Report 96.013

Magnetic susceptibility of sedimentary rocks
from shallow cores off Mid Norway and
crystalline rocks from adjacent onland areas
NAS-94 Interpretation Report
Part IIB: Petrophysical data
Revised version

NORGES GEOLOGISKE UNDERSØKELSE

Postboks 3006 - Lade
7002 TRONDHEIM
Tlf. (07) 90 40 11
Telefax (07) 92 16 20

IKU SINTEF GROUP

REPORT

Report no. 96.013	ISSN 0800-3416	Grading: Confidential to 2000

Title: Magnetic susceptibility of sedimentary rocks from shallow cores off Mid Norway and crystalline rocks from adjacent onland areas. NAS-94 Interpretation Report Part IIB: Petrophysical data, Revised version

Author:	Client:
Mai Britt Mørk and Odleiv Olesen IKU Petroleum Research and NGU	Amoco Norway
County: Nordland and Nord-Trøndelag	Commune:
Map-sheet name (M=1:250.000) Svolvær, Bodø, Mo i Rana, Vega and Namsos	Map-sheet no. and name (M=1:50.000)
Deposit name and grid-reference:	Number of pages: 42 Price: Map enclosures: 1

Fieldwork carried out:	Date of report:	Project no.:	Person responsible:
	9.01.96	61.2543.44	[signature]

Summary:

This report has been modified from the 'NAS-94 Interpretation Report, Part II: Petrophysical data'. The revised report presents results from 428 magnetic susceptibility measurements on cores from the IKU shallow drilling programme in the Nordland IV, V, VI and VII areas in addition to susceptibility, remanence and density measurements on approximately 4100 bedrock samples from the coastal area of Nordland and North Trøndelag (crystalline basement). Together the measured cores represent a > 1090 m rock column through the Triassic, Jurassic, Cretaceous, and Lower Tertiary. The Pleistocene cover has also been measured. The magnetic susceptibility data have been compared for different lithologies and sediment composition and mineralogical analysis by SEM and XRD methods have been performed in order to identify the mineralogical source of the magnetic properties. These results have been used to aid in interpretation of aeromagnetic measurements from the NAS-94 Project.

Keywords: Geofysikk	Berggrunnsgeologi	Mineralogi
Magnetometri	Kontinentalsokkel	Mikrosondeanalyse
Petrofysikk	Kjemisk analyse	Fagrapport

CONTENTS:

1. INTRODUCTION

This report has been modified from the 'NAS-94 Interpretation Report, Part II: Petrophysical data' (Mørk & Olesen 1995) for Amoco Norway. Since Amoco has not acquired the Helgeland 92 shallow drilling data (IKU) this has resulted in a reduction of the database from 1659 to 428 susceptibility measurements. Much of the basis for studying the susceptibility and magnetic minerals in sandstones (Chapter 6) is unfortunately missing because of this data exclusion.

The Nordland Aeromagnetic Survey 1994 (NAS-94) reveals numerous high frequency anomalies originating from magnetic sources within the sedimentary sequence. To enable us to carry out an interpretation of this data-set it is of vital importance to have access to the magnetic properties of these sediments. The Geological Survey of Norway (NGU) and IKU Petroleum Research have therefore carried out a measuring programme within the framework of the NAS-94 Project. These petrophysical measurements are reported in the present study as Part II of the NAS-94 interpretation report. Some of the susceptibility data were also presented in the NAS-94 Interpretation Report Part I, Aeromagnetic data (Olesen & Smethurst 1994). The petrophysical data were applied in the combined interpretation of aeromagnetic and gravity data which is reported as Part III of the NAS-94 interpretation report (Olesen & Smethurst 1995).

The purpose of the petrophysical study is: 1) to measure the magnetic susceptibility of sedimentary rocks from shallow IKU cores as a basis for interpretation of the contribution to magnetic anomalies from the sedimentary rock section, 2) to relate the measured values to the lithological section, and 3) to study in detail the mineralogy of selected samples to identify the minerals with high magnetic susceptibility.

A total of 428 susceptibility measurements were carried out on core samples from IKU's shallow drillings off Helgeland 1982 and off Nordland VI and VII and shallow seabed samples from a cruise in 1982 (a total of 14 wells and 7 shallow samples). The shallow cores cover a stratigraphic section which ranges in age from the Early Triassic to Early Tertiary and Pleistocene. Stratigraphic and lithological background data are based on IKU shallow drilling reports (Hansen et al. 1992, Mørk et al. 1983, Skarbø et al. 1983 and supplementary studies by Vigran et al. 1994 and references therein). Technical information for the cores are shown in Table 1, and a location map is shown in Fig. 1.

Regional magnetic and gravimetric anomalies within the project area are partly continuous from land onto the continental shelf. It is therefore important to know the density and magnetic properties of the rocks on land when interpreting potential field data covering offshore areas. Approximately 4100 rock samples from the nearby mainland, collected during geological mapping (Gustavson 1981, Gustavson & Gjelle 1991, Gustavson & Bugge in press., Solli et al. in press, Nordgulen 1993) and geophysical studies (Schlinger 1985, Midtun 1988, Skilbrei 1988, Olesen & Torsvik 1993), have been measured with respect to density, susceptibility and remanence. This adjacent onshore area is covered by five 1:250.000 scale bedrock maps (Bodø (Gustavson & Blystad in press), Mo i Rana (Gustavson & Gjelle 1991), Vega (Gustavson & Bugge in press), Mosjøen (Gustavson 1981) and Namsos (Solli et al. in press)) and consists mainly of three Precambrian basement terrains and two Caledonian Nappe complexes. The Lofoten-Vesterålen area, Høgtuva-Sjona tectonic windows and the Western Gneiss Region (Vestranden) make up the Precambrian basement terrains to the north, central and south, respectively. The Rødingsfjell and Helgeland Nappe Complexes are situated to the north and south, respectively, of the Høgtuva-Sjona tectonic windows. The Bindal batholith is situated within the Helgeland Nappe Complex. The sample locations of both hand specimens and offshore cores are shown on Map 1 (Enclosure) and Fig. 1. The THEMAP map production system (Kihle 1992) was used to produce the map.

Table 1 *Technical data for IKU shallow cores*

Core no	Latitude N	Longitude E	Water depth	Quat. over-burden	TD (below seabed)	Penetra-tion in bedrock
Shallow Drilling off Helgeland 1982:						
IKU82-10	65°05′57.3″	10°31′38.9″	241 m	3.0 m	11.5 m	4.4 m
IKU82-8	65°05′59.4″	10°13′6.6″	258 m	1.0 m	24.5 m	23.5 m
IKU82-11	65°05′59.9″	10°32′08.0″	241 m	4.2 m	10.7 m	6.5 m
IKU82-8B	65°06′13.1″	10°09′43.6″	255 m	13.1 m	19.0 m	5.9 m
IKU82-4	65°38′30.1″	11°02′49.3″	298 m	5.1 m	10.5 m	5.4 m
IKU82-2	65°59′16.0″	11°23′41.6″	173 m	6.0 m	23.6 m	17.6 m
Shallow Drilling Nordland VI and VII:						
6710/03-U-01	67°48′16.4″	10°57′25.3″	241 m	18.5 m	193.4 m	174.9 m
6710/03-U-02	67°53′34.7″	10°48′06.4″	193 m	21.2 m	198.5 m	177.3 m
6710/03-U-03	67°51′08.0″	10°59′57.6″	191 m	2.0 m	174.2 m	172.2 m
6711/04-U-01	67°44′12.2″	11°06′34.3″	232 m	10.0 m	171.3 m	161.3 m
6814/04-U-01	68°39′10.9″	14°11′08.9″	241 m	10.0 m	178.6 m	168.6 m
6814/04-U-02	68°39′45.8″	14°09′47.1″	233 m	7.0 m	191.3 m	184.3 m

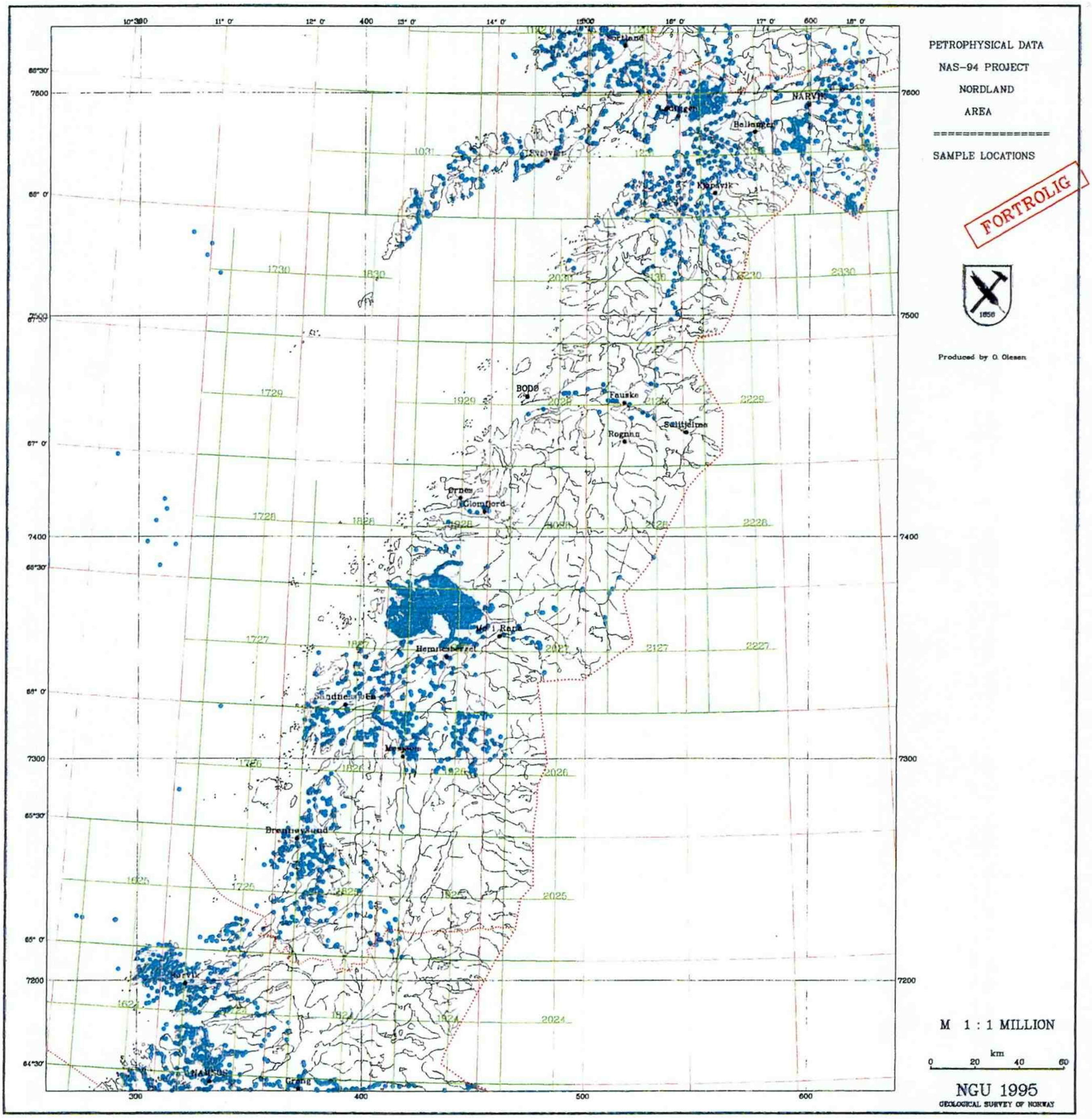


Fig. 1 *Sample locations, 12 offshore wells and 7 shallow seabed samples (IKU shallow drilling program) and 4100 onshore rock samples measured with respect to petrophysical properties (susceptibility of cores and susceptibility, remanence and density of bedrock samples from the coastal area of Nordland and Nord-Trøndelag).*

2. ANALYTICAL METHODS

The magnetic susceptibility measurements on the cores were carried out by using the JH-8 Susceptibility Meter from Geoinstruments Ky.

The function of JH-8 is based on electromagnetic induction. There are two coils placed orthogonally to each other in the detector head, which is mounted in the bottom of the instrument case. In non-magnetic environment the voltage induced from transmitter coil to receiver coil is zero. When a sample is brought near the coils, a voltage which is proportional to magnetic susceptibility of the sample is induced to the receiver coil. This signal is detected by a phase-locked amplifier and after rectification it is used to drive an analog panel meter, which is thermally compensated and directly calibrated for susceptibility. Improved sensitivity is achieved by this method, which makes the use of low frequency possible. This reduces the error caused by possible electric conductivity in the sample to a normally insignificant value.

The accuracy of the instrument is $20x10^{-6}$ SI.

The Bartington MS2 Magnetic Susceptibility System was used for measurements of the Helgeland 1992 cores. These measurements are, however, excluded from this report since the client has not acquired the data from these IKU cores.

The measurement procedure of the petrophysical measurements on hand specimens is described by Torsvik & Olesen (1988). The sample locations of both hand specimens and offshore cores (IKU's shallow drilling) are shown on Map 1 (Enclosure) and Fig. 1. The data are stored in the national petrophysical database (Torsvik & Olesen 1992, Olesen et al. 1993) at NGU, and the results for the main rock units are shown in Appendix A and Table 2. Q-values, the ratios of remnant to induced magnetisation, are reported rather than NRM intensities. The Q-value was not calculated if the susceptibility is below 0.00150 SI units, since the accuracy of remanence measurements is relatively poor for samples with low induced magnetisation.

Compositional data for sandstones refer to petrographic thin section analyses and semiquantitative XRD bulk rock analyses in IKU shallow drilling reports and supplementary studies of selected samples. The analytical work included thin-section preparation, heavy liquid mineral-separation, XRD (semiquantitative) analyses of bulk rock samples, XRD analyses of heavy mineral separates, SEM analyses of thin-sections and SEM analyses of slabs with heavy mineral grains mounted on tape. The SEM analyses included both backscattered electron image analyses, EDS analyses and quantitative mineral chemical X-ray spectrometer analysis. The quantitative analyses were performed in order give a proper identification of haematite, magnetite, ilmenite and FeCr-minerals, using standard procedures at the IKU SEM lab.

3. DATA: SUSCEPTIBILITY, DENSITY AND Q-VALUES

The raw data on susceptibility measurements of the IKU shallow drillcores with reference to lithology (428 measurements) are enclosed as Appendix A. Statistical data on these measurements in addition to density, susceptibility and Q-values on hand specimens from the Caledonides and Precambrian mainland of Nordland and North Trøndelag are shown in Table 2. A few IKU core samples with high magnetic susceptibility were also measured in the laboratory at NGU (Table 3). The variation in the susceptibility data is represented graphically in Figures 2-7 for different groupings of the data with respect to age and lithology. Variations in magnetic remanence and density for the onshore samples are shown in Figures 8 and 9.

Table 2 *Statistical data; density susceptibility and Q-value for main rock-units from drill-cores of IKU shallow drilling programme and density susceptibility and Q-value on hand specimens from the Caledonides and Precambrian on mainland Nordland and North-Trøndelag. Sample locations are shown in Fig. 1. The letters a, b and c denote total sample, low-magnetic fraction and high-magnetic fraction, respectively. units are in SI.*

ROCK UNIT/TYPE		No.	DENSITY				No.	Q-VALUE				No.	SUSCEPTIBILITY			
			min	max	mean	std		min	max	mean	std		min	max	mean	std
PLEISTOCENE												55	0.00006	0.00625	0.00107	0.00151
OLIGOCENE												8	0.00006	0.00081	0.00032	0.00027
PALAEOCENE												5	0.00013	0.00024	0.00019	0.00004
UPPER CRETACEOUS (incl. siderite)												25	0.00010	0.00256	0.00060	0.00071
LOWER CRETACEOUS (incl. siderite)												45	0.00006	0.00320	0.00092	0.00073
UPPER CRETACEOUS (excl. siderite)												14	0.00010	0.00027	0.00017	0.00005
LOWER CRETACEOUS (excl. siderite)												19	0.00019	0.00112	0.00034	0.00022
CRETACEOUS siderite												37	0.00006	0.00320	0.00129	0.00071
UPPER JURASSIC												37	0.00006	0.00159	0.00040	0.00049
MIDDLE JURASSIC												50	0.00001	0.00200	0.00010	0.00028
LOWER JURASSIC												73	0.00001	0.00300	0.00038	0.00049
LOWER TRIASSIC												120	0.00002	0.00088	0.00027	0.00017
PRECAMB. IN THE LOFOTEN	a	508	2579	3553	2775	135	520	0.00	67.63	1.06	4.05	520	0.00002	4.94550	0.04961	0.22372
AREA	b											142			0.00078	0.00070
	c											378			0.06796	0.26003
RØDINGSFJELL NAPPE	a	411	2311	3430	2798	142	217	0.00	175.11	3.34	12.91	411	0.00000	6.00000	0.02855	0.30248
COMPLEX	b											351			0.00046	0.00047
	c											60			0.19291	0.77143
HØGTUVA -SJONA TECTONIC	a	1141	2541	2976	2643	39	9	0.00	13.97	3.14	5.53	1141	0.00001	0.14727	0.00839	0.01160
WINDOWS	b											448			0.00082	0.00081
	c											693			0.01329	0.01265
HELGELAND NAPPE COMPLEX	a	506	2488	3273	2808	128	497	0.00	251.76	4.13	15.37	506	0.00000	0.67692	0.00461	0.03468
	b											465			0.00056	0.00057
	c											41			0.05058	0.11199
BINDALEN BATHOLITH	a	315	2521	3219	2733	137	315	0.00	161.89	3.85	13.60	315	0.00000	0.14690	0.00358	0.01329
	b											266			0.00048	0.00053
	c											49			0.02040	0.02828
WESTERN GNEISS REGION	a	419	2581	3300	2729	106	415	0.02	45.59	1.04	2.76	419	0.00001	0.45812	0.00912	0.02599
(Trøndelag)	b											241			0.00074	0.00072
	c											178			0.02045	0.03697

Table 3 Laboratory measurements on selected samples from the IKU cores.

