Potential Shale Plays in Sub-Andean Basins of Peru*

Diego Timoteo[1]

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[1]Institute of Geosciences, University of Brasilia, Brasilia, Brazil (diego.timoteo.martinez@gmail.com)

Abstract

The growing importance of U.S. shale oil/gas resources is reflected in the worldwide extension of unconventional shale plays market. This fact has motivated its exploration and exploitation in South America; where the extensive exploitation of conventional hydrocarbons on the sub-Andean Basins added to the proven shale plays resources in Argentina (Tithonian-Berriasian Vaca Muerta Formation) and positive early exploratory assessments in Brazil (Devonian Jandiatuba Formation), Colombia and Venezuela (Turonian-Santonian La Luna Formation), Bolivia (Devonian Tomachi Formation) and recent evidence of gas shows in shales of Ucayali Basin (Devonian Cabanillas Formation), increase the exploration chances in the sub-Andean Basins of Peru.

The purpose of this study is to discuss Peru’s potential for shale plays exploration based on geological and geochemical keys: the organic content and type, thermal maturity, thickness, areal distribution, and present-day depth; other properties such as mineralogy, permeability, rock mechanics, and adsorption capacity are excluded from this presentation since their public knowledge is very limited or nonexistent. Preliminary results suggest very favorable potential for eight shale units within the Peruvian sub-Andean Basins.

Introduction

The sub-Andean foreland basins span the length of the Andes from Venezuela in the north to the southernmost tip of South America. All the major basins and many of the smaller basins are hydrocarbon bearing. The Marañon, Ucayali, and Madre de

Dios are the principal Peruvian Foreland Basins. Each has subsidiary basins, such as the Ene, Huallaga, and Santiago basins, where they have been deformed and partitioned in the foothills of the Andean fold and thrust belt. Up to date the Marañon Basin has a cumulative production over 1 billion bbl of oil, likewise Ucayali Basin has cumulated a production over 32 million bbl of oil, 201 million bbl of condensate and 1.7 tcf of gas. On the other hand several wells in the Peruvian Madre de Dios Basin have important oil test and shows; the most relevant is the Candamo-1X well, which after several DSTs (cumulate production test of 10.5×10^6 cfg/d) revealed a significant gas discovery. In addition 32.4° API oil was recovered at the Pando Field in Bolivia (20 million bbl of oil as potential resources).

Basin Setting

Late Cretaceous–Cenozoic orogenesis built the Andean fold and thrust belt as well as the flexural foreland basins. Compressive reactivation and inversion of the older basement-involved fault system dissected and partitioned the foreland basin into several depocenters. The sub-Andean foreland basins of Peru contain a sedimentary fill up to 10,000 m thick.

The Marañon Basin is located in the northeastern jungle of the upper Amazonas hydrographic system, it is the largest Peruvian sedimentary basin, occupying an area of 350,800 km^2, and has an asymmetric and N-S elongated shape with maximum subsidence to the West. It is bounded to the west by the sub-Andean thrust belt, to the east by the Iquitos Forebulge Arc, to the north by the Cutucú uplift and to the south by the Contaya High. However, geologically the Marañon Basin is part of a larger sub-Andean basin that extends into the Oriente Basin in Ecuador and the Putumayo Basin in Colombia.

Its tectonic setting has changed through time. During the Paleozoic (Ordovician-Early Permian) the basin area was part of a passive margin and had an intra-cratonic rift-setting (syn-rift to post-rift sag). During the Late Permian-Jurassic, a rift setting (syn-rift to post-rift stage) prevailed as a result of a back-arc extension related to a Permo-Triassic continental volcanic arc to the west. The area evolved into a convergent margin during the Cretaceous, starting probably in the Late Cretaceous a foreland basin setting. The present foreland basin outline was defined during the last phase of the Andean tectonic movements.

The sedimentary fill of the Marañon Basin ranges in thickness from 3,700 m to 10,000 m, with ages of sedimentary sequences from Early Paleozoic to Quaternary. The succession consists of Ordovician–Devonian marine shales deposited on Precambrian basement in a rift setting, the Carboniferous–Permian sequence were deposited in a post-rift sag setting, the Late Permian–Jurassic sequences in rift-post rift setting, and Cretaceous–Cenozoic sequences in a foreland setting.

Ucayali Basin is formed into a series of west dipping asymmetric lows by massive basement-involved east-verging thrusts. There are two principal depocenters, the West Ucayali Basin (or Pachitea Basin) and the East Ucayali Basin, which coalesce to the north.

The Ucayali Basin is bounded on the north by the Contaya High, on the west by the overthrusted Andean range, and on the south by the Fitzcarrald High that constricts the basin. This high is associated with a northeast-trending normal fault system of Paleozoic origin and with an abrupt change in the trend of the Andean Cordillera and associated faults. The sedimentary fill of the Ucayali Basin is similar to the Marañon Basin, varies in thickness from 1000 m to about 10,000 m, with ages of sedimentary sequences from early Paleozoic to Quaternary.

The Madre de Dios Basin is situated in southeastern Peru and extends into northern Bolivia, covering about 77,500 km^2 in Peru. It is bounded on the southwest by the Azulmayo Thrust, on the north and northeast by the Brazilian Shield, on the south and southeast by the Madidi Arch, and on the north and northwest by the Manu Arch. The tectonic setting of the basin evolved from a Paleozoic intra-cratonic basin into a late Mesozoic–Cenozoic Andean type foreland basin.

