Development of a Petroleum System in a Young Rift Basin Prior to Continental Breakup: The Albertine Graben of the East African Rift System*

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Abstract

The Albertine Graben forms the Northern termination of the Western arm of the East African Rift System (EARS). It stretches from the border between Uganda and Sudan in the north to Lake Edward in the south. It is a Tertiary intra-cratonic rift that developed on the Precambrian orogenic belt of the African Craton. Rifting is interpreted to have been initiated during Early Miocene about 17 Million Years ago.

The East African Rift System has been interpreted as a continental extension probably caused by a plume head underneath East Africa. It is a classic example of the processes of continental break up, from incipient rifting in the Botswana Rift, southwestern branch, to initiation of sea floor spreading in the Afar depression at the Red Sea, Gulf of Eden triple junction (Figure 1).

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 in contrast to half graben structures of the Tanganyika and Malawi rifts.

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 section in some basins in the graben indicate that the neo-tectonic processes are compressional.

The Albertine Graben has undergone substantial tectonic movements and thick sediments (approximately 6 km) have been deposited in lacustrine and fluvial – deltaic environments. 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 hydrocarbon exploration wells drilled in the Albertine Graben have proved deposition of source, reservoir and cap rocks.

The Graben is characterized by highly asymmetrical deep tertiary basins that are separated by complex transfer zones (Figure 4). These zones act as pathways for sediment input into depo-centers as well as favorable areas for development of diversity of hydrocarbon traps. Both structural and stratigraphic traps have been interpreted from geophysical data acquired in the Albertine Graben; however, only structural traps have been tested for hydrocarbons by drilling. All wells that have been drilled in the Albertine Graben have been on either positive flower (Palm tree) structures or on fault blocks (Figure 5). Fault closures against basin bounding faults or even intrabasinal faults have proved prolific for hydrocarbon trapping.

Commercial hydrocarbon production has not yet started in the Albertine Graben, but its hydrocarbon generating potential is no longer in question. Though under explored, a total of 22 exploration and 17 appraisal wells have been drilled in the Graben, and of these, 36 have encountered hydrocarbons, making this one of the highest success rates globally and confirming a working petroleum system. At the moment, two of the discoveries have progressed to Field Development level. The reasons behind development of a working petroleum system in a young rift basin, probably the youngest in the world to have generated, expelled and trapped hydrocarbons, are not yet clearly understood. However, this could be attributed to a high geothermal gradient, lack of initial sufficient clastic sediments due to drainage change allowing deposition of source rocks, rapid deposition during the Pliocene, creating thick sedimentary column and a late compression phase that has created structural traps.

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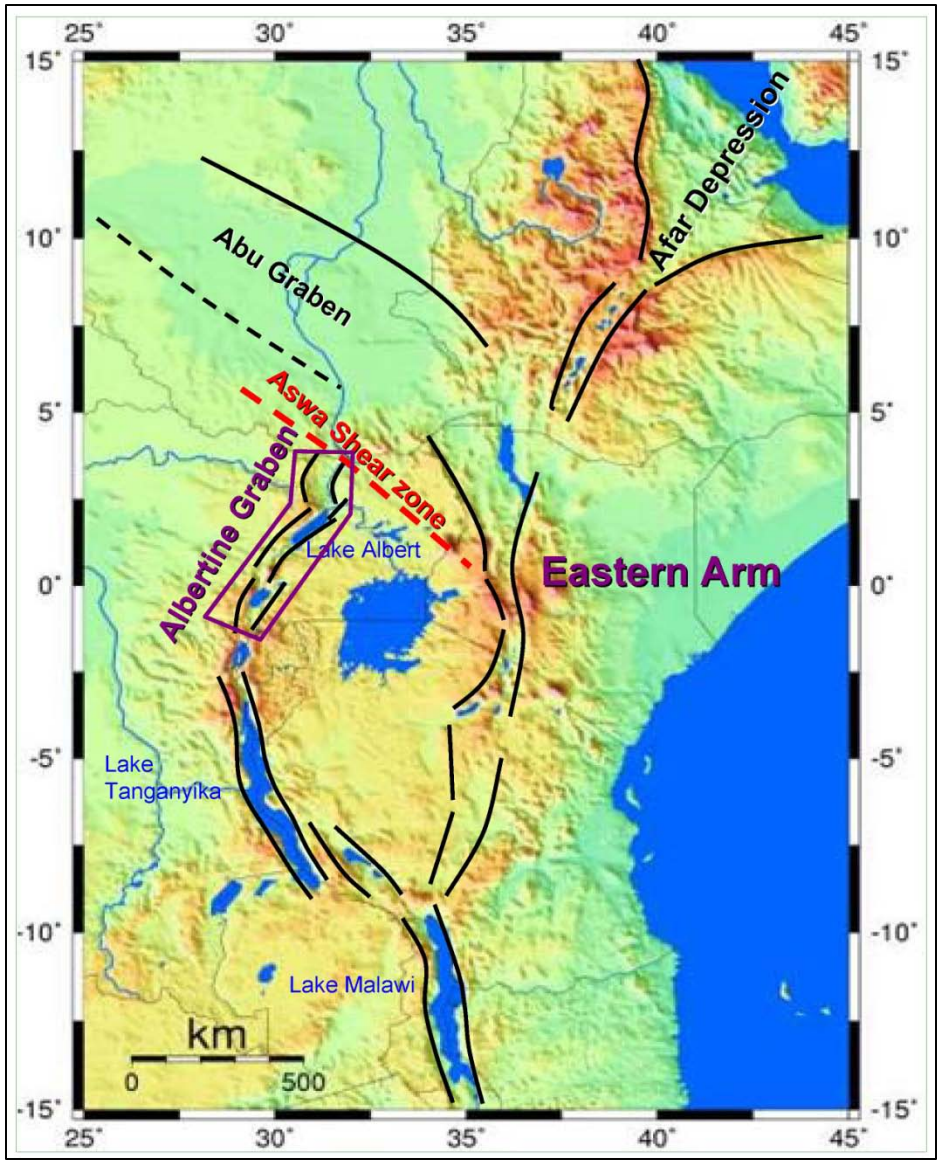

