warming, increasing temperatures would probably lead to increases in OH formation rates (20, 21) and an increase in the reaction rate between methane and OH [D. Raynaud, J. Chappellaz, J. M. Barnola, Y. S. Korotkevich, C. Lorius, *Nature* **333**, 655 (1988)], and therefore to increased rates of methane destruction. If so, the association of interstadial events with increased methane concentration suggests that methane source strength probably did not decrease and may have increased to a greater extent than indicated by the concentration variations.
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Late Pleistocene Desiccation of Lake Victoria and Rapid Evolution of Cichlid Fishes

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Lake Victoria is the largest lake in Africa and harbors more than 300 endemic species of haplochromine cichlid fish. Seismic reflection profiles and piston cores show that the lake not only was at a low stand but dried up completely during the Late Pleistocene, before 12,400 carbon-14 years before the present. These results imply that the rate of speciation of cichlid fish in this tropical lake has been extremely rapid.

Lake Victoria is second only to Lake Malawi in diversity of endemic species of cichlid fish (*1*). This rich diversity is somewhat surprising because Lake Victoria is known to be relatively young as compared with the large lakes occupying the East African Rift Valley. The rich diversity in Lake Victoria implies that its cichlid species flock evolved rapidly. But how rapidly? Did most of the species evolve over a span of a few hundred thousand years since the lake first formed, or did they appear more recently, since the lake was at a low stand during the late Pleistocene, when much of north and equatorial Africa was dry (*2*, *3*)? Were there small satellite lakes in the Victoria basin where these hundreds of species of cichlids could seek refuge and wait out the late Pleistocene arid period? If not, the rate of evolution of Lake Victoria's cichlids is the fastest ever recorded for such a large number of vertebrate species.

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We surveyed the floor of Lake Victoria in March and April 1995, using seismic reflection profiling and piston coring as part of the first expedition of the International Decade for the East African Lakes (IDEAL). One of the major objectives was to determine how much smaller Lake Victoria was during the late Pleistocene than today.

Lake Victoria straddles an ancient drainage system that flowed from east to west and was modified by uplift on the shoulder of the Albert Rift (*4*). Although this tectonic activity may have begun in the Miocene, river downcutting maintained westward drainage until the Pleistocene, when flow reversal created a lake substantially larger than the present one (*5*). Precisely when this occurred in the Pleistocene is not known. Doornkamp and Temple (*5*) and Bishop and Posnansky (*6*) estimated a middle to late Pleistocene age for the lake of [younger than 0.8 million years ago (Ma)] on the basis of lacustrine sequences exposed in the Kagera River valley approximately 100 km west of the lake and 130 m above its present surface. Kent (*7*) estimated an early to middle Pleistocene age (1.6 to 0.8 Ma), on the basis of lacustrine sequences 100 m above the present lake near the Kavirondo Gulf on the Kenyan side of the lake.

The lake level has varied by about 2 m during the past century in response to variations in rainfall and evaporation (*8*), and the lake was at least 65 m lower than at present at the end of the last glaciation, between 15,000 and 17,000 years before present (B.P.) (*9*). Lake Victoria's maximum depth is only 69 m, so the issue of whether one or more residual lakes survived this late Pleistocene arid interval, providing refuges for the extraordinary species richness of the lake's cichlid faunas, has been debated (*1*–*3*).

In our survey, we used an intermediate-resolution seismic reflection profiling system (Fig. 1) (*10*). Reconnaissance seismic profiles had been obtained along four track lines across Lake Victoria in the late 1980s

