Geological Survey of Finland, Current Research 1991—1992,
Edited by Sini Autio.
Geological Survey of Finland, Special Paper 18: 137—141, 1993.

ONE HUNDRED SEVENTY EIGHT THOUSAND PETROPHYSICAL PARAMETER DETERMINATIONS FROM THE REGIONAL PETROPHYSICAL PROGRAMME

by
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Key words (GeoRef Thesaurus, AGI): petrophysics, physical properties, rocks, mapping programs, Precambrian, Finland

Introduction

The aim of the regional petrophysical mapping programme was to collect information on the density, susceptibility and intensity of remanence from all over Finland (Korhonen et al. 1989), and thus to supplement the 98 000 petrophysical parameter determinations made on 41 000 samples by the Geological Survey of Finland (GSF) in 1954—1979 (Puranen 1989, 1991). This extensive gathering of petrophysical data has been a necessary step in utilizing aerogeophysical and gravity surveys in bedrock mapping, ore prospecting and crustal studies (Korhonen 1991).

Overview

Petrophysical parameters have been measured on samples collected for geological studies and mapping. In addition, special sampling (48 000 specimens) has been carried out in areas not represented by these samples. This sampling is now finished, almost all measurements have been made and the data input is nearly complete. By the end of 1992 the petrophysical register contained data on 315 230 petrophysical parameter values measured on 115 422 specimens. The data cover the whole country except for some map sheets on a scale of 1:100 000 in Central Finland, where the bedrock mapping will be completed within the next few years. The final report of the mapping programme and accompanying petrophysical maps will be prepared for publication in the Report of Investigation series of the GSF in 1993. The final report contains a detailed summary of the petrophysical properties of the major stratigraphic, lithological and structural units of Finland. Additional data sets will later be added to the petrophysical register when released from other projects of the GSF and its customers.

The interim report of the Petrophysical Programme was published by Korhonen et al. in 1989. Since then work has continued with Heikki Säävuori responsible for execution of the programme, Marit Wennerström for rock type determinations (28 000 specimens), Hannu Hongisto for ADP program maintenance, Liisa Kivekäs for measurements in the Otaniemi petrophysical laboratory and Seppo Lähde for data input to the petrophysical register. Helena Halme has made the petrophysical measurements and Aino Lehti has processed the archive material. The petrophysical laboratories in Rovaniemi and Kuopio have made measurements and supplied data for the Petrophysical Mapping Programme. Seventeen temporary employees — the majority undergraduates — have assisted in sampling and other duties.

Use of the data

New partial summaries of the data in the petrophysical register have been published. They concern previously existing data (Puranen 1989), the Nordkalott data (Henkel 1991), the data on the volcanites of Northern Fennoscandia (Airo 1991) and the data of some main rock types for

