The Great Rift Valley

Olduvai Gorge, in Tanzania's Great Rift Valley, is one of the most important sites for the study of human evolution. Olduvai, also known as Oldupai, was the site of a large lake 500,000 years ago.

Introduction to Rift Valleys – (excerpt from National Geographic – Education)

A rift valley forms where the Earth’s crust, or outermost layer, is spreading or splitting apart. This kind of valley is often narrow, with steep sides and a flat floor.

Rift valleys are also called grabens, which means “ditch” in German. While there is no official distinction between a graben and a rift valley, a graben usually describes a small rift valley.

Rift valleys differ from river valleys and glacial valleys because they are created by tectonic activity and not by the process of erosion.

Rift valleys are created by plate tectonics. Tectonic plates are the huge rocky slabs made up of the Earth's crust and upper mantle. They are constantly in motion—shifting against each other, falling beneath one another (a process called subduction), crashing against one another. Tectonic plates also tear apart from each other. Where plates move apart, the Earth’s crust separates, or rifts. Rift valleys can lead to the creation of entirely new continents, or deepen valleys in existing ones.

Many rift valleys have been found underwater, along the large ridges that run throughout the ocean. These mid-ocean ridges are formed as tectonic plates move away from one another. As the plates separate, molten rock from the Earth’s interior may well up and harden as it contacts the sea, forming new oceanic crust at the bottom of the rift valley.

This occurs along the northern crest of the Mid-Atlantic Ridge, where the North American plate and the Eurasian plate are splitting apart. The Mid-Atlantic Ridge rifts at an average of 2.5 centimeters (1 inch) per year. Over millions of years, the Mid-Atlantic Ridge has formed rift valleys as wide as 15 kilometers (9 miles).

In the Pacific Ocean, the East Pacific Rise has created rift valleys where the Pacific plate is separating from the North American plate, Riviera plate, Cocos plate, Nazca plate, and Antarctic plate. (The Pacific plate is the largest on Earth.) Like many underwater rift valleys, the East Pacific Rise is dotted with hydrothermal vents. The geologic activity beneath the underwater rift valley creates these vents, which spew super-heated water and sometimes-toxic vent fluids into the ocean.

There are only two rift valleys on Earth within continental crust, the Baikal Rift Valley and the East African Rift. Tectonic activity splits continental crust much in the same way it does along mid-ocean ridges. As the sides of a rift valley move farther apart, the floor sinks lower.

The deepest continental rift valley on Earth is the Baikal Rift Valley in the Siberian region of northeastern Russia. Lake Baikal, the deepest and oldest freshwater lake in the world, lies in the Baikal Rift Valley. Here, the Amur plate is slowly tearing itself away from the Eurasian plate, and has been doing so for about 25 million years. The deepest part of Lake Baikal is 1,187 meters (3,893 feet), and getting deeper every year. Beneath this is a layer of soft sediment reaching several kilometers. The actual bottom of the rift extends about 10 kilometers (6.2 miles) deep.

The Great Rift Valley

Historically, geologists and geographers referred to the "Great Rift Valley System" which stretched from the Middle East in the north to Madagascar in the south. The area is geologically active, and features hot springs, geysers, and frequent earthquakes. Today, however, the Great Rift Valley only remains as a cultural concept. Each of the rift valleys in the area are connected, but not part of a single system.

The Jordan Rift Valley stretches between Jordan and Israel in western Asia. The Jordan Rift Valley includes the Dead Sea, at 377 meters (1,237 feet) the lowest land elevation on Earth. Unlike Lake Baikal, however, the Dead Sea was not formed entirely by the rift beneath it. The so-called Dead Sea Transform is a very geologically complex area, where many tectonic plates interact in many ways.

South of the Jordan Rift Valley is the Red Sea Rift. Millions of years ago, the Arabian Peninsula was connected to Africa. The Arabian and African plates rifted apart and the Indian Ocean flooded the rift valley, creating the Red Sea. The rift continues, and the Red Sea, rich in marine life, widens every year.

South of the Red Sea Rift lies the massive, complex East African Rift. This system of rift valleys is usually what people think of as the "Great Rift Valley." Throughout the East African Rift, the African plate is splitting in two. The Nubian plate carries most of the continent, while the smaller Somali plate carries Horn of Africa. As the rift continues, the rift valley may sink enough that the Gulf of Aden will flood it. The Horn of Africa (sitting on the Somali plate) would become a continental island, like Madagascar or New Zealand.

