15 Lakes of the Gregory Rift Valley: Baringo, Bogoria, Nakuru, Elmenteita, Magadi, Manyara and Eyasi

Abstract

The lakes of the Gregory Rift Valley are protected in national parks, reserves and conservation areas. Many of the lakes occur in areas of spectacular landforms located at the base of prominent escarpments. Palaeo-lakes were on average far larger (and deeper) during the Pleistocene. Currently, lakes are mostly relatively small, finger-shaped bodies with a maximum length of a few tens of kilometres. Lake basins have limited catchment and few outlets; rift platforms are tilted outwards so that major rivers flow away from the rift valley. Evaporation exceeds inflow resulting in high levels of alkalinity and salinity. The high sodium content is enhanced due to erosion of the sodium-rich volcanic rocks that characterise the Gregory Rift Valley. Lakes Bogoria, Nakuru, Elmenteita, Manyara and Eyasi are typical in this regard: they are finger-shaped, extremely shallow and markedly alkaline. They have an average pH of 10. Lakes Magadi and Natron are extraordinarily toxic; they contain brines with a pH of 12 that fossilises trees and animals by replacing the wood or bones with sodium carbonate. The alkaline lakes include salt deposits which are a mixture of two naturally occurring compounds of sodium carbonate, trona and natron. The salt deposits of Lake Magadi are quarried for soda ash. Lakes Baringo and Naivasha differ from the alkaline lakes in that they have a more rounded form, occur in basins with larger catchments and are dominated by freshwater. Important vertebrate and hominin fossils have been discovered in the Miocene–Pleistocene sediments of the Tugen Hills, near Lake Baringo. Geysers and hot springs discharge sulphurous brines into some lakes, including Baringo and Manyara. The geysers associated with Lake Bogoria are particularly well known. Many lakes and foreshores sustain significant concentrations of wildlife and they are refuges for more than 400 species of birds. Huge concentrations of flamingoes occur on some of the alkaline lakes.

Keywords

Alkaline lakes • Flamingo • Geysers • Natron RAMSAR • Sodic brines • Trona

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Plate 15.1 Hot springs and algae associated with geothermal activity on the foreshore of Lake Bogoria. The Siracho Escarpment (the eastern wall of the rift valley) is visible in the background

15.1 Introduction

Many of the lakes in the Gregory Rift occur in areas of spectacular landforms and are protected in national parks, reserves and conservation areas. The larger lakes are restricted to the rift valley where they reveal characteristic finger shapes and are generally shallow, alkaline features. The lake basins are relatively small with few outlets. The restricted catchment means that evaporation typically exceeds inflow. Five of the lakes (from north to south), Bogoria, Nakuru, Elmenteita, Manyara and Eyasi are typical in this regard (Fig. 15.1). They have an average pH of 10. Lakes Magadi and Natron occur in an extremely arid area where extraordinarily toxic brines have developed. Lakes Baringo and Naivasha differ from the alkaline lakes as they report more rounded shapes and are dominated by freshwater. Lake Naivasha (Chap. 16) and Lake Natron (Chap. 17) are described separately, as is the ephemeral Lake Amboseli (Chap. 14). Small lakes occur in some of the large calderas, e.g. Ngorongoro and Empakaai (Chap. 10). The Momella lakes occur in the debris avalanche deposit (DAD) associated with Mount Meru (Chap. 13). Some lakes in the rift valley are associated with geysers and other evidence of geothermal activity (Plate 15.1). Lakes typically have unusually high contents of fluorine, in addition to sodium, both elements derived from weathering of the alkaline volcanic rocks which are so charcteristic of the region (Baker 1987; Dawson 2008). According to Gaciri and Davies (1993), some rural communities suffer from the disease of fluorosis, a result of drinking untreated water high in fluorine and exasperated by a regular diet of lake fish.

