The Proton Magnetometer: New Tool for Archeologists and Treasure-Hunters

This exciting electronic prospecting instrument has opened new paths to the past

By E. H. MARRINER

Archeologists can save precious time with a new instrument: the *proton magnetometer*. Just recently, it has found stone-age civilization sites in England and probed Etruscan tombs in Italy. Now investigators are using it in the USA. No longer must archeologists drill holes and dig trenches just to learn whether there might be anything down there worth looking for. With the proton magnetometer, the center of a site can be plotted on a map long before anyone brings out the shovels.

An electrical method of probing has been used for some time. It works by passing a current into the ground through two outer electrodes in a line of four. The resistivity can then be calculated from a simple formula involving the measured resistance between the inner pair of electrodes and their distances apart. The success of a site survey depends on having a measurable contrast in resistivity between the structures sought and the surrounding ground. The contrast depends on the moisture content of the ground; this, being a variable, can be compensated for on the chart. Information is gathered by making a measurement spread through a right angle. Then the data are processed. A pattern 25 feet wide and 55 feet long can be plotted in hour, against days of digging by the old method.

Elsec Proton Magnetometer—a commercial unit.

This method of locating sites has been used in Europe for several years but has only recently been tried in this country. The University of California found a new San Dieguito Indian complex in San Diego County, California, on the first field trial. But the resistivity method is being supplanted by a new method, using the *proton magnetometer*.

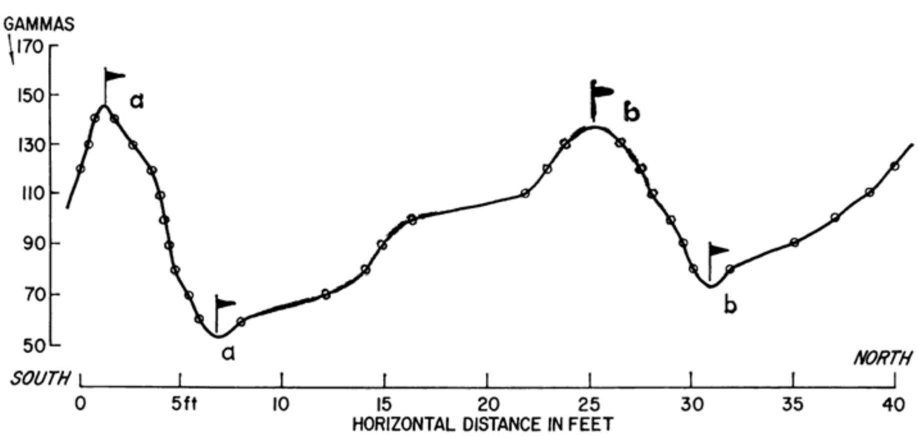


Fig. 1—Magnetometer readings are plotted along a straight line. Points between which magnetic susceptibility changes rapidly (as between the little flags a-a and b-b) define the areas where the searcher looks for objects of interest.

Any instrument that measures a magnetic field is called a magnetometer. Such instruments have been used in geophysical studies for many years.

The original magnetometer was called the Swedish mining compass. It was developed about 100 years ago and used only to detect ore bodies. About the turn of the century the Hotchkiss dip needle and super-dip were developed. During World War II, aircraft detection of submarines came out of this principle, although these devices were actually a type of variometer (instrument used to measure variations in magnetic fields).

In 1956 a group of research geophysicists developed the proton magnetometer. This instrument measures the magnitude of the earth's magnetic field. The operator of the device can detect a magnetic anomaly spatially on a chart (Fig. 1).

Systematic variations in the physical properties of the earth are what enable the magnetometer to find the structures that cause them. These variations are called anomalies. Anomalies due to magnetic material can be detected by the proton magnetometer. Two distinct types sought by the archeologist are those produced by soil of high susceptibility in comparison with its surrounding material, and those caused by the ferrimagnetic properties of heated material, which is termed *thermoremanent* magnetism.

The magnetometer is one of the few devices that have been adapted in the past few years to archeological surveying.

