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# Comparison of handheld magnetic susceptibility meters for drill core measurements

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Title of report
Comparison of handheld magnetic susceptibility instruments for drill core measurements

Abstract
This report compared five KT-series (KT-6, KT-10, KT-20) handheld magnetic susceptibility measurement instruments: their properties, different types of sensorheads and instrument performance in drill core measurements at the Geological Survey of Finland. The results show that the KT-20 device with a rectangular sensorhead produces most accurate data when compared against laboratory measurements.

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# 1 INTRODUCTION

This report compares five KT-series (KT-6, KT-10, KT-20) handheld kappameters (magnetic susceptibility measurement instruments), their properties, different types of sensorheads and instrument performance in drill core measurements at the Geological Survey of Finland. The aim is to determine the quality, accuracy and comparativity of data acquired using different instruments.

# 2 INSTRUMENTS AND DATA

## 2.1 Instruments

The five instruments used in the test are displayed in Figure 1. The instruments are presented from oldest to the most recent, i.e. KT-6 represents the oldest instrument generation.


*Figure 1. a) Kappameters' display and control panels, and b) sensorheaads. 1 = KT-6 with a round sensor, 2 = KT-10 v2 with a pin sensor, 3 = KT-10 v2 with a rectangular sensor, 4 = KT-20 S/C with a round sensor, 5 = KT-20 S/C with a rectangular sensor.*

Specifications for the instruments used in this test are listed in Table 1 based on the instrument manuals (Georadis 2007, GeoRESULTS, Terraplus):

- Coil / sensorhead (see Fig. 1):
  - The pin sensor is designed for rough surface measurement such as outcrop
  - A rectangular coil (sensor) is optimal for core measurements with diameter smaller than 66 mm (preferably with diameter correction). (NB

a curved drill core sensor is also nowadays available from the manufacturer for BQ, HQ, NQ and PQ core sizes.)
    - The round coil (sensor) is optimal for samples large samples (e.g. outcrop samples), but can also be applied in drill core measurements (preferebly with diameter correction)
- Conductivity: The KT-20 sensor can also measure the apparent conductivity of the sample via electromagnetic induction (range 1 – 100,000 S/m: note that the conductivity of rocks without sulphide or graphite minerals is typically below the lower detection limit)
- Diameter correction: The devices assume that the measured material below the sensor forms a homogeneous magnetic half-space. When a cylindrical drill core is measured, a geometric correction factor should be applied to correct the results - without the correction they are systematically too low.
- Operating frequency 10/100 kHz (if the latter is available): of these frequencies, 10 kHz is optimal for magnetic susceptibility measurements, but 100 kHz in KT-20 provides improved sensitivity for conductivity measurements
- Discrete mode: The devide performs single point measurements, averaging of results (if available) is applied to all measurements in one measurement session (unless the user resets the average using the instrument menus)
- Borehole mode: A handy mode for conducting discrete measurements for a drill hole. The user enters the drill hole name, starting depth and measurement interval, and the measurement software automatically proceeds to the next depth after storing measurement results for a certain depth. If repetition measurements are performed, in the KT-20 device these are averaged for each depth.

The KT-6 sensor, being the oldest of the tested sensors, has least options for data acquisition and download. The download software for the KT-6 was located on a floppy disk but wasnot tested as it probably isn’t compatible with modern operating systems. Thus, the data must be written down manually after each measurement. The device manual recommends that for KT-6 the sample size should be no less than 100 mm in diameter and 60 mm in thickness (Georadis, 2007).

KT-10 and KT-20 user interfaces and options are rather similar for basic use. The most notable difference in drill hole measurements is the lack of data averaging in the borehole mode of KT-10. The data transfer software for these two instruments can be downloaded from the manufacturer’s website (may require a firmware update to individual instruments).

*Table 1. Specifications for the instruments used in this test.*

| *Instrument* | *KT-6* | *KT-10 V2* | *KT-10 V2+* | *KT-20 S/C* | *KT-20 S/C* |
|---|---|---|---|---|---|
| *Manufacturer* | SatisGeo | Terraplus (Georadis) | Terraplus (Georadis) | Terraplus (Georadis) | Terraplus (Georadis) |
| *Serial #* | 2414 | 9865 | 9861 | 68 | 69 |
| *Coil / sensor* | Round | Round + pin | Rectangular | Round | Rectangular |
| *Conductivity* | No | No | No | Yes | Yes |
| *Diameter correction option* | No (correction factors listed in the manual for diameters > 60 mm) | Yes | Yes | Yes | Yes |
| *Sensitivity* | 1 x $10^{-5}$ SI | 1 x $10^{-6}$ SI | 1 x $10^{-6}$ SI | 1 x $10^{-6}$ SI | 1 x $10^{-6}$ SI |
| *Range* | < 9999 x $10^{-3}$ SI | 0.001 - 1999.99 x $10^{-3}$ SI | 0.001 - 1999.99 x $10^{-3}$ SI | 0.001 - 1999.99 x $10^{-3}$ SI | 0.001 - 1999.99 x $10^{-3}$ SI |
| *Operating frequency* | 10 kHz | 10 kHz | 10 kHz | 10/100 kHz | 10/100 kHz |
| *Battery* | 9V standard type 6LF22 | 2 x AA battery | 2 x AA battery | Li-ion 8.4 V (re-chargeable) | Li-ion 8.4 V (re-chargeable) |
| *Data transfer options* | No | with GeoView | with GeoView | with GeoView | with GeoView |
| *Discrete mode* | Yes | Yes | Yes | Yes | Yes |
| *Borehole mode* | No | Yes | Yes | Yes | Yes |
| *Data averaging* | No | For discrete mode | For discrete mode | For discrete and borehole modes | For discrete and borehole modes |

