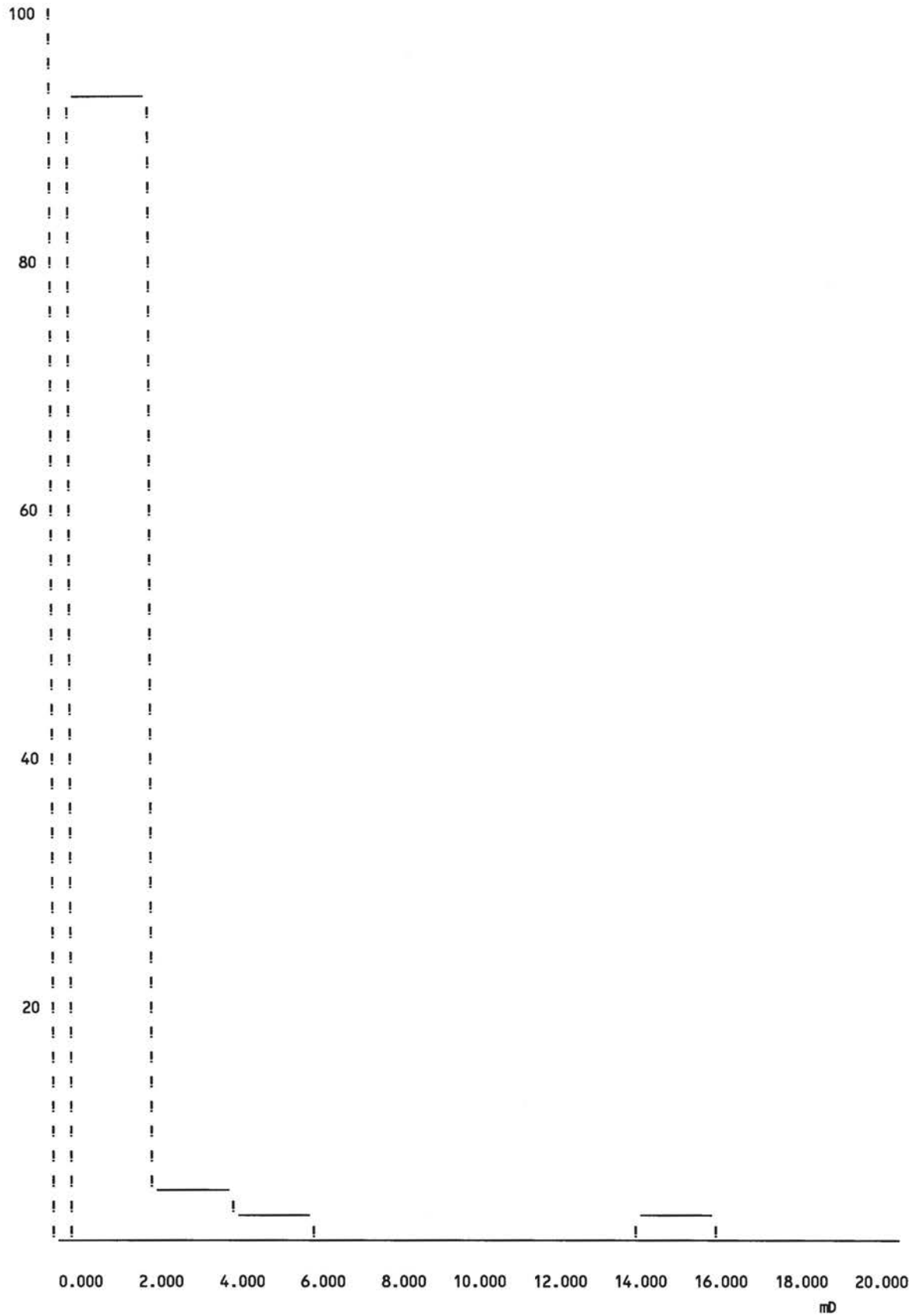
SAMPLE NO.	DEPTH METER	GAS PERM mD	POROSITY %	GRAIN DENS. G/CCM	COMMENT
1117	163.24	1.63	9.69	2.631	
1118	163.70	1.26	6.99	2.703	
1119	163.87	0.246	5.09	2.682	
1120	164.16	0.488	7.13	2.670	
1121	164.56	2.45	7.65	2.647	
1122	164.92	1.16	7.71	2.649	
1123	455.08	0.252	7.53	2.677	
1124	455.35	0.184	5.40	2.736	
1125	455.62	0.368	7.42	2.683	
1126	455.92	0.248	7.69	2.698	
1127	456.24	0.041	4.00	2.755	
1128	456.36	0.387	8.34	2.713	
1129	456.69	1.96	7.94	2.746	
1130	456.98		5.69	2.842	
1131	457.27	1.56	7.66	2.765	
1132	457.46		15.98	2.834	
1133	457.73	0.038	5.84	2.835	
1134	457.98	0.435	8.60	2.717	
1135	458.24	0.138	5.87	2.702	
1136	458.53	0.116	4.54	2.805	
1137	459.07	0.020	2.45	2.793	
1138	459.42	0.042	3.82	2.752	