The first use of the proton magnetometer for archeological surveying was in the winter of 1957 at Huntingtonshire, England, by a group of Oxford University scientists. They detected a number of Roman and medieval walls and house outlines made of clay.[1]

A few years later a group from the Indiana Historical Society used the device to find a pre-Columbian village in southern Indiana and produced enough evidence to map in detail the entire fortified village.[2]

A proton magnetometer of different design was used in the German Rhineland. This instrument produced readings unaffected by diurnal variations or magnetic storms. It proved of real value in this area since there is a great variety of subsoils in the pits and ditches. The Roman city of Xanten was explored with the proton magnetometer, and the survey data produced detailed maps of the city's foundations and defenses.[3]

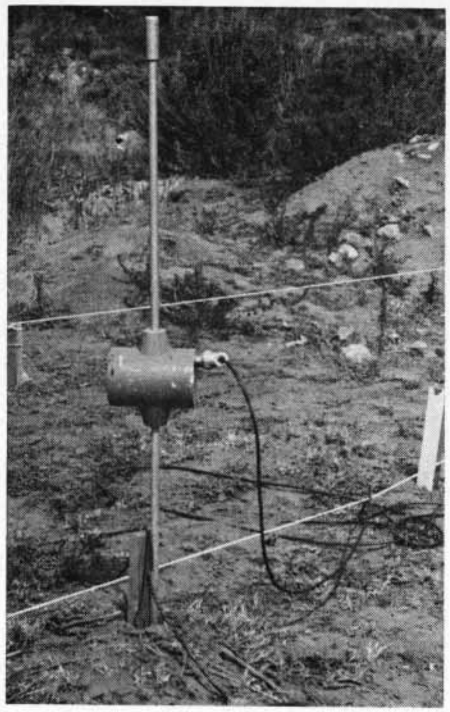


Fig. 2—The "bottle" section of a proton magnetometer.

Physical description

The proton magnetometer is composed of a control box and the *bottle* (Fig. 2). In the bottle is a plastic container called the sensing head, 1.85 inches in diameter. The bottle holds about a pint of distilled water. (Alcohol is used in arctic climates.) The bottle is surrounded by a coil of wire (1,250 turns of No. 22 SWG) which serves the dual purpose of polarizing the protons and receiving the signal produced by the precession of the protons. In the receive position, the weak signal is amplified by an amplifier connected to the bottle unit by a cable. Digital indicators read this amplified signal and record the measurements.

A magnetometer is a rather simple device, though it depends on nuclear reactions. It can best be described in the words of an article by Dolan Mansir in the April 1960 issue of RADIO-ELECTRONICS, which also showed some of the electronic circuitry used to amplify and detect the magnetometer output. Part of the article is reprinted here.

How a magnetometer works

"Protons are simply the nuclei of hydrogen atoms, and there are two reasons why they can be used to measure magnetic fields: Protons have magnetic moments, like very small bar magnets, and they spin on an axis through their magnetic poles - or at least their behavior indicates they do.

The magnetic moment and spin determine a property known as a gyromagnetic ratio. This merely means that the tiny bar magnets, spinning on their axes will *precess* at a given frequency (like a spinning gyro, which will wobble but not fall if tipped) if they are placed in a given magnetic field - and if you follow the right sequence of steps to cause the precession to occur.

Causing and detecting precession

What does it take to cause a free precession and how do you detect it? If a bottle of water or other substance containing many hydrogen atoms is placed in a strong nonoscillating magnetic field, the nuclei of a majority of the atoms will align themselves with the applied magnetic field. Now, if the magnetic field is suddenly removed, the spinning atomic gyroscopes are given a "push" by the earth's magnetic field, and they start to precess in phase. After a few seconds, the phase relationship is lost as the nuclei align with the earth's field and it is necessary to start over with the aligning process.

If the aligning field is exactly in the same direction as the earth's field, the protons do not get a push and no precession occurs. For best signal amplitude, the aligning field should be at right angles to the earth's field. Alignment

Two archeologists make a field survey with the proton magnetometer.

affects only the signal amplitude, not the signal frequency.

