The history of hydrocarbon exploration in Panama

La historia de la exploración de hidrocarburos en Panamá

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ABSTRACT

This article presents the history of hydrocarbon exploration in Panama and the scientific contribution that it made to the geological knowledge of Panama. The thirteen sedimentary basins—eight of which have been drilled, though only three in significant detail—include forearc, foreland, interarc, and backarc basins of late Cretaceous to Cenozoic age, associated with the Panama volcanic arc. Additionally, strike-slip pull-apart basins have formed as a result of the collision between the Panama Arc and the Northern Andes Block of the South American Plate since the Miocene. Panama has had more than one century of oil and gas exploration since 1912 but has never had any commercial production, and there are no established, economically recoverable reserves. Exploration originally targeted natural oil seeps. Hydrocarbon exploration took place in five stages: 1) an initial period of onshore exploration (1912-1928); 2) post-World War Two revival in onshore exploration (1945-1949); 3) an onshore exploration peak (1953-1962); 4) offshore shallow water exploration (1969-1991); and 5) recent offshore shallow water exploration, but with no drilling (2001-2017). Thirteen wells discovered oil and/or gas shows out of a total of 36 wells that were drilled between 1919 and 1989. The majority of the wells were drilled onshore. Eight wells were drilled offshore in shallow water, comprising five in the Gulf of Panama and three in the Caribbean and Bocas del Toro. Exploration was driven by the global economy and oil price, advances in exploration and drilling technology, and hydrocarbon legislation.

Keywords: Panama, hydrocarbon exploration, oil and gas shows, exploration history, oil wells.

RESUMEN

Este artículo presenta la historia de la exploración de hidrocarburos en Panamá y el aporte científico que hizo al mapa geológico y al conocimiento de Panamá. Las trece cuencas sedimentarias —ocho de las cuales han sido perforadas, aunque solo tres con detalle— incluyen cuencas de antearco, antepaís, interarco y trasarco, de edad Cretácico tardío a Cenozoico, relacionadas con el arco volcánico de Panamá. Asimismo, se identifican cuencas de desgarre de rumbo asociadas a la colisión del arco de Panamá con el Bloque Andino del Norte de la Placa Sudamericana, ocurrida desde el Mioceno. Panamá ha tenido más de un siglo de exploración de petróleo y gas desde 1912, pero nunca ha tenido ninguna producción comercial y no hay reservas establecidas y económicamente recuperables. La exploración inicial se enfocó en los derrames naturales de petróleo. La exploración de hidrocarburos se llevó a cabo en cinco etapas: 1) un período inicial de exploración en tierra (1912-1928); 2) un resurgimiento de la exploración en tierra después de la Segunda Guerra Mundial (1945-1949); 3) un pico de exploración en tierra (1953-1962); 4) exploración en aguas someras en alta mar (1969-1991); y 5) exploración reciente en aguas someras en alta mar, pero sin perforación (2001-2017). Trece pozos descubrieron indicios de petróleo y/o gas de un total de 36 pozos que se perforaron entre 1919 y 1989. La mayoría de los pozos se perforaron en tierra. Ocho pozos se perforaron en altamar, en aguas someras, que comprenden cinco en el golfo de Panamá y tres en el Caribe y Bocas del Toro. Las etapas de exploración fueron motivadas por la economía global y el precio del petróleo, avances en la tecnología de exploración y perforación, y la legislación de hidrocarburos.

Palabras clave: Panamá, exploración de hidrocarburos, indicios de petróleo y gas, historia de exploración, pozos petrolíferos.

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1. Introduction

This article presents the history of the century-long search for petroleum in Panama, both onshore and offshore, within its geological context. It is intended to be a companion paper to my previous articles on the history of mining and mineral exploration in Panama (Redwood, 2020b) and the mineral deposits of Panama (Redwood, 2020c). While the search for petroleum is a commercial activity, it is also part of the story of the geological mapping of the isthmus. As a result of this exploration, as well as the studies of the canal and other possible canal routes, the geology of the sedimentary basins of Panama is much better known than that of the volcanic arcs. Thus, petroleum exploration made a scientific contribution to the geological knowledge of Panama.

The article also includes, where documented, the stories of some people and communities involved. The Darien writer, Teodoro E. Méndez, described the petroleum exploration in the province of Darien (Aparicio, 1999; Méndez, 2004). More recently, Raúl E. Forde told the story of the remote village of Garachiné in Darien, where oil was first discovered in Panama (Forde, 2007). Stories about oil exploration in the province of Bocas del Toro were shared by Clyde S. Stephens, a scientist and historian who has lived there for more than six decades (Heckadon-Moreno, 2011; Stephens, 2008, 2023).

2. Sources of data

Hydrocarbon exploration in Panama is described by Shelton (1952), Quirós-Ponce (1975), Sossa (1981), González (1984), Aparicio (2003), and Samudio (2011). The narrative has been enriched with information from various sources, including press coverage, mineral yearbooks, company press releases and annual reports, scientific publications, and specialized reports. This is further complemented by the author's thirty years of experience in mineral and hydrocarbon exploration in Panama.

The location of the well logs, reports, seismic surveys, gravity surveys, and magnetic surveys is in the data room of the General Directorate of Hydrocarbons of the National Secretariat of Energy, in Panama City. It is not known which service companies carried out the original well logging and downhole surveys. Many papers have used seismic surveys and well logs as cited in the text (*e.g.*, Mann and Kolarsky, 1995; Coates *et al.*, 2004; Barat *et al.*, 2014).

3. Chronology of hydrocarbon exploration

Hydrocarbon exploration in Panama took place in five stages:

1. Initial period of onshore exploration, 1912-1928.
2. Post-World War Two onshore exploration revival, 1945-1949.
3. Onshore exploration peak, 1953-1962.
4. Offshore shallow water exploration, 1969-1991.
5. Recent offshore shallow water exploration, with no drilling, 2001-2017.

Seismic surveys were carried out between 1938 and 2017 (Table 1). Thirty-six exploration wells were drilled between 1917 and 1989 (Figure 1, Table 2).

4. Hydrocarbon legislation

Hydrocarbon concessions were originally covered by a mining law. Upon its establishment in 1903, the Republic of Panama adopted the Colombian mining code from 1875 and 1887, subsequently updated by Panamanian legislation in 1904 and 1916. Petroleum exploration, initially spurred by the 1953 Hydrocarbons Law, faced a setback with the 1964 Mineral Resources Code, halting it for ten years until special contract laws provided a solution. Subsequently, a new Hydrocarbons Law

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Table 1. Seismic surveys carried out in Panama (modified from González, 1984).

Year	Company	Contractor	Area	Line km
1938	Sinclair Oil		Colon Island	
1957	Delhi Petrolera	NAMCO International Inc..	Upper Chucunaque	
1958	Corporación Petrolera		Laguna Chiriqui	
1969	Mobil	Petty Ray	Gulf of Panama	240
1971	Mobil	Digicon	Gulf of Panama	668
1971	Oceanic Exploration	Petty Ray	Gulf of Panama	1,700
1972	Oceanic Exploration	Western Geophysical	Gulf of Panama	912
1971	Texaco	Seismic Exploration International S.A.	Gulf of Chiriqui	500
1971, 1975, 1976	Texaco		Gulf of Mosquitos	2,334
1982	Sossa Petroleum	Petty Ray	Gulf of San Miguel	227
1987-1988	Idria Oil & Gas		Garachiné, Gulf of Panama	
2017	Panama Government	GX Technology Corp. (ION Geophysical Corp.)	Caribbean spec survey	9,000

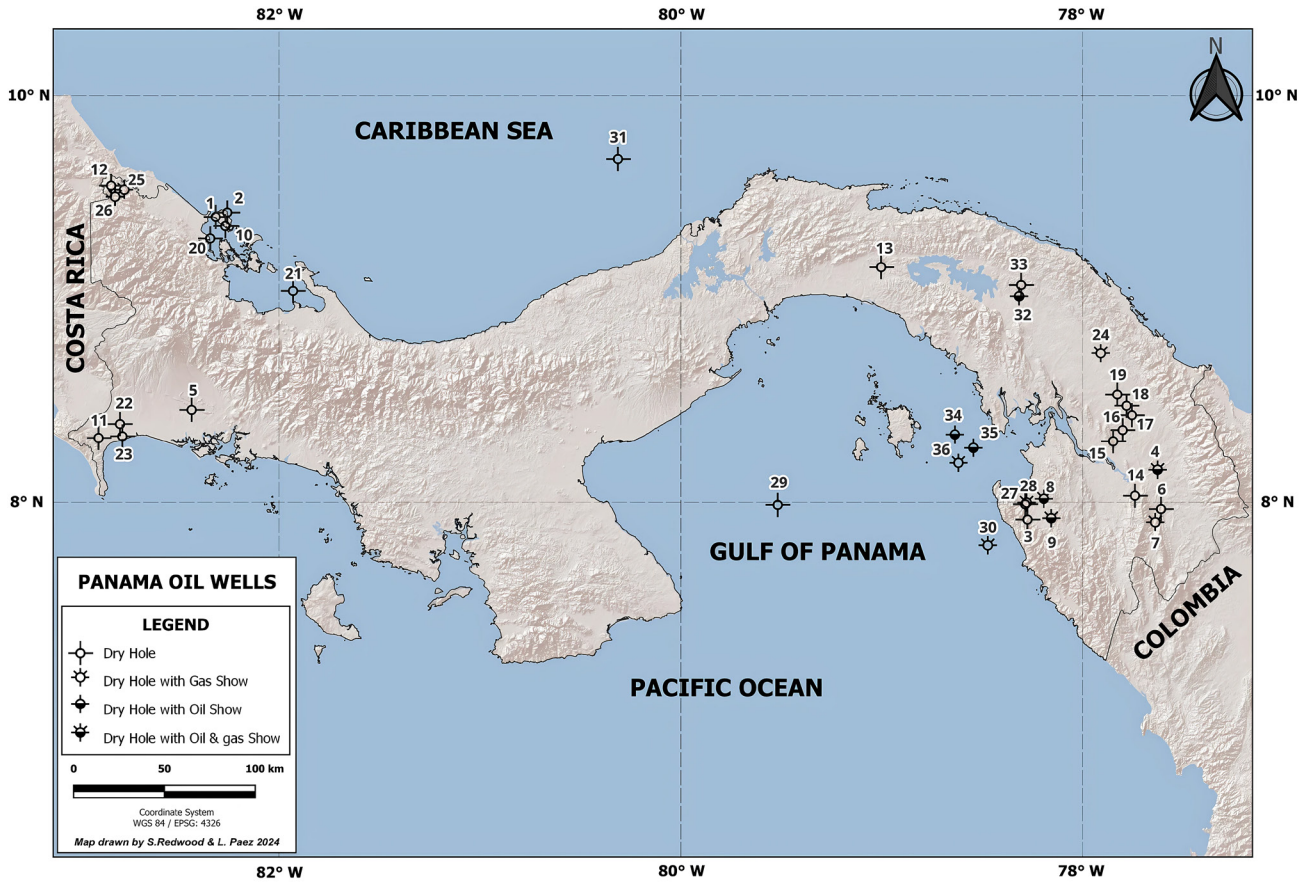

Figure 1 Map of the exploration wells drilled in Panama, 1919-1989 (modified from Quiros-Ponce, 1975). See Table 2 for the list of well numbers.

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Table 2. List of exploration wells drilled in Panama.

Number	Company	Well	Feet	Meters	Year	Location	Result
1	Sinclair Panama Oil Company	Colon No. 1 (Big Bight No. 1)	1,625	495	1919	Bocas del Toro	
2	Sinclair Panama Oil Company	Colon No. 2 (Big Bight No. 2)	3,325	1,014	1923	Bocas del Toro	
3	Gulf	Garachiné No. 1	3,332	1,016	1924	Darien	
4	Sinclair Panama Oil Company	Yape No. 1	3,503	1,068	1925	Darien	Oil and gas shows last 200 ft.
5	Texas	Chiriqui No. 1	3,862	1,177	1925	Chiriqui	
6	Sinclair Panama Oil Company	Capeti No. 1	995	303	1926	Darien	Well lost
7	Sinclair Panama Oil Company	Capeti No. 2	3,300	1,006	1926	Darien	Gas shows
8	Gulf	Garachiné No. 2	3,069	936	1926	Darien	Oil and gas shows
9	Gulf	Garachiné No. 3	4,984	1,520	1928	Darien	Oil and gas shows
10	Sinclair Panama Oil Company	Bocas del Toro No. 1	8,621	2,628	1948	Bocas del Toro	
11	Sinclair Panama Oil Company	Corotu No. 1 (1949) (*Corotú No. 1A)	9,715 (*9,320)	2,962 (*2,841)	1949	Chiriqui	
12	Union Oil	Yorkin No. 1	5,500	1,677	1956	Bocas del Toro	
13	Corporación Petrolera	Hato Bayano No. 1	1,648	502	1956	Panama	
14	Petrolera Golfo Darien	El Real No. 1	1,651	503	1956	Darien	
15	Delhi Petrolera	Chucunaque No. 1	1,196	365	1957	Darien	
16	Delhi Petrolera	Chucunaque No. 2	1,660	506	1957	Darien	
17	Delhi Petrolera	Chucunaque No. 3	1,432	437	1958	Darien	
18	Delhi Petrolera	Chucunaque No. 4	1,288	393	1958	Darien	
19	Delhi Petrolera	Chucunaque No. 5	800	244	1958	Darien	
20	Champlin Oil	Almirante No. 1	6,678	2,036	1958	Bocas del Toro (offshore)	
21	Champlin Oil	Anita Bay No. 1	9,537	2,908	1958	Bocas del Toro (offshore)	
22	Petrolera Chiricana	Corotú No. 1 (1958) (*Corotú No. 1A)	1,661 (*8,606)	506 (*2,623)	1958	Chiriqui	
23	Petrolera Chiricana	Corotú No. 2 (*Corotú No. 1B)	1,367 (*1,660)	417 (*506)	1959	Chiriqui	
24	Delhi Petrolera	Rancho Ahogado	10,491	3,198	1961	Darien	Gas shows
25	Caribbean Gulf	Senosri No. 1	9,700	2,957	1962	Bocas del Toro	Gas shows
26	Caribbean Gulf	Soledad No. 1	8,002	2,440	1962	Bocas del Toro	Gas shows
27	Sossa & Hosterret y Petrolera Golfo del Darien	Garachiné No. 1	708	216	1962	Darien	
28	Sossa & Hosterret y Petrolera Golfo del Darien	Garachiné No. 1 A	2,096	639	1962	Darien	Gas shows 600 to 2,080 ft. Asphalt grains 1,950-2,080 ft.
29	Corvus S.A. & El Paso Panama Co.	Corvus No. 1	8,614	2,926	1974	Gulf of Panama	
30	Plaris S.A. & El Paso Panama Co.	Plaris No. 1	9,407	2,867	1974	Gulf of Panama	Gas shows 1,800 to 7,100 ft.
31	Panama Exploration (Texaco)	Marea No. 1	6,685	2,037	1978	Caribbean	
32	Sossa Petroleum S.A.	Canazas No. 1	3,283	1,000	1979	Panama	Oil shows 1,845-2,567 ft.
33	Sossa Petroleum S.A.	Canazas No. 2	4,000	1,219	1981	Panama	
34	Idria Oil & Gas	Anayansi No. 1	4,504	1,372	1989	Gulf of Panama	
35	Idria Oil & Gas	Cemaco No. 1	~8,000	~2,438	1989	Gulf of Panama	Oil shows 590-680 ft, 7,740-7,770 ft.
36	Idria Oil & Gas	Bayano No. 1	~8,000	~2,438	1989	Gulf of Panama	Gas multiple shows.

