Journal of Paleolimnology **24:** 231–235, 2000.

The International Decade of East African Lakes (IDEAL) drilling initiative for the African Great Lakes

A. S. Cohen,[1] C. A. Scholz[2] & T. C. Johnson[3]
[1]*Department of Geosciences, University of Arizona, Tucson, AZ 85721, USA (E-mail: acohen@geo.arizona.edu)*
[2]*Department of Earth Sciences, Syracuse University, Syracuse, NY 13244-1070, USA (E-mail: cascholz@syr.edu)*
[3]*Large Lakes Observatory, University of Minnesota, Duluth, MN 55812, USA (E-mail: tcj@d.umn.edu)*

Received 3 March 2000; accepted 7 March 2000

Key words: paleoclimate, tropical lakes, rift lakes, species flocks, human evolution, Lake Malawi, Lake Tanganyika

Background

The Great Lakes of East Africa are one of the most exciting targets for obtaining long core records on Earth. Since their early exploration by 19th century naturalists their unique geological and biological attributes have been objects of curiosity for scientists from a wide range of disciplines. Since early in the 20th century it has also been evident that an extremely long and detailed history of regional paleoclimate and paleoenvironments could be gleaned from the study of their sediments. Beginning in the 1980s seismic reflection profiling of Lakes Malawi and Tanganyika revealed extremely thick packages (up to several km) of rift-related sediments lying on the bottoms of these lakes (Rosendahl et al., 1986), indicating histories extending back to the Miocene.

The International Decade of the East African Lakes (IDEAL) was formed to promote investigation of these limnological and paleolimnological aspects of the African lakes. IDEAL is a multidisciplinary science initiative and is a component of the PAGES Core Project within IGBP. One of the central themes of IDEAL since its inception has been to advance our understanding of the history of the African Great Lakes through coordinated programs of paleolimnological and paleoclimate research (Johnson & Odada, 1996). Much of this work to date has involved the collection and interpretation of relatively short core records and seismic data on the various Great Lakes, to better define the most promising target areas for a program of scientific drilling. Our long-term goal is to obtain climate and paleoenvironmental records that cover the past several million years at stratigraphic resolutions comparable to ice cores, but in a part of the world that has been critical for ecosystem (and notably human) evolution.

Obtaining such records is now within our grasp. The recent decision of the International Continental Drilling Program (ICDP) and the US National Science Foundation (NSF) to fund the purchase and testing of the GLAD 800 drilling system means that a community resource for deep lake drilling will be available within the next few years. Given this recent development and a background of considerable prior research in the Great Lakes region, the IDEAL Steering Committee sponsored a planning workshop for a drilling campaign on what are arguably the two most exciting targets of 'deep-time' paleolimnological research on Earth, Lakes Malawi and Tanganyika.

The IDEAL drilling workshop

The NSF/ICDP/IDEAL-sponsored workshop was held October 10–16, 1999, at Club Makakola, on the southwest shore of Lake Malawi. A group of 47 scientists, engineers and local government ministry representatives attended this meeting, with representatives of 11 countries in attendance. The structure of the workshop was kept relatively informal to promote a maximum amount of time for detailed discussion of potential science and drilling objectives, and to allow the maximum give and take between the enthusiastic science groups and the pragmatic engineering groups in attendance. The workshop had two ultimate goals:

1. identify the most important scientific questions that could be addressed from drilling these two lakes for

the various disciplines interested in the project: paleoclimatology, continental dynamics, evolutionary biology and paleoecology, and hominid evolution,
2. identify promising target areas for drilling, recognizing that not all of the science objectives arising from the wide array of scientific disciplines supporting this endeavor can be met from a single drill site.

The first two days of the conference were used for formal introductory remarks, engineering reviews and science overviews concerning our state of knowledge of the two lakes and their histories. The importance that the government of Malawi attaches to the successful completion of this project was evident from the attendance and opening remarks of the Honorable Minister of Natural Resources and Environmental Affairs, Harry Thompson. Both Malawian and Tanzanian governmental officials indicated their strong support for seeing this project move forward and their eagerness to be active participants in all scientific aspects of the project. These are important steps in what will no doubt be a complex international operation.

