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Extensional Folding in the Eastern Venezuela Basin: Examples from Fields of Oritupano-Leona Block.

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Introduction

A large variety of folds have been identified in the Oritupano-Leona area. The Oritupano-Leona Block is located at the Greater Oficina Trend (Figure 1). More than 12 isolated oil fields constitute the block. Structurally, the fields are located in the southern flank of the Eastern Venezuela Basin (EVB), in the foredeep platform zone (Parnaud et al., 1995) (Figure 1). The field is affected by normal faulting mainly trending N60°E (Figure 2a). Productive section is represented by the Oficina Formation (Early Miocene), although uppermost reservoirs of the underlying Merecure Formation (Oligocene) have produced an acceptable volume of oil. Cumulative oil production of the block is over 340 MMbbls since its discovery in the40's. Reservoirs are composed by sandstones of estuarine to shallow-marine environments (Figura 2b).

Detailed 3D seismic interpretation distinguished various types of folds in the area: **normal- and reverse-drag fold, composite fold structure and folds related to plastic flow**. Longitudinal folds that include normal- and reverse-drag folds are common features in several fields and reported by different workers (Mencher et al., 1953; González de Juana et al., 1980; Azalgara et al., 2000; Porras et al., 2001). These folds are responsible for major oil accumulations. Normal-drag folds form the largest and extended reservoirs in the footwall of master normal faults (Azalgara et al., 2000) whereas reverse-drag folds provide the structural closure for trapping in the hanging wall, especially in Leona Field (Porras et al., 2001). Composite fold structures and folds related to plastic flow are also described. The Junta field trap results of a complex structure made by a combination of folds related to normal fault growing, linkage, and interaction.

Structural Framework

The southern flank of the Eastern Venezuelan Basin represents a relative stable region characterized by extensional tectonics. The study area shows a regional dip about 4 degrees North. The fault planes display a general planar geometry and dip around 45°. Two main fault systems are identified, which follow a NE-SW and W-E trend (Figure 2a). Both main fault systems control trapping.

The first fault system is parallel to the southern hinge of the basin. The NE-SW fault system has synthetic dips, with dipping planes to NW. The fault planes affect the whole section, including the basement. In general, this system corresponds to regional lineaments and shows syn-sedimentary characters. The Guara-Leona and Junta-Merey trends correspond to this system (Figure 2a). Fault throws can reach 1000 feet. Their origin is associated to the flexural uplift which affects the basin during the Oligocene - Miocene times (Elrich & Barrett, 1992).

The second fault system, trending W-E, display both antithetic and synthetic dips. The fault traces show a dogleg pattern. It derives from linkage of segmented fault planes (Laubscher, 1956, Cartwright et al., 1995; Marchal et al., 1998). Longitudinal folds are mainly related to this fault system and constitute the most important traps in the study area. This fault system seems to be in relation with the extensional strain resulting of dextral strike-slip movements along the boundary of South-America and Caribbean plates (Elrich & Barrett, 1992).

Local Extensional Folding

In the Oritupano-Leona area, the production comes mainly from reservoirs located in the upper and middle section of the Oficina formation.

Normal-Drag Folds

Normal-drag folds are recognized in most of the fields of the Oritupano-Leona Block (Figure 3a). They form anticlines in the footwall of main antithetic faults and synclines in the hanging wall. The hinges of these normal-drag folds are parallel to the fault strike. Even though the largest reservoirs of the Oritupano-Leona Block are located in the footwall (Figure 3a), significant hydrocarbon production has come from traps located in the hanging wall (e.g. 41 MMBbls of oil in Oritupano B and 400 MBbls of oil in Oritupano C). In the Leona Field these folds reach their maximum expression.

Reverse-Drag Folds

Reverse-drag folds are well expressed in Leona Field (Figure 3b). They form anticlines in the hanging wall of main faults. A narrow, 10-km long discontinuous belt of fold is defined in the hanging wall of the main Leona fault and shows a hinge parallel to the fault. Five major folds are identified. They affect the middle section of Oficina formation in areas where the fault planes change their dips. Several wells have penetrated these folds, confirming their hydrocarbon potential. More than 2.7 MMbbls of oil has been produced from this type of traps. Minor reverse-drag folds have been also observed in Oritupano-Leona area but they have not associated oil production.

Composite fold structures

In some fields of Oritupano-Leona area, normal-drag folds are associated to reverse-drag structures in vertical section (e.g. Eastern Leona field, Figure 3c). The superposition of these two kind of fold is due to local complexity of the fault plane network. The coexistence of both major types of fold associated to normal faulting may leads to the juxtaposition of two traps formed by elongated anticline structure in both sides of the fault (Figure 3c). In the Leona Field, more than 2.7 MMbbls of light-medium oil has come from the reverse-drag folds.

