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Keck Geology Consortium: Projects 2009-2010
Short Contributions – ALASKA-KENAI

THE GEOMORPHOLOGY AND DATING OF HOLOCENE WATER LEVELS AT JIGSAW LAKE, KENAI PENINSULA, ALASKA

***GREG WILES*:** The College of Wooster;
***THOMAS V. LOWELL*:** University of Cincinnati;
***ED BERG*:** US Fish & Wildlife Service, Kenai National Wildlife Refuge, Soldotna, AK.

USING PEAT HUMIFICATION FOR HIGH RESOLUTION LAKE LEVEL RECONSTRUCTION: JIGSAW LAKE, KENAI LOWLANDS, ALASKA.

ALENA GIESCHE
Middlebury College
Research Advisors: Jeffrey Munroe and Pete Ryan

BASIN SUBSIDENCE INFERRED USING GEOPHYSICAL DATA, JIGSAW LAKE, KENAI PENINSULA, ALASKA

JESSA V. MOSER
University of Cincinnati
Research Advisor: Thomas V. Lowell

RECONSTRUCTING THE PALEO-ENVIRONMENT: EARLY HOLOCENE MOISTURE VARIABILITY OF THE KENAI LOWLANDS, ALASKA

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Funding provided by: Keck Geology Consortium Member Institutions and NSF (NSF-REU: 0648782)

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BASIN SUBSIDENCE INFERRED USING GEOPHYSICAL DATA, JIGSAW LAKE, KENAI PENINSULA, ALASKA

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INTRODUCTION AND GEOLOGIC SETTING

Jigsaw Lake (60º44.5478'N, 150º29.9810'W) is located in the Kenai National Wildlife Preserve on the Kenai Peninsula, AK. The pro-glacial lake complex lies on a groundwater divide, and is made up of a topographically closed group of small basins, charged by precipitation and groundwater seepage. For the purposes of this study, these basins have been subdivided into five individual subbasins (Fig. 1). All are hydrologically connected by groundwater, four connected by surface water and one located just to the Northeast of the main complex. Previous study of the lakes by Kaufmann, 2001, revealed a thin layer of peat 12 m below the sediment-water interface, dated at ~9.5 cal kya. The purpose of the current study is to determine whether this terrestrial peat was deposited at its present elevation which would make it a useful indicator of paleohydrology, or if it is found at its present depth due to basin subsidence, which would make it useful tool for understanding regional geomorphology.

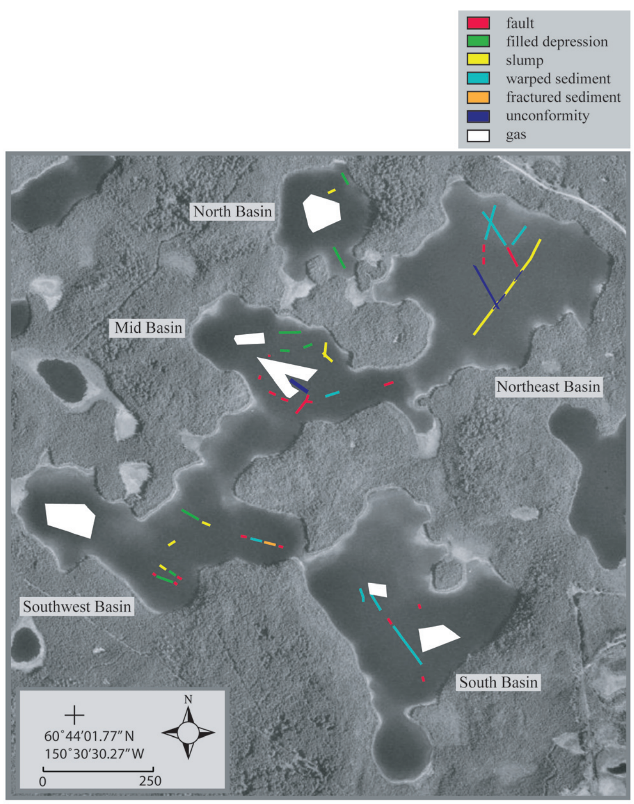

Figure 1. Aerial photo of Jigsaw Basin with notated interpreted features most diagnostic of subsidence. Lake complex has been subdivided into five basin units: North Basin, Northeast Basin, Mid Basin, Southwest Basin, South Basin. Features (as found linearly along seismic transect lines) include: faults, filled depressions, slumps, warped sediment, broken sediment and unconformities. Polygons represent areas where gas obscured seismic signals.

