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PALEOCEANOGRAPHIC MAPPING PROJECT
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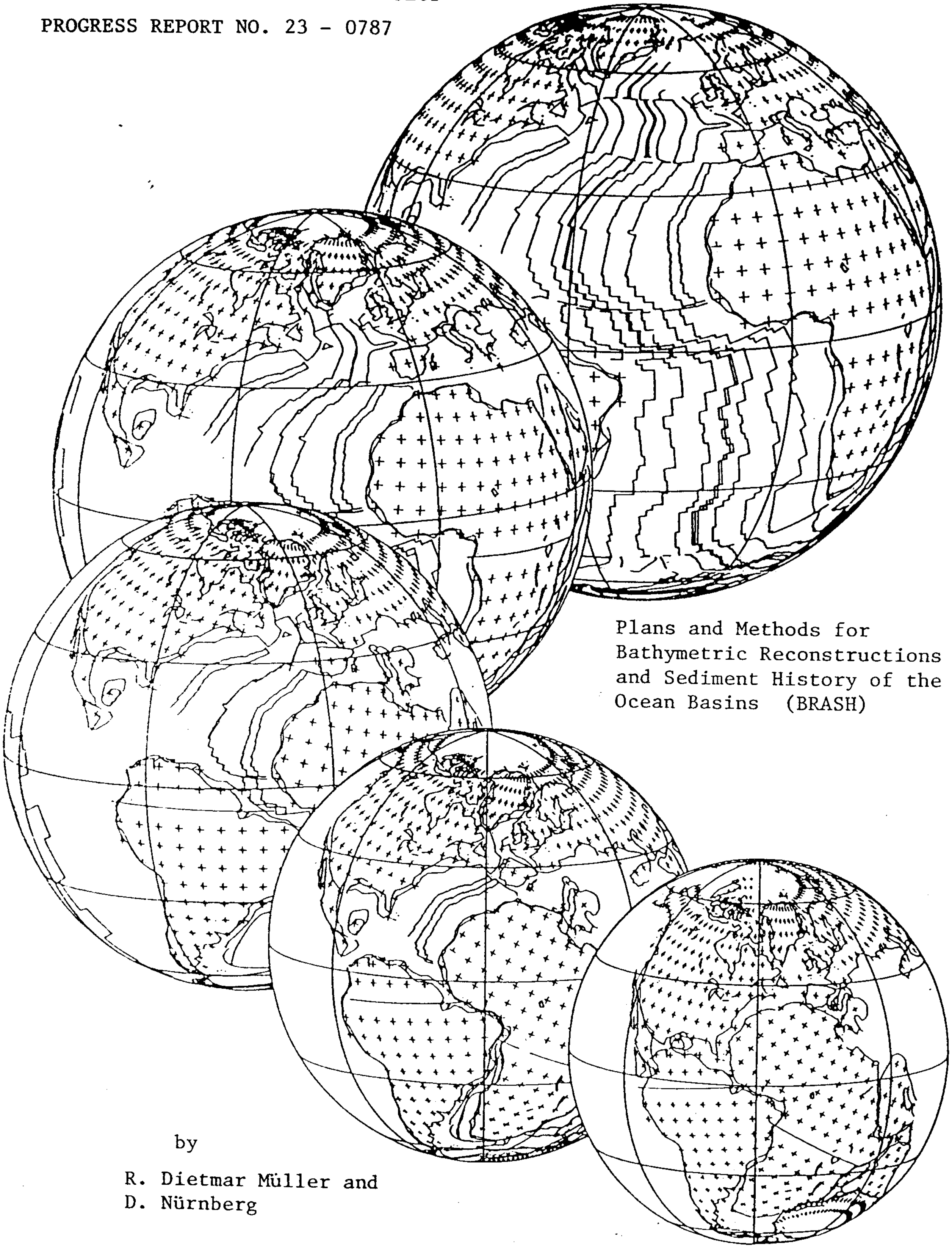

