The Agua Caliente Oilfield and the Boiling River of the Peruvian Amazon*

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Search and Discovery Article #70354 (2018)**
Posted August 6, 2018

*Adapted from article, by the same author with the same title, in THE AAPG EXPLORER, Historical Highlights, March 2018.

Introduction

The presence of petroleum in Peru has been known for several centuries from the numerous oil seeps and outcrops of heavy black asphalt located in the Talara coastal region. Ages before the Spanish presence, the natives prepared the pitch for mummifying their dead, for waterproofing boats, and as fuel for light. The earliest Spanish explorers used the pitch from these seeps to caulk their boats and tar their ropes. As Spanish shipping increased, the importance of the tar pits increased, and they were soon systematically exploited, becoming the site of South America's oldest petroleum production. Finally, in 1869, the La Brea-Pariñas oilfield was discovered by cable-tool drilling, making it one of the first oil production fields in the world.

During the mid-19th and early 20th century, most of the exploration and production effort in Peru was focused in the Talara coastal region. It was not until after World War I, when the petroleum possibilities of the remote Peruvian Amazon region started to interest some U.S. companies. Field geological mapping for exploration purposes started in the early 1920s, but the absence of an encouraging Peruvian petroleum law to overcome the difficulties and high exploration costs in the Amazon region made most of the companies stop such work.

A Surprising Prospect from the Air

In the late 1920s, Peru was seeking to expand its Amazonian development and better connect cities like Pucallpa with the rest of the country. In 1929, American geologist Robert B. Moran (Figure 1) conducted an aerial survey from a plane over the Ucayali region for a railroad construction project across the Andes, to connect the Pacific coast with the Peruvian Amazon. About 60 kilometers southwest of Pucallpa, adjacent to the meandering Pachitea River (Figure 2) near its junction with the Ucayali, a major tributary of the Amazon River, he spotted a large, elliptical-shaped landform rising out of the jungle, with a different type and shade of vegetation, standing above the surrounding swampy low land.

Moran was one of the first geologists to take advantage of air flights and aerial photos for geological reconnaissance and mapping, and thus had a practiced eye. He immediately identified this protruding structure as an anticline and a potential oil prospect. He had the pilot fly over the area in several directions in order that he might study the feature further. In later years, a reporter asked Moran how he recognized an anticline. His laconic and arrogant reply was, “How do you recognize a cow?”

After the air flights, Moran immediately took steps to obtain an exploration license covering the dome and the adjoining terrain, and in 1930 he convinced the Selden Breck Construction Company to apply for a license to explore in the Pachitea region – not an easy matter after the Wall Street Crash of 1929.

Geological Fieldwork under Difficult Conditions

In the early 1930s, in collaboration with the geologist Douglas Fyfe and engineer Glenn M. Earl, and on behalf of the Selden Breck Construction Company, Moran organized several field reconnaissance expeditions to the Agua Caliente dome. In a 1933 paper, Moran and Fyfe released the results of the geological fieldwork, also describing the access routes, topography, weather, sanitation, and the local population. They mentioned that, due to the mosquitoes – especially those locally known as “mantablanca” – the riverbanks were poorly inhabited. There were “not 50 people living in the Agua Caliente district,” and most of these were “descendants of the people who came into the district during the rubber boom.” Their paper also describes “a few wild Indians living back from the main rivers” that are “seldom seen, and their numbers are practically negligible.”