1) The source is Quiros Ponce (1975) with later additions by the author. The Year is the year of well completion. 2) There are two wells named Corotú No. 1. In order to distinguish them, the year has been added to each in brackets. 3) Data marked * are different well names and depths for 3 wells from Kolarsky and Mann (1995).

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was enacted in 1987 and later amended in 2007 and 2013 (Table 3).

5. Regional geology

There are thirteen sedimentary basins in Panama that are described briefly in this section; for context, see Figure 2. A detailed description of the onshore basins and stratigraphic units is given in the Stratigraphic Lexicon of Panama (LeBlanc, 2021), while a concise overview of Panama's geology is provided by Montes and Hoyos (2020).

5.1. BURICA BASIN

The Burica Basin is an inverted outer forearc basin that forms the Burica Peninsula and is south of the Térraba Basin. It has 3,500-4,000 m of Plio-Pleistocene deep-to-shallow-water trench slope marine sediments of the La Peñita, Burica, and Armuelles Formations (Brandes and Winsemann, 2018; LeBlanc, 2021). It has been tested by three wells (Figure 3). Sinclair Oil drilled one well, Corotú No. 1 (9,715 feet), near Puerto Armuelles in 1949. Petrolera Chiricana, S.A., a subsidiary of the United Fruit Company, drilled two stratigraphic wells, Corotú No. 1 (1,661 feet) and

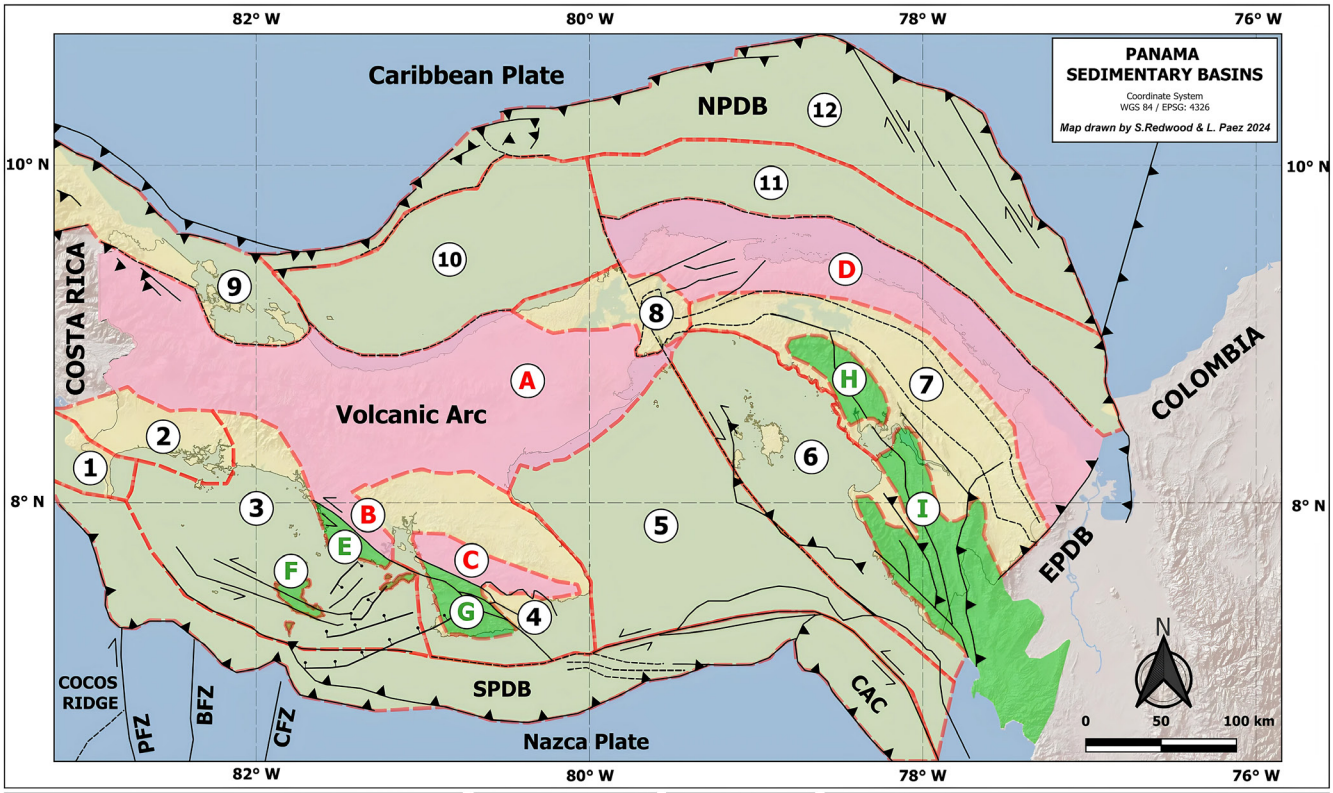

Figure 2 The sedimentary basins of Panama.

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Table 3. Legislation governing hydrocarbon exploration and production in Panama.

Law No.	Year	Official Gazette No.	Title
292	1875		Mining Code
153	1887		State of Antioquia Mining Code of 1867 was applied to the whole of the Republic of Colombia in 1887.
76	1904	32	Reform of Mining Code, refers to Law 2922 of 1875 and 153 of 1887.
2	1916	241	Civil Law which refers to Mining Code.
19	1953	12049	Hydrocarbons Law
23	1963	15162	Mineral Resources Code
8	1987	20834	New Hydrocarbons Law
39	2007	25857	Modifies Law 8-1987
53	2013	27369-B	Modifies Law 8-1987

The Panamanian laws are available online in the Gaceta Oficial (Official Gazette) at https://www.gacetaoficial.gob.pa/. They are organized by year and Gazette number.

Corotú No. 2 (1,367 feet) at Puerto Armuelles in 1958-1959. Note that Kolarsky and Mann (1995) cite different names and depths for these wells: Corotú-1A (1949) at 9,320 feet, Corotú-1A (1958) at 8,606 feet), and Corotú-1B (1958) at 1,660 feet.

5.2. TÉRRABA BASIN

The Térraba Basin, Chiriqui, is an inverted forearc basin with one well, Chiriqui No. 1 (3,862 feet) drilled near David in 1925 (Figure 3). The basin is south of the volcanic arc and extends west into Costa Rica. The basin comprises 4,000 to 5,000 meters of Paleocene to lower Miocene volcaniclastic turbidites, shallow-water ramp carbonates, and bioclastic turbidites of the Brito and Térraba Formations. These are unconformably overlain by Miocene to Pleistocene shallow-marine to terrestrial volcaniclastic sediments of the Curre and Paso Real Formations (Kolarsky *et al.*, 1995; Brandes and Winsemann, 2018).

5.3. CEBACO BASIN

The Cebaco Basin, Gulf of Chiriqui, is an offshore, active pull-apart basin with no wells. It has up to 2,000 m of Plio-Pleistocene deepwater turbidites (Kolarsky *et al.*, 1995; Kolarsky and Mann, 1995; Brandes and Winsemann, 2018).

5.4. TONOSI BASIN

The Tonosi Basin is on the Azuero Peninsula and Coiba Island. It is an inverted forearc basin from the Eocene to the Miocene period. It is made up of turbidites and shallow-water marine limestones from the Covachón, Tonosi, and Santiago Formations. These layers are 840–1,500 m thick and lie on top of the basement of a volcanic arc from the late Cretaceous to the Eocene period, as well as accreted Cretaceous oceanic crust and Paleogene seamounts (Buchs *et al.*, 2011; LeBlanc, 2021). The Azuero Peninsula was explored by Petroleos Panama S.A. in 1953-1954 by geological mapping and geophysics, which concluded that the dominant volcanic nature of the basin reduced the oil potential, and no drilling was carried out (Sossa, 1981).

5.5. GULF OF PANAMA BASIN

The Gulf of Panama basin is an active foreland basin with one well. It is the western part of the Gulf of Panama. There is a thick sedimentary sequence of Eocene to Pleistocene age, with a depocenter west of the Pearl Islands (Mann and Kolarsky, 1995). Corvus No. 1 was drilled in 1974 west of the Pearl Islands at 324 feet of water depth and to a depth of 8,614 feet (Figure 4). Oil and

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gas shows were absent. However, an interval of immature, pre-petroleum-grade organic material was intersected, along with a small quantity of thermally mature organic material (González, 1984). Mann and Kolarsky (1995) analyzed the geology and tectonics of the Gulf of Panama and the East Panama Deformed Belt, using Mobil seismic surveys (1,600 km, 1969-1972) and two El Paso offshore wells (1974). Subsequently, Coates *et al.* (2004) extended the stratigraphy from the Chucunaque Basin (detailed below) to encompass the Garachiné, Plaris, and Gulf of Panama basins.

The regional geology of the Gulf of Panama was revised based on mapping in the Pearl Islands, which defined the new Pedro González Formation (Redwood *et al.*, 2022). This formation is a submarine volcano-sedimentary sequence composed of lavas, dykes, volcanic breccias, and tuffaceous sediments of basaltic to andesitic composition that were deposited in volcanic islands in the Oligo-Miocene. The Quaternary to Recent sea level change of the Gulf of Panama was described by Redwood (2020a).

5.6. GARACHINÉ BASIN

The Garachiné Basin (or Sambú or Garachiné-Sambú Basin) is an active pull-apart basin in the eastern part of the Gulf of Panama that extends onshore at Sambú. Together with the Plaris Basin in the southeastern Gulf of Panama, there are >6,000 km of 2D seismic surveys and 9 wells, including 7 with oil or gas shows (Figure 4). The basins are part of the East Panama Deformed Belt

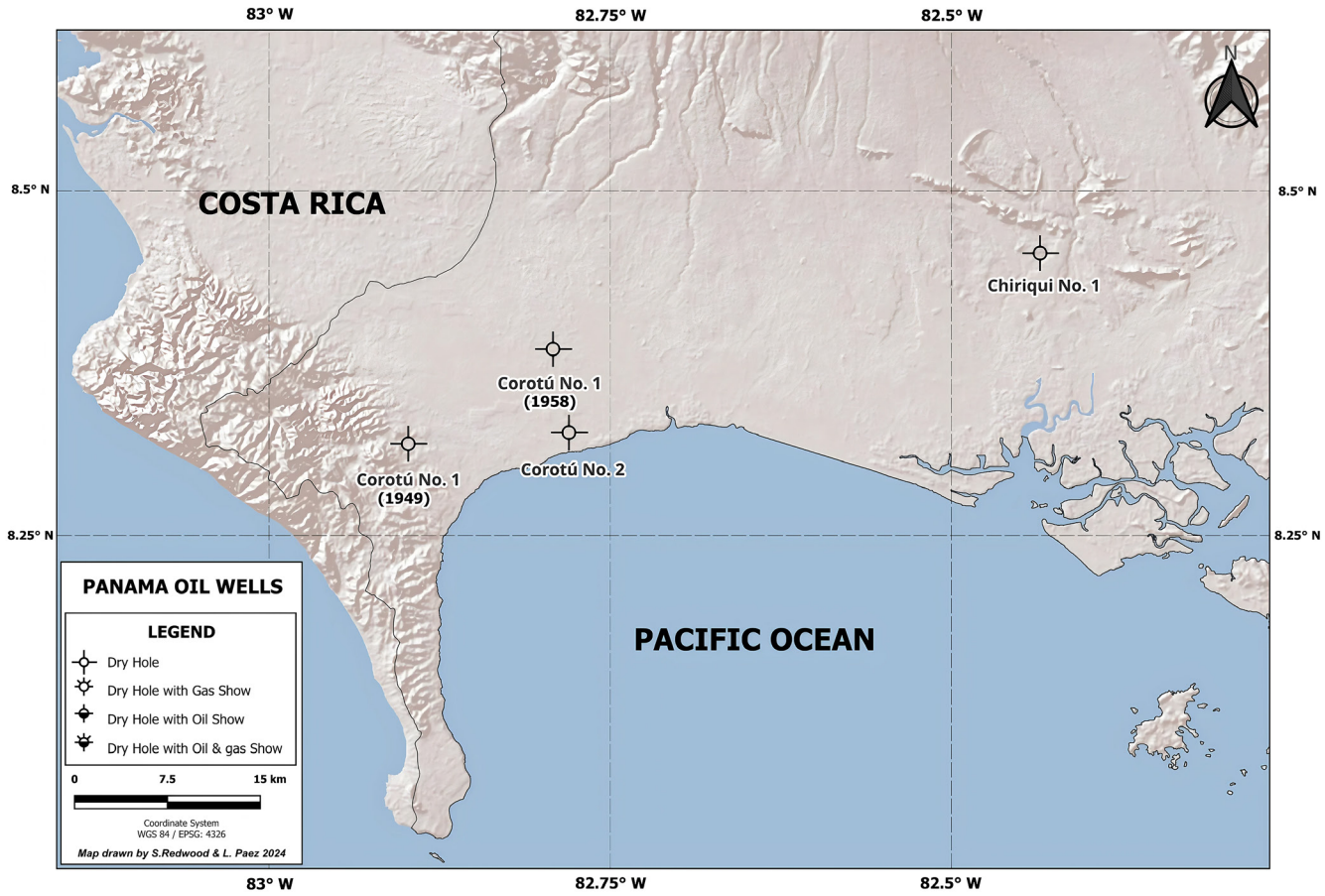

Figure 3 The oil wells of the Burica and Térraba basins.