Lake evolution was investigated using seismic profiles and side-scan imaging. These data were collected by geophysical survey along 110 transects throughout the lake complex. Profiles were examined for evidence of subsidence, such as normal faulting, fractured stratified successions, collapsed blocks, rotational slides, and gently warped sediments (Eyles et al., 2003; Hofmann et al., 2006).

METHODS

Geophysical data were collected in two manners. Water depth and side-scan sonar images were acquired with a Hummingbird 789 SI combo, which uses 83 and 200 kHz frequencies for depth and 455 kHz for side imaging. The output is 500 watts (RMS), or 4000 watts (Peak-to-peak). Sub-bottom sedimentary stratigraphy acoustics were captured with a SyQwest Stratabox unit which uses a pulsed 10 kHz frequency, with an output of 1000 watts, or 300 watts, if pulsed. Both devices were attached to a canoe and used to acquire a geophysical survey set 110 transects from all five lake basins. All sonar signals were fed into a Panasonic Toughbook, where they were recorded and analyzed. Data was georegistered using proprietary software, then post-processed in a variety of formats.

Bathymetry maps were rendered with data collected by the Hummingbird 789 SI, as were hardness maps, which show the gradation between hard and soft sediments on the basin floor.

RESULTS

Seismic stratigraphy revealed subsidence features in a variety of forms, throughout all five subbasins (Fig. 1). Horizontal units were found vertically displaced between gravity driven normal faults. Slumping was noted on slopes between these displaced units, as well as in the form of secondary, rotational slumps, where the normal faults showed secondary gravity driven subsidence, causing gently dipping horizontal units deposited more recently than those that were affected in the original subsidence event. Sediment was also found warped and fractured in some regions where strong evidence of faulting was absent. A selection of transects from the Northeast basin were chosen as a representation of the general basin features characteristic the Jigsaw Lake (Figures 2-4). These were examined in detail because seismic profiles from this basin were particularly illustrative of subsidence related features, were free of gas (which obscured some seismics signals), and represent the same basin from which Kaufmann collected data in 2001.

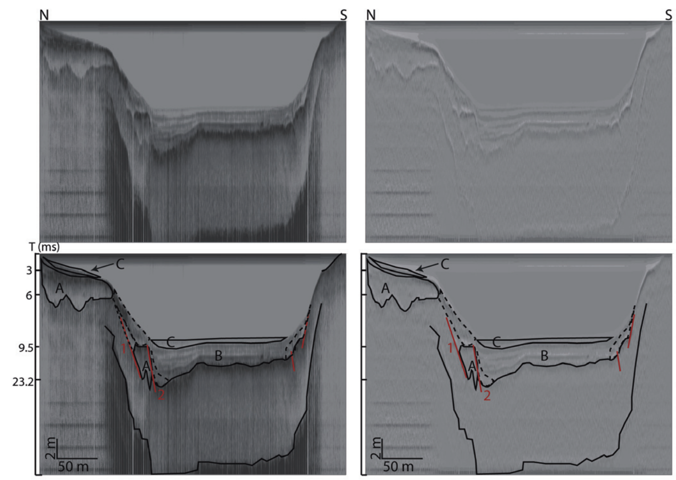

Figure 2. Northeast basin seismic profile 20090612155529. Images to left reflect raw data as collected. Images to right post-processed using a band-pass filter. Sediment package A broken into upper, northernmost unit, and vertically displaced lower block. Unit A bounded at its base by a hard reflector, and at top by Unit B. Unit B bounded at base by hard reflector, at top by Unit C. Fault 1 (faults in red) representative subsidence associated with dislocation of sediment package A and slump directly above fault line (slumped sediments delineated by dashed lines). Fault 2 evidences secondary subsidence event, resulting in rotational slump of sediment package B and upper slumped units. Most recent unit C horizontally distributed where present.