The Agua Caliente dome was covered by thick vegetation, but the streambeds, the clearing of trails and the rugged topography allowed observation and measurement of stratigraphic sections and strike and dip readings in good rock exposures. It was an admirable example of detailed fieldwork by canoe and on foot under hazardous conditions, exposed to high temperatures coupled with humidity and sporadic heavy rains; the annoying mosquitoes were the greatest inconvenience. Finally, the dome was confirmed as an anticline, 8 kilometers long and 5 kilometers wide, with the major axis trending northwest to southeast, covering some 35 square kilometers (Figure 3). The fold is asymmetrical with the northeast flank rather steep (20 to 35 degrees) dip, whereas the southwest flank was gently dipping (10 degrees). The oldest rocks were sandstones of Early Cretaceous age found outcropping at the core of the anticline (Figure 4)

Moran and Fyfe named these the Agua Caliente Formation, which became a generally accepted term in the Peruvian Amazon stratigraphy. These sandstones were surrounded concentrically by the marine calcareous shales of the Chonta Formation (Late Cretaceous), overlain by the Vivian sandstones (also named “Sugar sandstones”), which provide a prominent and continuous ridge. On top of the Vivian lie the Cachiyacu shales that represent the uppermost part of the Cretaceous sequence.

Hot water springs (“agua caliente” in Spanish) were found in the core of the anticline and geologists became concerned about the dome being a volcanic rather than a sedimentary structure, as hydrothermal volcanic fluids can overcook hydrocarbon source rocks and destroy oil reservoirs. No igneous rocks were found nearby: Moran and his colleagues finally concluded the hot water springs were non-volcanic in origin, and they opportunely found several natural live oil seeps (“chapapoteras” in Spanish) in outcrops of Cretaceous rocks in the Shira Mountains, a prominent uplifted tectonic unit located some 35 kilometers south of the Agua Caliente dome; this clearly indicated favorable conditions for the existence in the region of what we know today as a working petroleum system.

First Exploration Well in the Amazon

During the 1930s, the Great Depression was in full swing and these were times of insurmountable difficulty. It took several years before a group could be found to finance the drilling venture. In 1937, Moran and a group of friends organized the "Compañía de Petróleo Ganso Azul Limitada," which then negotiated the Agua Caliente license and a cost-plus contract with a California drilling company. After all kinds of problems with the initial shipment of drilling equipment from California to Pucallpa and then by river to Agua Caliente, the well was finally spudded on July 4, 1938. It was the first well ever drilled in the Amazon region.

The Agua Caliente-1 well (Figure 5) was located in the center of the anticline, on top of a steep and small hill about 600 feet (180 meters) above the Pachitea River. The well was drilled to a depth of 3130 feet (954 meters), recording oil shows in sandstone cores of Lower Cretaceous age taken from 1100 to 1260 feet (340 to 390 meters), but the well was not completed and was temporarily abandoned on February 11, 1939. The rig was immediately skidded 24 feet (7 meters) to drill a second well (Agua Caliente-1A), spudded on February14, drilled to a total depth of 1,175 feet (358 meters) and open-hole completed on February 26 as the Agua Caliente oil discovery, which was also known as the Ganso Azul (Blue Goose) oilfield.

The stratigraphy drilled by the discovery well was a sequence of Early Cretaceous age, composed of the Agua Caliente sandstones, outcropping at surface, then the Raya marine shales interbedded with minor siltstones and sandstones and below, the massive sandstones of the Cushabatay Formation, lying unconformably over Paleozoic rocks. Oil was tested in the sandstone beds of the Upper Cushabatay to Lower Raya formations, with reservoir porosities ranging from 17 to 25 percent. The initial production rate was up to 700 barrels per day of 45-degree API oil on natural flow with no water, and gas practically absent.

The first exploration well drilled in the Amazon region resulted in an oil discovery and attracted considerable attention to the eastward region of the Andean Cordillera as a petroleum province, offering an area of enormous size for those interested in exploration in South America.

Since 1938, a total of 35 wells have been drilled in the Agua Caliente Field, of which 31 were completed and four abandoned. Subsurface maps were obtained from well data only, clearly showing the four-way dip closure with minor normal faulting detected by the well penetrations. Seismic coverage is quite poor, limited to a few 2-D good quality seismic lines that clearly reflect the structural configuration of an anticlinal fold associated with high-angle reverse faulting sub-parallel to the Andean tectonic thrust front (Figure 6).