Plans and Methods for Bathymetric Reconstructions and Sediment History of the Ocean Basins (BRASH)

by

R. Dietmar Müller and
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Introduction

The project "Bathymetric Reconstructions and Sediment History of the Ocean Basins" (BRASH) will attempt to produce a global synthesis of paleobathymetry maps, which will be used as basis to reconstruct the sediment accumulation history of the ocean basins. The Paleoceanographic Mapping Project (POMP) will complete a global model for Mesozoic and Cenozoic plate motions by the end of 1987. One of the major products of POMP-1987 will be the synthesis of a global isochron map of the ocean floor, which will allow us to produce a set of paleobathymetry maps for all ocean basins using standart depth-age relations (Parsons & Sclater 1977). The main goal of BRASH is to compile a standardized database of all DSDP- and ODP- sediment data and to use this information along with the paleobathymetry maps to reconstruct the sediment accumulation history of the ocean basins. This project is planned to run for three years.

Up to now, approaches to quantify the temporal and spatial distribution of marine sediments by calculating accumulation rates have been largely descriptive, since supra-regional models of paleoclimate and paleoceanography were lacking. For BRASH we plan to develop a conceptual model that will allow us to address the interaction between the plate tectonic evolution of an ocean basin with the basin's sediment flux rates and distributions, the extent and facies patterns of ancient epicontinental seas and with the paleoclimate and its impact on ocean circulations.

Principal investigators

The principal investigators for BRASH will be Dr. Thomas Davies and Dr. John Sclater, both at the Institute for Geophysics, University of Texas at Austin. Tom Davis will be the coordinator of the project and responsible for the supervision of the processing and synthesis of the DSDP- and ODP-data. John Sclater will be the main supervisor of the paleobathymetry reconstructions. The project is planned as a loosely-knit joint operation between the two main investigators and Dr. Jörn Thiede at the Institut für Geologie und Paläontologie, Christian-Albrechts Universität in Kiel, F.R. Germany. Jörn Thiede will contribute his extensive experience in work on the depositional history and paleoceanography of ocean basins. As a part of this cooperation R. Dietmar Müller, who is a student of Jörn Thiede, will be working on paleobathymetry and sediment history reconstructions in the Central and North Atlantic. Dirk Nürnberg, who finished his master's degree under supervision of Jörn Thiede, will work on a similar project in the South Atlantic, supervised by John Sclater and Thomas Davies.

Objectives

Paleodepth reconstructions and paleogeography

Refined global plate reconstructions of the Paleoceanographic Mapping Project (POMP) will provide the base for the construction of detailed paleodepth charts for the Atlantic, Indian and Pacific Oceans. These charts will take into account both simple subsidence of the normal ocean floor and the effect through time of residual depth anomalies. The subsidence of about 60% of all oceanic crust with age is principally due to cooling and thermal contraction following a simple age/depth relationship (Parsons & Sclater 1977). The remaining oceanic crust does not follow this subsidence curve (Sclater et al. 1985). These so-called residual depth anomalies mainly comprise aseismic ridges and mid ocean swells. Elongated regions of aseismic ridges, associated with fracture zones and often generated at sea-level, are thought to be the result of excess volcanism on the ocean floor (Sclater et al. 1985). Examples are the Iceland Swell and the Azores/Great Meteor Rise in the North Atlantic, the Rio Grande Rise - Walvis Ridge complex in the South Atlantic and the Ninety-east Ridge in the Indian Ocean. Much broader types of depth anomalies are mid ocean swells without relation to fracture zones. They are thought to be related to upwelling thermal convection cells in the upper mantle (Sclater et al. 1985). Examples are the Cocos and Nazca Ridges in the South Pacific, the Hawaian Swell and the Emperor Seamount Chain in the North Pacific and the Kerguelen Plateau in the Indian Ocean.

The reconstruction of the subsidence history of residual depth anomalies due to excess volcanism is of particular importance for this project since volcanic swells generated at or near sea level act as barriers to oceanic circulation. They may in fact control the circulation of deep water in the oceans, thus affecting the formation of evaporites or sediments with high contents of organic carbon in restricted basins. In order to derive the paleodepth charts, the global plate tectonic model of POMP will be used to rotate isochrons and continents to their past positions for a set of pre-defined time slices. The appropriate latitudinal paleopositions will be determined by use of paleomagnetic data. The paleodepth of normal ocean floor will be calculated according to Parsons & Sclater (1977); the subsidence history of residual depth anomalies will be treated separately before being added to the paleodepth charts. Paleo-coastlines will be added to the paleobathymetry maps utilizing the best available geologic literature (e.g.Tucholke & Mc Coy (1986) for the North Atlantic).