Sample no. Rem mA/m.	Depth m	UTM zone	UTM coord 10 m	UTM- coord. 10 m	Lith. code	Rock type	Volume cm^3	Density kg/m^3	Susceptibility. SI	Rem. mA/m
6710/3U1-a	25.4	32	58249	752257	M23	cemented nodule	65.1	2654	0.00198	37.6
6710/3U1-b	34.0	32	58249	752257	M23	carb.cement.brown bed	64.8	2831	0.00220	63.6
6710/3U1-c	40.1	32	58249	752257	M23	light carb.cem. bed	93.8	2781	0.00154	33.7
6710/3U1-d	74.0	32	58249	752257	M23	carb.concretion	111.1	2786	0.00171	12.7
6710/3U1-e	161.5	32	58249	752257	M23	siderite cem.	40.6	2706	0.00167	34.8
6710/3U1-f	174.7	32	58249	752257	M26	caliche/mottled mudst.	119.7	2661	0.00096	
6711/4U1-a	119.7	32	58918	751522	M23	carb.cem. bed	62.8	2348	0.00166	35.6
6711/4U1-b	161.4	32	58918	751522	M23	cem.,lam. mudstone	88.9	3338	0.00331	
6814/4U2-1	22.5	33	70946	762575	S20	claystone	71.7	2248	0.00026	
6814/4U2-2	24.4	33	70946	762575	S20	claystone	67.9	2209	0.00027	
6814/4U2-3	29.8	33	70946	762575	M23	claystone w/siderite	150.8	3095	0.00191	9.4
6814/4U2-4	36.8	33	70946	762575	M23	claystone w/siderite	117.2	3322	0.00256	
6814/4U2-5	115.6	33	70946	762575	S21	silty mudstone	40.7	2712	0.00096	
6814/4U2-6	117.7	33	70946	762575	S21	silty mudstone	104.3	2329	0.00012	
6814/4U2-7	122.3	33	70946	762575	S21	silty mudstone	102.0	2510	0.00035	
6814/4U2-8	122.4	33	70946	762575	M23	mudstone w/siderite	69.9	2832	0.00127	
6814/4U2-9	127.6	33	70946	762575	S20	mudstone	61.1	2448	0.00033	
6814/4U2-10	127.8	33	70946	762575	M23	mudstone w/siderite	152.3	2921	0.00127	

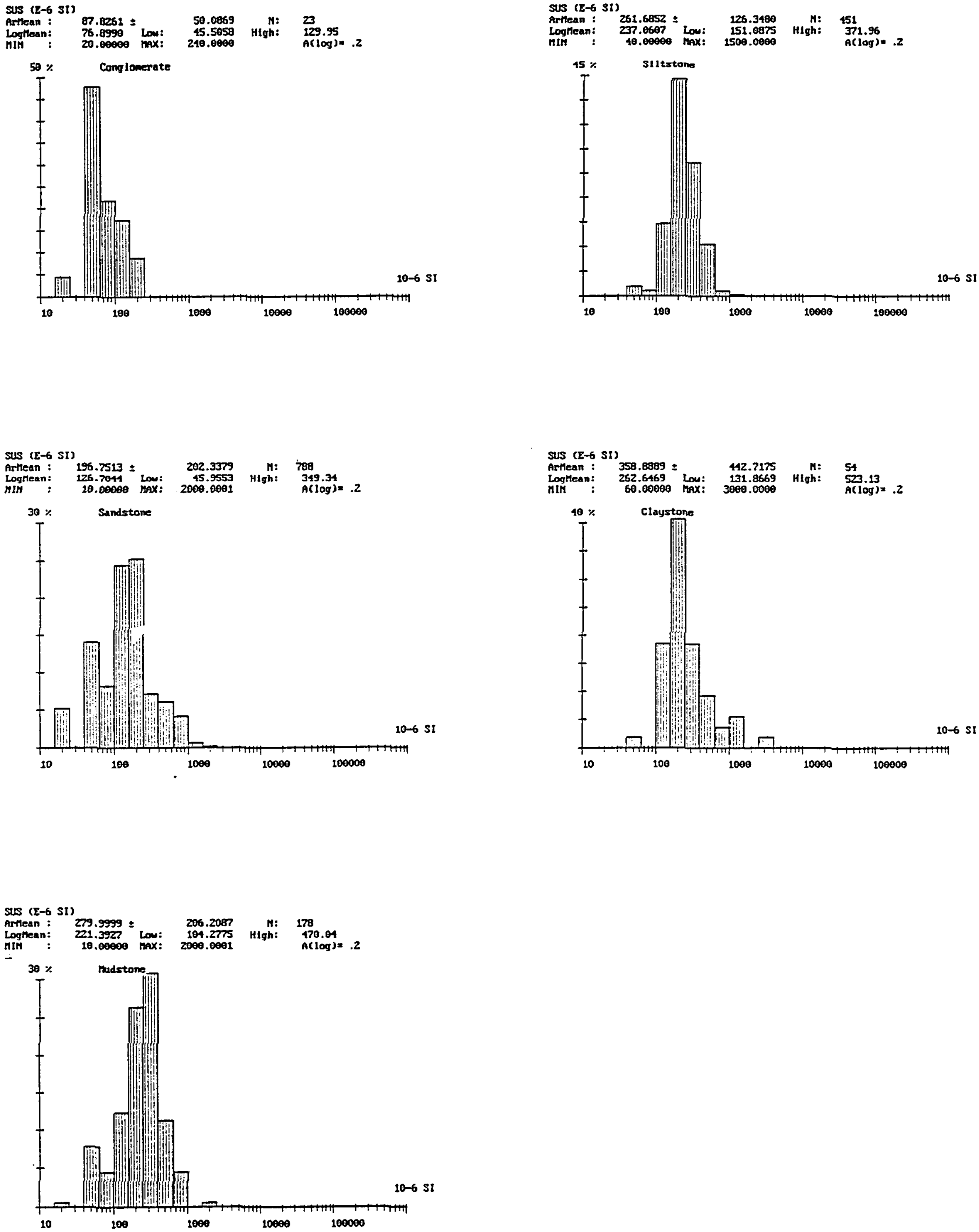


Fig. 2 *Susceptibility spectra of measurements on cores from IKU's shallow drilling programme. Lithological units: conglomerate, sandstone, mudstone, siltstone and claystone.*

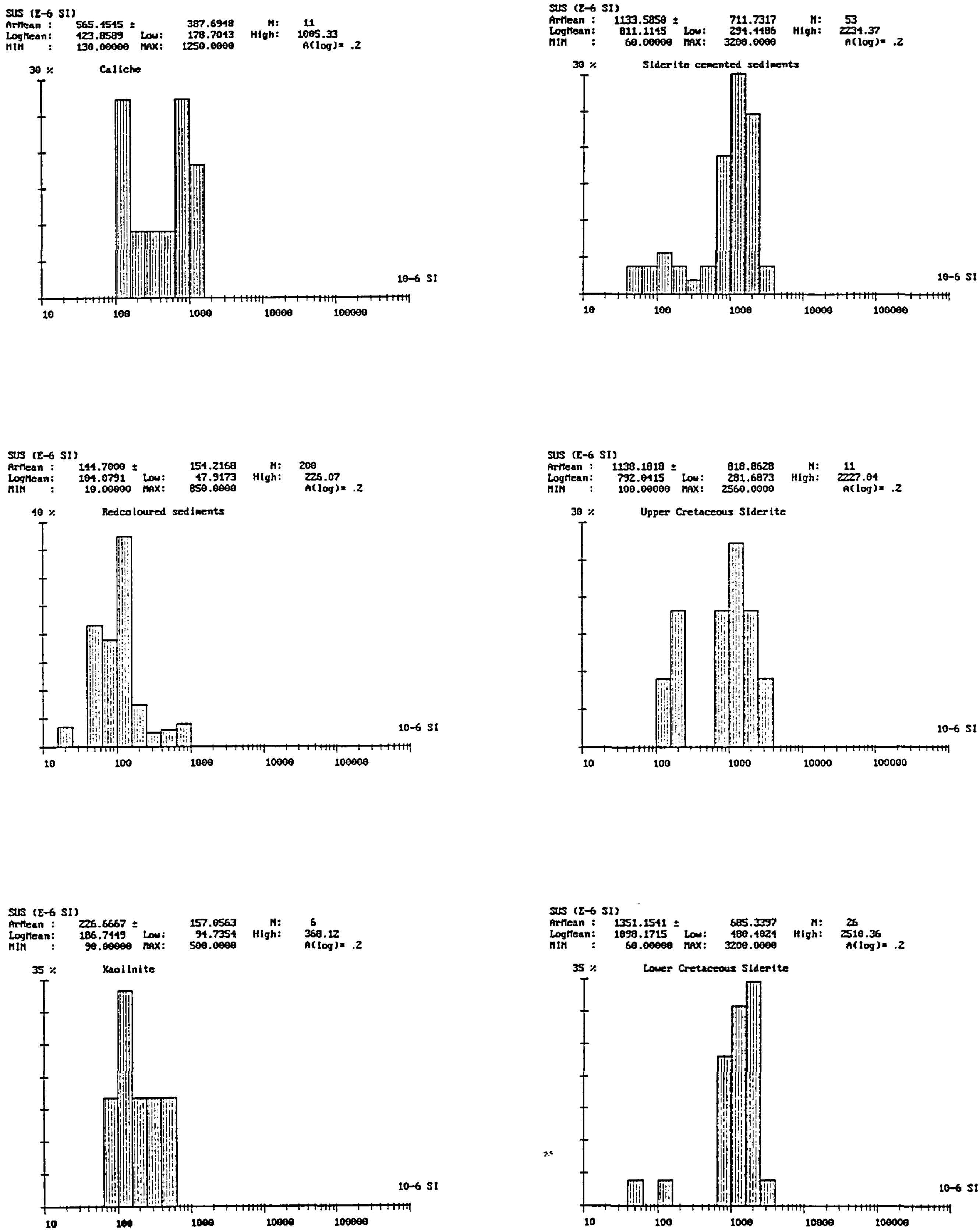


Fig. 3 *Susceptibility spectra of measurements on cores from IKU's shallow drilling programme. Lithological units: caliche, red-coloured sediments, kaolinite-weathering of basement, siderite-cemented sediments (mainly of Cretaceous age), Upper Cretaceous siderite, Lower Cretaceous siderite.*

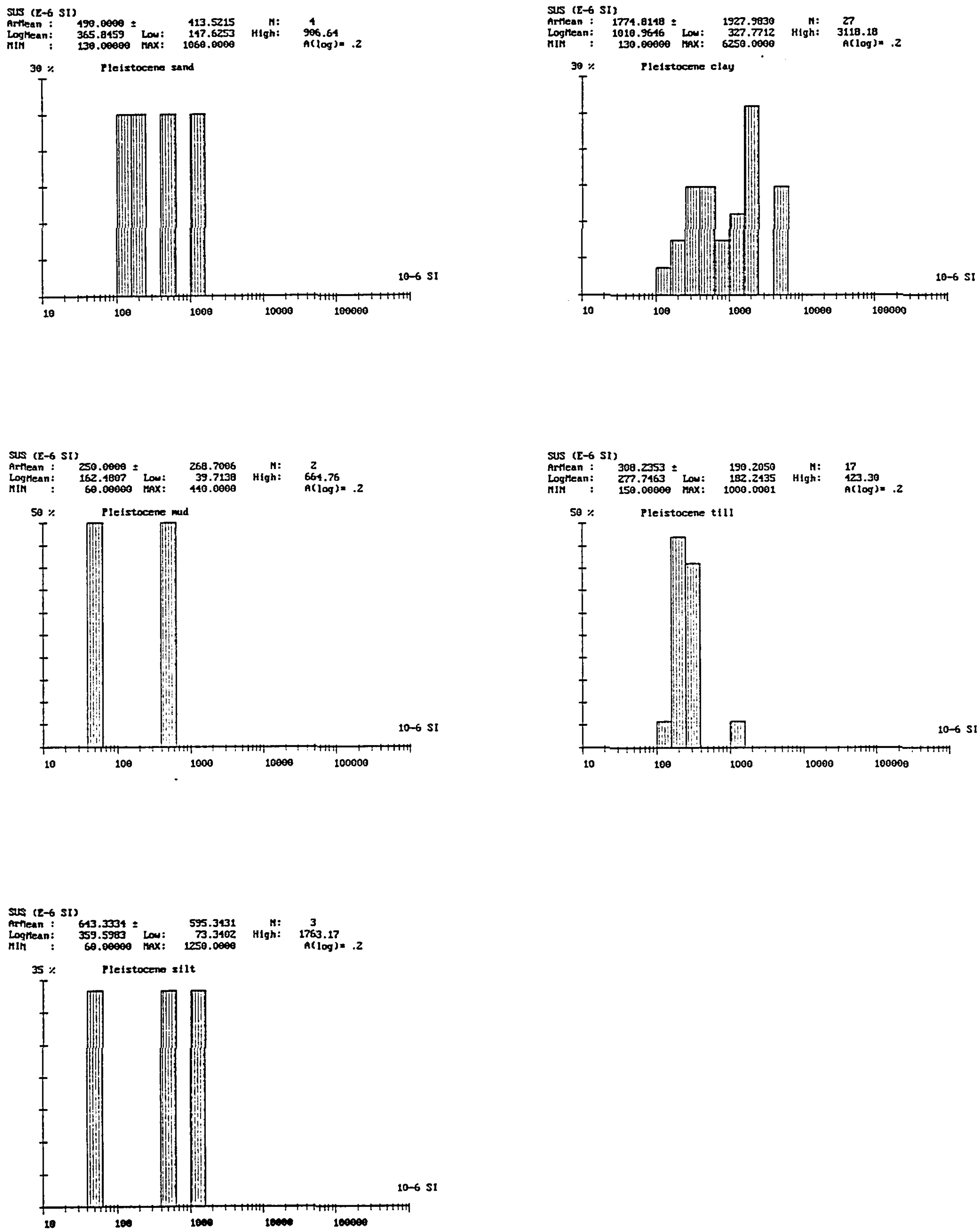


Fig. 4 *Susceptibility spectra of measurements on cores from IKU's shallow drilling programme. Lithological units within Pleistocene: sand, mud, silt, clay and till.*

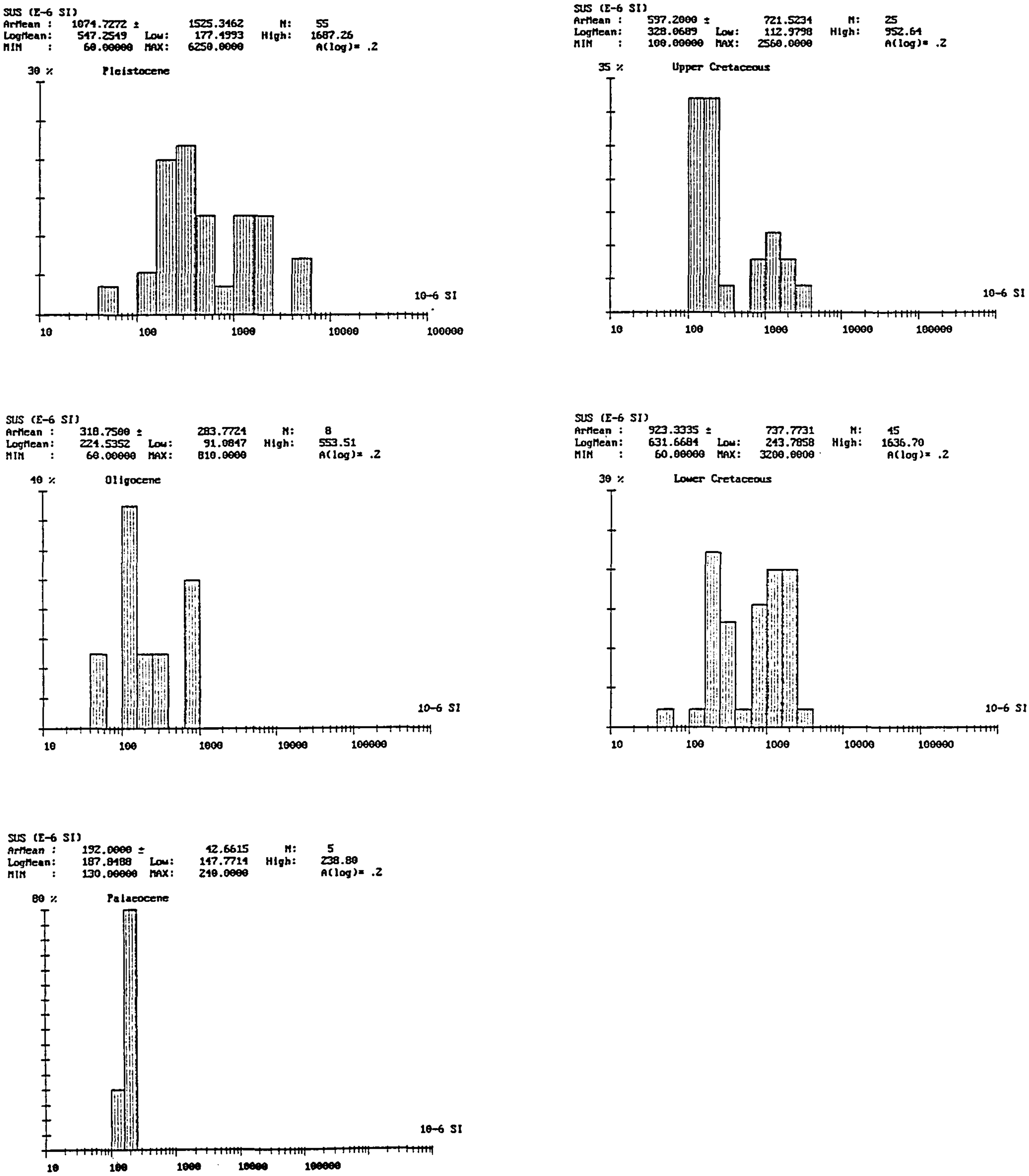


Fig. 5 *Susceptibility spectra of measurements on cores from IKU's shallow drilling programme. Stratigraphic units: Pleistocene, Oligocene, Palaeocene, Upper Cretaceous and Lower Cretaceous.*

