From 3-D Photogrammetric Outcrop Model towards Reservoir Models: An Integrated Modeling Workflow*

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Abstract

3D technologies are now widely used in geosciences to reconstruct outcrops in 3D. The technology used for the 3D reconstruction is usually based on Lidar, which provides very precise models. Such datasets offer the possibility to build well-constrained outcrop analogue models for reservoir study purposes. The photogrammetry is an alternate methodology which principles are based in determining the geometric properties of an object from photographic pictures taken from different angles. Outcrop data acquisition is easy, and this methodology allows constructing 3D outcrop models with many advantages such as light and fast acquisition, moderate processing time (depending on the size of the area of interest), and integration of field data and 3D outcrops into the reservoir modelling tools. Whatever the method, the advantages of digital outcrop model are numerous: collection of data from otherwise inaccessible areas, access to different angles of view, increase of the possible measurements, attributes analysis, fast rate of data collection, and of course training and communication. This paper proposes a workflow where 3D geocellular models are built by integrating all sources of information from outcrops (surface picking, sedimentological sections, structural and sedimentary dips…). The 3D geomodels that are reconstructed can be used at the reservoir scale, in order to compare the outcrop information with subsurface models: the detailed facies models of the outcrops are transferred into petrophysical and acoustic models, which are used to test different scenarios of seismic and fluid flow modelling. The detailed 3D models are also used to test new techniques of static reservoir modelling, based either on geostatistical approaches or on deterministic (process-based) simulation techniques. A modelling workflow has been designed to model reservoir geometries and properties from 3D outcrop data, including geostatistical modelling and fluid flow simulations. The case study is a turbidite reservoir analog in Northern Spain (Ainsa). In this case study, we can compare reservoir models that have been built with

conventional data set (1D pseudowells), and reservoir model built from 3D outcrop data directly used to constrain the reservoir architecture. This approach allows us to assess the benefits of integrating geotagged 3D outcrop data into reservoir models.

Reference Cited

Arbués, P., D. Mellere, O. Falivene, O. Fernández, J. A. Muñoz, M. Marzo, and J. M. de Gibert, 2007, Context and architecture of the Ainsa-1-quarry channel complex, Ainsa Basin, Eocene south-central Pyrenees, Spain: in T. H. Nielsen, R. D. Shew, G. S. Steffens, and R. J. Studlick, eds., Atlas of deep-water outcrops: AAPG Studies in Geology 56, CD-ROM, 20 p.

