3D-STRUCTURAL ANALYSIS OF A SALT-CORED ANTICLINE IN THE PACHITEA SUB-BASIN, WESTERN UCAYALI BASIN, PERU

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ABSTRACT
The Iscozacin Anticline is located in the Cordillera Oriental, more specifically, in the southern part of the Oxapampa Foldbelt (Pachitea Sub-Basin), Peru. It is a NW-SE trending and northeast verging anticline with marked surface expression at the Vivian- and Chonta Fm. level and – according to seismic and well data – its core consists in pre-Cretaceous evaporates, mainly gypsum, halite and minor carbonates. The scope of this investigation was to map the 3D geometric variations across the anticline, to assess the mechanisms of its growth, to calculate the shortening across the structure, as well as to better understand the halokinetic vs. tectonic contribution to the overall structuring. Another objective was to find out what role transcurrent movements (either dextral or sinistral) played in the formation of the anticline. Structural analysis revealed a convex and relatively steep geometry of the forelimb with dips reaching 30 degrees locally. Highest curvatures are found along the southeastern part of the crest and southeastern plunge of the structure. The anticline is tighter in the east than in the west. Based on the overall orientation, geometry and vergence, we propose that a significant sinistral-transpressional component acted during the formation of the anticline. Shortening across the anticline is small, in the order of 3% (based on line-length comparison). However, the San Matias thrust-sheet in which it is hosted and in which it was tectonically transported, has a significantly higher shortening rate. Hence, we interpret the Iscozacin Anticline as a detached lift-off structure with a moderate halokinetic component.

GEOLOGIC SETTING

The Iscozacin Anticline is located in the south-western Pachitea Sub-Basin of south-central Peru (**Fig. A**). It is located between the highly shortened Cordillera Oriental and the San Matias thrust front, western Ucayali Basin. The local structural domain, of which is forms a part, is also known as the Oxapampa Fold and Thrust Belt. It reveals a NW-SE trend, which is oblique to the current orogenic front. To date, no modern and detailed geometric-structural analysis of the Iscozacin Anticline is available.

OBJECTIVES

The main objective of this assessment was to understand in a detailed way the structural geometries and variations of this oblique and complex salt-cored anticline. Secondary objectives were to understand the impact of lateral structural variations, to understand the structural growth mechanism, to quantify the shortening, to better distinguish the halokinetic versus the tectonic component, to confirm or exclude the presence of transcurrent components, and to understand if the two wells, drilled on the structure, have been placed in favourable positions.

DATABASE

The following independent data sources were used for this evaluation:

- Six regional seismic sections (only one regional section is shown here)
- Digital elevation model (source: NASA, 30m resolution)
- Surface geologic maps
- Well tops and well reports from two exploration wells
- Literature and reports

WORKFLOW

In a first step, all data was loaded into 2D Move and georeferenced correctly. After mapping six target horizons in 2D, the data was transferred into a 3D Move and a pseudo-3D model was generated **(Fig. B)**. Finally, 3D-surfaces of the target horizons were constructed and the mapping of geometric parameters conducted.

GEOMETRIC PARAMETERS

For the Cushabatay Formation 3D-surface, three different structurally important geometric parameters were mapped: depth, structural dip and curvature. The colour coded **depth** map reveals a broad central crest, a slightly narrowing northwest plunge and a significantly narrowing southeast plunge. The structurally highest part of the anticline is located around the area of the two wells “A” and “B”. The northeast limb (front limb) reveals an outward curving geometry, while the southwestern limb (back limb) has a more linear or straight appearance. The entire anticline changes shape significantly along strike. The western part is broad and outward curving, while the eastern part is much more narrow (**Fig C**).

Using the same 3D-surface of the top Cushabatay Fm., the **structural dip** was mapped with the intention to distinguish between areas with high and low structural dips (**Fig. D**). The dip mapping revealed that the crestal area of the anticline represents low structural dips, generally no more than 13 degrees. The intermediate parts of both limbs show structural dips between 13 and 20 degrees, while the lower parts of the limbs locally reveal structural dips of up to 30 degrees. The largest domains of high dips are found at the lower parts of both limbs, in the vicinity of the southeastern plunge of the structure.

