

Borehole image techniques applied to identification of chert and dolomite layers in lacustrine sediments

Técnicas de imagen de sondeo aplicadas a la identificación de intervalos chert y dolomita en sedimentos lacustres

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Abstract: Geophysical logging tools, particularly ultrasonic acoustic borehole image techniques, are applied on two different wells (CP1 and CP2) to identify and characterize the lacustrine interval (40m) of the *Camp dels Ninots* maar-diatreme infill (Pliocene, Catalan Coastal Ranges). The CP1 well was cored and also geophysical logs and oriented borehole images were acquired. CP2 hole was partially cored but logging (geophysics and borehole images) was fully undertaken. Continuous core recovery in CP1 is compared with oriented images and is further used to identify and characterize highly reflective signals in a section of CP2 borehole that was not cored. These signals are related to silicified zones and belong to discontinuous centimetric chert nodules, while indurated massive carbonates are characterized as intervals of continuous reflectance. Despite opal nodules (chert) can be relatively small, they have a distinctive response in the ultrasonic borehole images.

Key words: Borehole imaging, acoustic televiewer, silicification.

Resumen: En este estudio se han aplicado técnicas de testificación geofísica de sondeos y, en especial el televiewer acústico, en dos sondeos (CP1 y CP2) para identificar y caracterizar el intervalo lacustre (40m) del relleno del maar-diatrema del Camp del Ninots (Plioceno, Cadenas Costeras Catalanas). El sondeo CP1 se ha testificado con sondas geofísicas y se ha perforado con recuperación continua de testigo (wireline). El sondeo CP2 solo se recuperó parcialmente pero se ha testificado en su totalidad (geofísica y sondas de imagen orientada). La recuperación continua de CP1 se ha comparado con las imágenes de testificación y se han utilizado para identificar en el pozo CP2 niveles reflectivos del tramo donde no se recuperaron testigos. Los niveles reflectivos están relacionados con zonas silicificadas y se corresponden a nódulos discontinuos centimétricos de chert y los tramos de carbonato masivo se reconocen como niveles reflectivos continuos. A pesar de que los nódulos de ópalo (chert) pueden ser relativamente pequeños, su reflectividad facilita su identificación sobre las imágenes del televiewer acústico.

Palabras clave: sondas de imagen orientada, televiewer, silicificación.

INTRODUCTION

Fresh water lake environments affected by volcanism are commonly characterized by high Mg and Si activity coupled with high carbonate alkalinity and microbial influence, which can potentially generate a complex set of abiotic and biotic interactions and mineral products (Wright, 2012). Some of these early diagenetic mineral products include opal nodules and dolomite.

Here we explore borehole imaging techniques and sonic logging as a potential tool to identify these silicified and dolomite horizons without continuous rock recovery. Therefore, in this study we compare

logging coupled with core recovery to characterize and better interpret further wells where logging is the only available data. This is applied to the Camp dels Ninots maar.

GEOLOGICAL SETTING

The Camp dels Ninots maar-diatreme (CNMD) is a Pliocene volcano located near Caldes de Malavella (Girona, NE Spain) and is located at the margin of the La Selva Basin (Pous et al. 1990). This volcano is part of the Catalan Volcanic Zone (Gómez de Soler et al., 2012), one of the European Rift System provinces (Figure 1). The CNMD origin is related with the NW-

