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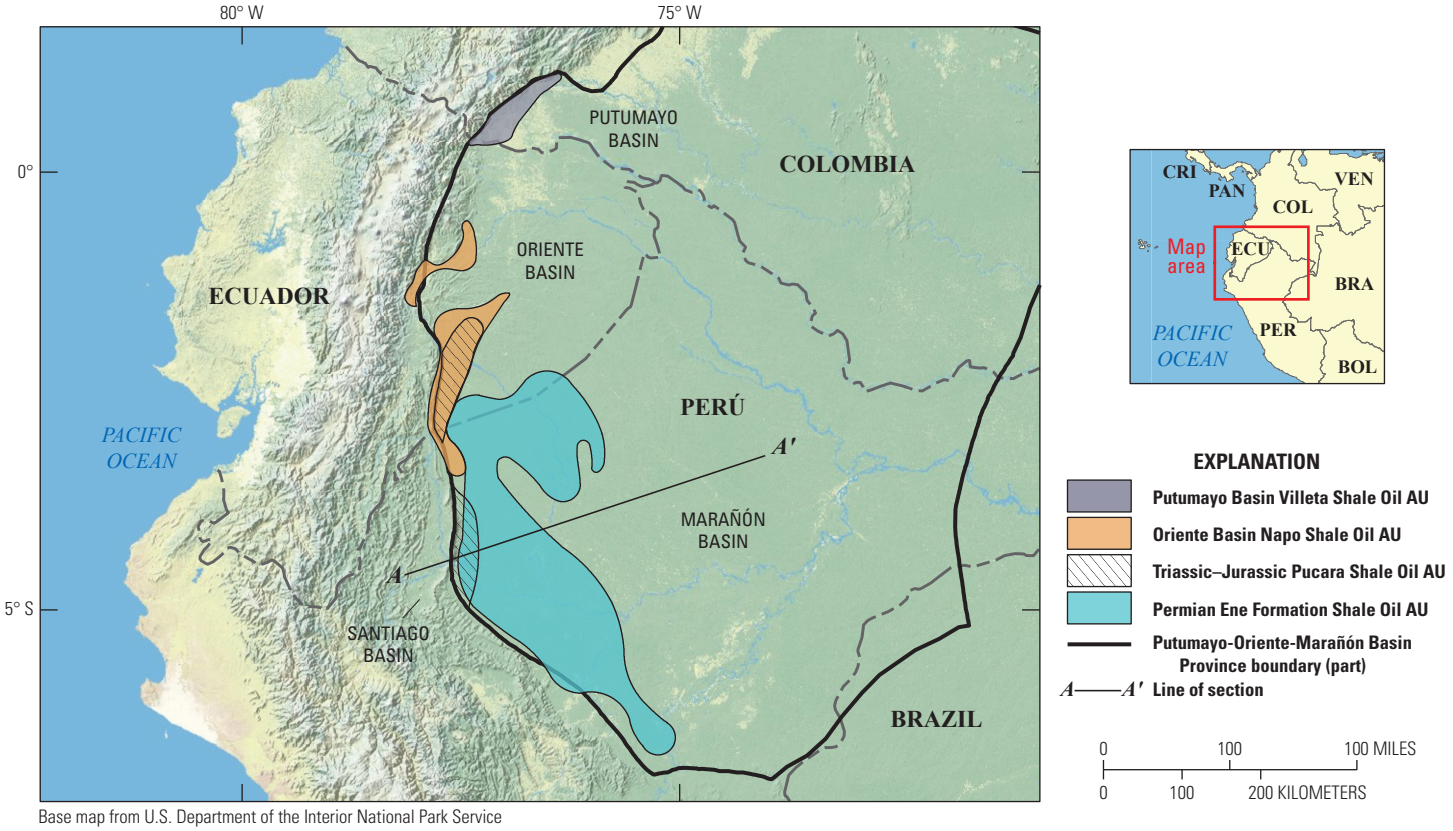
National and Global Petroleum Assessment

Assessment of Continuous Oil and Gas Resources of the Putumayo-Oriente-Marañón Basin Province of Colombia, Ecuador, and Perú, 2018

Using a geology-based assessment methodology, the U.S. Geological Survey estimated undiscovered, technically recoverable mean resources of 1.1 billion barrels of oil and 793 billion cubic feet of gas in the Putumayo-Oriente-Marañón Basin Province of Colombia, Ecuador, and Perú.

