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PALEOMAGNETISM OF CORED SEDIMENT FROM LAKE ATITLAN, GUATEMALA: A PRELIMINARY STUDY[1]

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RESUMEN

Estudios de arcilla y limo de un núcleo de perforación (longitud de 4 m) proveniente de la cuenca profunda del lago Atitlán, Guatemala, indican que estos sedimentos poseen una magnetización remanente de alta intensidad y cuya dirección es estable durante desmagnetización por campos magnéticos alternos. Con objeto de evaluar las propiedades de los sedimentos en estudios de variación secular, se utilizó un par de muestras de la profundidad de 263.5 cm y ocho muestras espaciadas entre los 276.4 y 282.7 cm. La inclinación media determinada en este estudio es de 25.9°, la cual es cercana a la inclinación dipolar axial (27.7°) para el lugar. El portador de la magnetización remanente en los sedimentos es probablemente magnetita.

ABSTRACT

Clay and silt in a 4-meter piston core from the deep basin of Lake Atitlan possess a strong and stable remanent magnetization when subjected to alternating-field demagnetization. We used paired samples from 263.5 centimeters and eight closely spaced samples between 276.4 and 282.7 centimeters to assess the sediment for a study of paleomagnetic secular variation. Average inclination of 25.9° is close to the inclination of an axial dipole field (27.7°), and magnetite is the probable carrier of magnetization.

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INTRODUCTION

Sediment in caldera lakes in Central America is amenable to paleomagnetic investigation for several reasons – there is a rapid and presumably continuous supply in a deep-lake (quiet-bottom) environment, magnetite derived from rocks of the enclosing volcano produces a strong and stable remanent magnetization, and tephra layers are often preserved that allow correlation of sedimentary layers within the lake. Also, the tephra might be traced to historic volcanic eruptions or be dated otherwise.

With those attractions in mind, we made a paleomagnetic investigation of cored sediment from Lake Atitlan in southwestern Guatemala (Fig. 1) to ascertain its potential for a study of paleosecular variation. If the strata could be dated accurately, a follow-up investigation might provide data that augment archeomagnetic curves for Mesoamerica (Wolfman, 1973) and perhaps elsewhere (Bucha, 1971; Aitken, 1974; DuBois, 1975; Kovacheva, 1972; Kovacheva and Veljovich, 1977; Du-

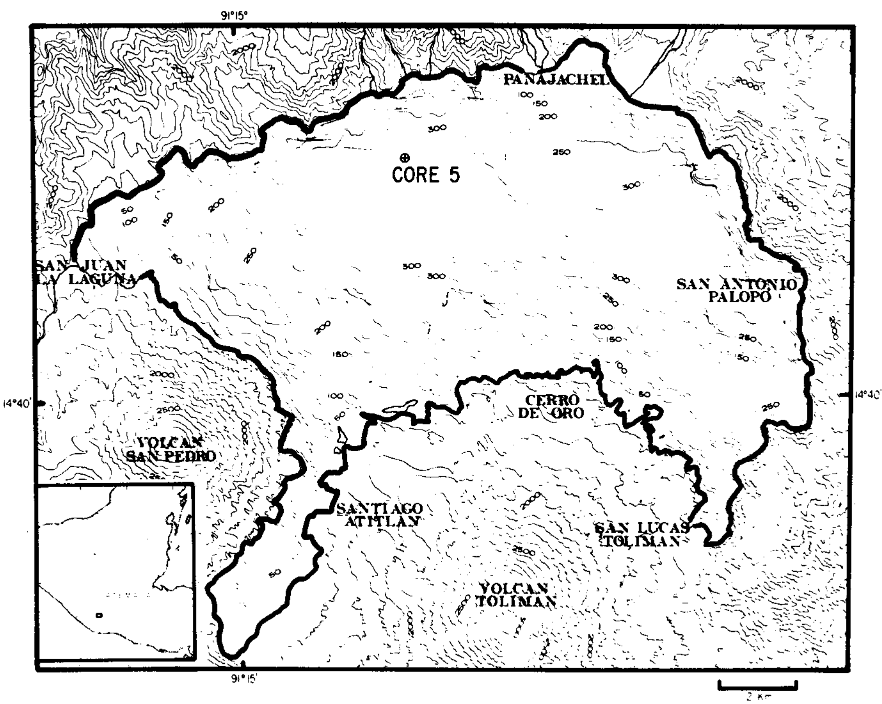

Fig. 1. Location map of core 5 in Lake Atitlan, Guatemala. Bathymetry is from the Instituto Geográfico Nacional, Guatemala, C. A., Mapa Hidrográfico, Lago de Atitlán.

Bois *et al.*, 1981; Wei *et al.*, 1981). Although a subsequent and more comprehensive investigation has not been attempted by us, the preliminary data reported herein suggest that sediment in caldera lakes in the highlands of Guatemala is appropriate for a study of paleomagnetic secular variation.

