Earth resistivity meter

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From gold to archaeological remains — this simply constructed instrument will assist your prospecting.

An earth resistivity meter can be used to identify the composition of various earth strata and the depth at which each strata occurs and by detecting changes in earth composition, to point to the existence of buried objects.

An earth resistivity meter may be used to locate archaeological objects to assist in finding conditions favourable for alluvial gold or gemstones, or even for such prosaic duties as determining where to locate a septic tank!

These instruments are not expensive compared with most electronic instrumentation. Nevertheless at $1000 or so they are way above the budget of most amateur archaeologists or rock-hounds.

But for such people all is not lost — it is possible to construct a simple dc operated resistivity meter for a mere fraction of the price of commercial units.

For this to be possible we have to accept a few operating limitations — primarily of operating depth — for whereas a commercial unit may be used to depths of 100-200 metres, our unit is limited to 15 metres or so. But unless you are hoping to locate oil bearing deposits in your backyard the limitation on operating depth should not be a problem.

The basic instrument is extremely simple — four equally spaced electrodes are placed in line in the earth. An accurately known current is caused to flow from one outer electrode to the other and a measurement is taken of the voltage between the two inner electrodes.

Having measured both voltage and current, a simple formula is used to establish depth and composition of the strata.

Professional earth resistivity meters use alternating current across the earth electrodes in order to eliminate the effects of the small galvanic voltages caused by the earth.

This effect cannot be totally eliminated with dc instruments but it can be minimised by switching the battery across the electrodes in alternate polari-
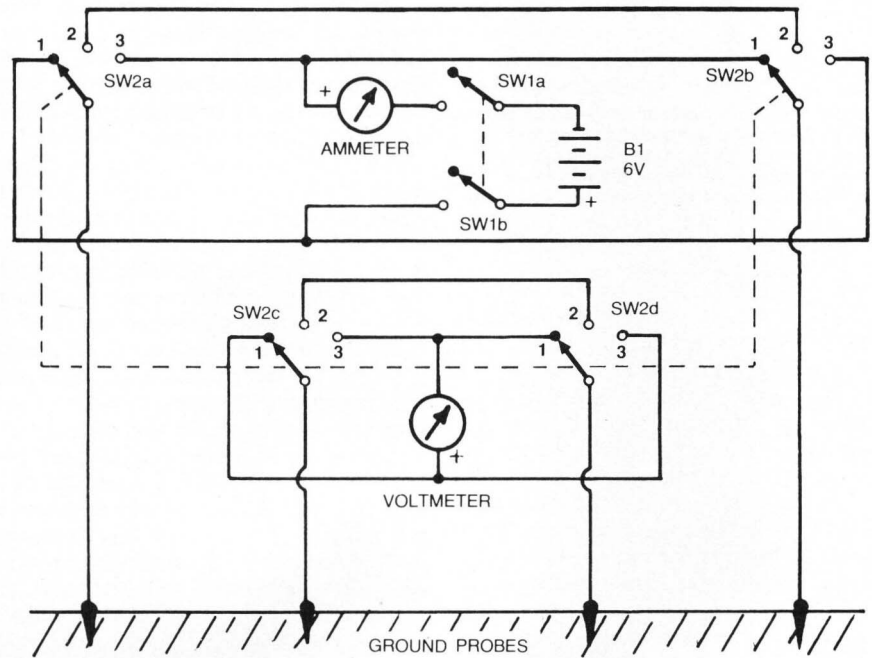
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Figure 1. **Circuit diagram of resistivity meter.**

ties — a centre position of the switch (SW2) meanwhile short-circuits the two centre electrodes between readings to discharge the galvanic potential.

Figure 1 shows the circuit diagram of the instrument. A connection diagram is reproduced in Figure 2.