Figure 1. Map showing the East African Rift System and the Albertine Graben.

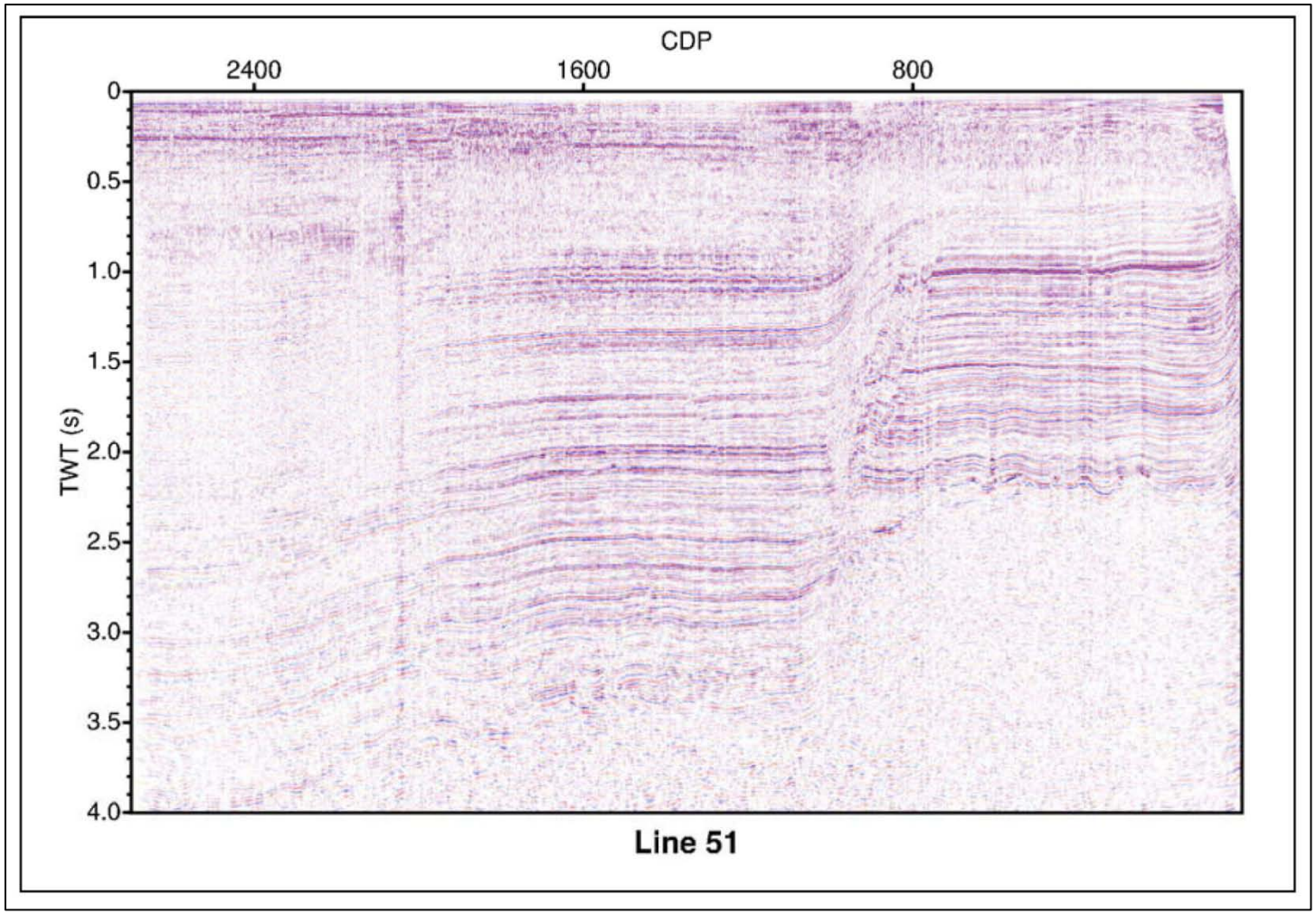

Figure 2. An E-W seismic cross section across Lake Albert showing an almost full graben structure.