Initially the oil was shipped down-river by barges and refined in Brazil. In 1956, a pipeline was completed from the field to the small Pucallpa refinery, and production from the field rose steadily up to 2350 barrels of oil per day, enough to satisfy local demand. During the early 1970s, the field production started to decline and Petroperu – the Peruvian national company – acquired the exploitation rights after the field had produced a total of almost 13 million barrels of oil. In 1994 the company Maple was awarded a 30-year concession to further develop the field.

At the end of 2017 the field was being operated by Petróleos de la Selva, producing an average of 80 barrels of oil per day of 43-degree API with 90 percent water cut from 10 active wells, including the Agua Caliente-1 discovery well. Oil is transported to Pucallpa by trucks since the old pipeline had been dismantled. After nearly 80 years of production, the field is now close to its ultimate recovery level of 15 million barrels of oil.

During the years following the Agua Caliente discovery, the exploration in the northern Ucayali Basin was based on photogeology and field surveys, aimed at locating anticlines where Cretaceous rocks were exposed. The next success, however, was not until 1957 with the discovery of the Maquia oilfield by a joint Peruvian-German venture. One year later, the small Pacaya field was discovered based on additional seismic survey. In 1961, Mobil made a gas condensate discovery at Aguaytia within the Cushabatay sandstones, in an anticline that had been seismic surveyed in the northwest part of the Ucayali Basin. Through most of the remainder of the ‘60s and into the early ‘70s, exploration was virtually non-existent in this region.

During the late years of the 20th century, Ucayali saw a renewed interest. Different 2-D seismic vintages were acquired, but all exploration wells were dry holes, although oil and gas shows were commonly recorded. It was not until 2013 when the Spanish company CEPSA discovered the Los Angeles oilfield, located some 40 kilometers west of Agua Caliente, reopening the prospectivity of the northern Ucayali Basin. An average of 3500 barrels per day of 45-degree API oil are currently being produced from the prolific Cushabatay Formation in the Los Angeles active wells, oil being trucked to the Pucallpa port and then exported by barges down the Ucayali River.

The Boiling River and Its Geothermal Origin

The local name Agua Caliente (“hot water” in English) clearly reflects the presence of thermal springs in the area, surely well known by the local people since ancient times. According to the 1933 paper by Moran and Fyfe: “An interesting feature in the Agua Caliente sandstone is that there are numerous springs of boiling water,” adding that “within the Agua Caliente concession there are some important hot springs warming a tributary river of the Pachitea, where hot water may run even after flowing several kilometers” (Figures 2 and 4).

The hot springs are located at the core of the Agua Caliente anticline, roughly 2 kilometers north of the oilfield discovery well. The hot water flows into the river at different places, bubbling up and heating the running water to temperatures as high as 90 degrees Celsius. The water gets so hot that it can cause severe burns, and small animals that fall in get cooked to death.

Generally, hot water springs around the world are associated with volcanic terrain, but springs in Agua Caliente do not have any relation with it since the area is far from any volcanic center. Andrés Ruzo, a Peruvian geothermal geologist, has investigated this curious natural phenomenon, later popularized by his TED talk and a book he authored entitled “The Boiling River.”

The steam released into the air by the hot springs results in a spiritual and magic aura, which caused the river to be considered sacred by the locals and referred to as “Shanay-timpishka” in the indigenous language, which translates to “boiled with the heat of the sun.” The Agua Caliente creek holds two shamanic centers, which have become a place of pilgrimage that has attracted a large number of visitors, chiefly Europeans and North Americans interested in the hot springs and the traditional natural medicines of the Peruvian Amazon and the local shamans.