The participants then considered the implications of this drilling project for regional development concerns in natural resources and education. Ulrich Harms (ICDP) and Steve Colman (US NSF and member of the Science Advisory Group of ICDP) discussed the structure of ICDP, its funding priorities, and the background of lake site consideration and prioritization for PAGES and ICDP. Dennis Nielsen from DOSECC (the U.S. continental drilling consortium) discussed the drilling potential of the GLAD 800 rig, a modified Christiansen 1500 mining engineering drill rig for which DOSECC will develop appropriate coring tools. This rig can be barge or ship-mounted, and can support up to 800 m of ODP-equivalent drill string, or up to 1200 m of slightly narrower string, placing those constraints on the combined water+sediment drilling depths from which the rig can operate (for example, using the 800 m design, to collect up to 300 m of continuous core in 500 m water depth). The first day concluded with an overview of the limnology of Lake Malawi, presented by Harvey Bootsma (University of Wisconsin-Milwaukee). For a variety of logistical reasons Lake Malawi is IDEAL's preferred first target among the two lakes, and was the focus of most detailed engineering and logistical considerations for the workshop attendees.

On the second day a series of science overviews presented the workshop attendees with our current state of knowledge of the rift context of the two lakes, and our current knowledge of their paleoclimate and evolutionary biological histories. Andy Nyblade (Pennsylvania State University) explained the geophysical and regional geological context of the two lakes, with emphasis on illustrating the major tectonic questions remaining to be resolved in the region. Jean-Jacques Tiercelin (University of West Brittany) and Kiram Lezzar (Syracuse University) gave presentations on the tectonic and stratigraphic framework of Lake Tanganyika as it is currently understood, emphasizing existing sedimentological and seismic stratigraphic data collected over the past 20 yrs. Chris Scholz (Syracuse University) and Leonard Kalindekafe (Malawi Division of Mines) gave similar overviews for Lake Malawi, looking at the relationship of sediment input to tectonic setting and our understanding of sedimentary mineral formation as an indication of paleoenvironmental history. Seismic records and prior coring efforts provide abundant evidence that these two lakes have undergone significant (100s of m) lake level fluctuations during the Pleistocene, variations that are primarily climate controlled and probably operate on Milankovitch time scales (Figure 1). Fundamental issues in tectonics and basin analysis that will be addressed by drilling Lakes Malawi and Tanganyika include:

1. determining the principal controls on deposition of the main sedimentary facies in tropical rift basins,
2. determining the rates of basin forming and filling processes and watershed development,
3. determining the rates of earthquake recurrence and other aspects of active tectonics of the rift, and their relationship to the recent geomorphic evolution of the rift uplifts and basin,
4. determining the nature of heat flow across the lake basins, and the effect of thermal history on the evolution of extensional faulting,
5. determining the history and directionality of rifting and responses of the rift basins to fundamental lithospheric stresses, and
6. combining uplift and depositional histories to unravel aspects of deep crustal and upper mantle evolutionary constraints on the history of rifts.

A series of presentations on the potential of the two lakes to provide important and long paleoclimate records followed. Tom Johnson (Large Lakes Observatory, University of Minnesota, Duluth), Françoise Gasse (CNRS), and Chris Scholz (Syracuse University) discussed the extraordinary potential these two ancient lakes have for providing long and extremely high resolution (frequently annually laminated) records over a significant