LAKE ATITLAN AND SEDIMENT

Lake Atitlan is in a steep-walled caldera of dimensions 19 by 21 kilometers and rim height of nearly 1700 meters. The lake is oval-shaped on an east-west axis and covers an area of about 25 square kilometers. Elevation at water level is 1562 meters and maximum water depth is 324 meters.

In January 1979, seven piston cores having diameter of 3.8 centimeters and length of 4 meters were taken in Lake Atitlan. The sites were selected after analysis of 230 kilometers of seismic profiles. The profiles showed an upper transparent acoustic layer 20-meters thick covering a layer of flat-lying, laminated sediment at least 175-meters thick in the deep basin (Newhall, 1980). The upper layer is formed of clay, silt, and diatomaceous sediment containing cinder and andesitic ash. Some of the cores have diatomaceous layers that are about 1 centimeter apart.

The sediment in the deep basin is highly charged with gas, which we presume is biogenic methane. Because of the reduced confining pressure at the lake surface, the expanding gas forced the sediment out the end of the core barrel. As a result, some of the sediment developed gas-filled pockets up to 10-centimeters long, or small cracks; overall lengthening of the core was approximately 10 percent. Although this was common in most of the cores, the diatomaceous layers remained intact and horizontal, suggesting that homogeneization of the sediment did not occur.

SAMPLES AND MEASUREMENT OF REMANENT MAGNETIZATION

Inspection of the cores in August 1979 showed that Core 5 taken in 314 meters of water would be the best-suited for our purpose. We selected the interval between 263.5 and 282.7 centimeters for sampling because it appeared undisturbed. Because the sediment possesses a relatively strong remanence (about 2.5×10^{-5} emu/cc; $\times 10^{-2}$ A/m) and measurement would be in a cryogenic magnetometer, only small samples were required. Furthermore, by taking small samples we were able to restrict sampling to the center of the core, thereby avoiding the edge that might be disturbed during coring.

The samples are 1.2-cc cylinders (drinking straws 1.5-centimeters long) that were glued into 6.6-cc polythyrene boxes for insertion in the magnetometer. We took side-by-side samples at 263.5 centimeters and single samples at intervals down the

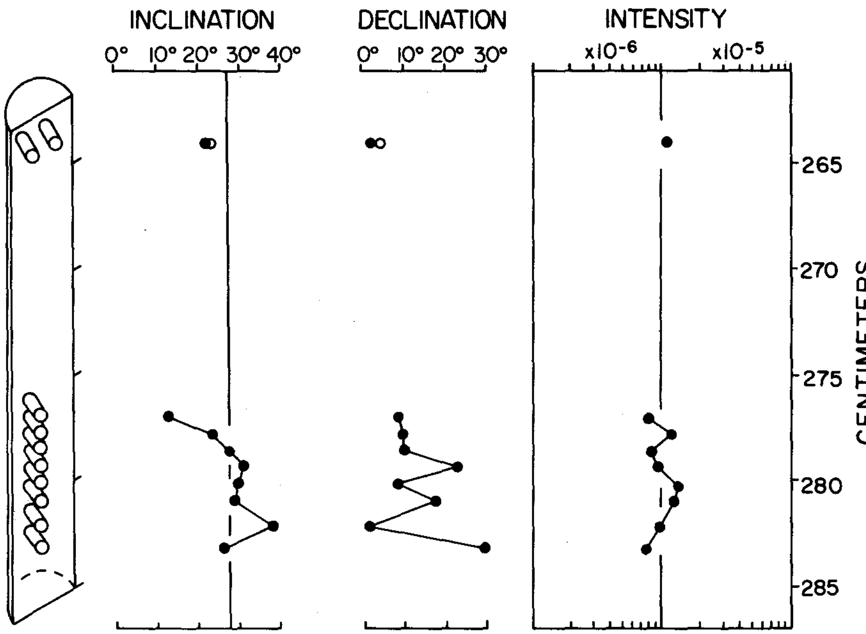

Fig. 2. Paleomagnetic data after a.f. demagnetization at 200 oersteds for samples from Core 5, Lake Atitlan. Cylinders in the stratigraphic column indicate the position of the samples. Data for both samples from 263.5 centimeters are indicated. Declination is relative, and inclination of a geocentric axial dipole field is 27.7°. Intensity is in emu/cc.

core of approximately one centimeter below 276.4 centimeters (Fig. 2). All the samples have identical orientation, and azimuth is relative because no attempt was made to orient the core other than vertically.

