[PS]Cliff Mapping of Surface Outcrops in the Powder River Basin Using Unmanned Aerial System*

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Abstract

As an abundant petroleum producer since the late 1800s, the Powder River Basin continues to be a location of great interest for the oil and gas business. Continual advances in technology allow for enhancements in exploration and production. Formed during the Laramide Orogeny, it is a structural basin with abundant stratigraphic components. During the Cretaceous, the Powder River Basin was filled by the Western Interior Seaway which deposited numerous sandstone-shale sequences corresponding to numerous transgressions and regressions. The unit of interest for this study is the Campanian Shannon Member of the Cody Shale. The Shannon Member is laterally extensive in the Powder River Basin; it is thicker in the west and thins to the east. In the western portion of the basin the Shannon Member has several surface exposures that reach heights of up to 36 meters. These outcrops are steep cliffs of friable sandstone that pose safety risks for detailed mapping in close proximity.

Unmanned Aerial Systems, commonly referred to as drones, can allow for detailed imaging of the outcrops without the risk to an individual. This detailed imaging will be high enough in quality to identify facies changes and sedimentary structures. Using a drone to survey these outcrops will produce a map equal to or higher in quality than existing maps. Cliff mapping of the Shannon outcrops in Natrona County, Wyoming near Edgerton, Wyoming, will be performed with a rotor copter during the summer of 2017. After collection of the high resolution imagery, the images will be imported into Agisoft Photoscan which will allow for the creation of a detailed three dimensional map of the outcrops. This can then be compared to existing maps including the United States Geological Survey map MF- 2095 by Margaret Ellis.

Cliff Mapping of Surface Outcrops in the Powder River Basin Using Unmanned Aerial Systems

Master's Thesis by: Emily Sundell

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INTRODUCTION

Geologic maps present geologic information about the structure and stratigraphy of a particular area. They have been used in modern society since the late 18th century and are crucial for studying the past, understanding the present and predicting the future. These maps are also fundamental to the study and assessment of an area's energy, mineral and hydrologic resources. Geologic maps were first created by hand using pencils and paints. Over the past few decades GPS and GIS have become the essential tools for mapping. Coupled with satellite imagery, these tools have created more accurate, detailed data than ever before. As technology continues to advance so will mapping tools and techniques.

Perhaps one of the most important advances in recent technology has been the advent of and growing obtainability of unmanned aircraft. Unmanned Aerial Systems (UAS), commonly known as drones, are being used heavily in agricultural and photography industries. The machines are small, lightweight and are remotely piloted, meaning that they can access places people and manned aircrafts could not. UAS have been utilized for surface mapping, but are also well suited for vertical or cliff mapping.

Wyoming has copious surface outcrops, many of which are steep and unstable, making them difficult to study closely. This project will evaluate the ability of drones to collect detailed images of steep outcrops which can then be compiled into a comprehensive three dimensional model.

POWDER RIVER BASIN GEOLOGIC HISTORY

The Powder River Basin (PRB) is located in Northeastern Wyoming and Southeastern Montana. The basin is an elongate north-northwest trending syncline and is both a structural and topographic basin (Beikman, 1962). Structural deformation in the PRB began during the Upper Cretaceous and continued through the Eocene (Curry, 1971). During the Paleozoic and Mesozoic the PRB was periodically flooded by the epicontinental sea when clastic and carbonate sediments were deposited. Although there are numerous unconformities representative of non-deposition or erosion, rocks from the Cambrian to Cretaceous ages are largely concordant. Cretaceous rocks of the PRB are predominantly sandstones and shales which have generated numerous stratigraphic traps, often in close proximity to their source beds.

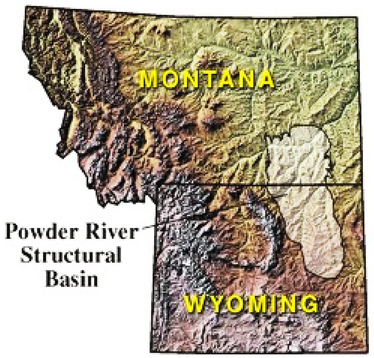

Figure 1. Location of the Powder River Basin

Trap formation was influenced largely by mountain building events, specifically the Sevier Orogeny and Laramide Orogeny. The Sevier Orogeny, part of the Cordilleran Thrust Belt, resulted from the oceanic Farallon Plate subducting beneath the continental North American Plate and occurred roughly 140-50 million years ago. Approximately 80-40 million years ago the Laramide Orogeny took place, also as a result of the Farallon Plate being subducted under the North American Plate (WGS, 2017).

