PS Geostatistical Modelling of Hydrothermal Dolomite by PluriGaussian Simulation from Digital Outcrop Dataset (Latemar, N-Italy)*

Nadya Kulyukina¹, Olivier Dubrule^{1,2}, and Carl Jacquemyn¹

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Abstract

A number of carbonate reservoirs show hydrothermal dolomite imprint, however little information exists on the geometry and distribution of dolomite bodies in these reservoirs. The spectacularly exposed Laternar platform (Northern Italy) represents an outcrop analogue for carbonate reservoirs affected by hydrothermal dolomitization genetically linked to igneous activity. Detailed lithological information obtained from digital outcrop dataset and outcrop observations of a hydrothermal dolomitized carbonate platform has been used to constrain the detailed modelling of the 3D dolomite body architecture. PluriGaussian Simulation (PGS) has proved useful in other instances to model carbonate reservoirs and is an improvement of previous effort to model the Laternar dolomites by Sequential Indicator Simulation because it allows modeling multiple lithologies and preserving their connectivity. Six detailed pseudo-wells were "drilled" in the digital outcrop, and used as the data to constrain the modelling. The quantitative architectural information derived from the digital outcrop consists of the variograms of the observed lithologies (high-permeability dolomite, low-permeability limestone and magmatic dikes) and the cross-variograms between these three. The input to PGS consists of vertical proportion curves of the lithologies, and truncation diagrams or lithotype rules, which are used to constrain the transitions between lithologies. The lithotype rules are a graphical representation of facies or lithology relationships. The models obtained with PGS satisfy the vertical proportion curves, truncation diagram and (cross-) variograms. In this study, different lithotype rules are tested and compared to determine the most representative rule for modelling hydrothermal dolomite bodies. The resulting 3D model conforms outcrop observations and shows dolomite bodies which are elongated in dike-parallel directions and a preferential transition from dike to dolomite, with some degree of randomness allowing direct limestone to dikes transitions. The 3D model, after truncation by the digital outcrop topography, shows a satisfying resemblance with the real outcrop. This study shows that PluriGaussian simulation has the potential to be applied more generally to subsurface cases of hydrothermal dolomitization. Also, other plays where diagenetic fluids come up along faults and alter the surrounding rocks would benefit from a similar approach.

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Jacquemyn, C., M. Huysmans, G. Casini, D. Hunt, and R. Swennen, 2015, Multi-scale 3D distribution of fracture- and igneous intrusion-controlled hydrothermal dolomite from digital outcrop model (Latemar platform, Dolomites, northern Italy): AAPG Bulletin, v.99, p. 957-984.

Jacquemyn, C., H. El Desouky, G. Casini, D. Hunt, and R. Swennen, 2014, Dolomitization of the Latemar platform (Dolomites, northern Italy): fluid flow and dolomite evolution: Marine and Petroleum Geology, v.55, p. 43-67.

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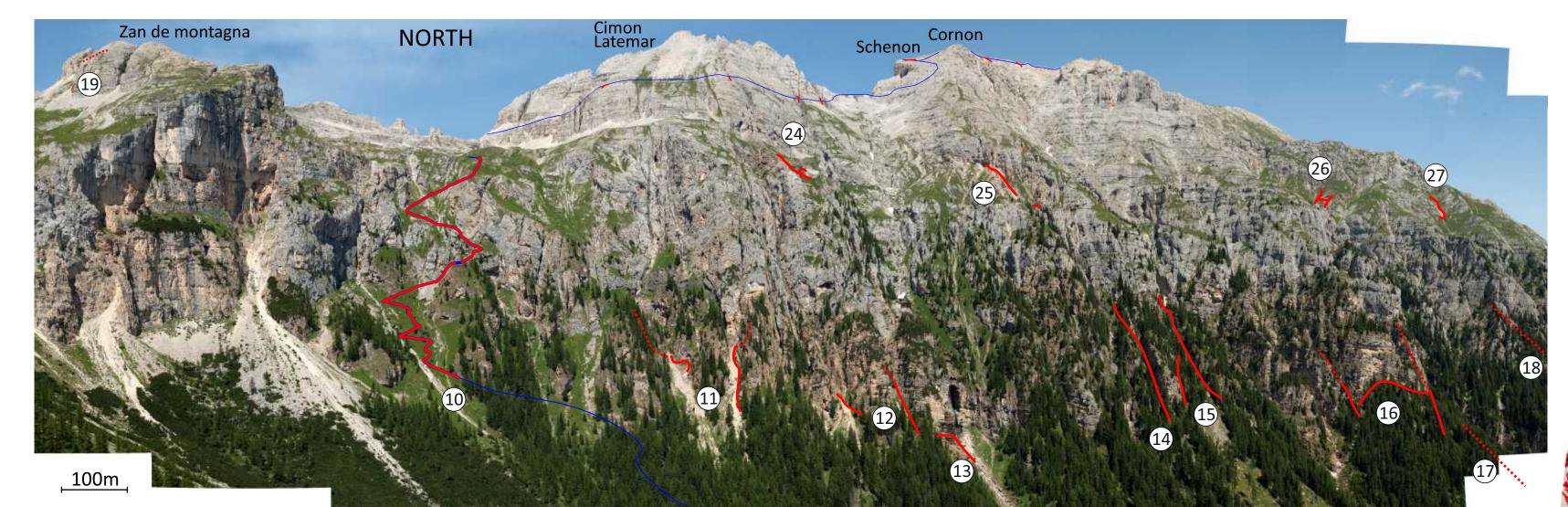
1. Introduction & Aims

- Hydrothermal dolomitization is common in many carbonate reservoirs, however little information exists on the geometry and distribution of dolomite bodies in these reservoirs.
- This valuable spatial heterogeneity information can be quantified from outcrop analogues, but is difficult to obtain from subsurface.
- Incorporating the spatial organization of such complex heterogeneity still forms a challenge.

