PS Constraints on Intraplate Mountain Building Stages in Central Patagonia Determined From the Analysis of 2-D and 3-D Seismic and Borehole Data: San Bernardo Fold and Thrust Belt*

Facundo Pagan[1], Guido Gianni[2], Andres Echaurren[2], Cesar Navarrete[3], Andres Folgueras[2], Octavian Catuneanu[4], and Alfonso Encinas[5]

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[1]Exploration Department, YPF S.A., Buenos Aires, Argentina (facundo.j.pagan@ypf.com)
[2]Universidad de Buenos Aires, Buenos Aires, Argentina
[3]Universidad San Juan Bosco, Chubut, Argentina
[4]University of Alberta, Edmonton, Canada
[5]Universidad de Concepción, Concepción, Chile

Abstract

Intraplate belts are considered among the most enigmatic features in plate tectonic theory. Their origin remains not completely understood as well as their episodic character, usually concentrating long lasting uplift and deformational activity. In this work we analyze borehole, 2D and 3D seismic data in an intraplate belt crossing the Patagonian region with the aim of revealing its multi-episodic character. Seismic data tied to borehole and surface data show internal unconformities affecting synrift deposits of the Neocomian and lower D-129 Formation associated with initial stages of the Pangea break up. Above these erosional features a first canyon incision and important thickness variations characterize the upper D-129 Formation and the Matasiete Formation in association with contractional structures and strike slip faults, interpreted as synorogenic strata. Then an erosive unconformity separates Cretaceous from Paleogene strata, being these in turn incised by deep canyon features. Horizons slices performed at different time intervals allow deciphering variable sediment supply and structural control, through the identification of distributary fluvial and deltaic morphologies, with a nearly constant source in the northwest.

These features indicate that the San Bernardo fold and thrust belt uplifted and structured through the Late Early Cretaceous times through isolated uplifts in a context of highly oblique convergence, and Late Cretaceous to the Cenozoic in a context of more orthogonal convergence, showing that Central Patagonia has absorbed variable amounts of shortening and strike slip deformation, which constitutes valuable information for biota and paleogeographic reconstructions as well as for oil exploration.

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Constraints on intraplate mountain building stages in central Patagonia determined from the analysis of 2-D and 3-D seismic and borehole data: San Bernardo Fold and Thrust Belt

F. Pagán[1], G. Gianni[2], A. Echaurren[2], C. Navarrete[2], A. Folgueras[2], O. Catuneanu[3], A. Encinas[4].

1 Exploration Department YPF S.A., Buenos Aires, Argentina; 2 Universidad de Buenos Aires, Buenos Aires, Argentina; 2 Universidad San Juan Bosco, Chubut, Argentina; 3 University of Alberta, Edmonton, Canada; 4 Universidad de Concepción, Concepción, Chile.

INTRODUCTION AND AIM

✓ Intraplate belts are considered among the most enigmatic features in plate tectonic theory. Their origin remains not completely understood as well as their episodic character, usually concentrating long lasting uplift and deformational activity. In this work we analyze borehole and 2D and 3D seismic data in an intraplate belt crossing Patagonian region with the aim of revealing its multi-episodic character.

BACKGROUND

✓ Intraplate mountain belts around the world intrigue scientists about their development and occurrence. These show generally a polyphase character since they are usually linked to longstanding intraplate weaknesses that can be determined from synorogenic strata and thermochronological data (Gianni et al., 2017). The Andes are locally associated with intraplate mountain belts separated from the orogenic wedge and interrupting the flat morphology that characterizes the foreland zone. That is the case on northern Patagonia, where the typical flat-lying topography of the foreland zone is interrupted by a prominent relief that exposes Mesozoic to Cenozoic rocks in the San Bernardo fold and thrust belt, a major intraplate belt crossing Patagonia.

✓ Even though this intraplate deformation has been analyzed from different perspectives determining contrasting uplift stages during the last decades, in the last years considerable understanding has resulted regarding timing and orogenic mechanisms from extensive work focused on the San Bernardo fold and thrust belt (Gianni et al., 2015; Navarrete et al., 2015; Echaurren et al., 2016). This belt is interpreted as related to the tectonic inversion of Early to Mid Jurassic extensional structures in successive contractional and transpressional stages spanning from the late Early Cretaceous to the Neogene (Gianni et al., 2017; Navarrete et al., 2017). Its uplift has constituted itself in a mountain system morphologically independent from the Andean orogenic wedge to the west. Therefore this system has compartmentalized Patagonia in two sectors with implications in biota evolution and climate (Folguera et al., 2017).

✓ The first orogenic event is thought to have happened in late Early Cretaceous times and was responsible for constituting an orographic barrier that limited the westward Atlantic sea advance of the Maastritchian-Danian transgression that affected vast sectors of northernmost Patagonia (Navarrete et al., 2015; Gianni et al., 2015). After this transgression Eocene contractional reactivations are inferred on the basis of identification of synorogenic strata of the Río Chico Formation (Gianni et al., 2017). A Neogene contractional component is determined from the deformation of Miocene strata that flank the main folds that constitute this belt (Gianni et al., 2015).

METHODOLOGY

✓ During the last years, from numerous exploratory drilled projects on the west flank of the Golfo San Jorge Basin, it was possible to verify observations made on the timming of the structure of the folded belt in different locations. For this, more than 500 km of 2D lines and 5000 km2 of 3D seismic, of different acquisition and reprocessing campaigns were used. We also analyzed more than 100 key wells for the seismic tying of the stratigraphy. Synthetic attributes, sequence stratigraphy and seismic geomorphology were the main methods used to interpret stacking patterns and their lateral variations at different scales of resolution, vertical and horizontal.

