Structural Modelling Techniques to Minimise Uncertainty in Subsurface Exploration

Oskar Vidal Royo[1], Alejandro Amilibia[1], David E. Mendoza Ticona[2], Frederic O. Escosa[3]

[1]Terractiva Consulting SL
[2]Petrobras Bolivia SA
[3]Terractiva Consulting SL

Abstract

Structural modelling techniques have proven useful in enhancing success and decreasing the uncertainty associated to subsurface exploration of natural resources. Definition of trap configuration, timing of uplift and erosion, evolution of structural tilt, or detailed analysis of intra-reservoir structure are just a few instances where structural modelling can assist exploration geoscientists.

The term Structural Modelling covers a broad range of tools and techniques guided by structural geology principles and concepts: balancing, restoration, kinematic forward modelling, backstripping, Statistical Curvature Analysis (SCAT), fault and horizon geometry prediction at depth, etc. Structural modelling is based on known geometric relationships between stratigraphic horizons and faults, developed over the years as a result of painstaking geological observations and descriptions of natural rock behaviour during fieldwork.

Initially applied to onshore provinces where scarce data were available (e.g. exposed fold-and-thrust belts, extensional and inverted basins), their use is widespread in exploration cases worldwide, both onshore and offshore. Although firstly done by hand, significant investments have been made in recent decades to incorporate these methods in software applications, speeding up the modelling workflow while allowing for greater sophistication, accuracy and uncertainty assessment. The use of structural modelling, however, requires a solid understanding of the principles and processes behind rock deformation, as well as the regional geological context. Oftentimes, geoscientists lacking such knowledge may accept as valid structural models that do not honour either of those, despite their apparent validity.

In this work we present an example from the Subandean fold-and-thrust belt in Bolivia, showcasing the integration of different structural modelling techniques with the ultimate goal of minimising uncertainty in the subsurface interpretation of the Lower-Middle Devonian main reservoirs (i.e. Santa Rosa, Icla and Huamampampa Formations).

The Subandean is characterised by scarce and sparsely distributed surface data, few wells of varying penetration depth, and mostly 2D seismic data of poor to fair quality. The poor imaging is especially obvious in the steep anticlinal forelimbs, where seismic tend to display shallowly dipping reflectors that do not match with the steep bedding and structural complexity evidenced by surface geology and dipmeter data. The Silurian to Neogene stratigraphic record documented in the area is characterised by the presence of multiple ductile units acting as regional décollements, virtually invisible on seismic. This combination of factors consequently challenges subsurface interpretation and trap definition. The integration of fault and horizon geometry prediction, SCAT, sequential kinematic forward modelling and restoration, however, allowed us to propose a valid interpretation along a selected transect, defining the geometry of the structure at depth and its structural evolution though

time. The work resulted in the definition of several four-way closure and sub-thrust play types that would have otherwise remained obscured by the seismic. Among the multiple possible interpretations allowed by the data, only the ones integrating structural modelling, structural evolution and regional geology constraints turned out to be valid, allowing us to make economic decisions further down the exploration funnel.