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TALES OF THE TWENTIETH CENTURY: OIL EXPLORATION, GEOLOGICAL AND PALEONTOLOGICAL LABORATORIES, AND THE DEVELOPMENT OF PALYNOLOGY IN VENEZUELA

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ABSTRACT

Exploration for oil expanded quickly in several regions of the world during the first part of the twentieth century. All around the globe, teams of field geologists were surveying sedimentary basins where oil seeps had been reported. They sought the right geological conditions to find significant oil reservoirs. Still, many of the best reservoirs were in terrestrial sections, so it was tough to age date them using the traditional paleontological and micropaleontological fossil groups known at the time.

The search for oil started later in Venezuela than in Mexico and the US, but the quick decline of the known reservoirs and the political turmoil in the early decades of the 1900s in Mexico favored intensive surface oil exploration campaigns in nearby Venezuela, a country previously known to the industry for the oil seeps along its coast, some "artisanal" oil production in the Andes, and the asphalt production from Bermudez-Guanoco Lake. The first and best-documented exploration campaign was led by Ralph Arnold from 1912 to 1916 on behalf of the General Asphalt Company, which successfully identified what would become the country's main producing fields in the following decades. With the extensive discoveries that followed in the 1930s and 1950s, successive exploration campaigns by different companies and interested groups seeking new or additional concessions in the country set the stage for the accelerated development of the application of palynology to the oil industry in Venezuela.

Just before the Second World War, some companies started research in palynology in their home countries by consulting with renowned coal palynologists at universities. Immediately after the end of the war, the Caribbean Petroleum Co. (later Shell de Venezuela) and the Lago Petroleum Co.–Standard Oil de Venezuela (later Creole Petroleum Corporation) started devoting considerable resources to advancing this application in Venezuela. Still, palynology results were kept confidential for many years due to its extraordinary success and the leading edge they provided these companies. For exploratory and operational reasons, early palynological studies focused on the country's Late Cretaceous and Paleogene sections. Therefore, proprietary palynological zonations for the Paleogene were extensively applied in Shell and Creole concessions from the 1940s. In the 1950s, other companies opened geological-paleontological laboratories with palynology sections—e.g., the Mene Grande Oil Company and the Texas Oil Company (Texaco). In the 1960s, there was a steep decline in oil exploration activities in the country. Then, the new palynological laboratory of the Corporacion Venezolana del Petroleo (CVP) started operation in Maracaibo. On December 31, 1975, all concessions were reverted to Venezuela's government, including all its properties, plants, equipment, and geological-paleontological laboratories.

By the early 1980s, only three nationalized companies (Lagoven, Maraven, and Corpoven) and one research institute (INTEVEP) remained; all had active and prolific geological-paleontological laboratories. On December 31, 1997, a change in the corporate structure of the Venezuelan oil industry took effect with the merger of the three companies into Petroleos de Venezuela (PDVSA), and their geological-paleontological laboratories became one under the umbrella of the Exploration Business Unit, with regional laboratories in the East (Puerto La Cruz–El Chaure), the West (Maracaibo–La Concepcion), and Caracas. The paleontological laboratory of INTEVEP (Los Teques) remained independent after the merger. Palynology continued to thrive in all those laboratories from 1978 to 2000, preserving their memory and expanding and modernizing the knowledge gained by their successful predecessors.

RESUMEN

Historias del siglo XX. Venezuela: Exploración petrolera, laboratorios geológicos y paleontológicos y desarrollo de la palinología.

La exploración de petróleo se expandió rápidamente en varias regiones del mundo durante la primera parte del siglo XX. Equipos de geólogos de campo exploraban cuencas sedimentarias en todo el mundo donde se habían reportado menes de petróleo. Buscaban las condiciones geológicas adecuadas para encontrar importantes

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yacimientos de petróleo. Aun así, muchos de los mejores yacimientos se encontraban en secciones terrestres, por lo que era difícil datarlos utilizando los grupos de fósiles conocidos y usados en la industria en ese momento.

En Venezuela, la búsqueda de petróleo comenzó más tarde que en México y EE. UU., pero el rápido declive de los yacimientos conocidos y la agitación política de las primeras décadas del siglo XX en México favorecieron las campañas intensivas de exploración de petróleo en la vecina Venezuela, un país conocido en la industria por los menes de petróleo a lo largo de su costa, alguna producción de petróleo "artesanal" en los Andes y la producción de asfalto del lago Bermúdez-Guanoco.

Probablemente la primera y mejor documentada campaña de exploración en el país fue la liderada por Ralph Arnold entre 1912 y 1916 en nombre de la General Asphalt Company, que identificó con éxito los que serían los principales campos productores del país en las décadas siguientes. Los extensos descubrimientos que siguieron durante las décadas de 1930 y 1940, producto de sucesivas campañas de exploración por parte de diferentes empresas y grupos interesados que buscaban nuevas o adicionales concesiones en el país, fueron la razón de fondo del acelerado desarrollo de la aplicación de la palinología a la Industria Petrolera en Venezuela.

Justo antes de la Segunda Guerra Mundial, algunas empresas comenzaron su investigación en palinología en sus países de origen consultando con palinólogos del carbón de renombre dentro del ámbito universitario. Sin embargo, inmediatamente después del final de la guerra, la Caribbean Petroleum Co. (luego Shell de Venezuela) y la Lago Petroleum Co. - Standard Oil de Venezuela (luego Creole Petroleum Corporation) comenzaron a dedicar una cantidad considerable de recursos para acelerar el desarrollo de esta aplicación en Venezuela. Aun así, los resultados de palinología se mantuvieron confidenciales durante muchos años debido a su extraordinario éxito y a la ventaja competitiva que proporcionaron a estas empresas.

Por razones exploratorias y operativas, los primeros estudios palinológicos se centraron en las secciones del Cretácico Superior y Paleógeno del país. Por lo tanto, las zonaciones palinológicas propietarias para el Paleógeno se aplicaron ampliamente en las concesiones de Shell y Creole desde la década de 1940. Durante la década de 1950, otras empresas abrieron laboratorios paleontológicos con secciones de palinología, como por ejemplo, la Mene Grande Oil Company y la Texas Oil Company (Texaco). Durante la década de 1960, una fuerte caída en las actividades de exploración de petróleo golpeó al país. Es en ese entonces cuando inició operaciones en Maracaibo el nuevo laboratorio palinológico de la Corporación Venezolana del Petróleo (CVP). El 31 de diciembre de 1975, todas las concesiones fueron revertidas al gobierno de Venezuela, incluyendo todas sus propiedades, plantas, equipos y laboratorios geológicos-paleontológicos.

A principios de la década de 1980, después de un intenso proceso de racionalización de operaciones solo quedaban tres grandes empresas nacionales (Lagoven, Maraven y Corpoven) y un Instituto de Investigación (INTEVP); todas contaban con activos y prolíficos laboratorios geológicos-paleontológicos en funcionamiento. El 31 de diciembre de 1997 se produce un cambio en la estructura societaria de la Industria Petrolera Venezolana con la fusión de las tres empresas en una sola, Petróleos de Venezuela (PDVSA), y sus laboratorios geológicos-paleontológicos se unificaron bajo el paraguas de la Unidad de Negocios de Exploración. La estructura incluyo tres laboratorios regionales: uno en Oriente (Puerto La Cruz-El Chaure), uno en Occidente (Maracaibo-La Concepción) y uno en Caracas. El laboratorio paleontológico de INTEVEP (Los Teques) permaneció independiente después de la fusión. La palinología siguió prosperando en todos estos laboratorios desde 1978 hasta al menos el 2000, conservando la memoria, pero ampliando y modernizando la experiencia adquirida por sus exitosos predecesores.

Palabras Clave: Exploración geológica, Palinologia, Paleontología, Laboratorios, Venezuela, Petróleo
Keywords: Geological exploration, Palynology, Paleontology, Laboratories, Venezuela, Oil

Foreword

I learned palynology in Venezuela and in the Netherlands in the early 1980s. At that time, I was fortunate to have the opportunity to meet a few of the palynologists who developed the application of stratigraphic palynology in the oil industry. Their recounting of their memories fascinated my young mind. Still, at the time, I did not fully grasp the immensity of these pioneers' work in solving geological puzzles while facing challenges away from home.

So, I tell this story partly based on my imperfect memories of these conversations. In addition, this story is informed by a review of unpublished reports and field books from the early oil exploration era in Venezuela, then kept in the basement library of Maraven S.A., as well as the maps in the drawing department. These experiences awakened an immense curiosity, which led me to read through any publication related to what was happening in Venezuelan oil exploration and the development of "oil" palynology during the early years. I did not want those pioneers' names and work to be forgotten. So, to keep their memory, I decided to write about their stories, which you will find in this history.

INTRODUCTION

The oil industry was expanding rapidly in the world in the first part of the twentieth century. Teams of field geologists were surveying the major sedimentary basins where oil seeps were reported, searching for the right geological conditions to

find oil. From 1912 to 1916, a team of professional geologists under the coordination of Ralph Arnold carried out the first systematic exploration project in Venezuela across the country's sedimentary basins. The success of that team led to what was to become one of the most amazing stories of oil exploration and production success in the world.

Between the First World War and the end of the Second World War, many companies and individuals came to the country to search for their fortunes. In the following years, conditions changed. The Second World War had almost stopped oil exploration, but companies after the war had already found plenty of oil in commercial quantities, especially in Venezuela. Still, it was the moment to search for new technologies and methodologies to increase the success of oil exploration and production.

Just before the Second World War, a couple of companies had started to assess pollen science[2] as a possible age dating and correlation tool in the vast but mainly unknown oil-bearing sedimentary basins. The war halted the assessment, but pollen science developed immediately after the end of the war as a tool for oil exploration, and it was then that oil exploration in Venezuela played a key role in the development of the application of that science in the industry. But memory fades as time passes, and the names of the protagonists and witnesses of this history have become blurred.

The objective of this work is to help maintain the memory of the findings, contributions, achievements, and names of those geologists and paleontologist-palynologists who contributed to making Venezuela a key country in the twentieth century for the production of hydrocarbons and the development of new technologies, methodologies, and even "new" sciences.

This work presents a chronicle of what happened based on the work of Ralph Arnold and his teammates, Arnold's photography collection, and news articles published between 1910 and 1965 in different newspapers in North America and Europe. It is also based on articles published in different journals from 1947 to 1977 by paleontologists working in the country. All these materials are mingled with my memories and recollections of conversations I had many years ago with some of these pioneers—Jan Muller, Thomas van der Hammen, Estela de Di Giacomo, Angel Fuemayor, Max Furrer, Virgil Winkler, Levinus Nijssen, and J. P. H. Kaasschieter, among others.

A BRIEF HISTORY OF OIL EXPLORATION IN VENEZUELA

The oil industry expanded quickly in several regions of the world during the first part of the twentieth century. Teams of field geologists surveyed sedimentary basins where oil seeps had been reported, looking for the right geological conditions to find major oil reservoirs. Venezuela was one such place near the US to look for oil. The presence of oil in the country had been known for many years; the natives used it for different purposes, including medicinal uses, even before the arrival of colonizers (see Video 1). Still, the country's undeveloped and unexplored conditions made it less attractive for oil companies than Mexico.

Arguably, the first published descriptions of Venezuela's widespread occurrence of oil seeps date back to Alexander von Humboldt. In 1822, he recounted his memories of travels in 1799–1800 to the tropical areas of South America, mentioning the occurrence of hydrocarbons described as asphalt, petroleum, or naphtha in different locations along the coast between Trinidad and Maracaibo, as well as around Lake Maracaibo, in the Peninsula of Araya, in river margins like the Buen Pastor spring in the Areo river (today, Guanoco Asphalt Lake), and in the country's interior lands.

Video 1. *A clip from the 1950 video "PEOPLE AND PETROLEUM, THE STORY OF CREOLE IN VENEZUELA" by the Creole Petroleum Corporation, preserved in Reel America, C-Span3, American History TV. To visualize the video, visit the link: https://www.c-span.org/video/?c4964273/user-clip-oil-maracaibo*

From a commercial point of view, small-scale oil exploration projects had been active in the country since the late 1800s. As a curious anecdote, in western Venezuela in 1870, physician Dr. González Bona, in one of his frequent visits to patients in the Rubio area of Tachira State, noted in "La Alquitrana" ravine a residue that he later identified as petroleum. Aware of the importance of the substance, Dr. González Bona contacted his friend, the owner of the land, Mr. Manuel Antonio Pulido, and proposed to start a company to produce petroleum. At that time, his friend was not enthusiastic about the idea; it was not until five years later, on May 18, 1875, that an intense earthquake made the oil flow from the ground in the area. The farmhands, known as "peones," ran to tell Mr. Pulido the news, and he saw some of his coffee and banana crops spoiled by a dark and viscous fluid. With such decisive evidence, Mr. Pulido called a few of his best friends, including Dr. González Bona, and they started the Compañía Hullera del Táchira and signed

[2] Pollen science is an old synonym of palynology. The word palynology was coined in 1944.

a private contract to operate. This was the first oil company in Venezuela, and Mr. Pulido received exclusive rights to explore and produce coal, pitch, and tar in an area of 100 hectares from the Andes government. Their first productive well was Eureka No. 1, drilled circa 1878. Although the company was active for several years, it was not until July 30, 1882, that it was formally registered and named the Compañía Nacional Minera Petrolia del Táchira (SVIP, 2002).

According to George Macready (in Arnold et al., 1960), "In 1890 a man named Graham drilled a well near the south edge of the Capure pitch lake seepage.[3] The casing of the hole can still be seen protruding above the ground. Reports about this well are conflicting." Also, according to Macready "Control of the Pitch Lake on the Island of Trinidad was extended in 1893 to the Bermudez or Guanoco asphalt lake in eastern Venezuela. Barber's business has been conducted through various subsidiaries and several consolidations have taken place, but it was known as General Asphalt Company, which pioneered for petroleum in Venezuela."

Thus, in 1900 the English company Asphalt Paving began asphalt exploitation in Pedernales, and the United States and Venezuelan Co. received a concession to exploit asphalt in Carrasquero (Zulia). In 1901, the New York and Bermudez Company began to extract asphalt in Lake Guanoco (Sucre), a 420-hectare asphalt lake, arguably the biggest (or the second biggest) asphalt lake in the world, which contained an estimated 75 million barrels of oil. The company became infamous for supporting the so-called Liberation Revolution to overthrow President Cipriano Castro, who, when victorious, took measures against the company (Giacopini Zárraga, 1986, in Silva Calderon, 2006). The situation led to the Asphalt War, a term mentioned in *The New York Times* as early as January 6, 1901.

Castro (Fig. 1) initially demanded $9,650 from the New York and Bermudez Asphalt Co. on July 12, 1904, on the allegation that the company had given material aid to the revolutionary movement. On August 1, the Venezuelan government seized the property; in February of the following year, the Venezuelan Court ordered the sequestration of the asphalt company property. Castro refused any arbitration with the US government regarding the situation (*The New York Times*, May 21, 1905) until the case was fully resolved in Venezuelan courts. By September 1905, the demand reached $11,000,000 (*The New York Times*, September 28, 1905). In 1907, the US held the sentence of a $4,600,000 fine because of the alleged connections with the Matos rebellion. This fine was finalized in July 1908 with no possible appeal (*The New York Times,* August 20, 1907; July 3, 1908). Other expenses were also allowed to be recognized.

The seizing of the Guanoco (Bermudez) asphalt lake created a major diplomatic issue between the US and Venezuelan governments, adding to the already very complex political situation during Castro's presidency (1899–1908). In addition, Venezuela confronted several European countries, including the Netherlands, England, Italy, and Germany. Those governments established a blockade of the country, sinking several ships and carrying out cannon fire attacks on coastal towns.

In 1910 and 1912, Juan Vicente Gómez, President of Venezuela, granted two concessions to the General Asphalt Company (Barber Asphalt Co.) to improve relationships with the US. These concessions consisted of "1. A concession in 1910 which comprised certain acreage around the (Bermudez o Guanoco) pitch lake, which they could exploit for petroleum; and 2. A concession in 1912 comprising practically the whole of Venezuela north of the Orinoco and Apure rivers, with the exception of a few central states" (Macready in Arnold et al., 1960). A new company, the Caribbean Petroleum Company, was incorporated with the General Asphalt Co. in November 1911 in New Jersey as a sole proprietor to hold this vast second concession.

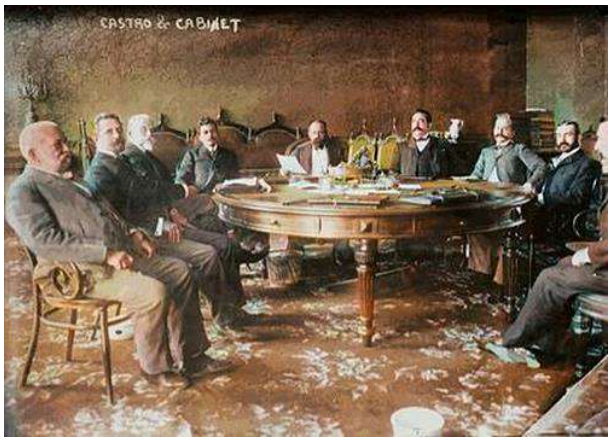


Figure 1*. Cipriano Castro in a cabinet meeting in the troubled early 1900s. Image of unknown date, taken from Potenziani Bigelli (2009). Photography colorized.*

The president of the General Asphalt Company, John M. Mack, hired Ralph Arnold (Fig. 2), an American geologist and petroleum engineer, to survey oil in Trinidad, Venezuela, and the West Indies. According to Arnold (1960, p. 11), "My instructions from the company were to 'get all the men I needed,' which was not easy. At that time there were few geologists available and practically none had experience in oil. I employed graduate students from the geology departments of Stanford, University of Chicago, Cornell, Harvard, Yale, Columbia, and other colleges over the country (US). My first group consisted of about five or six men. However, before the survey was completed, I had employed fifty-two American geologists for this work."

In January 1912, Dr. Arnold started his exploration project to look for oil using geological methods. He began in Trinidad,

[3] According to the work of Urbani (2022, p. 55) this belongs to Pedernales.

but the conditions with the British were not auspicious for exploration, so he moved the campaign to the west. Venezuela was a huge area—approximately 1,000 miles long by 300 miles wide—and Arnold needed to select an area of 500 hectares by 1913 for the Bermudez Co. and another area by 1914 for the Caribbean Petroleum Co. In July 1912, his geological crews started to work in western Venezuela. Although he envisioned the huge potential of the Maracaibo basin in the early exploration stage, his first report, dated November 27, 1912, enticed Shell to join General Asphalt in Venezuela. According to Arnold et al. (1960), it was at the London office of the Royal Dutch/Shell Oil in 1913 when Shell realized the value of the Venezuelan concessions and negotiated the acquisition of 51% of the General Asphalt Company's Caribbean Petroleum Company, paying $10,000,000 for that participation.

During the first year of the exploration project, Arnold worked under the direction of John M. Mack, the president of the General Asphalt Co. A list of the geologists from the Arnold team includes Dan Nolan, Clarence Peterson, Harold E. Boyd, A. H. Garner, Franklin S. Prout, "Pike" A. S. Henley, "Brick" Elliott, Fred Feisthammel, Will Fowler, Harold Boyd, Han Garner, Barnabas Bryan, Emil Huguenin, Dell B. Arrel, T. A. Bendrat, Byron Jackson, Bernard Hasbrouck, Floyd C. Merritt, Garnet A. Joslin, Charles R. Eckes, and Martin Tovar. In the Maracaibo Basin, the geologists working since December 1912 were McKee, Burnett, Wilson, Hammer, Bjorge, Taylor, R. W. Merritt, White, Dagenais, and Donnelly. In January 1913, Dixon, Burton W. dark [*sic*], Nash, and Herold arrived. Elliott and Jeffreys were compiling all the information in Caracas and correlating the field work of the other geologists. Later in 1913, more geologists came to the country—namely, McCullough, Noehl, Gehrmann, Nobs, Wilde, Lewis, Andresen, Sinclair, Packard, and Jeffreys.

During the first year of their field work in the country, many of them became ill with malaria and fly bites, which infected them with worm eggs that grew below the skin; they were forced to return to the US within a few months. Sadly, one geologist, Walter R. Nobs, died in Maracaibo in September 1913 from a fly bite complication with malaria and a tetanus infection from a wrongly applied quinine injection. Two other geologists, Charles Eckes and Louis Dagenais, were saved from typhoid fever in extremis.

This was a chaotic time from the exploration point of view. As Macready (in Arnold et al., 1960, p. 19) explained, "only three projects had been drilled in Venezuela, two abandoned as unproductive, and a third with a production of one barrel a day." Moreover, drilling results in Trinidad were catastrophic, and the huge amount of money invested in the adventure produced extensive restlessness among investors in the US, leading Mack to resign as the president of the company on March 13, 1912 (*The New York Times,* February 15, 1912). Thanks to Arnold's team's field work, however, "Within two years a thousand-barrel well was discovered, the first oilfield in eastern Venezuela at Guanoco, in 1913. Within three years the first oil-field in Maracaibo basin was discovered at Mene Grande in 1914 with a thirty thousand barrel well" (Macready in Arnold et al., 1960, p. 19).

The No. 1 well was located close to Guanoco Lake. Arnold's team visited the location and took a photo, shown in Figure 3. Arnold's team proposed an initial well, Bababui Well #1, that produced commercial oil near the shores of Guanoco Lake: "Bababui Well #1 was started in August 1912, and after great difficulty — because of heavy oil—was suspended in August 1913 at a depth of 615 feet, flowing up to 1,000 barrels of heavy oil daily as the discovery well for the first commercial oil field in Venezuela" (Macready in Arnold et al., 1960, p. 29).

