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Geophysical Methods & Systems



# "PUGLIE" PROSPECTING PERMIT

# MAGNETOTELLURIC SURVEY

AUGUST 1-23, 1980

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As per REIT Dept request we have planned and carried out an experimental magnetotelluric (MT) survey in the "Puglie" prospecting permit area with the purpose to evidence the possible presence of conductive formations underlying Burano fm and to study their structural trend.

Field operations, processing and interpretation of MT data were performed by C.G.G. (Compagnie Générale de Géophysique), Paris.

## SURVEY PROGRAMME

The initial programme, consisting of 50 soundings distributed over 5 profiles, has been prepared taking into account the experimental nature of the use of MT for the peculiar target dealt with in this study.

The factors affecting the definition of the programme were in particular:

- need to test the method in the different parts of the permit area;
- indications on structural trends as obtained by other methods;
- location of the known noise sources;
- thickness of the conductive cover formation caused by invasion of brackish water, as obtained from logs in Foresta Umbra 1 and Canosa 1 wells.

In particular, line 500 was positioned outside the area of primary interest in order to get as closest as possible to Foresta Umbra 1 well, where stratigraphic conditions seem most favourable for a good use of the method.

The initial programme was reduced by 9 soundings since profile 400 had been interrupted after the first two measurements because of big environment disturbances.

The locations of the soundings made are shown on the attached map, 500,000 scale.

SHORT DESCRIPTION OF MT METHOD - FIELD OPERATIONS

The MT method utilizes the propagation in the ground of natural electromagnetic waves which are probably due to currents caused in the ionosphere by the sun action.

The MT method consists in measuring the time variations of the magnetic and electric (telluric) components of the electromagnetic field , which are evidently correlated one another.

By applying the electromagnetic laws it is possible to obtain the apparent resistivity, that is a function of frequency if the rock resistivity varies in depth.

In order to obtain the MT basic relationships it is not possible to consider the electromagnetic phenomena in their complexity; by introducing schematizations of the natural medium it is possible to calculate the underground apparent resistivity from measurements made on surface.

MT basic relationship is:

$$\rho_a = 0.2\, T \left| \frac{E}{H} \right|^2$$

where:

E = electric field carrier

H = magnetic field intensity carrier

T = time in seconds

$\rho_a$ = apparent resistivity (Ohm.m)

Only in the case of flat and parallel layers does not depend on E and H directions.

In the reality, apparent resistivity depends on the electrode alignment direction since changing the azimuth usually changes the underground geoelectric section.

From a particular linear combination of the values calculated in two directions perpendicular to each other is obtained a $\rho_a$ value called "Invariant", which does not depend on the electrode alignment azimuth and can therefore be considered as the characteristic value of the subsoil on the measure spot.

The method investigation depth increases as T time increases due to the skin effect. Introducing the apparent resistivity versus time in a bilogarithmic diagram, we obtain a resistivity curve similar to that of the electric logs. The interpretation of the apparent resistivity curves ( $\rho_a = f(T)$) of MT soundings enables us to obtain geoelectric sections.

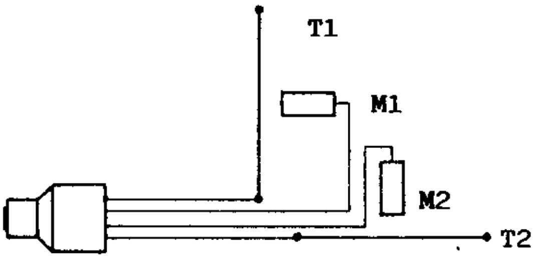
Solving by this method is limited by the following properties:

- the deeper a formation lies the thicker it must be in order that its effect be noticed on the resistivity curve;
- for the conductive formations lying between two resistive layers, it is possible to define only their conductivity and to a certain extent only ($C = \sigma \cdot h$, where $\sigma$ = conductivity and h = thickness);
- as for the resistive formations lying between two conductive layers, it is possible to define only their thickness.

These properties make interpretation all the more difficult because many geoelectric sections may fit one curve.

Performing an MT sounding consists in measuring the electromagnetic field components along two directions perpendicular to each other.

This figure represents the electrode alignment for measuring. At both ends of the two telluric lines T1 and T2, used to measure electric field E, non polarizable electrodes are placed, which must be accurately put in contact with the ground.




To measure the magnetic field two magnetometers (M1 and M2) are used, placed at a right angle with the telluric lines.

The telluric line length is a function of the signal intensity (in our survey it ranges between 100 m and 250 m).

At each measuring point 4 components are recorded, 2 electric and 2 magnetic (horizontal), through connection of the telluric lines and the two magnetometers to a digital recording lab.

