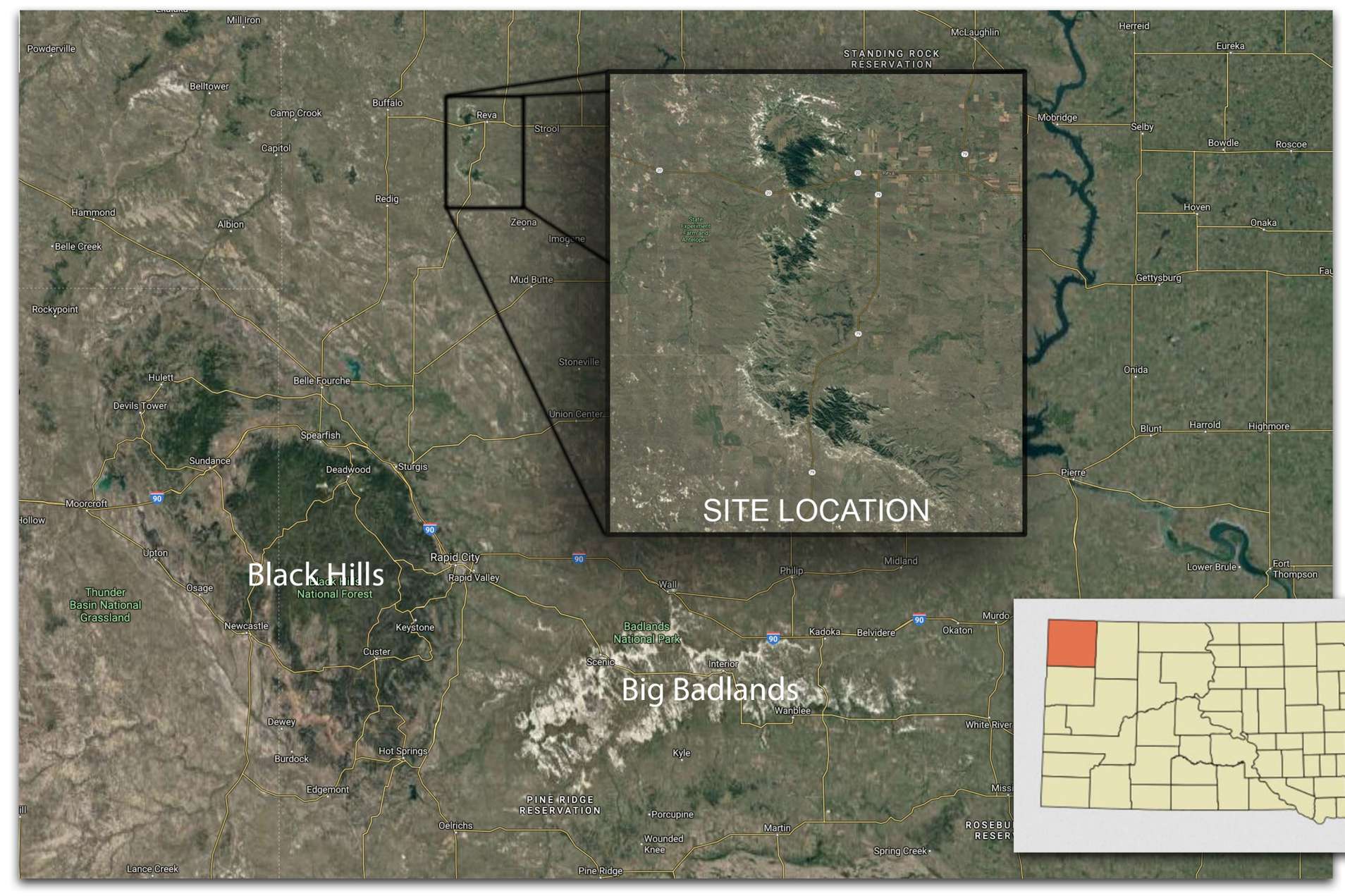
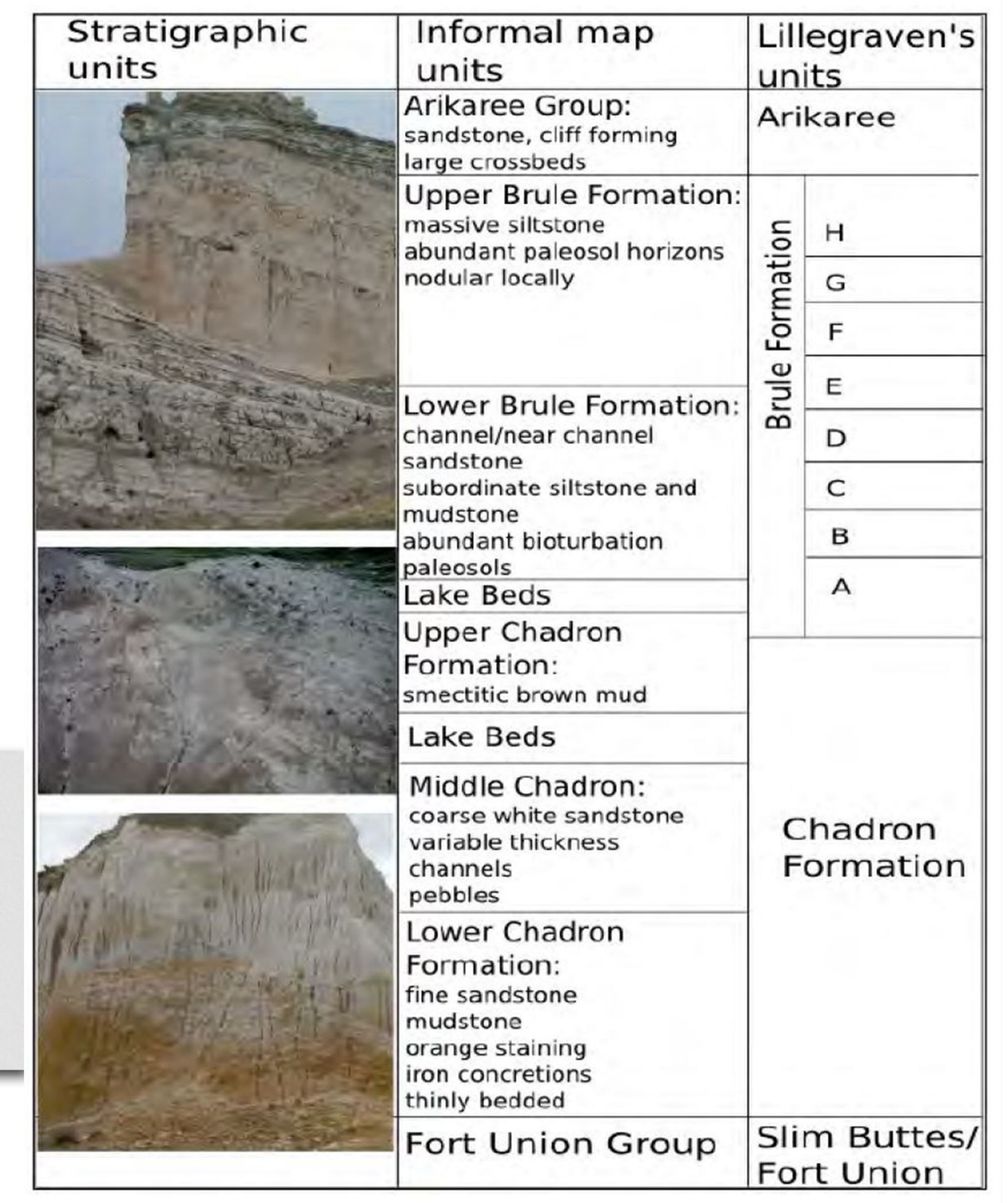
Abstract:

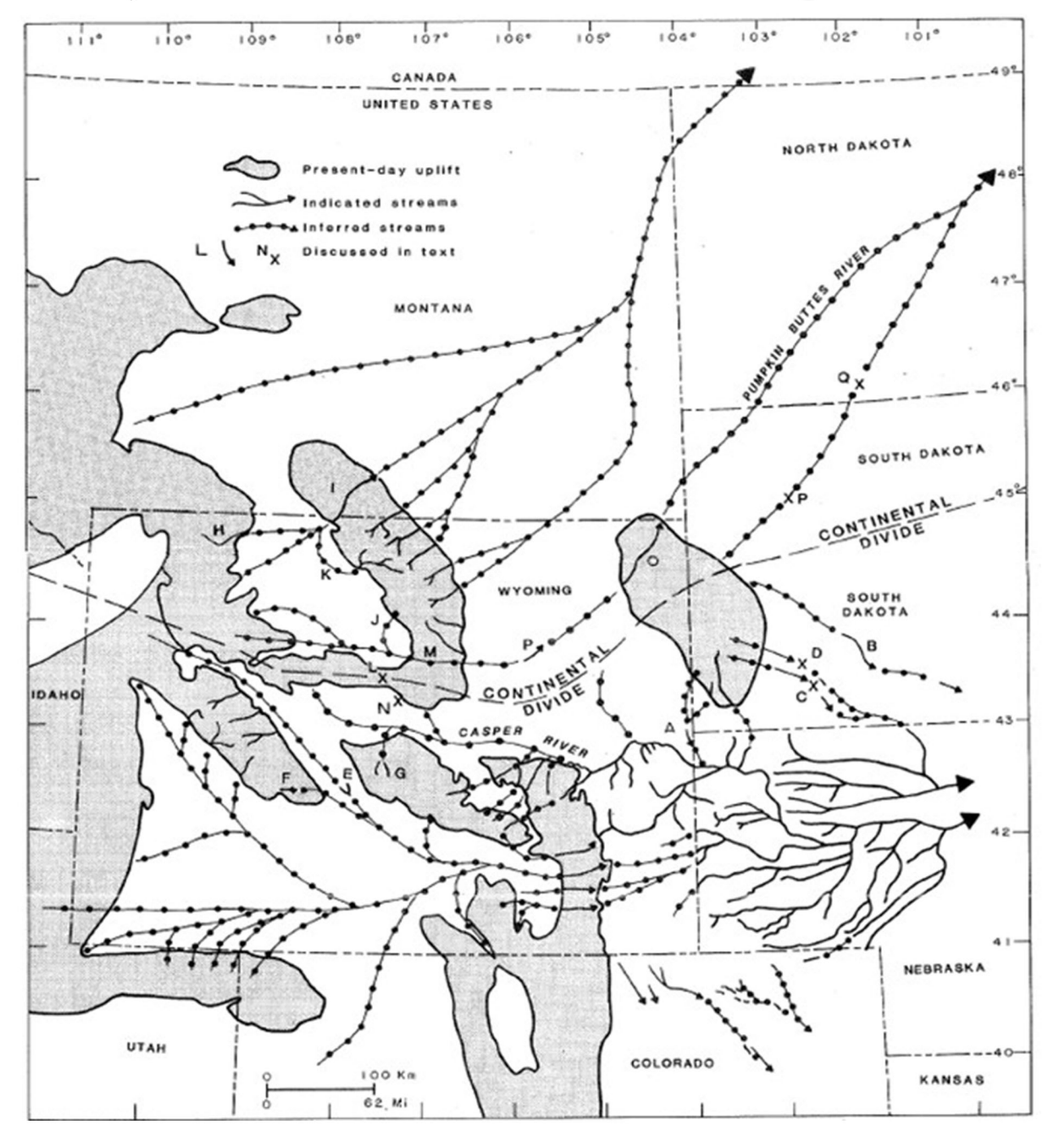
Slim Buttes, located in NW South Dakota, is one of the few areas north of the Black Hills where the geology of the White River Group are well exposed, including the Chadron Formation and the overlying Brule Formation. Cliff exposures of these formations locally stretch semi-continuously for several kilometers. There is a major angular unconformity between the overlying Arikaree Group and faulted Brule Fm. strata. Both units contain evidence of nested river channel complexes, with > 15 m of relief on individual channels. Building upon previous studies at Slim Buttes, drone/UAV technology was used to capture and map some of these formations in order to create 3D virtual outcrops that can be studied offsite and expand/complement previous findings. Collecting photogrammetric information in 3D and being able to model it in a quantifiable format gives the geologic community a powerful tool to add to traditional field work. This data can be ultimately shared with other geology professionals and academic entities. The final product is a high resolution, photorealistic 3D model from which measurable features can be extracted, including the orientations of fractures and cross beds, stratigraphic thicknesses, and xyz positions. Analysis is presently focused on identifying evidence of river channel morphology and fill architecture, as well as any lateral propagation of these channels. In our case, using UAV photogrammetry to map these geologic features not only provided visual access to normally inaccessible areas, it also provided the ability to gather large amounts of data in a short amount of time.



Site Study Area - Slim Buttes, Harding Co., South Dakota



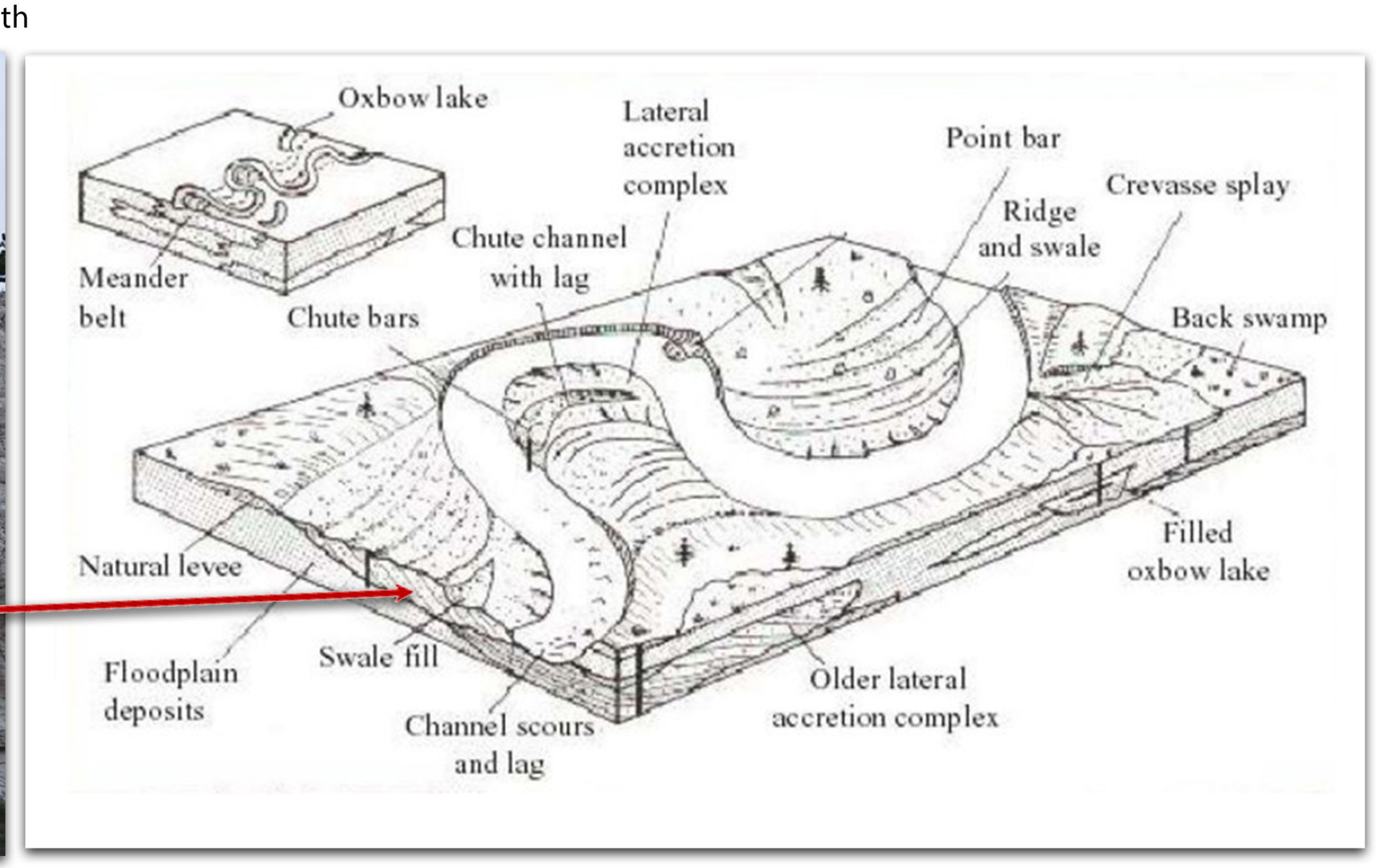
Slim Buttes Stratigraphy
Lillegraven, J. A. (1970). Stratigraphy, Structure, and Vertebrate Fossils of the Oligocene Brule Formation, Slim Buttes, Northwestern South Dakota. Geological Society of America Bulletin, v. 81, p. 831-850.


