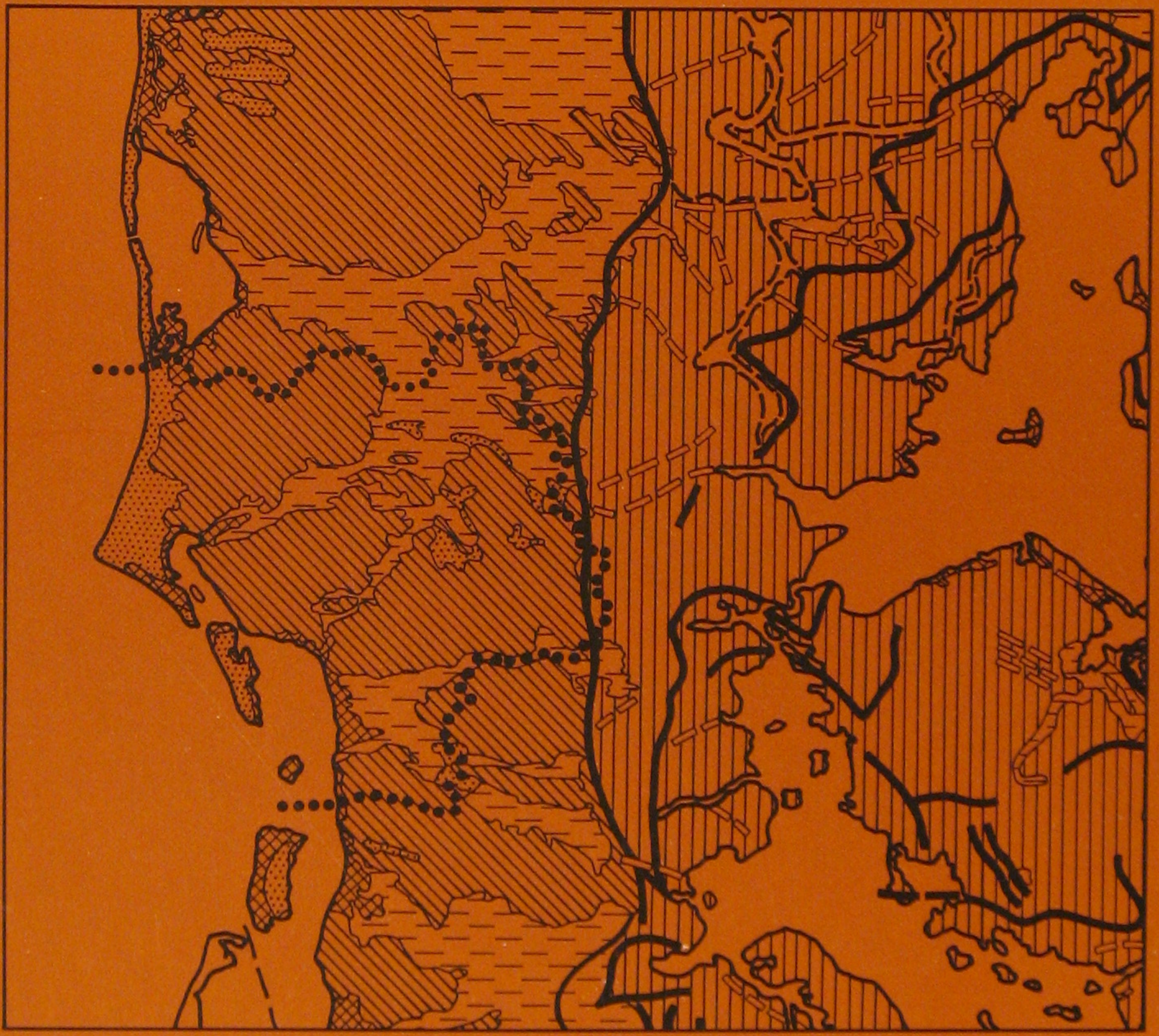
Improved graphical computer technique

Applied to mapping of geology and groundwater chemistry in Ribe Amtskommune, Denmark



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Applied to mapping of geology and groundwater chemistry in Ribe Amtskommune Denmark

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ABSTRACT

The article demonstrates the use of a new computer technique which has been used for the hydrogeological mapping in the county of Ribe (Ribe Amtskommune). Geological cross section plots and thematic maps, showing the groundwater chemistry in the two aquifers in the area, have been produced by computer. Contour lines and hatshing have been used to illustrate the chemical variations in the aquifers. Besides the paper summarizes the geology, hydrogeology and hydrochemistry in Ribe Amtskommune.

INTRODUCTION

In Denmark a number of duties concerning physical planning are imposed upon the county authorities. The administration of for instance the Raw Material and Water Supply Acts implies a basis of regional estimates. In this connection a need exists for map material etc. to collocate the large amount of data available concerning geology, hydrogeology, and groundwater chemistry.

The Geological Survey of Denmark have for a number of years been working with these problems in collaboration with the county authorities. The work has, among other things, been concerned with the question of using computers for mapping purposes.

According to the Water Supply Act (1978) the Danish county authorities and Hovedstadsrådet (Greater Copenhagen Council) are to prepare so-called hydrogeological maps. These maps are used especially for the planning of the water supply.

The following maps are included in the standard hydrogeological map series:

- geological basic data maps (cf. Andersen, L.J., 1973)

- piezometric head and the transmissivity of the aquifers

- hydrochemical basic data maps (cf. Villumsen, A., and Jacobsen, J., 1977).

Guide lines for hydrogeological mapping are experience obtained from mapping have been published by Miljøstyrelsen (1975, 1976 and 1979) and Bækgaard (1980).