Throughout the Northeast basin is a hard reflector of highly irregular surface geometry, above which is a thick soft reflector. The unit comprised of these two reflectors is referred to as unit A, and can be seen in Figures 2-4. Throughout the basin, this Unit A is associated with closed depressions which are likely kettle features. As an example, parts of the same kettle can be seen in Figures 2-3, to the north side in both profiles. (A similar feature is seen in the North Basin in Figure 5). Unit A also shows fault bounded slumps, associated with vertical displacement along normal faults (Fig. 2).

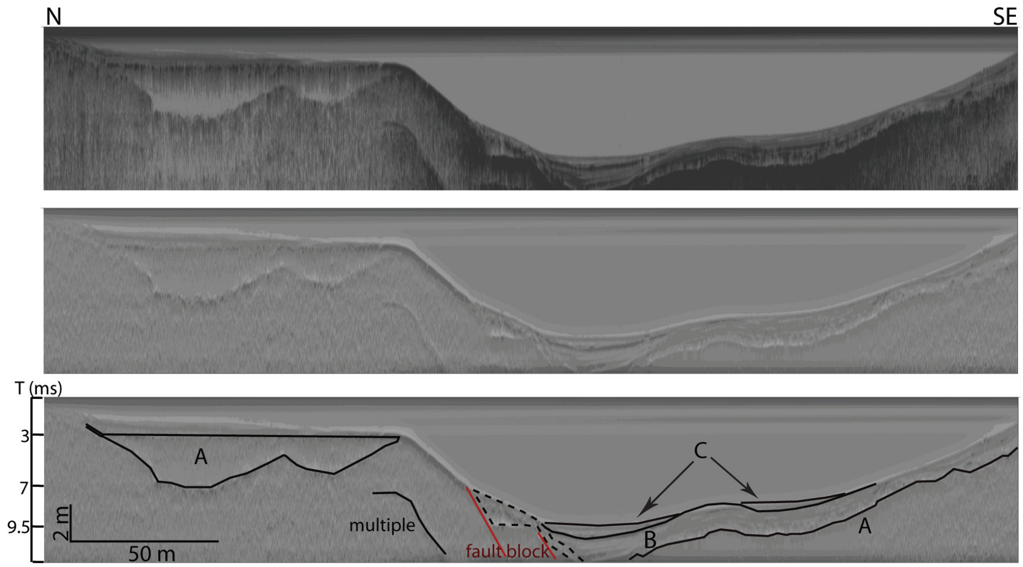

Figure 3. Northeast basin seismic profile (20090612142348). Upper profile shows raw seismic images as collected. Post-processing filter has been applied to lower two images. Interpreted lower profile shows unit A, to NW, as kettle features, and warped and draped by warped Unit B to SE. Unit B is bounded by the hard reflector at the top of Unit A and by horizontally distributed Unit C. Sediments in Unit B warped, indicating features in Units A and B resultant sequential subsidence events due to differential melting of buried ice. Slumped sediments delineated by dashed lines.

Unit B is distinguished as the first hard reflector overlying unit A. It is dominantly a gently warped horizontal unit (Fig. 3), with some fracture (Fig. 4), indicating a secondary subsidence event within the basin. The secondary nature of this event is most evident in Figure 2, where the unit juxtaposes a fault associated with Unit A, along which it shows rotational slumping. Finally, unit C is evenly distributed lacustrine sediment, its horizontal placement and average thickness (~0.6 m, but as great as 1.2 m) similar throughout transects in this basin.
Side-scan imaging revealed a gravel patch on the floor of the North basin near a slump feature (the latter from the seismic dataset), both of which are illustrated in Figure 5. The gravel spans ~46 x 50 m, and is located, ~60 m from the north shore and ~14 m from the E shore.