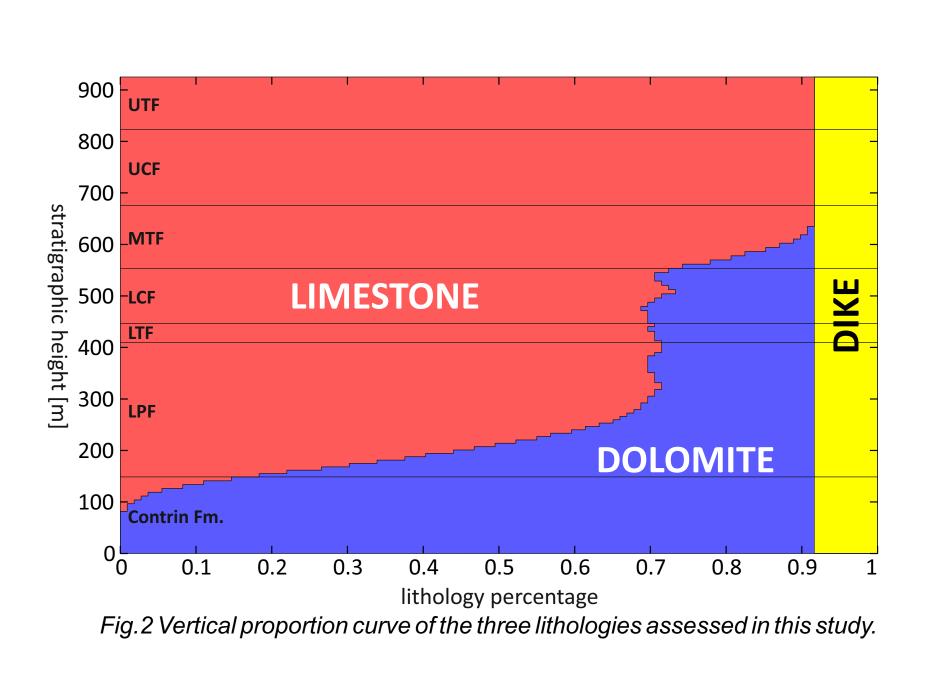
- Testing the use of PluriGaussian Simulations to populate reservoir models with complex heterogeneity such as hydrothermal dolomite.
- Setting up suitable facies lithotype rules that allow to model dolomite body geometry realistically.
- Compare to Sequential Indicator Simulation approach of Jacquemyn et al. (2015).

