GEOPHYSICAL SURVEYING OF CAVE SITES

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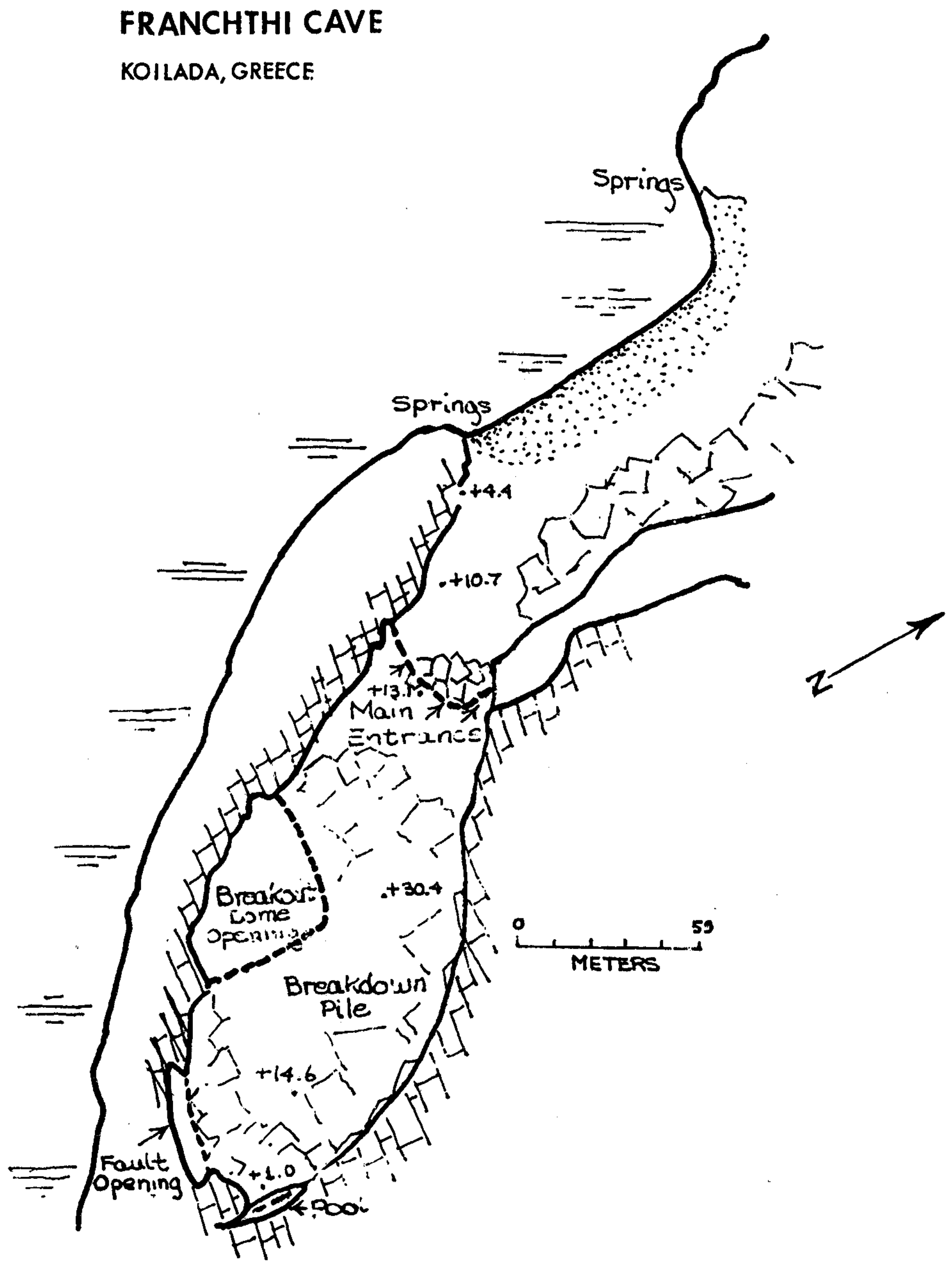
It is desirable in surveying caves and rock shelters as potential archaeological sites to determine the depth of the deposits and approximate stratigraphy without digging trenches. Much time and effort can be saved if geophysical equipment is used to quickly assess the site's possibilities prior to excavation.

