Linking micro & macro scale deformation features with experimental and modelling techniques for fractured carbonate reservoirs & beyond

Stephanie G Zihms Heriot-Watt University, Edinburgh UK
Tiago Miranda, Universidade Federal de Pernambuco, Recife Brazil

Newton Research Collaboration Programme

6 months | ***Brazil*** | ***Incoming/outgoing***

OBJECTIVES OF THE EXCHANGE

Link deformation features from laboratory scale to field scale using a range of techniques

The main objectives of this project are:

a) Develop a better understanding of the relationship between deformation controls at different scales and which deformation features and properties are scale independent or dependent
b) Catalogue relationships of deformation features in relation to mineralogy, grain size, petrophysics and scale
c) Develop a close working relationship between the two academic groups at UFPE and HWU involved in this project by using overlapping expertise to build new knowledge and exchange ideas

RESEARCH UNDERTAKEN

Lab work:
Different carbonates rock samples from Crato Formation, which crops out in the Araripe Basin, NE Brazil, were tested, deformed and analysed at the rock mechanics lab at Heriot-Watt University. These Crato Formation laminites were analysed and characterised using petrophysical and visual techniques, such as porosity, microscopy, X-ray tomography and photographs. After initial analysis over 20 samples were deformed triaxially using a range of confining pressures (20MPa - 50MPa), mimicking reservoir conditions. The deformed samples were then analysed again to determine post-deformation characteristics such as porosity.

Field work:
During the visit in Brazil we spend some days in the field to analyse fracture networks, take scanline measurements and take more samples for further testing at Heriot-Watt University.

Results:
Even though different deformation responses were observed the overall increase in porosity due to fracturing for non-faulted laminites was 5.94% (±1.66). Laminites sampled from a small fault zone showed an increase in porosity of 17.11% (±4.48) due to triaxial deformation.

This indicates that deformation behaviour for laminar laminites could be predicted based on key properties such as porosity, permeability and mineralogy. However, for previously faulted samples these properties alone cannot predict deformation behaviour.

There is still more data being processed, as well as plans to use this data to help develop a numerical simulation to model triaxial deformation for laminites and other carbonate rocks. But we are quite confident that fracture characteristics for these types of carbonates can be compared very well across scales using a range of analytical methods e.g. scanlines.

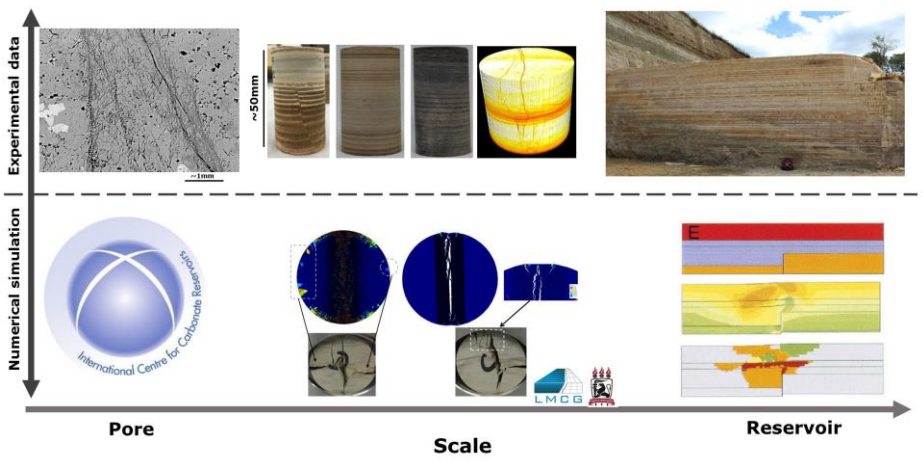

Figure 1. Summary of the scales covered by this research project

IMPACTS AND OUTCOMES

Impact:
Improving understanding and prediction of behaviour of laminites is particularly important for hydrocarbon extraction from carbonate reservoirs in the Brazilian marginal basins (subsalt section). Successful extraction depends partly on the understanding and forecasting of the reservoir to changing subsurface conditions due to hydrocarbon extraction.

During this research exchange we had the opportunity to spend 1 week at CENPES – the Research & Development Center from Petrobras to conduct some flow experiments. This visit also allowed us to share new insights with industry and to discuss further research projects to meet the industry needs. Petrobras is a publicly owned company and must invest parts of profits in Brazil. Enabling Petrobras to increase their profits due to a better understanding of their hydrocarbon reservoirs will directly increase their re-investment.

Outcomes:
We presented preliminary results at the Conjugate Margin Conference in Porto de Galinhas, Brazil in August and we just submitted an abstract to the AAPG Annual Convention in Salt Lake City, USA for May 2018. We are also working on a joint research paper that we plan to submit by January 2018.

At a follow up meeting in September 2017 at Heriot-Watt University we discussed future joint proposals and collaborations, as well as the possibility to recruit a joint PhD student.

This exchange allowed us to better understand how we can share the expertise at each institution and further collaborate together. The exchange was particularly great for the early career scientists involved as it meant establishing a high potential research relationship that would last beyond changing positions or institutions in the future. This would probably not be possible without this exchange.

Figure 2. Crato outcrop during the field trip with engineers from Petrobras

Figure 3. The team at the CENPES research laboratories in Rio de Janeiro (left) & at the rock mechanics laboratory at Heriot-Watt University (right)

FUTURE PLANS

Outputs:
A collaborative abstract to the AAPG Annual Convention & Exhibition May 2018 has been submitted.

Research:
Dr Miranda is now a professor at UFPE and Dr Zihms started a new postdoc in the Lyell Centre at Heriot-Watt University – both are planning to continue working together.

ROYAL ACADEMY OF ENGINEERING
Newton Fund