We have not provided any mechanical assembly drawings, for this will depend almost entirely upon the meters used. A pair of cheap multimeters are ideal but if these are not available then a voltmeter and a milliameter with switchable ranges should be used. The milliameter should be capable of measuring from microamps to a maximum of 100 milliamps or so, the voltmeter should cover a range from approximately 100 microvolts to three volts or so and should have a sensitivity of about 20 000 ohms per volt.

Switch SW2 is a three-pole four-way wafer switch. All switching contacts are located on one wafer. Each of the four segments shown in the wiring diagram (i.e: SW1 SW2 etc) consists of a wiping contact and three fixed contacts — the connections will be readily appar-

ent when the wiring diagram is compared with the switch.

The ground probes should ideally be made of copper coated steel or brass — however electrodes made from 25 mm to 50 mm steel tubing or rod will work quite well as long as they are kept clean. It is of course essential that they make the best possible contact with the surrounding earth. Electrode cable connections must be securely made using proper terminals — remember that you are looking for fairly minor changes in earth resistance.

Operating voltage is not critical — a six or twelve volt dry cell is adequate for most applications.
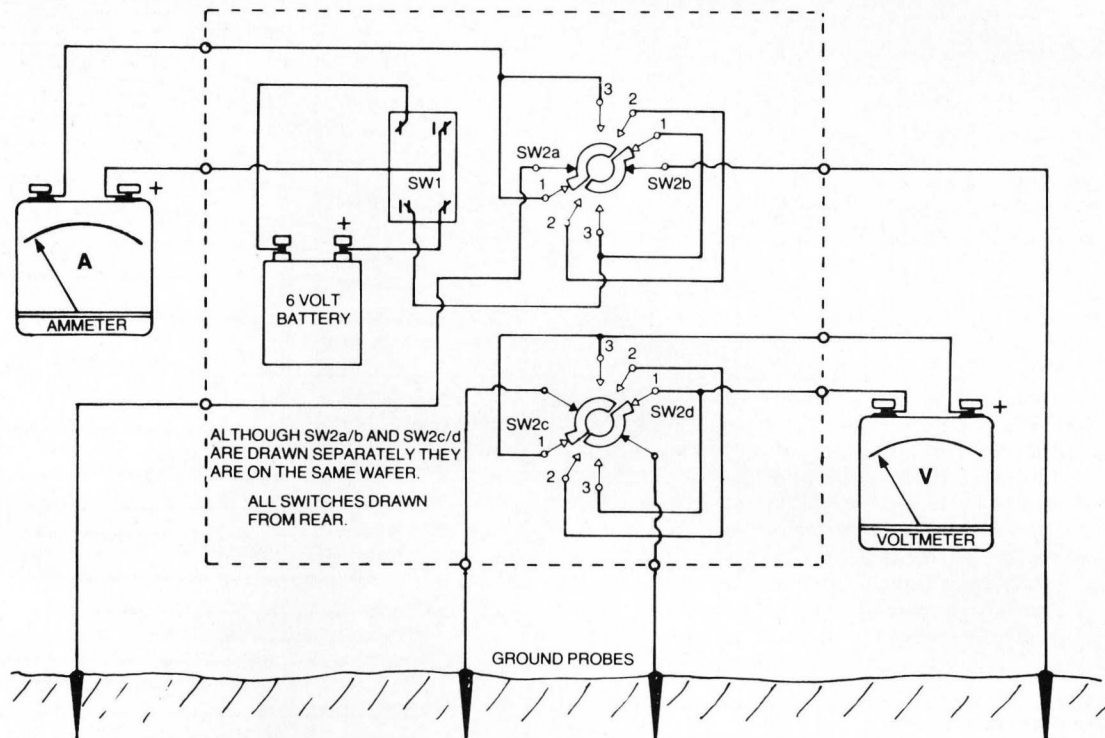
Figure 2. **How the components are interconnected.**

Text inside figure:
ALTHOUGH SW2a/b AND SW2c/d ARE DRAWN SEPARATELY THEY ARE ON THE SAME WAFER.