The Junta field is made of a composite system of folds (Figure 3d). The secondary features of two interacting fault systems make the structural closure of this field: the first is composed by fault zone made of left-stepping en echelon fault segments striking NE-SW and the second is represented by a W-E striking fault (Figure 4). Associated to the main fault zone (NE-SW) dipping NW, a parallel set of compensation fault segments dipping SE is defined. The trap is divided in two parts: the first part is composed by the footwall anticline associated to normal-drag folding on a compensation fault segment; the second part is made by a residual high located in the hanging wall of the main fault zone. Located at the relay zone formed by two overlapping normal fault segments, this high consists in a residual topography between two syncline structures due to normal drag folding in the hanging wall of each fault segment, which belong to the NE-SW main fault zone (Figure 4). The Junta trap has been drilled by 55 wells and has produced more than 14 MMbbls of oil.

Minor folding can be also due to ductile deformation in the ramp of a relay zone formed by two overlapping faults. This kind of folding is characterized by structural highs in the overlapped zone. Folds associated with relay ramps, related to segmented en echelon faults, are frequently seen in the Oritupano “A”, “B” and Leona fields.

Plastic Flow

In Adobe field, located in the central part of the area, W-E cross sections have allowed to identify particular small features, wavy-shaped in the Oficina Formation (Figure 3e). This type of folding could be related to plastic flow deformation (slumping), determined by the competence of sediments. This type of structure is rare in the area and its economic potential has not yet been established.

Conclusions

1. The use of 3D seismic allows the identification of favorable structures, of various scales, for oil trapping. Normal- and reverse-drag folds represent new exploration and re-development opportunities for these mature oil fields. Reverse-drag folds have been

successfully drilled in Leona Field. Many gas and oil reservoirs have been discovered in the last years.

2. These types of traps constitute an important economic up-side potential for the block. Their identification can be used as a critical element for searching for new reservoirs in developed areas.

3. Further detailed studies of fault-related folding will led to a better understanding of the sealing capacity of faults, fluids movements and reservoir charging in order to improve oil recovery on fields.

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Figures

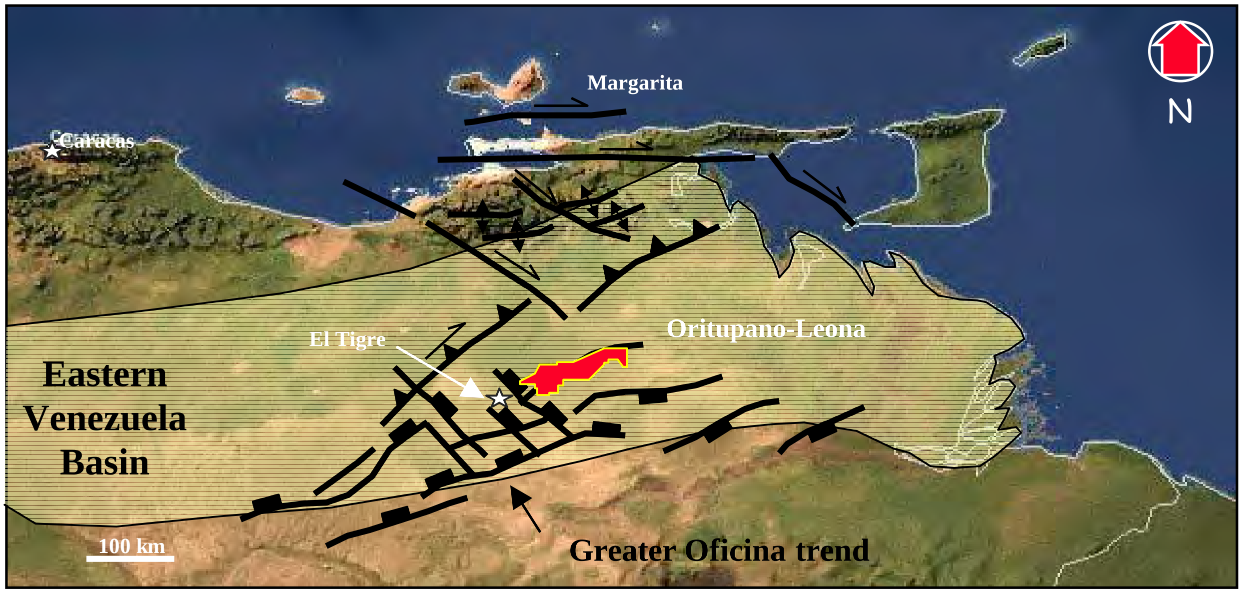


Figure 1. Oritupano-Leona location map. The study area is located in the southern flank of the Eastern Venezuela Basin, in the foredeep platform zone.

