Relating Background Fractures to Diagenesis and Rock Physical Properties in a Platform-Slope Transect, Example of Maiella Mountain (Central Italy)*

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Abstract

Naturally fractured reservoirs are considered as a double porosity medium where fractures provide the main path for reservoir fluids (Warren and Root, 1963; Kazemi et al., 1976). Most of the fractures affecting a reservoir can be assimilated to background fractures which correspond to early inherited fracture sets homogenously distributed throughout the reservoir (Bazalgette, 2004; Vitale et al., 2012). However, partial subsurface data availability is not sufficient for a 3D fracture network prediction (Narr, 1996; Angerer et al., 2003; Ortega et al., 2006). Therefore, an analogue-based outcrop study can help in characterizing and understanding controlling parameters on fractures formation and distribution (Di Naccio et al., 2005; Wennberg et al., 2006; Olson et al., 2009; Zahm and Hennings, 2009; Barbier et al., 2012). For a better characterization of fracture patterns in subsurface reservoirs, field analogues provide a 3D overview of the fracture network and enable prediction of the geometry of a reservoir's fracture network since they allow deciphering the nature, origin and conditions for fractures formation through the geodynamic history of the reservoir. The example presented in this article is at Maiella Mountain (eastern Apennines, central Italy), where there are outcropping platform and slope-to-basinal carbonates (Figure 1) known to be analogue of southern Italy sub-surface reservoirs.

The main objective of the present study is defining controlling factors on fractures development through a platform-slope transect. Fractures in Maiella Mountain were characterized to understand how they developed and to explain host-rock control, i.e. diagenetic, sedimentological and mechanical control, on fractures development. Their occurrence has been deciphered through geodynamic history and related to host-rock diagenetic evolution and rock physical properties. Diagenetic sequences have been determined to relate fracture facies with the diagenetic history of host-rock. Fracture patterns are sorted based on geometric and kinematic criteria from field measurements and from host-rock analysis on thin-sections. Porous types and rock physical properties have been characterized in order to establish the impact of early diagenesis on facies evolution. Fracture sequences have been determined using cross-cutting relationships and compared with burial/uplift history deduced from subsidence curves and regional structural analysis.

The dataset is mostly composed of joints, veins and numerous bed-parallel stylolites which densities can be related to host-rock porosity. In each studied area, we observe a stage of perpendicular to bedding fracturing, synchronous with early burial and prior to major tectonic events. Despite the fact that depositional facies are different between the two studied formations, carbonates have undergone early diagenesis during a fast and early burial stage, conferring early brittle behavior (Figure 2). In addition, the amount of stylolites is not correlated to burial depth but to fracture density, porosity and free air P-wave velocity.

Structural analysis and fracture data collection enable us to determine that fractures developed in mode I opening due to a sediment-loading vertical σ_1 stress, when bedding was horizontal. Geometry does not reveal mechanical control of present-day stratigraphy but a pre-existing mechanostratigraphy while fractures developed. In Maiella, early burial processes such as diagenesis modified mechanical properties, giving brittle character to carbonates and thus, mechanical differentiation is early acquired in burial history. Fracture patterns are highly dependent on mechanical properties of the rock at the time of fracturing but also on pre-fracturing diagenetic events.

This study, and likewise a similar study in the Provence Basin of SE France (Lavenu et al., 2011; Lamarche et al., *Submitted*), suggest that most of the diffuse fracturing that generally provides the background fracture permeability in NFR's developed in response to early tectonic and diagenetic events which are not necessary related to localized, large scale deformation (and associated high permeability pathways) related to the anticline late development. Consequently, fracture modeling techniques based on correlation with large scale deformation (e.g. curvature, distance to fault, etc.) will provide only a part of the answer and might not be suitable for diffuse fracture modeling. Only a full understanding of the geodynamical basin history from early deposition to present day deformation and experience from outcrop analogues can provide us with the keys to properly model our reservoirs.

