USGS
science for a changing world

Time series analysis of physical properties from Ocean Drilling Program Sites 1018 and 1020, California Margin

Harry J. Dowsett
U.S. Geological Survey, 955 National Center, Reston, VA 20192

OFR99-134

INTRODUCTION

Analysis of climate indicators from several deep sea North Atlantic cores, European lakes and the GRIP ice core from Greenland suggest millennial scale climate variability is a component of earth's climate system during the last interglacial (marine oxygen isotope stage 5). The USGS is involved in a survey of high resolution marine records covering the last interglacial period (MIS5) to further document the variability of climate and assess the rate at which climate can change during warm intervals.

This report documents the existence of millennial scale cycles and abrupt transitions within MIS5 in marine sequences from the California Margin (Ocean Drilling Program Leg 167) using readily available and routinely generated physical property measurements.

MATERIALS

Ocean Drilling Program (ODP) Leg 167 consists of a series of drill sites along the California Margin of North America (Fig. 1). The 13 sites of Leg 167 are arranged in a series of depth and latitudinal transects to aid in study of the origin and development of the California Current and the Neogene paleoclimatic evolution of the eastern Pacific.

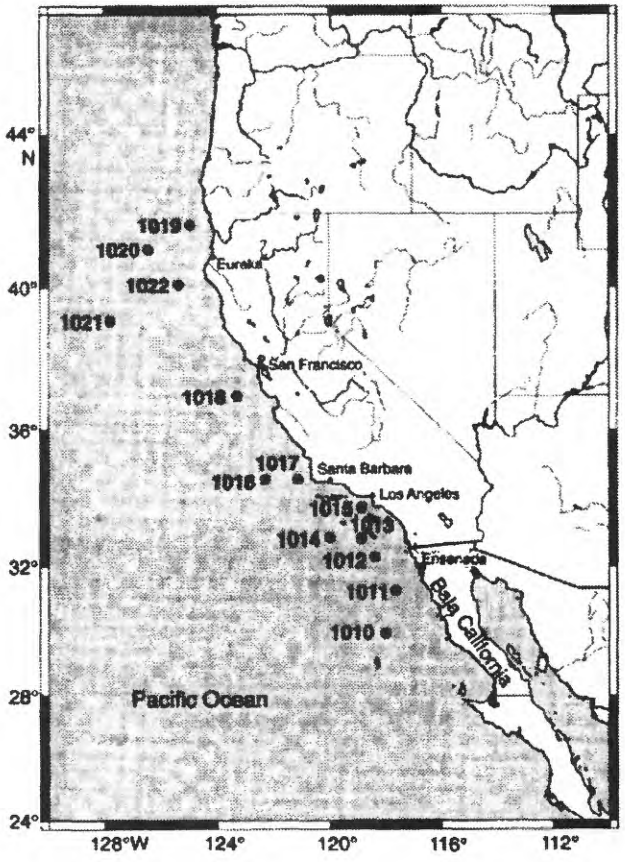


Figure 1. Location map for Leg 167 drill sites along the California Margin of North America. Sites 1018 and 1020 are discussed in this report.

Two sites, 1018 and 1020, were selected by the USGS Warm Climates Project because of their location, good core recovery, and relatively high sedimentation rates, which allow for discrimination of millennial scale events.

Site 1018 is located 36.99°N, 123.28° W, ~75 km west of Santa Cruz, California, south of Guide Seamount, in 2477 meters of water. The site is on a sediment drift that rises 400 m above the adjacent sea floor. The sediments are characterized by olive gray clay with silt (Shipboard Scientific Party, 1997a).

Weight percent calcium carbonate is low and varies between 1 and 5% with minimum values occurring during interglacials (Lyle, Boden et al., 1997). A preliminary age model based upon benthic $\delta^{18}O$ suggests MIS5 extends from about 18 to 27 meters composite depth (mcd; the spliced depth scale produced by the Shipboard Scientific Party, 1997a)(C. Ravelo, personal communication, 1998). This age model suggests accumulation rates within MIS5 of ~15cm ky^{-1}.

Site 1020 is located 41.00°N, 126.43°W on the east flank of the Gorda Ridge ~170 km west of Eureka, California in 3038 m of water. The site is on a hill that rises 50 m above the surrounding sea floor. Site 1020 is ideally located to monitor the strong summer upwelling associated with the California current system (Shipboard Scientific Party, 1997b).