SAMPLE NO.	DEPTH METER	GAS PERM mD	POROSITY %	GRAIN DENS. G/CCM	COMMENT
1139	459.70	0.037	3.12	2.804	
1140	459.99	0.020	1.04	2.933	
1141	460.45	0.644	9.84	2.717	
1142	460.76		12.49	2.791	
1143	461.09	0.022	2.37	2.742	
1144	461.36	15.4	11.91	2.830	
1145	461.88	0.018	1.16	2.936	
1146	462.19	0.031	3.90	2.721	
1147	462.59	0.158	6.65	2.727	
1148	463.38	1.30	8.18	2.710	
1149	463.38	0.194	6.66	2.694	
1150	463.69	0.036	3.48	2.751	
1151	463.88	0.040	3.21	2.792	
1152	464.13	0.035	2.57	2.761	
1153	464.44	0.081	4.04	2.739	
1154	464.77	0.066	3.02	2.813	

% OF SAMPLES

DISTRIBUTION OF GAS PERMEABILITY

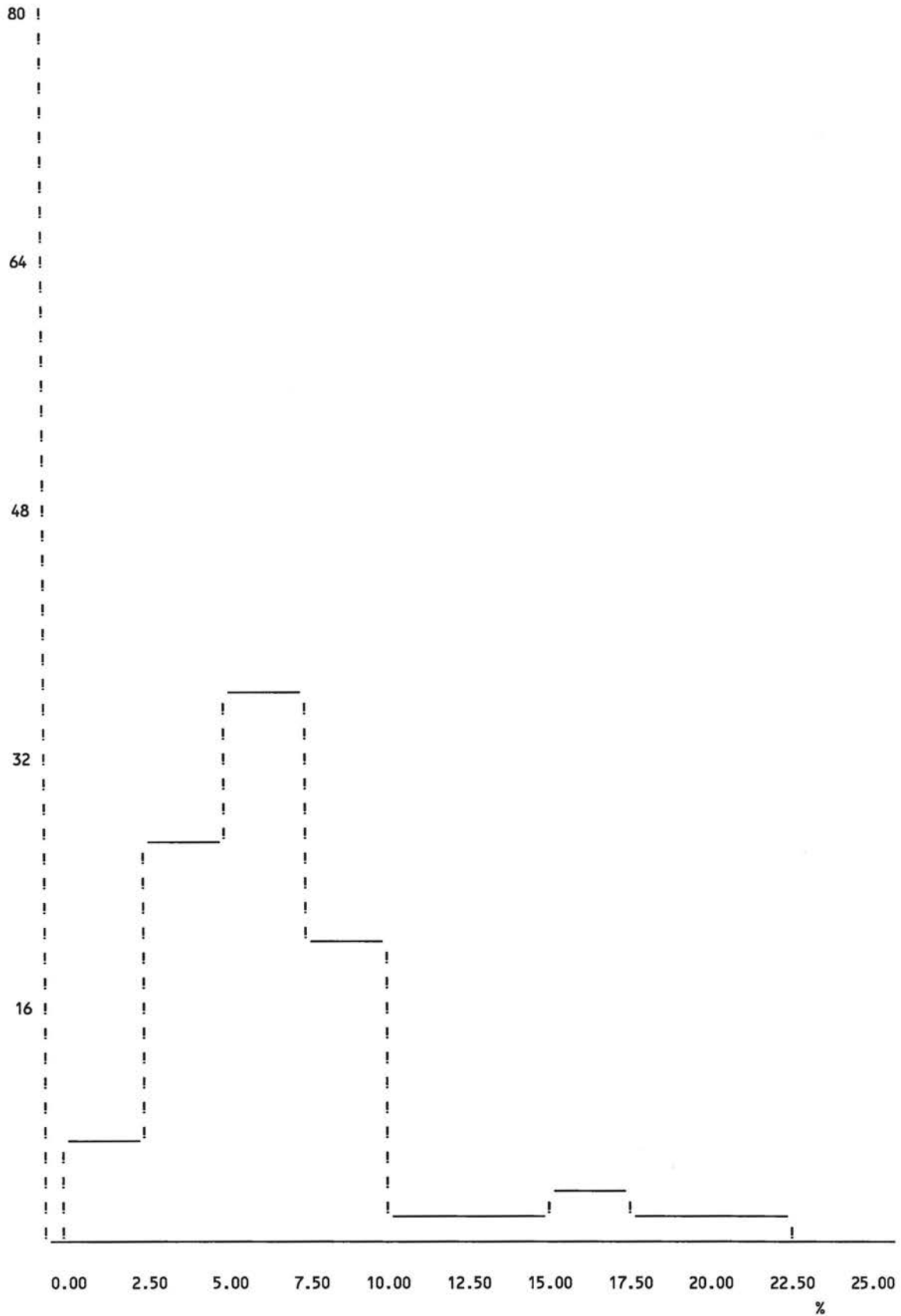
N = 96



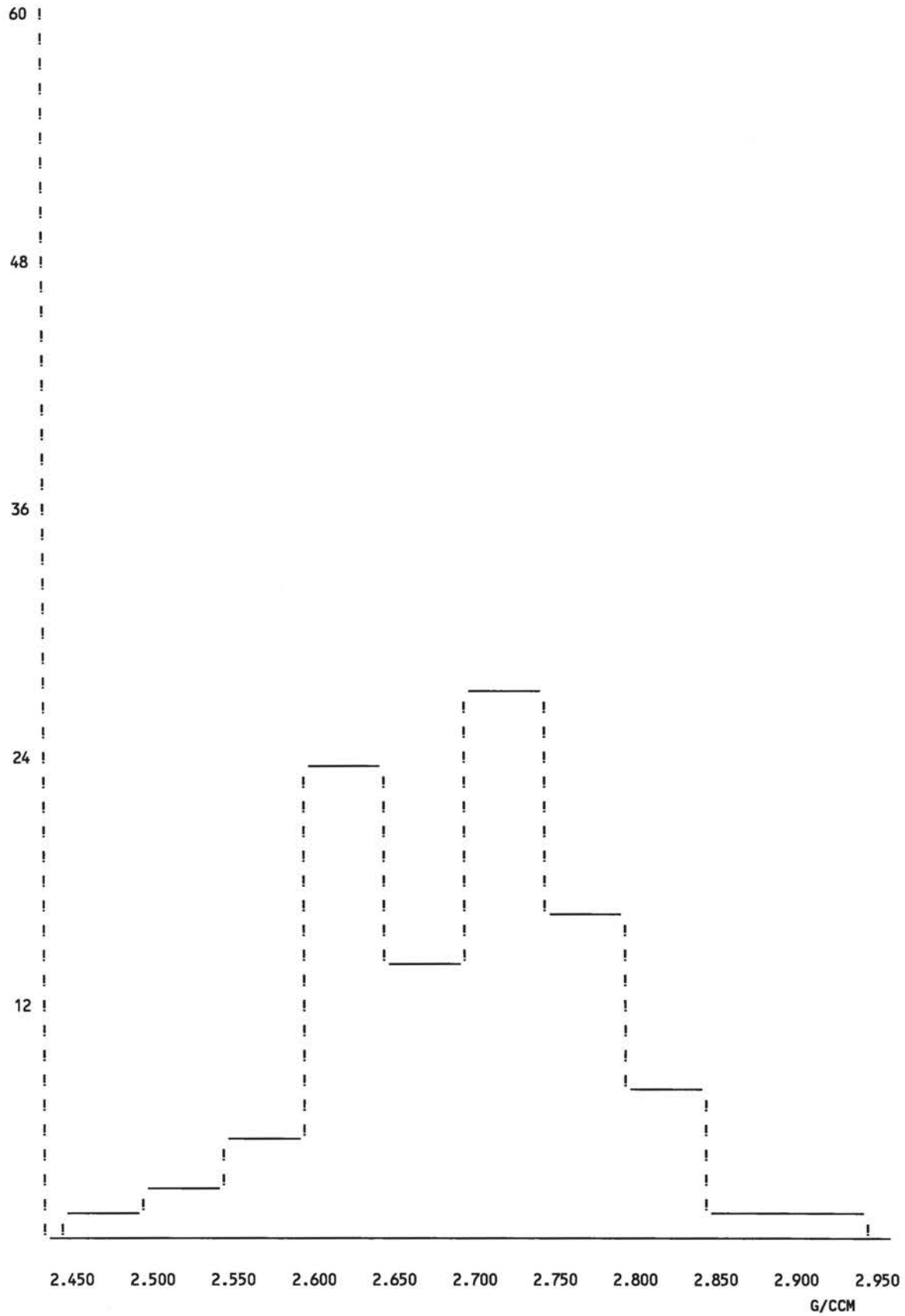
% OF SAMPLES

DISTRIBUTION OF POROSITY

N = 104



% OF SAMPLES

DISTRIBUTION OF GRAIN DENSITY
N = 104

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

NUMBER OF SAMPLES : 96

SINGLE-SAMPLE STATISTICS:

POROSITY:

MEAN POROSITY : 6.26 %
VARIANCE ON POROSITY : 9.81 %**2

PERMEABILITY:

GEOMETRIC AVERAGE : 0.23 mD
ARITHMETRIC AVERAGE : 0.73 mD
HARMONIC AVERAGE : 0.09 mD

STATISTICS CALCULATED FROM LINEAR REGRESSION OF PERMEABILITY ON POROSITY:

MODEL: $\text{LOG}_{10}(\text{PERMEABILITY}) = \text{INTERCEPT} + \text{SLOPE} * \text{POROSITY} + \text{RESIDUAL}$

