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Technical Note TN-26

'RELACON'

A VLF Magnetic Field "Relative Conductivity" Filter

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Patents applied for in U.S.A. and elsewhere

Principles of Operation

The RELACON filter is a digital filter (much like the well known Fraser filter) which, however, is used to convert a profile of VLF magnetic field data to a profile of relative conductivity data. It does this by spatially integrating the variations of the vertical component of the VLF magnetic field data along the survey line; the result of this operation will be seen to yield a profile which often resembles to a high degree the conductivity profile that would be measured, for example, with a Geonics EM34-3 with 20 m intercoil spacing. However, because the conductivity data is obtained by spatially interpreting the vertical VLF magnetic field data the zero level of the calculated conductivity profile is unknown, and the filter is said to yield "relative conductivity" only.

The data required for operation of the invention are values indicative of the relative magnitude of a vertical field component H_v as compared to the horizontal magnetic field component H_p produced by the VLF excitation. Examples of such values are the ratio of the in-phase vertical field component $H_v(I)$ to H_p. or the tangent of the tilt angle of the polarization ellipse of the field produced. Those values involving only in-phase components are preferred.

Assuming that data representing any of the above values is measured at a series of stations spaced along the survey line at an interval of Δx metres, and that the value measured at station i in the series, where $i \geq 0$, is V(i), all ratios being expressed as decimal fractions, then the result of spatial integration is

$$X(i)=X(i-1)+V(i).\Delta x.R$$

where X(-1)=0, X(i) is the spatially integrated value after station i, and R is an arbitrary constant or scale factor, and successive values for X(i) are plotted at plot points $x = (i+0.5).\Delta x$. If the units of Δx are metres, than a convenient value for R is unity, in which case experimentation shows that the data can be expressed approximately in terms of "relative conductivity" expressed in milliSiemens/metre (mS/m). The choice of R=1 where Δx is in metres) will usually result in the plotted values being of a similar order of magnitude to the actual conductivity.

An example using artificial survey data is shown in the following table:

TABLE 1

i	xi=i.Δx	V(i)	V(i).Δx	Xi	Plot Point $(i+\frac{1}{2}).\Delta x$
0	0	0	0	0	50
1	100	0	0	0	150
2	200	0.1	10	10	250
3	300	0.2	20	30	350
4	400	0.3	30	60	450
5	500	0.0	0	60	550
6	600	-0.3	-30	30	650
7	700	-0.2	-20	10	750
8	800	-0.1	-10	0	850
9	900	0.0	0	0	950

As will be seen from the subsequent examples a principle advantage of the filter is that, for the first time it allows the user to interpret the slowly varying excursions of the inphase component of the VLF vertical magnetic field profile, which have heretofore been ignored. Like the rapidly varying component, the slowly varying component often contains useful geological information. It will be noted that the action of the filter enhances the slowly varying component at the expense of the rapidly varying component, and its application is thus very complementary to that of the Fraser or Karous-Hjelt filters; use of both types of filter should improve the interpretability of VLF survey data.

Finally, as will be seen from Figure 3 the output of the filter is strongly non-linear with actual conductivity and it must be stressed that the resultant conductivity profile is definitely a profile of relative conductivity.

Comments on Figures

(In all cases the direction of the VLF survey is shown with an arrow)

Figure 1 Illustrates the current flow in the vicinity of a vertical contact and the nature of the resultant vertical magnetic field component. Clearly, spatially integrating the profile will give a measure of the change in conductivity.

Figure 2 The objective of the filter is to achieve a more graphical representation of the variations in terrain conductivity along the survey line.

Figure 3 Since the peak value of the vertical magnetic field anomaly across a vertical contact is a function of the resistivity contrast only, whereas the width of the anomaly is proportional to the square root of the resistivities themselves, the amplitude of the spatially integrated profile is a complicated function of the two resistivities, always, however, increasing with increasing conductivity.

Figure 4 Calculated response of vertical dikes of various conductances located in half-spaces of 8 000 and 800 ohm metres. The amplitude anomaly and width increase with halfspace resistivity as they should.

Figure 5 Compares the calculated response from a vertical and dipping dike with the original VLF responses.

Figure 6 Note the conductivity contrast at the contact, also evident on the resistivity profile but less evident from the raw VLF data. Note also the conductivity peaks at 101 and 115 metres respectively. Finally note that the actual location of the profile zero is, of course, unknown, and that the vertical location of the relative conductivity scale is completely arbitrary

Figure 7 The geology consists of faulted dolomite underlying a few metres of lacustrine clays. The EM34-3 and relative conductivity profiles are probably indicating areas of increased overburden thickness and if, for example, this was a survey for groundwater, the VLF anomaly at 120 metres would probably be the best target since the structure is more likely to be saturated with groundwater due to the increased overburden thickness

Figure 8 Same as Figure 7 except here the favourable target would be at 525 metres.

Figure 9 Here anomaly C is the most favourable target.

Figure 10 Note the excellent agreement between the structures shown on VLF with the EM34-3. Both the VLF apparent conductivity and the DC resistivity suggest that the conductivity is increasing beyond the base line.

