Structural Geology and Geomechanics: New Frontiers for Basin Modelling*

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Introduction

The increasing complexity of new prospects (subsalt, deeply buried reservoirs, unconventional, etc.) challenges basin models capabilities. These prospects are characterized by complex 3D kinematics and a stress evolution that has a big impact on seal integrity and reservoir petrophysics. In this context, evaluating the thickness of hydrocarbon columns is a task that could certainly benefit from collaboration between structural geology and geomechanics.

Structural geology aims at understanding the mechanisms that control the development of tectonic structures. In the oil and gas industry, this mainly means dating these structures, defining their structural style, and building 2D and 3D geometric models. On its side, geomechanics is mainly confined in our industry to the simulation and control of anthropogenic stimulation of reservoirs and their overburden by production or drilling activities. Therefore, it generally simulates small poro-elastic deformations of structures mechanically characterized by triaxial tests on plugs. Addressing different questions, these two disciplines therefore tend to work separately. However, when confronted to basin modelling challenges, more interaction is required.

This keynote illustrates specific topics where interaction between structural geology and geomechanics could lead to innovative achievements that would significantly broaden the scope of basin modelling. A particular attention is laid on the control of basin model boundary conditions by geodynamic models, the definition of mechanical properties at basin scale, and the improvement of seal integrity prediction. However, in order to be on time to the rendezvous, both structural geology and geomechanics must target new frontiers. A review of these new frontiers is proposed to open discussion.

New Frontiers for Basin Modelling

Structural geologists are trained to untangle complex structures. Basin models are now able to use this skill to improve the simulation of fluid displacements. Indeed, the very last generation of basin models is able to handle significant structural complexity. Cutting edge workflows combining 3D restoration and basin modelling will illustrate this point, using the beloved tool of structural geologists: analogue modelling (Figure 1). This innovation means that structural geologists can today provide sound kinematic scenarios to basin modellers.

However, complex kinematics somehow conflicts with the simplified mechanical concepts used in basin modelling: oedometric compaction. Some evidence that is recalled demonstrates in which condition this simple concept might fail as in the case of stress reorientation around salt diapirs and fault reactivation, for example. This draws one of the new frontiers for basin modelling: improving the simulation of the reservoir quality, fault properties, and seal integrity evolution using realistic mechanics.

New Frontiers for Geomechanics

When confronted to structural complexity, geomechanics is still confused today because most of the efficient numerical tools deal with small deformation hypothesis. A simple fully coupled hydromechanical computation in large strain demonstrates the impact of this hypothesis. However, fully coupled hydromechanical computation is still demanding a lot of computing power and is therefore mainly used for academic research. Some of the results, published in the last few years in 2D is discussed in the presentation. They certainly suggest that improving the numeric should provide very interesting tools in the future.

The computation limitation argues for uncoupling strategies as used in reservoir simulations. This is particularly true when the mechanical code is used to control the boundary condition of the basin model in term of stress and temperature. Some examples of coupling a mechanical code with a basin modelling tool at margin scale is used to discuss the issues raised by such coupling (Figure 2). This suggests that there is a very good opportunity of rapid improvement there.

Geomechanics faces a second major difficulty when working at basin scale: the definition of the mechanical behaviour to be used by the computation. Indeed, the gap in term of space and time scale between the triaxial tests run in the lab and the simulation fault trap growth through million years prevent simple upscaling. We discuss this point using some very stimulating papers which suggest that the homogenization over time and space does simply lead to a rescaling mechanical properties, but it can also induce a switch between constitutive laws. This discussion is used to introduce some new frontiers for structural geology.

New Frontiers for Structural Geology

As mentioned before, the contribution of structural geology to basin modelling consists in the delivery of consistent kinematic scenarios. However, structural geology courses are not restricted to this matter only.

First, the description of outcrop scale structures and microstructures provides key information on the type and chronology of deformation mechanisms active through time. This information can, in addition, be related to the history of fluid displacement using the characterization of diagenesis. Second, in academia, structural data are routinely used to constrain some components of the paleostress tensor, if not all. The recent development concerning paleo-piezometry is reviewed as well as recent evolution of stress inversion techniques. The value of this type of data is demonstrated on a real case at outcrop (Figure 3)**.** The results obtained on this example clearly assign an important target to structural geology: defining new tools to be able to perform routinely paleostress measurements in wells.

