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Fracturing and cementation of shallow buried Miocene proximal alluvial fan deposits

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ABSTRACT

Fluid flow in fractures and host rocks has been investigated in shallow buried Miocene alluvial fan deposits. A structural, petrographical (optical, CL, SE microscopes and XRD) and geochemical (microprobe and $\delta^{18}O$-$\delta^{13}C$ stable isotopes) study has been performed in normal faults affecting Serravalian-Tortonian siliciclastic rocks of the Vallès-Penedès basin. These faults formed during the development of the Vallès-Penedès fault-related syncline, which caused the rotation of the earliest fractures. Faulting occurred continuously before, during and after host rock cementation. Rocks affected by faulting are represented by clay-rich gouges, which formed thanks to the high phyllite clast content within the otherwise clean and mature sandstones and conglomerates. Despite the low permeability of these rocks, cross-fault and fault-parallel fluid flows occurred in most of the faults.

Host rocks and veins were cemented by two generations of calcite, i.e. Cc1 and Cc2. Cc1 precipitated from meteoric waters at shallow burial conditions whereas Cc2 precipitated from meteoric waters in a confined aquifer.

Palygorskite has been identified in shear zones within the gouges indicating their later formation by interaction of Mg-rich fluids with previous smectites. These fluids probably derived from Miocene seawater expelled from the underlying Transitional–Marine Complex “TMC” by compaction.

Sedimentation, fracturing and cementation occurred in a very short lapse time of about 6–7 Ma, between the Serravalian-Tortonian age of the sediments and the end of the extensional tectonics in the Vallès-Penedès fault (Pliocene).

1. Introduction

The decrease in conventional oil and gas reservoirs and the increasing demand in energy are requiring the exploration of more complex targets such as heterogeneous reservoirs. This is the case of alluvial fan reservoirs, which are heterogeneous both laterally and vertically due to the variable conditions during deposition (tectonics, climate…). During the last few years, the deposits of these environments have shown their real potential as reservoirs such as the Marmul oil field in South Oman (Heward, 1989), Argyll and Innes fields in the North Sea (Heward et al., 2003; Moscariello, 2005), Garfield field in Kansas (Rogers, 2007) and Karamay and Caiyu fields in China (Cao et al., 2005; Min et al., 2007). Alluvial fan environments are well-developed at the margin of extensional basins, where they can become very thick and laterally continuous, thus increasing their potential as hydrocarbon reservoirs (Moscariello, 2005). These locations, close to the margin of active basins, are especially affected by deformation linked to the major bounding fault, incorporating an additional factor of heterogeneity to the alluvial fan setting. Faults can act as conduits or barriers to fluid flow as a function of their architecture, the petrophysical characteristics of the fault rocks and the presence or not of cementation (Caine et al., 1996; Wibberley and Shimamoto, 2003; Rowland and Sibson, 2004; Berg and Skar, 2005). In addition, small-scale intrareservoir faults can lead to compartmentalization, which reduces the ultimate hydrocarbon recovery (Corrigan, 1993).

In order to predict the flow properties of faults several research approaches have been developed to assess the effect of specific processes on reservoir properties. Some are based on the distribution of clays along the faults as clay smear potential, shale smear

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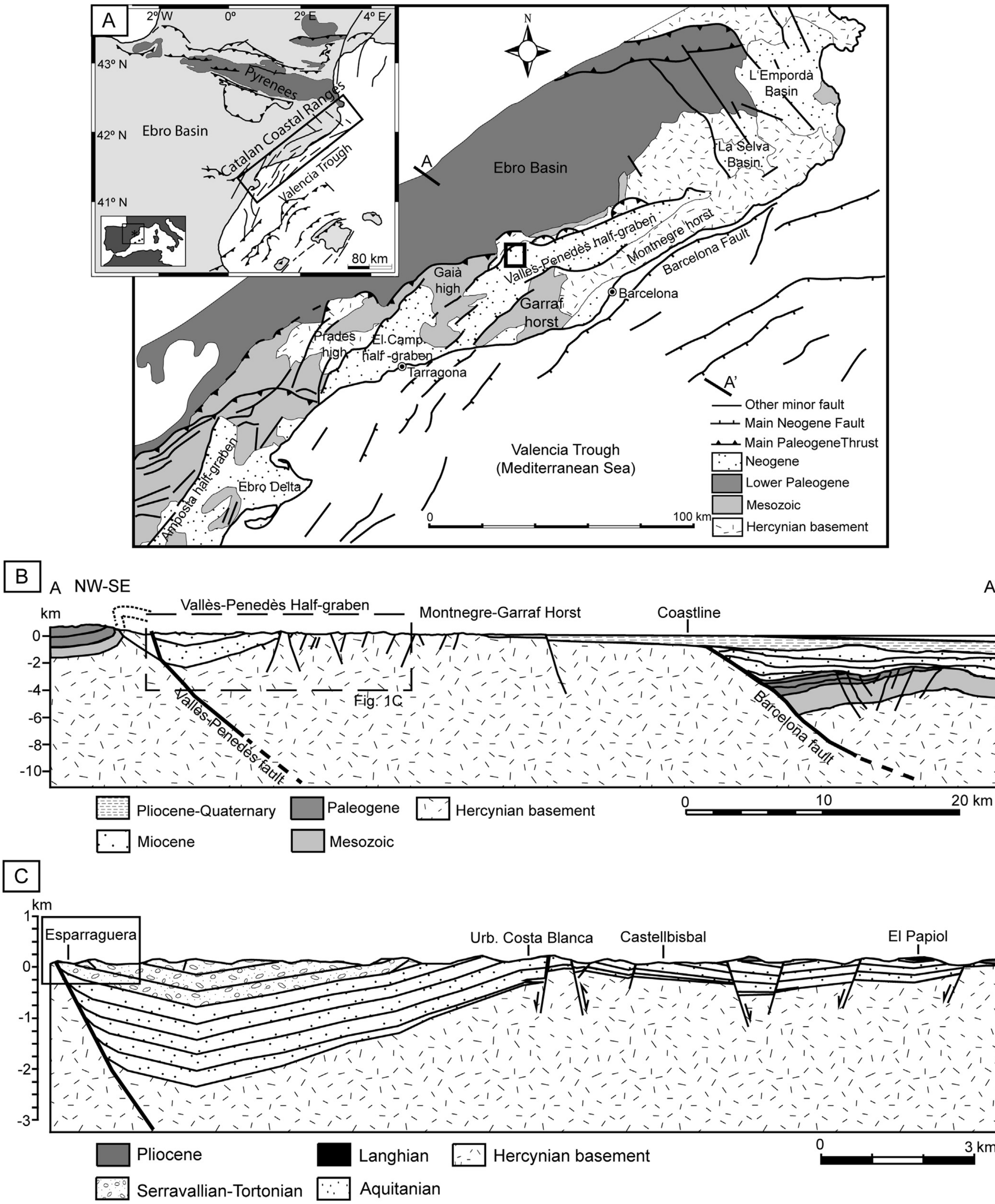

Figure 1. Geological setting. A) Location and schematic map of the Catalan Coastal Ranges. The square indicates the study area. B) Cross-section of the Catalan Coastal Ranges indicated in A (Travé et al., 2009). C) Detailed cross-section of the Vallès-Penedès half-graben (squared area in B) and location of the study area marked with a square (Travé et al., 2009).