PERFORMING 3D NUMERICAL MODELLING INCLUDING H/V TECHNIQUE AND BOREHOLES DATA FOR GROUND MOTION SIMULATION : GEOMETRY AND FACIES CHARACTERIZATION OF A TERTIARY RESERVOIR (CADARACHE, SE FRANCE)

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ABSTRACT

The geometry and facies characterization of a Tertiary reservoir in the CEA Cadarache Research Center (Provence, SE France) is performed using 3D numerical modelling and H/V technique. Outcrops, boreholes and geophysical data are integrated within the 3D geomodelling software gOcad for constructing a 3D facies model of the Cenozoic rocks in the Cadarache valley.

The reservoir geometry is provided by geophysical method (H/V technique) [1] for the Cretaceous bedrock and surface and sub-surface geological data for the main geological envelopes. The reservoir characteristics are determined by geostatistical approach from boreholes data. We calculated the facies spatial distribution in 3D in order to understand the complex the sedimentary pattern of Cenozoic rocks in the Cadarache Valley.

The 3D geological model of the Tertiary reservoir will be used by seismologists to produce a realistic ground motion simulation of the area, including the source, the regional attenuation and the local site effects.

INTRODUCTION

In field, Cenozoic deposits reveal a heterogeneous and complex sedimentary system. The observed sedimentary facies present various types (breccias, sands, sandstones and clays) with complex geometry and are affected by successive erosions and Durance river history. As a consequence, sedimentary bodies are discontinuous at large scale.

The intensive geoscientific drilling activity undertaken since 1959 in the Cadarache Nuclear Research Center led to an original subsurface database with a high density of boreholes. However, this huge database highlights a high heterogeneity of geological facies which seriously hampers the understanding of the complex sedimentary system and the realization of 2D facies correlations. The high complexity of this sedimentary system needs to be unravelled in 3D taking into account all available data (geological, geophysical, outcrops, boreholes …) considering the 3D structural framework and the facies distribution.

In order to understand, quantify and predict the geological and mechanical properties of the Tertiary rocks, the surface and subsurface data need to be integrated in a consistent 3D numerical database. This huge and heterogeneous database serves as support for the 3D modelling of the Cenozoic sedimentary filling-up of the Cadarache incised valley.

GEOLOGIC SETTING

Our study area is located in the CEA Cadarache Nuclear Research Center (SE France). This center is located in a valley filled with Cenozoic rocks (cover) unconformably lying on Cretaceous limestone bedrock.

The geological substratum of Cadarache includes Cretaceous to Quaternary formations separated by three major unconformities. These formations result from a complex sedimentary history marked by the transition from a marine (lower Cretaceous) to a continental environment (Tertiary and Quaternary) interrupted by successive erosions. The Cretaceous basement large-scale structure is flat, lying between two opposite vergency ramp-anticlines (Vautubière anticline to the south and Vinon-Gréoux duplexe to the North).

DATA BASE

In order to perform the 3D numerical model of the geological basement of the Cadarache Valley, the available database includes:

- A high resolution (~5m) digital elevation model (DEM),
- A high resolution geological and structural maps (1/5000),
- More than 1500 geotechnical wells with sedimentary facies and stratigraphic descriptions,
- Ten H/V ambient vibration measurements,
- Six geological cross-sections.

3D GEOLOGICAL MODEL: CRETACEOUS GEOMETRY AND TERTIARY FACIES SIMULATION

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MODELLING WORKFLOW

In a first step, we built a surfacic model (DSI [2]) composed of 3 major unconformity surfaces: the Top-Quaternary, the Top-Tertiary and the Top-Secondary. The geometry of the Top-Mesozoic is constrained by geological maps, 1225 boreholes and H/V profiles.

In a second step, a 3D stratigraphic grid with a cell size of 10x10x2 meter conditioned to the 3 major unconformity surfaces was achieved in order to define the stratigraphic framework of the facies modelling. The stratigraphic grid is divided into 2 regions: Quaternary (118 101 cells) and Tertiary (1 078 968 cells). Borehole data are integrated in the grid. Finally, we applied a variographic analysis and pixel-based simulation with indicator kriging [3] to simulate spatial facies distribution in 3D within Tertiary region.