## 2.2 Data acquisition

The drill core samples measured with the kappameters comprise 26 drill core samples from GTK's 2019 drill hole P4222019R7 in Emas, Kruunupyy, western Finland. The samples compose of volcanic rocks and graphite schists with varying amount of disseminated sulphides, including pyrrhotite. The samples are 50.7 mm in diameter (NQ2 drill core size). Nineteen of the samples have been split lengthwise and the other half has been sent to geochemical analysis. According to the KT-20 manufacturer, approximately 90% of the measurement signal is received from the top-most 20 mm of the core (Terraplus, pers. comm. 2019). Thus, the sample volume is assumed to be sufficient even for the split samples, as the reduced sample thickness should not result in significant signal loss.

Each sample was measured with each device three times at different locations on the convex surface. The final results represent the mean of the three measurements. The dry samples were held in the air away from any metal sources while measuring. The position of the sample in relation to the device was "vertical", i.e., the sample depth axis was oriented along the length axis of the instrument - previous empirical testing (Leväniemi 2019) has shown that this orientation provides best results also for rectangular sensors. For those sensors that offer the diameter correction option (all but the KT-6), a 5-cm diameter correction option was applied. All instruments were operated at 10 kHz frequency.

The handheld instrument data are compared against measurements performed in the Geophysical Laboratory of GTK with an in-house low-frequency AC bridge (Puranen & Puranen 1977). The bridge is suitable for measuring rock samples with maximum diameter of 10 cm, which allows the measurement of elongated drillcore samples.

## 3 RESULTS

Comparison against the laboratory measurement (Fig. 2) illustrates that none of the KT devices produced magnetic susceptibilities of equal level to the laboratory measurements. However, it is evident that the KT-20 models produce more accurate results than the previous models.

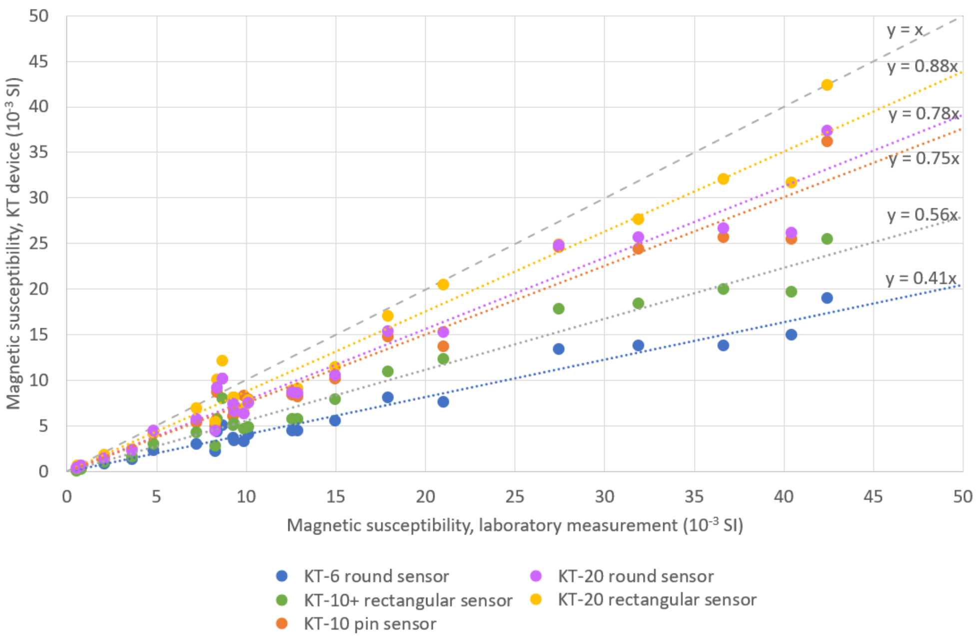


*Figure 2. KT instrument data compared against the laboratory measurements. The curve y=x represents ideal data fit.*

# 4 DISCUSSION AND CONCLUSIONS

Based on this test, the KT-20 devices produce more accurate data than the KT-10 and KT-6 devices. In another accuracy test, the KT-20 device with a rectangular sensor produced a linear fit of 0.96 in comparison to the laboratory measurements (Leväniemi & Hokka 2021). In this test, the slighly lower data readings of the KT-20 device in comparison to the laboratory measurements may be due to the fact that majority of the samples are split or compositional heterogeneity; the laboratory measurements represent bulk susceptibility whereas the handheld instrument data represent small-footprint point measurements. The rectangular KT-20 sensor produces more accurate results than the round sensor.

Somewhat surprisingly, the KT-10 device with the pin sensor performs better than the rectangular sensor. This may be due to instrument malfunction with the latter device.

The poor performance of the KT-6 sensor is likely due to the incomplete diameter correction; the correction factors are not available in the device manual (Georadis 2007) for core diameter of this size, but previous tests have indicated that the results are ca. 50% of the KT-20 results (Uula Autio, pers. comm. 2019 - the diameter of the core material in this test is not known but is assumed also to be NQ size), which is in line with the results of this study. The KT-6 accuracy could likely be improved by defining empirical diameter correction factors for small core diameters; however, the device's outdated data download software makes it an impractical choice for everyday use.

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