ALL SWITCHES DRAWN FROM REAR.

GROUND PROBES

Measuring earth resistivity

There are several methods of measuring soil resistivities, mostly variations of the original method devised by Wenner. This consists of driving four metal spikes (commonly called electrodes), into the ground, at equal intervals along a straight line as shown in Figure 3.

A current is passed through the outer electrodes C_1 and C_2 and the resulting voltage drop across the earth resistance is measured across the inner pair p_1 and p_2.

If the ground has a uniform resistivity p then

$$p = 2\pi a \ V/I = 2\pi a \ R$$

where 'R' is the apparent resistance measured between the inner potential electrodes.

Generally the current will flow in an arc between the electrodes and hence the depth penetrated will increase as the electrode separation is increased. The effective depth at which R is measured is usually taken as 0.6 times the separation 'a'.

For the greatest accuracy in determining the ratio V/I it is desirable that the current flow I be maximised and hence in dry surface conditions it is common to moisten the soil about the electrodes to reduce the contact resistance. The depth to which the electrodes are inserted must not exceed one-twentieth

of their separation. This is important if standard curves are to be used for the interpretation of the experimental data.

Having inserted the four electrodes an average value for both V and I must be determined for both polarities of the battery. Reversing the polarity removes the possibility that the earth may have its own potential due to galvanic reactions underground. From these measurements the resistivity p can be calculated.

Resistivity depth sounding

Consider for example the problem of measuring the depth beneath the ground of the water table or perhaps the thickness of soil overlying the bedrock. This type of situation is by far the most common — where a layer of resistivity $p1$ and thickness 'd' is overlying a layer of different resistivity $p2$.

We can determine the depth 'd' with the aid of 'standard curves'. The procedure is to measure the resistivity of the ground each time the electrode separation 'a' is increased about a central point. To use the standard curves provided it is necessary to plot the measured resistivity (p) on the vertical axis, against the electrode separation distance on log/log graph paper.

The standard curves provided (Figure 4), are also constructed on log/log graph paper i.e: graph paper that is ruled in both directions at logarithmic intervals. Each major division on the paper corresponds to a power of 10 and is therefore called a decade. We suggest that for plotting your data you purchase semi-transparent paper that has three decades on either axis and a decade separation of 2½ inches. The 2½ inch decade separation is most important as
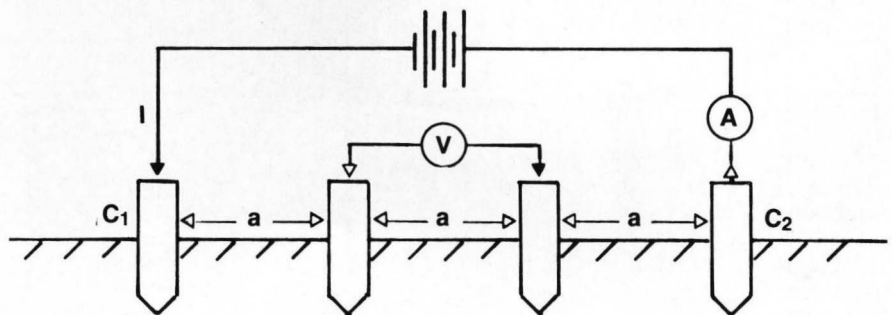