The signals pass through an amplifier-multiplexer-converter and can be seen through a double trace oscilloscope. The operator adjusts in an appropriate manner gains and filterings and optimizes the signals for recording. Recording is made in the analog form on paper to check measurement and in the digital form on magnetic tape.

Measuring is made through separate recording of high (HF), medium (MF) and low (LF) frequencies.

The following recording sequence was adopted:

- MF for 7'
- HF for 2'
- LF for 70'
- MF for 7'

Medium frequencies were recorded twice at different times in an attempt to obtain more easily times with a good signal-noise ratio in this frequency range which is basic for this survey purposes.

Sampling frequencies for analog-digital conversion were:

- for high frequencies (from 128 to 0.2 Hz) 512 Hz
- for medium frequencies (from 16 to 0.2 Hz) 64 Hz
- for low frequencies (from 1 to 0.01 Hz) 4 Hz

During recording operations the operator only watches the instruments while the rest of the party can align the electrodes on the following measuring points.

PARTY COMPOSITION - EQUIPMENT

The party consisted of:

- a geophysicist/ party chief
- an observer
- an assistant observer/topographer
- a ground assistant
- a mechanic
- 3 local labourers

The party was in total 8 people, two more than the number provided in the contract.

The measure instruments were installed on an air conditioned off-highway truck, and fed 220 V/50 Hz power by a 3 KVA alternator moved by the truck engine.

A belting system moved also the compressor for lab air conditioning.

The lab consisted of the following equipment:

- a double trace oscilloscope;
- an amplifier-multiplexer-converter with 6 channels and one synchronism channel;
- a microprocessor with control programming;
- an alpha-digital keyboard;
- an 800 BPI, 9 track, digital recorder;
- a 6 channel analog ink recorder.

The party was equipped also with 2 off-highway trucks and all geophysical material necessary for MT soundings:

- non polarizable cadmium/cadmium chloride electrodes;
- solenoid magnetometers with Mu-metal core;
- electrical cable and connections;
- spare parts and stock material for recording;
- a theodolite.

On the whole, the party and geophysical equipment performed MT soundings correctly.

## PRODUCTION - COSTS

The survey was performed from 1st to 23rd August 1980 totalling 20 work days. On 6th and 7th August no production was obtained due to technical troubles in the recording lab. On 20th August the party stopped recording of profile 400 and went to profile 500 for the aforesaid reasons.

Field operations are summarized in the following chart:

| | |
|---|---|
| survey days | 20 |
| stoppage days | 2 |
| soundings made | 41 |
| soundings/survey day | 2.05 |

Survey costs are tentatively indicated as follows:

| | | | |
|---|---|---|---|
| Move in/move out | Lit. | 2,820,000 | 5.4% |
| Move to following area | " | 2,050,000 | 4% |
| Data acquisition and processing | " | 47,560,000 | 90.6% |
| Total | " | 52,430,000 | 100% |
| Cost per sounding | Lit. | 1,280,000 | |

DATA PROCESSING

Data processing was performed by Contractor according to the following phases:

a) demultiplexing of the 4 channels recorded, with removal of most evident noises;

b) transfer from time domain to frequency domain through a Fourier transform and application to the spectra obtained of the corrections necessary to take into account the transfer function of the recording equipment;

c) examination of the spectra of telluric and magnetic components and calculation of resistivity curves $\varrho_a = F(T)$ for the two measure directions;

d) calculation of the "invariant" curve as linear combination of the two aforesaid curves.

In this survey it has not been possible to study the main structural trends owing to the insufficient quality of data.

In conclusion, 3 apparent resistivity curves were made for each sounding: two for measure directions (M1 T1 and M2 T2) plus the invariant curve.

In figures 1, 2 and 3 an example is given showing the curves pertaining to sounding No. 105.

For each time considered, the statistical distribution is represented of the resistivity values calculated for each of the sections into which the whole recording is divided. When there is high dispersal of such values due to the presence of a heavy environment noise, it is difficult to define the curve.

INTERPRETATION - RESULTS

To interpret MT soundings use is made mainly of the invariant resistivity curves.

The curves $\varrho_a = F(T)$ obtained by field data processing are heavily disturbed in the medium and low frequency ranges.

In particular, in the medium frequency range the environment disturbances, nearly identical in all soundings, are correlated in both telluric and magnetic channels, and cause a steep rise of the curve which hides completely the effect of a possible deep conductive layer. The steep rise of the M.F. curve seems to be caused by the noise since it could be explained only by the presence of too superficial, highly resistive layers.