Concession terms at the time required that the 500-hectare area selected must be surveyed and that the plan be signed by a Venezuelan engineer. At that time, the Venezuelan engineers working in eastern Venezuela were Rafael Torres, Santiago Aguerrevere, Enrique Aguerrevere, Pedro Aguerrevere, Martin Tovar, and Luis Pacheco. According to Macready (Arnold et al., 1960, p.75), the Caribbean Company concession expired on January 2, 1914: "By that time Company had filed selections for 789 areas in western Venezuela and 239 areas in eastern Venezuela, or a total of 1,028 areas. This is equivalent to 1,259,580 acres selected. This included Bermudez Company selections of 28 areas, or approximately 7,000 acres."

The location proposed by Arnold's team in Perijá struck oil in February 1914, but the field was not developed at that time due to World War I. Arnold called this exploration "the adventure of a lifetime" (Arnold et al., 1960) and left a well-organized photographic collection of his whereabouts through the years. Images from that collection of his and his team's work during the exploration of Venezuela between 1912 and 1916 are depicted in Figures 3, 4, 5, 6, 7, 8, 9, 10, 11, and 12.

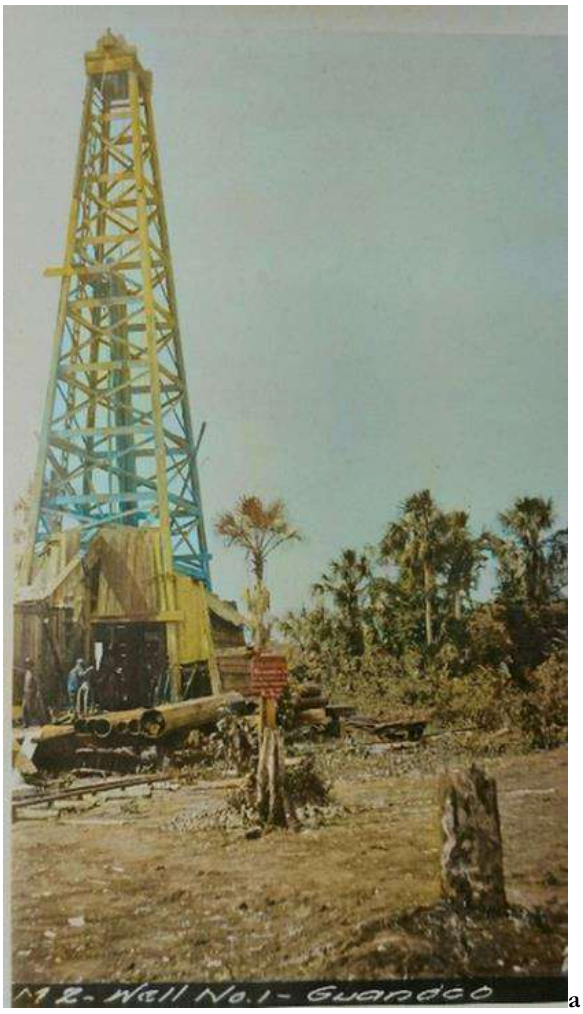
According to Macready (in Arnold et al., 1960), "By 1916 commercial oil production had been discovered in Mene Grand east of Lake Maracaibo, and from then on operations rapidly expanded with discoveries of new fields both in western and eastern Venezuela every year." World War I was ongoing in Europe (1914–1918), and oil proved a vital commodity for the transportation of troops and gear. Mexico was America's most important oil producer after the US during that time, but its productive oil fields in the "golden lane" had started declining. Also, the 1910s were chaotic political years due to the Mexican Revolution. These two factors pushed some companies to evaluate alternatives to replace Mexico's production in their portfolios: "By November, 1914 war in Europe had become so involved that all drilling operations in the Maracaibo district were shut down, and skeleton crews left to maintain production and equipment. Drilling was not resumed on any scale until 1919" (Macready in Arnold et al., 1960, p. 77).

This did not mean a complete standstill; drilling activity was ongoing between 1915 and 1916 in La Rosa, Rio de Oro, and Tarra. The geologists Dagenais and Garner continued their field work in the Maracaibo Basin. Also, in 1915, Ralph Arnold made a trip to Venezuela and Trinidad "to check the progress

of some of the principal oilfields which had been discovered during the past year" (Arnold et al., 1960, p. 83). Due to the interest and exploratory activity by Royal Dutch Shell in Venezuela, Standard Oil of New Jersey sent its teams of geologists in 1915 to survey the country but declined to buy any concessions. In 1919, another Standard Oil geologist reported that the country was unattractive (Brown, 1985).

Figure 2. *Geologist Dr. Ralph Arnold on a ferry in the Maracaibo Lake, circa 1913, according to Martinez (2014). Photography by an unknown author published in Martinez op. cita LadoB (CC BY-NC-SA 2.5 MX). Photo colorized.*

In 1919, Standard Oil of New Jersey decided to begin to acquire concessions for exploration from other companies already in the country because of the interest shown by their competitor Royal Dutch Shell. Standard approached British Controlled Oil Field and some private middlemen with government relations. Still, Standard Oil was not as successful as its competitor and drilled more than 40 wildcats without commercial success (Brown, 1985).



a

Figure 3.a. *Well No.1 Guanoco. Photo courtesy of the Ralph Arnold Photograph and Map Collection, The Huntington Library, Art Collections, and Botanical Gardens Photo Archives, Box 8, Ser. 2, Vol. 2_ Image 578. Photo colorized.*

b

Figure 3. b. *Geologist Charles Eckes canoeing in the swamps at Guanoco. Photo courtesy of the Ralph Arnold Photograph and Map Collection, The Huntington Library, Art Collections, and Botanical Gardens Photo Archives, Box 8, Ser. 2, Vol. 2_ Image 386. For reference, see Arnold (1955–1961). The image was colorized.*

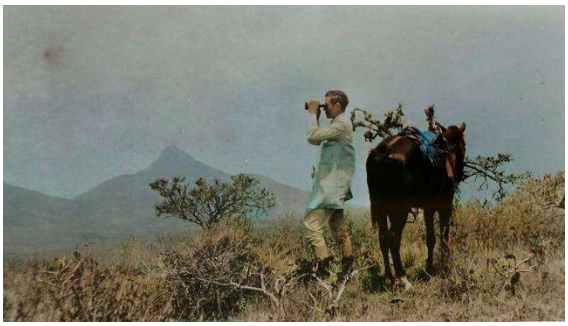


Figure 4. *A geologist of Dr. R. Arnold's team during the expedition survey for oil in Venezuela on behalf of the General Asphalt Co. and the Caribbean Petroleum Company, circa 1912. Photo courtesy of the Ralph Arnold Photograph and Map Collection, The Huntington. Library. Photo Archives, Box 8, Ser. 2, Vol. 2_ Image 573. The image was colorized.*

The country witnessed its first commercial oil discovery only two years after the Caribbean Petroleum Company obtained the concession over western Venezuela. On June 31, 1914, the Zumaque 1 well achieved a daily rate of 250 barrels of oil in Mene Grande. Further drilling confirmed this discovery, but none could match the famous blowout of the Los Barrosos 2 well in the La Rosa field of the Venezuela Oil Concessions Company in December 1922. With an astonishing initial production estimated at 100,000 barrels per day, it took nine days to control that blowout (Fig. 7).

Because of this success, the development of the Bolivar Coast in Zulia State was hectic over the next three years. The oil fields of La Rosa–Cabimas–Bachaquero and Lagunillas looked like a "forest of derricks stretching for 50 miles, for 5 miles deep in land, and 8 miles out in the lake" (Gunther, 1941, p. 49). Figure 8 shows the approximate extent of the Cabimas–Bachaquero production area during those times. Figure 14 shows an image of the first oil wells in the waters of Lake Maracaibo.

Other geologists did field work in western Venezuela related to exploration carried out by the Venezuela Gulf Oil Company and left important collections of documents with photographs, letters, and maps (Navarro, 2022). These include John Douglas, who lived in Venezuela in 1925–1926; Max L. Krueger, a consulting petroleum geologist who worked for Venezuela Gulf Oil Company in 1926–1929 in Venezuela and other areas of South America; John Gray Douglas, who worked as a subsurface geologist for Venezuela Gulf Oil Company in 1924–1927 and returned to Venezuela Gulf Oil, which was renamed Mene Grande Oil Company, in 1934–1955; and H. Harper McKee, who was a petroleum prospector in Central America, Texas, and Oklahoma in 1915–1920 and prospected in Venezuela sometime between 1915 and 1951 (his collection included maps of the country dated from 1948).

As the war in Europe continued in 1915, oil operations in Venezuela almost reached a standstill. According to Macready (Arnold et al., 1960, p. 83), "The Caribbean Petroleum Company did not drill any new wells and confined their operations to finishing up more important geological mapping and maintaining production at Mene Grande." Arnold's last trip to Venezuela started at the end of June and continued through July of 1916, when his exploration project was near the end. In his tour description, he talked about the companies' activities: "The Venezuelan Oil Concessions Company has a fine camp at La Rosa, southeast of Maracaibo in Bolivar, which Jeffreys and I used while we were in this part of the country. Here they have storehouses, blacksmith shop, stables for horses and mules, etc. The wells of the company are six miles east of La Rosa, near Majuga Hill. Good sized seepages are found three miles from the wells and six miles east of La Rosa. Well No. 5 was 1,112 feet deep and produced oil of forty-degree gravity. Well No. 1, at the south end of the lagoon one-half mile south of La Rosa, was 1,432 feet deep. Well No. 4, one mile south of La Rosa, was 1,220 feet deep" (Arnold et al., 1960, p. 91).

By the end of 1920, companies like Colon Development had 115 men engaged in exploration in the Colon District of Zulia State, and the Venezuelan Oil Concession had 45 local employees exploring the districts of Maracaibo and Bolivar in Zulia State. Shell controlled both companies. The British also were active in exploring the country. For example, by 1921, the North Venezuela Petroleum Company had a total of 71 employees and a concession in the districts of Acosta, Zamora, and Silva of Falcon State, and the British Controlled Oil Fields had 307 employees and a concession of about seven million acres that included the Caribbean Sea frontage in Falcon State. Other mixed capital companies (British, American, Scottish) also had concessions. Most of these companies were later acquired either by Standard Oil or Shell. Figures 13 and 15 show the location of the different petroleum concessions in Zulia and Falcon States around 1923–1925.

According to *The Petroleum Times* (November 12, 1921), "various American companies have also been active in buying up oil concessions, notably the Sun Oil Company of Philadelphia, Venezuela Oilfields Company, Ltd., Bolivar Oilfields, Ltd., Carabobo Oilfields, Ltd., Escalante Oilfields, Ltd., Merida Oilfields, Ltd., San Cristobal Oilfields, Ltd., Sucre Oilfields, Ltd., Trujillo Oilfields, Ltd., Tachira Oilfields, Ltd., Venezuela Sun, Ltd., and Zulia Oilfields, Ltd.; the Maracaibo Oil Exploration Company (subsidiary companies: the Mara Oil Exploration Company, the Miranda Oil Exploration Company, the Paez Exploration Company, the Perija Exploration Company); and the Colombian Petroleum Company, with interests in the Lake of Maracaibo district and the neighboring Republic of Colombia."

After 1921, Standard Oil and its affiliates became essential players in Venezuela (Fig. 16), where Dutch Shell had established itself as the dominant company. Standard Oil of New Jersey negotiated with smaller companies that were previously in the country, i.e., the 1,000,000-acre property of the Maracaibo Oil Exploration Company that was acquired two years earlier (Fig. 16). Then, Standard Oil incorporated a new company in Delaware, the Creole Development

Corporation, which contracted the F. S. Pearson Engineering Company of New York to develop its new land holdings in the Lake Maracaibo district (*The New York Times,* January 31, 1922).

In September 1922, the British Controlled Oil Field struck oil at a depth of 633 feet in its Well 8 in Buchivacoa Concession. At that time, Standard Oil of New Jersey, through its affiliates, already had agreements to develop about half of all the British Controlled properties in Venezuela and Colombia (*The New York Times*, September 21, 1922). The first great success of Standard Oil in Venezuela was in eastern Venezuela, in the Moneb 1 well in Quiriquire. Still, conditions for development had a higher degree of logistical difficulty in eastern Venezuela; Quiriquire, in 1924, was the first field opened in eastern Venezuela (Gunther, 1941).

Figure 6. *A geologist from Arnold's team and a local guide in an outcrop in Eastern Venezuela. Photo courtesy of the Ralph Arnold Photograph and Map Collection, The Huntington Library, Box 8, Ser. 2, Vol. 2_ Image 457. For reference, see Arnold (1955–1961). Photo colorized.*

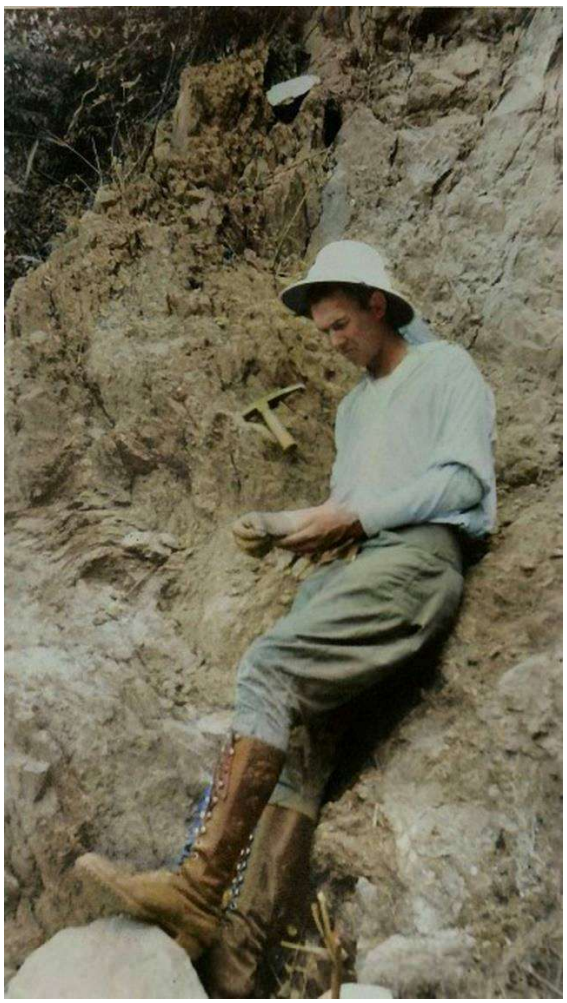


Figure 5. *A geologist from Ralph Arnold's team, maybe Barnabas Bryan, according to Professor Franco Urbani (personal communication), doing field work for the Caribbean Petroleum Corporation at La Laja, a location near Valera, Trujillo State, Venezuela, circa 1913. Photo courtesy of the Ralph Arnold Photograph and Map Collection, The Huntington Library, Art Collections, and Botanical Gardens Photo Archives, Box 7, Ser. 2, Vol. 1_ Image 56. Photo colorized.*

Figure 7. *Blowout of Los Barrosos 2 well. La Rosa Field, Zulia State, Venezuela, 1922 (photo Fundación Arquitectura y Ciudad, unknown author. Photo colorized. Source: https://fundaayc.wordpress.com/.*

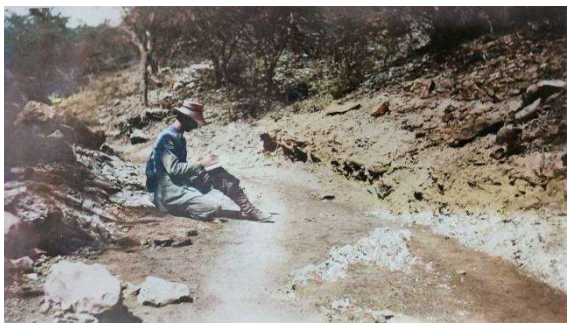


Figure 8. *Geologist from Arnold's team at work. Photo courtesy of the Ralph Arnold Photograph and Map Collection, The Huntington Library, Art Collections, and Botanical Gardens Photo Archives Huntington Collection, Box 7, Ser. 2, Vol. 1_ Image 43. Photo colorized.*

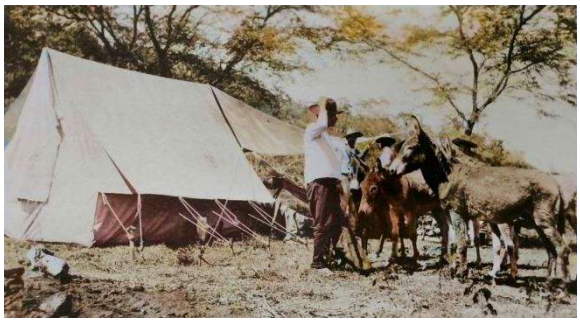


Figure 9. *Geology field camp, location unidentified. Photo courtesy of the Ralph Arnold Photograph and Map Collection, The Huntington Library. Photo Archives Huntington Collection, Box 7, Ser. 2, Vol. 1_ Image 280. Photo colorized.*

Figure 10. *Geology field camp, location unidentified. Photo courtesy of the Ralph Arnold Photograph and Map Collection, Photo Archives Huntington Collection, Box 8, Ser. 2, Vol. 2_ Image 452. Photo colorized.*

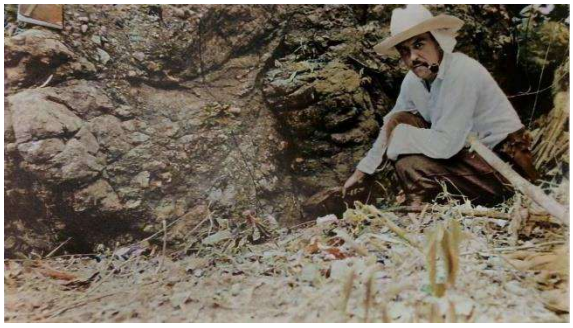


Figure 11. *Probably Dixon in an outcrop near Rio Socuy. Photo courtesy of the Ralph Arnold Photograph and Map Collection, Photo Archives Huntington Collection, Box 8, Ser. 2, Vol. 2_ Image 463. Photo colorized.*

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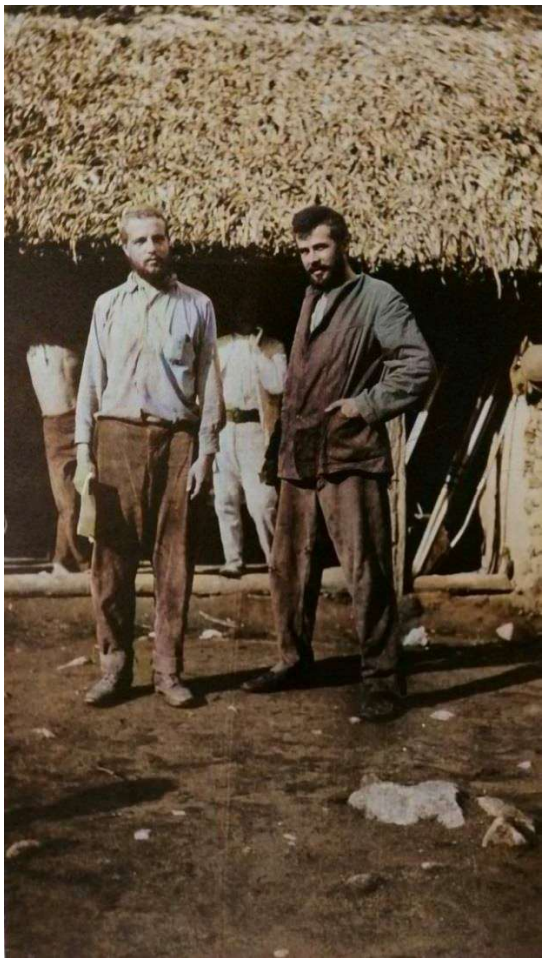


Figure 12. *To the left is probably Garner and to the right is Harold Boyd. Boyd and Garner investigated the northern portion of Monagas and part of Anzoategui in 1912. Photo courtesy of the Ralph Arnold Photograph and Map Collection, The Huntington Library, Art Collections, and Botanical Gardens Photo Archives Huntington Collection, Box 8, Ser. 2, Vol. 2_ Image 543. Photo colorized.*

Figure 13. *Lake Maracaibo East Coast fields development in the 1920s. Wells were drilled in the lake's water and inland, and the technology developed for drilling and producing in Lake Maracaibo was later used in the waters of the Gulf of Mexico.*

In 1924, J. S. Cosden, Payne Whitney, and their associates announced their success in obtaining 2,290,000 acres of land in Maracaibo, including Lake Maracaibo's bed. As a result, a new company was formed to drill for oil in that district, the Lago Petroleum Company. Maracaibo Lake has a maximum water depth of 30 feet; with most areas not over 10 feet deep, drilling operations were relatively uncomplicated. The company declared that similar attempts had succeeded (*The New York Times*, January 24, 1924). A few years later, stretches of Lake Maracaibo's east coast were populated by drilling rigs (Fig. 14).

By 1929, Venezuela was the largest oil exporter and the second largest oil producer, overtaking Mexico, which was living through politically chaotic times with the revolution and facing the decline of its "golden lane" oil fields. Very little is known about the first geological-paleontological laboratories in Venezuela. Among them was the geological-paleontological laboratory of the Caribbean Petroleum Company in Sibucara, near Maracaibo, which was fully operational well before 1930. Another established laboratory was the Orinoco Oil Co. laboratory in Maracaibo, where, as early as 1929, micropaleontologist Frances Charlton was transferred to Maracaibo from the Pure Oil laboratory in Arkansas. She remained in the Maracaibo Laboratory until 1931 as a staff micropaleontologist. Afterward, she returned to the country and, years later, became Professor Francis de Rivero, Head of the Geology Department at the Central University of Venezuela (Gries, 2017). This paper's Geological Paleontological Laboratories section discusses the history of the geological paleontological laboratories in the country.