Introduction

The U.S. Geological Survey (USGS) quantitatively assessed the potential for undiscovered, technically recoverable continuous (unconventional) shale-oil and associated gas resources in the Putumayo-Oriente-Marañón Basin Province (fig. 1). The development of several petroleum systems in this basin is related to the tectonic history of the western margin of South America (Wolaver and others, 2015; Calderon and others, 2017). Back-arc extension in the Permian and Early Triassic formed rift basins with synrift deposits that include organic-rich shales of the Permian Ene Formation (Boekhout and others, 2018). In the Triassic and Jurassic, back-arc marine conditions led to the deposition of organic-rich, carbonate-based marine shales of the Pucara Formation (Baby and others, 2006; Chalco and Valencia, 2008; Yinfu and others, 2010). In the Late Cretaceous, a passive margin existed along a large portion of the central and northwestern margin of South America, where organic-rich shales of the La Luna Formation and equivalents such as the Villeta Shale and Napo Shale were deposited. Renewed subduction in the Paleogene led to the formation of a complex fold and thrust belt and an adjacent foreland basin on the former passive margin (fig. 2). As sediments accumulated in the Paleogene foreland basin, organic-rich shales of Permian, Triassic–Jurassic, and Late Cretaceous age reached thermal maturity for oil generation. Following generation, long-distance migration of oil took place from west to east in the Paleogene foreland, where source rocks are thermally immature. In the



Base map from U.S. Department of the Interior National Park Service

Figure 1. Map showing the location of the four assessment units (AUs) in the Putumayo-Oriente-Marañón Basin Province of Colombia, Ecuador, and Perú. Province boundary is from Klett and others, 1997. The three basin names (Putumayo, Oriente, and Marañón) reflect country-specific nomenclature.