FIG 1

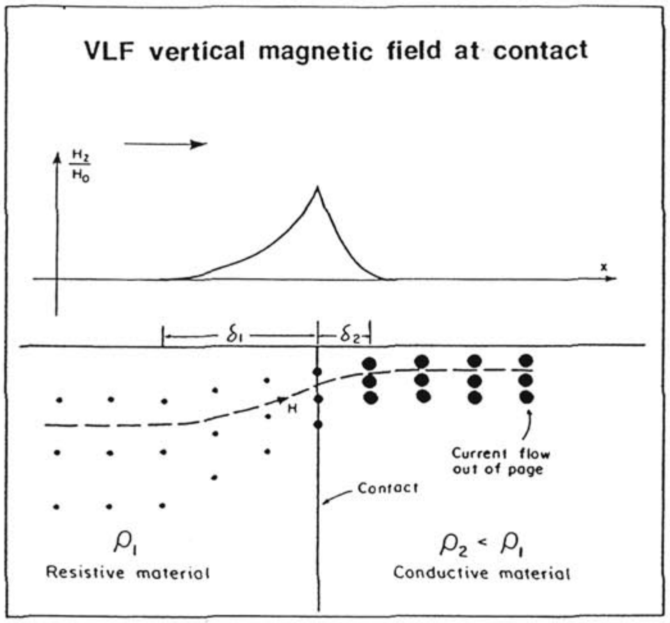


FIG 2

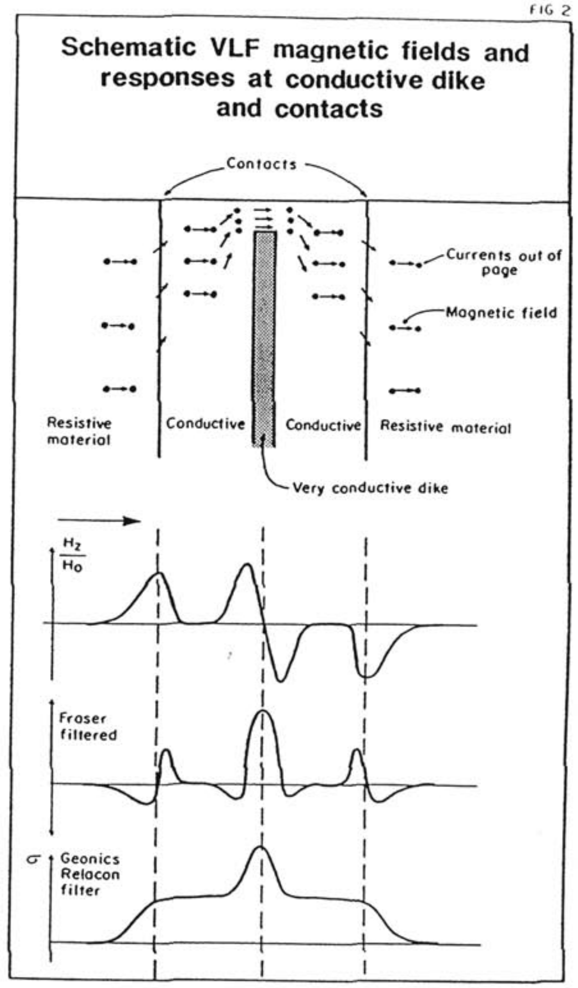


FIG. 3

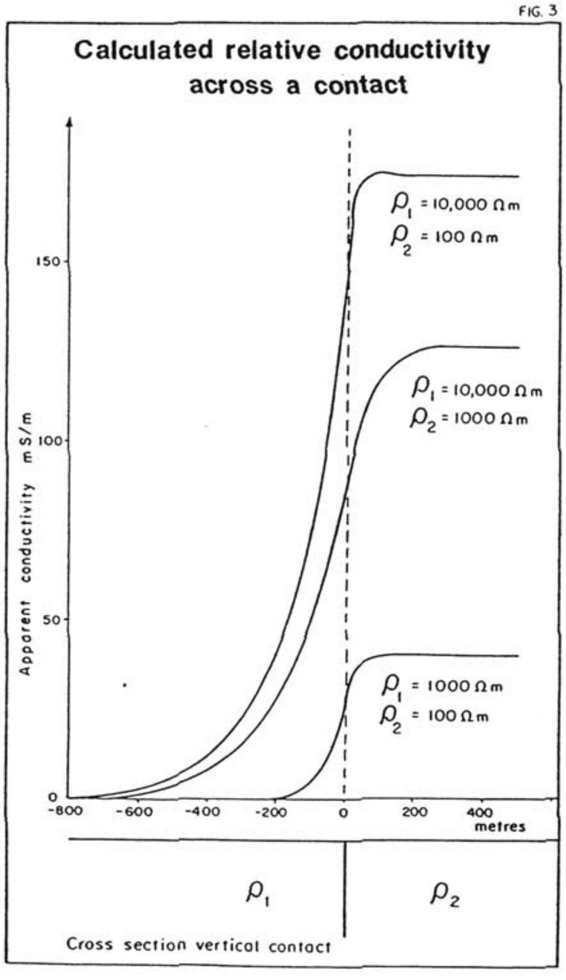