References

Angerer, E., P. Lanfranchi, and S.F. Rogers, 2003, Fractured reservoir modeling from seismic to simulator: A reality?: The Leading Edge, v. 22, p. 684-689.

Barbier, M., Y. Hamon, J.-P. Callot, M. Floquet, and J.-M. Daniel, 2012, Sedimentary and diagenetic controls on the multiscale fracturing pattern of a carbonate reservoir: The Madison Formation (Sheep Mountain, Wyoming, USA): Marine and Petroleum Geology, v. 29, p. 50-67.

Bazalgette, L., 2004, Relations plissement/fracturation multi échelle dans les multicouches sédimentaires du domaine élastique/fragile: Accommodation discontinue de la courbure par la fracturation de petite échelle et par les articulations. Possibles implications dynamiques dans les écoulements des réservoirs: Université Montpellier 2, Montpellier, 251 p.

Di Naccio, D., P. Boncio, S. Cirilli, F. Casaglia, E. Morettini, G. Lavecchia, and F. Brozzetti, 2005, Role of mechanical stratigraphy on fracture development in carbonate reservoirs: Insights from outcropping shallow water carbonates in the Umbria-Marche Apennines, Italy: Journal of Volcanology and Geothermal Research, v. 148, p. 98-115.

Kazemi, H., L.S.J. Merill, K.L. Porterfield, and P.R. Zeman, 1976, Numerical simulation of water-oil flow in Naturally Fractured Reservoirs: SPE Journal, p. 317-326.

Lamarche, J., A.P.C. Lavenu, B.D.M. Gauthier, Y. Guglielmi, and O. Jayet, Submitted, Relationships between fracture patterns, geodynamics and mechanical stratigraphy in carbonates (South-East Basin, France).

Lavenu, A., J. Lamarche, B.D.M. Gauthier, Y. Guglielmi, C. Pabian-Goyheneche, and J.-F. Ballard, 2011, Relating fracture patterns to geodynamics and petrophysics in naturally fractured carbonate reservoir analogue (Provence, S-E France): AAPG International Conference and Exhibition.

Narr, W., 1996, Estimating average fracture spacing in subsurface rock: AAPG Bulletin, v. 80, p. 1565-1586.

Olson, J.E., S.E. Laubach, and R.H. Lander, 2009, Natural fracture characterization in tight gas sandstones: Integrating mechanics and diagenesis: AAPG Bulletin, v. 93, p. 1535-1549.

Ortega, O.J., R.A. Marrett, and S.E. Laubach, 2006, A scale-independent approach to fracture intensity and average spacing measurement: AAPG Bulletin, v. 90, p. 193-208.

Vitale, S., F. Dati, S. Mazzoli, S. Ciarcia, V. Guerriero, and A. Iannace, 2012, Modes and timing of fracture network development in poly-deformed carbonate reservoir analogues, Mt. Chianello, southern Italy: Journal of Structural Geology, v. 37, p. 223-235.

Warren, J.E., and P.J. Root, 1963, The behavior of Naturally Fractured Reservoirs: SPE journal, p. 245-255.

Wennberg, O.P., T. Svana, M. Azizzadeh, A.M.M. Aqrawi, P. Brockbank, K.B. Lyslo, and S. Ogilvie, 2006, Fracture intensity vs. mechanical stratigraphy in platform top carbonates: the Aquitanian of the Asmari Formation, Khaviz Anticline, Zagros, SW Iran: Petroleum Geoscience, v. 12, p. 235-245.

Zahm, C.K., and P.H. Hennings, 2009, Complex fracture development related to stratigraphic architecture: Challenges for structural deformation prediction, Tensleep Sandstone at the Alcova anticline, Wyoming: AAPG Bulletin, v. 93, p. 1427-1446.