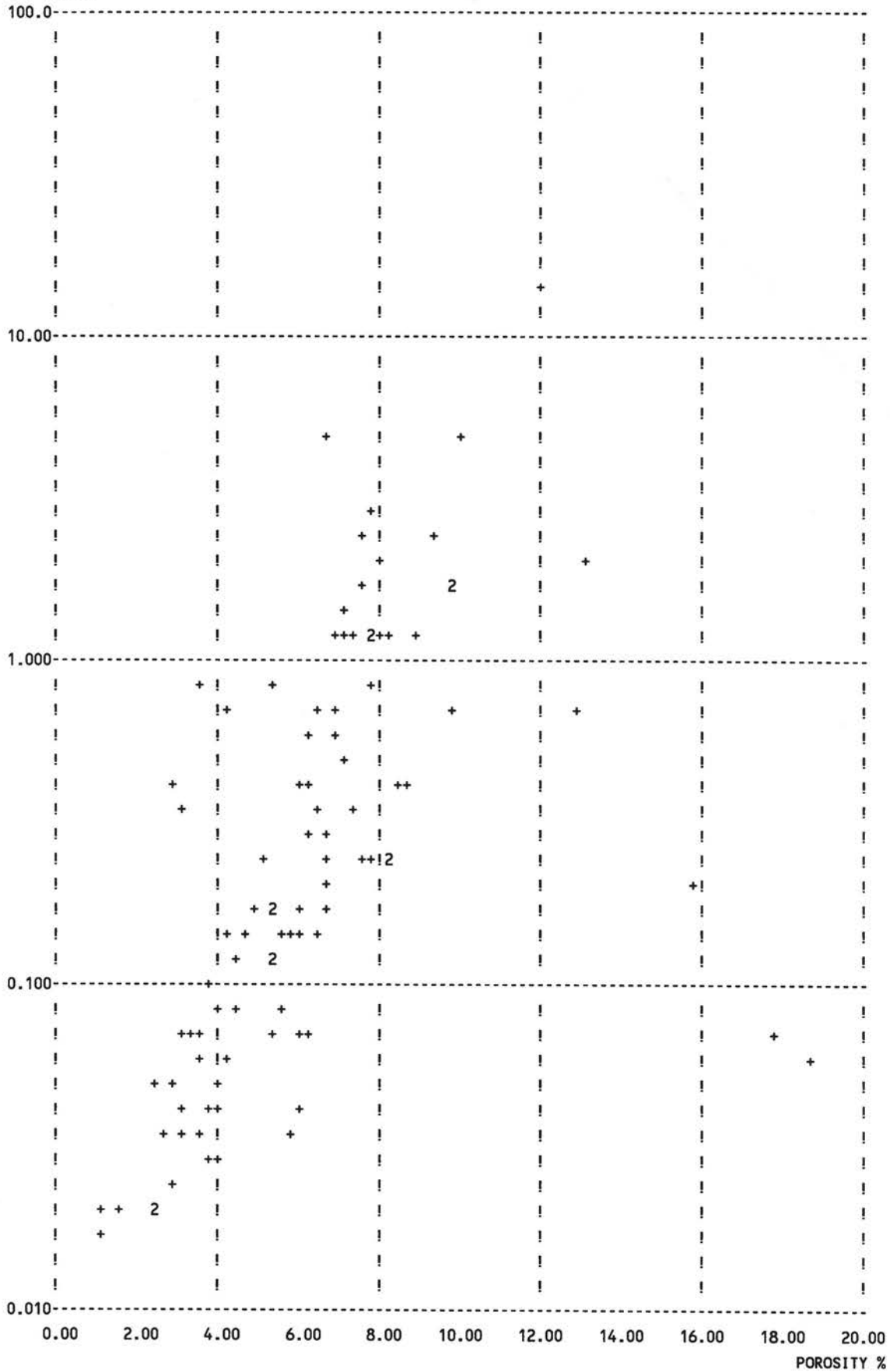
DEGREES OF FREEDOM : 94
COEFFICIENT OF DETERMINATION : 0.279
STANDARD ERROR ON THE REGRESSION : 0.558 log(mD)
ESTIMATED INTERCEPT : -1.330 log(mD)
ESTIMATED STANDARD ERROR ON INTERCEPT : 0.128 log(mD)
ESTIMATED SLOPE : 0.11019 log(mD)/%
ESTIMATED STANDARD ERROR ON SLOPE : 0.01827 log(mD)/%

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.

