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Ground-Penetrating Radar as a high-resolution tool to interpret carbonate platform geometries: a case study from the late Jurassic of the Paris basin (France)

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Ground-Penetrating Radar (GPR) is a now classical technique used for numerous sorts of geophysical prospections. Its rapid and easy setting in the field leads to improve studies concerning sedimentary strata. Nevertheless, and despite its capacity to provide high resolution data on sedimentary bodies, this technique does not seem to have been widely used for the recognition of geometries of ancient carbonate formations. The work presented here reports the results of a GPR prospection carried out in a late Jurassic reefal formation in the south-east of the Paris Basin. The aim of this study is to complete a sedimentological framework and to gain high resolution data at the scale of a clinoform.

A main sedimentological investigation was carried out on a recent roadcut, close to the city of Tonnerre. Large outcrops exhibit unreported upper Jurassic carbonate facies ("Calcaire de Tonnerre" Formation, late Oxfordian, Planula biozone) on a distance of about 400 m and a 25-m-high. These carbonates are made up of coral reef bioherms that laterally change into prograding and channeling pure carbonate sequences. The rather friable state of some of these sequences leads to rapid and intensive weathering, resulting in a difficulty for accurately mapping the lateral evolution of the bedding planes, especially the upper part of the outcrop.

In order to solve this problem, GPR profiling was carried out on the top of the cliff, associated with 200 and 400 MHz antennae working in monostatic mode. These mea-

surements were associated with Differential Global Positioning System (D-GPS) for topography calibration. The GPR results, directly correlated with the 25-m-high outcrop, show an impressive 350 ns two-way travel time (twt) useful range for the 200 MHz antenna, corresponding to a 19 m depth penetration with a velocity of 0.11 m/ns. Furthermore, the raw data clearly show very little noise. To our knowledge, such penetration depths seem to have never been reported hitherto within carbonate series for such central frequency antennae. Moreover, these results indicate a penetration depth at least equals to those gained with 50 to 100 MHz antennae in several studies devoted to carbonate facies (Pratt & Miall 1993, Grasmueck et al. 2004, see Neal 2004 for a synthesis), with a twice better resolution at least.

Correlated to a detailed sedimentological analysis on the different cropping units, the analysis of the GPR profiles allows to recognize the different bedding planes and major erosion surfaces, and to individualize different sedimentary facies characterized by distinct GPR facies. Another GPR profile, conducted at the base of the cliff, allows a 10 m depth penetration, corresponding to a 200 ns twt range with a velocity of 0.11 m/ns. A strong and continuous reflection level has been be clearly identified and can be, in first approach, interpreted as a palaeotopographic surface upon which settled the outcropping biohermal units. The superposition of the 2 GPR profiles gives a 30 m thick image of the whole reefal carbonate platform, going from the reefs settlement to their burying.

Several points can explain such a penetration depth. First, the entire carbonate formation is clay free. Analysis of the carbonate content on the different sedimentary facies indicates a pure carbonate system (100% $CaCO_3$ for the whole plugs). Furthermore, the absence of clay in the bedding planes as well as in the different sedimentary sequences leads in a rather loose attenuation compared to GPR prospections carried out in more usual (i.e. more clay-rich) carbonate environments. Secondly, the track on which the profiles were acquired is clay free as well. Then, the electromagnetic wave energy is close to its maximum when penetrating the ground.

These new findings on a late Jurassic carbonate formation clearly demonstrate the GPR ability for the identification and the interpretation of ancient carbonate platform geometries. Our results allow an observation scale ranging from some meters to some tens of meters. This observation scale perfectly fits between outcrop detailed sedimentological workscale (some few meters) and seismic scale (hundred of meters to several hundred of meters). Based on an outcrop analogue approach, GPR profiling may provide a precious help to enhance the correlations between outcrop and seismic data.

Key-words : Paris Basin, late Jurassic, coral reefs, carbonate strata, GPR.

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