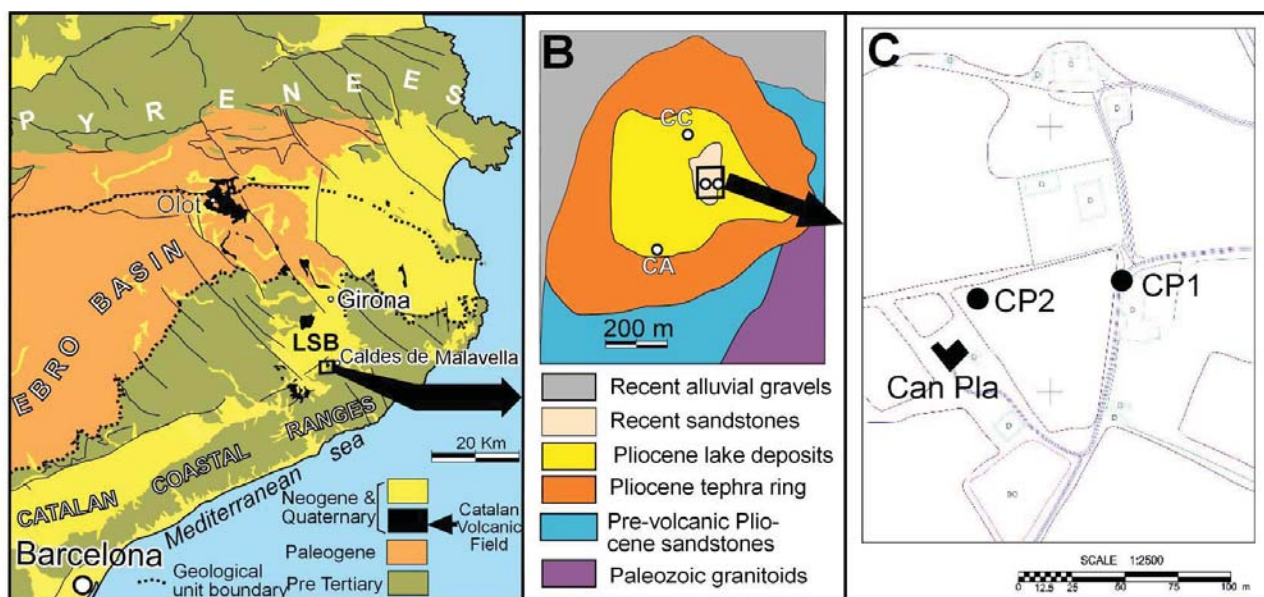


FIGURE 1: A) Location of the Camp dels Ninots maar diatreme within the Iberian Peninsula (upper left) and within the Catalan Volcanic Field. B) Simply geological map of Camp dels Ninots maar. C) Topographic map of the Camp dels Ninots maar showing the location of the CP1 and CP2 wells. A & B by Oms et al., 2015 (modified)

SE fault system, which limited the La Selva Basin, and it is classified as phreatomagmatic eruption, the most common in this area (Martí et al. 2011).

The earliest geologic study considered the Camp dels Ninots sediments as lacustrine deposits without any mention to volcanism (Vidal 1882), being Vehí et al. (1999) who identified these sediments as the infill of a maar. These maar sediments have been extensively studied due to their well-preserved Pliocene and Pleistocene fossil record (Campeny & Gómez de Soler, 2010; Gómez de Soler et al., 2012; Jiménez-Moreno et al., 2013; Claude et al. 2014). More recently, a detailed geological study of maar structure and infill sediments based on 8 cores and 9 electric resistivity tomography cross sections was reported by Oms et al. (2015).

The base of the CNMD is made of Late Carboniferous to Permian granites, schists, and Pliocene arkose clays, sands, and gravels from the La Selva Basin alluvial system (Figure 1). The lacustrine sediments fill a ring volcanic structure made of Pliocene tephra and have been classified in three main sedimentary facies: (i) white colour carbonates; (ii) green colour clays without organic matter, and (iii) black colour clays rich in organic matter. The CNMD lacustrine sediments are characterized by frequent early

diagenetic silicified horizons, which appear as chert nodules, and dolomitized horizons. Both types of diagenetic products, chert nodules and dolomite, are the object of this study

METHODS

This study is based in two boreholes drilled in 2015 time (see also Bolós et al., this volume): Can Pla 1 (CP1) and Can Pla 2 (CP2) (Table 1 & Figure 1c).

Well logging of CP1 and CP2 was performed by personnel of the Borehole geophysical logging laboratory at Institute of Earth Science Jaume Almera – CSIC (CSIC, Barcelona, Spain). A complete set of geophysical logs was acquired (table 1), including oriented televiwer images. The images were processed at the ICTJA-CSIC lab by specialists using WellCAD (ALT) and Techlog (Schlumberger) log processing softwares.

The CP1 well core sampled in order to elaborate thin sections (27) and collect powder samples (27) for X-Ray Diffraction (XRPD). XRPD scans of all samples hand-ground powder samples were acquired using a Bruker D8-A25 powder diffractometer equipped with a Cu x-ray source (Cu K α radiation) and a LynxEye

Well	Coordinates	Depth (m)	Core	Logging
Can Pla 1 (CP1)	483395,1 E; 4631445,5 N	112	continuous	Natural and spectral gamma ray, optical and acoustic televiwer, magnetic susceptibility, resistivity and sonic logs
Can Pla 2 (CP2)	483321,8 E; 4631437,5 N	145	80 to 145 m	

TABLE 1: Characteristics of the CP1 and CP2 wells drilled in the Camp dels Ninots.