GAS PERMEABILITY

CORE :

mD (Log)



Well: Gane-1

Core log 1

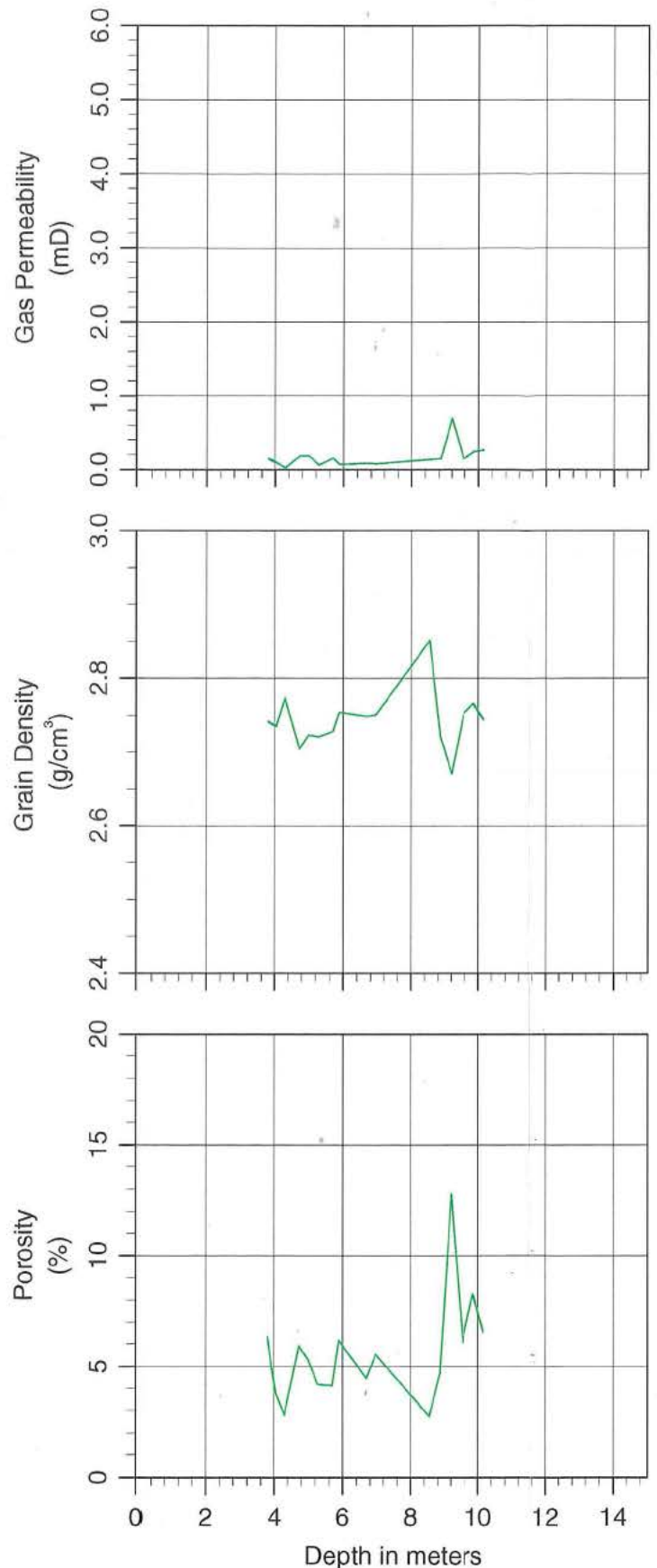
Depth vs.
Gas Permeability
Grain Density
Porosity