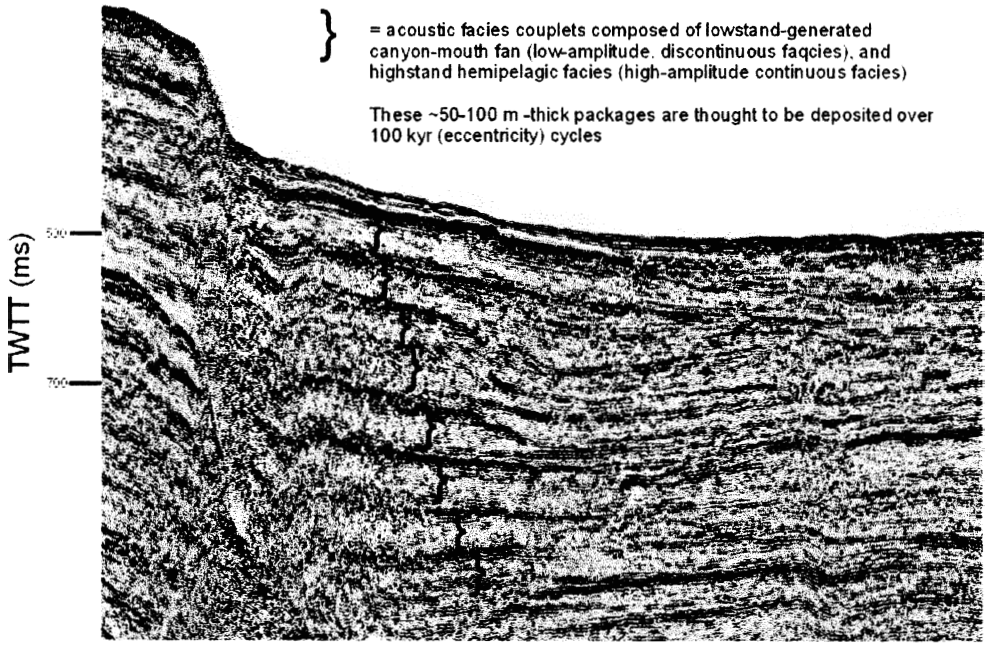

Figure 1. Acoustic facies couplets observed on a central L. Malawi seismic profile, suggesting 100 kyr lake level and depositional cyclicity. Almost identical cyclicity is observed in seismic profiles from Lake Tanganyika.

latitudinal range of the African tropics. Important issues in paleoclimatology that will be addressed by drilling Lakes Malawi and Tanganyika are addressed on two time scales – Milankovitch orbital frequencies (millennial) and the higher resolution annual to century scale variability. On the millennial scale:

1. What is the climatic linkage between tropical Africa and the high latitudes at orbital and longer-period time scales?
   – Did tropical African climate predominantly respond to changes in low-latitude precessional insolation (23–19 kyr) or high-latitude ice volume (100 kyr and 41 kyr) forcing?
   – Has Lake Malawi always responded to southern hemisphere insolation forcing, as data for the period since the last 40 kyr suggest?
2. What is the long-term evolution of tropical East African climate?
   – What is the dominant Milankovitch frequency back through time? i.e. do we see a shift from the present day 100 kyr dominance to 41 kyr dominance to 21 kyr dominance, as observed in the marine record?
   – In this region of tropical Africa, do we see a significant change in vegetation as the Earth shifted from a 41 kyr world to a 100 kyr world?

On the time scale of years to centuries:

3. Are high-frequency climate variations such as the Little Ice Age (LIA) (analogous to Dansgaard-Oeschger or Heinrich events) superimposed on glacial-interglacial time scale variations in wet and dry conditions, and how have these varied over time?
4. How has interannual African climate variability changed in association with longer-term climate variations?
   – What are the dominant interannual modes of variability (ENSO, NAO)? - How have these modes changed in association with changes in African climate?

Eric Odada (University of Nairobi) placed the potential of long paleoclimate records into a regional planning and educational framework. A major goal of IDEAL since its inception has been fostering the development of regional capacity in East Africa for undertaking paleoclimate and limnologic research at local institutions. Eric discussed how the drilling project might help achieve these ends. Peter deMenocal (Lamont Doherty Earth Observatory, Columbia University) discussed the potential of this record of climate change to resolve important issues of orbital forcing effects on the continents over multiple glacial/interglacial cycles, and the implications such a record would have for understand-

ing hominid evolution. Rick Potts (Smithsonian Institution) amplified on this latter theme, *in abstentia*, through a memo on the significance of African Great Lakes drilling for human evolution studies, circulated to workshop participants.