Sediment History

Methods

A vast amount of sediment data is available from DSDP-and ODP projects, but are not yet organized in a standardized database. An effective use of these data for time/space analyses of sediment accumulation rates is not yet possible. Having a complete sediment database will allow us to quickly adapt the data to a revised absolute timescale such as the DNAG timescale (Palmer 1983). This is only feasible by compiling all data from different DSDP- and ODP-sources into a standardized computer database. For this purpose we plan to use the Global Stratigraphic Synthesis Program that was originally written by Stratigraphic Services Co. and is now in use at Marathon Oil. This program will allow us to organize DSDP-and ODP-data into a standardized classification scheme consisting of four groups: biostratigraphic, lithostratigraphic, chronostratigraphic and spatial data. Age/depth relations for sediments can then be derived, which permit the calculation of accumulation rates in combination with density/porosity data (Fig. 1) Flux rates for the bulk sediment as well as for sediment components such as calcareous, siliceous, terrigenous particles and organic matter can then be derived. Subsequently, palinspastic maps will be plotted, which display the sediment flux pattern for different time intervals (Fig. 2).

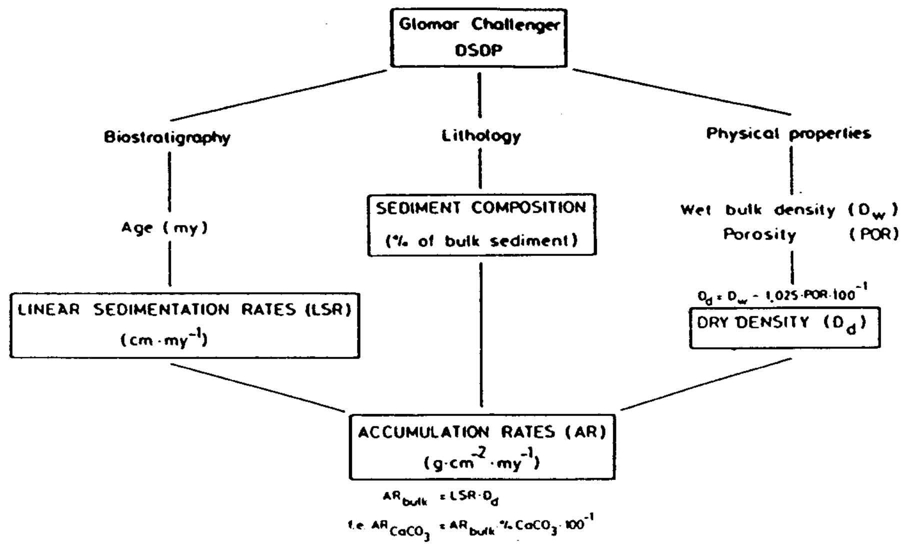
In previous work on the depositional history of ocean basins fixed time intervals of 3 or 4 Ma were chosen to calculate and plot sediment accumulation patterns through time (Davies & Kidd 1977, Worsley & Davies 1979, Ehrmann & Thiede1985), or else relatively long geologic epochs were chosen (Van Andel et al.1977). Consequence of using long epochs is that paleoceanographic events that resulted in erosion or dissolution of sediments are blurred. In this project we plan to define time units which are bounded by identified hiatuses, which are globally correlatable or at least traceable over large parts of an ocean basin. Hiatus data will be obtained by calculation of sediment accumulation rates for every drillsite and by published studies on hiatus distributions like Keller et al. (1986). In addition, seismic stratigraphy will be used to derive information about regionally synchroneous seismic reflectors connected with paleoceanographic events, as suggested by Mayer et al. (1986) for the Pacific Ocean. The bulk- and component accumulation rates will be calculated for predefined time intervals and the sediment flux distributions will be plotted onto the paleogeographic/-bathymetric base maps.

