Boletín de la Sociedad Geológica del Perú

journal homepage: www.sgp.org.pe ISSN 0079-1091

Age of the Juruá orogeny, Brazil and Peru

Mario Vicente Caputo

Geoarte Consultoria Geológica e Artística Ltda., Belém (PA), Brasil (caputo@interconect.com.br)

ABSTRACT

Field studies and reflection seismic data show a wide belt of ENE-trending deformation developed in the Solimões and Acre basins of Brazil and the sub-Andean basins in Peru. The 1400 km -ong ENE-striking belt in Brazil is interpreted as a shear zone that resulted from right-slip displacement in a transpressive regime. Structural inversion, block uplift, and an *en échelon* arrangement of asymmetrical folds are attributed to shearing along this tectonic belt. The deformation is of Late Jurassic age, probably coincident with opening of the Central and South Atlantic Ocean.

In Peru and the neighboring countries Bolivia, Ecuador and Colombia, the Juruá orogeny is also present and occurs as widespread regional uplift, structural inversion and asymmetrical folds beneath a pronounced regional unconformity of Early Cretaceous age, marking a first-order sequence boundary above the Upper Jurassic Sarayaquillo Formation. The major depositional hiatus at the end of the Jurassic is attributed to reorganization of stress fields that resulted in basin inversion. The Cretaceous and Cenozoic beds, deposited above this regional erosional unconformity, were not affected by this tectonism.

There is an apparent disagreement about the age of this Juruá orogenic event. Whereas Caputo (1991) proposed a Late Jurassic age, Barros and Carneiro (1991) suggested a Triassic age. Many investigators, following the Barros and Carneiro (1991) interpretation, accept a Late Permian-Triassic age for the Juruá orogeny. The main objective of this paper is to discuss the age of this major geotectonic event.

1. Introduction

The Acre Basin, about 40,000 km² in area, is a small sedimentary basin located near the border between Brazil and Peru. It is separated from the Ucayali Basin on the western side by the high-angle, basement-involved Divisor reverse fault, and from the Solimões Basin on the eastern side by the Late Jurassic Envira Arch of deformed Precambrian basement rocks. The basin coalesces with the Marañon Basin to the northwest. The E-trending Paraguá Arch, caused by the Juruá megashear, divides the basin into the Jaquirana Trough in the north and the Central Trough in the south. The Solimões Basin, about 440,000 km² in area, is separated from the Marañon and Acre basins on its western margin by the Envira Arch and in the east from the Amazon Basin by the Purus Arch. The basin is bounded on the north by the Precambrian Guiana Shield and on the south by the Precambrian Brazilian Shield. The intrabasinal Carauari High separates the basin into a western Jandiatuba sub-basin and an eastern Juruá sub-basin. The Acre and Solimões, Madre de Dios, Ucayali, Marañon and other sub-Andean basins originally formed a single major basin that was later subdivided during various tectonic phases. Previous studies of this structural framework and tectonism were carried out in Brazil by Szatmari (1983), Caputo (1985, 1991), Porsche (1985), Arana et al. (1990), Oliveira (1994), Oliveira & Zalán (1997), Zalán (2004). Barros & Carneiro (1991), Zelasco (2010), and other investigators, addressed specific Peruvian basins, but the age of the Juruá tectonism was not well constrained.

2. Stratigraphy

The Acre sedimentary basin contains a Phanerozoic stratigraphic section up to 6000 m-thick, very similar to that of the Ucayali Basin, but less complete. In the Acre Basin, Ordovician to Devonian formations are unknown because exploration drilling has not penetrated the deepest depocenters, but seismic data indicate their presence.

The oldest section observed in outcrop and wells, the Apuí Formation (conglomerates, sandstones, thin shales and diamictites), correlates with the Mississippian Ambo Group of Peru and Bolivia.

Above, the Lower Permian Cruzeiro do Sul Formation comprises the same lithologies (limestones, shales and fossils) as the upper part of the Copacabana Group of Peru and Bolivia. The uppermost part of the Cruzeiro do Sul Formation is anoxic shale correlated with the Ene Formation of Peru.