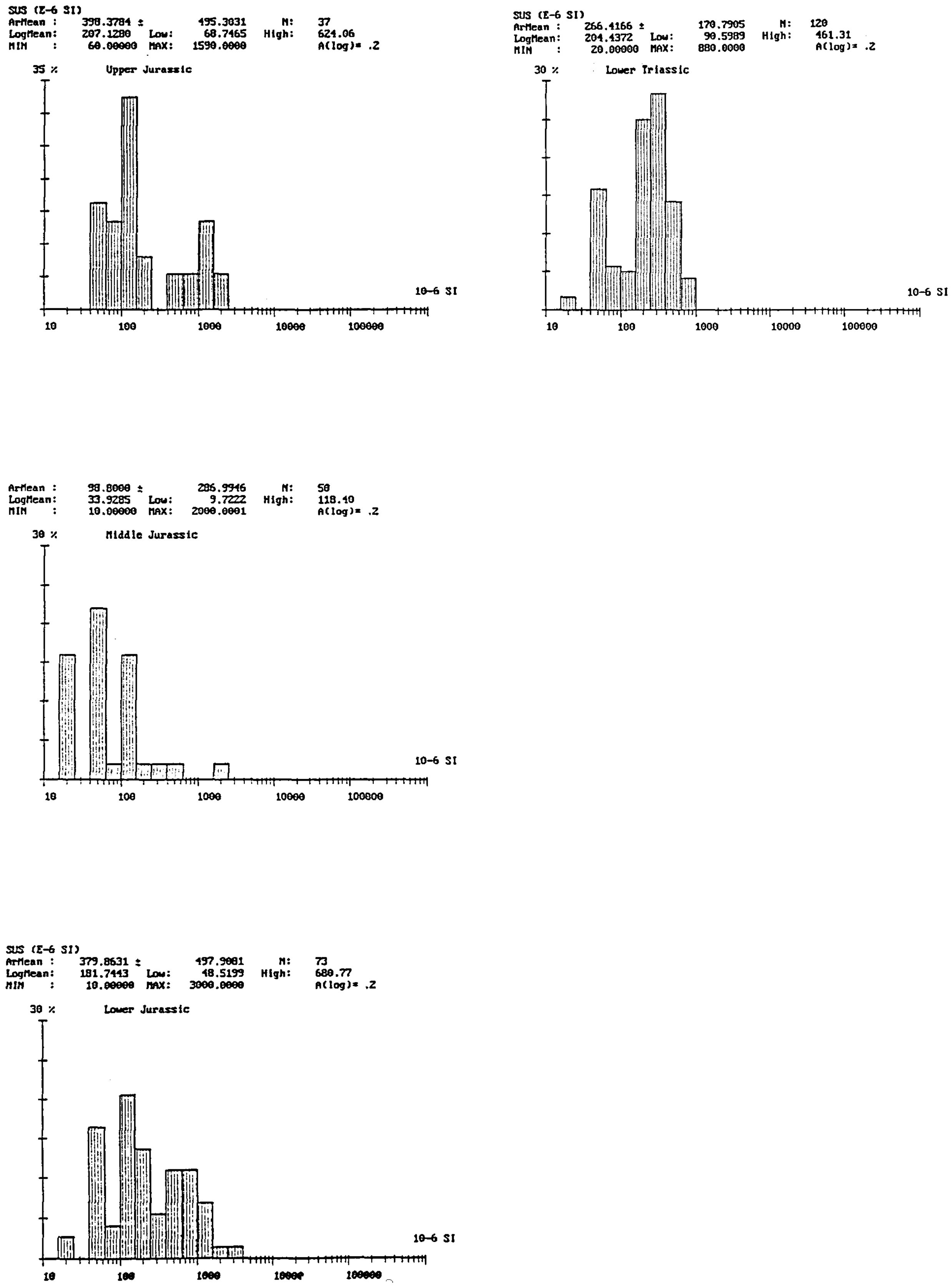


Fig. 6 *Susceptibility spectra of measurements on cores from IKU's shallow drilling programme. Stratigraphic units: Upper, Middle and Lower Jurassic.*

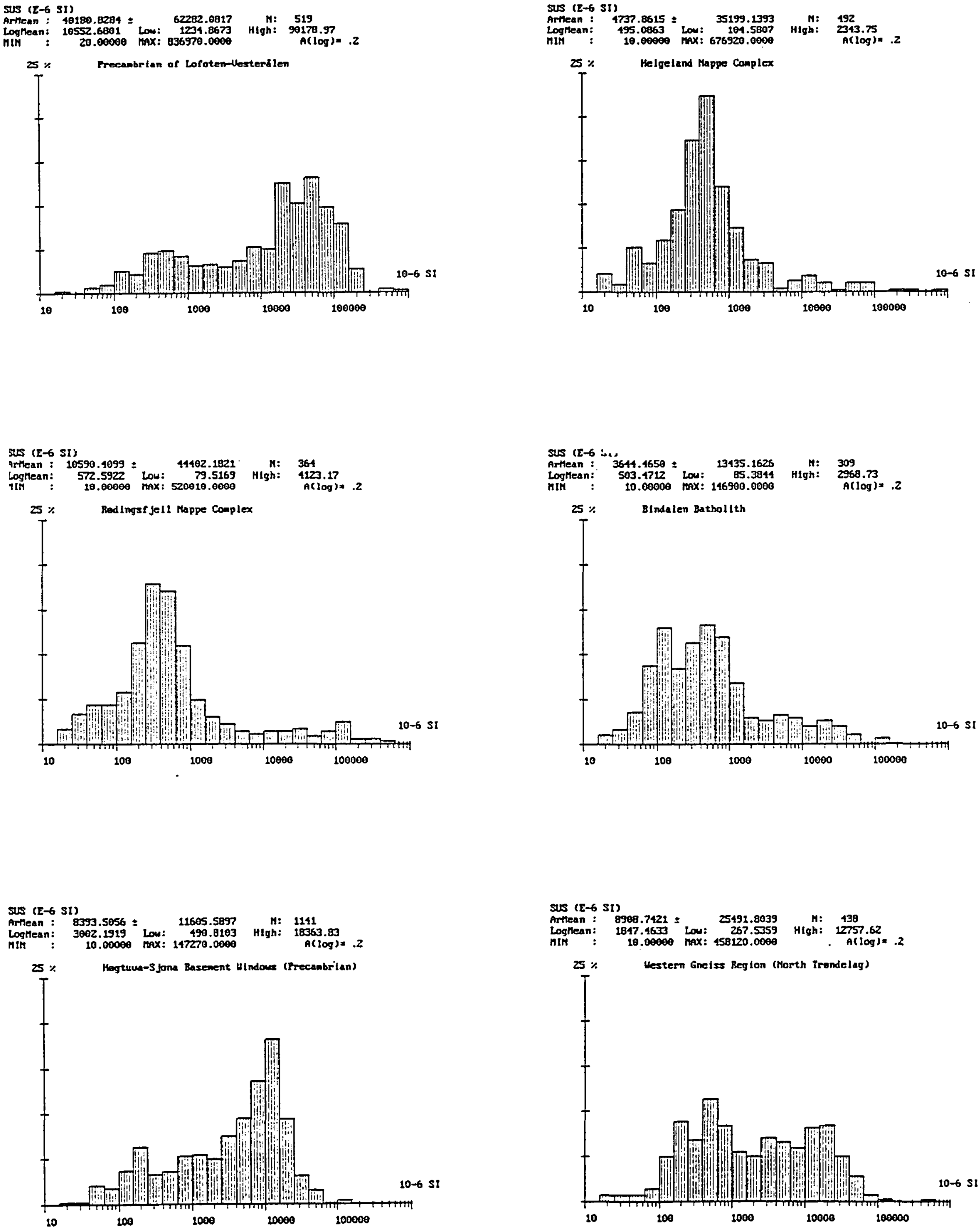


Fig. 7 *Susceptibility spectra of measurements on hand specimens from the Precambrian of Lofoten-Vesterålen, Rødingsfjell Nappe Complex, Høgtuva-Sjona Basement Windows, Helgeland Nappe Complex, Bindalen Batholith and Western Gneiss Region (North Trøndelag).*

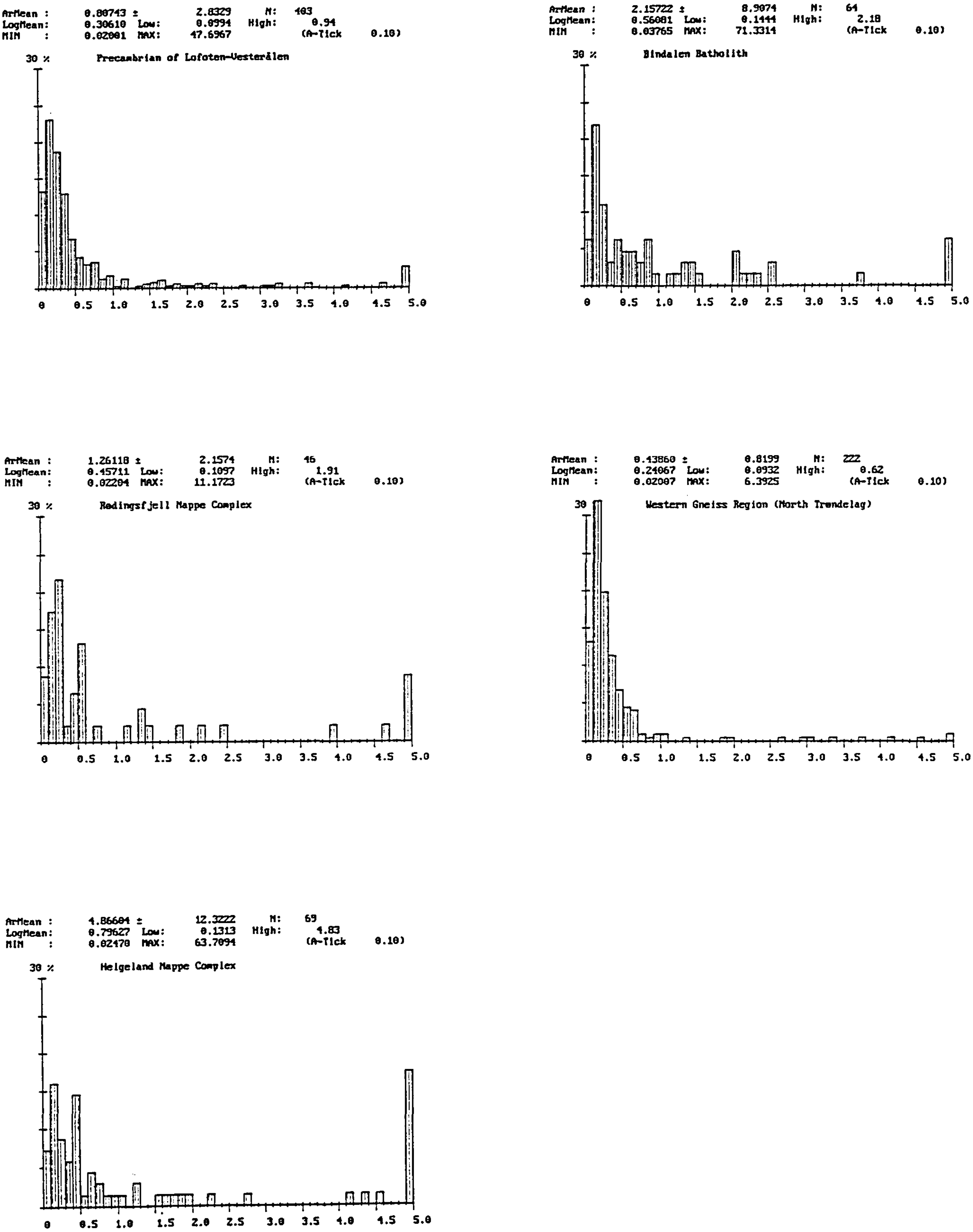


Fig. 8 *Q-value spectra of measurements on hand specimens from the Precambrian of Lofoten-Vesterålen, Rødingsfjell Nappe Complex, Helgeland Nappe Complex, Bindalen Batholith and Western Gneiss Region (North Trondelag).*

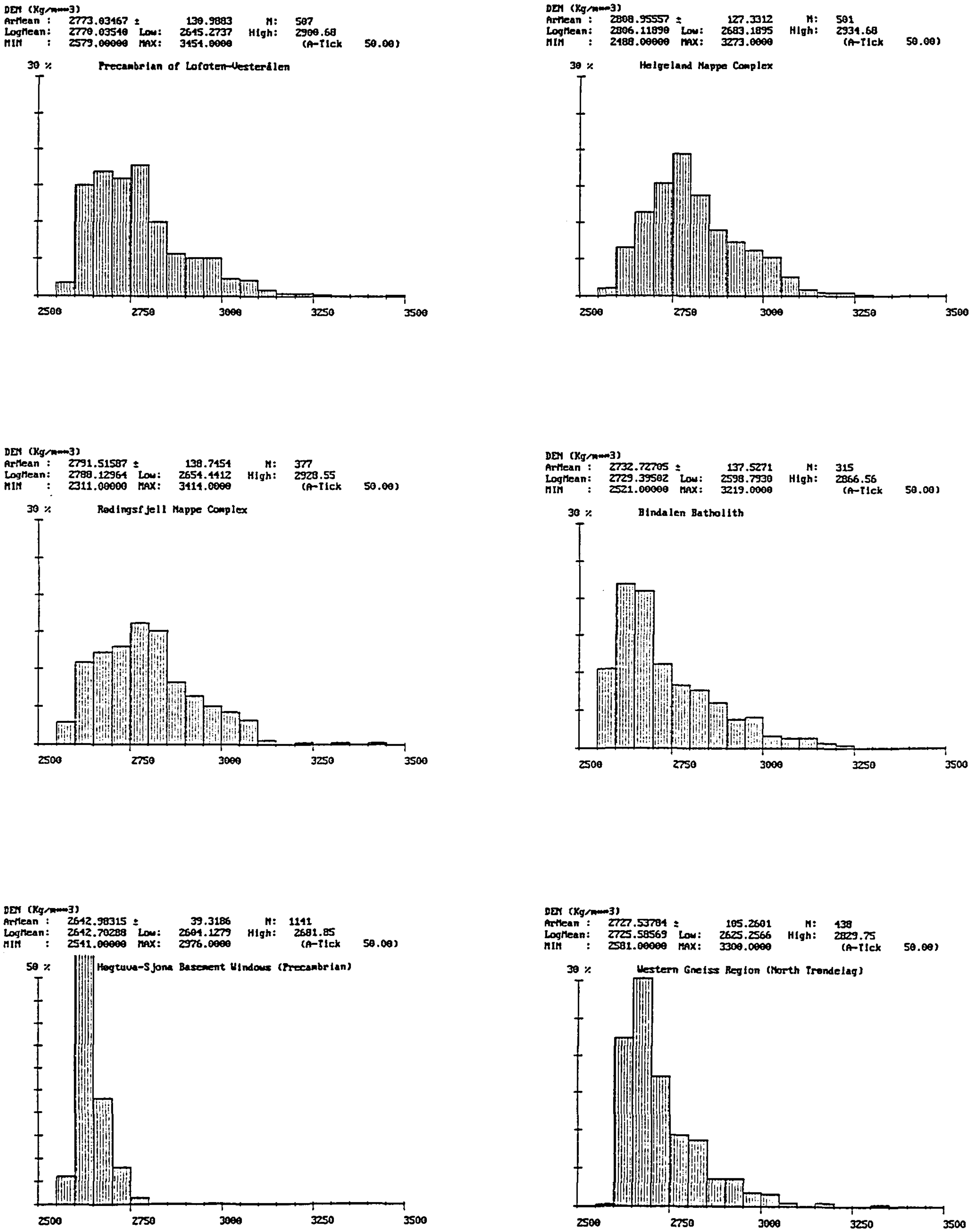


Fig. 9 *Density spectra of measurements on hand specimens from the Precambrian basement of Lofoten-Vesterålen, Rødingsfjell Nappe Complex, Høgtuva-Sjona basement windows, Helgeland Nappe Complex, Bindalen Batholith and Western Gneiss Region (North Trøndelag).*

4. MAGNETIC SUSCEPTIBILITY RESULTS FOR ONSHORE BASEMENT SAMPLES

Precambrian rocks (Lofoten area, Høgtuva-Sjona Tectonic Windows and Western Gneiss Region) are commonly highly magnetic and usually show wide and complex (multimodal) distributions in magnetic susceptibility (Fig. 7 and Table 2).