Seeland, D. (1985) Early Oligocene paleogeopgraphy of the nothern Great Plains and adjacent mountains. Rocky Mountain Section (SEPM)

Deposition Examples in Meandering Channel
Eagle Chief Creek Near Cleo Springs, OK Google Earth

Exposures of the Upper Brule and Arikaree Formations


Large Cross-beds in Arikaree Formation Approx. 50 Meters Above Ground



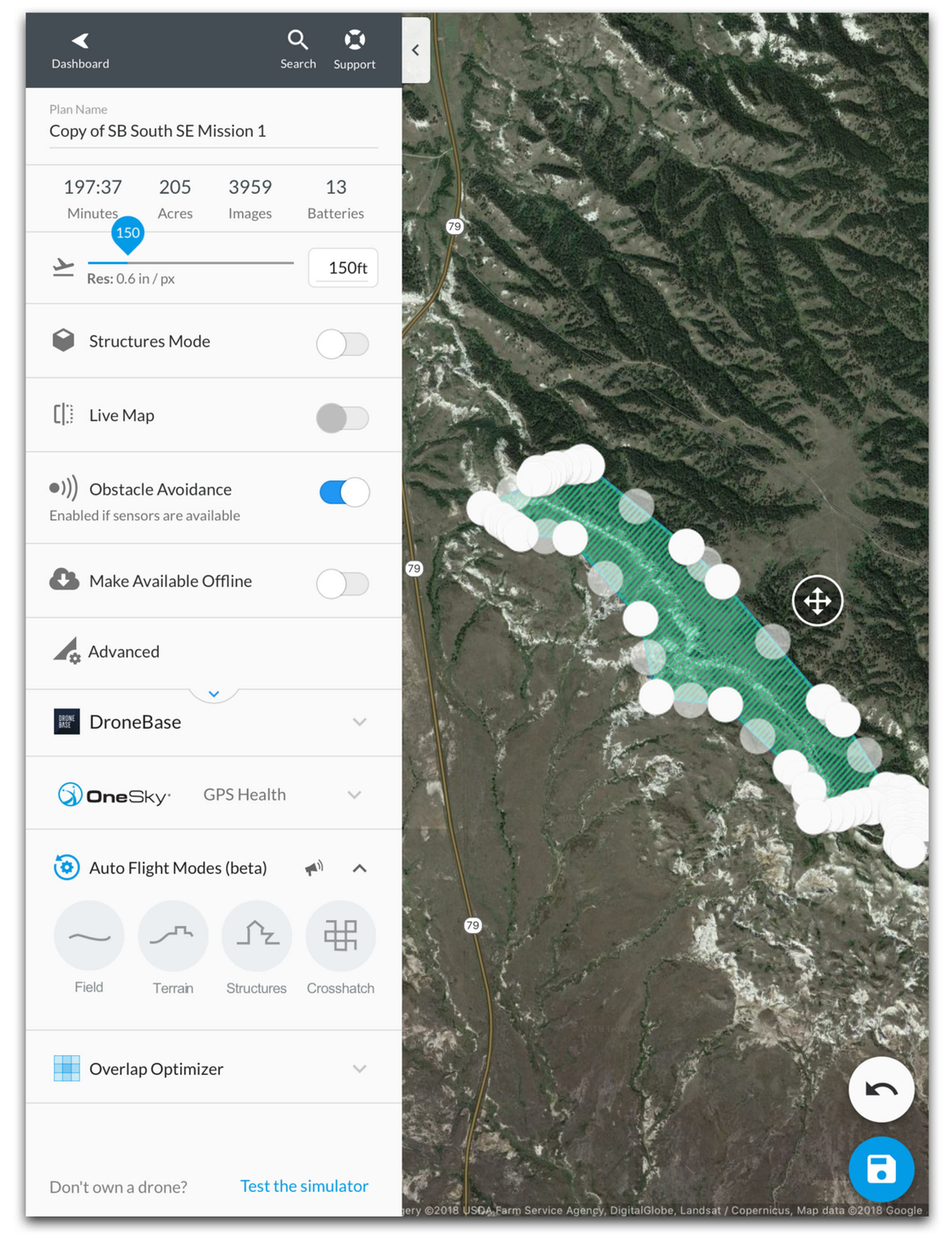
Typical Stream Channel Diagram
Einsele, G. (1992). Sedimentary Basins. Germany: Springer-Verlag

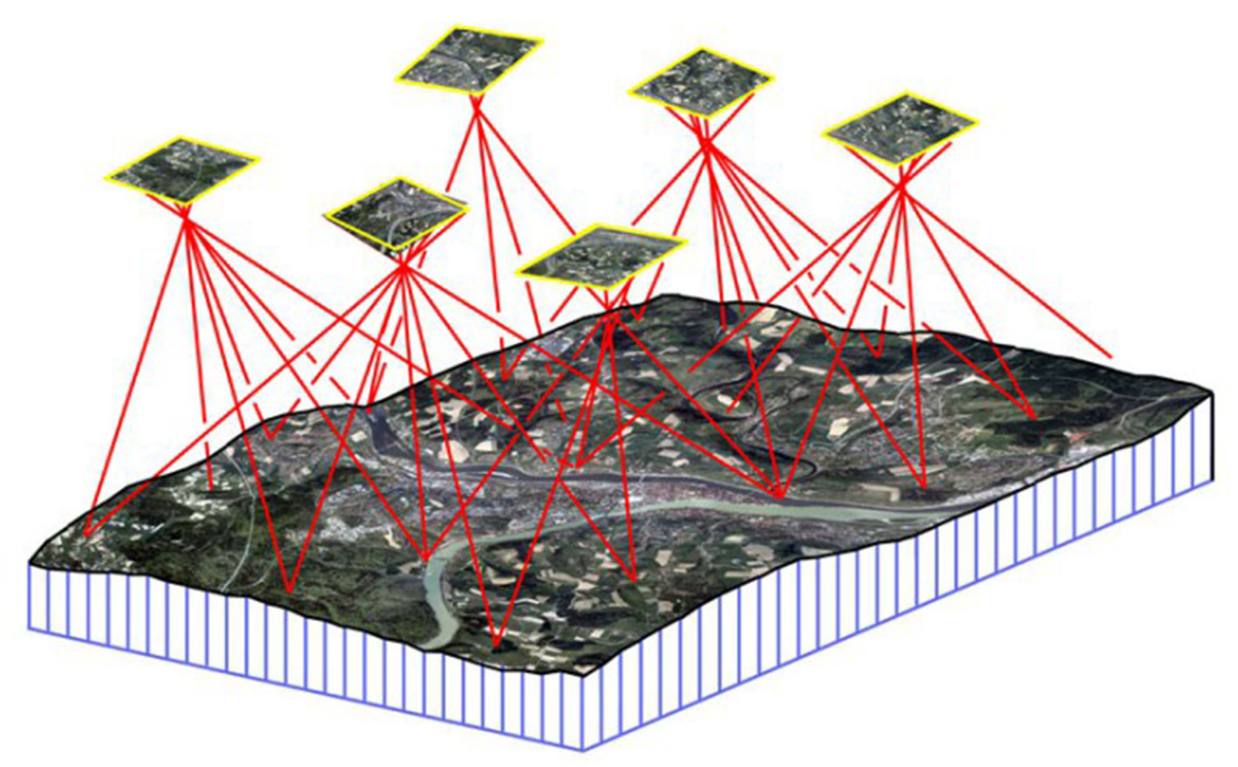
Mapping Slim Buttes Stratigraphic and Structural Features by UAV Photogrammetry

