PSHow to Train Your Fracture Network Simulation? 2-D to 3-D Fracture Network Detection and Forecasting in a Carbonate Reservoir Analogue Using Multiple Point Statistics (MPS)*

Pierre-Olivier Bruna[1], Nico Hardebol[1], Kevin Bisdom[2], Julien Straubhaar[3], Grégoire Mariethoz[4], and Giovanni Bertotti[1]

Search and Discovery Article #42168 (2017)**
Posted December 26, 2017

*Adapted from poster presentation given at AAPG International Conference and Exhibition, London, England, October 15-18, 2017

[1]Department of Geoscience and Engineering, Applied Geology section, TU Delft, 2628 CN, Delft, Netherlands (p.b.r.bruna@tudelft.nl)
[2]Shell Global Solutions International, 2288 GS Rijswijk, Netherlands
[3]Centre d'hydrogéologie et de géothermie (CHYN), Université de Neuchâtel, CH-2000 Neuchâtel, Switzerland
[4]Institute of Earth Surface Dynamics (IDYST) UNIL-Mouline, Geopolis, University of Lausanne, 1015 Lausanne, Switzerland

Abstract

Natural fractures have a strong impact on flow in carbonate reservoirs. Their subsurface distribution is often unknown due to their sub-seismic size and to the scarcity of available well data. Therefore, the one of the way used to constrain the 3D architecture of fracture networks is to resort to outcrop analogues. Outcrops represent a local close-up of the present-day multiscale state of deformation. Outcrop data can be used to calibrate mechanical and fluid flow models to predict the impact of fractures on storage and flow. However, the geological complexity of outcrops requires simplifications to make reservoir-scale fracture modelling possible. A common approach is to use outcrop fracture data to populate subsurface reservoirs through stochastic discrete fracture network models. These models are generally based on limited amount of parameters implying a randomisation of the obtained realisations. Alternatively, we used Multiple Point Statistics (MPS) method. We create series of theoretical training images (TI) with varying fracture spacing, orientation, length and typology. The TIs were used in MPS process to build synthetic outcrop-scale models to demonstrate and quantify how key features of the fracture network can be reproduced by the MPS method. We applied our method to the Jandaíra carbonate Formation in the Potiguar basin (NE Brazil), which is analogue for some offshore Brazil reservoirs. A structural analysis (type, orientation, abutment) of exposed fractures was conducted both at the station scale (10 × 10 m) using a classical characterisation approach and at the outcrop scale (> 200 × 200 m) using photogrammetry models acquired from a drone. Four separate pavements interpreted this way, were used as input data to predict the geometry of the fracture network at reservoir scale (area > 10 km A planar 50 × 50 m synthetic TI representative of the complexity of the outcrop fracture pattern was used to generate series of MPS models. These MPS fracture models were compared to the outcrop fracture interpretation to quantify the degree of consistency. Ultimately, at the reservoir scale, one or more representative TIs per outcrop was created and simultaneously used during MPS runs. The obtained models forecast the fracture distribution at the reservoir scale considering the local fracture variability in the Jandaíra Formation. Our new approach can be applied to obtain more realistic reservoir scale fracture network models.

References Cited

Bisdom, K., 2016, Burial-related fracturing in sub-horizontal and folded reservoirs - Geometry, geomechanics and impact on permeability: Technische Universiteit Delft

Chugunova, T., V. Corpel, and J.-P. Gomez, 2017, Explicit fracture network modeling: from multiple point statistics to dynamic simulation: Mathematical Geosciences, v. 49, p. 13.

Comunian, A., P. Renard, and J. Straubhaar, 2012, 3D multiple-point statistics simulation using 2D training Images: Computers & Geosciences, v. 40, p. 49-65.

Karimpouli, S., P. Tahmasebi, H.L. Ramandi, P. Mostaghimi, and M. Saadatfar, 2017, Stochastic modeling of coal fracture network by direct use of micro-computed tomography images: International Journal of Coal Geology, v. 179, p. 153-163.

Lei, Q., J.-P.latham, c.-F. Tsang, J. Xiang, and P. Lang, 2015, A new approach to upscaling fracture network models while preserving geostatistical and geomechanical characteristics: Journal of Geophysical Research: Solid Earth, v. 120.

Liu, X., C. Zhang, Q. Liu, and J. Birkholzer, 2009, Multiple-point statistical prediction on fracture networks at Yucca Mountain: Environmental Geology, v. 57, p. 1361 -1370.

Mariethoz, G., 2009, Geological stochastic imaging for aquifer characterization, Universite de Neuchatel, 229 p.

Mariethoz, G., P. Renard, and J. Straubhaar, 2010, The Direct Sampling method to perform multiplepoint geostatistical Simulations: Water Resources Research, v. 46.