The high-amplitude magnetic anomalies in the Lofoten archipelago and the Svartisen area are caused by granulite-facies rocks and granites, respectively. The histograms (Fig. 8) and Table 2 also show that the Q-values are generally low, in the order of 0.5 or lower. Schlinger (1985) and Olesen et al. (1991) have also shown that the remanence of the rocks in the Lofoten-Vesterålen area is viscous and parallel to the present Earth's field, characteristics that make aeromagnetic interpretations in the area much simpler. The orthopyroxene isograd in the Vesterålen area coincides with the boundary between the high-magnetic and low-magnetic gneisses. West of this line the migmatites are in granulite-facies metamorphism whereas to the east they have amphibolitic metamorphic grade. Magnetite is formed during the prograde metamorphism. The understanding of this isograd is critical for the interpretation of the magnetic field on the mainland as well as on the continental shelf in the Lofoten-Vesterålen area (Schlinger 1985, Olesen et al. 1991). In this particular area the magnetic basement surface reflects the depth to the granulite-facies gneisses. We refer to these papers for a detailed discussion of the magnetic properties in the Lofoten - Vesterålen area. The granitic and migmatitic gneisses in the Western Gneiss Region (Vestranden) are also frequently magnetic. A detailed study of the magnetic properties of the rocks in the Roan area, located immediately to the south of the NAS-94 area, shows that magnetite is formed during the metamorphic transition from amphibolite- to granulite-facies metamorphism (Skilbrei et al. 1991), analogous to the Lofoten-Vesterålen area.

The average densities for Precambrian basement rocks in the Lofoten-Vesterålen area, the Høgtuva-Sjona windows and Western Gneiss Region (Vestranden) are 2770, 2640 and 2730 kg/m^3, respectively. The densities of the Rødingsfjell and Helgeland Nappe Complexes (Uppermost Allochthon within the Caledonian Orogen) are 2790 and 2810 kg/m^3, respectively. The samples from the Bindal Batholith which constitutes a significant portion of the Helgeland Nappe Complex, are excluded in the calculation of the density of this nappe complex. The average density of the Bindal Batholith itself is 2730 kg/m^3. The calculated mean density of the basement within the NAS-94 area is 2750 kg/m^3.

AGE		HELGELAND Lithology	HELGELAND Susceptibility: x 10^{-6}	LOFOTEN Lithology	LOFOTEN Susceptibility: x 10^{-6}
QUAT.		B-82 IKU82-8B	190-2500 150-380		
TERTIARY	U.				
TERTIARY	L.	IKU82-8,-1,8B	60-810 170-240		
CRETACEOUS	U.	IKU82-8		6711/04-U-01 6814/04-U-02	100-2560 60-3200
CRETACEOUS	L.	IKU82-7B		6710/03-U-01	120-2250
JURASSIC	U.	IKU82-C IKU82-5		6814/04-U-01	130-190
JURASSIC	M.	IKU82-3,4B IKU82-10,11	10-130	6710/03-U-01, 6814/04-U-01	10-130
JURASSIC	L.	IKU82-4	210-3000	6710/03-U-02 6710/03-U-01	10-1000 60-1250
TRIASSIC	U.	IKU82-4	50-1500		10-1000
TRIASSIC	M.				
TRIASSIC	L.	IKU82-2	380-690	6710/03-U-03	50-240
P.C.				6710/03-U-03	100-620

adm2300\ils\2300\232522\Fig_2.ai\03.01.95\ils

Fig. 10 *Overview of core age, lithology and magnetic susceptibility ranges for each stratigraphic unit, IKU shallow cores.*

5. IKU SHALLOW CORE DATA: LITHOLOGICAL CHARACTERISATION AND MAGNETIC SUSCEPTIBILITY RESULTS

Magnetic susceptibility ranges for the sedimentary rocks are generally wide, varying by one or two orders of magnitude (Figures 2-6). The susceptibility variation is described in more detail below for each of the stratigraphic units, and the susceptibility ranges are summarised in relation to lithology and stratigraphic age in Fig. 10. As a basis for interpretation and comparative studies, sedimentological and mineralogical background data from the IKU shallow drilling reports (see introduction) are also presented with the susceptibility data in this section. Sandstone classification refers to the modified Dott system (Pettijohn et al. 1972).

Shallow cores off Helgeland

Lower Triassic core IKU82-2 (23.6-6.0 m)

The core consists of laminated siltstone and mudstone with thin sandstone ripple laminae, deposited in a shallow marine environment. The compositions of both the fine clastics and the sandy laminae are rich in feldspar and mica. The sandstones are classified as arkosic arenite. Fe-bearing minerals include micas, chlorite, and accessory amounts of garnet, epidote and tourmaline. Pyrite and siderite cement are present in a few samples.

The magnetic susceptibility values (19 measurements) are in the range 380-690x10^{-6} SI with similar values for mudstone and siltstone/sandstone.

Upper Triassic of core IKU82-4 (10.5-7 m)

The cored section consists of alternating matrix-rich conglomeratic sandstone and sandstone overlain by more silty sediments at the top of the interval. Mottled intervals with root beds indicate a continental environment for the deposits. The sandstones are lithic graywackes with a dominance of quartz in the coarse fraction, and with a kaolinite-rich matrix. Fe-bearing detrital grains such as Fe-Ti oxides, staurolite, garnet and tourmaline are present in accessory amounts. Haematite has formed in response to weathering and/or early diagenesis, and was largely replaced by siderite and pyrite spots during a later diagenetic stage.

The magnetic susceptibility values are in the range of 50-1500x10^{-6} SI (13 measurements) with highest values in the mottled silty sandstones.

Lower Jurassic of core IKU82-4 (7-5.2 m)

The Lower Jurassic upper part of the core consists of kaolinitic mudstones with a shallow marine contribution. Siderite has a similar occurrence as in the upper part of the Upper Triassic interval of the core.

The magnetic susceptibility values are in the range 210-3000x10^{-6} SI (4 measurements). The highest values were found in a red claystone bed and in a silty mudstone bed.

Lower - Middle Jurassic cores IKU82-10 (11.5-3 m) and -11 (10.7-2.0 m)
These cores consist of light grey coloured, rapidly deposited shallow marine sandstones. The sandstone section of core IKU82-10 fines upward to silty mudstone in the upper part. The sandstones are classified as lithic arenites (core -10) and lithic graywackes (core -11), and the coarse fraction is rich in quartz and quartzite fragments. Fe-minerals include very minor amounts of detrital micas and chlorite (core -11) and occasionally diagenetic siderite cement which has been observed by XRD analysis.

The magnetic susceptibility values of the sandstones are generally very low in both cores with ranges of 10-130x10^{-6} SI in core IKU82-10 and 20-40x10^{-6} SI in core IKU82-11. An anomalously higher value of 2000x10^{-6} SI was measured for a rusty conglomerate at 9.0 m in core IKU82-10. Part of the core was disturbed during drilling, so the latter sample may be contaminated by Quaternary material.

Upper Palaeocene of core IKU 82-8B (19-13.1 m)
The six metre thick core interval of Upper Palaeocene sediments consists of well-sorted glauconite sand and silty, micaceous mudstone. The sandstone contains abundant ooides of Fe-bearing minerals (glauconite and goethite). Fe-bearing minerals in the mudstones are micas, chlorite and small amounts of pyrite and dolomite.

The magnetic susceptibility of the mudstone is in the range of 170-240x10^{-6} SI (four measurements).

Pleistocene of core IKU82-8B (13.1-4 m)
The Pleistocene section consists of glacial till comprised of a dark grey brownish, sandy clay with abundant sediment clasts of older formations. The claystone compositions are similar to the underlying Upper Palaeocene clays, except that calcite cement is present in stead of dolomite. Fe-bearing phases are micas and chlorite.

The magnetic susceptibility of the till is in the range of 150-380x10^{-6} SI (16 measurements).

Shallow cores off Lofoten (Nordland VI and VII)

Precambrian basement of cores 6710/03-U-03 (174.2-167.4 m) and 6814/04-U-01 (178.6-170.5 m)

Basement of core 6710/03-U-03 consists of granitic augengneiss with finer-grained granitic interlayers. This gneiss may be an analogue to the amphibolite facies gneisses of the present Lofoten Archipelago. Fractures in the upper part are cemented by calcite. The basement sample at 6814/04-U-01 consists of strongly kaolinitic weathered gneiss. At both locations the gneisses are overlain by conglomeratic debris flow deposits.

The magnetic susceptibility of the cored basement gneiss at 6710/03-U-03 is in the range 100-620x10^{-6} (6 measurements). The susceptibility of the weathered gneiss and the overlying unit at 6814/04-U-01 is similar (90-500x10^{-6} SI) (5 measurements of gneiss and 7 measurements of overlying mudstone). These values are comparable with the non-magnetic amphibolite facies gneisses from the Lofoten-Vesterålen area.

Lower Triassic of core 6710/03-U-03 (167.4-2.0 m)
A thick Lower Triassic, subarial debris flow conglomerate lies directly above the Precambrian augengneiss section and shows evidence for a local provenance similar to the underlying gneiss. The section above 138 m consists of alternating sandstone, mudstone and conglomerate beds. The sediment composition is rich in feldspar and mica. Fe-minerals include both haematite, which may reflect oxidation in response to weathering, and diagenetic pyrite. Siderite is occasionally present in trace amounts, and chlorite is also present.

The magnetic susceptibility is in the range of $50\text{-}240 \times 10^{-6}$ SI (16 measurements) which is lower than for the underlying granitic basement.

Upper Triassic of core 6710/03-U-01 (193.4-173.6 m)
This unit consists of alternating channel sandstones and floodplane mudstones and may be analogous to the Triassic "red beds" of Dalland et al. (1988). The sandstone compositions are moderately mature. Fe-minerals include micas and pyrite and trace amounts of siderite, 7 Å chlorite, and goethite have been identified in the mudstones.

The magnetic susceptibility is in the range $10\text{-}1000 \times 10^{-6}$ SI (20 measurements) with the highest values in mottled mudstones and the very low values in light-coloured sandstone beds.

Upper Triassic - Lower Jurassic core section of 6710/03-U-01 (173.6-148.7 m)
The unit consists of delta plain sandstones and mudstones and includes root zones and coal beds. The detrital composition is similar to the underlying unit, but parts of this unit were more strongly influenced by weathering and diagenesis. Iron minerals present are mica, chlorite and siderite. Siderite has formed by extensive diagenetic replacement of detrital grains in some beds.

The magnetic susceptibility is in the range $60\text{-}1250 \times 10^{-6}$ SI. The highest value was measured in a caliche bed with siderite cement at 162.0 and 162.4 m levels.

Lower Jurassic core 6710/03-U-02 (198.5-21.2 m)
The core is dominated by sandstone with a few intervals of mudstone deposited in a delta plain environment. The sandstones are mineralogically moderately mature with subarkose to sublitharenite composition and display a variegated heavy mineral composition. Fe-bearing minerals present are biotite, chlorite, Fe-Ti oxide, garnet, staurolite in very minor amounts and variable content of early diagenetic, pore-lining siderite cement.

The magnetic susceptibility is $10\text{-}1000 \times 10^{-6}$ SI (21 measurements) and the total range is represented by the sandstone samples, with the higher susceptibility values in yellow or laminated sandstone and carbonate concretions.

Middle Jurassic of cores 6710/03-U-01 (148.7-132.4 m) and 6814/04-U-01 (163.4-49.2 m)
The Middle Jurassic sandstone intervals are closely related with respect to age and composition. The shallow marine sandstones are quartz rich and have fairly mature

sublitharenite compositions. Fe-bearing minerals include mica which is concentrated in distinct laminae, and occasional grains of garnet, tourmaline and opaques. Small siderite rhombs have grown very locally within biotite grains. Chlorite and pyrite are present in the mudstones.

The magnetic susceptibility is very low: 10-130x10^{-6} SI (29 measurements in core 6710/03-U-01 and 1 measurement in core 6814/04-U-01).

Upper Jurassic of core 6814/04-U-01 (49.2-29.8 m)
This core interval consists of micaceous, muddy siltstone deposited on a shallow marine shelf. Fe-bearing minerals present are mica/illite, chlorite, pyrite and occasional siderite.

The magnetic susceptibility is low in all samples: 130-190x10^{-6} SI (11 measurements).

Lower Cretaceous of core 6710/03-U-01 (132.4-18.5 m)
This core interval comprises a thick section of dark claystones deposited in an offshore environment. Fe-bearing minerals in the claystones are mica/illite, chlorite, 7Å chlorite, and occasionally haematite, goethite, siderite and pyrite.

The magnetic susceptibility ranges between 120-2250x10^{-6} SI. The higher values are recorded in carbonate concretions and carbonate cemented beds (690-2250x10^{-6} SI) whereas non-cemented "background" claystone commonly has values of 190-310x10^{-6} SI.

Upper Cretaceous core 6814/04-U-02 (191.3-7 m)
The 184 m-thick upper Cretaceous section comprises dark laminated pyritic claystones, calcite cemented siltstones with abundant limestone nodules and beds, and dark mudstone with thin carbonate beds. Fe-bearing minerals include mica/illite, chlorite, pyrite and siderite. The carbonate beds are micritic and include ankerite, siderite and calcite. One sample at 150 m is rich in marcasite.

The magnetic susceptibility of the core has a total range of 60-3200x10^{-6} SI (29 measurements). The very low values are, however, restricted to a calcite cemented interval of the middle part with values in the range (60-150x10^{-6} SI). Carbonate cemented beds or nodules of yellowish colour (siderite) have distinctly higher values in the range 1000-3200x10^{-6} SI (11 measurements), whereas common claystone is in the range of 150-440x10^{-6} SI.

Upper Cretaceous of core 6711/04-U-01 (171.3-10 m)
The core consists of marine silty claystones in the lower part and sandy siltstones to very fine-grained sandstones in the upper part. The sandstones are glauconitic and the diagenetic cements include siderite rhombs. Other Fe-bearing minerals include mica, chlorite, pyrite, garnet and Fe-Ti oxide. Siderite and pyrite cements are also present in the silty claystones.

The magnetic susceptibility is in the range 100-2560x10^{-6} SI with the highest values in brown or yellow (siderite) carbonate-cemented beds. Calcite-cemented beds and non-cemented claystone have low values (100-270x10^{-6} SI).

Shallow sampling 1982 (B82)

Quaternary seabed samples

Quaternary seabed samples from stations B82-180, -184, 185, -186, -189, -190 and -192 have been measured for magnetic susceptibility. The samples include mainly clay and some sandstones with a total susceptibility range of 190-2500x10^{-6} SI (26 in total). Glaciomarine clay of station B82-180 has consistently high values: 1060-2500x10^{-6} SI.

Samples of inferred Oligocene age have been measured at B82-190, -189, -186 185 and -184 (8 in total). The magnetic susceptibility ranges from 60x10^{-6} SI (sand at B82-190) to 810x10^{-6} SI (sand at B82-186).

6. Mineral analyses of selected samples

A few samples with relatively high magnetic susceptibility values were selected for mineral identification and for interpretation of the source of the magnetism. Magnetic properties of various minerals of sedimentary rocks and some minerals which may contribute to the magnetisation are shown in Table 4. Greigite-containing sediments have also been reported to be an important source of aeromagnetic anomalies in sedimentary basins. Greigite-containing Cretaceous sediment from the North Slope Basin, Alaska have similar susceptibility to the siderite cemented sediments in our study, i.e. 200-5000x10^{-6} SI (Reynolds et al. 1994)

Table 4 *Magnetic properties of some selected minerals (from Telford et al. 1976, Thompson & Oldfield 1986).*

Mineral	**Susceptibility x 10^{-6} SI**		**Mineral**	**Susceptibility x 10^{-6} SI**	
	Range	Average		Range	Average
Quartz	-	-10	**Limonite**	-	2,700
Rock salt	-	-10	**Goethite**	-	2,800
Anhydrite, gypsum	-	-10	**Haematite**	500 - 37,000	7,000
Calcite	-10 - -7	-	**Chromite**	3,000 - 120,000	7,500
Coal	-	20	**Pyrrhotite**	1,200 - 6,000,000	1,600,000
Clays	-	200	**Ilmenite**	300,000 - 3,700,000	1,900,000
Siderite	1,200 - 3,900	-	**Magnetite**	1,200,000 - 20,000,000	5,000,000
Pyrite	50 - 5,200	1,600			

Table 5 *Semiquantitative XRD bulk rock analyses of claystones with moderately high magnetic susceptibility.*

Sample	Qtz	Kfs	Plg	Chl	Kao	Mic	ML	Sm	Cc	Dol	Sid	Pyr	Gy	Am
Quaternary **B82-180/2 2 m**	26	18	25	2.8	1.5	22	0.1	0.5	0.0	0.5	0.0	0.5	0.5	2.2
E. Jurassic **IKU82-4 6.0 m**	0.4	0.3	0.5	0.6	85	5.8	1.4	0.5	0.0	0.0	5.9	0.0	0.0	0.0
L. Triassic **IKU82-4 8.05 m**	0.2	1.6	0.0	1.5	60	0.0	2.0	0.0	0.0	0.0	31.4	3.5	0.0	0.0

Abbreviations: Qtz = quartz, Kfs = K-feldspar, Plg = plagioclase, Chl = chlorite, Kao = kaolinite, Mic/ill = mica/illite, Sm = smectite, Cc = calcite, Dol/ank = dolomite/ankerite, Sid = siderite, Pyr = pyrite, Gy = gypsum, Am = amphibole.

