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Subsoil Maps on the Basis of Engineering Geology

Cartes du sous-sol dressées sur une base géotechnique

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Summary

The content and manner of description of a number of Subsoil Maps that were prepared in Germany for projects and reconstructions after 1945 are discussed. The maps were principally prepared on the basis of engineering geology and, to some extent, also on examination of the physical characteristics of the soil. By way of example, reference is made to the Subsoil Maps of Hildesheim, Hannover, Kiel, Hamburg, Ulm, Bremen and Gelsenkirchen; the latter is prepared on a geologic-agronomic basis.

In conclusion ten rules are furnished for the preparation of such maps and "Subsoil Quality Maps" are discussed in particular. Such maps should be prepared with great caution.

In difficult circumstances Subsoil Maps should not replace special subsoil explorations.

Sommaire

Le présent rapport traite du contenu et de la présentation d'un certain nombre de cartes de sous-sol établies en Allemagne après 1945 pour faciliter des projets de construction et de reconstruction. Leur élaboration s'appuyait surtout sur des recherches géotechniques et, dans une certaine mesure, sur des travaux concernant les propriétés physiques du sol. L'auteur passe en revue les plans du sous-sol de Hildesheim, Hanovre, Kiel, Hambourg, Ulm, Brême et Gelsenkirchen, dont le dernier s'appuie sur des études géologiques et agronomiques.

Partant de ce qui précède l'auteur suggère 10 règles pour la préparation des cartes géotechniques et discute en particulier les «Plans de Qualité des Sols de Fondation» qui sont à établir prudemment.

Dans les cas offrant des difficultés particulières les cartes de sous-sol ne pourront jamais remplacer l'exploration du sol de fondation.

Introduction

On various occasions subsoil maps were prepared for projects and, to some extent, published in Germany even before the war, but much more so since 1945 for the reconstruction of towns and industrial areas. These maps are essential for the designs of town and country planners with foresight and are just as much needed by architects and engineers engaged on construction.

In preparing these subsoil maps various considerations served as basis for the work and various manners of representation were employed. In late years, quite considerable public funds were expended on the preparation of subsoil maps. The experience gained makes it advisable to submit certain standards for the preparation of subsoil maps for critical review by a large number of persons, if only for the purpose of obtaining the best possible results with the available means.

The following details are devoted solely to subsoil maps prepared on the basis of engineering geology and physical soil characteristics. Among others, they are the result of a number of discussions on the subject by the Working Committee, Geo-

logy and Subsoil, of the German National Committee in the International Society of Soil Mechanics and Foundation Engineering.

The maps prepared so far have only been published in very exceptional cases. It is an unavoidable disadvantage of this report that no specimens of subsoil maps can be appended. For more detailed information, interested parties are referred to the preparers of the maps named herein.

Discussion of Subsoil Maps prepared up to the present time

Only a few typical maps will be discussed. Completeness is not intended. The maps were prepared by the official Geological Service of the individual "Länder" of Germany.

(1) *Subsoil Map of Hildesheim*

Prepared after 1945 by the Amt für Bodenforschung, Wiesenstrasse 72-74, Hannover, by the District Geologist Dr. A. Graupner;

the map is not printed; one map, done by hand, is available at the Stadtplanungsamt Hildesheim. In a detailed paper by *Graupner* (1950) these maps are published in a reduced scale. Scale 1:10,000, topographic data of a town plan with marked estate boundaries but no details as to heights. The Special Geological Map 1:25,000, original topographic surveys, and the soil profiles of numerous older borings, available in the local archives or in the hands of drilling firms, served as basis for the preparation. For lack of means only a few new borings could be made, but many physical soil tests were carried out.

The map is divided into 4 separate maps:

Boring Map showing the position of all drill holes. The soil profiles are recorded in special archives of boring.

Water Chart: Hachures and indications permit the following distinctions: brooks and rivers and existing stages of damming—filled-up lakes and piped water courses—spring-limits of inundation areas, the highest water level observed of the “Innerste” river and, finally, areas of varying height of the highest ground water level (0 to 1 m; 1 m to 2 m; 2 m to 10 m, and more than 10 m below ground).