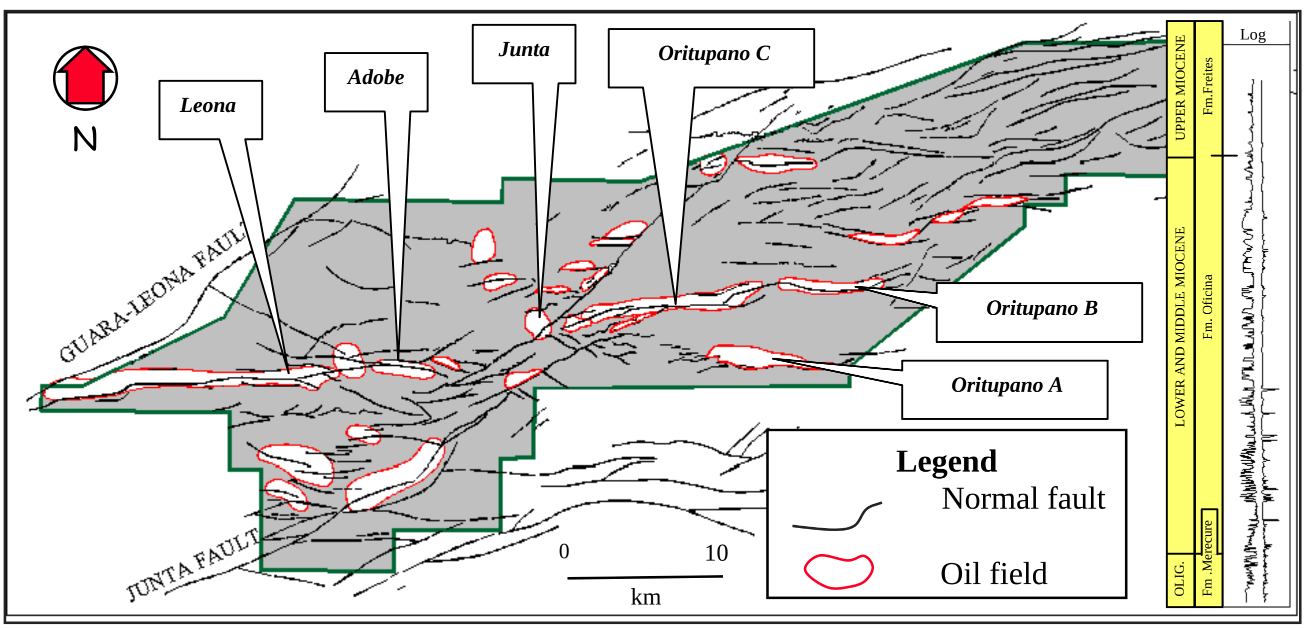


Figure 2. Map showing normal faults trending and major oil fields in the Oritupano-Leona Block.

