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**Recognition of Tectonic Events in the Conformation of Structural Traps in the Eastern Oriente Basin, Ecuador.**

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## 1. INTRODUCTION

The Oriente Basin in Ecuador can be divided into two different physiographic-structural domains. The moderate to strongly, eastward verging Sub-Andean fold and thrust belt, to the west, and the topographically low, jungle-covered Eastern Region. The stratigraphic succession in Oriente Basin comprises Precambrian metamorphic and plutonic rocks of the western Guyana Shield, underlying three sedimentary cycles: Pre-Cretaceous pre-rift and rift, Late Cretaceous post-rift and Tertiary foreland deposits (Dashwood and Abbotts, 1990). This paper is focused in the recognition of tectonic events in the generation of structural traps in the Eastern Region (Figure 1).

## 2. TECTONIC EVENTS

Interpretation of seismic and well data indicates a complex structural history in which extensional and compressional tectonics took place. The main tectonic features recognized are: 1) Precambrian and Early Paleozoic basement fabrics, 2) Early to Late Jurassic extensional faulting, 3) Early Cretaceous uplifting and 4) Late Cretaceous to Recent inversion tectonics and strike-slip systems. The main structural features observed in the study area are shown in the subcrop map at the Aptian Unconformity (Figure 1).

### 2.1. Extensional Tectonics

The Late Silurian to Permian pre-rift and Jurassic rift sequences were mapped to define the extensional depocenters: to the east, the north-northeast trending, west verging Ishpingo-Tiputini-Tambococha (ITT) half-graben; to the west, the north-northwest trending, west verging Obe half-graben, and the north trending, east verging Capirón and Pañacocha half-grabens (Figure 1).

The architecture of the half-grabens was controlled by fault geometries, which were heavily influenced by pre-existing basement fabrics. In the study area, Precambrian and Early Paleozoic basement fabric controlled the geometry of the half-grabens, developed under a west-northwest extension direction. The basement generally presents a diffuse seismic character, but in some places distinctive linear reflections truncate at the basement upper surface (Figure 3). Metamorphic foliation pattern, thrust faults or shear zones are inferred to be responsible for these basement fabrics. South of the Obe half-graben, the basement fabric dips parallel to the extensional west-verging master fault, coincidental with the major extension. To the north, the basement fabric dips to the east, generating a high angle between the fabric and the master fault, inhibiting the extension along the fault and aborting the half-graben development.

The three main transfer zone geometries proposed by Morley (1995) were recognized in the study area (Figures 1 and 2): The conjugated convergent Tivacuno transfer zone, a relatively positive structural feature representing a change along-strike in the half-graben polarities and offset of depocenters, the west verging Obe half-graben with the east verging Capirón half-graben. The divergent conjugated Yuturi transfer zone connecting the west verging Obe half-graben with the east verging Pañacocha half-graben. Finally, the synthetic conjugated ITT transfer zones, where the half-graben master fault are occasionally segmented. The displacement transfer between individual segments is accomplished by relay maps (Figures 1 and 4).

### 2.2 Compressional Tectonics

The notion that the half-grabens were positive inverted previously to the Aptian unconformity is visible in the study area. Regional uplifting at the Aptian time and the ensuing erosion generated the Aptian unconformity, well documented in Oriente Basin. These compressional events are related to the accretionary allochthonous terranes in the Cordillera Real, called Peltetec by Aspden and Litherland (1992), and recognized by Ruiz et al. (1999) in the Sub-Andean fold and thrust belt of Ecuador.

From Aptian onward, fault-controlled subsidence was replaced by regional subsidence. Several episodes of structural inversion modified the shape of the depocenters and rejuvenated fringing sedimentary source areas. Main features of the Andes were acquired during Miocene and just a few changes have occurred since then. Neotectonics studies show the Subandean zone and Oriente Basin in Ecuador dominated by an E-W to SW-NE compressional stress regime during the Quaternary (Jaillard et al., 2000). In the study area, from Late Cretaceous to Recent, several episodes of strike-slip fault systems and inversion tectonic took place. The final structural configuration of this tectonic evolution is shown in Figure 5, interpreted as a result of the principal stress field ($\sigma_1$) oriented 75-85ºE.