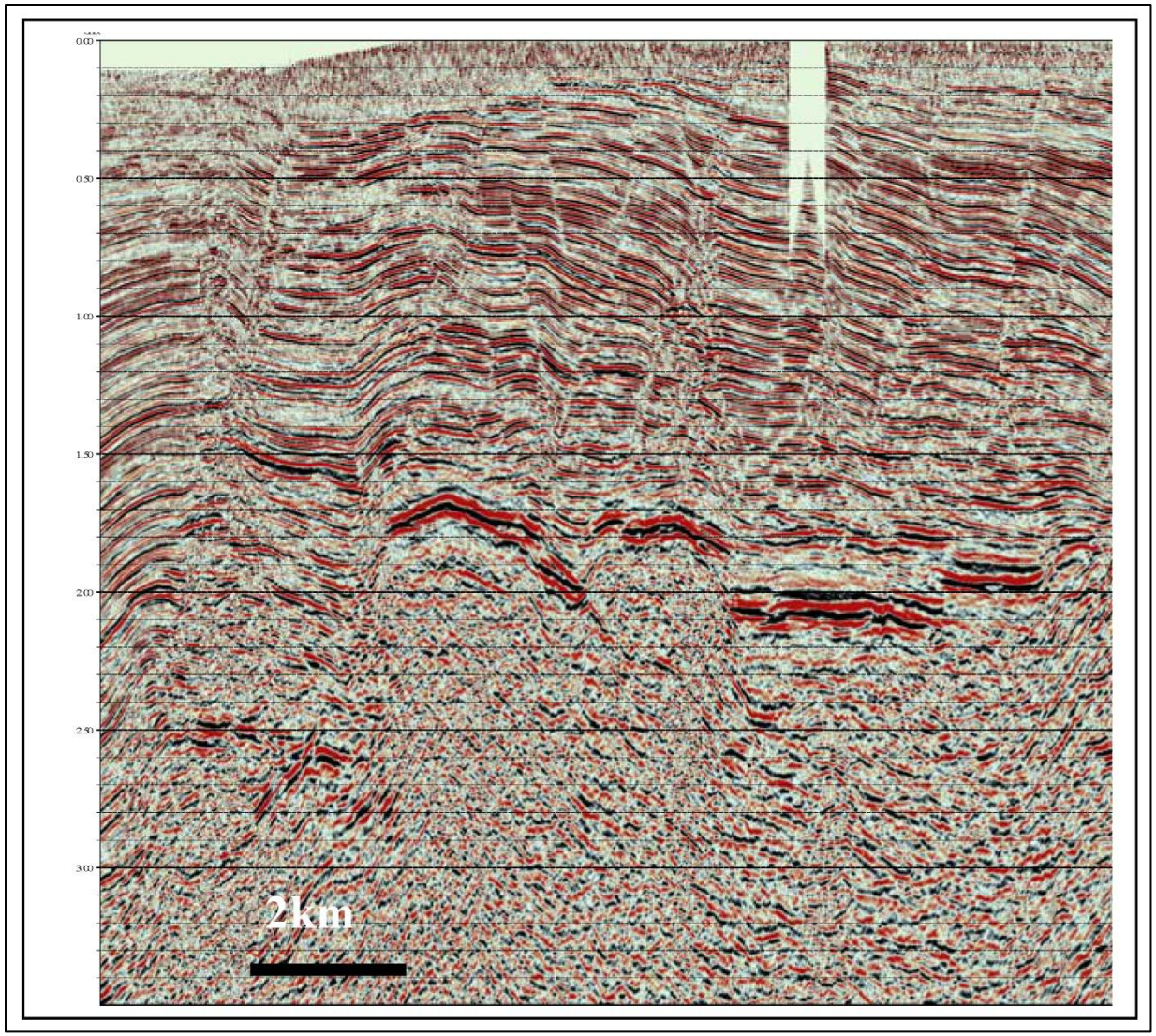

Figure 3. Seismic section showing positive flower structures persisting up to the top of the section, indicating a recent compression episode.

