Project: Ha 2193/3 „Magnetostratigraphie und Gesteinsmagnetik an Bohrungen aus der Unterkreide (Hauterive bis Alb) des Niedersächsischen Beckens (Teilantrag zum BCCP)“, Project Leader: U. Hambach (Köln)

Preliminary Results of High Resolution Magnetic Susceptibility Measurements on the Research Cores Kirchrode I and II: Milankovitch Forced Sedimentation during the Upper Albian

Regards,
Thomas Rose

Thomas Rose, Ulrich Hambach & Klaus Krumsiek

Area of Study: Lower Saxony Basin, NW-Germany
Stratigraphy: Lower Cretaceous, Albian
Depositional Setting: Epicontinental basin
Facies: —
Organisms: —
Controlling Factors: Milankovitch forcing, sealevel variation
Research Topic: Magnetic properties of sediments, cyclic sedimentation, paleoclimate, time-series analysis
Projects/Programs: BCCP, Albicore, Apticore, CRER, Global Sedimentary Geology Program

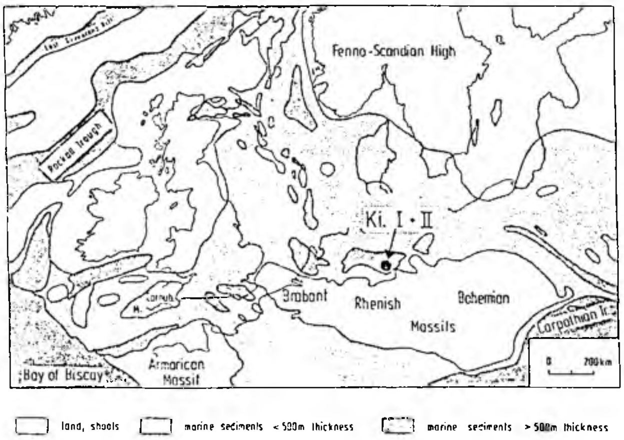

Fig. 1: Land-sea distribution in the early Cretaceous (simplified map after ZIEGLER 1991) with the location of the research wells Kirchrode I and II).

Abstract

Spectral analysis of magnetic susceptibility measurements on the Kirchrode cores testify that the sedimentary environment at the sites was influenced by cyclic processes with frequencies corresponding to the Milankovitch frequency range. The volume susceptibility measurements allow the correlation of both cores, yielding an integral susceptibility profile of 371 m of Later Middle to Later Late Albian sediments. The susceptibility record is mainly inversely correlated with the $CaCO_3$ content, which indicates, that the generation of the susceptibility signal is governed by the ratio of detrital versus biogenic input which in turn is driven by climate-induced sealevel variation. Paleontological information allow the determination of the time interval represented by the cores and, consequently, the estimation of sedimentation rates. In several parts of the profile the susceptibility data show distinct periodic variations, that are most probably caused by eccentricity. A strong signal of unknown origin with a period situated between the frequency range of eccentricity and obliquity occurs, as well.

1 Introduction

Kirchrode I and Kirchrode II (KI, KII) were drilled approximately 2 km apart in the Lower Saxony Basin at the edge of the Lehrte-Sehnde salt dome near Hannover, Germany (Fig. 1). The drilling program is part of the Boreal Cretaceous Cycles Project (BCCP) which in turn is part of the Cretaceous Resources, Events and Rhythms program (CRER) with its sub-projects ALBICORE and APTIRORE under the auspices of the Global Sedimentary Geology Program.

The principal aims of the BCCP are the detection and description of sedimentary cycles and events in boreal shelf basins and the search for the factors that control the generation of such cycles and events during a "greenhouse world". The paleo- and rockmagnetic research on KI and KII focus on the detection and analysis of sedimentary cycles by means of measuring magnetic susceptibility and on the investigation of its correlation with geochemical measurements and logging data.

It is well known, that sedimentary cycles may reflect climatic fluctuation which in turn is driven by the periodic variation of the earth orbital parameters: eccentricity, obliquity and precession (BERGER 1989).