Indeed combining kinematics definition and paleostress measurement can be somehow viewed in a way as making a natural triaxal test at basin scale. This would provide at least a bridge between structural geology and geomechanics as illustrated in a simple case from the Paris Basin.

Conclusion

The development of image logs twenty years ago completely changed our understanding of fractured reservoirs, leading to the development of innovative modelling workflows including Discrete Fracture Networks. We can foresee that the development of paleostress measurement will promote new basin modelling workflow including appropriate mechanics. This keynote hopefully contributes to initiating discussion on the developments that should be targeted by structural geology and geomechanics to reach this new frontier.

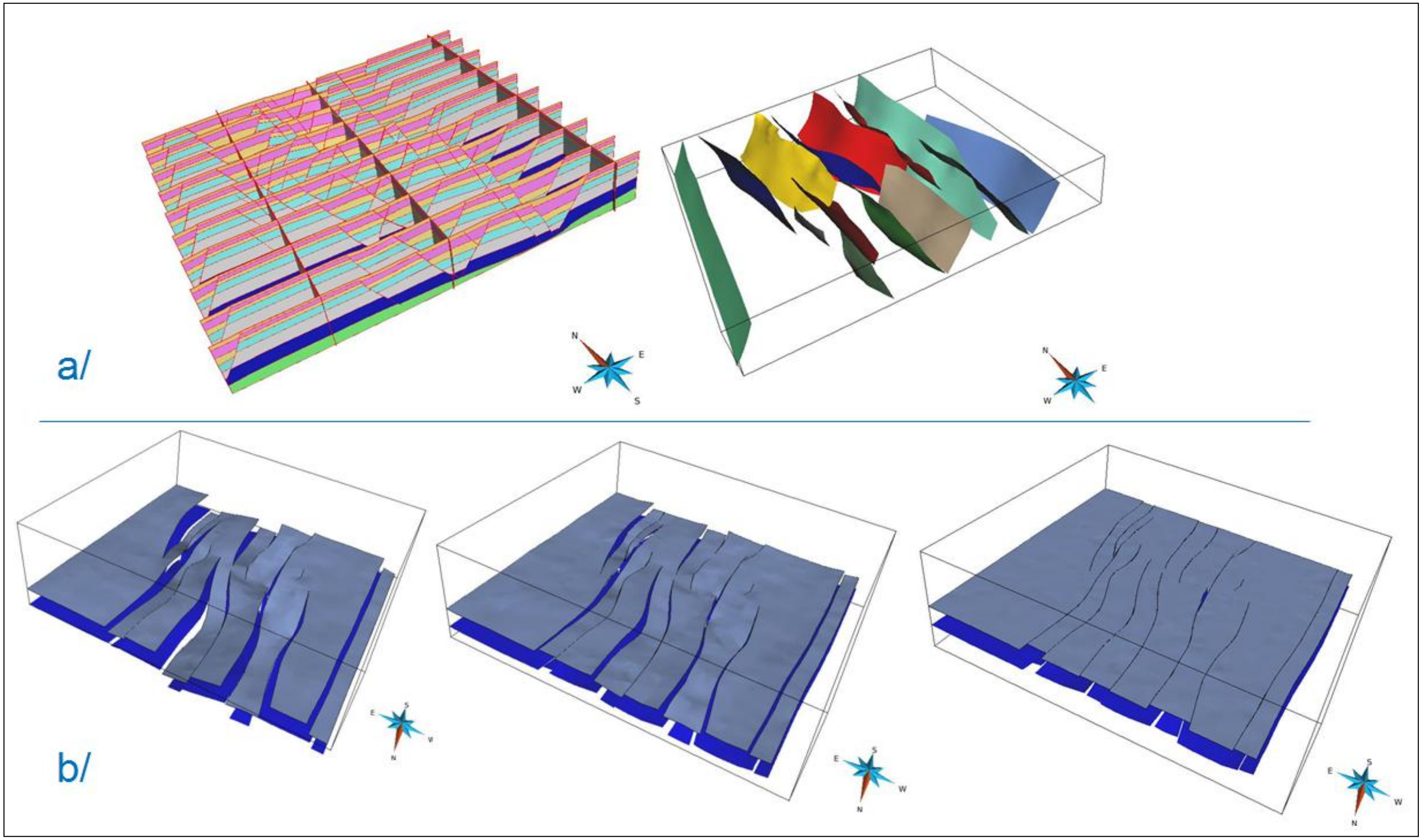

Figure 1. Example of 3D kinematic. a/. Serial cross section through 3D model, 3D fault pattern. b/. 3D Evolution of the top and base of the light blue layer in a/.