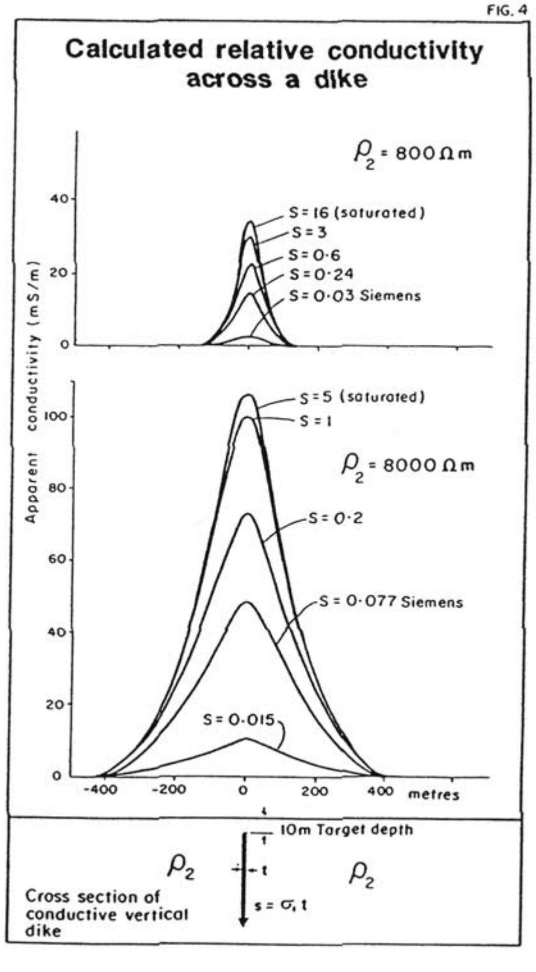
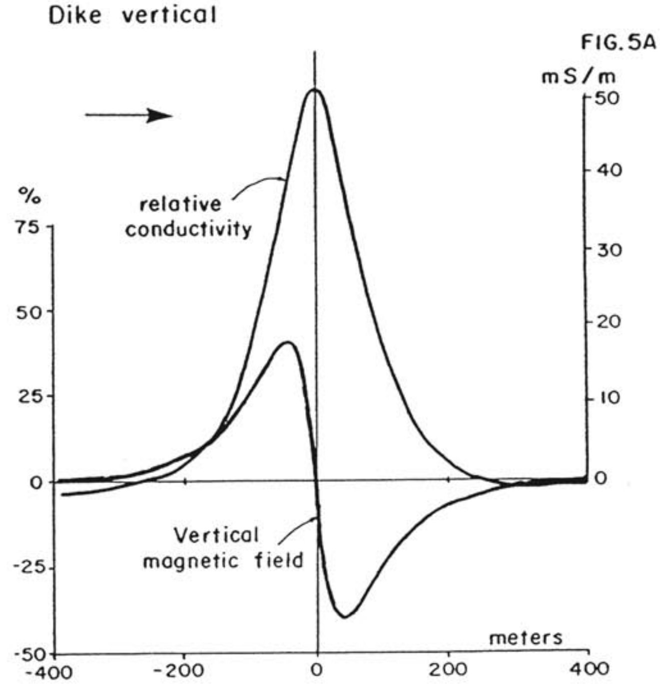
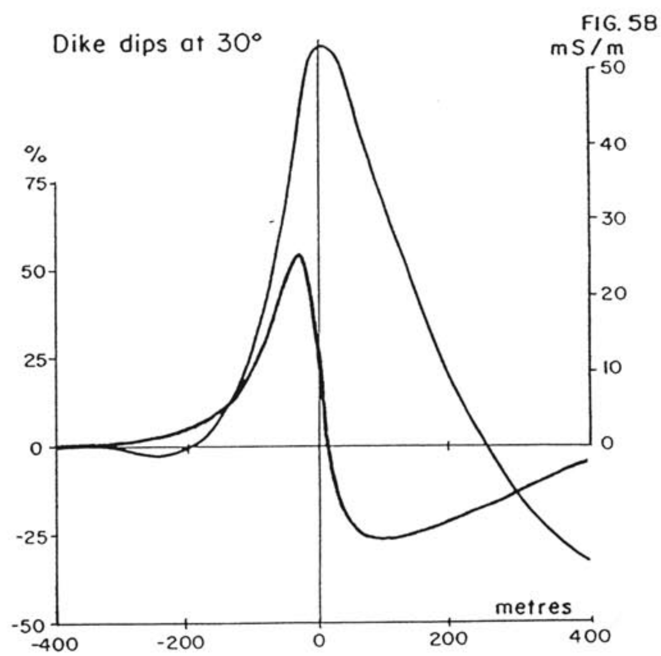