As a supplement to the standart hydrogeological map series, thematic maps are often prepared, e.g. contour maps, geological maps of the Pre-Quaternary surface, and maps showing the nitrate content of the groundwater.

The maps are mainly based on data from groundwater wells and chemical analyses of groundwater. These data are available in the files of the Geological Survey of Denmark.

In 1982 the geology and groundwater chemistry in Ribe Amtskommune (county) were mapped. In addition to the above-mentioned standard maps the hydrogeological map series for Ribe Amtskommune includes a number of hydrochemical thematic maps which have been drawn by the use of a new computer technique described in this paper.

For geological and hydrological interpretation, geological cross sections through the area in question are usefull. The paper also contains a presentation of a computer programme which has been used to produce cross section plots in Ribe Amtskommune.

In order to illustrate the geological and hydrochemical framework in which the two computer techniques have been used, the geology and the groundwater chemistry of Ribe Amtskommune are outlined in brief.

The chapter dealing with the computer-aided illustration of geology was written by Åge Nielsen. The chapter: "Technical preparation and lay-out for maps of aquifer-related groundwater chemistry" was written by Per Jacobi. Jens Bruun-Petersen is responsible for the geological interpretation of the wells from Ribe Amtskommune. Arne Villumsen has written the general chapters and the groundwater-chemistry chapter.

A BRIEF OUTLINE OF GEOLOGY AND HYDROGEOLOGY OF RIBE AMTSKOMMUNE

Ribe Amtskommune is situated in the southwestern part of Denmark, fig. 1.

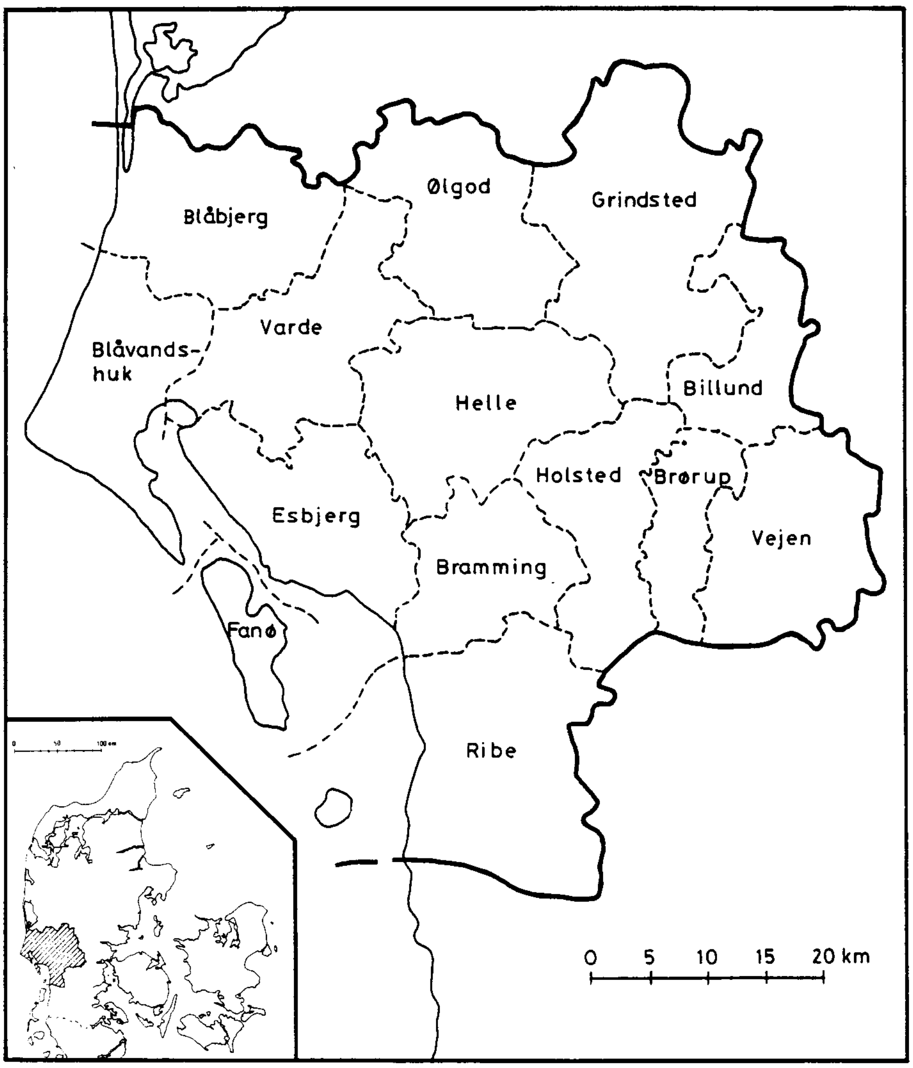


Fig. 1. Location of Ribe Amtskommune and its municipalities.

In Ribe Amtskommune, as in large parts of western Jutland, Quaternary and Tertiary sandy sediments are found at depths of 100 to 350 m below surface. Below this level sticky Early Tertiary clay is found (Dinesen et al. 1977).

The water supply interest in Ribe Amtskommune has so far mainly been restricted to the upper 50-100 m of the geological column, which corresponds to the normal maximum depth of wells in the area. Two main aquifers are located within this interval, namely a Miocene sand aquifer, containing mica and quartz and Quaternary aquifer, composed of glaciofluviatile sand.

