

Diatoms are cool, yet do they indicate dramatic climate shifts during the Holocene, or are they just full of silica?

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Introduction

Diatoms are an important component of lacustrine phytoplankton and have been used extensively as indicators of past water chemistry and quality in lakes. Analyses of fossil diatom populations in lacustrine sediment cores of lakes have also been used to develop decadal to millennial scale climate histories. Research on present day diatom populations has shown that specific diatom species dominate specific ranges of ecological conditions, and thereby record the changes in biology, chemistry and water levels of lakes as lakes adjust to shifts in climate. Thus, from analysis of fossil diatom populations one can infer past limnologic changes and paleoclimatic information.

Lake Tanganyika is the second deepest lake in the world and the largest lake in the East African Rift zone. Because of its size, depth and age, it is considered to be an unparalleled archive of climate change in the African Tropics (Hayberyan and Hecky, 1987). Diatoms have been analyzed in lacustrine sediment cores from Tanganyika to study millennial-scale changes in lake conditions in response to climate shifts. One such study was conducted by Hayberyan and Hecky (1987) on core T-2, a 10-meter Kullenberg piston core extracted from the southern end of the lake in 440 meters water depth. The authors developed a sequence of changes in fossil diatom populations that likely indicate shifts in lake nutrient, water level, and upwelling conditions, and thus climate. This climate history includes low lake levels during the last glacial maximum, a wet and turbulent early Holocene, and a drier late Holocene with a less stable water column and more turbulent mixing.

Due to the complex structural geometry of Lake Tanganyika, some areas have been found to be accumulating autochthonous pelagic sediment at a very slow rate and are protected from the influx of marginal watersheds. One such area is the Kalya Horst, a sub-aqueous structural platform at the center of the lake at the base of the Mahale Mountains. Previous coring on the platform has determined sediment accumulation rates of 0.1 to 1.0 mm/yr., with laminated sediments ideal for paleoclimate studies (Zilifi and Eagle, Nayzna report 2001). In 2004, a new suite of piston cores was collected to test the vertical extent of fossil diatom preservation and to compare core data to other studies in the area and region. Are millennial-scale climate shifts and Holocene trends that are evident at a mid-lake in the Kalya region similar to the changes recorded at the southern end of the lake? Is there evidence from changes in fossil diatom populations from Kalya for climate variability during the Holocene? To answer these questions, diatom data from the Kalya core was analyzed and compared to regional records of Holocene climate variability as well as past studies from Lake Tanganyika.

Methods

In July 2004, four cores were recovered by Kullenberg piston coring of the Kalya horst and slope from the *M/V Maman Benita*, a 30-meter Congolese shipping vessel, during an 8-day cruise on Lake Tanganyika. Core NP04-KH-1-1K, a 534 cm Kullenberg piston core, was extracted from 303 meters water depth at location latitude S 06° 33' 147", longitude E 029°, 58', 480". Once the core was recovered and at rest on the deck of the ship, it was cut into roughly 1.5-meter sections for storage and shipment back to the TAFIRI (Tanzanian Fisheries Research Institute) lab. In the lab, core sections were split longitudinally; one half of the core section was used for sampling, and the other half was sealed as an archive section. Samples of approximately 20 mg of sediment were taken from core sections II, III, and IV at roughly 20-centimeter intervals using a 1-centimeter wide spatula (section I was sampled and analyzed by Kevin Robinson, see Robinson report 2004). Using the roughly 20-centimeter sampling interval strategy allowed analysis of major stratigraphic changes within the core. Samples were immediately placed in 15 ml centrifuge test tubes and stored for slide preparation. For each sample, section number and depth in centimeters below the top of the core section (top of section is closest end to sediment/water interface) was recorded in the project log book. A total of 24 samples (Slides M1-M24) were analyzed.

For slide preparation 3-5 ml of hydrogen peroxide (50%) was added to the sediment sample in the 15 ml centrifuge test tubes and allowed to react for 5-minutes. Test tubes were then placed in a glass beaker and allowed to boil and further react for 60-minutes at a medium temperature on a hot plate, then neutralized with 5-ml of distilled H₂O. Samples were allowed to settle for 8-hours, then the hydrogen peroxide/H₂O solution was pipetted off, and 12 ml of distilled H₂O was added and the sample and was again allowed to settle for 8-hours before final pipetting was completed. Samples were then placed in a glass beaker and diluted with distilled H₂O to volume desired for optimal diatom population counts on slides. The solution was pipetted off after mixing, and placed on 22x22mm glass cover slides and allowed to dry overnight. Coverslips were mounted onto slides with one drop of Permout mounting solution and heated on a hotplate until slight changes in color were noted. Slides were left to cool, extra Permout was removed, and slides were filed until ready for identification.