The next section is the Rio do Moura Formation composed of brown sandstone and sandy siltstone, gray shale, and thin limestone beds of Late Permian age. It correlates with the Mitu Formation and Lower Pucará Formation.

The succeeding Juruá Mirim Formation is a red bed succession: sandstone, evaporites and red siltstone beds. This upper red siltstone unit is now designated the Batã Formation. There are two lava flows in the Juruá Mirim Formation, dated by the K-Ar method to 194 ± 12 Ma and 177 ± 8 Ma. The lower part of the Juruá Mirim is as old as Late Triassic, the evaporites possibly Jurassic, and the Batã Formation is of Middle to Late Jurassic age. The Lower Juruá Mirim stratigraphy is believed to correlate with part of the Pucará Formation, and the Batã Formation with the Jurassic Sarayaquillo Formation.

The next section comprises clastics of the Capanáua, Moa, Rio Azul and Divisor formations as old as Aptian to Campanian. The Cushabatay, Agua Caliente, Chonta and Vivian formations correlate with the Brazilian Cretaceous formations.

The Cenozoic section consists of the Ramon (green beds; Paleocene-Eocene?) and Solimões (red and gray beds; Oligocene?-Miocene) formations.

It appears that each formation has disconformable contacts, except for the anoxic shale (Ene) and Cruzeiro do Sul succession. The stratigraphy of the Solimões Basin is similar to that of the Acre Basin, except for the absence of the Triassic-Jurassic sedimentary section. In the Solimões Basin, lava flows are absent, but diabase dikes and sills as old as Late Triassic occur. The Peruvian Oriente, Acre and Solimões basins were uplifted during the Late Jurassic, and at the end of this event they were subjected to extensive peneplanation before deposition of Cretaceous strata. The Late Jurassic age of the Juruá orogeny is supported by magmatism, sedimentary petrography, seismic surveys, and structural studies.

