Anker Weidick

LATE QUATERNARY FORAMINIFERA FROM VENDSYSSEL, DENMARK AND SANDNES, NORWAY

ROLF W. FEYLING-HANSSEN, JØRGEN ANKER JØRGENSEN, KAREN LUISE KNUDSEN AND ANNE-LISE LYKKE ANDERSEN

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Rolf W. Feyling-Hanssen: *Weichselian interstadial Foraminifera from the Sandnes-Jæren area.* Five shallow borings in the town of Sandnes, south of Stavanger, revealed clay deposits with marine fossils under a cover of sandy till with large blocks of Archaen rocks. This clay is called the Sandnes Clay. It is stiff and pre-consolidated, and disturbed only in the uppermost part. Four foraminiferal zones were distinguished, 1) the *labradoricum-norcrossi* assemblage, 2) the upper zone with scattered specimens, 3) the *asklundi-bartletti* assemblage, 4) the lower zone with scattered specimens. The assemblages are usually dominated by *Elphidium clavatum* and *Cassidulina crassa,* and turn out to be of Middle Weichselian (Middle Wisconsin) interstadial age. Deposits of corresponding age were found in the district of Jæren and on the island of Karmøy.

Jørgen Anker Jørgensen: *The Quaternary of Vendsyssel.* The content of foraminifera in samples from the Quaternary of some classical localities in Vendsyssel has been studied. The average frequency distribution of the most characteristic species from each locality is illustrated in diagrams. The assemblages revealed the following stratigraphical units at the localities: Interstadial Older *Yoldia* Clay, Lateglacial Younger *Yoldia* Clay, Lateglacial *Zirfaea* layers and Postglacial *Littorina* deposits.

Karen Luise Knudsen: *Late Quaternary Foraminifera from the Løkken area.* Foraminiferal assemblages from marine late Quaternany deposits of the Løkken area in Vendsyssel have been analysed quantitatively. Samples were collected from four boreholes in Løkken and from the coastal cliff north of Løkken. The following marine deposits are present in the area: Postglacial *Littorina* deposits, Lateglacial Younger *Yoldia* Clay, and interstadial Older *Yoldia* Clay. The environmental indications of these faunas are discussed. The assemblage

of the Older *Yoldia* Clay compare well with those recorded from the *Portlandia arctica* Zone of the Skærumhede boring, those from zones A and C in Hirtshals (Andersen, this paper), and those from the Sandnes Clay of southwest Norway. The Older *Yoldia* Clay at Løkken is suggested to be of Weichselian interstadial age.

Anne-Lise Lykke Andersen: *Foraminifera from the Older Yoldia Clay at Hirtshals.* Hirtshals coast cliff is situated southwest of the town of Hirtshals in Vendsyssel, north Jutland. Older *Yoldia* Clay crops out in the lowermost part of the cliff over a distance of about 300 m. 255 samples from the Older *Yoldia* Clay have been examined for their content of foraminifera. A subdivision into 7 zones of the Older *Yoldia* Clay at Hirtshals, based on changes in the composition of the foraminiferal faunas, is proposed. The stratigraphic relationship between the zones in the much disturbed Older *Yoldia* Clay has not yet been completely solved. However, based on observations of the structural setting of the sediments and the variations of the foraminiferal faunas, a succession is suggested. An ecological interpretation of the zones on the basis of comparison with Recent faunas has been attempted. Radiocarbon datings made on shells of *Zirfaea crispata* and on plant material, both from zone E, show that the material is older than 35,000 years B.P. On the basis of comparison with foraminifera assemblages found in other Quaternary deposits, it is suggested that the Older *Yoldia* Clay at Hirtshals is of Weichselian age, probably including two interstadials.

