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Influence of volcaniclastic sedimentation on spring-related continental carbonate sedimentation: a potential giant South Atlantic hydrocarbon reservoirs analogue

Federica Barilaro (1) and Andrea Di Capua (1,2)

(1) Department of Science and High Technology, University of Insubria, Como, Italy (federica.barilaro@uninsubria.it), (2) Institute for the Dynamics of the Environmental Processes, Italian National Research Council, Milan, Italy

The role of pyroclastic/volcaniclastic sedimentation in hydrocarbon accumulation is still poorly explored and includes large uncertainties and approximations. Although the discovery of giant South Atlantic carbonate reservoirs suggests a possible, important link between volcanic activity, continental carbonate sedimentation, and hydrocarbon accumulation, few and slow are the improvements in the recognition of its prominent role in hydrocarbon generation and accumulation in non-marine sedimentary basins.
In view of all the above findings, a multidisciplinary and multi-scale investigation on a Pleistocene, composite tongue-shaped geological body located in Tuscany, Central Italy, is here presented. This fascinating, plurimetric-scale, sedimentary body is formed by an alternation of three different pyroclastic and volcaniclastic units (emplaced during different volcanic manifestations) and travertine wedge-like buildups (directly precipitated from thermal springs) stacked in aggrading and prograding patterns. The test-site fall within an area where volcano-tectonics favored the growth of the Mt. Amiata volcano during Pleistocene time.
The pyroclastic and volcaniclastic units vary in color from dark gray, green and gray in the field and exhibit a variable thickness that are 1 m, 0.2 to 2.5 m and 0.3 m, respectively. The lowermost and the uppermost deposits are composed of fine ash, with accidental lithics of burnt travertine, aphyric green volcanic and quarzite that can reach the pebble size. The second unit is reverse to normal graded, with particle size ranging from fine to coarse ash. Accretionary lapilli are present.
Petrographic analysis reveals eutaxitic textures generally replaced by clay minerals (illite and montmorillonite – XRD). Main mineralogical phases are sanidine (partially replaced by kaoline - XRD), quartz (volcanic and minor plutonic), augite (almost replaced by halloysite - XRD), chloritized biotite, and minor zoned plagioclase. Accidental lithics are burnt travertine fragments, orthoderives and rare plutonics. All the above observations documented that primary volcanic characteristics have been deeply modified by the continuous hydrothermal flowing water. SEM-EDS exhibiting a pervasive presence of organic matter (e.g. bacteria, fungi) suggest a later biological contribution to the decomposition of glass and minerals.
A large variety of depositional and diagenetic travertine fabric types with peculiar porosity have been individuated. Evaluation of petrophysical proprieties conducted on selected samples suggests that travertine may represent good reservoir quality rocks. However, another innovative outcome established by this work has resulted in the identification of a peculiar class of hybrid fabric types formed by the contemporaneous travertine and volcanic sedimentation. These “hybrid” fabrics are enriched in organic matter and show evidence of the first stage of hydrocarbon generation.
This study for the first time defined: 1) the emplacement mechanisms of pyroclastic and volcaniclastic flows on the travertine structures in relation to their preserved volcanological features; 2) the diagenetic history of those deposits and 3) their relevance in the generation of hydrocarbons. It represents a breakthrough in the coupling between reservoir modeling and the study of geological analogs, giving feedbacks that can favour a better understanding of the important role of volcanically-controlled sedimentation in sedimentary system, with a particular reference to non-marine carbonate settings, and improves the understanding of comparable reservoirs in the sub-surfaces.