CHAPTER 72

A New Method for the Representation of Sedimentary Sequences in Coastal Regions

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1. Introduction

Coastal lowlands usually consist of a body of unconsolidated sediments of up to 30 m thickness which have been deposited under the influence of a rising sea level during the past 10,000 years. These lowlands increasingly are acquiring importance for industrial plants, harbour construction, pipelines, and for the exploration of mineral resources. Consequently a basis for planning is required which will permit an economic exploitation of the coastal zone.

Geological mapping at scale of 1 : 25 000, which has been going on in Germany for more than 100 years, is of fundamental importance for this. Especially the newest type of geologic maps - the sequence map - offers the possibility of classifying and representing (BARCKHAUSEN, PREUSS & STREIF 1977) the costal deposits in a way that is well suited for technical and scientific purposes.

Its range of application covers tidal flat areas, marshes and coastal bogs, as they occur for example in the coastel zone of the southern North Sea. Combined with a documentation system of the field data and the techniques of automatic data processing this type of map offers new aspects which by far exceed the possibilities of conventional geological mapping.

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2. The system of classification and representation

Conventional geological maps - so called surface maps - represent the geographical distribution of individual layers within 2 m of the surface. The sequence map in oontrast offers the possibility of representing the spatial extension of complete sedimentary sequences - so called profile types (DE JONG & HAGEMANN 1960, HAGEMAN 1963) - in the body of coastal deposits. This gives the sequence map a three-dimensional character.

A hierarchic system of lithological classification has been developed, based on the vertical succession and the lateral interfingering of clastic sediments on the one hand and peat on the other hand. Three different hierarchic levels can be distinguished in the new system of classification (BARCKHAUSEN, PREUSS & STREIF 1977). Complexes (with 3 profile types), sequences (with 12 subordinate profile types), and facies units (with a variable number of special profile types).

This lithological system has to be linked with a chronostratigraphic system based on radiocarbon ages (BARCKHAUSEN, PREUSS & STREIF, 1978: Fig 4.). As the time interval represented by a specific sedimentary layer or peat horizon varies from place to place, the lithological classification system on the one hand and the chronostratigraphical system on the other hand, must be regarded as two independent methods of subdividing the Holocene. A clarification of the coastal development in terms of time and space, i.e. in a paleogeographic sense, can be done only with a combination of both systems.

2.1. Complexes

In the first level of the hierarchic system the following 3 lithological complexes and 3 profile types have been established (Fig. 1):

- a clastic complex (seaward region)
  a body of clastic sediments without intercalated peat layers.