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(Mann and Kolarsky, 1995; Redwood, 2019). The Garachiné Basin is a left lateral pull-apart basin controlled by the NW-trending Sambú Fault and is separated from the Plaris Basin by a deformed anticlinal belt exposed in the Pearl Islands (Figure 5; Derksen *et al.*, 2003). The stratigraphy of the onshore Sambú Basin is mapped as lower middle Miocene Clarita Formation limestone overlain by lower upper Miocene Tuira Formation graywacke and siltstone (Coates *et al.*, 2004). The Garachiné and Plaris basins have about 1,200 m of Eocene volcanic and sedimentary rocks overlain by 2,300-5,300 m of Oligocene to Pliocene shale, siliciclastic sediments, and carbonates (Mann and Kolarsky, 1995; Derksen *et al.*, 2003). These are deformed by east-dipping, west-vergent thrust faults in a 90 km wide belt of Middle Miocene to Plio-Pleistocene age that is mostly buried, part of the East Panama Deformed Belt (Mann and Kolarsky, 1995).

Three wells were drilled at an oil seep at Garachiné in 1924-1928 called Garachiné No. 1 (3,332 feet), Garachiné No. 2 (3,069 feet) and Garachiné No. 3 (4,984 feet). Shows of oil and gas were reported in Garachiné No. 2 with considerable flow of heavy oil (Shelton, 1952), slight shows in Garachiné No. 3, but none in Garachiné No. 1. The oil was produced from the Lower Gatun Formation (Shelton, 1952). Sossa (1981) considered that Garachiné No. 2 and No. 3 "*could have been converted into producing well, under modern completion technique.*" These were followed up in 1962 by two new wells, Sossa Garachiné No. 1 (lost at 708 feet) and Sossa Garachiné No. 1A (2,096 feet) which reported gas from 600 to

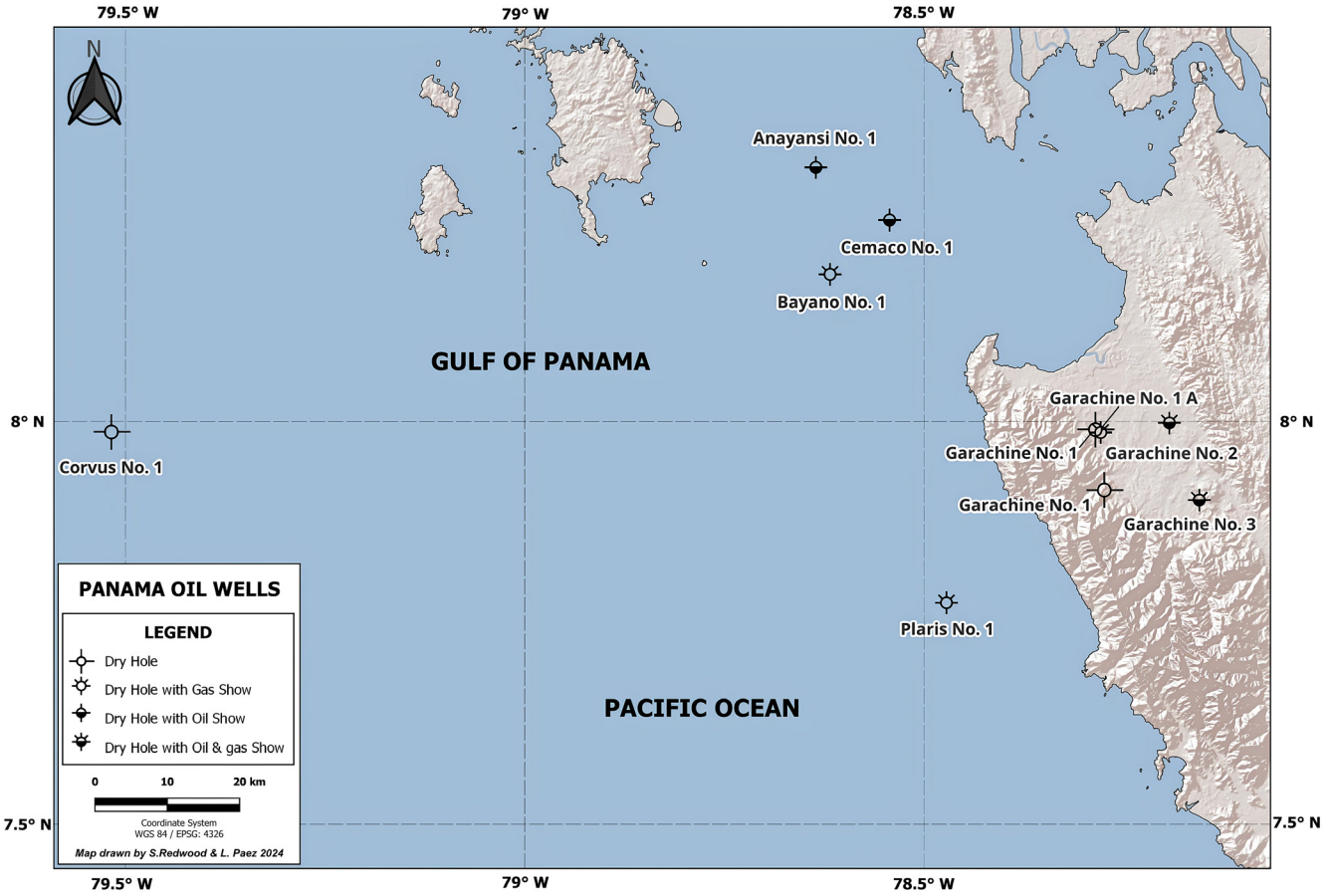

Figure 4 The oil wells of the Gulf of Panama, Garachiné and Plaris Basins.

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2,080 feet and asphalt grains from 1,950 to 2,080 feet. Three wells were drilled in the offshore part of the Garachiné basin in 1989; Anayansi No. 1 and Cemaco No. 1 had shows of oil at 590-680 feet and 7,740-7,770 feet, and Bayano No. 1 had multiple zones of gas.

5.7. PLARIS BASIN

The NW-trending Plaris Basin is located in the southeastern Gulf of Panama. It is separated from the Garachiné basin by a deformed anticlinal belt, which is exposed in the Pearl Islands (Figures 4 and 5; Derksen *et al.*, 2003). The basins are part of the East Panama Deformed Belt (Mann and Kolarsky, 1995; Redwood, 2019). The Plaris Basin was tested by one well in 1974, Plaris No. 1, which was drilled offshore near Garachiné Point in 250 feet of water depth and to a depth of 9,407 feet. It reported gas from 1,800 to 7,100 feet, with the highest concentration at 3,800 to 4,800 feet. The well log data was published by Mann and Kolarsky (1995).

5.8. CHUCUNAQUE BASIN

The Chucunaque Basin (or Chucunaque-Tuira Basin) in the Darien Region, which includes the basins of the Rivers Bayano, Chucunaque, and Tuira Rivers, is an inverted intra-arc or forearc basin that has been tested by 14 wells, including 5 wells with oil or gas shows (Figure 6).

The basin has 4,000 m of arc-related volcanic and sedimentary rocks and limestones

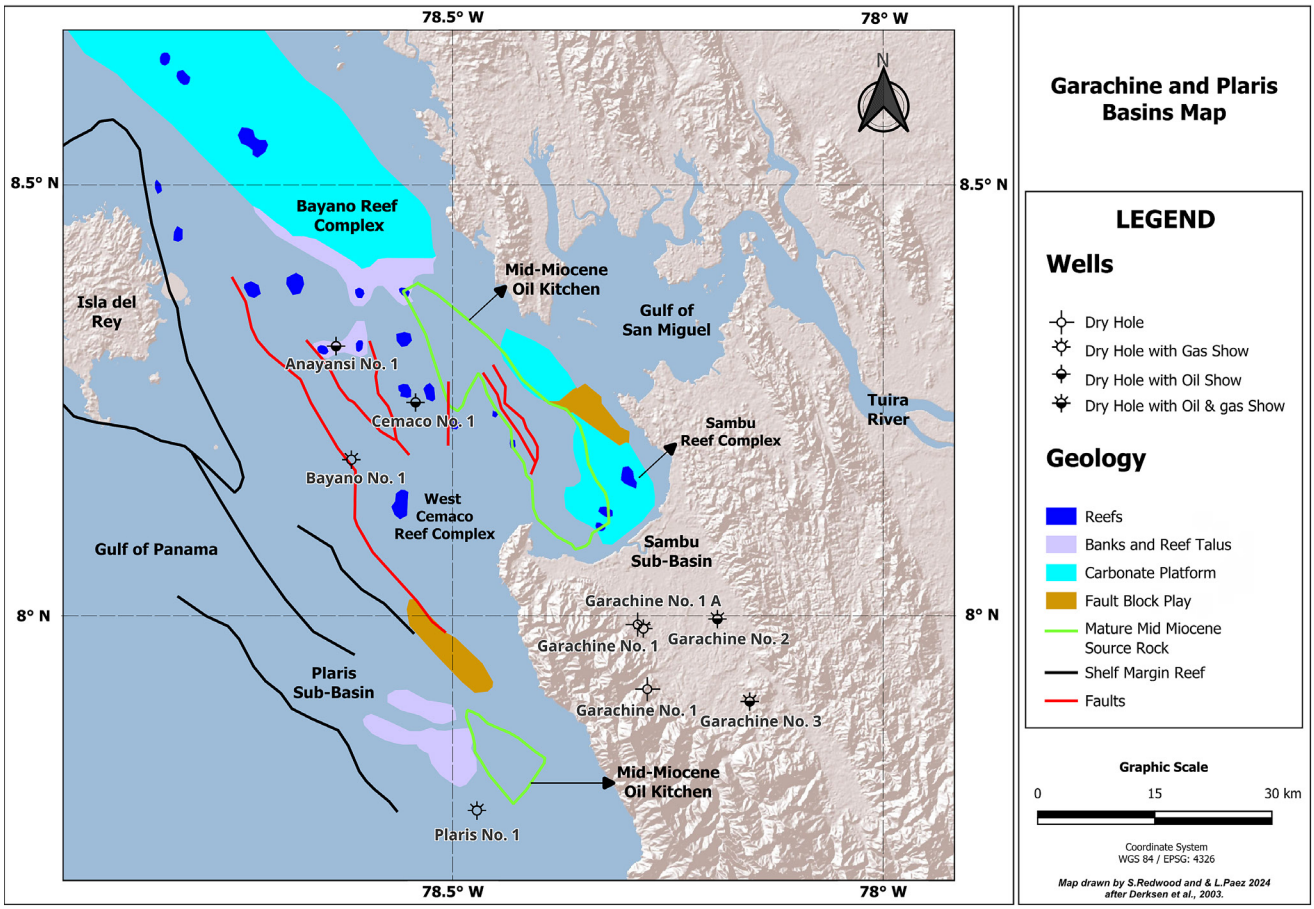

Figure 5 Geology and oil wells of the Garachiné and Plaris basins (after Derksen *et al.*, 2003).