For example, in the invariant curve of sounding No. 105 (see fig. 3) the rise caused by noise can be noticed from a 0.4 second time. At around 100 seconds a steep dip of the curve occurs and the low frequency section (up to 100 seconds) lets appear the natural signal.

The curve rise in low frequency range(i.e. high time values, in curve right section) enables us to determine the total conductivity of the subsoil. However, because the curve central part is lacking , it is not possible to determine whether such conductivity is due to a superficial or deep conductive formation.

In order to evidence these observations two models of the same sounding were made (see fig. 4 and 5); both presented the same total conductivity, due to a conductive formation which is superficial in the first model and deep in the second.

It can be noticed that both models fit the real curve in the high and low frequency ranges, whereas they differ from each other in the central section where we have no reliable real data.

As regards most of the other soundings, interpretation is even more difficult since the steep rise of the curve in MF continues also in LF, and not even total conductivity can be determined.

CONCLUSION

According to what has been said above it is evident that it is not possible at this stage to answer the queries dealt with in this study.

At present we are reprocessing the data to try to reduce the noise; this is done in two phases: in the first are considered noisy only the telluric channels and in the second only the magnetic channels.

But no satisfactory result can be expected due to the noise conformity in both channels.

Moreover, since the noise effects are very similar in all soundings, it should be concluded that the disturbances are spatially consistent within a vast area, and therefore the simultaneous recording of several soundings should not bring further improvements.

At a second stage, there will be studied the advisability to repeat certain soundings if the curves resulting from the reprocessing under way provide indications helpful for determining recording ways which would allow a further attenuation of the environment noises.

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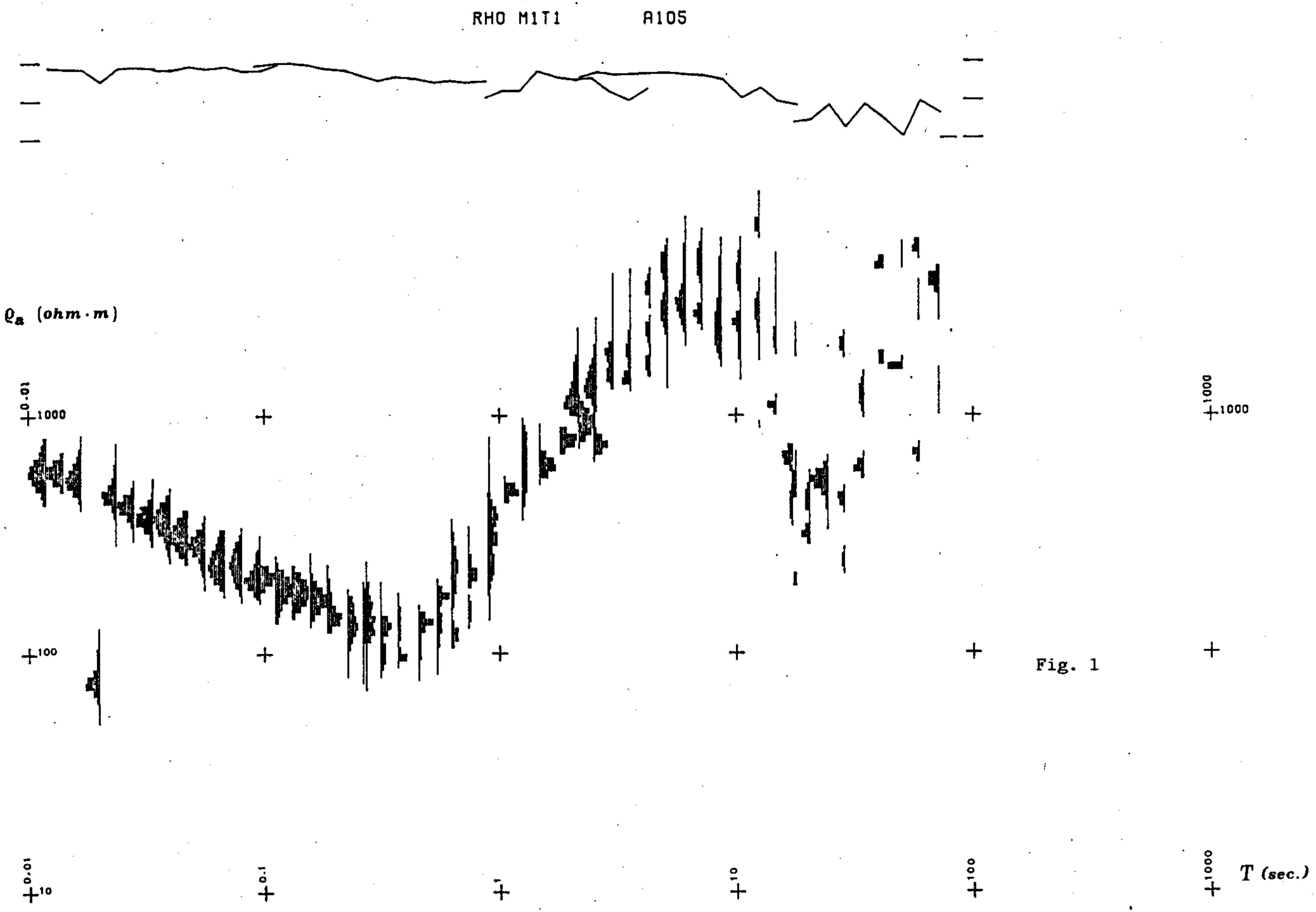