Fig 1a

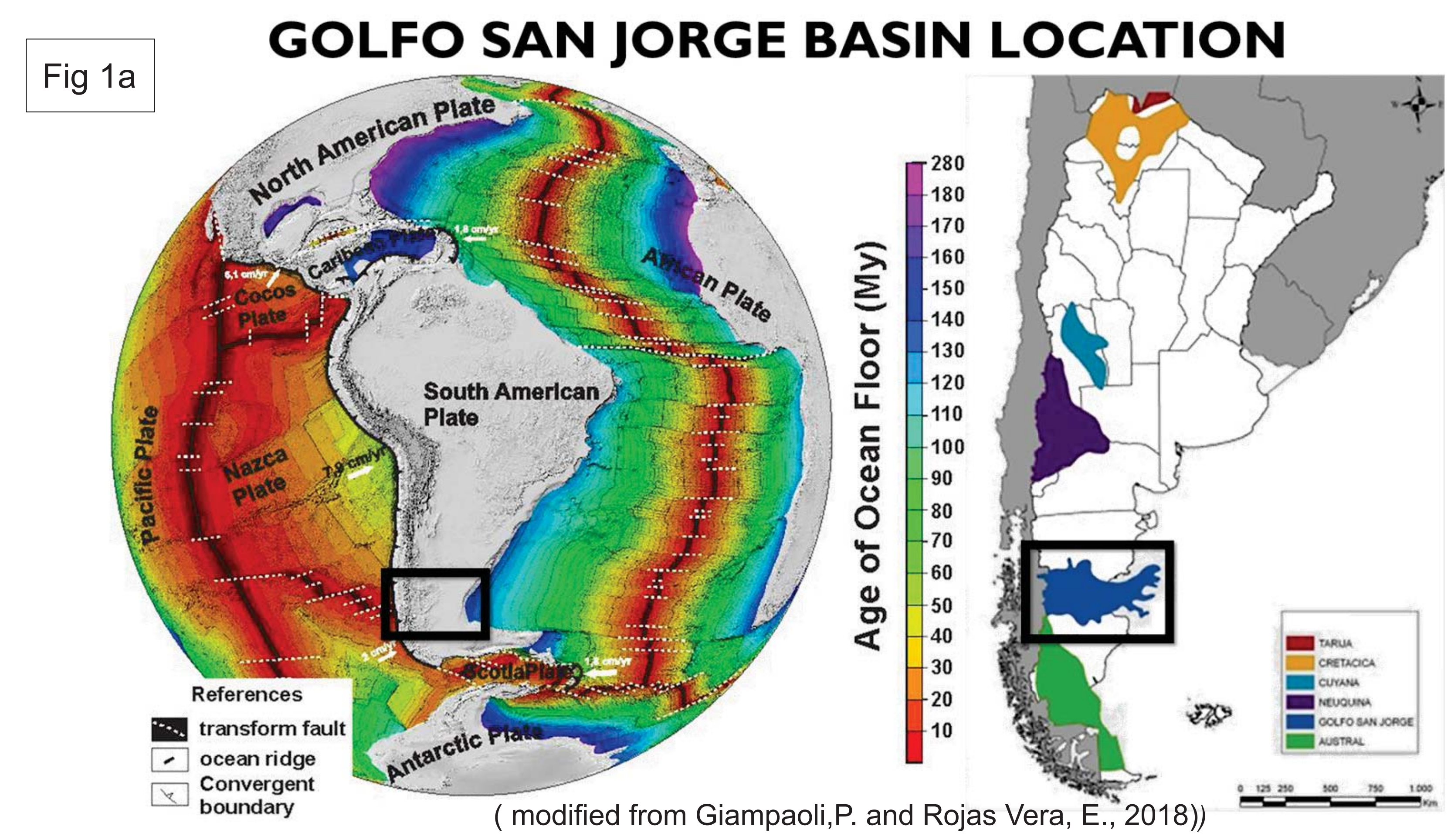


Fig 1b

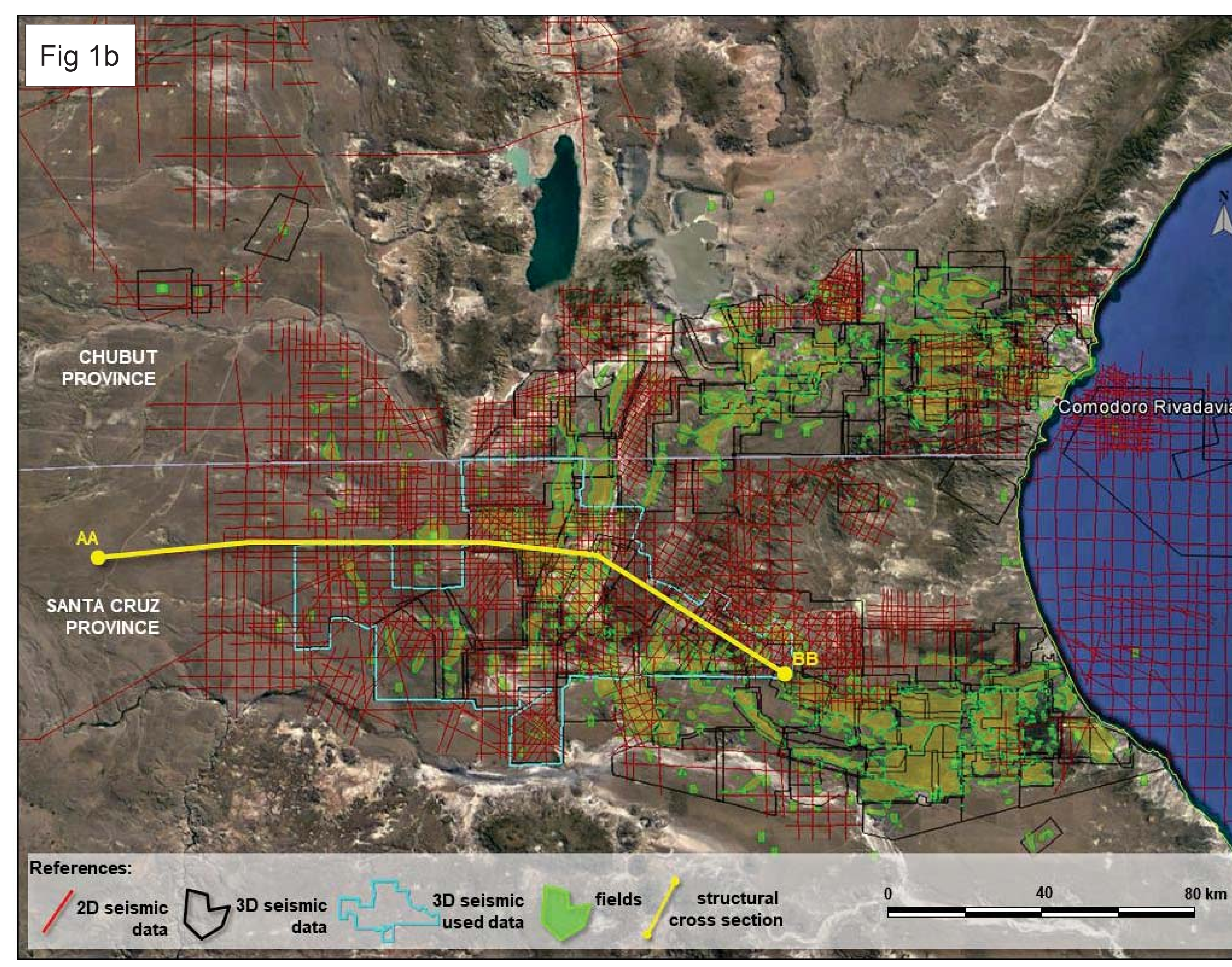


Fig 1c

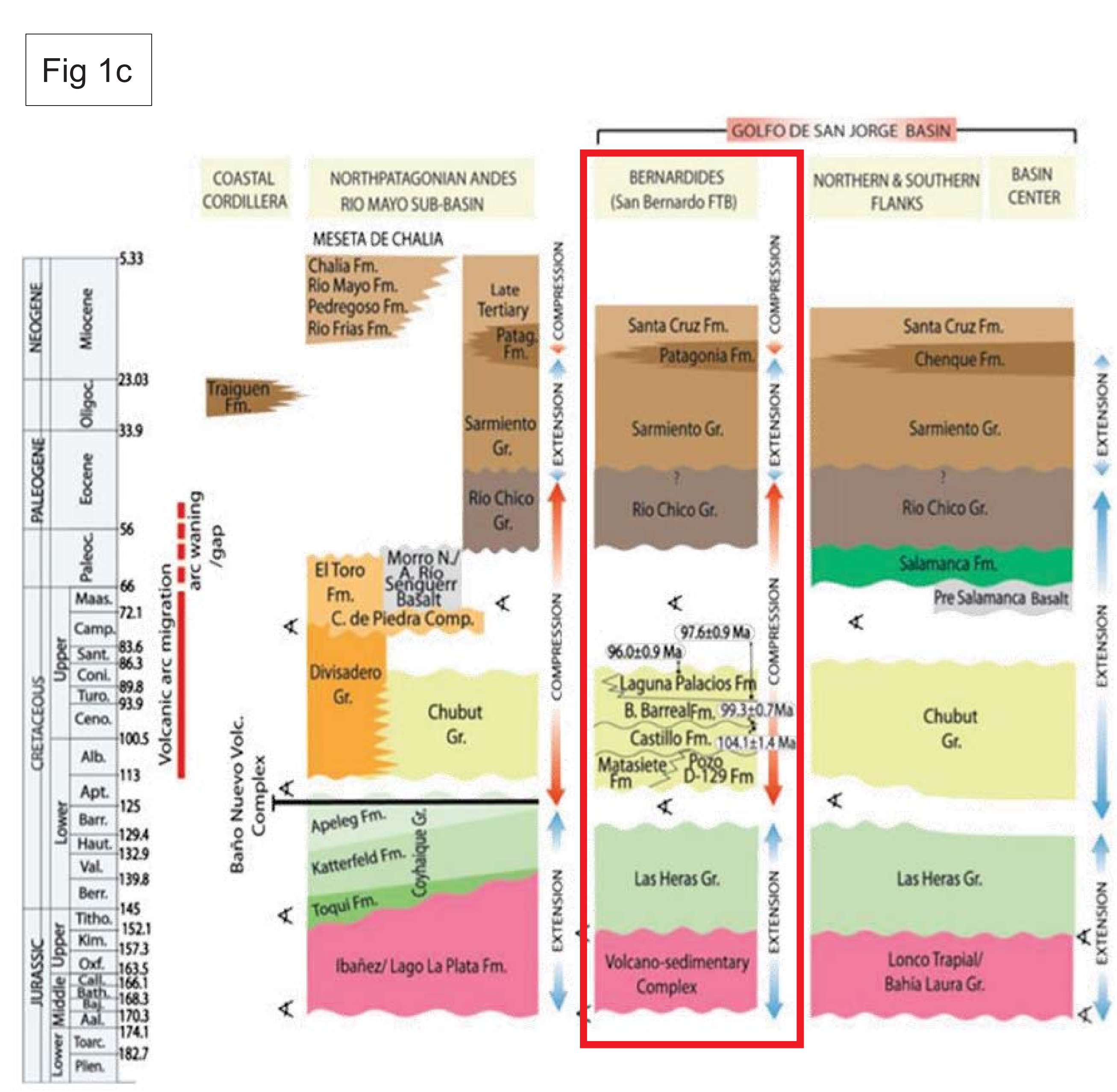


Fig 1d