Calcium carbonate ranges between 1 and 20% and is highest during glacial intervals. Accumulation rates are estimated to be ~9 cm ky^{-1} and MIS5 should occur between ~9.5 and 15.2 mcd based upon $\delta^{18}O$ stratigraphy provided by A. Mix (personal communication, 1998).

Physical properties were measured on Leg 167 sites as an aid for hole-to-hole correlation, to provide estimates of properties related to composition and consolidation history of sediments and to provide data for the calculation of synthetic seismograms.

Bulk density, magnetic susceptibility, natural gamma ray emission and P-wave velocity were measured on the multi sensor track (MST) on whole core sections. After being split, the archive half of all cores was used for non-destructive measurement of color reflectance and for recording digital color images.

Three physical properties (bulk density, magnetic susceptibility and color reflectance) were selected for time series analysis. The following descriptions of these properties were summarized from Lyle et al. (1997).

GRAPE bulk density. Whole round-core sections from Site 1018 and 1020 were logged with the Gamma-Ray Attenuation Porosity Estimator (GRAPE). This device measures the electron density which is related logarithmically to the gamma-ray attenuation. Electron density can be related to bulk density. GRAPE bulk density measurements were made at 4-cm intervals on all Site 1018 and 1020 cores.

Magnetic Susceptibility. Magnetic susceptibility was measured on the MST using a Bartington susceptibility meter MS1 with a 8 cm loop at low sensitivity (1 s measuring time). Sample periods were 4 s and sample intervals 4 cm.

Spectral Reflectance. The Oregon State University spectral reflectometer was used to make measurements of the relative spectral reflectance of Site 1018 and Site 1020 sediments. Reflected light was measured in 10240.68-nm-wide bands ranging from 250-950 nm. These measurements were taken at 4- 6 cm intervals from both Site 1018 and 1020. Raw data was converted to 4 50-nm-wide bands defined as ultraviolet (UV; 250-300 nm), blue (450-500 nm), red (650-700 nm), and near infrared (nlr; 850-900 nm). The blue band was used for time series analysis.

ANALYSIS

GRAPE density, magnetic susceptibility and color reflectance data are plotted in Figures 2 and 3 against composite depth. The MIS5 interval, defined by oxygen isotopic stratigraphy, is highlighted in gray. All three records at both sites show regular periodic variations as well as abrupt transitions occurring over several centimeters.

Spectral analysis of all three physical properties was performed for the MIS5 interval in each core using the SPECTRAL module of the ARAND[1] software. Due to uncertainties in the age model and thus accumulation rates, all analyses were done in the depth domain and all data were sampled every 4 cm. The three physical properties from each site are displayed in the frequency domain in Figures 4 and 5.

At Site 1018, the GRAPE density data shows periodicity's of 21, 23.5, 26, 32.8, and 38.5 cm. Magnetic susceptibility shows periodicity's of 21.9, 25.3, 28.6, 33.9, and 40 cm. Color reflectance data show periodicity's of 21, 25.3, 28.6, 33.9, and 44.4 cm. These periodicity's correspond to ~1500 to ~2200 year cycles. Due to the 4 cm sample interval it is not possible to find cycles with periods less than about 1300 years.

Similar millennial scale variability is seen at Site 1020. Grape density data shows 21.7, 24, 29.9, 37, 41.2 and 50 cm periodicity's. Magnetic susceptibility shows periodicity's of 21.3, 24.7, 27.7, 33.9, 39.2, and 45.5 cm. Color reflectance shows periodicity's of 22.2, 29.9 and 48.7 cm. These periodicity's correspond to 2300 to 5000 year cycles.

Allowing for uncertainties in the age model and minor fluctuations in accumulation rate within MIS5 at both sites, it seems likely that both sites are exhibiting a 2200 – 2300 year cyclicity.