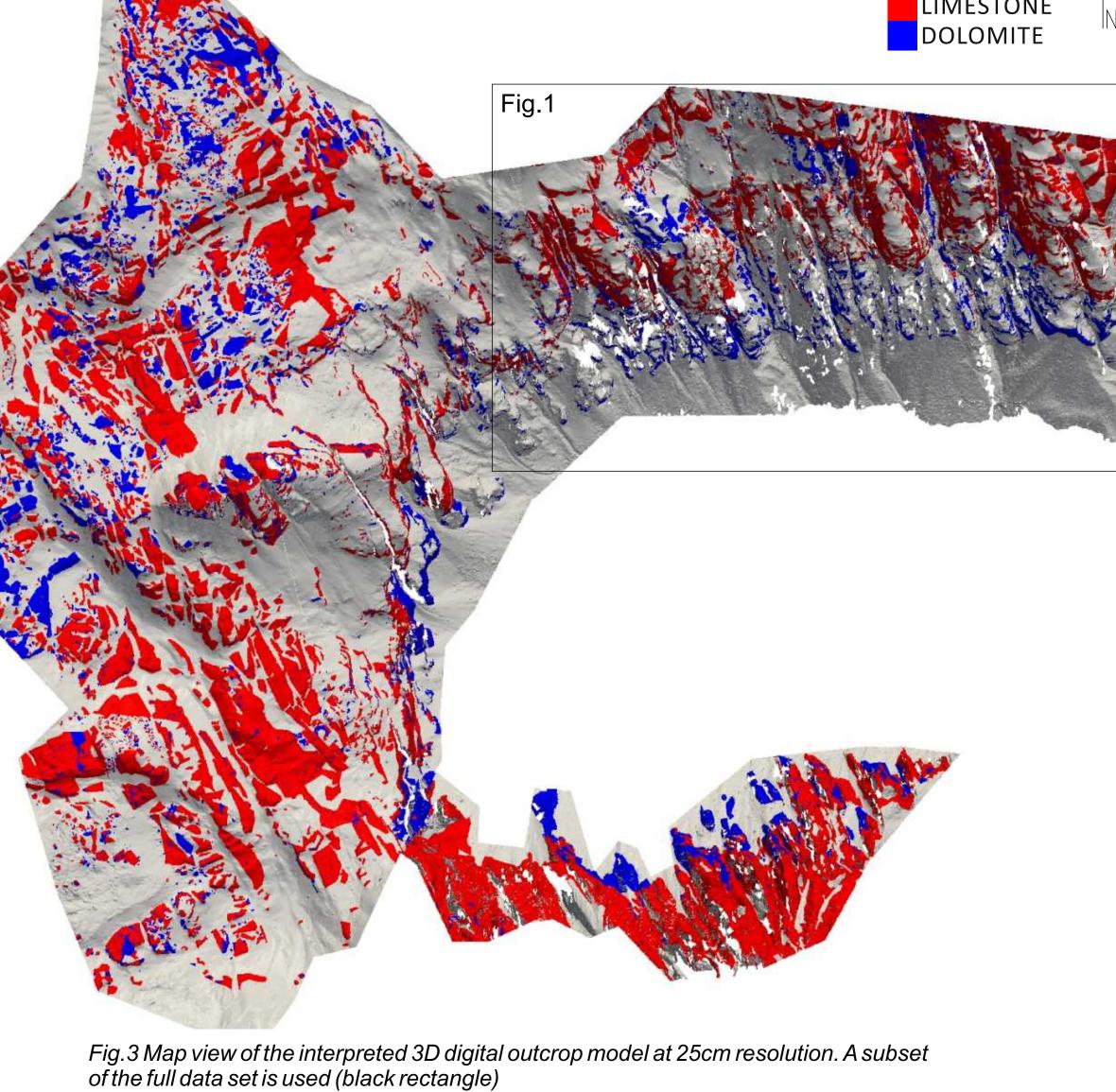
2. Study area & Data

- The Triassic Latemar platform in the Dolomites (N-Italy) is a spectacularly exposed carbonate platform that has been crosscut by mafic dikes and subsequently dolomitized extensively (Fig.1).
- Hydrothermal fluids likely interacted with magmatic rocks that used mafic dikes as a pathway into the platform and caused dolomitization (Jacquemyn et al, 2014).
- The complex 3D topography allows to obtain a good 3D understanding of dolomite body distribution.
- A high-resolution 3D digital outcrop model (Fig.2) provides quantitative data to assess spatial distribution.



crosscut the platform. Lines in red highlight sampling sections for groundtruthing

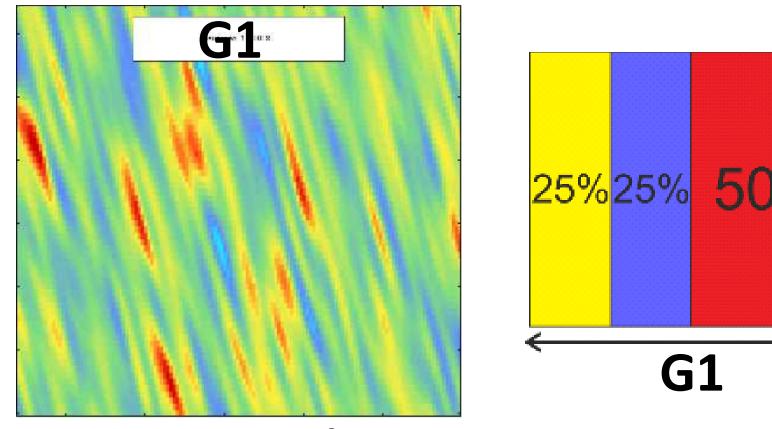


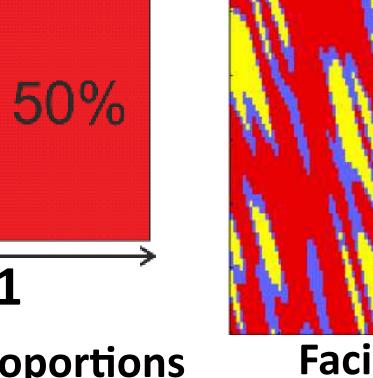


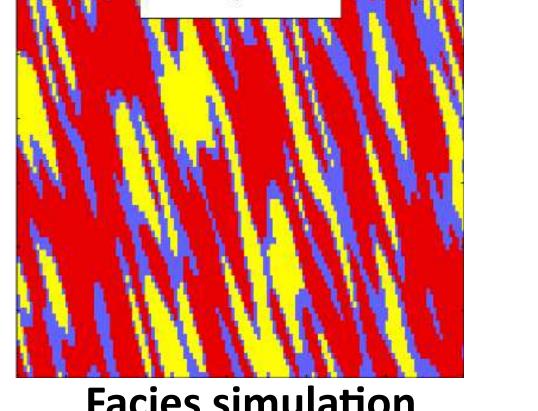
3. PluriGaussian Simulation

3.1 Truncated Gaussian Simulation

- Simulation of 1 random Gaussian variable (Fig3.A) based on variograms.
- Construction of lithotype rule based on observations and/or conceptual models (Fig.4B).
- Simulation of facies based on truncating of Gaussian variable according to lithotype rule in Fig.4C.

