Transfer Zones and Hydrocarbon Accumulation in the Albertine Graben of the East African Rift System*

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Abstract

Fault systems initiate as simple fractures and propagate radially. As displacement on each fault strand increases, the tips sense and propagate towards each other and eventually link up. The linked system then begins to operate as a single fault segment. The resultant fault segment also propagates radially and may link up with another fault segment to form a larger fault (Figure 1). The area where fault segments link up is called a transfer zone and is highly deformed. There are two types of transfer zones: accommodation zones and relay ramps. There are several pronounced transfer zones in the Albertine Graben, both accommodation zones and relay ramps. Due to relative displacement on the two linking faults, complex structuring develops in these zones. In the Albertine Graben, however, the amplitude of the structures, especially in the hanging wall, indicate that there could be an element of lateral movement along strike.

The Albertine Graben forms the northernmost termination of the western arm of the East African Rift System. Rifting was initiated during the Miocene and thick sediments have accumulated in asymmetric basins along strike of the rift system. The rift is highly segmented and bordered by en echelon linked border faults typically ten to twenty kilometers long. These faults are separated by relay ramps and accommodation zones. The Graben can be divided into three structural domains based on structural geometry and trend: the southern, central and northern domains. The structural elements in the southern domain trend in a NNE-SSW direction, structural elements in the central domain change to a NE-SW direction, while the structural elements in the northern domain return to a NNE-SSW trend. These structural domains are separated by accommodation zones (Figure 2).

The Albertine Graben has been under exploration for hydrocarbons for the last twenty five years. Initial data acquisition concentrated on geological mapping and gravity and magnetic data acquisition. The acquired geological data indicated there are several hydrocarbon seeps distributed in the transfer zones formed by major fault linkages along strike. The acquisition and interpretation of 2D and 3D seismic data have confirmed complex structural patterns in the transfer zones, including high amplitude folds and highly faulted blocks. Most of these structures have now been drilled and found to contain hydrocarbons. Currently, significant amounts of discoveries have been made in the Graben that warrant development and production. The trapping mechanism has largely been formed by structures within transfer zones as most of the discoveries to date are within these zones. Understanding structural evolution within transfer zones will play a crucial role in future exploration efforts in the Albertine Graben and the entire East African Rift system.

There are many transfer zones in the Albertine Graben of Uganda and in this article we describe the transfer zones that have been explored and now confirmed to contain hydrocarbon accumulations. These transfer zones include the Kaiso-Tonya breached relay ramp, Butiaba-Wanseko area which includes the Sonso relay ramp, Waiga-1 relay ramp, Waiga-2 relay ramp zones, and the Pakwach Basin which itself is a transfer zone from the Lake Albert Basin to Rhino Camp Basin. There is also another group of the less explored transfer zones including those found in the Lakes Edward-George basins and Semliki sub-basin.

Kaiso-Tonya Transfer Zone of Lake Albert Basin

Kaiso-Tonya is located in the Lake Albert Basin. Lake Albert Basin represents a full graben structure bounded by border faults both on the Eastern and Western flanks. Like most rift basins, the Albertine Graben sub-basins are asymmetric and the fault systems are highly segmented. Faults are characteristically irregular, highly segmented and in a process of growth, trying to achieve fault linkage among the individual fault segments. These are typical characteristics of the young rift system. Kaiso-Tonya has a relay ramp described as a breached relay forming a rider block between two fault segments. The area is filled with sediments that have been deposited since Early Pliocene. The two big fault segments forming the relay ramp are one in the south that dies into Lake Albert (the platform fault) and the second one (referred to as the Bunyoro Fault) that takes over to the northern through a breaching fault creating space in between for sediment accumulation (Figure 3). The Kaiso-Tonya area has undergone intensive exploration for hydrocarbons and more than 500 MBO of oil in place has been discovered.

Butiaba-Wanseko Transfer Zones

There are several transfer zones in the form of relay ramps along the eastern basin margin fault in the Butiaba-Wanseko area. Some of these relay ramps have been drilled and found to contain hydrocarbons. The Taitai and Karuka discoveries are examples of hydrocarbon accumulation in these relay ramps (Figure 4).