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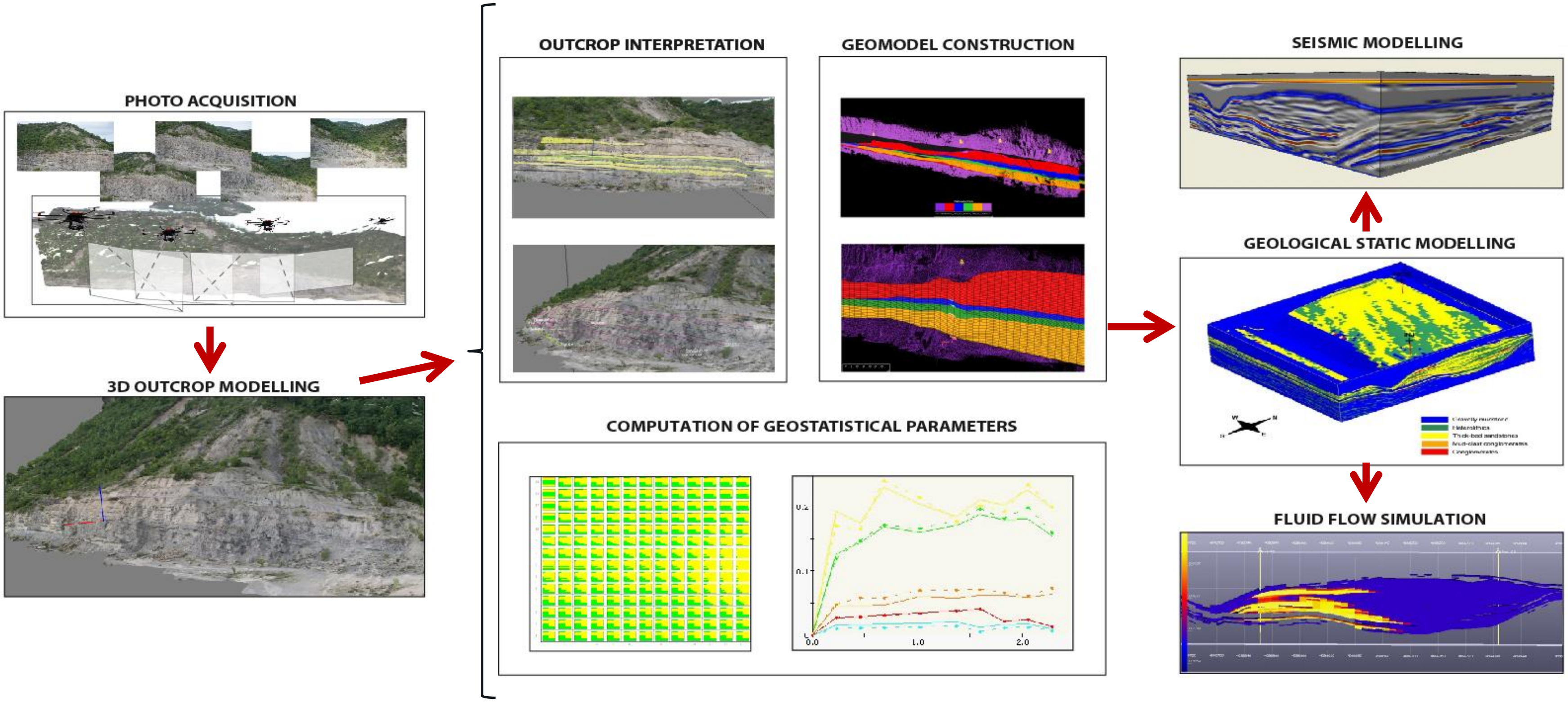
Objectives

- To enhance reservoir characterization & modelling using outcrop reservoir analogs
  - 3D digital outcrop models
    - From photogrammetry
  - Outcrop models interpretations
    - 3D interpretation of facies, surfaces, fractures…
  - Easy integration of field data
    - Sedimentary logs, dips and strikes…
  - Link with geomodelers (Petrel, Gocad)
    - Interpretations used as constraints for models

Workflow description

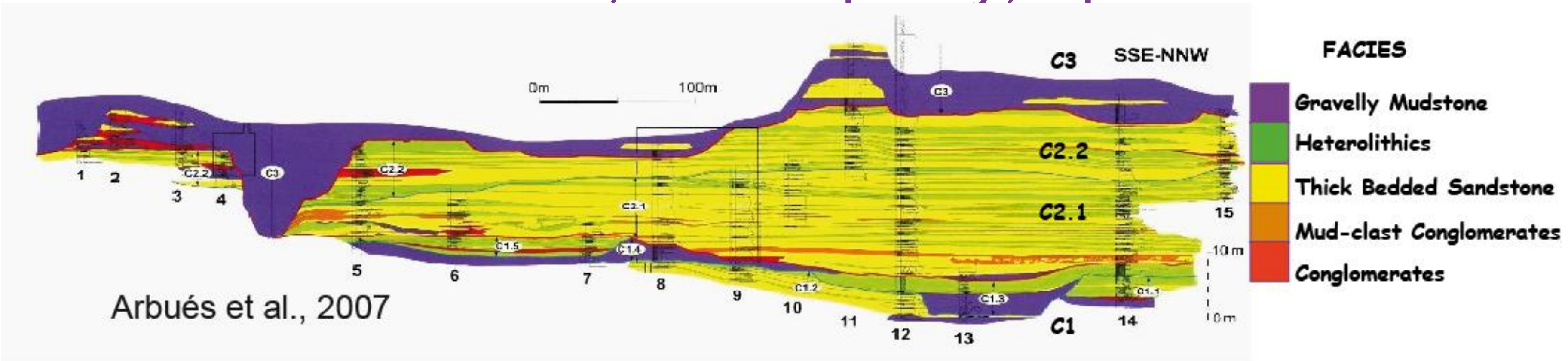
From outcrop data acquisition to modelling