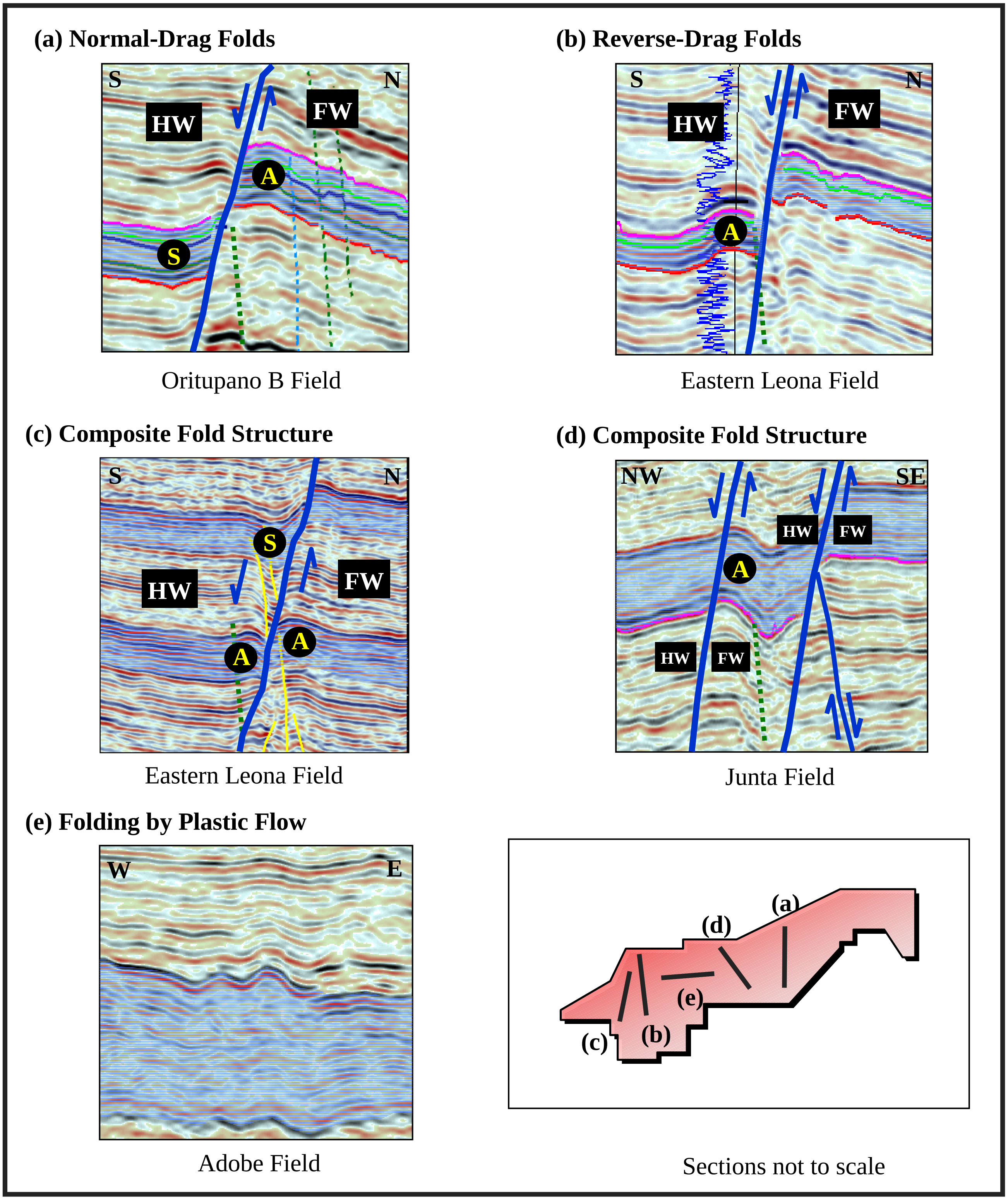
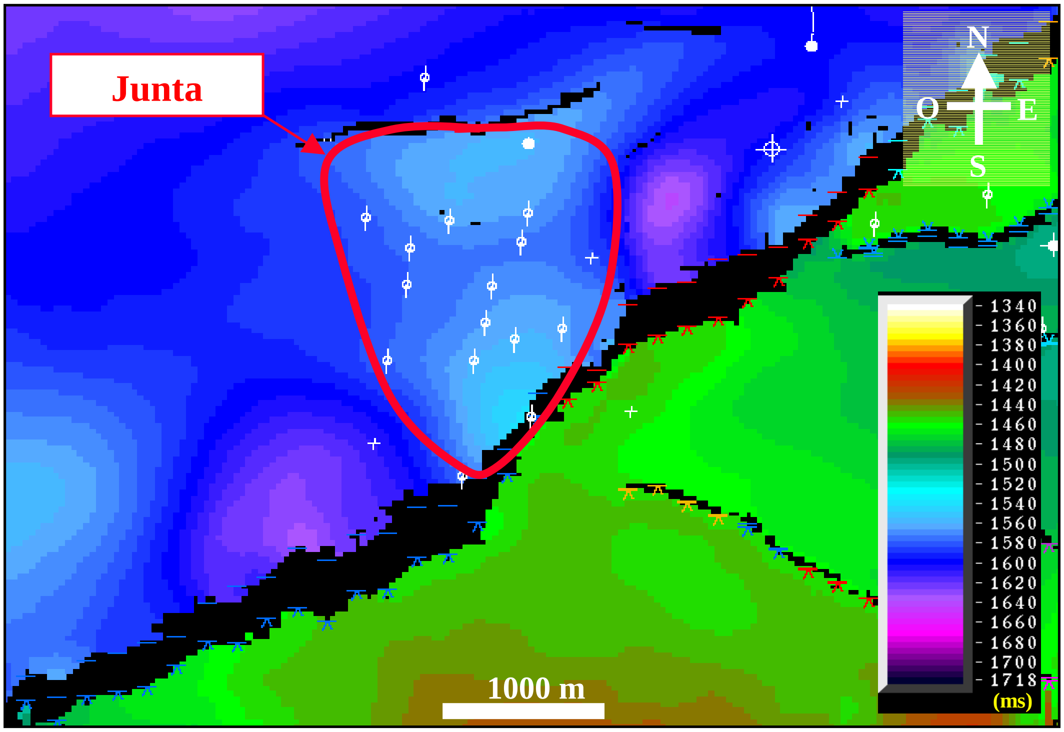