Generally, a surface examination will reveal traces of human activity. But, what time period is representend by the deposit? The answer to this question is usually supplied by digging. The writer has found that utilizing average rate-of-deposit figures and establishing the depth of the deposit by the electrical resistivity method produces fast, reasonably accurate resuls. Three examples of the resistivity method of site survey will be given: two from Mallora and one from Greece.

Before describing applications, the various geophysical techniques available to the archaeologist at reasonable cost — cesium magnetometer, seismograph, and electrical resistivity — will be considered in this context. The cesium magnetometer is without question the fastest method for archaeological site survey of surface sites. Without having tested it in caves the writer feels that not enough magnetic anamolies would be present to produce significant results. Futhermore, the magnetometer is not used in determining depths of sediments; its value lies in revealing archaeological features near the surface and these, of course, if present, would be deeply buried in pre-Neolithic cave sites. The seismograph can be used in certain caves, but, depending as it does on sound wave velocity in individual strata, it has serious limitations. It will, with great accuracy, provide data on deposits with approximately equal or decreasing sound wave velocities — the ususal cave deposits of clay, silt and sand. But, if traverfine floors (suelos de estalagmita) or bedrock ledges intrude into the de-


FRANCHTHI CAVE
KOILADA, GREECE
Springs
Springs
+4.4
+10.7
+13.1
Main Entrance
Breakout Dome Opening
+30.4
Breakdown Pile
+14.6
Fault Opening
+1.0
Pool
0
50
METERS
N

posit, all strata below these will be masked. Such intrusions are usually present in cave deposits. The electrical resistivity technique eliminates most of the above problems (Kopper, 1970).

Having determined the depth of the deposit by the resistivity method — as described in the following examples — average rate-of-deposit figures can be used to determine the approximate time period represented by the strata. The following depositional rates from various cave sites in the Mediterranean area from Farrand (1972, personal communication) and personal measurements:

Abri Pataud (France):	Rockshelter in temperate area from 34.000 to 20.000 B.P. 55 cm/1000 yrs. overall rate including individual periods up to 100-182 cm./1000 yrs.
Ksar Aqil (Lebanon):	Rockshelter in semi-arid area from 44.000 to c.26.000 B.P. 82 cm./1000 yrs.
Hava Fteah (Libya):	Large cave from 50.000 B.P. to post-Neolithic «20-30 cm./1000 yrs.» (after McBurney).
Tabun (Israel):	Relatively small cave but more than 20 m. of sediments (in semi-arid area) between 20 and 50 cm./1000 yrs., depending on chronology used.
Franchthi (Greece):	Large, extensively collapsed cave in semi-arid zone from 22.000 B.P. to present 53 cm./1000 yrs.
Canet (Mallorca):	Medium sized cave, semi-arid zone 20.000 B.P. to present ± 31 cm./1000 yards.