Counts on diatoms were conducted using a Leica microscope with 1000X magnification in oil immersion in top to bottom transects across the slide until a minimum of 400 diatom frustules were counted. In slides where diatom populations were too low, a minimum count of 300 was used. Counts were conducted at the genus level, based on taxonomic literature by Cocquyt (1998) and Gasse (2000), and recorded as quantity and percentages (Figure 1). To test the hypothesis of the study, diatom data was compared to the diatom data acquired by Hayberyan and Hecky (1987).

NP04-KH1-1K Diatom Analysis, M. Steinkamp

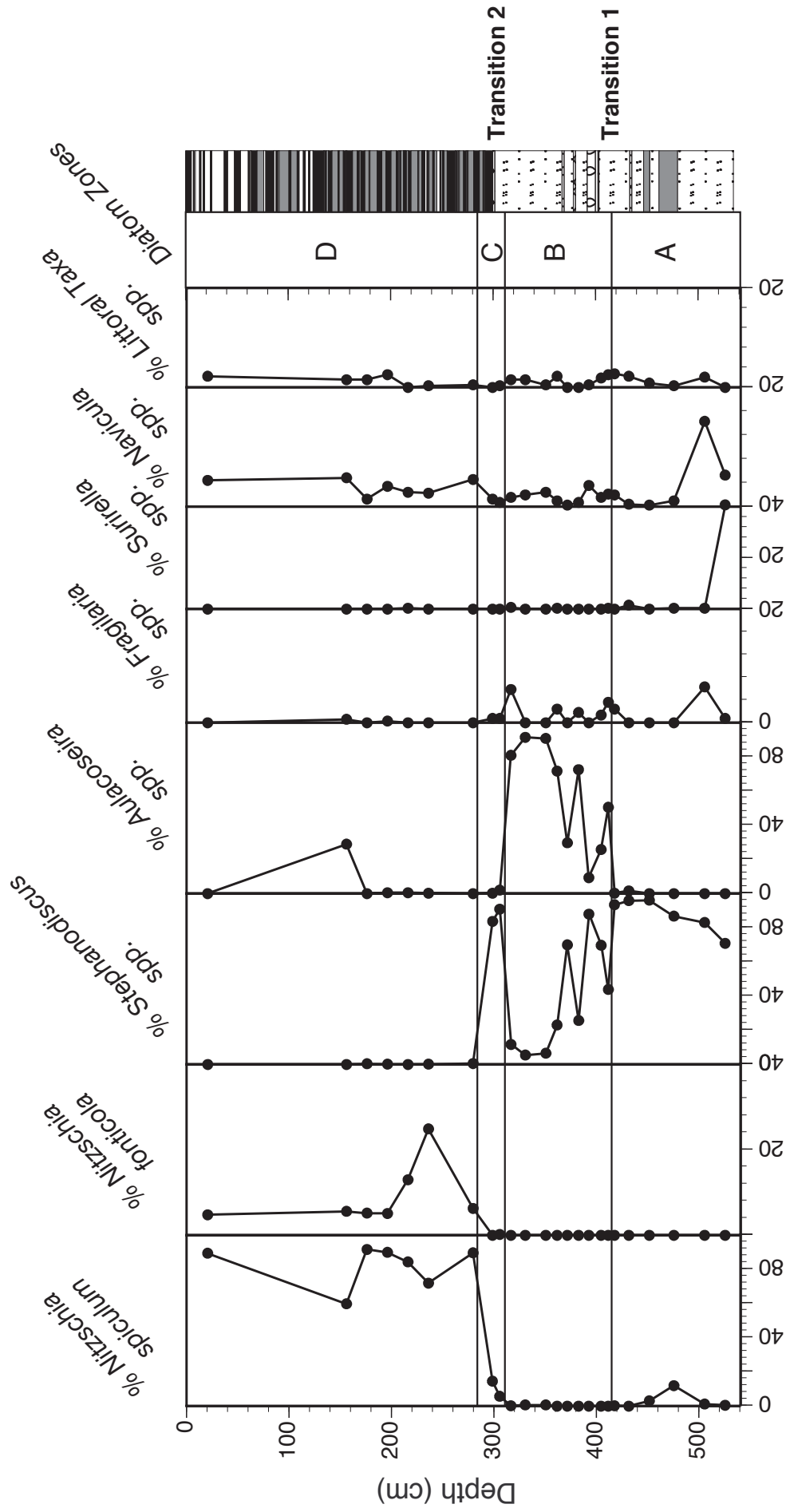


Figure 1. Diatom and gross sedimentary stratigraphy of Core NP04-KH-1-1K. Zones A, B, C, D mark the changes in diatom dominance. Transitions 1 and 2 define transition from late Pleistocene (Transition 1) at around 11,000 cal. yr. B. P., and mid-Holocene (Transition 2) at around 5500 cal. yr. B. P., as described in text. Gap in data points from 160-20 cm is section of core analyzed by Robinson (See Robinson report 2004).