Lakes Malawi and Tanganyika house enormous numbers of endemic species of fish and invertebrates, and have become textbook cases of evolution in isolation. Andy Cohen (University of Arizona), Ellinor Michel (University of Amsterdam) and Lisa Park (University of Akron) presented a summary of our current knowledge of these extraordinary 'species flocks' and how scientific drilling would allow qualitative advances in this understanding. Important questions that could be addressed with invertebrate and diatom fossil records from the lakes include:

1. What is the tempo and mode of diversification during species radiations and subsequent extinctions?
2. Can changes in these rates be linked to specific external forcing mechanisms, in particular climatically-induced lake level fluctuations or tectonically-induced changes in basin configuration?
3. What has been the tempo and mode of ecological change and development of species interactions in the complex and diverse ecosystems of these two lakes?

The science overviews were concluded with a presentation by John King (University of Rhode Island) of the potential for obtaining good geochronologic age models from the lakes for the pre-radiocarbon portions of their histories using geomagnetic techniques. This led into a more general group discussion of various geochronologic tools of potential benefit to the African lakes drilling project.

Over the next two days of the workshop breakout groups and plenary discussions refined the goals of drilling, considered hypotheses that could realistically be tested given the constraints of the drilling rig and coring tools, and discussed potential target sites in the two lakes. A white paper with a detailed discussion of our objectives has been prepared for NSF and ICDP and is available from its senior author (C.A. Scholz) on request. We considered various combinations of deep water and shallow water sites, coupled with offset drilling, to achieve the different objectives of the various research groups represented. For example, the highest resolution and longest duration paleoclimate records are likely to be obtained from very deep basinal sites that have undergone little or no desiccation during the lake's histories, and obtaining such records is one of our highest priorities. However these sites will not be best suited for certain questions pertaining to paleoclimate or evolutionary biology, which require shallower sites, or sites situated closer to the northern and southern ends of the lake basin, where a broader range of proxy signals may be found. The engineering group (Gene Pollard, ODP liaison to ICDP, and Robert Goodden, Seacore Ltd.) presented its preliminary recommendations for a positioning system and platform, based on the developing consensus of target localities, probable wave environments and water depths. These recommendations, along with previously commissioned ICDP engineering studies and refined with forthcoming logistical and safety information, will form the basis of an informed operations proposal to ICDP and NSF for funding the drilling operation.

Conclusion

We are entering a very exciting phase in the developing understanding of the history of the African Great Lakes. Qualitative advances in our knowledge of climate history, tectonic and biologic evolution of rift lakes, and the environmental context of human evolution may well arise from drilling efforts on Lakes Malawi and Tanganyika over the next decade. Events are moving quickly; since the initial submission of this report both ICDP and NSF have decided to fund the drilling proposals for Lake Malawi, with field work to begin in 2002.

Acknowledgements

We would like to thank NSF and ICDP for financial support of this and previous IDEAL and deep lake drilling workshops (NSF ATM-9818267 and ATM-0000411 to Syracuse University). Thanks also to the government and ministries of Malawi represented at the workshop for their enormous efforts in making this meeting a success. This is contribution #81 of the International Decade of the East African Lakes.

References

Johnson, T. C. & E. O. Odada, 1996. The Limnology, Climatology and Paleoclimatology of the East African Lakes. Gordon and Breach Publ., Amsterdam, 664 pp.

Rosendahl, B. R., D. J. Reynolds, P. M. Lorber, C. F. Burgess, J. McGill, D. Scott, J. J. Lambiase & S. J. Derksen, 1986. Structural expressions of rifting: lessons from Lake Tanganyika, Africa. In Frostick, L. E., R. W. Renaut, I. Reid & J. J. Tiercelin (eds), Sedimentation in the African Rifts. Geol. Soc. London Spec. Publ. 25: 29–43.