NOAH
North Sea Observation and Assessment of Habitats

Porosity of Marine Sediments

GENERAL OVERVIEW

Dataset name:
Sediment grain size data were taken to assess porosity of the North Sea surface sediments

Project:
North Sea – Observation and Assessment of Habitats (NOAH)

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DATASET SPECIFICATIONS

Dataset Parameter(s) and supplied Unit(s):
Permeability

Date(s) available:
missing

Validated:	**Version Date:**
See Notes and Limitations	*23.05.2014*

Current State:
final

Format:
Raster (tiff)

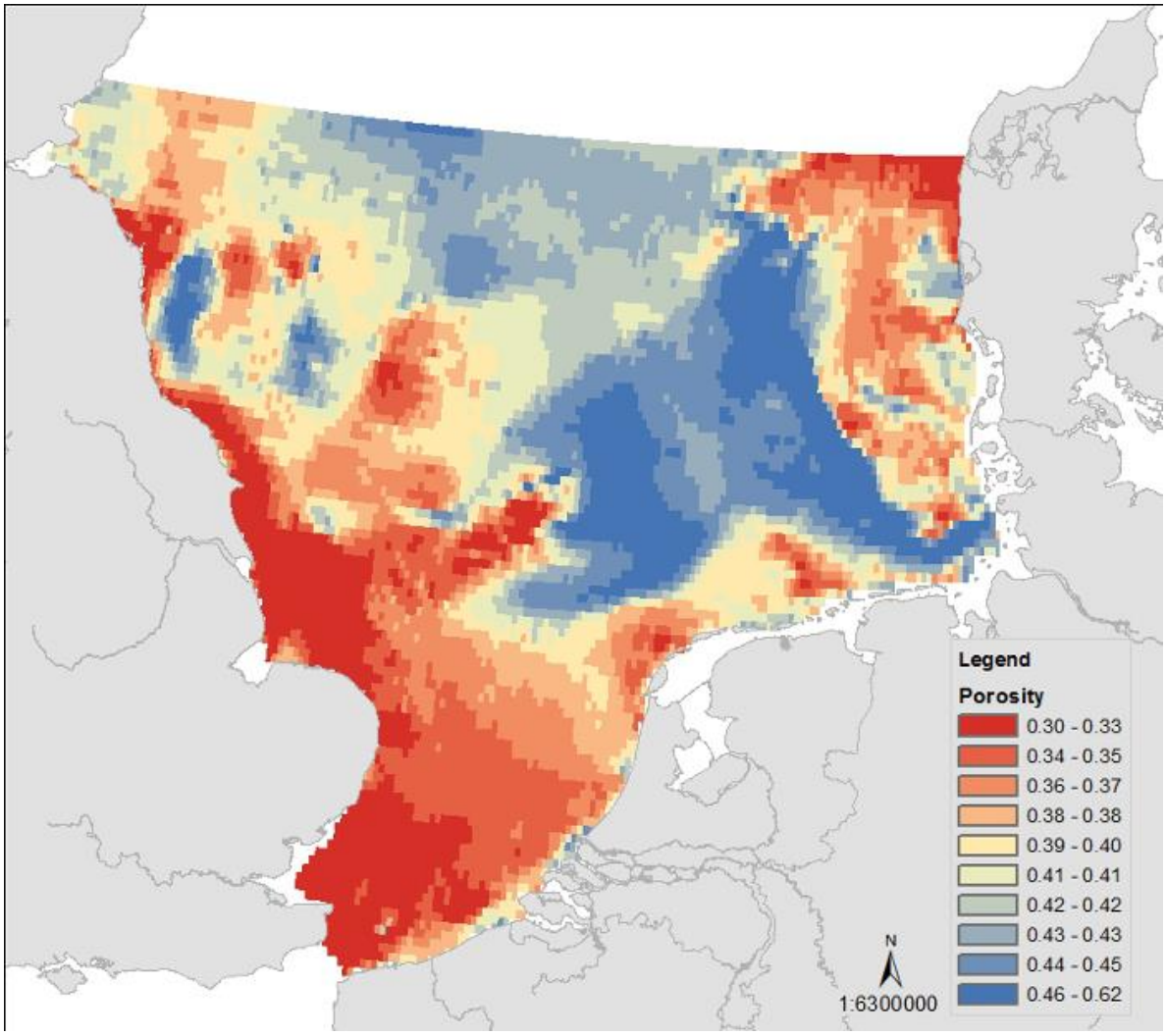
Citation:
Ruardij, P., and W.van Raaphorst (1995): „*Benthic nutrient regeneration in the ERSEM ecosystem model of the North Sea", Netherlands Journal of Sea Research, Volume 33, Issues 3-4, 453-483*

Soulsby, R., (1997) "Dynamics of Marine Sands: A Manual for Practical Applications". Thomas Telford Ltd, London.