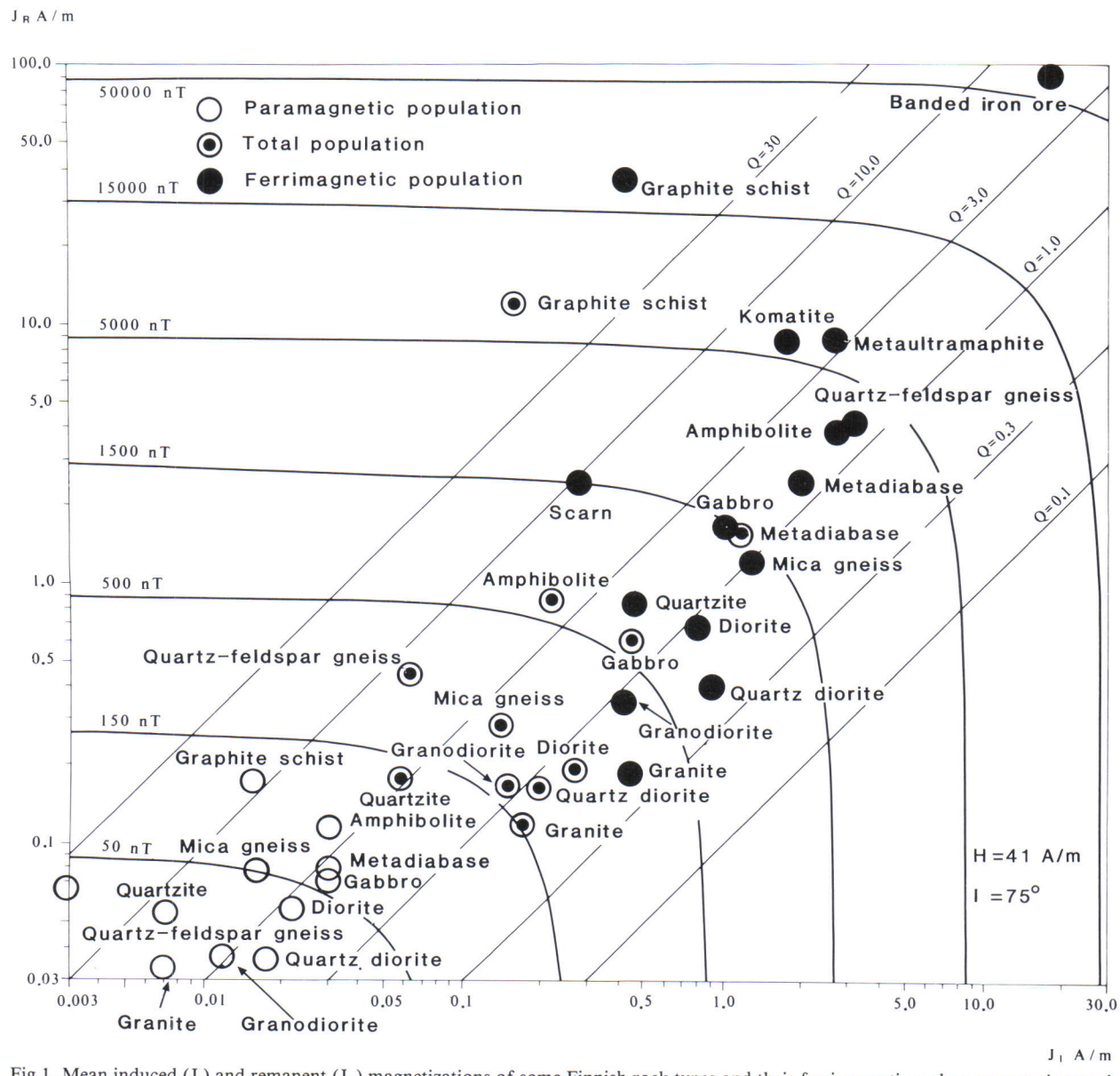

Fig 1. Mean induced (J_I) and remanent (J_R) magnetizations of some Finnish rock types and their ferrimagnetic and paramagnetic populations. Q = Königsberger ratio. Field strength is calculated on the surface of a magnetized half plane (H = 41 A/m, I = 75°).

the Atlas of Finland (Korhonen 1992). Summaries of the properties of the Wiborg rapakivi for regional interpretation and the data of paramagnetic and ferrimagnetic populations for a textbook of prospecting methods are in press (Elo & Korja; Korhonen 1993). A description of the petrophysical properties of the geological units in Peräpohja Schist belt is in preparation (Säävuori). The petrophysical register has been used not only by the geological mapping programmes and mineral prospecting but also by the Crustal Model programme of the GSF, the Internordic Midnorden project, the GGT projet, the IGCP-257 and IGCP-275 projects, and the project for outlining the Precambrian bedrock in and around of the Gulf of Finland.

