Seismic Reflection Studies in Support of Scientific drilling for human origins: Exploring the Application of Drill-Core Records to the Understanding of Hominin Evolution (Assembled Dataset 15-011)

PI: Dr. Roy A. Johnson
University of Arizona

Experiment Description

This experiment was designed to acquire relatively high-resolution 2-D multichannel seismic reflection data to help characterize the thickness and structure of lacustrine sedimentary rocks in the Ledi-Geraru area of Ethiopia and the western Lake Turkana area of northwestern Kenya. The areas of study are located very near significant hominin fossil localities to help guide scientific drilling and recovery of sediment cores for paleoclimatic analyses. Data collection on the first of two intersecting seismic profiles in Ethiopia began on May 19, 2008 south of the Weranso River near the town of Mille. Data collection was completed on the second profile in Ethiopia on May 26, 2008. Equipment was transferred to Kenya, where recording on another two intersecting profiles on the western side of Lake Turkana began on June 13 and ended on June 23, 2008.

In each of the two survey areas, two intersecting linear seismic reflection transects were acquired using a 100-lb (45-kg) hydraulic, nitrogen-gas-accelerated weight-drop seismic source rented from Geo-Survey Systems, Conroe, Texas. The source energy was normally recorded into 72 receiver channels for each source impact. Ten source impacts at each source location (with a few exceptions) were summed during recording to produce each shot record. Receiver-station (geophone) spacing used in the acquisition phase of the experiment normally was 5 m, and normal source-station spacing was 10 m. For Turkana Line 2, station spacing was 2.5 m and source spacing was 5 m. Field acquisition parameters were determined by tests in the field at the beginning of the project to produce the best results under extant conditions and time constraints.

General Data Acquisition Parameters

Recording Equipment:

- 24-Channel Geode dataloggers, 3 Geodes used, total 72 channels. (4 Geode dataloggers were used at the end of Ethiopia Line 2).
- PC compatible software interface/controller
- 72 Sercel L-28-3D, 4.5-Hz, 3-component geophones, using only the vertical component of each geophone. (88 geophones were used at the end of Ethiopia Line 2).

Energy Source:

- 100-lb (45-kg) hydraulic, nitrogen-gas-accelerated weight-drop seismic source (Fig. 1) rented from Geo-Survey Systems, Conroe, Texas. This source operates by propelling a ~45 kg mass onto a base-plate assembly (on the ground) using a small, compressed-nitrogen-gas cylinder to increase delivery force. A 12-volt electric motor drove the hydraulic system to raise the source mass for each impact.

- For each source position, usually 10 impacts were summed to produce 1 shot record.

Figure 1. Hydraulic lift, nitrogen-gas-accelerated weight-drop seismic source mounted on the back of a Toyota Land Cruiser. Photo taken close to the end of Line 1, West Turkana seismic survey.