[1] The ARAND Software package is available from Philip Howell, Brown University Geological Sciences by contacting Philip_Howell@brown.edu

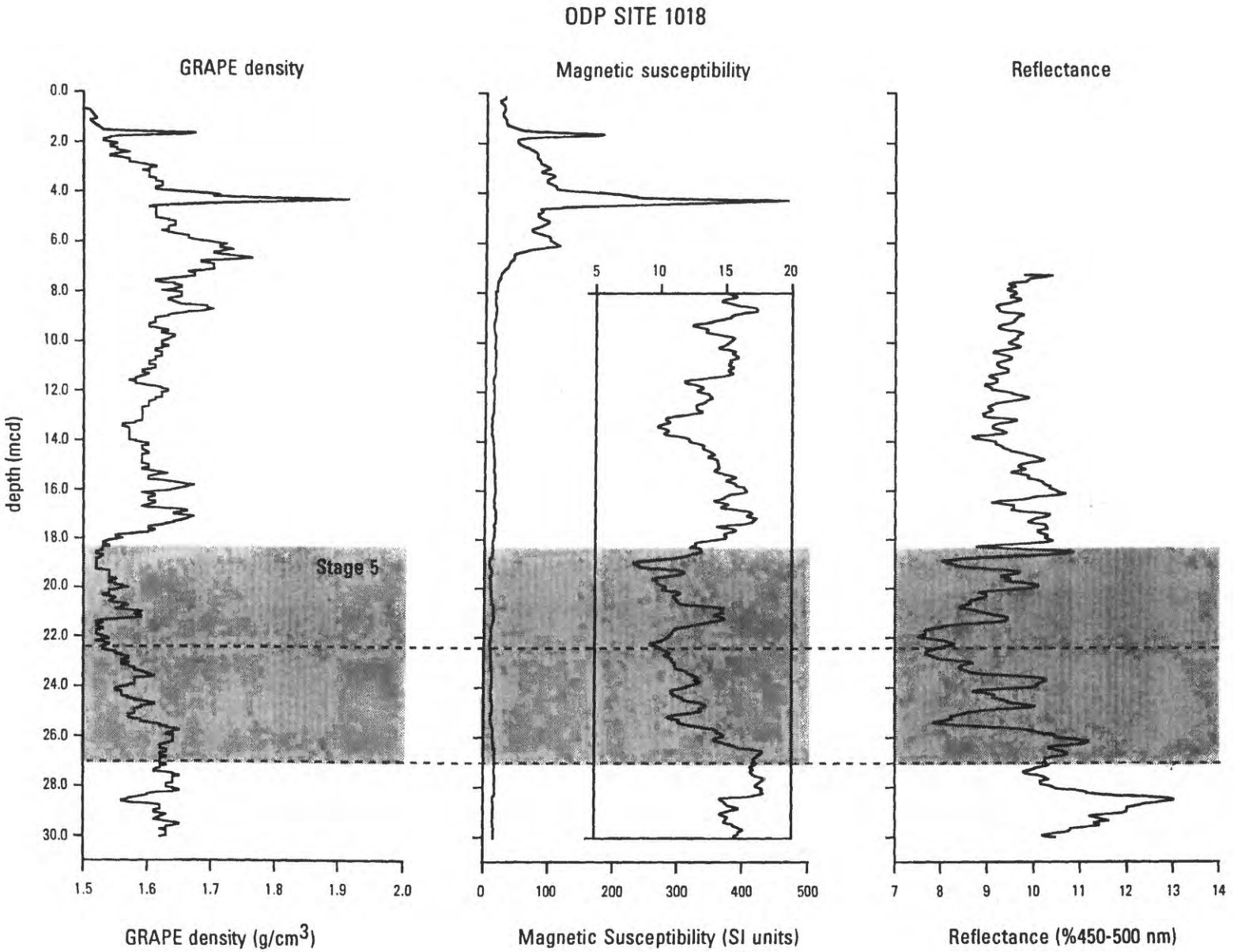


Figure 2. GRAPE density, magnetic susceptibility and color reflectance records from Site 1018. Gray box highlights MIS5 interval