Figure 3. **The electrodes are driven into the ground at equal intervals and in a straight line.**
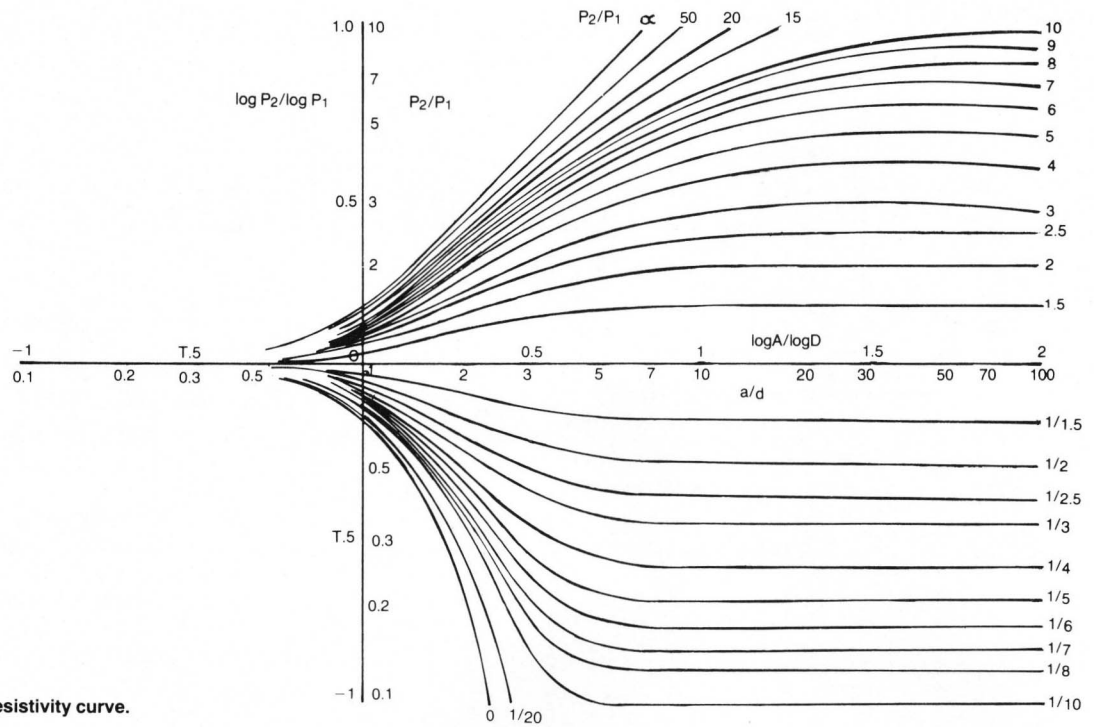
Figure 4. **Standard resistivity curve.**

paper having other decade separations will not allow your plotted results to be overlaid on the standard curves. This paper should be readily available from major stationary suppliers such as John Sands or Dymocks.

Figure 5 shows a typical plot of field data overlaid onto the standard curve.

To do this, place your plotted curve over the standard curve and slide it horizontally until you find the standard curve that best matches your plotted curve.

When the best matching curve has been found, note where the vertical axis of the standard curve intersects the 'ab' curve of your plotted data. This line extended vertically downwards to intersect the 'electrode separation' axis of your plotted data will show the depth of the first layer — in our example this is 4.25 metres.

We know from our plotted data that the resistivity $p2$ is about 1000 ohms/metre and the standard curve that is a best match shows a $p2/p1$ ratio of one tenth, that is $p2$ equals 0.1 $p1$.

Thus $p2$ is approximately 100 ohms/metre. Relating these figures to Table 1 we see that the most likely strata formation is two layers of sandstone of different densities or a top layer of sandstone and a lower layer of limestone.

