

Offshore bathymetric mapping at the mouth of the forested Kalande and deforested Ngelwa watersheds, Lake Tanganyika, Tanzania: Influence of rift tectonics on sedimentary pathways and accumulations

Student: Emily Hamecher Astley

Mentor: Kiram Lezzar

Introduction

During the Nyanza Project 2006 field season, the geological research team focused on paleoclimate issues and anthropogenic effects within two watersheds feeding into Lake Tanganyika, north of Kigoma, Tanzania. The goals of these investigations were to determine what differences exist between the forested Kalande Stream watershed, located in the protected Gombe Stream National Park, and the deforested Ngelwa Stream watershed, located north of the fishing village of Mtanga (just south of the National Park).

Lake Tanganyika is located in the Western Branch of the East African Rift Zone, and is composed of a series of half grabens formed by the N-S and NW-SE fault bounded edges of the trough in which it lies (Rosendahl et al., 1986). The drainages alternate between steep fault escarpments and shallowly dipping platforms. The study location is located in an escarpment margin drainage, consisting of steep gradients with no significant fan deltas. Previous sedimentologic studies of this area have shown that the bathymetry of the lake floor is steep, and that the water depth drops to 200 m within 2 km of the shoreline, due to a major basin border fault (Soreghan and Cohen, 1996).

In this project, high-resolution echosounder profiling was used to investigate the bathymetry of the lake bottom offshore of each watershed. The echosounder emits acoustic energy (sound pulses) through the water, to the bottom of the water body, where the energy is reflected back to the transducer. The water depth is determined by the length of time it takes between the transmission of the energy and the detection of the reflected energy by the transducer. A goal of this project was to produce bathymetric maps of the lake floor where each stream enters the lake, to constrain the geomorphology of the littoral escarpment margins and to determine what differences in sediment discharge, if any, exist between the two watersheds. In addition to the bathymetry, the survey provided information to create depth profiles (cross sections) of the lake bottom. These profiles provide a wealth of information for comparison of the two areas: differences in slope of the lake bottom, extent of the offshore platforms, and location of tectonic features, such as tilted blocks, border faults, and sub-lacustrine channels and canyons. The bathymetric survey also provided the other members of the geological research team with the information required to identify appropriate locations for grab sampling and gravity coring.

Methods

Bathymetric data was collected at the two study locations north of Kigoma. Several transects of bathymetric data were taken, forming a grid of data points. Data was continuously recorded by hand at 60-second intervals, from the *R/V Echo*, traveling along planned transects at a speed of approximately 3.5 knots. The depth information was obtained using a Raytheon V8010 Color Echosounder, and latitude and longitude coordinates were taken using a GPS unit mounted onboard the *R/V Echo*.

As our sites were previously unexplored nearshore, a reconnaissance trip was initially taken on the *R/V Echo* to record preliminary bathymetry data, in order to help my teammates determine appropriate sites for grab sampling and gravity coring off the *M/V Maman Benita* the following week. Three transects were taken off each stream: one extending approximately orthogonal offshore of the stream mouth, a second extending northwest, and the third to the southwest. These transects were run to a greater depth than required for the purposes of this project; a maximum depth of 715 m offshore of Kalande and 950 m offshore of Ngelwa were recorded. GPS locations and depth information from the echosounder were recorded for each grab sample and gravity core attempt, and these data were also included as points in the bathymetric grid (Figure1).

Following the reconnaissance mission and field cruise, additional EW and NS transects were plotted in ArcView GIS, in order to determine the GPS points needed to direct the *R/V Echo* to, for completion of the grid for the bathymetric survey. Five approximately EW transects, three short NS transects, and one long NS transect were run

for the Ngelwa location; six approximately EW transects, two short NS transects and one long NS transect were run for the Kalande location (Figure 2). These transects formed a dense grid of points, with an approximate 500 m interval between transect lines. The depth, latitude, and longitude data collected for each point were later entered into ArcView GIS. All of the data points collected with depths down to 160 m were used to create the grid, since both the “land-water interaction (0-60 m)” and the “deep-water paleoclimate (60-160 m)” groups of the geological research team needed the maps. Then, using the Create Contours command in ArcView GIS, smooth contours were created to connect common water depth points, thus producing bathymetric maps offshore of the two watersheds.

