Modelling of an Ancient Fluvial Depositional Environment Using 3D-Photogrammetry and Paleohydrology, the Middle Pennsylvanian Allegheny Formation, South-Central West Virginia, USA*

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Abstract

This project uses state of the art 3D photogrammetry combined with paleohydrologic analysis of an ancient fluvial system to better define the facies architecture and facies association of the ancient fluvial channel. Fluvial systems are composed of sedimentary deposits in channelized environments dominated by flowing water. The morphology of fluvial systems is influenced by sediment supply, accommodation space and intensity of flow within the channel. Fluvial geomorphic response to these factors are characterized by a change in channel geometry and the formation of distinct sedimentary features which are distinguished based on geometry, scale and facies. Paleohydrologic analysis employs empirical equations for estimating paleochannel dimensions. The paleochannel dimensions estimated for static modelling, include paleochannel depth and width. 3D photogrammetry is used to construct a 3D photomosaic that captures sedimentary features from an outcrop of an ancient fluvial deposit. This data is then combined with channel dimension information acquired through Paleohydrologic analysis, and data from measured outcrop section, to develop a 3D model of the ancient fluvial depositional environment. The 3D photogrammetry and paleohydrologic analysis were used to investigate and model the Middle Pennsylvanian Allegheny Formation (MPAF). The MPAF is a northwest prograding clastic wedge, which originated from tectonically uplifted highlands along the east-central Appalachian basin. Preliminary sedimentary data showed that sandstone deposits below the Lower Kittanning Coal (LKC) member of the MPAF were more arenitic than the sandstone deposits above the LKC. Preliminary estimates of channel dimensions revealed channel flow depth ranging from 7m to 11m for the MPAF deposits immediately above the LKC and, 7m to 12m for the MPAF deposits immediately below the LKC. The use of 3D Photogrammetry to construct a photomosaic, combined with paleohydrologic analysis of ancient fluvial deposits improves the ability to define accurately, the facies architecture and facies association of the ancient fluvial channel from an outcrop data. The ability to determine the thickness and width of a channel is essential in estimating reservoir extent in exploration and development of petroleum resources of a fluvial depositional system.

Selected References

Bridge, J.S., and R.S. Tye, 2000, Interpreting the dimensions of ancient fluvial channel bars, channels, and channel belts from wireline-logs and cores:


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1) Abstract
This project uses state of the art 3D photogrammetry combined with paleohydrologic analysis to study the Middle Pennsylvanian Allegheny Formation (MPAF), a north-west prograding clastic wedge in the Appalachian basin. The morphology of fluvial members of the MPAF is influenced by factors such as sediment supply, accommodation space and intensity of flow within the channel. Fluvial geomorphic response to these factors are characterized by a change in channel geometry and the formation of distinct sedimentary features which are distinguished based on geometry, scale, and facies. 3D photogrammetry is used to construct a 3D photomosaic which captures detailed sedimentary features from outcrops. This data is then combined with estimated channel dimension information acquired through paleohydrologic analysis, to construct a static model of the ancient fluvial channel.

Preliminary sedimentary data showed that sandstone deposits below the Lower Kittanning Coal (LKC) member of the MPAF were more arenitic than the sandstone deposits above the LKC. Preliminary estimates of channel dimensions revealed channel flow depth ranging from 3m to 6m for the MPAF deposits above the LKC and, 4m to 6m for the MPAF deposits below the LKC.

The similarity in channel dimensions, even though the fluvial channel above and below the LKC have different mineral compositions, suggests input from different sources under similar allocogenic factors controlling the channel morphology. Future study involves the development of a stratigraphic framework which would be used to better differentiate the factors that influenced the depositional character of the MPAF.

2) Location and Geologic History

3) Methods

Paleohydrologic Equations Workflow

- Acquire Data
- Direct Measures of Flow and Width, etc.
- Use input from field
- Use input from tide
- Use flow from river

3D Photogrammetry Workflow

- Acquire Data
- Take photos from site
- Use input from image
- Use input from field

4) Result 1

Table Showing Estimated Channel Dimensions from Paleohydrologic Analysis

<table>
<thead>
<tr>
<th>Channel ID</th>
<th>Avg. Cross Set Thickness (cm)</th>
<th>Estimated Dune Height (Lecot, 2003) (cm)</th>
<th>Estimated Flow Depth(s) (Bridge and Tye, 2000)</th>
<th>Estimated Channel Width (m) (Bridge and McKay, 1993)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel above LKC</td>
<td>22.41</td>
<td>64.99</td>
<td>3.89 - 6.49</td>
<td>105.69 - 267.12</td>
</tr>
<tr>
<td>Channel below LKC</td>
<td>23.47</td>
<td>68.06</td>
<td>4.08 - 6.81</td>
<td>114.77 - 291.57</td>
</tr>
</tbody>
</table>

5) Result 2

Example of interpreted sedimentary feature using 3D Photogrammetry.

- a) Interpreted lateral accretion surfaces from MPAF members below the LKC (see location in outcrop image above).
- b) Interpreted lateral accretion surfaces from MPAF members above the LKC (see location in outcrop image above).

6) Interpretation/ Analysis

- Sandstone sample from MPAF members below the LKC (Magnification 2 x 0.5mm).
- Sandstone sample from MPAF members above the LKC (Magnification 2 x 0.5mm).

- 2D reconstruction of fluvial channel based on identification sedimentary features from 3D photos and estimated channel dimensions.

- Lateral Accretion Surace

7) Interpretation/ Analysis 2

MPAF Modern Analogue, The Magdalena River in Columbia, Comparism of Channel Morphology and Dimensions

- Map of the Magdalena River, Columbia.

8) Conclusions and Future Work

Conclusions:
- 3D Photogrammetry was useful in creating outcrop images that improved identification of sedimentary features of the outcrop.
- Sandstone deposits of the MPAF above and below the LKC differ in mineralogical composition. This might be due to change in sediment source or addition of new type sediment source.
- Even though sandstone deposits of the MPAF above and below the LKC have different mineralogical composition, estimates of pelecplexions both sandstone deposits are similar. This might be due to some sandstone when deposited by channels influenced by similar allocogenic factors.
- The fluvial morphology of the Magdalena river, a modern analogue, shows the possibility of relatively smaller fluvial channels, which merge with a larger axial channel, having sediment sourced from different areas compared to the large channels.

Future Work:
- Development of a stratigraphic framework which would be used to better differentiate the factors that influenced the depositional character of the MPAF.