Even though the susceptibility measurements are not time-, but depth-calibrated, we can still test the influence of orbital fluctuations by examining whether spectral peaks revealed by time series analysis have periods with the correct ratios for Milankovitch frequencies. For this analysis we used the Milankovitch frequencies that were calculated for the Mid-Cretaceous by BERGER et al. (1989a, b), i.e. 18.5 and 22.3 kyrs for precession (P1, P2; 19 and 23 kyrs today) and 39 and 51 kyrs for obliquity (O1, O2; 41 and 54 kyrs today), respectively. The periods of eccentricity (E1, E2, E3; 95, 123, 413 kyrs) are assumed to be equal to those of today. The reason for this assumption as well as the influence of the variation of these orbital parameters on insolation is discussed elsewhere (ROSE et al. in press).

Throughout the Albian the Lower Saxonian Basin was an epicontinental sea and the sites of deposition were possibly influenced by both, cold Arctic and warm Tethyan waters. The material of these two cores consists of entirely marine, mainly gray marly claystones with interbedded high suscep-

---

REITNER, J., NEUWEILER, F. & GUNKEL, F. (eds., 1996): Global and Regional Controls on Biogenic Sedimentation. II. Cretaceous Sedimentation. Research Reports. – Göttinger Arb. Geol. Paläont., **Sb3**, 13-16, Göttingen

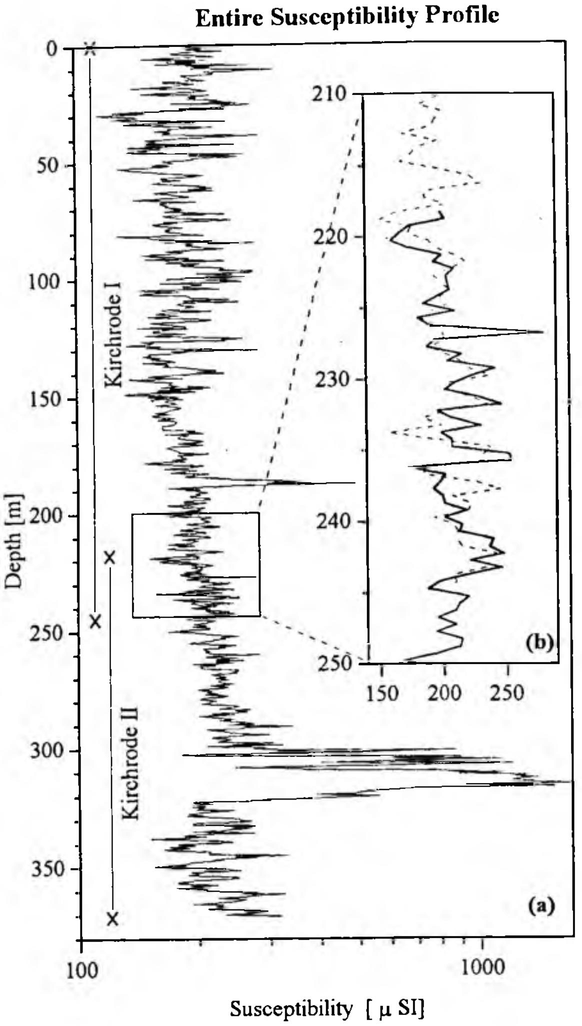

Fig. 2: a): The integral susceptibility profile from cores KI and KII covering 371 m of Albian sediments. Note the logarithmic scale of the susceptibility axis. b) 92 m had to be added to the depth of KII to match the susceptibility pattern of KI.

tibility carbonatic Fe-, P- and Mn-concretions. KI was drilled to a depth of 245 m and KII to a depth of 279 m, respectively. The drillings are two kilometer apart. Due to the dipping of the beds 92 m can be added to the depth values of KII to obtain a continuous profile of 371 m length of marine sediments of the Middle to the Late Albian (Fig. 2).

2 Methods

2.1 Susceptibility Measurements

Relative susceptibility measurements were carried out with an MS2 Magnetic Susceptibility System using the MS2F probe (BARTINGTON INSTR., Ltd., Oxford, UK). The average measuring distance was some 20 cm. To calibrate the relative readings, absolute susceptibilities have been measured at selected intervals with an average sampling distance of 50 cm using the KAPPABRIDGE KLY-2 (GEOFYZIKA, Brno, CR). Fig. 2a displays the susceptibility profile obtained after the depth of KII had been adjusted to the depth of KI (data are resampled to 0.5 m distance). Fig. 2b shows the depth interval that was found to occur in both cores. The susceptibility distinctly deviates from the average signal from 324 to 299 m and from 190 to 183 m depth due to red marls with increased content of ferromagnetic (s.l.) minerals and due to the increased occurrence of high susceptibility carbonatic Fe-, P- and Mn-concretions.