Petrophysical results

The mapping programme has produced new information on the regional variation in petrophysical properties. The number of determinations of the intensity of remanence has increased more than fourfold. Remanent magnetization accounts for a greater proportion of total magnetization than does induced magnetization (Fig 1). The average Q values for paramagnetic and ferrimagnetic populations are 5.0 and 1.6 respectively, when the population limit is based on the magnetic susceptibility distribution. The proportion of remanent magnetization relative to total magnetization is higher in supracrustal than in igneous rocks.

The regional distributions of petrophysical

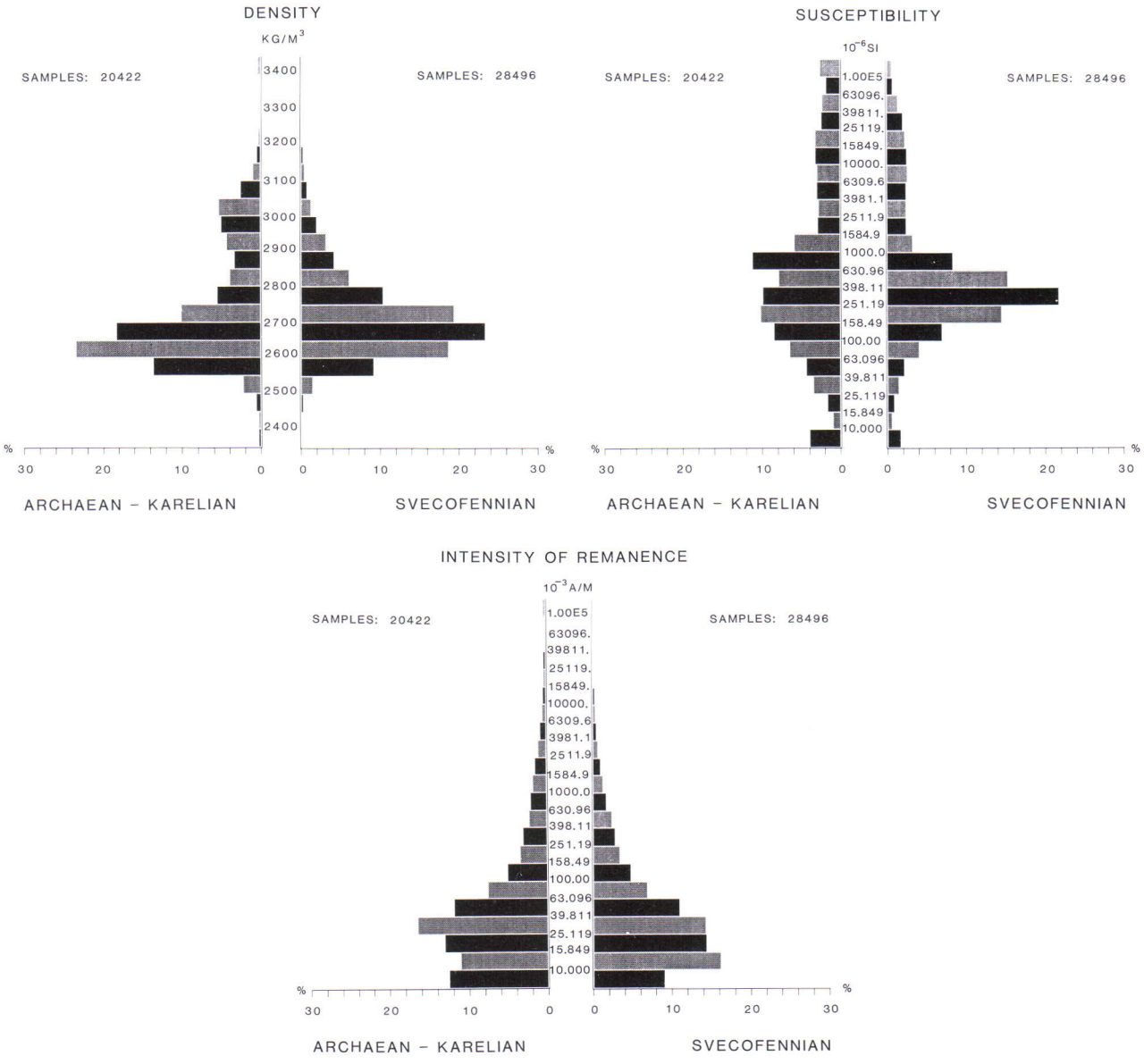

Fig 2. Frequency distributions of density, magnetic susceptibility and remanent magnetization within Archaean-Karelian and Svecofennian areas.