15.2 Palaeo-Lakes

The lakes of the East African Rift System (EARS), including those in the Albertine Rift (Chap. 3) provide a unique record of climatic changes over the past several million years (Nicholson 1996). Street and Grove (1979) have focused on changes over the previous 30,000 years with data from fluctuations in the size and depth of palaeo-lakes. Some of these changes reflect climatic shifts on a global scale. The palaeo-lakes of the Gregory Rift Valley varied considerably as a consequence of climatic cycles during the Late Pleistocene and Early-mid Holocene (Olago et al. 2009). The size and depth of lakes have an important effect on the alkalinity and salinity. During the wetter periods of the Holocene (Sect. 6.3), many lakes that are now shallow and alkaline were far deeper and freshwater. Some lakes were conjoined into much larger palaeo-lakes (Fig. 15.1) and many of the lake basins were reshaped during the tectonically active Late Pleistocene (and to a lesser extent during the Early-mid Holocene). The differential rise of rift platforms in some areas has had the effect of channelling water into distal basins whilst bypassing nearby lakes. Finally, the rise and tilting of rift platforms has persisently reduced the overall flow of rivers into the rift valley.

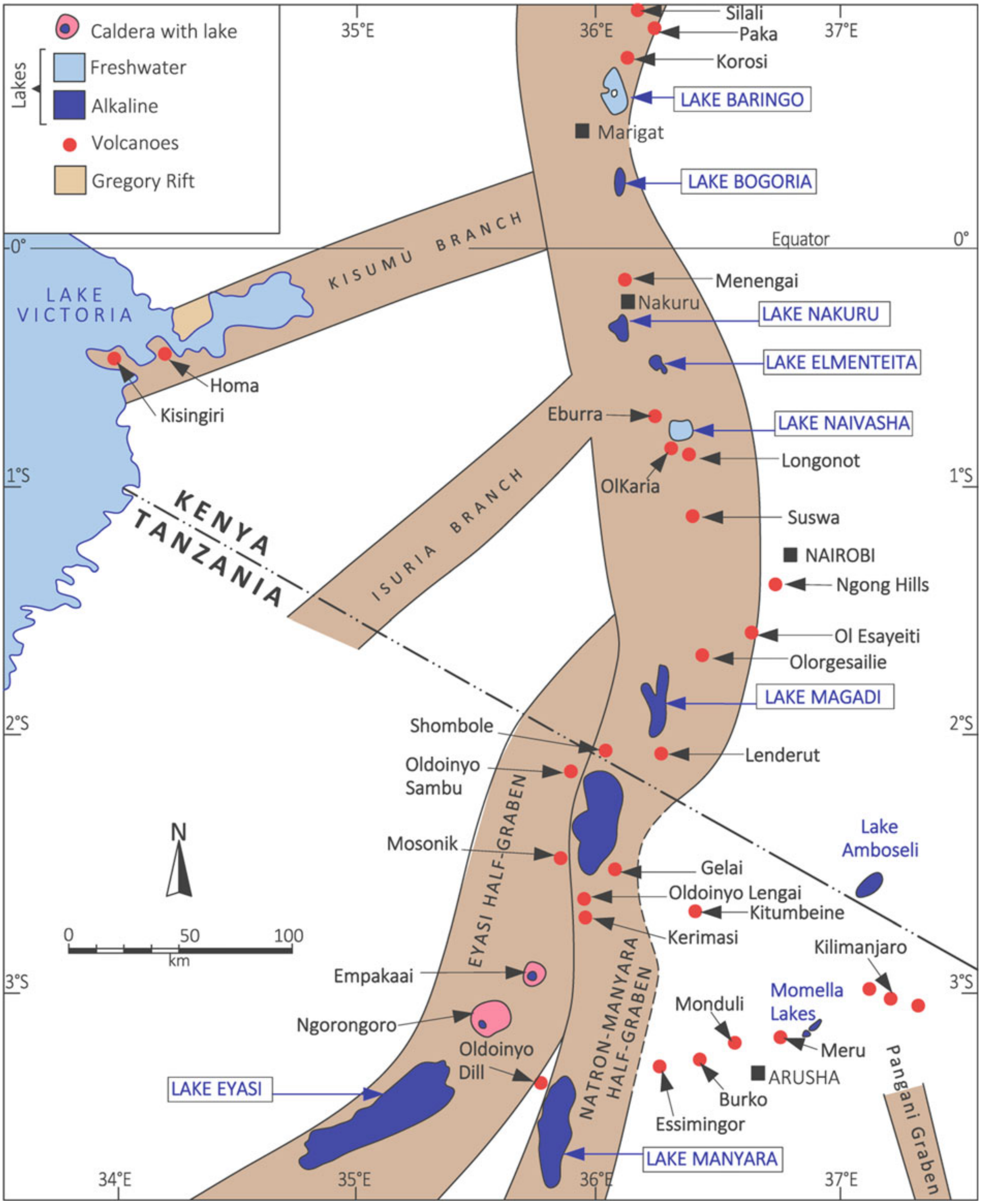

Fig. 15.1 Lakes in the Gregory Rift Valley of central/southern Kenya and northern Tanzania. Small lakes occurring outside of the rift valley are restricted to very specific localities such as calderas (e.g. Ngorongoro), debris avalanche deposits (e.g. Momella), or warps on the regional plateaus (e.g. Lake Amboseli)

15.3 Lake Baringo National Park

Lake Baringo, the most northerly of the lakes described here, has a distinctive rounded shape and a surface area of 130 km^2. The lake and its islands are protected in a national park served by the regional town of Marigat. Lake Baringo occurs in a relatively low-lying (970 m) section of the Gregory Rift Valley which includes Lake Bogoria (Fig. 15.2). The rift here is comprised of a half-graben with prominent escarpments restricted to the eastern side. The