Results

Seventeen genera were identified and counted in diatom slides. Of these, the three planktonic genera, *Stephanodiscus spp.*, *Aulacoseira spp.* and *Nitzschia spp.*, dominated the fossil assemblage. Diatoms from the genera *Navicula spp.*, *Fragilaria spp.*, *Surirella spp.* and other littoral were also present but exhibit little coherent variation and will not be discussed further.

Total diatom counts for each slide ranged from 303 to 460. Variations in the planktonic genera *Nitzschia spp.* (*N. spiculum*), *Aulacoseira spp.* and *Stephanodiscus spp.* allow us to divide the core into 4 biozones; Zone A, B, C and D from bottom to the top of core (Figure 1). Comparison of these biozones are made in correlation to the Hayberyan and Hecky core T-2 from the southern end of the lake and are referred to below as (HHA₄), for example, which means Hayberyan and Hecky Zone A, sub-zone 4.

Zone A (HHA₄) (Slides M1-M5, M19)

Zone A is located at the basal end of core NPO4-KH-1-1K, from 534-411.5 cm. *Stephanodiscus spp.* dominates the zone, interrupted briefly in a thin zone by a small increase of *Nitzschia spiculum* at 475.5 cm (Figure 1).

Zone B (HHB) (Slides M6-M10, M20-M23)

Zone B occurs from 411.5-305.5 cm. The transition of Zone A to Zone B is Event 1 in core NPO4-KH-1-1K, which correlates to Zone B of Hayberyan and Hecky, dated to about 11,000 cal yr. B.P. Zone B is marked by a shift to alternating dominance of *Stephanodiscus spp.* and *Aulacoseira spp.* diatoms. The transition from Zone B to Zone C appears correlated with the start of Transition 1 in core NPO4-KH-1-1K.

Zone C (HHC) (Slides M11, M24)

Zone C, located at 305.5-279.5 cm, marks the start of Event 2 in which there is a distinct shift from *Aulacoseira spp.* dominance to *Stephanodiscus spp.* dominance (Figure 1). At 305.5 cm, *Stephanodiscus spp.* makes up 90% of the sample, and at 298.5, 84%. *Stephanodiscus spp.* then decreases rapidly to only 3% at 279.5, the transition from Zone C to Zone D. The next most abundant genus in Zone C below *Stephanodiscus spp.* is *Nitzschia (N. spiculum)*, which only makes up 5-14% of the samples.

Zone D (HHD_{1D2}) (Slides M12-M17)

Zone D, located up core from Zone C, from 279.5-156.5, is separated from Zone C by a rapid change in dominance from *Stephanodiscus spp.* to the species *Nitzschia spiculum*. *Nitzschia spiculum* sample percentage ranges from 60-92% in this zone. *Aulacoseira spp.* reach abundances of 29% at the top of the zone (156.5). Also notable in this zone is the abundance of *Nitzschia fonticola* (6-25%). The remainder of the core was sampled and analyzed by Kevin Robinson (2004).

Discussion

Diatom data from core NPO4-KH-1-1K from the Kalya horst correlate well with the Hayberyan and Hecky (1987) core T-2 from the southern end of the lake. This suggests that climatic effects evident in the southern basin sediments are similar to climate-driven paleolimnological changes at the center of the lake (Figure 1). Furthermore, the similarity of the diatom fluctuations observed at the two sites allows us to develop a preliminary chronology for core NP04-KH-1-1K. Finally, the strong similarity of diatom changes in the southern and mid-lake sites could allow us to infer variability in the entire southern basin of Lake Tanganyika from our mid-lake site, the Kalya region.

The results of this study indicate two dramatic shifts in diatom genera in samples from core NPO4-KH-1-1K that coincide well with the changes shown by Hayberyan and Hecky (1987). These dramatic changes are labeled Transition 1 (transition A/B (HHA₄/B)), and Transition 2 (transition B/C (HHB/C) (Figure 1)). Using the chronology of HHB, these two transitions indicate climate shifts at the start of the early Holocene (Transition 1) around 11,000 cal. yr. B.P., and from early to late Holocene (Transition 2) around 5500 cal. yr. B.P. Transition 1 represents a shift from dry to wet and Transition 2 a shift from wet to dry, essentially the beginning and end of the African Humid Period.