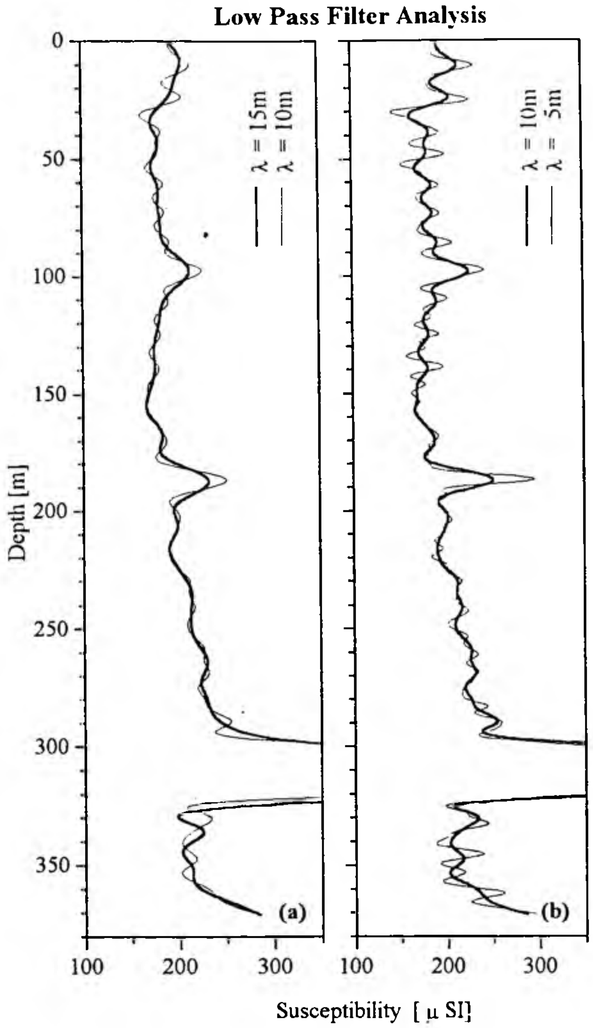

Fig. 3: a) The original data set has been low pass filtered using periods of 15 and 10 m. The filtered signals differ over almost the entire susceptibility profile indicating the existence of a strong period between 10 and 15 m. b) Filtering the susceptibility data with a 5 m period, reveals an additional high frequency component below 107 m depth.

2.2 Selection of Core Intervals for Spectral Analysis

In order to analyze the frequency content of the susceptibility record the entire profile was subdivided into several sections. The sections were chosen based on the results of initial low pass filtering analysis and upon wavelet analysis. The very first step was to resample the initially inequidistant original data set to a sampling distance of 0.5 m. We removed linear trends and the data set was mean-value corrected before any frequency or correlation analysis was performed.

We then successively filtered the original susceptibility data set with increasing low pass frequencies, and we observed whether additional information occurred in the progressively calculated outputs. Except from approximately 230 to 150 m depth, the 15 and 10 m output differ significantly over almost the whole profile (Fig. 3a), indicating the contribution of a strong signal with a wavelength between 10 and 15 m. The difference between the 10 and 5 m filtered curves are only evident below 107 m (Fig. 3b). Therefore, either an additional high frequency signal contributes to the susceptibility signal that is absent above 107 m or the signal generating mechanism remains constant while sedimentation rate changes. Even a mixture of several processes cannot be excluded. Additional wavelet