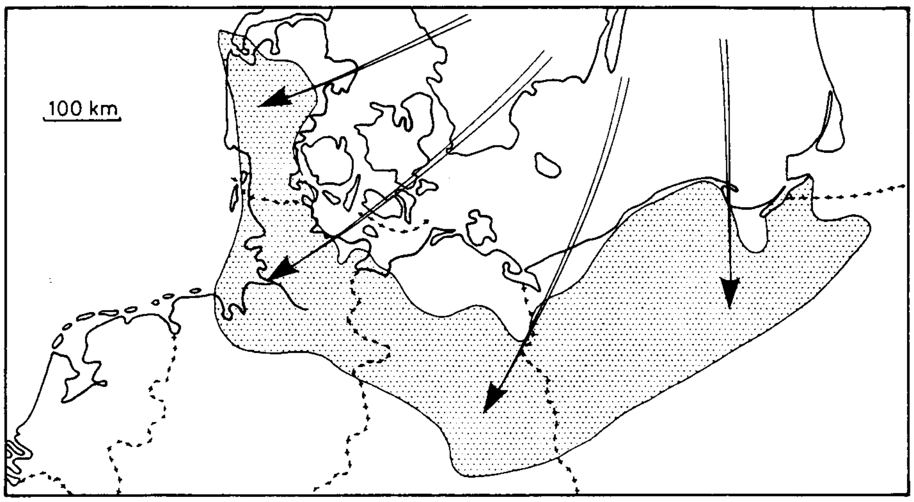


Fig. 2. Maximal extension of Miocene delta sand formations. The arrows show the assumed direction of the material transport of the streams (from Bijlsma, 81, modified by Grambo-Rasmussen, 82.)

Miocene

During Miocene time major sand deltas, fig. 2, were built up in Jutland as well as outside Denmark. A simplified geological cross-section through the Miocene sediments in Jutland was published by Rasmussen (1966), fig. 3. Fluctuations in the Miocene sea-level occured several times leading to the sedimentation of limnetic sand in the eastern part, while marine mica clay was deposited to the west, fig. 3.

In accordance with this simplified model, Miocene mica sand and quartz sand aquifers are predominant in the eastern part of Ribe Amtskommune. The transmissivity of these deposits is high, and the aquifers are therefore exploited for water supply. This is especially the case in the municipalities of Billund, Grindsted, and Vejen, fig. 1. Farther west, mica clay and mica sand are found in varying proportions in an area including the municipalities of Ølgod, Helle, Holsted, and Brørup, fig. 1. In this area the Miocene transgressions and regressions have replaced each other successively. The water supply potential from the Miocene deposits in this area is varying. Tertiary deposits in the western part of Ribe Amtskommune, (the municipalities of Ribe, Bramming, Esbjerg, Varde, Blåvandshuk, and Blåbjerg) are mainly clayey and of no interest with regard to water supply.

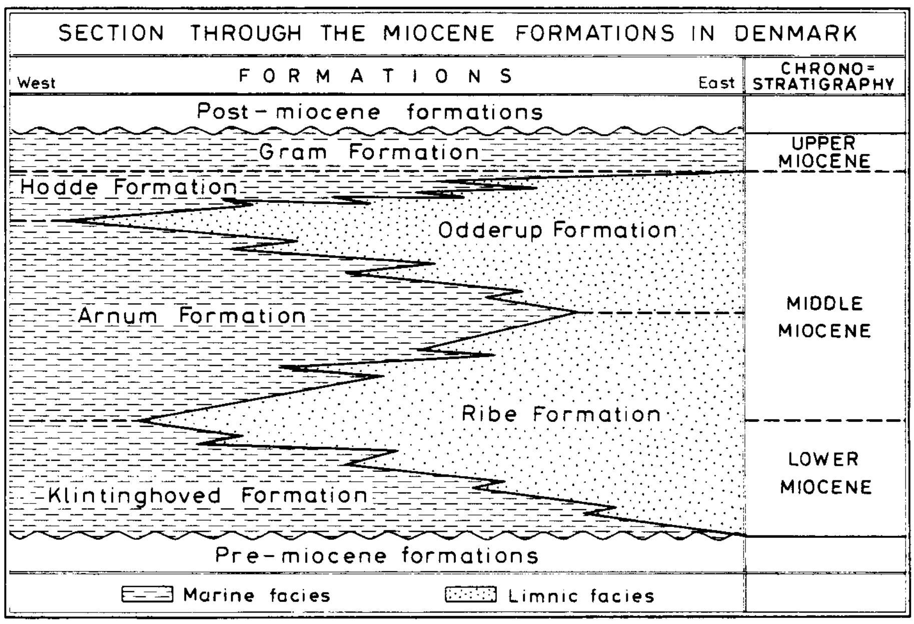
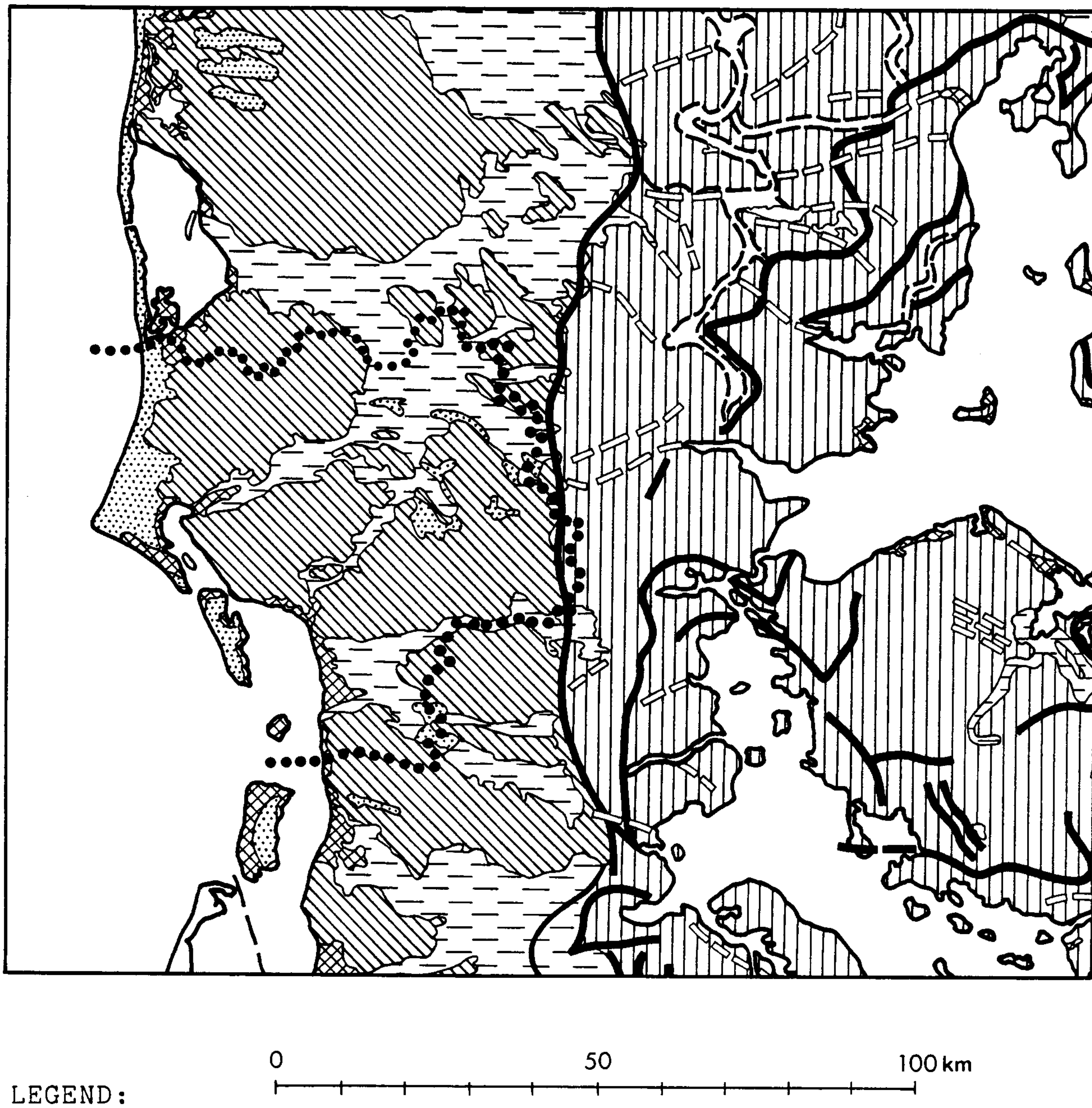


