The Age and Origin of Lake Ejagham, Cameroon: 9,000-Year-Old Sediment Evidence Suggests Possible Bolide Impactor

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Abstract

Lake Ejagham is a relatively small lake (54 hectares) located in the south-western region of Cameroon, Africa. Two sediment cores, EJ1 and EJ2, were extruded in 1987 by Dr. Dan Livingstone, preserved, and analyzed in 2016. Sediment and diatom analyses were performed in conjunction with radiocarbon dating, which suggests the maximum age of the lake itself is about 9,000 years old. The age of the lake was confirmed by both the radiocarbon dating of the sediment as well as the dating of wood fragments found at the base of the EJ2 core. The diatom analyses indicate that in recent times high percentages of planktonic diatoms were present, which suggests a relatively wetter hydroclimate than in the past. In the mid-section of EJ1 those planktonic diatom percentages were lower, which indicates drier climates or changes to the lacustrine environment. The consistency in the sediment and climate record suggest that Lake Ejagham has been uninterrupted by environmental catastrophes, which provided suitable conditions for endemic cichlids to evolve via sympatry, particularly *Coptodon ejagham*. Lake Ejagham has been thought to have formed as a solution basin, when water dissolves and carries away underground minerals forming a depression. Instead, the bedrock beneath the lake contains both soluble and insoluble layers, which prevent this from happening. Here we assert that the EJ1 and EJ2 cores support an alternative origin, possibly from a bolide impactor, however this is not conclusive.

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Table of Contents

List of Tables and Figures

Introduction

The mid-section of the African continent, from the equatorial rain belt forest to the Saharan zone in the North, is a significant region that contains gaps of paleoclimatological data (Nguetsop et al., 2013; Nguetsop et al., 2004; Stager et al., 1999). In the past, paleorecords have been collected from the Saharan zone in the North and in the equatorial rain belt to the south. The Saharan zone records indicated critical climate events during the end of the Tertiary period to the early Quaternary. African sub-equatorial rain belt forests have been discredited as unchanging ecosystems by paleorecords (Nguetsop et al., 2013) that indicate increased rainfall and northward shifting of the Intertropical Convergence Zone (ITCZ) (Nguetsop et al., 2013). While these zones have been documented at some length the land in between (the Sudanian zone) is ripe with potential new data.

Lake Ejagham in Cameroon of West Africa, is a relatively small lake (54 hectares), habitat for numerous species of endemic cichlid fish, and of perplexing origins (Martin et al., 2015). It is nestled in the crook of Africa just North of the equator, in the Sudanian area of interest. The small size and location of Lake Ejagham suit it as a data point for climatological study. There is a benefit to collecting paleorecords from small lakes; small lakes are sensitive to local and regional hydrological variations (Nguetsop et al., 2013). Larger lakes are often studied in detail, but this pattern can lead to biased figures (Nguetsop et al., 2004), because greater numbers of data points, in varied locations, and varied source characteristics mitigate regional and local paleoenvironmental anomalies (Nguetsop et al., 2013).

Recent studies have been conducted in Lake Tizong of Cameroon (~533 km, ENE), where sediment cores revealed diatom records representing the last 4100 years (Nguetsop, et al. 2013). Additional studies have been conducted in the crater Lake Bambili where a sediment core with 24,000 years of diatom records was collected and limnological data was recorded at elevation (2264 m AMSL) (Stager et al., 1999). Sediment core and diatom analysis from Lake Ejagham would expand on localized data already reported while corroborating the regional climate scheme (Nguetsop et al., 2013).

In this study we compared the Lake Ejagham diatom record to other paleorecords, such as those from Lake Bosumtwi, Ghana. Evaluation of the diatom species, sediment analyses, combined with radiocarbon stable isotope analysis provides depth of continuity to the paleoenvironmental record of the Sudanian subequatorial zone. Further goals of this study are to discuss age related factors of Lake Ejagham, its endemic fishes, and its origin.

Material and Methods

Study site

Lake Ejagham (5^{o} 45'N 8^{o} 59'E; 200 m AMSL) is a small lake with an area roughly 54 hectares (Martin, C. et al., 2015), in south western Cameroon, approximately 12 km from the Nigerian border. The morphology of the lake is circular with a sandy shoreline that quickly becomes steep. The perimeter of the lake is surrounded by dense green riparian vegetation viewable via satellite imagery. However, apart from one village to the north called Eyumajok, the surrounding locality is sparsely populated denoted via the absence of anthropogenic development. During the summertime, the monsoon season begins in the region, which brings rain totaling on average 3 m, and typically lasting from April to October. Surface air temperatures of the wet season average 33^{o}C and 16^{o}C in the dry season. Lake Ejagham has a maximum depth of 17 m, and a mean depth of 11 m characterizing it as a relatively shallow basin. Additionally, the bottom of the basin is mostly flat and defined by fine-grained sediment, whereas the shoreline has a gentle sandy slope (Schliewen et al., 2001; Dunz and Schliewen, 2010).

A spine of ancient volcanos runs NE-SW through the middle of Cameroon, several of those volcanoes have become basins and lakes. The geology that Lake Ejagham rests directly upon is concealed by fluvio-lacustrine sedimentary deposits, although to the East deposits of Basalt predominate the area, which is representative of volcanic activity; local soils are mostly sandy. The basin is drained via a surface outlet into the Cross River watershed (Kling, 1987; Tokam et al., 2010).

According to studies conducted in 2008 and 2009, the most common planktonic autotrophic species, during both wet and dry seasons, were stated to be cyanobacteria. Specifically, those cyanobacteria were analyzed to be *Oscillatoria* and *Microcystis*, although some amounts of *Cyclotella, Melosira, Rhizosolenia, Synedra*, and *Tabellaria* diatoms were also observed (Offem et al., 2011).

