

Petroleum Exploration and Development in a Frontier, Remote Rift Basin: the Albertine Graben of the East African Rift System*

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Abstract

The East African Rift System is a major tectonic feature stretching from the Red Sea in the north to the Okavango Delta in the south. The system bifurcates in southern Sudan/Ethiopia to form the eastern arm that continues south through Kenya, and the western arm that includes the rift valleys around Lakes Albert, Edward and George in Uganda and continues further south to Lake Tanganyika and the Mbeya triple junction where the two merge and propagate through Lake Malawi. The rift system was initiated in the Late Oligocene/Early Miocene.

The Albertine Graben is a Tertiary intra-continental rift that developed on the Precambrian orogenic belt of the African Craton. It forms the northern termination of the Western arm of the East African Rift System (EARS) ([Figure 1](#)). It stretches from the border between Uganda and Sudan in the north to Lake Edward in the south. The available geological and geophysical data indicates that rifting could have been initiated during Early Miocene with the accumulation of thick sediments in asymmetric basins along strike of the rift system and the subsequent formation of Lakes Albert, Edward and George on the rift floor. While many of the rift segments contain deep water lakes, such as Lake Malawi (> 700 m) and Lake Tanganyika (> 1,400 m), the Albertine Graben has relatively shallow lakes (maximum 112 m, Lake Edward).

Tectonic History

The Albertine Graben has undergone substantial tectonic movements and thick sediments (over 4 km) have been deposited in lacustrine and fluvial-deltaic environments ([Figure 2](#)). The sedimentary layers dip gently towards the depo-centre on the western margin of the rift. Rapid tectonic subsidence coupled with limited sediment input led to deep stratified lakes with the accompanying deposition of source rocks.

The Pliocene Rwenzori uplift, in the middle of the rift, provided a sediment barrier to the Lake Albert basins and also to the southern areas. Secondly, with increased uplift and the breakthrough of some of the drainage channels, the mountain became a major sediment source into the Lake Albert basins creating a huge sedimentary section in the Pliocene especially in the Semliki Basin. Most researchers have concentrated on the Eastern arm of the East African Rift System (Ethiopia, Kenya, Malawi and partly Tanganyika rifts) leaving the western arm, especially the northern part including the Albertine Graben least studied.

The tectonic evolution of the Albertine Graben is little understood. It does not fit well with traditional models of rifted continental basins, defined by discrete basin bounding faults opposed by a low gradient flexural margin, especially over Lake Albert. Almost similar amounts of displacement on the eastern border faults and western border fault produce close to a full graben structure that gently dips towards the west (Figure 2) in contrast to half graben structures of the Tanganyika and Malawi rifts (Figure 3). The available geological and geophysical data indicate that the Graben has gone through extension and compression episodes resulting in a variety of structures. Deformation and prevalence of flower structures in the shallow sedimentary sections in some basins in the graben indicate that the neo-tectonic processes are compressional (Figure 4).

Petroleum Exploration

The Albertine Graben has been the subject of sporadic interest for petroleum exploration since Wayland's first report in 1925, when he identified 52 seeps around the shores of Lake Albert. Seventeen (17) of these oil seeps are still active and have been confirmed by the Petroleum Exploration and Product Department (Figure 5). In 1938 the first petroleum exploration well in East Africa, Waki-1, was drilled near Butiaba on an anticline defined by correlations between a series of 20 shallow surface bore holes. The well encountered basement at 1,221 m, but more significantly "oil shales" were found and an "asphaltic oil" show was described close to basement (Figure 6). Clearly even at this time there was evidence for hydrocarbon accumulation that was not followed up.

Exploration stagnated during the following years mainly due to the Second World War, the political upheavals in Uganda and the zoning of East Africa as an agricultural area rather than an oil producer by the colonial government. The remoteness of the Albertine Graben must have greatly contributed to this decision.