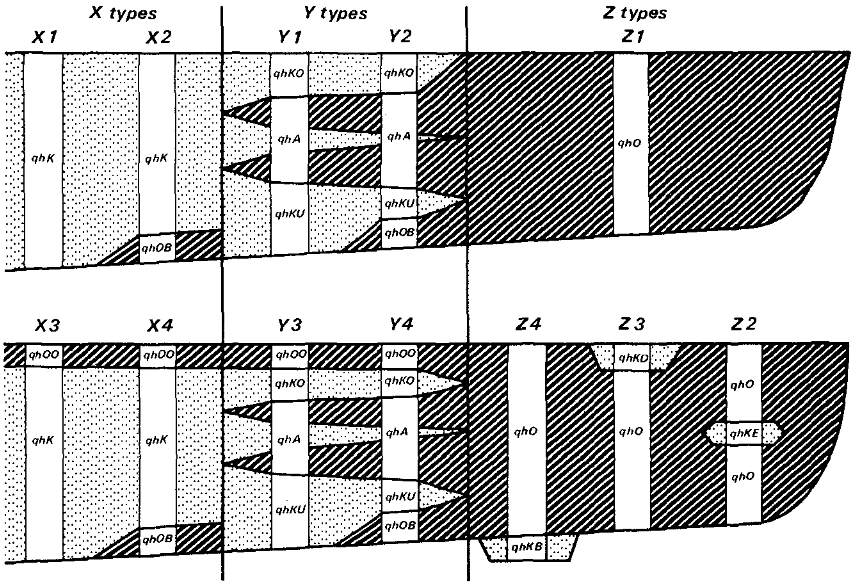

Fig. 1: Schematic cross section through the coastal deposits with the lables for the principal profile types (X_1, X_2, X_3, X_4, Y_1,... etc. Z4). The sequences are labeled with stratigraphic symbols according to BARCKHAUSEN, LOOK, VINKEN & VOSS (1975). qhK = clastic sequence, qhOB = organic basal sequence, qhOD = organic cover sequence, qhKU = lower clastic sequence, qhA = splitting up sequence, qhKO = upper clastic sequence, qhO = organic sequence, qhKB = clastic basal sequence, qhKE = clastic interbedded sequence, and qhKO = clastic cover sequence.

Peat may occur, however at the base or on top of the complex. Sediments are dominant in this complex,

- an <u>interfingering complex</u> (transition zone)
  a body of coastal deposits in which clastic sediments are intercalated by peat layers. Sedimentary and sedentary deposits are occuring in this complex mutually,
- a <u>peat complex</u> (back swamp region)
  a body of peat and limnic ooze. Thin layers of clastic sediments can either be intercalted in the peat complex or can occur as a single layer at the base or on top of the peat complex. Sedentary organic deposits are dominant in this complex.

These complexes can be represented in sequence maps in the form of prinoipal profile types. Thereby, the clastic complex is labeled as X-profile type, the interfingering complex as Y-type, and the peat complex as Z-type (Fig. 1). Usually the use of the principal profile type without subdivisions is limited to maps at a small scale. A more detailed subdivision of the coastal Holocene deposits can be achieved on the second level of the hierarchic system.

2.2 Sequences

Sequences are units of lithological classification which rank in the middle of the hierarchy. They are subdivisions of the above mentioned complexes and consist of one or more facies units. Some interrelations-hips between organic and clastic deposits can be deduced from the vertical succession and the lateral interfingering of the sequences. The variety of possible interrelations is represented in Fig. 1 in form of a schematic section. The vertical lines indicate the boundaries between the above mentioned complexes. The sequenoes, which are defined in the following, are looked upon as stratigraphical elements and therefore are labeled with stratigraphic symbols (Fig. 2) according to "Symbolschlüssel Geologie" (Symbol Key Geology, BARCKHAUSEN, LOOK, VINKEN & VOSS 1975).

Nr. der TK	Name Aufschluß Nummer	LK-Zähler	Einlieferer	Koordinaten	Höhe über NN (m)	
2608	216	0	GEK	R 2567660 H 5917200	- 0.75	Spalten 1–39 allgemeiner Teil

Bearbeiter	Jahr	W	AA	M	V	Dateihinweise, z.B. Fachbereiche	
Barckhausen	973	1	SR				Spalten 40–80 Fachteil

Tiefe bis (m) bzw. Mächtigkeit /	Stratigraphie /	Petrogr./Genese/Farben/Formenelemente und Zusatzzeichen/ Proben (Entnahmebereich, Probenmaterial, Untersuchungsmethode, Ergebnis)	Persönliche Notizen (nicht zur ADV) Tag, Monat:
0.50	qhKO	U-fS;k/bo,u	
1.00		U-fS;t,efle2,k/br,wa/gr	
1.50		fS;u,t1,wg,efle,k4/wa/gr,rf	
1.90		U;fs5,wg,t,k/wa/blgr	
3.80		U;t,fs,lag(wg),lag(T,u),k/wa	
.		/blgr-dgr	
8.75	qhKO	U;t,fs,lag(fS,u),ss,k/br,wa/	
.		gr/XE	
8.95	qhA	F;pr3,pf	
9.05		Hc;F,pr3	
9.15	qhA	Hp;f	
9.25	qhKU	T;ssmm,pfh,kf/la/dgr	
9.80		T;pr2,pf	
10.80		T;pr1,hw,pf,kf/la/bngr	
11.30		T;pr1,pf4,hwa/la/gr	
12.30		T;u,hlw1,k2/br/gr	
12.46	qhKU	T-F/la,l/grbn	
12.70	qhOB	F;sub(Hl)	
12.91	qhOB	Hl;Hle////,,(Y2)	
12.95	qp,qh	fS;h2//dgr	
.			