Core sedimentology

In 1985 two rod-driven piston cores, EJ1 and EJ2 (2.5 m and 6 m long respectively) were extruded from Lake Ejagham using a raft which was anchored to the center of the lake as a platform. The extrusion itself was performed by Livingstone who recorded no overlaps or gaps between the two cores in his field notes. The steel tubes containing the sediment were secured and transported to Duke University. Core EJ2 was extruded in 10 cm increments and subjected to weight loss on ignition testing (WLOI; 500 ^{o}C and 900 ^{o}C), the results were recorded in a notebook which was transferred along with the cores to Stager in 2016.

The EJ1 core was obtained in three segments of steel piping which had been unopened until that time in 2016. Upon opening, core EJ1 was found to be intact and was thus extruded from its casing at Paul Smith's College. The core was then sampled at 10 cm increments for diatom analysis and radiocarbon dating.

Diatom and stable isotope analysis

Diatoms were sampled, in EJ1, by mixing sediment in 10 cm increments with distilled water. The slurry of raw sediment and distilled water was then applied to glass coverslips. This process yielded samples containing adequate concentrations of diatoms, which were readily visible and identifiable. Chemical treatment was not required in order to identify diatom species. At least 400 diatoms were counted per sample.

The condition of EJ2 was found to be dry and characterized by disruption throughout the core in 2016. Samples of the top and bottom of the lowermost EJ2 pipe were prepared and shipped out for radiocarbon dating by LacCore.

Results

Radiocarbon Dating

Near the bottom of the EJ2 core, 580 cm depth, a wood fragment was retrieved for radiocarbon dating analysis. The age of the wood fragment was determined to be 7940 ± 35 ^{14}C years BP (Table 1, Figure 6), which when calibrated to calendar years with the online CALIB 7.1 program, shows that the maximum age of the lake is around 9,000 years old. At a depth of 526 cm fine-grained sediment was discovered and radiocarbon dated, which was determined to have an age of 5130 ± 25 ^{14}C years BP. Including the mud-water interface at the top of the core and accounting for the upper the 526 cm, the mean chronological span of a one centimeter increment in the upper 526 cm of the core is approximately 11 years. The bottom or base layer of the core EJ2 has a ca. 3,000-year age difference from that of the upper and lower dated portions. This discrepancy suggests that the core may have been compacted or else became discontinuous throughout the lower layers.

The disturbed nature of the EJ2 core was unique and unlike the observed quality of the EJ1 core, which was discovered to be moist, intact, and undisturbed. The leaf discovered in the 34-35 cm interval in subsection EJ1-2B (114 – 115 cm composite depth; Table 1, Figures 5 and 6) was radiocarbon dated and compared to bulk sediment from the same region. These results yielded a ca. 100-year difference between samples and thus established a 100-year offset between the radiocarbon ages for bulk sediments and the calculated calendar year ranges (Table 1). The radiocarbon dating suggests that the last 3300 years of lake record is represented by the EJ1 core (Figure 3). Therefore, the EJ1 core has sediment age increments ranging from 6 to 16 years/cm, for all three subsections of the core (Figure 3 and 4).

Diatom Analyses

The EJ1 core was dominated by two taxa: *Aulacoseira granulate var. muzzanensis* (F. Meister) Simonsen and small sized humerus-shaped *Eunotia zasuminesis* (Cabejszekówna) Körner. The habitats of both taxa range from planktonic to tychoplanktonic in temperate and tropical lakes (Gasse, 1986; Kociolek, 2005; Lange-Bertalot et al., 2011; Nicholls and Carney, 2011). Similar *Aulacoseira* and *Eunotia* were also found in nearby Cameroon crater lakes Nyos and Monoun, 1985 by Stager. Throughout the EJ1 core percentages of the two dominant taxa, *Aulacoseira* and *Eunotia*, ranged from 69% to 97%. The highest percentages of the planktonic species fell within the 154 to 159 cm core interval, while the lowest percentages were in the bottom 10 cm and upper 20 cm of the EJ1 core (Figure 3 and Figure 5). Additional species of littoral pennates belonging to the genera *Eunotia*, *Pinnularia*, and *Navicula*, as well as other *Pennales* were observed.

Within the upper section of the core, samples most commonly contain *A. granulata* and *E. zasuminsensis*, with traces (<20%) of other species such as *Pinnularia* and various benthic *Eunotia* spp. Although the core lengths were not recorded, the lowermost core samples consisted of similar comparative quantities of *Aulacoseira* and pennate diatoms, however *A. zasuminsensis* was only occasionally present to absent.

Higher percentages of planktonic diatoms were present in the mid-lake samples of the sediment-water boundary compared to samples from the littoral region. Bottom dwelling *Eunotia*, including *E. cf. pectinalis*, were the dominant taxa in the sandy sediments collected by hand from the littoral region in 2016 by Dr. Chris Martin (University of North Carolina), along with smaller fractions of *A. granulata*.

Sedimentological Analyses

Dr. David King (Auburn University, AL) carried out the mineralogical analyses of the EJ2 core, and his findings are summarized here.

Core EJ2 contained profiles of organic matter and carbonate content, which displayed minimal variability, averaging 35 - 40% except for the coarse-grained sediments located at the base, below approximately 5.6 m depth. The coarse-grained sediments exhibited organic matter and carbonate content levels much lower than the consistent percentages mentioned (Figure 2). Coarse-grained sediment particles are mostly irregular mineral grains; however small fragments of wood were also present in the sediment (Figure 6).