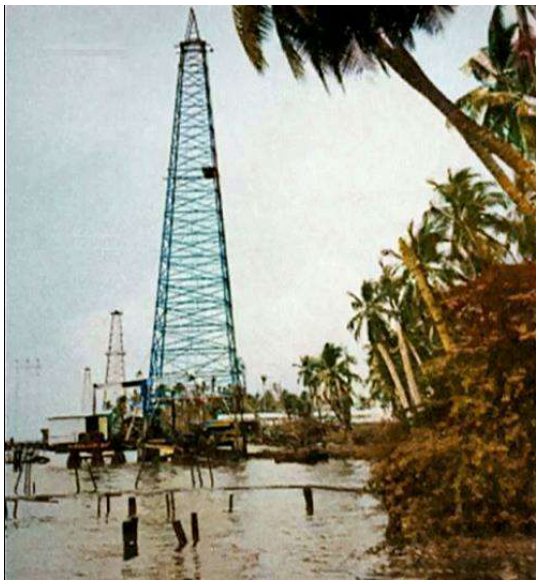


Figure 14. *First rigs on the water at the east coast of Maracaibo Lake, probably in the late 1920s. The author of the photo is unknown. The image belongs to the public domain. Photo colorized.*

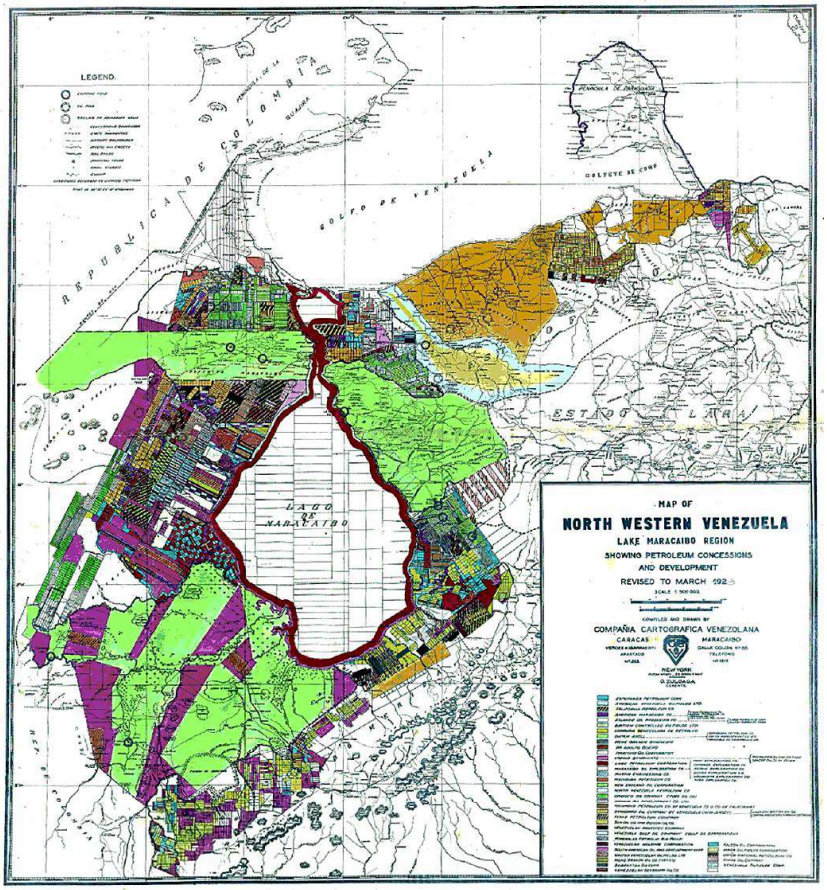


Figure 15. *A map of Lake Maracaibo and Falcon Concessions by the Compania Cartografica Venezolana (March 1923?), compiled and drawn by O. Zuloaga, Manager, Edwin B. Hopkins. From https://geologiavenezolana.blogspot.com/p/mapas-geologicos.html.*

Figure 16. *News about Standard Oil of New Jersey closing negotiations with the other companies that held land properties in Venezuela (*The New York Times*, from April 12, 20, and 22, 1921, and January 31, 1922).*

From 1929 onward, oil exploration continued progressing at a feverish pace. As a result, companies established local geological-paleontological laboratories to deal with a vast number of legacy samples from field surveys and wildcats. In 1929, Standard Oil of New Jersey was negotiating the acquisition of the Creole Syndicate, which was in an arrangement with the Gulf Oil Corporation, one of the most important operators in the country, as part of Standard Oil's strategy to transfer operations from Mexico to Venezuela. By 1928, the world's leading oil companies included Standard Oil and its seven sisters, Shell Oil, Gulf Oil, Anglo-Persian Oil, Texas Corporation, Union Oil, California Petroleum, Pure Oil, and five others.

It was also in 1928 when these oil companies started conversations to hold an international conference to seek an agreement to avoid further oil overproduction and oil wars among the companies, such as the one between Standard Oil of New York and Royal Dutch Shell over Soviet oil. However, there were many divergent views among the companies, so a smaller conference was proposed to consider restrictions on production in Venezuela and other South American countries (*The New York Times,* July 19, 1928).

In the first six months of 1928, Venezuela produced 46,000,000 barrels, with all but 1,000,000 exported. Production in the country was increasing rapidly; it was only held back by inadequate transportation facilities (*The New York Times,* July 22, 1928). In March 1928, the Creole Petroleum Corporation was created as a result of an agreement between Standard Oil of New Jersey and the Creole Syndicate, which merged the properties of both companies in Venezuela, creating an aggregate 6,250,000 acres of land to move into an intense development program (*The New York Times,* March 2, 1928).

The efforts to curtail oil production in Venezuela failed, with Royal Dutch Shell (Fig. 17), the Gulf Oil company (Fig. 18), and Lago Petroleum being the three major oil producers in the country (*The New York Times,* March 4, 1928). By November of that year, the curtailment of oil production in Venezuela was again on the table, but with no success in the discussions.

Figure 17. *The first headquarters of the Caribbean Petroleum Company was in Maracaibo in 1922. The building's original name was "Palacio Roncajolo," and it was the biggest (in meters) construction in Maracaibo city when it was built in the 1800s. Source: https://fundaayc.wordpress.com/2018/01/31/1922%e2%80%a2-la-caribean-petroleum-company-alquila-el-palacio-roncajolo-maracaibo/. Photo colorized.*

Figure 18. *Headquarters of the Venezuela Gulf Oil Company in Maracaibo. The building construction was finished in 1927. Photo colorized. Source: https://fundaayc.wordpress.com/2014/05/04/1951%e2%80%a2-edificio-de-oficinas-de-la-mene-grande-maracaibo/.*

Venezuela's economy was flourishing, so in January 1930, the government announced that it was reducing the national debt. A few months later, in July, the country liquidated all external debt to celebrate the anniversary of the Libertador's death. In 1929 and 1930, Venezuela was the second largest oil producer in the world, only behind the US, with Royal Dutch Shell producing 40% of all its oil from the country. However, in 1931, its position of world oil production dropped to third place, behind the US and Russia.

In the 1930s, other companies moved their exploration and production activities to Venezuela, like the Socony-Vacuum oil company that contracted with the government for the exploration and exploitation rights to 750,000 acres in the states of Anzoátegui, Monagas, and Guárico (*The New York Times,* August 29, 1936). News of a field worker strike in Maracaibo at this time reached the US press (*The New York Times,* December 15, 1936). After the government jailed the men who participated in the strike, it declared that the strike had ended. However, the unrest persisted. Some of the

workers' demands, such as free transportation and paid holidays, were granted to national employees of the companies working in Maracaibo by October 1936.

Other events of interest in those years included the Gomez government sending troops to control the arrow-shooting native inhabitants (Motilone) who were defending their ancestral lands; they had been held responsible for the death of oil prospectors near the Colombian border (*The New York Times,* May 21, 1933). A fire erupted in seven crude oil tanks in the Curacao refinery of Royal Dutch Shell (*The New York Times*, July 17, 1936). The high oil field pay of eight bolivars daily lured Venezuelan farmhands to the oil fields. It produced severe consequences in other areas of the country's economy, as the coffee planters offering the pay of two bolivars a day did not find enough workers for coffee picking (*The New York Times,* March 30, 1937).

In January 1939, Charlton Ogburn wrote about the strategic importance of Venezuela to the US because of its large oil production and proximity to the Panama Canal and Europe (Venezuela accounted for about 75% of British petroleum consumption during this time). But he also noted that the cost of living in Caracas was probably the highest in the world and that, besides the oil companies, the country's economy was in the hands of some 20 families who administered and controlled the leading banks, industries, and commercial institutions. In addition, most of the population suffered from poor sanitation, poor health services, illiteracy, and malnourishment (*The New York Times,* January 29, 1939). It was in 1939 that the first payment to employees was distributed under the government's new Profit-Sharing Law, which was retroactive until July 1936. This law was one of the government's first attempts to improve workers' conditions (*The New York Times,* March 19, 1939).

A tragic event was the fire that destroyed Lagunillas, a town on the coast of lake Maracaibo, in November 1939. Hundreds of people died or were seriously injured in the fire. The fire spread quickly over the oil film on the lake's surface, burning down close to 200 wooden houses built over the water on the shores of the lake. The town of 25,000 inhabitants, all believed to be natives and employees of the oil companies, was wiped out within four hours by the flames (*The New York Times,* November 15 and 16, 1939).

Then, the Second World War started on September 1, 1939. The war continued until September 2, 1945. One curious side effect of this war is the delay it caused to the development of palynology application in the oil industry as a dating and stratigraphic correlation tool.

Between 1934 and 1939, pollen science (palynology) was proposed to age date sedimentary rocks from terrestrial environments. This type of rock proved impossible to date with marine invertebrate paleontology or with the new science of micropaleontology, which was commercially developed in the 1920s and was a technological breakthrough that became the more important subsurface correlation tool available for decades when electric and other geophysical well log tools were in their infancy and seismic applications were very limited (Gries, 2017). In 1925, geologists Alva Christine Ellisor, Esther Richards Applin, and Hedwig T. Kniker published the first paper applying micropaleontology to the oil industry: "Subsurface Stratigraphy of the Coastal Plain of Texas and Louisiana" (Applin et al., 1925). They have been credited as the geologist-paleontologists who made the micropaleontology breakthrough.

From the beginning of the twentieth century, pollen science had been used to study coal mining and bog sediments as indicators of past vegetation and climate. But it had never been used before in the oil industry. What happened before and after the Second World War in the breakthrough of applying pollen science to the oil industry and the key role played by oil exploration in Venezuela is described later in this paper when discussing the topic of laboratories and palynology in Venezuela.

Although Venezuela was relatively far from the epicenter of the war, several related events shook the country during the war years. Extraordinary steps were taken to guard the oil fields, airports, and industrial and military establishments to prevent sabotage (*The New York Times,* December 9, 1941). Among those events was the burning of four Italian and one German ship by their crews in Puerto Cabello (*The New York Times*, April 22, 1941).

In 1941, the oil production in Venezuela exceeded that of any previous year, pushing the country back to being the second largest oil producer in the world. In February 1942, news broke that seven ships were torpedoed in the Caribbean between Aruba and the coast of Venezuela. Shipments in the area were held indefinitely because of the attacks, while the Standard Oil office in Maracaibo ordered 14 tankers en route to Aruba to return to port (*The New York Times,* February 17, 1942).

The country's unemployment rate was rising because raw materials could not be obtained. In January 1942, to prevent oil sabotage, the rights of foreigners to change residence were suspended, as well as their ability to move in or through petroleum regions, leave or enter the country, and assemble and form associations. Constitutional guarantees against arrest and other rights were also suspended.

By September 1942, many oil wells were sealed due to the lack of tankers, so the government started a plan to relocate workers to agricultural camps. Early in 1943, new petroleum legislation was announced by President Isais Medina Angarita to Congress. The new legislation included a rise in the oil royalty tax to a minimum of 16.7%. At the end of 1943, the president of Standard Oil of New Jersey told the press that Venezuela and Colombia held the greatest future for expanding the world's oil production capacity and revealed that its affiliate, the Creole Petroleum Corporation, was drilling test wells along the coast of Falcon.

In mid-1944, Standard Oil of California had plans to renew the search for oil in Venezuela and set up a new subsidiary, the Richmond Exploration Company of Venezuela, to conduct the exploration, and the Phillips Venezuelan Oil Company received four exploratory concessions and three parcels of national reserve leases all in the Maturin Basin. However, Socony–Vacuum Oil Company suddenly quit the country at the end of 1944 with no explanation.

In May 1945, there was news a plot by the German High Command to sabotage Venezuela's oil fields and blow up allied tankers carrying fuel to Western Europe. The 10 Germans involved in the conspiracy were detained in the village of Rubio, while the other two managed to return to Germany (*The New York Times,* May 25, 1945). A few months later, in October 1945, a group of young intellectuals and military members rose against Medina Angarita, taking over the government. Romulo Betancourt became the president and was quickly recognized by Paraguay, Ecuador, and Cuba. About a week later, the US also recognized the new government.

In 1946, the Shell Group increased its investment in Venezuela, with special attention to western Venezuela. After two months of negotiation, the oil companies agreed with the Oil Workers' Federation for a 19-month collective contract, including a wage rise of two bolivars daily and many other concessions. Also, by the end of 1946, the government had passed a new income tax reform bill, making the high-income brackets pay 28% in taxes, depending on the profit.

In 1947, Venezuela was still the second largest oil producer in the world. In May 1948, the Venezuelan government declared that while it would respect the integrity of the oil concessions already granted, it did not plan to give any more. Dr. Jose Martorano Battisti, the president of the country's petroleum bureau, said, "It is our desire to see present concessions fully exploited before considering development of new areas." In November 1948, the Orinoco Oil Company, for which the Pure Oil Company was the principal stockholder, sold all its properties and facilities to the Mene Grande Oil Company, a Venezuelan Corporation subsidiary of the Gulf Oil company. A coup ousted the country's president on November 24, 1948. Lieut. Col. Marcos Pérez Jimenez announced that the army had taken control of the country.

In December 1948, the Pantepec Oil Company announced a new oil discovery in deeper horizons in the El Roble concession. The discovery well drilled to 11,829 feet and produced 900 barrels/day of 49.5 gravity oil. A few months later, this company signed a contract with the Creole Petroleum Corporation to develop all its properties in Venezuela. In December of that year, Venezuela replaced the US as the leading oil supplier to Canada, and the first pipeline to carry oil from Lake Maracaibo to the ocean terminal began its operations (*The New York Times,* December 24, 1948). In May 1949, the production of Creole Petroleum Corporation declined. A curiosity was the report of a violent hurricane that smashed Maracaibo on August 29, 1949, causing extensive damage (*The New York Times,* August 29, 1949).

During the 1950s, exploration for oil continued vigorously in Venezuela, Trinidad, and Colombia. At the climax of the oil boom in the country, the government and the oil companies actively promoted life and work in Venezuela with multiple pamphlets, newspaper advertisements, and movie clips. Some of the movies are historic documents about how life was for nationals and expatriates in those days. They are also documents that showcase the contrasts in a country experiencing accelerated development. Among those films are *Margarita, Venezuela* (1950), originally sponsored by Venezuela's government (https://www.youtube.com/watch?v=ZNPNcDxsPk4), and the movie *Assignment: Venezuela – 1956*, sponsored by Creole de Venezuela, which gives a complete view into the life and work of the expatriates in a company camp (Lagunillas), as well as an overview of Maracaibo and Caracas in the 1950s (https://www.youtube.com/watch?v=uJdsIeM8SVE). These were in shocking contrast with the conditions that Arnold's exploration team experienced and described just decades earlier.

In the 1950s, Venezuela's news frequently appeared in the international press. There were reports about the wealth of the country, such as "Venezuela post record income," (*The New York Times*, June 12, 1954), "Venezuela riding prosperity wave" (*The New York Times*, January 5, 1955), "Venezuela's income at new high in 1954" (*The New York Times*, July 20, 1955), "Oil exports spurs Venezuela boom" (*The New York Times*, September 18, 1955), and "Venezuela says economy is good" (*The New York Times*, August 9, 1959).

The new areas open for concession bids, oil discoveries, and new infrastructures were of major interest to the press and the companies. There was significant pressure regarding the opening of new concession bids, since the last time new concessions were granted was in 1945, when the country adopted a policy of no further concessions. A strong campaign for the opening of new concessions in Venezuela began in 1953 (*The New York Times,* August 17, 1953), with large American companies without concessions sending permanent representatives to the country to argue their case. The local press often remarked on the increase in the number of these visits. The pressure of this campaign bore results in 1956, when the government approved around 17 new concessions all around Lake Maracaibo or near the Colombian border (July 27, 1956), although the total number of those new concessions is not very clear. The price paid was as high as $6,000/hectare.

The new concessions included Shell (10,000 hectares), Creole (10,000 hectares), Mene Grande Oil Co. (20,000 hectares in Lake Maracaibo), Sun Oil Co (10,000 hectares in Lake Maracaibo), and Signal Exploration Co. (10,000 hectares) in Lake Maracaibo. Shell Oil Company and the Venezuelan American Independent Oil Producers Association officially requested two oil concessions in Lake Maracaibo (*The New York Times,* August 6, 1956). In 1957, another round of concessions yielded $300,000,000 to the Government of Venezuela, added to more than $700,000,000 (about $400,000,000 paid) for the first lot of concessions in 1956.

The new concessions were granted on Lake Maracaibo, Barinas, and the Gulf of Paria. The list of new companies in the country that received concessions included Kerr-McGee Oil Industries, Inc., Standard Oil Co. (Indiana), Sunray-Mid-Continent Oil Co., Cities Service Co., Richfield Oil Corporation, Sun Oil Co., Seaboard Oil Co., Continental Oil Co., and Ohio Oil Co. Among the companies that already produced oil in the country and received new grants were Phillips Petroleum Co., Venezuelan Petroleum Co., Atlantic Refining Co., Texas Co., and Shell de Venezuela.

Major new applications were those of Creole Petroleum Corporation for more than 140,000 hectares of oil concessions, which included 69 concessions in Monagas and Sucre states (approximately 60,616 hectares) and eight concessions in the state of Barinas (approximately 80,000 hectares). Phillips Petroleum Co., representing a group of companies, received four concessions, one in Lake Maracaibo, another in the southern part of Monagas State, and two near the Venezuelan-Colombian border. Also, the government announced the cancellation of the concessions awarded to Start Oil Co., which had failed to pay (*The New York Times,* March 14 and 23 and May 10, 1957).

Also of interest is the concession of 150,000 hectares offshore the Gulf of Paria granted to a consortium of five American companies (Ohio Oil Co., Texaco, Continental Oil Co., Cities Services Oil Co., and Richfield Oil Co.). The concession was covered by an average of eight feet of water, and the bid amounted to $100,000,000 for the six blocks offered. Since the area was rather sheltered, drilling was supposed to be less difficult than in the open waters of the Gulf of Mexico off Texas and Louisiana (*The New York Times,* May 8, 1957).

During this period, the oil campaign discoveries publicly announced included those of Pancoastal Oil Company and the Venezuelan Atlantic Refining Co. in their joint oil concession in Tucupido (*The New York Times,* March 1950) and the Sinclair Oil Company's extensive exploration program in Monagas, Anzoátegui, Barinas, and Guárico (October 1952). The campaign led to the discovery of a new field in eastern Venezuela, with the discovery well Aguasay No. 3 drilled at a depth of 14,221 feet, totaling more than 200 feet of potential producing sand. Sinclair also completed 15 producing wells in the Barinas field (*The New York Times,* September 27, 1956). Another oil discovery in Barinas was by the Venezuelan Petroleum Company. Phillips Petroleum Co., the operator of a group of eight companies, announced in December 1958 a major oil discovery in its concession, farther southwest than any other major discovery in the lake to date (*The New York Times,* December 1, 1958).

An important event for the oil industry in the late 1950s was the opening of a channel connecting Lake Maracaibo with the Gulf of Venezuela for ocean-going tankers. According to *The New York Times* (June 2, 1956), "A channel 11 meters deep, 300 meters wide and 12 kilometers long was dragged at the neck of the lake." It took about three years to be completed. Another important infrastructure was the construction of the bridge across Lake Maracaibo, which began in 1957, with an estimated cost of $95,000,000 at the time. In 1959, the government announced plans to create a national oil company.

During the 1960s, the country experienced a progressive contraction in oil exploration activities due to major changes in the country's tax system for the oil companies and back-tax claims that sought to balance the country's budget, oil workers' strikes, and the worker's unions requiring a revision of the work contract every three years, which carried about a 10% increase on the workers' total retribution with each new contract revision. Guerrilla attacks near oil production areas in eastern Venezuela further complicated the situation. In 1965, guerrillas dynamited seven pipelines near Barcelona. The most heavily damaged properties were those of Texaco and Mobil Oil Company (*The New York Times,* October 14, 1965).

The ending of new concessions and the initial steps taken by the government to nationalize the other industries, including ore and gas, created a high level of uncertainty toward the end of the decade regarding the future of companies in the country, in addition to impacting their baseline.