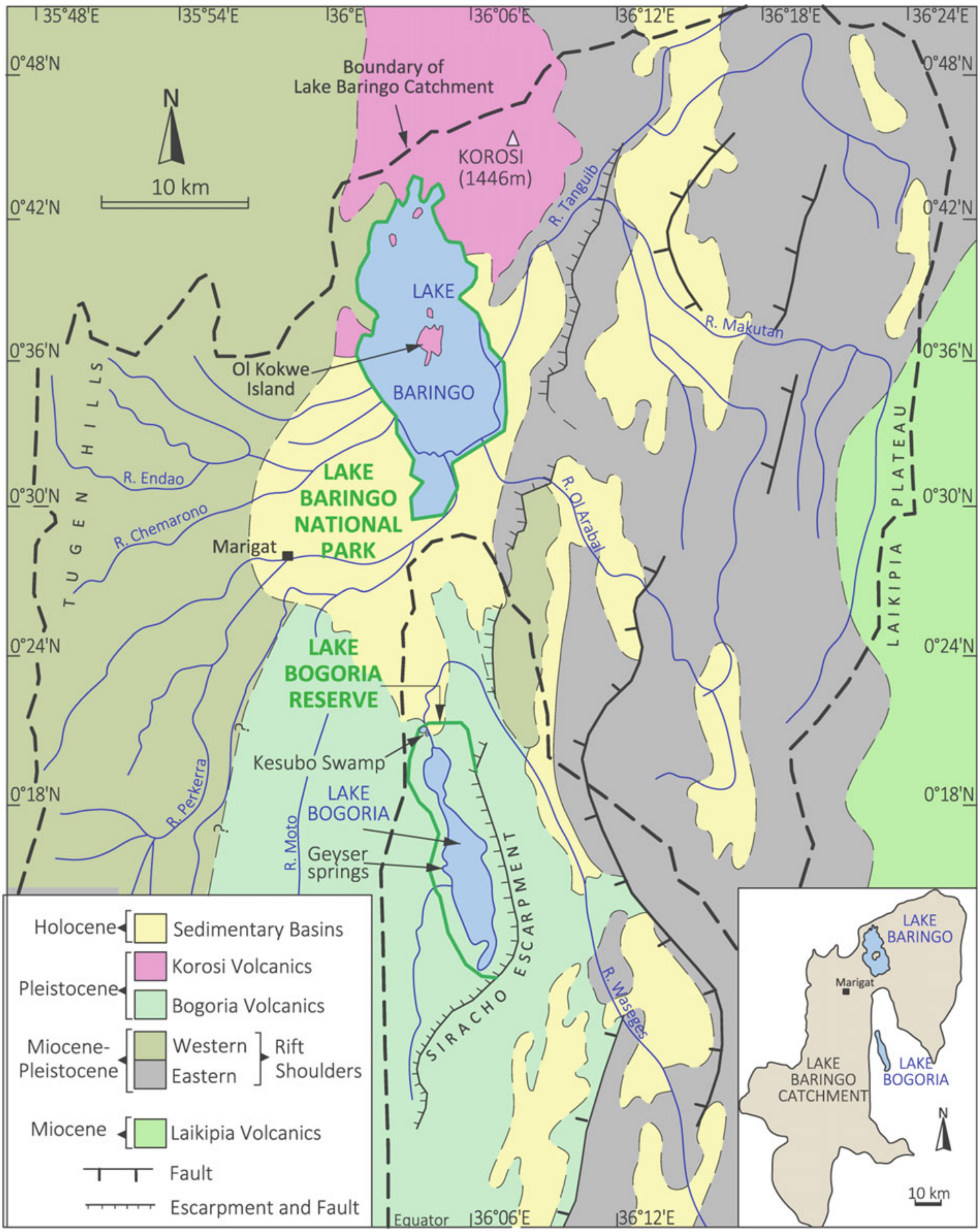

Fig. 15.2 Geological map of the area around Lakes Baringo and Bogoria simplified from various sources including Woolley (2001)

western side of the valley is rather poorly defined. Lake Baringo is fed from a relatively large basin with rivers flowing from both the north and south. The absence of outlets causes the depth of the lake (average of 5 m) to vary considerably. The level has risen almost 5 m in recent years, probably due to increased rainfall. Lake Baringo supports fishing for both the local population and tourists (several endemic freshwater fish occur). During times of drought, when grazing was poor on the foreshore, one of the local tribal groups, the Njemps (or Il Chamus) also known as the 'People with the Swimming Cows' traditionally migrated to the islands with their cattle swimming next to their canoes.

The unusual shape of the Baringo catchment (inset, Fig. 15.2) is ascribed to detachment blocks on the edge of the Gregory Rift Valley, i.e. the Aberdare Mountains to the east and the Elgeyo Block to the west. Two examples illustrate the complexity of the drainage due to recent tectonism. The Molo River drains part of the Mau Escarpment near Lake Natron and yet flows northwards, skirting Lake Bogoria before feeding Lake Baringo. Conversely, some rivers that rise near Lake Baringo channel water either northwards into Lake Turkana or southwards into Lake Nakuru. The uplifted fault block on the eastern extremity of the Baringo basin is comprised of the Early Miocene-age Laikipia Plateau Volcanics (Woolley 2001). The shoulders of the eastern and western rift platforms are dominated by volcanic groups which cover Late Miocene, Pliocene and Pleistocene ages. The volcanics include thick units of resistant lavas through which rivers have carved narrow gorges (Plate 15.2a).

The stratigraphy of the Baringo basin has been investigated using radiometric dating of the volcanic rocks as part of calibrating the interrelated fossiliferous sedimentary units in the region. These latter include the Tugen Hills, an uplifted block located in this relatively wide section of the rift valley, which encompass a period of at least 14 Ma, from the Late Miocene through to the Pleistocene. Paleontological finds include vertebrates which have yielded evidence of a relatively rapid evolutionary pattern (Hill et al. 1986). The Tugen Hills has also yielded important hominin finds (Wood 1999). Fossils from this area are exhibited in the Smithsonian Museum, Washington.