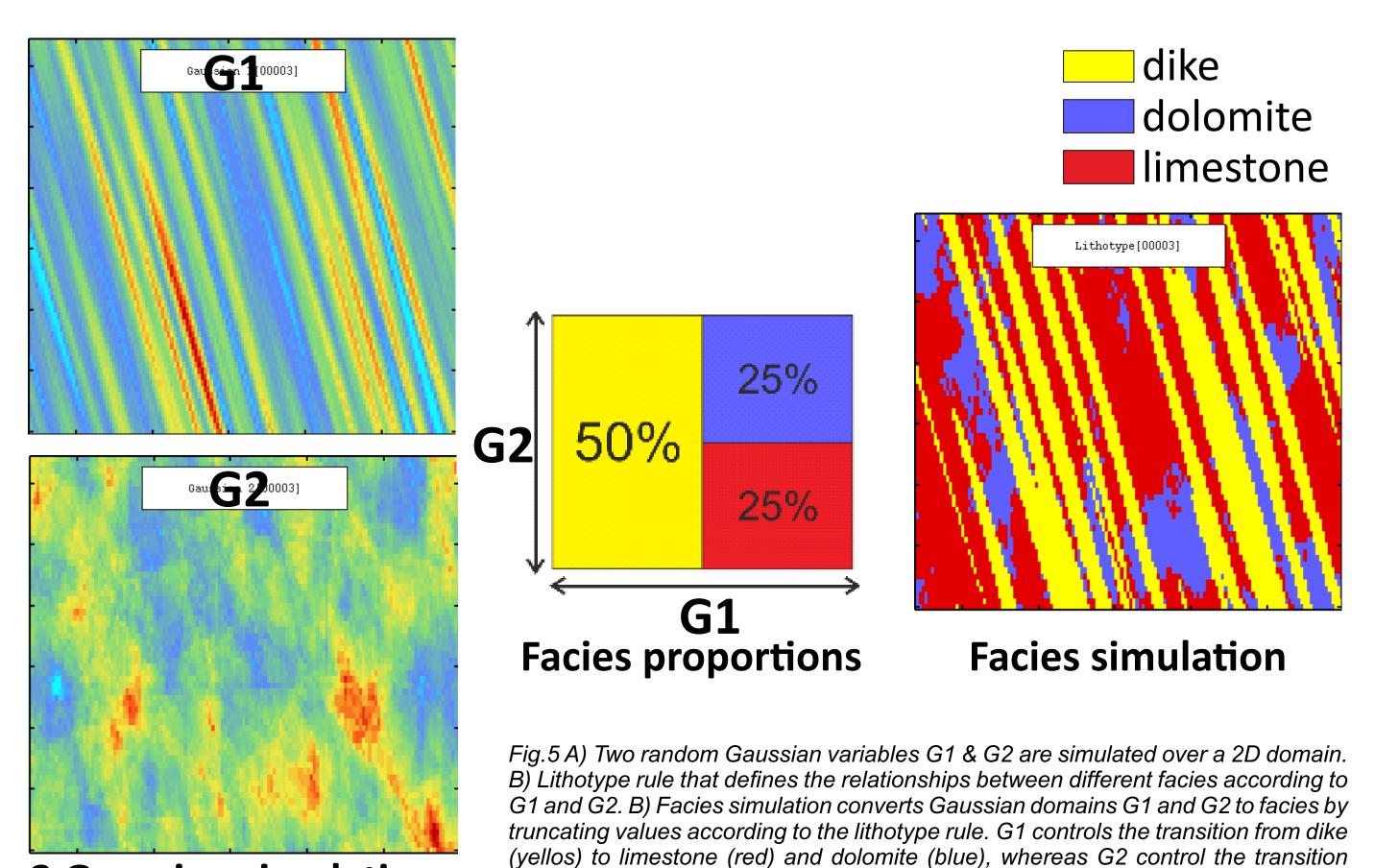






3.2 PluriGaussian Simulation

- Simulation of 2 random Gaussian variables (Fig5.A) based on
- Construction of lithotype rule based on observations and/or conceptual models (Fig.5B).
- Simulation of facies based on truncating of both Gaussian variables according to lithotype rule (Fig.5C).