Fig. 3. Simplified section through the Miocene formations in Denmark (from Rasmussen, 1966).

Quaternary

Quaternary sediments in Ribe Amtskommune include till, fluvioglacial sand and clay, deposited mainly during the Quaternary glaciations.

Jutland was covered with glaciers at least three times in the Quaternary period. During the last glaciation (Weichsel) the ice reached a main stationary line, fig. 4, which coincides approximately with the eastern border of Ribe Amtskommune.



LEGEND:

1. Mainly Pre-Weichselian sediments
2. Weichselian deposits
3. Meltwater sediments
4. Tunnel valleys
5. Extra-marginal meltwater valleys
6. Ice border lines
7. Late Glacial marine sediments
8. Post Glacial marine sediments
9. Eolian deposits
10. County border

Fig 4. Main lines of Quaternary geology in SW-Jutland (from Hansen and Milthers, 1954)

The Quaternary landscape in the main part of the County therefore consists of sandy outwash plains, deposited from melt-water streams from the Weichselian ice, alternating with the older glacial landscape from the Saale glaciation. Interglacial marine and limnetic sediments (clay and sand) also occur.

The water supply potential from the Quaternary deposits is the greatest in the aquifers consisting of sand and gravel, situated nearest the former ice margin. To the west the water supply potential decreases, due to a decreasing grain size of the outwash sand.

Fluvioglacial sand deposits from the older glaciation are found all over the County and are usefull aquifers. The amount and qualitry of the water from these aquifers are varying. The youngest Quaternary deposits, Postglacial marine and eolian sediments, are found in the west coast region, especially in the municipalities of Blåvandshuk and Fanø (fig. 1). The water supply from these deposits is limited for two reasons. Firstly, because of a generally unacceptable water quality caused by a content of peat and pyrite clay in the sediments; secondly, because of the risk of seawater intrusion.

In conclution there are two main aquifers in Ribe Amtskommune, namely the Quaternary aquifer consisting of sand and gravel, and the Tertiary aquifer built up of quartz-sand and mica sand.

The extent and the limitation of these aquifers were evaluated, using the geological and hydrogeological information.

COMPUTER-AIDED ILLUSTRATION OF GEOLOGY

Geological and hydrological data obtained from groundwater wells, raw material drillings, and geotechnical borings are stored on magnetic discs at the Geological Survey for easy access and are presented by the so-called cyclogramtechnique (Andersen, 1973) as well as by other computer based methods. Improvements are continuously under consideration.

Cross-Sections

The Geological Survey have recently implemented an interactive computer programme for producing geological cross-sections.

In order to draw cross-sections by computer the user has first to determine a geographical area and within this area select a straight line or a line composed of straight segments. When a narrow band along this line has been selected the geological information from the wells within this band will be projected on the selected line(s).

The programme needs a specification of the coordinates of the cross-section endpoints. The band width, horizontal and vertical scales along with various drawing instructions have to be given, too. These instructions can easily be given by the user. To secure a clear output the user can detach selected wells or lithological elements of special interest. An example of a cross-section plot is shown in fig. 5 (in separate pocket).