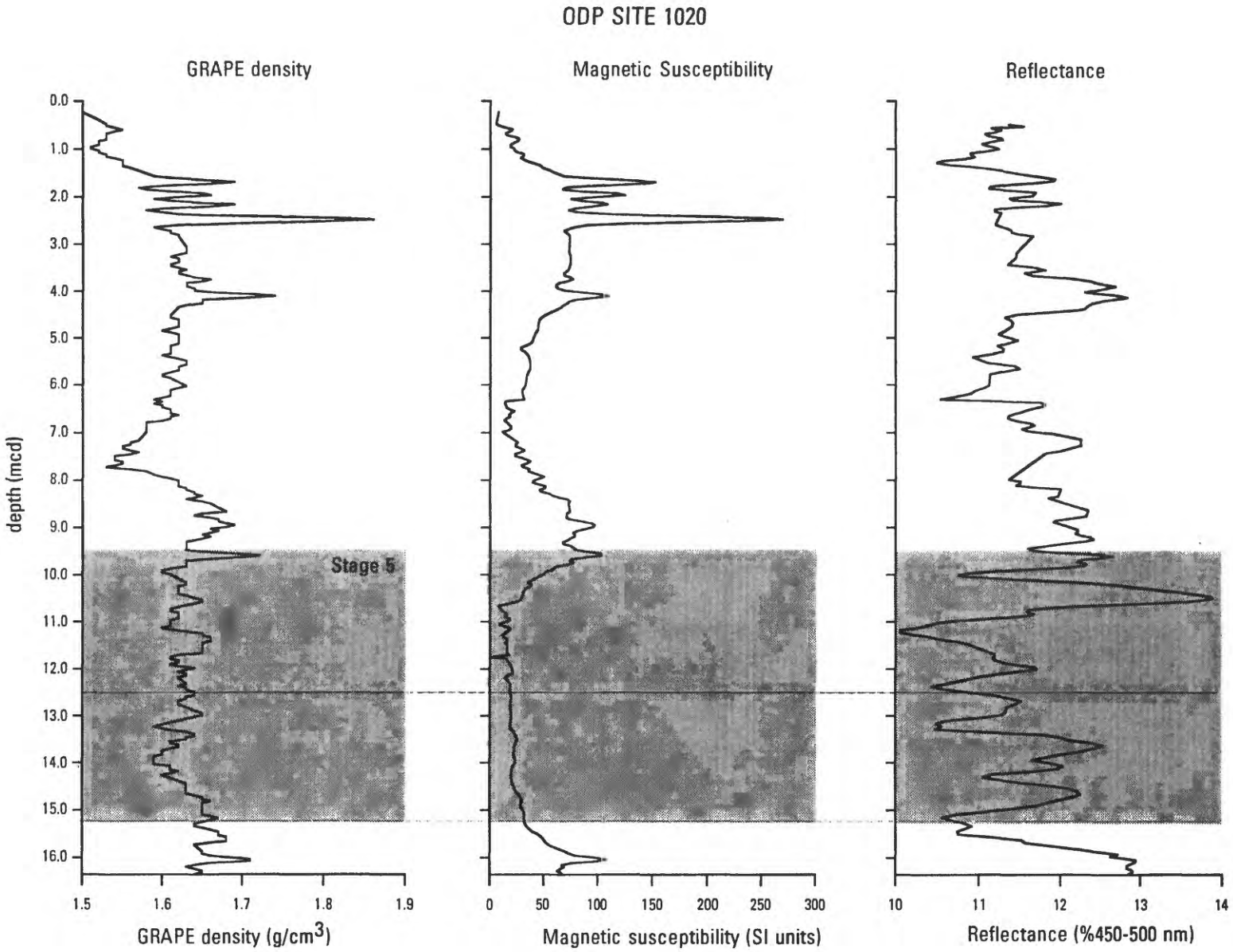
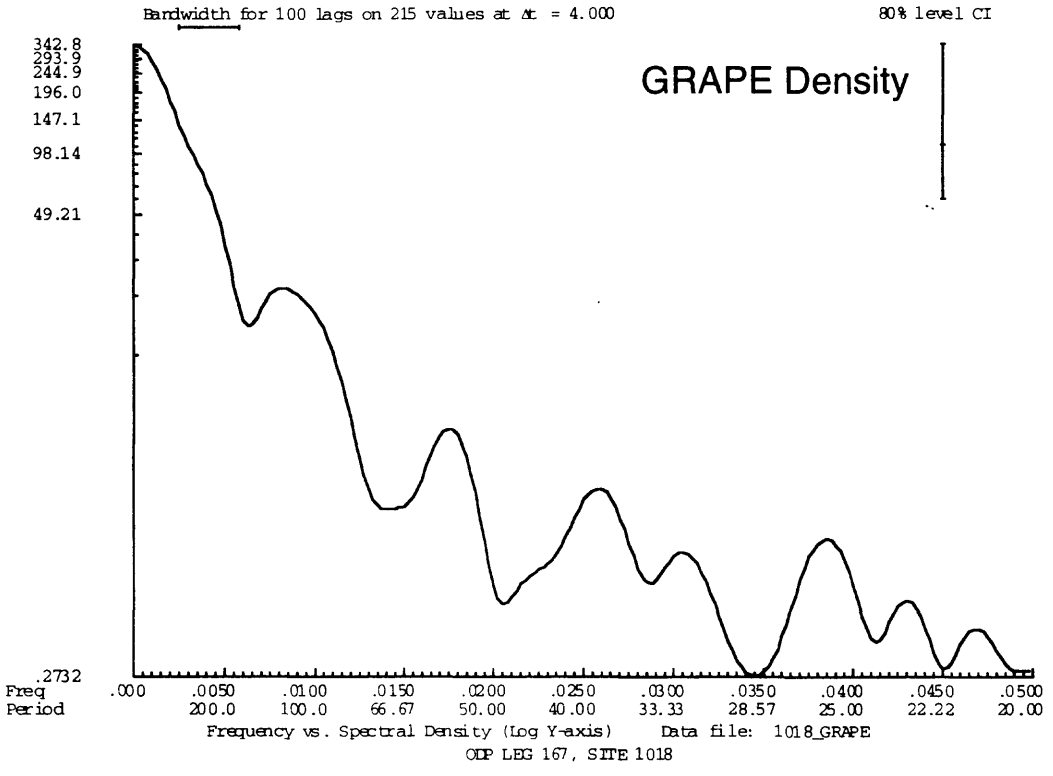