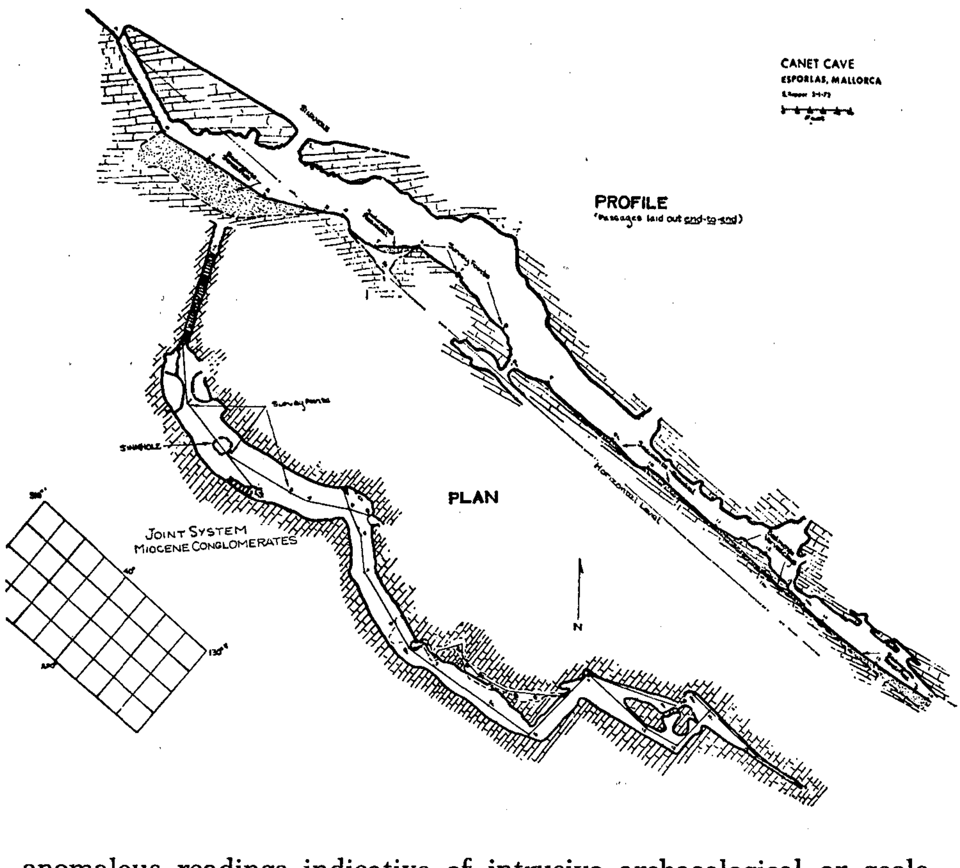
As a conservative rate 25-30 cm. / 1000 yrs. might be applied for late Pleistocene and Holocene cave deposits.

Franchthi Cave Resistivity Survey

Using electrical resistivity equipment, a survey was made in and in front of the cave in an attempt to determine the depth of the cave deposit and to gain an idea of subsurface startigraphy. This work was done with a Bison Instruments, Inc. 2350A meter which is primarily used in prospecting for ground water.

With sufficient output — 540 volts a.c. — and sensitivity to provide stratographic information to a depth of 100 to 150 ft. in soils, the Bison uses four or five electrodes for sounding or profiling surveys.