The Ucayali region is a foreland basin formed by the Andes thrust-sheet loading to the west. Many of the structures present in the Ucayali have surface expression, such as the Agua Caliente anticline. They were mainly developed during the latest Andean orogeny in the Pliocene-Pleistocene, which, from a geological point of view, is more like just yesterday. The rapid and recent uplift to near-surface from deeper zones where temperatures were greater than 100 degrees Celsius did not give enough time for rocks to cool enough and to equilibrate at a shallower depth. This makes present-day temperatures, as measured in the wells from the Agua Caliente field, reach as high as 100 degrees Celsius at only 300 meters depth! This abnormally high temperature at such shallow depths is simply due to the recent, rapid tectonic uplift and exhumation of the anticlinal crest.

The Cretaceous sandstones show excellent reservoir properties with a good regional hydraulic continuity, being excellent carrier beds for fresh-water recharge from the Shira Mountains. There, the high elevation in outcropping Cretaceous sandstones provides the drive for active recharge into the basin of fresh water, as proven by the low salinity (2000 parts per million sodium chloride) in the oilfield formation waters. No pressure data are available for the Agua Caliente field; however the production history suggests the presence of an active and large aquifer. Meteoric waters produce a hydraulic head, as demonstrated by the increase in water production in the Agua Caliente wells during the rainy season. The meteoric water percolating downward into the sandstones flows laterally and is heated at relatively shallow depths, rising buoyantly upward along faults and fractures, leading to the hot springs that heat and are the source of the high temperature of the boiling river.

Regrettably, deforestation by locals and settlers has turned a great extension of jungle not protected by the Agua Caliente oilfield or by the shamanic centers into scrubland, showing how the oil production operation is serving as a protector of the jungle, saving it from poachers, illegal loggers, and especially the clear burners – one of the greatest threats facing the Peruvian Amazon. Geologist Andrés Ruzo is working with some major conservation groups, both in Peru and internationally, to preserve this special area, not only because of the geologic and geothermal aspects, but also its cultural relevance.

References

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Author

Jorge Navarro Comet (Figure 2) is currently vice president of the AAPG-affiliated Association of Spanish Petroleum Geologists and Geophysicists (AGGEP). He is geology manager in CEPSA where he is responsible for coordination, management and supervision of the petroleum geology studies and works in regions where CEPSA is currently active: South America, North/East Africa, Middle East, South East Asia and Spain. He is also an active member of different professional associations of petroleum geoscientists such as AAPG, EAGE, PESGB and AGGEP.

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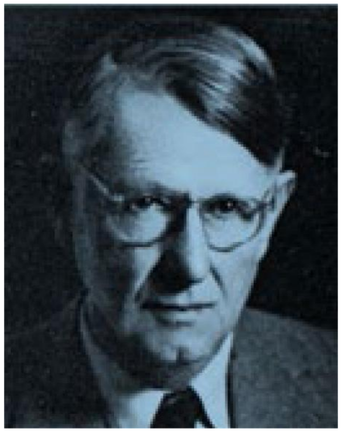

Figure 1. Robert B. Moran (1879-1961).

Figure 2. Navarro Comet next to the Pachitea River in the NE flank of the Agua Caliente anticline.

