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SPECIFICATIONS OF PETROPHYSICAL SAMPLING AND MEASUREMENTS

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The three area offices (Espoo, Kuopio, Rovaniemi) of the Geological Survey of Finland (GSF) have petrophysical laboratories where magnetic and electric properties, as well as (grain) densities of rock, ore and soil samples have been systematically measured for several years, as described by Puranen (1989a). The measurements are used for quantification of geophysical interpretations, and they also have direct geological applications. The physical properties of geological materials typically show great variations even within distances of a few meters. Hence, representative estimates of the properties must be based on large amounts of samples, whose average behaviour may reveal regularity hidden within the scatter of individual observations (e.g. Puranen, 1989b). Accordingly, laboratory apparatus has been developed for rapid measurement of many samples with reasonable precision, instead of thorough analysis of a few samples at maximum accuracy.

Numerous rock and soil specimens are collected for various purposes at GSF so that separate petrophysical sampling is only needed in the case of oriented specimens. Geologists have willingly made their samples available for petrophysical measurement, because the specimens are not destroyed or even changed in the process. The petrophysical measuring apparatus is so designed that measurements can be made on arbitrarily shaped hand specimens and on core samples, whose average volumes are 200 and 50 cm^3, respectively. The flexibility of the apparatus speeds up the measuring process, because a large number of samples requires no preparation. Most of the samples are directly suitable for measurement of density, of magnetic susceptibility and of remanent magnetization. For resistivity measurements it is sufficient to smooth the ends of samples. More laborious preparations of oriented cylindrical specimens (length/diameter-ratio about 0.85, volume approximately 22 or 11 cm^3) are needed only for measurement of anisotropy of magnetic susceptibility (AMS) and for accurate determinations of remanence directions.

The mechanical construction, electronic design and measuring practice of petrophysical apparatus is thoroughly described in a technical report by Puranen & Sulkanen (1985). Here the operation principles of the apparatus are briefly reviewed and the measuring precisions (standard errors of repeated measurements) are reported. The precision of parameter determinations is also affected by sample preparation methods. Densities are determined by weighing the samples in air and water with a repeatability of about 2 kg/m^3, when average sized (200 cm^3) hand specimens are treated. The determinations are made on dry samples, which results in a small underestimation of densities due to the porosity of rocks. This (systematic) error is generally below 1 %, because the porosity is low (0—3 %) in crystalline rocks of Finland.

The susceptibilities are measured with AC-bridges, whose theory and calibration have been reported elsewhere (Puranen & Puranen, 1977). These low-frequency (1025 Hz) bridges are composed of two coils and two resistors. When a sample is inserted into the measuring coil, the coil inductance is changed and the bridge output voltage increases proportionally to the susceptibility

(K) of the sample. The measuring field parallel to the coil axis is about as strong as the Earth's magnetic field. When weakly magnetic samples ($K < 1500 \cdot 10^{-6}$ SI) of average size are measured, the precision is approximately $5 \cdot 10^{-6}$. In strongly magnetic samples ($K > 50000 \cdot 10^{-6}$) the effect of shape demagnetization is corrected for. Even in the case of irregularly shaped hand specimens with strongly magnetic inclusions, the measuring result is not altered more than 5 % when sample locations are varied within the homogeneous field of measuring coils. In the central part of the coils the field variations stay below 1 %, and the AC-bridges can thus also be used for AMS-measurement. The rotatable design A composed of 12 measuring directions (Hext, 1963) is applied in the AMS-analysis of cylindrical samples.

The fluxgate elements of remanence meters are shielded with two coaxial Mu-metal cylinders (diameter of about 20 cm and length 80 cm). The magnetic field strength is less than 100 nT and the noise level below 0.1 nT in the shielded measuring space, into which the samples are taken to different positions by using cubic sample holders. The samples cause changes in the magnetic field, and the changes are proportional to the sample remanence component which is in the direction of fluxgate element. The effect of induced magnetization is eliminated with the aid of a measuring system composed of 6 measuring directions for hand specimens and 12 directions for cylindrical samples (Puranen, 1978). The measuring precision is about $3 \cdot 10^{-3}$ A/m for weakly magnetic samples of average size. However, the measuring data of strongly magnetic hand specimens can vary by more than 10 % if magnetically inhomogeneous samples are placed in different locations within the sample holder. The demagnetization effect due to the shape of strongly magnetic samples is corrected for by calculations.

Specific resistivities are usually determined at three frequencies (0.1, 10, 500 Hz), which also makes it possible to estimate the polarizability of samples. Before measurement, the samples are soaked in tap water for 2—3 days, after which the sample surfaces are dried with compressed air (see Puranen & Sulkanen, 1985). The sample is then fixed between wet electrodes, which together with a known serial resistor form the measuring circuit. The measuring current is monitored across the known resistor, and the resisitivity of samples can be determined either from their ends or sides (2- or 4-point system). The stardard error of repeated measurements of electronic samples is less than 2 % in the resistivity range 10^2—10^7 ohms. The corresponding range for specific resistivity of rock samples depends on their size and can be adjusted by changing sample dimensions. Repeated resistivity estimates of rocks can vary by tens of percentages if the measuring direction or water content of samples is altered, but through a standardized measuring practice the variations can be kept below 10 %. The most versatile version of resistivity apparatus at GSF can determine amplitudes of complex resistivities at eight frequencies (0.1—500 Hz) and phase angles at a precision of 0.5 degrees (Eskola et al., 1984).

In order to facilitate handling of large sample amounts, petrophysical measuring apparatuses are controlled by microcomputers, which reduces operating errors, automatizes data storage and systematizes data treatment. The computerization of apparatus simplifies and speeds up the measuring practice so that one physical parameter can be determined in most cases within 30 seconds and always within two minutes. At such speeds each petrophysical laboratory could handle, in theory, more than 10000 samples per year. The measuring results can be automatically transferred from the laboratory computers to the main frame computers, where the data on physical properties are combined with geologic information (sample location, rock type, etc.). The combined information is arranged into petrophysical data bases (see Puranen & Hongisto, 1989), and through a computer net the data are easily available to the users at all GSF area offices.

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