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RESEARCH PAPER

Division and resources evaluation of hydrocarbon plays in Putomayo-Oriente-Maranon Basin, South America

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Abstract: Based on the latest seismic, logging and reservoir reserve data, through hydrocarbon accumulation elements analysis, the play of Putomayo-Oriente-Maranon (POM) basin, South America is divided. The POM basin was divided into 9 plays, and the undiscovered petroleum resources of these plays are estimated as 11.0×10^8t by using subjective probability method and scale sequential method; and the total undiscovered petroleum resources of the Hollin sandstone play, Napo T member sandstone play, Napo U member sandstone play and Napo M1 member sandstone play are 10.4×10^8t (accounting for 94% of the whole basin). Based on hydrocarbon accumulation factors analysis, including source rock, reservoir, trap, migration, seal and preservation, the plays have been evaluated and ranked by using double factors method of resources-geological risks, including four class I plays, two class II and three class III plays. Favorable exploration areas have been optimized by using "play area overlaying" method: the central part of the basin is the class I favorable area.

Key words: South America; Putomayo-Oriente-Maranon basin; play; resources evaluation; favorable exploration area

1. Background and problems faced

The Putumayo-Oriente-Maranon basin (POM basin for short), with an area of 39×10^4 km^2, is a typical South America Sub-Andes foreland basin located in Columbia, Ecuador and Peru (Fig. 1). The POM basin is subdivided into three sub-basins, Putumayo basin in Columbia, Oriente basin in Ecuador and Maranon basin in Peru by the country boundary[1–2]. About 569 reservoirs had been discovered (562 oil reservoirs and 7 gas reservoirs) with recoverable reserves of more than 17.9×10^8 t in POM basin (about 17.1×10^8 t oil) by the end of 2015[3–5]. The discovered recoverable reserves in Putumayo, Oriente and Maranon sub-basin are 1.2×10^8 t, 13.8×10^8 t and 2.9×10^8 t respectively.

Lots of studies on sedimentary[9], structural evolution[10–11], petroleum geology[12–16], accumulation[17] and petroleum resources assessment[18–20] of single sub-basin have been done by domestic and oversee researchers, but as the sub-basins are divided by the country boundary rather than geological boundary, the research on single sub-basin can't reflect the general geological features of POM basin, obviously. USGS had predicted the oil and gas resources potential of POM basin twice by taking the petroleum system as assessment unit[21–22], but the parameters used in assessment were not published. Since 2011, the new round exploration of POM basin has collected several 3D seismic surveys and lots of well data, with dozens of reservoirs discovered. Consequently, it's urgent to re-evaluate resource potential of POM basin to better guide basin petroleum exploration. Fortunately, we have followed the latest progress of POM basin closely for years by taking part in exploration potential evaluation of several blocks in POM basin[17–18, 23]. In this study, by using the latest seismic data, logging and new discovered oil and gas reserves data, based on comprehensive analysis of accumulation elements, the basin plays have been divided centering on the reservoir, undiscovered recoverable resources of POM basin have been estimated by taking play as basic unit, favorable plays and favorable exploration area have been sorted out by using double factors method of resources-geological risks and play area overlaying method.

2. The petroleum geology

POM basin, steep in the west and gentle in the east, is a typical asymmetric foreland basin[1,8,15]. The basin is bounded by sub Andes thrust belt in west (Fig. 1), gradually overlaps to Guyana shield to the east, shares the Vaupés and Macarena uplift with Llanos basin in the north, and Contaya uplift with Ucayali basin in the south. From west to east, there develops Sub Andes thrust belt, fore deep zone and slope belt in order

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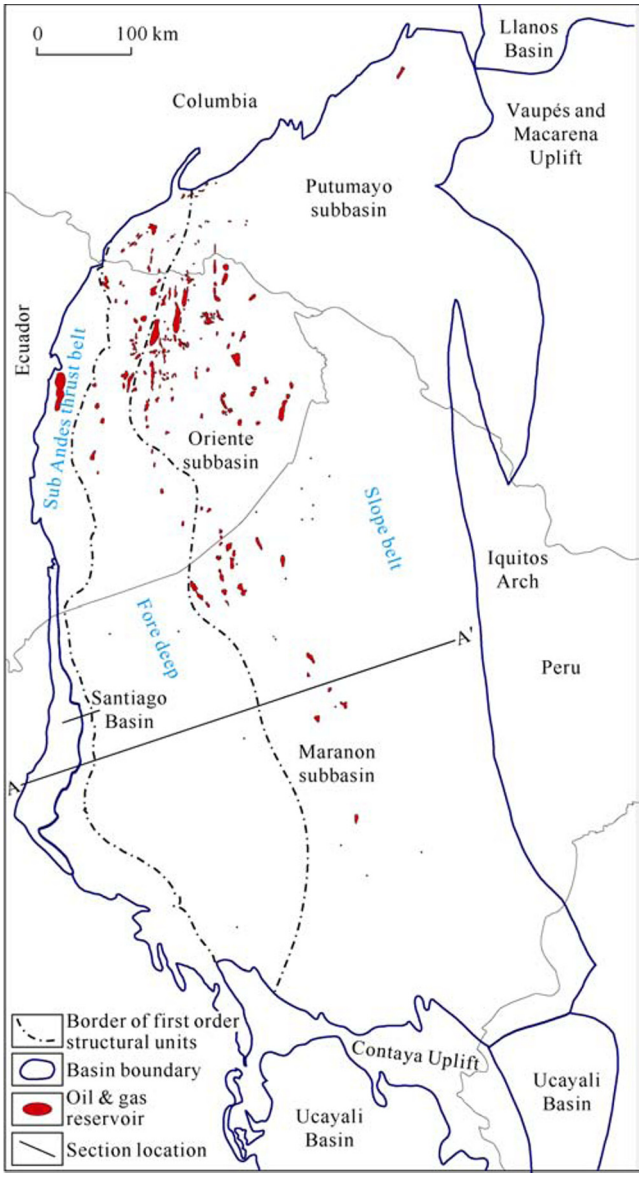