A crucial event for the world economy was the creation of the Organization of Petroleum Exporting Countries (OPEC) in 1960. Venezuela was a founder of the organization, represented by Dr. Juan Pablo Pérez Alfonso, Minister of Mines and Hydrocarbons. According to Reuters staff (2010), OPEC's timeline was the following: "September 10–14, 1960 – Baghdad conference creates the Organization of the Petroleum Exporting Countries. Five founding members are Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela. The producer countries are spurred into action by a decision by the so-called "Seven Sisters" – a group of multinational oil companies – to reduce the prices of crude they supplied."

In the early 1960s, oil production activity remained but showed some decline. For example, the government announced the completion of 31 wells in a month by 25 producers, but ciphers cited in the news indicated a decline in drilling and exploration from 1960 to 1961 in the country: "The average number of new wells being drilled at this time is 26 a week. In 1960 the number was 45 and in 1959 it was 80" (*The New York Times,* July 17, 1961). This contraction of oil activity in the country strongly impacted the activity of geological-paleontological laboratories, leading to the definitive closure of many. Only the largest laboratories survived, although they were reduced to their minimum expression by the end of the decade, keeping a small number of local specialists (usually no more than one or two) and returning all expatriate paleontologists to their home bases. The Geological-Paleontological Laboratories in Venezuela section of this paper provides a detailed chronology of the changes experienced by the different laboratories in the country.

From 1970 to 1975, the activity of oil companies in the country further deteriorated. The income of the country also

suffered, with news as alarming as "Oil fails to calm Venezuela's turbulent waters" (*The New York Times,* January 26, 1970) and "President says Venezuela lacks money to open schools in fall" (*The New York Times,* August 30, 1970). The Banking Reform Law in 1971 stunned foreign businesses, creating doubts about the future of business in the country (*The New York Times*, January 17, 1971).

President Rafael Caldera signed the Hydrocarbons Reversion Law on July 30, 1971. This law required all petroleum concessions to revert to the state without compensation starting in 1983 and that the companies invest large amounts of money in developing new reserves up to the end of their concessions. The reality proved very different from what was expected. This law impacted oil output, and the remaining exploration activity in the country was halted.

In addition to this situation, the countries in the Middle East did not increase their oil prices as much as Venezuela, becoming competitors in the international markets. Venezuela's oil output dropped from 4.76 MMb/day in 1970 to 3.61 MMb/day in 1971 and to 3.2 MMb/day by late 1972 ("Venezuela in 3rd Place in Oil Sales," *The New York Times,* September 16, 1972). Also, in 1971, Venezuela nationalized the natural gas industry and trade.

In 1972, Mobil Oil de Venezuela and Shell Sur del Lago C.A., in agreement with Corporacion Venezolana del Petroleo (CVP), suspended exploration in the southern portion of Lake Maracaibo after drilling several dry holes. Also, Mobil announced that the drilling was suspended at 17,632 feet, a record depth for South America at that time. But Occidental de Venezuela continued drilling two more wells. The three companies were acting under service contracts as contractors to CVP (*The New York Times,* August 24, 1972).

Nevertheless, oil discoveries continued to be announced during that time; CVP struck oil with wildcat drilling on the continental shelf off the country's northwest coast (*The New York Times,* September 20, 1972). Another success was the deepest wildcat well in Latin America, drilled in the south of Lake Maracaibo by Mobil Maracaibo, C. A. as a contractor of CVP, which tested an initial 5,424 bb/day (*The New York Times,* February 16, 1974).

In January 1974, the government began requesting companies to relinquish the concessions granted them for oil exploration. That year, all political parties supported an accelerated nationalization program for the oil industry. In an address to the country in May, President Carlos Andres Pérez indicated "that he thought it would be best if the structure of Creole, Shell and Mene Grande Oil Company (a subsidiary of the Gulf Oil Company) were maintained but under Venezuelan control" (*The New York Times*, May 18, 1974). The country moved to nationalize the iron ore industry and the oil industry in 1975. In 1975, oil production in the country averaged 2.4 MMb/day, an almost 19% reduction from the previous year, strongly influenced by the OPEC decision to cut back production to solve the excess of oil supply over demand in the world.

In this period, geological-paleontological laboratories across the country vanished. The remaining personnel were transferred to field areas or other departments within the companies' structure, and little to none of the laboratories that flourished in the country during the 1940s and 1950s survived the transition. The later sections provide a short history of what happened in the palynological areas of the laboratories during the post-nationalization period, 1976–2000.

HOW IT ALL STARTED IN PALYNOLOGY

In the early 1930s, paleontologists working in petroleum exploration in Mexico and the US took several samples of sandy and coaly rocks that turned out to be impossible to age date with the micropaleontological techniques commonly used in the oil industry at the time. Simultaneously, they realized that pollen analysis could be an option to date those samples. Pollen analysis had been widely used in coal mining but never in oil exploration.

In 1938, Dr. T. F. Grimsdale (Fig. 19) thought that some useful age information could be obtained if a coal palynologist were to study those samples. Thus, he sent them to the N.V. De Bataafsche Petroleum Maatschappij offices in the Netherlands, requesting their evaluation with pollen analysis. In a close-in-time event, the samples collected in the US by another geologist were also sent to a laboratory in the US for evaluation by pollen analyses. This was a turning point in the history of applied palynology!

THE DEVELOPMENT OF PALYNOLOGY IN THE OIL INDUSTRY: ITS ORIGIN IN THE 1930S

It was as early as 1933 when R. P. Wodehouse thought about the possibility of using pollen to study the Eocene oil shale of the Green River Formation in the US. All the progress that followed was possible thanks to the development of the maceration technique to recover pollen and spores from rocks, and L. R. Wilson (1946) credited the development of this technique to Raistrick and Simpson's work (1933).

Manten (1966) described the beginning of palynology in the oil industry as follows: "The first attempts to find out whether palynology could be useful to the geological activities of petroleum companies seem to have started in 1934, in the U.S.A. […] Thus, in 1938 and subsequent years, the Royal Dutch/Shell Group invited such specialists as Potonié, Florschütz, Stützer and Bode to undertake a study of Tertiary material from Mexico, Venezuela, Trinidad, the Far East, and Columbia, on a consultant basis, and also had their own palaeontologist T. F. Grimsdale to do some pioneering palynological work."

Palynologist Dr. R. Potonié, a botanist studying pollen and spores from the Cenozoic and Carboniferous coals in Germany, received from the N. V. De Bataafsche Petroleum Maatschappij a set of samples taken in Mexico by Thomas Grimsdale in 1936 with the request to examine them. He obtained encouraging results that were reported to the company in 1938. Unfortunately, Grimsdale was drafted by the German army soon after to fight in the Second World War, and Dr. Potonié was taken as a war prisoner. According to C. C. M. Gutjahr (1960), the Royal Dutch/Shell Group initiated palynological studies in 1938.

Figure 19. *Paleontologist T. F. Grimsdale. The photo was taken from* Tópicos*, a monthly magazine from the Caribbean Petroleum Company, 1941.*

THE INTERRUPTION OF THE SECOND WORLD WAR: SEPTEMBER 1939–SEPTEMBER 1945

In 1939, Dr. F. Florschütz, the founder of palynology in the Netherlands (Leyden), undertook the analysis of a group of shale and coaly samples taken by Shell geologists in the Caribbean and the Malay Archipelago (Manten, 1966; Kuyl et al., 1955). His results were encouraging and were reported to the company the same year. However, the outbreak of war closed the universities and forced them to end their collaboration with the oil industry. Thus, during the war, palynology in the oil industry made little to no advancement in Europe.

The Second World War disrupted the world, but it was during that period that Venezuela was a major supplier of petroleum to the Allies, increasing its production by 42% from 1943 to 1944 alone (Toro Hardy, 1994). However, those were also changing times in the country. Besides the uncertainty of the war, with constant attacks on ships in the waters between Aruba and Venezuela, the presence of German submarines along the coast, and the lack of basic materials, the government passed new hydrocarbon legislation in 1943, including 40-year-long concessions with the obligation to refine part of the oil in-country and new tax rates for the oil companies.

During the war, oil companies' geological-paleontological laboratories in Venezuela, with micropaleontologist teams, remained open, attending to the intense work related to the exploration and production of hydrocarbons. In addition, some geologist-paleontologists conducted field work in the country and in neighboring Colombia (Fig. 20).

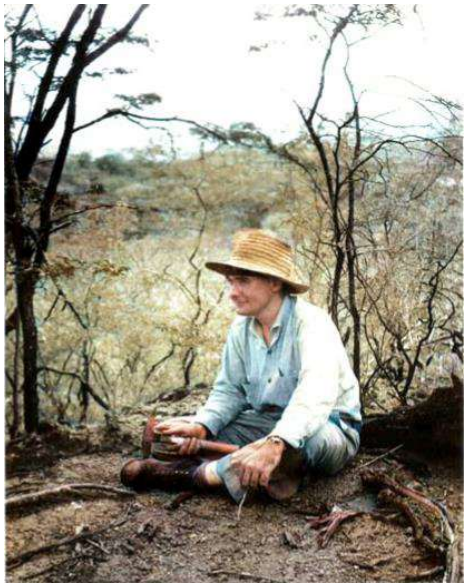


Figure 20. *Paleontologist Dr. V. Winkler. In one of the sampling expeditions to Colombia (1942–1943), he became sick with malaria; he was unconscious for two weeks and was saved by a German emigrant doctor who gave him doses of quinine in a barnyard. His crew nicknamed him "the stone warrior" (Osorio, 2007). Image courtesy of the University of Illinois at Urbana-Champaign Archives. Photo colorized.*

PALYNOLOGY IN THE OIL INDUSTRY AFTER THE SECOND WORLD WAR

At the end of WWII, oil palynology began taking its first steps in Venezuela and in the world. According to Larson (2021), "Soon after the war, Shell remembered Potonié's work and began palynological research in earnest, employing especially Dutch palynologists such as Waterbolk, whose ultimate palynological roots were in Holocene pollen analysis. Other, more geologically oriented persons such as Kuyl were soon involved." As soon as universities in the Netherlands reopened after the war, two young students enrolled in Dr. Florschütz's research program in palynology, Jan Muller and Thomas van der Hammen. A few years later, both became pioneers of research in palynology in northern South America.

Oil industry palynology in the 1940s and 1950s

The term "palynology" was coined in 1944, when Antevs started questioning if "pollen analysis" was the right word to describe the study of pollen and its applications. Names such as pollinology, pollen science, and micropaleobotany were considered. The word palynology by Hyde and Williams (1944), defined as "the study of pollen and other spores and their dispersal, and applications thereof," was finally accepted.

The name discussion ended when Hyde (1945) clarified that they did not intend to include viruses or dead organic dust. Also, according to Manten (1966a), it was R. Tschudy who introduced the term "palynomorphs" to refer to all the subjects studied by palynology.

In 1946, the company N. V. De Bataafsche Petroleum Maatschappij decided to create a section dedicated to palynology in its stratigraphy department in the Netherlands. This decision was based on the work started by the collection of samples by T. F. Grimsdale in 1936, the study of the samples by Potonié in 1938, and by Florschütz in 1939, as explained by Hopping (1967).

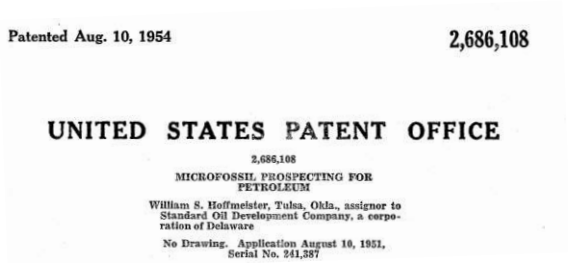
In this context, Jan Muller joined the company in 1946 and was assigned to the Maracaibo Laboratory of Caribbean Petroleum in 1947. Grimsdale and Kuyl were already working in that laboratory, and it was there that Muller became a crucial player in the development of palynology as a tool for oil exploration. According to Kuyl et al. (1955), "After the war, systematic research (in palynology) was also undertaken by the Royal Dutch/Shell Group itself, at first only in Maracaibo (1947)."

Meanwhile, Thomas van der Hammen joined the National Geologic Institute of the Ministry of Mines and Petroleum of Colombia. His work was oriented toward the morphological study of pollen and spores and the stratigraphic application of palynology. His research describing the flora of the Cretaceous and Tertiary sections of Colombia and British Guiana was published between 1954 and 1966.

In the US, in 1946, L. R. Wilson pointed out the possibility of using pollen and spores for correlating sedimentary rocks. However, during those initial years, all research in palynology carried out by the oil industry was confidential. As such, its development and use by the major companies in America were only publicly known in the early years of the 1950s: for example, "The Standard Oil Company of California (1952) and Carter Oil Company (Amstrong, 1953) have stated that they have taken up palynological research," Kuyl et al. wrote in 1955.

The use of palynology was so confidential that a patent application was submitted in 1951 by W. S. Hoffmeister as the assignor of Standard Oil Development Co., entitled "Microfossils Prospecting for Petroleum." The patent was finally granted in August 1954 under the number 2.686.108 to the Standard Oil Development Company (Delaware). The company patent states: "The process of this invention is adapted to locate and define ancient shorelines […] according to the process of this invention using a quantitative study of the microfossils deposited in the geological time period during which the ancient sea existed. As employed herein, 'microfossils' is used as a generic term to identify fossil spores, eggs, cysts, pollen, and the fossils of minute animals" (Hoffmeister, 1954).

In 1955, at the Society for Sedimentary Geology (SEPM) symposium on spores, pollen, and other microfossils useful in oil exploration, R. D. Woods reported: "A decade ago (1945), only one company in the United States, so far as known, was conducting research on the use of spores and pollen as a general stratigraphic tool." He also mentioned that by 1955, less than half a dozen companies were engaging in such work. He himself was working with the Humble Oil & Refining Company, while Dr. W. S. Hoffmeister, who collaborated with his presentation, was working at the Carter Research Laboratory and had obtained a patent for the use of microfossils in oil exploration by that time (Fig. 21). In the US oil industry of the 1950s, the pioneer palynologists were T. A. Armstrong, W. S. Hoffmeister, F. L. Staplin, R. E. Malloy, W. L. Norem, L. R. Wilson, R. Tschudy, and R. D. Woods.



Patented Aug. 10, 1954 2,686,108

UNITED STATES PATENT OFFICE

2,686,108

MICROFOSSIL PROSPECTING FOR PETROLEUM

William S. Hoffmeister, Tulsa, Okla., assignor to Standard Oil Development Company, a corporation of Delaware

No Drawing. Application August 10, 1951, Serial No. 241,387

Figure 21. *Microfossil prospecting for Petroleum. US Patent Office. https://patents.google.com/patent/US2686108A/.*

GEOLOGICAL-PALEONTOLOGICAL LABORATORIES IN VENEZUELA

By the 1940s in Venezuela, Caribbean Petroleum Co. (later Shell de Venezuela) and Lago Petroleum Co. (Standard Oil de Venezuela and later Creole Petroleum Corporation) had started their research in palynology in their Maracaibo and Caracas laboratories, devoting important resources to further advancing in its development. These companies also had smaller geological-paleontological laboratories operating in the oil fields to conduct the day-to-day analysis needed during drilling activities (Fig. 22 and Fig. 23).

To understand the monumental effort of developing palynology and further developing micropaleontology, it is important to know that in the 1940s and 1950s, oil companies were already exploring and producing hydrocarbons throughout the country. However, geologists found it difficult to stratigraphically correlate prospective Maracaibo Eocene and post-Eocene sections. Those sections consisted of several thousand feet of monotonous alternating layers of sand and shale, which were difficult to correlate with electric logs. In addition, they were frequently either barren of foraminifera or contained non-diagnostic specimens, so it was nearly impossible for the geologists to pinpoint and correlate the oil-rich sands within those thick sections.

Figure 22. *Lago Petroleum Corporation Geology Laboratory. Maracaibo Lago Field Camp, 1942. Photo courtesy of Doug Becker. Photo colorized.*

Figure 23. *Geology laboratory of Standard Oil of Venezuela (later Creole Petroleum Corporation). Caripito Field Camp, 1940. Photo courtesy of Doug Becker. https://www.randytrahan.com/ocov/images/Caripito/Caripito02/Geology_Lab_Caripito_1940.jpg. Photo colorized.*

That was when Royal Dutch Shell management "remembered" the evaluations on applying pollen analysis in difficult-to-date coaly sections, with samples from Mexico, Venezuela, and other places. Based on the reports by "Grimsdale (1937), Potonié (1938), Koch (1939), and Florschütz (1939)," the "palynological results and their stratigraphical evaluation led to the decision to establish a palynological section within the stratigraphical department of the company. This decision could not of course be affected until after the end of World War II. In 1946, 10 years after Grimsdale's suggestion, the first palynologists joined the company" (Hopping, 1967, p. 26). The decision to open a palynological laboratory in the company's headquarters in the Hague finally crystallized.

The history of what happened afterward in the development of palynology in Venezuela and in the world is based on many sources, including the contributions written by paleontologists working locally for different companies in 1946–1977 and published in *News*, 1947–1954, and *News Reports*, 1955–1977. In 1967, Hopping published the timeframe for the introduction of palynology in the headquarters and operational laboratories of Royal Dutch-Shell around the world (Fig. 24).

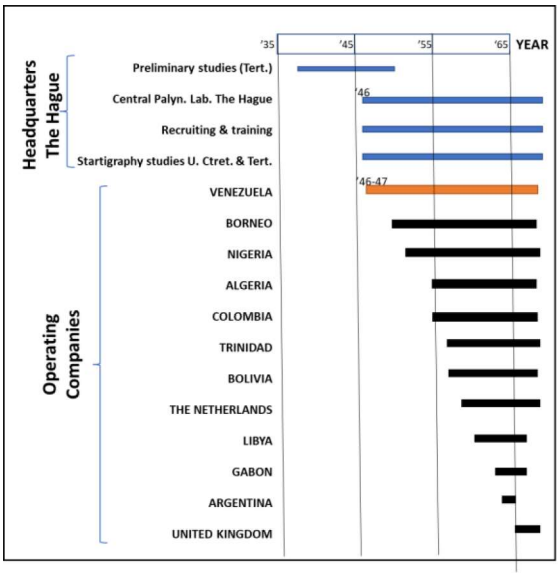


Figure 24. *The timeframe of the development of palynology laboratories within the global operations of Royal Dutch-Shell. Note that the Venezuela Laboratory was the first operating lab with palynology within the group. The figure was redrawn and simplified from the original published in Hopping (1967).*

This section reviews the developments in the geological-paleontological laboratories of 12 companies with concessions in Venezuela, even before World War II. It is based on different sources, including my conversations with some of the pioneers working in those laboratories and the short chronicles different paleontologists sent to the journals *The Microplaeontologist* and *Micropaleontology* from 1947 to 1977.

The Mene Grande Oil Company Labs.

The Mene Grande Oil Company operational laboratory was located in western Venezuela. However, that laboratory burned down during the war, and the company's other laboratory in Maracaibo was closed. All work in paleontology was centralized in the laboratory in Caracas. That laboratory was moved in May 1947 from the old downtown location to the modern headquarters northeast of Caracas (San Bernardino). Then the laboratory underwent a complete personnel turnover, losing almost all experienced personnel. Dr. H. H. Renz was named the new laboratory chief, the successor of Dr. H. Hedberg. That was when Dr. Gordon Young arrived from the US to join the team. In the 1940s and early 1950s, the laboratory conducted micropaleontological work but did not evaluate pollen and spores.

In 1953, W. K. MacFarquhar, who worked for Creole Petroleum Corporation in Venezuela from 1942 to 1949, moved to Mene Grande Oil and Company following a few years back in the US. He arrived at the Caracas laboratory in 1953. Cecilia Kavanagh de Petzall also joined the staff of this laboratory after graduating from the UCV in June 1953. In June 1955, B. J. Szenk joined the laboratory staff under Dr. H.

H. Renz (*News*, 1948, 1949, 1953, 1956, 1958), and L. R. Moore joined the team of the Caracas laboratory in 1958.

In the first half of 1958, the Mene Grande started to establish their pollen laboratory under the supervision of George Fournier to deal with the new concession in Lake Maracaibo. A 2,500-foot section of the Oligocene and Eocene section in a well was chosen to establish the type section and pollen and spore type collection. James E. Canright, a professor of palynology from Indiana University, joined the team for a couple of months. Initial conditions in the lab were challenging due to the hot and humid climate in the region. Alejandro Euribe joined the stratigraphic laboratory in Caracas, he had previously worked in Lima and later did his postgraduate studies at Stanford University.

In 1959–1960, the stratigraphic laboratory staff included the director H. H. Renz, Wade H. Hadley, and George Fournier, head of the palynological section. Fournier started routine operations at the beginning of 1959. Euribe worked with the biostratigraphy of subsurface samples. Ernest Murany and P. Parenti worked on surface geology, Luis M. Banks on mineralogy, and Gordon Young and B. J. Szenk on the stratigraphy of western Venezuela. Euribe left the company in July 1960 to become head of the IPC (Peru) in Talara Laboratory.

In 1961, there was a drastic reduction in the amount of work done in the stratigraphic laboratory. The personnel was reduced accordingly, with eight technicians and laboratory assistants laid off; some of whom had over 20 years of service.

Regarding the paleontologists, Gordon A. Young was transferred to the geology team. Hadley returned to the US, to the Gulf Oil Co. laboratory in Florida. Fournier was in charge of the newly created palynological section with one assistant and two technicians. H. H. Renz and B. J. Szenk kept their posts in Caracas. Figure 25 is a photo of the Headquarters of The Mene Grande Oil Co. building in Caracas.