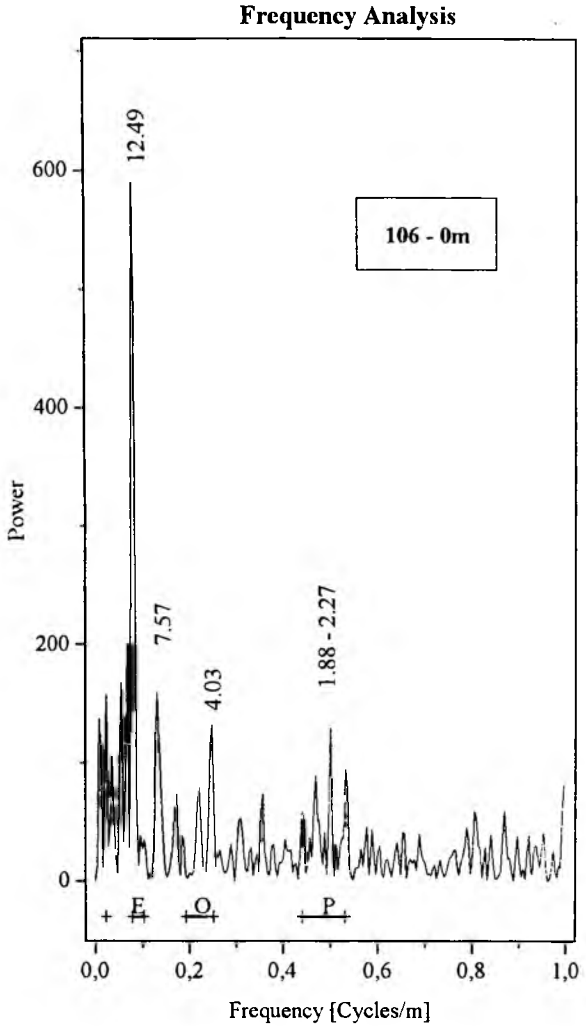

Fig. 4: Frequency spectrum of uppermost section of the Kirchrode I core. The frequency range of the orbital parameters based on the described assumption is given by bars below the spectrum.

analysis exhibits several distinct changes of the frequency content of the susceptibility record (Rose et al., submitted).

2.3 Geological Time Frame

Several data are available to constrain the time frame spanned by the Kirchrode cores. Firstly, the Albian/Cenomanian boundary has not been reached, since the *Mantelliceras perinflatum* ammonite subzone is missing (BCCP Group 1994). Secondly, Weiß (in press) reports, that the boundary between the Upper and Lower Late Albian occurs at approximately 150 to 130 m depth of the profile. Thirdly, Weiß reports, that the boundary between the Middle and Late Albian lies in the red marls below 300 m depth. From recent calculations of the length of the Albian (Gradstein et al. 1996) follows, that the uppermost 300 m of the susceptibility record represent the Late Albian with a duration of approximately 3 Myrs. Therefore the sedimentation rate during the Late Albian at the drilling sites in on the order of 10 cm/kyr.

3 Results

In this paper we concentrate on the results of the frequency analysis of the uppermost 106 m of KI (Fig. 4), which exhibits the best developed cyclic sedimentary record. An analysis of the remaining sections can be found in Rose et al. (submitted).

Eight distinct cycles can be identified in the 10 m-low-pass filtered susceptibility data of this section above 106 m (Fig. 3). This variation can as well be observed in geochemical and geophysical data of Prokoph (1994) already estimated the sedimentation rates of KI to be between 8 and 12 cm/kyr, hence the eccentricity cycles E1 and E2 refer to wavelengths between 7.6 and 14.8 m.

If the signal with a wavelength of λ=12.49 m (Fig. 4) is caused by the eccentricity with a period of 123 kyrs, then obliquity and precession signals can be detected, too. The main obliquity signal (λ=4.03 m) has a period of 39.7 kyrs, precession consists of several periods ranging from 18.5 to 22.4 kyrs (1.88-2.27 m). However, the precession signal should not be over-interpreted since the susceptibility measurements were performed on split cores of one meter length. Hence, a signal with a wavelength around 2 m is most probably caused by harmonics of the 1 cycle/m signal. The distinct peak with a wavelength of 7.57 m represents a period of 74.5 kyrs and does not match obliquity nor precession. The main peak of 12.49 m is related to the other peaks in ratios that we found in the remaining core intervals, too. The average sedimentation rate of this upper most section equals 10 cm/kyr.