The centre of the rift valley in the vicinity of Lake Baringo is dominated by Pleistocene-age volcanics (Fig. 15.2). They include the Korosi Volcanics (0.38–0.10 Ma), derived from a large cone that rises some 500 m above the valley floor to the northeast of the lake (Woolley 2001). The dominantly basaltic and trachytic lavas of this volcano cover an area of 260 km^2, including large areas around the lake and several islands. The northern part of the Ol Kokwe Island is formed by a coalescence of basaltic scoria cones (Plate 15.2b), with the southern part associated with trachytic lava flows. Sulphur-rich fumaroles, hot springs and gossans (hydrothermally altered rocks with oxidised sulphides) occur on this and other islands in Lake Baringo (Fig. 15.3a). Discharge into the lake causes small bays to concentrate sulphurous waters. A large sedimentary basin dominated by Holocene fill occurs to the south of Lake Baringo.

15.4 Lake Bogoria National Reserve

J. W. Gregory described Lake Bogoria, where the Siracho Escarpment rises some 600 m above the rift valley as having the 'most beautiful view in Africa'. This lake is well known for geothermal features including geysers and hot springs (Plate 15.1). The abundance of geothermal features has resulted in sulphurous waters ponding near the foreshore in some areas (Plate 15.3a). The reserve was established in 1973 to protect the remote wilderness area of an area formerly known as Lake Hannington (Plate 15.3b). The northern foreshore can be a relative hostile environment with extensive salt flats and volcanic cliffs (Plate 15.3c). The length of 35 km and width of 3.5 km is characteristic of many of the alkaline lakes of the Gregory Rift Valley, as is the alkalinity (pH of 10.5). Most water in the Bogoria basin is sourced from the Waseges (or Sandai) River, which rises on the lower slopes of the Aberdare Range (Fig. 15.2). Lake Bogoria is somewhat deeper (maximum depth of 10 m) than many of the other alkaline lakes. The absence of outlets has retained a palaeo-stratification: less dense surface waters overlie denser, more saline basal waters. The composition shows considerable variability and high concentrations of the metals sodium, potassium, arsenic, fluorine and the rare earth elements, typical of the surrounding volcanic rocks have been identified (Jirsa et al. 2013). Several hundred hot (alkaline) springs located near the lake supply high concentrations of acids (including HCO_3^- and CO_3^{2-}), as discussed by Renaut and Tiercelin (1993, 1994). The rocky, barren shores of the lake include flows of phonolite, part of the Pleistocene-age Lake Bogoria Volcanics (Plate 15.3c). Fluviolacustrine sediments with reddish coloured beds, rich in zeolitic clays, which are up to 1 m thick, occur on the northern foreshore (Renault 1993).

Lake Bogoria was part of an enlarged palaeo-lake which included Lake Baringo in the Early Holocene (Fig. 6.1). Drill cores of sediments underlying the lake reveal evidence of regular changes from alkaline to freshwater during the Late Holocene. Some access roads within the reserve have been submerged since 2013 and the level remains anomalously high. New access tracks, cut through the poorly vegetated lava flows, enhance the feeling of a barren landscape. Geothermal activity on the shores of the lake includes geysers, hot springs and steam jets (Renaut and Owen 2005). Eighteen geysers have been documented (they once spouted to heights of 5 m), although activity has waned in recent years and is currently restricted to small fountains and hot pools, typically with abundant sulphur and algae. The colour of the hot pools is related to temperature, a feature that is well known from the geyser fields in the Yellowstone National Park in the state of Wyoming. Yellow and green pools contain algae and report temperatures of 60–70 °C and 50–60 °C, respectively. The brown pools contain mosses, crustaceans and insects at temperatures of 27–50 °C.

15.5 Lake Nakuru National Park

Lake Nakuru is located near the regional town of the same name and has long been protected in a national park famous for both large herbivores and aquatic birds (Fig. 15.3). The lake occurs at an altitude of 1,754 m, considerably higher than the lakes farther north. The size is very variable (5–45 km^2) and the depth is rarely more than 3 m. In the early 1990s, the lake almost dried up entirely. The lake is moderately alkaline (pH of 10). During a drought in 2009 when the water level dropped drastically, the total salinity rose from 20% to a remarkable 63% (Jirsa et al. 2013). In recent years, however, the lake has been so full as to be less saline and has flooded parts of the foreshore (Plate 15.4a). The principal water source is the Njoro River which flows eastwards from the Mau Forest. Aquifers in the basin are composed of lacustrine deposits derived from erosion and redeposition of volcanic rocks (McCall 1967). Views from Baboon Cliff, an eroded lava flow on the western shore provide an excellent panorama (Plate 15.4b). Hyrax Hill is an important archaeological site with Neolithic and Stone Age remains.