Results

Bathymetric map for the forested Kalande watershed (Figure 3)

The Kalande stream enters the lake, and initially forms a wide channel in the shallow water platform (SWP). This channel marks a boundary between a high angle platform to the north, and a lower angle platform to the south. The northern platform extends to a distance of approximately 330 m offshore and to a water depth of about 45 m. The southern, shallow dipping platform extends approximately 480 m offshore and to a water depth of 55 m. A shallow water delta lobe (SWDL), an area of some sediment accumulation, is evident in the bathymetry. Lakeward of the shallow water platform, the contours become much tighter and more V-shaped, indicating a steep canyon. This canyon can clearly be seen in the profile of the long NS transect, LT10 (Figure 4). North of the canyon, the slope of the lake bottom becomes very steep with a NS trend, while south of the canyon, a more gently sloping NE-SW trend is seen. The slope angle of the steepest slope (maximum found in our studied areas) to the north of the canyon is 25 degrees, while the slope angle south of the canyon is 16 degrees, showing that the slope of the lake bottom decreases south of the stream. At the foot of the steep slope, the contours again widen and become more U-shaped, where the canyon becomes a wide channel. Here, the bathymetry shows what appears to be a deep lacustrine fan delta (DLFD). This area is also seen as a flat on DT4 (Figure 5). However, repeated attempts at gravity coring on this flat were unsuccessful, suggesting that little or no soft sediment is accumulating here

Bathymetric map for the deforested Ngelwa watershed (Figure 6)

Ngelwa shows a much narrower littoral zone than that of the Kalande. The northern platform extends to a distance of approximately 150 m offshore and to a water depth of about 55 m. The southern, shallow dipping platform extends approximately 200 m offshore and to a water depth of 55 m. A shallow water delta lobe is also evident here, with a wide channel entering the lake. However, this channel is restricted to the mouth of the stream, and rapidly becomes a steep canyon, with a much steeper gradient closer to the shoreline than that seen in the bathymetric map of the Kalande. The same trend is seen in the steep slope here as in that of the Kalande: north of the canyon, a NS trend is evident, while south of the canyon, a NE-SW trend is seen. The slope angle of the steep slope to the north of the canyon is 20 degrees, whereas the slope angle south of the canyon is 15 degrees. However, in this map, a deep lacustrine fan delta is not seen in the bathymetry, but we know that soft sediments are present in this flat area, since a core was collected at 106 m (Figure 7).

Discussion & Conclusion

The bathymetry of both areas shows NS and NE-SW trending fault blocks. This suggests that the streams are entering in an area of fault linkages, which is common in rift environments (Lezzar et al., 2002).

The bathymetry shows that the deforested Ngelwa has a narrower littoral zone than forested Kalande. We expected to find wider area of sediment accumulation offshore the deforested area, since deforested streams carry more sediment than forested streams. The steep gradient offshore of Ngelwa allows the sediments to be carried away from the shallow water platform quickly, explaining why there is not much of an accommodation area for the sediments close to shore. This interpretation is confirmed by the presence of coarse sediments in the core recovered from 106 m.

The bathymetric map offshore from the Kalande watershed shows the location of a deep lacustrine fan delta. However, no soft sediments were recovered by gravity coring in this area. This area could be interpreted as an old shallow water platform delta, a remnant of a time of when the lake level was lower than it is today. Alternatively, this flat area could be a paleo-delta fan, formed during a period of past deforestation, before the area was protected as a national park. A deep lacustrine fan delta is not shown in the bathymetric map offshore of Ngelwa, although we

know that sediments have accumulated in this flat area, since this is the location of the recovered gravity core. The concentration of data points in this location is very coarse, and a denser grid of data is required in order to accurately represent the bathymetry in this area.

The Kalande and Ngelwa watersheds were chosen for this year's study because of rough offshore seismic data from previous studies and similarities in their onshore characteristics: surface area, gradient, and lithology. However, a major finding of this bathymetric study is that the topographic features seen on land are not sufficient to correlate the offshore behavior of two similar watersheds. In future work, preliminary high-resolution, high-penetration acoustic surveys should be undertaken prior to sediment sampling. Additionally, a much higher density of data points is needed to accurately represent the bathymetry of a complex tectonic system such as that of the littoral zone of Lake Tanganyika.