The next significant activity was an aeromagnetic survey acquired over the Albertine Graben in 1983-84. Subsequent gravity and magnetic surveys by the government added to the database. In the early 1990's Fina held an exploration license over the entire graben, but relinquished the license before any significant work program. The recent exploration commenced in 1997 when Hardman Resources and Heritage Oil and Gas were respectively awarded Exploration Areas 2 and 3. Hardman relinquished the license because of other commitments and the collapse of oil prices, but Heritage continued and acquired 181 km of onshore seismic in the Semliki area in 1998. In 2001 Hardman returned to EA2, joined by Energy Africa (now Tullow Oil) and acquired a 50% interest. Energy Africa also farmed into EA3 for a 50% and another 229 km of

seismic was acquired in 2001. Heritage drilled three wells on the Turaco structure from 2002 to 2003 and encountered natural gas, but heavily contaminated with carbon dioxide. The first oil discovery was made by Hardman at Mputa structure in the Kaiso-Tonya area in 2006. Since then several exploration and appraisal well have been drilled.

Development of Reserves

Commercial hydrocarbon quantities have now been established in the Ugandan part of the Albertine Graben. The Government of Uganda, together with the international oil companies operating in the country has embarked on plans to commercialize the discoveries that have been made. This will be the first commercial oil production in the East African Rift system.

Discovered reserves now stand at over 1000 million barrels equivalent and plans are underway to commercialize these reserves. Uganda is a landlocked country, 1200 km from the nearest coast, Mombasa, and there is no hydrocarbon development and production infrastructure in the country. The challenge for early commercialization of the reserves is putting up the required infrastructure.

The Uganda government hired a reputable firm (Foster Wheeler) to undertake a feasibility study on refining in the country. The feasibility study has indicated that the refinery project in Uganda is a highly profitable venture given the demand for petroleum products in the region. Refinery development in Uganda is therefore considered by the Government as the best option for development and production of petroleum in a remote basin like the Albertine Graben.

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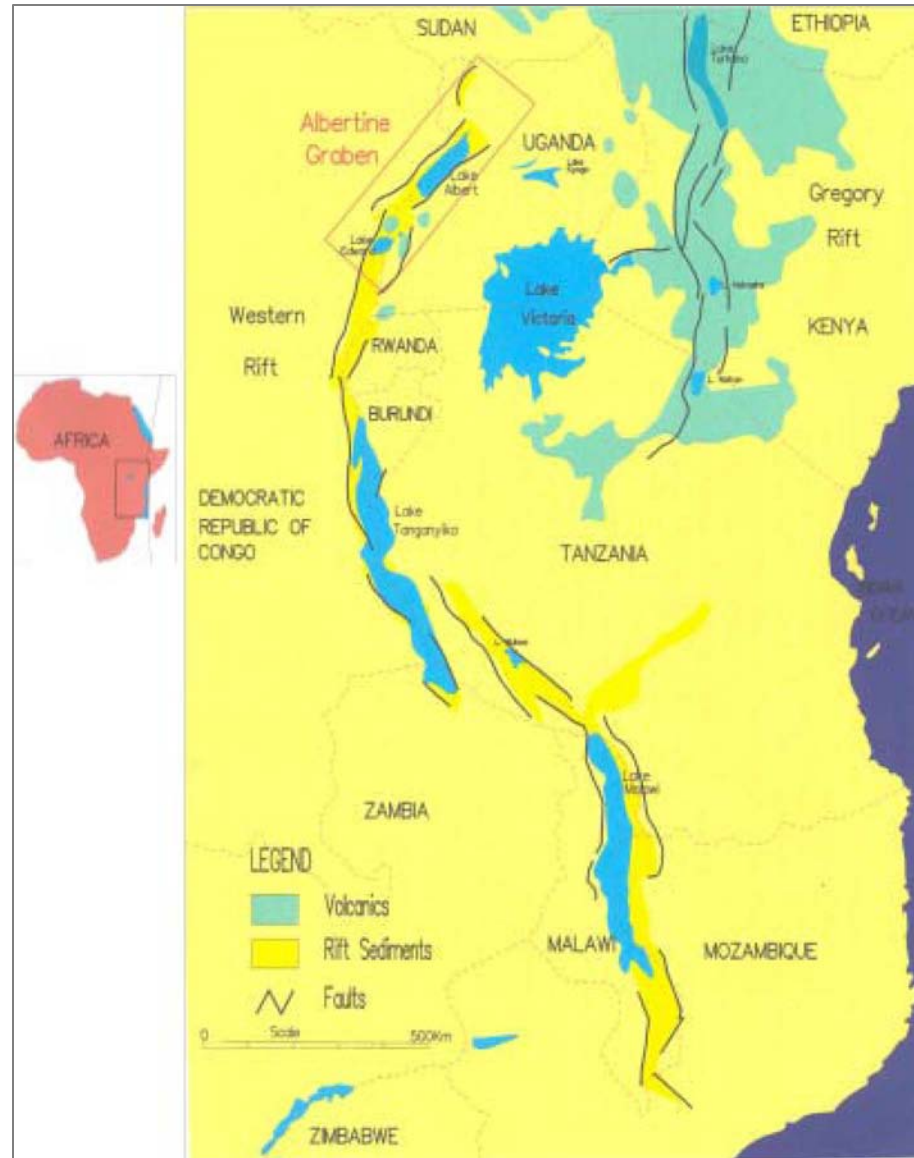


