[PS]Petroleum System Modeling in Complex Structural Settings: Application to the Bolivian Southern Andean Foothills*

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Abstract

Petroleum system modeling is recognized as a critical step in exploration workflows. However, fold and thrust belts are typical regions where classic basin modeling tools do not accurately manage the combination of lateral and vertical tectonic displacements. These complex areas require more accurate modeling approaches integrating active faulting, folding and fluid flow. The basin burial and geometry reconstruction, and fault connectivity should thus account for the horizontal deformation through time. Then, the basin simulator should use the produced kinematic scenario for the forward simulation of heat transfer, pressure, hydrocarbon generation, migration and accumulation considering the faults impact on fluid flow.

An application case from the Bolivian Southern Andean foothills illustrates the applicability of these technology and workflow. Preliminary structural reconstruction work detailing the main deformation phases of the area is used to guide the complete kinematic scenario. Forward basin simulation is then run and the model calibrated to available well, outcrop, and field data, allows testing the impact of thrusting on maturation, migration pathways, and hydrocarbon charge. The model is made of 15 stratigraphic units from Paleozoic to Present Day. Three source rock levels are included in the model, and the main reservoirs are good sands deposited during the Paleozoic. The initial shortening occured between 12 and 10 Ma from the Inter-Andean and was transmitted to the East until the present day, resulting in a complex succession of thrusts, out of sequence thrusts and back-thrusts. The model shows good maturity levels with high transformation ratios for the deepest source rocks. Hydrocarbon generation started during Permian-Triassic time and was boosted during Pliocene. This leads to a favorable timing for hydrocarbon trapping with deformation in the Western area where we observe accumulations in structural and fault traps. In particular, the existing accumulations are well reproduced, and the model predicts favorable charge conditions for a prospect that is about to be drilled.

Petroleum System Modeling In Complex Structural Settings
Application To The Bolivian Southern Andean Foothills

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ABSTRACT: Petroleum system modeling is recognized as a critical step in exploration workflows. However, fold and thrust belts are typical regions where classic basin modeling tools do not accurately manage the combination of lateral and vertical tectonic displacements. These complex areas require more accurate modeling approaches integrating active faulting, folding and fluid flow. The basin burial and geometry reconstruction, and fault connectivity should thus account for the horizontal deformation through time. Then, the basin simulator should use the produced kinematic scenario for the forward simulation of heat transfer, pressure, hydrocarbon generation, migration and accumulation considering the faults impact on fluid flow.

An application case from the Bolivian Southern Andean foothills illustrates the applicability of these technology and workflow. Preliminary structural reconstruction work detailing the main deformation phases of the area is used to guide the complete kinematic scenario. Forward basin simulation is then run and the model, calibrated to available well, outcrop, and field data, allows testing the impact of thrusting on maturation, migration pathways, and hydrocarbon charge.

The model is made of 15 stratigraphic units from Paleozoic to Present Day. Three source rock levels are included in the model, and main reservoirs are good sands deposited during the Paleozoic. The initial shortening is received between 12 and 10Ma from the Inter Andean and transmitted to the East until present day, resulting in a complex succession of thrusts, out of sequence thrusts and back-thrusts. The model shows good maturity levels with high transformation ratios for deepest source rocks. Hydrocarbon generation started during Permian-Triassic time and is boosted during Pliocene. It leads to a favorable timing for HC trapping with deformation in the Western area where we observe accumulations in structural and fault traps. In particular, the existing accumulations are well reproduced, and the model predicts favorable charge conditions for a prospect that is about to be drilled.

INTRODUCTION & METHODOLOGY

A new 2D kinematic restoration tool, KronosFlow™, has been specifically developed to rapidly produce consistent geological scenarios for basin modeling in structurally complex areas. It allows respecting present and past geometries and accounting for both lateral and vertical displacements through time, while remaining compatible with basin simulation with the generation of a unique unstructured grid continuously deformed, critical for mass balance preservation.