Sediment flux data: Basic tools for their interpretation

The regional as well as oceanwide characteristics of biogenic and terrigeneous sediment fluxes through time are controlled by a complex climatic - oceanographic - depositional - plate tectonic system. Some of the most important parameters of this system are outlined in the following section in order to clarify our strategy to interpret sediment fluxes. The sediment components affected by processes described below are abbreviated as follows:

T	=	Terrigeneous components
C	=	Calcareous components
BS	=	Biogenic silica
OM	=	Organic matter

1. The width of an ocean basin controls the proximity of the basin floor to land areas and thus affects terrigeneous input including nutrients for biogenic productivity (T, C, BS, OM).



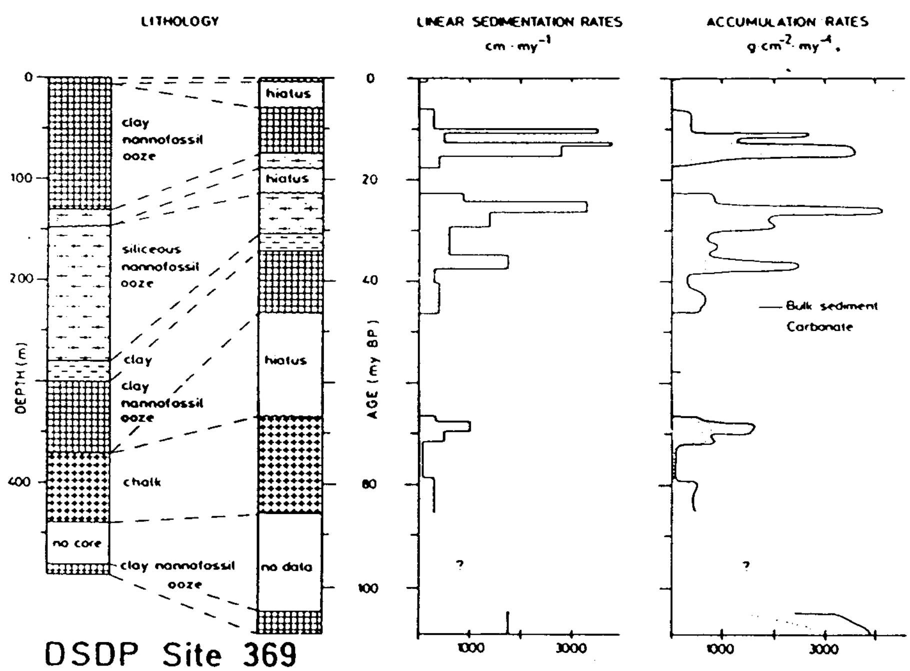


Fig.1: The upper figure shows a flow diagram for calculating accumulation rates from DSDP/ODP sediment data. The lower figure displays a graphic example for data processing: The left column shows the lithologic information (simplified) as found in the Initial Reports of the Deep Sea Drilling / Ocean Drilling Project. In the right column lithology is plotted versus age. Hiatuses are marked where appropriate. Linear Sedimentation rates are plotted for all determined stratigraphic intervals. By correcting them for compaction accumulation rates are determined for every one million year time increments (from Ehrmann & Thiede 1985).