POWDER RIVER BASIN GEOLOGIC HISTORY

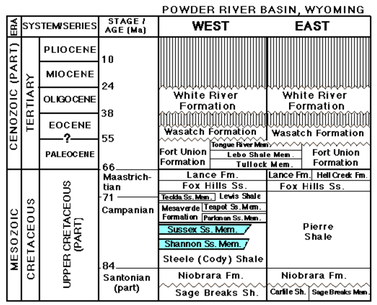

Figure 2. Stratigraphic Column of PRB

Wyoming was on the west side of the epeiric sea and deposition of Late Cretaceous rocks occurred in continental, nearshore marine and offshore marine environments; these rocks represent a minimum of six transgressive and regressive marine cycles, with some corresponding to eustatic events (Merewether, 1996). The sediments deposited during this time were predominantly derived from erosion in western Montana, eastern Idaho, and northwestern and central Wyoming. During the Late Cretaceous the average rates of sedimentation were 12.1-13.6 cm (4.8-5.4 in.)/1,000 years in the southern part of the basin and 8.1 cm (3.2 in.)/1,000 years in the northern parts (Merewether, 1996).

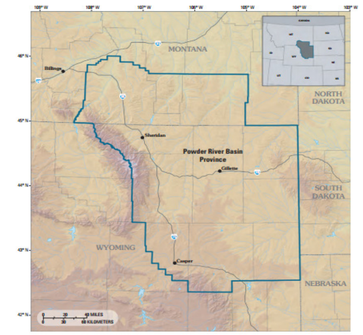

Figure 3. Powder River Basin Boundary

OBJECTIVES

The primary objective of this project is to create a three-dimensional model of the Shannon Sandstone outcrops known as the "Rim-Rocks" near Midwest, WY. This model will be interactive so it can be turned and viewed at different angles and at a range of distances. It will allow for close study of the unit which may include sedimentary structures and changes in lithology.

The secondary purpose of this project is to demonstrate that mapping with UAS can produce a map that is better than those already in existence. To test this the map created from this project will be compared to a map of the Powder River Basin and surrounding areas, published in 1989 by Margaret Ellis.

STUDY AREA

The outcrops of interest are in the northeast corner of Natrona County in central Wyoming. Located roughly 5.3 km west of Edgerton, WY, they are on a private ranch. The outcrops span a few square kilometers, but a central coordinate of the area is latitude: 43.362315° and longitude: -106.251606° (Figure 5). Google Earth can give a precise location for the outcrops, but has very poor resolution within a few kilometers of the rocks making it impossible to accurately detect or map any details such as facies changes or sedimentary structures. These outcrops are approximately 1 km East of the oldest field in Wyoming, Salt Creek Oilfield, the largest pool ever found in the Rocky Mountain region, and one of the largest in the United States.

Figure 4. Google Earth view of location

SHANNON SANDSTONE

- First well drilled in 1890 by Philip Martin Shannon
- Completely encased in Cody Shale
- Deposited in Upper Cretaceous, Campanian ~80 million years ago
- Sands are light gray, gray-green or buff in color
- Very fine-grained sands and silts interbedded with shale (Watson, 1980)
- Thickness ranges from 80' to 260' and averages 160'
- Permeability ranges from 1 mD to over 100 mD and averages 20 mD
- Oil gravities fall between 35 to 39 API
- Gas to Oil Ratio ranges from 300 to 2,100 CFG/bbl and average 800 CFG/bbl
- Drilling depths usually between 7,000' and 11,000'
- Multiple interpretations of depositional history
  - Offshore bars (Tillman and Martinsen, 1984)
  - Lowstand shoreface deposits (Walker and Bergman, 1993)
  - Incised channels

Figure 5. The "Rim-Rocks," Shannon Sandstone Outcrops

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METHODS

Located on private land, the Salt Creek Ranch, there will be little to no interference or threat to people or animals due to its remote location.

This project will be accomplished using a DJI Phantom 4 aircraft and the attached camera. The aircraft will be flown within a few feet of the outcrop and capturing images every few seconds. The camera has a 35 mm lens with 12.4 effective pixels. It has an ISO range of 100-1600, a shutter speed of 1/8000 s and has maximum image size of 4000x3000. Images will be in JPEG format.