Pakwach Transfer Zone

At the northern tip of Lake Albert, the NE-SW faults die and switch to a N-S trend in the Pakwach Basin before changing polarity into Rhino Camp Basin. Figure 5 shows various faults dying out with others taking over through relay structures (or transfer faults). Because in the EARS, extension is still low as the rift is still evolving, the accommodation zones are topographic highs (e.g. Morley et al., 1990). This is the case within the Albertine Graben in which such highs act as sediment sources to the sub-basins. Fluvial systems have directed sediment accumulations in the Pakwach Basin as a result of this accommodation zone and consequently excellent reservoirs in the area are accounting for more than 800 MBO in place for the already discovered resources.

Conclusions

- In the Albertine Graben major structures have been formed in transfer zones along major faults.
- Some of these structures have been drilled and found to have significant amounts of hydrocarbons.
- Understanding the role of transfer zones in the formation of hydrocarbon traps is essential for future exploration efforts.

References

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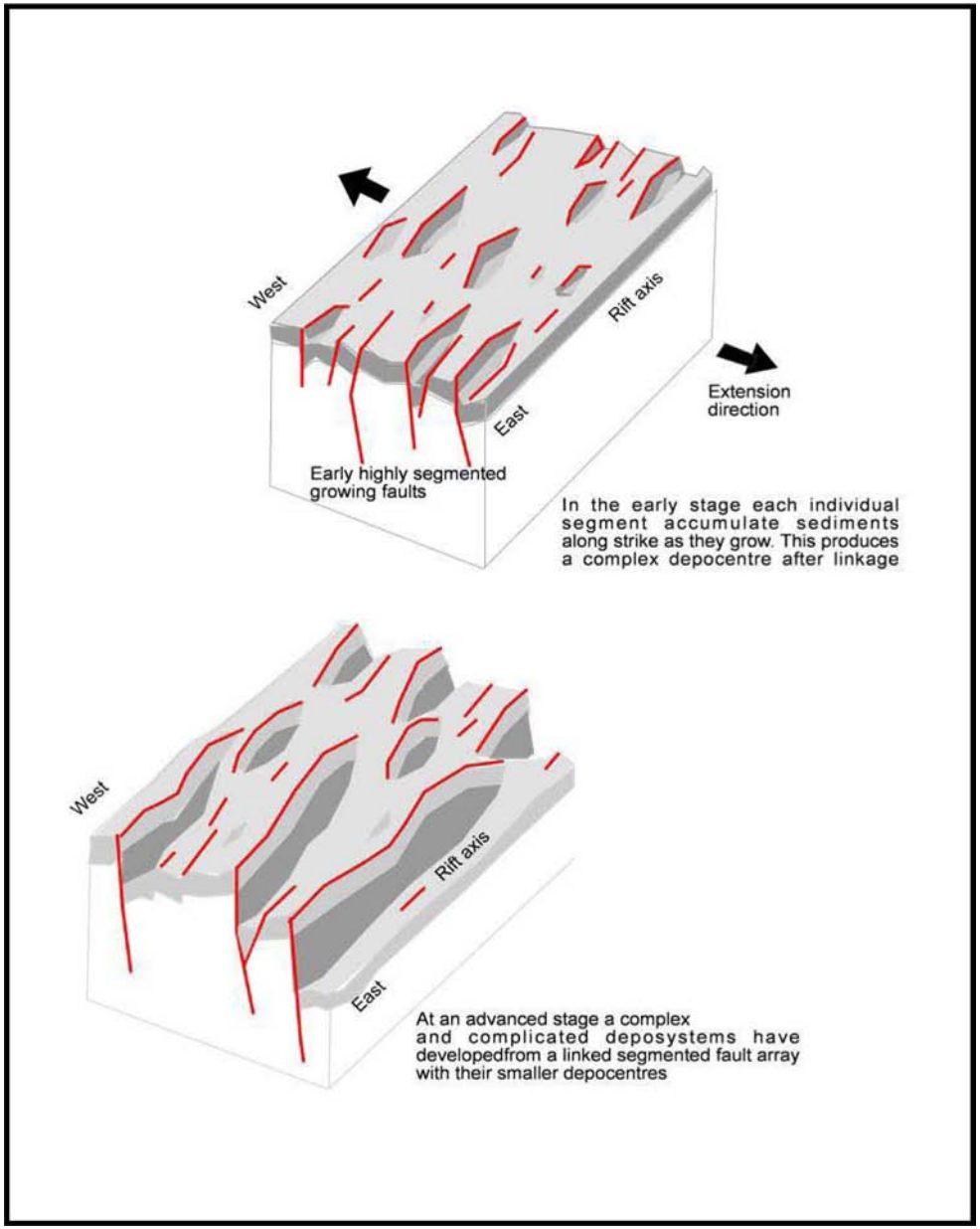