Figure 3. GRAPE density, magnetic susceptibility and color reflectance records from Site 1020. Gray box highlights MIS5 interval



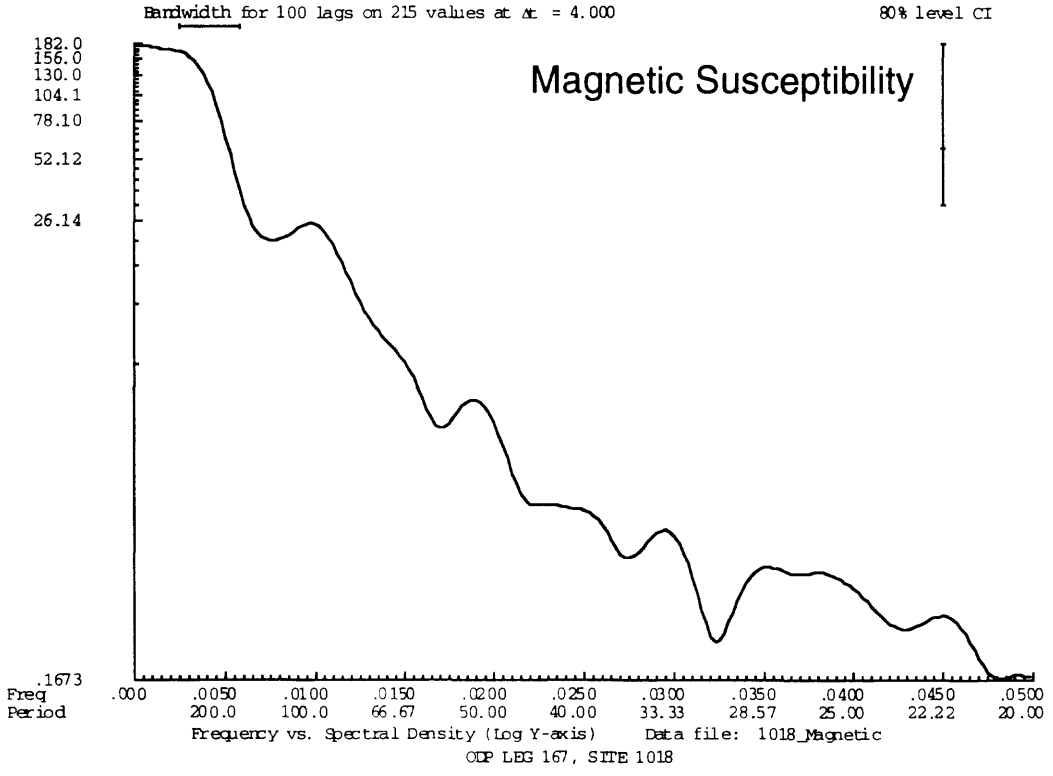


Figure 4. Results of spectral analysis of GRAPE and magnetic susceptibility data from MIS5 interval of Site 1018.