The plot contains the selected information concerning scale, filename and a heading. The cross-section includes a line indicating sea level and vertical scales at each endpoint. Each well contains, at the top, the well number and the altitude above sea level and at the bottom, the depth of the well below surface.

For each layer a signature indicates the lithology, and a letter code indicates lithology and age. Additional symbols indicate screened interval, groundwater level etc.

The cross-section plot includes a small map of the area of interest showing the actual wells and their well number.

GROUNDWATER QUALITY

The chemical composition of Danish groundwater reflects mainly the chemical interactions between water and sediments during infiltration and percolation in the aquifers. The original chemical compostion of precipitation has only a minor effect on the actual groundwater quality, except concerning the chloride content. As for the other chemical substances present in the groundwater the water-rock interactions during infiltration and in the aquifers are decisive for the quality.

Major Pre-Quaternary as well as Quaternary geological differences within Denmark as a whole, are clearly expressed in the chemical composition of Danish groundwater. Regional differences in the amount of net-precipitation are of great importance too. An example of this is the regional difference in alkalinity, hardness and pH-level. These values are high in the east of Denmark and low in western Jutland, as an effect of the lime content of the Quaternary and Pre-Quaternary sediments, which is high in the east and low or absent in the western part of Denmark.

Besides, fluoride seems to have migrated from most of the upper sediments in western Jutland, as a low F-content in the groundwater is normal in this region. Additionally, the groundwater is corrosive when lime is absent, and increased iron and manganese concentrations in the water are frequent.

Aquifer-related groundwater chemistry

The above-mentioned regional differences in groundwater quality are clearly reflected in the chemical compostion of the two aquifers. Consequently it is convenient to draw groundwater chemistry maps for each aquifer. Maps of aquifer-related groundwater chemistry supplement the ordinary hydrochemical basic data maps (Villumsen and Jacobsen, 1977), where all the analyses from the area in question are shown as pie-diagrams on a single map.

For Ribe Amtskommune groundwater quality maps have been drawn for the Quaternary and Pre-Quaternary aquifer types respectively. The following chemical variables have been mapped (each variable on separate maps): nitrate, iron, manganese, excessive carbon dioxide, chloride, sulfate, fluoride, alkalinity, and pH.

TECHNICAL PREPRATION AND LAY-OUT FOR MAPS OF AQUIFER-RELATED GROUNDWATER CHEMISTRY

The use of graphical data processing makes it possible to automate the process of mapping so that resources used for the preparation of a map can be kept at a low level. This makes it possible to produce thematic maps, preparing every single variable on separate maps.

The Data Basis

As mentioned, two main aquifers in Ribe Amtskommune could be distinguished.

About 800 analyses were available from the files of the Geological Survey; they were checked manually and split up into two groups, one for each aquifer, to be used in the mapping of the two aquifers.

The extension of the two main aquifers was drawn manually and transferred to the computer using a digitizer.

Interpolation

The preparation of maps by computer requires an even distribution in a certain area of the data which are to be plotted. As the data derives from wells which are not evenly distributed it is necessary to process the data with the purpose of distribution the information evenly over the whole area.

The investigation area is divided into a regular square grid. The choise of grid size determines the degree of detail in the map to be produced. The density of wells and their distribution in the area must be considered before choosing grid size. In this case a 500 x 500 meter grid forms the starting ponint for the further manipulation.

For each grid center a value is ascribed based on interpolation of the values measured in the five nearest wells.

The grid values are calculated using:

$$val_k = \frac{\sum_{i=1}^{5} (B_i/dist_i)}{\sum_{i=1}^{5} (1/dist_i)}$$

where

val_k: interpolated value ascribed to the center

B_i : values measured in the five nearest bore-holes

$dist_i$: distance to the five nearest bore-holes.

<u>The Matrix</u>

The result of the interpolation is a matrix, each matrix element representing the value of a 500 x 500 m square in the investigation area.

The size of the matrix is 160 x 152 corresponding to a rectangular area of 80 x 76 km, covering Ribe Amtskommune. One matrix is produced for each variable investigated. Each matrix corresponds to a thematic map of the variable in question.

<u>Undefined Areas</u>

The elements of the matrix representing sections outside the investigation area i.e. the actual main aquifer (and outside Ribe Amtskommune) contain to values.

<u>Contouring</u>

On the basis of the produced matrix the contours are drawn in the investigation area for the chosen values. The trace of the contour lines is estimated by linear interpolation of the grid center values.

Contour lines are only drawn inside the investigation areas, i.e. the parts of the matrix containing values.