When examined under the microscope, the core samples from the 566-569 cm and 578-582 cm depth ranges display abundant grey-brown, clay-bearing detrital grains entrenched within a grey-brown clay matrix (Figure 6). The clay to detrital grains were in approximately equal proportion to each other. The color was dark amber in a thin section and contained roughly 30% very soft organic material and a few woody fragments, but is primarily composed of opaque particles 10-15 μm in diameter. The clay portion was virtually free of mica flakes.

Quartz and feldspar comprised most the detrital grains observed. The mean grain size of the detrital material was ca. 0.5 mm, and can be classified as either medium or coarse (Wentworth, 1922), but overall the quartz grains were larger than the feldspars. The size distribution was distinct and bimodal between the grain sizes larger than 0.004 mm in diameter. Roughly 65% of the detrital grains had diameters of 1 to 4 mm, or very coarse granule size, the remainder being finely grained sand and silt with diameters of 0.25 mm to 0.004 mm. The characteristics of the larger detrital grains were slightly frosted or polished on their exterior surfaces. This is indicative of chemical weathering and possibly wind activity, which would have occurred prior to enclosure in the lake deposits.

Discussion

The physical condition of the EJ1 and EJ2 cores represents a chronological record of the history of Lake Ejagham, from its beginning to near present. Clear stratification of the EJ2 core reveals the layering of coarser inorganic grains beneath finer organic grains (Figure 2). The radiocarbon, geochemical, mineralogical, and diatom data of the EJ1 and EJ2 cores we analyzed suggests that the small fresh water Lake Ejagham has a maximum age of 9,000 years and that the lake itself experienced hydroclimatic variability, similar to a high-resolution oxygen isotope record from Bosumtwi that suggests the same (Figure 5). Evidence of the origin of the lake, while not entirely clear, appears to contradict previous solution basin theories, and instead suggests, but does not confirm, creation by an impactor.

The core sediments contained grains of quarts and feldspar, which likely originated from the weathering of the underlying Precambrian bedrock (granites, gneisses, and migmatites; Fairhead et al., 1991) and/or formations of sandstone from outcroppings of the Mamfe basin and Benue Trough from Lower Cretaceous bedrock foundations. However, the angular to sub-angular nature of the grains favors the Precambrian bedrock source (Figure 6) versus sandstone grains, which would wear faster and produce rounded to sub-rounded grains. Additionally, the quartz remains were observed to be polycrystalline and contain interlocking grain domain boundaries. The quartz also featured miniscule needle-like rutile inclusions, which suggests a plutonic igneous origin source. The mineral grains at the base of EJ2 are significant because they demonstrate that Lake Ejagham was not formed from the local basalts. The presence of relatively large quartz grains and the absence of basalt fragments in the sediment confirm this point.

The disparity between the radiocarbon dates of the bulk sediment and that of the leaf fragment in core EJ1 can be explained by possible contamination of Lake Ejagham's sediments, and/or disturbance by bioturbation. Both could contribute ancient carbon from nearby limestone deposits, petroleum, and even natural gas (Ndougsa-Mbarga et al., 2007), including increased levels of carbonate in the EJ2 core (Figure 2).

Regarding the concentrations of planktonic diatoms as bio-indicators, deep-water habitats and/or wet climate conditions can be deduced from fossilized remains of diatom assemblages (Laird et al., 2010; Stager et al., 2005, 2012). Although this practice is not exact, it does provide substantial and reliable qualitative data of past hydroclimate characteristics. The high percentages of *A. granulata* and *E. zasuminensis*, taken from the center of Lake Ejagham, are used to represent past open water conditions. The particularly high percentages of *E. zasuminensis* within the upper portion of the EJ1 core and the low percentages below the upper interval describe a recent dry period ca 1,000 or 500 years ago, which is also consistent with findings at nearby Lake Bosumtwi (Figure 5; Shanahan et al., 2009) in addition to more local Cameroon lakes.

The planktonic diatom percentages recorded in EJ1 indicate wetter climate which is consistent with the hydroclimate of nearby Lake Bosumtwi in Ghana (Figure 5). This is significant because it establishes the stability of the Ejagham lake basin and its water levels. If desiccation or severe drought had occurred it would be reflected in Ejagham and Bosumtwi's record, but it does not, at least for the last 3,500 years. The stability of Lake Ejagham's environment and water levels are necessary to sustain fish populations such as its endemic cichlids. It is reasonable to suggest that Lake Ejagham did not dry out before its suggested formation 9,000 years ago because the climate inferred from core EJ1 matches the climate at Bosumtwi. Any event that would have been able to dry out Ejagham would also have dried out Bosumtwi, but the Bosumtwi record does not show a severe drying event. This means that the Ejagham basin did not likely exist prior to 9,000 years ago, and that it was filled with water during a wet hydroclimate.

Age of Lake Ejagham

The woody debris collected from the coarse sediments of core EJ2 seem unlikely to have been polluted by older forms of carbon that could skew the radiocarbon dating performed, due to the presence of lacustrine sediment above it in EJ1. It is possible, however, that the woody debris of core EJ2 traveled some degree through its settling process over time.

The sediment settled at a mean rate of approximately 25 years/cm, so an expected age for the 526 cm interval of the core amounts to more than the radiocarbon date of the lowermost portion of EJ2, with a maximum age of 9,000 years old. The mean sediment accumulation rate of 25 years/cm is consistent with EJ1. The calculated radiocarbon age of the sediment at the 580 cm depth of core EJ2 extrapolates to a maximum age of 8,000 years at the base of the core. The calibrated radiocarbon age of the lake is 9,000 years, which means that the sediment between the 526 cm 580 cm intervals is either highly compressed, therefore not represented by the mean sediment accumulation rate, or else has been mixed to some degree. A final explanation, though less likely, involves the loss of structural integrity of the EJ2 core during its long term storage at Duke University.