Figure 1. Fault initiation stages and propagation to link up into a single main fault.

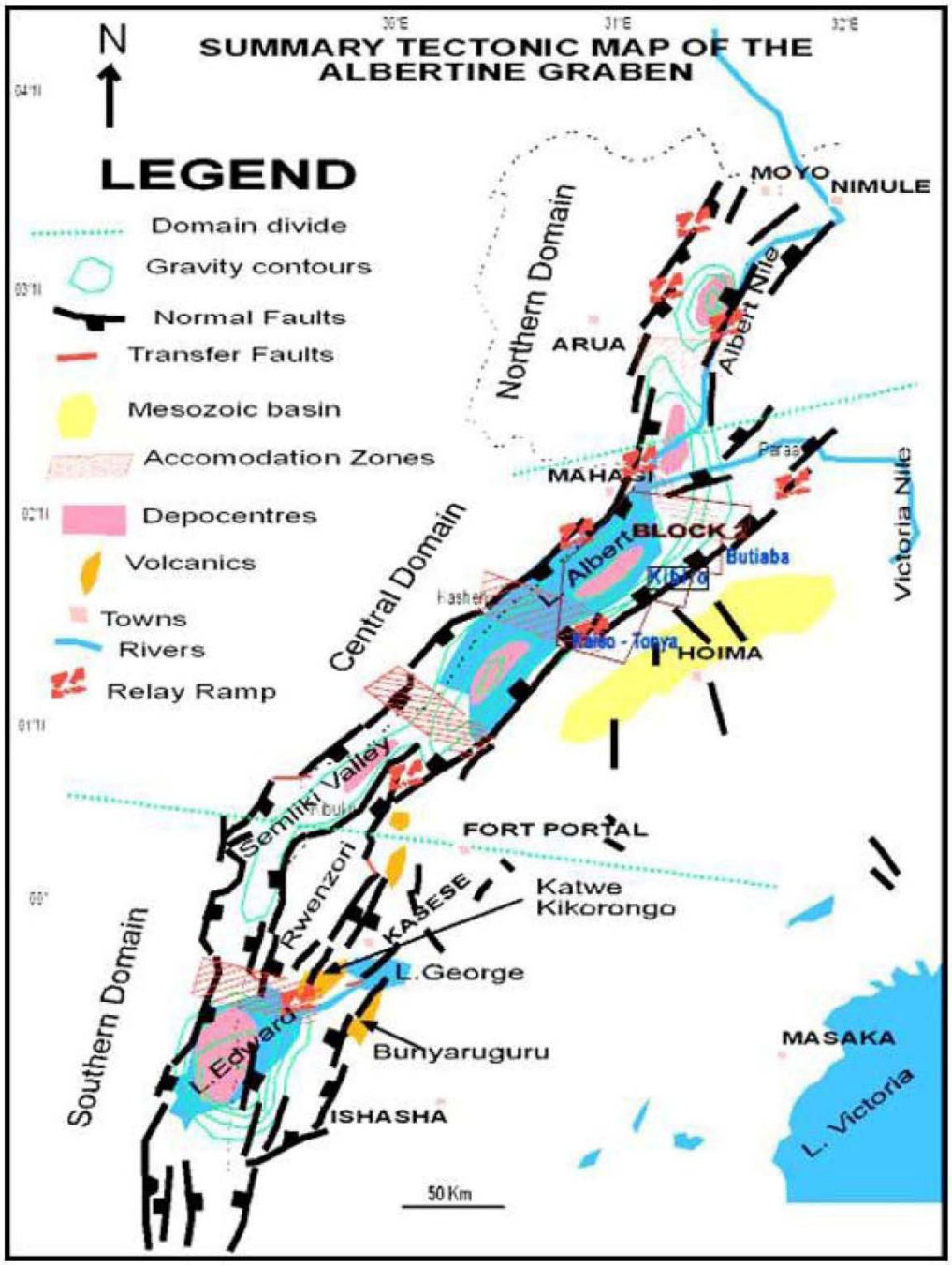

Figure 2. Map showing the structural elements in the Albertine Graben.

