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POSSIBILITIES AND LIMITATIONS IN THE USE OF THE ELECTRIC RESISTIVITY METHOD IN QUATERNARY GEOLOGY

(a case study from the Dutch-Belgian Campine area)

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ABSTRACT. - The application of the geoelectric method is illustrated for the use in unconsolidated sediments. The Quaternary geology of the northern Campine area is studied by means of vertical electric soundings. The various lithologic units are detected and their lateral extent is determined. The properties of the method are discussed.

INTRODUCTION.

Quaternary deposits generally consist of unconsolidated near-surface sediments. This offers specific problems which may largely be grouped in three categories : items of solely scientific interest (geological, geomorphological) of economical interest (location of deposits) and of engineering geological interest (supply of background information). In some instances geophysical methods may be of considerable help in solving such problems. The significance of geophysical methods is to be found in a.o. the identification of lithology and the determination of layer thicknesses, the detection of nature and depth of a hard or unconsolidated subsoil, the delineation of zones favourable to and influential on groundwater, investigations of mass movements on slopes, etc...

One of the most appropriate geophysical methods for Quaternary research is the electric resistivity (geoelectric) method. As with all geophysical methods, the geoelectric method tries to define a physical parameter of the soil studied and its spatial variation, in this case the electric specific resistivity (ρ). For a detailed description of the method it is referred to general manuals (e.g. PARASNIS, 1979; KELLER & FRISCHKNECHT, 1967; etc...) or more specialized work (e. g. KOEFOED, 1980).

GENERAL METHOD.

The geoelectric method is one of the geophysical techniques that artificially supplies energy to the earth. In the case study illustrated here a direct current of 100 à 800 V at max. 1,5 A is generated in a Schlumberger-array. As the investigated depth is rather shallow, the maximum half electrode distance of the vertical electric soundings is kept at 100 to 150 m. Souding curves are constructed in the field for each sounding in order to have the possibility to correct for technical errors.

Interpretations are carried out after the field work. In a first step a "resistivity transform curve" is calculated from the original field curve (GHOSH, 1971) and from this resistivity transform a resistivity model is derived (KOEFOED, 1970). In the second step this model is checked by numerical methods against the original field curve and the model is adapted until the difference between all the points on the field curve and the calculated curve differ by less than 3% (VANDENBERGHE, 1981 and 1982).

The construction and adaptation of the resistivity model are made in accordance with a few geological guidelines. In the first place it is necessary to have an idea of the min-max values of the specific resistivity of a certain later. This may

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be effectuated by "mini-electric" measurements in situ where the layer studied is outcropping (VANDENBERGHE, 1982). Also electric logging data may be helpful. Finally the geologic "translation" of the ultimate resistivity model has to be carried out. This may be done from reference electric soundings near boreholes.

In unconsolidated dry sediments the specific resistivities are mainly a function of lithology (mineralogy, compaction, clay content). In wet conditions porosity, degree of water saturation and salinity of the water are the determining factors.

CASE STUDY : QUATERNARY DEPOSITS OF THE NORTHERN CAMPINE REGION (fig. 1)

The survey concerns the uppermost 20 to 30 m of Early and Middle Quaternary strata which are slightly dipping to the north. Part of the study has been performed by E-W profiles in order to delineate the Quaternary fault system as the southwestern border of the Central Graben (VANDENBERGHE, 1982). Here a N-S profile is described to show the general stratigraphy and to illustrate the properties and possibilities of the geoelectric method in geological mapping.

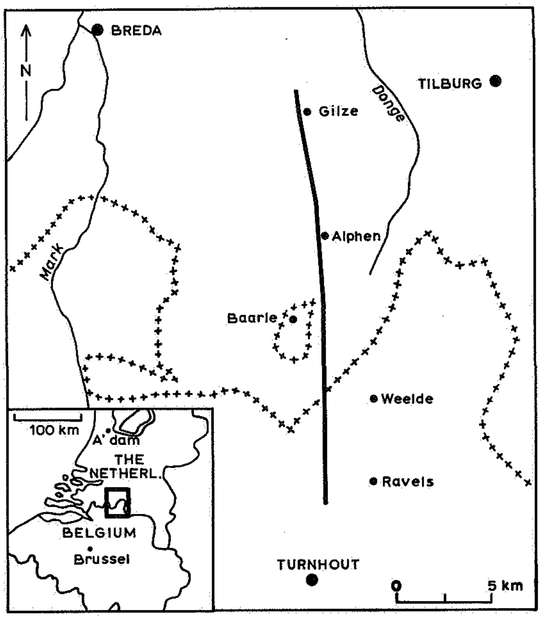

Fig. 1 - Location of the geoelectric section in the Campine area.