Rolf W. Feyling-Hanssen, Jørgen A. Jørgensen, Karen Luise Knudsen & Anne-Lise Lykke Andersen, Department of Micropalaeontology, University of Aarhus, Universitetsparken, DK-8000 Aarhus C, Denmark. *May 12th, 1971.*

This paper deals with investigations carried out on late Quaternary foraminifera by a group of micropalaeontologists at the University of Aarhus, Denmark. The work concentrated upon foraminifera from marine deposits in Vendsyssel, which is the northernmost part of Jutland in Denmark, and in Sandnes and some localities in the district of Jæren, southwestern Norway, i.e. deposits belonging to the Scandinavian border area of the North Sea Basin (see fig. 1). A major part of these deposits, the so-called Older *Yoldia* Clay of Vendsyssel and the submorainic clays of Sandnes and Jæren, turned out to correspond both in age and, in many cases, also in facies. They contain foraminiferal faunas of striking similarity, many of the species are the same, and even their frequency distributions match to a high degree. These sediments were, as demonstrated here, deposited during a Weichselian interstadial of long duration in coastal waters of moderate depth. The Lateglacial faunas from different localities in Vendsyssel have most of their species in common, and many of these species occur also in older deposits.

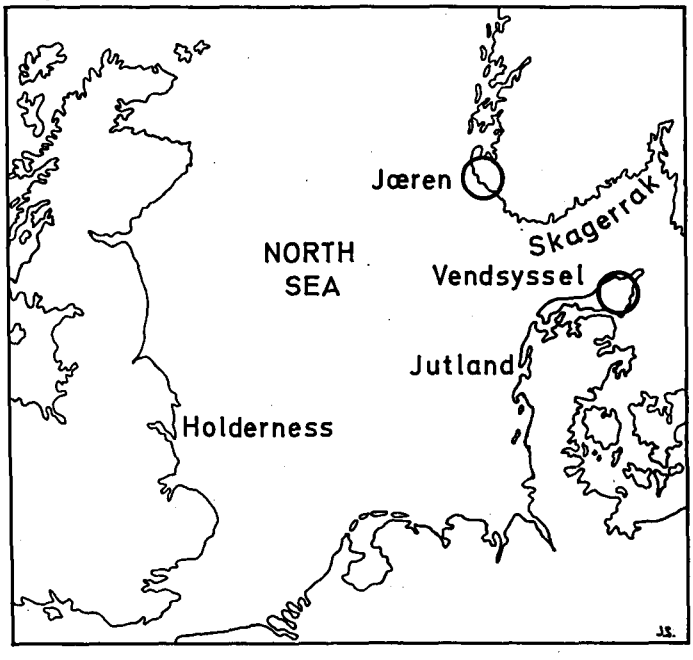

Fig. 1. Location of the investigated regions.

The Postglacial assemblages are also closely comparable between localities in Vendsyssel.

For these reasons, the present group of micropalaeontologists decided to prepare a joint presentation of the results. Each member of the group has given an account of her, or his, investigation in their respective area, whereas the systematic-palaeontological part of the paper and the reference list are joint. The systematic part and the reference list were compiled by Karen Luise Knudsen from notes provided by each member of the group. The present introduction was written by Anne-Lise Lykke Andersen and Rolf W. Feyling-Hanssen, whereas the final conclusion with the stratigraphical chart for the marine deposits of Vendsyssel was written and constructed jointly.

Methods

The samples were collected in different ways by the different authors, and each author has, therefore, explained the method applied in their own investigation.

The laboratory treatment of samples was uniform and largely as described by Wick (1947), Bartenstein (1954), Feyling-Hanssen (1958 and 1964 a)

and others: Every collected sample was dried and carefully cleaned of foreign material adhering to its surface. It was then fragmented by hand or, if hard, by the aid of a hydraulic vice until no fragment was larger than 1 cm^3. For further examination an amount of 100 g, sometimes more, sometimes less, was weighed out of the sample, and soaked for about 15 minutes in a 2 % to 5 % solution of hydrogen peroxide (H_2O_2). After disintegration the sample was washed through two sieves, the screen of the upper one having a mesh diameter of 1.0 mm and that of the lower one a mesh diameter of 0.1 mm. The residues upon the screens were afterwards dried and weighed, and the foraminifera in the size fraction 0.1–1.0 mm were concentrated by means of a heavy liquid, in this case carbon tetrachloride (CCl_4).