DATASET DETAILS

Abstract
The map shows the spatial distribution of sediment porosity of surface sediments in the southern North Sea. The porosity map originates from a map of median sediment grain-sizes.
The porosity is defined as "volume of water/total volume", with "total volume" meaning "volume of water plus volume of grains".

Sediment grain size data was taken to assess porosity of North Sea surface sediments from the median (D50) of the particle size distributions. Results were mapped using Kriging technique to help understand the spatial dynamics of sediment diagenesis and consolidation.



Acquisition and Processing Description:

Acquisition:

The sediment porosity is calculated from the sediment's median grain-size. The median grain-size data consists of more than 50,000 individual sample values. Only samples from the sediment surface (maximum sub-bottom depth 10 cm) were taken into account. The grain-size data were collected from more than 10 institutions and databases. The oldest data were measured during the fifties. All collected data are united into the same data set, disregarding the date of sampling.

Processing Description:

The sediment porosity is calculated from φ50, with φ50 being the median grain-size in φ-units. The porosity formula is derived from Fig. 12a of Ruardij and van Raaphorst (1995). In Fig. 12a the "porosity of the sediment as measured in the North Sea" is plotted against the sediment's median particle size in a log-log plot. The D50-range of the plotted data points is between 10 µm and 300 µm (corresponding to φ50 between 6.644 and 1.737). A straight line is fitted by eye through the plotted data points. The equation of this line is

$$porosity = 0.2603 * 1.20325^{\Phi 50}$$

The limits of this so-called RvR formula are:

(1) A "maximum porosity" was taken from data measured in the Skagerrak by Bøe et al. (1996). For 39 samples with φ50 > 9.97 (D50 < 1 µm) the mean porosity was 0.823. The RvR formula yields this maximum porosity at φ50 = 6.22 (D50 = 13.4 µm).

(2) The "minimum porosity is 0.3". In his Table 5, Soulsby (1997) gives as the lowest porosity of "natural sand beds" a value of 0.3 for well-mixed and densely packed sand. The RvR formula yields this minimum porosity at φ50 = 0.767 (D50 = 588 µm).

$$porosity = 0.2603 * 1.20325^{\Phi 50} \quad for\ 0.767 < \Phi 50 < 6.22$$
$$porosity = 0.3 \quad for\ \ \Phi 50 \leq 0.767$$
$$porosity = 0.823 \quad for\ \ \Phi 50 \geq 6.22$$

To produce an area-covering porosity map the first step was the generation of an area-covering median grain-size map.
The generation of a map covering the North Sea area of interest is done by Co-Kriging using the R-routine "krige" (R-library "gstat"). The values of the primary variable (median grain-sizes of individual samples) are provided at the original sample locations. The values of the secondary variable are provided at the target grid nodes. The secondary variable (log-converted %mud) is known at all the target grid nodes.
The result of Co-Kriging is a full-coverage estimation of the primary variable at the target grid nodes. Co-Kriging tends to produce a smoothed image. Along with the estimate of the primary variable ("kriging mean"), kriging gives an estimate of the estimation error ("kriging variance") at every target grid node.
After having generated a median gran-size map, the final step is the application of the RvR porosity formula to convert the median grain-size map into a porosity map.

Notes and Limitations:

Data Quality:

The quality of the porosity map depends (a) on the quality of the median grain-size map which is considered here and (b) on the quality of the porosity formula obtained from Ruardij and van Raaphorst (1995).

For the formation of the porosity formula, the porosity data of Ruardij and van Raaphorst (1995) were selected. There were two reasons for that: (1) the data were measured in the North Sea and (2) the median grain-size was used as independent variable. The median grain-size is a more stable (more accurate) variable than e.g. the sediment's mud content.

Results of the Ruardij-van Raaphorst formula were compared with porosity data measured in the North Sea, see error estimation.