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of Eocene to lower Miocene age of the Darien, Porcona, and Clarita Formations. They are overlain unconformably by 3,000 m of coarse-to fine-grained siliciclastic sedimentary rocks and turbiditic sandstone of upper middle to latest Miocene age of the Tapaliza, Membrillo, Tuira, Yavizas, and Chucunaque Formations (Coates *et al.*, 2004; Barat *et al.*, 2014; Redwood, 2019; LeBlanc, 2021). Northward on a lap of Eocene–Oligocene strata onto the deformed basaltic/granitic basement complex of the San Blas Range, and a corresponding southward thickening of the same strata, show that the basin was inclined to the south (Montes and Hoyos, 2020). These sediments were folded to form the Bayano-Chucunaque-Tuira syncline after deposition of the upper Miocene Chucunaque Formation. The strata are deformed in the eastern part of the basin in the East Panama Deformed Belt of NW- and NE-trending left lateral strike-slip and reverse faults and an echelon, doubly plunging folds (Coates *et al.*, 2004). Undeformed late Pliocene-Pleistocene sediments bury deformed Neogene sediments in the East Panama Deformed Belt and the Gulf of Panama (Mann and Kolarsky, 1995).

The Yape and Capeti anticlines on the upper River Tuira were drilled in 1925-1926 to test an oil seep on the Tapaliza River near Tacarcuna Village (Shelton, 1952). Yape No. 1 well reported gas and light oil from a 200 feet zone of soft sandstone at 3,303-3,503 feet depth, but with saline water flow of 1,920 barrels per day with sand grains coated with a film of oil (Sossa, 1981). The test was abandoned due to the saltwater flow. The source of

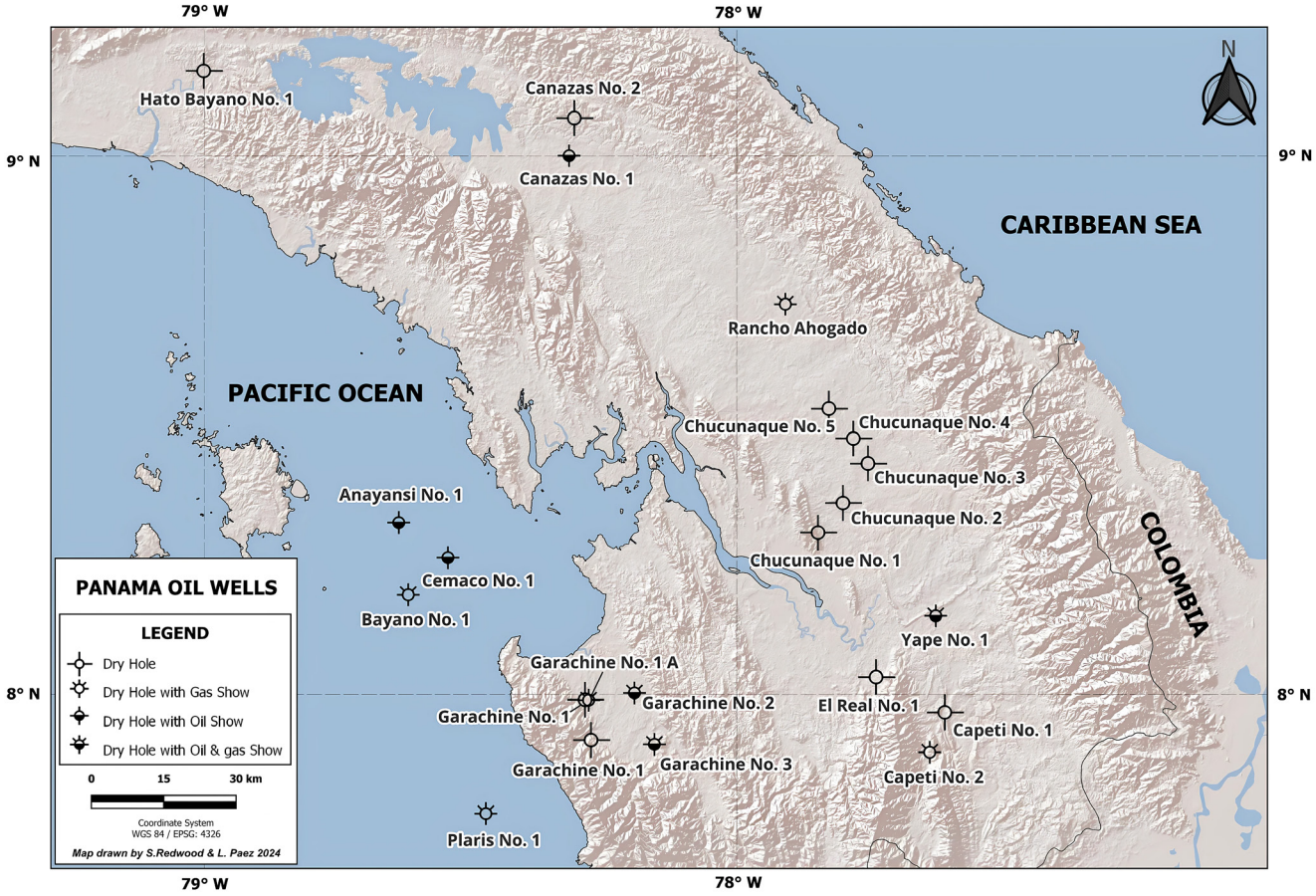

Figure 6 The oil wells of the Chucunaque Basin and the adjacent Garachiné and Plaris Basins.

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the water was the Aquaqua Formation, now called the Clarita Formation (Shelton, 1952). The Capeti No. 1 well was lost at 995 feet. Oil was reported in Capeti No. 2 (3,300 feet), which reached the same stratigraphic horizon that had shown in Yape No. 1, but the hole was abandoned as dry without testing the rest. The well had a strong gas show, which caught fire or exploded, and the well was plugged and abandoned (Shelton, 1952; Sossa, 1981).

In 1952, Bert Shelton, a Panamanian geologist then with Sinclair Oil, completed his Master's thesis at Oregon State College. This work focused on the petroleum geology of the Chucunaque Basin and featured the initial geological maps of the basin, including the Rancho Ahogado anticline–Membrillo River area (Shelton, 1952). The study was based on work conducted for Sinclair Oil under the supervision of Robert A. Terry between 1946 and 1949. In later years, Shelton went on to teach geology for many years in the Faculty of Agronomy at the University of Panama (Aparicio, 2003).

Five stratigraphic wells called Chucunaque No. 1 to 5 were drilled in 1957-1958 and another in 1961, Rancho Ahogado (10,494 feet), the deepest well drilled in Panama, which reported minor gas. Two wells were drilled on the Cañazas Dome in the upper River Bayano basin in 1978-1979, Cañazas No. 1 (3,283 feet), and in 1981, Cañazas No. 2 (4,000 feet), to confirm the results of exploration carried out in 1958-1962. The first well had oil shows between 1,845 feet and 2,567 feet, but the second well was dry. The well was to test the Clarita Limestone Formation. It cut 150 feet of limestone and 40 feet of the underlying Porcona Formation.

The geology and stratigraphy of the Chucunaque Basin were mapped by Coates *et al.* (2004). This was part of the Panama Paleontology Project (PPP) from 1986 to 2013 to study the major sedimentary basins of Panama. Led by Laurel S. Collins of Florida International University, Miami, and Anthony (Tony) J. Coates of the Smithsonian Tropical Research Institute (STRI), Panama, this major collaborative project involved 35 geologists from 20 institutions in 7 countries (Collins and Coates, 1999). The Darien data was collected by field mapping and logging sections by boat along river traverses made on six expeditions from 1990 to 1996. They also used the results of oil company mapping and stratigraphy in publications (Shelton, 1952; Terry, 1956; MacDonald, 1969; Wing and MacDonald, 1973; Mann and Kolarsky, 1995), unpublished reports, and the results of mapping potential canal routes (Bandy, 1970; Bandy and Casey, 1973). The stratigraphy and tectonics of the basin were later studied by Flore Barat for her doctoral thesis at the University of Nice-Sophia, France (Barat *et al.*, 2014).

5.9. PANAMA CANAL BASIN

The Panama Canal Basin is an active marine-terrestrial volcano-sedimentary rift basin of Eocene to Recent age that has been studied in detail since the mid-nineteenth century for engineering geology for railroad and canal construction. The excavations provided abundant marine and terrestrial fossils for paleontological study (*e.g.*, MacDonald, 1915; Jones, 1950; Woodring, 1957; Stewart *et al.*, 1980; Montes *et al.*, 2012; Farris *et al.*, 2017; Buchs *et al.*, 2019; LeBlanc, 2021). No hydrocarbon exploration was ever carried out, and no wells were drilled because the watershed is protected for the canal and was mostly within the U.S.-administered Canal Zone (1903-1999). The sediments are in four sub-basins, each with about 500 m thickness. The sequence begins with Upper Eocene shallow-marine limestones and tuffaceous mudstone-sandstone of the Gatuncillo and Caimito Formations in the Quebrancha and Alajuela (Lake Madden) sub-basins. The Culebra Cut sub-Basin is of upper Oligocene to Miocene age and comprises the Bas Obispo Formation volcaniclastic fluvial sediments, Bohio Formation conglomerate, Las Cascadas Formation tuffs, Culebra Formation shallow marine, bathyal, and estuarine sediments including the Empire Limestone Member, Cucaracha Formation

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tuffaceous paleosols and fluvial sediments, La Boca Formation coastal sediments and tuffs, and Pedro Miguel Formation basalt plugs, lavas, tuffs, and diatremes (Montes *et al.*, 2012; Farris *et al.*, 2017; Buchs *et al.*, 2019). Sedimentation in the Gatún sub-Basin took place in the late Miocene to Pliocene, with shallow marine sediments of the Gatún Formation and the Chagres Sandstone and basal Toro Limestone or Toro Point Member (Coates *et al.*, 1992). Finally, unconsolidated Quaternary muds of the Atlantic and Pacific Muck overlie the sequence.

5.10. BOCAS DEL TORO BASIN

The Bocas del Toro Basin is an inverted back-arc basin with 8 wells. It continues west in Costa Rica, where it is called the Limón basin (Figure 7).

Three wells were drilled on Colón Island: Colón No. 1 in 1919 (1,625 feet), Colón No. 2 in 1923 (3,325 feet), and Bocas del Toro No. 1 in 1948 (8,621 feet). One well was drilled in the Changuinola area, Yorkin No. 1 (5,500 feet), on the Yorkin River, close to the Sixaola River, near the border with Costa Rica in 1956-1957. Two wells were drilled in the lagoon in 1958, Almirante No. 1 (6,678 feet) in Almirante Bay and Anita Bay No. 1 (9,537 feet) on the far western side of Chiriqui Lagoon (González, 1984). The sections lacked porosity and permeability, and no further exploration was carried out. Gulf Oil Co. (Caribbean Gulf) drilled two wells in Bocas del Toro near the border with Costa Rica in 1962, the Senosri No. 1 well (9,700 feet), with minor gas shows, and the Soledad No. 1 well (8,002 feet),

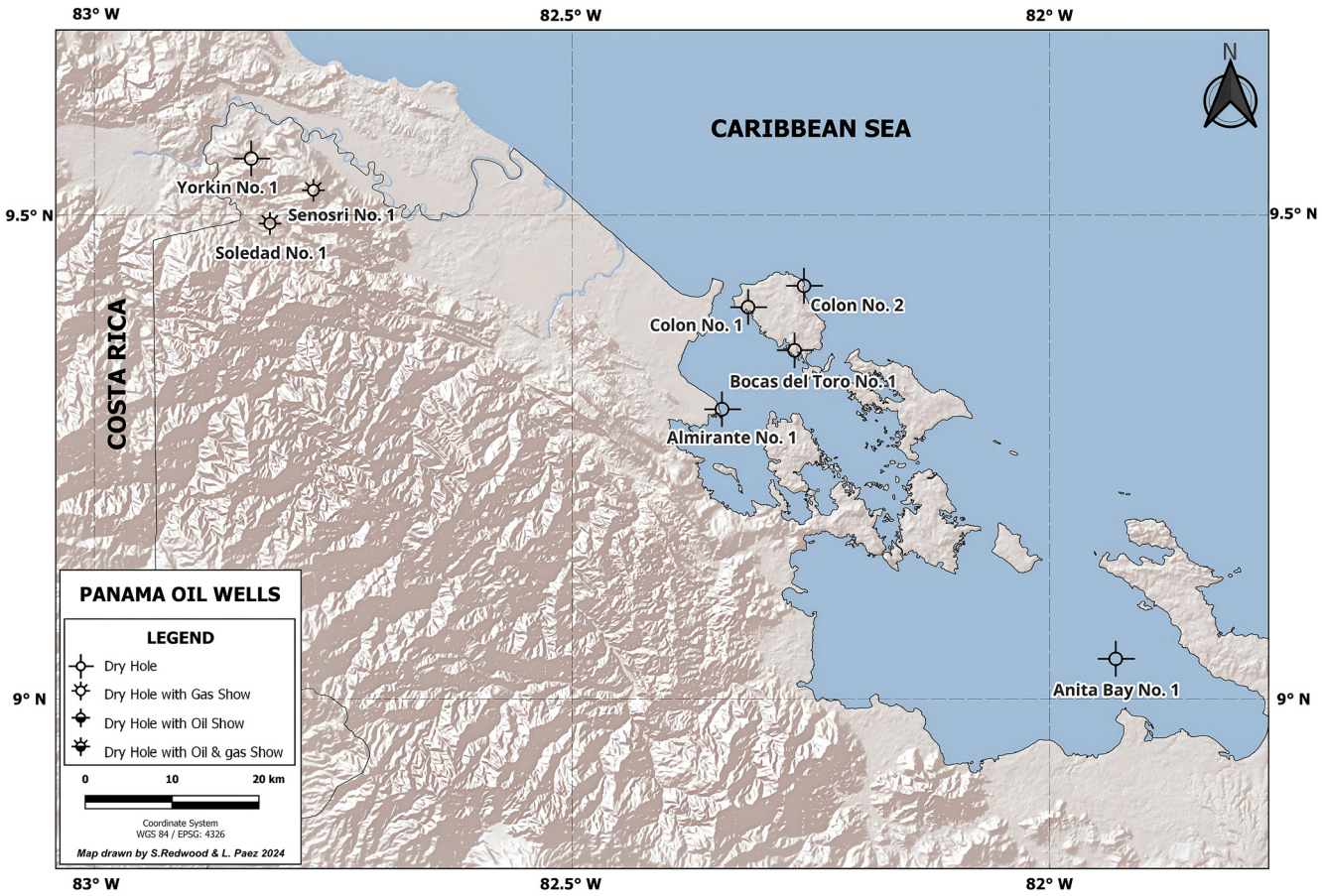

Figure 7 Oil wells drilled in the Bocas del Toro basin.