**2.2a. *Strike-Slip Fault Systems***

Under this compressional stress field, preexisting steeply dipping extensional faults and basement shear zones favored the displacement along strike. Most, especially those trending NE-SW, were reactivated as right-lateral strike-slip faults, as the majority of the reactivated faults in Oriente Basin (Baby et al., 1997). Example in the study area is the Minta structure, formed by a vertical fault, trending NNE-SSW with slight *en-echelon* offsets of the main fault segment (Figure 6). Where the strike-slip fault become curved they formed either restraining bends (structural high) or releasing bends (structural low), associated to zones of compression or extension. The final picture shows *en-echelon folds* alternating positive and negative flower structures.

Left-lateral strike-slip faults are less common in Oriente Basin. An example in the study area is the Obe-Pimare-Yuturi trend, formed by a high angle (almost 85°) NW-SE fault. Here, the displacement affected both, the hangingwall of the previous extensional fault, generating the Obe fault anticline to the south, and the footwall, generating the Pimare and Yuturi fault anticlines to the north (Figure 3).

**2.2b. *Inversion tectonics***

Inversion was favored where the compressional stress field reactivated moderate dipping (45°-55°) preexisting listric fault planes. Example in the study area is the ITT structure, where the positive inversion uplifted the hangingwall of the north-northeast, west verging half-graben (Figure 4). The main detachment fault propagated into the overlying post-rift strata with the same geometry as the listric extensional segment. Moderate right-lateral strike-slip displacement is expected along the fault plane according to its orientation relative to the regional stress field.

**3. TRAP**

The study area accounts for about 30% (2,200 million bbl.) of the total hydrocarbons discovered in Oriente Basin, Ecuador. Commercial oil fields range from 50 to 1,400 million bbl. The main reservoir is the Cretaceous Napo formation (T, U and M1 sandstones). In general the oil is biodegraded and ranges from 10° to 39° API. The main hydrocarbon charge proceeded form the west and southwest of the basin. The Tertiary units deposited during the Andean tectonics mainly in the Miocene – Pliocene triggered the maturation, explusion and migration of hydrocarbons. Possibly a pre-Oligocene pulse also occurred (Dashwood and Abbotts, 1990).

Main oil accumulations and exploratory prospects in the eastern Oriente Basin are related to structural traps, generated by combination of some of the structural styles previously described (Figure 5):

~ Faulted nticlines associated to inversion tectonics (Ishpingo, Tiputini, Tambococha and Capiron oil fields and Imuya structure).
~ Footwall faulted anticlines in left-lateral strike-slip systems (Yuturi oil field and Pimare structure).
~ Hangingwall faulted anticlines in left-lateral strike-slip systems (Obe and Dumbique fields).
~ Hangingwall faulted anticlines in right-lateral strike-slip systems (Apaika field and Minta structure).

**4. CONCLUSION**

Even though the final trapping mechanism was mainly controlled by the Tertiary compressive events, the geometric configuration of the traps was strongly influenced by the previous extensional structures developed during Jurassic times. In the same line of thought, these extensional features seem to be controlled by weakness zones in the igneous-metamorphic basement.

The understanding of these different tectonic episodes in the conformation of the structural traps helps in reducing the exploration risk in the Eastern Region of Oriente Basin.

**5. REFERENCES CITED**

Aspden, J. A. and M. Litherland, 1992, The Geology and Mesozoic collisional history of the Cordillera Real, Ecuador: Tectonophysics, v. 205, p.187-204.