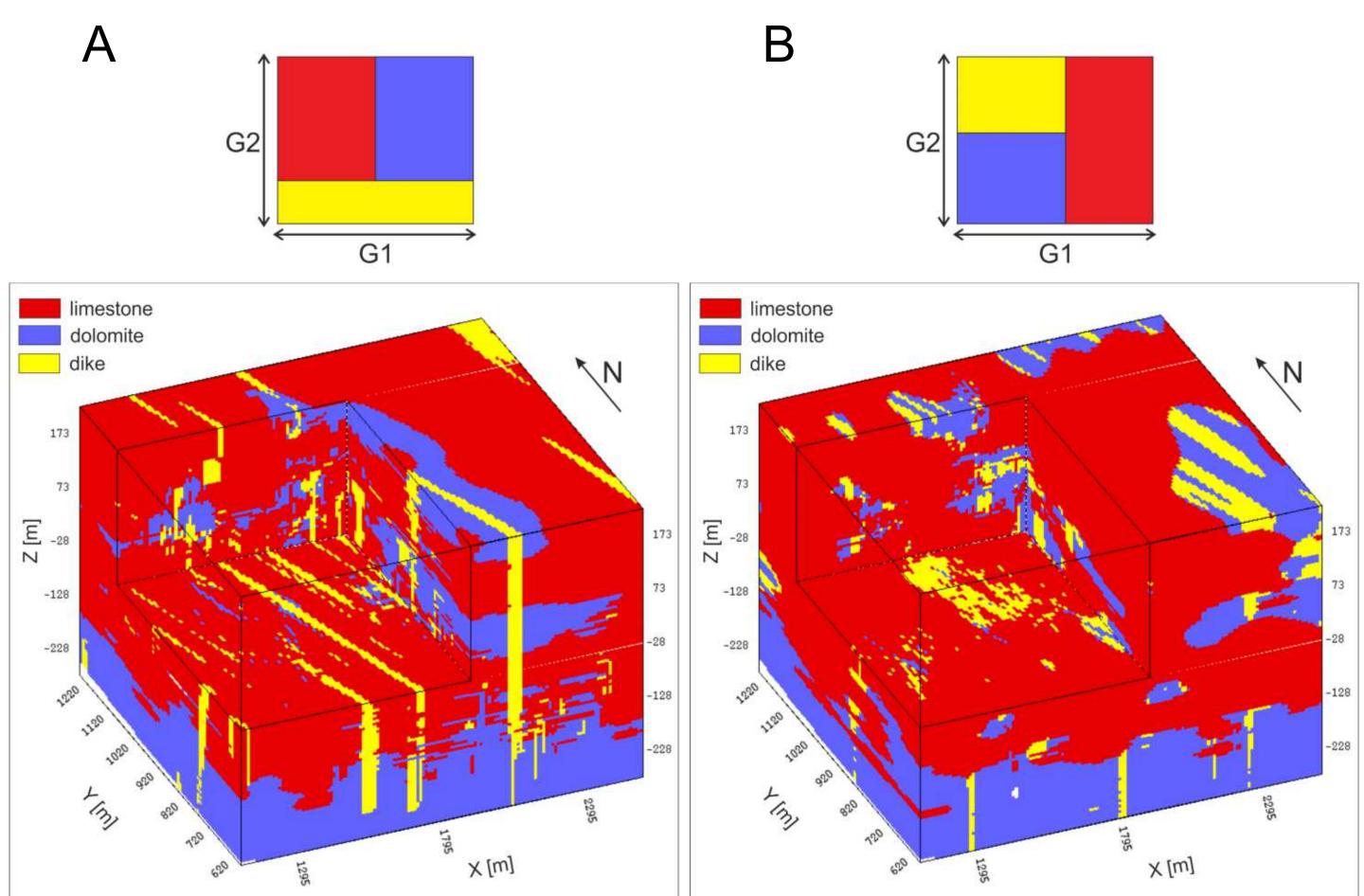


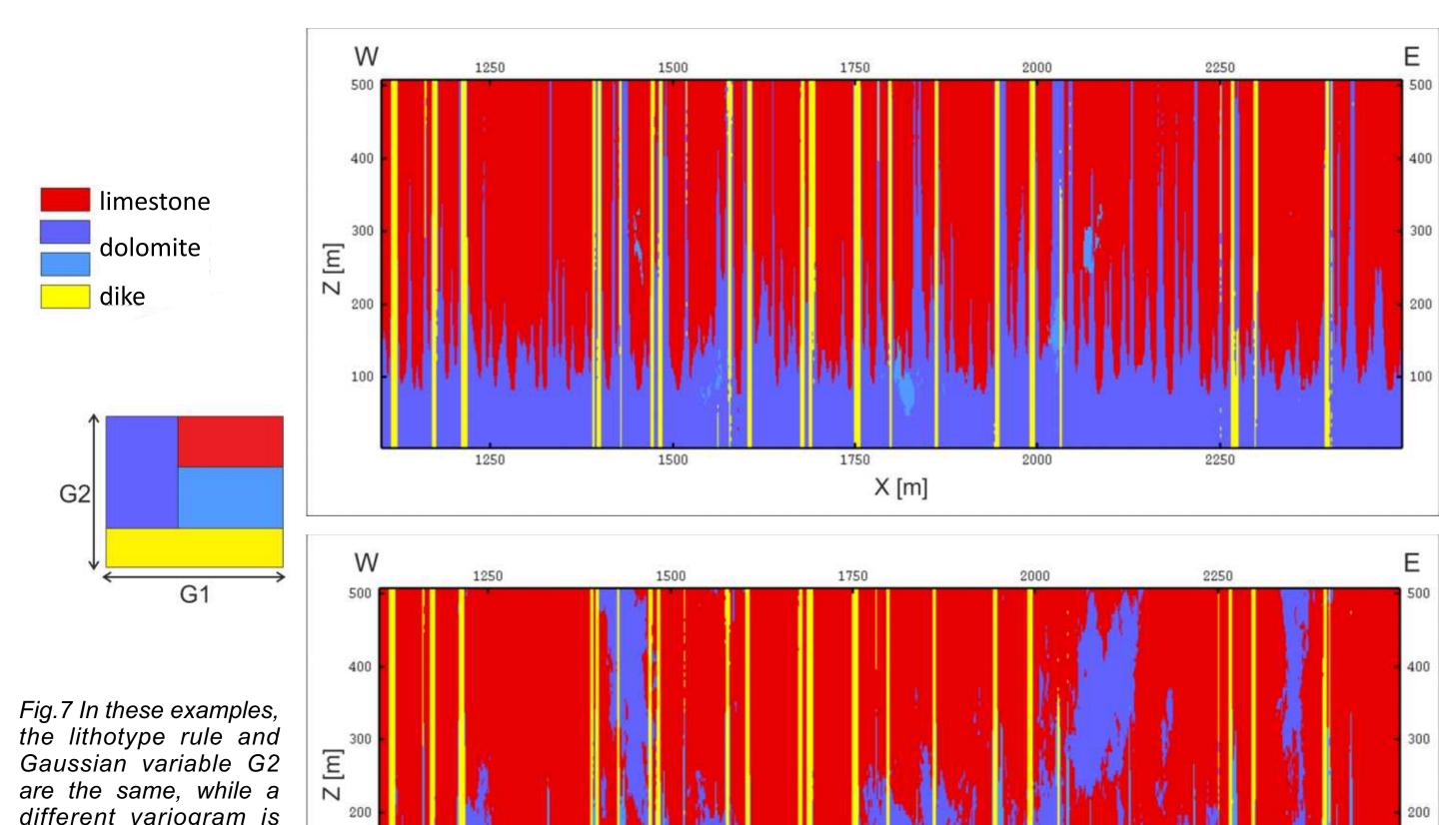
3. Gaussian and Lithotype rule choice

- Gaussian variables are simulated taking into account 3D variogram models that are based on outcrop observations (Jacquemyn et al, 2015).
- Different degrees of anisotropy can exist in different gaussians.
- Lithotype rules define facies relationships
- Usually based on:
- outcrop observations
- → borehole logs