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with small gas shows at 2,400 feet (González, 1984). Texaco Exploration Panama Inc. was awarded Blocks 1 and 2 (450,488 ha) in Bocas del Toro Province, both onshore and offshore, in 1991 and explored until 1993 but did not drill (USGS, 1991, 1993; López-Schaw, 1992).

The older sedimentary sequence extends from the Campanian to Pleistocene in a NW-trending, NE-verging fold-thrust belt exposed in the Talamanca Cordillera, the River Teribe, and the River Changuinola, as described by German researchers (Mende, 2001; Brandes *et al.*, 2007; Brandes and Winsemann, 2018). The sequence consists of 4,300 m thickness of Campanian to Lower Eocene Changuinola Formation pelagic limestones and volcaniclastic rocks and Tuis Formation volcaniclastic turbidites, debris flow deposits, lava flows, and tuffs, representing a prograding, deep-water apron. They are overlain unconformably by middle Eocene to late Oligocene Las Animas Formation shallow-water limestone (150-200 m) and Senosri Formation (700-900 m), hemipelagic mudstones, calcareous turbidites, and carbonate debris flow deposits. They are overlain unconformably by the late Oligocene to lower Miocene Uscari Formation of 2,000 m of organic-rich, shallow-water volcaniclastic sediments interpreted to be delta-influenced shelf deposits and by the Middle Miocene to Pleistocene Rio Banano and Suretka Formations.

The geology of the Neogene Bocas del Toro Basin was described by the PPP and STRI (Coates *et al.*, 1992, 2003, 2005; Collins *et al.*, 1995), including a detailed study of Colón Island as a modern analogue for buried reefal platforms (McNeill *et al.*, 2013). This has about 1,000 m of shallow marine sediments of upper Miocene-Pleistocene age. The southern region (Valiente Peninsula) consists of volcanic arc basalts, deep-water sediments, volcaniclastic sediments, and patch reefs of the lower Miocene Punta Alegre and Valiente Formations overlain unconformably by non-reefal marine shelf sediments of the Bocas del Toro Group (Tobabe Sandstone, Nancy Point, Cayo Agua, Shark Hole Point, and Escudo de Veraguas Formations; Coates *et al.*, 2005). The northern region (Islands of Colón, Bastimentos, and others) comprises basal Valiente Formation basalt (Bastimentos) or 2,600 m thick inner shelf sandstone of the Old Bank Formation (Colón) unconformably overlain by Plio-Pleistocene coral reef shelf limestones of the Isla Colón Formation and Urracá Formation (Coates *et al.*, 2005; McNeill *et al.*, 2013).

The frontal thrust of the western end of the North Panama Deformed Belt (NPDB) changes orientation and runs near shore on the north side of the Bocas del Toro basin and along the coast in the Limón basin in eastern Costa Rica, causing strong seismicity and uplift (Reed and Silver, 1995; Silver *et al.*, 1995).

5.11. GULF OF MOSQUITOS BASIN

The Gulf of Mosquitos Basin is a little-studied active back-arc basin that was explored by Texaco, Inc., between 1974 and 1993. It drilled one dry well in 1978, Marea No. 1 (6,685 feet). It was concluded that the strata were immature for hydrocarbon generation (USGS, 1979, 1990, 1991, 1993; González, 1984; López-Schaw, 1992).

5.12. SAN BLAS BASIN

The San Blas Basin is an active back-arc basin. It was explored by Texaco, Inc., between 1974 and 1993, but it drilled no wells (USGS, 1979, 1990, 1991, 1993; González, 1984; López-Schaw, 1992). Sediment is transported 300 km to the west in an axial channel, being deflected by the San Blas Ridge on the north side (Reed and Silver, 1995).

5.13. NORTH PANAMA DEFORMED BELT

The San Blas Basin is bounded on the north side by the San Blas Ridge (SBR) and the North Panama Deformed Belt (NPDB), which continues west to the Costa Rica border and bounds the northern side of the Gulf of Mosquitos basin as well. The NPDB-SBR is an accretionary wedge of middle Miocene to Recent age formed by the southward

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underthrusting or subduction of the Caribbean Plate beneath the Panama Microplate (Reed and Silver, 1995; Camacho *et al.*, 2010). The shallow (800 m) San Blas Ridge is a wider part of the NPDB formed by backthrusts. The stratigraphy at the NPDB thrust front begins with upper Cretaceous to Eocene pelagic sediments followed by Eocene clastic and hemipelagic sediments and late Miocene turbidites (Reed and Silver, 1995). NW-trending strike-slip faults with sinistral movement in the eastern part of the NPDB are the result of the collision of the Panama Microplate with the South American Plate (Reed and Silver, 1995).

The eastern part of the NPDB, SBR, and San Blas Basin were explored by Circle Oil plc of Dublin in 2005-2007, which was granted a Geological, Geochemical, and Geophysical Prospecting Permit of 3 million acres (1.2 million hectares) on Block A in water depths of 500-3,000 m. A review of existing data identified two areas with significant hydrocarbon potential, but it did not drill (Circle Oil, 2005, 2006, 2007).

6. Stage 1: Initial onshore exploration period, 1912-1928

After the discovery of an oil seep in Panama in 1912, exploration was carried out in the period of 1917 to 1928, when 9 wells were drilled in Bocas del Toro and Darien by Sinclair Oil Corporation, Panama Gulf Oil Company, and Texas Company. Other companies that explored but did not drill included Royal Dutch Shell, British Controlled Oil Fields, Ltd., Gulf Oil Company, and Cities Service Company (Sossa, 1981; González, 1984).

6.1. DISCOVERY OF OIL, 1912

Oil seeps were known at several localities in Panama by the locals, who used the asphalt to caulk their boats well before oil companies arrived. The oil seeps at Garachiné, Darien, are located in the mangroves of Quebrada Lagarto stream, close to the "costa" (a strip of dry land on the inner edge of the mangroves rather than the outer limit with the sea), between the village of Garachiné and the mouth of the River Sambú (Figure 8). They were described as "*some springs of a dark, viscous material similar to that which crabs remove from the mouth of their holes, material that was used by the local inhabitants to smear on their boats, as a substitute for tar*" (Méndez, 2004; Forde, 2007). In 1909, Adolfo Aleman of Panama took samples from an oil seep in the Azuero Peninsula to the US to raise interest (Sossa, 1981).

The first reported oil claim in Panama was made on September 13, 1912, when an American citizen, Rox Underwood, presented the mayor of Chepigana with a request for mineral rights for an oil find near the River Sambú at Garachiné, to be registered in the name of Mr. H. R. Woods, also an American citizen. The mayor informed the Secretary for Development who authorized the award of the claim. This was opposed on December 10, 1912, by Arturo Muller in representation of Dr. Sylvanus M. Pearman, who had bought the land rights on June 2, 1911. Dr. Pearman won the case in the second circuit of Panama on April 15, 1914, but lost the appeal at the Supreme Court in 1915 (Méndez, 2004; Forde, 2007).

6.2. SINCLAIR OIL CORPORATION, 1917-1928

The pioneer oil exploration company in Panama was Sinclair Panama Oil Corporation, which explored from 1917 to 1928 in Bocas del Toro (Figure 9) and Darien. The Sinclair Oil Company was founded by Harry F. Sinclair in New York in 1916 and still operates as a family-owned company to this day. The first chief geologist was Donald F. Macdonald (Sossa, 1981), probably in 1917-1920, previously with the Isthmian Canal Commission. He was succeeded by Robert A. Terry, who worked for Sinclair Panama Oil from 1920 to 1927 and later wrote the first memoir on the geology of Panama (Terry, 1956; Redwood, 2021). Sinclair Oil drilled two wells on Colón Island, Bocas del Toro: Colón No. 1 (or Big Bight No. 1) in 1918

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and Colón No. 2 (or Big Bight No. 2) in 1922. The well location was recorded as Big Bight on Columbus Island, as Colón was then known; the locality is believed to be Big Creek in the middle of the island, close to Gruta Cave. The road was built by the oil company and is today the paved road to Boca del Drago (C. Stephens, *pers. comm.*, 06-10-21). The New York Times of December 21, 1918, reported that oil had been discovered in "*paying quantities*", which caused excitement in Bocas del Toro, and that the company was developing it for production. However, the announcement was premature, and there were no further reports.

Sinclair Oil also explored on the Costa Rican side of the border in Limón Province from 1917 because of oil seeps at the confluence of the Yorkin and Sixaola Rivers, and the Uscari and Amaurí Rivers (González, 1984). Sinclair Oil drilled a well in this area with gas shows. Union Oil Company later drilled the first commercially producing well in Costa Rica in the same zone, which produced almost 2,000 barrels per day until water influx killed it, after drilling several dry wells (González, 1984). Three oil wells are shown on a United Fruit Company small-scale map of banana fincas dated 1931 and revised 1958 (C. Stephens, *pers. comm.*, 07-10-21): one well on the shore at Cahuita Point ("Oil well" marked) and two wells beside the Tuberi River ("Sinclair Oil Co. oil wells"), a branch of the Telire River, which is the major tributary of the Sixaola River.

Sinclair Oil then turned its attention to the Darien in 1923-1926 under the direction of Robert Terry. It explored the Chucunaque Basin, where Terry reported an oil seep on the Tapaliza River near Tacarcuna village in 1923 (Shelton, 1952). It drilled three wells, with Cities Services Company as contractors, in the Yape and Capeti anticlines on the upper River Tuira, between the communities of Yape and Capeti or Capetuira,

Figure 8 Oblique air photo looking southwest of Garachiné Point and the mouth of the River Sambú in Garachiné Bay, Darien. Natural oil seeps were discovered near Garachiné in 1912 and were drilled in 1924-1928 and 1962. (photograph by Stewart Redwood, 2023).

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in 1925 to 1926. The Yape No. 1 well, drilled in 1925, reported gas and light oil from a 200 feet zone of soft sandstone at 3,303 to 3,503 feet depth, but with saline water flow of 1,920 barrels per day with sand grains coated with a film of oil (Sossa, 1981). The test was abandoned due to the saltwater flow. The source of the water was the Aquaqua Formation (Shelton, 1952).

The Capeti No. 1 (995 feet) and Capeti No. 2 (3,300 feet) wells were drilled in 1926. The first was lost at 995 feet. Oil was reported in Capeti No. 2 which reached the same stratigraphic horizon that had shown in Yape No. 1, but the hole was abandoned as dry without testing the rest. The well had a strong gas show, which caught fire or exploded, and the well was plugged and abandoned (Shelton, 1952; Sossa, 1981).

6.3. PANAMA GULF OIL COMPANY, 1922-1928

The Panama Gulf Oil Company, a subsidiary of Gulf Oil founded in Pittsburgh in 1901 (and merged with Standard Oil of California in 1985), explored an oil seep at Garachiné in the Darien from 1922, the year in which the Province of Darien was created, to 1928. The oil seep was in the inner, dry edge of mangroves, known as the "costa" (coast), at Quebrada Lagarta, between the village of Garachiné and the mouth of the River Sambú (Méndez, 2004).

Gulf Oil Company drilled three wells in 1924, 1926, and 1928 called Garachiné No. 1 (3,332 feet deep), Garachiné No. 2 (3,069 feet), and Garachiné No. 3 (4,984 feet). Shows of oil and gas were reported in Garachiné No. 2, slight shows in No. 3, but none in No. 1. One report describes

Figure 9 Oblique air photo looking south at the Bocas de Toro Archipelago and the Talamanca Cordillera, showing Chiriqui Lagoon, Almirante Bay, and the islands of Bastimentos and Colón (photograph by Stewart Redwood, 2005).

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considerable flow of heavy oil (12 API) in No. 2 (Shelton, 1952). There are oil seeps at the well-head to this day. The oil was produced from the Lower Gatun Formation (Shelton, 1952). Sossa (1981) considered that wells No. 2 and No. 3 "*could have been converted into producing well, under modern completion technique*."

The company set up offices and residences for the managers on the northwestern side of the village of Pinuguilla beside the sea, known as Boca del San Antonio (the San Antonio River mouth is at Garachiné). This exclusive area comprised several identical "pretty" bungalows painted grey. The natives called it "The Zone", a tongue-in-cheek reference to the American-controlled Canal Zone, a name that stuck for long after. It was later destroyed by the sea and moved to Jesús (Méndez, 2004). The company made a road to the village where the workers lived and had two motor ships called La Garachiné and La Margarita for access to the project and the capital. They employed many people, and the community flourished (Méndez, 2004).

6.4. TEXAS COMPANY, 1925

The Texas Company drilled one well in Chiriqui in 1925 (Chiriqui No. 1) in the Carib Syndicate with Sinclair Oil Corporation. The Texas Company (or Texas Fuel Company) was founded in Texas in 1902, changed its name to Texaco in 1959, and became ChevronTexaco in 2001 until 2005, when it became a brand of Chevron.

