Generation of a Three-dimensional Geo-cellular Outcrop Model for Use as a Training Image to Model Fluvial Systems

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Introduction: Modelling of fluvial reservoirs

- Object-based & pixel-based modelling methods
- Multiple levels of heterogeneity within fluvial reservoirs
- Modelling of small scale heterogeneities using Multiple-Point Statistics algorithm in order to increase accuracy
Introduction: Multi-Point Statistics

- Multi-Point Statistics (MPS) algorithms rely on the use of training images (TI)

- Training images can either be two- or three-dimensional, e.g. maps, aerial photographs, satellite images, outcrop data

- The training image should represent the repetitive geometrical structure of the reservoir

- 2 types of training images: stationary & non-stationary
Introduction: Methodology

- Outcrop photopanels (Arnot et al. 1997) & GPS data & digital elevation model

Optimal position of camera for collection of outcrop photopanels with minimal distortion within and between frames (after Arnot et al. 1997).

Scale changes between adjacent frames can be significantly reduced by maintaining a constant distance from the outcrop and overlapping adjacent frames by 50–60% (after Arnot et al. 1997).
Introduction: Methodology

- LiDAR survey (Bellian et al. 2005)

Example of LiDAR equipment.
Description of study area

A) Map of the United States (www.onlineatlas.us); B) Location of the field area (in Google Maps®) and of a cross section through the Morrison Formation; and C) Detailed map showing the location of the field area.
Palaeogeography & tectonic setting

Palaeogeographic map of North America during the late Jurassic (150 Ma) (from www.cpgeosystems.com), including schematic block diagram of the Morrison depositional basin (after Demko et al. 2004; ages from Kowallis et al. 1998).
Geologic background

- Upper Jurassic (148 – 155 Ma) (Kowallis et al. 1998)
- Tidwell, Salt Wash & Brushy Basin Member (Peterson 1980)
- Salt Wash Member: fluvial environment
- Palaeolatitudes of 30 – 35°N (Van Fossen & Kent 1992)
- Warm & dry palaeoclimate (Robinson & McCabe 1998)
Field season 1 (Oct.-Nov. 2010)

- 3D exposure → combination of plan view and cross sections

- Log sections (60 logs; combined thickness ~ 600 m)

- Palaeocurrent data (1041 measurements in plan view)

- Outcrop photographs (~ 350 photopanels)

Google Earth® satellite image showing the extent of the field area.
General stratigraphy

- Up to 4 sandstone packages divided by fine grained strata
- 5 different sandstone lithofacies

Log section, illustrating general stratigraphy.

Position of log section within field area.
Six different lithofacies can be distinguished: A) Pebby sandstone and conglomerate; B) Planar bedding and low angle lamination; C) Planar cross-bedding; D) Trough cross-bedding; E) Fine-grained sandstone, ripple laminated; and F) Mudstone, siltstone and fine grained sandstone.
Outcrop photographs

An example of outcrop photopanels, taken on the outer side (western side) of the first bend (displayed extent 11 m).
Log positions

Google Earth® satellite image showing where sections were logged.
An example of log sections which were taken on the inner side (eastern side) of the first bend.
Modern day example

Example from the Mississippi of how individual bars develop on the larger point bar (Google Earth® satellite image).
Field season 2 (May 2011)

- LiDAR survey
- Mapping of lithofacies
Results: LiDAR data

LiDAR data after texturing and draping of pictures (in profile).
Results: Interpretation

Interpretation of LiDAR data.
Results: 3D digital outcrop model

3D digital outcrop model created in Paradigm GOCAD 2009.3p3.

- mudstone/siltstone/
  fine-grained sandstone

- planar bedded and low angle lamination sandstone

- planar cross-bedded sandstone

- trough cross-bedded sandstone
Results: 3D digital outcrop model

3D digital (“sugar box”) model based on outcrop data, created in Paradigm GOCAD 2009.3p3, displaying lithofacies.

Cross-sections of the 3D digital model, displaying lithofacies.

Realisation based on 3D digital model, displaying lithofacies.
Discussion

- Series of cross-cutting bars
- Trough & planar cross-strata, separated by large scale strata → lateral accretion surfaces (?)
- Characteristics of a braided system
- Deposition in a sinuous channel system (morphology, palaeocurrents)
- Field data might need to be simplified to provide an appropriate training image
Conclusion

- The deposits of meandering and braided systems look similar in the rock record.

- There are various scales of heterogeneity within a reservoir (e.g. rock properties, lithofacies, facies,...), which need to be represented individually.

- Field data have to represent the appropriate scale of heterogeneity (e.g. the data collected in Utah might be used to populate single bars with different lithofacies).

- A simple training image, capturing only the main features might result in more accurate realisations than a complex training image.
Thank you!
Bibliography


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