RHO M1T1 A105
$\varrho_a$ (ohm·m)
1000
100
10
0.01
0.1
1
10
100
1000
T (sec.)


Fig. 1

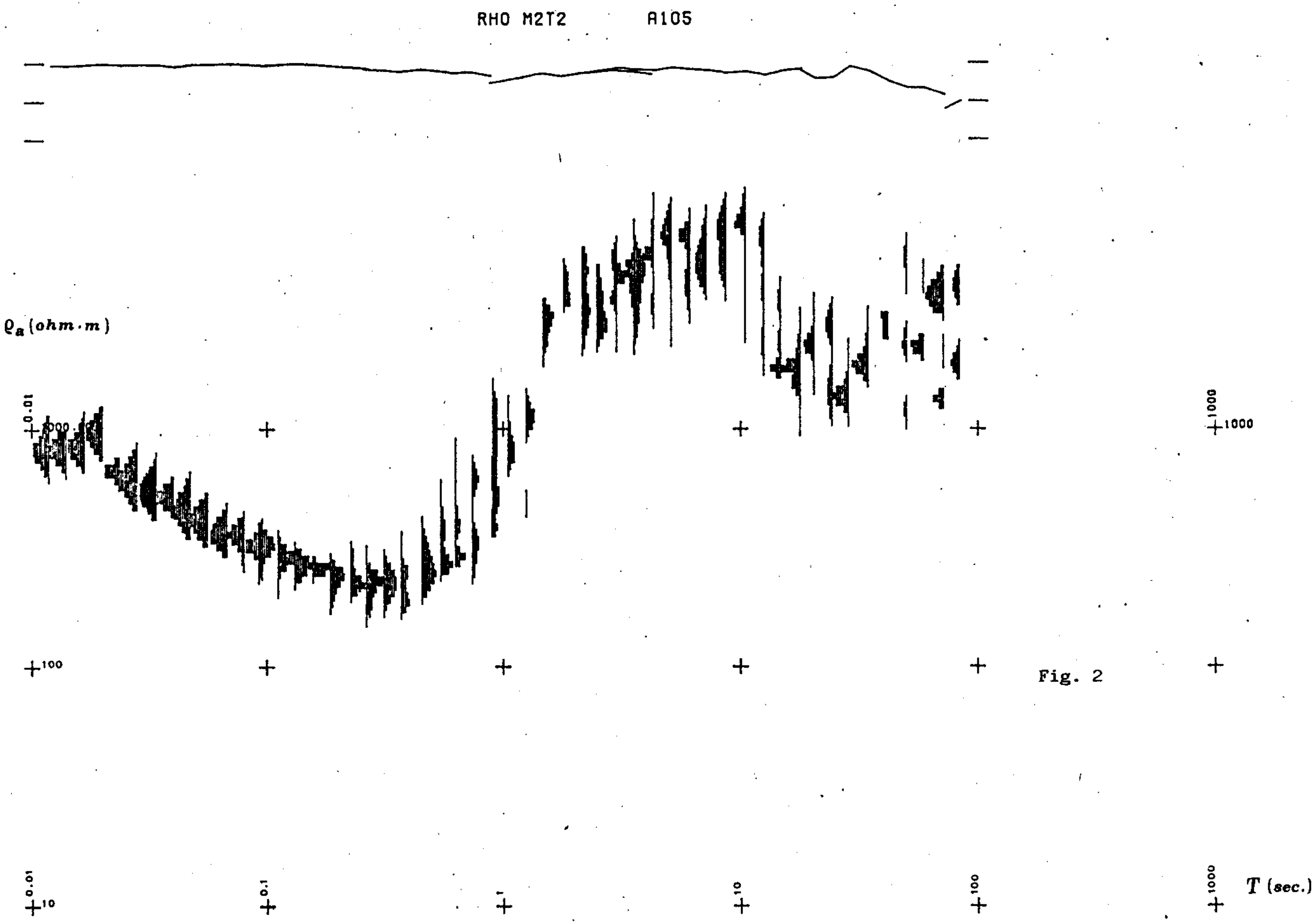
RHO M2T2
A105
$\varrho_a$ (ohm·m)
1000
100
10
0.01
0.1
1
10
100
1000
T (sec.)