Example from turbiditic reservoir analog, Ainsa quarry, Spain



Case study

Turbiditic channel, Ainsa quarry, Spain



- Turbiditic channel
- Lots of heterogeneities
  - Heterolithics
  - Mud clasts conglomerates
  - Muddy debris flow

1- Acquisition

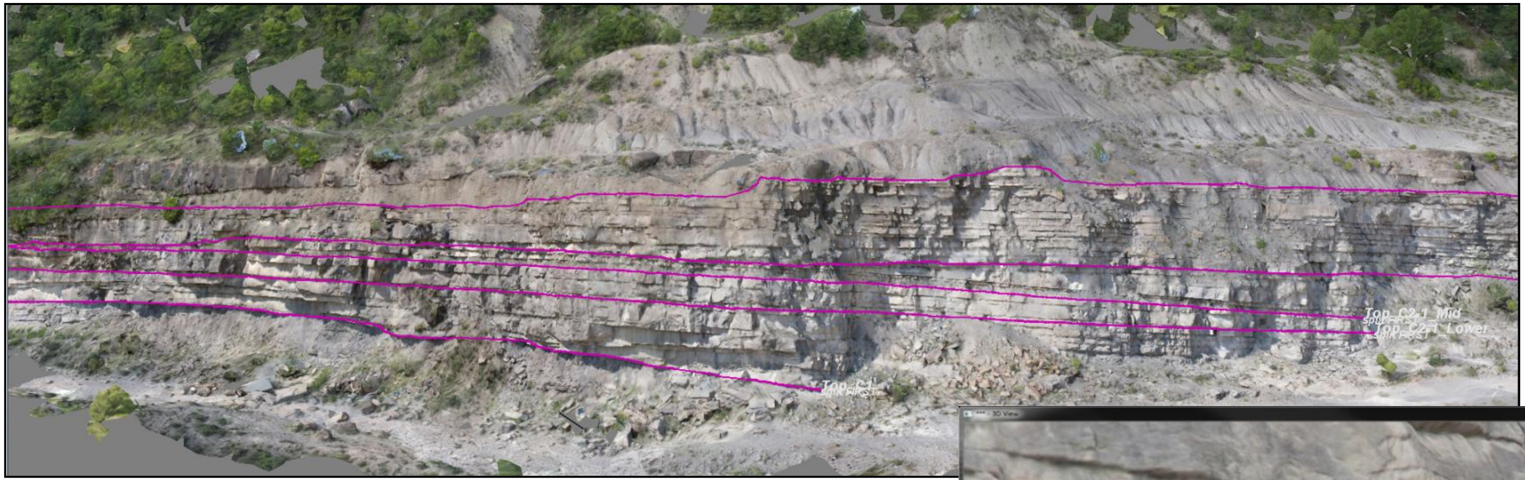
- Photogrammetry
  - Technique of triangulation process using angle measurements of images
- Aerial or ground acquisition
  - Fast acquisition