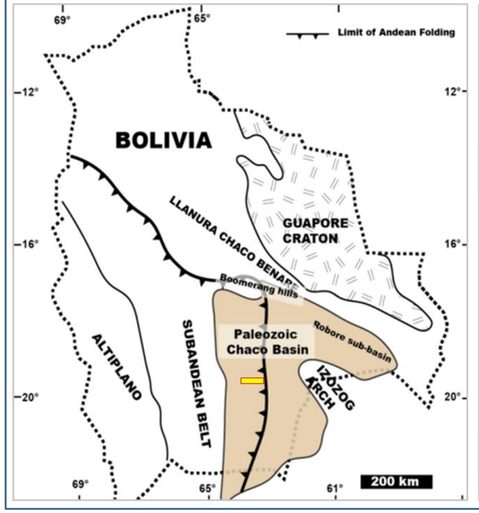
This kinematic tool is part of a four-step workflow when combined with TemisFlow™, in which a specific basin simulator has been developed to simulate faults impact on maturity, pressure, and hydrocarbon generation, migration and accumulation.

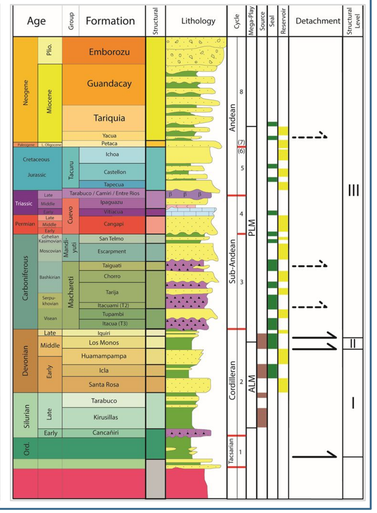
1. Present day model building → 2. Step by step backward restoration → 3. Computation of a single mesh through time → 4. Basin modeling forward simulation

STUDY AREA

This workflow has been applied in the southern sub Andean basin of Bolivia, across the thrust belt, on a ~50 km cross section from West to East. A complete and nearly continuous sedimentary record from Ordovician to Pliocene was used to constrain the model stratigraphy and lithology distributions.

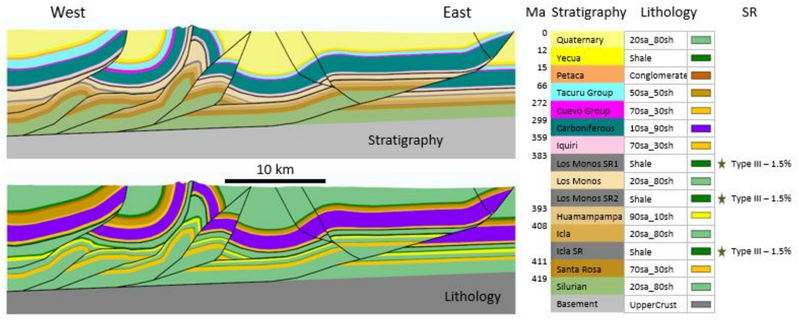
Six wells from the area with temperature and vitrinite reflectance data were made available for calibration.





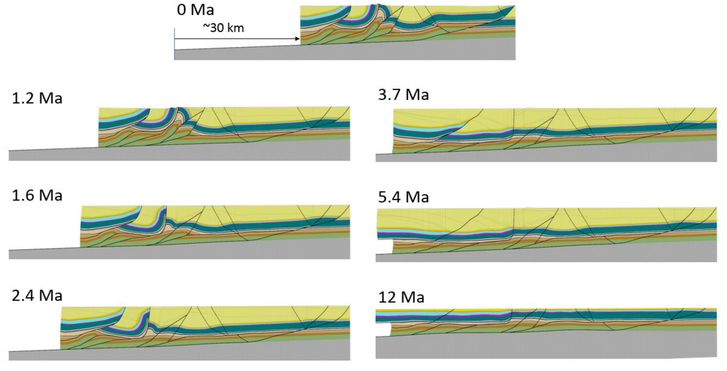
STRATIGRAPHY, FACIES & PETROLEUM SYSTEM

The model is made of 15 stratigraphic units from Paleozoic to Present Day. Three Devonian source rock levels are included in the model, and main reservoirs are sandstones deposited during the Paleozoic.