7. Stage 2: Onshore exploration revival, 1945-1949

After a hiatus in oil exploration of two decades from 1928 to 1945 due to the Great Depression and World War Two, the period of 1945-1949 saw a post-war exploration revival (Shelton, 1952). The only exploration carried out during the hiatus was a seismic survey on Colón Island in 1938 (Sossa, 1981).

7.1. STANDARD OIL COMPANY, 1945-1946

The Standard Oil Company of New Jersey explored the Darien from 1945 to 1946 but did not drill (Shelton, 1952).

7.2. SINCLAIR OIL CORPORATION, 1946-1949

After a break of twenty years, Sinclair Oil returned to Panama from 1946 to 1949 to explore the Darien, Bocas del Toro, and Chiriqui (Shelton, 1952). It drilled two more wells: Bocas del Toro No. 1 from August 1947 to October 1948, and Corotú No. 1 near Puerto Armuelles in Chiriqui in 1949. The former was located at Big Creek on Colón Island, the source of which is La Gruta cave in the middle of the island. There are photos of the rig and the inauguration ceremony with local dignitaries at Bocas del Toro No. 1 well in 1947 (Figures 10 and 11).

Local historian Clyde Stephens recently discovered the well-head (Figure 12). Panamanian geologist Bert Shelton worked for Sinclair Oil under Robert A. Terry in the Darien from 1946 to 1949 and then wrote a master's thesis at Oregon State College that included geological maps of the Chucunaque basin and the Rancho Ahogado Anticline–Membrillo River (Figure 13; Shelton, 1952).

Don Teofilo Alvarado of Changuinola, a United Fruit Company manager, recalled in an interview in 1987 (interview by Ibu Alvarado, original syntax, courtesy of Clyde Stephens) that: "*Early 1950s a subsidiary of Sinclair Oil Company explored Isla Colon and fila [ridge] above Sixaola River for oil. They brought in their own labor supply of trained people and lots of elaborate equipment, shops, supplies, offices, housing, boats. Then came platform off-shore drilling rigs. Jefe [the boss] had a super speed boat. At a big despedida [farewell party] at governor's house in Bocas, this yankee jefe departed by telling the public that Bocas would soon be converted into another Maracaibo. Everyone believed him. They led a rich life*."

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Figure 10 Drilling rig being rigged up to drill Bocas del Toro No. 1 in 1947. The block-line has not been installed yet (photograph by Abraham A. Balid, courtesy of Simon Balid).

Figure 11 Inauguration ceremony for Bocas del Toro No. 1 well in 1947. The local dignitaries are 1) Don Abraham Abadi Balid C., a businessman and counselor in the Municipality of Bocas del Toro, 2) Lic. Hernando Santos K., former notary public, Bocas del Toro, 3) Rev. Ángel Gómez, 4) Don Eduardo Thomas, businessman, Liberal Party politician, and ex-Governor of the Province of Bocas del Toro, and 5) Don Florencio de Icaza, prominent citizen and ex-functionary of the provincial public administration (photograph courtesy of Simon Balid).

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Figure 12 Clyde Stephens at the Bocas del Toro No. 1 wellhead in 2022 (photograph courtesy of Clyde Stephens).

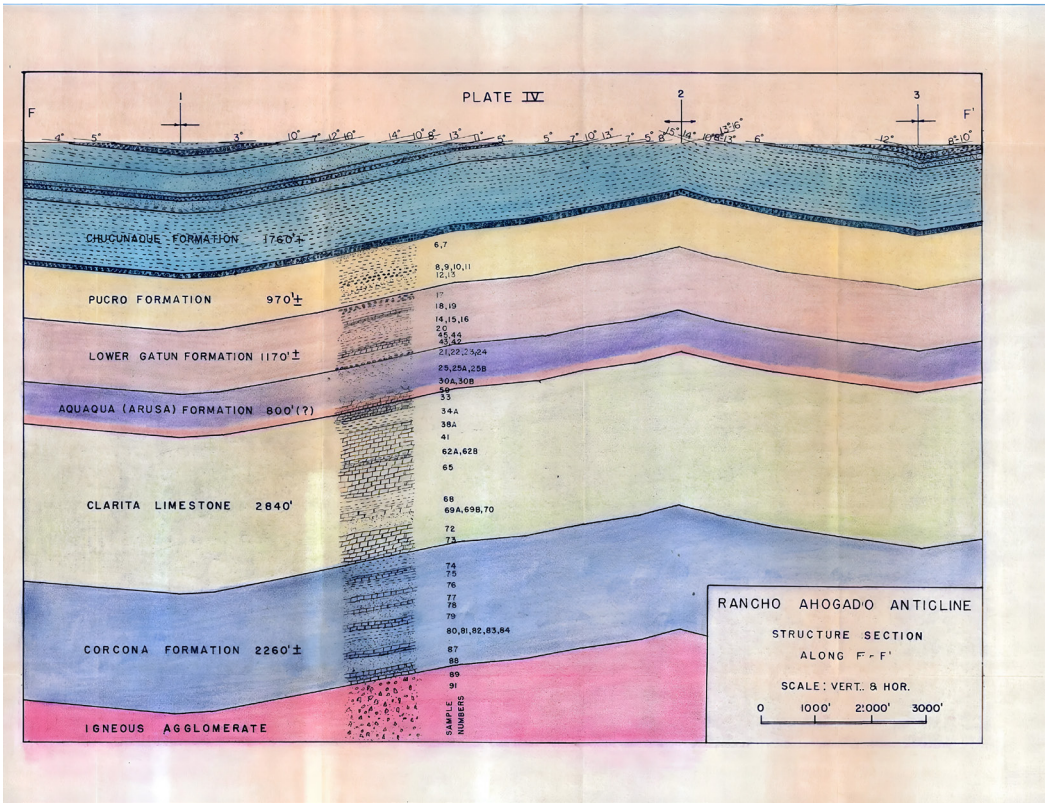

Figure 13 Hand-colored geological cross-section of the Rancho Ahogado anticline from the thesis of Sheldon (1952).

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8. Stage 3: Onshore exploration peak, 1953-1962

The period of 1953-1962 was the peak of oil exploration in Panama, when eight companies drilled 17 wells in eight years. It was prompted by a new hydrocarbons law: Law No. 19 of February 24, 1953, passed during the government of President Jose Antonio Remón Cantera.

8.1. SOSSA PETROLEUM COMPANY, INC., 1955-1986

Sossa Petroleum Company Inc., a Panamanian company owned and operated by Tony Sossa, participated in 12 of these 17 wells. José Antonio (Tony) Sossa Dutary (1914-active until 1985), a Panamanian engineer and businessman, dominated oil exploration in Panama for three decades (Sossa Development, 1985). He originally worked for Union Oil Company of California in Panama as plant superintendent for oil storage at Balboa (1936-1944). He was seconded to California (1939-1940) to study petroleum engineering and lubrication at Long Beach Night College, California, and the University of Southern California. Subsequently, he was responsible for marketing in Central America (1944-1945) and was president and manager of the Atlantic Area (1949-1952). He formed the Compañía Petrolera del Golfo de Panamá S.A. in 1949 with Enrique A. Jimenez (1888-1970), ex-President of Panama (1945-1948), and was later joined by Colonel Saturnino Florez, who became his long-term associate. He became independent in 1952 and promoted Law 19 in 1953. In the same year he formed Petroleos Panama S.A. and Compañía Petrolera del Golfo del Darién S.A. In 1955 he formed Sossa Petroleum Co. Inc., which actively explored until about 1985. He drilled 12 of the 17 wells in the 1953-1962 exploration peak through various joint venture agreements that brought foreign investment to Panama.

Sossa Petroleum's geologist was Dr. (Melvin) Darwin Quigley (1918-2011; Sossa Development, 1985). He was awarded a B.Sc. in Geology from Michigan State College in 1941. He served in World War Two in the U.S. Naval Bureau of Ordinance, Washington, D.C. (1942-1945), as a physicist working on demagnetization of ships. He was awarded an M.Sc. in Geology from Northwestern University in 1947 and a Ph.D. in Geophysics from the California Institute of Technology in 1950. He worked for Sinclair Oil & Gas Company from 1948 to 1954. He first came to Panama in 1955 as a consulting geologist and started a long collaboration with Tony Sossa. For the next 26 years, he was the consulting geologist and vice president of exploration and production for Sossa Petroleum Co. Inc. (1955-1981).

8.2. PETRÓLEOS PANAMÁ S.A., 1953-1954

The first exploration concession awarded under the new hydrocarbons law was granted to Petróleos Panamá S.A., which was financed by the Panama American Petroleum Corporation of Delaware. It carried out a geological and geophysical exploration program in the Azuero Peninsula in the provinces of Cocle, Herrera, Los Santos, and Veraguas. This showed the dominant volcanic and intrusive nature of the sedimentary basin, reducing the oil potential, and the concession was dropped without drilling (Sossa, 1981).

8.3. CORPORACIÓN PETROLERA S.A., 1956-1958

Corporación Petrolera S.A., a Sossa company, drilled one stratigraphic well, Hato Bayano No. 1 (1,648 feet), in 1956 at the confluence of the Mamoní River with the Bayano River in Panama Province. This corporation held concessions in the Lower Bayano basin and also in Chiriqui Lagoon, Bocas del Toro (Sossa, 1981). It partnered with Champlin Oil to explore Chiriqui Lagoon in 1958.

8.4. COMPAÑÍA PETROLERA DEL GOLFO DEL DARIÉN, S.A., 1956-1962

Exploration was carried out in the Darien in 1953-1954 by DeGolyer and MacNaughton, Inc. of Dallas, Texas, under contract with World

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Commerce Corporation and Compañía Petrolera del Golfo del Darién.

The exploration work continued in 1955-1956 under the direction of Dr. M. Darwin Quigley under agreements with International Oil & Metals, of Los Angeles (and their subsidiary, Caribbean International, S.A., of Panama) over concessions granted to Compañia Petrolera del Golfo del Darién, S.A. (1953) and to Sossa Petroleum Co. Inc. (1955) in the upper Bayano basin, the Chucunaque-Tuira Basin, and the Sambù-Garachiné Basin. The El Real No. 1 well (1,641 feet) was drilled in the mid-Tuira area near the town of El Real in 1956 (Sossa, 1981; González, 1984).

In 1962, Sossa & Hosterrer Drilling Co. Inc., with World Commerce Corporation and Compañía Petrolera del Golfo del Darién, drilled two wells in the Garachiné Basin at Garachiné Point. The concession was transferred from Delhi Petrolera. Garachiné No. 1 was lost at 708 feet and Garachiné No. 1A was drilled to 2,096 feet and reported gas from 600 to 2,080 feet and asphalt grains from 1,950 to 2,080 feet. Sossa (1981) explained that there were two shallow wells drilled in the same place as the Garachiné No. 2 well in 1924 to reach the same producing zone and acidize and/or crack it to induce a larger flow of oil to make it a commercial producer. The lack of adequate drilling equipment made the operation fail.

In 1974-1975, Sossa and Quigley interested Diamond Shamrock Corporation of Amarillo, Texas, in exploring for petroleum in Panama. However, the project was not favorably received by the Panamanian government officials because Sossa had been severely critical of the 1963 Mineral Resources Code (below). As a result, Diamond Shamrock abandoned the project, and the Compañía Petrolera del Golfo del Darién S.A. abandoned concession Contract No. 71 of 1956 (Sossa, 1981).

8.5. DELHI-TAYLOR OIL CORPORATION (DELHI PETROLERA), 1957-1961

In 1957, the Delhi-Taylor Oil Corporation of Dallas, Texas, through its Panamanian subsidiary Delhi Petrolera, promoted by Sosa and Quigley, signed agreements with Compañía Petrolera del Golfo del Darién, S.A., and Sossa Petroleum, Co. Inc., taking over International Oil & Metals share of interests. It drilled five stratigraphic wells in Darien in 1957-1958 (Chucunaque No. 1 to 5) and another in 1961, Rancho Ahogado (10,491 feet), the deepest hole drilled in the country, which reported minor gas after a seismic survey over the Rancho Ahogado anticline (Sossa, 1981).

8.6. UNION OIL COMPANY OF CALIFORNIA (UNOCAL), 1956-1958

Union Oil Co. of California explored in Costa Rica from 1950 and drilled several deep wells. It extended exploration across the border in Bocas del Toro and drilled one dry well on the Yorkin River, close to the Sixaola River, near the border in 1956-1957 (Yorkin No. 1, 5,500 feet; González, 1984).

8.7. CHAMPLIN OIL & REFINING CO., 1958

Champlin Oil & Refining Co. and Kerr McGee Industries, under agreements with Corporación Petrolera, S.A., carried out a seismic survey in the Chiriqui Lagoon, Bocas del Toro Province, and drilled the first two offshore wells in Panama in the shallow waters of Almirante Bay in 1958, Almirante No. 1 (6,678 feet) in Almirante Bay, and Anita Bay No. 1 (9,537 feet) on the far western side of Chiriqui Lagoon (González, 1984). The sections lacked porosity and permeability and no further exploration was carried out.