Figure 1. Map of the East African Rift System and the Albertine Graben.

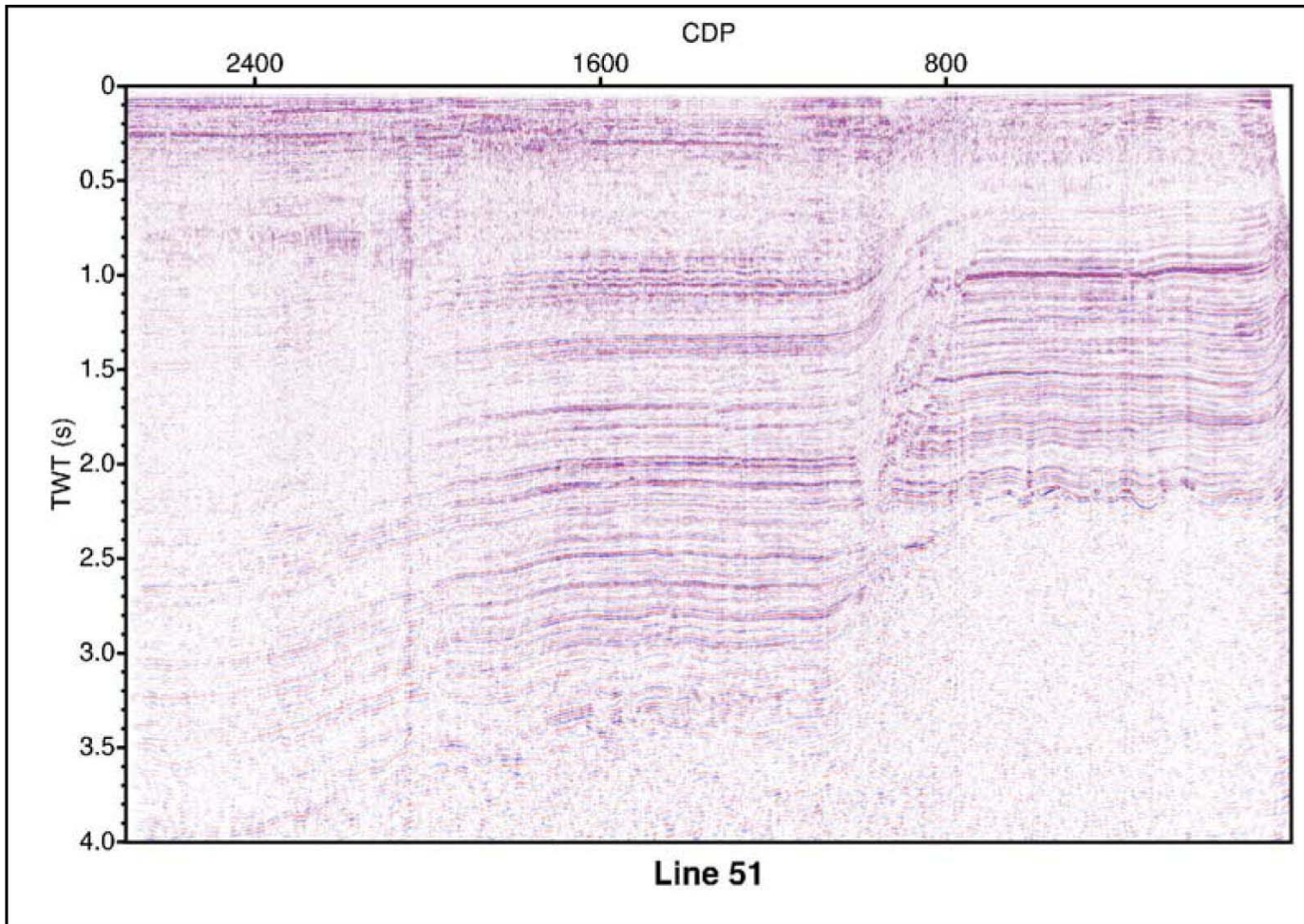


Figure 2. An E-W seismic section across Lake Albert showing an almost full graben structure.