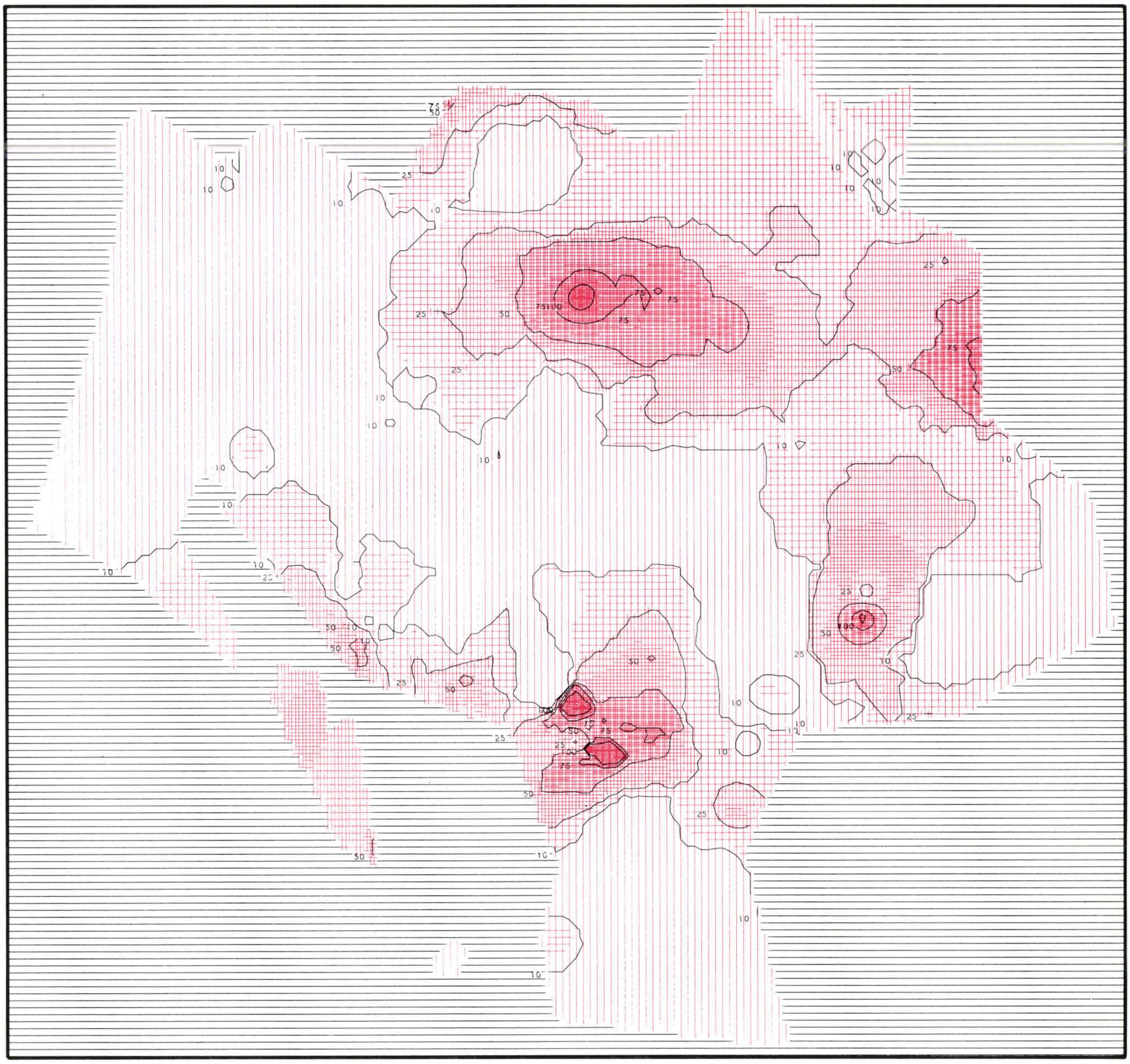
Hatching

In order to visualize the results each map is supplemented with hatching in addition to the contour lines. Increased density of the hatching indicates the quantity of the variable measured. The density of the hatching varies from open to very close hatching in sixteen steps, linear or exponential according to the map in question. The density of the hatching is selected in order to show the maximum values for the various parameters allowed for drinking water by the Danish Ministry of Environment: Dense hatching means values above allowed maximum; intermediate hatching, values at maximum allowed values; and open hatching, values below that.

DESCRIPTION OF SELECTED THEMATIC MAPS FOR RIBE AMTSKOMMUNE

Figs. 6-8 are examples of computer-processed thematic maps.

An estimate of the reasons for the mapped anomalies, f.ex. geochemical conditions and/or pollution, has been considered to be outside the scope of thise paper. Some main features can be found in Ribe Amtskommune (1984).