FIG. 4



Infinitely conductive dike – vertical magnetic field and relative conductivity

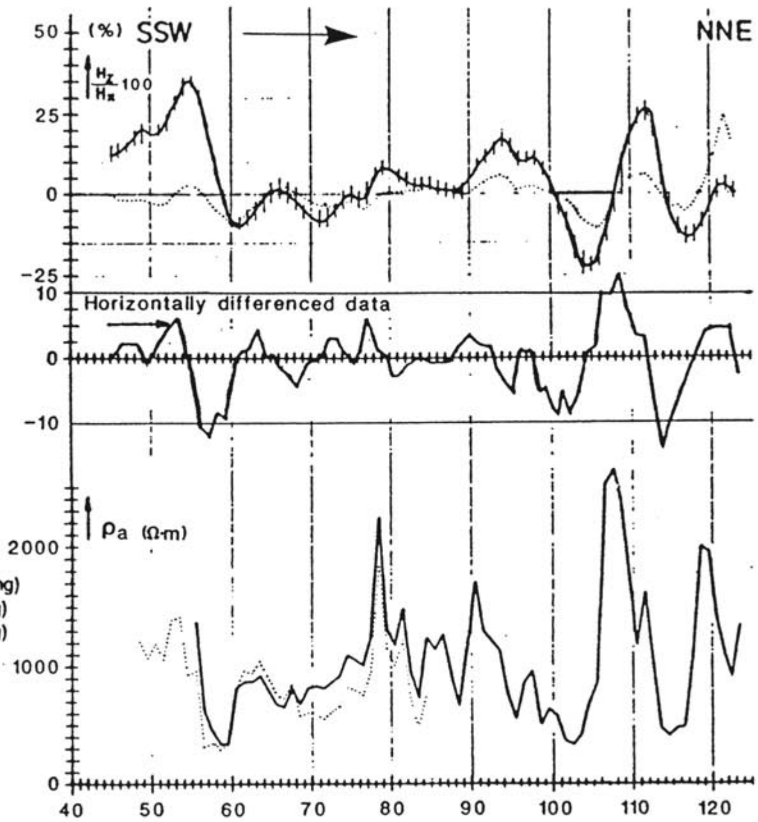




FIELD EXAMPLE – PRAKLA SEISMOS

VLF–measurement

Transmitter: GBR (Rugby-England)
Frequency : 16 kHz
→ Survey direction
+++++++ Line points (spacing 10 m)
H_z Vertical component
H_x Horizontal component
——— Inphase component (corrected values)
.... Out of phase component (corrected values)



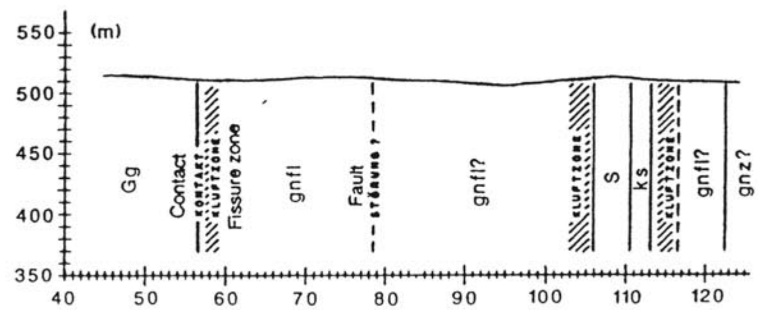
Resistivity profiling

$$\rho_a = \frac{U}{I}\cdot\pi\cdot\frac{(L/2)^2-(a/2)^2}{a} \quad (\Omega\text{·m})$$

$a/2$ = 5 m (half potential electrode spacing)
——— $L/2$ = 205 m (half current electrode spacing)
.... $L/2$ = 105 m (half current electrode spacing)

Topography and Geology

S = Serpentinite
ks = Calcium Silicate rock
Gg = younger medium grain Granite
gnfl = Biotite-Plagioclase-schist Gneiss
gnz = Biotite-Plagioclase-slip band Gneiss