Meerschman, E., G. Pirot, G. Mariethoz, J. Straubhaar, M. Van Meirvenne, and P. Renard, 2013, A practical guide to performing multiple-point statistical simulations with the Direct Sampling Algorithm: Computers & Geosciences, v. 52, p. 307-324.

Strebelle, S., 2002, Conditional Simulation of Complex Geological Structures Using Multiple-Point Statistics: Mathematical Geology, v. 34, p. 1-21

HOW TO TRAIN YOUR FRACTURE NETWORK SIMULATION?

2D to 3D fracture network detection and forecasting in a carbonate reservoir analogue using Multiple Point Statistics (MPS)

Pierre-Olivier BRUNA, Nico HARDEBOL, Kevin BISDOM, Julien STRAUBHAAR, Grégoire MARIETHOZ and Giovanni BERTOTTI*

ABSTRACT

Natural fractures have a strong impact on flow in carbonate reservoirs. Their subsurface distribution is often unknown due to their sub-seismic size and to the scarcity of available well data. Therefore, one of the ways used to constrain the 3D architecture of fracture networks is to resort to outcrop analogues. Outcrops represent a local close-up of the present-day multiscale state of deformation. Outcrop data can be used to calibrate mechanical and fluid flow models to predict the impact of fractures on storage and flow. However, the geological complexity of outcrops requires simplifications to make reservoir-scale fracture modelling possible.

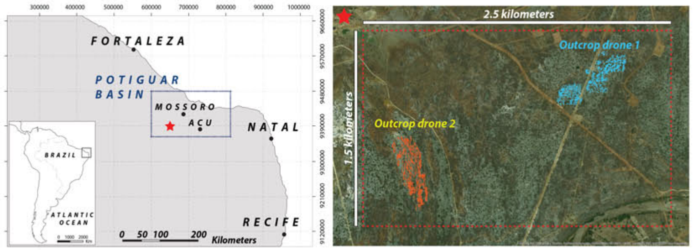
A common approach is to use outcrop fracture data to populate subsurface reservoirs through stochastic discrete fracture network models. These models are generally based on a limited amount of parameters implying a randomisation of the obtained realisations. Alternatively, we propose to use the Multiple Point Statistics (MPS) methods, consisting of stochastic simulations reproducing patterns present in a conceptual model: the training image (TI).

We applied our method to the Jandaíra carbonate Formation in the Potiguar basin (NE Brazil), which is an analogue for some offshore Brazil reservoirs. A structural analysis (type, orientation, abutment) of exposed fractures was conducted both at the station scale (10 × 10 m) using a classical characterisation approach and at the outcrop scale (> 200 × 200 m) using photogrammetry models acquired from a drone. Two separate pavements interpreted this way, were used as input data to predict the geometry of the fracture network at reservoir scale (area of 2.5 × 1.5 km).

At the outcrop scale, fracture parameters were used to define a partition of the simulation domain and a representative TI for each part. At the reservoir scale, each of these TIs were used during MPS runs, according to probability maps beforehand defined and covering the entire reservoir. This allows us to account for the uncertainty of the network structure where no data values are available and to generate models with smooth transitions.

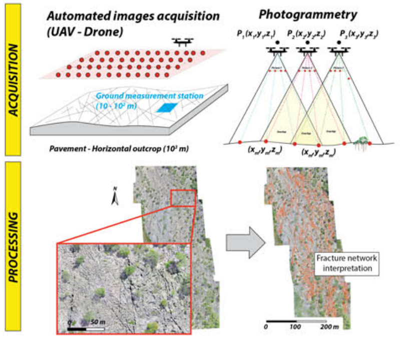
The obtained models forecast the fracture distribution at the reservoir scale considering the local fracture variability in the Jandaíra Formation. The next step of our work will be to transfer the method to the subsurface, to generate 3D fracture network models and to test series of parameters such as the mechanical and hydraulic aperture under subsurface conditions in the simulated fracture networks.

POTIGUAR BASIN ANALOGUE

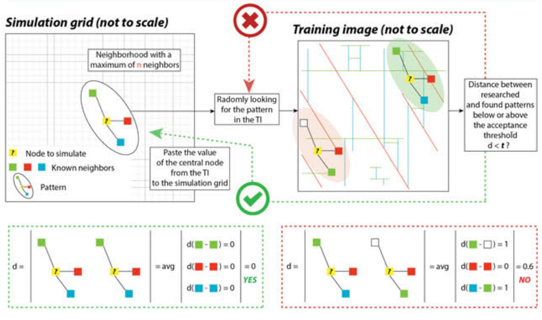


The Potiguar Basin is a rift basin located in the easternmost part of the Equatorial Atlantic continental margin. The basin was structured by two successive rifting events followed by post-rift deposition phases. The carbonate Jandaíra Formation, deposited at the transition from syn- to post rift phase (Turonian to Campanian) is the focus of our study. In the area of interest, the stress field affecting the Jandaíra Formation is mainly N-S during the Campanian to the Miocene compression. Fracture patterns observed in outcrop drone 1 (E-W stylolite / N-S veins) and 2 (conjugate veins N-S and NNW-SSE) are both consistent with a N-S oriented compression.