Figure 25. *The Mene Grande Oil Company Headquarters building in Caracas, where a company paleontological laboratory was functioning between the late 1950s and early 1960s. Photography from Caracas Ayer y Hoy, courtesy of Gilberto Ospino. Photo colorized.*

In 1963, H. H. Renz was transferred to London to organize company laboratories in Africa. He left the country after 17 years of prolific work and numerous relevant contributions to the country's micropaleontology and stratigraphy. That year, paleontological work in eastern Venezuela was halted, while most of the work was on Lake Maracaibo. The laboratory had one micropaleontologist with two assistants and one palynologist with three assistants.

In December 1964, the palynology laboratory of Mene Grande Oil Co. in Caracas stopped functioning when Fournier was transferred to Gulf Technical Services in Houston, Texas. That US laboratory provided palynological services to the Gulf Coast and Venezuela. The micropaleontological laboratory in Caracas continued open under the supervision of Szenk.

The Texas Oil Company (Texaco) Labs.

This company had a geological-paleontological laboratory in Ciudad Bolivar headed by Michael Zaikowski. The micropaleontological laboratory was inaugurated in Caracas in 1942 but operated only for about a year before moving to eastern Venezuela (Rincon, Anzoategui). Less than a year later, the laboratory was moved back to Ciudad Bolivar.

From 1945 to March 1947, Dr. Jacobus George Bursch was the micropaleontologist; he was replaced by Martin Forrer when he left to organize the Phillips Petroleum Co. laboratory in Caracas. In 1948, Swiss micropaleontologist Dr. Martin Forrer was transferred from Ciudad Bolivar to Maracaibo and opened a small laboratory. In November 1951, C. M. Bramine Caudri, a micropaleontologist from the Bogota laboratory, was transferred to Caracas, and M. W. Zaikowsky was moved from Caracas to southern California. S. Brown, a micropaleontologist, arrived in August 1953 and, after several months as a well site geologist, was reassigned to the Caracas laboratory to assist Dr. Caudri. Both worked from 1953 to 1954 in the routine micropaleontology of well samples from north-central Falcon.

L. M. Balseiro joined the professional staff of the Caracas Laboratory in 1955. In 1957, B. J. Szenk worked in the Caracas Laboratory, and Dr. Caudri worked on the larger foraminifera of Trinidad. Caudri retired in 1961, while Balseiro continued her studies of foraminifera from western Venezuela. The steady reduction of paleontological staff in the company continued in 1967. Finally, only Vernon Hunter was left on the staff of the Texas Petroleum Company.

According to M. Furrer (*News Report*, 1969), E. Gonzalez joined the company in December 1967 to work as a palynologist. He obtained his PhD under Professor van der Hammen in Holland. In Venezuela, Gonzalez extended the studies to comprise all the Eocene sediments west and southwest of Lake Maracaibo. In 1969 and 1970, Hunter oversaw all paleontological work by Texaco in the country. His main project was the regional stratigraphy of western Venezuela. Gonzalez was the company's palynologist working

on problems connected with the late Tertiary stratigraphy of Falcon State. Unfortunately, Texaco closed down its laboratory in 1974, and Hunter was transferred to Bogotá, Colombia, in January of that year.

The Corporacion Venezolana del Petroleo (CVP) Lab.

In 1969 and 1970, CVP had a laboratory in Maracaibo that was expanding its palynology activities under Ana Ortega's supervision. No foraminiferal work was done in that laboratory (M. Furrer, in *News Report*, 1969 and 1971). Unfortunately, there is no information from 1971 to 1973. By 1974, the CVP laboratory in Maracaibo was only doing work in foraminifera because Euribe, who oversaw the establishment of the palynological section, returned to Perú that year.

MAJOR GEOLOGICAL LABORATORIES WITH PALYNOLOGY IN VENEZUELA

The two major oil-producing companies in the country, Caribbean Petroleum–Shell de Venezuela and Creole Petroleum Corporation, established geological and paleontological laboratories in the 1930s to support their exploration campaigns and field operations. The following section describes these laboratories and activities and the paleontologists involved.

The Caribbean Petroleum Company/Shell of Venezuela Labs.

Caribbean Petroleum Co. had already created a laboratory in 1927, operating in Sibucara, located north of Maracaibo city. This Research Unit supported the exploration geologists' teams surveying the Maracaibo and Falcon Basin. To visit the laboratory in Sibucara (Fig. 26), however, a geologist needed ride horses and mules for several hours on dusty roads, something usual for geologists at that time.

In 1928, the company's headquarters, Edificio Las Laras, was built in Maracaibo (Fig. 27). The building's design was adapted to the tropical conditions of the city. The name is derived from the "rain trees" surrounding the building, locally known as *laras*. It is a two-story building organized around a central patio, and it was one of the first buildings in the city to have air conditioning. The Sibucara laboratory was moved to Maracaibo sometime in the early 1930s.

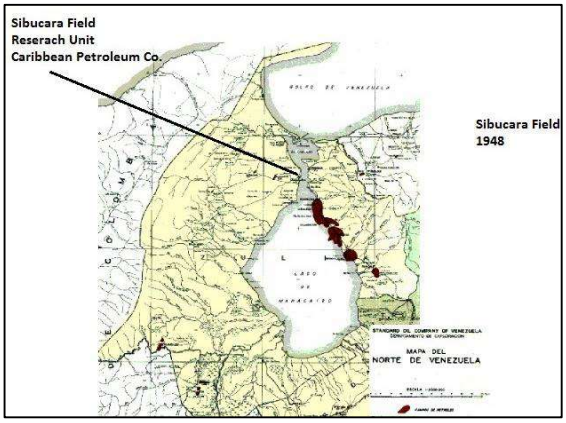


Figure 26. *Approximate location of the Sibucara Research Unit of the Caribbean Petroleum Company in the 1930s. The map also shows the oil fields in the Maracaibo Basin at the time (Image modified from the "Mapa del Norte de Venezuela" Standard Oil de Venezuela, 1939. LEV).*

Figure 27*. Edificio Las Laras, the headquarters of Caribbean Petroleum Co. in Maracaibo, built in 1928. It served as the company's headquarters until 1956. The building was declared a National Monument in 1991. Source: Institutional Assets and Monuments of Venezuela https://iamvenezuela.com/2016/01/edificio-las-laras/. Photo colorized.*

Figure 28. *Front of the laboratory building of the Caribbean Petroleum Corporation in Maracaibo. It was the company's regional laboratory. Photo taken from Westermann,* Tópicos Shell de Venezuela, *1941. Photograph colorized.*

By 1941, Caribbean Petroleum had a regional laboratory in Maracaibo dedicated to paleontological and mineralogical operations (Fig. 28). In December of that year, the laboratory was featured in an article in the monthly institutional magazine *Tópicos Shell*. The head of the lab, Dr. J. H. Westermann (Fig. 29), described fossils and their use in petroleum exploration: "The foraminifera specimens are placed on cardboard slides to be examined by the paleontologist, who studies them carefully under his microscope and tries to classify them in the existing system. In addition, conclusions are made regarding the geological age of the foraminifera and the layers from which they were obtained. The results of this test are finally written in reports and maps."

The laboratory had a group of technicians that picked the foraminifera from the samples: A. Ojeda, R. S. Nava, M. Morales, and V. C. Vivas (Fig. 30). There were also two paleontologists, Dr. T. F. Grimsdale (Fig. 19) and Dr. J. H. Westermann (Fig. 31). Both paleontologists oversaw the final identification of the fossils, interpreted the results, and did the reporting. There are no indications of pollen analysis being conducted in the laboratory at that time. The war also impacted the Maracaibo Laboratory, when Dr. J. H. Westermann was mobilized in 1943 (Fig. 31a). There is no information about who was left in charge of the laboratory.

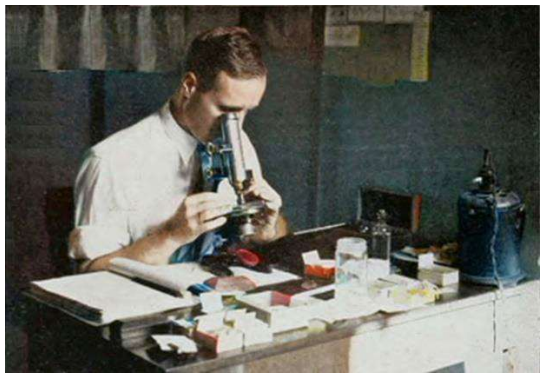


Figure 29. *J. H. Westermann at the microscope studying heavy minerals in the Caribbean Petroleum Maracaibo Laboratory. Dr. Westermann was also a paleontologist. (*Tópicos Shell de Venezuela*, December 1941, figure 16). Photo colorized.*

Figure 30. *From left to right, the technicians foraminifera picking in the Maracaibo Laboratory: A. Ojeda, R. S. Nava, M. Morales, and V. C. Vivas. Paper by J. H. Westermann dedicated to the laboratory personnel (Tópicos Shell – December 1941). Photo colorized.*

Figure 31a. *The original legend of this figure reads (translation from Spanish): "Dr. Juan Hugo Westermann, Dutch, married, was born in Loosdrecht, Holland, on June 1, 1907, and began to work for the 'Shell' Group on February 1, 1934, rendering his services in various places in the Dutch East Indies. He was transferred to Venezuela, arriving on January 21, 1940. From that date, he worked as a paleontologist in our Geology Department until July 28, 1943, when he left Venezuela to enlist in the Dutch armed forces. Good luck to you."* Tópicos Shell – *September 1943.*

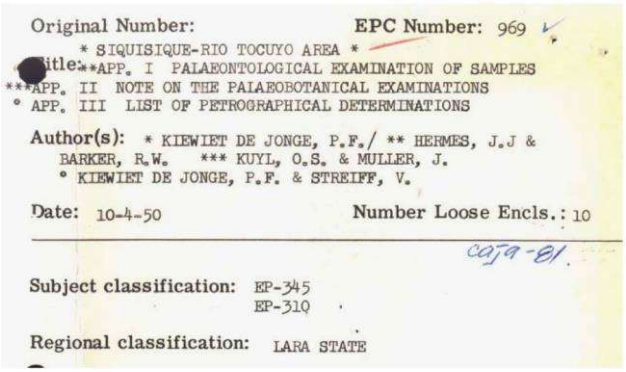
Thomas Grimsdale (Fig. 19), a member of the laboratory team at that time, was the geologist who first collected rock samples in Mexico and sent them to the Hague to evaluate the possibility of using pollen to date the rocks. Dr. Jan Muller joined the Royal Dutch/Shell Group in 1946 and was assigned to the Maracaibo Laboratory of Caribbean Petroleum in 1947. T. Grimsdale and O. S. Kuyl were already working in the laboratory, and it was there that Muller and colleagues became key players in the development of palynology as a tool for oil exploration.

By 1946–1947, the laboratory had several expatriated specialists as part of its staff, including Dr. J. Dufour (laboratory chief), William E. Crews (senior micropaleontologist), Dr. Wright Barker (paleontologist), A. ten Broeck (foraminiferal micropaleontologist), William A. van der Bold (ostracod micropaleontologist), O. S. Kuyl (palynologist), and Jan Muller (palynologist). On October 4, 1947, a new Shell laboratory building was opened in Maracaibo to meet the operational needs of the Shell company in Latin America and Venezuela in particular. The project's total cost was around one million bolivars at the time. This modern laboratory was comprised of two sections: the production laboratory and the geological laboratory.

Dr. Dufour oversaw the geological laboratory, which was divided into two technical areas: micropaleontology and macropaleontology. The micropaleontology area was headed by Mr. Crews, Mr. Hermes, and Mr. Romero, while Mr. Barker, Mr. Ten Broek, and Mr. van Raadshooven oversaw the

macropaleontology area. The laboratory also had a team of selectors, mainly consisting of Venezuelan personnel, including Víctor C. Vivas, Albino Ojeda, and Jose Boscan. When the laboratory was inaugurated, Ojeda and Boscan had had 18 and 20 years of experience, respectively. Furthermore, the laboratory boasted an extensive paleontology library containing approximately one thousand volumes; it was considered one of the most comprehensive collections in the world at the time (Tópicos Shell de Venezuela, 1947).

The company opened a laboratory in Caracas in 1943, and J. U. Todd was its chief until 1947, with an assistant, Dr. A. L. F. J. Maurenbrecher, who arrived that year. In 1949, Dr. G.J.R. Tepstra took over the Caracas Laboratory, and Todd was transferred to the Maracaibo Laboratory. By 1948–1949, Shell had two micropaleontologists in the Caracas laboratory, G. R. J. Terpstra and Dr. A. L. F. J. Maurenbrecher, and eight in the Maracaibo laboratory, J.U. Todd, R. Wright Barker, Dr. J. J. Hermes, B. van Raadshoven, O. S. Kuyl, J.M. Zimkstok, J. Muller, and R. A. Romero. Of these micropaleontologists, at least three were working on pollen and spores: Van Raadshoven, Kuyl, and Muller (see Fig. 31b). By 1956, the personnel had been moved around. Dr. E. N. Spiker was transferred from Maracaibo to Caracas and later to Shell Trinidad Ltd., while A. Oosterbaan was transferred from Caracas to Maracaibo to take over the position of Dr. Spiker, and B. van Raadshoven was transferred from Maracaibo to the Shell offices in Houston.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Title: * SIQUISIQUE-RIO TOCUYO AREA *
**APP. I PALAEONTOLOGICAL EXAMINATION OF SAMPLES
***APP. II NOTE ON THE PALAEOBOTANICAL EXAMINATIONS
° APP. III LIST OF PETROGRAPHICAL DETERMINATIONS
Author(s): * KIEWIET DE JONGE, P.F./ ** HERMES, J.J & BARKER, R.W. *** KUYL, O.S. & MULLER, J. ° KIEWIET DE JONGE, P.F. & STREIFF, V.
Date: 10-4-50 Number Loose Encls.: 10
caja-81
Subject classification: EP-345 EP-310
Regional classification: LARA STATE

Figure 31b. *An index card showing O. S. Kuyl and J. Muller as the authors of the Appendix with the palaeobotanical examination in an internal report of the Caribbean Oil Co. from 1950. Image colorized.*

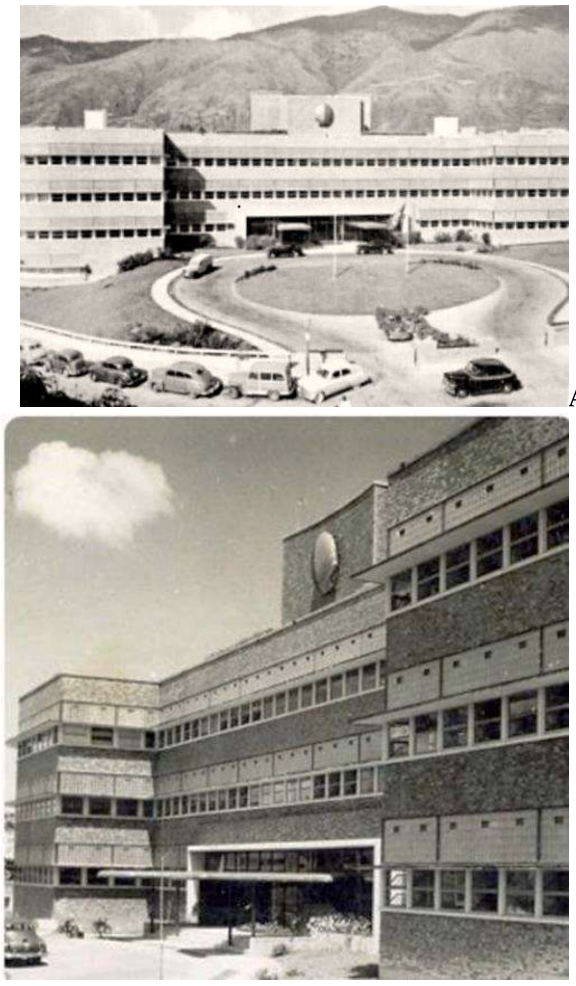
According to Kuyl et al. (1955), palynological zones from the Upper Cretaceous to the Oligocene were established in the laboratory and applied to correlate wells and surface sections across the Maracaibo Basin, including the Perijá foothills, the Colon area, and the Andean foothills. Some comments in the same paper indicate that work on a palynological zonation framework for post-Eocene strata was already underway.

The Maracaibo laboratory team of pioneers in palynology included Dr. O.S. Kuyl (since 1947), Dr. T. Waterbolk (since the early 1950s), Dr. B. van Raadshoven (also a micropaleontologist), Dr. J.H. Germeraad (since 1953), Dr. J. Muller (since 1947), Dr. R. de Haan (no date known), and, years later, L. Nijssen (in 1963) and Estela Bradley (later de Di Giacomo). Mrs. Bradley de Di Giacomo was a local who joined the laboratory in 1957 and learned the craft, from the sample processing to the identification and preparation of pollen diagrams. She was very clever and progressed quickly through the learning stages. By the 1960s, she was in charge of calculating the species percentages based on counts done by the team of technicians and palynologists in the laboratory.

In Maracaibo, two to four senior palynologists were involved in palynology. The palynologists in 1949 were Kuyl and van Raadshoven, and a group of about 20 technicians assisted them. A team of four to six senior micropaleontologists from 1941 to 1951 included micropaleontologists J. U. Todd (transferred to the US in 1951), R. Wright Barker, Dr. J. J. Hermes, Ten Broeck, T. F. Grimsdale (moved to the Hague in 1951), W. Gigon (joined the team in 1951 from Basel University), R. A. Romero, Dr. W. L. Buning, W. A. Mohler (transferred to Maracaibo by the end of 1951), and Zinkstok. Some 30 assistants helped them (Bradley de DiGiacomo, personal communication; A. N. Dusenbury in *News*, 1950).

Shell Petroleum Company also had a smaller laboratory in Caracas in 1949. Dr. G. J. R. Terpstra became head of the Caracas laboratory, while J. U. Todd was appointed as the head of the Maracaibo Laboratory (*News*, 1949). In 1949, the Caracas Laboratory moved from its original downtown location to the new headquarters in San Bernardino (Fig. 32). Dr. A. Oosterbaan, a micropaleontologist, was assigned to the Caracas Laboratory by the end of 1952.

The teams of palynologists and technicians in these laboratories searched samples for specimens to create the reference collections based on single mount specimens. They also conducted the species counting for the thousands of samples arriving at the Maracaibo laboratory from surface geological surveys and drilling operations, as well as the legacy samples from surveys done in the first quarter of the 1900s, like the one by Arnold in the 1910s (Fig. 33).



A

B

Figure 32. *Two views of Shell de Venezuela Headquarters in Caracas.* ***A:*** *Front view of Edificio Shell, designed by Badgeley & Bradbury 1946–1950, San Bernardino, Caracas, Venezuela, Fundacion Arquitectura y Ciudad, UCV (https://fundaayc.com/2017/03/23/1950-edificio-sede-de-la-royal-dutch-shell-de-venezuela/).* ***B:*** *Oblique view of the façade. The photo was taken circa 1960 by Últimas Noticias (photo courtesy of Villota Pena, 2008).*

Based on that work, the Maracaibo Laboratory reference collection of fossil pollen and spores contained close to 1,000 different species (Fig. 34), consecutively numbered, without scientific names assigned. At that time, standardized ways to formally describe and publish palynomorph species were not yet widely adopted among the workers in palynology. The fossil species were compared with recent material obtained from analyses of pollen herbarium samples worldwide during the 1950s and 1960s.

The Maracaibo laboratory created two reference collections, the fossil sporomorph collection and a recent sporomorph collection, based on the material received from the herbaria worldwide. Both collections were duplicated; one set was housed at the Maracaibo Laboratory and later at the Caracas Laboratory, while the other set was housed at Shell's laboratory in the Hague.

Figure 33. *A group of the Maracaibo laboratory personnel (J. A. Boscan, M. Morales, R. S. Nava, A. Ojeda, and V. C. Vivas) working with surface samples. Photograph taken and modified from Westermann (1941, fig. 10). Photo colorized.*

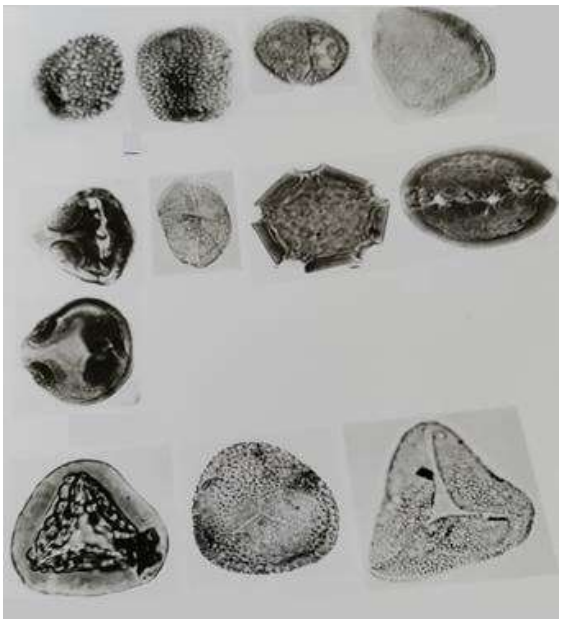


Figure 34. *Photographs of different species taken from single-mount pollen grains from Maracaibo's Laboratory Fossil Sporomorphs Collection. The image is from an unpublished working photo album. Most species have been published by Germeraad et al. (1967) and Muller et al. (1987).*

The company's pollen and spore collection consisted of numbered species with no formal binomial nomenclature. The grains in the fossil samples frequently could not be directly compared with those of specific modern plants. From the 1930s to the 1950s, many discussions were held among palynologists working in different areas of the world regarding the nomenclature of these palynomorphs.