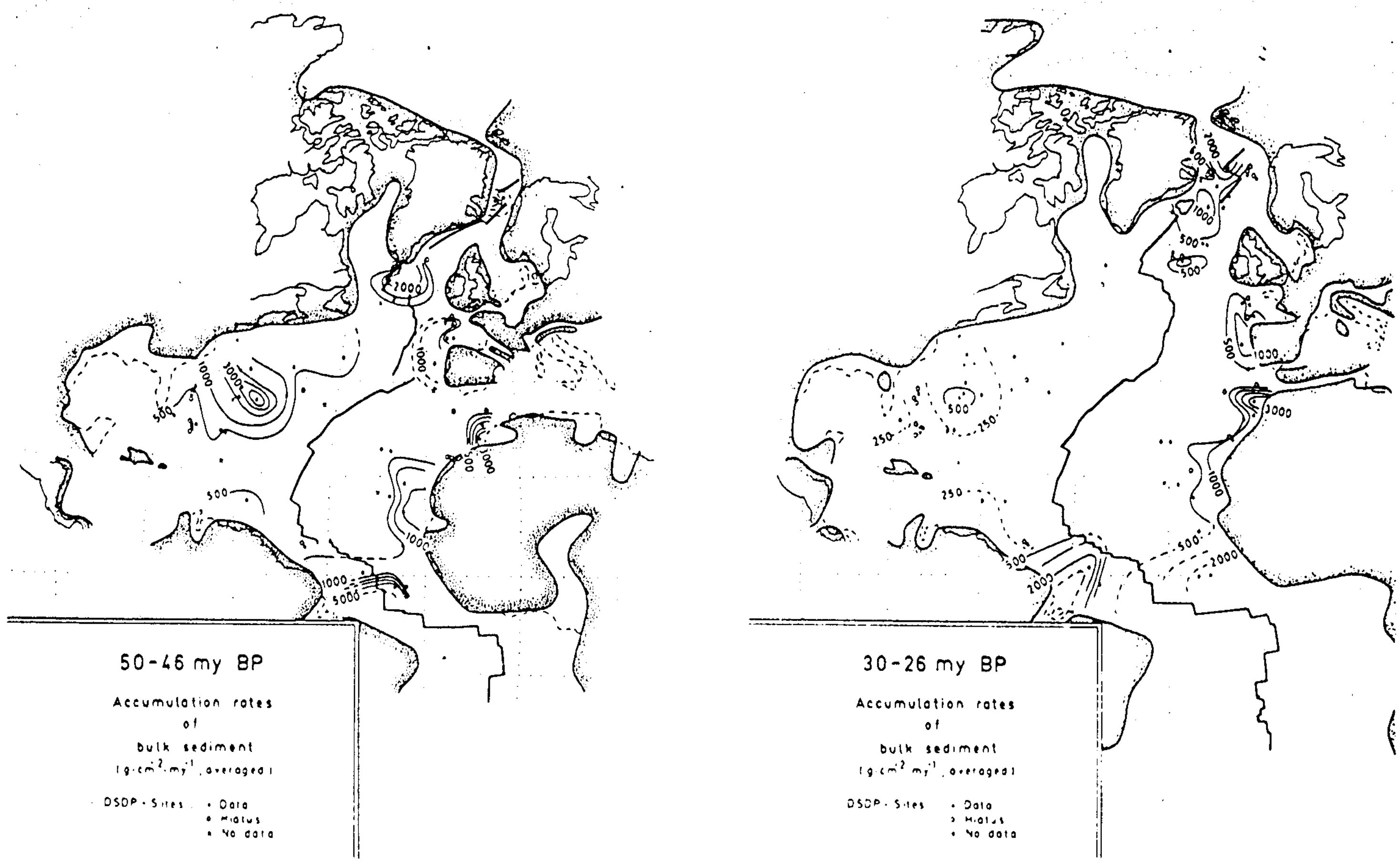


Fig. 2: Accumulation rates of bulk sediment in the North Atlantic for two time intervals in the Eocene and Oligocene (from Ehrmann & Thiede 1985).

2. Erosion rates on continents are dependent on humidity/aridity, geologic setting and vegetation. For example, high amounts of eolian dust are typical for semi-arid regions. The whole input of terrigeneous material into ocean basins may reflect the global land/ocean ratio and the erosion rates (T, C, BS, OM).

3. The extent and facies patterns of epicontinental seas, which are a function of eustatic sea level, régional subsidence and sedimentation rates, influence the transport of terrigeneous matter into ocean basins, the oceanic productivity and the Carbonate Compensation Depth (CCD). Epicontinental seas represent a potential location for bottom water formation in arid low latitudes or at high latitudes, when latitudinal temperature gradients are accentuated (T, C, BS, OM).