The third geometric parameter that was mapped, was the **curvature** of the Cushabatay Fm. Large parts of the limbs show mostly low curvatures, while the crest shows significant variation in curvature: The lowest curvatures are observed in the central portions of the front limb and back limb (**Fig. E**). The western part of the crest reveals medium curvatures. Along the crest, east of the apex, the highest curvatures appear. Further domains with high curvatures occur on the back limb and fore limb, around the eastern plunge, but below the main crest. Another localized area of increased curvatures appears at the western plunge of the structure.

INDICATIONS FOR TRANSCURRENT COMPONENT

According to published data provided by the World Stress Map project (Heidbach et al., 2008), the present-day principal horizontal stress is oriented in a WSW-ENE direction, in the Pachitea Sub-Basin. This orientation is approximately perpendicular to the main Andean deformation front, the Cordillera Oriental and the San Matias Thrust System. However, the axis of the Iscozacin Anticline is oriented obliquely to this vector. Hence, based on the regional geologic context, the regional horizontal stress vectors and the orientation of the anticlinal axis, we infer, that the structural growth of the Iscozacin Anticline was related to a sinistral-transpressional component. This hypothesis is supported by the observation that the eastern plunge of the anticline is significantly tighter than the western plunge. This hypothesis will also have profound implications for the internal architecture of the anticline (e.g. secondary fault systems, fracture networks, strain distribution etc.), which are beyond the scope of this paper.

CALCULATION OF SALT VOLUME

Near the crest of the anticline, the salt thickness locally reaches up to 1700m. The salt is also seen on the 2D seismic data. After mapping all six target horizons, including the top and the base of the pre-Cretaceous salt, a so-called "tetra-volume" was calculated, in order to determine the volume of the salt in the core of the anticline. The total salt volume was determined to be >31km^3. This volume is equal to a cube with a diameter of 3.1km. It has to be stated that this volume is not all pure salt. According to the well reports of well "A" and "B", it is a lithology mix, which contains predominantly evaporates, halite, gypsum, anhydrite, but also occasional limestones and clastics.

KEY RESULTS

(1) Iscozacin Anticline is a four-way dip anticline of NW-SE orientation and vergence to the NE.

(2) It is interpreted as a "lift-off" structure with salt core.

(3) The exact stratigraphic age of the salt in the core is not well constrained, possibly Jurassic.

(4) Structural dips are horizontal along the crest and reach maximum values of ~30 degrees on both limbs.

(5) The age of the anticline is likely Late Miocene-Pliocene, possibly even younger, based on deformed seismic reflectors.

(6) Three domains of increased curvature can be mapped, concentrated around the southeastern plunge.

(7) Based on the orientation of the axis and the regional stress field, we propose that the structure has a sinistral transpressional component.

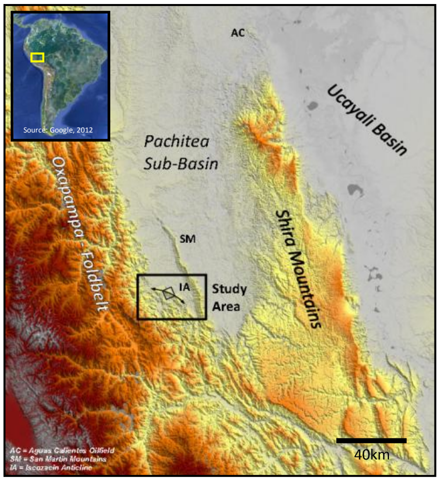

Fig A: Location map and study area.