UNIVERSITY OF NEBRASKA AT OMAHA

Jeffrey Pope & Dr. Harmon Maher,
Department of Geography/Geology, University of Nebraska at Omaha, Omaha, NE 68182


UAV Launch/Landing Site


Example Mission - Drone Deploy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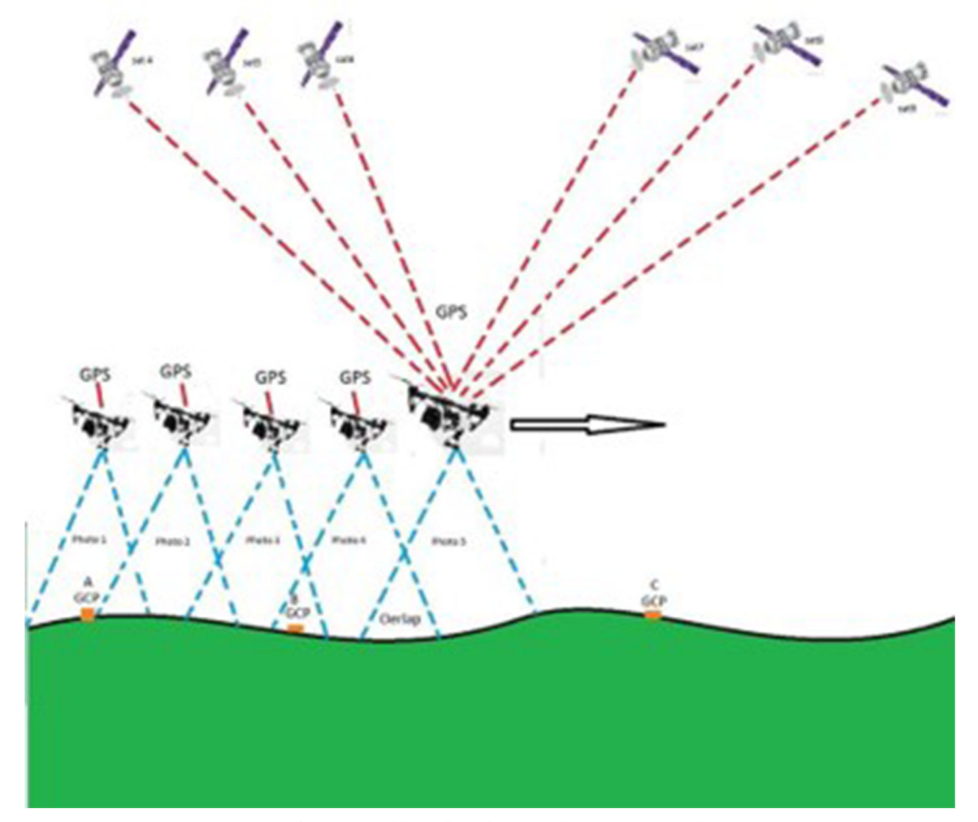
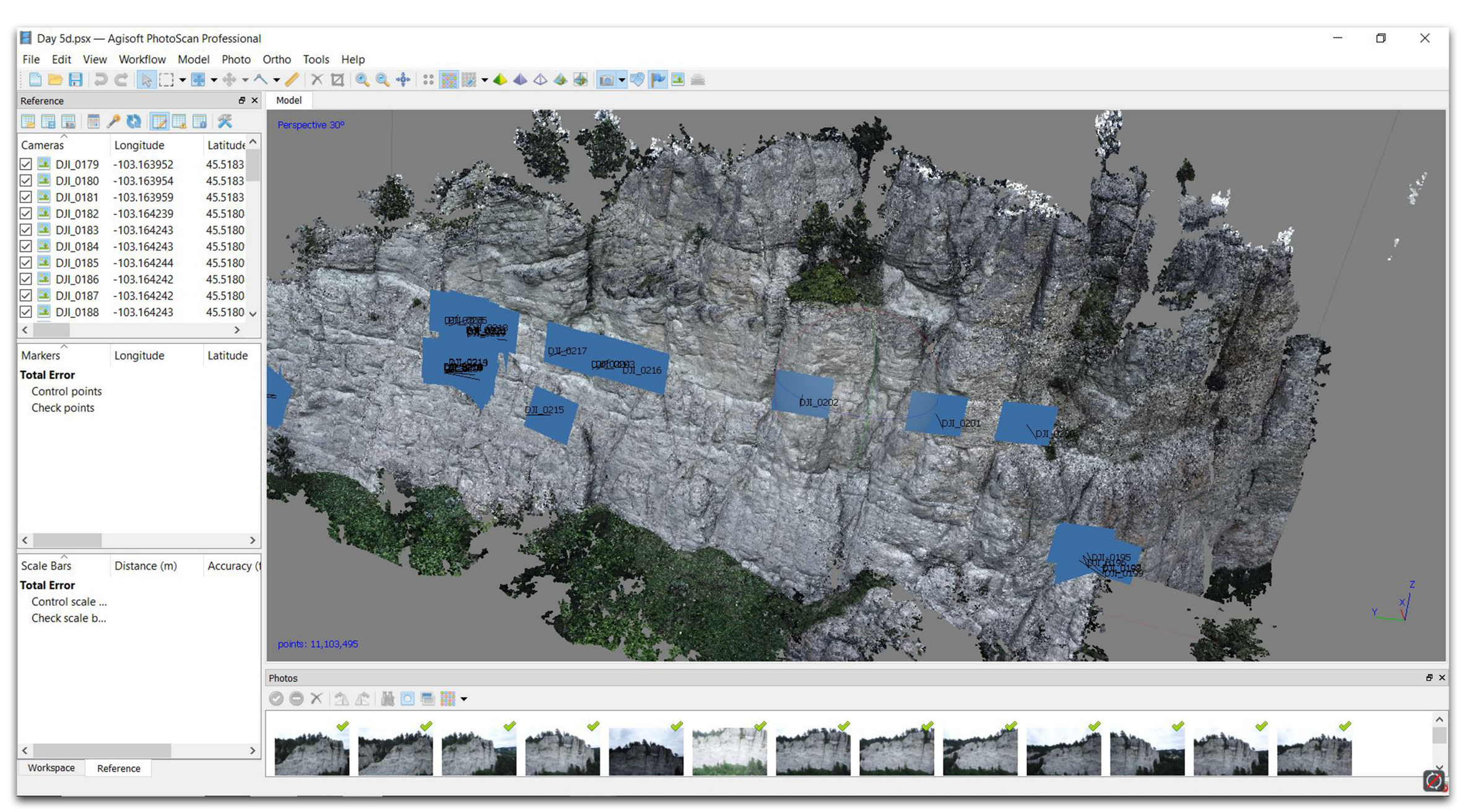
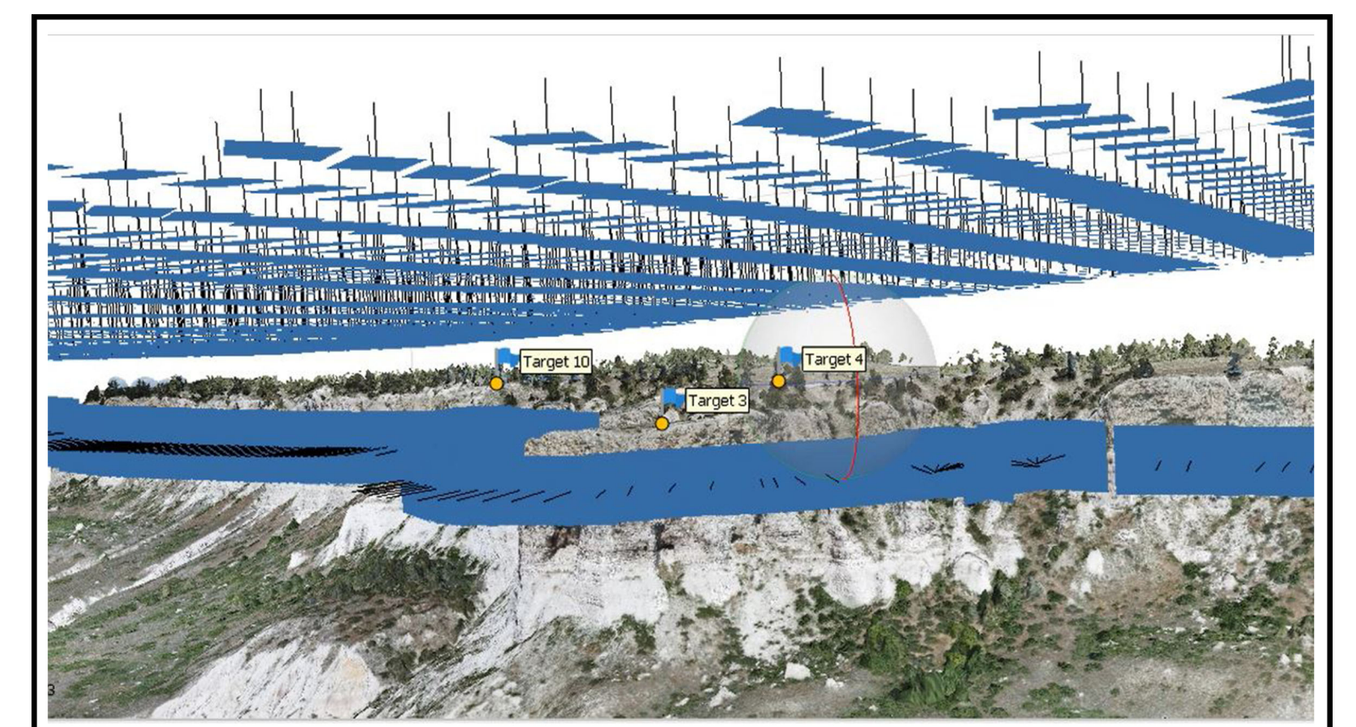