DISCUSSION

Stratigraphic deformation in pro-glacial regions can be generated from a variety of processes, including glaciotectonic thrusting, melting of buried ice, or isostacy (Eyles et al, 2003). However, given the distal location of the Jigsaw unit from previous ice sheet margins, and the small scale normal faulting in the basin, both glaciotectonic thrusting and isostacy are unlikely. The subsidence features found here in the seismic data are consistent with those found in cases where buried or dead ice contributed to basin evolution (Eyles et al, 2000, 2003; Van Rensbergen et al, 1999). The interpretation of seismic profile features in the Northeast basin is as follows. Two major stages of subsidence are evident in Units A and B. Unit B shows differential melting, manifested in several distinct warping episodes (Fig 3).

The kettle features in Unit A result from subsidence due to the melting of buried glacial ice, the hard reflector at the lower boundary of the unit representing glacial sediments; as the ice melted the sediments within would be deposited as ablation till (Henrickson et al, 2003). The thick soft reflector is the subsequent infill of lake sediments. This hypothesis is supported by the profile in Figure 2, where subsidence has caused gravity driven normal faulting that has vertically displaced a whole block of Unit A. Similar subsidence driven faulting is the cause of fractured sediment in figure 4.

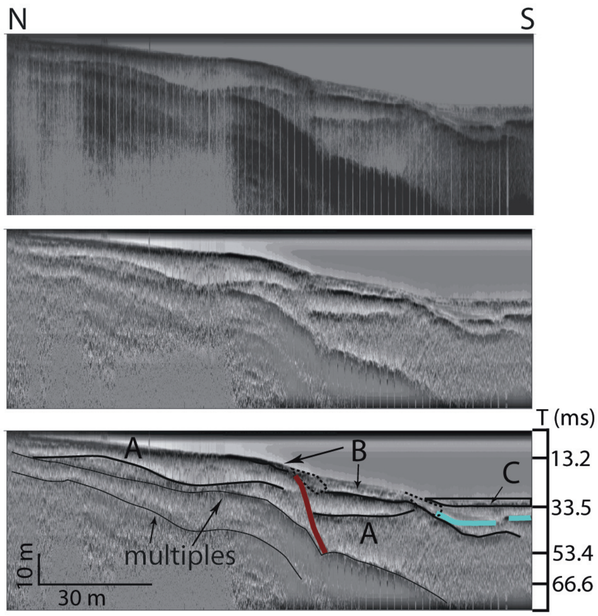

Figure 4. Northeast basin seismic profile 20090628212315. Top: unprocessed stratigraphic profile. Middle: post-processing applied. Lower: interpretation of units. Initial subsidence caused fault 1 (shown in red) resulting in the breakup of unit A. Unit B was then deposited, and later slumped due to secondary subsidence event, which also resulted in fracture within the units above the B horizon (fractured sediment in blue). Unit C deposited most recently. Dashed lines delineate sediments that slumped with faulting.

Unit B was deposited after the initial subsidence event associated with the displacement of Unit A, as B is distributed over the upper boundary of A in all profiles. This unit evidences secondary subsidence, resultant further melting of remaining buried ice from the prior subsidence event. The differential melting of this buried ice propagated faulting up through the units into Unit B (Henrickson, 2003). This can be seen in Figures 1 and 3 where unit B gently warps down into a rotational slump associated with southernmost fault involved in the earlier displacement of the block from unit A.

