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Mechanical stratigraphy of deep-water sandstones: insights from a multisciplinary field and laboratory study

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Turbidite sandstones found in deep-water fold-and-thrust belts are increasingly exploited as hydrocarbon reservoirs. Within these rocks, the fluid flow is profoundly affected by the complex interaction between primary sedimentological and stratigraphic attributes (i.e, facies, layering, reservoir quality, stacking patterns, bed connectivity and lateral extent) and fracture characteristics (i.e., length, spacing, distribution, orientation, connectivity). Unfortunately, most of these features are at, or below, the resolution of conventional seismic datasets and, for this reason, their identification and localization represent one of the fundamental challenges facing exploration, appraisal and production of the sandstone reservoirs. In this respect, whereas considerable effort has been afforded to a characterization of the sedimentological and stratigraphic aspects of sandstones, detailed analysis of fractures in this type of successions has received significantly less attention.

In this work, we combine field and laboratory analyses to assess the possible mechanical control exerted by the rock properties (grain size, intergranualr porosity, and Young modulus), as well as the influence of bed thickness, on joint density in turbidite sandstones. Joints are mode-I fractures occurring parallel to the greatest principle stress axis, which solve opening displacement and do not show evidence of shearing and enhance the values of total porosity forming preferential hydraulic conduits for fluid flow. Within layered rocks, commonly, joints form perpendicular to bedding due to overburden or exhumation. The empirical relation between joint spacing and bed thickness, documented in the field by many authors, has been mechanically related to the stress perturbation taking place around joints during their formation. Furthermore, close correlations between joint density and rock properties have been already established. In this present contribution, we focus on the bed-perpendicular joint spacing/bed thickness (S/T) relationships on sandstone bodies that experienced similar diagenetic and tectonic histories.

The field area is located in the Periadriatic foreland basin, eastern central Italy, which show late Pliocene slope turbidites in excellent 3d views. The Periadriatic foreland basin is an elongated, roughly N-S oriented trough located immediately east of the Apennines fold-thrust belt. The basin fill mostly consists of deepwater Plio-Pleistocene sediments partially incorporated into the frontal part of the orogenic wedge. During the late Pliocene, gravel and sand originated from the uplifting Apennines were abundantly supplied to the deep-water basin through a series of erosional conduits that, in the rock record, appear as a series of N-S oriented slope submarine canyon systems deeply incised into the hemipelagic mudstones of the adjacent slope. The studied exposure allows direct observation of spatial and temporal relationships among the various depositional elements comprising the canyon system and related lithofacies, as well as the bed-perpendicular joint density within each lithofacies.

We performed a multidisciplinary work involving the following tasks: (i) 3D stratigraphic model of the depositional architecture of the Castignano and Ascensione canyon systems (Marche region, Italy); (ii) 2D scanline survey of several outcrops displaying bed-perpendicular joints; (iii) digital image analysis of selected thin-section obtained from oriented hand samples to characterize the 3D intergranualr porosity; (iv) Stiffness analysis of representative sandstone bodies by mean of Schmidt hammer tests. The first results of this ongoing study on the mechanical stratigraphy of the two Late Pliocene canyon systems are consistent with the joint density being effected by both geometrical (i.e., bed thickness) and mechanical properties. This data set will help field and experimental geologists to better define common strategies to assess the controlling factors on joint distribution within layered media. Furthermore, this knowledge can be very important in order to make predictions on the modalities of subsurface fluid flow through deep-water sandstone rocks.