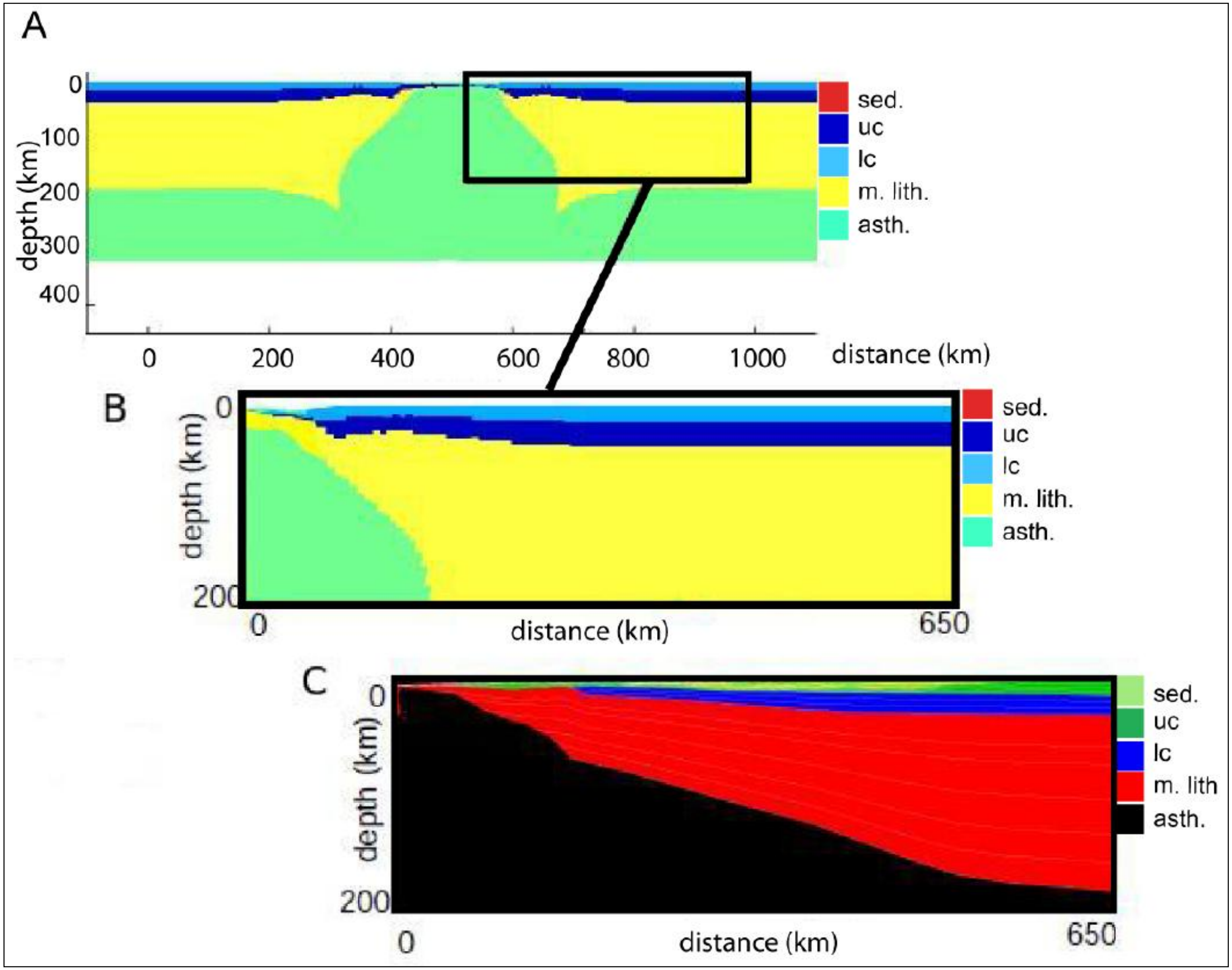

Figure 2: Linking geodynamic model to basin model. A. large scale mechanical model of rifting. B. Zoom on one margin. C. Basin model constrained by B.