Acknowledgements

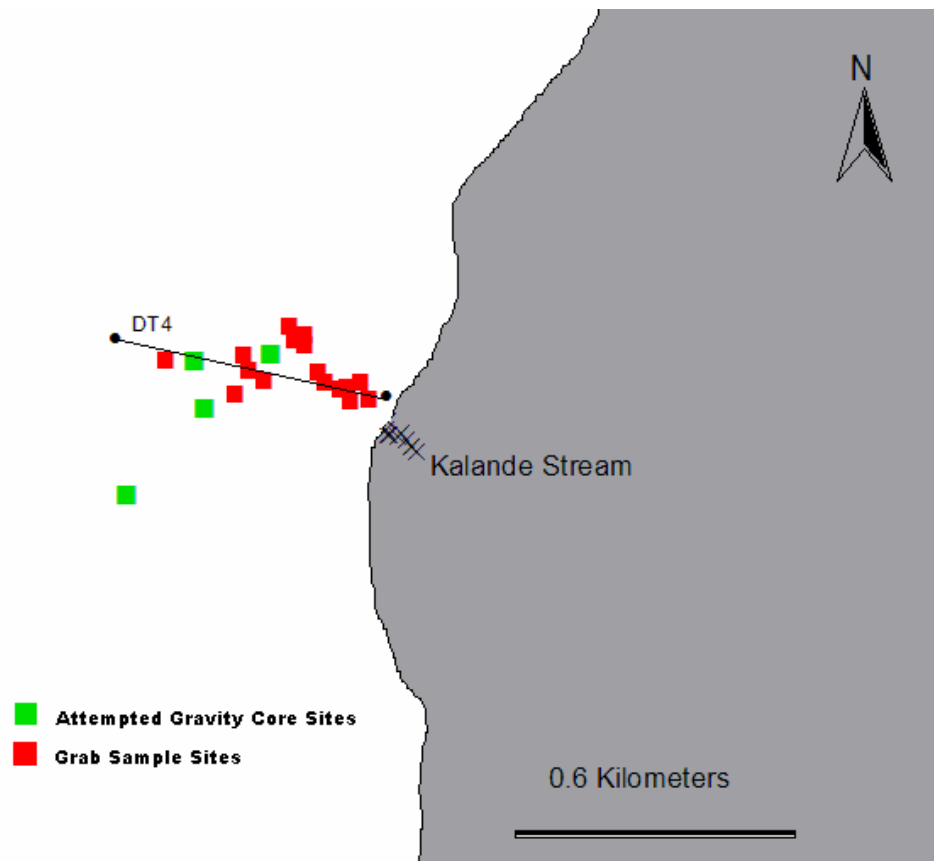
Many thanks to Kiram Lezzar and Mike Soreghan for their guidance and expertise in the design and completion of this project. I would also like to thank the crews of the *R/V Echo* and the *M/V Maman Benita*, as well as Mike Strickler for his introduction to ArcView GIS. This project would not have been possible without the assistance of the Tanzanian Fisheries Research Institute (TAFIRI), the University of Arizona, the University of Dar es Salaam, the Tanzanian Government. This research was supported by NSF grants ATM 0223920 and DBI-0608774.

References

Lezzar, K.E., Tiercelin, J.-J., Le Turdu, C., Cohen, A.S., Reynolds, D.J., Le Gall, B. & Scholz, C.A., 2002, Control of normal fault interaction on the distribution of major Neogene sedimentary depocenters, Lake Tanganyika, East African Rift: *AAPG Bulletin*: "The Structure and Sequence Stratigraphy of Rift Systems"

Rosendahl, B. R., D. J. Reynolds, P. M. Lorber, C. F. Burgess, J. McGill, D. Scott, J. J. Lambiase, and S. J. Derksen, 1986, Structural expressions of rifting: lessons from Lake Tanganyika, Africa, *in* L. E. Frostick, R. W. Renaut, I. Reid, and J. J. Tiercelin, eds., *Sedimentation in the African rifts*: Geological Society Special Publication 25, p. 127-139.