Origin of Lake Ejagham

There are no conclusive reports regarding the origin of Lake Ejagham itself, some have hypothesized that it resulted from geology consistent with solution basin lake formation (Schliewen et al., 1994 and 2001). Maps of the local geography do not reveal the required geology, such as soluble geologic deposits. However, the soluble deposits that do exist, such as some thin layers of limestone, marl, and halite, are laced with other insoluble shales and sandstones. Those insoluble layers do not allow bedrock to dissolve and form a lakebed depression below the surface (O.A. Njoh,.2016). In addition to the subterranean characteristics, mentioned above, that do not advocate for a solution basin origin, there are no obvious karst solution type features in the vicinity, adding more doubt to the solution basin hypothesis.

Another unlikely scenario involves Lake Ejagham forming via a climatic event, 9,000 years ago per our data, similar to what Lake Victoria did after its desiccation event roughly 17,000 years ago (Stager and Johnson, 2007; Stager et al.,2011). The EJ1 diatom record and hydrological variability appears to resemble a similar pattern from the Bosumtwi $\delta^{18}O$ isotope record (Figure 5; Shanahan et al., 2009), and the reduced lake levels as well as possibly reduced rainfall, that occurred approximately 2,000 years ago and again approximately 1,000 years ago, coincide with the low percentages of planktonic diatoms in the EJ1 core and relatively high $\delta^{18}O$ in the Bosumtwi record as well as nearby Barombi Mbo (Giresse et al., 1994; Lebamba et al., 2012), Mblang, and Ossa Lakes (Nguetsop et al., 2010, 2011). Given this information it is likely that the hydroclimate of Lake Ejagham is comparable and similar to other lakes within the West African region, mentioned above, which experienced abnormally wet conditions during the early Holocene (approx. 11,700 years ago). This increase in wet season derived precipitation emanated from the insolation-driven strengthening of the West African summer monsoon. It is therefore quite reasonable to conclude that the aforementioned coarse sediments at the base of EJ2 do not correspond to any known desiccation event. Rather the core suggests that the lake basin itself formed about 9,000 years ago and that the wet climate at that time would readily fill and sustain the lake from that point onward (Giresse et al., 1994; Peck et al., 2004; Shanahan et al., 2009; Lebamba et al., 2012).

Resting 200 feet above the surrounding terrain, Lake Ejagham is protected from the impacts of major rivers and floodplains, a fact which would alienate the body from any fluvial geomorphic processes and inputs. Without fluvial inputs to fill the lake sized depression about 9,000 years ago, and elevated above the floodplain, a fluvial origin seems unlikely.

It is possible, however not conclusive, that the lakes origin is the result of an explosive impactor such as a bolide, as suggested by Livingstone and other (Burress, 2015). The wood fragments located at the base of EJ2 are consistent with this hypothesis, however the presence of shock quartz or other minerals have not been positively identified. The obvious lack of any visible ejecta field is another issue with this hypothesis, but this does not readily omit the possibility of an extraterrestrial impactor origin.

Endemic Cichlids

The above the oldest sediments, at the bottom of core EJ2, the organic matter and water content are consistent and lacking any major variability. Significant erosion and/or drying events would be indicated in the organic matter and water content of the core if these environmental events occurred. Apart the absence of any notable chemical inconsistencies within either core, the visual consistency of both cores also indicates that sediment deposition was regular and uninterrupted. The EJ1 core is continuous, according to our age model, except for the last five centuries, in which no exceptionally severe droughts occurred according to the records of Barombi Mbo and Bosumtwi. Additionally, the dominance of a single assemblage of planktonic diatom taxa in the EJ1 core, which supports the conclusion that Lake Ejagham itself has not likely been disturbed or complicated from severe environmental events, nor has it varied significantly from its current state and depth since it formed roughly 9,000 years ago.

The suggested stability of the environment and water depth of Lake Ejagham for the last 9,000 years are appropriate conditions for sympatric speciation, evolving from a single ancestor species in the same geographic region, to occur in. The evidence for evolution by sympatry is strengthened by the existence of two genetically distinct lineages of cichlids, which have speciated in the small Ejagham lake body; multiple speciating cichlid descents within a single lake is unique to Ejagham among all known crater lake cichlid radiations (Seehausen 2006).

Lake Ejagham cichlids and those of Lake Bermin (9 endemic species) and Lake Barombi Mbo (11 endemic species), also in Cameroon, represent strong examples of sympatric speciation (Coyne and Orr 2004; Schliewen et al., 2006; Bolnick and Fitzpatrick 2007). The possibility that speciation occurred by sympatry is likely, however we cannot eliminate the possibility of allopatric speciation, common speciation by physical separation of biological populations and restricted gene flow, because it is unknown if nearby riverine cichlids were able to periodically colonize Lake Ejagham. For this reason, it cannot be definitively determined whether some speciation occurred via sympatry or from the additional genes of colonizing cichlids. Initial analyses indicate that two of the three *Coptodon* species in Ejagham (the benthivore *C. deckerti* and zoopanktivore *C. fusiforme*) may have risen from secondary colonization, while the third species (the predator *C. ejagham*) may have diverged in sympatry (Martin et al., 2015; Poelstra and Martin, unpublished data).