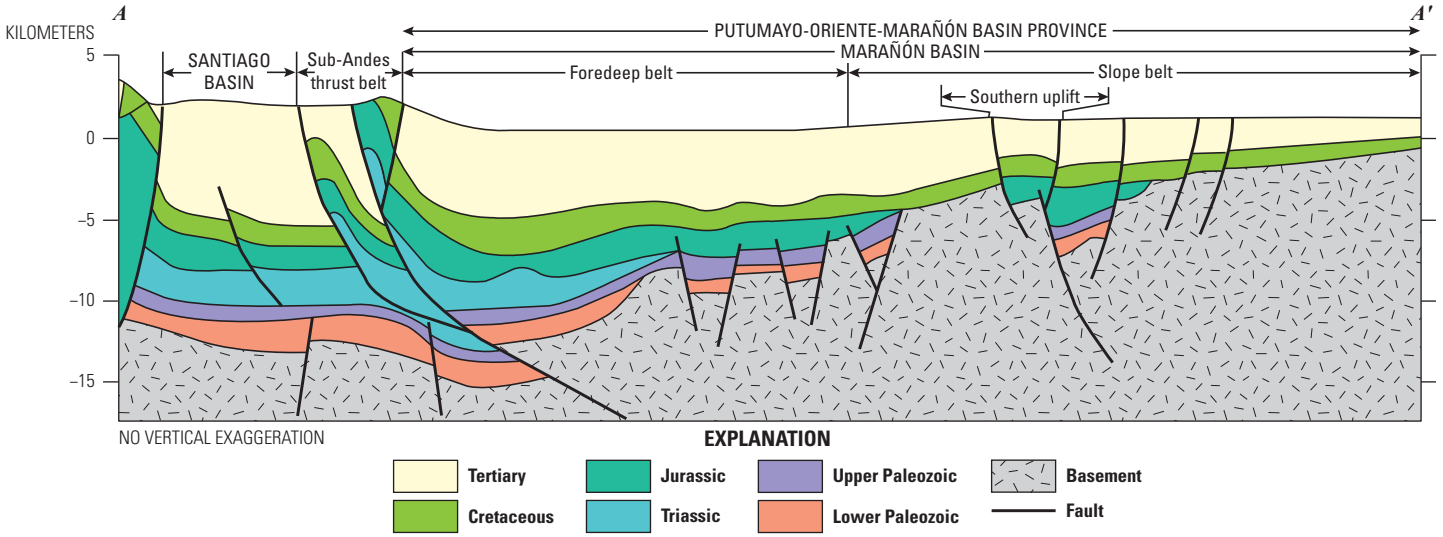


Figure 2. Structural cross section across the Marañón Basin, Perú (starting at the Santiago Basin). The assessment units in this study are located along the western part of the foredeep belt (from Zhongzhen and others, 2017).

Neogene, the Cordillera Oriental fold and thrust belt developed east of the Paleogene structures, effectively segmenting the older foreland (Jacques and others, 2000; Wolaver and others, 2015; Boekhout and others, 2018). The area of the Neogene foreland thus contains only limited areas of thermally mature source rock compared to the Paleogene foreland. Much of the thermally mature source rock resides in basins west of the Cordillera Oriental (Dashwood and Abbotts, 1990).

Total Petroleum Systems and Assessment Units

For continuous oil resources, the USGS defined an Upper Cretaceous Total Petroleum System (TPS) with a Putumayo Basin Villeta Shale Oil Assessment Unit (AU) and an Oriente Basin Napo Shale Oil AU, a Triassic–Jurassic Pucara TPS with a Triassic–Jurassic Pucara Shale Oil AU, and a Permian Ene Formation TPS with a Permian Ene Formation Shale Oil AU. The AUs correspond to those areas that are interpreted to have (1) thermally mature source rocks, (2) source rocks with greater than 2 weight-percent total organic carbon (TOC), and (3) greater than 15 meters of viable source rock. Synrift shales of the Permian Ene Formation contain Type I and Type II kerogen, have TOC values of as much as 6 weight percent, and are as much as 600 meters thick (Mathalone and Montoya, 1995; Jacques and others, 2000; Brisson and others, 2010; Timoteo, 2015; Calderon and others, 2017). Triassic–Jurassic Pucara Formation shales contain Type II kerogen, have TOC values of as much as 14 weight percent, and are as much as 2,000 meters thick (Perupetro, 2003; Yinfu and others, 2010; Calderon and others, 2017). Upper Cretaceous Villeta Formation and Napo Formation shales contain Type II and Type IIS kerogen, have TOC values of as much as 12 weight percent, hydrogen index values of as much as 580 milligrams of hydrocarbon per gram of organic carbon, and are as much as 800 meters thick (Pinilla and Kairuz, 2006; Chalco and Valencia, 2008; Mancilla and others, 2008; Tocco and Hermoza, 2009; Timoteo, 2015; Calderon and others, 2017). These organic-rich shales have only reached a maximum thermal maturity of peak-oil generation in the western part of the present foreland of the Putumayo-Oriente-Marañón Basin Province. Uncertainty in the assessment is largely related to defining the areas of thermally mature source rocks with greater than 2 weight percent TOC (Baby and others, 2006; Barragan and others, 2013) and to the retention of oil within the shales following Neogene deformation.

Assessment input data are summarized in table 1. Input data for drainage areas, success ratios, and estimated ultimate recoveries are taken from geologic analogs in the United States.

Table 1. Key input data for four assessment units (AUs) in the Putumayo-Oriente-Marañón Basin Province of Colombia, Ecuador, and Perú.

