33 The Western Rift branch

A REGION OF GEOLOGICAL, MORPHOLOGICAL AND BIOLOGICAL RECORDS

DAMIEN DELVAUX

Lake Kivu, bordering Rwanda and the Democratic Republic of the Congo, lies in the western branch of the East African Rift system.

THE WESTERN RIFT VALLEY is an arcuate zone of contrasted relief with large deep lakes, fertile valleys, steep mountains and high plateaus affected by volcanism, earthquakes and landslides. This 2,600km-long geographical feature stretches from Lake Albert between Uganda and the Democratic Republic of the Congo (DRC) in the north, to the Indian Ocean at Beira in Mozambique in the south, with lakes Edward, Kivu, Tanganyika, Rukwa and Malawi in between. It separates East Africa from the DRC, Zambia and Malawi and played an important role during early European exploration of Central Africa, such as the quest for the source of the Nile and the snow-capped 'Mountains of the Moon' (Ruwenzori Mountains).

The large lakes promoted exchange (such as the Arabic influence and the Swahili language), and travelling from the Indian Ocean coast extended westwards across the great lakes, up to the north–south stretch of the upper part of the Congo River, beyond which starts the rainforest. The region also played a role in the development of early hominids.

Geological development

The East African Rift System is a major tectonic zone that separates the Nubian plate ('stable' Africa) from the Somalian plate, with the eastern and western rift branches isolating the smaller Victoria and Rovuma crustal blocks between them (**figure 33.1**). The rift is spreading in a general east–west direction at a rate of a few millimetres per year. The western branch developed in a series of narrow and deep fault-controlled basins with limited volcanism restricted to the junctions and accommodation zones between the major basins. This was largely controlled by old basement structures in a series of successive tectonic stages that reactivated the Neoproterozoic basement. The internal structure of the basins is characterized by an assemblage of grabens or half-grabens, which are the building blocks of the rift architecture.

It is difficult to define a starting date for the beginning of rifting in East Africa as there have been several periods of rifting since early Permian times, about 300Ma. The

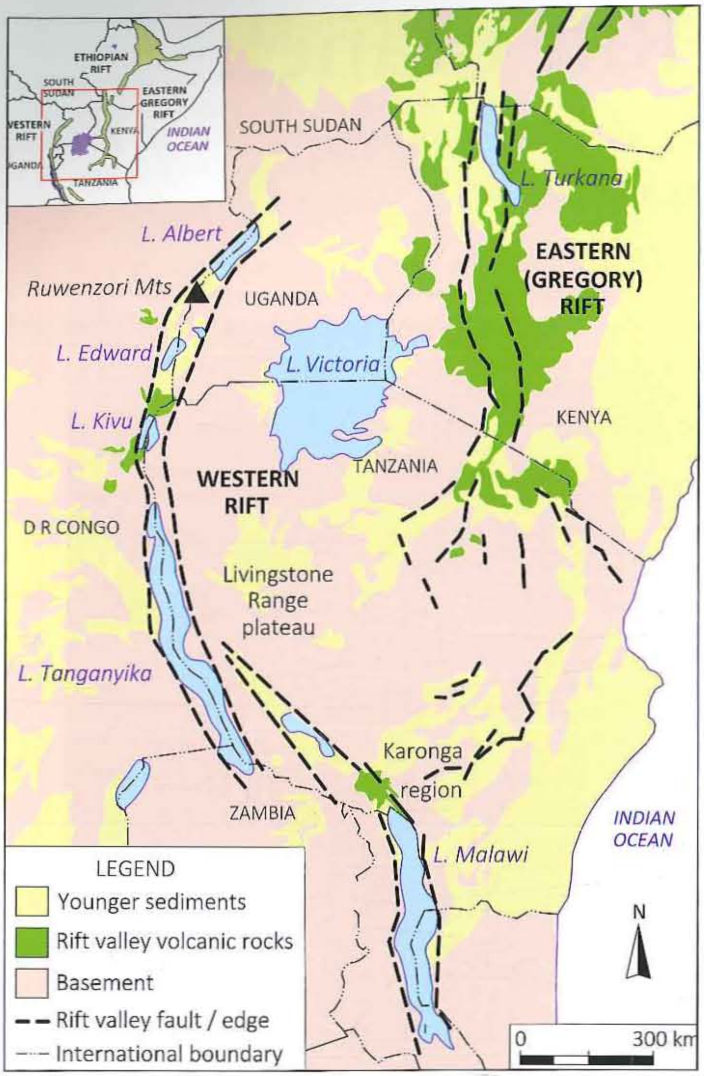

Figure 33.1 The African Rift System. The S-shaped Western Rift is a narrow zone of strongly contrasting relief with large, deep lakes bordered by high mountains and plateaus.