4 Discussion

The knowledge about Milankovitch forced insolation influences on sedimentation during the Cretaceous is by far less than for example during the Pleistocene. However, Milankovitch forcing is the only influence that is known to happen periodically. The uppermost section of the susceptibility record shows distinct cyclicity with the frequency ratios, common to those of the Milankovitch frequency range. We take this as an indication that the cyclicity is indeed Milankovitch forced. The occurrence of the signal with a frequency between that of eccentricity and obliquity can be followed up over almost the entire susceptibility profile and may be due to an additional Milankovitch frequency proposed by Berger (1977).

A plausible explanation for the good inverse correlation of the susceptibility data with the eustatic curve as published by Haq et al. (1988) and with the carbonate record (Rose et al. in press) is the reduced terrigenous input during highstands due to an increased distance from the sediment source to the location of deposition. It is well possible, that the source of minerals is located elsewhere below 190 m than above 180 m, since during sealevel highstands mineral sources can change and alter their geographical positions or totally vanish. The dislocation of the source is supported by the clay mineralogy, that changes above 180 m (BCCP-Group 1994). The amount of chlorite is rapidly reduced and kaolinite content decreases between approximately 180 and 110 m.

5 Conclusions

From the analysis of the magnetic susceptibility measurements and from the comparison of the susceptibility data with other available data we draw the following conclusions:

- The susceptibility record reflects the variation of the water depth at the site.
- Global and regional/local effects on the sealevel can be distinguished.
- The Albian is characterized by global sealevel rise with superimposed transgressive/regressive cycles which are triggered by the influence of eccentricity variation.
- Susceptibility records of sedimentary sequences and their spectral analysis is an accurate, rapid and sensitive tool

to detect and describe cyclic variations in sedimentary environments.

Acknowledgements

This research is supported by DFG-grant Ha 2193/3 "Magnetostratigraphie und Gesteinsmagnetik aus der Unterkreide (Hauterive bis Alb) des Niedersächsischen Beckens". The authors like to thank U. Bleil (Bremen), E. Appel (Tübingen) for providing us with portable measurement equipment and the "Bundesanstalt für Geowissenschaften und Rohstoffe" for providing us with measurement equipment and other facilities.

References

BCCP-Group (1994): The Upper Albian of Northern Germany: Results from the Kirchrode 1/91 borehole, Boreal Cretaceous Cycle Project (BCCP). – Zbl. Geol. Paläont., Teil 1, **7** (8), 809-822, Stuttgart

BERGER, A. (1977): Support for the astronomical theory of climatic change. – Nature, **269**, 44-45, London

BERGER, A. (1989): The spectral characteristic of pre-Quaternary climatic records, An example of the relationship between the astronomical theory and geosciences. – In: BERGER, A., SCHNEIDER, S. & DUPLESSY, J.C. (eds.): Climate and Geo-Sciences, 47-76, Dordrecht (Kluwer Academic Publishers)

BERGER, A., LOUTRE, M.F. & DEHANT, V. (1989a): Pre-Quaternary Milankovitch frequencies. – Nature, **342**, 133, London

BERGER, A., LOUTRE, M.F. & DEHANT, V. (1989b): Astronomical frequencies for pre-Quaternary palaeoclimate studies. – Terra Nova, **1**, 474-479, Oxford

GRADSTEIN, F.M., AGTERBERG, F.P., OGG, J.G., BACKSTROM, S. & HARDENBOL, J. (1996): Recent developments in the Cretaceous Time Scale. – Jost Wiedmann Symposium: "Cretaceous stratigraphy, paleobiology and paleobiogeography", Tübingen, Germany, 43-50, Tübingen

HAQ, B.U., HARDENBOL, J. & VAIL, P.R. (1988): Mesozoic and Cenozoic chronostratigraphy and eustatic cycles. – S.E.P.M., Spec. Publ., **42**, 71-108, Tulsa

PROKOPH, A. (1994): Zyklische Sedimentation im Oberalb des Norddeutschen Beckens. – Tübinger Geowissenschaftliche Arbeiten, Reihe A, Band 19, 163 pp., Tübingen

ROSE, T., HAMBACH, U. AND KRUMSIEK, K. (in press): Magnetic Susceptibility Measurements on Research Cores Kirchrode I and II: Indication for Sea Level Variations and Milankovitch forced Cyclicity. – Sedimentary Geology

WEIß, W. (in press): Late Albian immigrations of planktonic foraminifera into the Boreal Sea. – Sedimentary Geology