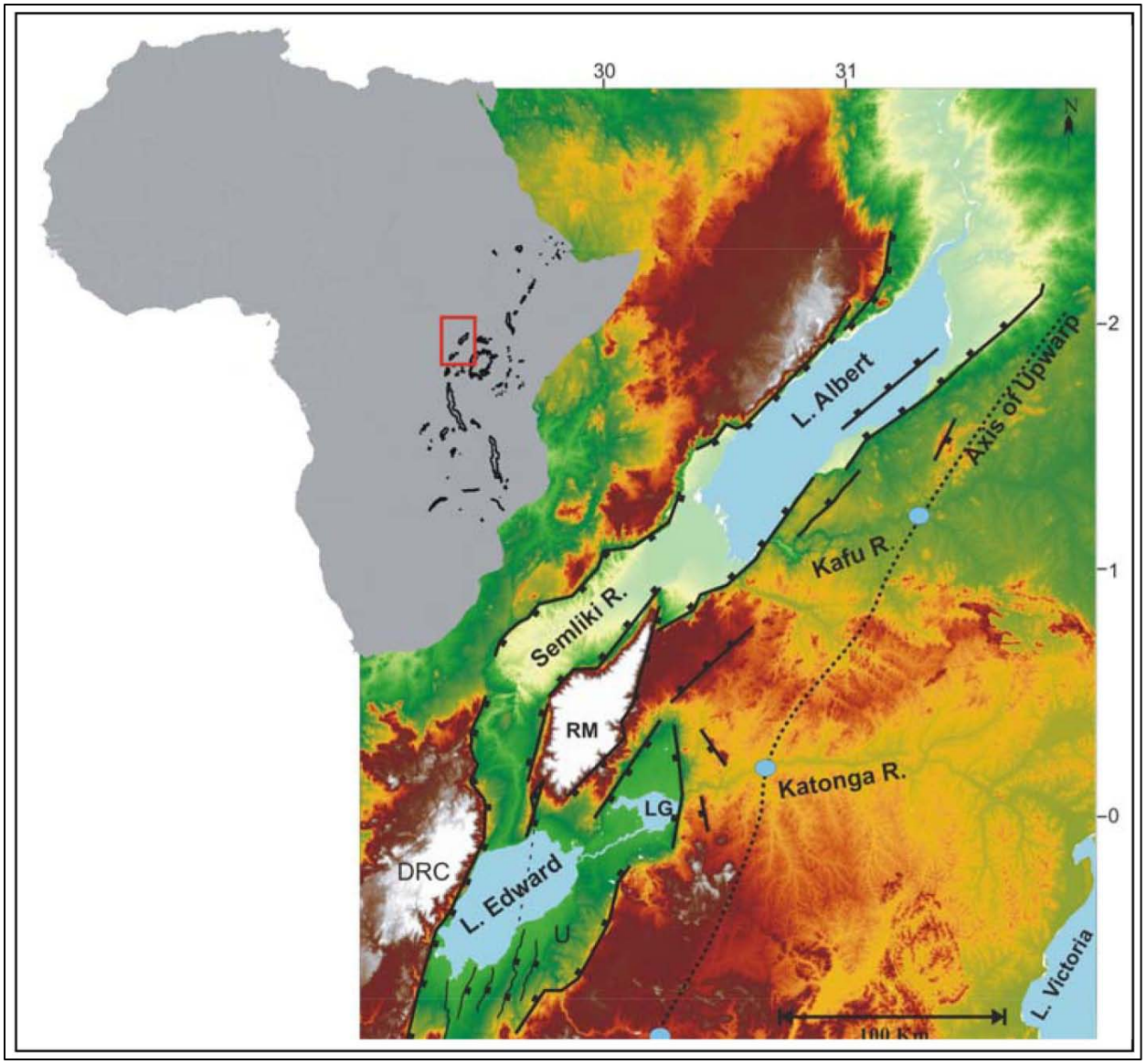

Figure 4. Tectonic setting of the Albertine Graben showing fault segmentation along relay ramps and accommodation zones.