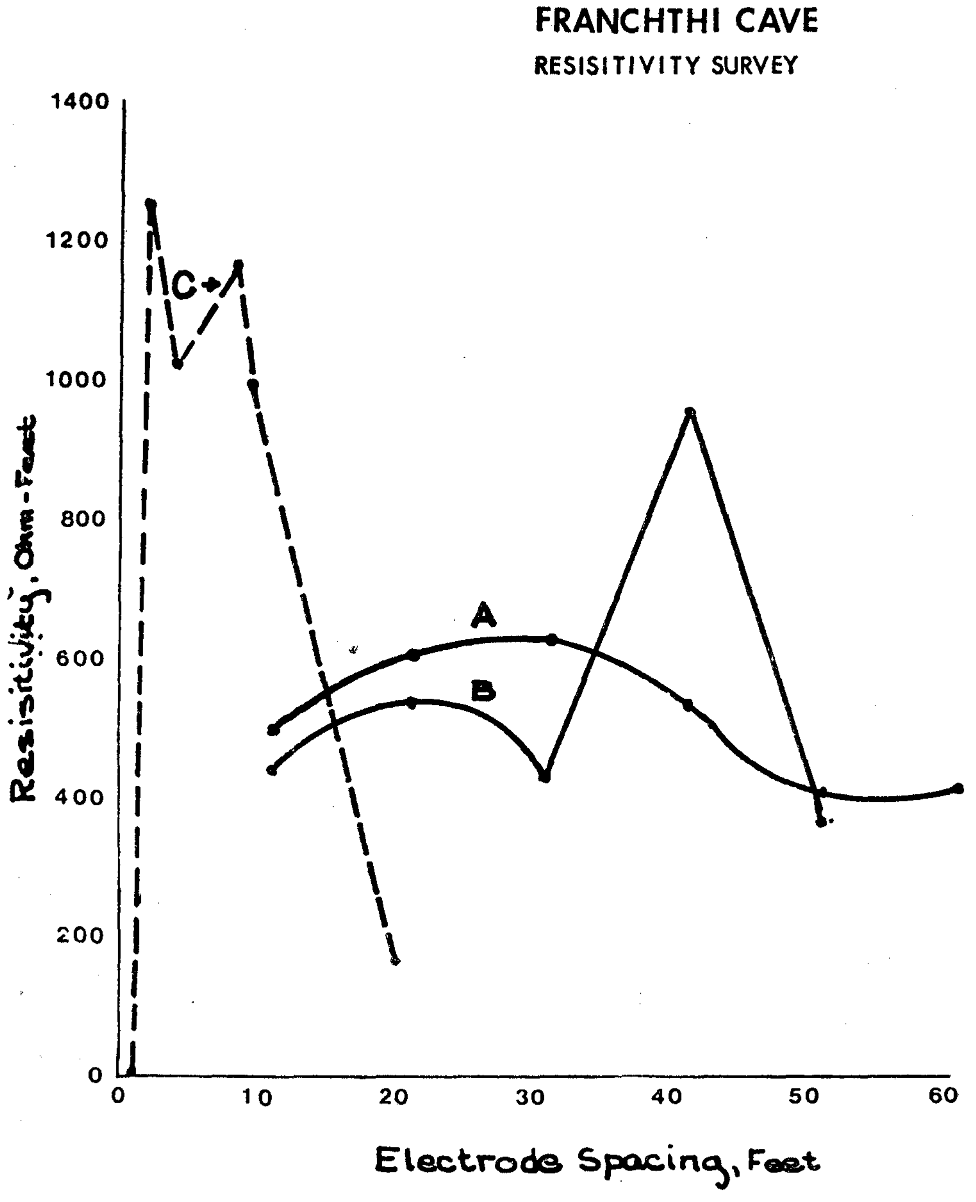
The former method was the one employed at Franchthi since the vertical succession of strata to the bottom of the cave was what was of interest. (Profiling utilizes a fixed depth of penetration of the electrical current and the electrodes are moved across a traverse in order to find



anomalous readings indicative of intrusive archaeological or geological features.)

In a sounding survey the electrodes are spaced at successively greater intervals with the distance between them approximately equalling the depth of penetration of the current. By plotting resistivity values against electrode spacing on a graph, breaks in the curve indicate changes in the strata (Bison Instruments, 1970). Apparent resistivity is obtained by multiplying meter readings by electrode spacing.

Depth to the cave floor being the most important information sought, soundings were first made in front of the cave mouth to