Soreghan, M. J., and A. S. Cohen, 1996, Textural and compositional variability across littoral segments of Lake Tanganyika: the effect of asymmetric basin structure on sedimentation in large rift lakes: *AAPG Bulletin*, v. 80, p. 382-409.



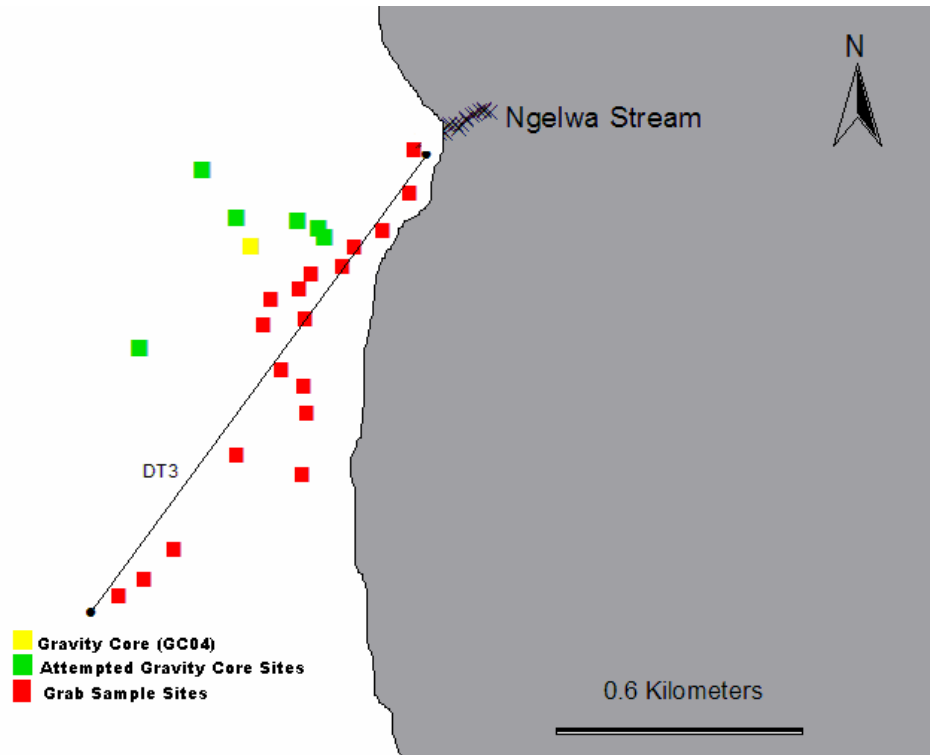


Figure 1. Location of grab samples and gravity cores

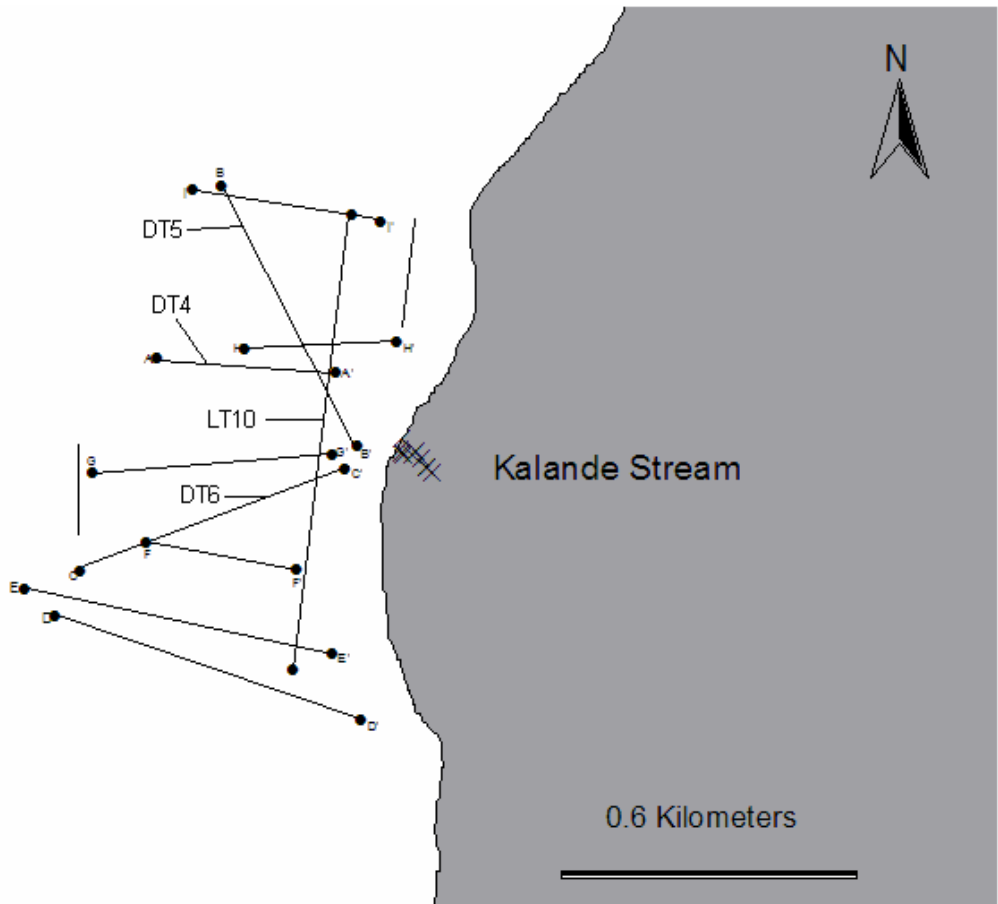
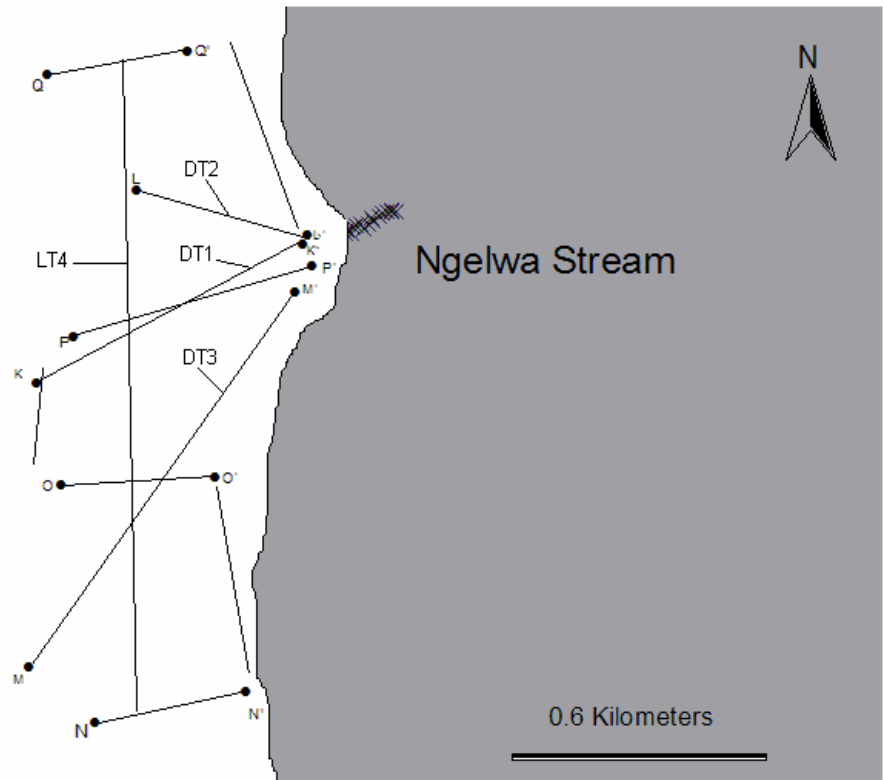
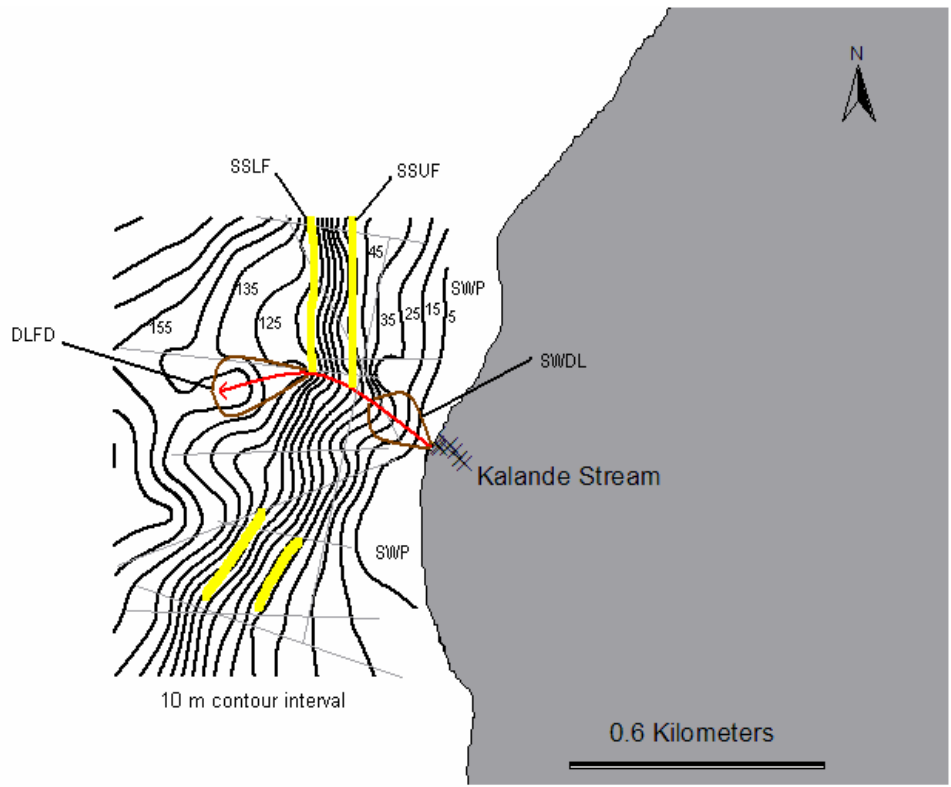