Core 6710/03-U-01, uppermost Triassic

SEM analysis was performed on a polished thin section of mottled, kaolinitic mudstone with siderite cloths and scattered, variably dissolved quartz grains (161.55 m, Fig. 11). The analysis confirms the presence of diagenetic siderite cloths in a matrix of kaolinitic clay. Other heavy minerals include pyrite, zircon and monazite. Fe-oxides were not observed.

Core IKU82-4, Upper Triassic and Lower Jurassic mudstone

Magnetic susceptibility values in the range of 150-3000x10^{-6} SI were measured on the mudstones section below and above the Lower Jurassic unconformity in core IKU82-4. Semiquantitative XRD analyses of the bulk composition are shown in Table 5. These mudstones are very kaolinitic and display characteristic red-brown spots of siderite cement. XRD analyses confirm the presence of minor or trace amounts of pyrite. Supplementary studies were made by heavy liquid separation, elimination of siderite by dissolution in warm HCl and SEM analyses of the concentrated heavy mineral fractions (samples 6 m and 8.05 m). In addition, SEM analyses were also performed on polished thin section of the sandy, mottled sample at 8.05 m (Upper Triassic). Finally, XRD analyses was performed on a heavy mineral fraction of the same sample.

The SEM image (Fig. 12) illustrates the occurrence of the diagenetic siderite cloths within a fine-grained kaolinite dominated matrix. Light patches within the siderite consist of pyrite, whereas the nearly invisible light spots in the matrix include both pyrite and detrital heavy minerals like zircon and rutile. SEM analyses of the heavy mineral concentrates confirm the presence of zircon, Ti-oxide (possible rutile), pyrite, zircon, Ti-Fe oxide and barite. The Ti-Fe oxides are enriched in Ti relative to Fe. The XRD spectrum of the heavy mineral fraction shows the presence of pyrite, siderite and kaolinite. It can neither be excluded nor proven that magnetite is present due to complex peak overlaps. Haematite and goethite are not present.

6814/04-U-02, 36.75 m, Lower Cretaceous mudstone

The sample is cemented by massive, microsparitic aggregates of carbonate. SEM polished thin section analysis shows the carbonate cement to have an Mg-rich, Ca-bearing sideritic composition (possible ankerite, Fig. 13). Detrital grains of plagioclase are occasionally preserved within the cement and question a volcanic origin for the fine-grained sediment. A few skeletal, very small pyrite grains have also been observed.

B82-180/2, 2 m, Quaternary clay

One sample was selected from an interval with magnetic susceptibility values of $2500x10^{-6}$. Semiquantitative, bulk-rock XRD analysis shows the composition to be rich in quartz, plagioclase, K-feldspar, and mica/illite. Fe-bearing minerals such as chlorite, dolomite/ankerite, pyrite and amphibole are present in very small amounts. SEM analyses of heavy liquid separates of the 63-125 and 45-63 µm fractions were performed. The heavy mineral compositions include both Fe-oxide, Fe-Ti oxide, pyrite, zircon, monazite and rutile. Quantitative analyses of the Fe-oxides are generally associated with oxide sums below 90%, which reflects either that the analyses are not optimal due to topographic effects (this preparate was powder, not a polished thin section), or that the composition is haematite rather than magnetite. The EDS spectra indicate that the Fe-Ti oxides have different compositions and may include both ilmenite, altered Ti-enriched phases and Ti-bearing haematite or magnetite.

XRD analysis of the heavy fraction shows a complex spectrum with extensive peak overlap. Peaks which fit with minerals such as ilmenite, pyrrhotite, magnetite and haematite are present, but due to the peak overlaps, the presence of the different minerals cannot be proven. Amphibole and dolomite are positively identified.

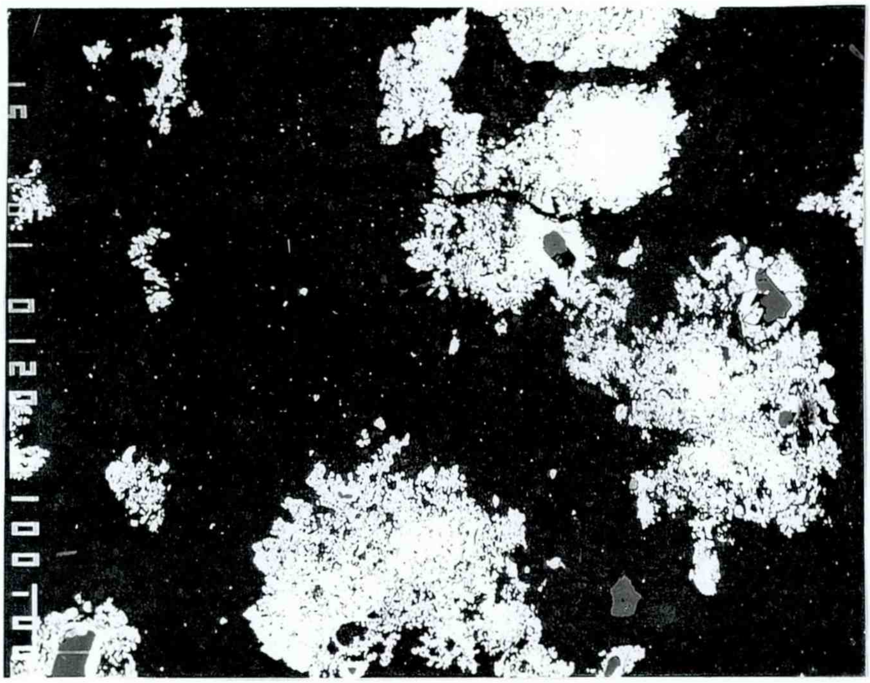


Fig. 11 *SEM BEI of diagenetic siderite cement (light colour) in kaolitic sandy mudstone (dark) from core 6710/03-U-01, 161.55 m.*

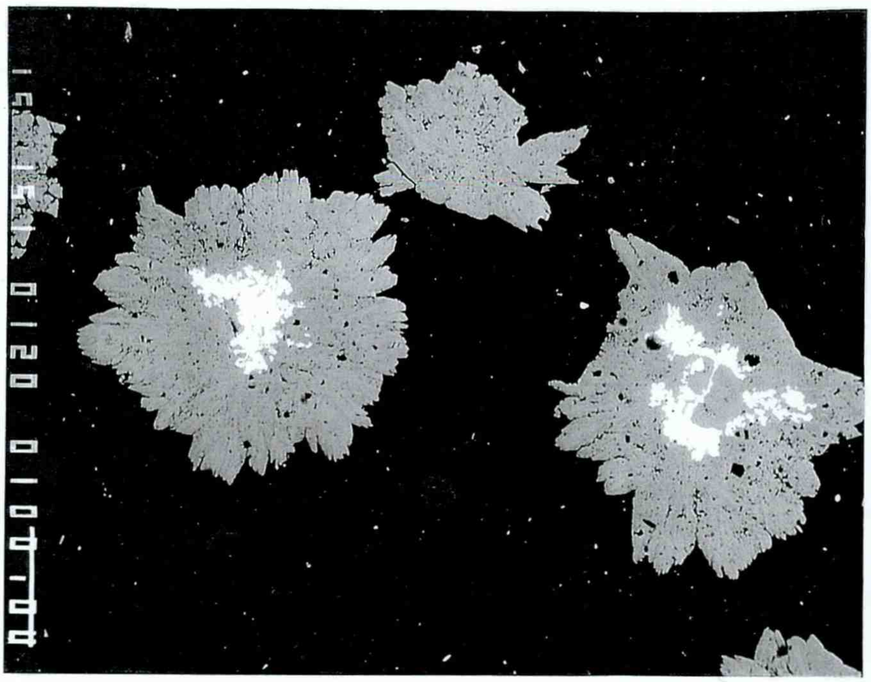


Fig. 12 *SEM BEI of diagenetic siderite cement "flowers" (light grey colour) in a kaolitic mudstone matrix (dark), core IKU82-4, 8.05 m. The light grains in the central part of the siderite grains are pyrite. The very small light grains in the matrix are zircon and Ti-minerals.*

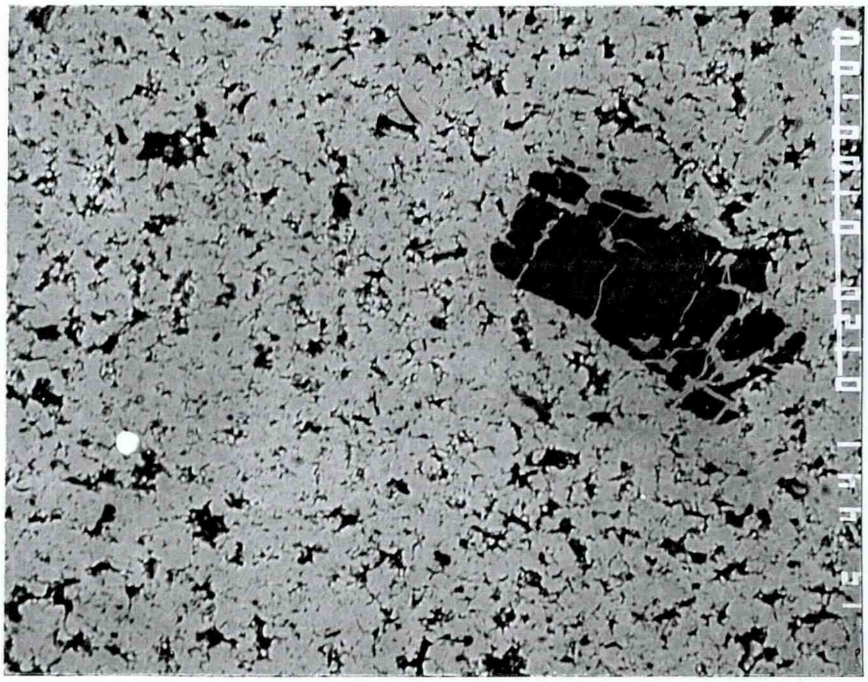


Fig. 13 *SEM BEI of carbonated cemented mudstone (?former ash) from core 6814/04-U-02, 36.75 m. The carbonate (light grey, main mineral) is sideritic to ankeritic in composition. The very small light grain is pyrite, whereas the dark grain is a partly dissolved, detrital plagioclase grain.*

7. SUMMARY AND CONCLUSION

The frequency distributions of the magnetic susceptibility measurements of the shallow cores are generally wide and span one or two orders of magnitude. Quartz sandstone has a generally lower susceptibility than mudstone, siltstone and claystone, 50-300x10^{-6} SI versus 150-600x10^{-6} SI. However, the results from the different units illustrate that the susceptibilities of the sandstones and claystones depend on factors like compositional maturity, provenance and cementation/diagenesis.

The sandstones off Helgeland and Lofoten show an increase in mineralogical maturity from the Triassic cores to the Middle Jurassic cores. The susceptibility of the Middle Jurassic quartz-rich, mature sandstones is very low (10-130x10^{-6} SI in cores IKU82-10 and -11, 6710/03-U-01 and 6814/04-U-01). This is comparable with on land data on metamorphic quartzites. The immature (feldspathic) Triassic sandstones have somewhat higher susceptibility values which is similar for sandstones and interbedded mudstones and this corresponds to the susceptibility of metamorphic micaschist - metawacke equivalents on land.

The effect of provenance is best documented by the Triassic sediments. Moderately low susceptibility values of the continental debris (core 6710/03-U-03) off Lofoten reflect the low susceptibility of the adjacent granitic basement gneiss (100-620x10^{-6} SI) that acted as a sediment source (Fig. 10). The Triassic sediments off Helgeland display somewhat higher susceptibility values. The onshore gneiss samples from Lofoten showed a large range in susceptibility, and the cored basement at 6710/03-U-03 compares with the onshore values with lowest susceptibility.

The Upper Triassic - Lower Jurassic section with alternating sandstones and mudstones shows a considerable range in susceptibility (10-3000x10^{-6} SI), and the high values are recorded in "red beds" and mottled, siderite cemented sandstones and mudstones (including root beds and caliche) in cores IKU82-4, 6710/03-U-01 and -U-02. The high content of siderite is a possible source of the high susceptibility. In core IKU82-4 siderite and minor pyrite has formed diagenetically by reduction of iron oxides. It cannot be completely ruled out that Fe-oxides have contributed to the susceptibility, but they were not detected in the studied preparates.

The mudstones show a somewhat larger range in magnetic susceptibility than the sandstones (Fig. 2), and the most susceptible samples were measured in the Cretaceous claystone section off Lofoten. The highest values were always detected in siderite-cemented beds and nodules (1000-3000x10^{-6} SI) in all the three cores of Lower and Upper Cretaceous age. The non-cemented or calcite-cemented intervals, which make up most of the cores, have susceptibility values one magnitude lower. The susceptibility of the total section is thus dependent on the content and distribution of siderite-cemented beds and nodules. Other Fe-rich minerals present which may contribute to the high susceptibility within these siderite cemented beds are goethite and haematite (6710/03-U-01) and pyrite ± Fe-Ti oxide (6814/04-U-02, 6711/04-U-01).

High susceptibility values 1060-2500x10^{-6} SI are also found in glaciomarine clay from the sampling stations off Helgeland (B82-180 and B82-190), whereas the other Quaternary samples have much lower values. The high susceptibility values of the glaciomarine clay reflects the presence of magnetite and/or haematite, Ti-Fe oxide and pyrite; pyrrhotite may also be present.

In conclusion, the susceptibility distribution of the sediments from the shallow cores is comparable with the susceptibility of the metamorphosed paramagnetic equivalents on land (e.g. the metasediments within the Rødingsfjell Nappe Complex (Fig. 7)). Ferro-magnetic meta-sediments in the crystalline basement on the mainland may, however, have more than two orders of magnitude higher susceptibilities than the paramagnetic equivalents.

The bulk of the sediments on the continental shelf are characterised by diamagnetic or paramagnetic behaviour, or a combination of both. However, units of the stratigraphy also contain ferromagnetic minerals. The susceptibility values of the sediments vary between -20 and $6000x10^{-6}$ SI. Quartz sandstones have lower susceptibilities than mudstone, shale and crystalline basement. However, red-coloured sandstones often have higher susceptibilities than other kinds of sediments within the NAS-94 area, and can be as high as $1000x10^{-6}$ SI. The highest susceptibility recorded in bedrock lithologies was encountered in siderite cemented clay- and siltstones of Cretaceous age: up to $4000x10^{-6}$ SI. These cemented zones occur in 5-20 cm-wide sections in the IKU cores and seem locally to be associated with small-scale faulting. Caliche, a lithified desert soil formed by the near surface crystallisation of calcite and/or other soluble minerals by upward-moving solutions, has intermediate susceptibilities reaching $1000x10^{-6}$ SI.

The Quaternary overburden, especially glaciomarine clay, has even higher susceptibilities than the underlying sedimentary rocks. The source of these Quaternary sediments is partly magnetic crystalline basement rocks on mainland Norway.

8. ACKNOWLEDGEMENTS

The NAS-94 Project was financed by Mobil Exploration, Norsk Hydro, Statoil and the Geological Survey of Norway. Svein Gjelle, Ingvar Lindahl, August Nissen and Øystein Nordgulen provided bedrock samples from the coastal area of Nordland. Finn Ove Pettersen and Hans Rendal assisted during the petrophysical laboratory measurements. The mineralogical analysis was assisted by Unni M. Wang and Reidar Bøe (XRD analysis) and Sølvi Stene and Tony Boassen (mineral separation and SEM analysis). Dr. Elizabeth Eide read the report and made suggestions towards its improvements. We express our sincere thanks to these persons and institutions.

9. REFERENCES

Dalland, A., Augedahl, H.O., Bomstad, K. & Ofstad, K., 1988: The post-Triassic succession of the Mid-Norwegian Shelf. In: Dalland, A., Worsley, D. and Ofstad, K. (eds.): A lithostratigraphic scheme for the Mesozoic succession offshore mid and northern Norway. *NPD-Bull. 4,* 5-42.

Dearing, J. 1994: *Environmental Magnetic Susceptibility, Using the Bartington MS2 System.* Bartington Instruments Ltd., Oxford, 102 pp.

Gustavson, M. 1981: Geologisk kart over Norge. Berggrunnskart MOSJØEN, M. 1:250 000. *Norges geologiske undersøkelse.*

Gustavson, M. & Gjelle, S.T. 1991: Geologisk kart over Norge. Berggrunnskart MO I RANA, M. 1:250 000. *Norges geologiske undersokelse.*

Gustavson, M. & Blystad, P. in press: Geologisk kart over Norge. Berggrunnskart BODØ, M. 1:250 000. *Norges geologiske undersokelse.*

Gustavson, M. & Bugge, T. in press: Geologisk kart over Norge. Berggrunnskart VEGA, M. 1:250 000. Norges geologiske undersokelse.

Hansen, J.W., Bakke, S., Fanavoll, S., Loseth, H., Mørk, A., Mork, M.B.E., Rise, L., Smelror, M., Verdenius, J.G., Vigran, J.O. & Weiss, H.M., 1992: Shallow Drilling Nordland VI and VII. Main Report. *IKU Report 23.1594.00/02/92,* Restricted, 390 pp.