Conclusions

Located in Cameroon of Western Africa, Lake Ejagham is small (54 hectares) and appears to be a relatively young lake of about 9,000 years old, as suggested by the well preserved EJ1 and EJ2 sediment cores. The base of the EJ2 core contains coarse sediments and wood fragments, which were dated to confirm this assertion of age, along with diatom analyses to confirm the recorded history of hydroclimate variability in the region against “nearby” lakes. Long term stable environmental and lake depth conditions are consistent with those required for speciation of endemic cichlids to occur. However, extraneous gene flow cannot be ruled out and therefore it is thought that *C. ejagham* is the only cichlid species to diverge from sympatry. The origin of the lake is still not clear; however, the prevailing hypothesis, origin by means of solution basin, is not supported by the sediments in the base of the EJ2 core, and instead we assert that there is reasonable evidence that the origin of the lake may be the result of an extraterrestrial bolide impactor.

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Appendix

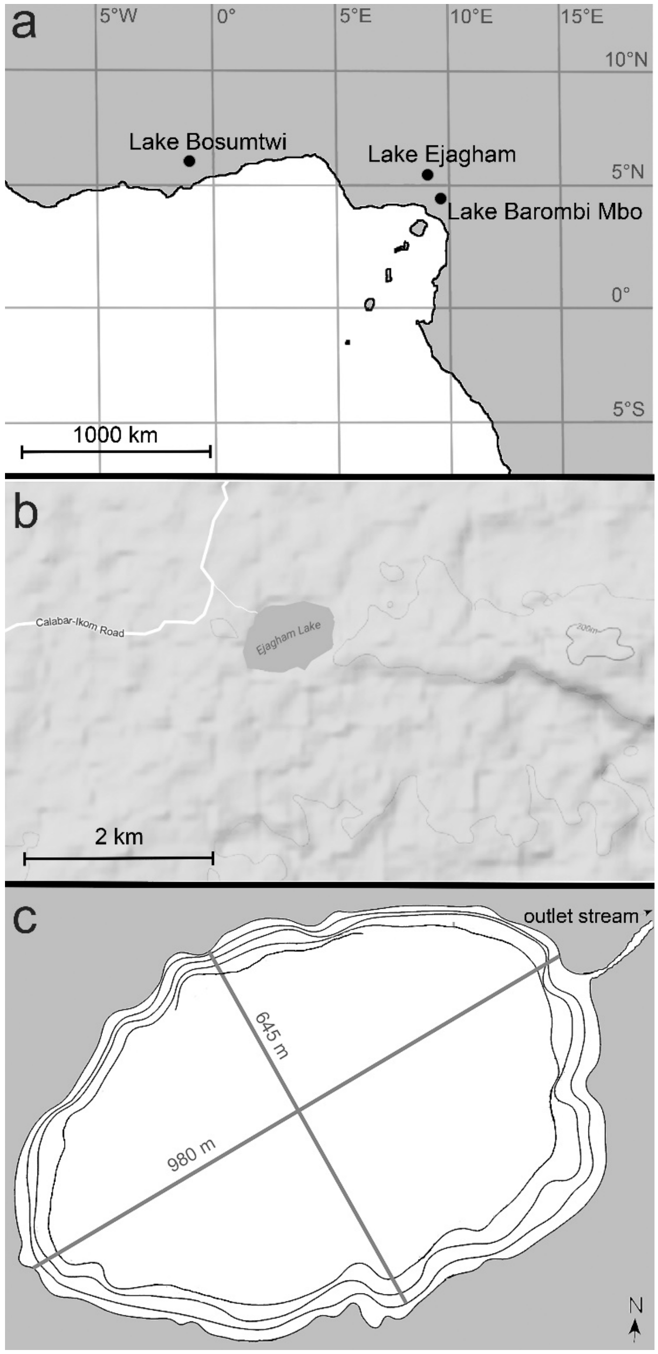

Figure 1: Site map. a. Regional map of West Africa. b. Detail of the vicinity of Lake Ejagham. c. Bathymetric map of Lake Ejagham. Each contour represents 3m. Only partial representation of the 12m contour is currently available.