But the dynamics of the companies conducting explorations could not wait for a formal description of new species. Therefore, pragmatically, the species in their collections were numbered rather than named, which was also very convenient

for protecting the confidentiality of their findings. Nevertheless, that is a different matter than the proposition of H. Geermerad from Shell's laboratory in the Hague to establish a numeric key to name the species based on the characteristics of the pollen grains (e.g., number of apertures, the sculpture of the exine, etc.). All this work laid the basis for the operational biostratigraphic zonation of the Venezuelan basins and the later publication of the palynological zonation for the tropical areas by Germeraad et al. (1967).

The ultimate fate of these collections is unfortunately unknown. The fossil collection was housed at the Shell Headquarters building in Caracas from 1976 to 1997, then at the Maraven, S.A. Headquarters, and from 1998 onward at the PDVSA Exploration Building. After 2002, it may have been moved to PDVSA's Core Storage at La Concepcion, together with the collection of field books from the geologists who worked in the early surface exploration campaigns of the Caribbean Oil Company. The duplicated collections in the Hague were housed at the Research Laboratory in Rijswijk for a while. Later on, at least some of the collections were donated to the University of Amsterdam, where I had the opportunity to look at the slides from the recent pollen and spore collection during my stay in 1992.

For exploratory and operational reasons, the initial focus of palynological research in Venezuela was in the Paleocene to Oligocene sections of the Maracaibo Basin. Because of this work, the palynological Eocene–Paleocene zonation was extensively used years before the Kuyl et al. (1955) publication (Fig. 35), showing the first known palynological correlation of sections around the Lake Maracaibo Basin. That paper shows correlations based on palynological zones from the Upper Cretaceous to the Oligocene defined across the Perijá foothills, the Colon area, and the Andean foothills.

Palynological zones were identified by letters, and the subzones were identified by consecutive numbers. The late Cretaceous and Paleogene zones were equivalent to the local stratigraphy defined in stages by the geologists of the group working in the country (Fig. 36). Some comments from Kuyl et al. (1955) indicated that work on a zonation framework had also been undertaken for the post-Eocene interval. The Maracaibo laboratory worked on the palynology of post-Eocene sections of the Falcon Basin as early as 1953.

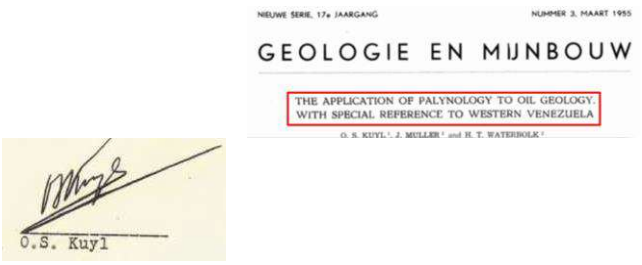


Figure 35. *The first publication about palynology applied to the oil industry by Kuyl et al. (1955) in the geological journal* Geologie en Mijnbouw *in the Netherlands. Signature of O. S. Kuyl courtesy of Prof. Franco Urbani.*

This research was initiated by B. van Raadshoven using surface samples. His work was completed in 1956, when he and J. H. Germeraad established a zonation for the Oligocene to the Pleistocene of this tropical area. This zonation was comprised of four major zones subdivided into nine subzones, providing an excellent correlation framework for the Maracaibo and Falcon Oligo–Pleistocene sections.

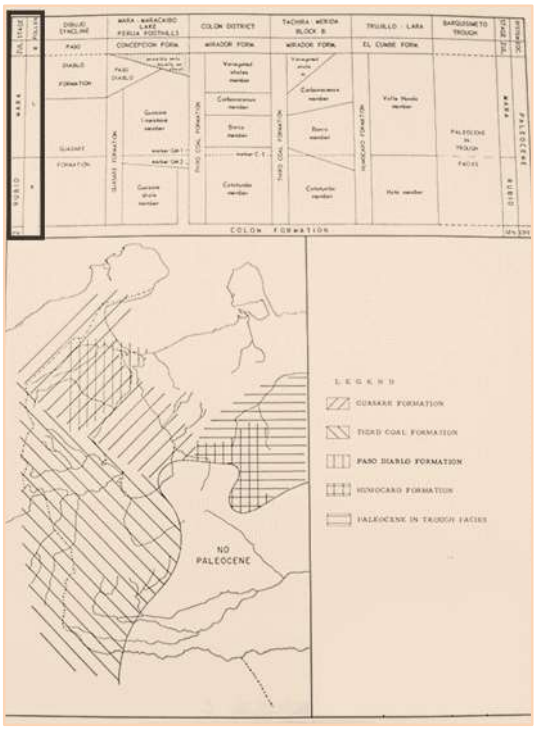


Figure 36. *A map with its stratigraphic table displaying the relationship among the lithostratigraphic units at the end of the Cretaceous–Paleocene in local stages, defined based on pollen zones. (Exploration Department, August 1956. Unpublished report from Shell de Venezuela).*

In 1954, J. Muller, at the Caribbean Petroleum Maracaibo laboratory, conducted the first studies about pollen's carbonization in geological samples from western Venezuela. His studies resulted in a carbonization map of this part of the country (unpublished), probably the first map of its kind in the entire world, years before Gutjahr's (1960) publication, which discussed using palynomorph carbonization as an indicator for rock maturation in petroleum.

The palynological zonation was refined in the late 1950s and early 1960s in this Maracaibo laboratory by J. H. Germeraad and later by R. de Haan. It included well samples from the eastern and western regions of the Falcon Basin. The eastern part of the Falcon Basin was well known for its rich foraminifera assemblages, while the west was known for carrying significant palynomorph assemblages. The studies performed over the planktonic foraminifera bearing post-Eocene marine deposits of the eastern Falcon area allowed them to find sporomorphs in sufficient numbers to establish a calibration between marine and continental assemblages. However, a good calibration was not

possible until the 1960s, when a robust planktonic zonation was established in eastern Venezuela and Trinidad. That calibration was published by Hopping (1967) and applied to the palynostratigraphy of the tropics by Germeraad et al. (1968).

Regarding staff changes, R. W. Pooley was moved from Maracaibo to Caracas to take charge of the laboratory at the end of 1956, and A. Ford joined the Maracaibo Laboratory in early 1957. In 1959 and 1960, Shell's Stratigraphic Laboratory for the Western Division (Maracaibo) was overseen by A. M. Oosterbaan, and W. E. Crews later replaced him. The staff consisted of two palynologists, J. H. Germeraad and R. de Haan, the micropaleontologist A. Ford, and the sedimentologist J. J. H. C. Houbolt. According to paleontologist B. J. Szenk (*News Report*, 1960), the palynologists were concerned with the correlation of post-Cretaceous flora in the Maracaibo Basin.

In 1961–1962, many changes happened to the personnel. For example, W. E. Crews, whose memories go back to the first applications of micropaleontology in Venezuela, returned to England in mid-1961. Dr. A. Ford left Venezuela, and Dr. Hans Bolli moved to Maracaibo. During Dr. Bolli's trip from Caracas to Maracaibo, he suffered an accident: the van caught fire, destroying his entire library and the laboratory foraminifera reference collection. At that time, R. de Haan oversaw the palynological section, and the entire laboratory was moved to Caracas when the Maracaibo laboratory closed in the spring of 1962.

Levinus Nijssen replaced R. de Hann as head of the palynological section in Caracas in August 1963, while R. de Hann moved to the Hague Laboratory. In August 1963, J.P.H. Kaasschieter replaced H. M. Bolli as the head of the laboratory. At that time, the laboratory team was engaged in the routine examination of samples. In 1967, J. P. H. Kaasschieter and L. Nijssen left Shell de Venezuela and returned to the Hague Laboratory. Only N. Fuenmayor and E. Bradley de Di Giacomo remained in the Caracas laboratory. Figure 37 shows one of the last photos of the exploration team with locals and expatriates in Caracas before most of the expatriates returned to their home countries. From 1969 until 1974, Shell's laboratory staff included N. Fuenmayor, a micropaleontologist, and Estela de Di Giacomo, a palynologist (Fig. 38). The laboratory technician was Cirilo Villalobos.

Figure 37. *The laboratory team in the exploration group: Dr. J. P. H. Kaasschieter (1), L. Nijssen (2), Ludmila Perez (3), Estela Bradley de Di Giacomo (4), and Cirilo Villalobos (5). Photo colorized.*

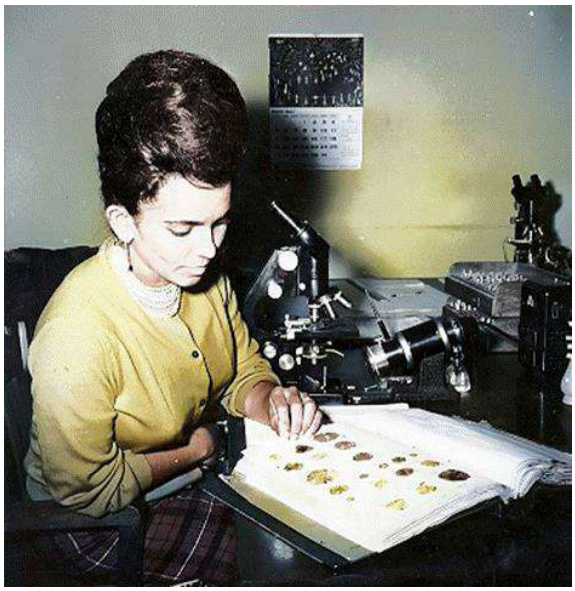


Figure 38. *Estela Bradley de Di Giacomo identifying species at the microscope. Note the species catalog she is using. The photo was taken circa 1960. Photo colorized.*

To end this section, I want to emphasize the essential and influential role of the Caribbean–Shell de Venezuela palynological section in the company's operations. This operational laboratory began the first applications of palynology to the company's exploration and production endeavors (Fig. 24). This type of work was only preceded by the Central Palynological Laboratory at the Hague, where the recruitment of young palynologists, staff training, and preliminary studies of samples started about a year before Venezuela's operational laboratory began this work.

The Standard Oil Co. of Venezuela (Creole Petroleum Corporation) Laboratories

Standard Oil of Venezuela has had geological-paleontological laboratories since 1939. The first report of their activity appeared in the monthly magazine *El Farol* (March 1942), describing the efforts of the company to encourage geology students from the Central University of Venezuela with internships in the operational areas: "At the Company's Geological Laboratory in Caripito, there are 13 Venezuelan employees and 4 foreign technicians, who help students in their investigations and provide them with all the data they need. In that laboratory (Caripito) employees of the Company examined 25,000 samples in 1939, 22,000 in 1940, and 10,000 in the first six months of last year (1941)" (see Fig. 39).

In 1941, Standard Oil of New Jersey worked in Venezuela through two subsidiaries, Lago Petroleum Corporation in western Venezuela and Standard Oil of Venezuela in eastern Venezuela. These companies had several geological and micropaleontological laboratories in the country. Lago Petroleum Corporation had one in Maracaibo with L. Becker as a micropaleontologist. Standard Oil of Venezuela's original

laboratory was in Caripito, Monagas state (western Venezuela), and was first established sometime in the 1930s (Fig. 40).

Due to the war and army enlistment, personnel were moved among the laboratories during the following years. Dr. V. Winkler arrived in the country from the US in 1941. In 1941, the Caripito laboratory had five micropaleontologists: M. W. Haas (lab chief), H. D. Borger, V. Winkler, A. N. Dusenbury, and W.K. MacFarquhar (Fig. 41). One paleontologist, L. L. Logue, left the lab to join the army.

By 1944, the two companies merged into the Creole Petroleum Corporation. The geological research of the combined companies was to be centralized at a new laboratory in Caracas, ready in 1945, and Dr. V. Winkler was placed in charge of the new lab in July 1945. In addition, a small lab was kept in Maracaibo and another in Jusepin. In 1945, just after graduating from the Central University in Caracas, several young geologists, including Leo Weingeist, Jean-Marc Sellier de Civrieux, and Roberto Pulgar Lopez, were added as staff to the lab.

Figure 39. *Students from the university in Caracas working with foraminifera samples on the microscope. The original caption translated from Spanish reads: "R. Tamoy, V. Pérez, V. Rondón, J. López and C. Tepedino, microscopically examining the samples to extract the foraminifera from them […] Mr. Hugo Campos studies the different types of Macrofossils"* (El Farol*, 1942). Photo colorized.*

Figure 40. *The Creole Petroleum Corporation Geology Laboratory in Caripito, 1942. (Photo by Dr. Hernan Leon, courtesy of Marianto Castro Mora). Photo colorized.*

Figure 41. *Dr. Virgil Winkler (left) in 1942, probably with H. D. Borger (right), working in his office at the Caripito laboratory. The photo was originally published in* El Farol *(1942). Image courtesy of the University of Illinois at Urbana-Champaign Archives. Photo colorized.*

Dr. V. Winkler was the director of the Venezuela laboratory by the time palynologist Dr. Tschudy joined the team. In 1945, Dr. R. Tschudy and Dr. B. Tschudy, his wife, also a palynologist, traveled to Venezuela "to establish a laboratory and develop techniques of studying palynomorphs in the Cretaceous and Tertiary rocks of Venezuela" (AASP, Dr. R. Tschudy). In the Caracas laboratory, Dr. R. Tschudy developed an operational palynological zonation for the Eocene sands of the Creole's concessions in the Maracaibo Basin. He carried out studies on recent palynomorph distribution in Lake Maracaibo, but this zonation was not published until J. Sulek demonstrated its application in 1969 at the Venezuelan Geological Congress.

In those years, Dr. R. Tschudy also studied mangrove pollen distribution in the upper Tertiary, but these results were never published, as he stated in 1961. During his time in Venezuela, Dr. R. Tschudy developed a sample preparation technique to extract palynomorphs. He studied the distribution, concentration, and preservation of recent palynomorphs at the bottom of Lake Maracaibo. Dr. R. Tschudy left Venezuela in 1950 and established his residence in Boulder, Colorado, where he and his wife, Bernadette, opened a private palynological consultancy and laboratory. Several years later, Tschudy (1957) proposed and published a system to classify pollen and spores

with a shorthand formula based on the general morphology of the specimens.

In 1946 and 1947, the paleontological division of the laboratory expanded with the addition of new specialists (e.g., Charles G. Spencer, Harry W. Anisgard, Jacque Guillaumin Jr., James S. Cullison, Miss Alba S. K. Mandra, Gordon M. Sowers, Pedro J. Bermudez, Jesse J. Howard, and the recently graduated Alirio Bellizia and Cecilia Martin). Some activity continued at the Maracaibo, Jusepin, and Quiriquire laboratories. Leroy E. Becker, head of the Maracaibo laboratory, was transferred to Caripito in 1953 but not to the laboratory, and H. W. Anisgard was transferred from the laboratory in Caracas to Maracaibo to replace Becker. Dr. R. M. Stainforth joined the Jusepin laboratory that year. In 1953, Maria Mercedes Natera and Brigido Natera were part of the laboratory staff, and both received scholarships to study in the US (Fig. 42).

María Mercedes Natera de Natera, of the Caracas laboratory staff, and her husband, Brígido Natera, have received scholarships from Creole granting them each a year of postgraduate study at the University of California at Berkeley. They are now taking a preparatory course in English at Queens College, New York City.

Figure 42. *An insert with news about paleontologists working in Venezuela from 1953. The source is unknown, probably from* El Farol.

According to Osorio (2007), from 1945 to 1955, the company "hired Venezuelan and North American specialists, trained assistant personnel, and organized three work shifts of 8 hours daily, each, to do all the microscopic work needed to study the legacy samples as well as all the samples coming from the fieldwork and the drilling operations that the company had in the country […] it was the greatest Geology Laboratory in the world, with 120 people working among professionals and processors." This opinion is supported by the comments of F. Brotzen, a micropaleontologist from Sweden, during his 1948 travels in Venezuela: "I have seen what is probably the biggest micropaleontological laboratory in the world that of the Creole Petroleum Corporation (in Caracas)."

In September 1946, *El Farol* included an article about the Caracas Geological Laboratory, stating that the centralized laboratory in Caracas received about 2,000 samples a week in 1945: "In order, organization and breadth, (the Caracas laboratory) is one of the best in the world. Large quantities of mineralogical and paleontological arrive daily from across the territory of Venezuela to be classified. Samples arrive by truck or air from places where the company makes explorations or studies […] Virgil Winkler directs the Laboratory, which is attached to the Geology Department. He is assisted by Mr. James S. Cullison" (September 1946, p. 11).

The sample workflow of the time included sample preparation, mounting, preliminary microscope examination, and fossil identification (Fig. 43). There were 17 microscopes in that section. Winkler described: "after the samples have passed through the microscopes are taken to the technician's department. There are six paleontologists and one mineralogist. The mineralogist is José Mas Wall. Among paleontologists, three are Venezuelans, Roberto Pulgar López, Jean-Marc Sellier, and Leo Weingeist, the last two nationalized, and three foreigners, Harry Anisgard, Arthur N. Dusenbury, and Charles Spencer […] in total, the laboratory staff consists of 85 employees, of which only five are not Venezuelans […] the staff is made up like this: Chief Mr. Winkler, a supervisor, three chief paleontologists, two assistants, and three lower graduations, a mineralogist, four employees of office, seven senior lab technicians with great experience and 64 junior lab technicians" (*El Farol*, September 1946, p. 12). Figure 44 shows the archive of processed samples in the Caracas laboratory. *El Farol* (September 1946, p. 12) also noted: "In the Maracaibo and Jusepin fields, the Creole Petroleum Corporation also has smaller laboratories for examining exploration samples, sending surface and drilling samples to Caracas."

Figure 43. *A technician picking microfossils (El Farol, September 1946). Photo colorized.*

In December 1946, a young female micropaleontologist joined the Maracaibo team. Her name was Alba Mandra: "Miss Mandra graduated as a geologist from Hunter College, New York. Later, Alba (from New York) interned at the University of Columbia in Paleontology. And in December 1946, she came to Venezuela to work with Creole, going to Maracaibo for an eight-week training course […] in her work as a paleontologist, Alba had to identify microfossils (shells of tiny crustaceans) separated from rock samples taken from oil wells. Once these microscopic forms have been classified, Alba analyzes the special problems indicated by their characteristics and reports on her findings. Sometimes, the meticulous study of the materials from wells in a certain area—from the surface layer to depths that sometimes reach 3,000 meters—is reflected in several volumes containing the research work of up to a whole year" (*El Farol*, March 1949).

Due to the number of personnel and the activity from 1945 to 1947, the laboratory required a bigger area. Therefore, in 1948, the laboratory moved to a new site besides the headquarters of ESSO/Creole Company in Caracas. As a result, the laboratory flourished in the 1945–1955 period.

By 1949, the Caracas laboratory was receiving 7,000 samples a month to be processed and studied. The other regional

laboratories continued to be active, as seen in a 1949 photograph of a micropaleontologist working foraminifera in the Quiriquire laboratory (Fig. 45). In 1949, Creole Petroleum dedicated an article in *El Farol* to the company's laboratories in the country, including graphics and information describing the work done there.

Figure 44. *Archive of processed samples at the Caracas Laboratory from the Creole Petroleum exploration and production areas. September 1946* (El Farol*). Photo colorized.*

Figure 45. *A micropaleontologist working with microfossils at the Quiriquire laboratory. The original image was published in* El Farol *in 1949. The photo has been colorized.*

The Caracas laboratory was initially based next to the headquarters of the Creole Petroleum Corporation in Caracas (Fig. 46 and Fig. 47). In February 1951, the Central Geological Laboratory was moved from Creole's headquarters to a remodeled warehouse next to Creole's employee sports club in Bello Monte, Caracas (*News*, October 1951). In 1953, several micropaleontologists, including Art N. Dusenbury, Leo Weingeist, Alba Mandra, and Jay Marks, worked in that laboratory.

In late 1953, due to Creole's decentralization policy, the company decided to close its Caracas Laboratory and split the personnel, equipment, slides, and samples between the eastern laboratory at Jusepin and the western division laboratory at Maracaibo. The Caracas laboratory was scheduled to close down at the end of 1954, while new larger quarters for the Jusepin and Maracaibo laboratories were planned.

By mid-1954, the splitting of the Caracas laboratory was well under way. Personnel were in the process of transferring to the Maracaibo and the Jusepin laboratories. By October 1954, the evacuation of the Caracas laboratory was practically complete. Some technical personnel were split between the Jusepin and Maracaibo laboratories, and other employees were assigned to non-paleontological jobs (*News*, October 1954).

The company's field work exploration program was suspended in 1955. That decision greatly impacted the future of this important laboratory, which was split into several operational units. In fact, the personnel working in the Caracas central laboratory were dispersed, and most were sent to the Maracaibo or Jusepín laboratories. Dr. V. Winkle coordinated the paleontological work in Maracaibo and Jusepin from the Caracas office. The Creole Petroleum laboratory in Caracas was relatively short-lived; after 10 years, in 1955, it was split into several operational units.

In 1955, the company moved its Caracas headquarters to its new impressive building (Fig. 48). A. N. Dusenbury Jr. and Dr. P. Bermudez were assigned to the Jusepin laboratory, with John Sulek as a new staff member. G. M. Sowers continued his supervisory role at that laboratory. The Maracaibo laboratory

received a new staff member that year, Lee Gibson. In 1956, four micropaleontologists were working in the Jusepin laboratory: Dr. P. J. Bermudez, A. N. Dusenbury Jr., G. M. Sowers, and J. A. Sulek. H. W. Anisgard was at the Maracaibo laboratory. Dr. Winkler continued coordinating the work between the central office in Caracas and the laboratories of Maracaibo and Jusepin. In 1958–1959, there were many changes in the supervision of the teams of the different labs; for example, G. M. Sowers was transferred to the Geological Department in Quiriquire, R. M. Stainforth became the head of the Jusepin laboratory, and J. L. Lamb joined that team. Meanwhile, A. N. Dusenbury was transferred to the Maracaibo lab.