Kihle, O. 1992: THEMAP - et Uniras-basert produksjonssystem for fargerasterkart. *NGU Internal Report 92.068,* 172 pp.

Midtun, R. 1988: Regional geofysisk og geologisk tolkning av Hogtuva- og Sjona-grunnfjellsvinduene. *NGU Report 88.127,* 77 pp.

Mørk, A., Aarhus, N., Bugge, T., Mills, N., 1983: Shallow Drilling off Helgeland 1982. *IKU Report P248/1/83,* Restricted.

Mørk, M.B. & Olesen, O. 1995: Magnetic susceptibility of sedimentary rocks from shallow cores off Mid Norway and crystalline rocks from adjacent onland areas NAS-94 Interpretation Report Part II: Petrophysical data. *NGU Report 95.039,* 68 pp.

Nordgulen, Ø. 1993: The Caledonian Bindal Batholith: regional setting based on geological, geochemical and isothopic data. *Dr. Scient. Thesis, Univ. of Bergen,* 143 pp.

Olesen, O., Henkel, H., Kaada, K. & Tveten, E. 1991: Petrophysical properties of a prograde amphibolite - granulite facies transition zone at Sigerfjord, Vesterålen, Northern Norway. In: P. Wasilewski & P. Hood (Eds.). Magnetic anomalies - land and sea. Tectonophysics 192, 33-39.

Olesen, O., Reitan, M. & Sæther, P.O. 1993: Petrofysisk database, PETBASE 3.0, Brukerbeskrivelse. *NGU Report 93.023,* 74 pp.

Olesen, O. & Torsvik, T.H. 1993: Interpretation of aeromagnetic and gravimetric data from the Lofoten-Lopphavet area. *NGU Report 93.032,* Restricted, 77 pp.

Olesen, O. & Smethurst, M.A. 1994: NAS-94 Interpretation Report: Part I: Aeromagnetic data. *NGU Report 94.074,* 44 pp.

Olesen, O. & Smethurst, M.A. 1995: NAS-94 Interpretation Report: Part III: combined interpretaion of aeromagnetic and gravity data. *NGU Report 95.040,* 50 pp.

Pettijohn, F.J., Potter, P.E. & Siever, R., 1972: *Sand and sandstone.* Springer-Verlag, New York - Heidelberg - Berlin, 618 pp.

Reynolds, R.L., Tuttle, L., Rice, C.A., Fishman, N.S., Karachewski, J.A. & Sherman, D.M. 1994: Magnetization and geochemistry of greigite-bearing Cretaceous strata, North Slope Basin, Alaska. *Am. Jour. of Science 294,* 485-528.

Schlinger, C. M. 1985: Magnetization of lower crust and interpretation of regional magnetic anomalies: Example from Lofoten and Vesterålen, Norway. *J. Geophys. Res. 90,* 11484-11504.

Skarbø, O., Bugge, T., Knarud, R. & Aarhus, N., 1983: Mapping of Mesozoic rocks off Helgeland, Northern Norway. *IKU Report P277/2/83,* Restricted

Skilbrei, J.R. 1988: Geophysical interpretation of the Fosen-Namsos Western Gneiss Region and northern part of the Trondheim Region Caledonides, Central Norway. *Nor. geol. unders. Spec. Publ. 3,* 70-79.

Skilbrei, J.R., Skyseth, T. & Olesen, O. 1991: Petrophysical data and opaque mineralogy of high-grade and retrogressed lithologies: implications for the interpretation of aeromagnetic anomalies in Northern Vestranden, Central Norway. *In:* P. Wasilewski & P. Hood (Eds.). Magnetic anomalies – land and sea. *Tectonophysics 192,* 21-31.

Solli, A., Bugge, T. & Thorsnes, T. in press: Geologisk kart over Norge. Berggrunnskart NAMSOS, M. 1:250 000. *Norges geologiske undersøkelse.*

Telford, W.M., Geldart, L.P., Sheriff, R.E. & Keys, D.A. 1976: *Applied Geophysics.* Cambridge University Press, Cambridge. Cambridge. 860 pp.

Thompson, R. & Oldfield, F. 1986: *Environmental magmatism.* Allen & Unwin, London. 227 pp.

Torsvik, T.H. & Olesen, O. 1988: Petrophysics and Palaeomagnetism initial report of the Norwegian Geological Survey Laboratory. *NGU Rapport 88.171,* 108 pp.

Torsvik, T.H. & Olesen, O. 1992: IMPPET - Petrophysical database system. *NGU Report 92.275,* 35 pp.

Vigran, J.O., Mork, M.B.E. & Bugge, T., 1994: The Mesozoic - Cenozoic succession off Helgeland - an updating based on Shallow Drilling Helgeland 1982 and related studies. *IKU Report 23.2525.00/01/94,* Restricted, 141 pp.

APPENDIX A, 8 pages

Susceptibility measurements on cores from IKU shallow drilling programme.

Lithologic codes:

S00	Conglomerate	S61	Till
S13	Sandstone	S62	Gravel
S21	Mudstone	S63	Sand
S22	Claystone	S64	Silt
S31	Coal	S65	Mud
S41	Chalk	S66	Clay
S48	*Gypsum*		

X	Red-coloured sediments
Y	Calcite-cemented sediments
*	Sample for laboratory measurements

Stratigraphic codes:

PLE	Pleistocene	UJU	Upper Jurassic
OLI	Oligocene	MJU	Middle Jurassic
PAL	Palaeocene	LJU	Lower Jurassic
UCR	Upper Cretaceous	LTR	Lower Triassic
LCR	Lower Cretaceous		

Appendix A, page 2.

Susceptibility measurements on cores from IKU shallow drilling programme.

Well No.	Sample No.	UTM zone	UTM-coord. 10 m		Lit. code	Strat. code	Rock type	Suscept. SI	Depth m
67103-1	1	32	58249	752257	S66	PLE	Clay, dark	0.00013	8.6
67103-1	2	32	58249	752257	S22	PLE	Clayst. dark	0.00031	15.0
67103-1	3	32	58249	752257	S22	PLE	Clayst. dark, thin	0.00125	15.7
67103-1	4	32	58249	752257	S22	LCR	Background", clayst.	0.00056	20.0
67103-1	5	32	58249	752257	M23	LCR	Carb. cem. nodule	0.00125	24.3
67103-1	6	32	58249	752257	M23	LCR	*Cemented nodule	0.00144	25.4
67103-1	7	32	58249	752257	M23	LCR	Clayst., carb. cem.?	0.00069	27.2
67103-1	8	32	58249	752257	S22	LCR	Clayst. brownish	0.00025	29.0
67103-1	9	32	58249	752257	S22	LCR	Clayst. reddish	0.00069	31.1
67103-1	10	32	58249	752257	M23	LCR	*Carb. cem., br. bed	0.00169	34.0
67103-1	11	32	58249	752257	M23	LCR	Carb. bed?	0.00081	34.3
67103-1	12	32	58249	752257	S22	LCR	Light clayst.	0.00031	38.4
67103-1	13	32	58249	752257	M23	LCR	*Light crb. cem. bed	0.00156	40.1
67103-1	14	32	58249	752257	S22	LCR	Grey clayst..	0.00025	44.5
67103-1	15	32	58249	752257	S22	LCR	Clayst.	0.00025	46.0
67103-1	16	32	58249	752257	M23	LCR	Yellowish concretion	0.00075	49.4
67103-1	17	32	58249	752257	S22	LCR	Grey clayst.	0.00019	53.3
67103-1	18	32	58249	752257	M23	LCR	Yellowish concretion	0.00088	57.0
67103-1	19	32	58249	752257	S22	LCR	Clayst.	0.00019	57.1
67103-1	20	32	58249	752257	M23	LCR	Carb. cem. bed, yel.	0.00088	60.2
67103-1	21	32	58249	752257	S22	LCR	"Background" clayst.	0.00025	60.3
67103-1	22	32	58249	752257	S22	LCR	clayst	0.00019	63.5
67103-1	23	32	58249	752257	M23	LCR	Carb.cem.mult.phases	0.00200	68.0
67103-1	24	32	58249	752257	S22	LCR	Clayst.	0.00025	72.0
67103-1	25	32	58249	752257	M23	LCR	Br. carb.concretions	0.00112	72.4
67103-1	26	32	58249	752257	M23	LCR	*Carb. concretion	0.00175	74.0
67103-1	27	32	58249	752257	M23	LCR	Carbonate concretion	0.00100	74.5
67103-1	28	32	58249	752257	S22	LCR	Clayst.	0.00027	77.4
67103-1	29	32	58249	752257	M23	LCR	Carbonate bed	0.00187	81.5
67103-1	30	32	58249	752257	M23	LCR	Yell. carbonate bed	0.00137	98.5
67103-1	31	32	58249	752257	S22	LCR	Clayst.	0.00112	112.8
67103-1	32	32	58249	752257	M23	LCR	Clay, carb concr.	0.00225	116.0
67103-1	33	32	58249	752257	M23	LCR	Carbonate concretion	0.00163	125.0
67103-1	34	32	58249	752257	S13	MJU	Sandst.	0.00001	137.8
67103-1	35	32	58249	752257	S13	LJU		0.00004	152.0
67103-1	36	32	58249	752257	S13	LJU	Grey	0.00019	153.0
67103-1	37	32	58249	752257	S28	LJU	Grey siltst.	0.00005	153.4
67103-1	38	32	58249	752257	S21	LJU	Mudst.	0.00013	153.6
67103-1	39	32	58249	752257	S13	LJU	Brownish?cem.sandst.	0.00050	156.4
67103-1	40	32	58249	752257	S13	LJU	Sandst.	0.00013	158.2
67103-1	41	32	58249	752257	M23	LJU	*?Siderite cemented	0.00100	162.0
67103-1	42	32	58249	752257	M23	LJU	Brownish cem.sandst.	0.00038	162.2
67103-1	43	32	58249	752257	S13	LJU	Grey, lam. sandst.	0.00006	163.5
67103-1	44	32	58249	752257	M26	LJU	Scattered caliche	0.00125	162.4
67103-1	45	32	58249	752257	S13	LJU	Sandst.	0.00002	165.0
67103-1	46	32	58249	752257	S13	LJU	Sandst.	0.00004	166.3
67103-1	47	32	58249	752257	S13	LJU	Sandst.	0.00062	167.7
67103-1	48	32	58249	752257	S13	LJU	Grey sandst.	0.00013	168.0
67103-1	49	32	58249	752257	S13	LJU	White sandst.	0.00002	168.2
67103-1	50	32	58249	752257	S13	LJU	Light sandst.	0.00031	170.6
67103-1	51	32	58249	752257	S21	LJU	Dark mudst.	0.00006	171.8
67103-1	52	32	58249	752257	M26	LJU	Caliche/mottl.mudst.	0.00038	173.7
67103-1	53	32	58249	752257	M26	LJU	Caliche/mottl.mudst.	0.00100	174.6
67103-1	54	32	58249	752257	M26	LJU	Caliche/mottl.mudst.	0.00075	175.0
67103-1	55	32	58249	752257	S21	LJU	Reddish/yell.mudst.	0.00075	175.5
67103-1	56	32	58249	752257	M26	LJU	Caliche	0.00062	176.0
67103-1	57	32	58249	752257	M26	LJU	Caliche, red mudst.	0.00013	177.0
67103-1	58	32	58249	752257	M26	LJU	Caliche/mott.mudst.	0.00013	177.3
67103-1	59	32	58249	752257	S22	LJU	Reddish clayst.	0.00050	178.1
67103-1	60	32	58249	752257	S22	LJU	Clayst.	0.00025	178.7
67103-1	61	32	58249	752257	M26	LJU	Mottl. yell.red mud.	0.00088	178.9
67103-1	62	32	58249	752257	S21	LJU	Mudst.	0.00013	179.5
67103-1	63	32	58249	752257	S13	LJU	White sandst.	0.00001	180.4
67103-1	64	32	58249	752257	S21	LJU	Dark mudst.	0.00006	181.1
67103-1	65	32	58249	752257	S13	LJU	Sandst.w.kaol.grains	0.00001	182.1
67103-1	66	32	58249	752257	S13	LJU	Sandst.	0.00038	183.7
67103-1	67	32	58249	752257	M26	LJU	Brownish sand/mudst.	0.00069	184.5
67103-1	68	32	58249	752257	M26	LJU	Yellowish, mottled	0.00025	186.0
67103-1	69	32	58249	752257	S21	LJU		0.00009	191.1

Appendix A, page 3.

Susceptibility measurements on cores from IKU shallow drilling programme.

Well No.	Sample No.	UTM zone	UTM-coord. 10 m		Lit. code	Strat. code	Rock type	Suscept. SI	Depth m
67103-1	70	32	58249	752257	M26	LJU	Mottled	0.00014	192.0
67103-1	71	32	58249	752257	S21	LJU	Reddish mudst.	0.00013	193.4
67103-2	1	32	57566	753222	S65	PLE	Dark mud	0.00044	17.0
67103-2	2	32	57566	753222	S64	PLE	Light ?silt	0.00006	20.7
67103-2	3	32	57566	753222	S13	LJU	Sandst.	0.00005	81.0
67103-2	4	32	57566	753222	S13	LJU	Dark strata	0.00004	86.0
67103-2	5	32	57566	753222	S13	LJU	Light sandst.	0.00001	86.3
67103-2	6	32	57566	753222	S13	LJU	Yellow sandst.	0.00088	89.7
67103-2	7	32	57566	753222	S21	LJU	Dark mudst.	0.00016	90.3
67103-2	8	32	57566	753222	S13	LJU	White, cem. sandst.	0.00013	101.8
67103-2	9	32	57566	753222	S21	LJU	Darker clayey strata	0.00025	101.9
67103-2	10	32	57566	753222	S13	LJU	Lighter strata	0.00010	101.9
67103-2	11	32	57566	753222	S13	LJU	White, cem. sandst.	0.00011	102.5
67103-2	12	32	57566	753222	S13	LJU	?Sandst.	0.00021	103.8
67103-2	13	32	57566	753222	S22	LJU	Dark clayst.	0.00044	106.4
67103-2	14	32	57566	753222	S22	LJU	Dark clayst.	0.00013	110.5
67103-2	15	32	57566	753222	S31	LJU	Coal	0.00001	112.0
67103-2	16	32	57566	753222	S22	LJU	Light clayst.	0.00006	113.8
67103-2	17	32	57566	753222	S22	LJU	Lam. clayst.	0.00013	116.5
67103-2	18	32	57566	753222	M23	LJU	Thin carbonate bed	0.00050	124.4
67103-2	19	32	57566	753222	S13	LJU	Lam. sandst.	0.00100	126.3
67103-2	20	32	57566	753222	S13	LJU	Light sandst.	0.00008	127.6
67103-2	21	32	57566	753222	M23	LJU	Yellow carb.concr.	0.00050	127.8
67103-3	1	32	58410	752794	S21	LTR	Grey/reddish mudst.	0.00036	3.0
67103-3	2	32	58410	752794	S21	LTR	Lam.mudst. br./grey	0.00040	4.9
67103-3	3	32	58410	752794	S21	LTR	Lam. mudst.	0.00039	6.4
67103-3	4	32	58410	752794	S21	LTR	Lam. mudst.	0.00044	7.9
67103-3	5	32	58410	752794	S21	LTR	Lam. mudst.	0.00038	8.7
67103-3	6	32	58410	752794	S21	LTR	Lam. mudst.	0.00036	18.4
67103-3	7	32	58410	752794	S21	LTR	Lam. mudst.	0.00038	19.6
67103-3	8	32	58410	752794	S21	LTR	Greenish mudst.	0.00025	20.7
67103-3	9	32	58410	752794	S21	LTR	Mudst. with sand	0.00017	23.0
67103-3	10	32	58410	752794	S13	LTR	Sandst.	0.00008	26.0
67103-3	11	32	58410	752794	S21	LTR	Green mudst.	0.00044	29.3
67103-3	12	32	58410	752794	S21	LTR	Lam. green mudst.	0.00038	29.7
67103-3	13	32	58410	752794	S21	LTR	Brownish mass.mudst.	0.00068	31.4
67103-3	14	32	58410	752794	S21	LTR	Brownish mudst.lam.	0.00049	31.5
67103-3	15	32	58410	752794	S21	LTR	Lam. mudst.	0.00039	32.5
67103-3	16	32	58410	752794	S13	LTR	Sandst.	0.00006	35.3
67103-3	17	32	58410	752794	S21	LTR	Mudst.	0.00038	36.5
67103-3	18	32	58410	752794	S21	LTR	Lam. sandst/mudst.	0.00024	37.0
67103-3	19	32	58410	752794	S21	LTR	Mudst.	0.00031	37.6
67103-3	20	32	58410	752794	S13	LTR	Sandst.	0.00024	38.4
67103-3	21	32	58410	752794	S21	LTR	Mudst.	0.00026	38.7
67103-3	22	32	58410	752794	S21	LTR	Lam. mudst.	0.00025	41.8
67103-3	23	32	58410	752794	S21	LTR	Lam. mudst.	0.00027	43.2
67103-3	24	32	58410	752794	S21	LTR	Lam. mudst.	0.00024	45.1
67103-3	25	32	58410	752794	S21	LTR	Redbrown mudst.	0.00060	46.5
67103-3	26	32	58410	752794	S21	LTR	Lam. mudst.	0.00033	47.6
67103-3	27	32	58410	752794	S21	LTR	Brownish mudst.	0.00025	49.8
67103-3	28	32	58410	752794	S13	LTR	Lam. sandst.	0.00024	51.0
67103-3	29	32	58410	752794	S21	LTR	Dark mudst.	0.00025	51.2
67103-3	30	32	58410	752794	S13	LTR	Mica-r.sandst/mudst.	0.00019	55.7
67103-3	31	32	58410	752794	S21	LTR	Dark mudst.	0.00025	56.0
67103-3	32	32	58410	752794	S13	LTR	Mica-r.lamin.sandst.	0.00017	56.7
67103-3	33	32	58410	752794	S13	LTR	Mica-r.lamin.sandst.	0.00020	57.7
67103-3	34	32	58410	752794	S13	LTR	Mica lamina	0.00006	59.2
67103-3	35	32	58410	752794	S13	LTR	Mica-rich sandst.	0.00016	60.5
67103-3	36	32	58410	752794	S13	LTR	Very coarse sandst.	0.00004	63.7
67103-3	37	32	58410	752794	S21	LTR	Green mudst.	0.00029	65.4
67103-3	38	32	58410	752794	M23	LTR	Br. mud, ?carb. cem.	0.00069	66.1
67103-3	39	32	58410	752794	S21	LTR	Darker, muddy int.	0.00021	67.6
67103-3	40	32	58410	752794	S21	LTR	Greygreen mudst.	0.00031	67.8
67103-3	41	32	58410	752794	S21	LTR	Green.mudst./l. sand	0.00044	69.0
67103-3	42	32	58410	752794	S22	LTR	Redbrown clayst.	0.00029	71.1
67103-3	43	32	58410	752794	S22	LTR	Redbrown clayst.	0.00026	74.2
67103-3	44	32	58410	752794	S22	LTR	Redbrown clayst.	0.00024	74.8
67103-3	45	32	58410	752794	S22	LTR	Greenish clayst.	0.00016	75.6
67103-3	46	32	58410	752794	S21	LTR	Redbrown mudst.	0.00029	75.9

Appendix A, page 4.