Actual Subsoil Map: The extent of the individual geological formations is illustrated; overlying layers of special importance for judging the soil, such as loam, loess, sand, gravel, etc., are more clearly defined in profiles. A special analytical chart shows by markings for the different kinds of soil (rocky soil, loose soil, filling) the most important physical characteristics, for example, usual earth pressure for structures above ground, observed settlements, and the risk of sliding and of frost action.

It is only with the printed detailed explanations that the maps convey a comprehensive view of the subsoil geology of Hildesheim.

(2) *Subsoil Map of Hannover*

The map is prepared by order of the Bauverwaltung vom Amt für Bodenforschung, Wiesenstrasse 72–74, Hannover (Dr. *Graupner*, Dr. *Henrici*, Dr. *Dietz*). The Bauverwaltung will have a restricted number of the maps printed. The work will be finished about 1953; so far 3 partial maps have been printed. All of the 9 partial maps (78 × 85 cm) cover 360 km²; scale 1:10,000, material for basis as above, no special borings, but 4,000 older borings are utilised.

A subsoil map was desired without details as to the quality of the soil; particular importance was attached to a simple representation and to easy reading. Each partial map was therefore divided into 3 separate maps (boring map, water chart, subsoil map); in addition there is a record of borings (collection of soil profile records). Together with the first printed map, which was shown in 1951 at the exhibition “Constructa” in Hannover, an explanatory booklet and the legends for all maps were furnished.

The *Boring Map* shows the site of all borings taken into consideration marked in colours as to depth (less than 5 m; 5 to 10 m, and above a depth of 10 m).

The *Water Chart* shows in different colours springs, rivers, ditches, watersheds, highwater limits, soil reclaimed from water, dams and the ground-water levels, the latter areally in 5 stages (0 to 1 m; 1 to 2 m; 2 to 5 m; lower than 5 m under ground and fissure water). It is a drawback, likely to be encountered in most instances, that observations of the ground-water level extending over a good number of years are lacking, and thus also details regarding peaks.

The *Subsoil Map* shows the kinds of soil in colours, and they are intentionally divided into only a few categories: gravel, sand, clay, loam, peat, mud (i.e. Gytja), sandstone and limestone—in all 11 different colours. The geological structure of

the region of Hannover permits this collective treatment and renders a detailed illustration of the strata of different soils unnecessary, anyhow the money was lacking.

In the subsoil map of Hannover the kind of soil found at a depth of 2 m below ground (i.e., the ordinary foundation depth) was defined in the map plane, and a distinction was thus made between surface soils and load bearing soil (from a depth of 2 to 10 m).

The manner of representation of this subsoil map is characterised by the following extract from the legend:

Shown are:

- I. The *Load Bearing Soil* = soil at a depth of 2 m under ground
 - (1) Loose Soils: by surface colour;
 - (2) Rock Soils: by broad coloured stripes.
- II. The *Surface Soil* = soil from 0 to 2 $\frac{1}{2}$ m below ground
 - (1) natural
 - a) if of the same kind as the load soil: not specifically indicated;
 - b) if different from the load soil: brown dots and lines on the colours (or between the coloured stripes) for load soil.

The thickness of the cover layers appears from the boring card-index; it is not entered in the map.

 - (2) artificially fill:

filled ditches, banks, dumps	by red surface colours, respectively hachures.
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- III. *Distributing of Load Soil*:

down to 10 m below ground: (thickness and depth appear from the boring card index)	by green lines.
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- IV. *Strata under Load Soil*: by coloured figures.

Likewise indicated by markings: zones of decay of solid rock, outlines of salt deposits (salt and gypsum in the subsoil), areas of settlement, rural and national preserved areas.

(3) *Subsoil Map of Kiel*

Undertaken by the Landesanstalt für angewandte Geologie, Gartenstrasse 7, Kiel, and prepared by Engineering-Geologist Dr. *Habetha*; available only in one manuscript copy (in the form of an atlas of 38 leaves 1:5,000 with legends).