Figure 3. Different features of folding in Oritupano-Leona Block.
a) Normal-drag folds. b) Reverse-drag folds. c) and d) Composite fold structures. e) Folding by plastic flow. See inset for location of sections. A: anticline structure, S: syncline structure, HW: hanging wall, FW: footwall.

a)



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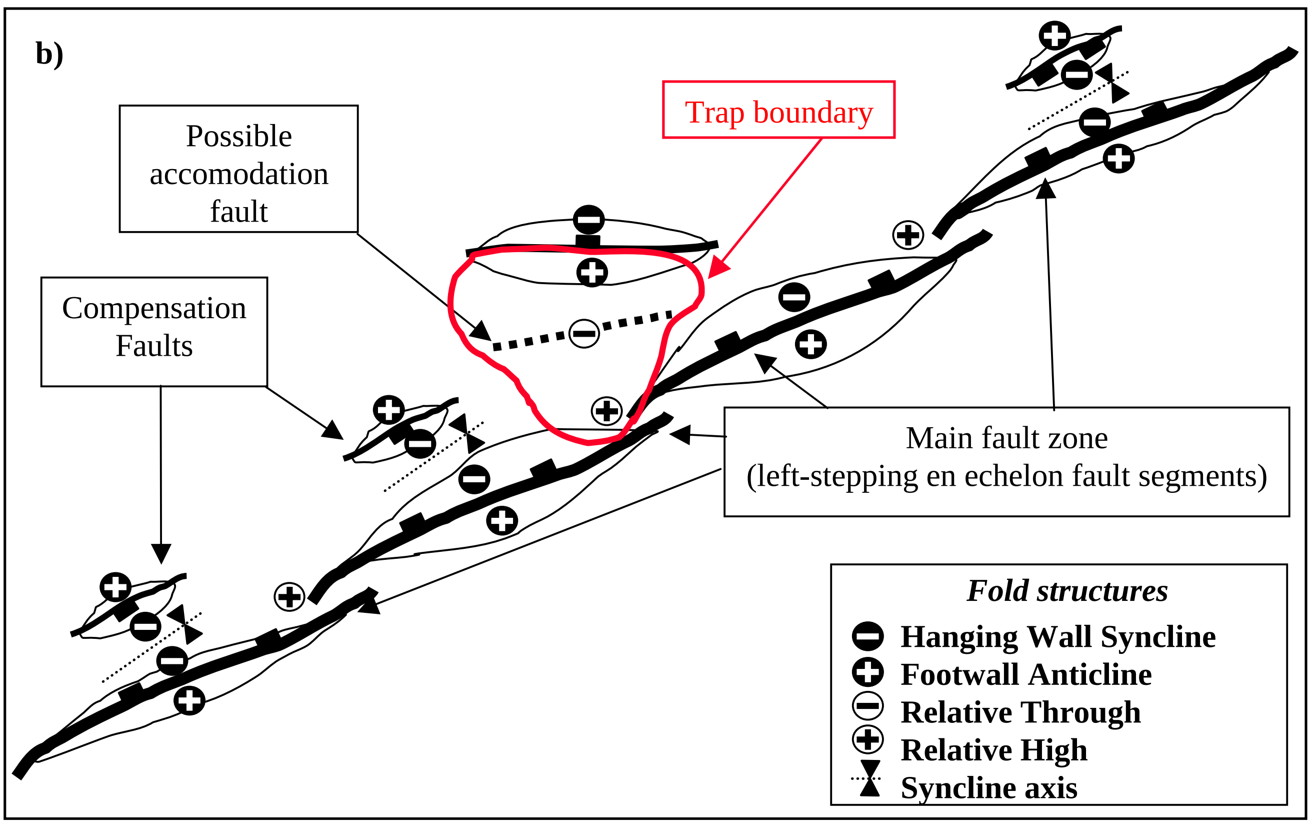

Figure 4. Junta field structure.
a) Time map of Base Oficina. b) Line drawing with the interpretation of the structural elements.