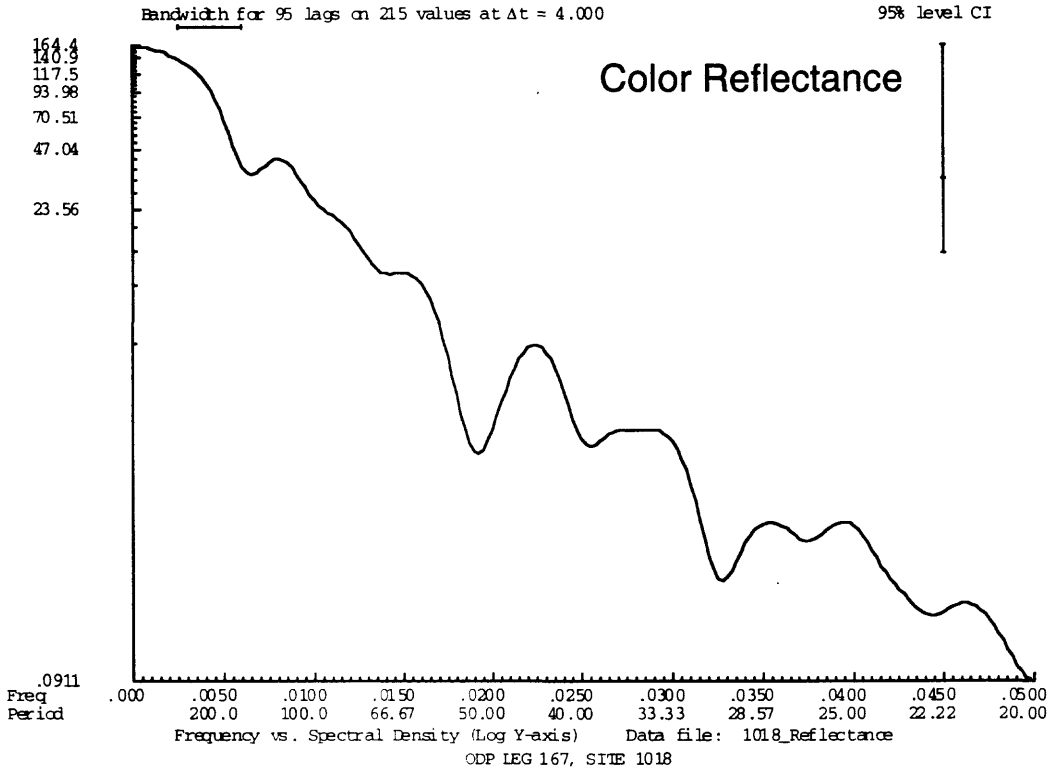
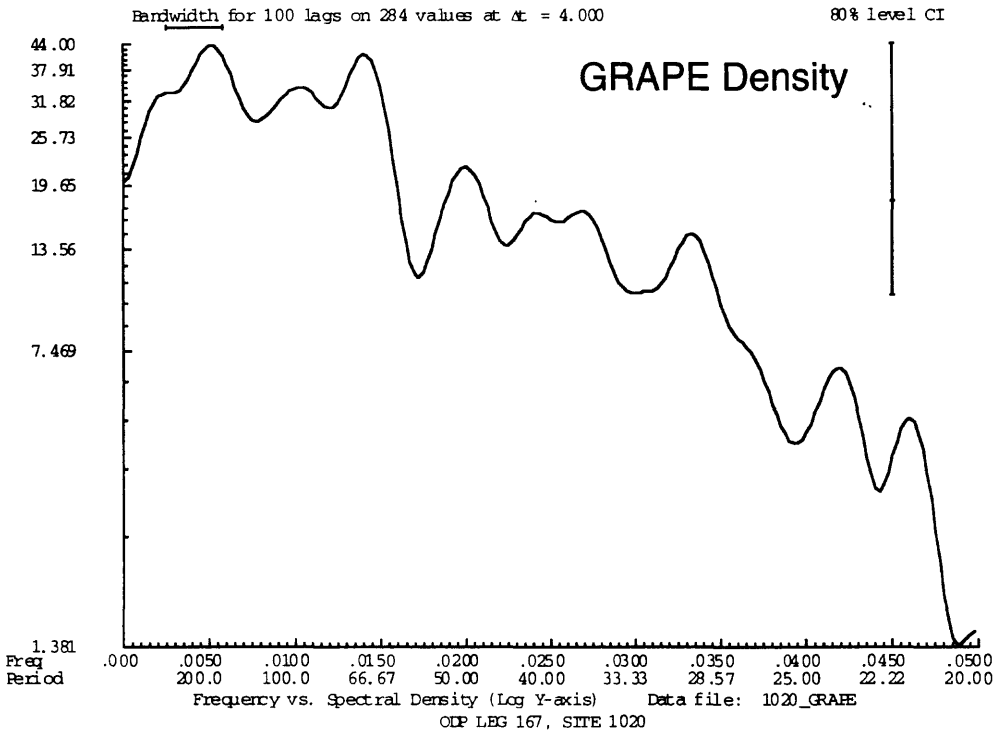