Figure 46. *Headquarters of the Creole Petroleum Corporation, Avenida Mexico, Caracas. The Geology Laboratory moved to a new site beside the headquarters building. Photo colorized.*

Figure 47. *The main entrance of the Creole Petroleum Co. building in Caracas (El Conde), where the company's main laboratory was housed between 1945 and 1951. Photo of unknown author. Photo colorized.*

In 1957, American micropaleontologist and stratigrapher Dr. R. M. Stainforth traveled to Venezuela on contract with Creole Petroleum Corporation to be the head of the Jusepin laboratory (Castro Mora, 1992). The personnel in Creole's Maracaibo laboratory by the end of 1957 were Charles E. Key (head), J. J. Howard, L. B. Gibson, G. Fraunfelter (macrofossil paleontologist), and P. Ronai. Creole's Jusepin laboratory staff consisted of G. M. Sowers (head), to be replaced by R. M. Stainforth, Dr. P. J. Bermudez, A. N. Dusenbury, and J. Sulek. Dr. V. Winkler continued coordinating the work in both labs from the Caracas offices.

In 1959–1960, Creole's Maracaibo laboratory staff consisted of Carlos E. Key, who oversaw four micropaleontologists, A N. Dusenbury Jr., J. J. Howard, L. B. Gibson, and P. Ronai. That year, L. B. Gibson resigned to pursue PhD studies at the University of Oklahoma. After R. H. Tschudy returned to the US, all palynological work within Creole was contracted to his laboratory in Jamestown, Colorado.

Figure 48. *The Creole Petroleum Corporation building was constructed in 1955. The geology laboratory was dispersed to the operational areas before moving to the new building. A smaller version of the laboratory was built as an annex in the back of the main office building. In 1970, Creole closed its palynology laboratory. Photography from Caracas Ayer y Hoy, courtesy of Gilberto Ospino. Photo colorized.*

Starting in 1960, the Maracaibo laboratory was equipped to do the most urgent routine palynological work. Peter Ronai oversaw the palynology operation. Also, in the first part of 1960, Creole's Jusepin laboratory was overseen by R. M. Stainforth, with John A. Sulek and James L. Lamb. That year, Pedro J. Bermudez was on a one-year leave of absence. Later in the year, the Jusepin laboratory was shut down, and the personnel transferred to Maracaibo, where all the paleontological work of the company was done from that moment onward. Arthur N. Dusenbury retired in 1960 after 20 years in Venezuela. Lee Gibson and P. Ronay also resigned and returned to the US. In 1961, the staff of the Maracaibo lab consisted of R. M. Stainforth, John A. Sulek, James L. Lamb, J. J. Howard, H. Ancieta, who returned from his Ph.D. and was in a special paleontological project, and J. W. Funkhouser, who was in an accelerated program in palynology.

In 1962, R. M. Stainforth, the correspondent of *News Report* (1962), reported that the ranks of active micropaleontologists in the country had declined since the previous year, reflecting the reduced exploration activities of the oil companies. At that time, he believed that foraminifera studies had a minor application in routine oilfield development, while the palynological approach had the greatest importance. That year, only J. A. Sulek (palynology) and J. L. Lamb (foraminifera) were still conducting paleontological studies. All other paleontologists had returned to their countries or had been reassigned to regional studies. In 1962, the regional laboratory was moved from Maracaibo to Caracas. Alfredo Mederos (Fig.

49) joined the palynological section of the laboratory in Caracas that year.

In 1963 and 1964, J. A. Sulek oversaw the laboratory in Caracas and was assisted in the palynological studies by Alfredo Mederos. In 1965, J. L. Lamb left Venezuela for a post at the Houston laboratory of Esso Production Research Company and was replaced in the Caracas laboratory by M. Furrer. In 1967, the laboratory remained under the charge of J. A. Sulek, with M. A. Furrer (micropaleontology) and A. Mederos (palynology). R. M. Stainforth was no longer working in paleontology but was working with applying paleontological data to regional stratigraphy.

By 1969, Dr. R. M. Stainforth had retired; the remaining laboratory staff of Creole consisted of J. A. Sulek, the supervisor and in charge of the palynology section, with Alfredo Mederos as palynologist and Dr. Max Furrer as micropaleontologist. At that time, all of them were engaged in regional studies. In 1971, M. A. Furrer supervised all micropaleontological work for Creole Petroleum Corporation and was engaged in studying the Eocene of Venezuela. In 1973. M. Dr. Furrer left Venezuela and was transferred to Esso's European Production Research unit in Begles, France.

Figure 49. *Palynologist Alfredo Mederos joined Creole Petroleum Co. in 1962 in Caracas (Photography taken circa 1980, courtesy of Marianto Castro Mora). Photo colorized.*

SUMMARY OF ACHIEVEMENTS OF PALYNOLOGY IN VENEZUELA (1945 TO 1960)

Pioneer palynologists who worked in Venezuela in this period were well ahead of their time. They understood the cyclicity signals in sedimentary sections. They developed the idea that palynological zones, controlled by climatic oscillations, reflected regressive–transgressive cycles that could be identified from local areas to entire basins, establishing zones with true chronostratigraphic value. Still, many of those ideas were never published or published only after many years of delay.

By 1955, palynology was already an essential tool for oil exploration in Venezuela. Moreover, it was developed and applied in the country far more extensively than in any other place in the world. At this time, Shell decided to authorize the publication of the first paper dedicated to the oil industry and palynology, "The application of Palynology to oil geology, with special reference to Western Venezuela" by O. S. Kuyl and J. Muller, both palynologists working at the Maracaibo lab, as well as H. T. Waterbolk, a palynologist working at the N. V. De Bataafsche Petroleum Maatschappij, in the Hague laboratory. This zonation of the Paleogene and Neogene using pollen and spores was widely applied in the production of shallow marine to terrestrial reservoirs in western Venezuela.

The research and application of palynology were intense during this period. An example is the publication of the paper "Palynology of recent Orinoco Delta and shelf sediments" (Muller, 1959), a groundbreaking study about the transport and deposition of pollen in clastic environments, a work initiated as early as 1956 with a scientific expedition to the delta. Additionally, during his time in the country, Dr. R. Tschudy studied the distribution, concentration, and preservation of recent palynomorphs at the bottom of Lake Maracaibo. He found that sorting, floating, stirring, and resettling altered the distribution and concentration of the palynomorphs in the samples, although his research was not published until 1969.

The work of Muller and Dr. Tshudy on the recent distribution of palynomorphs laid the basis for the early understanding of the relevance of fossil pollen and spore assemblages as paleo-environmental indicators. Outside Venezuela, it was not until 1952 and 1953 that Standard Oil Co. of California and the Carter Oil Company announced that some palynological research was carried out (Kuyl et al., 1955): "Palynologists are also working in British Borneo and Nigeria, while preparatory investigations of other operational areas, such as Colombia, Trinidad, and New Guinea, are being carried out in The Hague."

Other paleontological laboratories (without palynology)

Between the 1930s and the early 1960s, several other geological-paleontological laboratories operated in Venezuela; most of them focused on micropaleontological and sedimentological studies, according to the letters from different paleontologists published in *News* (1947–1954) and *News Report* (1955–1957).

The Phillips Petroleum Company Lab.

This company hired Dr. J. G. Bursch to organize its paleontology laboratory in Caracas in 1947. The company moved its headquarters, including the laboratory, in June 1947. This laboratory was working only in micropaleontology.

The Sinclair Oil Company Labs.

From 1946 to 1948, a subsidiary of Sinclair Oil Co. owned a small laboratory operated by W. O. Clift in the Santa Barbara camp in the northern part of the State of Monagas. This

laboratory was scheduled to move to Sinclair's new headquarters building in Caracas in 1948. In April 1948, a new micropaleontological laboratory was opened in Caracas. This laboratory studied samples from Venezuela, Colombia, and Panama (*News*, 1949), but it is unknown whether it conducted studies on pollen and spores.

In 1953, E. P. Lancaster replaced A. Martinez in the Santa Barbara laboratory. In January 1954, the laboratory suspended its micropaleontological studies due to the resignation of E. P. Lancaster. Then, in 1956, William MacFarquhar, a paleontologist formerly with Mene Grande, joined the geology staff in the Santa Barbara camp.

The Socony-Vacuum Oil Company Labs.

Socony opened its laboratories in Venezuela sometime in the 1930s, with a small laboratory in Pariaguan that later was moved to Guario, both in Anzoátegui. In 1943, the company centralized all its South American laboratories in Bogota, Colombia. Still, the experience of a centralized laboratory was not entirely satisfactory, so it was reversed in 1948.

In September 1948, the company transferred Donald Nelson from Bogota to Caracas to set up a new micropaleontological laboratory. Before then, Socony, a Standard Oil of New York subsidiary, had sent all its samples from Venezuela to their central laboratory in Bogota (*News*, 1948, 1949). Finally, in November 1950, the Caracas Laboratory was closed.

The laboratory in Anaco had been dormant since 1943, but it was reactivated by Donald O. Nelson when he was transferred from the Caracas Laboratory to the Anaco camp. Later, in 1952, F. G. Engelberts was transferred from Bogota to the Anaco Laboratory to assist Nelson. In 1953 and 1954, there were several changes in the staff due to resignations to join other laboratories and new employment (C. C. Kersting). By 1956, the company's name had changed to Socony Mobil Oil Company de Venezuela. Nelson, the paleontologist at Socony's Anaco laboratory, was transferred to the Libyan branch of the Mobil Oil of Canada in Tripoli. F. D. Smith Jr. returned to the Anaco laboratory after finishing his postgraduate studies in New York.

The Venezuelan Atlantic Refining Company Lab.

In 1943, Donald W. Gravell started a temporary micropaleontological laboratory in the company offices in Caracas to support the company's revived exploration activities in the country. In 1946, micropaleontologist Louita G. Dodson joined the staff. The space for the laboratory was increased when the company moved again, and Dr. Wolf Maync, an experienced micropaleontologist, was added to the team. Dr. Maync resigned in 1956, and Dr. Frans Keijzer took over his position.

In 1958, H. M. Bolli accepted the position of Chief Paleontologist at the company's Geological Laboratory of Venezuela. In 1960, he continued holding that position and studied Upper Cretaceous and lower tertiary planktonic foraminifera with M. B. Cita from the University of Milano. In February 1960, the laboratory was closed.

The Richmond Exploration Company Lab.

The Richmond Exploration Company started a temporary laboratory in the Creole's Maracaibo camp in 1944 due to its renewed exploratory activity in Venezuela. William E. Pappert, a geophysicist with training in micropaleontology, was in charge of the laboratory. In 1945–1946, he was replaced by L. W. LeRoy, and a permanent laboratory was built in Richmond's camp in the south of Maracaibo. LeRoy resigned in 1948 and returned to the US as an associate professor at the Colorado School of Mines. In 1949, a new micropaleontologist, F. Amato, was added to the laboratory staff to assist K. L. Edwards.

In 1953, A. Martinez started working for the Maracaibo laboratory. In 1954, W. Weaver joined the Caracas Laboratory staff and stayed at the company for two years. In 1956, micropaleontologist Robert Jaroska joined the company in the Maracaibo laboratory. In 1960, two staff micropaleontologists in the Maracaibo laboratory, R. Jaroska and A. B. Whitman, worked on correlations, stratigraphy, and regional problems related to the company's concessions in western Venezuela.

The Pan Venezuelan Oil Company Lab.

In 1958, the company named A. E. Wirz as a head paleontologist, but no information confirming that the company had a laboratory in Venezuela has been found.

The Mobil Oil Company of Venezuela Lab.

The Mobil Oil Company had a laboratory in Anaco, with Foster D. Smith Jr. in charge and working on eastern Venezuela's regional geology and micropaleontology. Stephen F. Percival Jr. worked on western Venezuela's micropaleontology and Caribbean pelagic foraminifera. By 1962, Mobil had no paleontologists active in Venezuela.

Independent Consultants.

In 1957, Frank Amato opened a micropaleontology and stratigraphy consulting office in Caracas. He had extensive experience with Standard of California in Venezuela, Colombia, and Peru. He used a breakdown method called an "osterizer" to prepare washed samples. In 1958, he started the installation of a laboratory for pollen research studies in the Maracaibo Basin. He was also engaged in routine paleontological and lithological studies, providing sample preparation, picking, thin sectioning, and storage for companies that did not wish to establish paleontological laboratories in the country. With so much activity in 1959 and 1960 that required micropaleontological studies, the palynology research project was shelved.

Besides Amato, the staff consisted of one assistant trainee micropaleontologist, as reported by B. J. Szenk (*News Report*, 1960). In 1960, Amato mainly worked on samples from Gulf of Paria subsurface projects. (*News Report*, 1961). In late 1961, Amato left Venezuela and moved to Mexico, ending the activity of paleontological consultants in the country in the 1960s.

Palynology in Venezuela: The 1960s and early 1970s

The early 1960s brought new challenges to palynology in Venezuela and the world petroleum industry. The Venezuelan government took several major steps in the 1940s and 1950s, including not granting new concessions, establishing the fifty-fifty distribution profits scheme, and the Hydrocarbons Law of 1943. All of them led to advancing toward the nationalization of the oil industry. In 1960, the government created the Venezuelan Petroleum Corporation (CVP) and granted the company areas for exploration and exploitation called assignments (Martinez, n.d.). As a consequence of all this turmoil, by 1960, exploratory work started to slow down, with a consequent downsizing of the geological-paleontological laboratories in the country. In some cases, the entire laboratory staff was transferred to different functions in the companies or in other geographic areas.

The early 1960s also brought new challenges to palynology in Venezuela. Secondary oil recovery operations, already in place at Shell's Tia Juana field's post-Eocene section, required a very detailed knowledge of the sand distribution and correlation, for which logging tools and other available techniques frequently did not give detailed enough results for precise correlation. So, it was crucial to further develop palynology to help geologists and petroleum engineers find and produce the oil trapped in those Tertiary sections.

With that goal in mind, Shell's Venezuelan laboratories and the Hague laboratories began to study a series of transgression-regression cycles within a single palynological zone. These analyses combined with observations of quantitative changes in the hinterland sporomorph associations tied well to the palynological cycles and zones. This technique produced outstanding results by establishing sand continuity in those reservoirs considered for steam injection.

The Shell Maracaibo Laboratory moved to Caracas around 1962. Once in Caracas, L. Nijssen, Shell's highly experienced palynologist, refined the pollen color scale previously developed by J. Muller. In addition, Nijssen refined Muller's original carbonization map for the Maracaibo and Falcon basins before leaving Venezuela in the late 1960s. In the years that followed, the Shell laboratory in Caracas downsized, following the trend set by the Creole laboratory. The future of Venezuela's concessions was on the table, and companies were already reducing their investment in exploring the country. In addition, strong rumors about possible nationalization were floating around in 1966, and many companies reacted by returning expatriates to their home countries. From his memories, D. Goddard relates that in 1965, Mene Grande (Gulf Oil) sent many expatriates back to their countries of origin, mainly the US. He describes that by 1966, there were so many empty houses in the San Tome Camp that singles were allowed to live in the two-room family houses (Irureta, 2018).

In the late years of that decade, Shell sponsored a comprehensive paper on the palynological zonation established by this company in Venezuela, Borneo, and Nigeria, the well-known Germeraad et al. (1968). T. van der Hammen helped those authors with naming some key species according to the standard scientific nomenclature, showing good collaboration among universities and companies in the 1960s. Surprisingly, Germeraad et al. (1968) is still the only available palynological zonation that applies to all tropical areas of the world, demonstrating the outstanding quality of the research carried out inside these companies during those early years. The centennial jubilee AAPG Committee recently chose this paper as one of the essential publications in biostratigraphy for the oil industry.

The early 1970s was a time of extreme downsizing of oil corporations in Venezuela. If there were any paleontologists at all, companies retained not more than one micropaleontologist, maybe one palynologist, and one sample preparation technician in their labs. Expatriates were returned to their main corporate offices in the US and Europe. Nationalization by the end of 1975 was a turning point for Venezuela and the laboratories of the oil industry in the country.

Despite the progressive reduction of resources and personnel that happened to paleontological laboratories in the late 1960s and early 1970s, palynologists like Estela Bradley de Di Giacomo, A. Mederos, and A. Euribe, as well as micropaleontologists Angel Fuenmayor and Dr. Max Furrer, took up the challenge of preserving the type collections, internal reports, and knowledge on palynology and micropaleontology accumulated over the 1940–1975 period in Venezuela. They transferred the pioneers' legacy to the younger generations of paleontologists that emerged from Venezuela's universities from 1976 onwards and were employed in Venezuela's oil industry.

1975: The end of an era.

In January 1975, V. F. Hunter, correspondent of *News Report* for Venezuela, said, "With exploration activity on the decline, many of the foreign oil companies are closing or reducing their biostratigraphic laboratories, and consequently their micropaleontologists are being transferred to other parts of the globe."

Palynology in Venezuela after Nationalization

On December 31, 1975, all concessions were reverted to Venezuela's government. As of that date, the assets, plants, and equipment, among other aspects of the foreign concession

companies, became the property of the state. On January 1, 1976, Petroleos de Venezuela Sociedad Anonima (PDVSA) effectively assumed all the functions of the oil industry by acquiring all the shares of the 14 companies that replaced the concessionaires at their nominal value (about 1,054,000,000 dollars, 117,000,000 in cash and the rest in public debt bonds). These companies were already subsidiaries of PDVSA. Creole became Lagoven; Amoco, Amoven; Shell, Maraven; Phillips, Roqueven; Talon, Taloven; Mito Juan, Vistaven; Mene Grande Oil Company, Meneven; Las Mercedes, Guariven; Sun Oil, Palmaven; Sinclair, Bariven; Mobil, Llanoven; Chevron, Boscanven; Texas, Deltaven; and CVP went from an autonomous institute to a public limited company (Socorro, 2020).

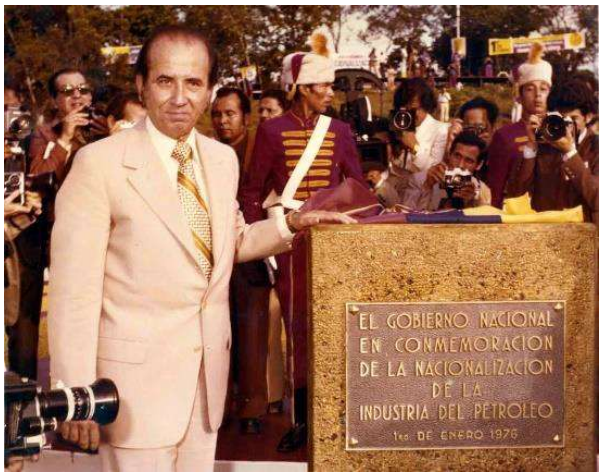


Figure 50. *Carlos Andres Pérez, President of Venezuela, the day the oil industry was nationalized. Image from the archive "Fotografia Urbana," taken from Bulletin PRODAVINCI (Socorro, 2020).*

In the following years, several successive mergers among the nationalized companies significantly reduced the number of national oil companies. As a result, by the early 1980s, only three companies (Lagoven, Maraven, and Corpoven) and one research institute (INTEVP) prevailed. All these companies had paleontological laboratories (including palynology) that were very active and prolific. Like a phoenix, these post-nationalization laboratories began to flourish again in the early 1980s, with new generations of palynologists and micropaleontologists. These laboratories were in Caracas (Maraven, S.A. and Lagoven, S.A.), Los Teques (INTEVEP), and Puerto La Cruz (Corpoven, S.A.).

Palynology thrived in all these laboratories from 1978 to 2000. From nationalization until 1997, four laboratories continued to apply and develop palynology in Venezuela, one for each PDVSA affiliate company. From 1998 onward, the laboratories were integrated into one organization within PDVSA's Exploration Business Unit, except for the Pedro J. Bermudez library and the paleontological laboratory, which remained in the structure of PDVSA's research company, INTEVEP.

The list of palynologists working in those laboratories from 1978 to 1997, as well as some of their achievements, is as follows:

Lagoven: Alfredo Mederos, Pedro Rojas (RIP), and Elizabeth Teheran (later in INTEVEP). The Lagoven team published their work (Rojas et al., 1997) on determining the Oligocene in the south of Lake Maracaibo. The members of the Lagoven Team were also very active, helping to publish several stratigraphic units for the last paper edition of the "Lexico Estratigrafico de Venezuela" and presenting papers at different conferences. They were also part of the "Comite Interfilial de Biostratigrafia."

Maraven: Estela Bradley de Di Giacomo, Maria Antonieta Lorente, Miguel Velásquez, Valentí Rull, Luis Mata, Anton van Erve, and Tony Evans. Palynology technicians were Mercedes Hidalgo and Clever Contreras. Relevant publications from that team include the Boesi et al. (1985) integrated stratigraphic study of the northern Andes foothills and Lorente (1986), a work about the palynology and palynofacies of the upper Tertiary in Venezuela. In 1987, a significant international publication by Muller et al. (1987) presented a palynological zonation for northern South America's Cretaceous, Tertiary, and Quaternary. In the late 1980s, Lorente's work on the palynological organic matter from the point of view of quantitative textural characterization led to the development of new methodologies and technology published in Lorente (1990a, 1990b), as well as a patent (Lorente, 1990c). Lorente and Van Bergen (1991) published a classification of organic matter using different microscopy techniques. V. Rull, who was part of the team, produced many publications during the 1992–2000 period (a complete list of his publications is at http://publicationslist.org/vrull). The primary expertise of this team was pollen, spores, and palynological organic matter.