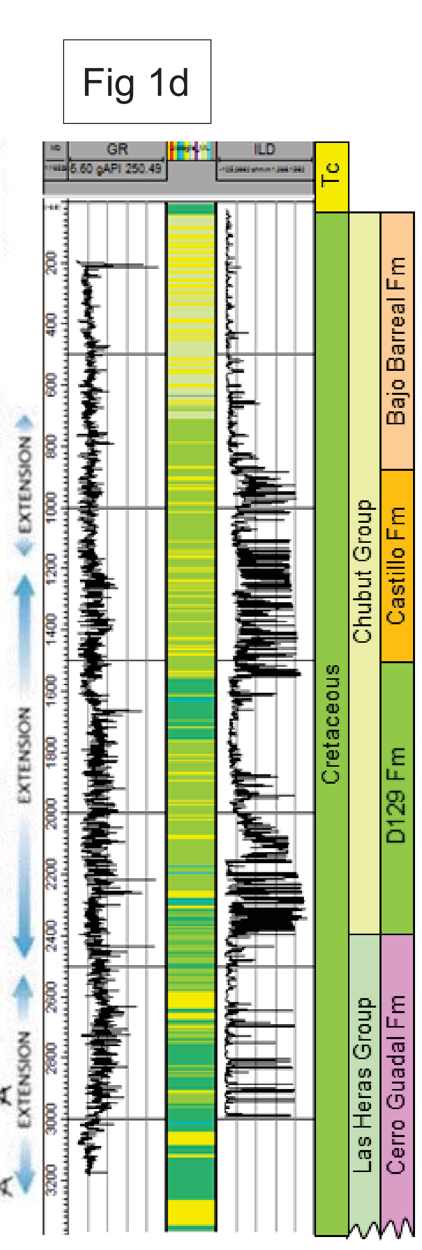
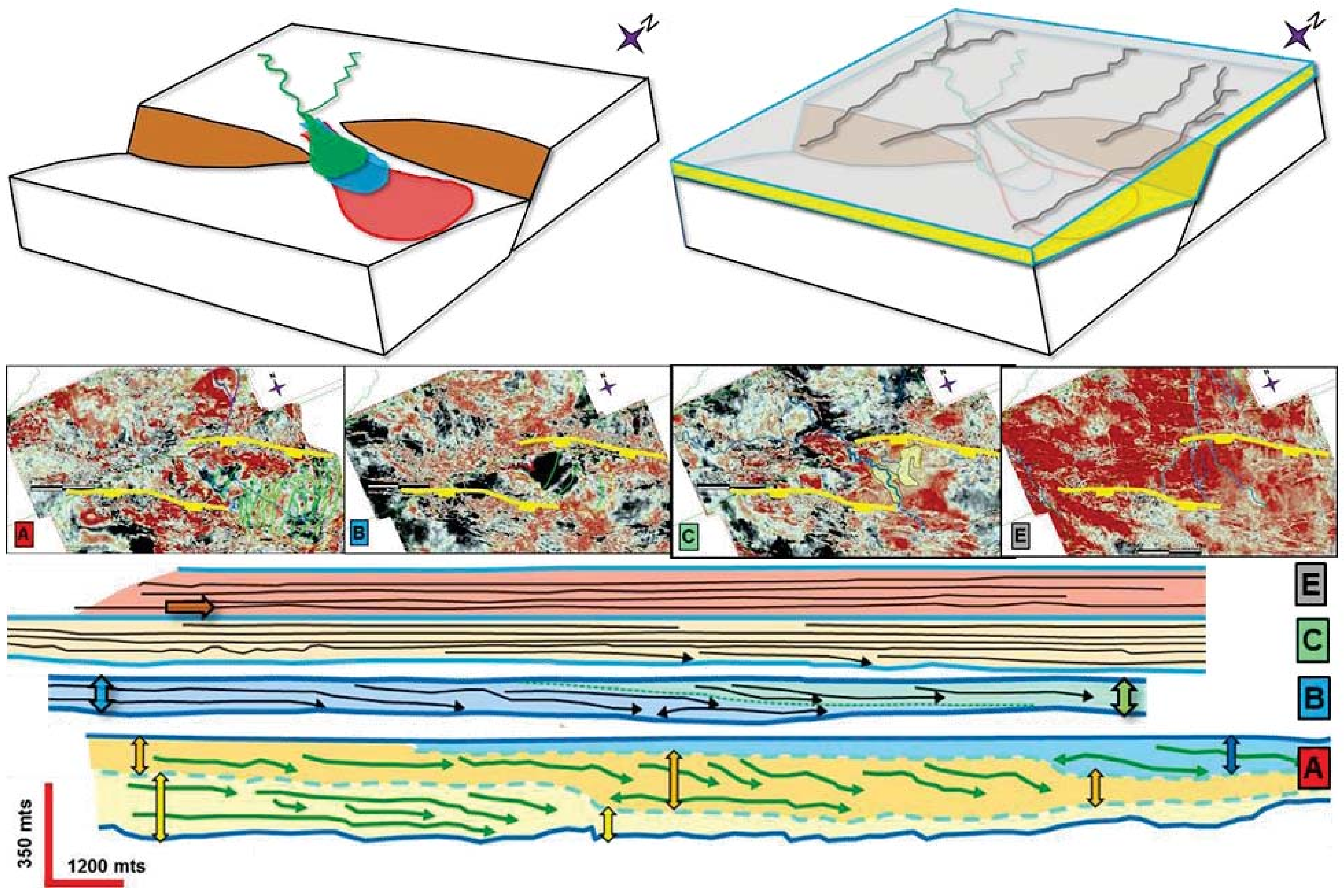
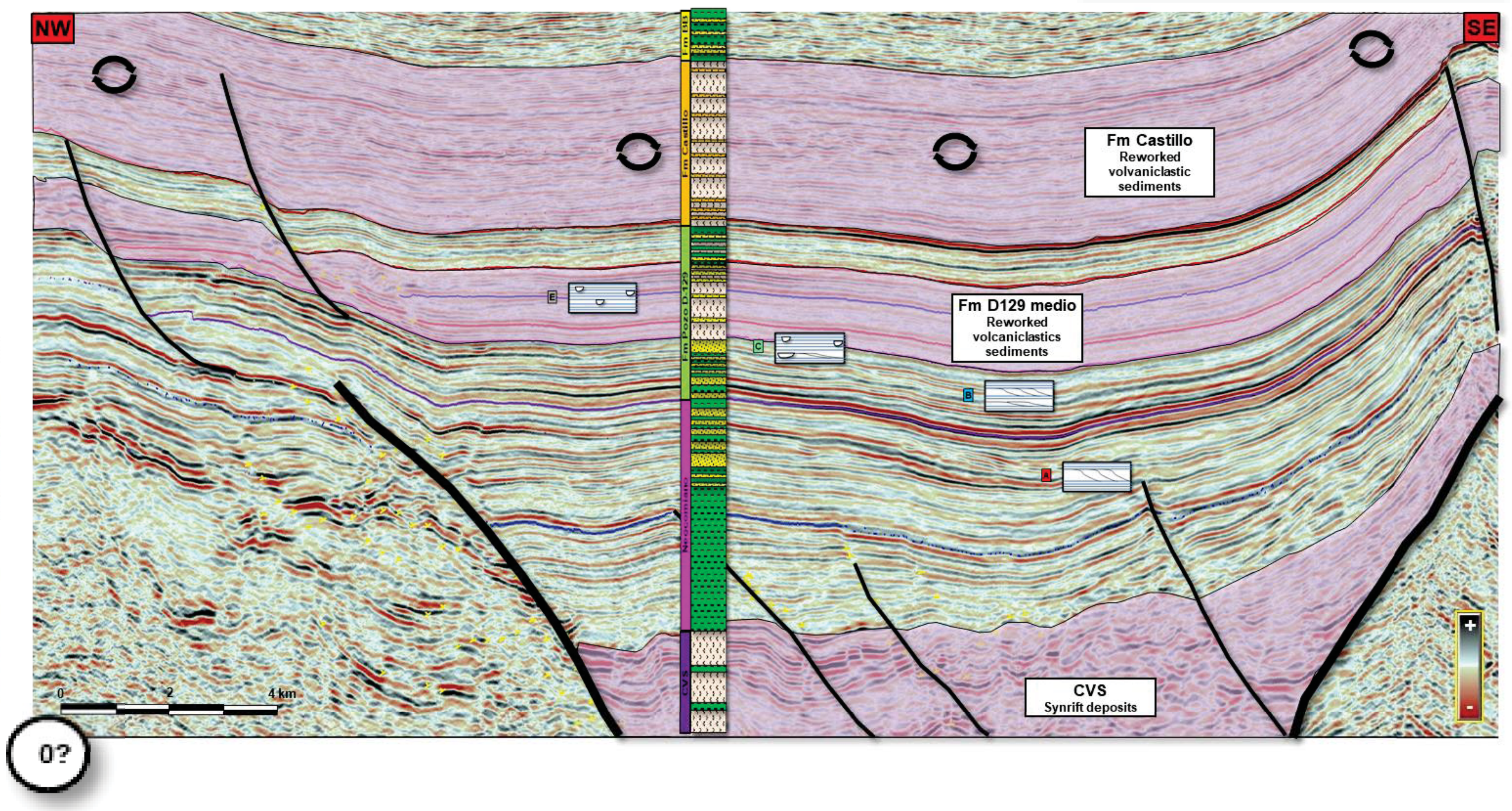
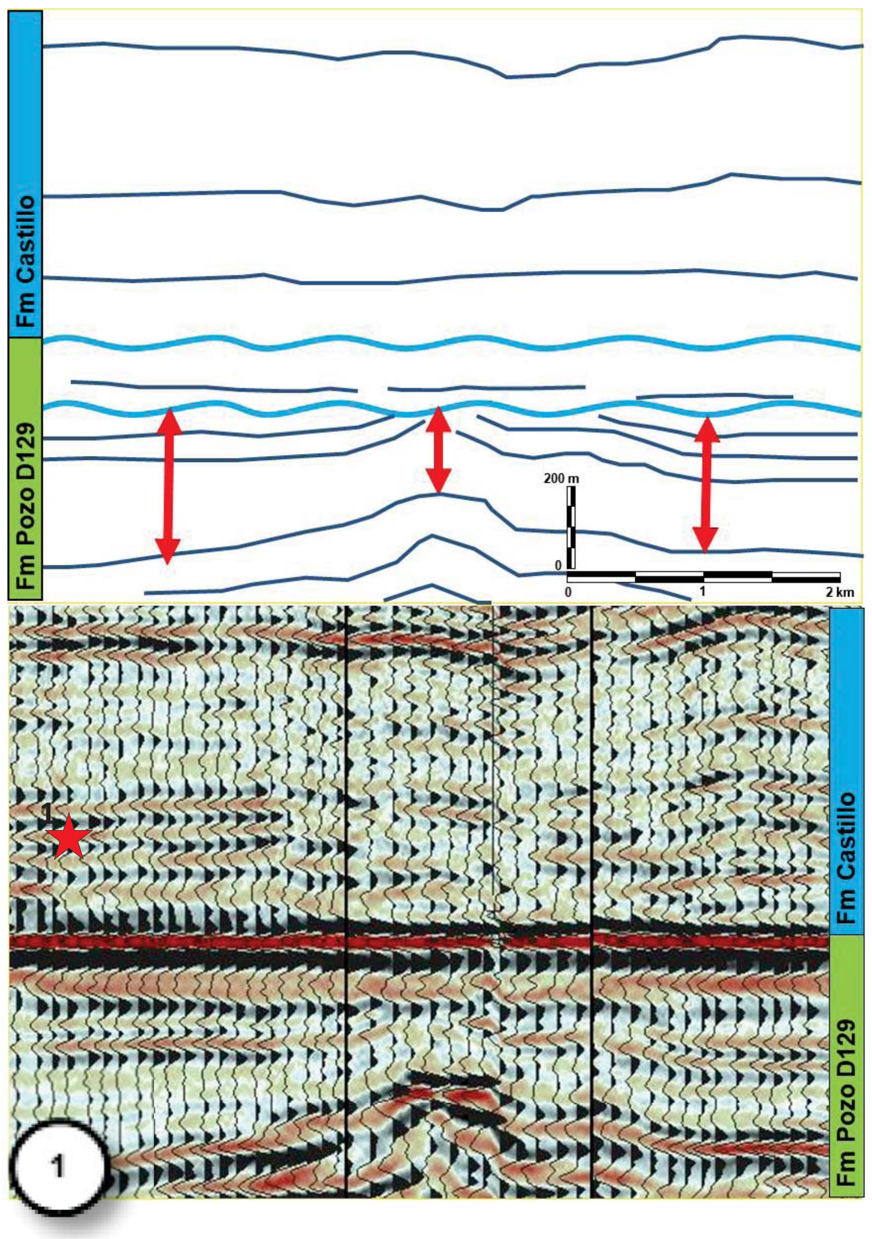