2- 3D outcrop modelling

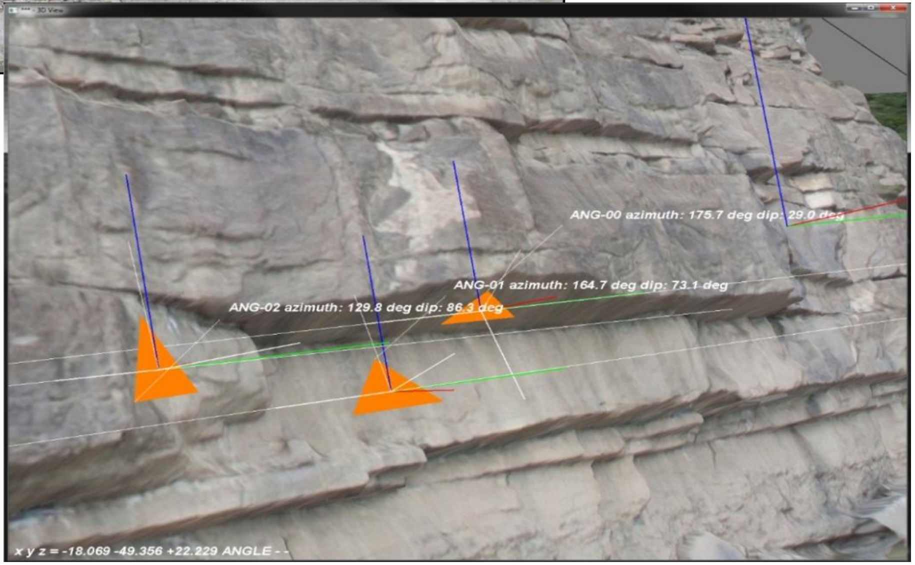
- Automated method with moderate computation time
- High precision for reservoir models

3- Outcrop interpretation

- Horizon picking



- Litho-units definition
- Export in geomodel
  - Surface construction
  - To build the reservoir grid