- The relation between lithology and specific resistivity.

In this area Quaternary deposits consist of an alternation of clays, fine sands and coarse to gravelly sands. This leads to the problem of electric "equivalence". This means that in the electric sounding curve changes in thickness may be compensated by changes in specific resistivities. Thus it is necessary to determine one of both as accurate as possible by other means (reference soundings, mini-electric measurements, electric logging, etc...). For specific resistivities of the water-saturated sediments the following values are found in this region as function of the lithology (VANDENBERGHE, 1982) :

7- 40 Ωm : clays, loams, sandy clays;
41- 73 Ωm : loamy or clayey sands, very fine sands;
73-190 Ωm : fine to medium fine sands;
> 190 Ωm : medium sands (190-260 Ωm) and coarse to more or less gravel-bearing sands (> 260 Ωm).

Dry or partly saturated sediments obviously show much higher specific resistivities. Since the water table commonly occurs near to the surface in humid terrains, these deposits are generally thin and have only a limited significance for the general stratigraphy.

- The N-S geoelectric section (fig. 2).

The lateral and vertical variability of specific resistivities shown in the profile illustrates the inhomogeneous character of the Quaternary deposits in the Campine area. Rapid facies changes and fluvial incisions often cause irregular boundaries between lithologies and thus also between specific resistivities. Fortunately a few "marker horizons" can be distinguished. In most borings and in the deeper electric soundings a sharp boundary exists between the lowermost sediments with high specific resistivities (generally > 220 Ωm) which correspond in the borings with gravelly coarse (sometimes shell-bearing) sands A and the overlying fine deposits B with lower specific resistivities (generally < 100 Ωm). The lowermost unit (A) corresponds in the northern part of the section with the marine "Maassluis Formation". In figure 2 its top is indicated by vertical hatching. To the south the equivalent "Merksplas Formation" is not shell bearing everywhere. It seems to be locally finer and thus showing lower specific resistivities. Where the base of the overlying unit (B) also consists of (coarse) sand a lithologic contrast fails and of course no resistivity contrast may be detected (soundings 1 to 3, 36).

The deposits B have a considerable thickness (several tens of metres) when not eroded. They consist mainly of fine sands, clays and alternating fine sands and clays showing low specific resistivities. Local gullies are filled up with coarse sediments characterized by high specific resistivities (e. g. soundings 30, 31, 36 and 37). The top of series B is indicated by cross marks in fig. 2. This unit corresponds to the Lower Pleistocene "Campine Clay and Sand Formation" of fluvio-estuarine origin. It comprises the "Kedichem" and "Tegelen Formation" which cannot be distinguished here by their specific resistivities nor on lithological grounds. The clay beds have economic significance for the brickyard industry. Hydrogeologically the Campine clay has long be considered as an impervious horizon between the aquifers of the Tertiary sands and the (smaller) near-surface aquifers. As may be seen from the geoelectric section clay is not present everywhere in unit B (e. g. large parts between soundings 7 and 12, 21 and 23, 26 and 28). Consequently in these areas water from the surface can easily sink into series A. Then layer B can no longer be considered as a reliable water-retaining layer because it is leaky locally.