The drilling rig used was of interest because it was an early model jackup rig owned by drilling contractor The Offshore Company, formed in 1953, a pioneer in jackup rigs (now Transocean Offshore Deepwater Drilling Inc.; Offshore, 2007). A photo of the rig (Figure 14) shows that

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it has open truss legs on which the platform was raised and lowered using a hydraulic-pin drive or rack-and-pinion drive. It is probably one of the first such rigs, either Offshore Company Rig 54 or Rig 55, both built in 1955 (J. Cobbett, *pers. comm.*, 20-07-22; he spent 1974 on Rig 54 in offshore Qatar). Champlin Refining Company was founded in 1917 by Herbert Hiram Champlin (1868-1944) at Enid, Oklahoma, after making an oil discovery and buying a refinery at Enid (U.S. Congress, 1966; Weaver, 2010). It was bought by Chicago Corporation in 1954, and they merged in 1956 to become Champlin Oil & Refining Corp. The company explored Panama in 1958. It was bought by Celanese Corporation of America in 1964, and it changed its name to Champlin Petroleum Company. Champlin was bought by the Union Pacific Resources Company in 1970, a division of the Union Pacific Corporation. Anadarko Petroleum acquired Union Pacific Resources in 2000.

8.8. PETROLERA CHIRICANA, S.A., 1958-1959

Petrolera Chiricana, S.A., a subsidiary of the United Fruit Company, was awarded a hydrocarbons concession near Puerto Armuelles in Chiriqui Province in 1958. Presumably the concession was in its banana plantation. It drilled two stratigraphic wells, Corotú No. 1 (1,661 feet) and Corotú No. 2 (1,367 feet), in 1958-1959 under contract with Ball Associates of Denver, Colorado (González, 1984; Sossa, 1981). Finca Corotú is a banana farm near Puerto Armuelles. The wells were located on the edge of Puerto Armuelles town beside a steep, deep creek called Alto de San

Figure 14 Almirante No. 1 well being drilled in the shallow water of Almirante Bay in 1958 by an early jackup rig, probably Offshore Company Rig 54 or Rig 55, for Champlin Oil (photograph courtesy of Joyce Robinson and Stanley Heckadon-Moreno).

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Vicente Creek, a tributary of the Corotú River, and 200 m below an old steel bridge that carried a water pipe (Tony González, ex-United Fruit Company, and Clyde Stephens emails, *pers. comm.*, 26-11-22; Clyde lived in Puerto Armuelles from 1982 to 1986 in the very last house by the bridge.)

8.9. GULF OIL CO. (CARIBBEAN GULF), 1962

Gulf Oil Co. (Caribbean Gulf) took over the concession rights from Union Oil Co. of California in 1962 and drilled two wells in Bocas del Toro near the border with Costa Rica: the Senosri No. 1 well (9,700 feet), with minor gas shows, and the Soledad No. 1 well (8,002 feet), with small gas shows at 2,440 feet (González, 1984).

9. Stage 4: Offshore shallow water exploration, 1969-1991

Oil exploration was seriously affected and subsequently abandoned when the Mineral Resources Code Decree Law 23 of August 22, 1963, was published and became law on July 13, 1964, during the presidency of Roberto F. Chiari, superseding Law 19 of 1953. Union Oil Co. and Gulf Oil abandoned their concessions and left the country. After a lost decade of exploration, the government officials found a work-around to avoid the 1963 law by granting special exploration concessions by special contract laws (Sossa, 1981).

After a gap of seven years, the next phase of exploration from 1969 to 1991 was offshore with 6,350 km of 2D seismics acquired in ten surveys (1969-1989), six wells drilled using drill ships and jackup rigs, and two wells drilled onshore (1974-1991).

9.1. MOBIL EXPLORATION, 1969-1972

Mobil Exploration and Production Services Company carried out geological mapping onshore around the Gulf of Panama and the Pearl Islands in 1971-1972 and collected 1,600 km of 2D seismic surveys in the Gulf of Panama between 1969 and 1972 but did not drill (González, 1984). The seismic data was published by Mann and Kolarsky (1995).

9.2. EL PASO NATURAL GAS CO., 1974

Corvus S.A. and Plaris S.A. of Panama obtained special contract laws in the Gulf of Panama. El Paso Natural Gas Co. of El Paso, Texas, drilled two wells in the Gulf of Panama in 1974 with the drill ship Glomar II (built in 1962) owned by Global Marine, Inc. (now Transocean Ltd.). Corvus No. 1 was drilled on the Corvus concession west of the Pearl Islands in 324 feet water depth and to a depth of 8,614 feet. The operator was El Paso Panama Company, and the partners were Santa Fe Minerals (Panama) Inc., Pacific Lighting Gas Development Company, Great Plains (Panama) Ltd., Mono Power Company, and Corvus S.A., a subsidiary of Oceanic Exploration Company. Drilling took 80 days between January 9 and March 30, 1974. There were no oil and gas shows. It intersected an interval of immature organic material at pre-petroleum grade and another interval of thermally mature organic material but in small quantity (González, 1984).

Plaris No. 1 was drilled with Plaris S.A., a subsidiary of Santa Fe International Corp., near Garachiné Point on the eastern side of the gulf, in 250 feet of water-depth and to a depth of 9,407 feet. It reported gas from 1,800 to 7,100 feet, with highest concentration at 3,800 to 4,800 feet. The well log data for both holes was published by Mann and Kolarsky (1995).

9.3. ESSO EXPLORATION AND PRODUCTION PANAMA, 1969-1973

Esso Exploration and Production Panama explored a concession of 2,930 km^2 in the Darien in 1969-1973 with geological mapping, air photo interpretation, radar image interpretation, and several short (~30 m) stratigraphic holes, but did not drill (Esso, 1970, 1971a, 1971b; González, 1984; Coates *et al.*, 2004).

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9.4. TEXACO INC., 1975-1993

Texaco Inc., formerly the Texas Company, was awarded 33,286 km^2 of offshore concessions covering the entire littoral Caribbean from San Blas to Bocas del Toro in the San Blas and Gulf of Mosquitos basins between 1974 and 1993. The first concession was awarded to its subsidiary Panama Exploration Inc. in 1974 or 1975 (497,762 ha). It carried out a seismic survey and drilled a dry well with Amerada Hess Corp. in 1978 (Marea No. 1, 6,685 feet), located on a seamount NW of Colon (USGS,1979; González, 1984). The strata were classified as immature for hydrocarbon generation.

In 1978, Texaco was awarded five concessions to five subsidiaries: Carib Exploration Inc. (499,764 ha); San Blas Exploration Inc.; Colón Exploration Inc. (465,315 ha); Balboa Exploration Inc. (418,290 ha); and Isthmus Exploration Inc. (499,508 ha). In 1991, Texaco Exploration Panama Inc. was awarded Blocks 1 and 2 (450,488 ha), Bocas del Toro Province, both onshore and offshore, which it explored until at least 1993. (Sossa, 1981; USGS, 1979, 1990, 1991, 1993; López-Schaw, 1992).

9.5. SOSSA PETROLEUM CO. INC., 1978-1986

Sossa Petroleum Co. Inc. drilled two onshore wells in the eastern part of Panama Province on the Cañazas Dome in the upper Bayano basin in 1978-1979 (Cañazas No. 1, 3,283 feet) and 1981 (Cañazas No. 2, 4,000 feet) with Tacoma Resources to confirm the results of prior exploration carried out in 1958-1962. The first well had oil shows between 1,845 and 2,567 feet, but the second well was dry. The second well was drilled with a National 50 rig by Norsul Oil & Mining Co. (Sossa, 1981; Figure 15). Very heavy rain throughout the year paralyzed the operation, and the rig could not be demobilized until late in the year. The well was designed to test the Clarita Limestone Formation. It cut 150 feet of limestone and 40 feet of the Porcona Formation. The wells were located on the Cañazas structure but were considered to have inadequate structural control based only on mapping the strata in river sections but without a seismic survey (González, 1984).

According to the USGS (1980), Sossa Petroleum announced an oil discovery in the Darien Strait with plans to develop it. An oil discovery was also reported off the San Blas coast. This appears to be a misreport of an oil discovery made in Colombia by Ecopetrol in the Darien near the Panamanian border (Washington Post, 1979).

In 1982, Sossa Petroleum farmed out the Zone 4 concession in the Bay of Garachiné, to Aracca Petroleum Corp., New York, and Oxoco International Inc., Houston, with equal shares, with Sossa retaining a 12.5% interest (USGS, 1982; Sossa Development, 1985). They carried out a seismic survey and planned to drill offshore but did not (USGS, 1986).

9.6. IDRIA OIL & GAS COMPANY N.V., 1986-1989

In 1986 a contract was awarded to Idria Oil & Gas Company N.V. for blocks DGH 1 and DGH 2 in the Pacific. It carried out a 2D seismic survey in the Garachiné block in the Gulf of Panama in 1987-1988 and drilled 3 wells with a jackup rig in 1989. The rig was the JFP-III 300 ft cantilever jackup, owned by FP Energy Inc., Houston. The wells were Anayansi No. 1 to 4,504 feet depth, Cemaco No. 1 to about 8,000 feet depth with oil shows at 590-680 feet and 7,740-7,770 feet, and Bayano No. 1 to about 8,000 feet depth with multiple zones of gas. Idria let a turnkey contract to Triton International Corporation of Brampton, Ontario, to drill and test the wells.

Idria Oil & Gas Company was a private Iranian company founded in the 1980s by Prince Shazdeh Abolfath Mirza Mahvi-Qajar (1915-2009), a Prince Royal of Iran, and economic adviser to the Shah of Iran, whose story is told in an interesting book by his son (Mahvi, 2010). He was known as the "Oil Man of Iran." He joined the Anglo-Persian Oil Company in 1955 as a director, and later, as managing director of Pan American Oil Company, a division of AMOCO, brought the company to the Persian Gulf. Subsequently, he joined Standard Oil Company's

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subsidiary Iran Pan American Oil Company, now BP (Idria Energy, 2021). Ali Pascal Mahvi, his son, was the managing director of Idria (Mahvi, 2010). The award of the contract in 1986 by the de facto government of General Manuel Noriega is believed to have been a consequence of the de facto government of General Omar Torrijos having granted asylum in Panama to the Shah of Iran in 1979-1980, and the Idria investment was considered as a mark of gratitude.

Idria Energy, LLC, New York, and Idria Consulting Services Limited, Hong Kong, were created as the successors to Idria Oil & Gas by Pascal Mahvi, Director and CEO, in 2013. They formed a joint venture with an American drilling company, ENERSEP, in 2013 to carry out further exploration in Panama, but it did not come to fruition.

9.7.NEW HYDROCARBONS LAW, 1987

A new Hydrocarbons Law was enacted as Law No. 8 of June 16, 1987, by the de facto government of General Manuel Noriega. This was near the last phase of exploration, and only the Idria wells have been drilled since then. It was modified by Law 39 of August 14, 2007, and by Law No. 53 of September 9, 2013.

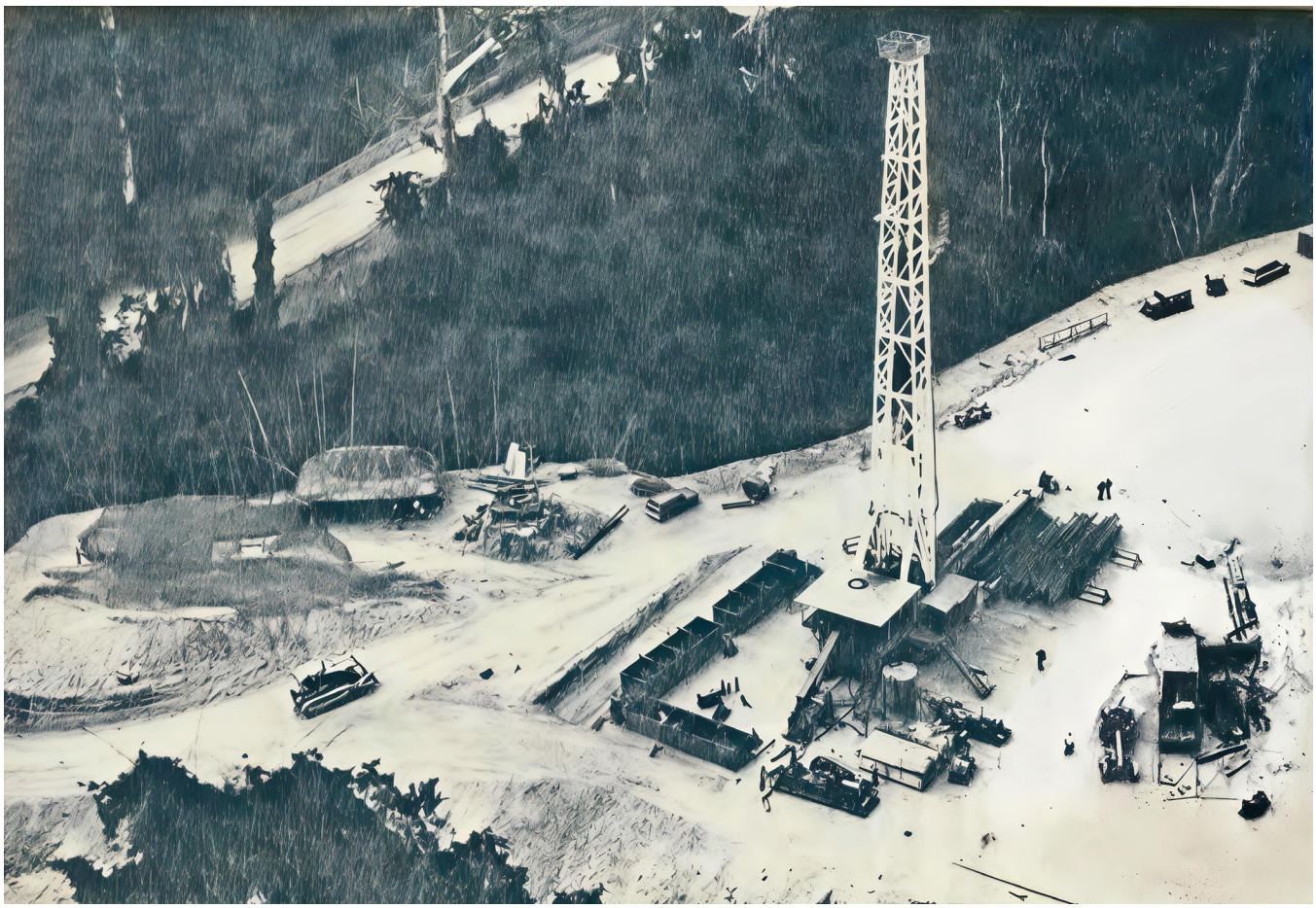

Figure 15 Norsul Rig No. 1 (National 50) at the Sossa Cañazas No. 2 well site, 1981 (photograph by Sossa Petroleum Prospectus, June 15, 1985, courtesy of James Cobbett).

