Modeling heterogeneous geological reservoirs using multiple-point statistics simulation

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Introduction

Aim: simulate heterogeneous geological reservoirs from:
- a conceptual geological model: analogue site, training image (TI),
- conditioning data (field observations).

Motivation:
- evaluate the impact of heterogeneities on physical processes such as flow and transport,
- improve management decisions in a context of uncertainty.

Multiple-point statistics (MPS) simulation

Basic principles of MPS simulation for populating the simulation grid (SG) [4,2]:
- assign the conditioning data,
- visit all unsimulated nodes of the SG, and for each one:
  - retrieve the pixel configuration in the neighborhood of the node,
  - compute a conditional probability density function (cpdf) from the TI,
  - draw a facies randomly according to the cpdf.

The following illustrations are performed using Impala (parallel software) integrating a newly developed MPS technique [3] and accounting for the non stationarity of the geological formations.

1st case study: Lena River

2D example, simulation of a delta:
- 3 facies (channels, lakes, land),
- non stationarity handled with auxiliary variable (distance to coast) and zones for rotations,
- conditioning data in sea (in the SG).

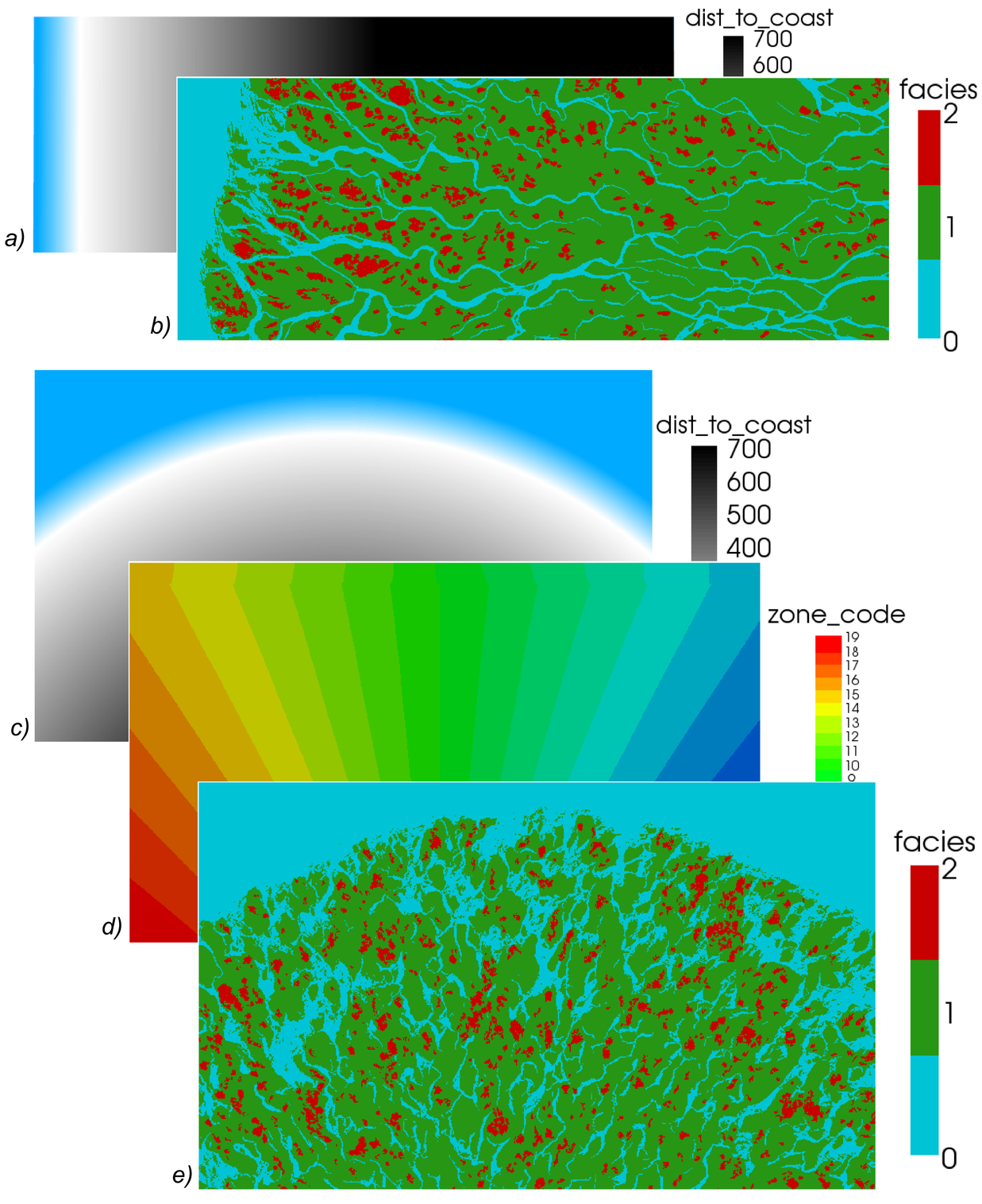

Fig.1: *a)* auxiliary variable (distance to the coast) for the TI; *b)* TI (size 1501 x 501), delta of the Lena River (Russia) (ref.: Landsat 7 image, USGS/EROS project and NASA Landsat project); *e)* simulated delta structure (size 1500 x 900) based on the TI in *a)* and its auxiliary variable map *b),* and conditioned to *c)* auxiliary variable (distance to the coast) for the SG, and *d)* orientation zones map for the SG.