[AU, assessment unit; %, percent; EUR, estimated ultimate recovery per well; MMBO, million barrels of oil. Well drainage area, success ratio, and EUR are defined partly using U.S. shale-oil analogs. Shading indicates not applicable]

Assessment input data—Continuous AUs	Putumayo Basin Villeta Shale Oil AU				Oriente Basin Napo Shale Oil AU			
	Minimum	Mode	Maximum	Calculated mean	Minimum	Mode	Maximum	Calculated mean
Potential production area of AU (acres)	200	402,500	805,000	402,567	200	1,327,000	2,655,000	1,327,400
Average drainage area of wells (acres)	80	120	160	120	80	120	160	120
Success ratio (%)	10	50	90	50	10	50	90	50
Average EUR (MMBO)	0.01	0.06	0.2	0.067	0.01	0.06	0.2	0.067
AU probability	1.0				1.0			
Assessment input data—Continuous AUs	**Triassic–Jurassic Pucara Shale Oil AU**				**Permian Ene Formation Shale Oil AU**			
	Minimum	**Mode**	**Maximum**	**Calculated mean**	**Minimum**	**Mode**	**Maximum**	**Calculated mean**
Potential production area of AU (acres)	200	1,005,500	2,011,000	1,055,567	200	3,500,000	13,975,000	5,825,067
Average drainage area of wells (acres)	80	120	160	120	80	120	160	120
Success ratio (%)	10	50	90	50	10	30	70	36.7
Average EUR (MMBO)	0.01	0.04	0.1	0.043	0.01	0.04	0.1	0.043
AU probability	1.0				0.6			

Undiscovered Resources Summary

The USGS quantitatively assessed shale-oil and associated gas resources in four continuous assessment units (table 2) in the Putumayo-Oriente-Marañón Basin Province of Colombia, Ecuador, and Perú. For undiscovered, technically recoverable continuous resources, the mean totals are 1,109 million barrels of shale oil (MMBO), or 1.1 billion barrels of oil, with an F95–F5 fractile range from 134 to 3,112 MMBO; 793 billion cubic feet of associated gas (BCFG) with an F95–F5 fractile range from 86 to 2,282 BCFG; and 3 million barrels of natural gas liquids (MMBNGL) with an F95–F5 fractile range from 0 to 9 MMBNGL. Of the mean estimate of 1,109 MMBO, about 57 percent (634 MMBO) is in the Triassic–Jurassic Pucara Shale Oil AU and Permian Ene Formation Shale Oil AU, and 43 percent (475 MMBO) is in the Putumayo Basin Villeta Shale Oil AU and the Oriente Basin Napo Shale Oil AU.

Table 2. Results for four assessment units (AUs) in the Putumayo-Oriente-Marañón Basin Province of Colombia, Ecuador, and Perú.

[MMBO, million barrels of oil; BCFG, billion cubic feet of gas; NGL, natural gas liquids; MMBNGL, million barrels of natural gas liquids. Results shown are fully risked estimates. F95 represents a 95-percent chance of at least the amount tabulated; other fractiles are defined similarly. Fractiles are additive under the assumption of perfect positive correlation. Shading indicates not applicable]

Total petroleum systems and assessment units (AUs)	AU probability	Accumulation type	Total undiscovered resources											
			Oil (MMBO)				Gas (BCFG)				NGL (MMBNGL)			
			F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
Upper Cretaceous Total Petroleum System														
Putumayo Basin Villeta Shale Oil AU	1.0	Oil	22	91	267	111	13	54	162	67	0	0	1	0
Oriente Basin Napo Shale Oil AU	1.0	Oil	73	302	869	364	42	179	529	219	0	1	2	1
Triassic–Jurassic Pucara Total Petroleum System														
Triassic–Jurassic Pucara Shale Oil AU	1.0	Oil	39	156	397	179	31	124	323	143	0	1	1	1
Permian Ene Formation Total Petroleum System														
Permian Ene Formation Shale Oil AU	0.6	Oil	0	282	1,579	455	0	223	1,268	364	0	1	5	1
Total undiscovered continuous resources			**134**	**831**	**3,112**	**1,109**	**86**	**580**	**2,282**	**793**	**0**	**3**	**9**	**3**

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The original authors' diacritical mark usage varies for Marañón and Perú in this "References Cited" section.

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For More Information

Assessment results are also available at the USGS Energy Resources Program website at https://energy.usgs.gov.

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