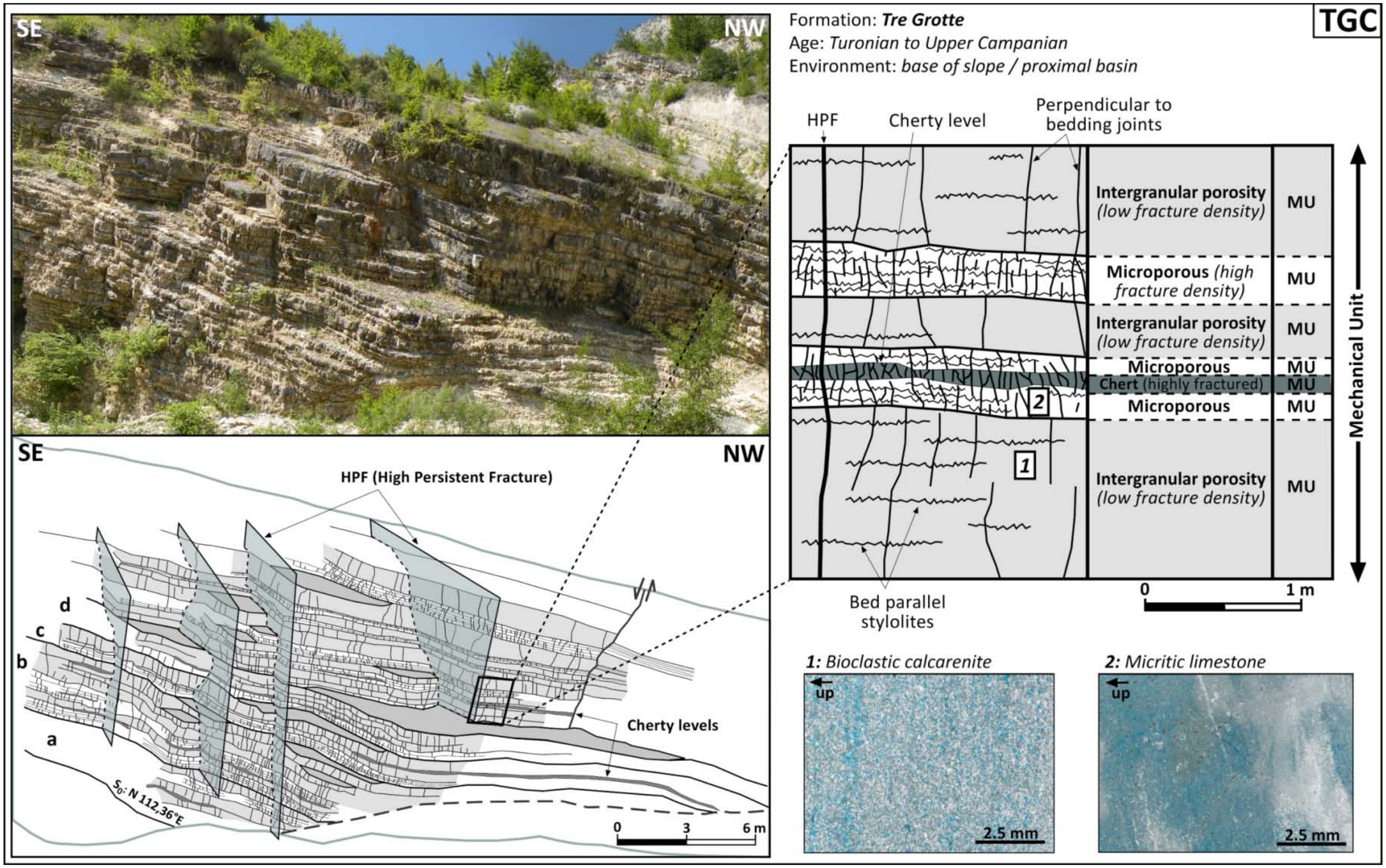

Figure 1. Example of one of the studied outcrops of the Tre Grotte Formation (slope formation).