Baby, P., M. Rivadeneira, C. Davila, M. Galarraga, J. Rosero and J. Vega, 1997, Estilo tectónico y etapas de deformación de la parte norte de la Cuenca Oriente Ecuatoriana: VI Simposio Bolivariano "Exploración Petrolera en las Cuencas Subandinas", Memorias Tomo I, p. 288-302.

Dashwood, M. and I. Abbotts, 1990, Aspects of the petroleum of the Oriente Basin, Ecuador, *in* J. Brooks, ed., Classic Petroleum Basins: Geological Society Special Publication, No. 50, p.89-117.

Jaillard, E., G. Hérail, T. Monfret, E. Díaz-Martínez, P. Baby, A. Lavenu and J. F. Dumont, 2000, Tectonic Evolution of the Andes of Ecuador, Peru, Bolivia and Northernmost Chile, *in* U. G. Cordani, E. J. Milani, A. Thomaz Filho and D. A. Campos, eds., Tectonics Evolution of South America, Rio de Janeiro, p 481-559.

Morley, C., 1995, Developments in the structural geology of rifts over last decade and their impact of hydrocarbon exploration, *in* Lambiase, J., ed., Hydrocarbon habitat in Rift basins: Geological Society Special Publication, No. 80, p.1-32.

Ruiz, G., R. Spikings, W. Winkler and D. Seward, 1999, Apatite and zircon fission track analysis of the Ecuadorian Sub-Andean (Napo) zone: a record of the Oriente geodynamics since early Jurassic: Fourth ISAG, p. 634-635.