During the laboratory processing, drying, disintegration and washing, some foraminifera with a delicate test or with a loosely cemented arenaceous test may be damaged and broken to such an extent that they are lost. Furthermore, if the sediment has a high content of plant material, the use of hydrogen peroxide may cause the liquid to become acidic with the risk that calcareous tests may be corroded, or completely dissolved.

Foraminifera containing secondary pyrite will, after the gravity separation, be found in the heavy fraction and not among the concentrated foraminifera. Therefore, the heavy fraction was also inspected during the examination of the samples. Fortunately, except in some samples from zone 3 of the Sandnes borings, only a few of the specimens from samples dealt with in the present paper contained pyrite.

The investigation of the fossil foraminifera was arranged in such a way that the assemblage of every sample was revealed, as far as possible. This was achieved by picking the concentrated foraminifera from a so-called extraction tray under the binocular microscope. Each specimen was identified, counted, listed and transferred to a fauna slide. In poor samples the entire content of foraminifera was counted, whereas, in rich ones only a part of the assemblage, but not less than 300 specimens, was counted. The remaining part of such assemblages was examined to see if species other than those present in the counted part occurred. If such additional species did occur, they were listed with the counted part. Total populations were estimated by extrapolation (Phleger, 1960). The result of such an analysis is a list of species, the frequency of each species, and its percentage of the counted assemblage. Reworked specimens from the Upper Cretaceous, which are quite common in samples from the *Yoldia* clays of Vendsyssel, were neither counted, nor considered in the present research.

Walton's (1964) two measures of fossil foraminiferal assemblages were applied in the present investigation. The first is the faunal dominance which is the occurrence in percent of the most frequent species in the assemblage.

High faunal dominance indicates extreme environmental conditions, e.g. low temperature or low salinity, turbulent water, very shallow water, turbid water of low transparency. The second measure is the faunal diversity which is the number of ranked species in a counted assemblage, whose cumulative percentage accounts for 95 % of the total assemblage. High diversity would, generally, indicate favourable conditions whereas low diversity (and, consequently, high dominance) would be the faunal response to severe conditions. On the whole, consideration of complete assemblages from every sample and every zone forms a safer basis for ecological as well as stratigraphical conclusions than a one-sided hunt for index fossils.

The number of different species of fossil foraminifera recorded from the late Quaternary of the area investiated is 73. Nearly all of them are referable to known species. Only one new genus and two new species are established; open nomenclature was used for a few.

The symbols used in the range charts of the present paper are shown below.

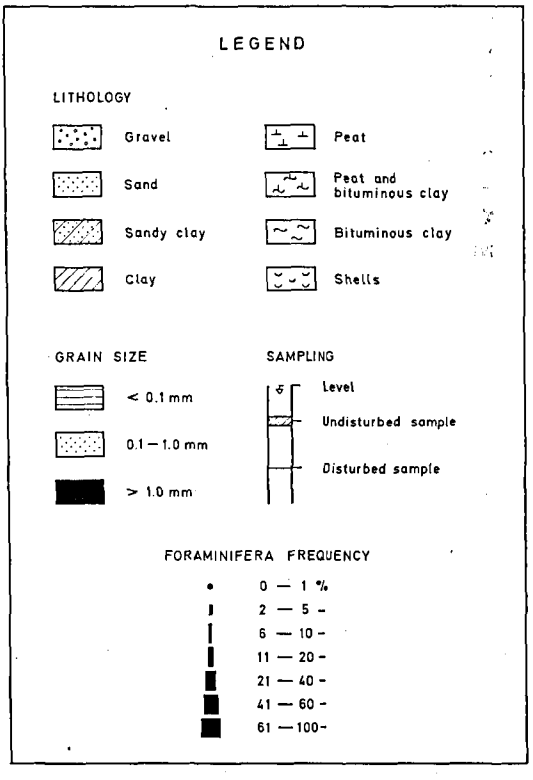

Fig. 2. Symbols used in the range charts.