

**PS Insights on the Complexity of a Paleokarst Reservoir:
Examples from a World-Class Outcrop Analogue (Southern Italy)***

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Abstract

Karst reservoirs are widely distributed throughout the world, spanning from Cambrian to Neogene. The predictability of a karst reservoir is usually quite difficult as they are the result of a more or less extensive and long-lasting exposure of carbonates to meteoric waters. The use of analogues could strongly improve the understanding of the karst structure and evolution.

A research project has been carried out focusing on the paleokarst features that are impacting the dynamics and modelling of a hydrocarbon reservoir.

A series of analogues has been studied in a quarrying district of southern Italy, representative of the karst profile of some oilfields in the Adriatic Offshore. The Lower Cretaceous limestones of the Apulian Platform have been subject to polyphased karstification since Cenomanian until Messinian, developing a complex karst pattern, with infillings of multiple ages.

The vertical karst profile we observed is the classical one, with the succession of unconformity, epikarst with variable thickness, the vertical transfer zone (vadose zone) and the phreatic one.

We observed that the boundary between the vadose and the phreatic zone is never sharp, but is controlled by variations of the groundwater level developing highly dissolved horizons that act as high porosity/high permeability horizontal streaks. The impact of these features is an increased connectivity of the reservoir also above the main phreatic zone, leading to very high horizontal permeabilities, draining limited areas of the reservoir. The presence of these horizontal streaks is of fundamental importance, as it demonstrates that in the vadose zone there is the possibility of strong lateral connectivity within the reservoir; a very similar situation is also observed in modern karst systems where cross flow between conduits could be controlled by “old” phreatic horizons.

Karst reservoirs are extremely complex and only their dynamic zonation can help to model them properly. The estimation of permeabilities in these systems is fundamental to avoid an increase in the water break-through. The presence of extensive, but spatially limited, features with very high permeabilities and porosities is in fact improving the drainage of the reservoir volumes and also better connecting the fracture networks. These features are usually underestimated in karst reservoirs, while their impact is dramatic on production.

INSIGHTS ON THE COMPLEXITY OF A PALEOKARST RESERVOIR: EXAMPLES FROM A WORLD-CLASS OUTCROP ANALOGUE (SOUTHERN ITALY)

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ABSTRACT

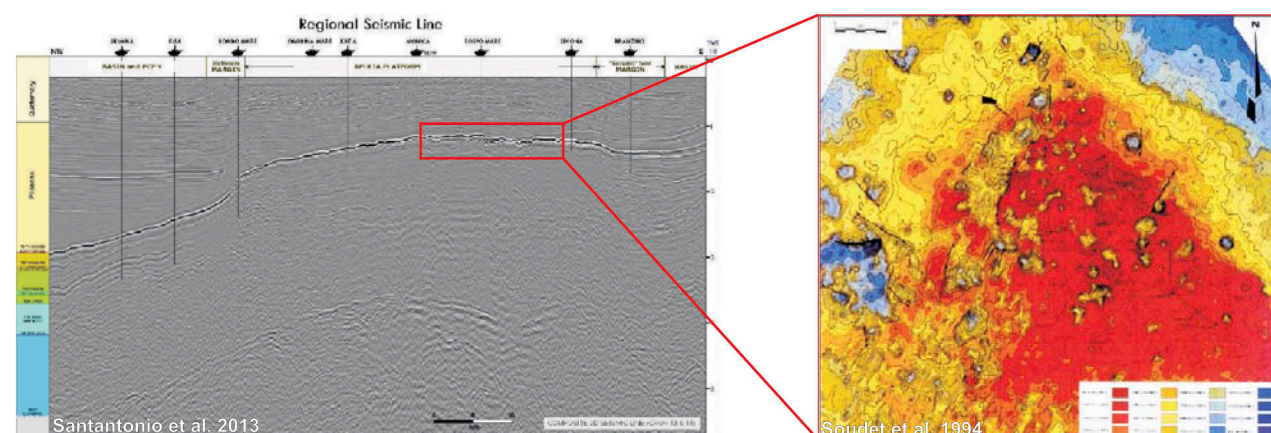
Karst reservoirs are widely distributed throughout the world, spanning from Cambrian to Neogene. The predictability of a karst reservoir is usually quite difficult as they are the result of a more or less extensive and long-lasting exposure of carbonates to meteoric waters. The use of analogues could strongly improve the understanding of the karst structure and evolution. A research project has been carried out focusing on the paleokarst features that are impacting the dynamics and modeling of an hydrocarbon reservoir. A series of analogues has been studied in a quarrying district of southern Italy, representative of the karst profile of some oilfields in the Adriatic Offshore. The Lower Cretaceous limestones of the Apulian Platform have been subject to polyphased karstification since Cenomanian until Messinian, developing a complex karst pattern, with infillings of multiple ages. The vertical karst profile we observed is the classical one, with the succession of unconformity, epikarst with variable thickness, the vertical transfer zone (vadose zone) and the phreatic one. We observed that the boundary between the vadose and the phreatic zone is never sharp, but is controlled by variations of the groundwater level developing highly dissolved horizons that act as high porosity/high permeability horizontal streaks. The impact of these features is an increased connectivity of the reservoir also above the main phreatic zone, leading to very high horizontal permeabilities, draining limited areas of the reservoir. The presence of these horizontal streaks is of fundamental importance, as it demonstrates that in the vadose zone there is the possibility of strong lateral connectivity within the reservoir; a very similar situation is also observed in modern karst systems where cross flow between conduits could be controlled by "old" phreatic horizons. Karst reservoirs are extremely complex and only their dynamic zonation can help to model them properly. The estimation of permeabilities in these systems are fundamental to avoid an increase on the water break-through. The presence of extensive, but spatially limited, features with very high permeabilities and porosities are in fact improving the drainage of the reservoir volumes and also better connecting the fracture networks. These features are usually underestimated in karst reservoirs, while their impact is dramatic on production.