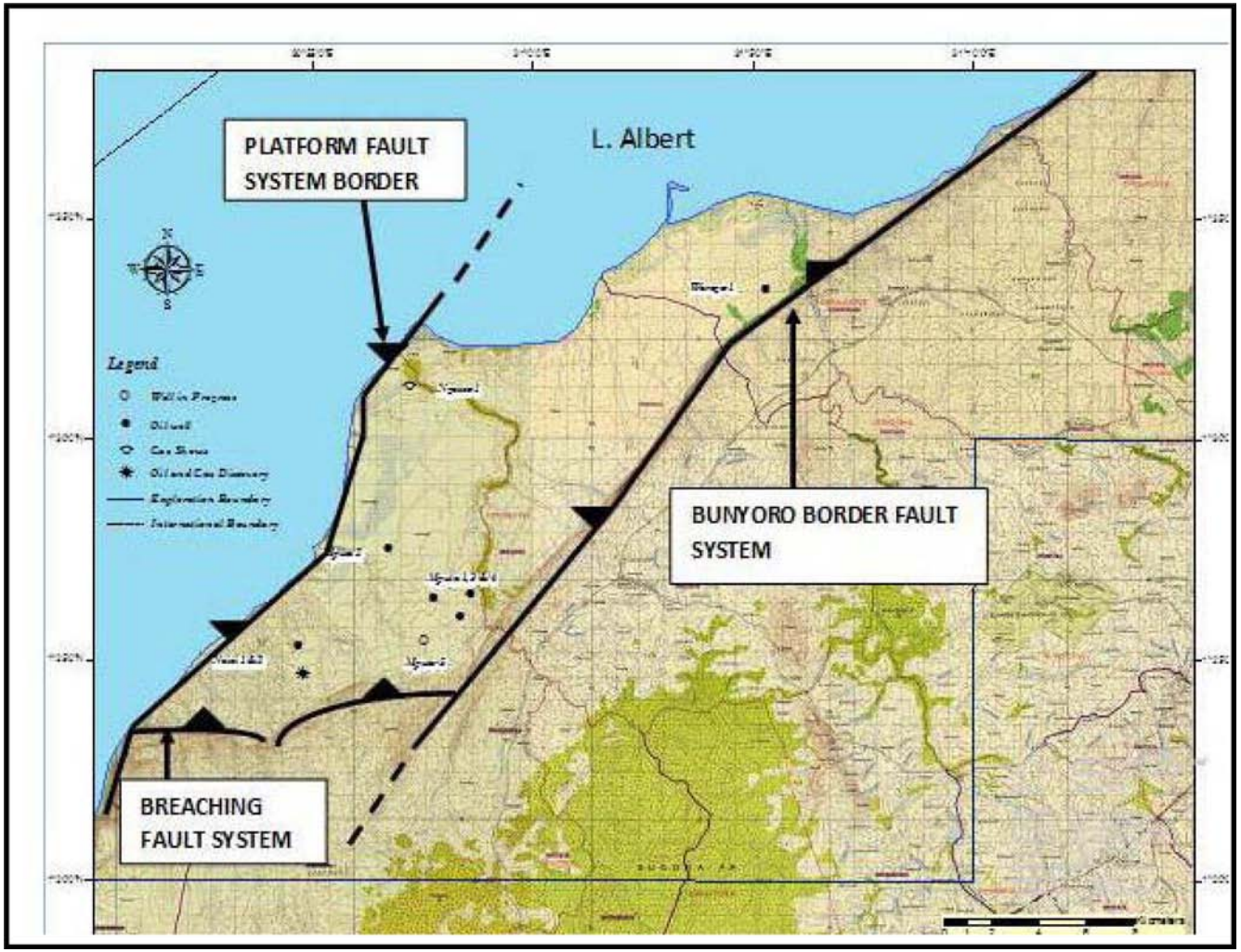

Figure 3. Kaiso-Tonya relay ramp.