Station Spacing

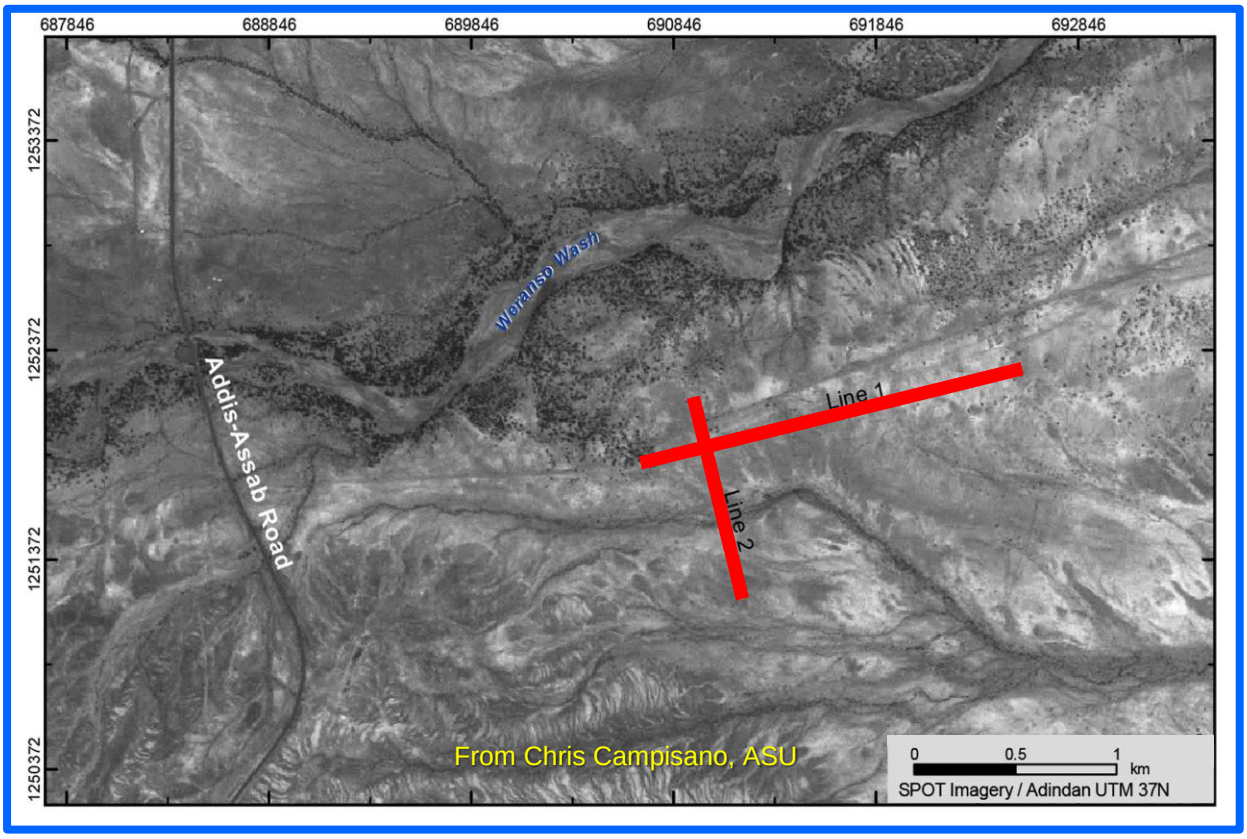
- Normal station spacing = 5 m. Station spacing on Turkana Line 2 was 2.5 m. Stations were chained with each station flagged and labeled. Station locations were surveyed using a hand-held GPS system to determine starting and ending UTM coordinates and line direction was confirmed using a Brunton compass and clear line of sight. Elevation of a base station was initially determined with a hand-held GPS system. A laser level was used to determine relative elevations from the base station to other receiver stations. Elevations were confirmed by comparison to map elevations. Relative elevations are very accurate.

Source Spacing

- Normal source spacing = 10.0 m with shots located between stations (i.e., shifted +2.5 meters toward higher station numbers). Source spacing for Turkana Line 2 was 5 m, with shots located between stations (i.e., shifted +1.25 meters toward higher station numbers). Because the weight-drop seismic source was mounted on the rear of a vehicle, the source was offset ~1 to 3 m perpendicular to the lines to avoid cable and equipment damage. In some cases, greater or lesser in-line and perpendicular offsets were necessary to avoid obstacles.

Weranso River Area, Ledi-Geraru (Afar) Ethiopia Seismic Survey

The Ethiopian study site (Fig. 2) is located in central Ledi-Geraru, ~2 km east of the main Addis-Assab Road, near the depocenter of a large, shallow paleolake and close to famous hominin fossil localities in the Afar region of the East African rift. The area has substantial volcanic rocks that are roughly coeval with the paleolake sediments. Volcanic rocks could create issues for drilling and recovery of sediment cores. The seismic profiles were designed to characterize the subsurface and potentially to help drill-site planners avoid shallow basalt ridges.



Recording Geometries: Afar Lines 1 and 2

Line 1 extended roughly from W to E (azimuth ~ 77°) and Line 2 extended from N to S (azimuth 166°); intersection of the two lines was about a third of the way from the western end of Line 1 (intersection between Stations 164 and 165) and the northern end of Line 2 (intersection at Station 2152).