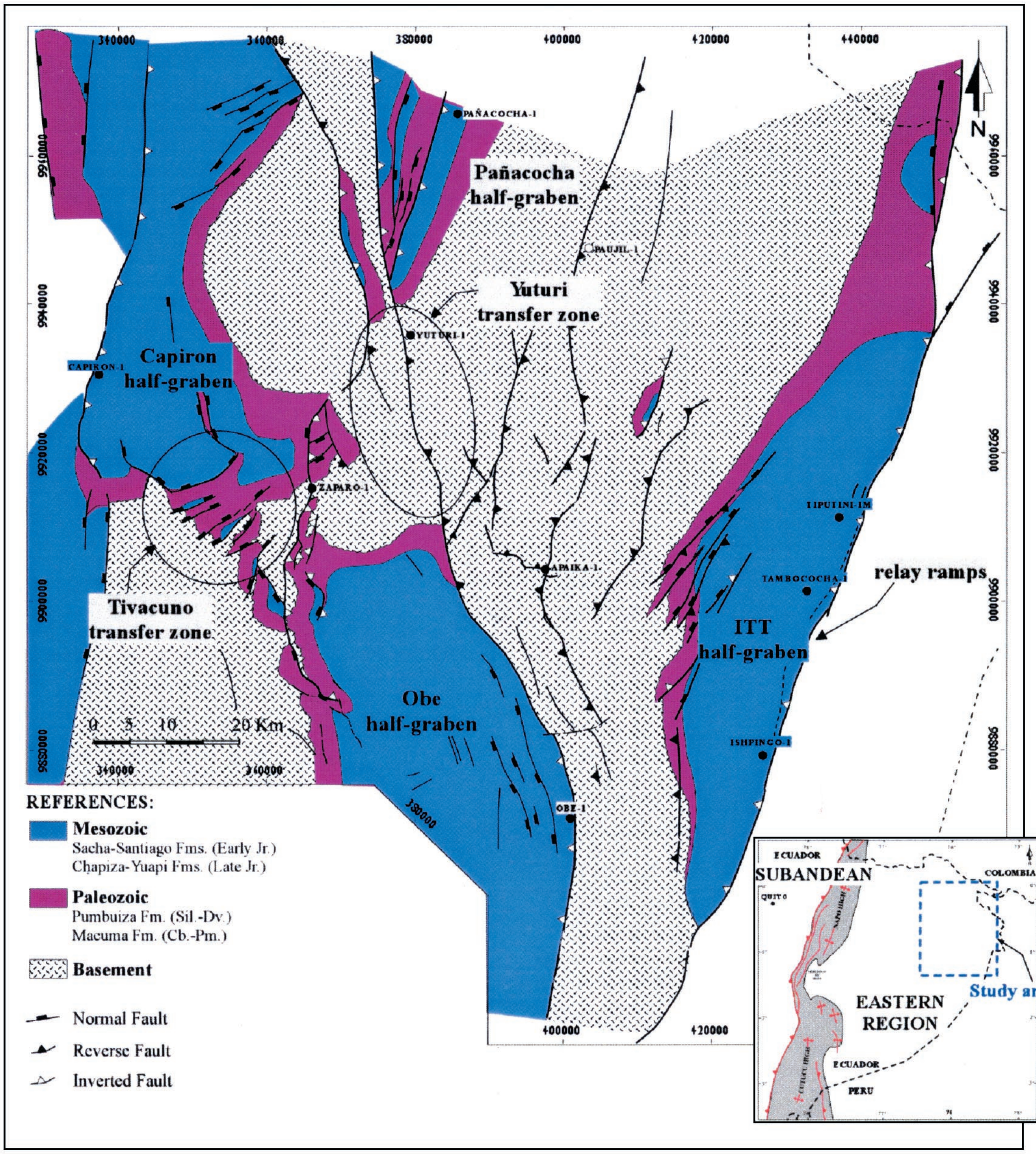



**Figure 1**_Subcrop map at the Aptian unconformity showing the present faults configuration and the pre-Aptian sequences (Precambrian basement, Silurian to Permian pre-rift and Jurassic synrift) recognized in the Eastern Region of Oriente Basin, Ecuador.

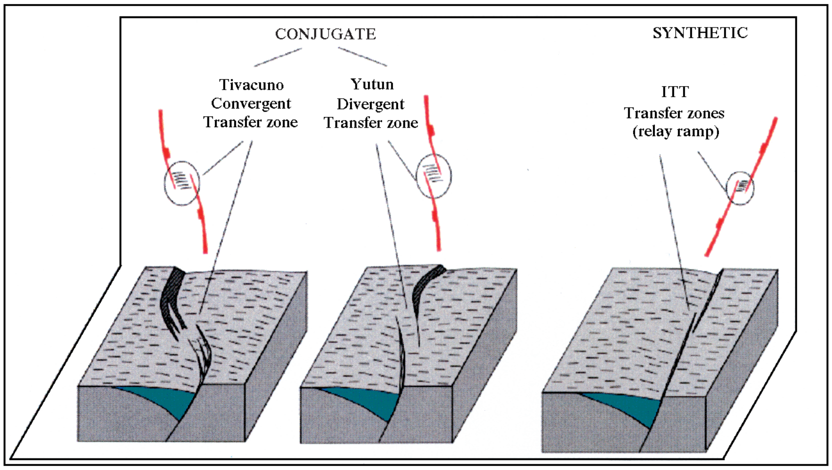



**Figure 2**_Sketch diagram of the three main transfer zone geometries: The conjugated convergent Tivacuno, the divergent conjugated Yuturi and the synthetic conjugated ITT transfer zones (modified from Morley, 1995).