Relative conductivity

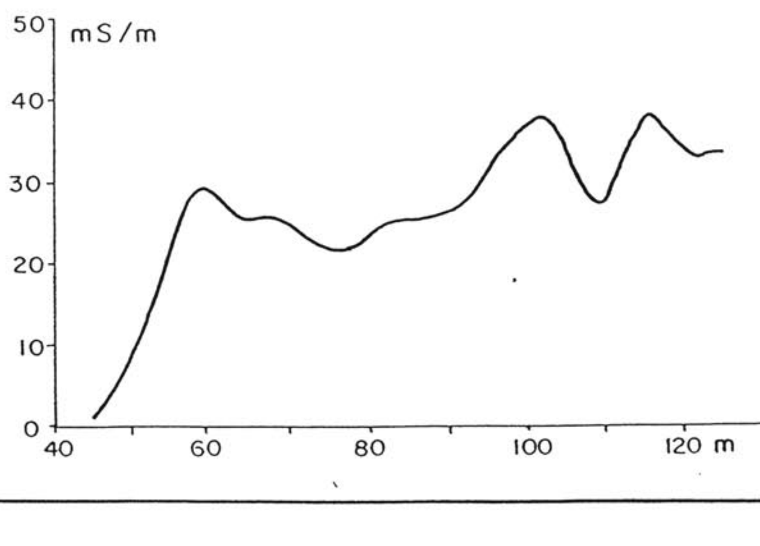


FIG. 7

FIELD EXAMPLE No.1 – NIAGARA, N.Y.
LINE 1500

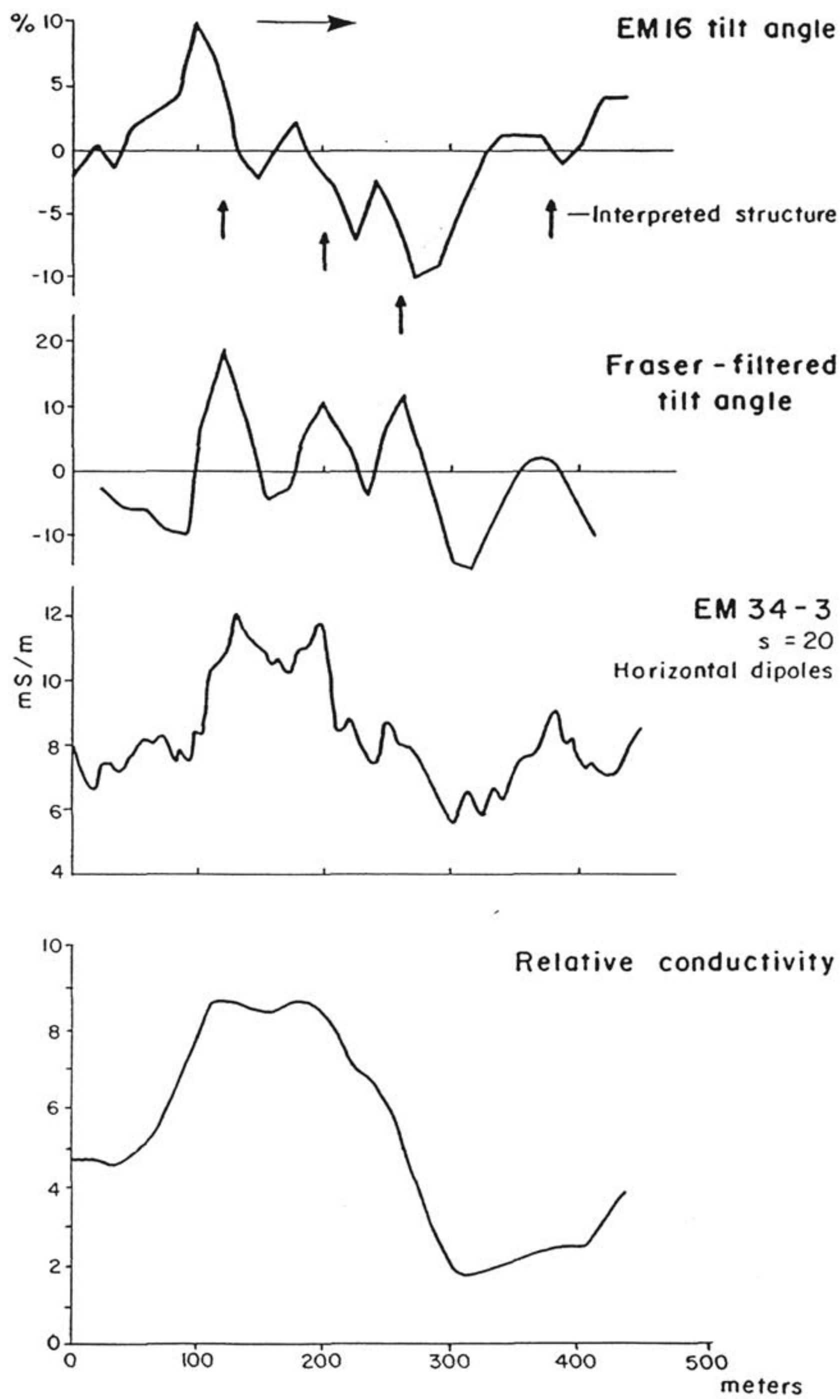


FIG. 8A

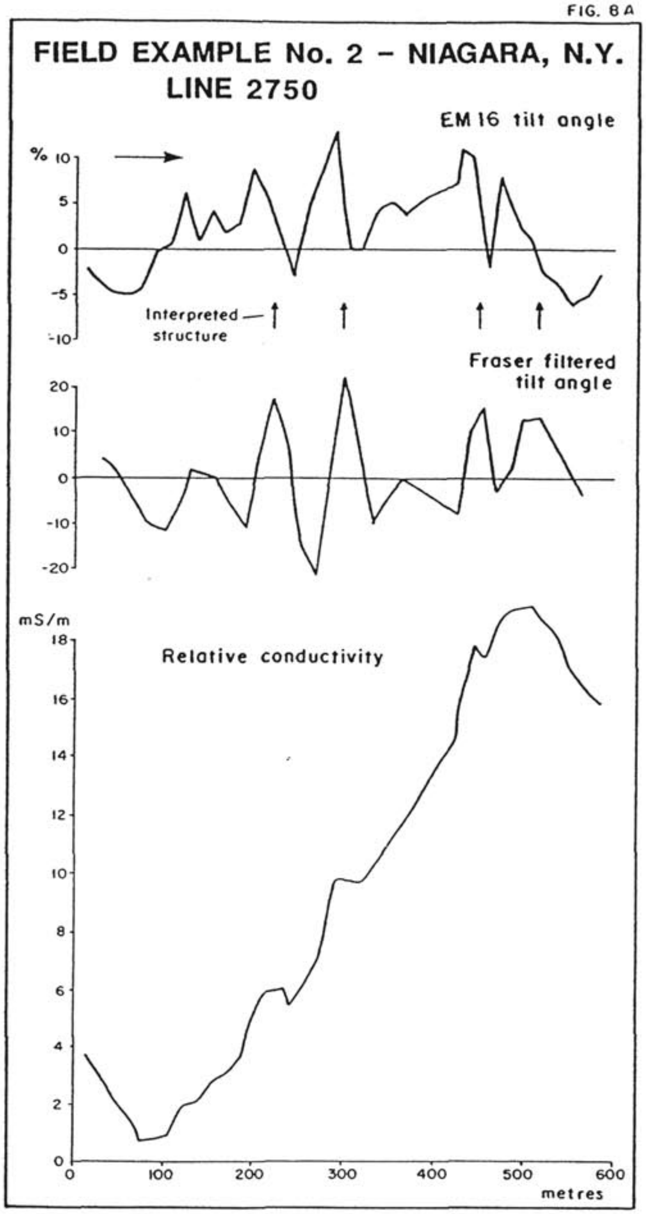

FIELD EXAMPLE No. 2 - NIAGARA, N.Y.
LINE 2750
EM16 tilt angle
%
Interpreted structure
Fraser filtered tilt angle
mS/m
Relative conductivity
metres