LOCATION AND GEOLOGICAL FRAMEWORK

The study area is located in Southern Italy, in the Puglia region close to the village of Apricena. Here, several quarries are present to dig out Lower Cretaceous Platform Carbonates as ornamental stones. The quarrying technique uses saws rather than explosives, allowing a perfect exposure of the sedimentary succession. The Lower Cretaceous platform carbonates were subject to several suberial exposure events, developing paleokarst.



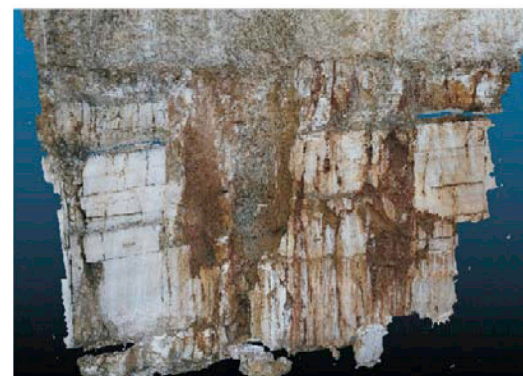
The latest and most important karst event is marked by an unconformity of Middle Miocene age, with the development of a mature epikarst, several pits, conduits and porous horizons interpreted as paleo-mixing zones. In the Adriatic offshore, few tens of kilometers north of the outcrops, this paleokarst is hosting the Rospo Mare Field, characterized by well developed karstic morphologies.



KARST FEATURES

Several elements of the karst system has been recognized, including epikarst features and epigenetic karst features, at different scales

VERTICAL PITS



ENLARGED FRACTURES (VERTICAL CONDUITS)



HORIZONTAL CONDUITS AND PALEOPHREATIC HORIZONS



STATISTICAL APPROACH

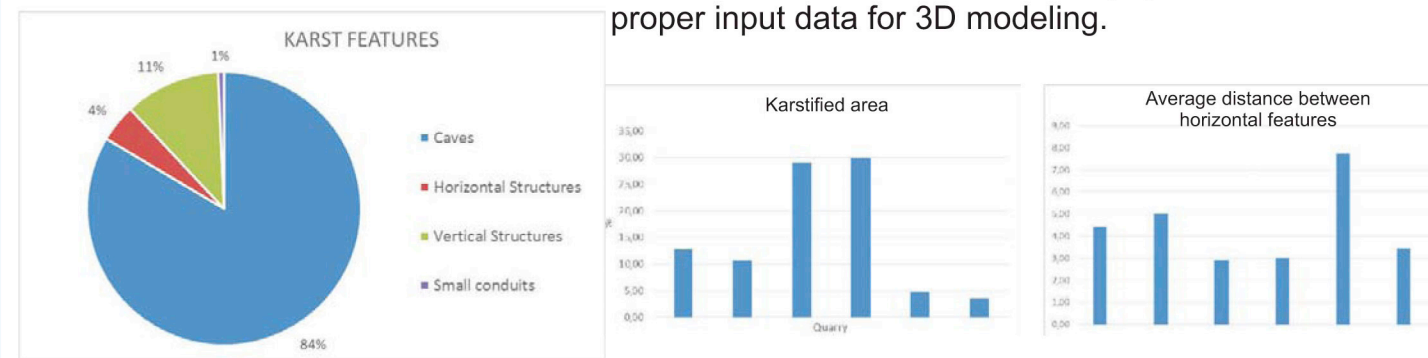


A statistical estimation of karst distribution has been done on the different outcrops. In this example, the vadose zone consists of:

- caves= 8.63%;
- subhorizontal paleophreatic zones = 0.75%;
- small conduits = 0.07%;
- vertical karst features (pits, enlarged fractures) = 1.16%.

