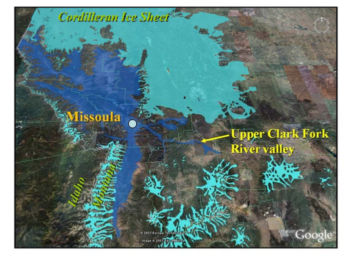
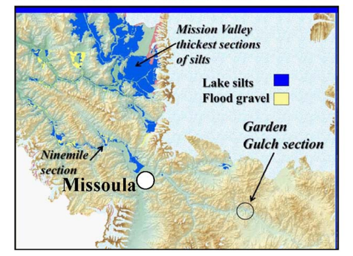
3D Outcrop Mapping by Photogrammetric Methods – Assessing Depositional and Erosional Events in Glacial Lake Missoula

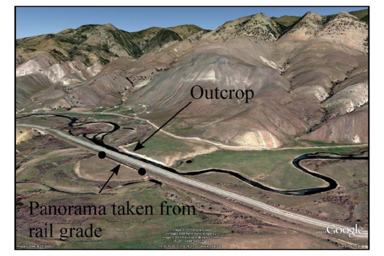
SMITH, Larry N., CHRISTENSEN, Shawn. M. D., and HOTALING, Aric J., Department of Geological Engineering, Montana Tech, University of Montana, 1300 W Park St, Butte, MT 59701
lsmith@mtech.edu

Location



- One of the shallowest-water sections of Glacial Lake Missoula deposits known
- Current altitude 1,175 m; ~100 m of water at highest stand of lake



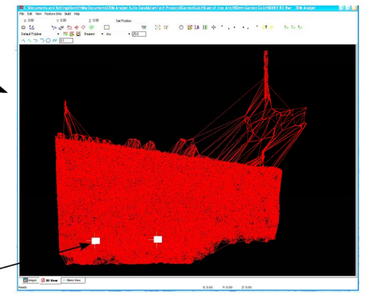


Using the photogrammetric modeling programs produced by AdamTech, 3D images were produced of Glacial Lake Missoula (GLM) sediments located in Garden Gulch, Montana

Methodology - Building Projects

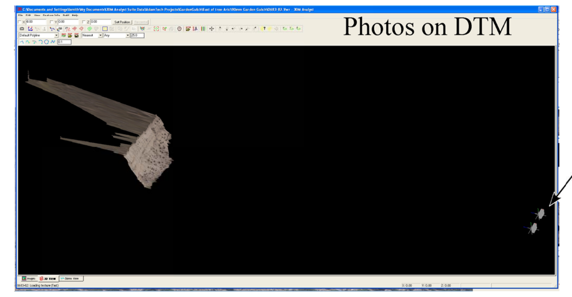
(1) Calibrate lens & camera body
(2) Place control point targets in field of views (~3-6 per frame)
(3) Take stereo photographs (~60% overlap)
(4) Use CalibCam to find additional control points (by pattern matching of pixels)

(5) Use stereo pairs to build DTMs from each overlapping pair

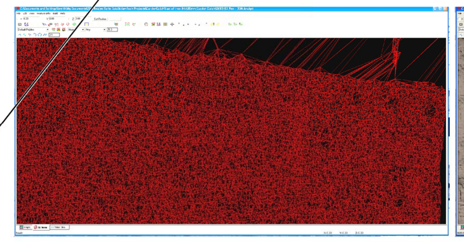


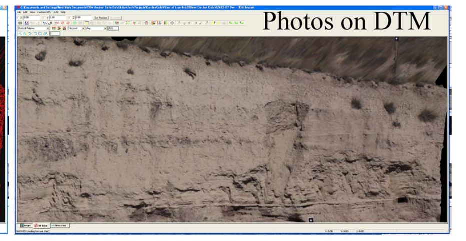
(6) DTMs are loaded into 3DM analyst
- full, panoramic DTM model is built
- epipolar images are tied to DTM forming fully rectified images

