

Western Paleomagnetic & Petrophysical Laboratory

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WPPL Measurement Services

Several kinds of physical property measurements and applications are described below. If you have further questions, please do not hesitate to ask.

Magnetic Susceptibility:

All magnetic susceptibility measurements are made on a benchtop Sapphire Instruments SI2b susceptibility meter. Prior to each suite of measurements, instrument calibration is tested with a MnO_2 reference sample. Susceptibility values are corrected for instrument drift during each specimen measurement cycle and normally two measurements are made for each specimen as a check on repeatability. Measurements are usually made with respect to sample mass, but can be made with respect to sample volume if volume is already known. Measurements can be readily converted to volume-based susceptibility in cgs or SI units (relevant for interpreting magnetic anomalies) if sample density is known.

Anisotropy of Magnetic Susceptibility (AMS):

Common magnetic susceptibility measurements assume a uniform distribution of susceptibility in the sample. This assumption may not necessarily be true, because it is possible to have a preferred orientation of platy minerals (hematite), or preferred distribution of minerals in a crystalline structure (magnetite), or elongate crystals along cleavage planes (magnetite). In these situations magnetic susceptibility can have a preferred orientation that reflects a magnetic fabric. Anisotropy of Magnetic Susceptibility (AMS) measurements seek to define the orientation and magnitude of this anisotropy by measuring susceptibility along 6, 9 or 18 different axes to define a susceptibility ellipsoid for each specimen. This is especially important in iron formations or layered igneous intrusions where the AMS fabric is often directly linked to the lithologic layering or magmatic flow fabric.

Magnetic Remanence (NRM):

The Natural Magnetic Remanence (NRM) of a sample is the permanent magnetization that it has acquired in its history. The NRM vector has an intensity in 10^{-3} A/m (or 10^{-6} emu/cm³ in the cgs system) and a direction. All specimen remanence measurements are made on a Schonstedt SSM-2 spinner magnetometer using a six-spin configuration to reveal intensity and

direction of the NRM. Calibration for intensity and direction is achieved using known reference samples. In the absence of sample orientation, data remanence directions are calculated relative to the axis of the specimen. For specimens obtained from cores it is possible to use the up/down configuration of the core to establish a positive or negative polarity for the remanence direction. It is possible to check if the observed magnetization is original or drill induced in core samples by obtaining three specimens from each sample with a known relative position to one another. For all specimen measurements, the intensity of the remanence vector is corrected for the volume of the sample. Measurement of weak intensity samples ($<10^{-6}$ emu/cm³) such as limestone or some hematite-bearing rocks can be done by arrangement using the 2G cryogenic magnetometer at the University of Windsor.

For interpretation of magnetic anomaly data, the Q ratio of the remanent magnetization to the induced magnetization (calculated as the product of magnetic susceptibility and the Earth's magnetic field strength at the sample site) is a useful quantity. If $Q > 1$, then the remanent magnetization of the rock can have a significant contribution to the observed magnetic anomaly.

Paleomagnetic Component Analysis:

The NRM of any sample is likely to be a vector sum of two or more different magnetic records with possibly different directions. The directional components can often be distinguished from one another by stepwise demagnetization techniques using an alternating field demagnetizer. A specimen is demagnetized and its remaining remanence is measured over a range of increasing demagnetizing fields, typically removing by 20 mT a modern remanence acquired from the present day Earth's field to reveal one or more ancient magnetic field directions. The easily-removed remanence can sometimes be used to help orient samples, and if the expected ancient direction is known, the ancient remanence can also be used to orient samples. If sample orientation is already known, then this type of analysis can recover the recorded paleomagnetic direction in the sample and potentially be used to estimate the age of the rock by comparison with the known paleomagnetic record of the continent.

Magnetic Coercivity Analysis:

Magnetic coercivity is a material property reflecting the ability of a sample to be permanently magnetized. Low coercivity (or magnetically 'soft') materials can be readily magnetized by low fields, whereas high coercivity ('hard') materials require a large applied magnetic field to become magnetized. This property can be used to investigate magnetic mineralogy and effective magnetic grain size in a sample by various methods.