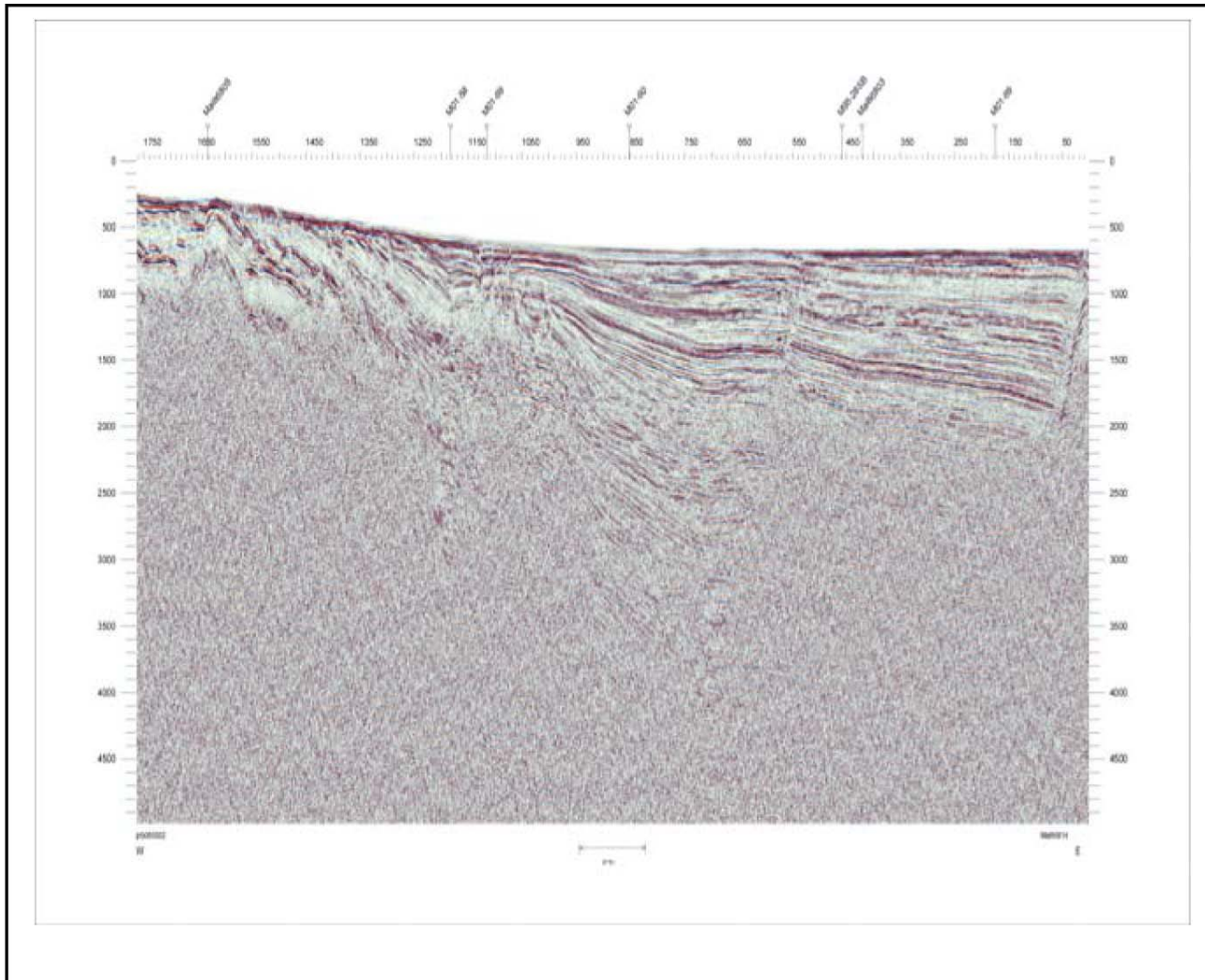


Figure 3. Seismic section across Lake Malawi showing half graben structures.

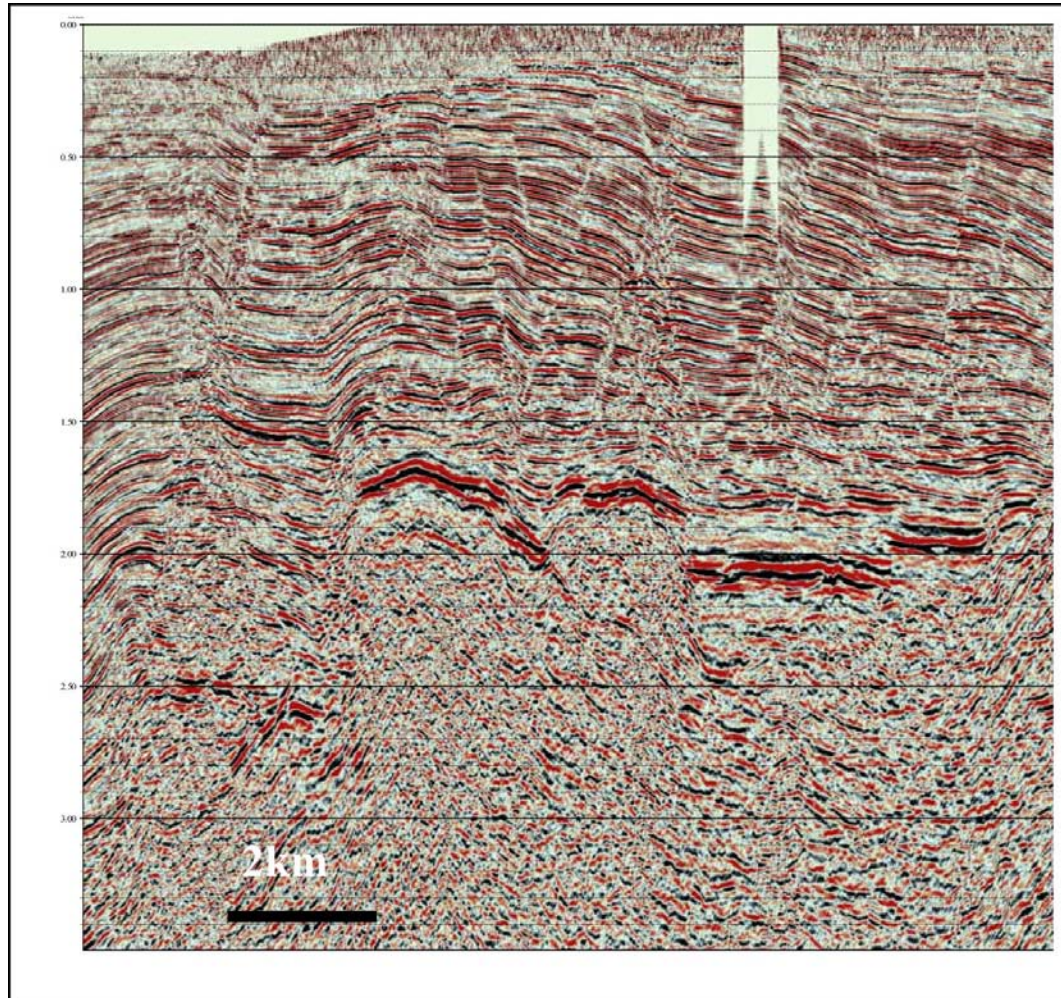


Figure 4. Seismic section showing positive flower structures persisting up to the top of the section, indicating recent compressional episodes.