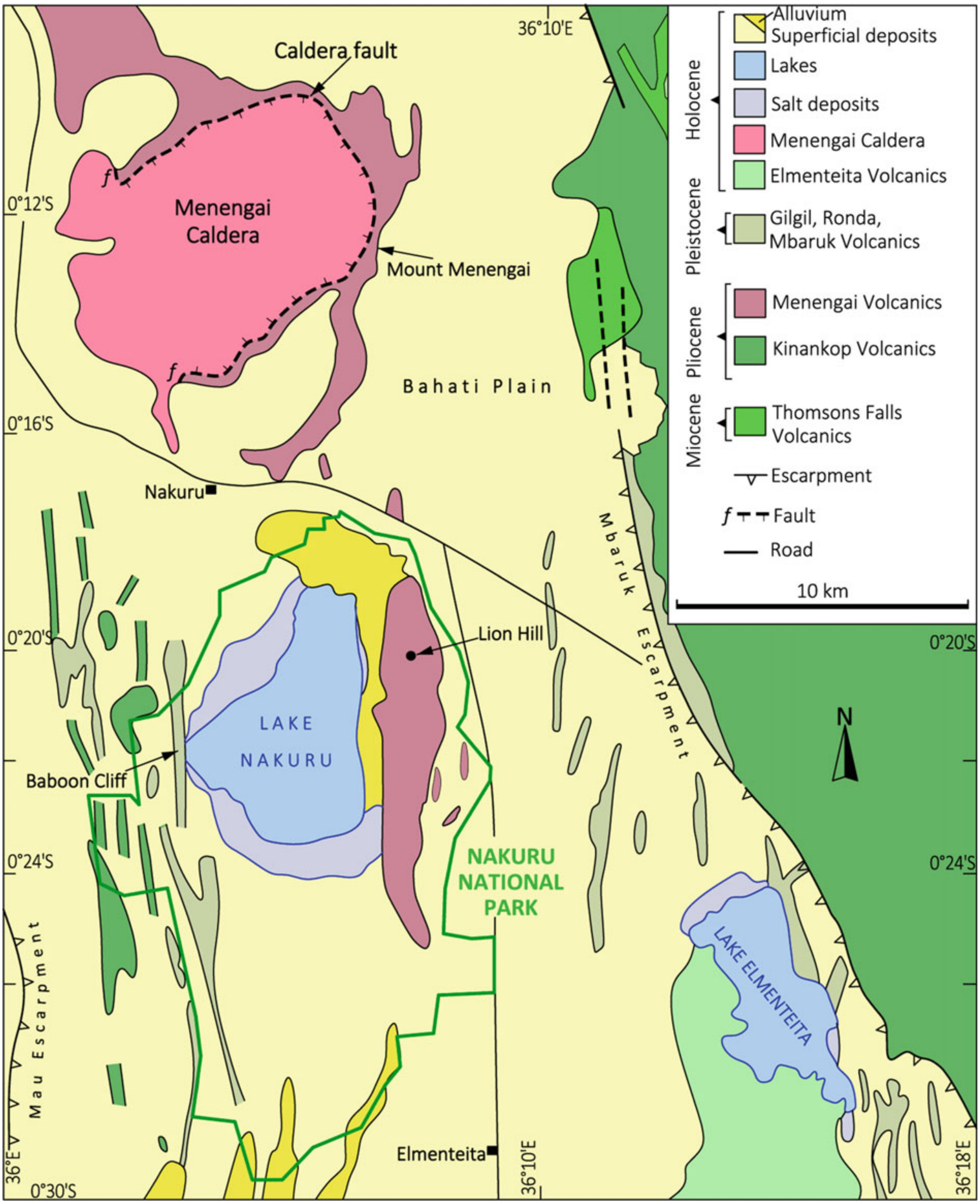

Fig. 15.3 Geological map of the area around Lakes Nakuru and Elmenteita simplified from the Nakuru Quarter Degree Sheet 43 (1966) and accompanying report by McCall (1967)