Any bulk sample magnetic physical property is controlled by three parameters: content of magnetic mineral, composition of the magnetic mineral, and grain size of magnetic mineral. Saturation remanence for magnetite is achieved using a pulse magnetiser producing a pulse DC

magnetic field of 1 T. A single straight line relationship between magnetic susceptibility and saturation remanence indicates that the variation in sample magnetization is controlled solely by changes in the magnetic mineral content. Multiple line segments indicate that grain size, and/or compositional variations are also present.

Effective magnetic grain size can be estimated by an experiment that interacts with the soft and hard magnetization fractions in a sample, using opposed pulse fields of 100 mT and 300 mT. According to work in environmental magnetism these applied fields are sufficient to differentiate between coarse and fine grained magnetite, and hematite.

Further coercivity parameters can be obtained through magnetic hysteresis loop experiments; please contact WPPL for further details on the cost and products from this type of analysis.

Resistivity:

The conductivity of a specimen is very dependant upon the presence of water in the pores of the rock. Prior to any electrical measurements all specimens are stored under water in a pressurized chamber for a minimum of two days. The intent is to water saturate the specimen to better represent its original subsurface conductive environment. During measurement the specimen starts to dehydrate, hence it is optimal to take the earliest reading. Resistance measurements are made using a two-wire bridge and a high-impedance voltmeter capable of measuring milliohms. Uniform contact with the specimen is achieved using copper electrodes and copper – sulphate saturated contact pads. Corrections are applied for specimen volume and specimen length to calculate resistivity from the measured resistance.

Induced Polarization (IP):

Like resistivity measurements the specimens are saturated prior to measurement. IP measurements are made using a four electrode configuration; with two potential electrodes and two current electrodes in a wenner configuration. Current is supplied by a BRGM IP pulse system using a 2 second pulse time and 1 microamp current. The resulting voltage decay after cutoff is measured with a digital oscilloscope. Commonly three complete cycles of on and off are recorded. After acquisition the voltage decay records 0.2 to 0.5 seconds post-cutoff relative to baseline are compiled in an Excel spreadsheet to provide information regarding chargeability of specimens.

P-Wave Velocity:

The acoustic travel time between two points is dependant upon the distance and the velocity of transmission in the medium. The length of each specimen is measured using a digital micrometer that gives values 10^{-3} cm. Travel time is established using first arrival using a digital oscilloscope capable of 0.01 microsecond resolution. Calibration is established using a reference block of aluminium of known thickness and density.

Bulk Density:

Bulk density (\sim Specific Gravity) is the mass / total volume of a specimen. For Specific Gravity measurements, a value for bulk density is obtained with reference to water, based on two weight measurements –one with the specimen suspended in air, the other with the specimen suspended in distilled water. An analytical balance is used, providing measurements in grams to four decimal places. Initial tare is applied to correct for minor weight of the suspension thread. Measurements are made on dry specimens prior to wet measurements. Care is taken that stable readings in water are obtained prior to absorption of water, which can be readily detected by the analytical balance. Comparison of the two weight readings provides a measure of the mass of water displaced, and assuming distilled water density of 1.00 g/cm^3 , the bulk sample volume is therefore known, which can then be used to calculate sample bulk density.

Other methods for obtaining bulk volume and therefore bulk density are available for samples that cannot be exposed to water, or very small samples. These alternatives are the benchtop Archimedean ‘glass beads’ fluid method or non-destructive imaging by laser camera, white light camera or by X-ray micro-computed tomography (CT imaging). Please ask about pricing and turnaround time for these alternative methods.

Grain Density:

Grain density is the mass / material volume of a specimen, leaving out pore space. Grain density more directly represents the intrinsic density of all materials in a specimen and therefore is a better measured comparison with models based on geochemistry/modal mineralogy and mineral densities. Grain volume is measured using a Quantachrome Multipycnometer employing helium as the inert gas to fill pore space in a sample. Sample “grain” volume can be calculated from a simple isothermal ideal gas law experiment in which He pressure is measured in the pressurized reference cell both before and after it is opened to share its He overpressure with the sample cell, which initially had He pressure set at atmospheric pressure. Each sample is measured at least five times to test reproducibility and assess measurement precision, typically producing grain density measurements to better than $\pm 0.005 \text{ g/cm}^3$.

Calibration is achieved using a suitable NIST reference volume sphere before sample measurements. Please see the Helium Pycnometry reference document for the range of sample cell sizes to accommodate a range of sample volumes and shapes.

If both bulk density and grain density are obtained for the same sample, then **sample porosity** can be readily calculated.