BEDROCK GEOMETRY

Using H/V method allows identifying a high seismic velocity contrast boundary between the Cretaceous marine limestones (bedrock) and the Quaternary and Tertiary continental deposits (cover) of the valley. Ten H/V profiles have been realized perpendicular and parallel to the valley. Geological data (geological map, boreholes) and the bedrock depth from H/V profiles have been compiled with gOcad in order to recover the surface of the Top-bedrock beneath the Cadarache Valley (Fig. 1).

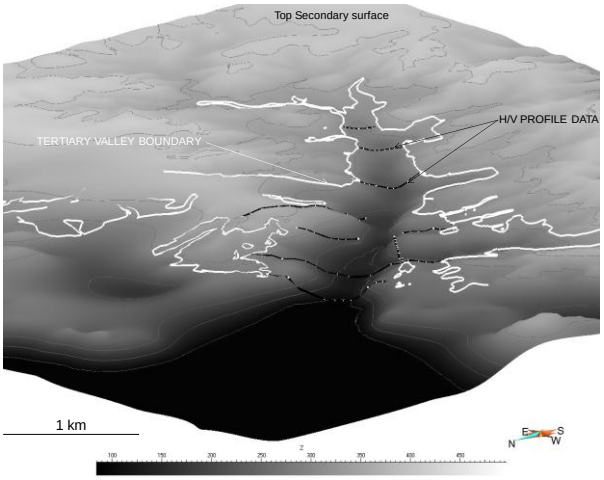

Fig. 1 Geometry of the Top-bedrock beneath the Cadarache incised valley.

FACIES SIMULATION

Producing a ground motion simulation need to understand the 3D distribution of depositional facies which control the reservoir properties such as porosity, permeability and seismic velocities. Based on the geological synthesis of 1344 boreholes and on the geological map, we identified ten major geological facies occurring in the geological substratum of the Cadarache Valley. These facies have been simulated in Tertiary region (Fig. 2).

We performed a variographic analysis on the boreholes crossing the Cenozoic region of the 3D stratigraphic grid and proceeded to 3D facies simulations. We obtained a 3D facies model for the facies distribution of the Cenozoic cover beneath the Cadarache Valley.

The performed sedimentary model reveals a sandy meandering fluvial deposit type [4]. The facies 3D spatial distribution is strongly controlled by the geometry of the bedrock.

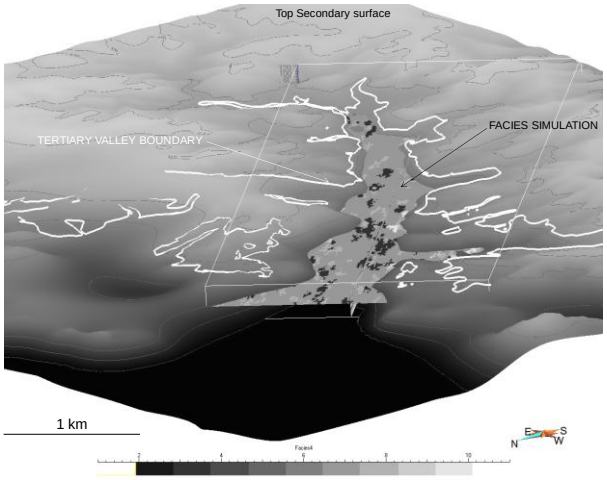

Fig. 2 Facies simulation of the Cadarache incised valley.

CONCLUSIONS

3D numerical modelling is an efficient tool to integrate a huge and heterogeneous database (1344 boreholes, high resolution geological and structural maps, H/V ambient vibration measurements and geological cross-sections) and better understand a complex sedimentary system. The 3D facies model of the cover of the Cadarache valley reveals a sandy meandering fluvial deposit model controlling the properties of the Tertiary reservoir. This depositional model is controlled by the Top-bedrock geometry (incised valley with sloping edges) and disturbed by important coarse (breccias) and fine materials (clays) from periodic inputs due to erosion and/or destabilization of the edges valley.

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