FIG. 8B

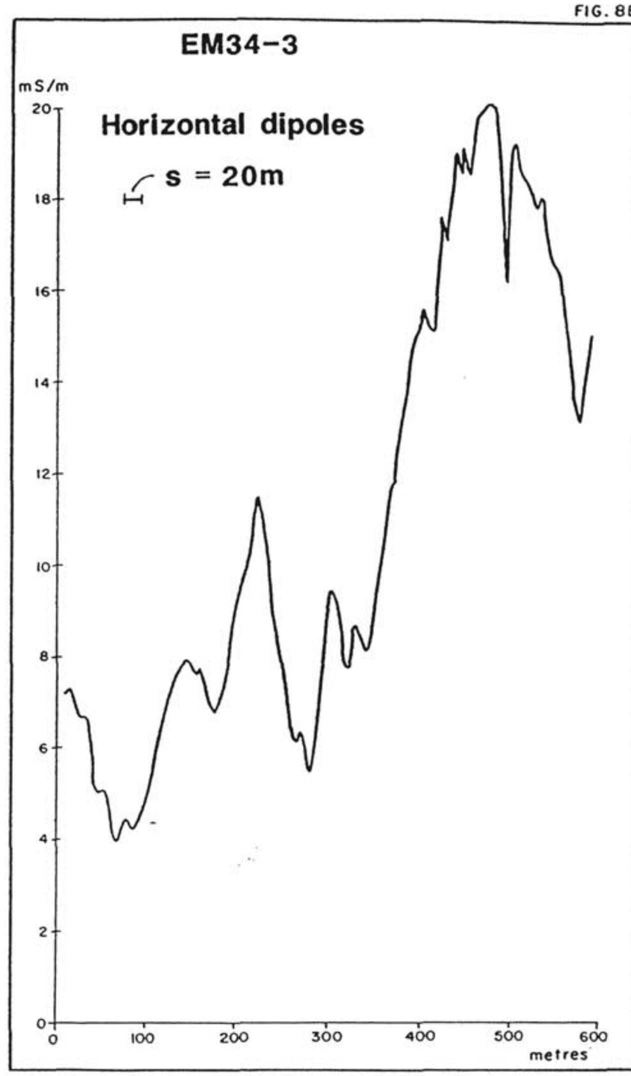
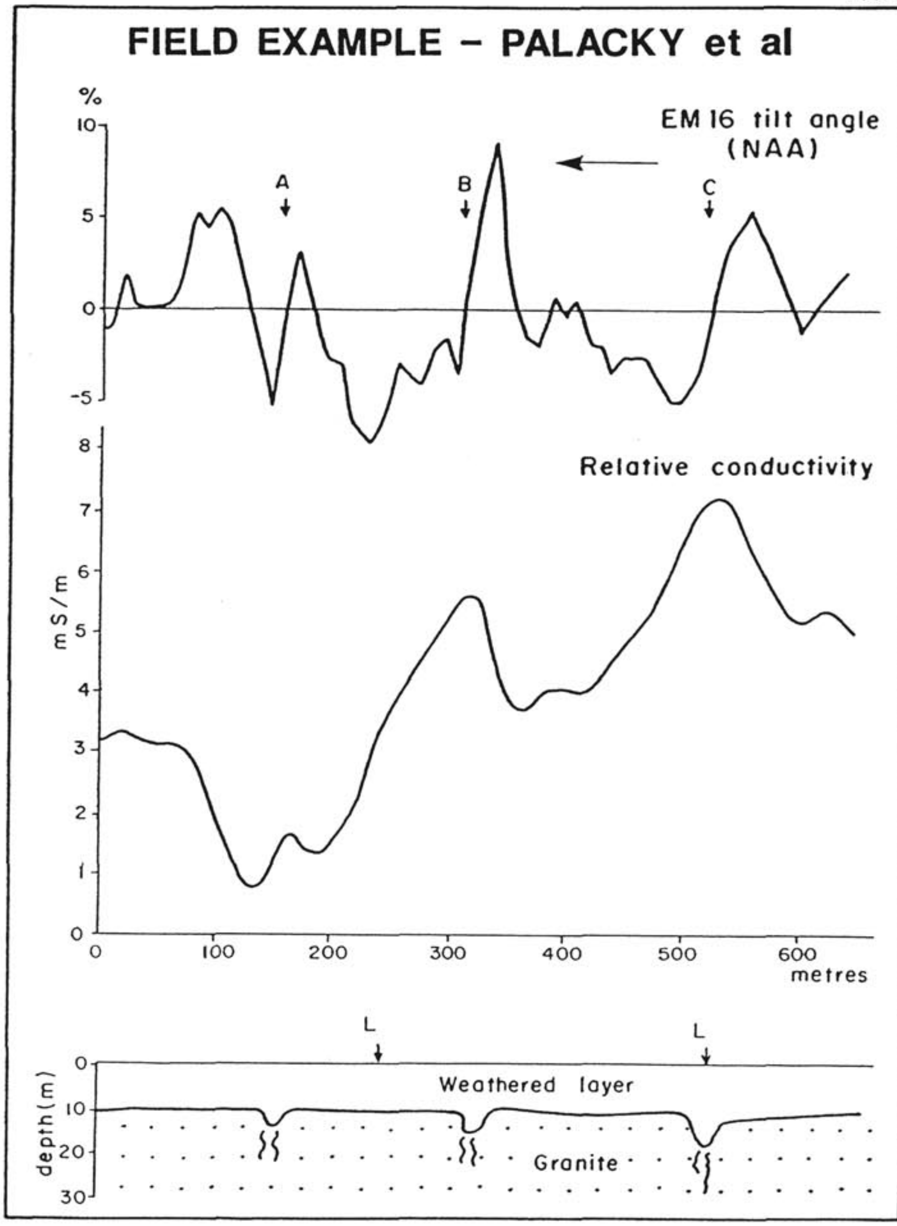