most recent period of rifting started in the Mid-Miocene, at about 13Ma. It likely initiated as isolated rift basins that progressively expanded longitudinally and connected to each other at accommodation zones, which host most of the volcanism (9–8Ma). A strong acceleration of basin down-faulting, mountain growth and volcanism occurred in the Plio-Pleistocene (3–2Ma), producing much of the topography we see today, which is therefore geologically very young.

Rift architecture

A rift system is a typical product of extensional tectonics. It consists of a depressed linear axial zone (rift valley), bordered by uplifted margins (rift shoulders). The East African Rift is considered to be the type example of a continental rift because it is almost entirely intracontinental and still active, and thus accessible for observation.

The two branches of the East African Rift System differ in their architecture. The western branch is composed of a narrow chain of long and deep rift basins (grabens) bordered on one or both sides by a single 'border fault' that concentrates much of the tectonic movements. Magmatism is relatively scarce, restricted to accommodation zones between different rift segments. In comparison, the eastern branch contains much smaller rift basins, but volcanism is far more extensive within the rift and on the eastern platform. The Western Rift has undergone more extension (possibly as much as 30km in the last 7Ma) than the Gregory (Eastern) Rift (8–0km from north to south over 5Ma).

Investigation of the Malawi and Tanganyika rift basins by seismic reflection profiles in the 1980s enabled the internal architecture of rift basins to be evaluated. It showed that the large rift basins, such as those of Malawi and Tanganyika, are commonly composed of a series of asymmetric down-faulted depressions (half-grabens, **figure 33.2**), which are bounded on only one side by a normal fault and related rift-flank uplift. These 'building blocks' are grouped in various ways, opposing or facing each other, and arranged in an alternating, en echelon or linear way to form long rift segments.

Kinematics of rift opening

The mechanism of formation of the rift system has intrigued many geologists and geophysicists. During the first half of the 20th century, it was believed that the rift basins in the Great Lakes region of Central Africa formed as a result east–west horizontal shortening. The presence of a negative gravimetric anomaly in the depressed axial zone of the rift was interpreted as reflecting the presence of a lighter crust there than on the rift shoulders. According to these researchers, such a lighter crust should be uplifted relative to the surroundings due to buoyancy forces. Instead it is depressed, requiring a mechanism to force it down. It was proposed that the rift border faults were dipping away from the rift axis and, under the action of horizontal compression, the rift shoulders were overriding the axial zone, forcing it down by their mass. This was known as a 'pop-down basin', which typically forms in a compressional environment. It was only after the installation of the IRSAC (Institut pour la Recherche Scientifique en Afrique Centrale) seismic network in the Kivu Rift Region that it was demonstrated that the rift formed in an extensional rather than a compressional context.

In the 1990s it was proposed that the central part of the Western Rift (South Tanganyika, Rukwa and North Malawi rift segment) acts as an intracontinental transform, accommodating dextral strike-slip movement along northwest-trending reactivated Precambrian discontinuities. This model implies a general opening of the East African Rift system in a northwest–southeast direction. It was based on remote-sensing interpretations, coupled with morphological observations,