East Africa's Great Rift Valley: A Complex Rift System

by James Wood and Alex Guth - Michigan Technological University

Part I. The East African Rift System

The East African Rift System (EARS) is one the geologic wonders of the world, a place where the earth's tectonic forces are presently trying to create new plates by splitting apart old ones. In simple terms, a rift can be thought of as a fracture in the earth's surface that widens over time, or more technically, as an elongate basin bounded by opposed steeply dipping normal faults. Geologists are still debating exactly how rifting comes about, but the process is so well displayed in East Africa (Ethiopia-Kenya-Uganda-Tanzania) that geologists have attached a name to the new plate-to-be; the Nubian Plate makes up most of Africa, while the smaller plate that is pulling away has been named the Somalian Plate (Figure 1). These two plates are moving away from each other and also away from the Arabian plate to the north. The point where these three plates meet in the Afar region of Ethiopia forms what is called a triple-junction. However, all the rifting in East Africa is not confined to the Horn of Africa; there is a lot of rifting activity further south as well, extending into Kenya and Tanzania and Great Lakes region of Africa. The purpose of this paper is to discuss the general geology of these rifts are and highlight the geologic processes involved in their formation.

Figure 1: Colored Digital Elevation Model showing tectonic plate boundaries, outlines of the elevation highs demonstrating the thermal bulges and large lakes of East Africa.

What is the East Africa Rift System?

The oldest and best defined rift occurs in the Afar region of Ethiopia and this rift is usually referred to as the Ethiopian Rift. Further to the South a series of rifts occur which include a Western branch, the "Lake Albert Rift" or "Albertine Rift" which contains the East African Great Lakes, and an Eastern branch that roughly bisects Kenya north-to-south on a line slightly west of Nairobi (Figure 2). These two branches together have been termed the East African Rift (EAR), while parts of the Eastern branch have been variously termed the Kenya Rift or the Gregory Rift (after the geologist who first mapped it in the early 1900's). The two EAR branches are often grouped with the Ethiopian Rift to form the East Africa Rift System (EARS). The complete rift system therefore extends 1000's of kilometers in Africa alone and several 1000 more if we include the Red Sea and Gulf of Aden as extensions. In addition there are several well-defined but definitely smaller structures, called grabens, that have rift-like character and are clearly associated geologically with the major rifts. Some of these have been given names reflecting this such as the Nyanza Rift in Western Kenya near Lake Victoria. Thus, what people might assume to be a single rift somewhere in East Africa is really a series of distinct rift basins which are all related and produce the distinctive geology and topography of East Africa.

How did these Rifts form?

The exact mechanism of rift formation is an on-going debate among geologists and geophysicists. One popular model for the EARS assumes that elevated heat flow from the mantle (strictly the asthenosphere) is causing a pair of thermal "bulges" in central Kenya and the Afar region of north-central Ethiopia. These bulges can be easily seen as elevated highlands on any topographic map of the area (Figure 1). As these bulges form, they stretch and fracture the outer brittle crust into a series of normal faults forming the classic horst and graben structure of rift valleys (Figure 3). Most current geological thinking holds that bulges are initiated by mantle plumes under the continent heating the overlying crust and causing it to expand and fracture. Ideally the dominant fractures created occur in a pattern consisting of three fractures or fracture zones radiating from a point with an angular separation of 120 degrees. The point from which the three branches radiate is called a "triple junction" and is well illustrated in the Afar region of Ethiopia (Figure 4), where two branches are occupied by the Red Sea and Gulf of Aden, and the third rift branch runs to the south through Ethiopia.

The stretching process associated with rift formation is often preceded by huge volcanic eruptions which flow over large areas and are usually preserved/exposed on the flanks of the rift. These eruptions are considered by some geologists to be "flood basalts" - the lava is erupted along fractures (rather than at individual volcanoes) and runs over the land in sheets like water during a flood. Such eruptions can cover massive areas of land and develop enormous thicknesses (the Deccan Traps of India and the Siberian Traps are examples). If the stretching of the crust continues, it forms a "stretched zone" of thinned crust consisting of a mix of basaltic and continental rocks which eventually drops below sea level, as has happened in the Red Sea and Gulf of Aden. Further stretching leads to the formation of oceanic crust and the birth of a new ocean basin.

Figure 2: Rift segment names for the East African Rift System. Smaller segments are sometimes given their own names, and the names given to the main rift segments change depending on the source.

Part II. The East African Rift

If the rifting process described occurs in a continental setting, then we have a situation similar to what is now occurring in Kenya where the East African/Gregory Rift is forming. In this case it is referred to as "continental rifting" (for obvious reasons) and provides a glimpse into what may have been the early development of the Ethiopian Rift.

As mentioned in Part I, the rifting of East Africa is complicated by the fact that two branches have developed, one to the west which hosts the African Great Lakes (where the rift filled with water) and another nearly parallel rift about 600 kilometers to the east which nearly bisects Kenya north-to-south before entering Tanzania where it seems to die out (Figure 2). Lake Victoria sits between these two branches. It is thought that these rifts are generally following old sutures between ancient continental masses that collided billions of years ago to form the African craton and that the split around the Lake Victoria region occurred due to the presence of a small core of ancient metamorphic rock, the Tanzania craton, that was too hard for the rift to tear through. Because the rift could not go straight through this area, it instead diverged around it leading to the two branches that can be seen today.