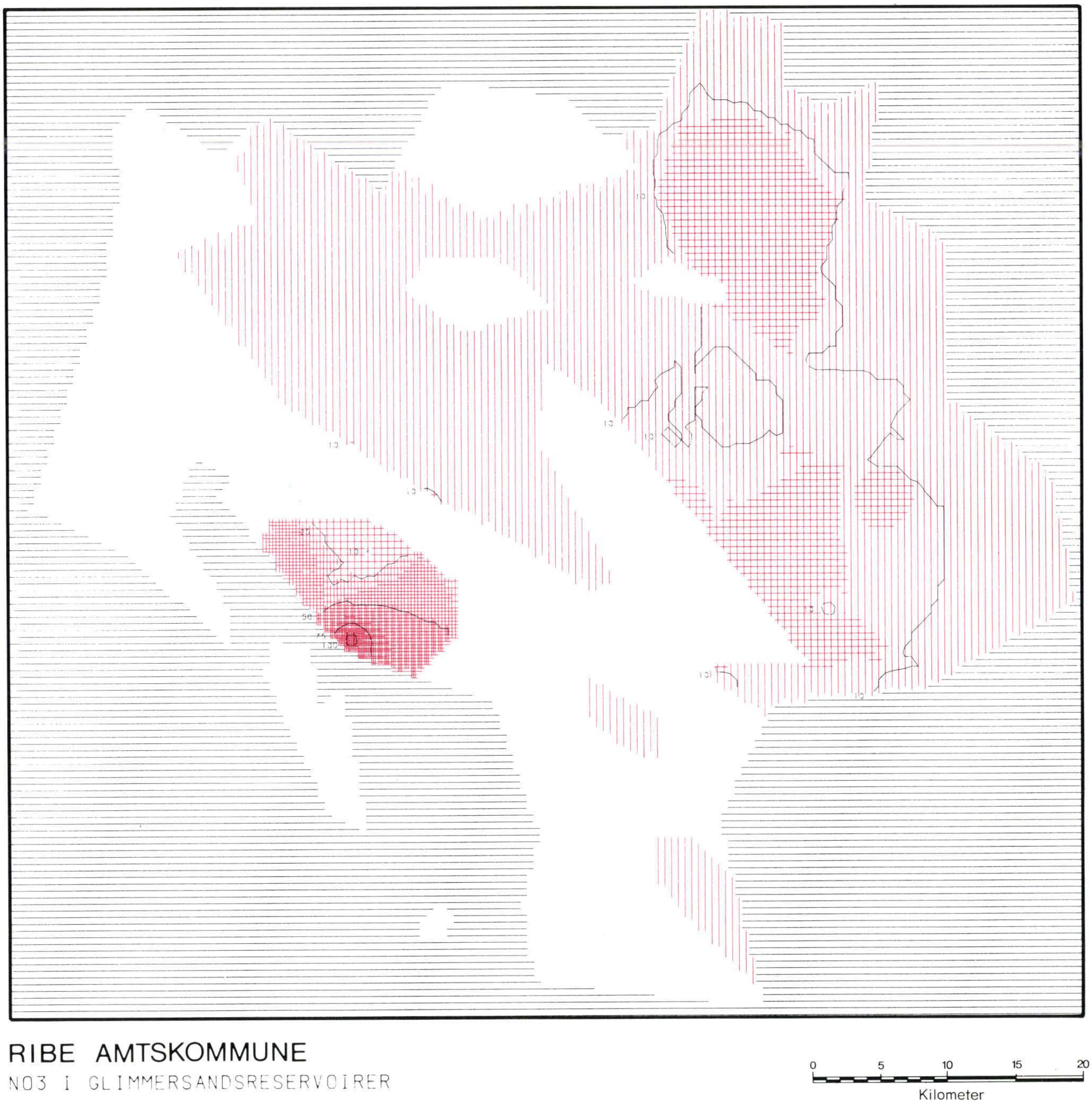


RIBE AMTSKOMMUNE

NO3 I SMELTEVANDSSAND OG -GRUSRESERVOIRER

0 5 10 15 20 Kilometer

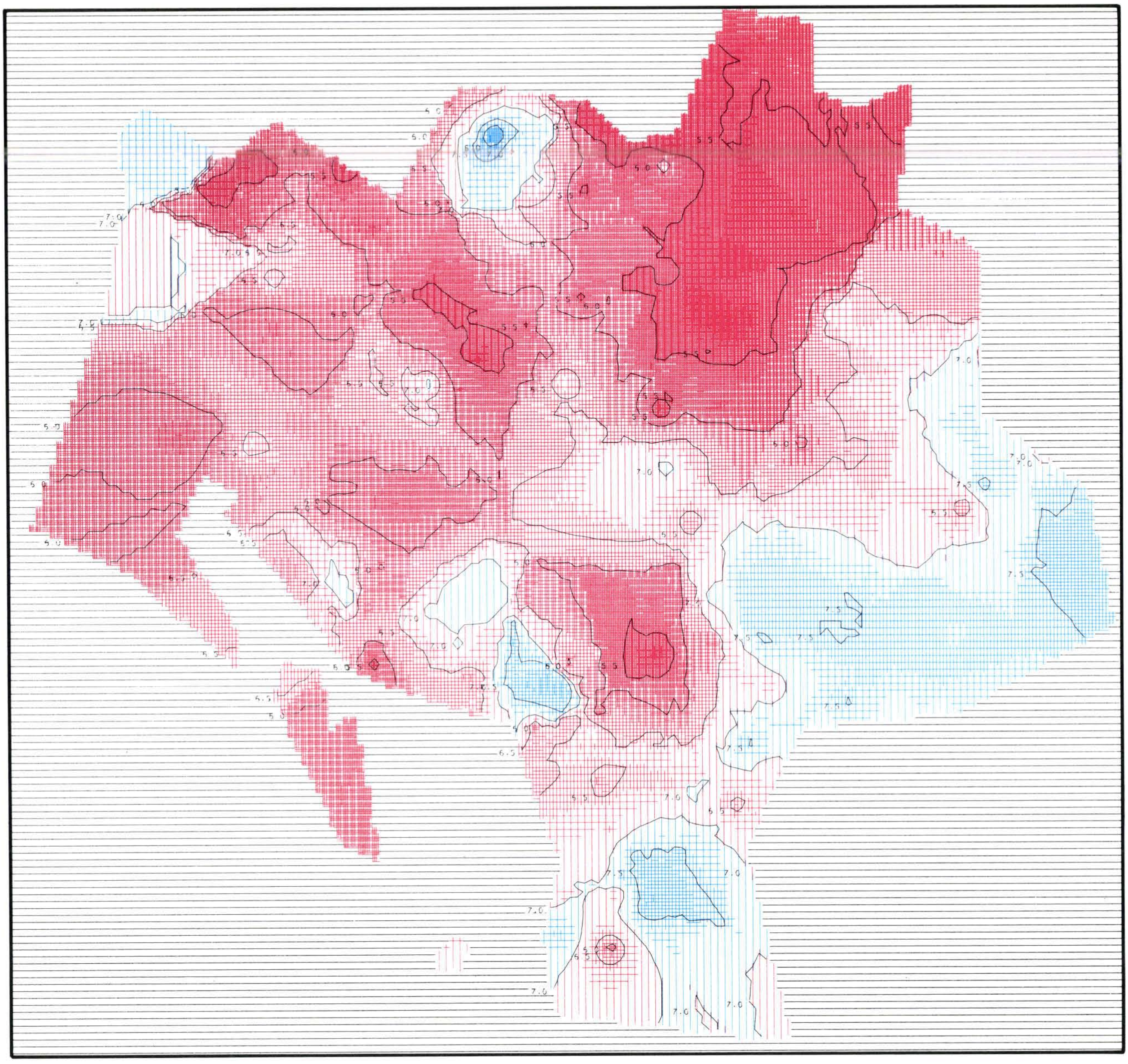
Fig. 6 shows the content of nitrate in the Quaternary sand and gravel reservoirs. It appears from the map that the nitrate content varies substantially. Modest values are found in a NW-SE zone throughout the county. NE and SW of this zone higher nitrate values appear. In some wells the nitrate content of the water exceeds 50 mg/l, which is the upper limit according to Danish rules.