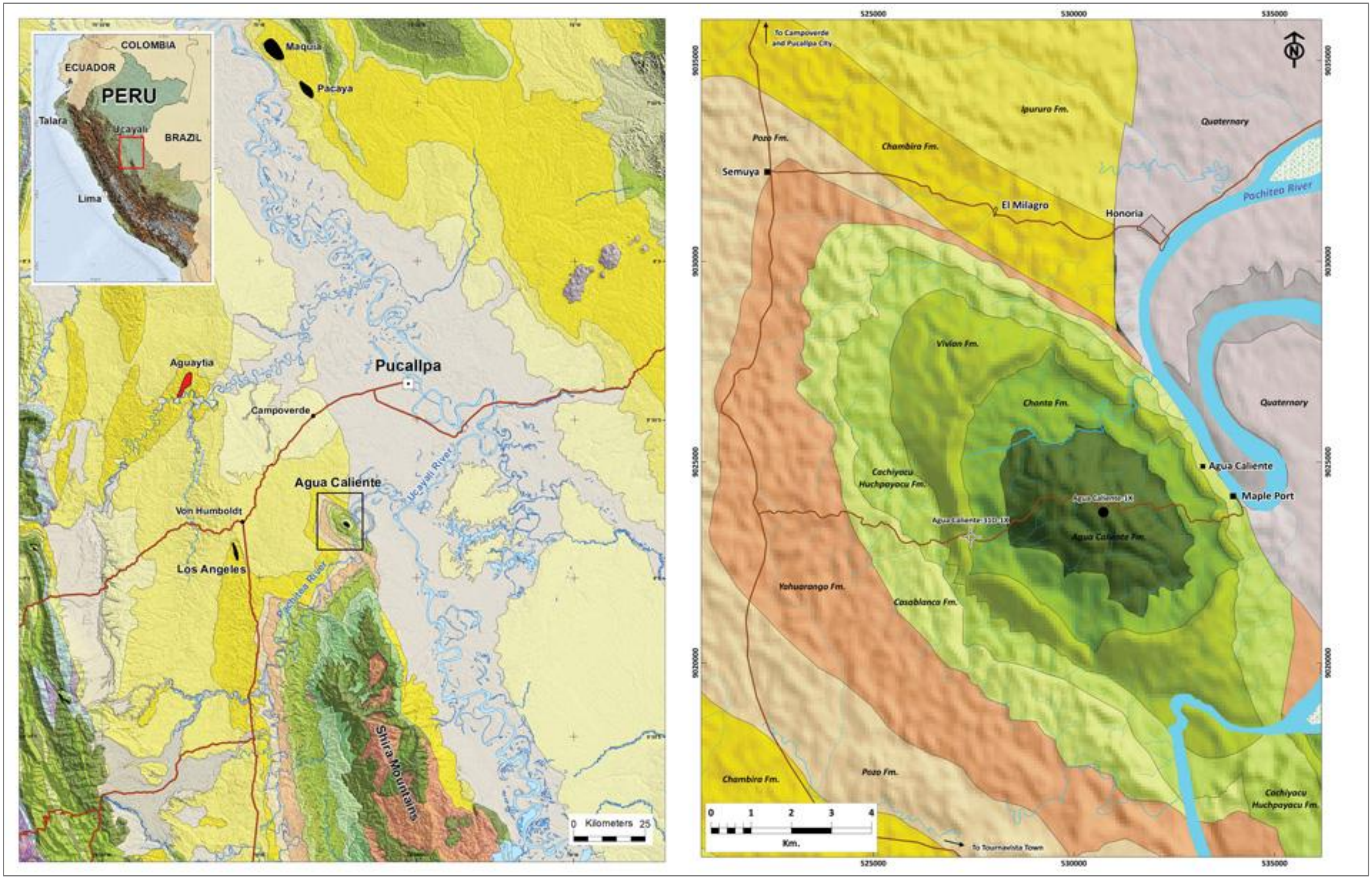

Figure 3. Left: Map showing the location of the Agua Caliente dome. Right: Geological map of Agua Caliente dome. The Agua Caliente sandstones are found outcropping at the core of the anticline.

Figure 4. Maestro Juan, an Asháninka healer and shaman, plays the flute atop an outcrop of Aqua Caliente sandstone. According to local tradition, the Boiling River is a place of tremendous spiritual power, where the steam creates a magic atmosphere. Photo by Sofía Ruzo of the Boiling River Project.

Figure 5. The Agua Caliente-1 well drilled in 1939 is still on production.

