field happens to he present. If the rock is allowed to cool with the same field present, the remanent magnetism locked in the rock becomes hardn and harder as the temperature decreases, finally becoming quite permanent. The acquired intensity is rather strong and while it may be masked by lower-temperature latter-day magnettizations, it is very difficult to destroy or damage. Reheating the sample beyond the Curie point will, of comse. erase the old field record and record a new one.

Other materials have temperatures equivalent to the Curie temperature. These are called the blocking temperature or the Neel temperature, depending on the material. Whenever these temperatures are exceeded, the material is very easy to magnetize. If allowed to cool with the field present, a remanence proportional to the applied field is picked up. The cooled sample is very hard magnetically and a locked-in record remains.

Chemical remanent magnetization is caused by chemical processes that change impurities in the rock from nonmagnetic to magnetic compounds, locking in the field at the time of the chemical change. Sandstone turning red with age is one example of this. Detrital remanent magnetization is caused by fine particles that slowly settle as dust or in water, aligning themselves with the applied field. Neither of these two latter processes is as strong, distinct, or as well-defined as the TRM process. Thus, at present, TRM is far more useful.

Samples with useful TRM come in many forms. Clay is one of the best behaved. Clay is fired by man in the form of pottery, kilns, and firepits, and it is fired by nature by forest fires and underground coal fires. Second best are volcanic lavas, with TRM taking place as the material cools on the surface of the earth or the bottom of the sea. Other materials, while useful paleomagnetically, often give less reliable results, with sediments or badly disturbed formations the poorest of all.

There are other ways magnetism can be picked up and methods by which the recording is either altered or made inherently misleading. Before a meaningful paleomagnetic measurement can be made, these other effects must be taken into account.

Viscous remanent magnetism is soft, modern magnetism acquired as a result of the Earth's modern magnetic field, or it can even be caused by leaving a crowbar or other tool near the sample for a period of time. VRM must be removed before measurement. This is usually done by a demagnetizing process to which the TRM is resistant but the VRM is not, and by making repeated measurements with the sample being stored in different positions for several weeks before each measurement.

Some rocks magnetize more easily in one particular direction, just as a sailboat will prefer to go forward even with the wind at an angle. When a rock does this, it possesses *magnetic anisotropy*, and a casual magnetic measurement will "lie" as to the actual field direction. Modern tests must establish the existence of anisotropy in many types of samples. This is often done by remagnctizing and noting any preferred dir- ections of remanent magnetism.

Arlisolropic remanent magnetism (ARM) is caused by lightning-which produces such strong fields that it literally blasts a record into the rock that has nothing to do with the Eartl1's field. For this reason, rock outcroppings, particularly those on the lops of mountains cannot produce reliable paleomagnetic records.

Other problems indude the relaxation time for very old work, tl1e linearity of the remanence (usually good because the intensitis are rathter low), selfl-reversals (a rare and peculiar way certain samples have of altering their records long after recording), and the need for many sample's to average out inconsistences and produce reliable results.

To be useful, the magnetic intensity and direction of a samplte must be measured to 1/2% and 1/2 degree accuracy, respectively. Samples are usually taken to a laboratory where

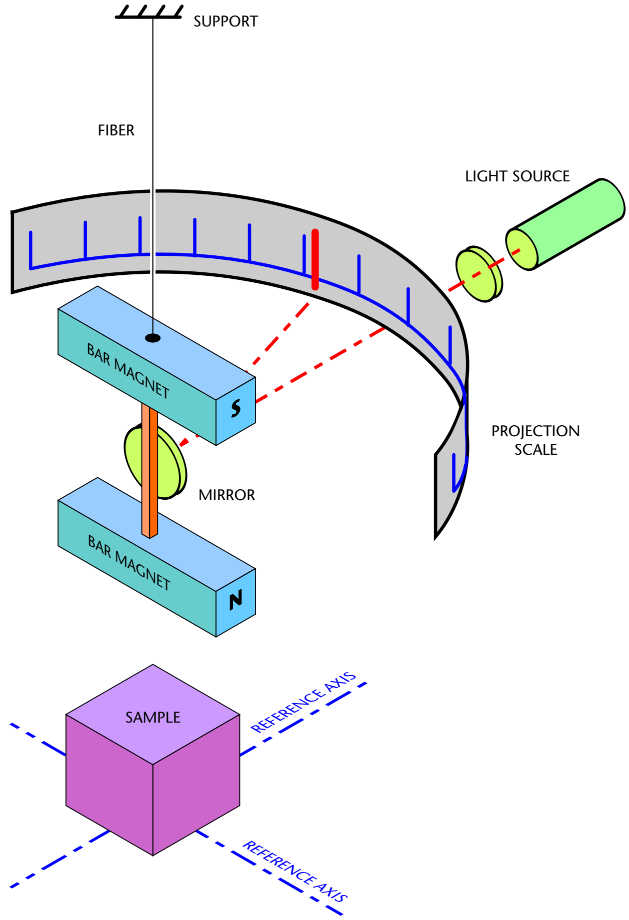

Fig. 3. Astatic magnetometer rotates in proportion to sample's remanent magnetism. Measurement on all three axes yields the total magnetic intensity along with inclination and declination.

this kind of control can be maintained instead of being directly measured in the field. Because of the low levels of magnetism involved and the required accuracy, considerable care and relatively fancy measuring techniques are needed.

An archeologist selects his samples from cultural remains, usually by isolating a smaller piece of firepit or kiln and, without disturbing its orientation, molds the sample inside a cubical plaster cast several inches on a side. After the plaster has set, its form is removed and the orientation of the sample with respect to horizontal and true north is carefully marked on the plaster surface. Whenever possible, several samples are taken from the same site.

A geologist usually uses a coring drill to obtain his samples. This drills a hollow circle through a rock stratum, leaving a core sample that may later be broken out and taken to the laboratory. Samples start out around an inch in diameter and several inches long; they are broken up into l-inch-high cylinders before measurement. Once again, the exact sample orientation is carefully noted.

Once in the laboratory, the samples undergo a week-long storage to eliminate any newly acquired VRM. They are then demagnetized at low temperatures by a relatively weak a.c. field that removes the VRM but leaves the TRM. The demagnetization is called magnetic washing, and after the a.c. field is applied it is gradually reduced in intensity until no field remains. To keep the present, modern Earth's field from introducing any bias into the readings, the entire dcmagnitizer is huilt inside a Helmholtz coil system. The Helmholtz coil system has currents flowing through it that neutralize the local effects of the present Earth field. After magnetoc washing, the sample goes to a magnetometer for measurement.

A magnetometer is an instrument that can measure the