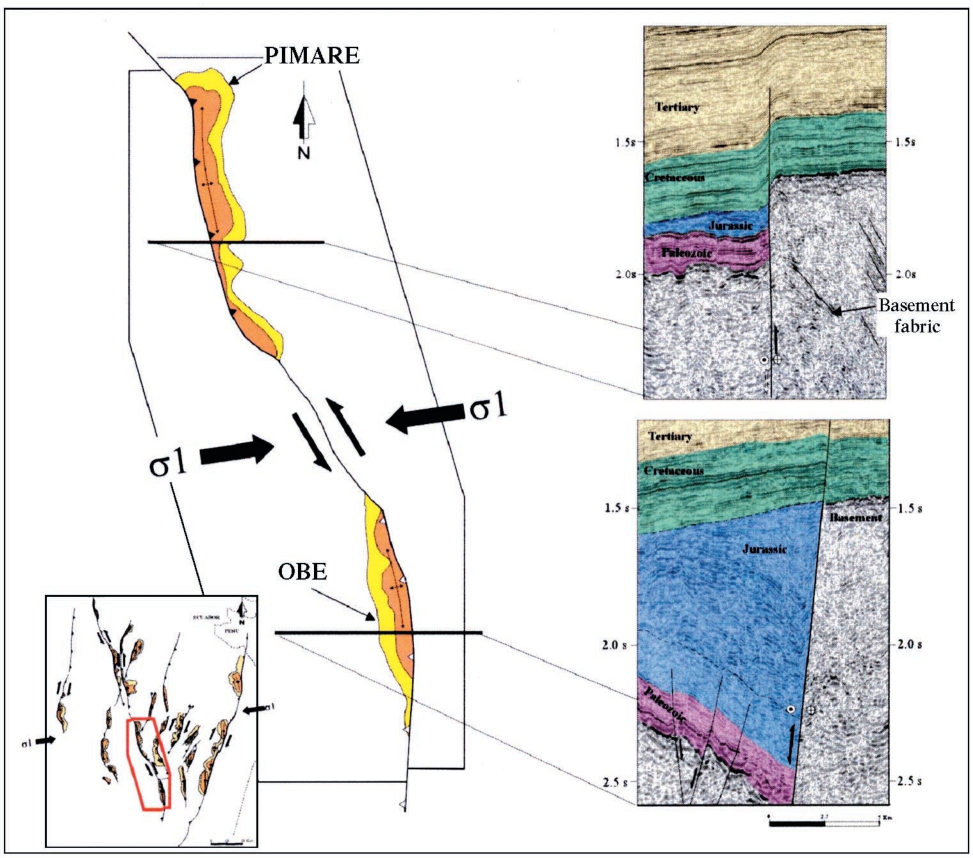
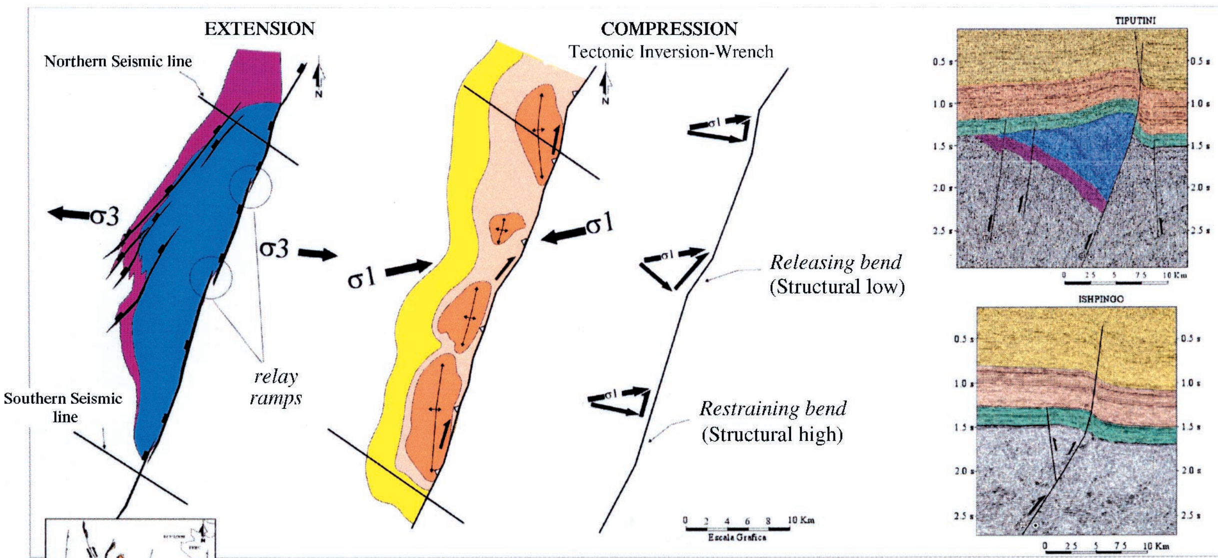



