

Heating in a cryogenic magnetometer – a new way of measuring remanences in paleomagnetism

Abstract:

Many paleomagnetic problems like the global field behavior requires that the number of samples analyzed have to be increased in order to answer detailed questions. Due to quite time-consuming laboratory procedures, it is necessary to think on new ways in the laboratory treatment of paleomagnetic samples. One attempt is to implant a thermal heating device directly in a cryogenic magnetometer. A technique like this allows measuring the magnetic remanences within a short period of time at elevated temperatures. This article describes such a device, which is based on the transmission of thermal energy to the sample by means of two quartz glass bars. This technique increases the speed of demagnetization and prevents the sample from unnecessary alteration.

Introduction:

A common way to gain the paleomagnetic information of a rock sample is the stepwise thermal demagnetization in an external furnace. The remanence of the sample is then measured after each temperature step in a cryogenic magnetometer. The hint of this procedure is the high potential of magnetic alteration in the sample caused by successive heating steps. Moreover, the handling itself is very time consuming and the remanence is only measured at room temperature. The later one opens the way to acquire laboratory remanences in the furnace during cooling, which can change the original signal of the sample. For strong samples like basalts Matzka et al. (2003) has already developed an insitu heating system for a less sensitive Spinner Magnetometer

The attempt to build a heating device into a cryogenic magnetometer is hampered by the geometry and material of the instrument itself. As the magnetic signal is measured by super-conductive coils (SQUIDs), the large Helium and liquid air tank of the cooling system allows only a small inlet for the sample covered by PVC. Therefore, any heating system should avoid heat radiation and the application of magnetic material in the sensitivity area of the SQUIDs.

Technical design:

The heating device is realized by the transmission the thermal energy of two high-energy lamps (1000 W lamps, Xerion GmbH, Freiberg i.Br., Germany) to the sample's frontal parts by means of two quartz glass bars (23 x 900mm, fire polished ends, SemiGuarz GmbH, Germany) used as light conductors (Fig.1). To avoid alteration a small slice of non-magnetic material is attached to the samples frontal part.

With this technique, the loss in energy between the light source and the sample is negligible.

An air-based cooling system is only required in the direct vicinity of the sample.

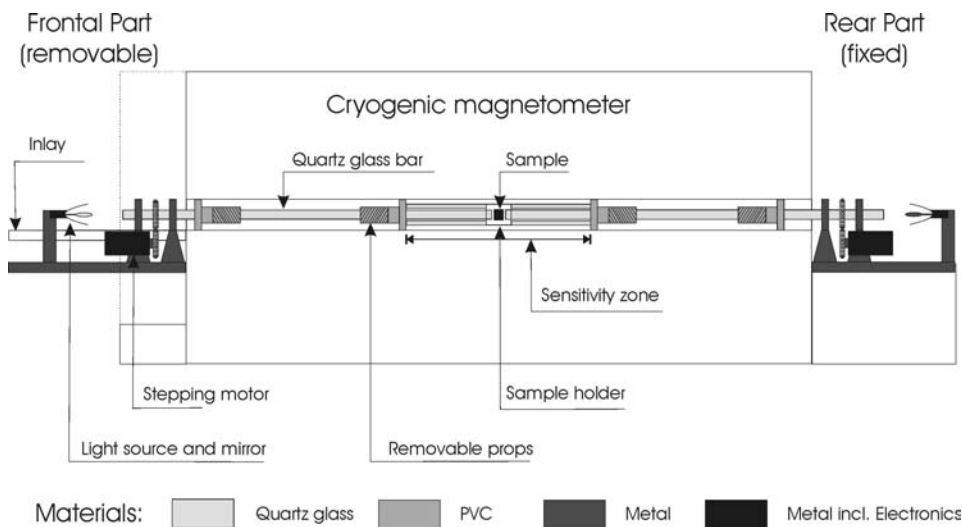


Figure 1: Conceptual sketch of the heating device for the cryogenic magnetometer (Wehland et al., subm.)

Only pure quartz-glass (non-magnetic) is used to build the sample holder in the sensitivity area of the SQUIDs. The ends of the holder are mounted on a PVC cylinder, which also serves as the prop for the bars. Overall, four PVC made cylinders are used to stabilize the quartz glass bars inside the cryogenic magnetometer. For the outer parts, also metal is used to construct the holder for the lamps and the stepping motor.

To load a sample into the device the complete frontal parts (lamps and holder) can be removed. Then the whole inlet is pulled out and – after removing the props – the sample holder can be opened.

The entire system is run by a homemade power supply controlled by a LabView[®] written program in combination with a FieldPoint[®] system (National Instruments, USA). For the communication with the SQUID electronics a subroutine was used written in LabView[®] by Christian Hilgenfeld, Thorsten Frederichs and Karl Fabian from the University of Bremen.

Calibration and experiments:

As only the frontal parts of are heated, the temperature distribution in the cylindrical samples will be inhomogeneous. Therefore, the thermal gradient in the sample while heating has to be determined. Moreover, the impossibility to use magnetic material such as thermocouples in the sensitivity area of the SQUIDs requires that the volt-temperature relation has to be determined externally.