Figure 1a. Location map of the Golfo San Jorge Basin. 1b. Available data and structural cross section. 1c. Stratigraphic chart of the Golfo San Jorge Basin. (modified from Gianni et al., 2015). 1d Log type.

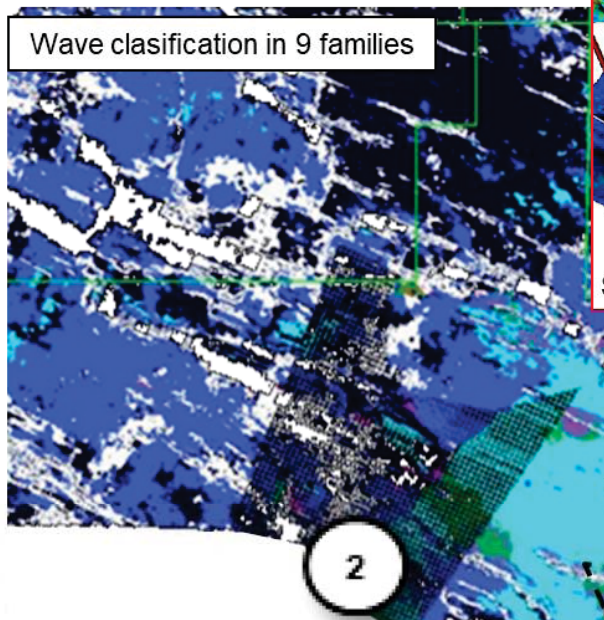


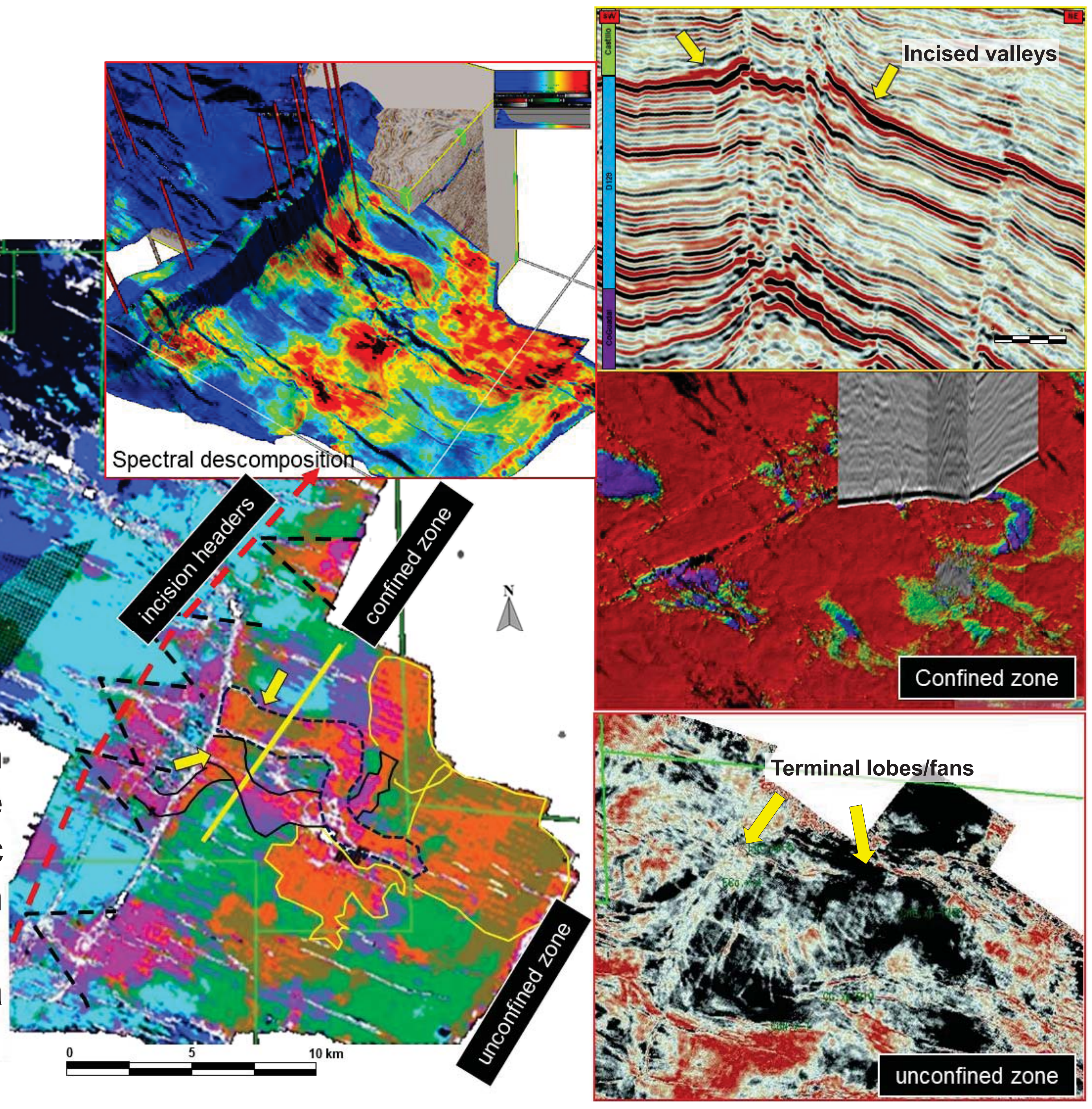


Extensional control exerted on Mid Jurassic depocenters of the Lonco Trapial Formation and lacustrine Neocomian units in the western limb of the Perales anticline. Deltaic lobes of ~100 km2 interpreted for the Neocomian sequences with a SE-directed distribution pattern. Interpretation of fluvial and deltaic patterns for the lower D-129 Formation that shows a strong control on extensional topography, similar to the underlying Neocomian sections. Extensional relay faults control fluvial and delta trajectory visualized from a horizon slice on 3D seismic information. Interpretation of fluvial patterns for the upper D-129 Formation that shows no control on previous extensional topography that controlled the lower D-129 Formation section. Note that this fluvial pattern is south-directed which contrasts with the lower pattern that is SE directed. (Pagan et al, 2017).