Fig. 2 Example of a data form for field data capture. The necessary characteristics of the bore hole are given in a fixed format. The strata description is recorded in a free format, and its various elements (depth, stratigraphy, petrography etc.) are separated from each other by a slash. The symbols of the sequences (qhKO, qhA, qhKU, and qhOB) are given in the column stratigraphy, the profile type (Y2) is given in the lowermost layer of coastal Holocene.

- clastic sequence (qhK): clastic sedimentary succession without intercalation of peat layers. Soil horizons and layers in which rootlets of phragmites are abundant are regarded as a part of the clastic sequence;
- organic basal sequence (qhOB): succession of peat and limnic ooze or organic soil horizons at the base of clastic Holocene deposits;
- organic cover sequence (qhOD): succession of peat or limnic ooze which occurs at the present surface and which is underlain by clastic Holocene sediments.

The organic basal sequence and the organic cover sequence can occur in the clastic complex as well as in the interfingering complex, but which may also be absent. The following elements are found only in the interfingering complex and are characteristic of it:

- lower clastic sequence (qhKU): clastic sedimentary unit at least 5 cm thick, which underlies the lowermost intercalted peat layer and may be underlain by an organic basal sequence;
- splitting up sequence (qhA) sedimentary succession between the bottom of the lowermost intercalated peat layer and the top of the uppermost one. Thus, the splitting up sequence consists of peat layers (in a special case only layer) as well as clastic sediments which lie between the intercalated peat layers;
- upper clastic sequence (qhKO) clastic sedimentary unit at least 5 cm thick which overlies the uppermost intercalated peat and may be overlain by an organic cover sequence.

The following sequences are found in the peat complex and are characteristic of it:

- organic sequence (qhO) succession of peat and limnic ooze with at most one interbedded layer of clastio sediments more 5 cm thick;

- clastic basal sequence (qhKB) clastic sedimentary unit which occurs in the basal part of the coastal Holocene deposits and which is covered by an organic sequence. The thickness of the basal clastic sequence is less than of the covering organic sequence;
- clastic interbedded sequence (qhKE) unit of clastic sediments which is interbedded in the organic sequence unrelated to an upper or lower clastic sequence as defined above or to clastic units of a splitting up sequence. This clastic interbedded sequence may not exceed 50 % of the total thickness of the organio sequence. The qhKE may consist of one individual layer and/or of several thin layers, less than 5 cm thick;
- clastic cover sequence (qhKD) clastic sedimentary unit which occurs at the present surface and which is underlain by the organic sequence. The thickness of the clastic cover sequence must be less than that of the underlying organic sequence.

There are 12 possible arrangements of these sequenoes as defined above. These possibilities define the 12 subordinate profile types and are labeled (Fig. 2) as X1, X2, X3, X4, Y1, ..., etc. (BARCKHAUSEN, PREUSS & STREIF 1977).

Any bore hole in the coastal zone can be immediately ascribed to one of the 3 main profile types and one of the 12 subordinate profile types in the course of the field data capture or during an evaluation of archive material (Fig. 2). If a bore hole does not penetrate the Holocene deposits, hence incomplete profile types are following. This is indicated by adding an "u" to the label. The following incomplete subordinate types are possible: X1u, X3u, Y1u, Y3u, Z1u, Z2u,and Z3u.

2.3. Facies units

A more detailed subdivision of the sedimentary units can be aohieved within the lowest hierarchic level of the system. The above-defined sequences often consist of several facies units; special profile types must then be defined for these cases. In contrast to the first and second levels, with their well-defined elements and their established number of profile types, the lowest level of the system is a variable one.