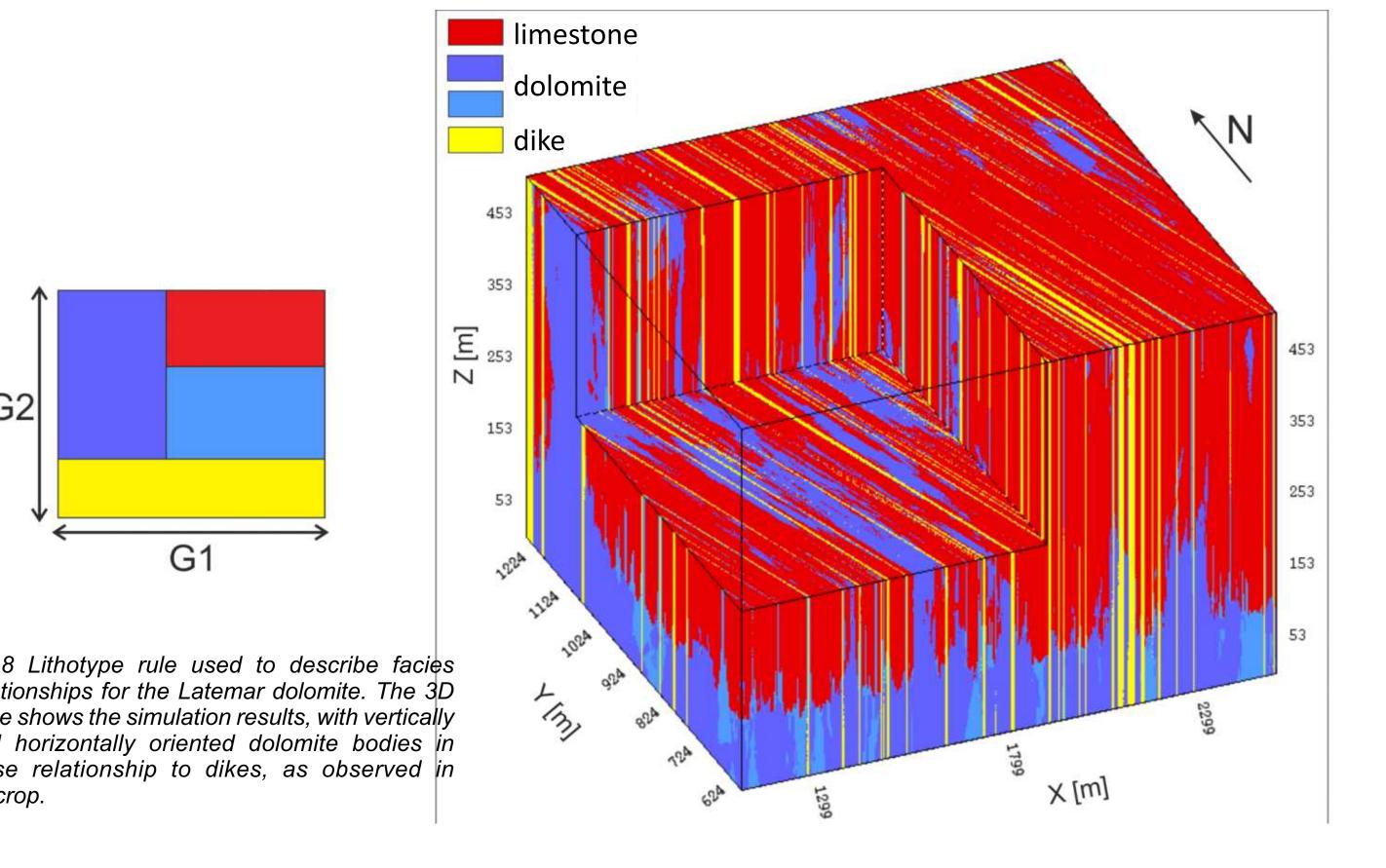
very different dolomite

→ conceptual geological models





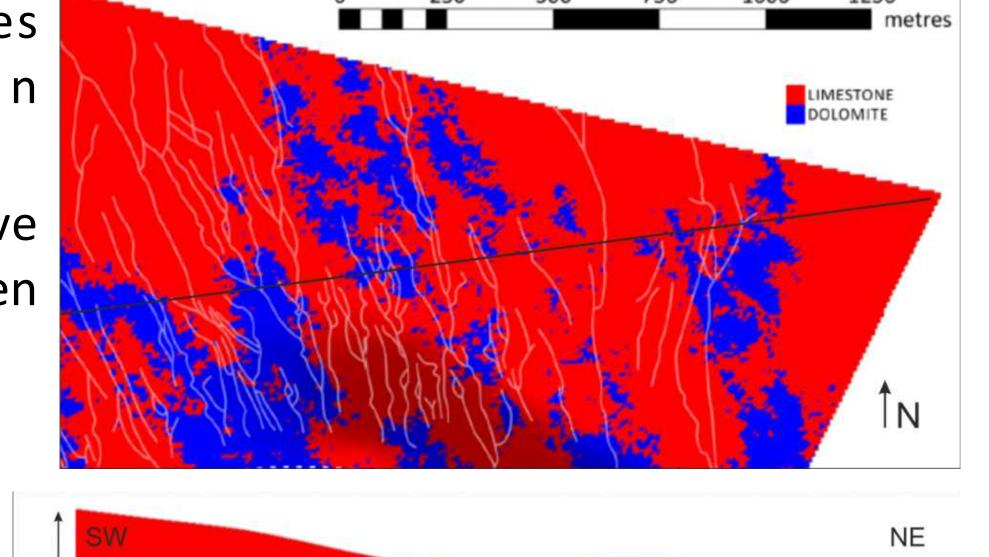
- Dolomite distribution was modelled using the lithotype rule below (Fig.8).
- Result corresponds best to observations in outcrop, such as:
- → Vertical and horizontally elongated dolomite bodies