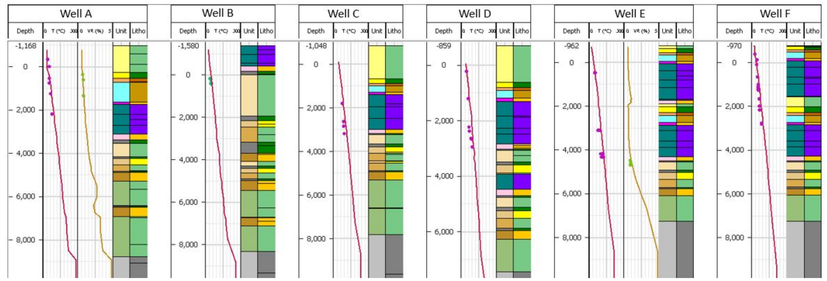
STRUCTURAL DEFORMATION SCENARIO

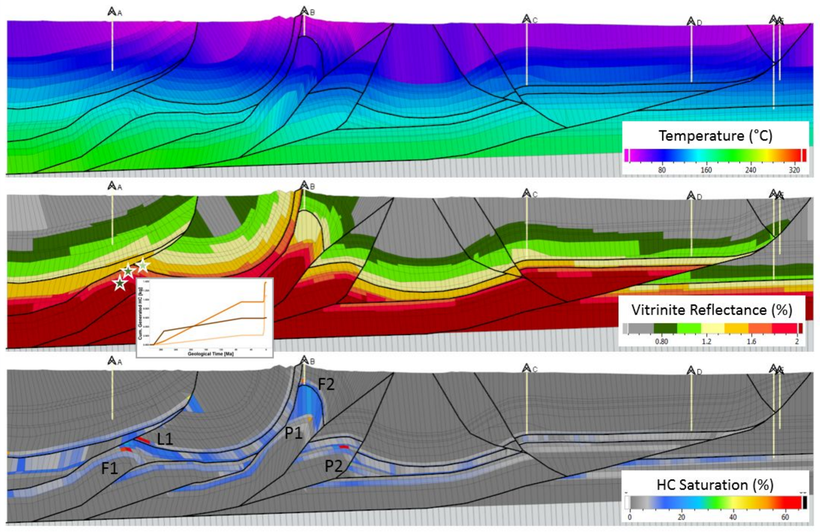
A regional structural restoration was used to guide the full kinematic scenario made of 20 steps. The initial shortening of the zone of interest is received between 12 and 10Ma from the Inter Andean and transmitted to the East until Present Day, resulting in a complex succession of thrusts, out of sequence thrusts and back-thrusts. In the zone of interest, total shortening is around 30 km.



At the end of the restoration, a single grid continuously deformed through time was built from the section topology.

RESULTS





Once calibrated with temperature and maturity data, the model shows good maturity levels with transformation ratios > 80% for deepest source rocks. HC generation starts in Permian and is boosted in Pliocene with very high sedimentation rates. It leads to a favorable timing for HC trapping with deformation in the Western area where we observe accumulations in structural and fault traps. It also allows understanding faults impact on fluid flow, connecting or disconnecting reservoirs as the deformation progresses.

In particular, the model reproduces the (projected) existing accumulations (F1 and F2). It also allows defining new plays such as the upward truncation of syncline flank (L1). Furthermore, the model predicts that the two identified prospect (P1 and P2) are likely to be charged. It should be noticed that prospect P1 is about to be drilled.

CONCLUSION

Allowing the quick generation of multiple time steps, KronosFlow™ outputs a unique and unstructured mesh directly adapted to basin simulations. Its application to the Bolivian foothills highlights the operational use of the technology and demonstrates its potential for the petroleum system analysis of structurally complex basins.

Once the model calibrated, the existing accumulations are well reproduced, and the model not only predicts favorable charge conditions for a prospect that is about to be drilled, but also allows identifying a new play.