Figure 2. Location of transect lines



Bathymetric map at mouth of forested Kalande watershed showing Shallow Water Platforms (SWP), Shallow Water Delta Lobe (SWDL), Deep Lacustrine Fan Delta (DLFD), Steep Slope Upper Fault (SSUF), and Steep Slope Lower Fault (SSLF)

Figure 3. Bathymetric map offshore of the forested Kalande Stream

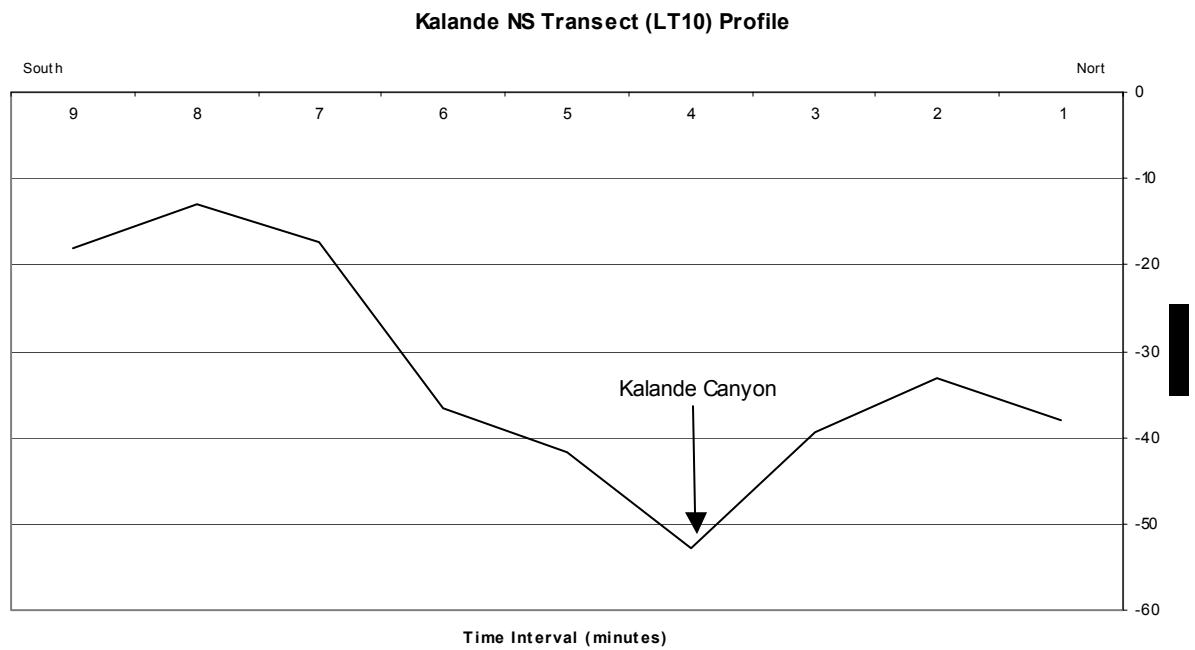


Figure 4. NS transect profile offshore of forested Kalande Stream

Kalade Depth Profile (DT4) with Grab Sample Locations

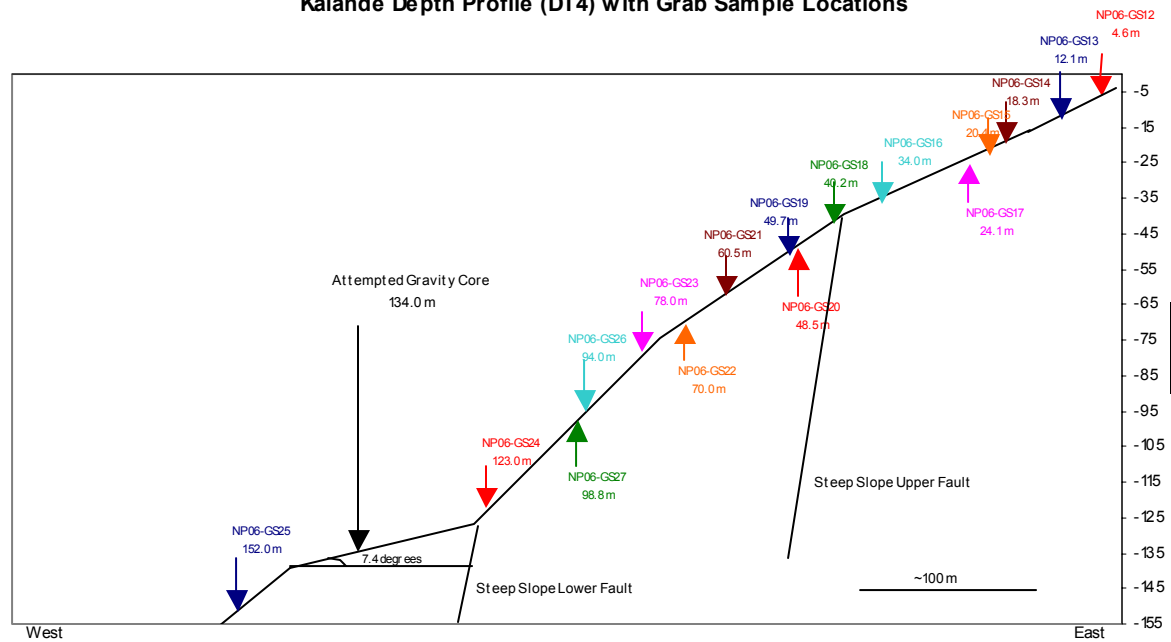
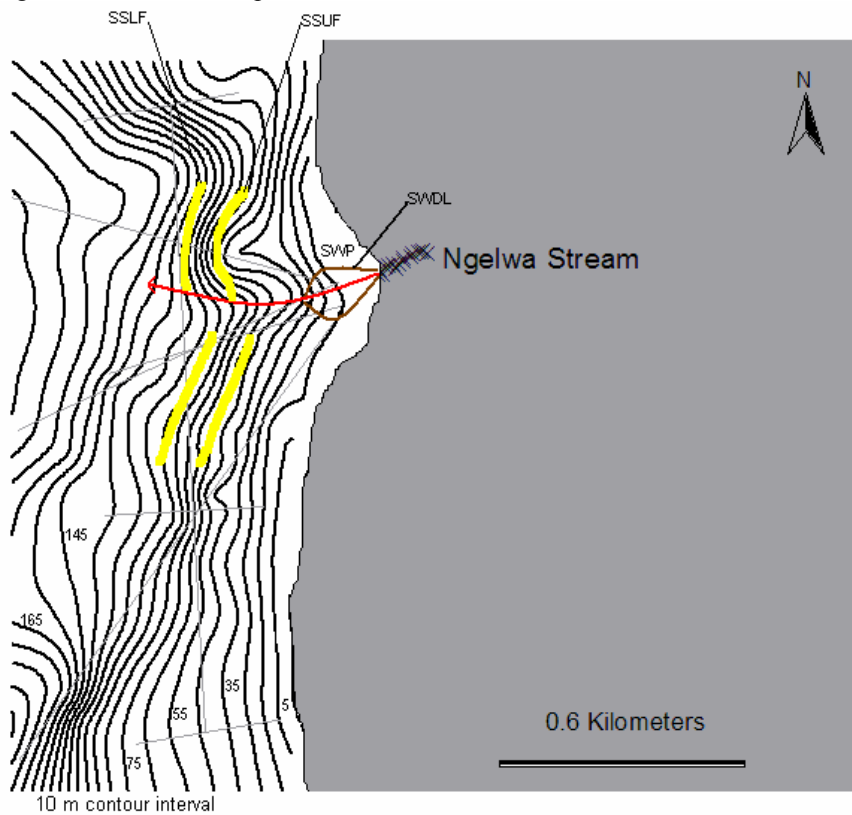