RIBE AMTSKOMMUNE

NO3 I GLIMMERSANDSRESERVOIRER

Fig. 7 shows the nitrate concentration in the Miocene quartz and mica sand deposits. It should be noticed that this type of aquifer is only found in part of the county. The nitrate content is much lower than in the Quaternary sand and gravel deposits.



RIBE AMTSKOMMUNE

PH I SMELTEVANDSSAND OG -GRUSRESERVOIRER

Fig. 8 is an illustration of the pH-level in the Quaternary aquifers. Red and blue colours show acid and alkaline values respectively. pH-values above 7 are found especially in the areas where tills, presumably with a certain lime content occur.

CONCLUDING REMARKS

The collecting of data concerning geology and groundwater chemistry in Denmark has been a task for the Geological Survey of Denmark for more than 50 years.

Great amounts of data are stored at the Geological Survey. In order to use this valuable information for planning purposes it is necessary and convenient to use computer technique and to improve the graphical lay-out of the data output. It is our opinion that the two methods described in this paper are suitable ways of facilitating the presentation of geological and chemical data.

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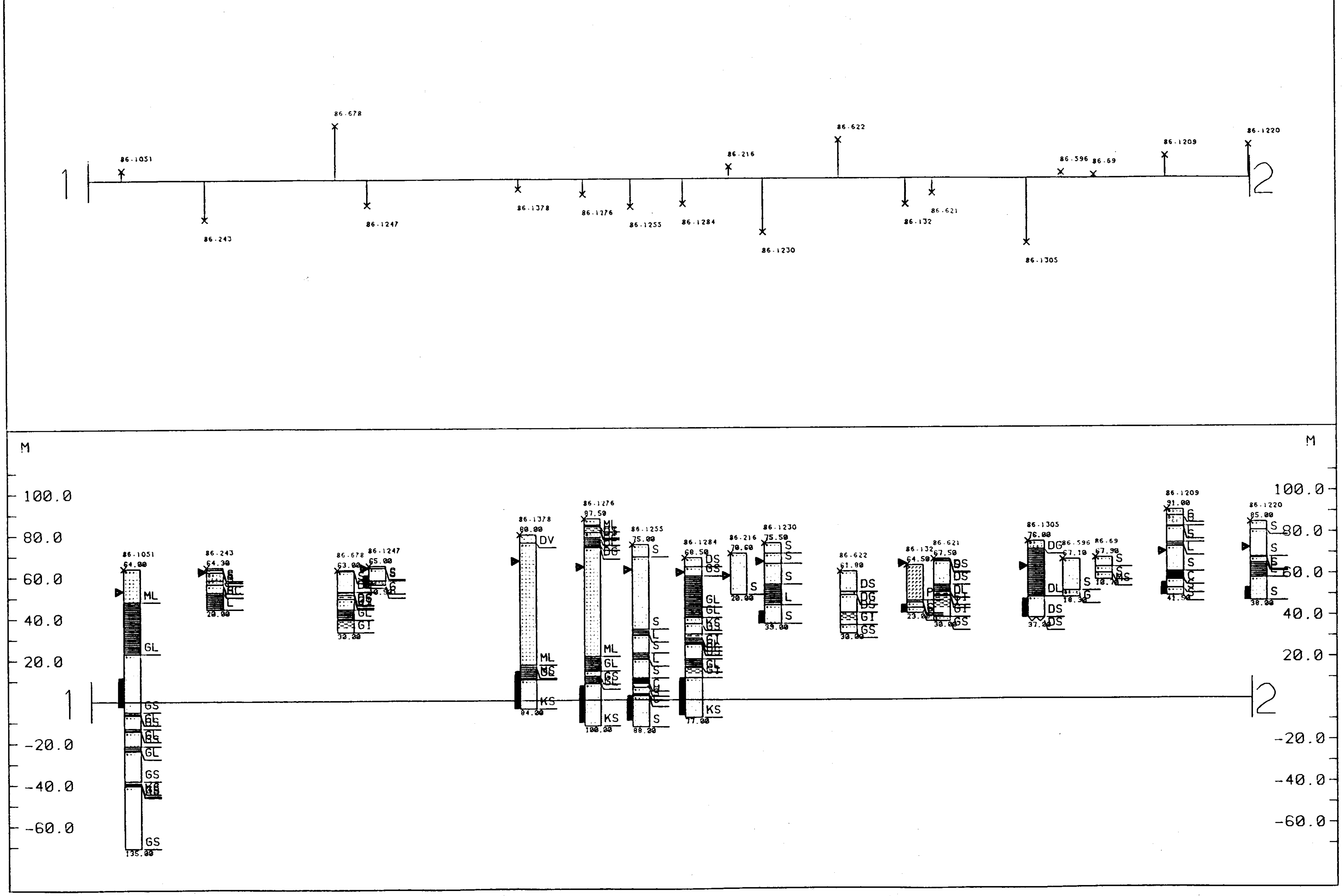

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The report demonstrates the use of a new computer technique which has been used for the hydrogeological mapping in the county of Ribe (Ribe Amtskommune). Geological cross section plots and thematic maps, showing the groundwater chemistry in the two aquifers in the area, have been produced by computer. Contour lines and hatshing have been used to illustrate the chemical variations in the aquifers. Besides the paper summarizes the geology, hydrogeology and hydrochemistry in Ribe Amtskommune.

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