Camera locations



DTM from one stereo pair





Concept

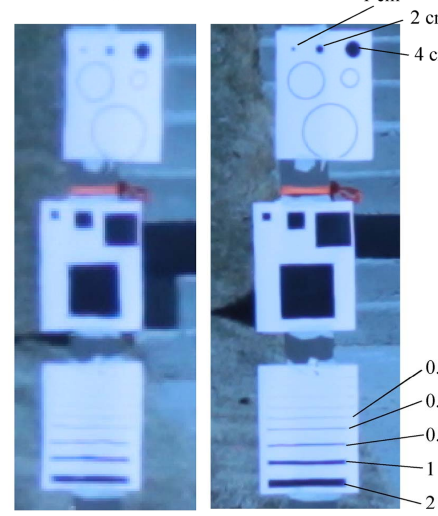
Digital Photogrammetry
AdamTech - 3D Digital Mapper
Produces 3D DTM - (digital terrain models) of outcrops
Uses standard digital photographs
Designed for use in geotechnical field for mapping bedding and fracture planes, doing volume calculations, and surface modelling
- surfaces are "correlated" and mapped on DTM

In contrast to LIDAR, DTM and photographic images are naturally linked
Field equipment is a camera
- large CCD camera systems are the best
- high-quality optics
- consistent lighting
Academic pricing for software ~$10k per license

Resolution

For this project we used a Canon 50D with a 90 mm telephoto lens.
We took the 65 photographs from about a 100-110 m distance.
The mapping resolution of the images is displayed below:

2 inch white target at ~110 m



Conclusions

Position closer than 100 m with a 90 mm lens
High contrast lighting is important
Minimal shadows
Use a tripod with a telephoto lens

ABSTRACT

Three-dimensional outcrop mapping of marine and terrestrial sequences has proven especially valuable in studies of facies geometry and sequence stratigraphy. Most recently published studies have used ground-based light-detection and ranging (LiDAR) techniques to develop highly accurate 3D clouds of survey points. A separate rectification step of digital photographs can produce 3D models on which mapping is done. While accurate, the instrument costs are substantial; purchase prices can be $50k-200k. Alternative methods to produce precise 3D models of outcrops include digital photogrammetric methods that employ stereo photographs and sophisticated software programs. At least two companies (Adam Technology and 3G Software & Measurement) have developed software packages for use in geotechnical fields for mapping bedding, fracture planes, surfaces, and volumes important to the mining industry and others. We used the AdamTech package in the current research.

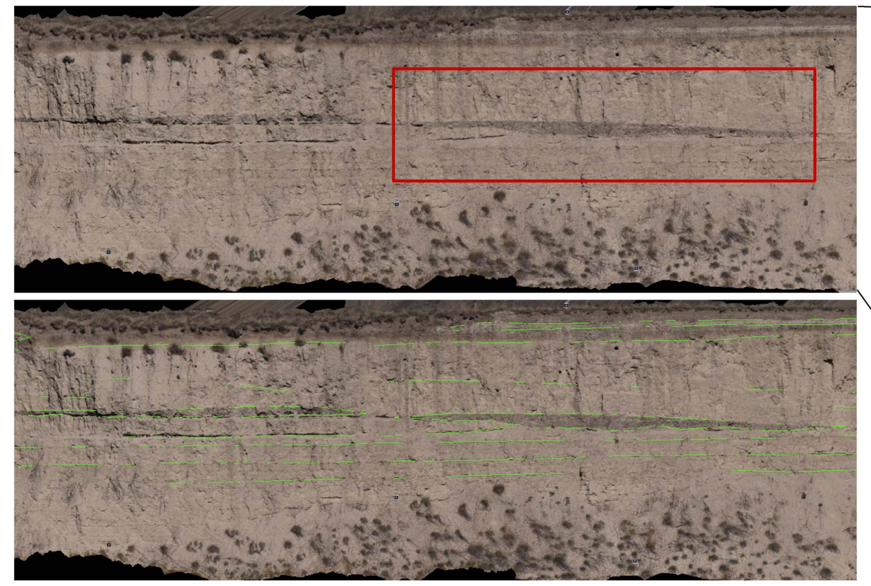
A well-exposed, 0.5 km-long, ~15 m-thick section of silty sediments deposited in a lake-bottom position was photographed using a Canon 50D digital camera. The apparent resolution is on the cm-scale over the 0.5 km map distance. A "strip" of overlapping photographs taken from a distance of about 100 m recorded subaqueous sedimentation of apparent varves, debris flows, and scour surfaces above clast-supported, fluvial, boulder-gravel and sands. The lacustrine section fines-upwards from gravel to rippled sand to rhythmically bedded very fine-grained rippled sand, silt, and minor clay. A paleosol developed in eolian loess and lacustrine silts caps the section. Lateral tracing of beds and mapping in the 3D model shows at least two unconformities, highlighted by soft-sediment loading of eroded silts by gravelly sand. Detailed mapping in the 3D model allows determination of dip amounts and truncation directions.