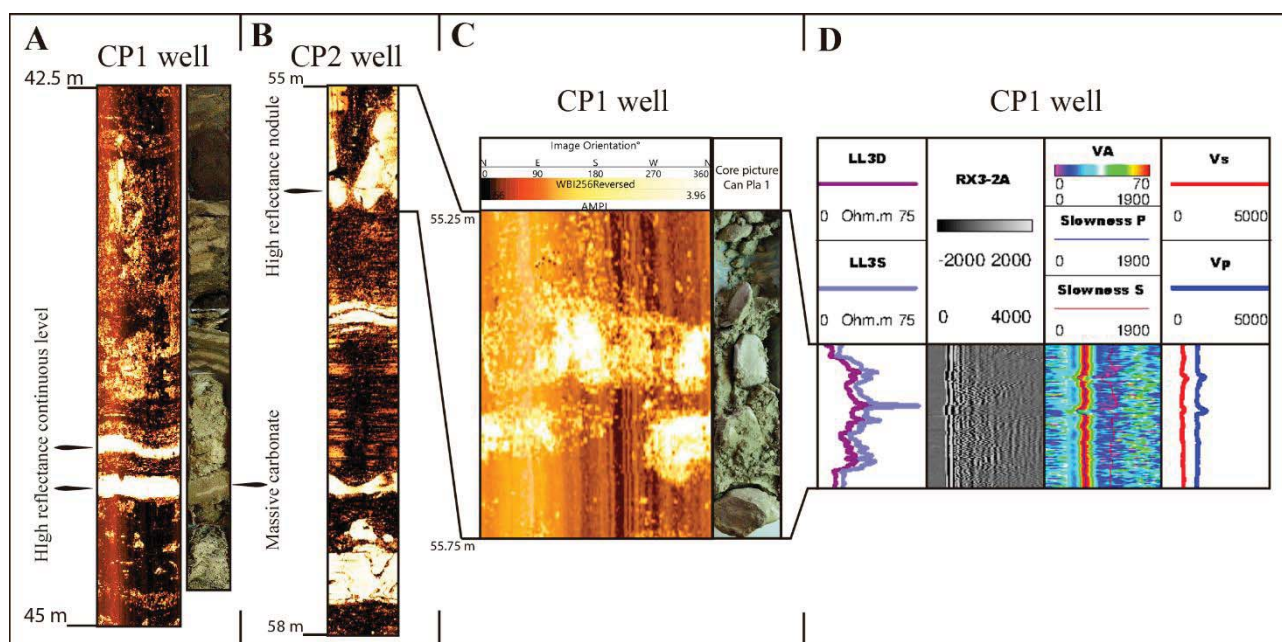


FIGURE 2: Log responses of the CP1 well & CP2 well. A) Section of the CP1 well between 42.5 m and 45 m. Televierer response of the core (left column). The right column is the core picture of the same section. . It can be seen that the carbonate massive layers produce a high reflectance in a log response; B) Televierer response from 55 m to 58 m of the CP2 well with different facies: nodular in the upper part and plane parallel into the middle and to the bottom; C) Another section of CP1 well between 55.25 m and 55.75 m. Televierer response and the core picture can be observed on the left and right images, respectively. The televierer response of the silica nodules can be observed in the picture; D) Resistivity and sonic log responses of the same section as in C (nodular facies).

position sensitive detector. The scans were recorded between 3° and 65° (in 2θ) with a 0.05° step size and equivalent integration times of 576 s per step. Phase identification was performed by using the Diffrac.EVA software in combination with the Powder Diffraction File (PDF-2) and the Crystallography Open Database (COD).

RESULTS AND DISCUSSION

Televierer image of CP1 and CP2 wells shows two types of stretches with high reflectance response. The first one is a continuous signal that is parallel to bedding and can be identified throughout the width of the well. The second one is irregular and discontinuous (Fig. 2A, 2B & 2C).

CP1 well core examination allows identifying the plane parallel continuous stretches as indurate carbonate horizons located between soft sediments (Fig. 2A). The XRPD analyses of these carbonate horizons reveals that are made of dolomite with minor amounts of other carbonates (ankerite & calcite) and feldspars (plagioclases & potassium feldspar). In a similar way, CP1 well core examination of the irregular and discontinuous stretches allows identifying these areas as chert nodules located within carbonates and clays (Fig. 2C). The XRPD analyses of the nodules reveals that are made of opal-A and opal-CT while the host rock are composed of carbonate (dolomite & ankerite & calcite) clays (smectite & illite & kaolinite),

feldspars (plagioclases & potassium feldspar) and quartz.

The excellent correlation between televierer images and mineralogical composition of the reported high reflectance stretches in the CP1 well can be used to infer mineralogical composition of the CP2 televierer imaging along sections not cored and/or with poor core recovery. Together with televierer, other geophysical signal such as resistivity or sonic logs also register a characteristic response of levels with dolomite or chert nodules horizons (Figure 2D).

CONCLUSIONS

The combination of geophysical logs, televierer oriented images logging and direct core examination (mineralogical determinations) has allowed us to characterize horizons rich in opal nodules and levels with dolomite.

The televierer image appearance of opal nodules is that of discontinuous reflective shapes while the carbonate layers appear as continuous highly reflective continuous bands.

Our results obtained by comparing geophysical logs and cores indicate that ultrasonic high resolution images obtained with the acoustic televierer are a good tools to identify even relatively small sized (3 – 5cm) opal nodules.

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