The map is of the “one-map-type”, which means that all observations are listed in one and the same map.

Contrary to the subsoil maps referred to previously, Dr. *Habetha* aimed at “the representation of the present subsoil condition by the introduction of the idea of the subsoil quality, that is, the degree of suitability for the foundation of buildings and structures of the most varied description”. It was possible to make this attempt because numerous original borings and physical soil explorations could be made.

Accordingly, the Kiel Map shows the types of soil by coloured markings while the grades of the quality of the subsoil are shown in full colour. The grades are divided according to all geological, hydrological and physical soil conditions down to a depth of at least 10 m or down to where the subsoil reaches bearing capacity.

In view of the fact that in the Kiel Map the attempt to divide the subsoil into grades quality was pursued with particular energy, it may be well to repeat here the principle on which the work was based. *Habetha* distinguishes as follows:

<i>Grade of Subsoil Quality</i>	<i>Types of Foundation</i>	<i>Suitable for</i>
I. good	Flat foundation, in general without restrictions	Industrial buildings, silos, tall buildings, heavy bridges, towers, heavy and heaviest structures
II. mean	Flat foundation, acc. to conditions, if necessary increased width of foundation	Structures acc. to conditions, as before, smaller industrial buildings, halls, dwelling houses of several floors, bridges
III. bad	Flat foundation only after previous examination, in general safety measures necessary, otherwise pile clusters, pointed and concrete piles	In general only settlement houses, small dwelling houses, heavy structures with foundation difficulties
IV. very bad	Difficult pile foundations, or floating	In general not suitable for structures without larger preparatory foundation work

of the Geological Section of the Württembergische Statistische Landesamt, Schützenstrasse 4, Stuttgart. Scale: 1:10,000, only available in one handwritten copy.

It is of the type of sectional maps. The basic map shows 11 different types of soil, rock and stone. The top layer is shown in surface colour, the lower layers by profiles. An accompanying table furnishes technical details about the types of soil; workability, stability (good—mean—bad), bearing capacity (likewise without factors), observed settlements, water channels, suitability for building purpose.

A ground-water chart is in preparation. As there was sufficient material available at the Town Surveyor's Office, a special map was made to show areas where settlements are likely to occur on soft layers, and another map has been prepared showing the depths where the soil has sufficient bearing capacity.

The author's intention was to make the map simple and easy to read.

(6) *Subsoil Map of Bremen*¹⁾

Made for "Allgemeine Bauverwaltung Bremen". Prepared by Amt für Bodenforschung, Wiesenstrasse 72-74, Hannover, Dr. *Graupner*. Scale: 1:10,000. Purpose: Representation of the soil conditions for industrial buildings and dwelling houses, including the suburban settlement. Extent: that part of the area of the State of Bremen intended for building purposes. The work was commenced in 1951. The map will not be printed.

While making this map it was possible to acquire a great deal of experience. The suburban (settlement) maps are prepared separately and are also agronomical. The map is of the multiple leaf type.

The *Boring Map* shows by means of different indications:

- boring points determinable according to the *Gauss-Kröger* co-ordinates;
- boring points determinable solely inside of lots and estates;
- pits and excavations;
- borings, trial pits or excavations worked on the basis of geotechnic; the depth of the drill holes is indicated in colours (5 sections).

The *Water Chart* shows in coloured indications all hydrographic details, including data about the tidal area, dikes, areas of artificial overdamming or constant high ground-water level, maximum high water levels observed, measuring wells, etc.

The Map indicating the *kinds of soil (subsoil map)* shows:

- in surface colours the areas in which firm foundation soil (sand, gravel, loam, clay) occurs within depths of 0 and 4 m;
- in coloured depth numbers the areas where firm foundation soil is met with at a depth of more than 4 m (i.e. floor of deep cellars);
- in coloured tracings the few stable formations (mud, peat, sapropel, fills) above the firm subsoil according to kind and extent;
- in coloured numbers the depth of the surface of loam or clay layer under sand.