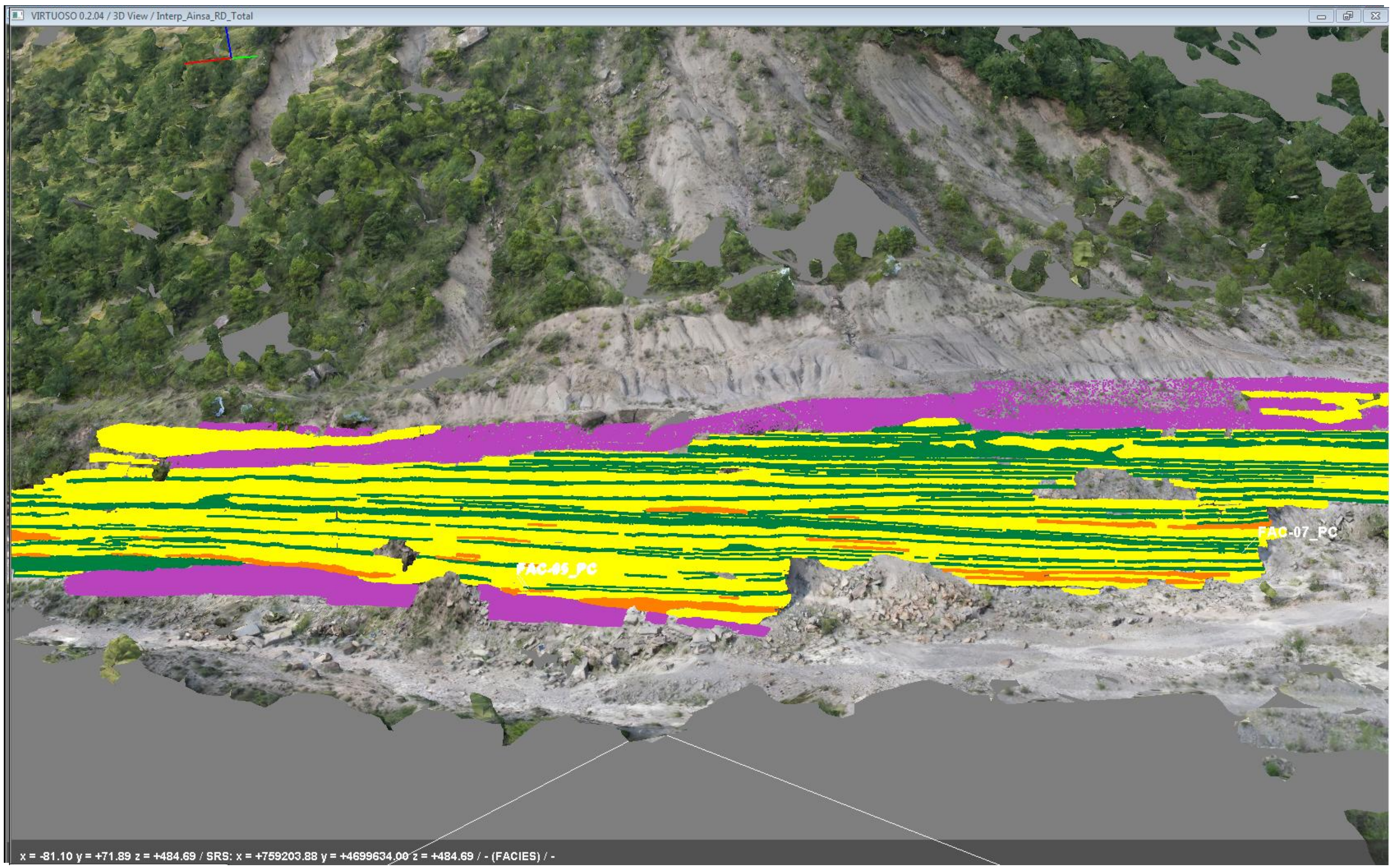


3- Outcrop interpretation

■ Property painting (facies)

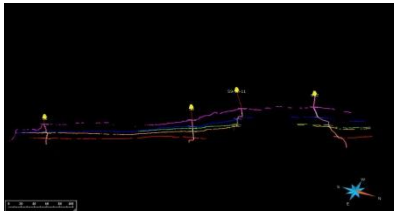
FACIES

- Gravelly Mudstone
- Heterolithics
- Thick Bedded Sandstone
- Mud-clast Conglomerates
- Conglomerates

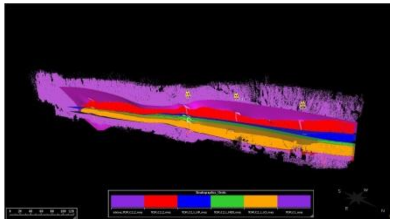


4- Model construction

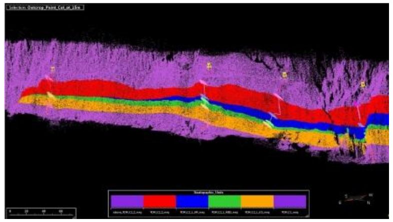
Geomodel



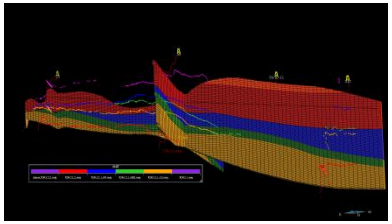
1 - Bounding horizons picked directly on the 3D outcrop model



2 - Surfaces reconstructed from polylines and structural dips



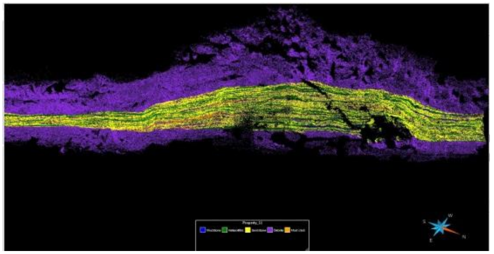
3 - Pointset extracted from the photogrammetric model