https://nebula.wsimg.com/307919a66338639474ba7ed330af2352?AccessKeyId=43C4A646490F5DC91BC0&disposition=0&alloworigin=1

Photogrammetry Principle

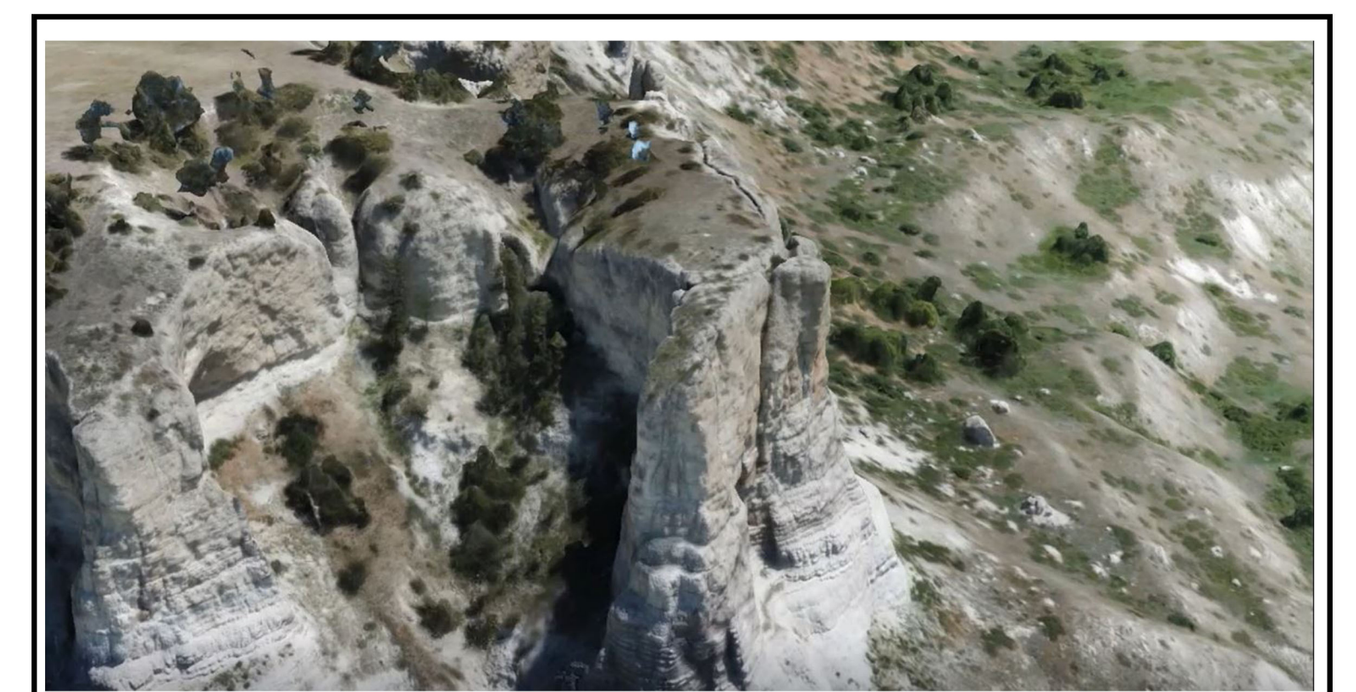
Methods:

- Scouted initial site locations using Google Earth
- Contacted required authorities to gain access to study sites and for permission to fly UAVs
- Researched local geodetic information for accuracy corrections located geodetic benchmarks
- Planned flight areas with Drone Deploy software
- Scouted take-off/landing sites on-site and modified flight areas accordingly
- Placed ground targets for each study site and recorded their x,y,z positions
- Executed daily missions and recorded gound target coords/elevations
- Dowloaded all files for initial processing with Agisoft Photoscan Pro
- Processed missions at high levels for input into MeshLab
- Converted and exported 3D models to LIME for data extraction
- Analyzed data further with other software (Surfer, Excel, Stereonet)


Agisoft Photoscan Pro Photogrammetry Software


Scan QR code for YouTube video
Video URL - https://youtu.be/tJHH91wk-Bs

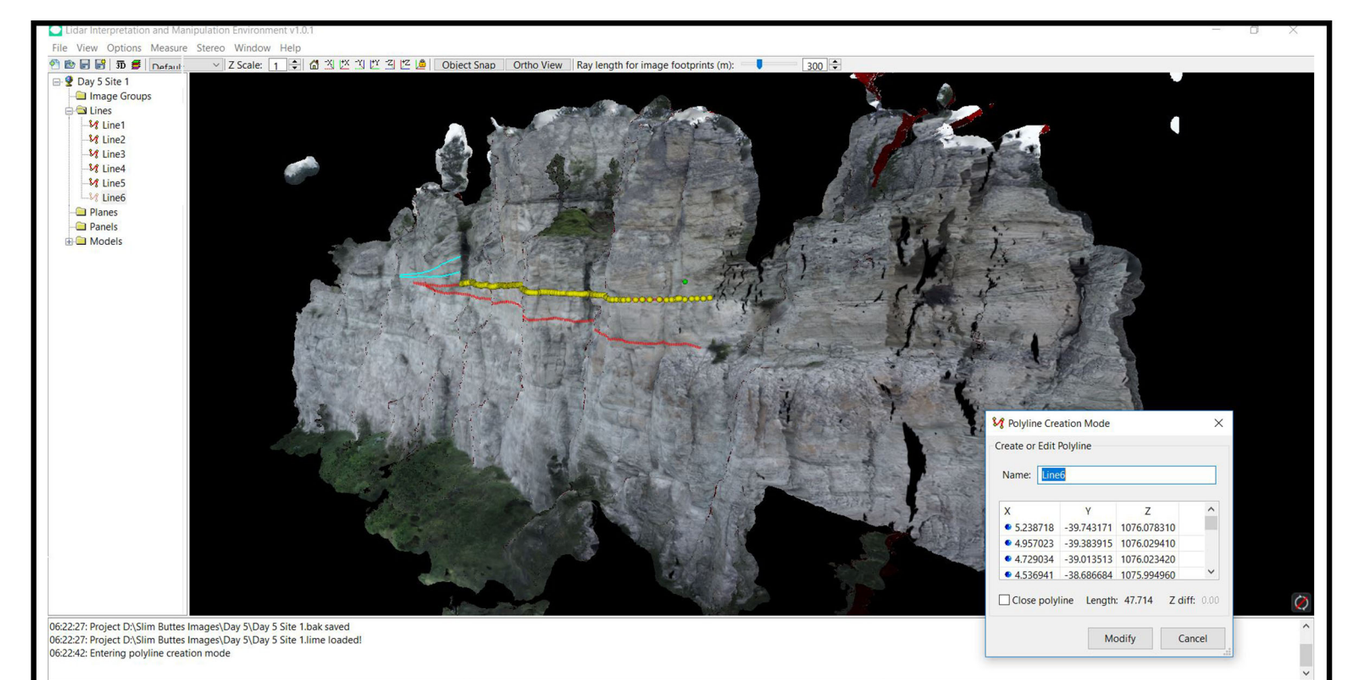
Sample 3D Model of Cliff Faces at Slim Buttes Showing Photo Coverage