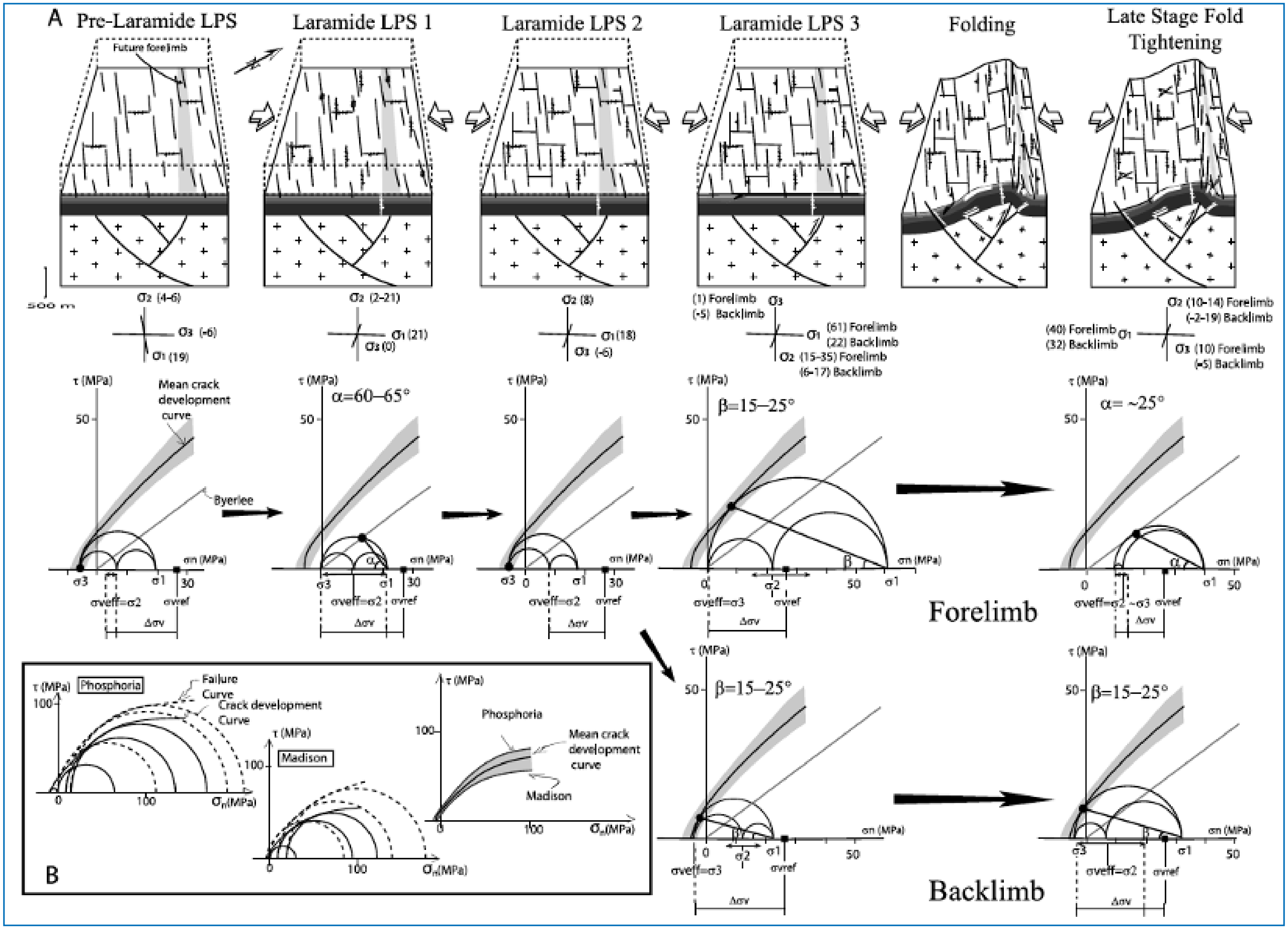

Figure 3: Example of paleostress history defined from microstructural data collected at core scale (Sheep Mountain anticline, Wyoming).