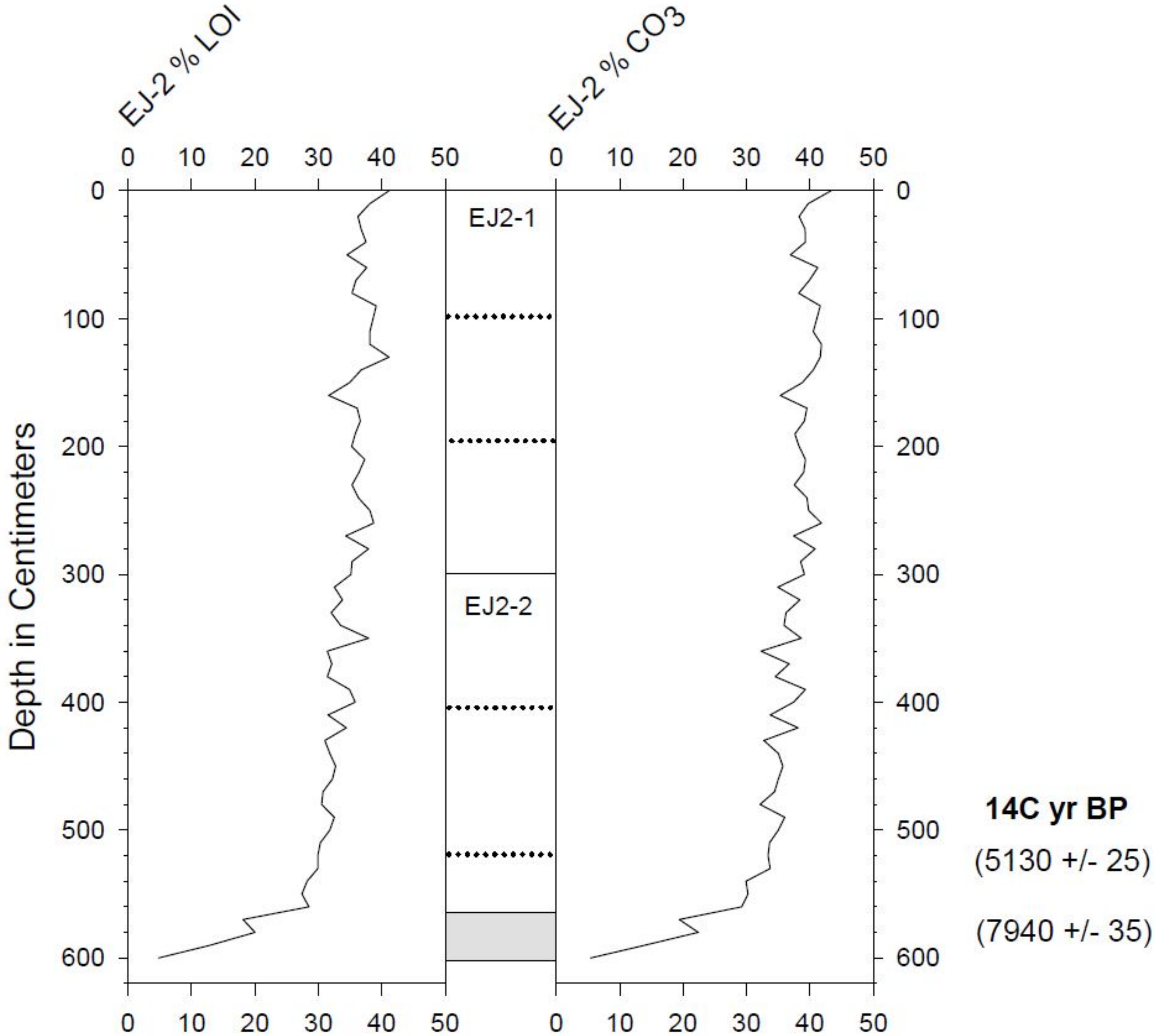

Figure 2: Estimated organic matter and carbonate content (by percent weight loss on ignition) of core EJ2. Grey shading indicates coarse-grained, disaggregated sediment.

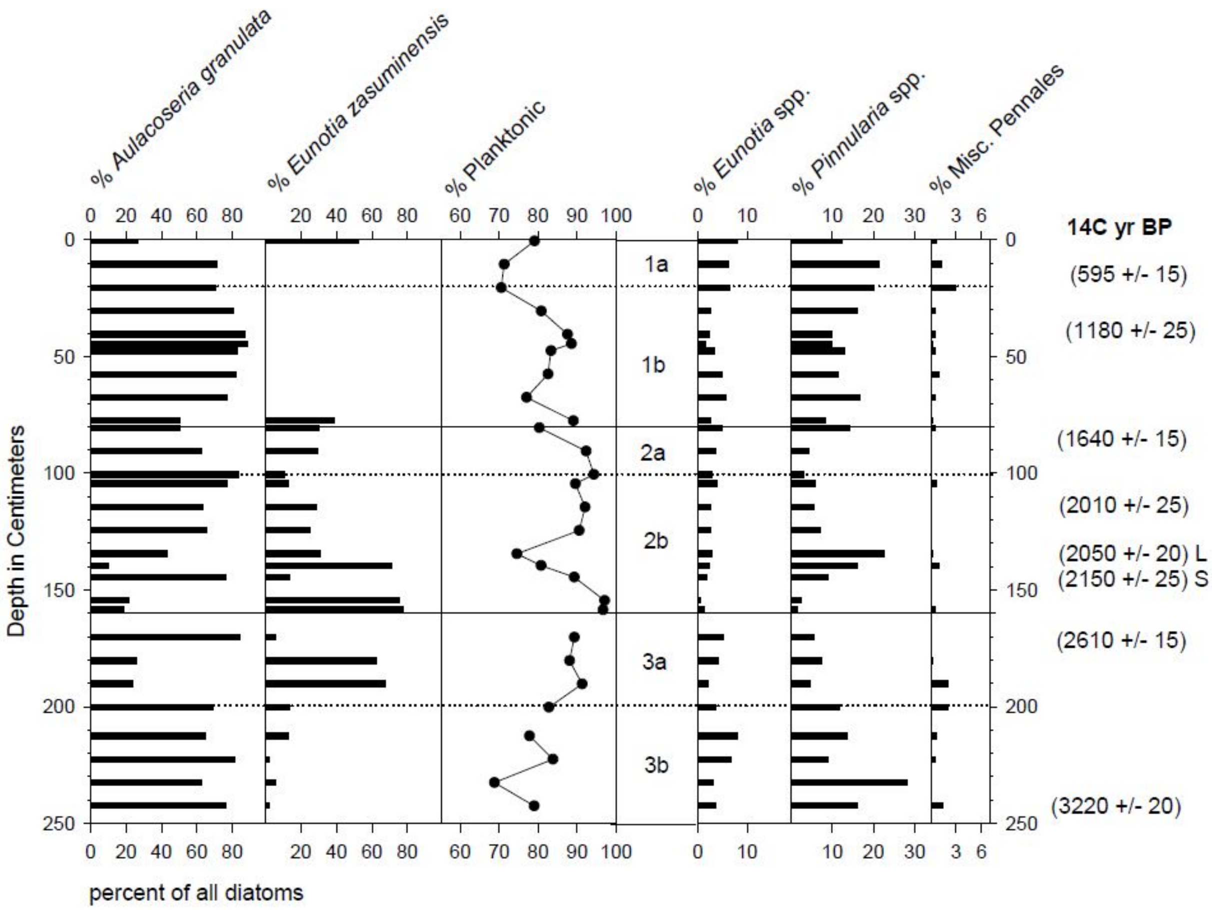

Figure 3: Diatom stratigraphy for core EJ1. Middle panel: the three main subsections of the core are delineated by solid lines; dotted lines indicate locations where the subsections were cut into smaller segments for storage. Radiocarbon ages to the right include two ages obtained for a leaf (L) and bulk organic sediment (S) from the same depth in the core.