15.6 Lake Elmenteita

Lake Elmenteita is located close to the Mbaruk Escarpment to the south of Lake Nakuru (Fig. 15.3). The lake is extremely shallow (less than 1 m deep) and moderately alkaline (average pH of 10). Lake Elmenteita is fed from the Mereroni River, which drains the Bahati Plain and highlands to the north and east within a small basin. Elmenteita may be connected with Lake Nakuru via underground aquifers. The lake is a protected RAMSAR site due to its birdlife and has been named by UNESCO as a world heritage site (Plate 1.2 e, f). The Kekopey hot springs at the southern end of the lake are the breeding site for an introduced species of tilapia that may have caused the flamingo population to decrease markedly. It has been estimated that the tilapia caused over a million flamingoes, which formerly bred on Lake Elmenteita, to migrate to Lake Natron.

15.7 Lake Magadi

Lake Magadi occurs in a large basin located at a relatively low altitude of approximately 600 m in southern Kenya. This section of the Gregory Rift Valley is unusually desolate and reports a hot, arid climate (Baker 1958; Vincens and Casanova 1987). The Magadi basin is surrounded by volcanic cones and plateaus with altitudes of up to 3,000 m. Views include the extensive Nguruman Escarpment on the western side of the rift (Plate 15.5a). The lake is rarely more than 1 m deep and in dry seasons, approximately 80% is covered by salt deposits. The concentrated and extremely dense alkaline brines (pH of 12) are caustic enough to burn the skin. Small pools on the margins of the lake are even more toxic and tree and animal remains are fossilised by sodium carbonate. There is little surface run-off and saline springs with temperatures of up to 85 °C are the main supply of brines. Lake Magadi contains a single species of cichlid fish (*Alcolapia grahami*) that has evolved to cope with both the extreme alkalinity and high temperatures (up to 45°). Extensive salt deposits have precipitated from the sodic brines in the vicinity of the lake (Eugster 1970, 1980; Jones et al. 1977). They include layers of sodium carbonate salt up to 40 m thick, some of which are quarried to produce soda ash. The salt is a mixture of two minerals, *natron* (mix of sodium carbonate decahydrate [$Na_2CO_3.10H_2O$] and sodium bicarbonate [$NaHCO_3$]) and *trona* (sodium sesquicarbonate dihydrate [$Na_3CO_3.HCO_3.2H_2O$]) (Behr 2002). The salt deposits are intercalated with the *Magadi chert* (microcrystalline silica) which is derived from the dissolution of a rare sodium silicate mineral (*magadiite*) first identified here. The chert also occurs as dyke-like bodies that were injected into the bedded deposits when the silica was soft enough to be deformed.

The source of the water in the Magadi–Natron Basin was investigated by Kaufmann et al. (1990) using the ^{36}Cl methodology. The chemistry of the surface brines is consistent with derivation from precipitation (with no evidence of dissolved Cl entering the system). Deeper level brines, however, reveal compositions indicative of recharge during a different climatic era. An age of 0.76 Ma for the accumulation of the salt deposits has been determined. This may correlate with the maximum age of the lake.

15.8 Lake Manyara National Park

Lake Manyara occupies some two-thirds of the park that is accessed from the small town of Mto-Wa-Mbu which nestles below the Western Escarpment of the Gregory Rift Valley, northern Tanzania. The setting, described by Ernest