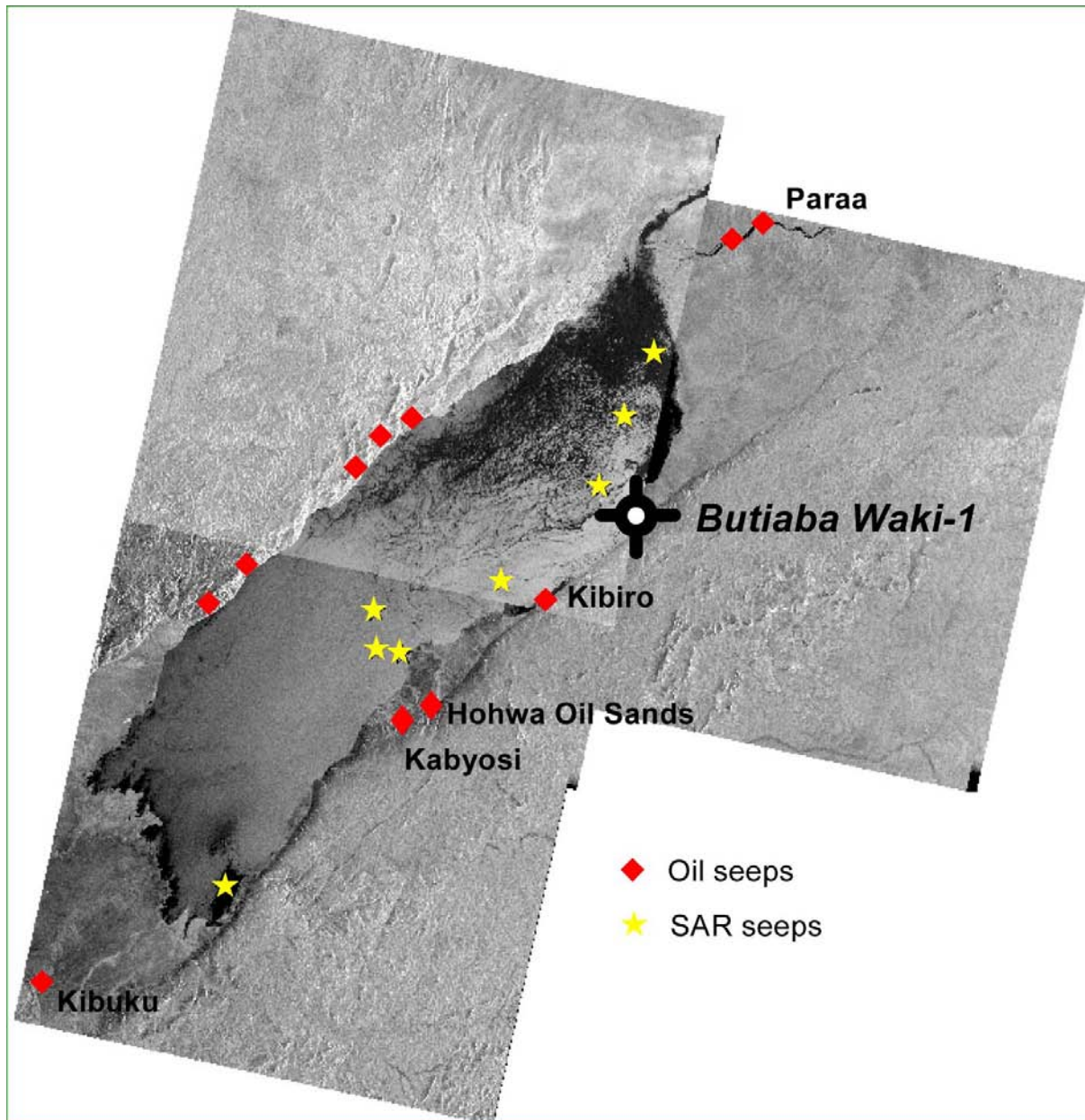


Figure 5. Oil seeps confirmed along the entire length of the graben.