Error Estimation:

The so-called RvR formula for the calculation of sediment porosities in the North Sea is

$$porosity=0.2603*1.20325^{\Phi 50}$$

- *The uncertainty of the calculated porosity originates from the uncertainty of φ50 from the uncertainty of the formula itself. This means: the porosity calculated by the formula may deviate from the true porosity even if φ50 is exactly known.*

- *The Kriging standard deviation of median grain-size φ50 of surface sediments in the southern North Sea is about 0.68 (φ-scale).*
- *To estimate the uncertainty of the calculated porosity, the results of the RvR formula were compared with two set of measured data. The two data sets were median grain-sizes and porosities of surface sediment samples (79 samples) from the Skagerrak. Most samples were taken in the deep part of the Skagerrak where the sediment is very muddy. The data were measured by Bøe et al. (1996).*
- *Median grain-sizes and porosities of surface sediment (62 samples) from the German Bight. Median grain-size is between 70 and 1000 µm. The data were measured by N. Lahajnar, Institute of Geology, Hamburg University.*
- *The two data sets were merged. The differences between the porosities predicted by the RvR formula and the measured porosities showed a negligibly small mean (the bias) and a standard deviation of 0.066.*
- *The uncertainty of the values in the porosity map are thus composed of the φ50 uncertainties shown in the appropriate map and of the uncertainty being inherent in the RvR porosity formula. Putting these two errors together is done by a Monte Carlo procedure.*
- *It is the aim to give each porosity value in the map (southern North Sea) its individual estimation of uncertainty. The Kriging mean and the Kriging standard deviation of φ50 are taken from the appropriate median grain-size maps. The random numbers for the Monte Carlo procedure were taken from a normal (Gaussian) distribution. Typically N = 10 000 realizations of the porosity were calculated during a Monte Carlo simulation run for one data point. The estimated standard deviation of porosity is obtained from the resulting distribution of the N simulated porosity realizations.*

Related Datasets:

Median grain-size of the surface sediment grain-size distribution

Data Sources

The data for the generation of sediment maps were obtained from the following institutions:

NAVAL OFFICES and RESEARCH INSTITUTES:
Forschungs- und Technologiezentrum Büsum, Germany
Bundesamt für Seeschifffahrt und Hydrographie (BSH), Hamburg, Germany
Senckenberg Institut Wilhelmshaven, Germany
Helmholtz Zentrum Geesthacht, Germany
Bioconsult Schuchardt & Scholle GbR, Bremen, Germany
Deltares, Utrecht, The Netherlands
British Geological Survey, Marine Information Project, Edinburgh, UK
Marine Scotland, Marine Laboratory, Aberdeen, UK
Universität Hamburg, Institut für Geologie und Paläontologie, Hamburg, Germany
Royal Netherlands Institute for Sea Research (NIOZ), Texel, The Netherlands
Geological Survey of the Netherlands (TNO), Utrecht, The Netherlands
School of Ocean Sciences, Bangor University, Menai Bridge, Anglesey, UK
CEFAS, Lowestoft, UK
Geological Survey of Norway (NGU), Trondheim, Norway
Geological Survey of Denmark and Greenland (GEUS), Copenhagen, Denmark
Bureau de Recherches Géologiques et Minières (brgm), Orléans, France

PROJECTS:
Management, Research and Budgeting of Aggregates in Shelf Seas related to End-users (MAREBASSE, 2002-2006), Ghent University, Belgium

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North Sea Benthos Survey 1987
North Sea Benthos Project 2000
Zirkulation und Schadstoffumsatz in der Nordsee (ZISCH, 1984-1989), Universität Hamburg
Biogeochemistry and Distribution of Suspended Matter in the North Sea and Implications to Fisheries Biology (TOSCH, 1984-1988), Universität Hamburg
Geopotenzial Deutsche Nordsee (GPDN, 2009-2013), Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) Hannover, Landesamt für Bergbau, Energie und Geologie (LBEG) Hannover, Bundesamt für Seeschifffahrt und Hydrographie (BSH) Hamburg, Germany

DATABASES:
Flanders Marine Institute (VLIZ) Data Centre, Ostend, Belgium
Management Unit of the North Sea Mathematical Models (MUMM), Brussels, Belgium
International Council for the Exploration of the Sea (ICES), Copenhagen, Denmark
Publishing Network for Geoscientific & Environmental Data (PANGAEA), Alfred-Wegener-Intitut (AWI), Bremerhaven, Germany