[PS]A New Kinematic Tool for Petroleum System Modeling in Complex Structural Settings: Application to the Andean Foothills*

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Search and Discovery Article #42360 (2019)**
Posted March 25, 2019

*Adapted from poster presentation given at AAPG Latin America & Caribbean Region, Optimizing Exploration and Development in Thrust Belts and Foreland Basins, Santa Cruz de la Sierra, Bolivia, June 6-8, 2018
 DOI:10.1306/42360Thebault2019

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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 where hydrocarbon expulsion from source rocks can be prior or simultaneous to compressive tectonics require more accurate modeling approaches integrating active faulting, folding and fluid flow. The basin burial and geometry reconstruction, fault connectivity and fluid movements should thus account for the actual horizontal deformation through time, which is impossible with a regular backstripping approach. This work introduces a 2D kinematic tool specifically designed to meet this objective. Starting from present day section digitalization, KronosFlow^{TM} aims at producing rapidly consistent geological scenarios for basin modeling purposes. The first challenge of this approach is related to the number of restoration steps to provide as basin modeling requires a detailed kinematic scenario with, at minimum, a basin geometry at the end of each simulated layer deposition. Combining several geometrical and mechanical methods, the tool thus focuses on ergonomics to enhance productivity and afford multiple scenarios testing. The second challenge is linked to the mesh preservation through time that we believe essential for mass balance. In this regard, a new meshing technology has been developed to track sediments deformation while being compatible with a simulator able to take advantage of an accurate description of the basin evolution through time. Running on unstructured meshes and accounting for lateral displacement, this basin simulator uses the produced kinematic scenario for the forward simulation of heat transfer, pressure, hydrocarbon generation, migration and accumulation. Faults impact on fluid flow is assessed through an implicit modeling of the gouge and damage zones properties through time. An application case from the Andean foothills illustrates the applicability of these new technology and workflow. Preliminary structural reconstruction work detailing the main deformation phases of the area is used to guide the complete kinematic scenario made of more than fifteen steps. Forward basin simulation is then run and the model, calibrated to available well data, allows testing the impact of thrusting on maturation, migration pathways and hydrocarbon charge and quality. Several scenarios are elaborated, contributing to reduce the exploration risk.

AAPG BOLIVIA 2018
Latin America & Caribbean Region
Geosciences Technology Workshop

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1. INTRODUCTION & METHODOLOGY

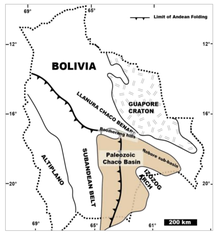
A new 2D kinematic restoration tool, KronosFlow™, has been specifically developed to rapidly produce consistent geological scenarios for basin modeling in structurally complex areas. It allows respecting present and past geometries and accounting for both lateral and vertical displacements through time,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

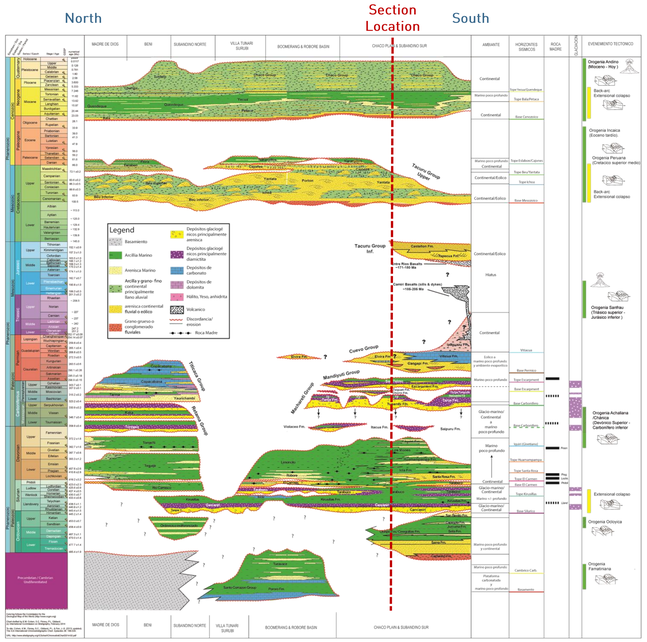
This kinematic tool is part of a four step workflow when combined with TemisFlow™, in which a specific basin simulator has been developed to simulate faults impact on maturity, pressure, and hydrocarbon generation, migration and accumulation.

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

2. STUDY AREA: THE BOLIVIAN THRUST BELT

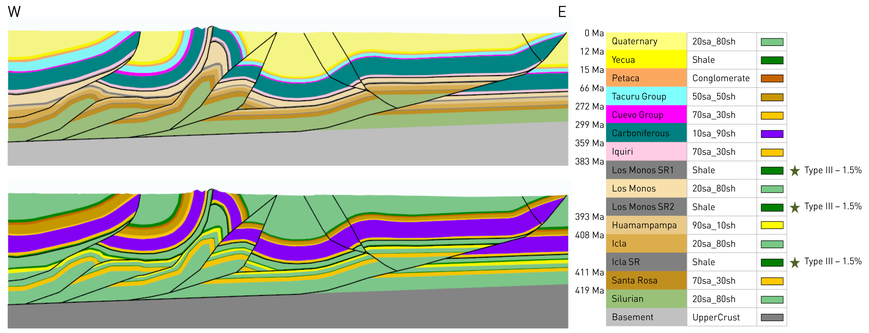
This workflow has been applied in the Paleozoic Chaco basin, across the thrust belt, on a 53km long section from West to East. A complete and nearly continuous sedimentary record from Late Proterozoic to Pliocene was used to constrain the model stratigraphy and lithology distributions.
Six wells from the area with temperature (uncorrected BHT) and vitrinite reflectance logs were available for calibration.