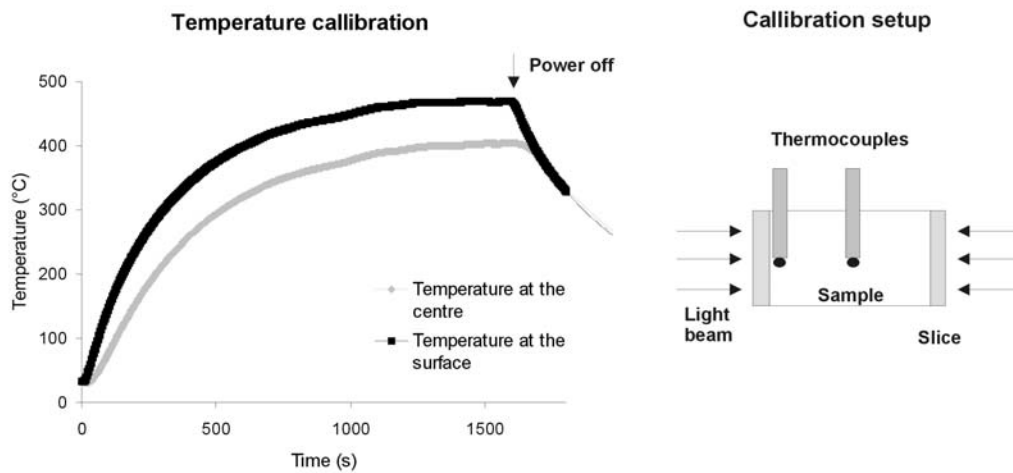


Figure 2: Left: Temperature curves for two positions in a paleomagnetic dummy sample (right sketch). Applied power of the lamps: 60% (600Watt, Wehland et al., subm.).

Figure 2 shows a calibration measurement in a dummy sample for an applied power of the lamps of 600Watt. The thermal gradient near thermal equilibrium is about 80°C between the frontal part and the center of the sample. It demonstrates that magnetic minerals with low Curie temperatures can be completely demagnetized within 800s. These test were performed for different power settings.

Pyrrhotite bearing samples - carrying an artificial thermomagnetic remanence (TRM) - were used to test the device within a cryogenic magnetometer. The unidirectional TRM was imparted using a MMTD1 thermal demagnetizer (Magnetic Measurements) and an applied field of 90µm. The demagnetization curve -using 60% (600Watt) of full power (Fig. 3)- shows a rapid decrease in intensity during the first 100 seconds. The demagnetization was stopped after ~400sec when a stable remanence was achieved. A complete demagnetization with this technique is - at this stage - not possible, as the temperature distribution is not

Comment: Ein thermal furnace wie vorgeschlagen macht keinen Sinn

completely homogeneous at the outer rims of the sample. During cooling, the remanence slightly increases again because of its temperature dependence.

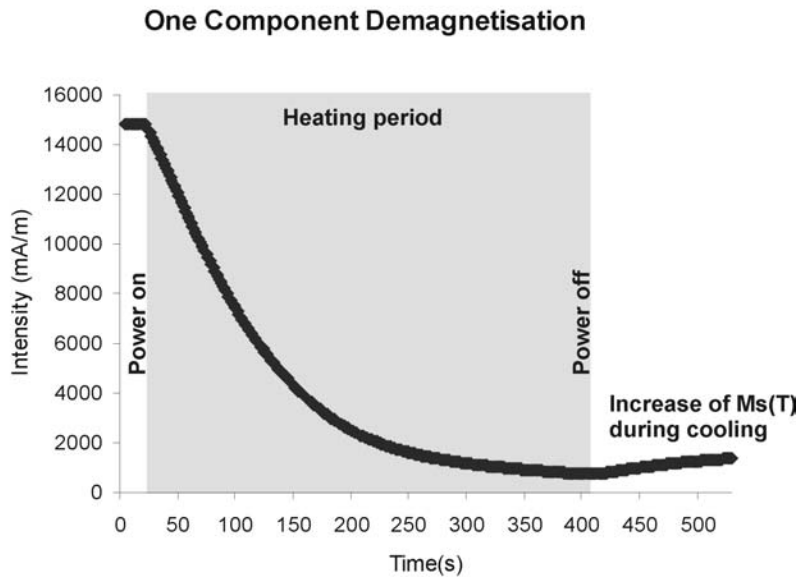


Figure 3: Thermal demagnetization of a single component using the new furnace device. Applied power of the lamps: 60%. Remanence reading: 1/sec (Wehland et al., subm.). Ms is the saturation magnetization.

Conclusions:

The new device allows to contemporary measure and demagnetize a paleomagnetic sample within a cryogenic magnetometer. For a pyrrhotite bearing sample full demagnetization is accomplished within 500sec. A comparable conventional demagnetization with only 2% of data output would take about 5h. Due to the setup of the system a small thermal inhomogeneity cannot be avoided. Consequently, thermal demagnetization of samples carrying different remanence direction will lead to an overlap of these directions.

References:

Matzka, J., Krasa, D., Kunzmann, Th., Schult, A., Petersen, N., 2003. Magnetic state of 10 to 40 Ma old ocean basalts and its implications for natural remanent magnetization, Earth Planet. Sci. Lett., 206(3-4),pp. 541-553.

Wehland, F., Appel, E., subm., Remanence measurements at high temperatures in a cryogenic magnetometer.

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How did I learn about the award: from my professor