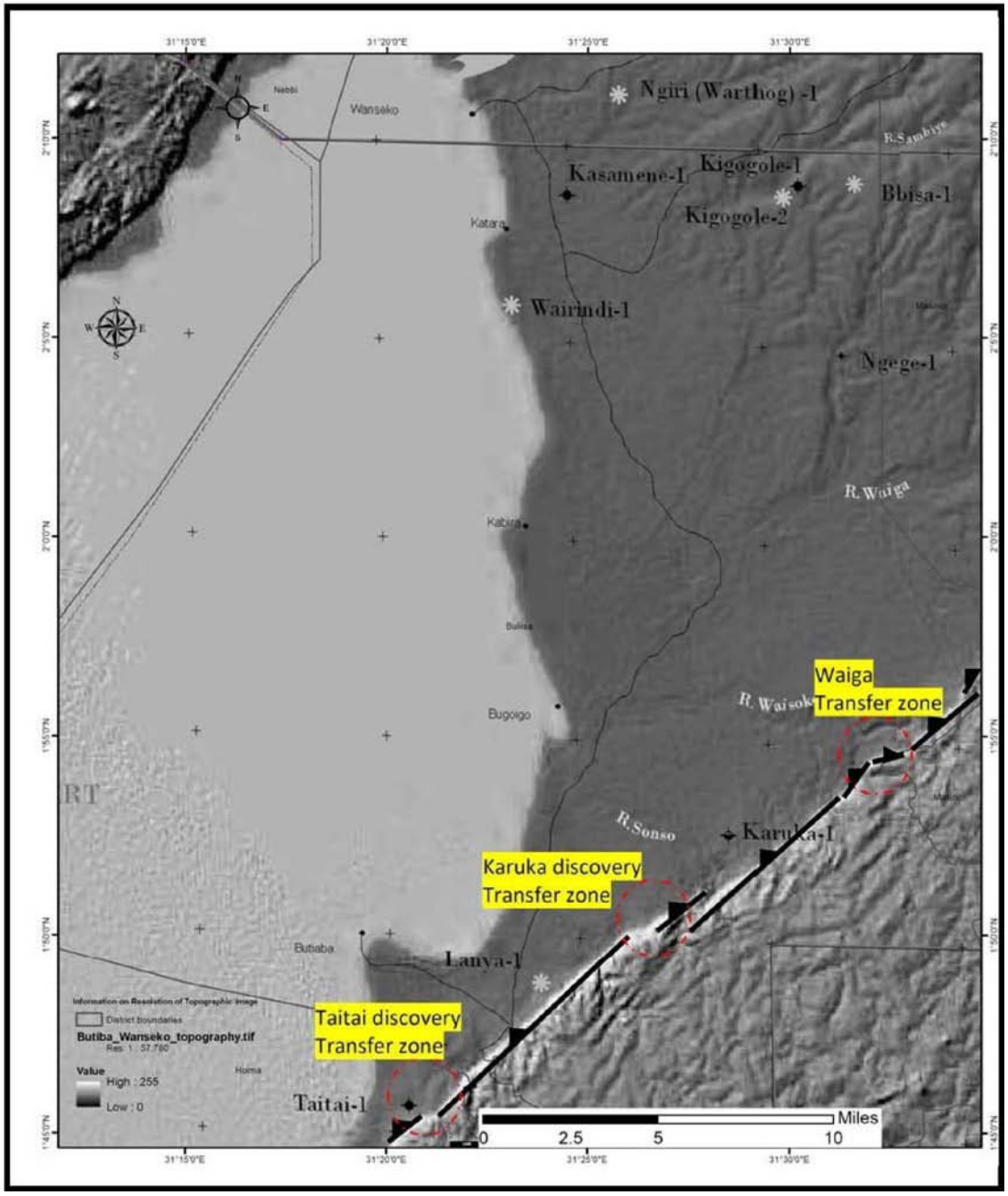

Figure 4. Satellite image showing the discovery areas of the eastern rift border margin located in transfer zones of the Butiaba-Wanseko area.

