WS5-P04

The Use of Outcrop Analogue Basement Rocks to Help Seismic Imaging of Buried Reservoirs

L. Bertrand (University of Lorraine), B. Walter* (University of Lorraine), G. Perry (University of Lorraine), Y. Geraud (University of Lorraine) & M. Diraison (University of Strasbourg)

SUMMARY

Basement rocks are well studied nowadays for their exploitation as geothermal reservoirs or for mineral exploration. In these rocks, the matrix permeability is poor and the fluid flow (geothermal resource or linked to mineral precipitation) is mainly controlled by the natural fracture and fault network and associated weathered materials. Unfortunately, the fracture and fault pattern at reservoir scale in the basement is not well known and is difficult to characterize with the actual geophysical tools. The use of analogue rocks at the outcrop is therefore an important tool for helping to the reservoir characterization. This study presents a synthesis of basement outcrops studies in different geological settings linked to crustal extension. The method used was to combine satellite pictures, field studies and laboratory measurements in order to define the faults, fractures and cracks network at the largest range of scales as possible. That has led us to construct a reservoir's model composed by blocks of different orders depending on their size bounded themselves by faults with decreasing thickness and lengths. This model is a key tool for the characterisation of fractured buried reservoirs by seismic imaging.

Introduction

Basement rocks are well studied nowadays for their exploitation as geothermal reservoirs or for mineral exploration. In these rocks, the matrix permeability is poor and the fluid flow (geothermal resource or linked to mineral precipitation) is mainly controlled by the natural fracture and fault network and associated weathered materials. Unfortunately, the fracture and fault pattern at reservoir scale in the basement is not well known and is difficult to characterize with the actual geophysical tools. The use of analogue rocks at the outcrop is therefore an important tool for helping to the reservoir characterization. This study presents a synthesis of basement outcrops studies in different geological settings linked to crustal extension. The aim of this synthesis is to develop a general model of fault and fracture network in basement reservoirs. This model will be helpful for the interpretation of seismic images in this kind of rocks.

Methods

The outcrop analogues of buried reservoirs have been studied from the regional scale with geological map and satellite pictures to the outcrop scale with field studies and hand sample collection coupled with laboratory measurements. The multiscale study of the faults and fracture network allows us to define the geometry parameters of the geological objects between the regional and the local scale. We could then construct a general model of faulting and fractured reservoirs in basement rocks, in particular for granitic lithology.

The studied areas were: 1) The Catalan Coastal Ranges were Hercynian basement outcrops thanks to the West European rifting active during the Oligocene and Miocene. 2) The Proterozoic basement in Yemen, in particular the Al-Mukalla horst located between two basins linked to two different extension stages: the Mesozoic basin of Marib-Shabwah-Hajar and the Cenozoic basin Mukalla-Sayut. 3) The Elba island granite is a very young (8.5-5.9 Ma) batholith emplaced linked to detachment fault activation during the opening of the Tyrrhenian sea.

These outcrops were also compared with buried reservoirs data, i.e. the Soultz-sous-Forêt EGS in the Rhine Graben where an Hercynian granite and its Triassic cover are exploited for geothermal energy production.

The model

The study of the different outcrops with a different geological context allows us to construct a general model of the fault network that could help for the seismic interpretations.

- From the regional to the metre scale, the faults are organized in different scale orders with characteristic parameters on each scale (length, thickness, orientation...). These faults separate the basement in individual structural blocks with different sizes depending of the scale of observation (*Le Garzic, 2010*)(*Fig. 1a*). Thus, the seismic fault pattern has to be extrapolated at the reservoir scale for the entire comprehension of the fluid flow in the reservoir.

- The seismic interpretation allows defining the general fault pattern, but the reservoir scale faults acting in the fluid flow are below the seismic resolution. The study of outcrop analogues is efficient for the validation of faults properties between the regional seismic scale and the local borehole data. For example, the fault lengths on the Catalan Coastal Ranges follow the same power-law in the whole range of the studied scales (centimetre to hundred of kilometre), in contrary to the faults orientation that is dependant of the scale of observation (Place, 2010; Bertrand et al. in review)(*Fig. 1b*).

- These structure and faulting parameters, namely their orientation, are highly dependant of the structural heritage and the different stages of fault reactivation. The field study of the outcrops allows to characterize the relative chronology of the fracture sets formation and to link them with the geological history of the basement. In Catalunya, the fractures at the field scale (centimetre to tens of metre) has shown a significant role in paleofluid flows hosted by the granitic rocks, although they are not visible on the seismic images scale. For reservoir modelling, the small scale fractures have therefore a significant weight and cannot be ignored. These fractures are linked to the geological history and are coupled with the regional scale faults, has shown on the Elba Island plutons where we

could linked each fracture set with the uplift of the magmatic pluton (Walter et al. submitted) (Fig. 1c).

Figure 1: a) Conceptual model of fault scaling in basement rocks constructed from different outcrops analysis (Le Garzic, 2010), b) Length and orientation distribution of faults and fractures on the Catalanian Coastal Ranges (Place 2010, Bertrand et al. in review), c) Conceptual model of plutons emplacement and link with fractures formation (Walter et al. submitted).

References

Le Garzic, E. [2010] Distribution multi-échelle de la fracturation dans les réservoirs cristallins, influence de l'héritage structural. In : PhD thesis. University of Strasbourg, France, 268 pp.

Place, J. [2010] Caractérisation des chemins de circulations de fluides dans le réseau poreux d'un batholite granitique. In: PhD Thesis, University of Strasbourg, France, 360 pp.