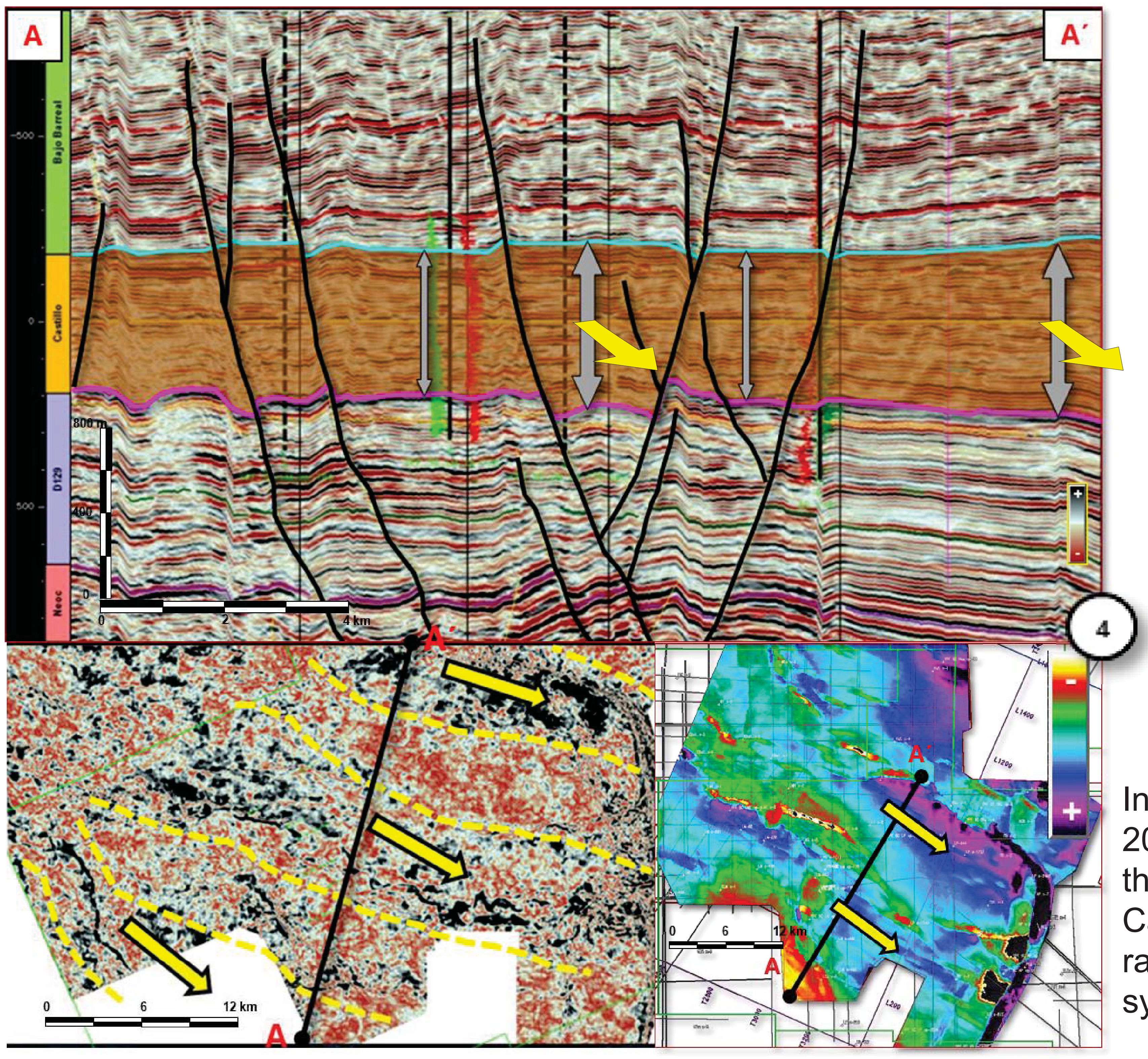


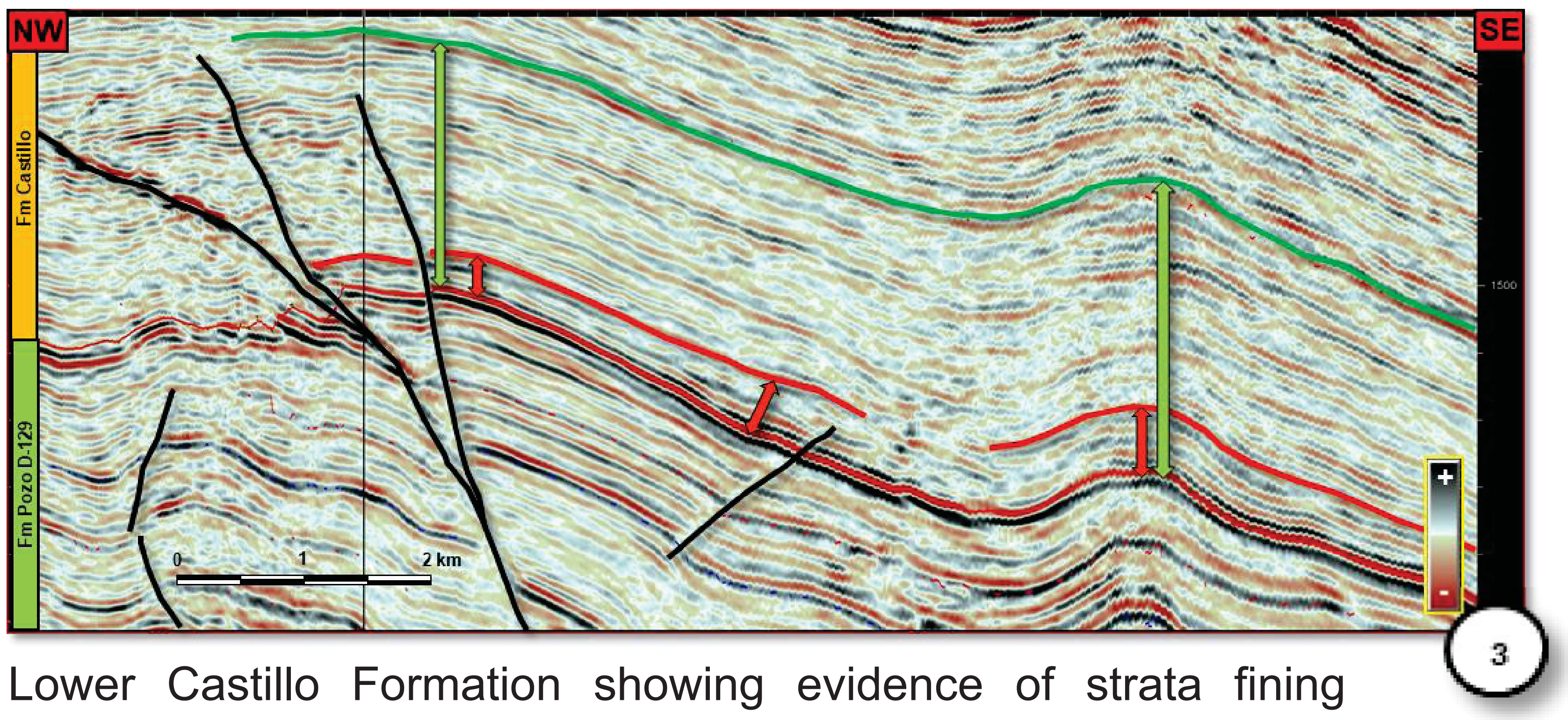
Erosive-angular unconformities in the forelimb of the Perales anticline affecting the upper D-129 Formation. This were interpreted as a product of local reactivations associated with compressive events.





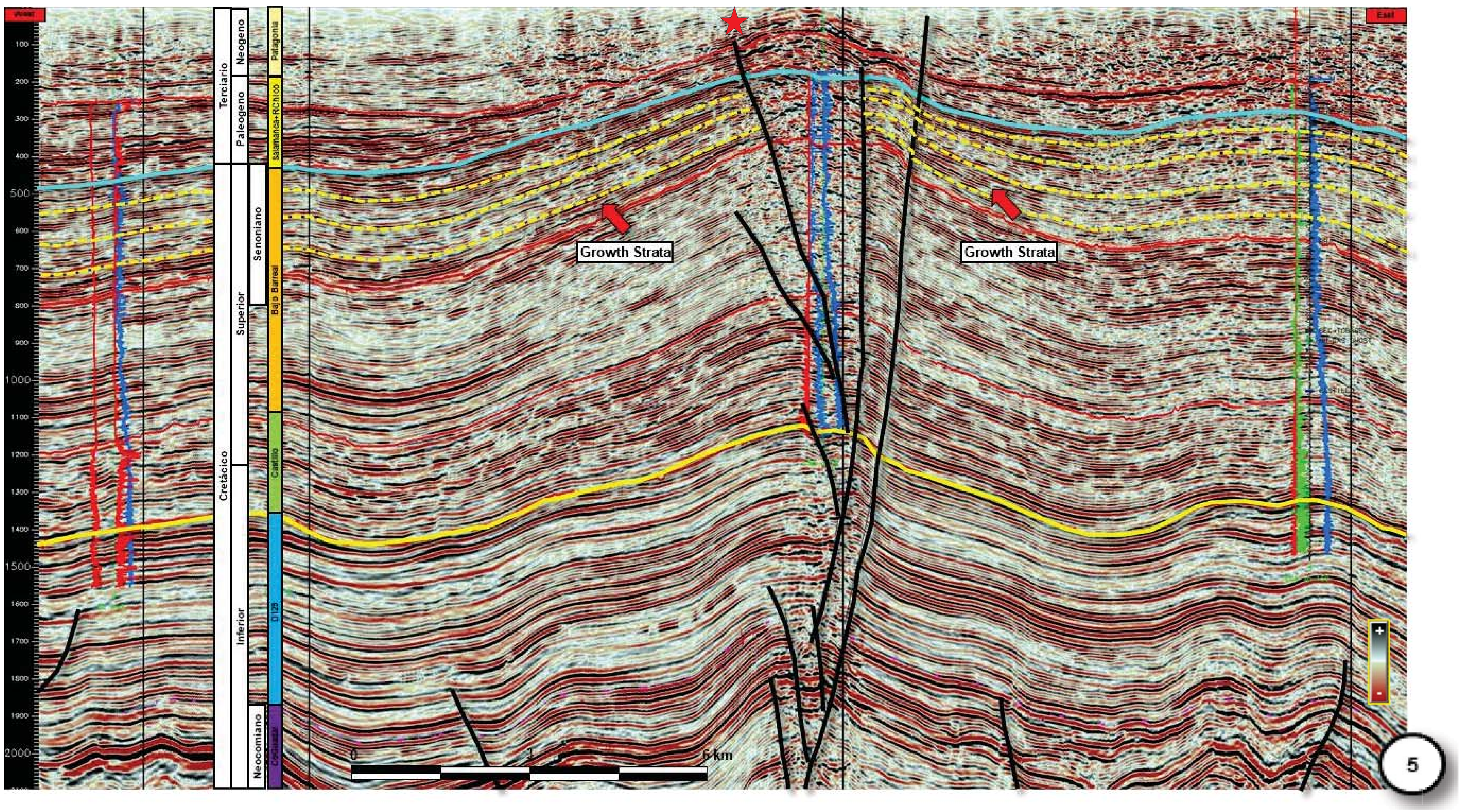
Evidence of up to 100 m deep canyon incision in the upper section of the D129 Formation in the forelimb of the Perales anticline. 3D seismic horizon slice reveals that the fluvial pattern drained to the SE after D-129 Fm deposition. Geoforms were interpreted as incised valley with a high degree of confinement prior to a uplift pulse.