- → Dolomite occurrences related to mafic dikes
- → Upwards decrease in dolomite/limestone ratio

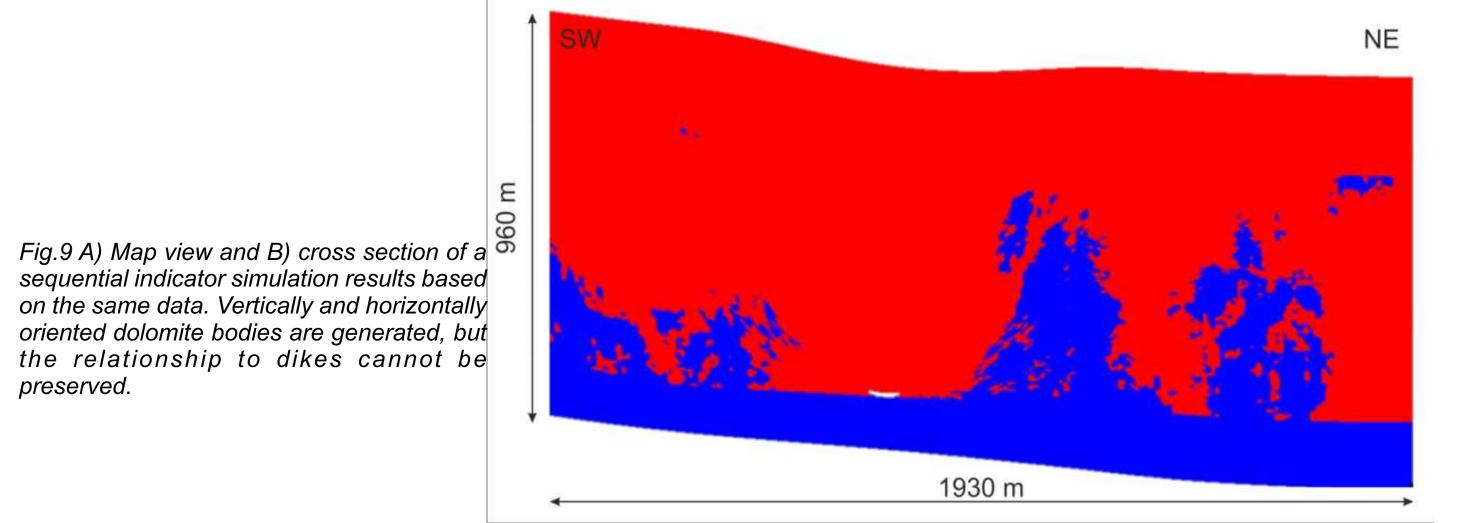


4. Comparison to SIS

- Sequential Indicator Simulation was applied on the same dataset by Jacquemyn et al (2015).
- Overall geometries and distribution results are similar.
- SIS cannot preserve relationship between dikes and dolomite.