Figure 4 continued. Results of spectral analysis of color reflectance data from MIS5 interval of Site 1018.



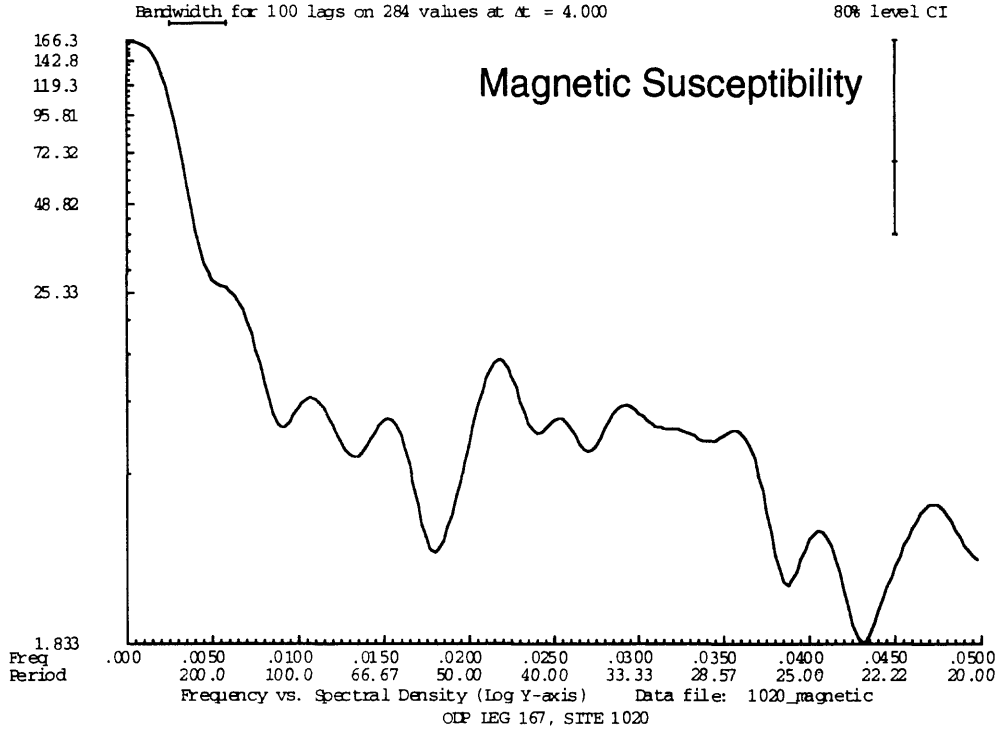


Figure 5. Results of spectral analysis of GRAPE and magnetic susceptibility data from MIS5 interval of Site 1020.