DRONE DATA

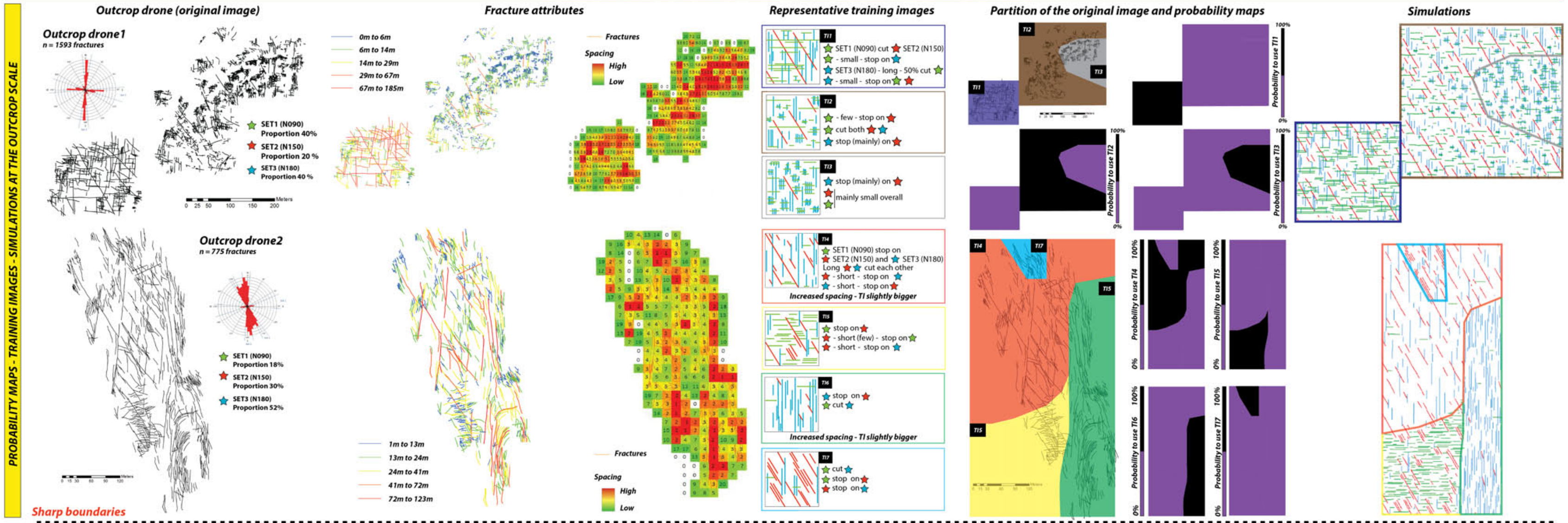


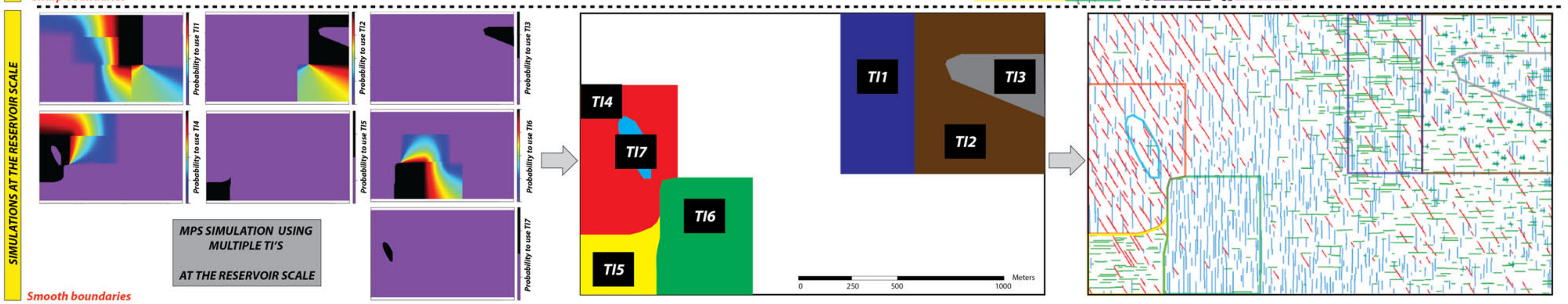
MULTIPLE POINT STATISTICS



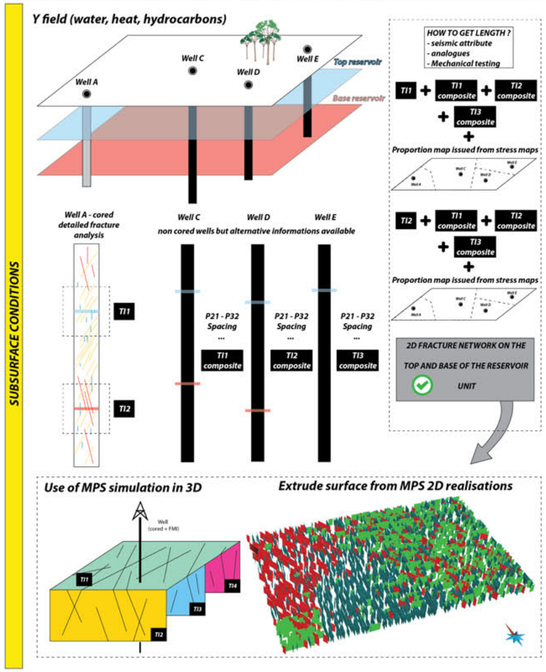
Sketch of the direct sampling algorithm (modfied from Mariethoz et al., 2010, Meerschman et al., 2013

SIMULATIONS PROCESS AND RESULTS





APPLICATIONS



CONCLUSIONS

We showed that Multiple Point Statistics is adapted to reproduce the complexity of natural fracture networks. The opportunity to consider multiple training images in a single realisation proposes an alternative to the classical workflow used in fracture network simulations. The same method developed on outcrop analogues can be transferable to sparse subsurface data in order to integrate non-stationarity in Naturally Fractured Reservoirs.

While orientation, spacing and topology relationships are generally taken into account in the MPS process, the fracture length is not taken into account in a fully satisfactory manner. Further developments will improve the quality of the generated network.

These "trained 2D fracture networks" can be extrapolated either via a combination of 2D MPS simulations in 3D or via a simple extrusion of fracture planes. When available, these models will offer a simple, easy-to-use and efficient alternatives to classic DFN methods.

REFERENCES

Bisdom, K., 2016, Burial-related fracturing in sub-horizontal and folded reservoirs - Geometry, geomechanics and impact on permeability, Technische Universiteit Delft.
Chugunova, T., V. Corpel, and J.-P. Gomez, 2017, Explicit fracture network modelling: from multiple point statistics to dynamic simulation: Mathematical Geosciences, v. 49, p. 13.
Comunian, A., P. Renard, and J. Straubhaar, 2012, 3D multiple-point statistics simulation using 2D training images: Computers & Geosciences, v. 40, p. 49-65.