Figure 5. Kalade DT4 profile



Bathymetric map at mouth of deforested Ngelwa watershed showing Shallow Water Platform (SWP), Shallow Water Delta Lobe (SWDL), Steep Slope Upper Fault (SSUF), and Steep Slope Lower Fault (SSLF).

Figure 6. Bathymetric map offshore of the deforested Ngelwa Stream

Ngelwa Depth Profile (DT3) with Grab Sample Locations

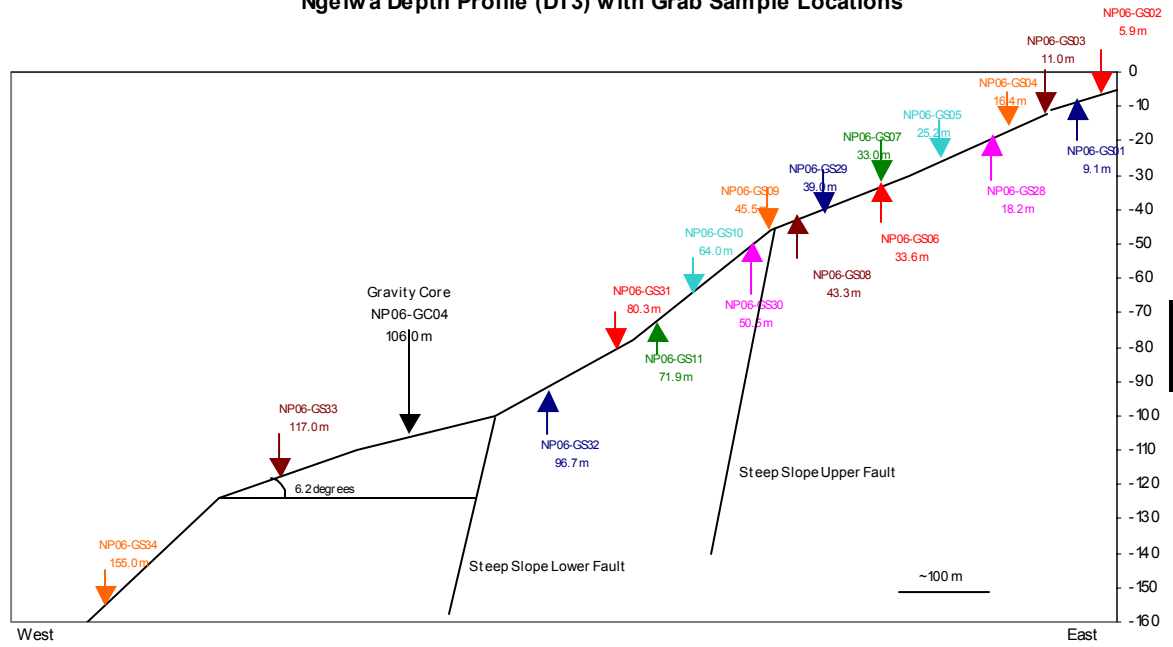


Figure 7. Ngelwa DT3 profile