Evaluation charts, added by special request of the Stadtplanungsamt, show with great accuracy the varying degree of suitability of the various areas for different types of buildings and structures according to the estimated cost of construction. They also show the kind of foundation of former buildings and damage to buildings due to the subsoil.

The division of the kinds of soils is indicated in great detail (83 indications). Bomb craters, edges, steep slopes and typical soil profiles are entered, but not the sites of the borings. Because of lack of records, the ground-water levels could be entered only in a greatly simplified manner.

By way of supplement a synoptic table is furnished showing the characteristics of the Kiel soils (grain size, consistency, plasticity, angle of friction, usual pressure in kg/cm², tendency of a soil to crack under freezing).

The Kiel Subsoil Map holds a special place among all German maps so far available. The number of entries, however, renders reading difficult.

(4) *Subsoil Map of Hamburg*

Prepared by Professor Dr. *Koch* of the Geologische Landesamt, Möllerstrasse, Hamburg; issued in 33 sections by the Vermessungsamt of Hamburg. Scale: 1:10,000, topographic data include all streets and their names, but no details about heights.

The map is of the single map type; it shows solely the geological-petrographic data in a simple form that is easy to read; in most instances the depth indicated does not exceed 2 m but, considering the geological conditions, this is usually sufficient.

Easily distinguishable colours show the kinds of soil (loam, sand, gravel, peat, mud, artificial fill). Markings indicate the soil profile down to a depth of 2 m. Layers of soils at a depth below 2 m, layers of peat and mud are shown, and also the lines of equal depth of sand subsoil of good bearing capacity in valleys filled with mud. Ground-water levels and sites of boring are not entered.

Apart from some references, in a brief explanatory note, the map does not contain details regarding the quality of the subsoil or its physical properties.

(5) *Subsoil Map of Ulm*

This map is referred to as an exemplary map of southern Germany with its various subsoil conditions. Prepared by Dr. *Groschopf*

¹⁾ According to information kindly furnished by Dr. *Graupner*.

(7) *Subsoil Maps on a Geological-Agronomical Basis*

The maps discussed above have been prepared solely from the point of view of geotechnic and are intended to serve as references especially for the foundations of buildings, in towns and industrial areas. But, in addition to these maps, numerous subsoil maps have been prepared in Germany in the course of the last 25 years to assist planning towns and country areas and for settlement purposes, mostly together with agronomical maps of various types. As for the latter type of map we cannot mention more than two in the present work (cf. especially the publications of *R. Müller*, 1942, and *Ostendorff*, 1942, included among the References).

On the other hand, special mention should be made of a particular kind of subsoil map which aims at a closer contact between planner and foundation engineer. Such subsoil maps are furnished within the ambit of geological-agronomical maps or urban areas and have been prepared by the Amt für Bodenforschung für Nordrhein-Westfalen, Westwall 124, Krefeld (so-called suburban maps, cf. treatise by Dr. *H. Wortmann*, 1949–50). The maps and the explanatory notes are printed. Scale: 1 : 10,000. Data: as usual; in addition 70 to 130 borings down to a depth of 4 m per km².

They include one agronomical soil map for each district of a town, one water chart and subsoil map, one soil suitability map and one boring map. The map showing the kinds of soil and their agronomical characteristics down to a depth of 2 m and, in some cases, down to a depth of 4 m, serves as a basis. The division into kinds of soil is naturally more specific than in the case of a detailed subsoil map for foundation purposes.

Water- and subsoil conditions are shown in one map because the water channels and the water sensitivity of the soil were considered decisive. Thus the foundation soil is evaluated principally according to the ground-water conditions; kinds of soil are not entered in the water and subsoil map.

The Map of Bottrop, for instance, indicates:

- (a) areas with constant ground-water and with a ground-water table at
 - 0 to 0.40 m below the surface
 - 0.40 to 0.80 m below the surface
 - 0.80 to 1.30 m below the surface
 - 1.30 to 2.00 m below the surface
 - 2.00 to 3.00 m below the surface
- (b) areas with temporary ground-water, divided into different sub-sections;
- (c) areas with damming moisture—temporary strong soaking of the upper layers above the ground-water level owing to slow seepage. Numerous sub-sections have also been worked out.