Fig. 1. Structural units and oil&gas reservoir distribution of POM basin (Modified from references [1, 6–8]).

in the basin (Fig. 2), in which the slope belt is where most discovered oil and gas reservoirs are, with Amazon rain forest surface[15]. The POM basin has gone through three evolution stages of pre-Late Paleozoic marginal Craton basin, Mesozoic rift basin and Cenozoic foreland basin[15] and two "marine-terrestrial" cycles[24]. The Paleozoic mainly consists of marine sediments with volcano rock on top in some areas; the Mesozoic is dominated by marine- terrestrial sediments; while in the Cenozoic, the whole basin was covered by fluvial-delta sediments. There are three sets of source rocks in the basin: Triassic-Jurassic Pucara Group, Devonian Cabanillas Group and Cretaceous Napo Formation, in which, the marine black shale of Napo Formation is the most important source rock, with type II and III kerogen, max TOC of 6.6%, average TOC of 2.5%[6,25–26]. The Napo source rock located in the present western basin boundary reached hydrocarbon generation peak at early-middle Eocene, while the Napo source rock in Napo uplift reached generation and expulsion peak in Neogene. The main reservoirs in the basin are marine- terrestrial sandstone of Cretacesous Hollin Formation and Napo Formation and fluvial-delta sandstone of Paleogene Basel Tena Formation[27–28]. The Tena mudstone is the regional caprock, and interlayer mudstone of Cretaceous Napo Formation also is an important seal (Fig. 3). There mainly develop low relief structural traps and structural-lithogical traps in the eastern slope belt[1,17–18,27–28].

3. Play division

3.1. Play division

Play refers to a group of perspective traps or reservoirs in the same reservoir with similar lithology under similar geological conditions. These traps or reservoirs are consistent in reservoir layer, reservoir lithology and reservoir-cap combination, and same source rock is not the necessary condition for play division[29–33]. Therefore, resources assessment centering on play has great guiding significance for selecting exploration layer and favorable exploration area.

The POM basin mainly has Silurian-Devonian sandstone reservoirs, Jurassic sandstone reservoirs, Cretaceous sandstone reservoirs and Tertiary sandstone reservoirs etc, and Cretaceous sandstones are the major reservoirs in most oilfields there. The Cretaceous reservoirs can be subdivided into

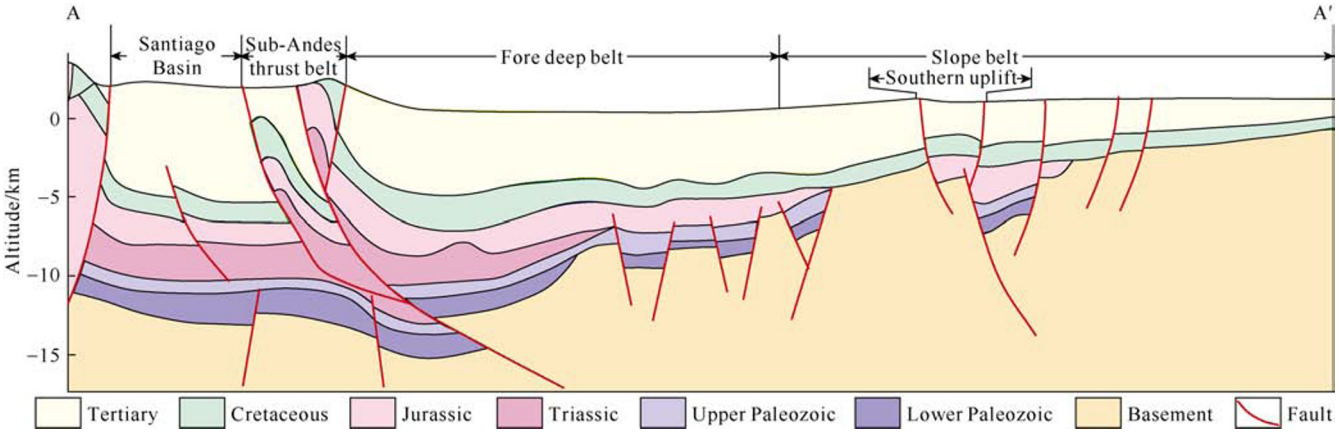

Fig. 2. EW strucural cross-section across POM basin (see Fig. 1 for section location).