The Garden Gulch section is interpreted to represent transgression of Lake Missoula beds over a stable late Pleistocene landscape. Two or three lake transgressions may be recorded based on the unconformities. The paleosol at the top of the Garden Gulch section can be traced parallel to the current landscape surface, indicating that most of the landscape was formed during the drainage of the last Lake Missoula.

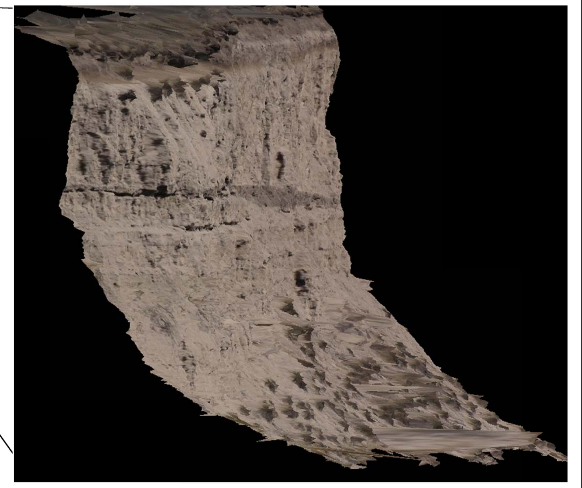
Methodology - Mapping projects

(1) Mapping tools allow interpretive mapping of surfaces on the DEM while viewing the images
(2) With digitized scale bars and vertical or horizontal lines, dimensions and dips can be precisely calculated

DTM with polyline mapping



View from the West of the DTM model



Evaluation of the software package:

- Works acceptably to make rectified images and DTMs on which to map sedimentary sequences
- Three-dimensional outcrops are ideal (test outcrop was essentially two-dimensional)

Recommendations

- Camera and lens
  - Check resolution to optimize resolution for mapping
  - Use high resolution telephoto lens on a tripod for distant outcrops
- Operation
  - Avoid vegetation
  - cannot interpret behind bushes or trees well
  - has some ability to see behind obstructions, in images with increased parallax
  - bedding surfaces are most easily mapped if there are topographic steps
- Workstation (from AdamTech)
  - CPU
    Intel Core i7, i5, and i3, and AMD Phenom II, (more expensive = better); 64 bit strongly recommended; Windows 7 preferred, Vista and XP supported.
  - GPU
    NVIDIA and AMD/ATI, (more expensive = better); advise against Intel
  - RAM
    At least 4 GB per channel (maximum overhead)

Garden Gulch Section
Interpretation of mapping

Paleosol(s) above Lake Missoula beds

Additional, more weakly developed profile in silty, and gravelly sand (Holocene slopewash deposits)