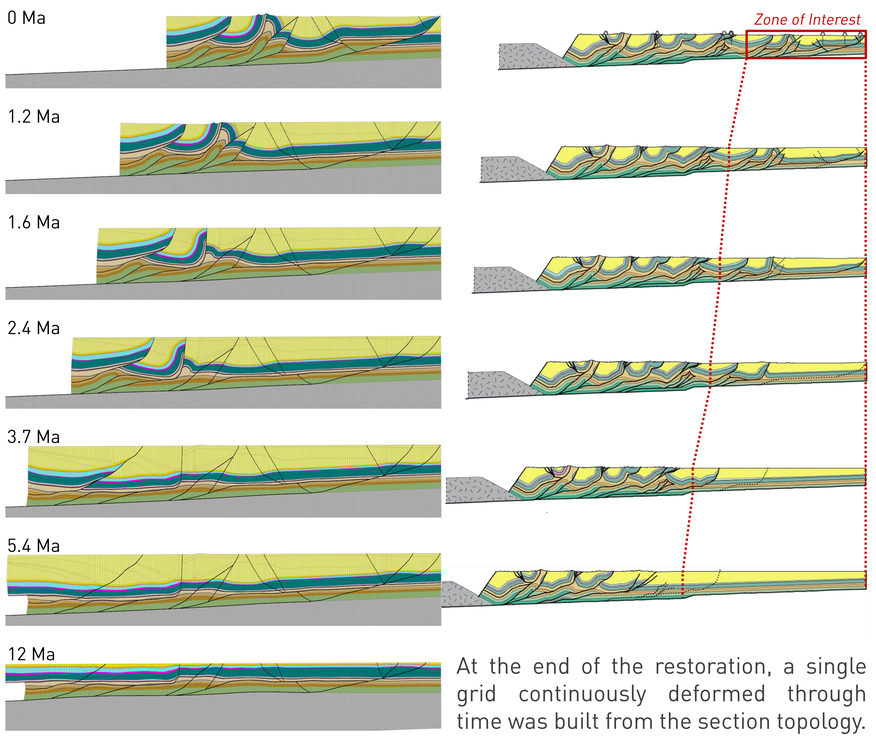
3. STRATIGRAPHY, FACIES & PETROLEUM SYSTEM

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 fairly good sands deposited during the Devonian as well.



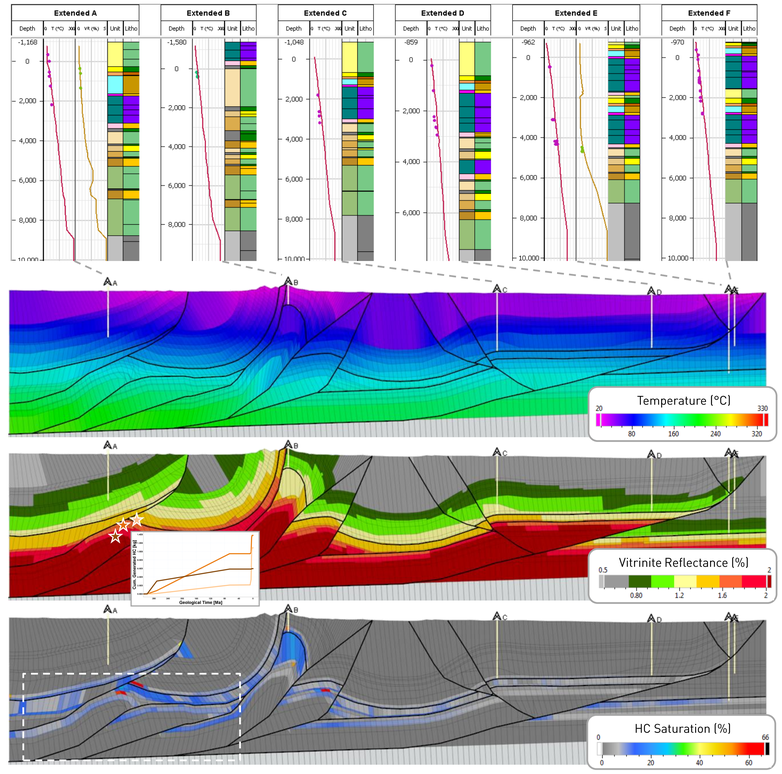
4. STRUCTURAL DEFORMATION SCENARIO

A regional structural restoration was used to guide the full kinematic scenario made of 20 steps. 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.
In the zone of interest, total shortening is of 31km.

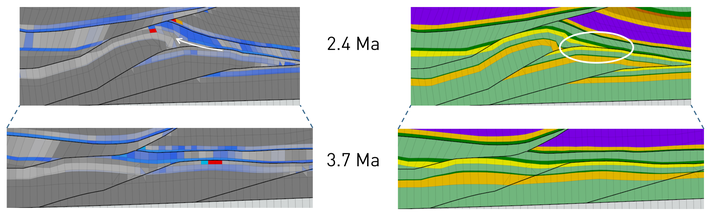


At the end of the restoration, a single grid continuously deformed through time was built from the section topology.

5. BASIN MODELING RESULTS



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.



6. 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.