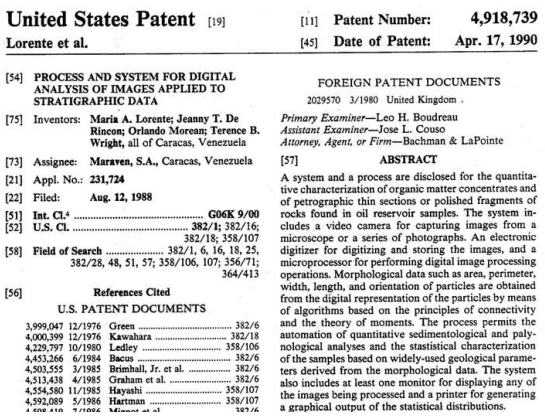
Corpoven: Zorena de Monroy, Clara de Guerra, Douglas Somoza, Javier Helenes, Alejandro Euribe, and Javier Vásquez. The important work done by this group includes the publications by Monroy et al. (1987) using palynology for age dating the Guafita Formation in the Barinas–Apure Basin subsurface. Also, in 1997 Clara de Guerra published her work about the palynological associations of the Cenomanian–Turonian in the Barinas Basin. The Helenes, De Guerra, Vasquez, and Somoza team published several papers from 1994 to 1999 about the palynology of the Upper Cretaceous in eastern and western Venezuela. This team was very knowledgeable about the application of dinoflagellates in palynology.

INTEVEP: Armando Fasola, Iraida Paredes de Ramos, Omar Colmenares, and Efe Sinanoglu. This group produced many contributions to Venezuela's palynology, several of which are in unpublished reports. The work of Sinanoglu on the palynology of a core from the Lower Cretaceous of the Orinoco Oil Belt in 1984 was the first publication reporting sediments of that age in the area. Omar Colmenares, in 1988, published a palynological study from three wells of the Boscan Field in western Venezuela. In 1991, Fasola and Paredes

published about the Late Cretaceous Palynological assemblages from the El Furrial area. This team was very experienced in the application of dinoflagellates in palynology.

In 1997, all affiliates were merged into a holding company, PDVSA E&P. All the geological-paleontological laboratories were integrated into two laboratories: El Chaure Laboratory in eastern Venezuela and the Headquarters of PDVSA Exploration in Caracas. In addition, a smaller operational laboratory was kept in Maracaibo to support the operations in western Venezuela.

From 1976 to 2000, essential advances were achieved in palynology. Among them, the first patent granted to a combination of software and hardware in the US, ADIE, was a digital image analysis system with patents in the US and Australia (Fig. 51). Also, an expert system for sporomorph identification named ESTELA, based on the experience of Estela Bradley de Di Giacomo, contains a catalog of pollen and spores for the Neogene and Paleogene of Northern South America in DVD format (Fig. 52).



United States Patent [19]
Lorente et al.

[11] **Patent Number: 4,918,739**
[45] **Date of Patent: Apr. 17, 1990**

[54] **PROCESS AND SYSTEM FOR DIGITAL ANALYSIS OF IMAGES APPLIED TO STRATIGRAPHIC DATA**

[75] Inventors: **Maria A. Lorente; Jeanny T. De Rincon; Orlando Morean; Terence B. Wright,** all of Caracas, Venezuela

[73] Assignee: **Maraven, S.A.,** Caracas, Venezuela

[21] Appl. No.: **231,724**

[22] Filed: **Aug. 12, 1988**

[51] **Int. Cl.**[4] **G06K 9/00**
[52] **U.S. Cl.** **382/1;** 382/16; 382/18; 358/107

[58] **Field of Search** 382/1, 6, 16, 18, 25, 382/28, 48, 51, 57; 358/106, 107; 356/71; 364/413

[56] **References Cited**
U.S. PATENT DOCUMENTS

3,999,047	12/1976	Green	382/6
4,000,399	12/1976	Kawahara	382/18
4,229,797	10/1980	Ledley	358/106
4,453,266	6/1984	Bacus	382/6
4,503,555	3/1985	Brimhall, Jr. et al.	382/6
4,513,438	4/1985	Graham et al.	382/6
4,554,580	11/1985	Hayashi	358/107
4,592,089	5/1986	Hartman	358/107

FOREIGN PATENT DOCUMENTS
2029570 3/1980 United Kingdom .

Primary Examiner—Leo H. Boudreau
Assistant Examiner—Jose L. Couso
Attorney, Agent, or Firm—Bachman & LaPointe

[57] **ABSTRACT**

A system and a process are disclosed for the quantitative characterization of organic matter concentrates and of petrographic thin sections or polished fragments of rocks found in oil reservoir samples. The system includes a video camera for capturing images from a microscope or a series of photographs. An electronic digitizer for digitizing and storing the images, and a microprocessor for performing digital image processing operations. Morphological data such as area, perimeter, width, length, and orientation of particles are obtained from the digital representation of the particles by means of algorithms based on the principles of connectivity and the theory of moments. The process permits the automation of quantitative sedimentological and palynological analyses and the statistical characterization of the samples based on widely-used geological parameters derived from the morphological data. The system also includes at least one monitor for displaying any of the images being processed and a printer for generating a graphical output of the statistical distributions.

Figure 51. *The US patent was granted to a computerized system developed for quantitatively characterizing palynological organic matter for palynofacies analysis purposes.*

Figure 52. *Front cover of the Pollen and Spores Catalog by Estela Bradley de Di Giacomo.*

Another application was of ECOSTRATIGRAPHY and ECOLOGS, concepts based on the ideas of Poumot (1967) that were adapted to Venezuela by Rull and Poumot (1997). A presentation of this work at an AAPG Annual Meeting was distinguished it as one of the event's best posters, and the authors were invited to the following year's event. Other interesting applications were high resolution palynology at basin level, enhanced correlation of reservoirs using palynology, and petroleum system timing to help determine the synchronization of oil generation and trap formation. The application of the "palynoblocks" concept, or blocks limited by faults characterized by a single palynological zone at its top, was very successful in structurally complex producing areas of Lake Maracaibo. Most of these developments are described in the paper "High Impact Palynology" (Rull, 2002).

OVERVIEW: STRATIGRAPHIC PALYNOLOGY IN THE REST OF THE WORLD (1938–1968)

Stratigraphic palynology was intensely developed from the early 1940s through the 1960s within the oil industry worldwide. It was considered a tool with high potential to give companies a competitive edge in exploration, so it was considered confidential. As a result, little was published compared to what was done inside the different companies' laboratories worldwide. More on that will be discussed in a future paper.

Suppose the number of publications is considered an indicator of the amount of work done in stratigraphic palynology during the period from 1950 to 1968. In that case, it is possible to see that the rate of publications was low between 1950 and 1963. From then, it increased slightly, with a major jump in 1967, when the *Review of Palynology and Paleobotany* started as a regular publication (Fig. 52). Also, it is possible to see in Figure 53 that the number of publications in 1950–1967 was higher for northern South America than for any other place in the world.

Two important and scientifically productive palynologists worked in northern South America, Thomas van der Hammen in Colombia and L. Wijmstra in Guyana. Moreover, since they were working for public institutions, the possibility of obtaining permission for publication was higher than for those palynologists working for the oil industry, where palynology work was strictly confidential. Even accounting for the impact of others, however, the publications of Kuyl et al. (1955), Hopping (1967), and Germeraad et al. (1968) were groundbreaking.

Germeraad et al. (1968) was chosen by the AAPG as one of the "Top 10 Landmark papers in Paleontology" within the "Additional selected biozonations used by industry and academia" category. Its merits were described as follows: "The Germeraad et al. (1968) zonation framework is so robust that after almost 50 years since its publication (1968 – 2016), it is still useful and a key reference for palynologists working tropical terrestrial floras. While the zonation framework is the

most obvious contribution of the paper, the authors extended the application of palynology as a stratigraphic tool in industry and academia through: 1) demonstration of the importance of quantitative and statistical analysis of pollen and spore assemblages for zonation recognition in the tropics, 2) discussed the transport and climate effects on the final characteristics of the assemblages, and 3) proposed botanical affinities for many of the key species to support their stratigraphic significance and geographic distribution. For all of the above, this is a unique and timeless contribution to the science of biostratigraphy and the value of 'terrestrial' palynology in biostratigraphy, especially for the oil and gas industry" (Armentrout et al., 2017).

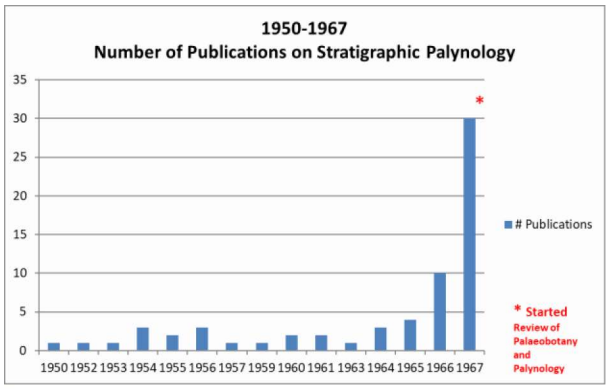


Figure 53. *Histogram of the total number of papers published in the period 1950–1968 about stratigraphic (pre-Quaternary) palynology in the different areas of the world.*

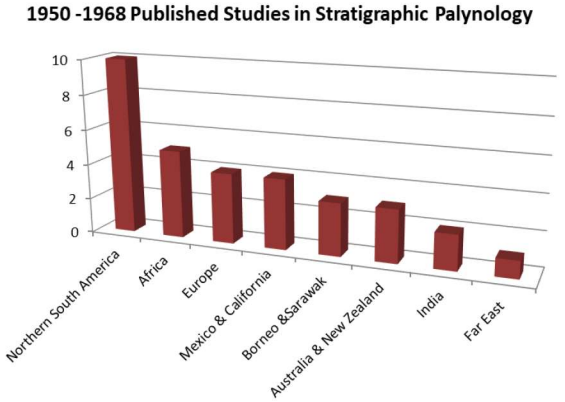


Figure 54. *Histogram of the number of papers per geographical area published between 1950 and 1968 about stratigraphic (pre-Quaternary) palynology.*

CLOSING REMARKS

The events discussed in this paper about the early years of the palynology as a tool for oil exploration focus on Venezuela because the first two major known laboratories dedicated to studying microfossils in the oil industry were established in the country in the early 1930s. At least two major oil corporations (Shell and Standard Oil) started their considerable efforts to develop palynology as a practical tool to apply to its exploration and production operations during and soon after the end of WWII. It was a time when the hydrocarbons of the world were vastly unexplored, and the success of using microfossils was so extensive that in 1954, Standard Oil patented in the US the use of what we know today as palynology as a tool for oil exploration. Other companies not mentioned here probably devoted significant efforts to developing palynology. Still, it is not easy to find any literature about it because everything done in those early years was kept confidential.

With this paper, I want to help preserve the memory of those palynologists and micropaleontologists working in Venezuela's oil industry laboratories. Their work was crucial to the success of the exploration and production of hydrocarbons in the twentieth century, the energy that is the very basis of the well-being of our modern society.

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REFERENCES

Applin, E. R., Ellisor, A. E., & Kniker, H. T. (1925). Subsurface stratigraphy of the coastal plain of Texas and Louisiana. *AAPG Bulletin*, *9*(1), 79–122.

Arnold, R. (1955–1961). *Ralph Arnold Photograph and Map Collection*, The Huntington Library, San Marino, California. Collection number, photo 311. Series 2. Vols. 1–5. Curacao, Grenada, Trinidad, and Venezuela, 1912–1918.

Arnold, R., MacCready, G. A., & Barrington, T. W (1960). *The first big oil hunt: Venezuela, 1911–1916*. Compiled by Edna Lines O'Gwinn. Vantage Press. Spanish translation and edition A. Duarte Vivas y H. Pérez Marchelli. *Venezuela Petrolera. Primeros pasos 1911–1916*. Fundación Editorial Trilobita, 2008).

Brown, J. (1985). Why foreign oil companies shifted their production from Mexico to Venezuela during the 1920s. *The American Historical Review, 90*(2), 362–385. doi:10.2307/1852670

Castro Mora, M. (1992). R. M. Stainforth: Su contribución a la estratigrafía en Venezuela. *Boletín de Historia de las Geociencias en Venezuela*, *46*, 1–10. https://mariantoc.github.io/biography.html

Creole Petroleum Corporation (1946). Un laboratorio de geología entre los primeros del mundo. *El Farol*, *8*(88), 10–13.

Creole Petroleum Corporation (1949). Laboratorios de la Creole. *El Farol*, *10*(124), 10-15.

Creole Petroleum Corporation (1955). *Working with Creole in Venezuela*. Creole Petroleum Corporation, Departamento de Relaciones Publicas..

Cross, A. T. (1964). Palynology and its relation to the exploration for oil. *The Mountain Geologist*, *1*(2), 91.

De Oteyza, C., & Alvarez, H. (2000). *Caracas la ciudad moderna.* CD Universidad Catolica Andres Bello.

Duarte-Vivas, A. (2013). The first Venezuelan geological oil map: The Ralph Arnold history 1911–1916. *AAPG Search and Discovery.* https://www.searchanddiscovery.com/abstracts/html/2013/90166ice/abstracts/duar.htm

Germeraad, J. H., Hopping, C. A., & Muller, J. (1968). Palynology of tertiary sediments from tropical areas. *Review of Paleobotany and Palynology, 6*, 189–348.

Giacopini Zárraga, J. (1986). Diez años de la industria petrolera nacional. Gráficas Armitano.

Gries, R. R. (2017). *Anomalies: Pioneering women in petroleum geology 1917–2017*. Jewel Publishing LLC.

Gunther, A. (1941). Venezuela in 1940. *The Geographical Journal*, *97*(1), 46–53. doi:10.2307/1787111

Hoffmeister, W. S. (1954). *Microfossil prospecting for petroleum*. Patent No. 2,686,108. United States Patent Office.

Hoffmeister, W. S. (1955). Microfossils provide new technique in exploration. *World Oil*, *140*(5), 156–164.

Hoping, C. A. (1967). Palynology and the oil industry. *Review of Paleobotany and Palynology*, *2*, 23–48.

von Humboldt, A., Bonpland, A., & Williams, H. M. (1822). *Personal narrative of travels to the equinoctial regions of the New Continent, during the years 1799–1804* (Vol. #1–5). Longman, Hurst, Rees, Orme, and Brown.

Irureta, A. (2018). *Explorando los minerales y el petróleo: Entre caballeros y sinvergüenzas*. Reprinted in *Boletín de Historia de las Geociencias en Venezuela*, *136*, 269–461, 2021. https://venezuelaamericanpetroleumasso.app.box.com/s/ebjqrldmrrug6ph8q44siwpj3jw8ysfv

Kalkman, C. (1984). In memoriam Dr. J. Muller. *Blumea*, *29*(2), 313–314.

Kuyl, O. S., Muller, J., & Waterbolk, T. (1955). The application of palynology to oil geology with reference to Western Venezuela. *Geologie en Mijnbouw, 17*(3), 49–76.

Larson, D. (2021). *Historical matters.* Fossil Hunters. https://www.fossilhunters.xyz/palynology/historical-matters.html

Manten, A. A. (1966). Half century of modern palynology. *Earth-Science Reviews*, *2*, 277–316.

Manten, A. A. (1966b). Some current trends in palynology. *Earth-Science Reviews*, *2*, 317–343.

Manten, A. A. (1967). Lennart von Post and the foundation of modern palynology. *Review of Paleobotany and Palynol*ogy, *1*, 11–22.

Martinez, I. (2014). *El hombre que halló petróleo en Venezuela*. Lado B.

Miranda Navarro, O. (2022, March 14). American oil exploration and memories of western Venezuela in the early 20th century. *Discover History*. https://ahcwyo.org/2022/03/14/american-oil-exploration-and-memories-of-western-venezuela-in-the-early-20th-century/

Muller, J. (1959). Palynology of Recent Orinoco delta and shelf sediments. *Micropaleontology*, *5*, 1–32.

News (1947–1954). *The Micropaleontologist*, *4*(1), 2–7, http://www.jstor.org/stable/1483826 through *8*(2), 4–30, http://www.jstor.org/stable/1484046

News Reports (1955–1977). *Micropaleontology*, *1*(1), 96–107, http://www.jstor.org/stable/1484417 through *23*(2), 235–23, http://www.jstor.org/stable/1485345

Norem, W. L. (1953). Separation of spores and pollen from siliceous rocks. *Journal of Paleontology*, *27*, 881–883.

Norem, W. L. (1955). Pollen, spores, and other organic microfossils from the Eocene of Venezuela. *Micropaleontology, 1*(3), 261–267. doi:10.2307/1484455

Norem, W. L. (1956). An improved method for separating fossil spores and pollen from siliceous rocks. *Journal of Paleontology*, *30*(5), 1258–1260. http://www.jstor.org/stable/1300623

Norem, W. L. (1958). Keys for the classification of fossil spores and pollen. *Journal of Paleontology*, *32*(4), 666–676. http://www.jstor.org/stable/1300785

Osorio, A. M. (2007). *Virgil Winkler: Pioneer of our country*. https://mariantoc.github.io/Resources/Biography%20Virgil%20Winker.pdf

Potenziani Bigelli, J. C. (2009). *When urological diseases changed history: Venezuela: Cipriano Castro and Juan Vicente Gómez. Cuando las enfermedades urológicas cambiaron la historia de un país. Venezuela: Cipriano Castro y Juan Vicente Gómez*, VITAE, Academia Biomédica Digital, Acumulado Julio-Diciembre 2021 (87-88) N°87, https://vitae.ucv.ve/index_pdf.php?module=articulo_pdf&n=4010

Poumot, C. (1989). Palynological evidence for eustatic events in the tropical Neogene. *Bulletin des Centres de Recherches Exploration-Production Elf Aquitaine*, *13*(2), 437–453.

Poumot, C., & Suc, J. (1994). Palynofacies et depots sequentiels dans des sediments marins au Neogene. *Bulletin des Centres de Recherches Exploration-Production Elf Aquitaine*, *18*, 107–119.

Reuters Staff (2010, September 13). *Timeline: 50 years of OPEC*. Reuters. https://www.reuters.com/article/us-opec-timeline-idUSTRE68C2NK20100913

Rey, O. (2016). Geologia, Frances Charlton de Rivero. In L. López & M. A. Ranaudo (Eds.), *Mujeres en Ciencia: Venezuela sus historias inspiradoras. Academia de Ciencias Físicas, Matemáticas y Naturales*.

Saravanan, G., & Dominic, J. (2014). A ten-year bibliometric analysis of the journal *Review of Palaeobotany and Palynology* (2003 – 2012). *Library Philosophy and Practice*, 1109. http://digitalcommons.unl.edu/libphilprac/1109

Silva Calderón, A. (2006). Trayectoria de la nacionalización petrolera. *Revista Venezolana de Economía y Ciencias Sociales, 12*(1), 109–123. http://ve.scielo.org/scielo.php?script=sci_arttext&pid=S1315-64112006000100008&lng=es&tlng=es

Socorro, M. (2020). *A 45 años de la nacionalización del petróleo en Venezuela.* https://prodavinci.com/a-45-anos-de-la-nacionalizacion-del-petroleo-en-venezuela/

Standard Oil Company of Venezuela, Lago Petroleum Corporation, & Compañia Petrolera Lago (1942). El laboratorio geológico. *El Farol, 3*(34), 12.

Sociedad Venezolana de Ingenieros de Petróleo. (2002). Petrolia sueño de futuro. *Los Pulido*, (4), 1–16. https://www.svip.org/files/Petrolia_svip.pdf

Sulek, J. (1969). Palinologia aplicada en los estudios de los sedimentos eocenos en la Cuenca de Maracaibo. *Memorias IV Cong. Geol. Venez.,* 939–950.

Stainforth, R. M. (1992). *R. M. Stainforth his contribution to stratigraphy in Venezuela*. A translation by RMS of a work presented at the Second Session on the History of the Geological Sciences, February 16, 1992, Caracas, Venezuela. http://rpasmd.org/rms/Bios_Frame.html

Stainy, H. J. (1961). Memorials: Ralph Arnold. *AAPG Bulletin*, *45*(11), 1897–1900.

Lidgett, A. (1921). *The Petroleum Times*.

Tópicos Shell de Venezuela (1947). Nuevo Laboratorio Shell. Maracaibo.

Tschudy, R. (1957). Pollen and spore formulae: A suggestion. *Micropaleontology*, *3*(3), 277–280. doi:10.2307/1484115

Tschudy, R. H. (1969). Relationship of palynomorphs to sedimentation. In R.H. Tschudy & R.A. Scott (Eds.), *Aspects of Palynology*, John Wiley & Sons (pp. 79–96).

Tschudy, R.H. taken from AASP bios. It was at www.palynology.org/robert-tschudy, but the page is currently under renovation, and the information is unavailable.

Urbani, F. (2022). *Tres episodios de la historia petrolera Venezolana: Pedernales, Escuque y Perijá*. Academia Nacional de la Ingeniería y el Hábitat y Fundación Geos. https://www.researchgate.net/publication/362886266

Vogelenzang, L. (1984). Bibliography of J. Muller. *Blumea*, *29*(2), 314-318.

Westermann, J. H. (1941). El Laboratorio de Geología de Maracaibo y una charla sobre los animales extintos. *Tópicos Shell, 3*(31), 2–9.

Wilson, L. (1946). The correlation of sedimentary rocks by fossil spores and pollen. *Journal of Sedimentary Petrology*, *16*(3), 110–120.

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