**Figure 3**_Compressional tectonic affecting the north-northwest trending, west verging Obe half-graben. As the result, the left-lateral strike-slip displacement along the Obe-Pimare trend formed positive structures both, in the hangingwall (Obe oil field), and in the footwall (Pimare structure) of the master extensional fault.



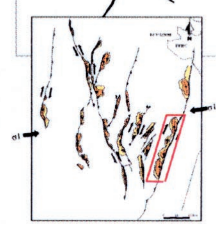


**Figure 4**_Extensional and compressional events in the ITT structure. The last compressional event occurred in the Late Tertiary generated the inversion tectonics of the half-graben. Small right-lateral strike-slip movement is expected along the fault plane.

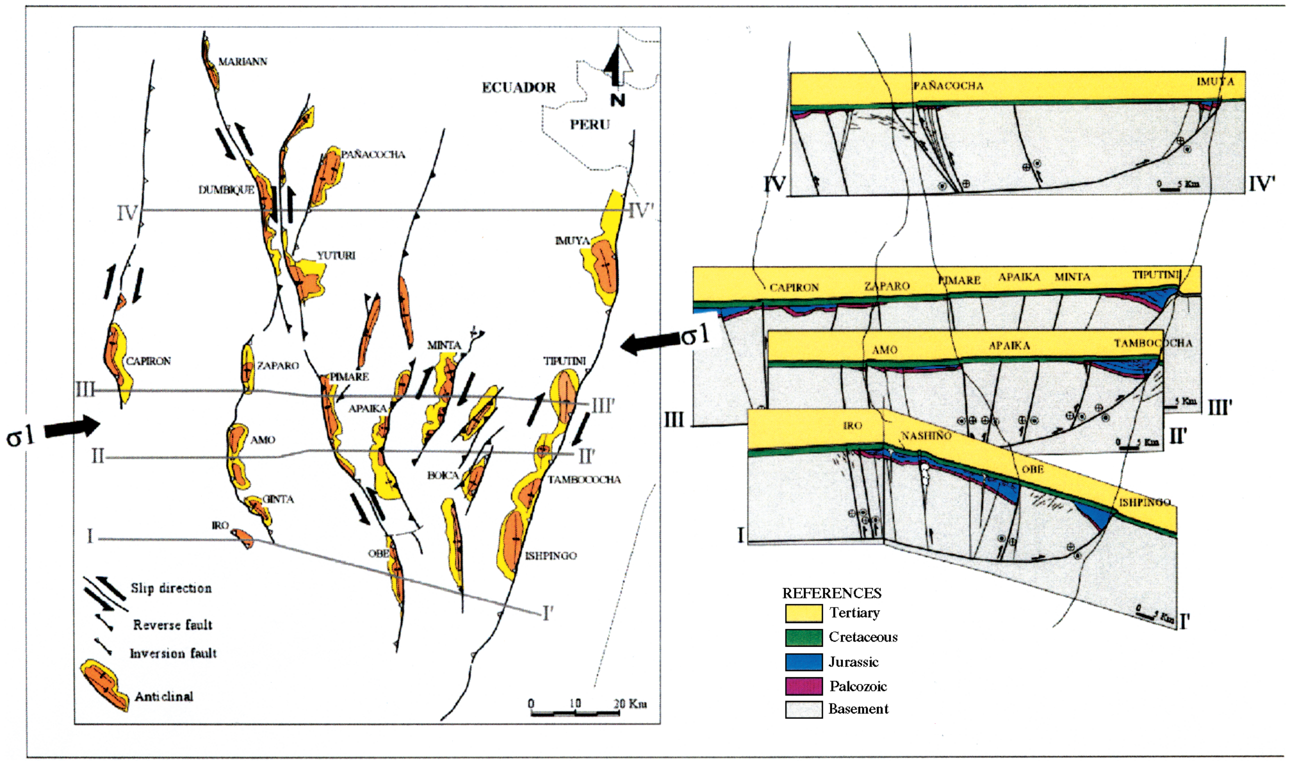