In Zone A (HHA₄), dominance of *Stephanodiscus spp.* indicates a shallow annual range of mixing in a well-stratified water column with low Si:P supply ratios (Hayberyan and Hecky, 1987). Low abundance of *Aulacoseira spp.* and *Nitzschia spiculum* are noted in Zone A, similar to the Hayberyan and Hecky data, though these genera are more abundant at the southern end of the lake during this time period, possibly due to less turbulence at the middle of the lake, or reduced nutrient supply as compared to more southerly sites. Conditions in the lake at this time consist of a well stratified lake, low surface water Si:P ratios, higher alkalinity and higher sedimentation rates. These reflect climatic conditions that were becoming wetter and lake levels that were rising from late Pleistocene lowstands and aridity (Hayberyan and Hecky 1987). Data accumulated by Bosworth (2004) show a slight decrease in mean grain size during this interval, a trend that could be associated with increase distance from clastic source regions.

In Zone B (HHB), there is a dramatic shift from a dominance of *Stephanodiscus spp.* to alternating dominance with *Aulacoseira spp.* for a short period, followed by an overall dominance of *Aulacoseira spp.* over *Stephanodiscus spp.*. The beginning of this period occurs around 11,000 cal.yr. B.P., at the transition from late Pleistocene to early Holocene. At that time climate in the Tanganyika basin shifted from dry to wet (Hayberyan and Hecky, 1987). This transition marks Transition 1 of the core NPO4-KH-1-1K, and provides an age estimate for the base of the core. The overall dominance of *Aulacoseira spp.* in the sediments agrees with the onset of wet conditions, as *Aulacoseira spp.* dominates during regimes of very wet and turbulent water conditions. This result is in agreement with the dominance of *Aulacoseira spp.* shown in Zone B

of Hayberyan and Hecky (1987). However, there are more pronounced fluctuations in the switch between *Aulacoseira spp.* and *Stephanodiscus spp.* in the NPO4-KH-1-1K than observed by HHB, which may indicate that the mid-lake area is more sensitive to slight changes in upwelling than southerly sites. Increased sedimentation rates recorded by Hayberyan and Hecky for this time period agree well with increased mean grain size recorded in core NPO4-KH-1-1K by Bosworth (2004).

The beginning of Zone C (HHC) is characterized by a shift to a drier, more stratified lake conditions as represented by the sudden shift from *Aulacoseira spp.* to *Stephanodiscus spp.*. This shift coincides well with Zone C of the Hayberyan and Hecky (1987) study. This is a period of permanent thermocline establishment, low Si:P in surface water, and lower sedimentation rates, which could reflect reduced rainfall and less nutrient influx favoring *Stephanodiscus spp.* over *Aulacoseira spp.*. Lower sedimentation rates in the Hayberyan and Hecky study agree well with the decrease in mean grain size recorded for core NPO4-KH-1-1K (Hayberyan and Hecky, 1987; Bosworth et al., 2004).

Zone D (HHD₁) marks the occurrence of Transition 2. This transition appears to have occurred during an abrupt climate change at the mid-Holocene at 5500 B.P., at which time conditions changed from wet to dry (Hayberyan and Hecky, 1987). This zone is marked by a dramatic shift in dominance by *Stephanodiscus spp.* in Zone C to *Nitzschia spiculum* in Zone D, which coincides well with the Zone C/D₁ transition of Hayberyan and Hecky. *Nitzschia spiculum* dominated the samples through the top of core section II and into core section I that was sampled and analyzed by Robinson (2004).

The results of this study show that trends in fossil diatom populations at central Lake Tanganyika compare well to the Hayberyan and Hecky (1987) study. This relationship suggests that records from the Kalya region can be used to study southern basin upwelling. Whether these trends are related to shifts in wind stress or other factors, such as temperature, that affect thermocline stability should be the focus of future studies. There are, however, differences between the two datasets that may reflect site sensitivity differences or other climate effects. For instance, our data shows more variability in millennial scale (and shorter) shifts of diatom assemblages than the Hayberyan and Hecky (1987) data that may signal climate variability, or as mentioned before, site sensitivity.

Conclusions

The results of fossil diatom analysis from core NPO4-KH-1-1K indicate that two dramatic climate shifts occurred during the 534 cm accumulation of sediment at the core site. Transition 1 is a shift in dominance from *Stephanodiscus spp.* to *Aulacoseira spp.*, which indicates a dramatic shift in climate. This transition is very similar to the Hayberyan and Hecky (1987) data, which is dated to the transition from late Pleistocene to early Holocene. Transition 2 is the second dramatic shift noted in the diatom data. Dominance in diatom genera shift from *Aulacoseira spp.* to *Stephanodiscus spp.* to *Nitzschia spiculum*, indicating a shift in climate from wet to dry at the transition from early Holocene

to late Holocene at around 5500 cal. yr. B.P.. This transition is very similar to the transition shown in the Hayberyan and Hecky (1987) study. These similarities signal similar climate effects at the Kalya region, central Lake Tanganyika and the southern basin of the lake.

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