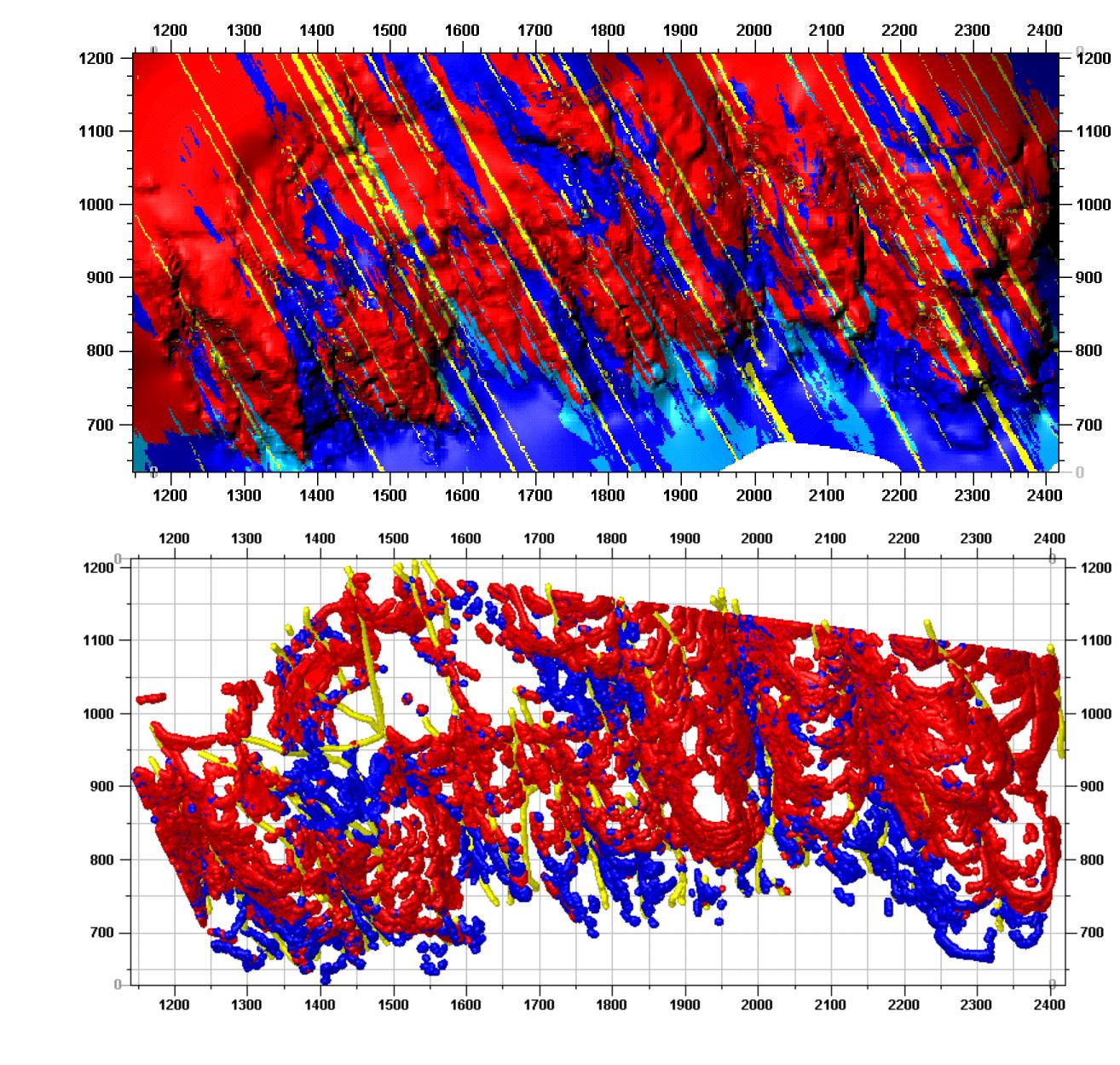
on the same data. Vertically and horizonta





5. Comparison to outcrop

- PluriGaussian Simulation conditioned by 6 pseudo-wells along the outcrop model.
- Visual comparison between the simulation (Fig.10A) and the outcrop exposure (Fig.10B) shows similar distribution of



6. Conclusions

- PluriGaussian Simulation is a powerful approach to preserve facies relationships in reservoir models.
- Input for PGS is flexible: conceptual models, borehole information, subsurface information...
- 3D geostatistical analysis of appropriate outcrops provide valuable quantitative data
- Applicable to most sedimentary and diagenetic heterogeneity

7. References

Jacquemyn, C., Huysmans, M., Casini, G., Hunt, D. & Swennen, R. (2015) Multi-scale 3D distribution of fracture- and igneous intrusion- controlled hydrothermal dolomite from digital outcrop model (Latemar platform, Dolomites, northern Italy). AAPG Bulletin, v.99, p. 957-984.

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