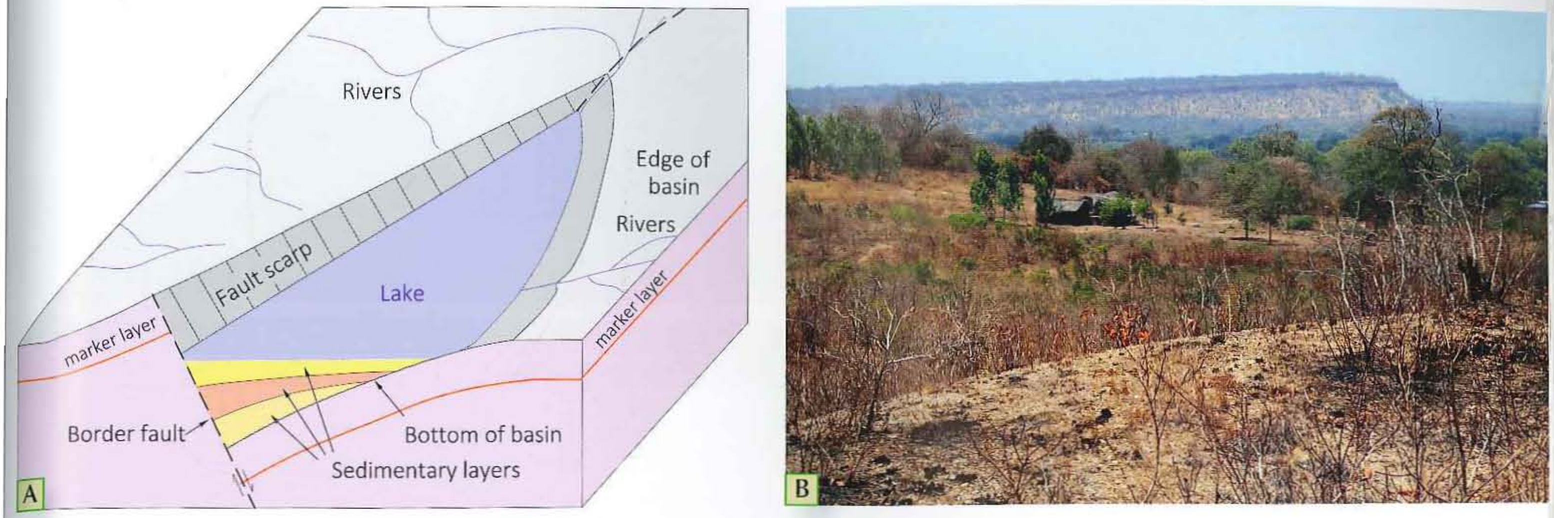

Figure 33.2 **(A)** Half-graben as a building block of the rift system, with rift sediments inclined towards a major border fault on one side and uplifted on the other. **(B)** The Karonga/Livingstone basin at the northern end of Lake Malawi illustrates this feature. On the Malawian side, in the region of Karonga, Pleistocene Chitimwe sandstones are uplifted above lake level and slightly tilted towards Lake Malawi. (After Rutgers University 1996)

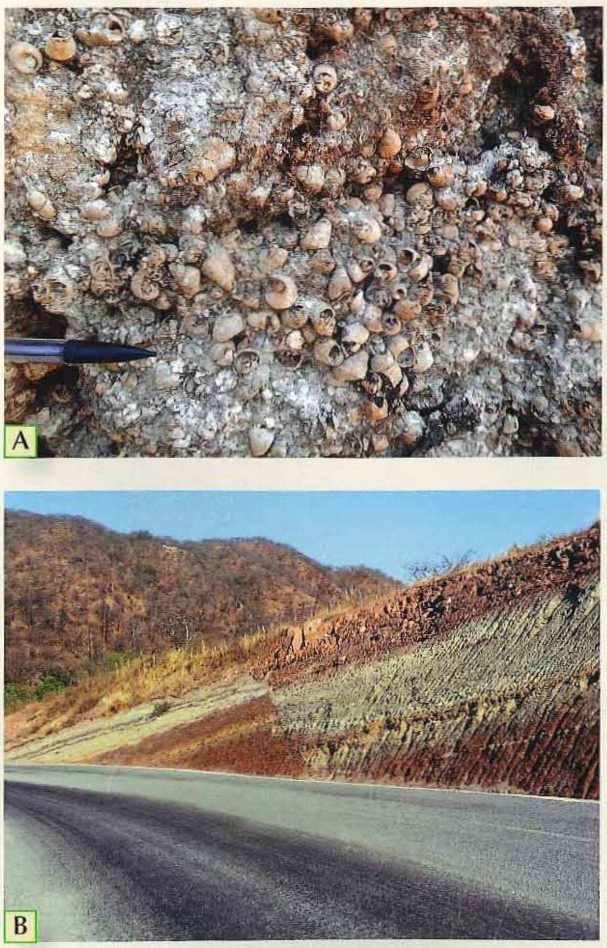

Figure 33.3 **(A)** Shell-rich bioclastic layer, Karonga region, Malawi. **(B)** Small fault affecting Permian sediments, deposited during an earlier rift stage, Karonga region, Malawi.