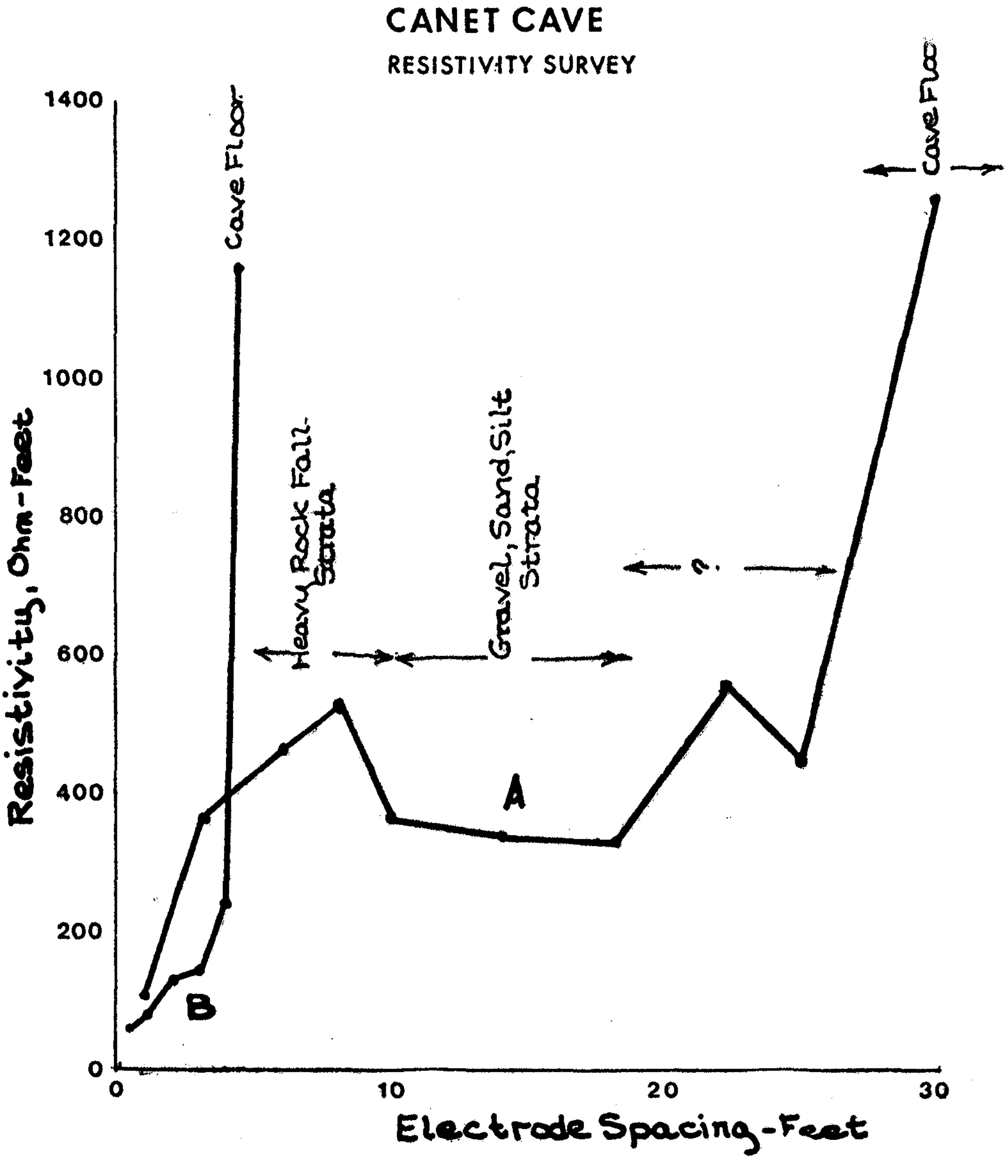

FRANCHTHI CAVE
RESISITIVITY SURVEY
1400
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
C→
A
B
Resisitivity, Ohm-Feet
Electrode Spacing, Feet

obtain average apparent resistivities for soil, dry limestone and sea water saturated limestone — the term, apparent resistivity, is used here to indicate the readings are not to be taken as absolute values, applicable anywhere. Various soundings made in and adjacent to the cave entrance area (see Map A); plots of electrode spacings (depth of penetration) vs. apparent resistivity are shown in Graph I. Sounding C, using an adjacent trench as control, provided the following readings:

Dry, rocky soil	± 500-700 ohm-ft.
Satured limestone	± 175-200 ohm-ft.
Drier limestone.	± 950-1150 ohm-ft.

With these figures, soundings of the main chamber deposit were then made using electrode spacings of 11, 21, 31, 41, 51 and 60 ft. An interpretation of the results plotted on sounding curves A & B, Graph I, reveals several interesting facts. In general, the progressive dampness of the deposit as it approaches sea level — note that the elevation in the center of sounding spread A is 12.1 meters or 39.98 ft. — dominates the readings. Because of the rapid reduction in resistivity immediately below the surface (sea water is an excellent conductor of electricity) separations between strata can not be inferred from the curves. The excavation trenches first show dampness of strata at about 10 m. above sea level. The rapid rise in resistivity in sounding B at the 41 ft. electrode spacing is interpreted as heavy rockfall or a void.