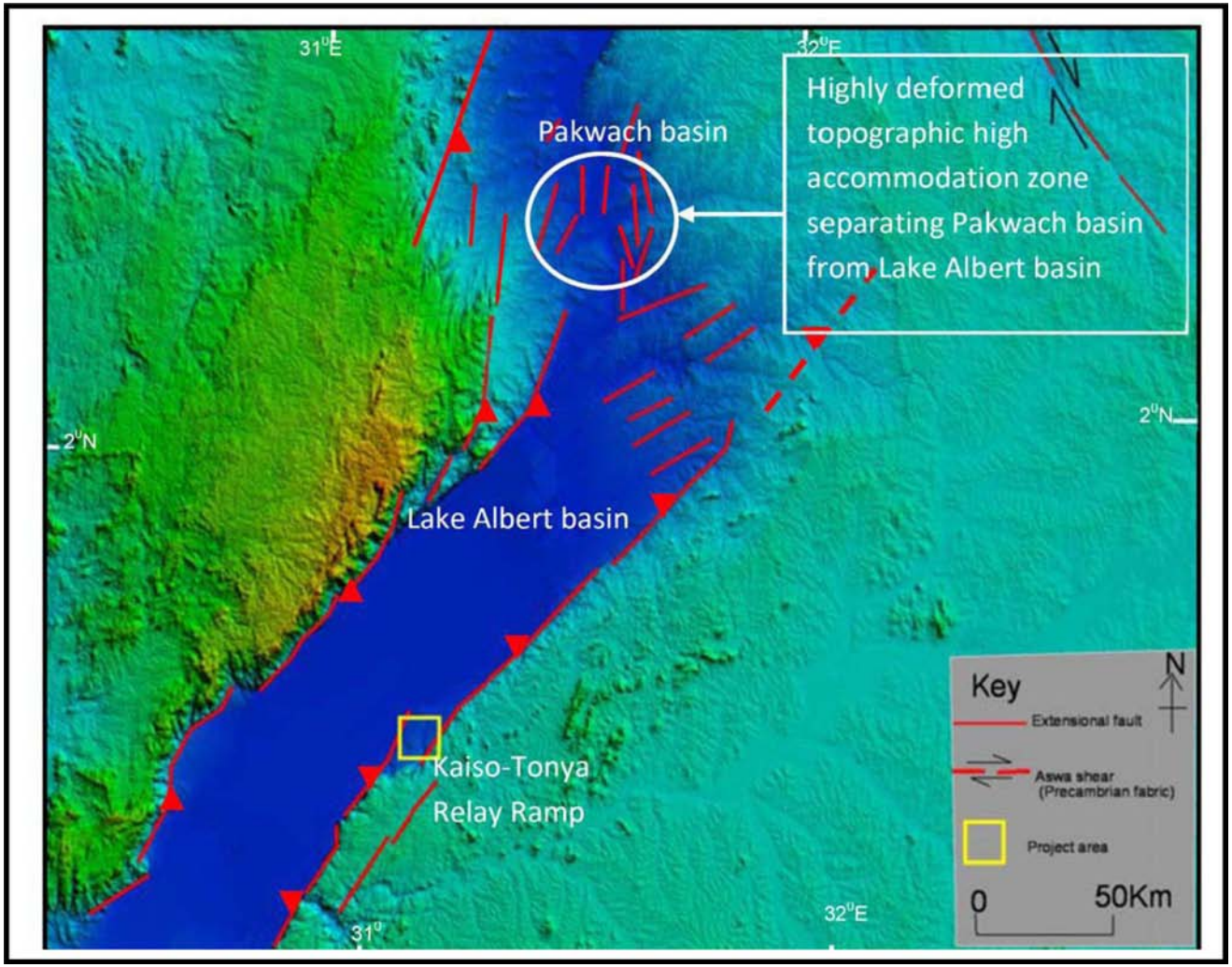

Figure 5. Digital elevation model map showing the transfer zone between the Pakwach Basin and the Rhino Camp Basin.