Line 1 Endpoints (Adindan/UTM 37N)

- Station 101: 690690.2 E, 1251837.0 N
- Station 500: 692634.1 E, 1252285.8 N

Line 2 Endpoints (Adindan/UTM 37N)

- Station 2101: 690938.8 E, 1252155.4 N
- Station 2308: 691189.2 E, 1251151.1 N

Afar Seismic Data

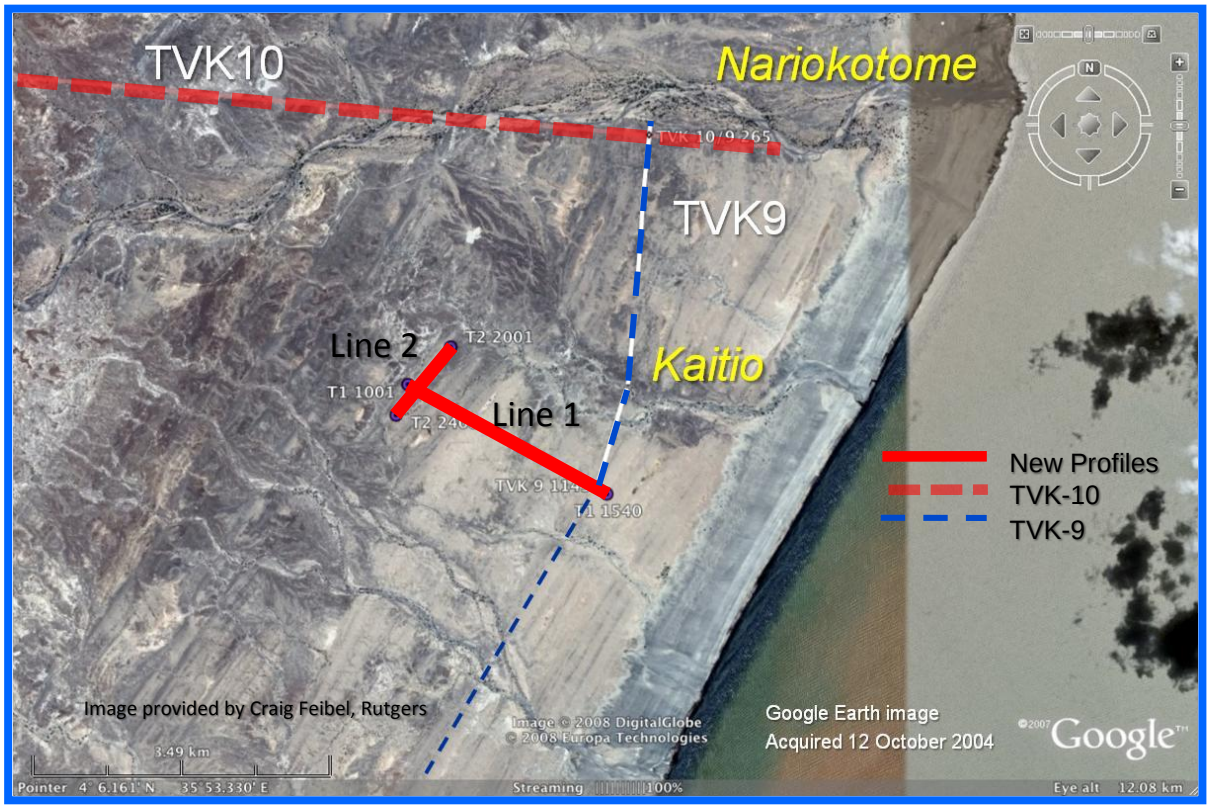
Shot records for each of the profiles are consolidated into SEG-Y-format files.

Line 1: 214 Shots; Field File IDs (FFIDs) 1-24, 26-73,75-86,88-151, 153-197, 206, 208-227.

Line 2: 105 Shots; Field File IDs (FFIDs) 2001-2014, 2016-2055, 2057, 2059, 2061- 2074, 2076-2110.

W. Lake Turkana, NW Kenya Seismic Survey

The NW Kenyan study site was located near the western shore of Lake Turkana, close to its N-S midpoint, south of the Nariokotome River and close to the Kaitio hominin fossil location. The seismic profiles were located to provide some depth control in an area of well-mapped stratigraphy and dated volcanic tuffs. The dip profile (Line 1) spans critical times intervals associated with hominin fossil finds at Kaitio. The strike profile (Line 2) was oriented for lateral structural control and topographic simplicity. Line 1 also ties to old Amoco Production Company seismic profiles in the area (intersecting TVK9 and just south of TVK10). These older lines are held by the National Oil Corporation of Kenya.