properties differ from each other (Fig. 2). In the area of Archaean basement and its supracrustal cover, to the northeast of a line running between the islands of Hailuoto and Valamo, the density distribution of the bedrock is bimodal, as it is also for each of the five major subareas in that part of Finland. The modes correspond to rocks of acid and basic composition. The susceptibility distribution is wide and shows the same peaks as the density distribution in the paramagnetic part of the range. The peaks are due to ions of iron and manganese in dark silicate minerals.

The densities of Svecofennian rocks are unimodal to the southwest of a line between the lower courses of the rivers Kalajoki and Vuoksi. Some densities correspond to basic rocks. However, they occur in decreasing frequency with increasing density, not as a mode of their own. The density mode corresponds to rocks of intermediate composition. The susceptibility mode is sharp, and strong values, higher than 0.06 SI units are more rare than in the Archaean basement. The mode of remanences is lower and the proportion of high remanences smaller than in the northeast of Finland.

Between these two lines is the ore-potential Ladogan-Bothnian Bay Zone, where susceptibilities show a statistical distribution of the Svecofennian type but the remanences are more like northeastern type (Arhaean-Karelian). The petrophysical distributions of Subjotnian rocks within the Svecofennian rocks are more like the Arhaean-Karelian type, but the magnetic susceptibilities of

Table 1. Average densities and magnetizations of all samples plus weakly and strongly magnetized subpopulations within the Archaean-Karelian and Svecofennian areas. A sample is said to be strongly magnetized when either remanent or induced magnetization exceeds 0.082 A/m; otherwise it is considered as weakly magnetized. N is the number of samples, D is the density, J is magnetization (the Earths field for induced component H = 41 A/m), Q is the Königsberger ratio and F is the proportion of the subgroup relative to all samples.

	N	D kg/m³	J A/m	Q	F %
	Archaean and Karelian area				
all samples	20422	2733.5	1.348	2.03	100
weak J	13748	2715.2	0.038	1.56	67
strong J	6674	2771.2	4.048	2.03	33
	Svecofennian area without Ladoga — Bothnian Bay zone				
all samples	28496	2715.0	0.511	1.74	100
weak J	21234	2703.4	0.036	1.49	74
strong J	7262	2748.5	1.923	1.83	26

the basic rocks are mainly in the ferrimagnetic domain, and weak remanences are less common.

Table 1 shows the average density and magnetization plus the ratio of remanent magnetization to induced magnetization (Q value) within the two major subareas, the Archaean-Karelian and the Svecofennian. The populations have been further subdivided into two subpopulations on the basis of their magnetization. The separation limit was 0.002 SI units for susceptibility and 0.082 A/m for magnetization. For both components, the definition corresponds to a maximum field strength of 50 nT on a surface of the source. It differs from the population division of Fig. 1 in such a way that strongly remanently but weakly inducedly magnetized samples are included in the same population as ferrimagnetic samples.

Twenty-six per cent of Svecofennian and 33 per cent of Arhaean-Karelian samples belong to the more strongly magnetic rock population that causes anomalies. The magnetic population of the latter major area is, on average, more highly magnetized than that of the former, and its Q values are also higher. The most magnetic part is incorporated in Paleoproterozoic supracrustal and hypabyssal rocks of intra- and epicontinental formations on the Archaean basement. Statistically, remanent magnetization is the dominant direct cause of magnetic anomalies, because the average Q-value is higher than 1 in all the groups of Table 1. There are rocks and geological formations, however, in which induced magnetization dominates, e.g. many of the formations of central Finnish Lapland. The more strongly magnetic groups are, on average, slightly denser (c. 50 kg/m³) than the more weakly magnetic groups. This may be partly attributed to the existence of dense and magnetic opaque minerals, but there are other reasons too.