Sedimentary fill in the Madre de Dios Basin vary from about 1000 m to 7000 m total thickness, with ages ranging from early Paleozoic to Quaternary. The succession consists of Devonian–Permian marine shales and carbonates deposited on Precambrian basement during the intra-cratonic basin stage, the Devonian sequences were deposited in a rift setting, the Carboniferous-Permian in post-rift sags setting, and thin Cretaceous continental strata and Cenozoic molasses sequences were deposited during the foreland basin stage.

Only eleven wells have been drilled in this remote basin (including five in Bolivia), where exploration focuses on Paleozoic intervals in contrast to the basins farther north where the Mesozoic section is the major target.

Data Analysis and Preliminary Results

Marañon Basin is characterized by the presence of five organic-rich shales. Devonian Cabanillas shales in the SE part of the basin contain fair to very good organic-rich (TOC: 0.79–4.70 wt%) and kerogen types II and III, its samples are within condensate–wet gas window (Ro: 1.11–1.35) and reach some high values of thermal maturity (2.16 %Ro), and have variable thickness (185–430 m).

Carboniferous Tarma shales in the southern basin contain good organic-rich (TOC: 1.05–1.65 wt%) and kerogen type II/III, its samples range from late oil window to main gas window (Ro: 1.1–1.45%), and its thickness range from 18 to 254 m. Based on outcrop samples the Triassic-Jurassic Aramachay shales bear very good to excellent organic rich (TOC: 2–14 wt%) and kerogen type II, its samples range from early to main oil window (Ro: 0.67–0.89%), and its thickness range from 350 to 600 m.

Cretaceous Chonta shales show good to excellent organic-rich (TOC: 0.98–6.00 wt%) and kerogen types II and II/III, its samples range from immature to main oil window (Ro: 0.45–0.95%), and have variable thickness. The Oligocene Pozo shales contain poor to very good organic rich (TOC: 0.5–3.5 wt%) and kerogen types I and II, its samples range from early to main oil window, have a widespread areal distribution, and variable thickness (50–200 m).

Ucayali Basin is characterized by the presence of five organic-rich shales. Ordovician Contaya shales contain fair to very good organic-rich (TOC: 0.46–2.65 wt%) and kerogen type II/III?, its samples range from early oil window to dry gas window (Ro: 0.78–3.7%), it has variable thickness, and its areal distribution is evidenced by wells in the northern part of the basin while in the southern part is interpreted within isolated depocenters.

Cabanillas shales bear fair to very good organic-rich (TOC: 0.65–2.34 wt%), its original kerogen types was likely type II and II/III, its thermal maturity range from main oil window to dry gas window (Ro: 0.84–2.18%), have variable thickness (200–1000 m), and widespread distribution evidenced by wells and also mapped by seismic. Carboniferous Ambo shales show fair to excellent organic-rich (TOC: 0.6–9.0 wt%) and kerogen types II/III and III, its samples range from early oil window to dry gas window (Ro: 0.77–1.96%), have variable thickness (25–515 m), and widespread and patchy areal distribution in southern and northern basin respectively.

Permian Ene shales (Shinai Member) contain good to excellent organic-rich (TOC: 1.5–4.0 wt%) and kerogen types I/II, II and II/III, its thermal maturity range from early to late oil window (Ro: 0.56–1.05%), have variable thickness (70–100 m), and are predominantly preserved in depocenters of the southern basin. Aramachay shales contain fair to very good organic-rich (TOC: 0.53–2.96 wt%) and original kerogen was type II, its samples range from early oil window to condensate–wet gas window (Ro: 0.58–1.40%), have an important thickness (50–150 m), and it extends in the northern part of the basin.

Madre de Dios Basin is characterized by the presence of three organic-rich shales. Cabanillas shales contain good to very good organic-rich (TOC: 1.6–3.8 wt%) and kerogen types II/III and III, moderate to very high thermal maturity (Ro: 0.64–3.8%), and have variable areal distribution and thickness (100–600 m).

The Ambo shales bear very good to excellent organic-rich (TOC: 2.3–25 wt%), moderate thermal maturity (Ro: 0.4–0.76%), kerogen type III, and have variable thickness (100–200 m). Finally Ene shales (Shinai Member) show good to very good organic-rich (TOC: 2.5–5.6 wt%), kerogen types II and II/III, and variable areal distribution and thickness (70–100 m).

These preliminary results predominantly suggest very favorable shale gas potential for five shale units within the Ucayali Basin and shale oil/gas potential for three shale units within the Madre de Dios Basin. In the same way within the Marañon Basin has three shale units with very favorable shale oil potential and two shale units with shale gas potential.

Conclusions

Preliminary list of potential shale plays in Peruvian sub-Andean basins is composed of eight shale units: Contaya (Ordovician), Cabanillas (Devonian), Ambo (Carboniferous), Tarma (Carboniferous), Shinai (Permian), Aramachay (Triassic-Jurassic), Chonta (Cretaceous), and Pozo (Oligocene).

Continuous developments of knowledge from potential shale plays in Peru will allow re-evaluation of the current limited economic-logistic viability.

Peruvian sub-Andean Basins have a sufficient amount of geologic and geophysical data for unconventional resource analysis.

It is necessary to compile information corresponding to reservoir parameters: clay mineralogical composition, permeability, pressure, and adsorption capacity to thereby generate a more robust integrated interpretation of potential unconventional reservoirs type shale plays.

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