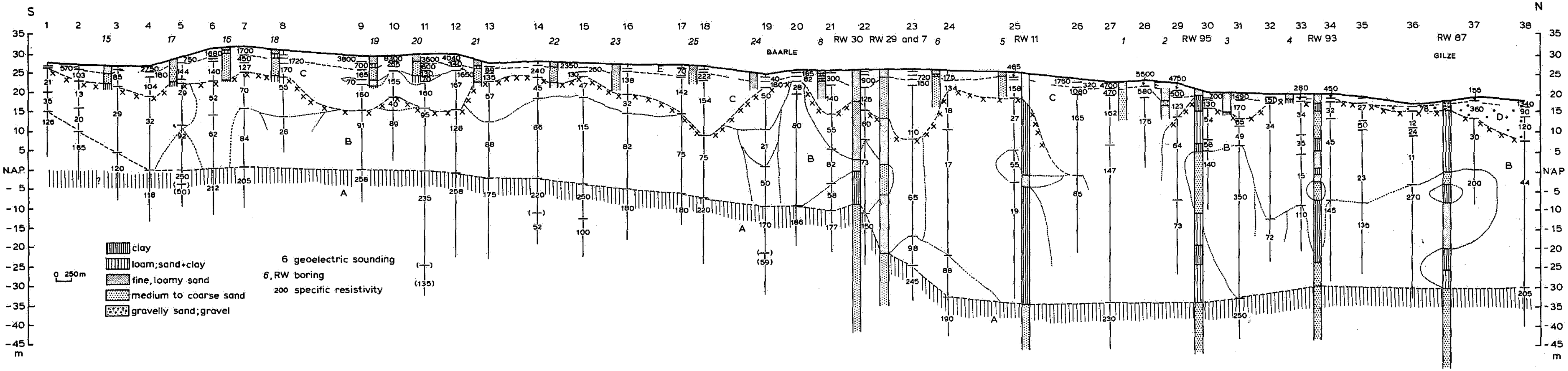

Fig. 2 - Geoelectric section (location see fig. 1). Borehole data (RW) are taken from the "Grondwaterkaart van Nederland", blad 50 Oost (1975).

Between soundings 2 and 32 series B is overlain by mainly medium to coarse sands with specific resistivities reaching 180 Ωm. Some minor silty intercalations have specific resistivities of ca. 70 Ωm. The fluvial origin of this layer (C) is clearly shown by the gullying character of its base (see geoelectric section) and by the sedimentary properties revealed in many handborings. Layer C represents the "Alphen Sands" as defined by VANDENBERGHE & KROOK (1981). Probably they are of final Early Pleistocene age. At the places where they erode the sandy facies of unit B it is difficult to determine the boundary with the Campine Clay and Sand Formation (e. g. between soundings 26 and 28).

At the northernmost part of the section coarse gravelly sands occur (series D, marked by black dots in the geoelectric section). They belong to the fluviatile "Sterksel Formation" which extends far more north- and eastward. Specific resistivities may reach values of several hundreds of Ωm. They show also a clear erosive character. The uppermost Late Pleistocene deposits (E) generally do not exceed a thickness of 2 or 3 metres. Very high specific resistivities point of their sandy nature and a position above the water table. Interlayered beds of 40 to 85 Ωm represent moist loams of min 1 m thickness. Figure 3 shows a few examples of field sounding curves, the corresponding calculated curves and their geoelectric interpretation.

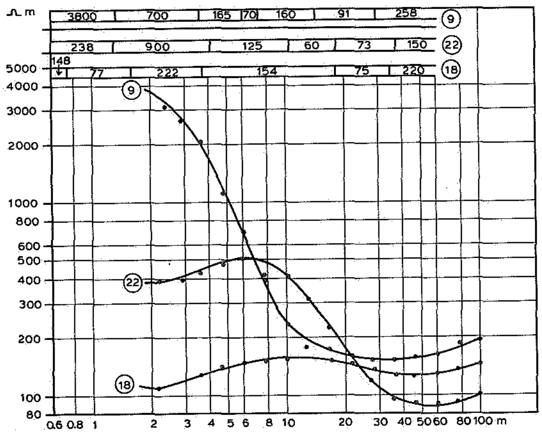

Fig. 3 - Typical electric sounding curves with their interpretation. The original field resistivity data are marked by dots and the final model curve is represented by a full trace. Location see fig. 2.

In contrast to E-W sections in the same region (VANDENBERGHE, 1982) no distinct traces of fault activity are detected in this profile. Only a sharp dipping of the lowermost layer boundary between soundings 22 and 24 may correspond to a fault of max. 20 (or several smaller ones). As this presumed fault finds no expression in unit C its activity ended before the late Early Pleistocene.

CONCLUSIONS.

The geoelectric method is an appropriate method for investigations in loose deposits. They may comprise geological mapping, hydrogeological exploration and regional inventorization of sedimentary raw materials. The outcome of the case study presented here illustrates the applicational significance of a detailed and carefully designed survey of electric soundings. It allows to distinguish the many beds of different lithology : clays, sands and all transitional sediments. Their lateral extent may be delineated. The degree of detail is diminishing with depth. It is clear from the studied section that the geoelectric method gives no result when stratigraphic boundaries are not corresponding with lithological boundaries. Checking of the geophysical data with well-known reference data is not only a useful help, but a necessity.

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