2nd case study: Herten aquifer analog

Reconstruction of the 3D structure of highly heterogeneous sedimentary deposits:
- Herten dataset [1]: six parallel outcrops (Fig.2*a*) of a quarry in the Rhine basin close to Basel,
- Ordinary Kriging for simulating large scale structures (Fig.2*b*),
- then, MPS for simulating small scale heterogeneities (Fig.2*d*).

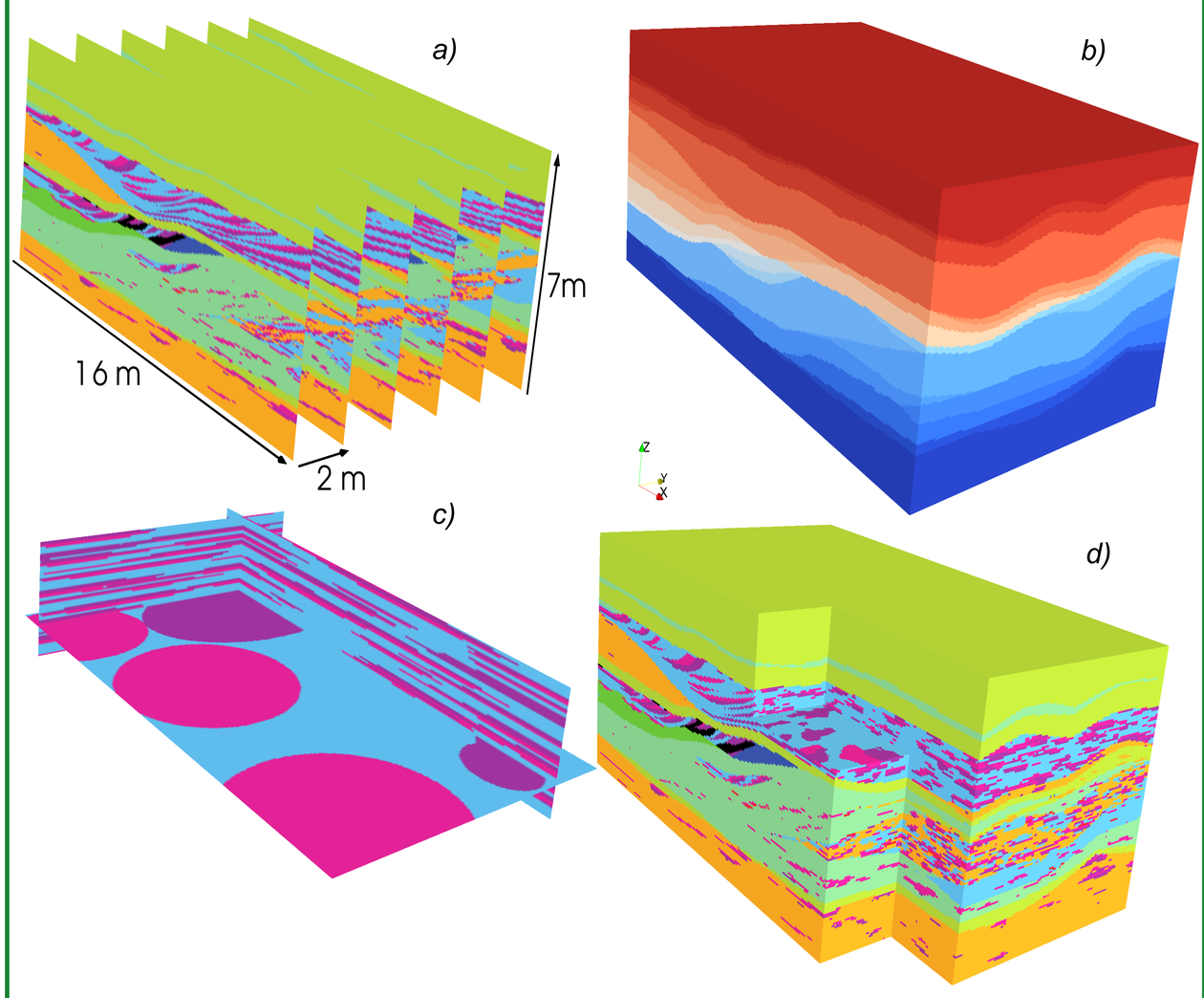

Fig 2: *a)* outcrop sections used to deduce the training structures and as conditioning data; *b)* large scale structures interpolated with ordinary Kriging; *c)* one of the training images used for the MPS simulation of a single layer of *b)*; *d) o*ne realization of the full 3D geometry obtained with the hierarchical approach.

Conclusion

MPS technique provides realistic and highly heterogeneous models accounting for:
- conceptual model (TI),
- conditioning data,
- non stationarity.

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