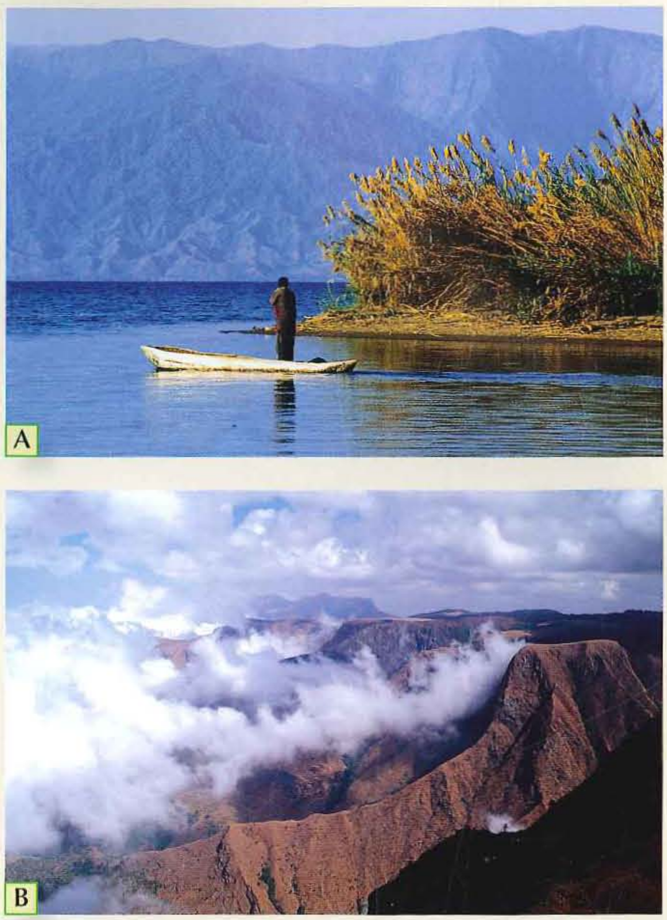

Figure 33.4 **(A)** Frontal view of the 2km-high Livingstone Fault scarp bordering the Livingstone Range plateau on the Tanzanian side. **(B)** Edge of the Livingstone Range plateau, Tanzania, etched by erosion owing to its strong uplift along the Livingstone Fault.

Figure 33.5 The Virunga volcanic massif viewed from Goma (foreground) at the northern extremity of Lake Kivu. On the left is the Mikeno volcano (4,437m) and in the centre is the Karisimibi volcano (4,507m).

and the first available fault-kinematic analyses. With the acquisition of earthquake, GPS geodetic and geological field data, it became clear that the overall extension across the system occurs in a general east–west direction. At the scale of the rift basins, extension tends to occur at a high angle to the trend of the basin. Oblique movements appear to be restricted to the area of interaction between different basins of the rift system (accommodation zones).

Geomorphology and natural hazards

A rift system is not just a large zone of extension formed between two blocks that are pulled apart and in which a piece of land is downfaulted. In the Western Rift, the rift floor, although sometimes strongly depressed relative to its surroundings, generally lies at altitudes much higher than the rest of the African continent (400m for the Malawi depression and up to 1,600m for the Lake Kivu depression). It is also bounded by mountain ranges that often reach 2,500–3,000m in height. The Ruwenzori Mountains, which actively rise between two overlapping rift segments, are composed of basement rocks that reach heights of 5,109m. The Virunga volcanoes (**figure 33.5**), which erupted in the middle of the rift valley, reach a height of 4,507m (Karisimbi). A lava lake began forming in the summit of the Nyragongo volcano (3,470m) in 1927 (**figure 33.6**). Since then it has erupted catastrophically, in 1977 and 2002.

This rugged and elevated region acts as a climatic barrier, separating the East African savanna from the rainforests of Central Africa. The region also acts as a refuge for animal species such as gorillas and chimpanzees and may have played a role in the development and speciation of early hominids.