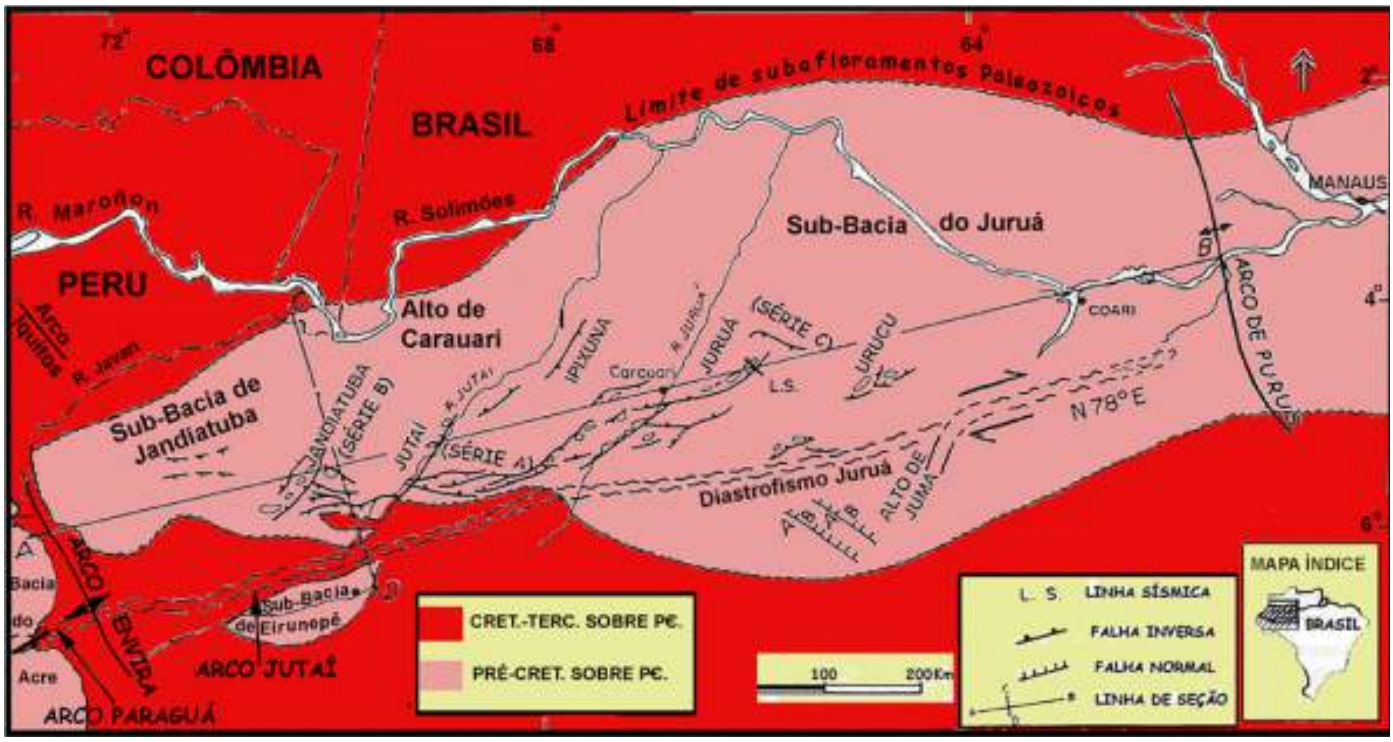

Figure 1. The location and structural framework map of Solimões and Acre basins with main structural features.

3. Magmatism

In the past, the diabase intrusions in the Solimões Basin were considered as old as 150, 180 and 210 Ma based on K-Ar dating, but Ar-Ar dating provided an age of ~204 Ma, suggesting a very short igneous event (Wanderley Filho et al., 2005). In the Acre Basin, younger lavas as old as 177 ± 8 Ma indicate a Middle Jurassic age for this magmatic event (Cunha, 2008). Juruá faults cut these basic igneous rocks in Acre and Solimões basins, so this tectonism should be younger than Triassic.

4. Sedimentary petrography

Based on authigenic illite K–Ar ages, two stages of illite authigenesis are observed in Carboniferous reservoirs in the Solimões Basin. According to Elias et al. (2007), the first is related to the voluminous Late Triassic basic magmatism (~204 Ma), and the second to Juruá stresses (~150 Ma).

5. Seismic surveys

Seismic lines in the Acre Basin show the Triassic-Jurassic sequence well-deformed and separated from the less-deformed Cretaceous strata by an angular unconformity. The Juruá tectonism affected Jurassic strata, indicating a post-Triassic age. The geological sketch of the seismic line 31-RL-183 (Fig. 2; from Zalán, 1997) shows tectonic tilting produced by the Juruá orogeny before Cretaceous sedimentation.

Zelasco (2010) presented an instructive seismic section in which the Contaya Arch in Peru was uplifted after deposition of the Upper Jurassic Sarayaquillo Formation and before the accumulation of Cretaceous strata. Also present in Zelasco´s section is a Triassic unconformity, possibly related to the breakup of Pangea and opening of the North Atlantic Ocean.

In the Ene Basin, the base-Cretaceous unconformity overlies stratigraphic units of different ages, including the Cabanillas Group, Ambo Group, Ene Formation, inferred Triassic units and the Sarayaquillo Formation, indicating that the same Late Jurassic tectonism affected the basin.

Flattening on the base-Cretaceous unconformity in the Huallaga Basin seismic lines (PARSEP, 2001) shows the tectonic deformation of the Sarayaquillo Formation below the Cretaceous unconformity. This Sarayaquillo deformation was caused by the Juruá orogeny. In a cross-section through the Shira Mountain (Perupetro sources), large-scale deformation of pre-Cretaceous formations is observed and is attributed to the Juruá orogeny (Perupetro, 2009). In Peru, this pre-Cretaceous orogeny is referred to as the Nevadan orogeny, after the Sierra Nevada and Klamath mountains of North America. However, the regional extent and geometry of the Nevadan structures in North America involved underthrusting of island-arc rocks on the west and significant crustal shortening in the central and eastern belts of California. These features suggest that the Nevadan orogeny resulted from the collision of the island arc (western belt) with an Andean-type arc (eastern belt) situated at the western edge of North America (Schweickert et al., 1984). For these reasons, it is better to use a South American local name for the Late Jurassic orogeny, with its unique characteristics.