The continuation of the mapping programme

Owing to the high proportion of remanent magnetization relative to total magnetization it is important that a follow-up study be conducted with a view to collecting information on the directional behaviour of remanence. The magnetic mineralogy of the different subpopulations, including sulphide bearing magnetic rocks, will be studied (Säävuori & Korhonen 1991). The geochemical background of magnetic populations will be determined.

The petrophysical register, which will constitute the central petrophysical file of the GSF, will be at the disposal of all GSF projects and customers. The register can already be used relatively easily by the other data systems of the GSF via the VAX 6000 mainframe computer. The ease of use will be enchanced by improving the form of the register and by preprocessing the information into geologically and interpretationally reasonable summary parameters. In this way the programme is expected to meet its original purpose, namely, to provide instantly real, measured petrophysical values from any investigation area for the interpretation of geophysical maps. It is on this that the reliable geological interpretation of magnetic and gravity maps ultimately depends.

References

Airo, M-L. 1991. Susceptibilities, intensities of remanence and densities of Precambrian and recent volcanic rocks: Examples from Iceland and Northern Fennoscandia. Geological Survey of Finland, Report of Investigation 93, 24 p.

Elo, S. & Korja, A. Geophysical interpretation of the Crustal and Upper Mantle structure in the Wiborg Rapakivi Gra-

nite Area, Southeastern Finland. Precambrian Research, (in press).

Henkel, H. 1991. Petrophysical properties (density and magnetization) of rocks in the Northern part of the Baltic Shield. Tectonophysics 192, 57—79.

Korhonen, J., Säävuori, H., Hongisto, H., Turunen, P., Kivekäs, L., Tervo, T., Lanne, E. & Tuomi, A. 1989. Regional petrophysical program for Finland 1980—1991. In: Autio, S. (ed.) Geological Survey of Finland, Current Research 1988. Geological Survey of Finland, Special Paper 10, 137—141.

Korhonen, J., 1991. Contribution of aeromagnetic survey programs to mineral resource assessment, prospecting, bedrock mapping, and crustal studies in Finland. In: Chandler, W. (ed.) Geophysical solutions to geologic problems of continental interiors: A Minnesota Workshop. Minnesota Geological Survey, Information Circular 35, 45—46.

Korhonen, J., 1992. Kallioperän magneettiset ominaisuudet. In: Suomen kartasto, vihko 123—126, pp. 26—29. Magnetic properties of the bedrock. Atlas of Finland, Appendix: 123—126, Geology, p. 15. Helsinki: Maanmittaushallitus.

Korhonen, J., 1993. Magneettiset kartat ja niiden käyttö malminetsinnässä. In: Haapala, I., Hyvärinen, L. & Salonsaari, P. (eds.) Malminetsinnän menetelmät. 30—57.

Puranen, R., 1989. Susceptibilities, iron and magnetite content of Precambrian rocks in Finland. Geological Survey of Finland, Report of Investigation 90, 45 p.

Puranen, R., 1991. Specifications of petrophysical sampling and measurements. In: Autio, S. (ed.) Geological Survey of Finland, Current research 1989—1990. Geological Survey of Finland, Special Paper 12, 217—218.

Säävuori, H. & Korhonen, J. 1991. Petrophysical properties of Finnish sulphide bearing rocks and their expression as geophysical anomalies in the central part of the Fennoscandian Shield. In: Autio, S. (ed.) Geological Survey of Finland, Current Research 1989—1990. Geological Survey of Finland, Special Paper 12, 201—208.

Säävuori, H. Aerogeophysical and petrophysical interpretation of Peräpohja Schist Belt. Geological Survey of Finland, Report of Investigation, (in prep.).