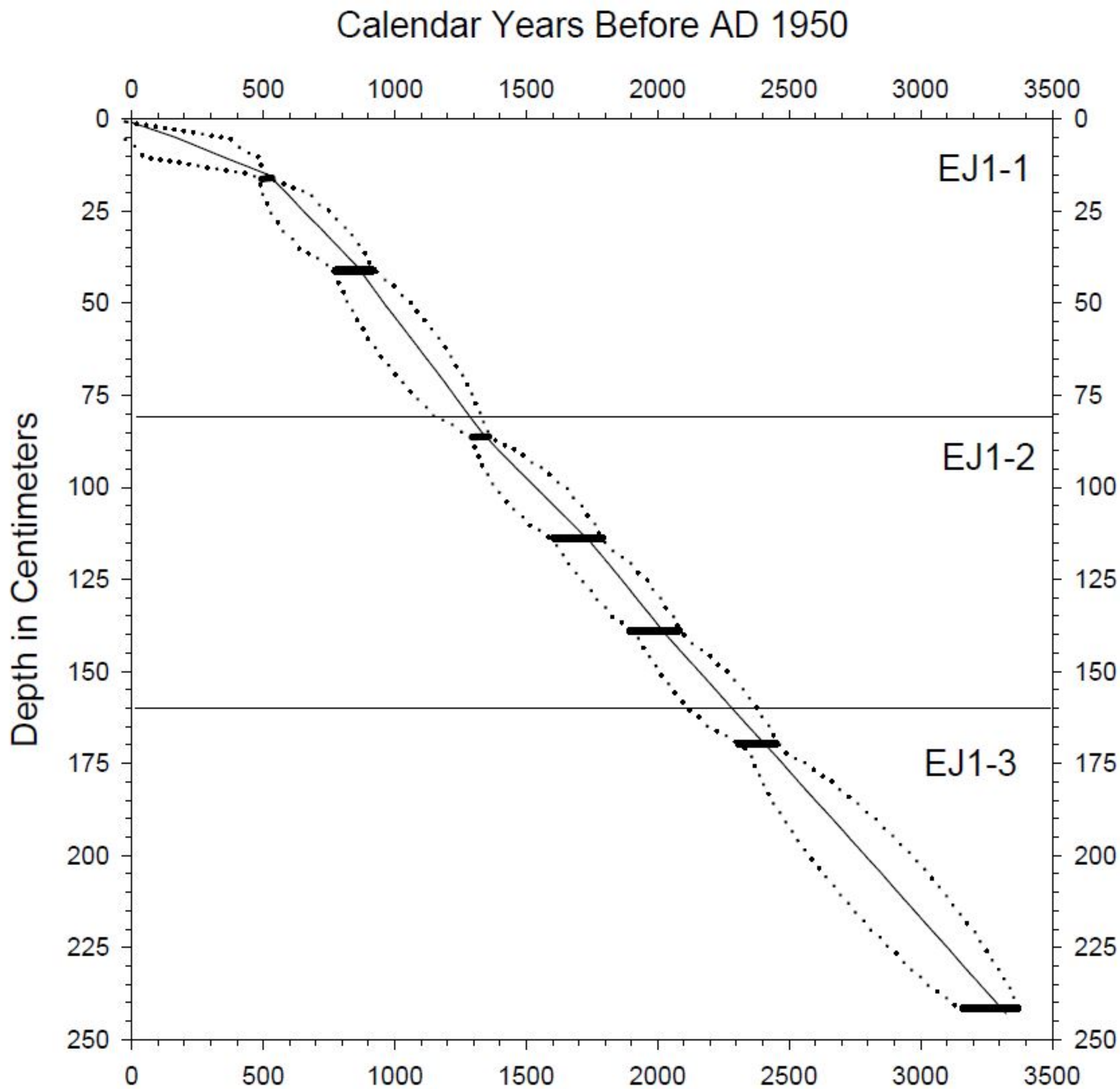

Figure 4: Age model for core EJ1 developed for comparison to the Bosumtwi oxygen isotope record (described in text). Horizontal bars indicate radiocarbon age ranges after conversion to calendar years. Dotted lines represent maximum and minimum age limits. Solid lines represent the mean ages, which were used to construct and age model for the EJ1 diatom record.