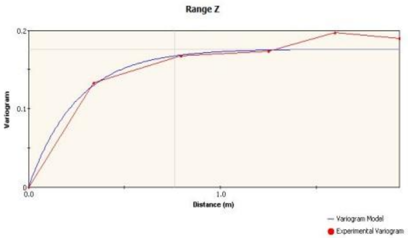


4 - Geological grid built from the surfacic model

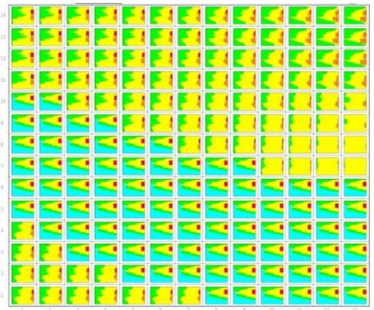
Geostatistics

1 – Computed from data interpreted on outcrop, directly from the interpretation (exported cloud of points)





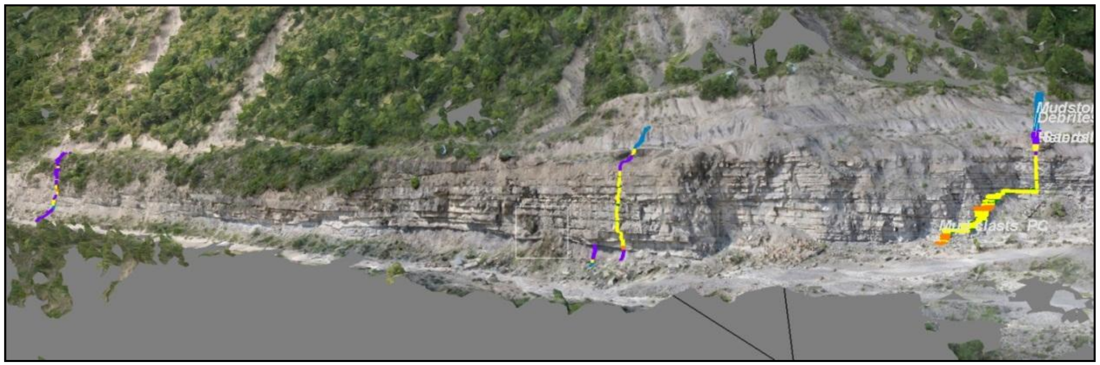
2 - Variograms are computed from the facies pointsets



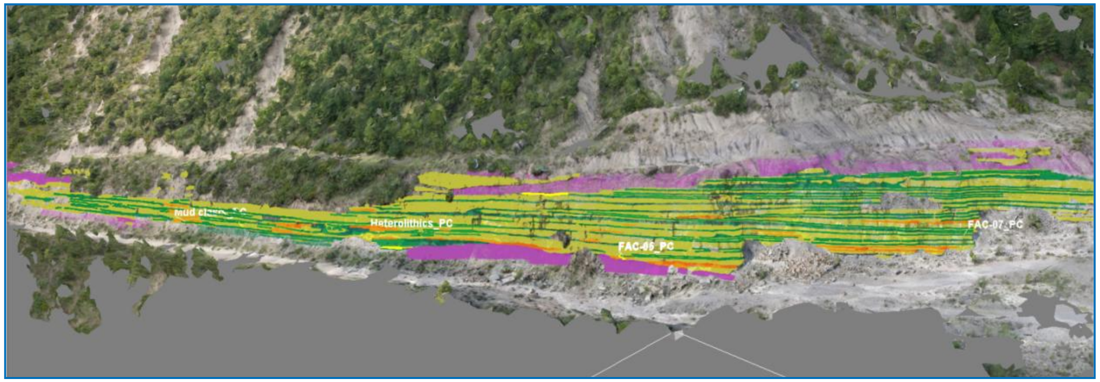
3- Vertical proportion curves and matrix of proportion computed from local VPC for each unit

4- Geological modelling

Objectives: Compare models using conventional dataset and 3D outcrop interpretation