The samples were partially demagnetized in alternating fields at 200 oersteds (20 mTesla) or smaller increments to a peak field of 600 oersteds, and possess a characteristic direction of magnetization above 100 oersteds. For most samples, the remanence is reduced 10-fold at 600 oersteds, and the median destructive field is about 200 oersteds (Fig. 3). Magnetite is identified in large quantities (as much

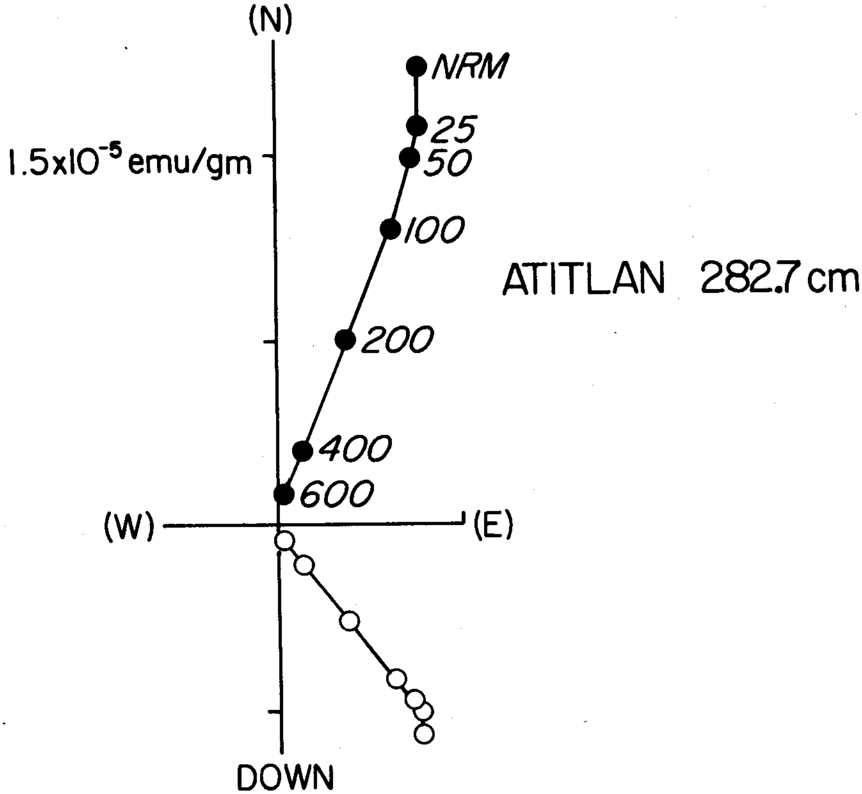

Fig. 3. Vector plot of paleomagnetic directions during progressive a.f. demagnetization for sample #11 (282.7 centimeters depth). The median destructive field is about 200 oersteds. Numbers in the plot indicate the level of demagnetization in oersteds. Declination is relative.

as 1.4 % of the total volume) in the sediment (C. C. Woo, written comm., 1981), which suggests that the dominant source of magnetization resides in that mineral. Although the sediment is rich in volcanic debris (Poppe *et al.*, 1981), none of the samples are of a tephra layer.

ANALYSIS OF PALEOMAGNETIC DATA

A plot of the paleomagnetic data is shown in Fig. 2. Unfortunately, these data are insufficient for comparison with archeomagnetic data for Mesoamerica (Wolfman, 1973). The average inclination of 25.9° is approximately 2° shallower than a calculated 27.7° inclination for the geocentric axial dipole field for the site latitude (14.7°N). Even with the sparcity of data, we infer that the "inclination error" (King, 1955) that appears to be present in dry lake sediments (Denham and Cox, 1971; Liddicoat, 1976; Liddicoat and Coe, 1979; Verosub *et al.*, 1980) is absent. This is consistent, however, with findings for cored sediments in some present lakes (Banerjee *et al.*, 1979) and suggests that the magnetic vector results from post-depositional remanent magnetization (Irving and Major, 1964). As such, there would be a time lag in the acquisition of remanence that we cannot document given the poor age control on the sediments.

Estimates of the age of the sediment at 3-meters depth in Core 5 differ by a factor of 30. The youngest age is about 50 yrs B.P. and is based on a sedimentation rate of 6 cm/yr (Dillon, 1980). The oldest age is perhaps 1500 yrs B.P. because preclassic Mayan pollen is present near the base of the core (E. Deevey, per. comm., 1980). That implies a sedimentation rate on the order of 0.2 cm/yr, but if the layering results from annual diatom blooms in the lake, the sedimentation rate could increase five-fold to 1 cm/yr. If we assume the faster rate is correct, then the 20-centimeter portion we used spans only 20 years. Yet, the fluctuations of inclination and declination seem large for such an interval, and greatly exceed our estimated orientation error of ± 2°. An alternative interpretation is that the sediment is not accurately recording the paleomagnetic field, but the excellent match-up of directions for adjacent samples at 263.5 centimeters (Fig. 2) indicate otherwise.

CONCLUSIONS

1. Sediment in the deep basin of Lake Atitlan is suitable for a study of paleomagnetic secular variation if gas-free cores are obtained. One could expect to obtain high-quality curves of paleomagnetic directions that would augment archeomagnetic data for Central America.

2. The apparent absence of "inclination error" and the presence of detrital (?) magnetite are indicative of magnetization by the process of post-depositional remanent magnetization. Seismicity that is well documented for the region might be the mechanism that initiated realignment of the magnetic grains.

3. With presently available chronologic information, we are unable to establish accurately the rate of sedimentation. Certainly, the fluctuations in the paleomagnetic field are typical of a span of time longer than a few decades, so the suggestion of a 6-centimeter annual accumulation rate appears incorrect.

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