Hemingway as 'the loveliest lake in Africa' includes views of the steep, thickly forested escarpment (Plate 5.1). The eastern side of the valley in this area (a half-graben) is a gently sloping plain. The extent (maximum area of 230 km^2), depth (average of 3.7 m) and alkalinity (pH of 9.5) of Lake Manyara vary considerably. Large areas of salt flats and mud banks are exposed during dry seasons. The lake is fed by the Simba and Makayuni Rivers. Hot springs and pools with multicoloured algae occur near the south-western shore (Plate 15.5b). The basin is partially infilled by the Manyara Group, a thick sequence of sediments and volcaniclastics (derived from the Ngorongoro Highlands) that have been described and investigated in detail by Schwartz et al. (2012). Modern vertebrate tracks have been used to ascertain the palaeobiological setting of the lake (Cohen et al. 1993). The western shore of Lake Manyara is nurtured by underground springs replenished from the Ngorongoro Highlands. The Kwakuchinja wildlife corridor, situated to the east of Lake Manyara, allows wildlife to migrate between the Tarangiri National Park, the Ngorongoro Highlands and the Serengeti Plains (Fig. 1.1).

15.9 Lake Eyasi

The seasonal, highly saline and alkaline Lake Eyasi, the southernmost of the large lakes in the Gregory Rift Valley is located below a huge escarpment capped by volcanic rocks of the Ngorongoro Volcanic complex. The principal inflow to the lake is from the Sibiti River on the southern end. The lake may dry completely during the dry season—when it can be exposed to severe aeolian deflation—and even during the wet season depths rarely exceed 1 m. The Mumba Rock Shelter has yielded important archaeological findings that include stone artefacts (Late Middle Stone Age as well ostrich eggshell beads. Fossil evidence suggests that *Homo sapiens* lived in the approximately 20 m high shelter at 130,000 BP. Lake levels in recent years have been sufficiently high as to partially submerge the shelter.

15.10 RAMSAR Status and Flamingo

Most lakes in the Gregory Rift Valley have been afforded RAMSAR status as they contain important wetlands. Some lakes are sanctuaries for as many as 500 bird species. Lakes Baringo and Naivasha in particular reveal a great diversity of birds, and reserves here include large mammals and reptiles. Concentrations of endangered species of large mammals are most notably protected in the Nakuru and Manyara National Parks. The latter is well known for studies of elephant behaviour. Many of the alkaline lakes are famous for one of the world's greatest spectacles: the concentration of flamingo (Plate 1.2e, f). They were formerly so numerous (several millions), as to change the colour of shorelines, most notably on Lake Nakuru. The flamingo has evolved remarkably efficient filtration systems to cope with lake brines that are poisonous to most other species. Their principal food is cyanobacteria which flourish in highly alkaline waters. At their peak, the flamingos were so numerous on Lake Nakuru, they consumed some 250,000 kg of algae per hectare of surface water annually. Some 20 years ago the number of flamingo decreased, either due to pollution from increased land usage in catchments, or simply higher rainfall. High water levels since 2013 have exacerbated the problem as decreased alkalinity inhibits algal growth. The loss of flamingo from Lake Nakuru was initially balanced by an incremental increase at Lake Bogoria, but recently the numbers have decreased here as well. Whether pollution or non-reversal climatic shifts are the cause is not known. In summary, lakes in the Gregory Rift are extremely sensitive to both climatic fluctuations and land-use changes in their catchment.

Plate 15.2 **a** Rivers in the Lake Baringo basin have carved narrow gorges in the volcanic lavas on the western side of the rift valley; **b** Basaltic lavas on Ol Kokwe Island, Lake Baringo

Plate 15.3 **a** Sulphurous waters near geysers and hot springs pond on the edge of Lake Bogoria; **b** The Lake Bogoria National Reserve was established in 1973 to conserve the area around 'Lake Hannington'; **c** The northern foreshore of Lake Bogoria includes extensive salt flats with cliff faces (foreground) of the Bogoria Volcanics and the Siracho Escarpment (background)

Plate 15.4 **a** The high water level in 2015 resulted in flooding of the northern foreshore of Lake Nakuru; **b** View of Lake Nakuru from Baboon Cliff, a resistant rampart of lavas and ashes

Plate 15.5 **a** View of the soda ash works on the eastern shore of Lake Magadi (centre) with part of the Nguruman Escarpment (background) in southern Kenya. Source: Public domain website https://www.flickr.com/photos/ninara/15563504833; **b** Hot springs have created deposits of travertine with algae on the western shore of Lake Manyara

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