Scale 1:200

Legend



Core



Well: Gane-1

Core log 2

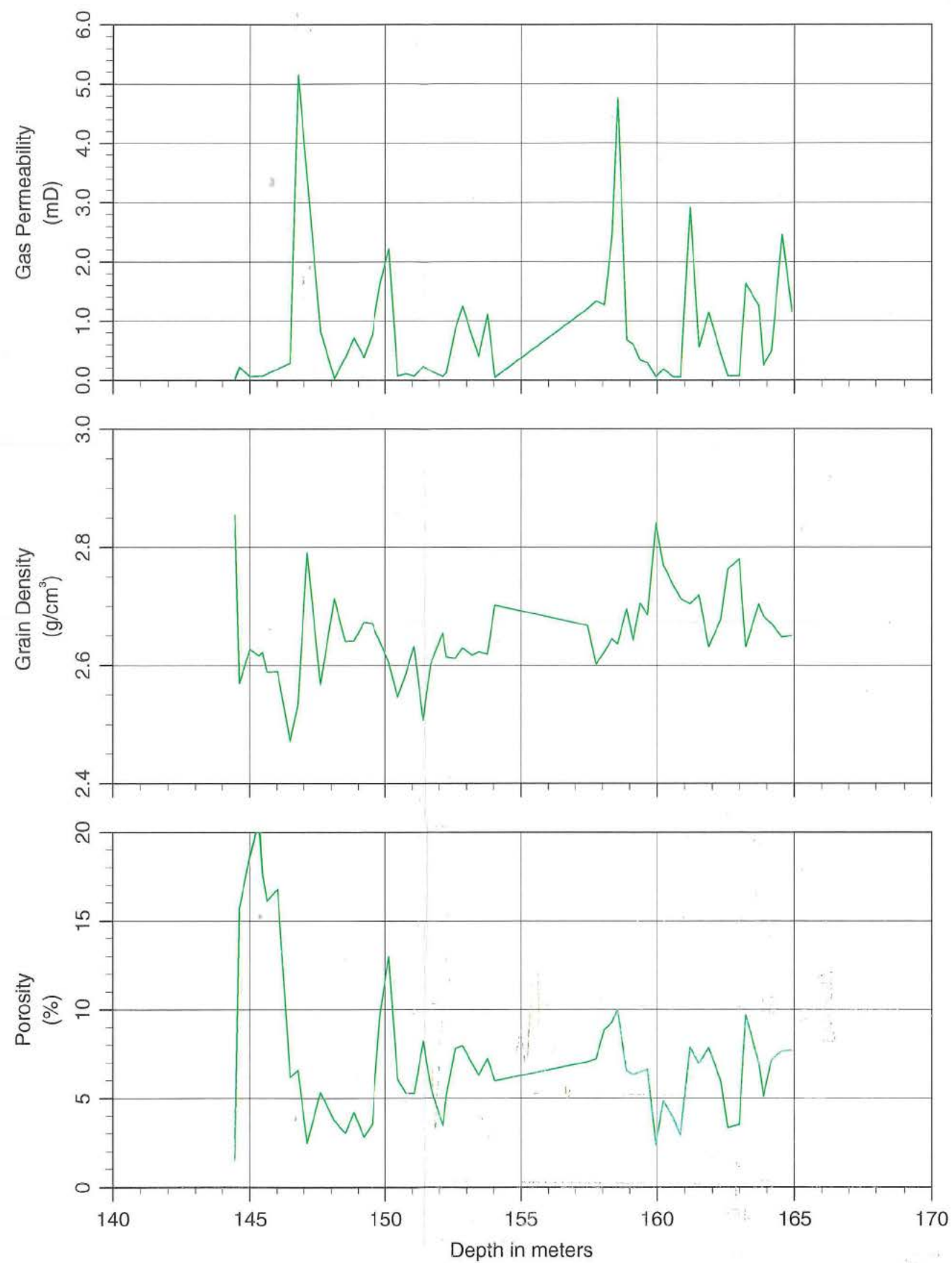
Depth vs.
Gas Permeability
Grain Density
Porosity

Scale 1:200

Legend



Core



Well: Gane-1

Core log 3

Depth vs.
Gas Permeability
Grain Density
Porosity

Scale 1:200

Legend



Core