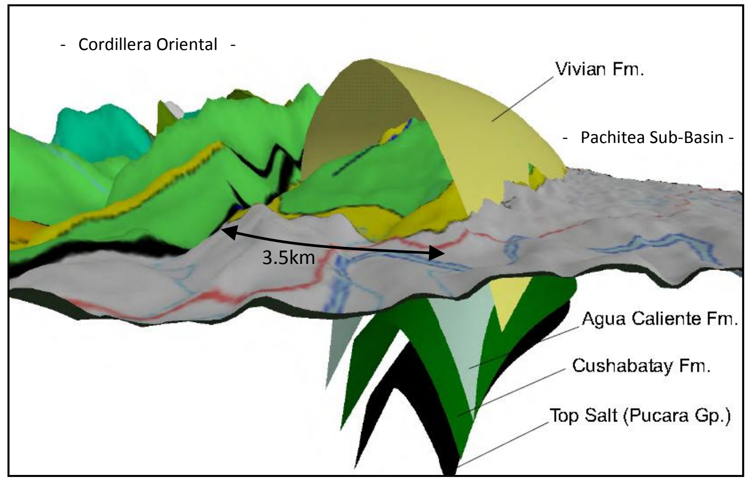

Fig B: Integrated topography, surface geologic map and formation tops, represented as 3D-surfaces. View is from East to West.

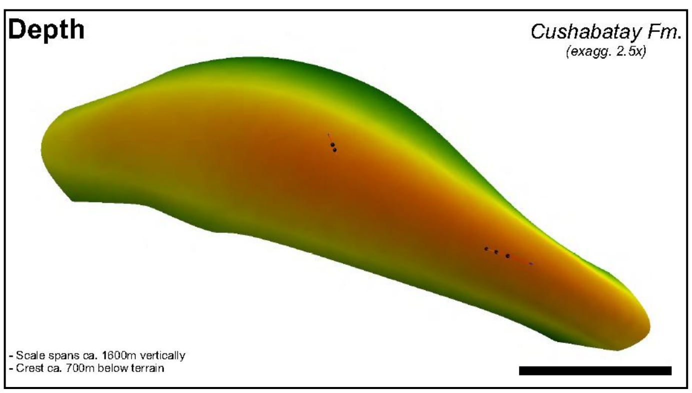

Fig. C: 3D-surface of top Cushabatay Fm.; colour coding represents depth. Red = high areas; green = low areas.
(scale bar = 5km; North=up).

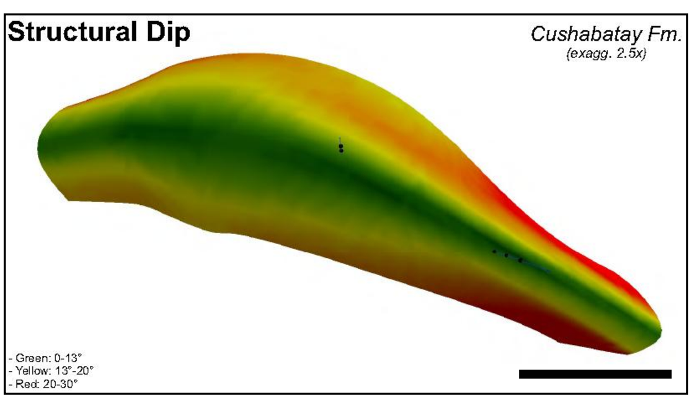

Fig. D: 3D-surface of top Cushabatay Fm.; colour coding represents dip. Red = high dips; green = low dips.
(scale bar = 5km; North=up).

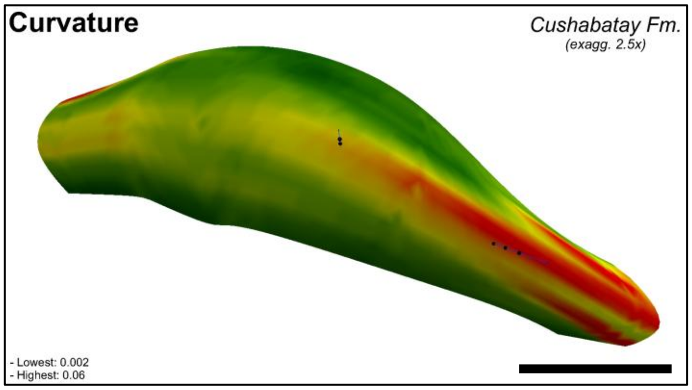

Fig. E: 3D-surface of top Cushabatay Fm.; colour indicates curvature. Red = highest, green = lowest curvature. (scale bar = 5km; North=up).

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