9 Lacustrine Systems

Introduction

Lacustrine systems have assumed new importance with the growing recognition that they contain some of the richest oil-prone source rocks, which in many extensional basins are located in zones of high thermal maturation, in close proximity to porous synrift or postrift reservoirs. Rift-basin lake systems underlie many passive-margin basins, where they may constitute a rich hydrocarbon source. Apart from their hydrocarbon potential, lacustrine systems host substantial coal and uranium resources, as well as bedded metalliferous ores and commercially important evaporites such as trona. Indeed, the physical and chemical environments encountered in lakes produce diverse mineral associations, some of which are diagnostic of lacustrine environments. Resources which are presently being recovered from the East African rift system, for example, include diatomites, zeolites, sodium silicate, metallic proto-ores, phosphates, and coal, while lake-floor sediments of Lake Kivu contain substantial volumes of methane, largely of bacterial origin (Tiercelin 1991).

The lingering imprint on the modern landscape of the Pleistocene Ice Age has placed considerable emphasis on lakes of glacial origin, which are generally numerous but small (Hakanson and Jansson 1983). Of the 25 largest lakes by surface area today, however, ten are of glacial origin, seven occupy cratonic depressions, and four are in rifts (Smith 1990). In contrast to the modern lacustrine landscape, over much of the geologic past large lakes were generally a product of tectonic processes. Therefore, despite the diverse range of modern settings, ranging from glacially scoured depressions and moraine- or lava-impounded valleys to meteorite-impact craters, the lacustrine systems of greatest interest to oil and mineral explorers originated in rift basins and structural sags.

Lacustrine models for petroleum exploration have focused in recent years on the East African rift system (Fig. 9.1). Some of these lakes are regarded as being closely analogous to major oil-producing provinces, such as Mesozoic rift basins along the South Atlantic margin (McHargue 1990; Abrahão and Warme 1990). Given the requisite tectonic and climatic setting, some of the richest oil-prone source rocks originated in large, long-lived lakes of equatorial latitude, low altitude, and moderate depth in the range of 50–400 m (165–300 ft) (Katz 1990), as well as deeper systems comparable to the modern East African rift lakes. Other ancient lake systems are gas prone as a result of abundant dispersed type III organic matter of land-plant origin (Smyth 1979; Smyth et al. 1992). Apart from hydrocarbons, the depositional lake margins provide a platform for peat accumulation and account for some of the world's largest coalfields, while the geochemical and permeability contrasts in fluvial and shore-zone systems bordering mud-rich lake facies are ideal for epigenetic uranium mineralization. Lacustrine sediments also include well-integrated aquifers and convergent groundwater-flow systems, which are a crucial resource in some arid interior basins.

Factors Controlling Lake Geometry and Hydrology

The overriding controls on lake geometry and hydrology are tectonism and climate. The size, configuration, and topographic relief of a lake basin and its catchment are generally determined by tectonism, while lake level and water chemistry are a function of climate.

Tectonism

Lakes occupying zones of crustal extension and wrench tectonics are typically deep and narrow,

W. E. Galloway et al., *Terrigenous Clastic Depositional Systems*

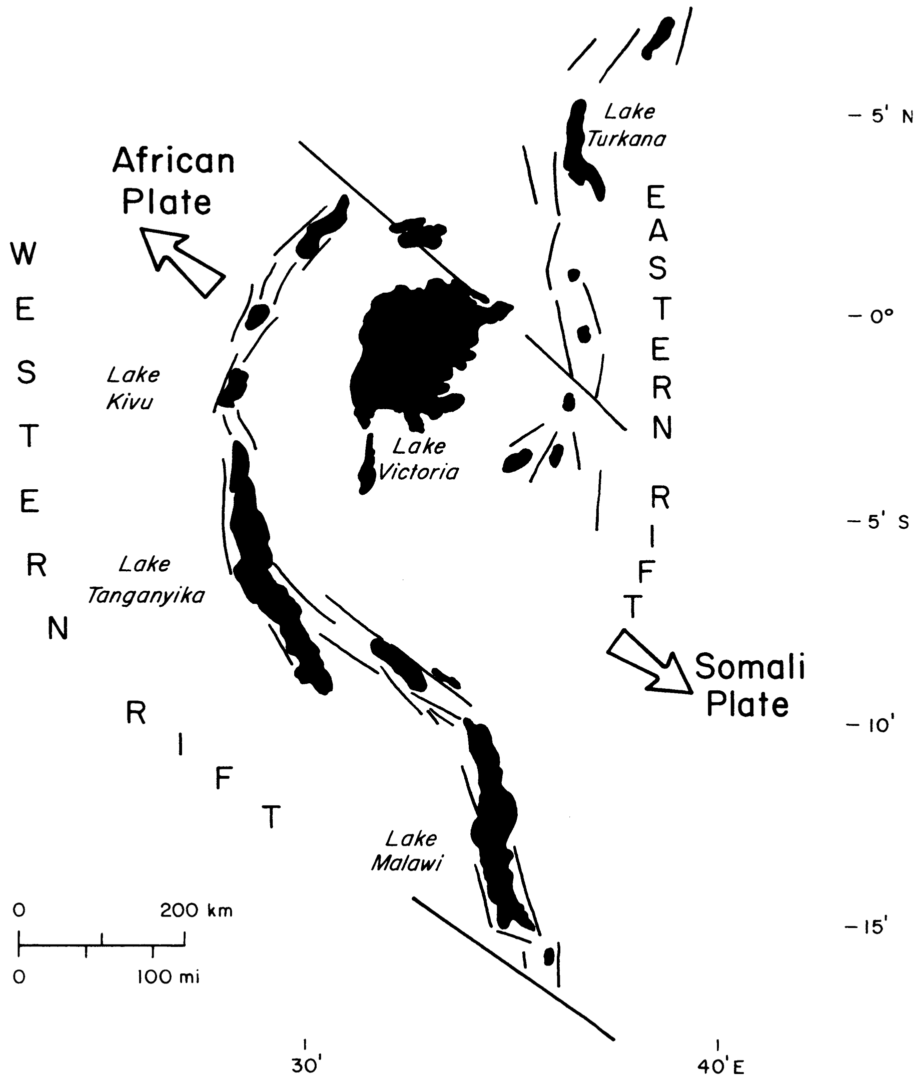

Fig. 9.1. Lakes of the East African rift system, showing distribution of lakes in the arid, volcanic Eastern Rift and more humid Western Rift. (Modified from Huc et al. 1990; Nelson et al. 1992b)

whereas lakes in cratonic sags, foreland basins, and nontectonic environments tend to be shallower relative to surface area (Katz 1990). Lake Victoria, for example, occupies a crustal sag and covers an area of 70 000 km^2 (27 000 mi^2) but is only some 80 m (265 ft) deep, whereas nearby Lake Tanganyika, located within the rift valley, is only one half of Lake Victoria's surface area but is 1500 m (5000 ft) deep. Tectonism also governs the drainage area and gradient of inflowing streams, and therefore the texture and volume of sediment supplied to the lake basin.

Rift-Valley Lakes

The East African Rift system comprises an eastern branch, where syntectonic alkaline volcanism has resulted in rapid basin filling, and a volcanically less active western branch with deeper lakes. Thicknesses of Cenozoic fill reach 6 km (20 000 ft) and 4.5 km (15 000 ft) beneath Lakes Tanganyika and Malawi, respectively (Tiercelin 1991).

Although some of the rift basins are symmetrical, most are asymmetric half-grabens, with a steep border-fault escarpment on one side and a