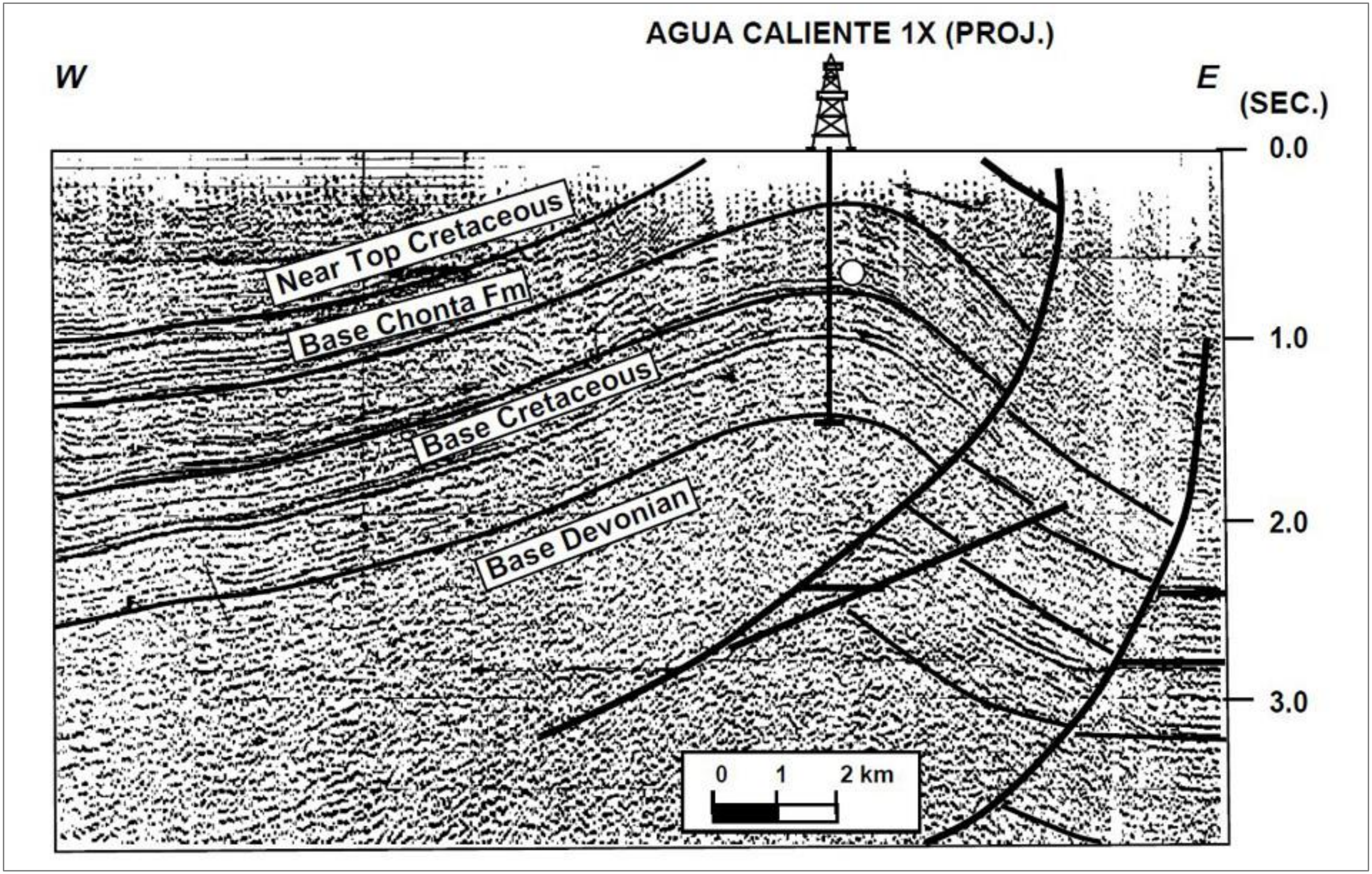

Figure 6. A 2-D seismic line showing the structural configuration of the Agua Caliente anticlinal fold associated with high-angle reverse fault sub-parallel to the Andean tectonic thrust front. Image from Mathalone and Montoya R. (1995).