Fig. 2

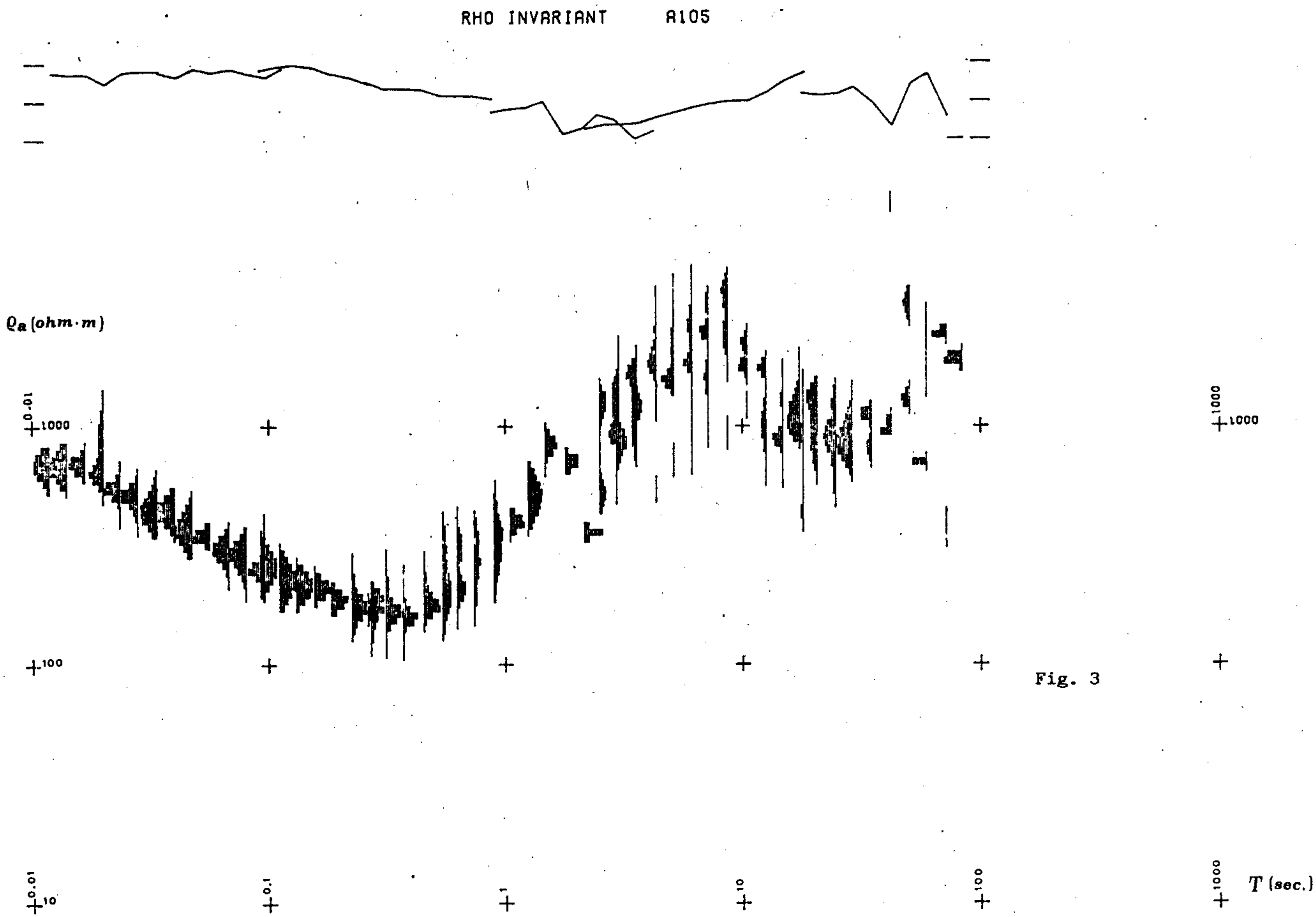
RHO INVARIANT A105
ϱa (ohm·m)
1000
100
10
0.01
0.1
1
10
100
1000
T (sec.)

Fig. 3