It is obvious from the curves that the cave floor has not been reached at the maximum possible electrode spacing of 60 ft. — this spacing actually means a depth of current penetration of 0,92×60 ft., or 54.2 ft. This interpretation is based on the facts that apparent resistivity does not approach the minimum value of 175 to 200 ohm-ft. for saturated limestone and because there are no breaks in the sounding curves A & B of the order demanded for such an abrupt change in stratigraphy. This interpretation was tentatively verified by geological evidence: An adjacent cave is reported to have a depth of 104 m. below present sea level and Franchthi, lying about 1 km. from it, most likely developed by the same mechanisms and would, therefore, have about the same vertical development. Additional verification of at least some downward extension of the cave below sea level is offered by the observation that the pool at the back of the cave is about 7 m. deep at several points. This pool's suface stands at 1 m. above sea level so it continues at least 6 m. below this level.


CANET CAVE
RESISTIVITY SURVEY
Resistivity, Ohm-Feet
1400
1200
1000
800
600
400
200
0
Electrode Spacing-Feet
0
10
20
30
Cave Floor
Heavy Rock Fall Strata
Gravel, Sand, Silt Strata
A
B

Canet Cave Resistivity Survey

A resistivity survey of Canet Cave, Esporlas, Mallorca, was made to determine the depth of the deposit in the main chamber (survey point 2, Map B) and at the back of the cave (survey point 15, Map B). The results of these two sounding surveys are plotted on Graph II. Curve A shows the main chamber deposit at survey point 2. Note that the sounding indicated strata with heavy rockfall as well as the cave bottom. This interpretation has been verified by coring the deposit.

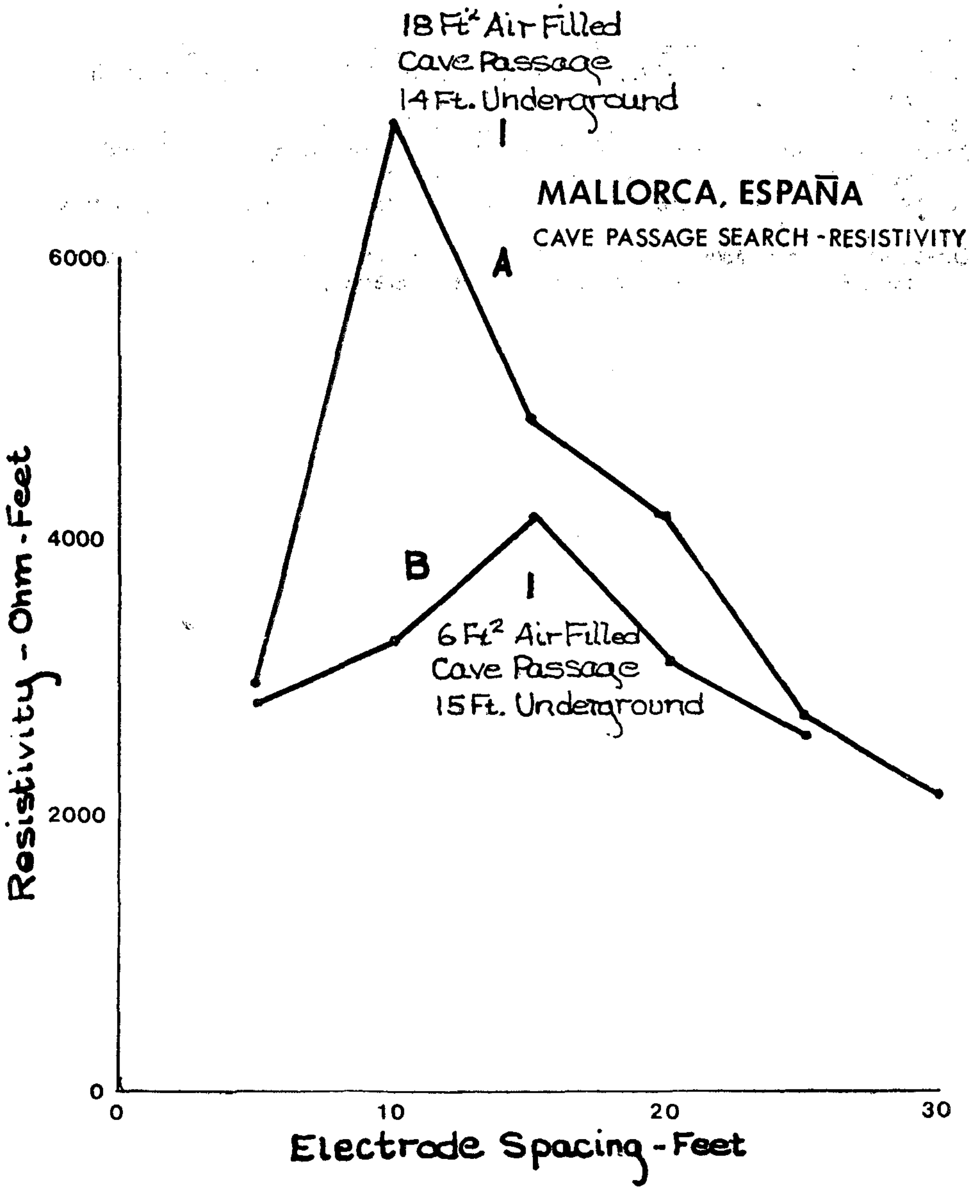
Curve B shows the sounding survey carried out in the shallow deposits at the back of the cave. The bottom at this point was indicated exactly as subsequent physical testing proved.