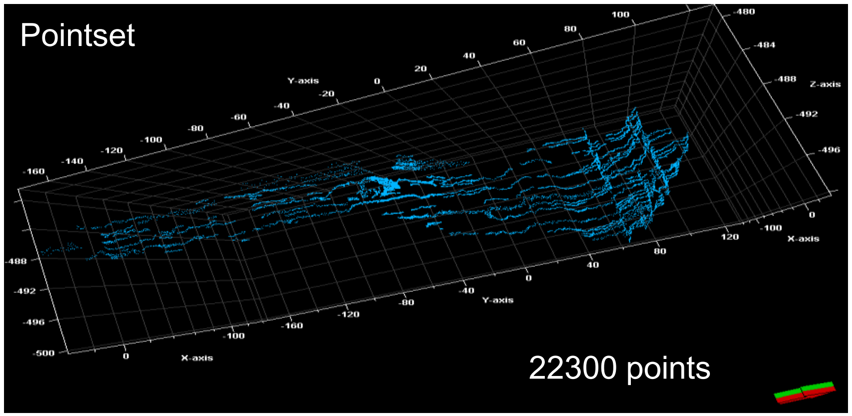
VS

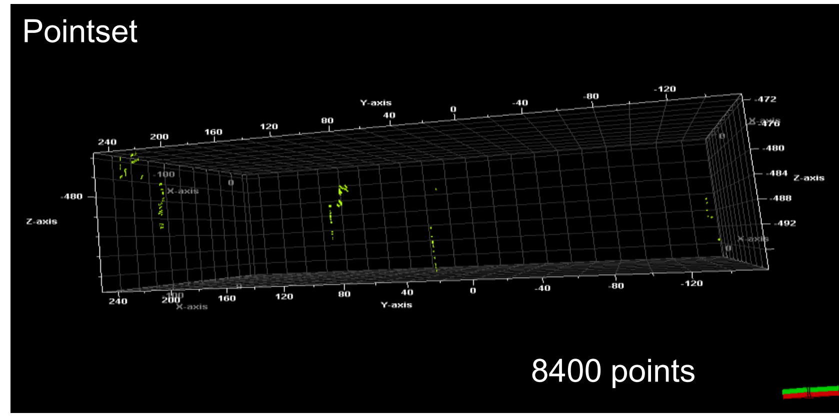


- Pseudo 1D dataset
  - 3 pseudo-wells with facies interpretation
- Fully interpreted outcrop