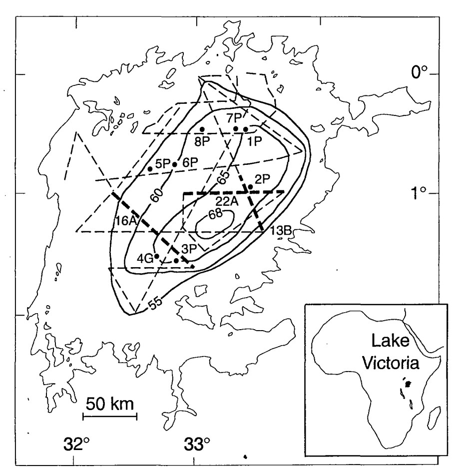

Fig. 1. Map of Lake Victoria showing the bathymetry where the water is deeper than 55 m, core locations (piston core sites are identified with the suffix P and the gravity core site with the suffix G), and seismic survey track lines (light dashed lines). Water depths are in meters (we have assumed a speed of sound of 1500 m/s). Locations of seismic reflection profiles in Fig. 3 are depicted with heavy dashed lines.

(*11*), and the lake's floor was originally mapped by the British Admiralty in the first decade of this century. Kullenberg piston cores retrieved from seven sites in the lake provided sedimentological information to assist in the interpretation of the seismic reflection profiles.

The seismic data show that the eastern two-thirds of the lake basin contains a relatively thin (~40 m) sediment cover consisting of about four main sequences separated by unconformities (*12, 13*). The top unit has low reflectivity, overlies a hard reflector, and is at most 8 m thick (Fig. 2). Two underlying units are also highly stratified but contain higher amplitude reflections and have a total thickness of about 23 m, if we assume a maximum speed of sound of 2 km/s in these units (Fig. 3). We also detected reflectors below the highly stratified units; these are discontinuous in some places, quite wavy in others, and appear to be substantially older than the overlying sequences.

A fourth distinctly stratified sequence dominated by high-frequency reflections was observed in the western third of the lake and is up to 35 ms (~35 m) thick. It tilts upward to the west and lies stratigraphically between the old, indurated sequence and the overlying stratified units in the region to the east (Fig. 3).

We interpret the highly stratified sequences to be lacustrine sediments deposited since Lake Victoria formed as a result of ponding of the preexisting river drainage system. Our piston cores recovered all of the top unit, A, and just the uppermost few tens of centimeters of the underlying sediment responsible for the high-amplitude reflection. Unit A consists of dark, organic-rich, diatomaceous muds. Its lower boundary is a stiff silty clay that contains poorly preserved diatoms, corroded sponge spicules, and locally abundant higher plant remains. The highly stratified sequences below unit A are probably similar in composition because their acoustic character (highly stratified and continuous) is the same. We suspect that the lowest, substantially older unit corresponds to the ~15-Ma Miocene lacustrine, fluvial, and volcaniclastic rocks that crop out on islands in the northeastern part of the lake (*14*).

If the highly stratified units represent the entire history of Lake Victoria, then the lake is mid- to late Pleistocene in age. The total thickness of sediments is no more than 60 m. Sedimentation rates in the Holocene sequence are about 0.7 m per 1000 years. We measured a drop in the water content from about 90% in the surface sediments to about 50% in sediments underlying unit A. This change indicates about a fivefold compaction of the sediments, so the thickness of the sequences could represent nearly 400,000 years of deposition. More than half of this deposition (~250,000 years) occurred in the time of the tilted sequence in the western part of the lake. Unfortunately, we cannot determine the length of time representing the depositional hiatuses at the boundaries of the seismic sequences.