The Western Rift hosts some of the longest, largest, deepest and most voluminous lakes in the world (Lake

Benoit Smets

Figure 33.6 Helicopter view of the Nyamulagira lava lake, west of Nyragongo volcano in the DRC, taken in 2011.

Figure 33.7 Aerial view of the Lake Tanganyika outlet into the Lukuga River at Kalemie on its western (DRC) side. The river was followed by Sir Henry Morton Stanley on his trip towards the Atlantic coast along the Congo River in 1874–1877.

Tanganyika, the longest at 677km and the second deepest at 1,433m, and Lake Malawi, the third largest and third deepest in Africa).

Since historical times, the region has attracted a large human population and, rather than acting as a barrier, the large lakes promoted exchange and travel from the Indian Ocean coast westwards. The relatively high-altitude relief and abundant surface waters make the region more fertile and hospitable than the surrounding dry savanna and deep rainforest (**figure 33.8**). Unfortunately, it is also prone to a spectrum of natural geological and hydrological hazards, such as earthquakes, volcanic eruptions, landslides, mud flows, inundations and soil erosion. The region is also one of the most populated regions of Africa, and the risk caused by these natural hazards to the population and infrastructure is particularly high.

Figure 33.8 Canyon of the Ruzizi River in the DRC, near the border with Burundi. Most of the steep flanks are cultivated but are also affected by large landslides.

Figure 33.9 Soft-sediment deformation induced by ancient earthquakes in 20,000-year-old sediments of the Rukwa basin, Tanzania. These deposits were introduced when the lake level was much higher than today.

Natural resources

Rift systems generally host a wide range of natural resources (**figure 33.10**), and this is particularly true in the case of the Western Rift branch. Large quantities of oil have been found in the northern end of the Albertine graben in Uganda and may also be present in other rift basins. Lake Kivu contains methane, which is being used in a pilot plant to produce electricity. Coal was found in early colonial times and supported industrial development and railways. Hydroelectric power plants have been installed or are under development in many locations.

Numerous hot springs occur throughout the region (**figure 33.11**) and the first hydrothermal plant in East Africa began operating as early as 1952 near Manono in the Upemba Rift of southeastern DRC, producing electricity for tin mining. The search for profitable hydrothermal energy sites is currently under way. Precambrian carbonatites are mined for various minerals and for cement factories. Travertine, produced by hydrothermal activity, is also used for making chalk, cement and ornamental marbles (**figure 33.12**).

Figure 33.12 Fossil travertine (Songwe deposit), mined from a thermal spring in the ancient Rukwa Lake, Tanzania. The deposit was formed as a result of hot mineralizing water rising through an open fissure and spreading horizontally on the lake floor, depositing horizontally banded travertine and vertically banded ore.

Figure 33.10 Ivuna salt pan in the floor of the Rukwa depression, Tanzania. The salt is introduced by a thermal spring. It is harvested using traditional methods.

The Western Rift branch hosts numerous natural parks, game reserves and sites of regional conservation interest. Among others, these include the national parks of North and South Luangwa and Mweru Wantipa in Zambia; Lake Malawi and Nyika in Malawi; Kitulo, Katavi, Mahale and Gombe in Tanzania; Kibira in Burundi and adjacent Nyungwe Forest Park in Rwanda; Kahuzi-Biega in the rift mountains along Lake Kivu in the DRC; the cross-border system of parks in the Kivu-Albertine rift segment, with the Virunga National Park in the DRC; Volcanoes Park in Rwanda; the Queen Elizabeth, Ruwenzori and Semliki Parks in Uganda, and the Murchison Falls National Park at the extreme northern end of the Albertine Rift Valley. The Virunga National Park is the oldest national park in Africa, created in 1925, and one of the most diversified in the world in terms of geology, landscape and biology. It was designated a UNESCO World Heritage Site in 1979, but was listed as 'World Heritage in Danger' since the Rwanda genocide in 1994.

Figure 33.11 Sempaya hot spring field at the northern tip of the Ruwenzori Mountains, Uganda.

Figure 33.13 View of the Semliki valley on the southwestern extremity of Lake Albert in the Virunga National Park, DRC.