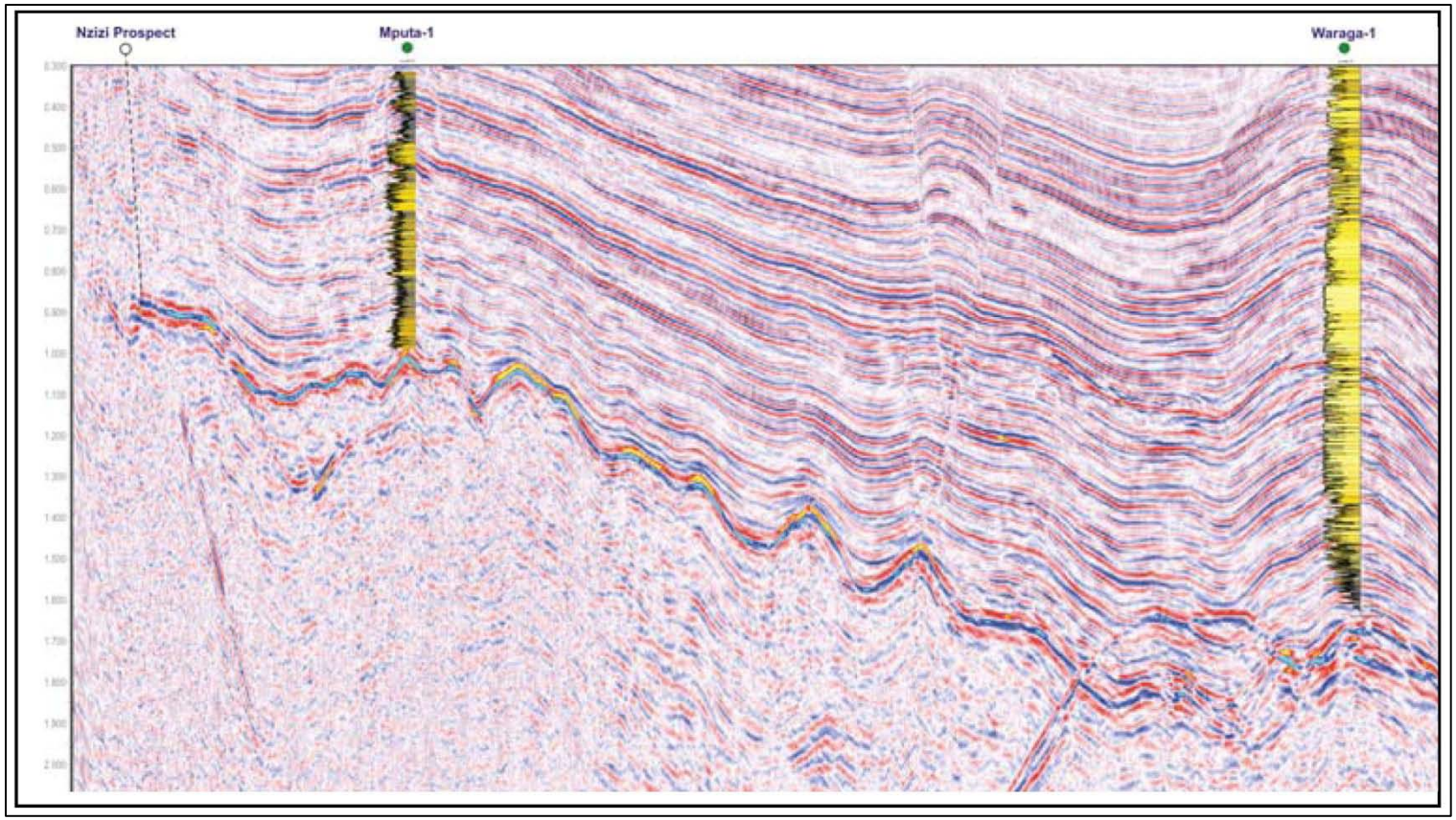

Figure 5. Seismic section showing anticline-syncline pairs in the Kaiso-Tonya area. The anticlines have been drilled and found to contain hydrocarbons.