From the section bc it is possible to calculate the resistivity and depth of the

Figure 5. **Typical field data plot superimposed over standard curve shown in Figure 4.**
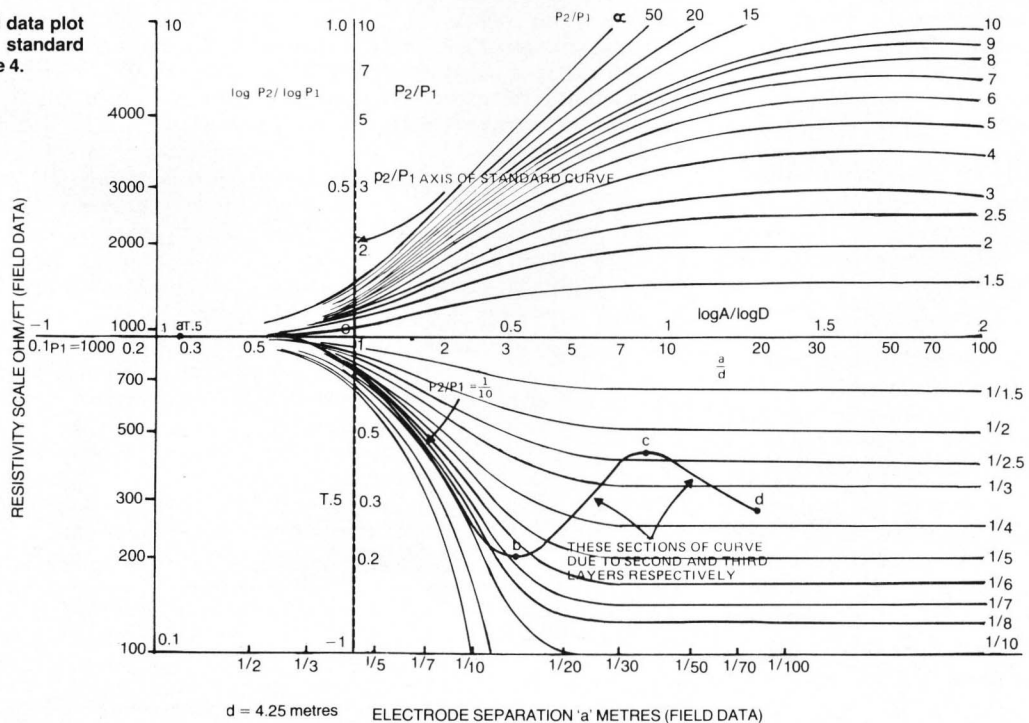
TABLE 1

Material	Resistivity (ohms/metre)
Clay	1-120
Water (fresh)	50
Sandstone	35-4000
Limestone	120-400
Granite	$5000\text{-}10^6$
Sand (dry)	$>10^6$
Marble	$>10^{12}$
Alluvium	Variable
Air	Infinite

second layer but this requires the use of a second set of auxiliary standard curves. These are very complex and beyond the scope of this article. Similarly section cd provides data on the third layer and so on. There are a number of standard texts on such measurement and the interested experi-menter should refer to these for further information.

Resistivity trenching

Another common application of the resistivity meter is in searching for buried objects such as large water mains, buried stream beds or underground sewerage tunnels. The method used is simply to decide approximately at what depth the object is likely to be found, and divide the distance by 0.6 to give a suitable electrode separation. Maintaining this same separation, the array of all four electrodes should be progressively moved in a line over the ground being explored. Readings of resistivity should be made at each point and the value plotted against distance moved. (See Figure 6 in our feature on Exploration Archaeology). The distance between each reading point should be no greater than half the dimension of the object to be located; in fact the closer the readings are taken, the greater will be the resolution.

If it is desired to follow the depth of bedrock beneath the surface, it is best to first carry out a vertical depth sounding to locate the bedrock. Then divide this depth by 0.6 to give the most suitable electrode separation. The depth sound will also tell you whether the bedrock has a higher or lower resistivity (from the ratio $p2/p1$). If $p2$ is greater than $p1$ then an increase in your measured resistivity will tell you that the basement is getting shallower and vice versa. Alternatively, if $p2$ is less than $p1$ an increase in resistivity will indicate that the basement is becoming deeper. This method is most suitable for looking for alluvial gold or heavy gemstones which tend to be concentrated in the hollows of the bedrock along alluvial creekbeds.

> **Earth electrodes should not be inserted into the ground to a depth greater than one-twentieth of the probe separation. Because of this, poor electrode/ground contact may result at close spacings. This problem can be reduced by using porous pots filled with copper sulphate solution. Electrodes specifically intended for such work are available from geophysical supply houses. www.250.org.ua**