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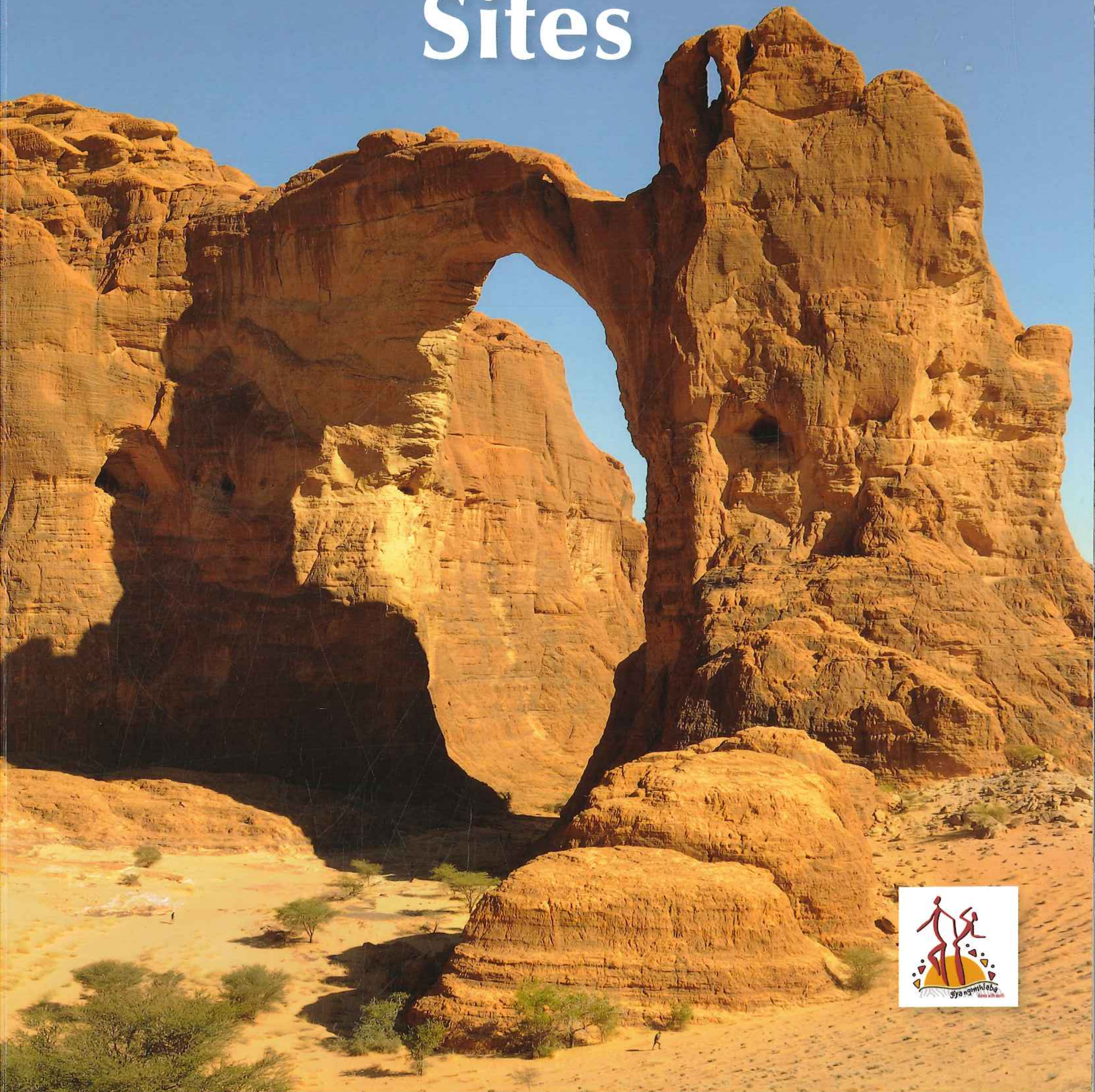

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COVER IMAGE: The Aloba Arch, composed of Palaeozoic sandstone, located on the Ennedi Plateau of Chad. Standing 210m tall, it is the second-largest natural arch in the world. PHOTO CREDIT: Jacques Taberlet
TITLE PAGE IMAGE: View of Cape Town with the Cape Town Stadium in the foreground, and with Signal Hill and Lion's Head embracing the 'city bowl' that lies at the foot of Table Mountain. Behind the 'table', the mountains snake south down the peninsula, all the way to Cape Point. PHOTO CREDIT: Alain Proust