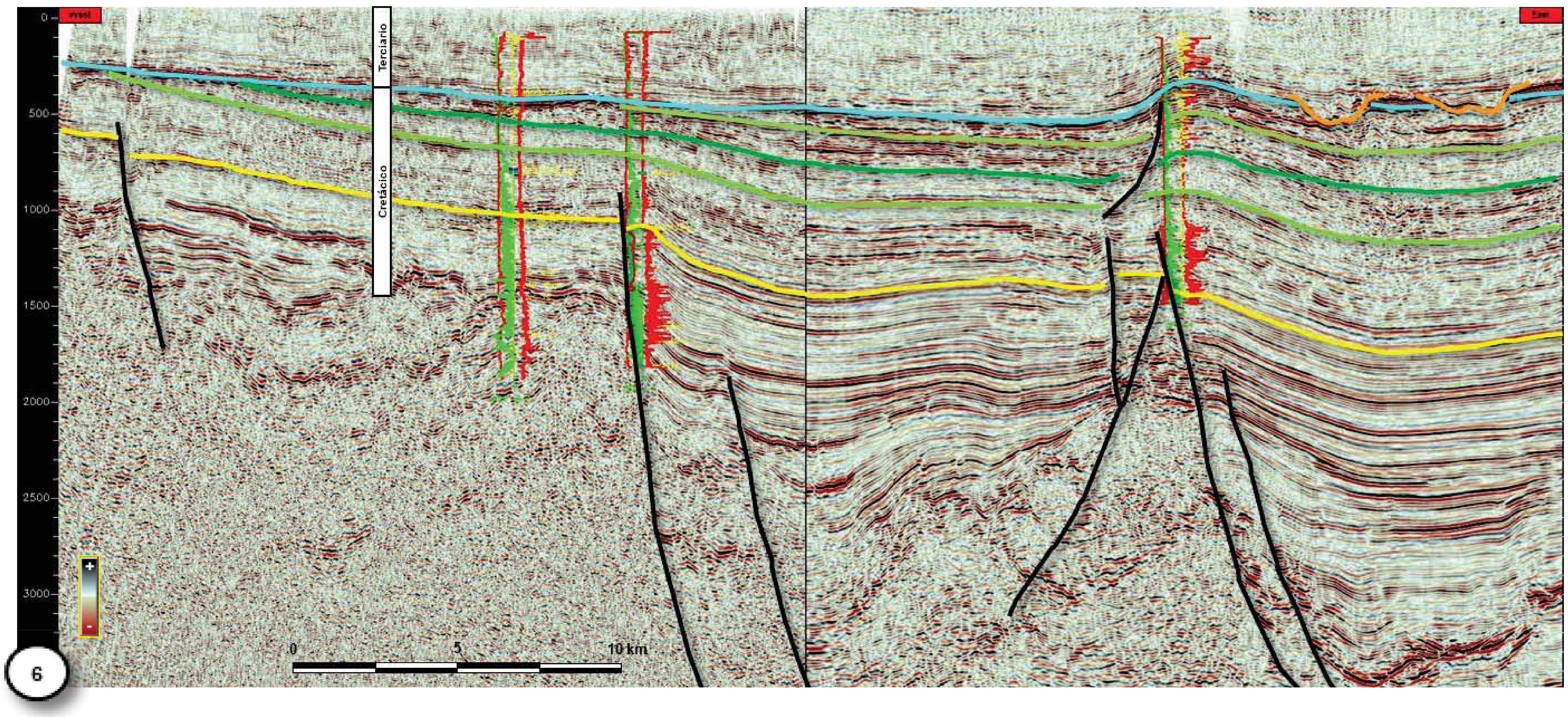


Lower Castillo Formation showing evidence of strata fining against the limbs of a compressive structure.

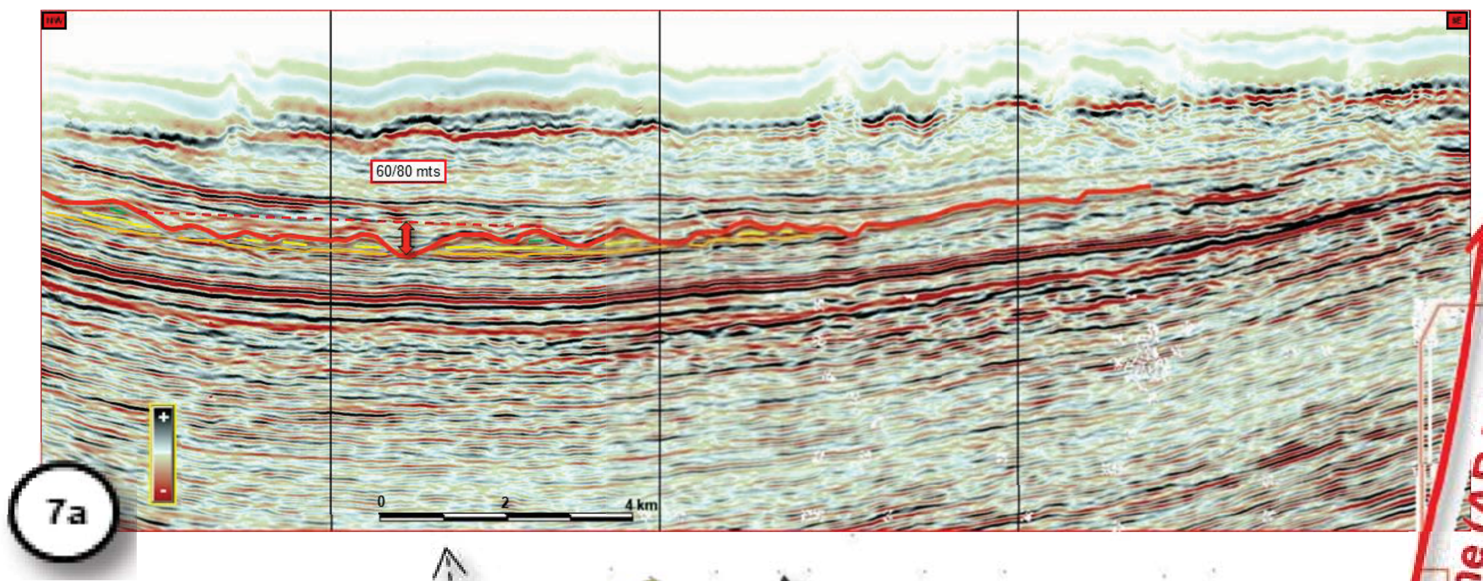
In the mid section of the Castillo Formation thickness variations up to 200 m are associated with strike-slip faults. Thickness anomalies are the product of channels belts with low amalgamation (LAST, Catuneanu, O., 2019) of layers (or high accommodation) and high ratio of flooding fine sediments vs channels (multi-historic channels systems).

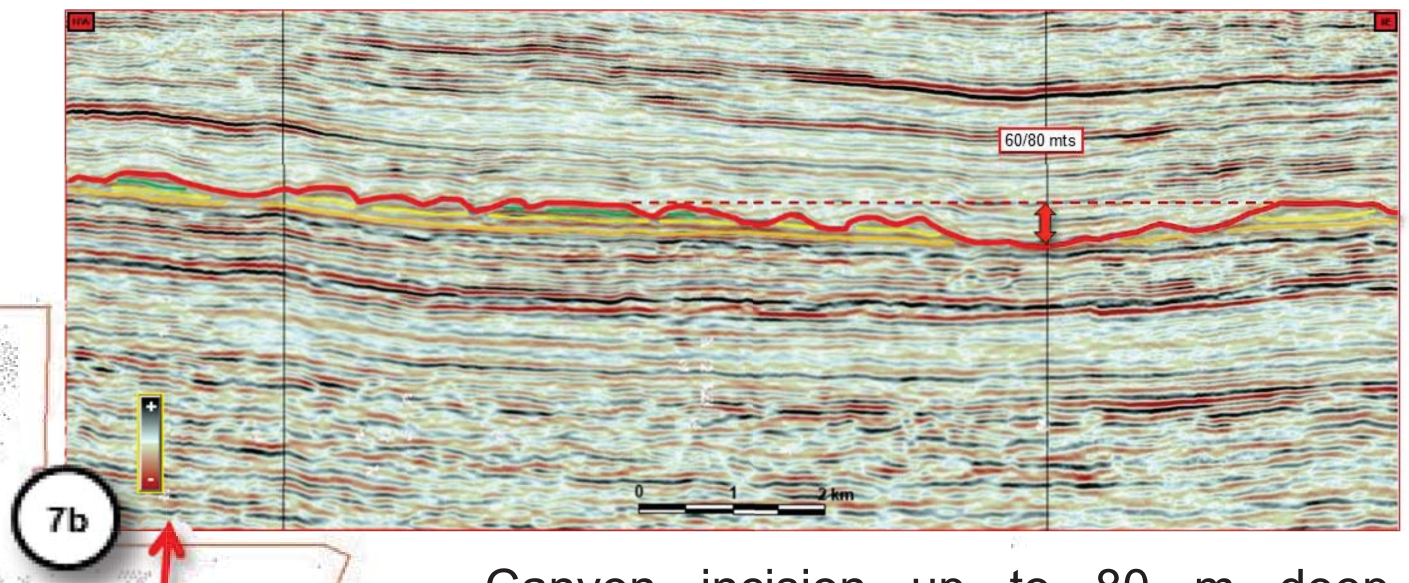


Fining strata against the fore- and back-limb of a contractional structure in the Bajo Barreal Formation. Variations of up to 200 m thick are recorded in distances less than 12 km.

