



Paleoenvironments, Evolution, and Geomicrobiology in a Tropical Pacific Lake: The Lake Towuti Drilling Project (TOWUTI)

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Lake Towuti (2.5°S, 121°E) is a, 560 km², 200-m deep tectonic lake at the downstream end of the Malili lake system, a set of five, ancient (1-2 MYr) tectonic lakes in central Sulawesi, Indonesia. Lake Towuti's location in central Indonesia provides a unique opportunity to reconstruct long-term paleoclimate change in a crucially important yet understudied region- the tropical Western Pacific warm pool, heart of the El Niño-Southern Oscillation. The Malili Lakes have extraordinarily high rates of floral and faunal endemism, and the lakes are surrounded by one of the most diverse tropical forests on Earth. Drilling in Lake Towuti will identify the age and origin of the lake and the environmental and climatic context that shaped the evolution of this unique lacustrine and terrestrial ecosystem. The ultramafic (ophiolitic) rocks and lateritic soils surrounding Lake Towuti provide metal substrates that feed a diverse, exotic microbial community, analogous to the microbial ecosystems that operated in the Archean Oceans. Drill core will provide unique insight into long-term changes in this ecosystem, as well as microbial processes operating at depth in the sediment column.

While the Malili Lakes have long been considered high-priority drilling sites, only now do we have the requisite site survey information to propose the development of ICDP's first lake drilling target in the tropical western Pacific. High-resolution seismic reflection data (CHIRP and airgun) combined with numerous long sediment piston cores collected from 2007-2010 demonstrate the enormous promise of Lake Towuti for an ICDP drilling campaign. Well-stratified sequences of up to 150 m thickness, uninterrupted by unconformities or erosional truncation, are present in multiple sub-basins within Towuti, providing ideal sites for long-term environmental, climatic, and limnological reconstructions. Multiproxy analyses of our piston cores document a continuous and detailed record of moisture balance variations in Lake Towuti during the past 60 kyr BP, highlighted by arid conditions during northern hemisphere stadials and the last glacial maximum, followed by a dry early and wet late Holocene. This history suggests that climate in central Indonesia responds most strongly to high-latitude climate forcing, despite Indonesia's remote location, and secondarily to southern hemisphere insolation forcing, a hypothesis we aim to test across multiple glacial-interglacial cycles through scientific drilling. Indeed, numerous high-amplitude reflectors in the upper 150 m of lacustrine fill suggest repeated cycles of moisture-balance variations in the tropical Pacific.

The principal objectives of our proposed ICDP deep drilling initiative are to:

- (1) Document the timing, frequency, and amplitude of orbital- to millennial-scale changes in surface hydrology and terrestrial temperature in the Indo-Pacific Warm Pool across multiple glacial-interglacial cycles;
- (2) Understand how variations in terrestrial hydrology and temperature in central Indonesia respond to changes in the mean state of the ENSO system, the monsoons, high-latitude forcing, and insolation;
- (3) Analyze the long-term stability and resilience of rainforest vegetation to changes in climate, greenhouse gases, and fire frequency;
- (4) Study the extent, biogeography, and metabolism of microbial life in the sediments of a non-sulfidic, ferruginous basin, and their relationships to carbon cycling, redox metal deposition, and the concentration of metal ore minerals;

- (5) Study the effects of climate-driven changes in the aquatic environment on both lacustrine microbial populations, and the geobiosphere within the lake's sediment;
- (6) Determine the age of Lake Towuti, and the ensuing rates of speciation of Towuti's endemic fauna and flora;
- (7) Identify the timing of past lake level fluctuations in Towuti, changes in hydrological connections among the Malili Lakes, and how these influenced biological colonization events, habitat stability, and modes of speciation (sympatric, allopatric).

We established an international science team, reviewed datasets from the site survey, and selected three drill sites that are best suited to address the objectives of the TOWUTI project during an ICDP and NSF sponsored workshop held in Bandung, Indonesia in March 2012. Important milestones concerning the operational and logistical preparation of a deep drilling at Lake Towuti have been achieved by the PI team in close collaboration with DOSECC, local authorities and businesses in Indonesia, and ICDP. A drilling proposal has been submitted to ICDP in January 2013 and proposals for matching funds will be submitted to national funding agencies in the course of 2013. Drilling operations are envisaged to commence in early 2015.