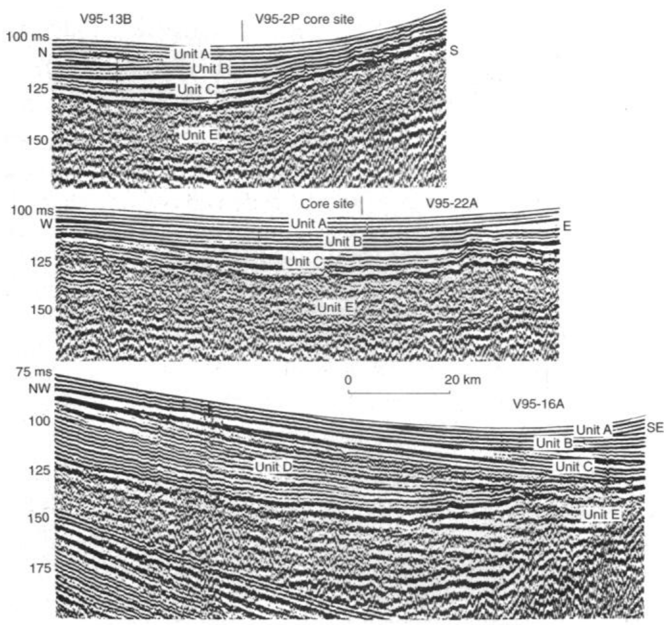

Fig. 3. Seismic reflection profiles along three track lines in the lake, illustrating the major sedimentary sequences. Track-line locations are shown in Fig. 1. Unit A has accumulated since the lake was dry at 12,400 years B.P. The difference in reflectivity of the Holocene versus the underlying units, illustrated in Fig. 2, is not shown in this figure because of the signal processing used.

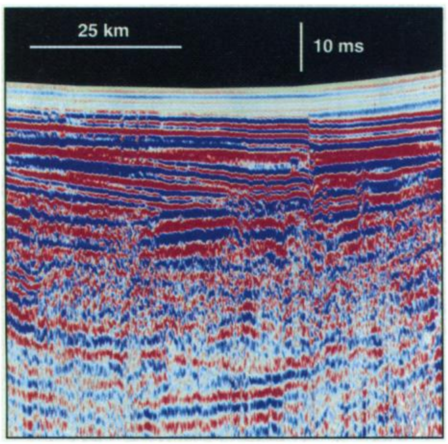

Fig. 2. A short section of a typical seismic profile taken from the lake with a small air gun, illustrating with color the dramatic difference in reflectivity between the Holocene (light) sequence at the top and the underlying units that have much higher amplitude reflections. The vertical scale of two-way travel time (10 ms) represents about 7.5 m in the Holocene (light) sequence and about 10 m in the underlying units. This contrast in reflectivity is found everywhere in the lake and, when combined with our core data, indicates that the basin completely dried out during the late Pleistocene.

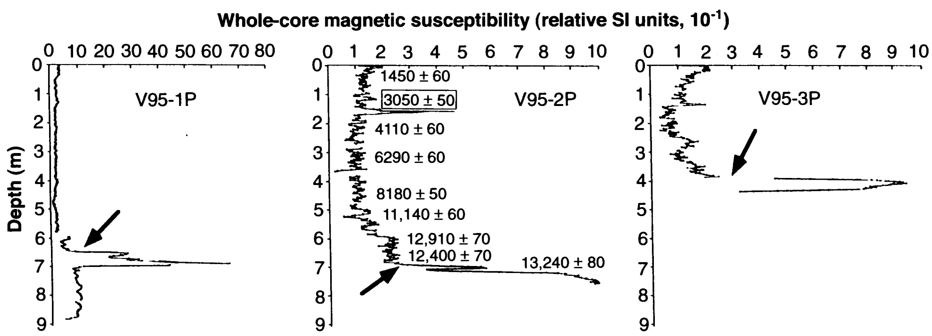

Fig. 4. Magnetic susceptibility profiles from three of the piston cores recovered from the lake. See Fig. 1 for core locations. Arrows show the rise in magnetic susceptibility that corresponds to the subaerially exposed sediment at the base of the Holocene sequence. The same feature is seen in the other cores not depicted here. AMS radiocarbon dates obtained for core V95-2P are shown at their respective depths. All dates are on pollen except for the bottom two dates, which were on plant macrofossils. All dates plot on a reasonably straight line with the exception of the dates of 11,140 and 12,910 years B.P. We suspect that these are too old as a result of reworked pollen deposited in the lake as it was first refilling at the end of the late Pleistocene arid interval. The two bottom ages are less likely to have been influenced by reworking because of the material dated.