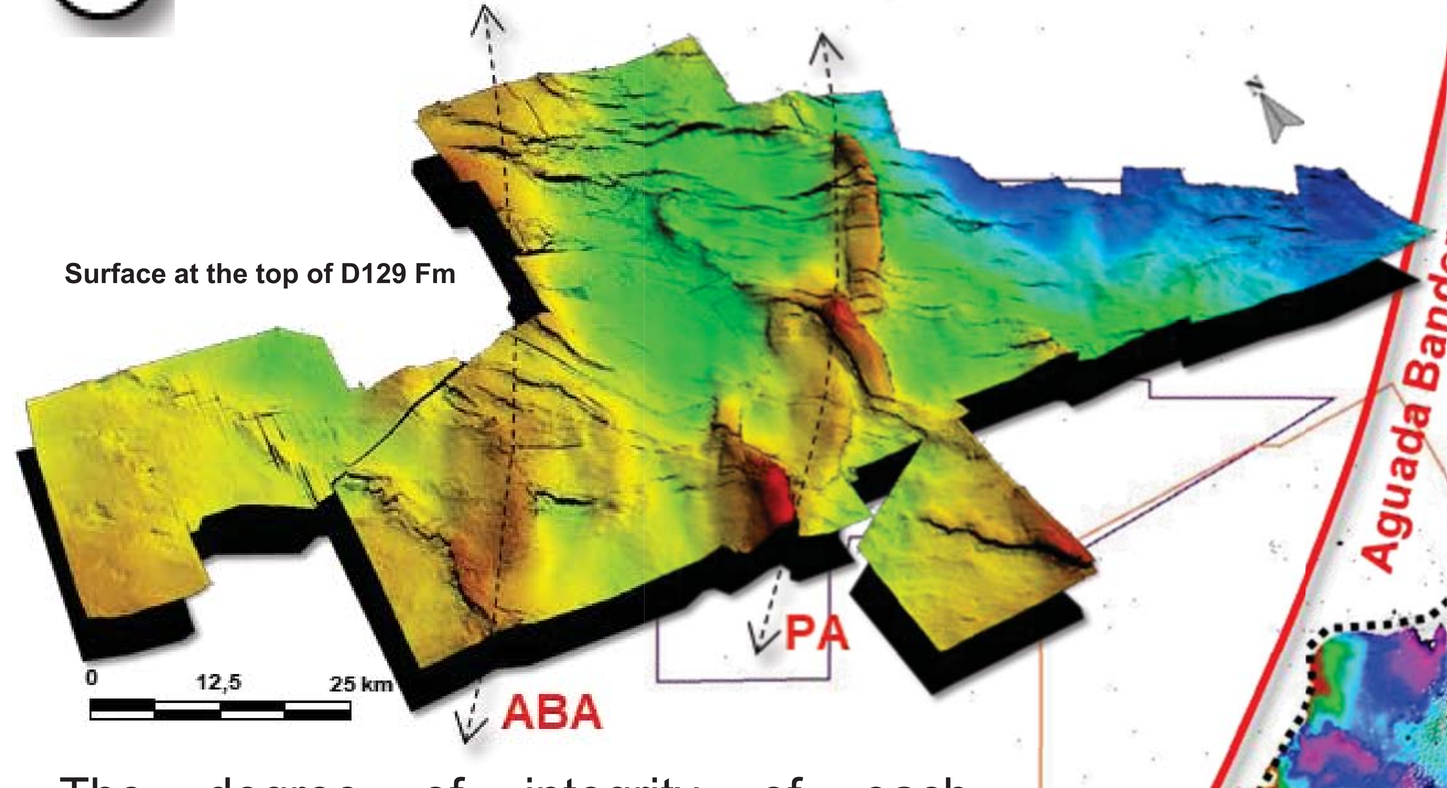


Regional angular unconformity (2-3º) between the upper Chubut Group and the Paleogene sections showing the mild rotation of the backlimb of the Aguada Bandera anticline after the Cretaceous and probably into the Paleogene.

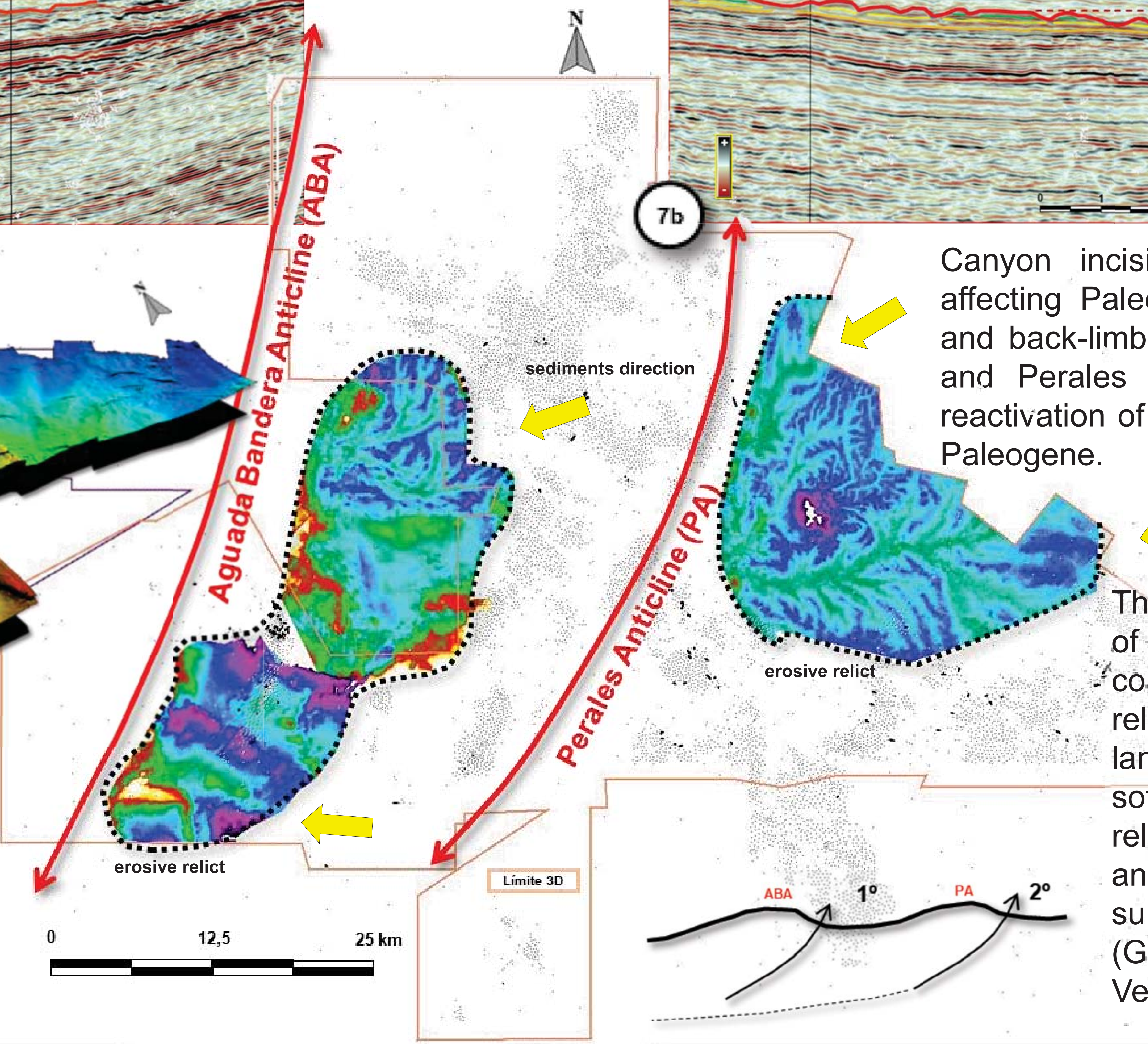




Canyon incision up to 80 m deep affecting Paleogene strata at the fore- and back-limbs of the Aguada Bandera and Perales anticline, indicative of a reactivation of previous structures in the Paleogene.



The degree of integrity of each deformation front and the continuity of its segments can be associated with their relative age. Therefore, greater continuity can be related to an older structure and less continuity, to a younger one. (Giampaoli,P. and Rojas Vera, E., 2018)



The degree of preservation of the eroded paleosurface could be associated with the relative age of the paleo landscape. Therefore, a softer surface could be related to an older surface and a more detailed surface, to a younger one (Giampaoli,P. and Rojas Vera, E., 2018).