Recording Geometries: Turkana Lines 1 and 2

Line 1 extended roughly from NW to SE (azimuth ~ 119°) and Line 2 extended from NE to SW (azimuth 219°); intersection of the two lines was close to the northwestern end of Line 1 (intersection between Stations 1030 and 1031) and about two-thirds of the way along Line 2 (intersection is between Stations 2228 and 2229).

Line 1 Endpoints (UTM 36N)

- Station 1001: 818422.39 E, 454313.95 N
- Station 1540: 820781.13 E, 453028.15 N

Line 2 Endpoints (UTM 36N)

- Station 2001: 818902.9 E, 454675.5 N
- Station 2408: 818262.5 E, 453884.8 N

Turkana Seismic Data

Shot records for each of the profiles are consolidated into SEG-Y-format files.

Line 1: 290 Shots; Field File IDs (FFIDs) 1001-1136, 1138-1176, 1178-1204, 1206-1208, 1210-1234, 1236-1295.

Line 2: 219 Shots; Field File IDs (FFIDs) 2001-2219.

Example EBCDIC header for SEG-Y files

The individual records for each line have geometry information entered in the trace headers with entries as shown in the SEG-Y EBCDIC header (example below). Each SEG-Y file contains all shot records for a particular line.

C 1 University of Arizona, Reflection Seismology
C 2 LINE: 2 AREA: Weranso Wash, Afar, Ethiopia MAP ID: Adindan/UTM 37N
C 3 INSTRUMENTS: 24-Channel Geometrics Geode Systems from PASSCAL
C 4 DATA TRACES/RECORD: 72/88
C 5 SAMPLE INTERNAL: 1 ms SAMPLES/TRACE: 2000
C 6 RECORDING FORMAT: SEGY MEASUREMENT SYSTEM: Meters
C 7 SAMPLE CODE: IBM REAL GAIN TYPE: FIXED
C 8 SOURCE: 45-Kg GeoSurvey Systems Weight Drop SP-INTERVAL: 10 m
C 9 SPREAD: Channels 1-72 (1-88 on FFIDs 2089-2110) GROUP INTERVAL: 5 m
C10 GEOPHONES/GROUP: 1 FREQ: 4.5 Hz MFG: Sercel MODEL: L-28-3D,
C11 3-component phones, using only vertical component of each phone
C12 MAP PROJECTION: UTM ZONE ID: Adindan/37N COORDINATE UNITS: Meters
C13 LINE START COORDS: Station 2101: 1252155.4 N, 690938.8 E
C14 LINE END COORDS: Station 2308: 1251151.1 N, 691189.2 E
C15 TRACE HEADERS BELOW: Header, Format, Start Byte

C16 Trace sequence number in line: Int (4-byte) Start: 1
C17 Trace sequence number in SEG Y file: Int (4-byte) Start: 5
C18 Original field record number (FFID): Int (4-byte) Start: 9
C19 Trace number in original field record: Int (4-byte) Start: 13
C20 Energy source point number: Int (4-byte) Start: 17
C21 CDP ensemble number: Int (4-byte) Start: 21
C22 Trace identification code (1 = data): Int (2-byte) Start: 29
C23 Number of source impacts this trace: Int (2-byte) Start: 33
C24 Distance source point to receiver: Int (4-byte) Start: 37
C25 Receiver elevation: Int (4-byte) Start: 41
C26 Surface elevation at source: Int (4-byte) Start: 45
C27 Scalar for elevations in bytes 41-68: Int (2-byte) Start: 69
C28 Scalar for coords in bytes 73-88 and 181-188: Int (2-byte) Start: 71
C29 Source coordinate X (times 10000): Int (4-byte) Start: 73
C30 Source coordinate Y (times 10000): Int (4-byte) Start: 77
C31 Group coordinate X (times 10000): Int (4-byte) Start: 81
C32 Group coordinate Y (times 10000): Int (4-byte) Start: 85
C33 Number of samples in trace: Int (2-byte) Start: 115
C34 Sample interval in microseconds (us): Int (2-byte) Start: 117
C35 Low-cut frequency (Hz): Int (2-byte) Start: 149
C36 X coordinate of CDP position of trace: Int (4-byte) Start: 181
C37 Y coordinate of CDP position of trace: Int (4-byte) Start: 185
C38 Shot-point number: Int (4-byte) Start: 197
C39 SEG Y REV1
C40 END EBCDIC