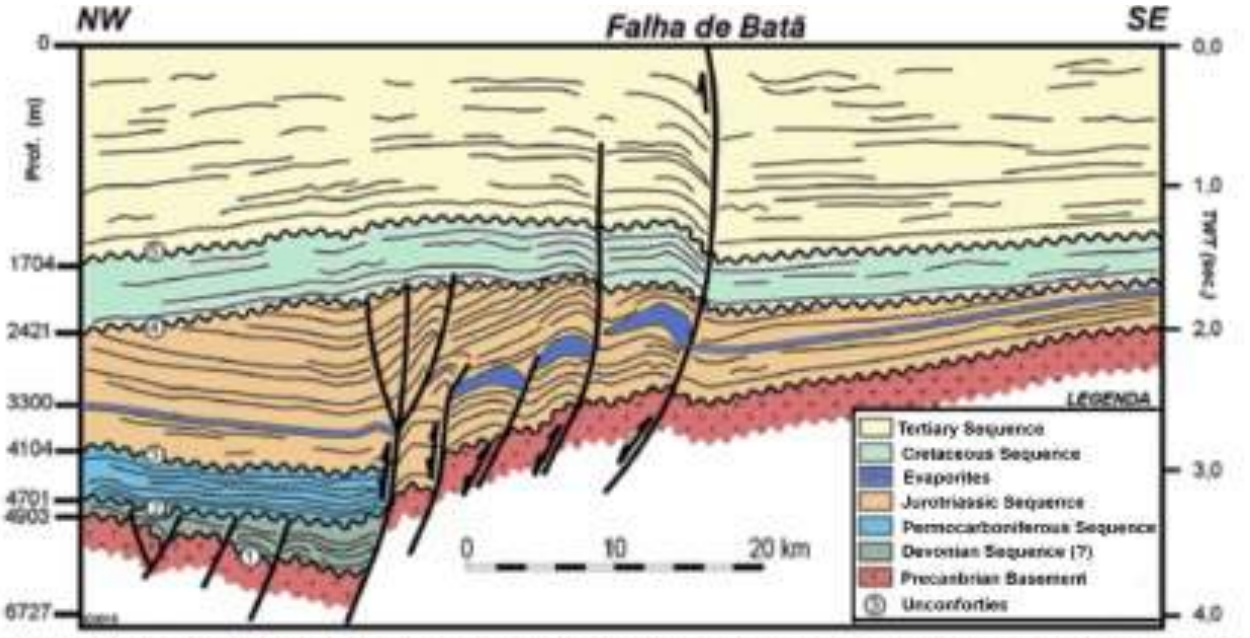

Figure 2 — Sketch of the seismic section 31-RL-183, in double time (vertical scale at right), from the Acre Basin. The vertical depth scale on the left is approximate, non-linear (it is dependent on the intervalar velocities of the sedimentary sequences) and is valid only for the northwest extremity of the line. Unconformities: (1) top of the crystalline basement, (2) Eo-Hercinian phase of the Hercinian Orogeny in South America (after Dalmayrac *et al* ., 1980, in Oliveira *et al* ., 1995), (3) neo-Hercinian phase of the Hercinian Orogeny in South America (after Dalmayrac *et al* ., 1980, in Oliveira *et al* ., 1995), (4) post Juruá Orogeny unconformity, (5) top of the Cretaceous. The harmonic folding of the unconformities (4) and (5) together with the cretaceous and tertiary strata, as well as the reactivation of the Batá Fault to the surface, reflect compressional tectonics related to the Quechua Phase of the Andean Orogeny (Miocene/Pliocene)(Oliveira *et al* ., 1995) Zalán, 1997.

6. Conclusions

A strong Late Jurassic diastrophism is responsible for the structural deformation observed in the Solimões and sub-Andean basins of North-Central South America. The Triassic age proposed by Barros and Carneiro (1991) for this Juruá orogeny is not appropriate. These authors were referring to a Triassic orogeny that is older and does not correlate with the Late Jurassic Juruá orogeny of Brazil.

Acknowledgements

I acknowledge Dr. Edgardo M. Latrubesse for useful improvements to this paper, and Dr. Anthony Tankard for constructive criticism and peer review of this manuscript.