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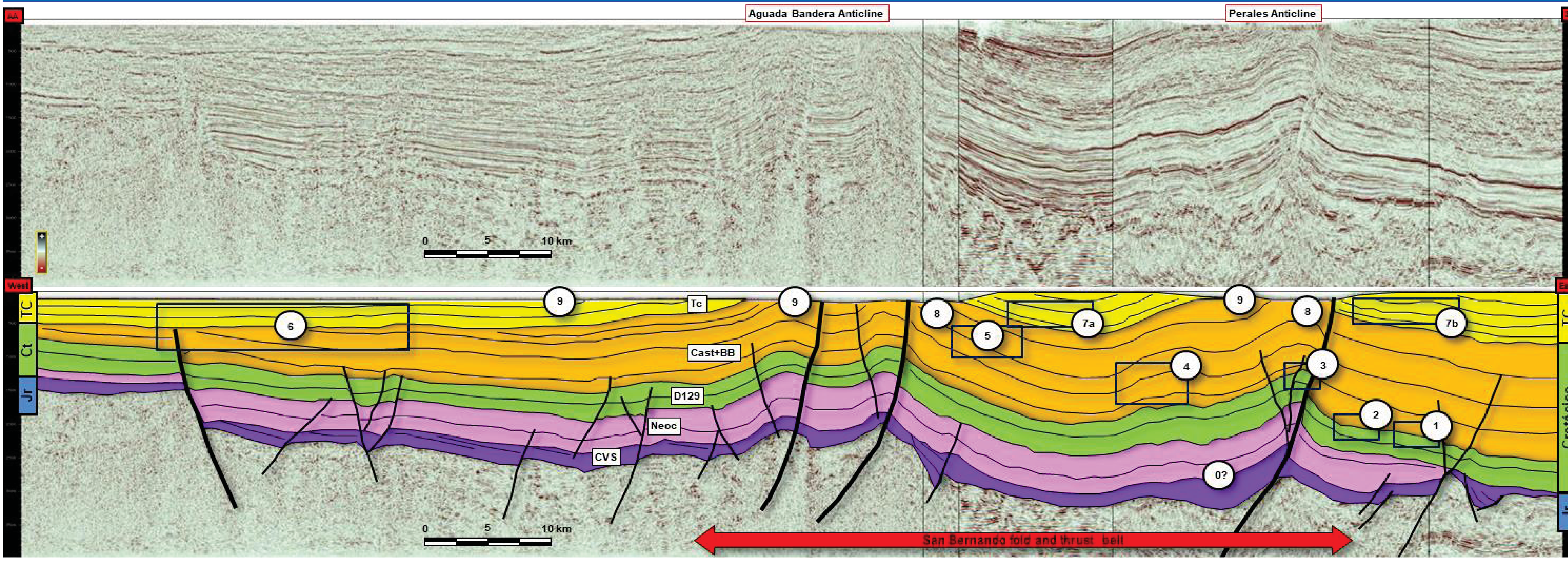
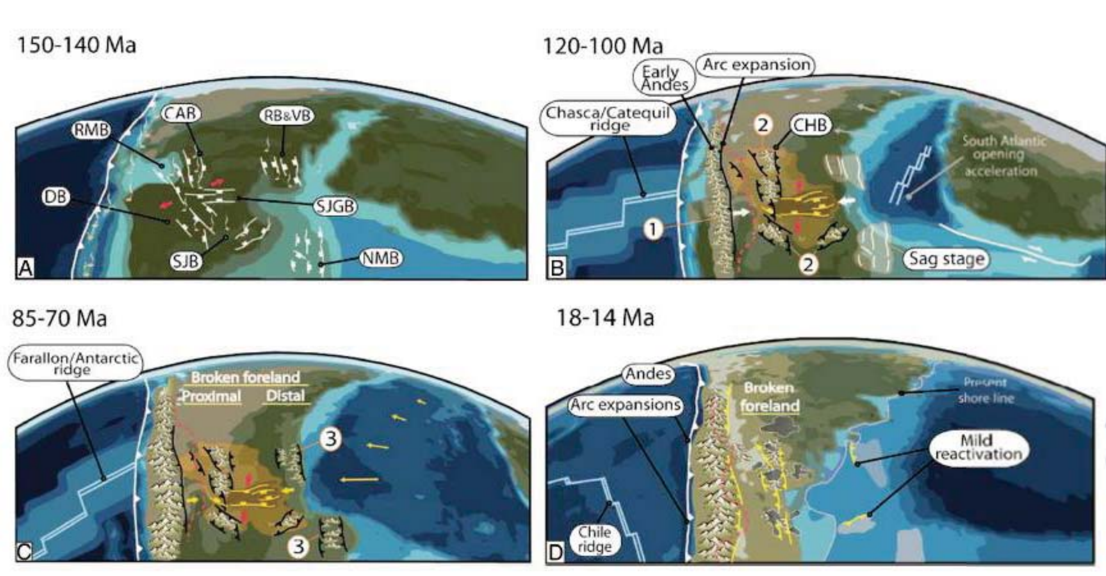
RESULTS

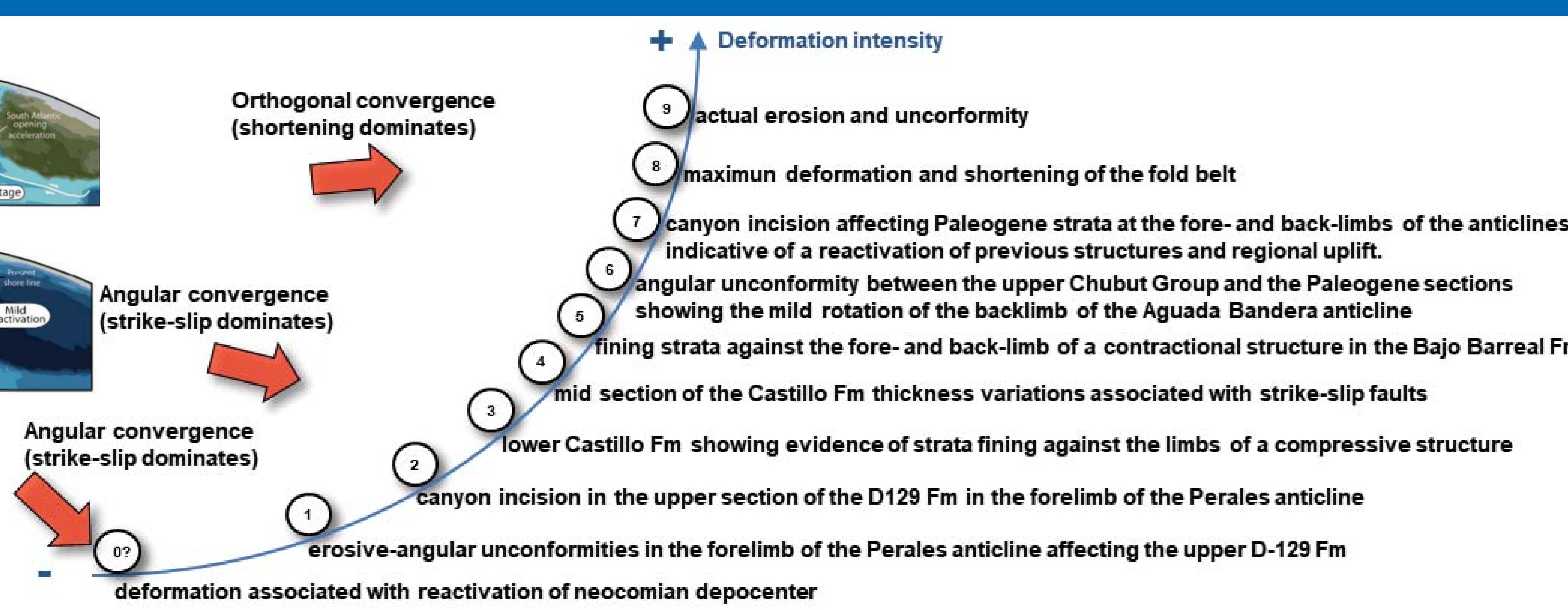


Structural cross section across the southern San Bernardo intraplate fold and thrust belt, builded from 2D-3D seismic and borehole data. The thickness of the sedimentary column between the anticlines exceeds 8000 m. See location in figure 1b. Summary of the location of the different deformational evidences and stages discussed and illustrated in this work respect to the different structures that constructed the Patagonian broken foreland system.

DISCUSSIONS



(Gianni, G.M., et al 2015)



The evolution through different stages of the intraplate belt in Patagonia from data collected in this work and previous data discussed in the text based on Gianni et al. (2015) and Müller et al. (2016). Note that between 120 and 100 Ma a nearly perpendicular collision of the Chasca-Catequil mid ocean ridge produced a highly oblique convergence between the plates, while was replaced by a more orthogonal convergence in Late Cretaceous times associated with the approaching of the Farallón-Antarctica ridge, which is compatible with strike slip deformation with localized uplifts in late early Cretaceous and purely contractional in Late Cretaceous times.

CONCLUSIONS

Seismic data compared with previous field work demonstrates that the Patagonian foreland was affected by polyphasic deformational events that started in the late Early Cretaceous and expanded up to the Neogene. Seismic evidence comprehends unconformities, thickness variations, onlap relations, identification of valley incisions, that constitute valuable information about synorogenic sedimentation and erosional gaps that affected the Patagonian foreland zone across the Aguada Bandera and Perales anticlines corresponding to the southern tip of the San Bernardo fold and thrust belt.

- ✓ **Jurassic to Early Cretaceous evidence of extensional deformation**
- ✓ **Late Early Cretaceous evidence of strike slip deformation and localized uplift**
- ✓ **Late Cretaceous evidence of contractional deformation**
- ✓ **Paleogene evidence of regional uplift**

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Contact Information: facundo.j.pagan@ypf.com / andresfolguera2@yahoo.com.ar