Survey For Buried Cave Passages

Another use of the resistivity method is to locate buried (filled) caves and cave passages. Caves are often encountered in which it is suspected side or lower passages exist that may have been filled with sediments. Further, the archaeologist may wish to locate entire cave systems whose entrances were covered over by earlier peoples in an effort to prevent domestic animals from entering them and perishing.

Experiments were made with the resistivity equipment to see if such caves and cave passages could be detected. Results are shown in Graph III. Curve A represents a sounding survey carried out over the man-made stairway entrance of Canet Cave. It can be seen that with an electrode spacing of between 5 and 15 feet, resistivity increased by a factor approaching 3 — measured depth below the surface at this point of the entrance is 14 feet. In another test, Curve B, a previously unknown cave, buried under a terrace, was located in Deyá, Mallorca. In this case resistivity increased by a factor of only about 1/2 owing to the smaller air space in the passage.

Success of the method depends on the existance of air in the passage because air alone, not filling material, is highly resistant to the conductivity of electricity. Thus, only passages containing air spaces can readily located by this method. Further, detecting such air spaces is a fairly laborious procedure limiting its usefullness to investigation of small areas where other indications of care passages are present.


18 Ft² Air Filled
Cave Passage
14 Ft. Underground
MALLORCA, ESPAÑA
CAVE PASSAGE SEARCH - RESISTIVITY
A
B
6 Ft² Air Filled
Cave Passage
15 Ft. Underground
Resistivity - Ohm - Feet
6000
4000
2000
0
0
10
20
30
Electrode Spacing - Feet

BIBLIOGRAPHY

ARTKEN, M. J. (1961): *Physics and Archaeology.* London; Interscience.

Bison Instruments, Inc. (1970): *Earth Resistivity Systems.* Minneapolis; Bison Instruments Inc.

COLOM, G. (1964): *El Medeo y la vida en Las Baleares.* Palma, Miramar.

Instituto Geológico y Minero de España (1963): *Mapa geológico de España,* nu meros 698 (Palma) and 670 (Soller). Madrid, Coullant.

KOPPER, J. S. (1970): *Cave Surveying with Electrical Resistivity Equipment M.A.S.C.A. Newsletter,* 6, 2, 4.

ORELLANA, E., and MOONEY, H. M. (1966): *Master tables and curves for vertical sounding over layared structures.* Madrid, Interciencia.