For all those areas, classified according to their water conditions, suitability for building purposes is indicated by markings and by additional explanatory notes. Because of the purpose the map is to serve, the data refer to dwelling houses of 2 to 3 floors and should be especially helpful in deciding whether the cellars of the buildings must be rendered impervious to water. For the general classification of the foundations soil—always according to water-level and damming moisture—numerous sub-divisions are indicated, for instance in the case of the Bottrop Map:

- subsoil very suitable
- subsoil fairly suitable
- subsoil conditionally suitable
- subsoil still conditionally suitable
- subsoil very restricted suitability
- subsoil unsuitable.

The ground-water level was only once observed during the preparation of the map; fluctuations and maximum levels, which are of particular importance in this connection, were deduced from the development of the agronomical soil profile.

For the uninitiated, among whom the architectural engineer may be found, the maps are difficult to read, but they furnish fairly exhaustive data.

Guides for Subsoil Maps based on Engineering Geology

It has been shown in the foregoing that, in Germany, subsoil maps based on engineering geology are prepared according to quite a number of principles. From experience gained up to now it has been possible to work out important general standards that should always be observed, although it is not possible to furnish standards applicable in every instance.

(1) Content and manner of description must, of course, always be in accordance with the intended purpose, the subsoil conditions and the means at disposal. *Good Subsoil Maps are expensive.*

(2) The scale 1:10,000 has proved a particularly good choice; Boring Maps of city areas will, at times, require a scale of up to 1:2,000. A good topographic basis is a prerequisite for a serviceable subsoil map.

(3) It should be a guiding principle that subsoil maps must be simple and easy to read.

(4) Subsoil Maps on the basis of geotechnic should always show:

- (a) the kinds of soil and rock that are to be taken into consideration for the foundation of buildings and structures, down to a depth of at least 10 m, as to kind, extent and profile succession. The subdivision into kinds of soil should not be unnecessarily subdivided. Profiles should be furnished. A sub-division of kinds of soil as in the case of agronomical subsoil maps and soil type maps is not necessary for foundation purposes and is also rather too individual;
- (b) the hydrographic and ground-water conditions, especially their maximum levels, and the saturation zones;
- (c) the location of all bore holes (not only of the borings made especially for the map), supplemented by a compilation of all boring results (archives of borings);
- (d) special observations important for foundations such as sliding areas, zones of subsidence, kinds of previous foundations, occurrence of quicksand or aggressive water, etc..

(5) In order to comply with the demands under (3) and (4), a Subsoil Map should consist of
Boring Map (with archives of borings),
Water Chart,

Structural Engineering Soil Map detailed and with explanatory notes, mentioning the more important physical characteristics of the individual kinds of soil.

This so-called “multiple leaf type”, compared with the “single leaf type”, has the advantage of being easier to read and simpler in its presentation.

(6) The subsoil maps should be accompanied by exhaustive details from the point of view of engineering geology and should also furnish information on the history of architecture. Very often valuable information may be compiled from technical periodicals and archives.

(7) A very difficult problem is the preparation of maps showing the quality, and the suitability of the soil for foundation purposes. In most cases the contracting engineer needs such a map, and it is indispensable for purposes of planning.

If the Subsoil Map is to serve as a basis for plans referring to superordinate aspects and large surfaces, a Subsoil Quality Map may be furnished, including a general estimation of the suitability of particular areas for building projects, or with a division, for instance, according to the building expenses. A division of the surfaces according to load, depth of "good bearing" foundation soil and the like, is, in general, not to be recommended.

(8) If time and means are lacking for a sufficient large number of deep borings (and taking of undisturbed samples), quality maps for the foundations of single structure are but of little value.

(9) Although Quality Maps are often demanded, it should always be pointed out that maps dealing purely with facts, v. point (5), are better and, in a juridical sense (price of building site), involve less risk than quality maps based on insufficient data.

(10) In every instance where a subsoil map is in preparation

it should be emphasized that, in difficult cases, it can never replace a special subsoil exploration.

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