Scan QR code for YouTube video
Video URL - https://youtu.be/bLh5jRBg-hQ

Sample 3D Model of Cliff Outcrop at Slim Buttes


Scan QR code for YouTube video
Video URL - https://youtu.be/kY1IOEQeD4c

Sample 3D Model of Cross-beds in the Arikaree Group at Slim Buttes


Scan QR code for YouTube video
Video URL - https://youtu.be/z8Nr8RMMXTc

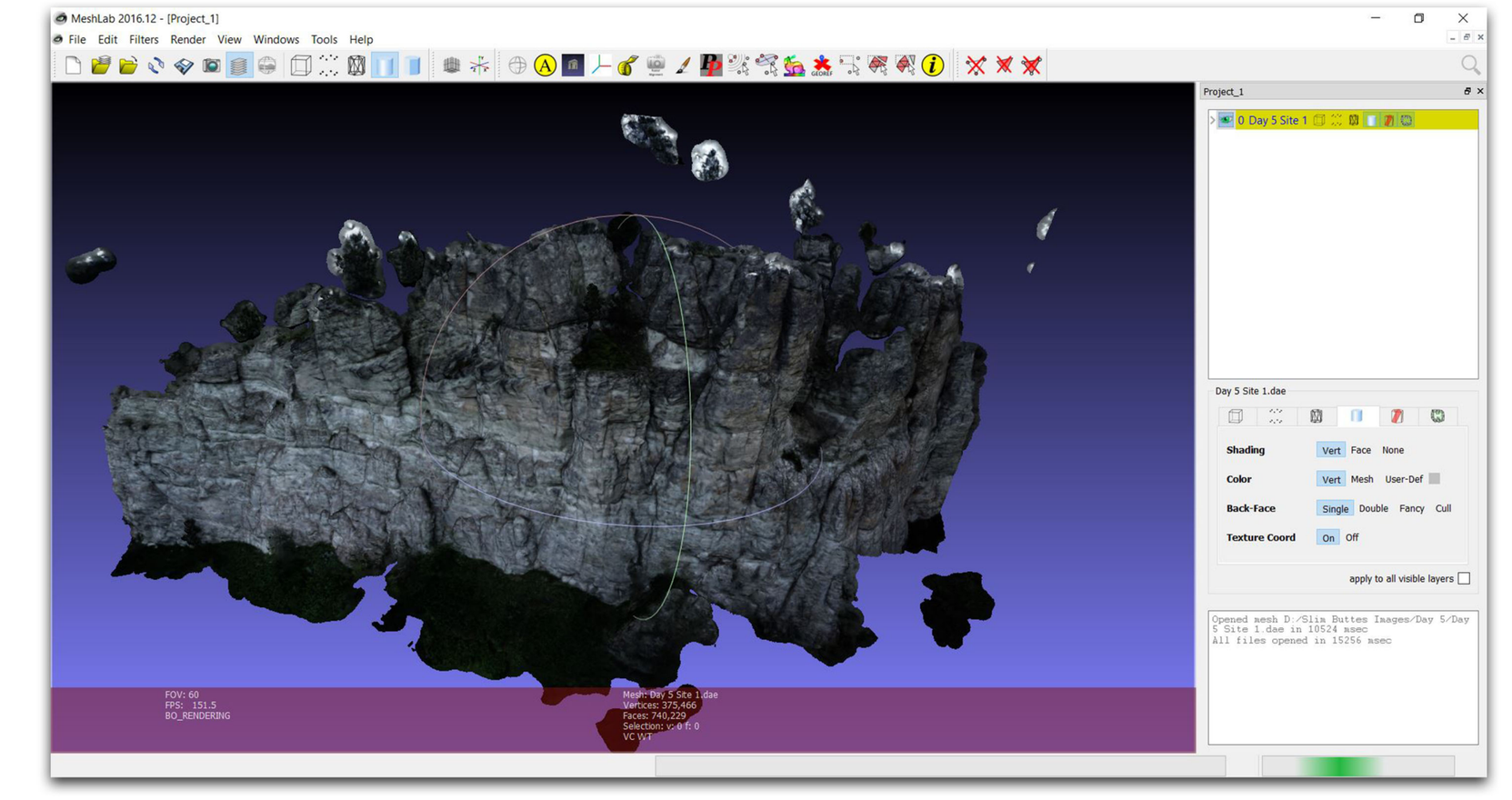
Identifying Cross-beds in LIME

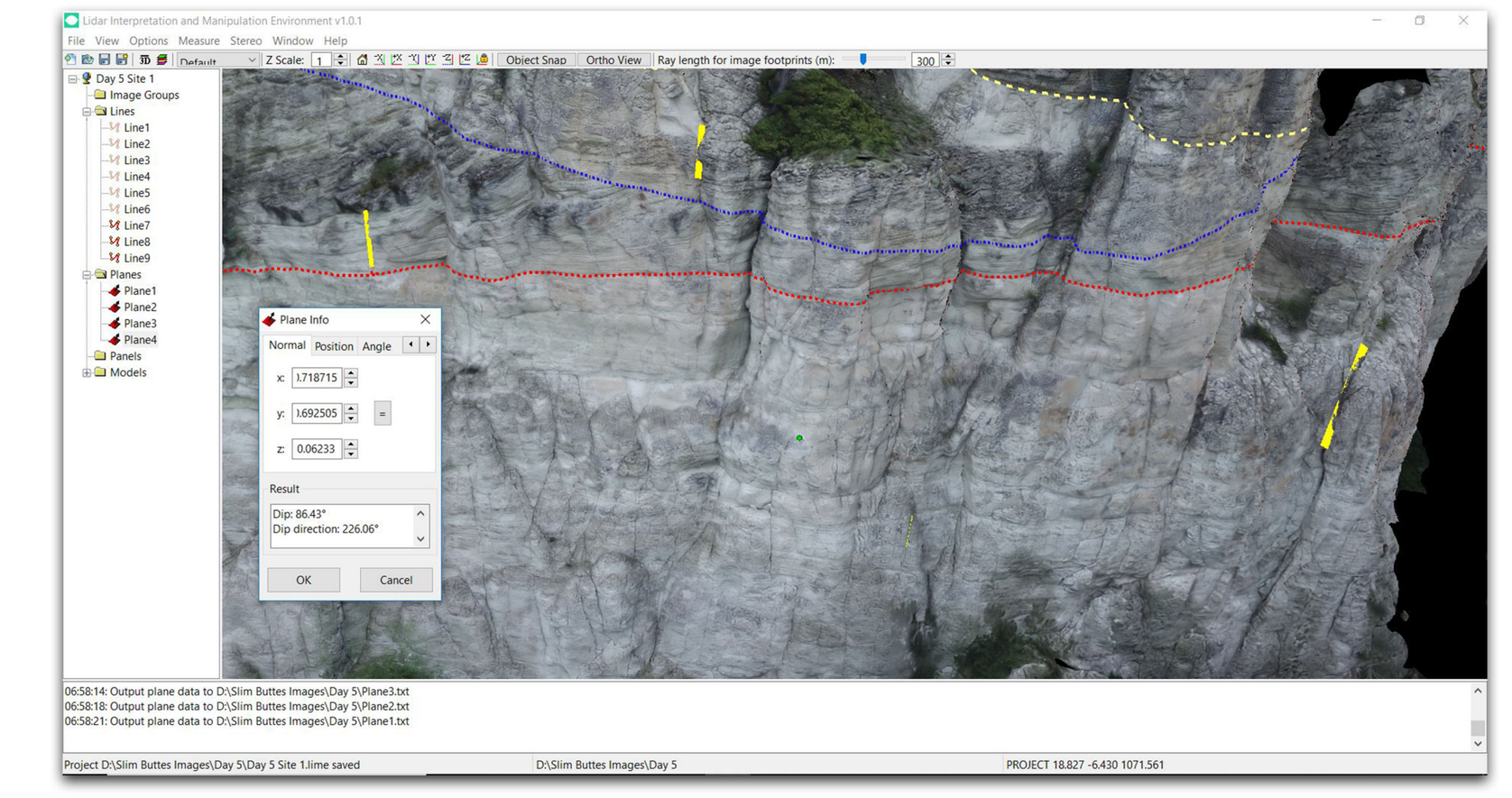
Acknowledgements:

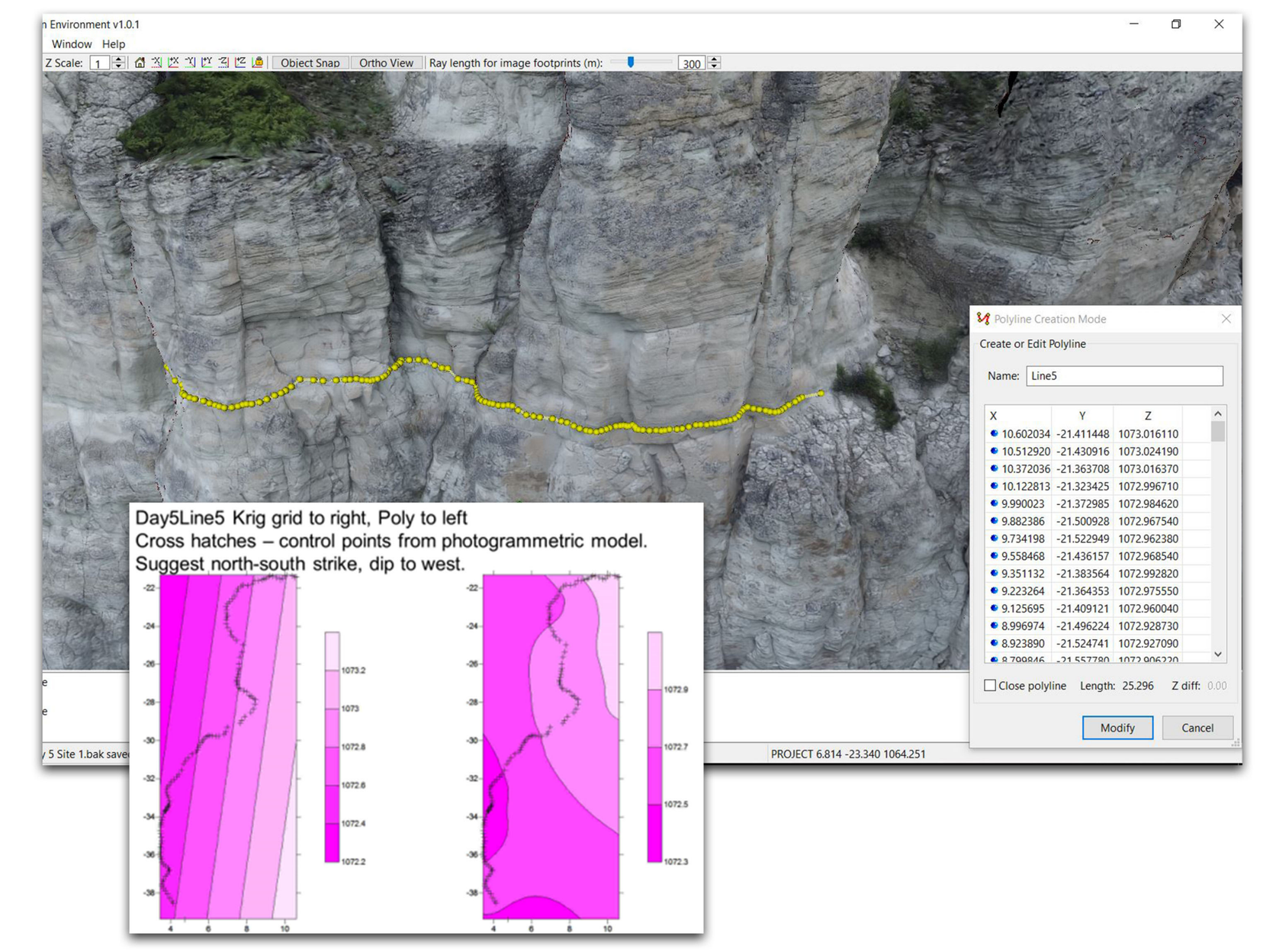
We would like to thank Dr. Harmon Maher, Kasie Knapp, Maggie Lanigan, the Nebraska Geological Society for the Yatkola-Edwards award, and the University of Nebraska at Omaha Geology and Geopgraphy Department for their help and support of this research project.

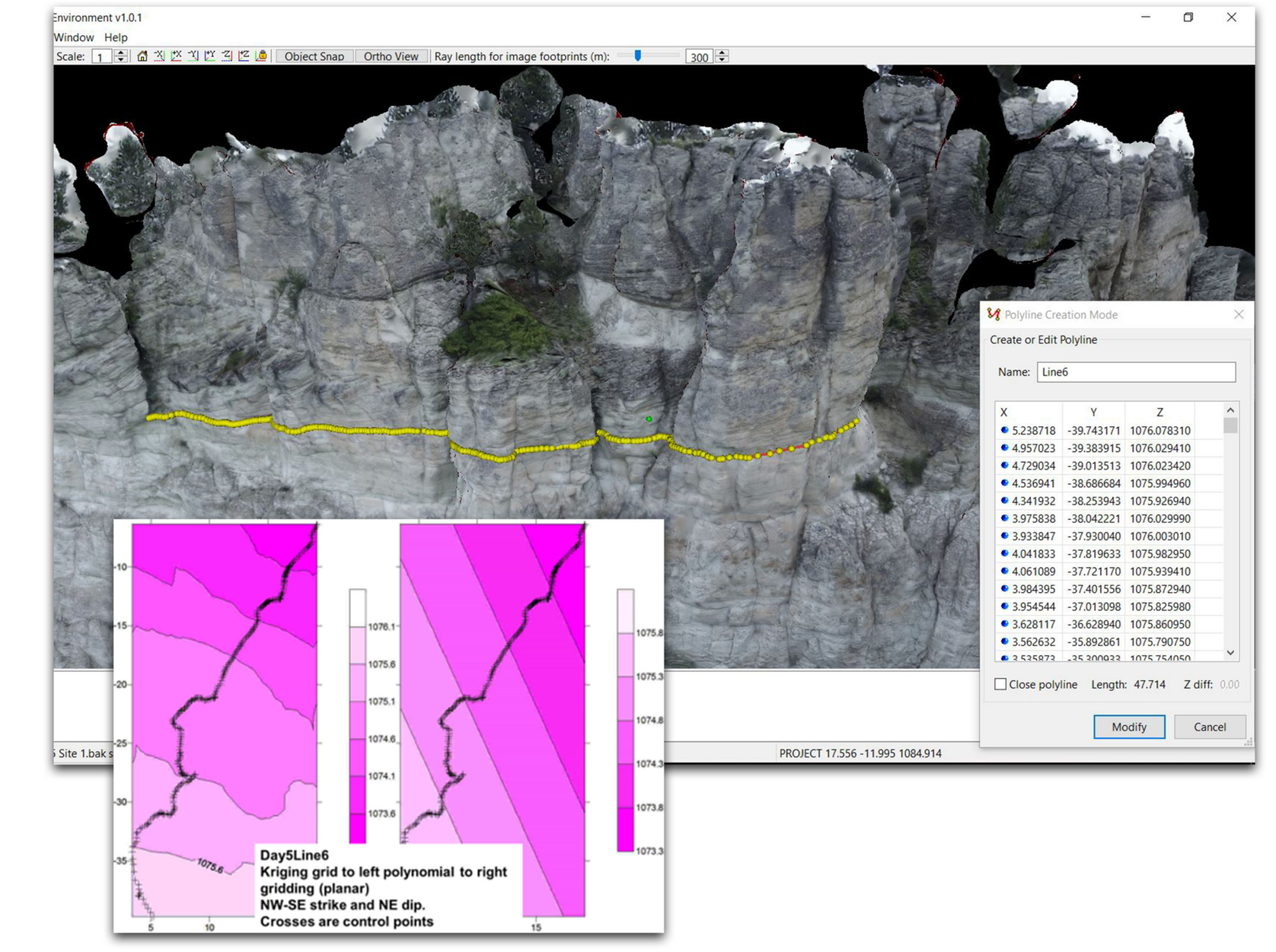
Results:

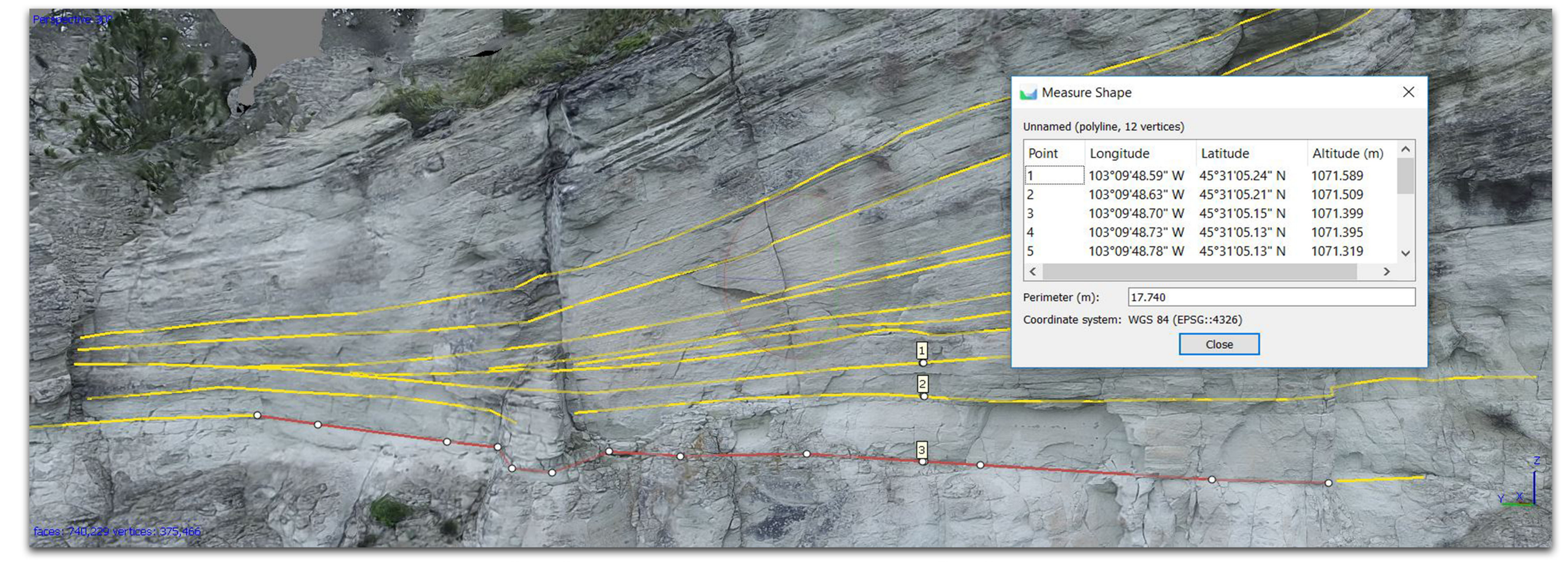
- Data acquired during this project resulted in 10+ 3D models
- Models range in size from 200 acres to 100 sq. meters
- Approximately 800 total acres of outcrops mapped and modeled
- Over 7,000 images collected in 6 days of total field time
- Explored and mapped sites that were previously inaccessible for study


MeshLab Viewing and Conversion Software

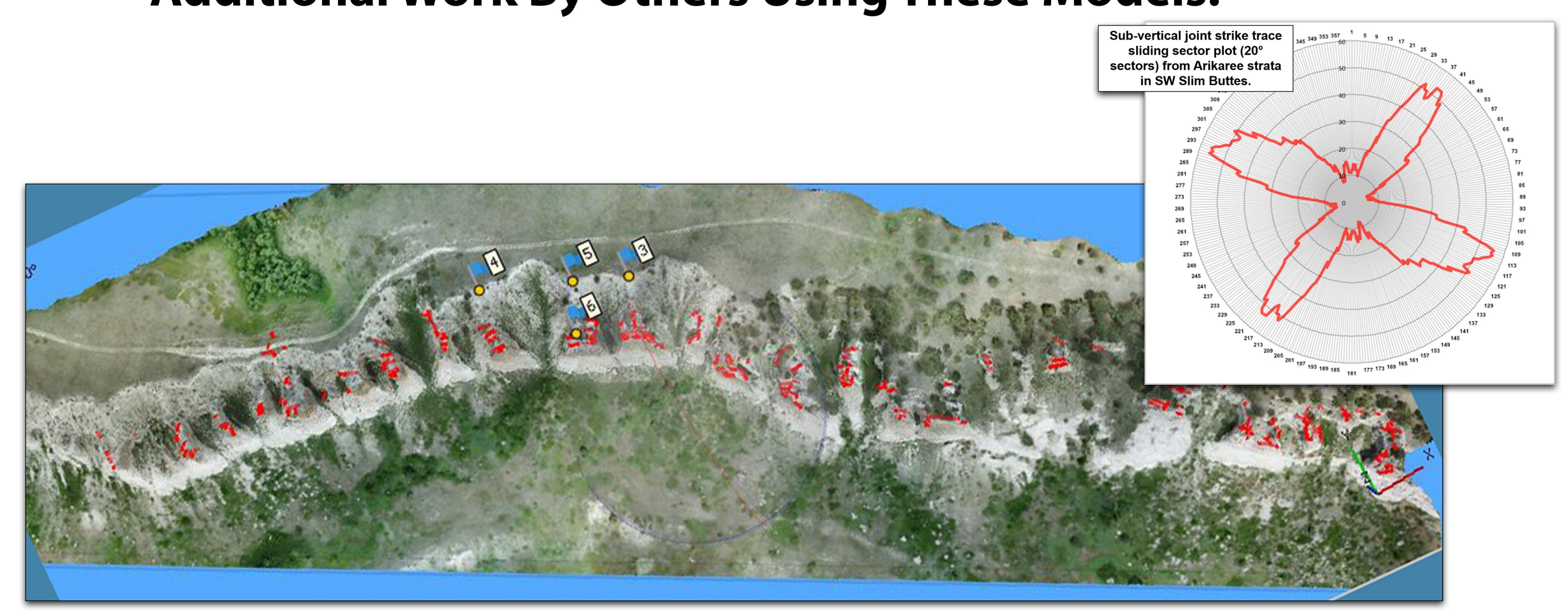

Extracting Strike and Dip Data from LIME Visualisation and Interpretation Software


Cross-bed Interpretation From LIME to Surfer - Example 1


Cross-bed Interpretation From LIME to Surfer - Example 2


Cross-bed Measurements in Agisoft Photoscan Pro

Additional Work By Others Using These Models:



Fracture Analysis of Cliff Exposures
Maher, H. (2019). History of Cenozoic Fracture Development at Slim Buttes, South Dakota

Conclusion:

- Gathered and processed large amounts of data in a short period of time
- Accessed areas that were too dangerous or impossible to reach for study
- Visualization of outcrops in 3 dimensions provided greater understanding of Slim Buttes geology
-Models show higher detail of cross-bedding in the inaccessible areas of the lower Arikaree sandstone
-Further verification of cross-bedding as point bar deposits in the lower Arikaree could reinforce previous hypotheses of differing flows and channel structures between the Brule Frm. and Arikaree Grp.
-3D outcrop models can be shared with other academic entities and departments for study
- Data and field processes from this study will be used as part of future geology curriculum at the University of Nebraska at Omaha
- Models currently being used in other Slim Buttes research projects
-Study to continue at graduate level and beyond