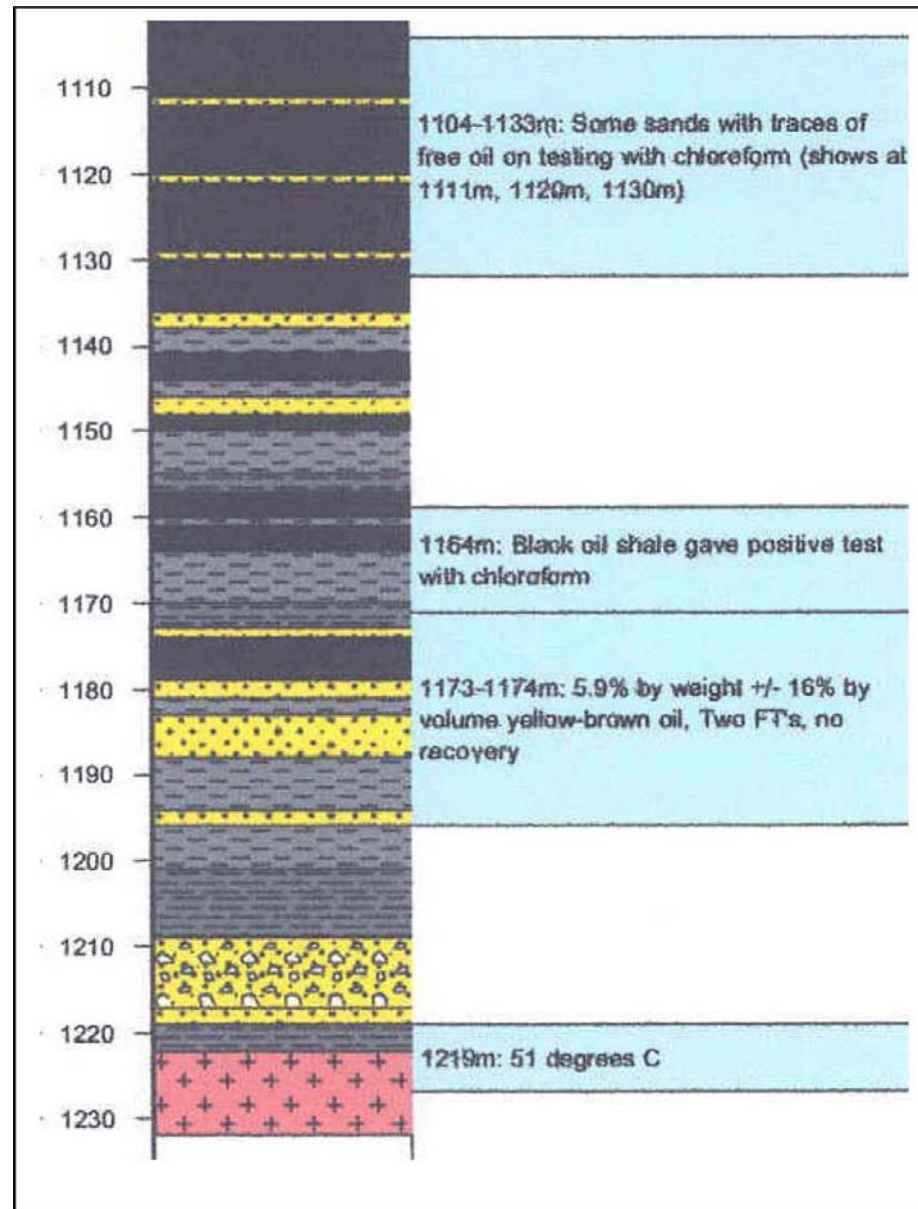


Figure 6. Section of the lithology log of the Waki B-1 well.