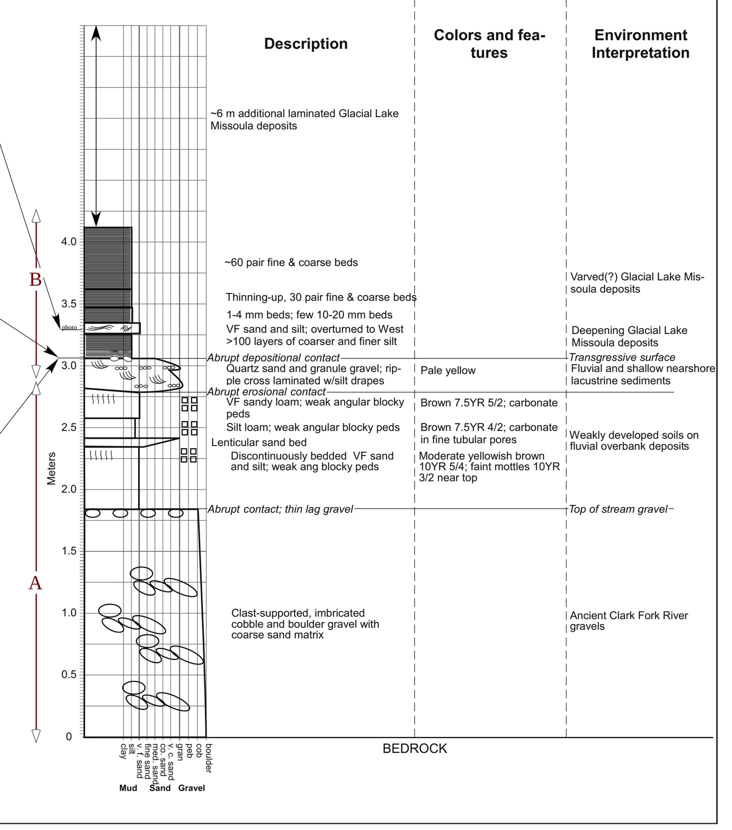
Main soil profile in silty, very fine-grained sand (lower Holocene loess)

Dark layers are sedimentary breccias

- angular clasts of Cretaceous sedimentary rocks from nearby hillslopes
  - planar tops to beds
  - basal contacts show they were deposited on soft sediment
  - few erosional (channelled contacts at base)

Interpretation:
- landslide deposits onto ice-covered lake, fell onto lake bottom at melt-out, or
- subaqueous debris flow sheets on lake bottom

Composite Measured Section



Interpretation of the outcrop

(1) Transgressive Lake Missoula beds over ancient Clark Fork River alluvium

(2) Climbing-ripple sedimentation is down the valley-axis

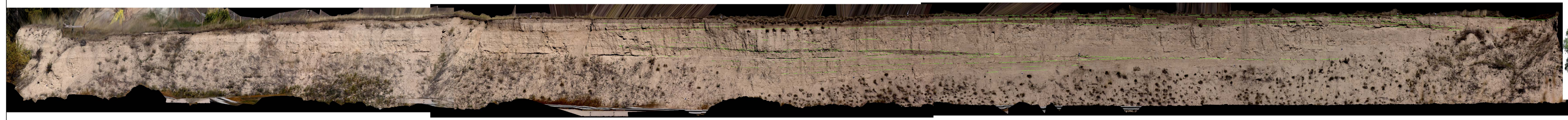
(3) Landslide deposits accumulated on wet (likely subaqueous) sediments

(4) No evidence (as yet) for desiccation

(5) Erosion and sedimentation reflected in angular unconformities appear to be suaqueous

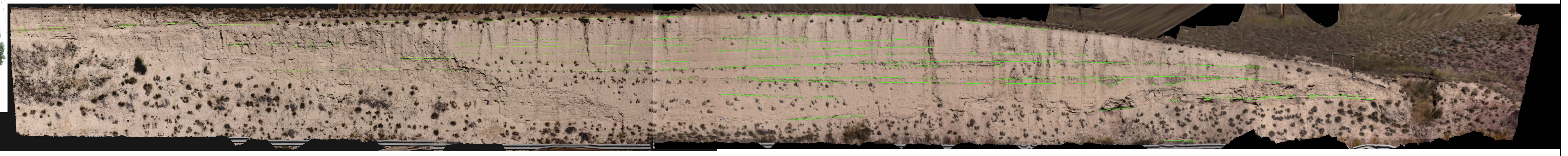
(6) Possible evidence for fluctuating lake levels, but not drain-and-fill cycles

(7) Draped paleosol suggests most downcutting of silts occurred during or shortly after drainage of last lake and eolian loess sedimentation



Western portion of outcrop

tree



Eastern portion of outcrop

Garden Gulch Section - overview