References

Arana, J., Della Giustina, I.D., Vaz, P.T., Barcelos, C.A. 1990. Bacia do Acre, arcabouço estrutural sísmico. Manaus, PETROBRAS/DENOC/DINTER, Internal report, 7 p.

Barros, M.C., Carneiro, E.P. 1991. The Triassic Juruá orogeny and the tectono-sedimentary evolution of the Peruvian Oriente Basin. Exploratory implications. In*:* ACGGP, IV Simpósio Bolivariano: Exploración Petrolera en las Cuencas Subandinas, Bogotá, Memórias, trabajo 6, 44 p.

Caputo, M.V. 1985. Gênese do alinhamento estrutural do Juruá, Bacia do Solimões, Brasil. In: Simpósio Bolivariano sobre Exploración Petrolera en las Cuencas Subandinas. Asociación Colombiana de Geólogos y Geofísicos del Petroleo, Bogotá, Colombia, 1985.

Caputo, M.V. 1991. Solimões megashear: Intraplate tectonics in norhwestern Brazil. Geology, v. 19. p. 246–249.

Cunha, P.R. da C. 2007. Bacia do Acre. Boletim Geológico da Petrobras, Rio de Janeiro, v. 15, p. 207–215.

Elias, A.D., Ros, L.F. de, Mizusaki, A.M., Kawashita, K. 2007. Isotopic evidence on the diagenetic evolution of coastal sabkha reservoirs from the Solimões Basin, northern Brazil. Gondwana Research, v. 11, p. 553–567.

Oliveira, C.M.M. 1994. Estilos estruturais e evolução tectônica da Bacia do Acre. M.S. thesis, Escola de Minas de Ouro Preto, 2006.

Oliveira, C.M.M. de, Zalán, P.V., Alkmin, F.F. 1997. Tectonic evolution of the Acre Basin, Brazil. VI Simpósio Bolivariano, Exploracion petrolera en las cuencas Subandinas, Memórias, Cartagena, Colombia, v. 1, p. 46-65.

PARSEP, 2001. The Huallaga Basin and adjacent areas. The hydrocarbon potential of NE Peru: Huallaga, Santiago and Marañon basins.

Perupetro, 2009. Peruvian Ucayali Basin hydrocarbon potential: http://www.perupetro.com.pe/wps/wcm/connect/6f269d804f9af3be8b6a8bf15c7c1f2a/03-Ucayali+Basin+Hydrocarbon+Potential.pdf?MOD=AJPERES&lmod=1289945638&CACHEID=6f269d804f9af3be8b6a8bf15c7c1f2a&Ucayali .

Porsche, E. 1985. Tectônica da faixa de dobramentos do Juruá, Bacia do Alto Amazonas – Um modelo estrutural (M.S. thesis). Ouro Preto, Brazil, Universidade Federal de Ouro Preto, 124 p.

Schweickert, R.A., Bogen, N.L., Girty, G.H., Hanson, R.E., Mergerian, C. 1984. Timing and structural expression of the Nevadan orogeny, Sierra Nevada, California. Geological Society of America Bulletin, v. 95, p. 967-979.

Szatmari, P. 1983. Amazon rift and Pisco-Juruá fault: Their relations to the separation of North America from Gondwana. Geology, v. 2, p. 300-304.

Wanderley Filho, J., Melo, J.H.G. de, Fonseca, V.M.M. da, Machado, D.M. da C. 2005. Bacia do Amazonas. Fundação Paleontológica Phoenix, v. 6, n. 82, 6 p.

Zalán, P.V. 2004. Evolução fanerozoica das bacias sedimentares brasileiras. In: Mantesso-Neto, V., Bartorelli, A., Carneiro, C. dal Ré, and Brito-Neves, B.B. (Eds), Geologia do Continente Sul-Americano, Editora Beca, Brazil, Evolução da obra de Fernando Flávio Marques de Almeida, p. 595-612.

Zelasco, L.D.N. 2010. Tectonic evolution of the Contaya Arch, Ucayali Basin, Peru. M.S. thesis, University of Texas, USA.