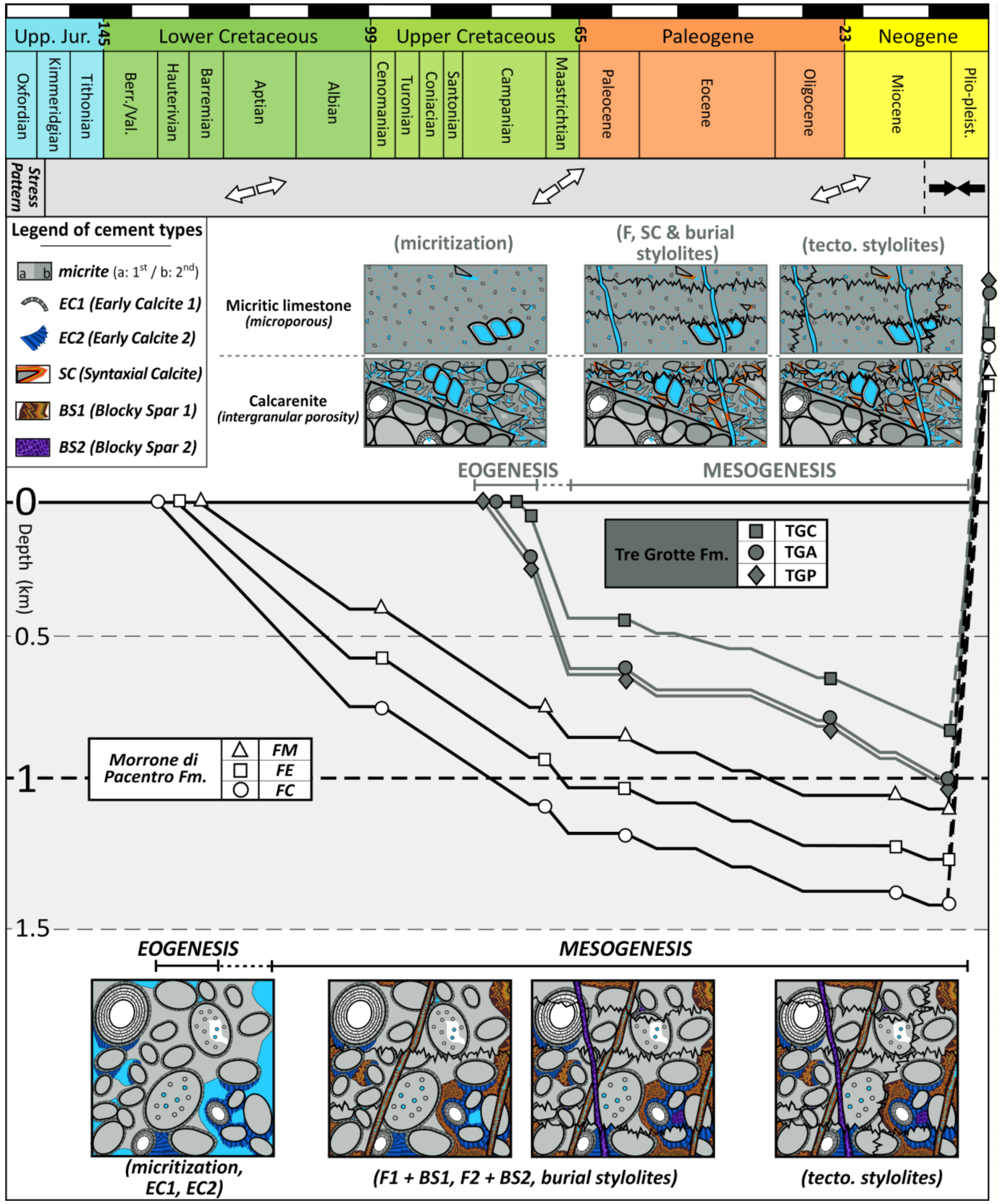

Figure 2. Diagenetic phases related to geodynamic history for both studied formations.