4. Atmospheric circulation and global temperatures affect eolian dust transport and govern oceanic surface circulation and thus the temperature distribution in surface water masses. Oceanic temperature gradients may have implications for deep water formation (T, C, BS, OM).

5. Surface circulation strongly controls productivity by initiating upwelling along coastal divergences and/or under divergent water masses in equatorial and subpolar regions (C, BS, OM).

6. Deep sea hiatuses, which seem to be connected with sea level fluctuations, often coincide either with observed downlap surfaces or with sequence boundaries in sediment sequences (Haq et al. 1987) (T, C, BS, OM).

7. Bottom water may be formed either by strong latitudinal temperature gradients and resulting downwelling of dense water masses in high latitudes, or by enhanced evaporation in restricted shallow basins in low latitudes. Bottom currents, deep water topography and interoceanic connections may result in distinct erosional and depositional patterns of contour currents (T, C, BS, OM).

8. Corrosiveness of bottom water (dissolved CO_2), which is dependent on inheritance, age and mixing with other water masses, controls the CCD and determines the dissolution of calcareous particles at the bottom (C). The amount of dissolved O_2 in bottom water is an important factor that controls oxidation of organic matter at the sediment surface (OM).

9. Primary biogenic production is mainly dependent on the nutrient supply as determined by factors such as up- and downwelling, the input of terrigeneous matter, and volcanic activity. The primary signal for the production of calcareous particles is often blurred because of dissolution below the CCD (C). The primary productivity signal of biogenic silica, dependent on the SiO_2-supply (e.g. by volcanism or by upwelling), often remains better preserved as a sediment signal because only minor dissolution occurs in the water column (BS). The primary signal of organic productivity, mainly dependant on water depth, may be strongly altered by subsequent oxidation or reworking in the water column or at the sediment surface, when exposed to oxygen-rich bottom water (OM).

Our strategy

The close interactions between climate, oceanography and sediment fluxes as outlined above make it evident that it is necessary to include models of paleoclimate and paleoceanography in this study in order to be able to interprete sediment accumulation patterns. Hence we will use generalized paleo-climatic and -oceanographic models that constitute a framework to understand the interactions with the depositional system.

A parametric computer program to model global maps of paleo-atmospheric circulation patterns based on Mesozoic and Cenozoic plate tectonic reconstructions, paleogeography and a set of basic climatic input parameters has been designed by Sotese & Summerhayes (1986). This simulation will be used as a basis to model the atmospheric and paleoceanographic surface circulation patterns. Paleomaps, displaying the oceanic surface circulation for different time slices, will be designed based on the atmospheric paleo-circulation and input parameters like the Ekman drift and intensification of western boundary currents. This model will allow prediction of upwelling regions and will be compared with observed biogenic sediment accumulation patterns.

Generalized paleo-surface temperatures will be added to the model by the input of estimated absolute values for Mesozoic and Cenozoic oceans (e.g. Savin 1977). This simulation will allow us to qualitively determine ancient latitudinal heat transfer. From consideration of global paleotemperatures and the latitudinal position and extent of shallow seas, a qualitative prediction of potential sites of bottom water formation will be attempted.

Epicontinental seas, being sites of temporarily high sediment fluxes, are a major influence on the sediment budget of the ocean basins. An analysis of the paleo-extent and facies patterns of epicontinental seas will be incorporated in this study. Because of major difficulties in calculating accumulation rates for these basins due to inconsistent biostratigraphies, sporadic onshore exposures and a general lack of accessable data, we have to confine ourselves to the record of published facies distribution patterns.

The established series of bulk- and component-accumulation maps, including hiatus occurences, will be compared with the paleoclimate models and all available evidence for paleoceanographic circulation and paleotemperatures. Sediment indicators for productivity, terrigeneous input, and erosional events will be verified by comparison with predictions of the model. The recognition of causal connections between model and observed sediment accumulation patterns will be clearly limited by insufficient preservation and/or recovery of sediments. Although it will not be possible to predict hypothetical sediment accumulation patterns quantitatively by means of the discussed model, an attempt will be made to roughly predict sediment flux patterns such as those resulting under high productivity zones in upwelling water masses.

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