Unit C is evenly horizontally distributed in all profiles, indicating that all buried ice in this basin has disappeared, or has become minimal at this point, and is not causing subsidence at present.
The gravel patch in the north basin could be a beach deposit representing a period of lower water level, or the result of sorting upon slumping of overlying sediments due to subsidence. The latter interpretation is favored as this gravel unit is located on the down slope of a slump region (see transects in lower Fig. 5) and there is no stratigraphic evidence of

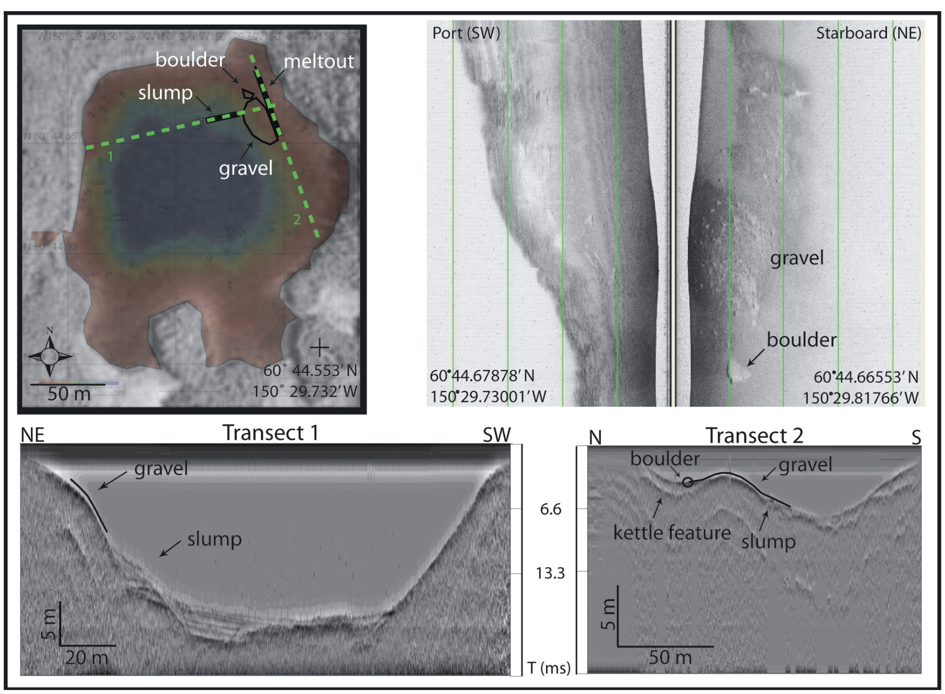

Figure 5. Upper Left: Jigsaw Lake, North basin. Dashed green lines represent transects of interest. Transect 1 is 20090622161734, transect 2 is 20090622150547. Upper Right: Side-scan image (R00220) showing gravel patch. Gravel spans ~46m, covering an area approximately twice as large as shown. Width of gravel deposit as measured in side-scan image it is ~50m. Lower Images: Seismic profiles, post-processed with band-pass filter and weighted. Note slump deposit downslope from gravel patch, indicating sediments were sorted upon slumping.

lower lake levels. This feature indicates subsidence was rather recent, since the gravel has not yet been overlain by lake sediments.

CONCLUSIONS

The results of this study support a subsidence model as the mechanism for the position of the terrestrial peat unit discovered by Kaufmann in 2001. The interpretation herein invokes subsurface ice melt of stranded ice blocks as a mechanism for subsidence of the terrestrial peat unit, as described by Branstrator et al., 2009. In this model, the formation of the Jigsaw Lake complex involves a dynamic history, glacially influenced, and appreciably affected by subsidence. This is evidenced by fault bounded displaced sediments, kettle features, gently warped sediments, slumping, and a sorted gravel feature distal from shore. The progression from complex to simple basin formation features as seen in units A-C in the Northeast basin of Jigsaw Lake follows expected glacial to lacustrine "type stratigraphy" of a glacial lake (Charlet et al, 2008; Van Rensbergen et al, 1998).

Future study of this complex basin structure should couple geophysics with core logs to determine age of subsidence events and the specific nature of depositional units. This would make the Jigsaw Lake a valuable tool in interpretation of regional geomorphologic evolution.

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