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10. Stage 5: Recent offshore contracts, 2001-2017

10.1. GLOBAL ENERGY DEVELOPMENT PLC (HARKEN ENERGY CORPORATION), 2001-2010

Global Energy Development plc of London, listed on the AIM stock market, a subsidiary of Harken Energy Corporation (HKN Inc. from 2007) of Houston, Texas, signed a Technical Evaluation Agreement in Panama in 2001 for 1.4 million acres (566,560 ha) in three blocks in the Gulf of Panama. The contract was in the name of subsidiary Harken de Panama Ltd. Harken Energy became famous because George W. Bush, later 46th Governor of Texas (1995-2000) and 43rd President of the United States of America (2001-2009), was a director of the company from 1987 to 1993 and was investigated and cleared of insider trading in 1990.

In June 2007, Global Energy signed an operations contract, the first since 1990, for the Garachiné Block Area covering 691,500 acres (280,000 ha) in the Gulf of Panama. The Garachiné Block Area is a pinnacle reef reservoir with a number of oil seeps. The area was first identified in the 1920s when several shallow wells drilled onshore found good oil shows in the mid-Miocene rock section. More recent offshore exploration confirmed the Miocene source potential and outlined the regional basin structure with a reconnaissance seismic grid. The contract had an initial 5-year exploration phase during which Global had to spend US$10 million on reprocessing and reinterpreting existing seismic, gravity, and magnetic data; acquire new seismic data; and drill two exploration wells. Global carried out little exploration. In 2009 it was reported that the contract was suspended while third-party marine archaeological issues were resolved. The government cancelled the contract in 2010 after the company had spent $1.2 million without drilling (Global Energy Development plc, 2001-2010).

10.2. CIRCLE OIL PLC, 2005-2007

Circle Oil plc of Ireland, listed on London's AIM stock market, was granted a Geological, Geochemical, and Geophysical Prospecting Permit of 3 million acres (1.2 million hectares) on Block A offshore in the Caribbean in the eastern part of the Northern Panama Deformed Belt and the adjacent San Blas basin on August 25, 2005. The permit expired one year later, and a two-year extension was requested over a larger area of 29,990 km2 (3 million ha). The block was in water depths ranging from 500 to 3,000 m. A review of existing data identified two areas with significant hydrocarbon potential. The first play was located in the northeastern part of Panama in the Darien re-entrant area, and the second play was located in the deep-water Darien Knolls area. The next stage planned was a 2,700 km seismic survey. Circle Oil farmed out a 33% interest in Block A to Montage Petroleum Ltd., Australia. The government did not grant the extension in 2007. (Circle Oil, 2005, 2006, 2007).

10.3. DEEP WATER EXPLORATION INTEREST, 2014-2016

Oil exploration companies from the UK and Australia tried to secure offshore deepwater blocks in the Pacific Ocean and Caribbean Sea in 2014-2016 but were told that the government was preparing a round of licensing, which has not happened yet.

10.4. SEISMIC SURVEYS, 2017

Three spec seismic survey contracts were awarded by the General Directorate of Hydrocarbons in 2017 to the following companies: 1) GX Technology Group (GXT), part of ION Geophysical Corporation, Houston, which carried out a Caribbean seismic survey in November 2017; 2) Spectrum Geo Inc., Houston, a subsidiary of Spectrum ASA, Oslo, was awarded a Caribbean survey; and 3) Geoex Ltd., Houston and Epsom,

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Surrey, England, was awarded Caribbean and Pacific surveys. Only the GXT survey in the Caribbean was carried out (Saucier, 2018). A spec survey is paid for by the government and sold to interested parties as a means of generating geological data and interest, usually before a licensing bid. There has been no further hydrocarbon exploration activity since the seismic survey in 2017.

11. Discussion: Exploration drivers

A timeline of the five exploration periods, wells drilled, and legislation is shown in Figure 16 in order to examine the drivers for exploration. These are the interplay of external events including the global economy, wars, and the oil price; advances in exploration technology; advances in drilling technology; and changes in Panamanian hydrocarbon legislation. The Stage 1 initial period of onshore exploration (1912-1928) was driven by the global quest for the new fuel, the strategic location of the new canal and the presence of oil seeps. Geological mapping and stratigraphic studies of Bocas del Toro and Darien were carried out during this stage. Stage 2 (1945-1949) did not take place until after a hiatus caused by the external factors of the Great Depression and World War Two and was driven by a post-war rise in demand. After a short hiatus, the Stage 3 onshore exploration peak in 1953-1962 was the direct result of the new Hydrocarbons Law of 1953, itself the result of industry lobbying. This stage saw the use of advanced exploration technology with widespread seismic surveys, and the use of new drilling technology to drill offshore using jack-up rigs. The exploration boom was halted by a change in legislation in 1963. Exploration stopped for a decade until a legal solution was found by creating special Contract Laws. Stage 4 from 1969-1991 was driven by new drilling technology which enabled offshore deeper shelf exploration using the first generation drill ships and larger jack-up rigs. Exploration was encouraged by a new Hydrocarbons Law in 1987. There was a 10 year gap in exploration until Stage 5 from 2001-2017 of offshore shallow water exploration, but with no drilling. In the final part of Stage 5 there was commercial interest in deep-water exploration but only one of three spec seismic surveys was carried out and the planned licensing round did not happen.

Hydrocarbon exploration contributed to regional geological studies of Panama by geological mapping, stratigraphy, and paleontology that resulted in the publication of geological maps and descriptions of Panama (Schuchert, 1935; Terry, 1935, 1956; Terry and Olsson, 1935). Initially, exploration targeted natural oil seeps and used geological mapping to map the stratigraphy and structure to define drill targets. Advances in exploration technology resulted in the widespread use of seismic surveys from 1958 which enabled exploration of larger areas onshore and exploration offshore. Airborne magnetic surveys and gravimetric surveys contributed to regional geology. The development of airborne (and later satellite) radar surveying enabled geological mapping by remote sensing by seeing through the jungle forest canopy (*e.g.*, MacDonald, 1969; Wing and MacDonald, 1973). These surveys together with well logs and company mapping were used by research geologists to map areas such as Darien (*e.g.*, Coates *et al.*, 2004), Bocas del Toro (*e.g.*, Collins *et al.*, 1995; Coates *et al.*, 1992, 2003, 2005), and offshore Panama (*e.g.*, Kolarsky and Mann, 1995; Kolarsky *et al.*, 1995; Mann and Kolarsky, 1995). As a result of this exploration, as well as the studies of the canal excavations and surveys of other canal routes, the geology of the sedimentary basins of Panama is much better known than that of the volcanic arcs. Hydrocarbon exploration advanced by better mapping and understanding of the regional geology, aided by technological developments, and in turn, exploration made a significant scientific contribution to the geological knowledge of Panama.

Exploration was also driven by advances in drilling technology. Drilling rigs were originally

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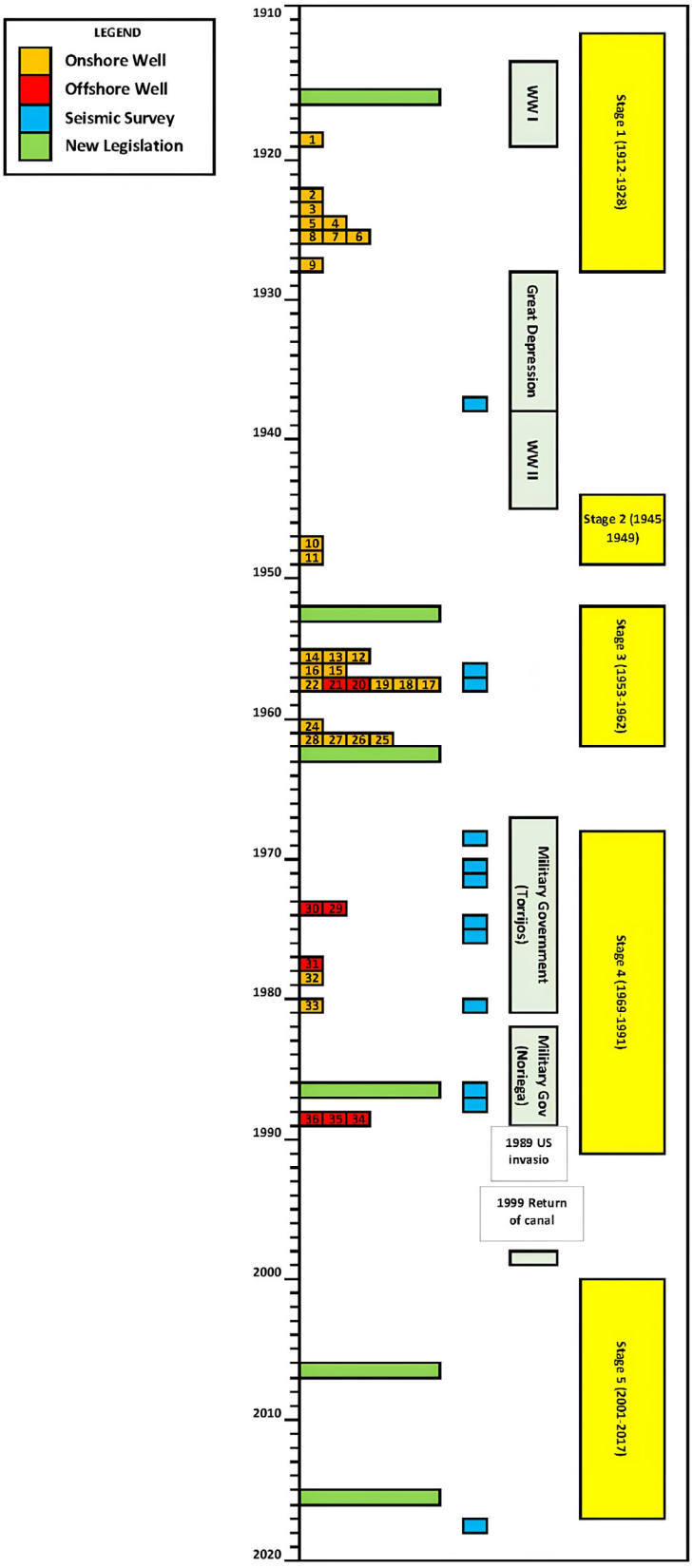

Figure 16 Timeline of hydrocarbon exploration in Panama. Well numbers refer to Table 2.

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limited to onshore. The development of the first jack-up drill rigs in 1953 enabled drilling in shallow water such as Chiriqui Lagoon, and the first purpose-built drill ship in 1962 and larger jack-up drill rigs in the 1960s opened up water depth up to 400 feet (122 m) such as the Gulf of Panama. Sixth generation drillships can now drill in water depths up to 12,000 feet (3,658 m) which prompted interest in deep water exploration in Stage 5 but, so far, none was carried out.

Finally, the laws governing hydrocarbon concessions can encourage or discourage exploration. Hydrocarbon exploration in Panama was covered by the mining laws for fifty years. The creation of a separate Hydrocarbons Law in 1953, in response to lobbying, boosted exploration, only to be replaced by a new Mineral Resources Code in 1964, which halted hydrocarbon exploration for a decade until a work-around was found by creating special Contract Laws. A new Hydrocarbons Law was passed in 1987 with modifications in 2007 and 2013 but their effect was limited and no wells have been drilled since 1989.

12. Conclusion

Panama does have potential for commercial hydrocarbon deposits as demonstrated by 13 wells with oil and/or gas shows, or one-third of all wells drilled. Some experts think that some wells with shows, such as Garachiné, could have been converted into producing wells with modern completion techniques (Sossa, 1981).

González (1984) considered that the 36 wells drilled were not enough to fully explore the country when compared with worldwide discovery rates of one well in nine with petroleum shows and one well in 44 making a potentially commercial discovery.

The offshore basins are virtually unexplored, and the deep-water basins are totally unexplored, with high potential shown by recent major gas discoveries of the Kronos-1 (2015), Purple Angel-1 (2017), Gorgon-1 (2017), and 2 (2022) wells in the Southern Caribbean of Colombia adjacent to Panama (Cavcic, 2022).

Panama depends on oil and gas for 65% of its total energy supply (TES) including road vehicles, marine bunker fuel, aviation fuel, domestic gas, and 19% of electricity generation (IEA, 2022). All of this oil and gas is imported. Domestic oil and gas production would surely be welcome for economic and geopolitical reasons to boost the gross domestic product (GDP) as well as guarantee security of supply.

Contributions of authors

The conceptualization of the topic, preparation of figures and tables, and analysis were carried out by the author.

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Conflicts of interest

The author has no conflicts of interest to declare.

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