In practice, the protons are actually placed in a bottle which is put in the center of a simple coil of wire. The coil does double duty - it furnishes the strong magnetic field to align (polarize) the protons, and the precessing magnetic moments of the protons induce the signal voltage in it. This is exactly analogous to an ac generator."

Magnetic susceptibility

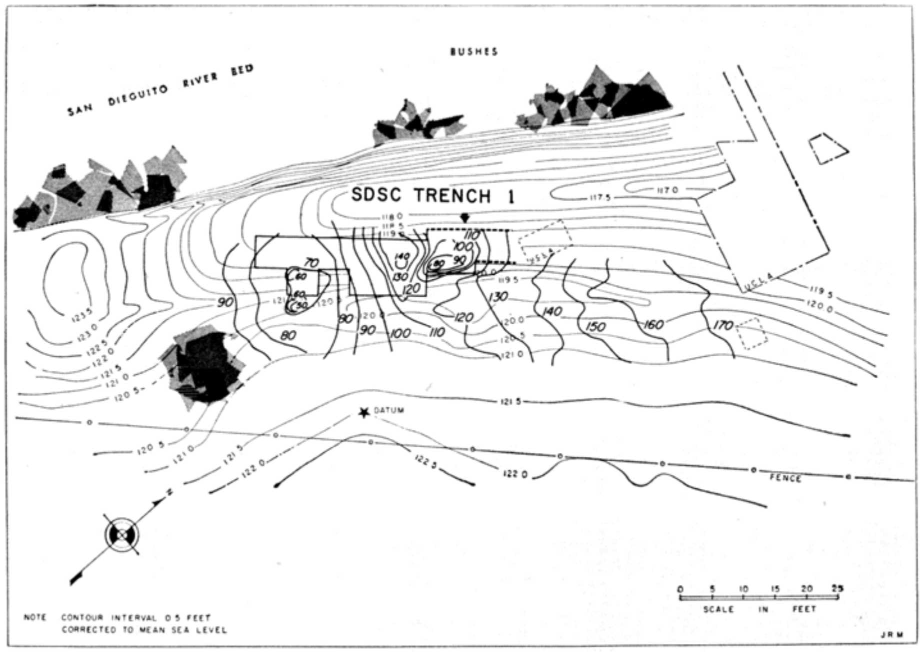
Magnetic susceptibility determines the magnetic moment induced in a sample when it has been placed in a magnetic field. By the susceptibility method the proton magnetometer can detect pits, ditches, walls and tombs. The amount of susceptibility in a pit is related to the amount of organic matter in the soil from food, waste material, burials or charcoal. Many tombs have air pockets which cause a change in susceptibility from the surrounding material, as was discovered by Dr. Lerici at a few sites in Italy.[4]

Iron oxides in pottery shards, kilns and furnaces produce the second type of variation, thermoremanent magnetism. The overall content of iron oxides on the earth's surface ranges from 0-1%. The oxide is normally magnetite, hematite, or maghemite, a structural combination of the first two. As pottery is fired, its temperature is raised, resulting in the alignment of the ceramic magnetic properties with the earth's field; on cooling, the domains are fixed in one direction, forming a weak permanent magnet.

Anomalies produced in these ways vary in range from 0-100 gammas,[5] which is equal to about 1/500 of the earth's magnetic field. Iron artifacts or deposits can produce even larger anomalies depending on their size and the depth at which they are buried.

The primary reasons for the success of the proton magnetometer are simplicity of operation, fast surveying, reduction of manual labor and relatively low cost compared with prices of other geophysical instruments.

The future of the device looks very promising. Many more discoveries, made with its help, will enlighten our record of man.



Magnetic contour map. Light lines and numbers are ordinary topographical contour lines; heavy lines and numbers are contours of magnetic susceptibility. Bunched contours represent sharp gradations in magnetic susceptibility and are the areas that interest researchers.

References

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