The facies units are variable in number and in range, so that petrographic, genetic, structural, and other criteria can be taken into account and represented in an unlimited number of special profile types. Thus, the facies units and the special profile types have to be selected or defined individually with respect to the specific objectives and the prevailing local conditions. Besides geological findings, special technical or economic factors can be evaluated and represented in these maps. For instance, the spatial extension of:

- sediments susceptible to compaction and therefore unsuitable for building foundation;
- deposits of special consistency, for which specific excavating and dredging methods are necessary;
- sedimentary units that contain raw material of economic interest such as sand, gravel or mineral deposits.

These examples of possible utilisation of this classification the system might be greatly enlarged. Consequently the lithological subdivision of the coastal deposits combined with the representation of profile types offers totally new aspects which by far exceed the possibility of conventional mapping.

3. Practical application

During the course of field data capture it is nearly impossible to foresee all the aspects which might be of technical or scientific interest. However, most of the information necessary for any application can easily be recovered from the pool of geological basic data by a systematic evaluation. A selection can be made from an immense amount of basic data within a very short time by computer methods.

A close link between the above-mentioned classification system for coastal deposits on the one hand and data bank management systems on the other hand has been achieved in the following way: All basic data are collected on special data forms (Fig.2) during the field data capture. All information, such as depth, stratigraphy, petrography, genesis, colour and additional remarks, is recorded according to a symbol key (BARCKHAUSEN, LOOK, VINKEN & VOSS 1975) on this data form. These strata descriptions are then stored on punch oards magnetic tape or disc. All necessary characteristics of the bore hole (such as bore hole number, longitude and latitude, elevation, etc.) are recorded in "fixed format"; description (depth, stratigraphy, petrography, genesis, colour, additional remarks, and samples) are recorded in a "free format". For instance: for the mapping of sheet Emden West, which is situated by the Ems River estuary, about 650 bore holes have been sunk. Altogether about 10,000 m of sedimentary cores have been described and about 25,000 to 30,000 individual layers have been distinguished and sedimentologically characterized.

The documentaion and retrieval system DASCH has been developed to handle such an immense pool of different data (MUNDRY 1975). The strata descriptions which were recorded and stored in a free format can be converted into a fixed format in so-called documentation lists. The various parts of the description such as depth, stratigraphy, petrography etc. are arranged in these lists in defined fields. The most important part of the DASCH system, however, is retrieval. A selection of specific data can be retrieved from the mass of basic data. This is done by a sequential search of all of the basic data. Those basic data that correspond to a retrieval query can then be printed out or stored on magnetic tape or disc for further processing. For practical use it is very important that the structure of the query is the same as the structure of the strata description. Thus, the DASCH system can be easily used by field geologists or technicians who are directly involved with the specific problems. Other data processing programs have been developed, especially for the production of geologic maps, profile and cross sections (MUNDRY 1975, BARCKHAUSEN 1973). At present we are able to produce starting the following constructions from the basic data:

- individual profiles, cross sections and profile maps;
- isoline maps (contourlines, isopach plans and geological boundaries constructions);
- signature maps, bore hole symbol maps;
- sequence maps or profile type maps.

These all have two objectives. One is the graphic representation for a general overview. Second, they serve as a base for specialized evaluations, whereby much troublesome and lengthy manual work is avoided.

The first sheet of this new type of geological map, the sequence map sheet Emden West 1 : 25,000, has been published (BARCKHAUSEN & STREIF 1978). Two further sheets, Wilhelmshaven and Emden are in preparation. The advantages of the new map are quite obvious. The system is more flexible and its utilization is easily manageable. Furthermore it offers the possibility of representing the whole sequence of sedimentary deposits in the coastal zone. Consequently, this new type of maps covers scientifical and practical requirements much better than conventional geological maps and is of better use for planning purposes. Combined with data bank management systems, the sequence map offers totally new aspects for geological mapping in coastal areas. This concerns the production of the maps as well as their practical evaluation. As the system of the sequence map can be applied to nearly all coastal lowlands, it may be regarded as an important part of the technical and scientifical know how of coastal engineering.

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