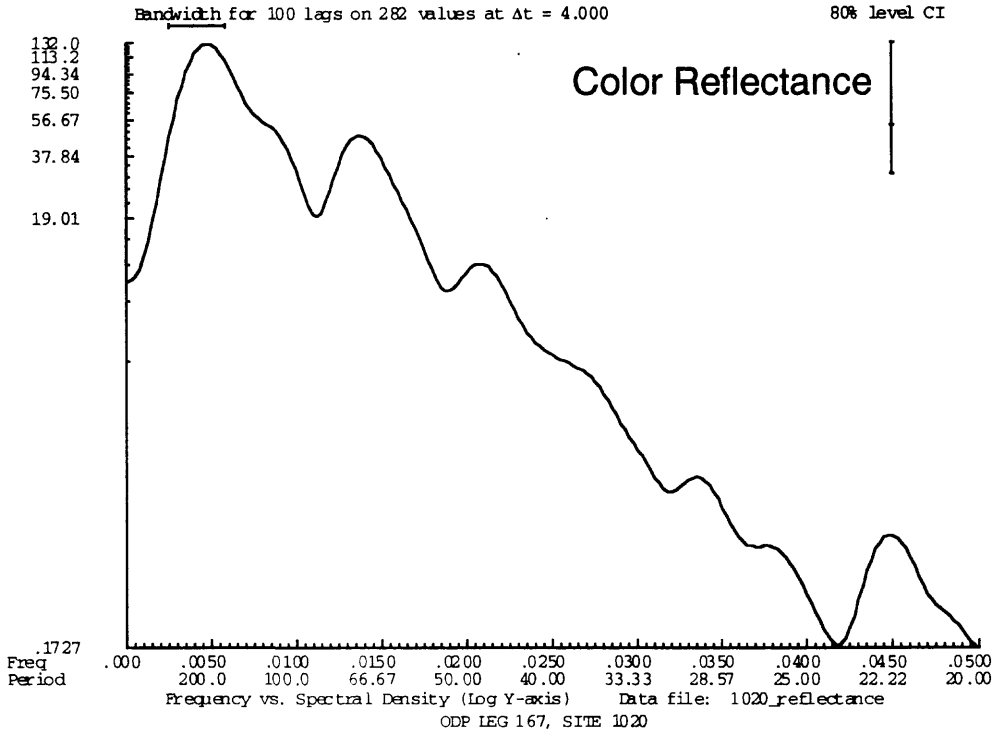


Figure 5 continued. Results of spectral analysis of color reflectance data from MIS5 interval of Site 1020.

SUMMARY AND CONCLUSIONS

The results of time series analysis are useful in two ways. First, these data provide evidence for millennial-scale climate variability in records along the western North American margin essentially identical in frequency to cycles found in records from the North Atlantic region. This indicates that millennial-scale climate variability during the last interglacial is possibly a global and not regional feature.

The results of this study can also be used to structure a sampling program that will capture the high frequency variability exhibited by the physical property data. This will allow a smaller number of samples to be analyzed for traditional paleoclimate proxies (benthic and planktonic foraminifers, diatoms and pollen.

ACKNOWLEDGEMENTS

This paper benefited from many discussions with Dick Poore and John Barron. I am grateful for the isotopic data and age models provided by Cristina Ravelo and Alan Mix and the physical property data provided by the Ocean Drilling Program. Aaron McMahon provided technical assistance. This work was supported by the USGS Global Change and Climate History Program.

REFERENCES

Lyle, M., Boden, P., Heusser, L., Pike, J., and Mix, A., 1997. A detailed window on climate change in Northern California. *JOI/USSAC Newsletter*, 10(3): 1-4.

Lyle, M., Koizumi,I., Richter, C., et al., 1997. *Proceedings of the Ocean Drilling Program, Initial Reports*, 167: College Station, Texas.

Shipboard Scientific Party, 1997a. Site 1018. *In* Lyle, M., Koizumi, I., Richter, C., et al., *Proceedings of the Ocean Drilling Program, Initial Reports*, 167: College Station Texas, 311-352.

Shipboard Scientific Party, 1997b. Site 1020. *In* Lyle, M., Koizumi, I., Richter, C., et al., *Proceedings of the Ocean Drilling Program, Initial Reports*, 167: College Station Texas, 389-429.