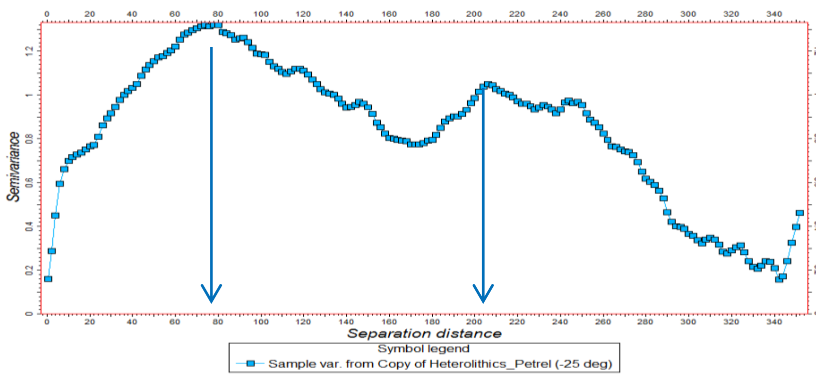
Geostat. parameters – Heterolithics

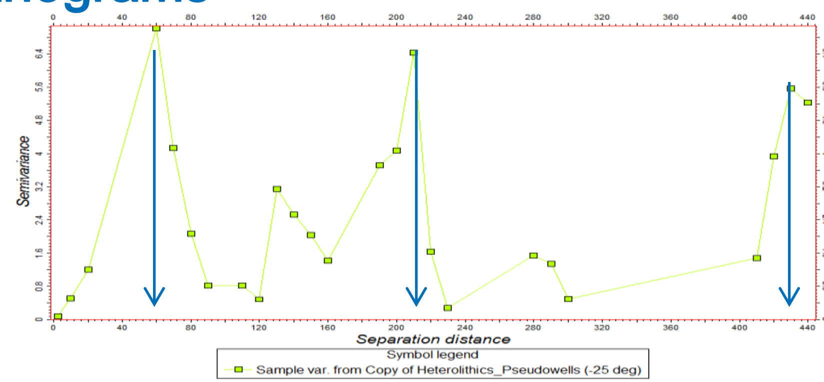
Full outcrop | Pseudo-wells





Horizontal variograms



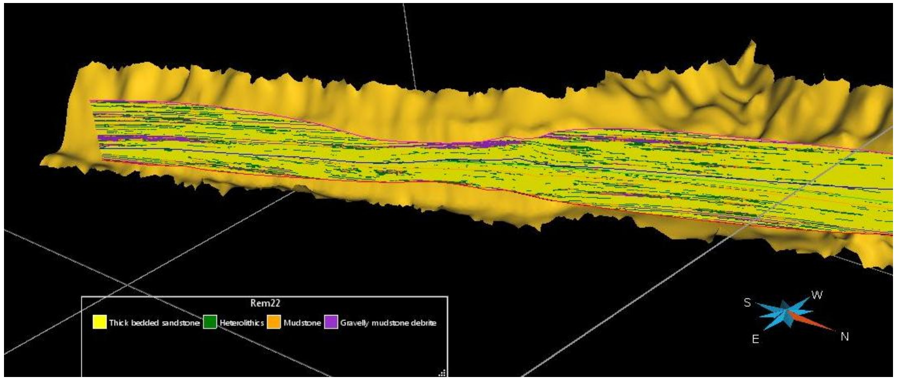


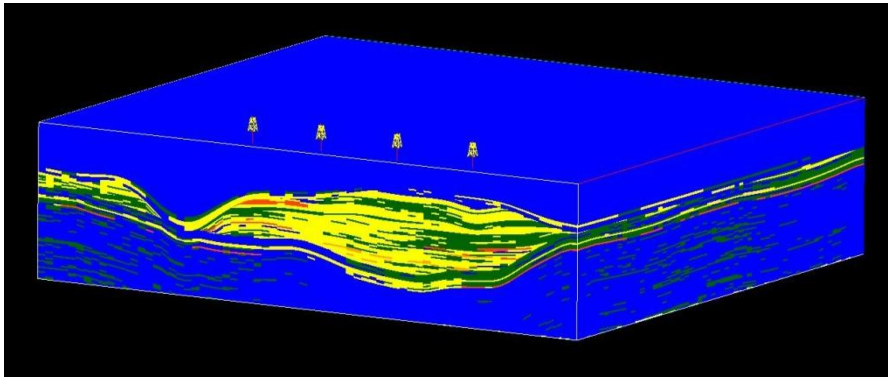
- 2 ranges corresponding to the outcrop configuration (channel bottom confinement)

- Ranges difficult to interpret
- Picks corresponds to pseudowells

Results

Dataset: pseudowells vs. outcrop interpretation





- **Full outcrop interpretation**
  - Continuous dataset
  - Heterogeneity continuity well represented
- **Pseudo 1D dataset**
  - 4 pseudowells with facies interpretation
  - Very smoothed facies distribution
  - Heterogeneity continuity poorly represented

Conclusions

- Workflow based on 3D photogrammetric data
  - 3D outcrop model used for reservoir analog studies
- Tool that includes property painting (facies) and horizon picking
  - Directly used as constraints for the geological model (Surface modelling, gridding and geostatistics)
- Geostatistical parameters better represent properties with outcrop interpretation dataset, compared to 1D "pseudo-wells" dataset

Perspectives

- Statistical toolbox
  - Statistical and geostatistical analysis to export in modelling softwares
- Object auto-tracking
  - Ex: Automatic fracture picking…
- Geo-positionning
- Possibility to add external constraints to correct the bias induced by the outcrop orientation
  - Ex: take paleocurrent directions into account for variogram definition

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