The uppermost transparent layer comprises Holocene lacustrine diatomaceous mud. It is thickest in the eastern, deepest part of the lake and thins gradually to the west, where there are extensive outcrops of the underlying sediments (Fig. 3). Five of the seven cores that we recovered from the lake penetrated the entire Holocene sequence and sampled a soil horizon. This horizon is clearly defined by profiles of magnetic susceptibility (Fig. 4) and water content in the cores, the presence of vertically oriented rootlets, and prismatic cracking characteristic of vertisols. Similar features have been described from Lake Victoria cores, but their locations were restricted to shallower water in the northern margin of the lake (*9*, *15*).

Our deepest core, V95-2P, recovered from a depth of ~67 m (Fig. 1), clearly shows the soil horizon with vertical rootlets at the depth where the porosity drops to 50%. Pollen is poorly preserved in the vertisol and is derived mostly from grasses. The Holocene sediment immediately overlying the vertisol, representing the earliest stage of the new lake, is dominated by *typha* (cattail) pollen. [We recovered a core in May 1996 from the deepest site in the lake (68 m), midway between sites V95-2P and V95-3P depicted in Fig. 1, and again recovered vertisol at the base of unit A.] This deepest part of the lake is not separated from the major inflowing rivers by any ridge that would pond water in another part of the basin. If this site was dry, then the entire lake basin was dry, at least on a seasonal basis. This conclusion is supported by our seismic reflection profiles, which show that the hard reflector is present everywhere beneath the Holocene diatom muds. An accelerator mass spectrometer (AMS) radiocarbon date on plant macrofossils taken from just above the soil horizon at site V95-2P indicates an age of 12,400 ± 70 ^{14}C years B.P. (Fig. 4). This age marks the onset of flooding of the lake basin at this site.

The lake level fell at ~17,300 ^{14}C years B.P. (*9*). If the deepest part of the lake basin was desiccated for several thousand years during the late Pleistocene, there would have been no lake-derived moisture, which contributes nearly 50% of the rainfall in the region today (*16*). Under these circumstances, satellite lakes could not have existed within the Victoria basin at that time. This result negates the possibility that the hundreds of endemic species of fish in modern Lake Victoria found adequate refuge during the arid period to maintain the diversity that they exhibit today. The alternative is that most of these species have evolved during the past 12,400 years. This conclusion is supported by evidence for the rapid speciation of cichlids in Lake Malawi (*17*) and by mitochondrial DNA evidence that the Lake Victoria species flock is young, certainly less than 200,000 years old and perhaps as young as 14,000 years, and is monophyletic or derived from a single ancestral species (*18*). Our results indicate that this evolution occurred in the past 12,000 years. The rich diversity of Lake Victoria cichlids is clearly associated with lacustrine instability, not with an ecosystem that has been well buffered from environmental disturbance.

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Simultaneous Measurement of Local Gain and Electron Density in X-ray Lasers

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X-ray lasers (XRLs) have experimental average gains that are significantly less than calculated values and a persistently low level of spatial coherence. An XRL has been used both as an injected signal to a short XRL amplifier and as an interferometer beam to measure two-dimensional local gain and density profiles of the XRL plasma with a resolution near 1 micrometer. The measured local gain is in agreement with atomic models but is unexpectedly spatially inhomogeneous. This inhomogeneity is responsible for the low level of spatial coherence observed and helps explain the disparity between observed and simulated gains.

Since the first demonstration of a collisionally excited laboratory-produced XRL in 1985 (*1*), much effort has been devoted toward understanding the production of the laser and enhancing the features that make XRLs powerful laboratory tools (*2*, *3*). The gain medium for the XRL is a plasma created by the heating of a target foil with an intense optical laser focused into a line along which amplification occurs. Atoms in the target plasma are ionized to a long-lived state, such as a neon-like state, and electron collisions within the plasma excite the upper lasing level, which spontaneously decays, emitting a photon at the laser wavelength λ. Amplification continues for as

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