**Figure 5**_Right: Structural configuration at the top of the Late Cretaceous in Eastern Oriente Basin, Ecuador. Left: East-west cross sections showing the lateral evolution of the half-grabens and the overlying sequences.

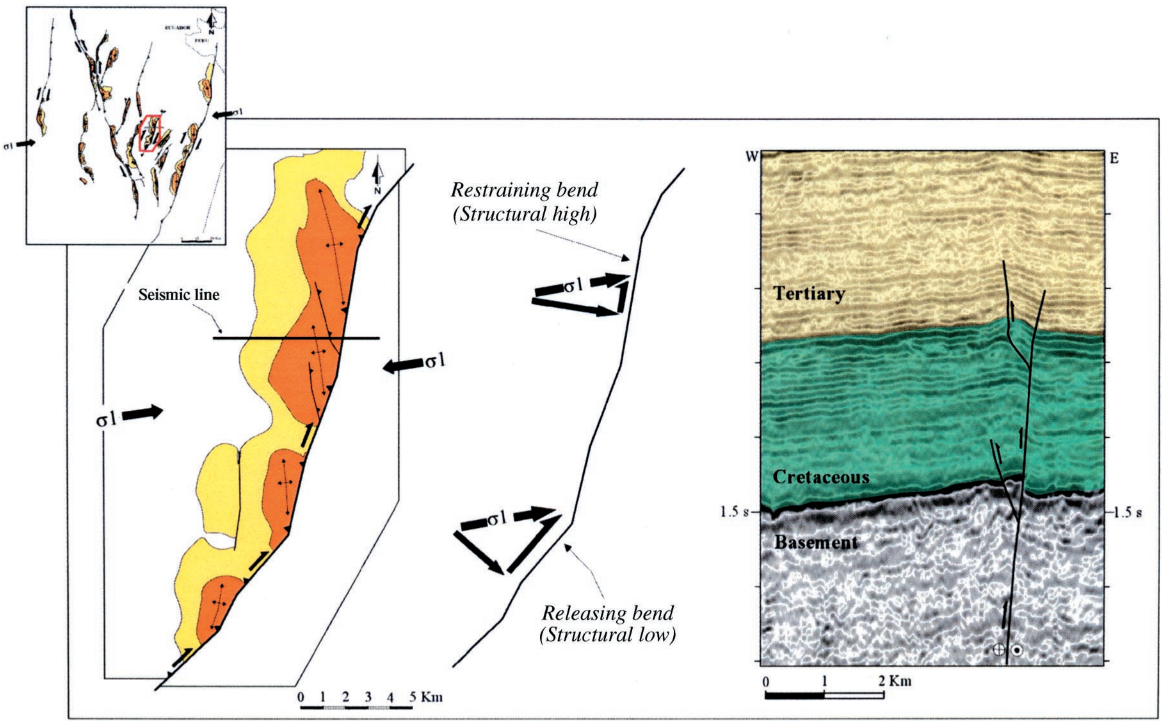



**Figure 6**_Minta structure: The basement fabric favored the displacement along strike during compressional events (right lateral). Where the strike-slip fault become curved they formed either restraining bends or releasing bends. The final picture is an *en-echelon fold*.