Karimpouli, S., P. Tahmasebi, H. L. Ramandi, P. Mostaghimi, and M. Saadatfar, 2017, Stochastic modeling of coal fracture network by direct use of micro-computed tomography images: International Journal of Coal Geology, v. 179, p. 153-163.
Lei, Q., J.-P. Latham, C.-F. Tsang, J. Xiang, and P. Lang, 2015, A new approach to upscaling fracture network models while preserving geostatistical and geomechanical characteristics: Journal of Geophysical Research: Solid Earth, v. 120.
Liu, X., C. Zhang, Q. Liu, and J. Birkholzer, 2009, Multiple-point statistical prediction on fracture networks at Yucca Mountain: Environmental Geology, v. 57, p. 1361-1370.
Mariethoz, G., 2009, Geological stochastic imaging for aquifer characterization, Université de Neuchâtel, 229 p.
Mariethoz, G., P. Renard, and J. Straubhaar, 2010, The Direct Sampling method to perform multiplepoint geostatistical simulations.: Water Resources research, v. 46.
Meerschman, E., G. Pirot, G. Mariethoz, J. Straubhaar, M. Van Meirvenne, and P. Renard, 2013, A practical guide to performing multiple-point statistical simulations with the Direct Sampling algorithm: Computers & Geosciences, v. 52, p. 307-324.
Strebelle, S., 2002, Conditional Simulation of Complex Geological Structures Using Multiple-Point Statistics: Mathematical Geology, v. 34, p. 1-21

ACKNOWLEDGEMENTS

The Authors want to thank the RANDLAB RESEARCH GROUP (University of Neuchâtel , Switzerland) to provide access to Deesse Algorithm.
The acknowledgements are extended to AR2Tech company to provide access to basic AR2Gems Licences.

CONTACT US

Dr. Pierre-Olivier BRUNA, TU Delft, CiTG, AGS
Stevinweg 1, 2628CN Delft , The Netherlands

+31657160202
p.b.r.bruna@tudeft.nl

POSTER

REFERENCES