Susceptibility measurements on cores from IKU shallow drilling programme.

Well No.	Sample No.	UTM zone	UTM-coord. 10 m		Lit. code	Strat. code	Rock type	Suscept. SI	Depth m
67103-3	47	32	58410	752794	S21	LTR	Greenish mudst.	0.00015	76.5
67103-3	48	32	58410	752794	S21	LTR	Redbrown mudst.	0.00031	78.2
67103-3	49	32	58410	752794	S21	LTR	Redbrown mudst.	0.00030	81.4
67103-3	50	32	58410	752794	S13	LTR	Wh. sandst. coarse	0.00006	83.3
67103-3	51	32	58410	752794	S13	LTR	Greenish sandst.	0.00019	84.4
67103-3	52	32	58410	752794	S13	LTR	Redbrown interval	0.00039	85.2
67103-3	53	32	58410	752794	S13	LTR	Grey sandst.	0.00024	89.5
67103-3	54	32	58410	752794	S13	LTR	Light grey sandst.	0.00010	89.8
67103-3	55	32	58410	752794	S13	LTR	Greenish+brown lam.	0.00025	90.0
67103-3	56	32	58410	752794	S13	LTR	Lightest	0.00009	91.0
67103-3	57	32	58410	752794	S13	LTR	White sandst.	0.00002	92.6
67103-3	58	32	58410	752794	S21	LTR	Redbrown mudst.	0.00030	93.6
67103-3	59	32	58410	752794	S13	LTR	Light sandst.	0.00024	94.5
67103-3	60	32	58410	752794	S13	LTR	White sandst.	0.00006	95.5
67103-3	61	32	58410	752794	S13	LTR	Light sandst.	0.00006	100.0
67103-3	62	32	58410	752794	S13	LTR	Sandst.	0.00002	101.8
67103-3	63	32	58410	752794	S21	LTR	Redbrown mudst.	0.00038	102.6
67103-3	64	32	58410	752794	S13	LTR	Light sandst.	0.00006	103.8
67103-3	65	32	58410	752794	S21	LTR	Greenish mudst.	0.00024	104.9
67103-3	66	32	58410	752794	S13	LTR	Coarse sandst.	0.00004	107.3
67103-3	67	32	58410	752794	S13	LTR	Coarse sandst.	0.00010	109.1
67103-3	68	32	58410	752794	S21	LTR	Lam. interval	0.00026	109.4
67103-3	69	32	58410	752794	S21	LTR	Redbrown mudst.	0.00031	111.3
67103-3	70	32	58410	752794	S21	LTR	Greenish mudst.	0.00025	112.0
67103-3	71	32	58410	752794	S13	LTR	White sandst.	0.00006	113.0
67103-3	72	32	58410	752794	S13	LTR	Sandst.	0.00019	114.2
67103-3	73	32	58410	752794	S00	LTR	Cgl/v.coarse sandst.	0.00005	114.7
67103-3	74	32	58410	752794	S21	LTR	Green mudst.	0.00029	114.8
67103-3	75	32	58410	752794	S21	LTR	Redbr./green mudst.	0.00025	115.0
67103-3	76	32	58410	752794	S13	LTR	Lam. fine sandst.	0.00036	118.3
67103-3	77	32	58410	752794	S00	LTR	Conglomerate	0.00006	119.8
67103-3	78	32	58410	752794	S21	LTR	Mica-rich mudst.	0.00034	119.9
67103-3	79	32	58410	752794	S13	LTR	Lam. sandst/green mu	0.00025	122.8
67103-3	80	32	58410	752794	S21	LTR	Lam. mudst/sandst.	0.00026	126.2
67103-3	81	32	58410	752794	S00	LTR	Congl. feldspar rich	0.00006	127.0
67103-3	82	32	58410	752794	S21	LTR	Reddish mudst. + san	0.00027	129.4
67103-3	83	32	58410	752794	S21	LTR	Reddish mudst.	0.00021	130.0
67103-3	84	32	58410	752794	S21	LTR	Grey conglomerate	0.00006	132.2
67103-3	85	32	58410	752794	S21	LTR	Lam. red, green muds	0.00016	133.4
67103-3	86	32	58410	752794	S00	LTR	Coarse congl. hetero	0.00009	138.4
67103-3	87	32	58410	752794	S00	LTR	Coarser conglomerate	0.00006	140.0
67103-3	88	32	58410	752794	S00	LTR	Conglomerate, darker	0.00019	140.9
67103-3	89	32	58410	752794	S00	LTR	Red coarse congl.	0.00024	141.8
67103-3	90	32	58410	752794	S00	LTR	Coarse feldspar auge	0.00013	144.2
67103-3	91	32	58410	752794	S00	LTR	Congl. granite gr.	0.00009	145.1
67103-3	92	32	58410	752794	S00	LTR	Congl. with red matr	0.00010	145.5
67103-3	93	32	58410	752794	S00	LTR	Conglomerate	0.00006	148.1
67103-3	94	32	58410	752794	S00	LTR	Congl.	0.00008	151.5
67103-3	95	32	58410	752794	S00	LTR	Congl.	0.00009	154.3
67103-3	96	32	58410	752794	S00	LTR	Cgl. brown matrix	0.00006	156.2
67103-3	97	32	58410	752794	S00	LTR	Cgl.	0.00006	156.6
67103-3	98	32	58410	752794	S00	LTR	Cgl.	0.00014	158.2
67103-3	99	32	58410	752794	S00	LTR	Cgl. light matrix	0.00005	161.2
67103-3	100	32	58410	752794	S00	LTR	Conglomerate	0.00006	163.0
67103-3	101	32	58410	752794	S00	LTR	Cgl.	0.00009	167.3
67103-3	102	32	58410	752794	M07	PLO	Augengneiss	0.00010	168.6
67103-3	103	32	58410	752794	M07	PLO	Augengneiss	0.00031	169.0
67103-3	104	32	58410	752794	I60	PLO	Green altered dyke	0.00025	169.4
67103-3	105	32	58410	752794	I60	PLO	Dark "blackwall"	0.00062	170.0
67103-3	106	32	58410	752794	M07	PLO	Augengneiss	0.00016	171.4
67103-3	107	32	58410	752794	M07	PLO	Augengneiss	0.00009	172.6
67114-1	1	32	58918	751522	S61	PLE	Till	0.00100	8.4
67114-1	2	32	58918	751522	S63	PLE	Sand	0.00025	11.4
67114-1	3	32	58918	751522	S65	PLE	Sandy mud	0.00006	10.3
67114-1	4	32	58918	751522	S28	UCR	Clayey siltst.	0.00013	13.0
67114-1	5	32	58918	751522	S28	UCR	Clayey siltst.	0.00014	15.0
67114-1	6	32	58918	751522	S22	UCR	Clayst.	0.00010	17.0
67114-1	7	32	58918	751522	S22	UCR	Clayst.	0.00011	19.0
67114-1	8	32	58918	751522	S22	UCR	Clayst.	0.00019	21.0
67114-1	9	32	58918	751522	M23	UCR	Carb.cem (calcite)	0.00010	42.0

Appendix A, page 5.

Susceptibility measurements on cores from IKU shallow drilling programme.

Well No.	Sample No.	UTM zone	UTM-coord. 10 m		Lit. code	Strat. code	Rock type	Suscept. SI	Depth m
67114-1	10	32	58918	751522	S22	UCR	Clayst.carb. nodules	0.00014	45.0
67114-1	11	32	58918	751522	S22	UCR	Clayst.carb. nodules	0.00013	47.0
67114-1	12	32	58918	751522	M23	UCR	Carbonate cem. bed	0.00025	48.4
67114-1	13	32	58918	751522	M23	UCR	Carb. cem. bed.	0.00025	56.2
67114-1	14	32	58918	751522	M23	UCR	*Carbonate bed	0.00106	119.7
67114-1	15	32	58918	751522	S22	UCR	Light clayst.	0.00021	120.0
67114-1	16	32	58918	751522	M23	UCR	Brownish, cem. bed	0.00225	128.8
67114-1	17	32	58918	751522	S22	UCR	"Background" clayst.	0.00013	132.0
67114-1	18	32	58918	751522	M23	UCR	Brownish bed	0.00081	134.9
67114-1	19	32	58918	751522	M23	UCR	Carb.cem.yell.brown	0.00082	136.8
67114-1	20	32	58918	751522	S22	UCR	"Background" clayst.	0.00017	137.0
67114-1	21	32	58918	751522	S22	UCR	Lam. clayst.	0.00025	148.0
67114-1	22	32	58918	751522	S22	UCR	Finely lam. clayst.	0.00027	158.0
67114-1	23	32	58918	751522	M23	UCR	Brownish carb.cement	0.00187	158.6
67114-1	24	32	58918	751522	M23	UCR	*Mudst. lam. cem.	0.00132	161.4
67114-1	25	32	58918	751522	M23	UCR	Mudst. lam. cem.	0.00256	161.6
67114-1	26	32	58918	751522	S22	UCR	"Background" clayst.	0.00025	163.0
67114-1	27	32	58918	751522	M23	UCR	Brownish carb.cem.	0.00123	166.0
67114-1	28	32	58918	751522	S22	UCR	Grey clayst.	0.00019	170.0
68144-1	1	32	71046	762475	S66	PLE	"borekaks"	0.00625	5.0
68144-1	2	32	71046	762475	S66	PLE	Dark clay	0.00500	5.1
68144-1	3	32	71046	762475	S66	PLE	Dark clay	0.00625	5.3
68144-1	4	32	71046	762475	S66	PLE	Dark clay	0.00250	5.2
68144-1	5	32	71046	762475	S66	PLE	Dark clay	0.00625	5.4
68144-1	6	32	71046	762475	S21	UJU	Lam.micac.dark mudst	0.00006	14.7
68144-1	7	32	71046	762475	S21	UJU	Lam.micac.dark mudst	0.00006	15.4
68144-1	8	32	71046	762475	S21	UJU	Lam.micac.dark mudst	0.00006	16.7
68144-1	9	32	71046	762475	S21	UJU	Lam.micac.dark mudst	0.00008	17.4
68144-1	10	32	71046	762475	S21	UJU	Lam.micac.dark mudst	0.00006	20.4
68144-1	11	32	71046	762475	S21	UJU	Lam.micac.dark mudst	0.00006	23.0
68144-1	12	32	71046	762475	S21	UJU	Lam.micac.dark mudst	0.00009	23.6
68144-1	13	32	71046	762475	S21	UJU	Lam.micac.dark mudst	0.00010	25.2
68144-1	14	32	71046	762475	S21	UJU	Lam.micac.dark mudst	0.00009	26.0
68144-1	15	32	71046	762475	M23	UJU	Brownish cem. mudst.	0.00008	27.0
68144-1	16	32	71046	762475	M23	UJU	Brownish cem. mudst.	0.00006	28.8
68144-1	17	32	71046	762475	M23	UJU	Brownish cem. mudst.	0.00009	29.3
68144-1	18	32	71046	762475	M23	UJU	Brownish cem. mudst.	0.00013	30.5
68144-1	19	32	71046	762475	S28	UJU	Sandy siltst.	0.00014	32.4
68144-1	20	32	71046	762475	S28	UJU	Grey siltst.	0.00015	35.7
68144-1	21	32	71046	762475	S28	UJU	Siltst.	0.00019	38.4
68144-1	22	32	71046	762475	S28	UJU	Siltst.	0.00019	40.9
68144-1	23	32	71046	762475	S28	UJU	Siltst.	0.00015	43.6
68144-1	24	32	71046	762475	S28	UJU	Siltsone	0.00013	44.9
68144-1	25	32	71046	762475	S28	UJU	Siltst.	0.00014	46.6
68144-1	26	32	71046	762475	S28	UJU	Grey siltst.	0.00017	47.5
68144-1	27	32	71046	762475	S28	UJU	Grey siltst.	0.00015	48.6
68144-1	28	32	71046	762475	S28	UJU	Grey siltst.	0.00015	48.8
68144-1	29	32	71046	762475	S13	MJU	White sandst.	0.00001	50.2
68144-1	30	32	71046	762475	S13	MJU	White sandst.	0.00001	50.3
68144-1	31	32	71046	762475	S13	MJU	White sandst.	0.00001	53.2
68144-1	32	32	71046	762475	S13	MJU	White sandst.	0.00002	53.6
68144-1	33	32	71046	762475	S13	MJU	White sandst.	0.00001	59.4
68144-1	34	32	71046	762475	S13	MJU	White sandst.	0.00002	62.1
68144-1	35	32	71046	762475	S13	MJU	White sandst.	0.00001	65.7
68144-1	36	32	71046	762475	S13	MJU	White sandst.	0.00002	68.8
68144-1	37	32	71046	762475	S13	MJU	Sandst.	0.00002	75.7
68144-1	38	32	71046	762475	S13	MJU	Sandst.	0.00006	80.0
68144-1	39	32	71046	762475	S13	MJU	Sandst.	0.00001	101.1
68144-1	40	32	71046	762475	S13	MJU	Sandst.	0.00001	103.5
68144-1	41	32	71046	762475	S13	MJU	Sandst.	0.00001	107.1
68144-1	42	32	71046	762475	S13	MJU	Sandst.	0.00002	109.6
68144-1	43	32	71046	762475	S13	MJU	Dark sandst.	0.00001	117.9
68144-1	44	32	71046	762475	S13	MJU	Dark sandst.	0.00001	121.5
68144-1	45	32	71046	762475	S13	MJU	Sandst.	0.00002	125.6
68144-1	46	32	71046	762475	S13	MJU	Sandst.	0.00001	125.8
68144-1	47	32	71046	762475	S13	MJU	Sandst.	0.00002	128.6
68144-1	48	32	71046	762475	S13	MJU	Sandst.	0.00001	130.3

Susceptibility measurements on cores from IKU shallow drilling programme.