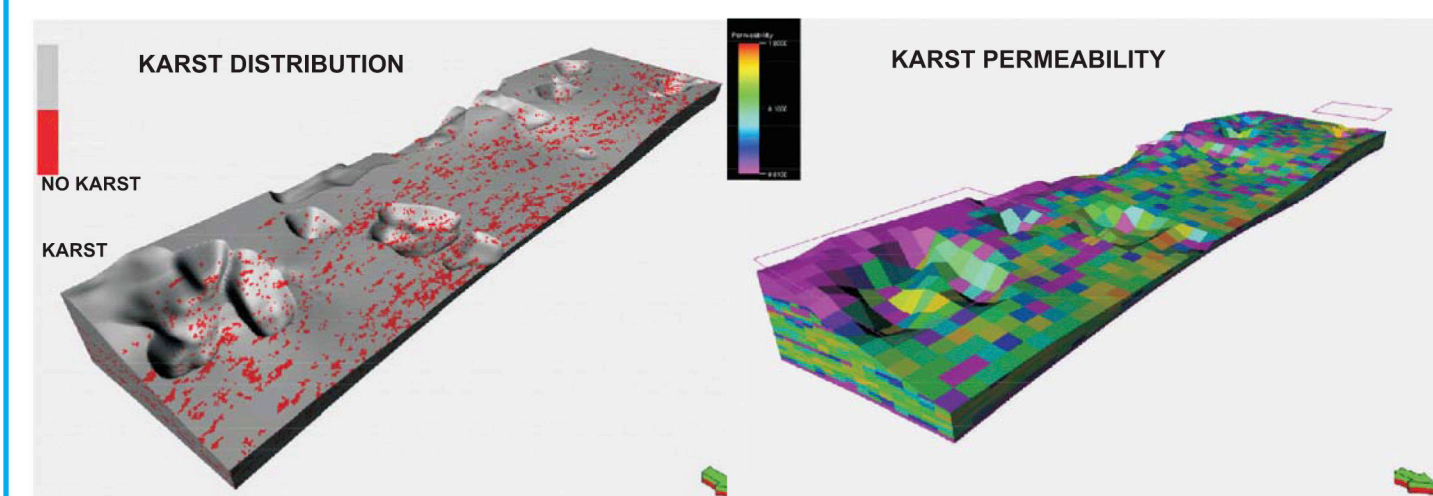
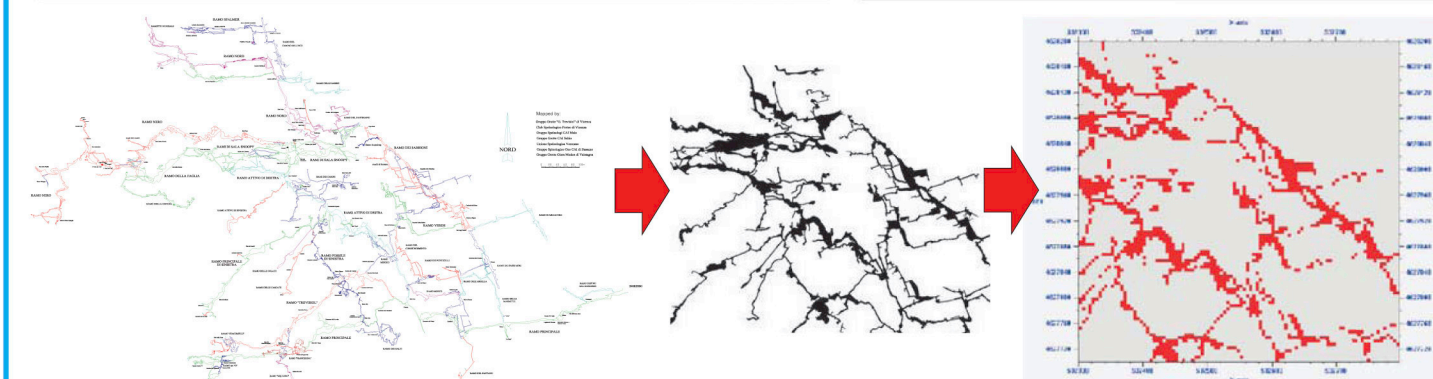
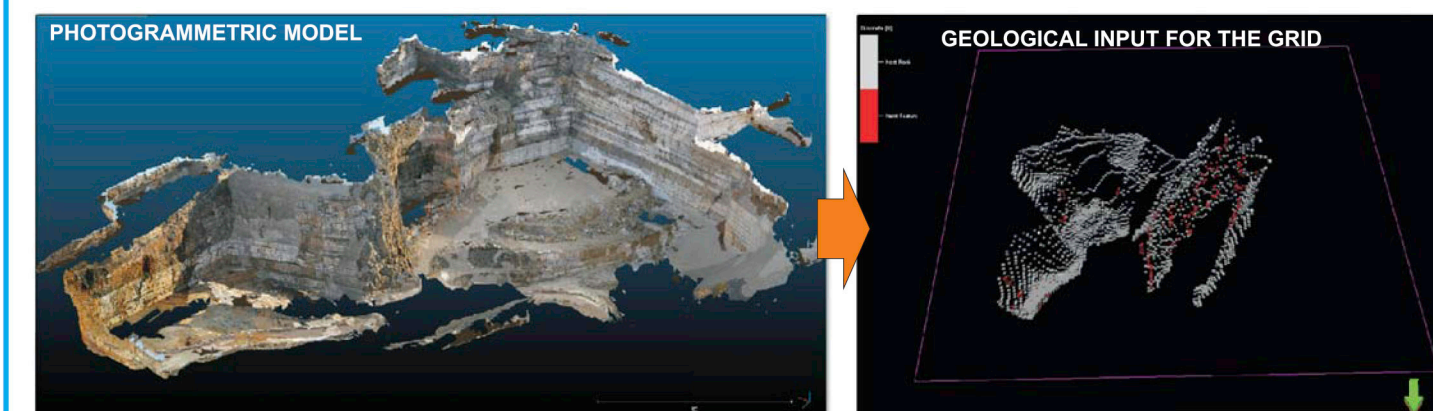
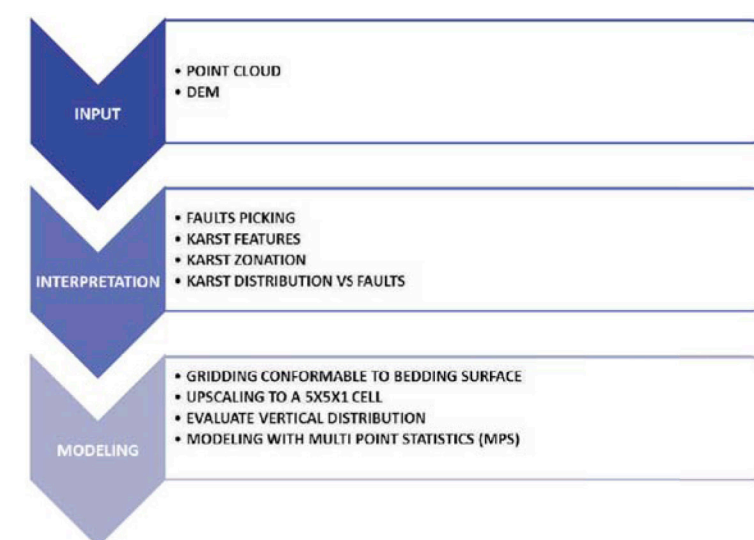
The karstified area represents roughly 10.6% of the vadose zone

These statistical data were used to understand the karst distribution in the examined outcrops, in order to have proper input data for 3D modeling.



KARST MODELING

We used the outcrops for creating a Petrel model of the karst outcrops. The input is derived from photogrammetric modeling of the outcrops, then by using MPS in order to propagate the karst elements in the grid. The training image for the MPS was selected from a real cave from the Italian Southern Alps, the Buso dea Rana/Pisatela Cave System and transformed as a gridded image.



KARST MODELING RESULTS

- Karst impacts mostly on permeability and connectivity rather than storage;
- Megavugs (caverns) are usually filled with terra rossa;
- Vertical dissolved fractures and horizontal paleophreatic horizons are not filled with terra rossa giving permeability and minor storage;
- Modeled karst connectivity is extremely high;
- Cell size is fundamental to capture the karst heterogeneity;
- Karst development and connectivity are strongly influenced by paleophreatic levels, occurred before the tilting phase.