EM34-3
mS/m
Horizontal dipoles
s = 20m
metres

FIG. 9



FIELD EXAMPLE - PALACKY et al
%
EM 16 tilt angle (NAA)
A
B
C
10
5
0
-5
Relative conductivity
mS/m
8
7
6
5
4
3
2
1
0
0
100
200
300
400
500
600
metres
L
L
depth (m)
0
10
20
30
Weathered layer
Granite

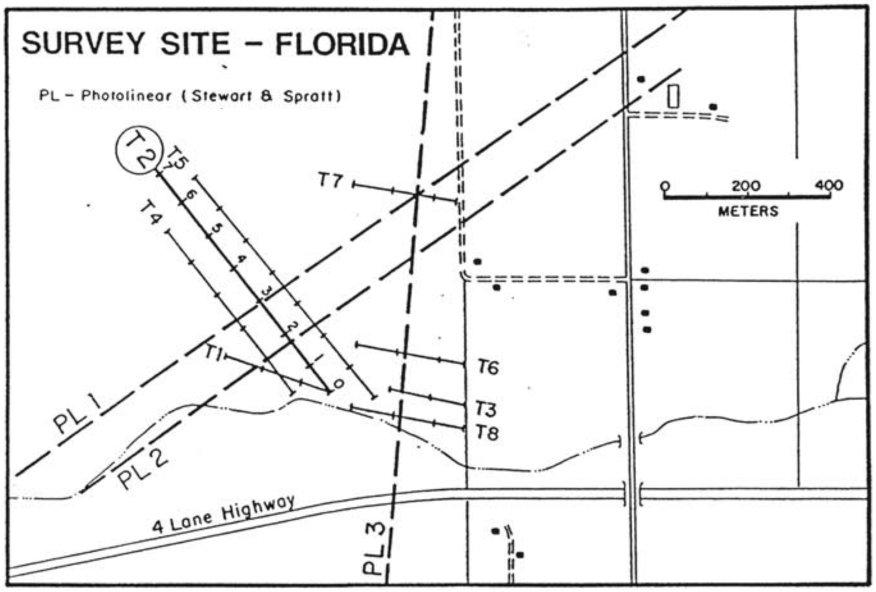


FIG. 10A

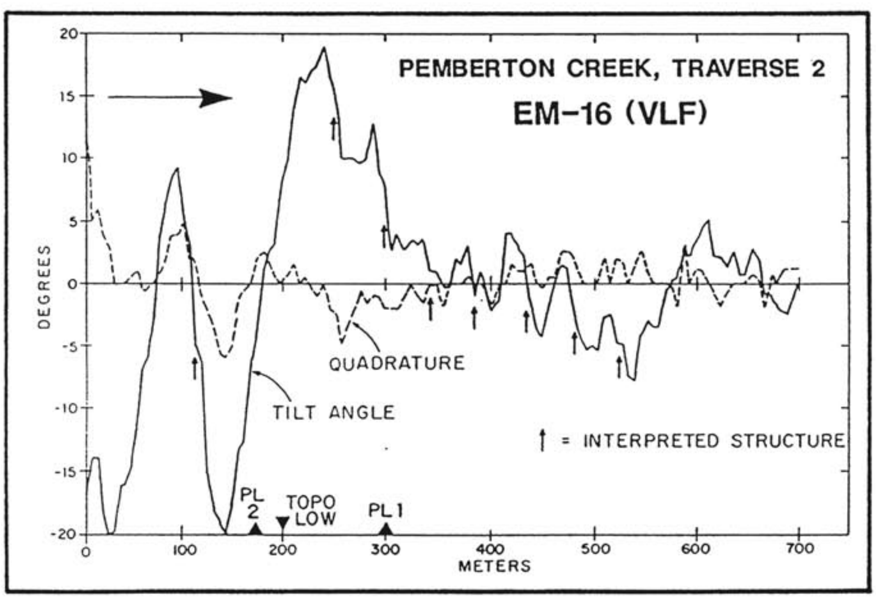


FIG. 10B

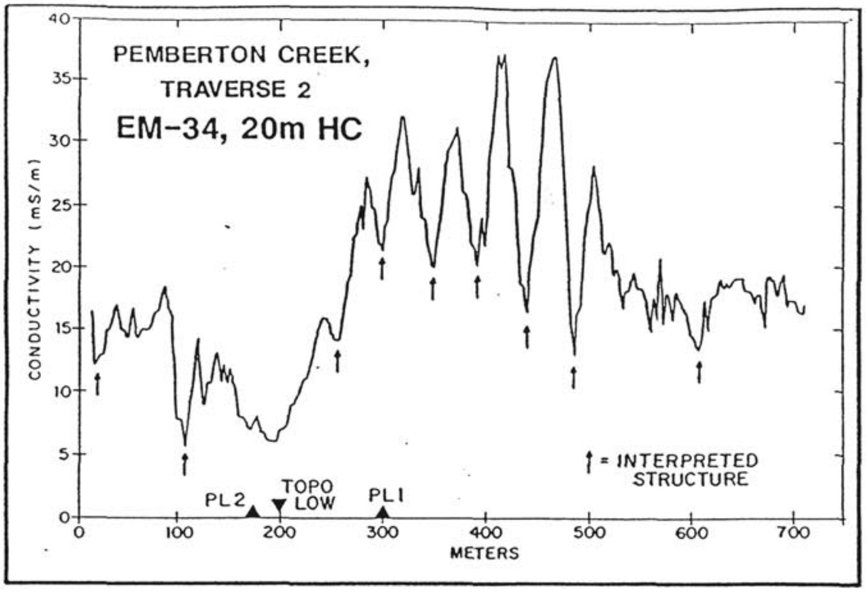


FIG. 10C

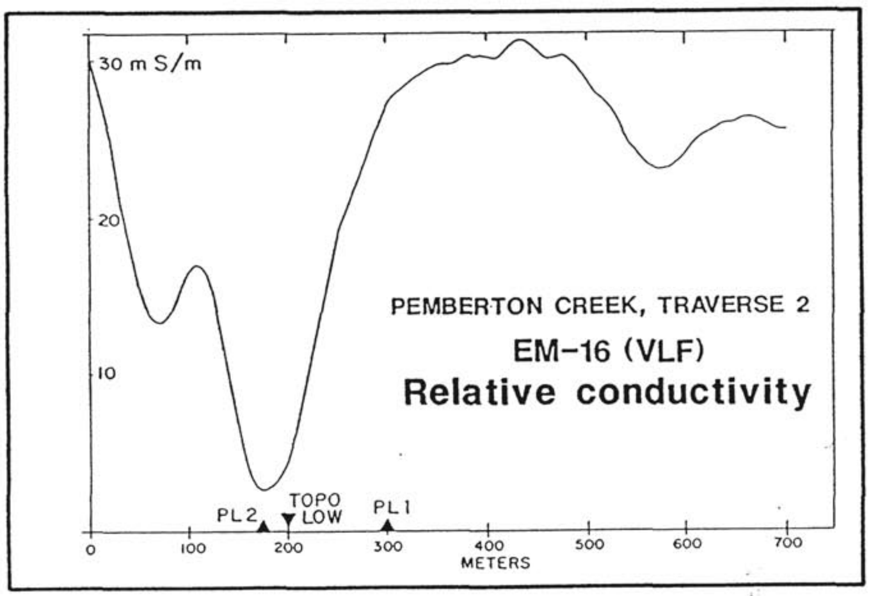


FIG. 10D

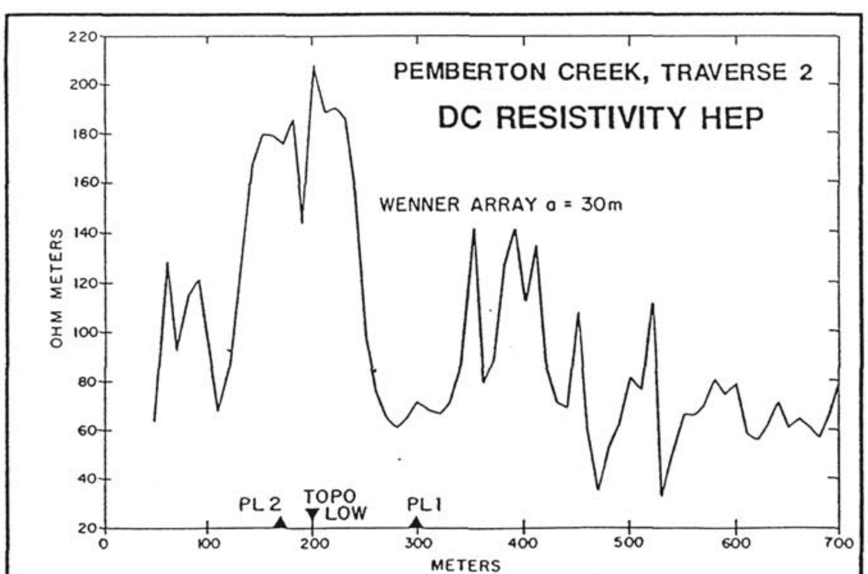


FIG. 10E