MULTI-SCALED 3D NUMERICAL CHARACTERIZATION OF A CARBONATE RESERVOIR ANALOGUE

Alex Hairabian[1,*], Jean Borgomano[1] and Sergio Nardon[2]
[1] *Laboratoire de Géologie des Systèmes et Réservoirs Carbonatés, Université de Provence, Marseille 13331, FRANCE*
Tel: +33-04-91-10-62-97, Fax: +33-04-91-10-85-23, E-mail: al.hairabian@hotmail.fr
[2] ENI S.p.A. Exploration & Production Division, Sedimentology, Petrography and Stratigraphy Dept., San Donato Milanese 20097, ITALY

Keywords: *carbonate, reservoir, heterogeneity, 3D modeling*

ABSTRACT

Detailed study of facies, architecture and petrophysical properties has been carried-out on well-exposed Upper Cretaceous carbonate outcrops of the Gargano (SE Italy). With the help of numerical tools, these data have been integrated within a 3D georeferenced framework to create precise and realistic multi-scaled 3D models of a carbonate reservoir analogue. These models support the understanding of reservoir properties development in 3D and better interpretation of sub-surface data specially for heterogeneous medium as carbonates.

INTRODUCTION

Although they have an homogeneous mineralogy (CaCO3), rocks of the carbonate family form complex and heterogenous sedimentary formations. Their high degree of spatial heterogeneity is a consequence of complex stratal geometries and facies and long term post-depositionnal processes (such as dissolution and cimentation). As carbonates contain more than 60% of the global hydrocarbon reserves, a better understanding of the origin and evolution of these heterogeneities represent a great challenge.

Field geology mapping of architecture and facies, high resolution numerical tools as LIDAR (Light Detection and Ranging) and petrophysical measurements are used to create multi-scaled 3D geologic models of an old carbonate margin outcropping in South-Eastern Italy. These quantitative models are of particular interest for the comprehension of spatial heterogeneities repartition in Southern Adriatic hydrocarbon field analogues. These static models could also be used as input for dynamic reservoir modeling with hydrocarbons or water and seismic synthetic modeling.

GEOLOGIC SETTING

The study is located in the Gargano promontory (Puglia region, SE Italy) which forms an elevated part of the Adriatic foreland and corresponds to a broad anticline dominated by Mesozoïc carbonates.

The studied outcrops, Cretaceous in age, enable the architecture and the processes of a platform-to-basin transition to be studied in detail.

The platform carbonates are juxtaposed to the deeper marine carbonates by the intermediary of a faulted scarp [1, 2]. The base-of-slope environment, which focuses our interest, is characterized by bioclastic and conglomeratic aprons interbedded with pelagic mudstones.

The Gargano presents exceptionally well-exposed outcrops forming a succession of N/S elongated crest bordered to the south by high cliffs delimiting the coastal plain of Adriatic sea. These exposures permit 3D views of depositional packages.

DATA BASE

Data used in this study are :

- a set of aerial orthophotos with 0.25 m pixel size;
- photopanels;
- a regional DEM (Digital Elevation Model) with homogeneous grid of 1 point every 40 m;
- x, y, z LIDAR data collected from helicopter survey in well exposed areas with ~ 1-2 m resolution;
- x, y, z and intensity data from terrestrial LIDAR scan over 3 cliffs with ~ 1cm resolution;
- a set of thin sections and 80 rock samples on which porosity, permeability, density, Vp and Vs were measured in laboratory.

ORIGIN & EXPRESSION OF HETEROGENEITIES IN CARBONATES

FACIES

The depositional facies and the post-depositional diagenetic modifications occurring in surface as in sub-surface are the major controlling factors on reservoir properties such as porosity and permeabiliy. Understand the origin and evolution of the carbonate sediments is of relevant importance for the comprehension of the reservoir properties developments in 3D.

GEOMETRIES

The geometries are function of the sediment nature (facies), depositional processes and environment. Their description is of major importance to characterize the connectivity between reservoir entities. Especially when the reservoir is made of sandy lenses (with high permeabilities) separated by impermeable layer.

*To whom all correspondence should be addressed.

PETROPHYSICAL PROPERTIES

The studied carbonates are weakly fractured and not karstified at large scale. Nevertheless the "matricial" physical property show a wide range of values (factor 1000 for permeabilities) (Fig.1). This well expresses the heterogeneity existing in carbonates.

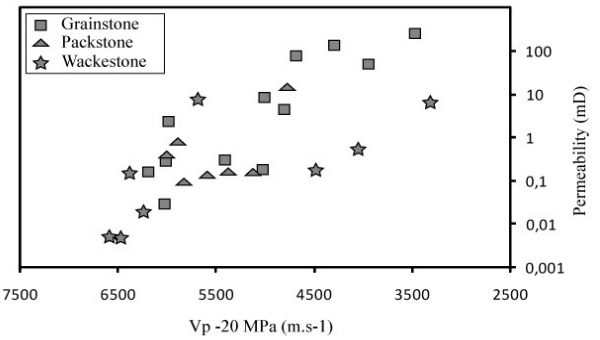

Fig. 1 Relationships between permeability and Vp coded with textures in Upper Cretaceous Gargano carbonates.

3D MODELING

REGIONAL 3D MODEL

Covering an area of 20x10 Km^2, the low resolution regional 3D model captures the main lithostratigraphic formations thickness variations and spatial distribution. Significant stratigraphic, structural (faults) contacts and facies are first mapped on printed photopanels and orthophotos on the field. These geologic interpretations are then integrated into a 3D numerical gOcad database as follow. Orthophotos are superimposed onto the DEM and stratigraphic and structural contacts are digitized as point lines within this 3D georeferenced system. Stratigraphic and structural surfaces are built in order to create a surfacic geologic 3D model.

Due to the depositional environment of the sediments along and at the bottom of a submarine slope, the stratigraphic contacts present complex morphologies related to erosion and fill (paleocanyons), lateral accretion, remobilisation by syn-sedimentary tectonic. All these aspects have major impacts on the reservoir architecture and flow units.

LOCAL 3D MODELS

Their extension is of 100's meters square. Digital field tecnologies as laser scanning combined with high resolution photos draping techniques give access to outcrop expressions of stratas. The so-built 3D georeferenced numerical outcrops are called DOMs (Digital Outcrop Models) [3]. DOMs give the possibility to create quantitative high resolution 3D models of sedimentary bodies (clinoforms, lobes) and complex geometries (channels, canyons) within the main lithostratigraphic formations.

In a second time, volumic models (3D grids) are created corresponding to cellular frameworks in which qualitative (facies) as quantitative (petrophysical property values) attributes can be inferred.

CONCLUSIONS

These methods combining detailed outcrop studies, numerical tools and petrophysic data allow a pertinent representation of subsurface reservoir entities. These realistic models can be used as input for flow simulation and/or synthetic seismic. In the same way, they support interpretation of geophysic, well or core data for sub-surface resources exploration.

REFERENCES

[1] J. Borgomano: *Am. Assoc. Petrol. Geologist Bull.*, **84** (2000) 1561.

[2] J.-P. Masse & J. Borgomano: *C. R. Acad. Sci.*, **304** (1987) 521.

[3] J. Bellian et al. : *J. Sed. Res.*, **75** (2005) 166.