Well No.	Sample No.	UTM zone	UTM-coord. 10 m		Lit. code	Strat. code	Rock type	Suscept. SI	Depth m
68144-1	49	32	71046	762475	S13	MJU	Mica-rich sandst.	0.00013	138.1
68144-1	50	32	71046	762475	S13	MJU	Mica-rich sandst.	0.00001	140.7
68144-1	51	32	71046	762475	S13	MJU	Sandst.	0.00001	141.8
68144-1	52	32	71046	762475	S21	MJU	Mudst.	0.00010	146.1
68144-1	53	32	71046	762475	S13	MJU	Sandst.	0.00001	148.0
68144-1	54	32	71046	762475	S21	MJU	Mudst.	0.00009	149.5
68144-1	55	32	71046	762475	S21	MJU	Mudst.	0.00006	152.0
68144-1	56	32	71046	762475	S21	MJU	Mudst.	0.00013	152.4
68144-1	57	32	71046	762475	S21	MJU	Sandst.	0.00001	155.4
68144-1	58	32	71046	762475	S13	MJU	Sandst.	0.00004	163.4
68144-1	59	32	71046	762475	S21	MJU	Dark mudst.	0.00011	165.8
68144-1	60	32	71046	762475	S21	MJU	Dark mudst.	0.00011	165.9
68144-1	61	32	71046	762475	S21	MJU	Dark mudst.	0.00026	166.5
68144-1	62	32	71046	762475	S21	MJU	Dark mudst.	0.00006	168.4
68144-1	63	32	71046	762475	S21	MJU	Dark mudst.	0.00050	169.7
68144-1	64	32	71046	762475	S21	MJU	Dark mudst.	0.00013	170.5
68144-1	65	32	71046	762475	M27	PLO	Kaolinite weathering	0.00009	171.9
68144-1	66	32	71046	762475	M27	PLO	Str.weathered gneiss	0.00010	172.6
68144-1	67	32	71046	762475	M27	PLO	Str weathered gneiss	0.00013	174.2
68144-1	68	32	71046	762475	M27	PLO	Weathered gneiss	0.00050	176.6
68144-1	69	32	71046	762475	M27	PLO	Weathered gneiss	0.00025	177.4
68144-1	70	32	71046	762475	M27	PLO	Weath. mang. gneiss	0.00029	178.6
68144-2	1	32	70945	762575	M23	LCR	Carb.cem. bed	0.00088	10.5
68144-2	2	32	70945	762575	S22	LCR	*Clayst.	0.00033	22.5
68144-2	3	32	70945	762575	S22	LCR	*Clayst.	0.00034	24.4
68144-2	4	32	70945	762575	M23	LCR	*Carbonate	0.00239	24.8
68144-2	5	32	70945	762575	M23	LCR	Yell. carb.cem. beds	0.00163	22.0
68144-2	6	32	70945	762575	M23	LCR	Yell. carb.cem. beds	0.00100	24.0
68144-2	7	32	70945	762575	S22	LCR	Clayst.	0.00022	30.0
68144-2	8	32	70945	762575	S22	LCR	Clayst.	0.00027	31.0
68144-2	9	32	70945	762575	S22	LCR	Clayst.	0.00030	32.0
68144-2	10	32	70945	762575	M23	LCR	Yell. carb.cem. beds	0.00320	36.8
68144-2	11	32	70945	762575	M23	LCR	Calcite cemented bed	0.00006	40.0
68144-2	12	32	70945	762575	S28	LCR	Siltst.	0.00019	45.0
68144-2	13	32	70945	762575	M23	LCR	White beds/carbonate	0.00015	47.0
68144-2	14	32	70945	762575	M23	LCR	Brownish carbonate	0.00163	63.0
68144-2	15	32	70945	762575	M23	LCR	Brownish carbonate	0.00125	64.7
68144-2	16	32	70945	762575	M23	UJU	Siderite	0.00137	70.0
68144-2	17	32	70945	762575	S22	UJU	Silty clayst.	0.00075	76.0
68144-2	18	32	70945	762575	S22	UJU	Silty clayst.(slip)	0.00112	95.9
68144-2	19	32	70945	762575	M23	UJU	Brown cement	0.00131	96.0
68144-2	20	32	70945	762575	S22	UJU	Clayst.	0.00014	99.0
68144-2	21	32	70945	762575	S22	UJU	Clayst.	0.00015	106.0
68144-2	22	32	70945	762575	M23	UJU	Br.lam.microfaults	0.00069	109.0
68144-2	23	32	70945	762575	M23	UJU	Cement?	0.00120	115.6
68144-2	24	32	70945	762575	S22	UJU	*Reference, clayst.	0.00015	117.7
68144-2	25	32	70945	762575	S22	UJU	*Ref.lam. clay/silt	0.00044	122.3
68144-2	26	32	70945	762575	M23	UJU	*Cem.clayst.microfa.	0.00159	122.4
68144-2	27	32	70945	762575	S22	UJU	*Ref., clay/silt	0.00041	127.6
68144-2	28	32	70945	762575	M23	UJU	*Yellowish cemented	0.00159	127.8
68144-2	29	32	70945	762575	M23	UJU	Yellowish cemented	0.00125	128.0
IK82-2	1	31	88030	734424	S28	LTR	Siltst.	0.00038	7.1
IK82-2	2	31	88030	734424	S28	LTR	Siltst.	0.00056	7.8
IK82-2	3	31	88030	734424	S21	LTR	Mudst.	0.00044	7.9
IK82-2	4	31	88030	734424	S21	LTR	Mudst. w. sand lam.	0.00044	8.5
IK82-2	5	31	88030	734424	S21	LTR	Mudst. w. sand lam.	0.00046	8.7
IK82-2	6	31	88030	734424	S28	LTR	Siltst.	0.00038	9.3
IK82-2	7	31	88030	734424	S28	LTR	Siltst.	0.00044	14.0
IK82-2	8	31	88030	734424	S28	LTR	Siltst.	0.00050	14.3
IK82-2	9	31	88030	734424	S13	LTR	Sandst. laminae	0.00069	15.0
IK82-2	10	31	88030	734424	S28	LTR	Siltst. w.sand lam.	0.00065	15.6
IK82-2	11	31	88030	734424	S13	LTR	Sandst. bed	0.00088	15.9
IK82-2	12	31	88030	734424	S28	LTR	Siltst.	0.00062	16.3
IK82-2	13	31	88030	734424	S13	LTR	Sandst. laminae	0.00038	16.3
IK82-2	14	31	88030	734424	S21	LTR	Mudst.	0.00040	20.0
IK82-2	15	31	88030	734424	S21	LTR	Mudst.	0.00038	20.5
IK82-2	16	31	88030	734424	S21	LTR	Mudst.	0.00041	20.6
IK82-2	17	31	88030	734424	S21	LTR	Mudst.	0.00050	21.6
IK82-2	18	31	88030	734424	S28	LTR	Siltst./mudst	0.00038	21.9

Appendix A, page 7.

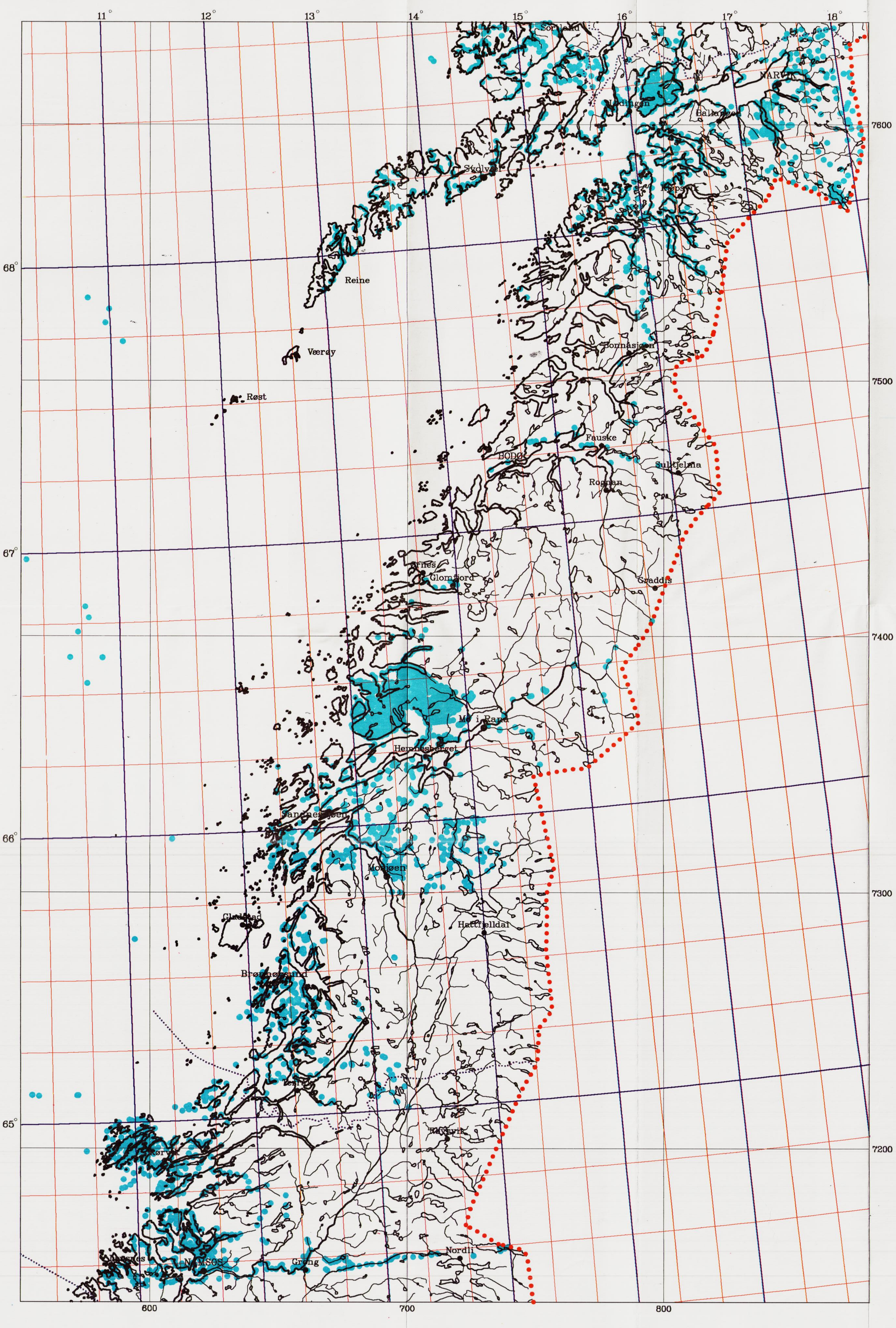
Susceptibility measurements on cores from IKU shallow drilling programme.

Well No.	Sample No.	UTM zone	UTM-coord. 10 m		Lit. code	Strat. code	Rock type	Suscept. SI	Depth m
IK82-2	19	31	88030	734424	S21	LTR	Mudst.	0.00044	23.0
IK82-4	1	31	86955	730385	S22	LJU	Red clayst. beds	0.00300	5.5
IK82-4	2	31	86955	730385	S21	LJU	Mudst.	0.00021	5.7
IK82-4	3	31	86955	730385	S21	LJU	Mudst.	0.00069	5.8
IK82-4	4	31	86955	730385	S21	LJU	Silty mudst.occ.sand	0.00200	6.7
IK82-4	5	31	86955	730385	S21	LJU	Mudst. occ.sand	0.00013	7.0
IK82-4	6	31	86955	730385	S13	LJU	Sandst. occ.granules	0.00081	7.5
IK82-4	7	31	86955	730385	S28	LJU	Sandy siltst. mottl.	0.00088	7.9
IK82-4	8	31	86955	730385	S28	LJU	Sandy silt, mottled	0.00150	8.0
IK82-4	9	31	86955	730385	S13	LJU	Sandst. mottled	0.00050	8.2
IK82-4	10	31	86955	730385	S13	LJU	Sandst. mottled	0.00025	8.3
IK82-4	11	31	86955	730385	S28	LJU	Siltst	0.00013	8.4
IK82-4	12	31	86955	730385	S21	LJU	Mudst.	0.00019	8.6
IK82-4	13	31	86955	730385	S13	LJU	Sandst.	0.00019	9.2
IK82-4	14	31	86955	730385	S28	LJU	Siltst.	0.00006	9.5
IK82-4	15	31	86955	730385	S13	LJU	Sandst. red	0.00008	9.7
IK82-4	16	31	86955	730385	S00	LJU	Conglomerate	0.00006	9.8
IK82-4	17	31	86955	730385	S21	LJU	Sandy mudst.	0.00005	10.5
IK82-8	1	31	83856	723914	S13	PAL	Sandst.	0.00013	19.0
IK82-8B	1	31	83588	723926	S61	PLE	Till	0.00038	4.0
IK82-8B	2	31	83588	723926	S61	PLE	Till	0.00025	4.3
IK82-8B	3	31	83588	723926	S61	PLE	Till	0.00031	4.8
IK82-8B	4	31	83588	723926	S61	PLE	Till	0.00033	5.2
IK82-8B	5	31	83588	723926	S61	PLE	Till	0.00038	5.3
IK82-8B	6	31	83588	723926	S61	PLE	Till	0.00021	6.0
IK82-8B	7	31	83588	723926	S61	PLE	Till	0.00019	6.3
IK82-8B	8	31	83588	723926	S61	PLE	Till	0.00015	7.6
IK82-8B	9	31	83588	723926	S61	PLE	Till	0.00025	8.5
IK82-8B	10	31	83588	723926	S61	PLE	Till	0.00030	9.0
IK82-8B	11	31	83588	723926	S61	PLE	Till	0.00022	10.1
IK82-8B	12	31	83588	723926	S61	PLE	Till	0.00017	10.4
IK82-8B	13	31	83588	723926	S61	PLE	Till	0.00025	11.2
IK82-8B	14	31	83588	723926	S61	PLE	Till	0.00029	11.4
IK82-8B	15	31	83588	723926	S61	PLE	Till	0.00031	13.2
IK82-8B	16	31	83588	723926	S61	PLE	Till	0.00025	13.3
IK82-8B	17	31	83588	723926	S22	PAL	Clayst.	0.00021	14.3
IK82-8B	18	31	83588	723926	S22	PAL	Clayst.	0.00024	15.6
IK82-8B	19	31	83588	723926	S22	PAL	Clayst.	0.00021	16.7
IK82-8B	20	31	83588	723926	S22	PAL	Clayst.	0.00017	16.9
IK82-10	1	31	85301	724077	S13	MJU	Sandst.	0.00006	3.0
IK82-10	2	31	85301	724077	S28	MJU	Sandy siltst	0.00013	3.2
IK82-10	3	31	85301	724077	S21	MJU	Mudst.	0.00013	3.5
IK82-10	4	31	85301	724077	S28	MJU	Siltst.	0.00021	6.9
IK82-10	5	31	85301	724077	S11	MJU	Downfall, quartzite	0.00001	7.1
IK82-10	6	31	85301	724077	S13	MJU	Rusty weath.congl.	0.00200	9.0
IK82-10	7	31	85301	724077	S13	MJU	Sandst. light	0.00006	9.6
IK82-10	8	31	85301	724077	S13	MJU	Sandst.	0.00006	10.0
IK82-10	9	31	85301	724077	S13	MJU	Sandst.	0.00005	10.6
IK82-11	1	31	85338	724089	S13	MJU	Sandst.	0.00004	2.0
IK82-11	2	31	85338	724089	S13	MJU	Sandst.	0.00002	4.1
IK82-11	3	31	85338	724089	S13	MJU	Sandst. occ.granules	0.00004	9.3
IK82-11	4	31	85338	724089	S13	MJU	Sandst.	0.00004	10.6
B82-180	1	32	55201	742986	S63	PLE	Sand	0.00106	0.1
B82-180	2	32	55201	742986	S66	PLE	Clay	0.00125	0.2
B82-180	3	32	55201	742986	S66	PLE	Clay	0.00187	0.5
B82-180	4	32	55201	742986	S66	PLE	Clay	0.00137	0.7
B82-180	5	32	55201	742986	S66	PLE	Clay	0.00213	1.0
B82-180	6	32	55201	742986	S66	PLE	Clay	0.00225	1.2
B82-180	7	32	55201	742986	S66	PLE	Clay	0.00250	1.3
B82-180	8	32	55201	742986	S66	PLE	Clay	0.00175	1.6
B82-180	9	32	55201	742986	S66	PLE	Clay	0.00163	1.7
B82-184	1	32	57485	741150	S66	PLE	Clay	0.00038	0.2
B82-184	2	32	57485	741150	S66	PLE	Clay	0.00019	0.2
B82-184	3	32	57485	741150	S66	PLE	Clay	0.00038	0.3
B82-184	4	32	57485	741150	S66	PLE	Clay	0.00027	0.4
B82-184	5	32	57485	741150	S63	OLI	Sand	0.00015	0.9
B82-185	1	32	57619	740714	S66	PLE	Clay	0.00031	0.2
B82-185	2	32	57619	740714	S63	PLE	Sand	0.00013	0.4
B82-185	3	32	57619	740714	S66	OLI	Clay	0.00038	0.9

Appendix A, page 8.

Susceptibility measurements on cores from IKU shallow drilling programme.

Well No.	Sample No.	UTM zone	UTM-coord. 10 m		Lit. code	Strat. code	Rock type	Suscept. SI	Depth m
B82-185	4	32	57619	740714	S63	OLI	Sand	0.00020	1.1
B82-185	5	32	57619	740714	S63	OLI	Sand	0.00013	1.2
B82-185	6	32	57619	740714	S63	OLI	Sand	0.00013	1.6
B82-186	1	32	57203	740157	S66	PLE	Clay	0.00069	0.4
B82-186	2	32	57203	740157	S63	OLI	Sand	0.00081	0.7
B82-189	1	32	56900	739164	S66	PLE	Clay	0.00062	0.2
B82-189	2	32	56900	739164	S63	PLE	Sand	0.00052	0.2
B82-189	3	32	56900	739164	S63	OLI	Sand	0.00069	0.4
B82-190	1	32	58164	739162	S64	PLE	Silt	0.00062	0.2
B82-190	2	32	58164	739162	S66	PLE	Clay	0.00052	0.5
B82-190	3	32	58164	739162	S66	PLE	Clay	0.00050	0.8
B82-190	4	32	58164	739162	S66	PLE	Clay	0.00137	1.0
B82-190	5	32	58164	739162	S66	PLE	Clay	0.00062	2.3
B82-190	6	32	58164	739162	S66	PLE	Clay	0.00075	2.7
B82-190	7	32	58164	739162	S63	OLI	Sand	0.00006	2.9
B82-192	1	32	57569	738150	S64	PLE	Silt	0.00125	0.2
B82-192	2	32	57569	738150	S66	PLE	Clay	0.00019	0.4



NGU

PETROPHYSICAL DATA
NAS–94 PROJECT
NORDLAND
AREA

SAMPLE LOCATIONS

FORTROLIG

Målestokk, *Scale* 1 : 1 000 000

20 0 20 40 60 80 100km

Datum: ED50
Map projection: Universal Transverse Mercator, midtmeridian 15° E.Gr.

NORDLAND AEROMAGNETIC SURVEY 1994
SAMPLE LOCATIONS, PETROPHYSICAL DATA
Hand specimens and IKU shallow cores
NGU Report 96.013 Map 1, Scale 1 : 1000 000