After the flights and the images have been transferred to a computer, they will be uploaded and processed by PhotoScan software by Agisoft. This software boasts numerous functions including: measuring distances, areas and volumes, panoramic stitching, and 3D model generation and texturing. The mapping process should take around six weeks working five days a week, but is largely weather dependent. Excessive wind and precipitation will cause delays. Another consideration is capturing images that are not obstructed by shadows. This will mean working early in the mornings and late in the afternoon and evenings so the light is directly on the cliff faces.

Figure 6. DJI Phantom 4, UAS flown for imaging

Agisoft PhotoScan 3D Modeling and Mapping

Figure 7. The software used for model creation

PRELIMINARY RESULTS

Issues encountered during mapping so far have been wind, rain and rattlesnakes. Also getting the best possible light for minimum shadows has also been tricky. Over 1,300 images of the first outcrop were captured in the first 5 days. Agisoft PhotoScan has worked well thus far in producing quality results, but it takes a very long time to process and align images, build point clouds and create models.

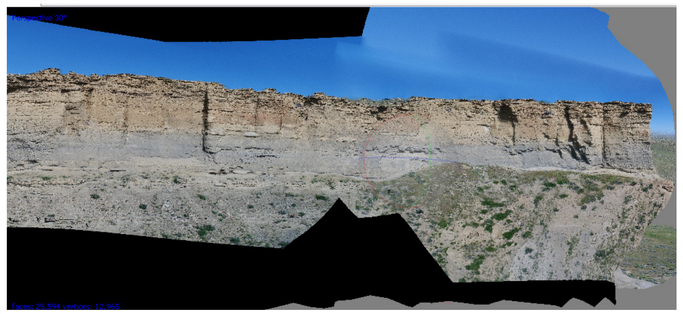

Figure 8. Photo of the West facing side of the first outcrop. Image stitching model generated with 23 photos and 21,602 points

PRELIMINARY RESULTS

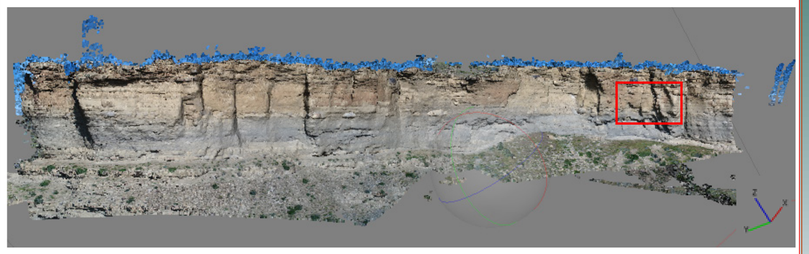

Figure 9. Photo of the West facing side of the first outcrop. Model generated with 63 photos and 28,272 points

Figure 10. After photos have been uploaded and aligned

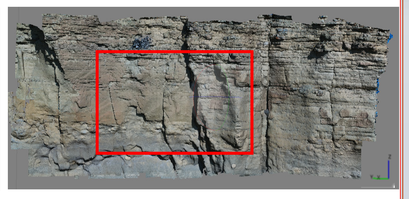

Figure 11. After photos are aligned and dense cloud is created

Both Figures 10 and 11: Top right corner of the West facing side of the first outcrop. Model generated with 72 photos and 73,765 points

Figure 12. Close up of Figures 9 and 11. West facing side of the first outcrop. Model generated with 63 photos and 28,272 points

These models were created on a medium resolution setting and have taken between 45 minutes and 2 hours to construct. The first step is to add the photos to the workspace; next the photos must be aligned, which takes about 15-45 minutes, and lastly a point cloud is constructed which takes anywhere from 30 minutes to an hour and a half.

CONCLUSIONS

The Southern part of the PRB is well explored, but the Northern part has received less attention. Drone mapping will make studying the Northern section of the basin quicker, easier and more accurate. The Shannon Sandstone is perfect for this project because it is laterally extensive and has excellent surface exposure. Creating continuous, detailed, lateral maps is best accomplished using UASs for great detail and safety reasons.

For future studies drone maps of surface outcrops will allow for interpolation of the Shannon Sandstone in the subsurface locations between outcrops in the West and horizontal drilling in the East. The data collected will be useful in gaining a better understanding and interpretation of the subsurface by comparing it with logs collected during lateral drilling. This should allow for more accuracy and precision during the drilling process. This process can be applied to any other unit of interest that has surface outcrops, including numerous other oil producing units in the Powder River Basin such as the Turner, Parkman, Niobrara and Frontier.

FIGURES

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