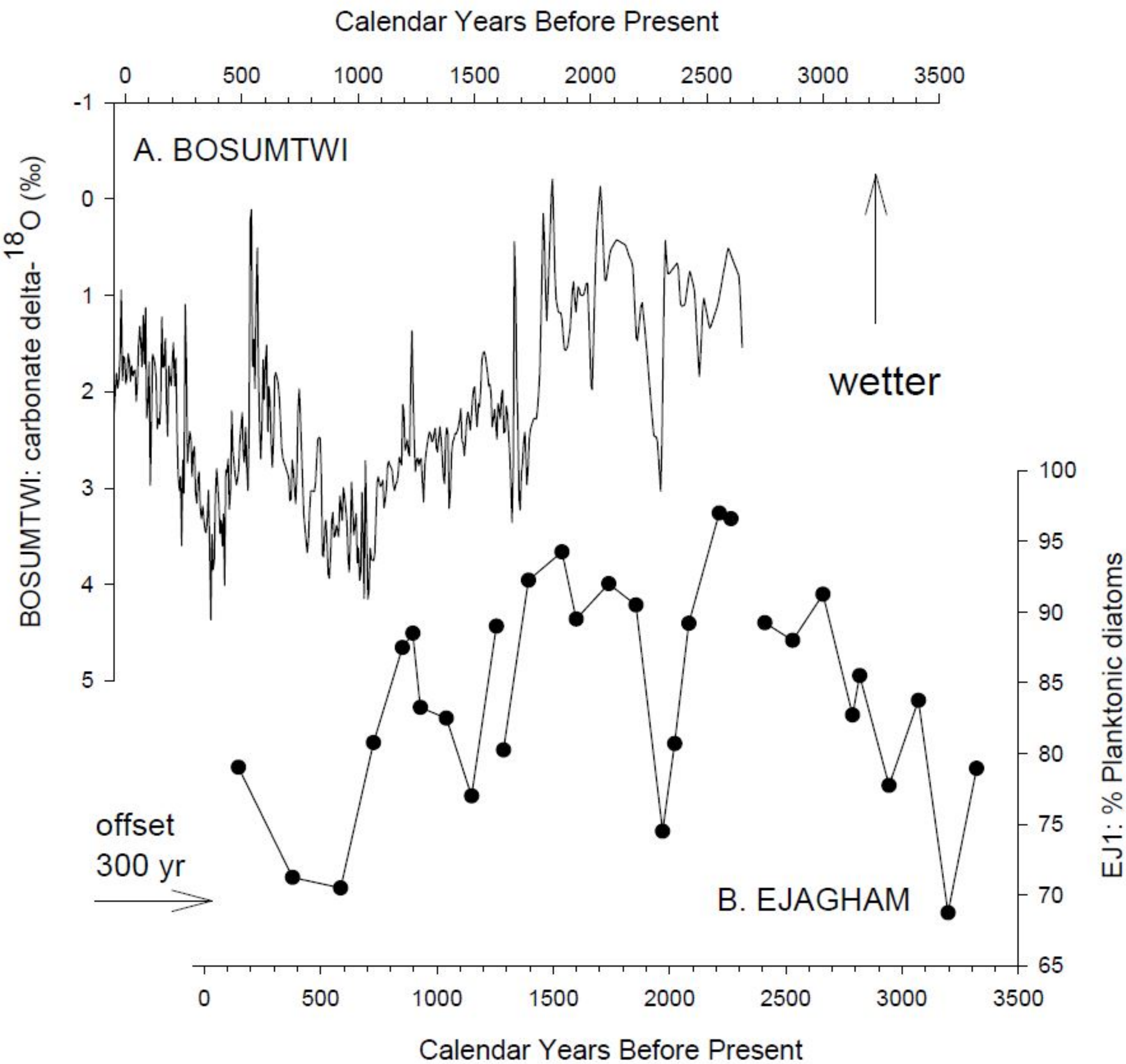

Figure 5: Comparison of (a) Lake Bosumtwi record of $\delta^{18}O$ (Shanahan et al., 2009) with (b) composite planktonic diatom stratigraphy in the three subsections of core EJ1. Shifting the provisional age model for EJ-1 by 300 years brings the diatom series into reasonably close alignment with the Bosumtwi isotope record. Bothe series indicate wetter climatic conditions upwards on the figure.

Figure 6: Coarse-grained, disaggregated sediments containing wood fragments at the base of core EJ2.

Table 1: Radiocarbon and calendar age ranges for samples from Lake Ejagham cores EJ1 and EJ2. Calendar year ages were determined with CALIB version 7.1 (Stuiver and Reimer, 1993) after subtracting 100 years from the Radiocarbon ages of all bulk sediment samples (described in text).

Core	Total Depth (cm)	Material	^{14}C age (yr BP)	Cal yr BP 2-sigma (prob.)	OS#
EJ1-1a	15.5	sediment	595 ± 15	510-536 (1.00)	125441
EJ1-1a	40.5	sediment	1080 ± 25	797-872 (0.49)	124660
				897-939 (0.50)	
				945-953 (0.01)	
EJ1-2a	85.5	sediment	1540 ± 15	1302-1356 (1.00)	125442
EJ1-2b	114.5	sediment	1910 ± 25	1632-1651 (0.04)	125276
				1695-1820 (0.96)	
EJ1-2b	139.5	leaf	2050 ± 20	1947-2064 (0.94)	125233
				2083-2108 (0.06)	
EJ1-2b	139.5	sediment	2150 ± 25	1934-1939 (0.01)	125275
				1943-2069 (0.90)	
				2078-2112 (0.09)	
EJ1-3a	170.25	sediment	2510 ± 15	2356-2472 (0.97)	125443
				2476-2485 (0.03)	
EJ1-3b	242.5	sediment	3220 ± 20	3254-3294 (0.29)	120775
				3324-3385 (0.71)	
EJ2-2b	525.50	sediment	5130 ± 25	5664-5674 (0.02)	124661
				5680-5687 (0.01)	
				5700-5798 (0.378)	
				5802-5893 (0.06)	
EJ2-2b	580.0	wood	7940 ± 35	8641-8815 (0.55)	125232
				8823-8979 (0.45)	