As is the case in Ethiopia, a hot spot seems to be situated under central Kenya, as evidenced by the elevated topographic dome there (Figure 1). This is almost exactly analogous to the rift Ethiopia, and in fact, some geologists have suggested that the Kenya dome is the same hotspot or plume that gave rise to the initial Ethiopian rifting. Whatever the cause, it is clear that we have two rifts that are separated enough to justify giving them different names, but near enough to suggest that they are genetically related.

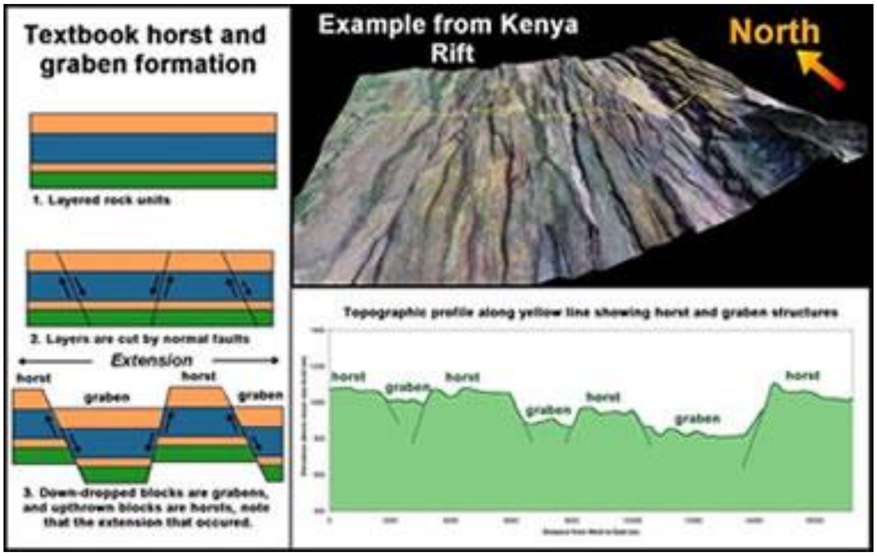

Figure 3: "Textbook" horst and graben formation (left) compared with actual rift terrain (upper right) and topography (lower right). Notice how the width taken up by the trapezoidal areas undergoing normal faulting and horst and graben formation increases from top to bottom in the left panel. Rifts are considered extensional features (continental plates are pulling apart) and so often display this type of structure.

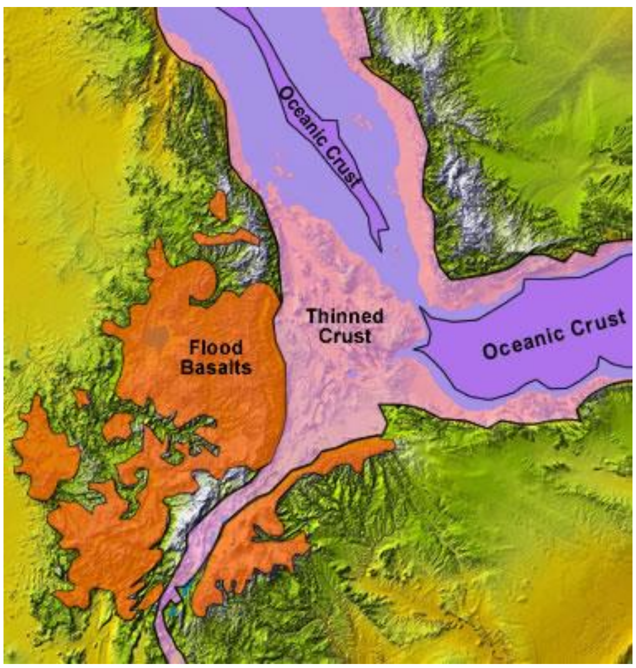

Figure 4: Triple Junction in the Afar region of Ethiopia. Image shows areas of stretched and oceanic crust as well as areas of exposed flood basalts that preceded rifting. Areas unshaded or covered by flood basalts represent normal continental crust. As the crust is pulled apart you end up with thinned crust with a complex mixture of continental and volcanic rock. Eventually the crust thins to the point where oceanic-type basalts are erupted which is the signal that new ocean crust is being formed. This can be seen in the Gulf of Aden as well as a small sliver within the Red Sea. The original extent of the flood basalts would have been greater, but large areas have been buried within the rift valley by other volcanic eruptions and sediments.

Other Points of Interest:

What else can we say about the Ethiopian and Kenya Rifts? Quite a lot actually; even though the Eastern and Western branches were developed by the same processes they have very different characters. The Eastern Branch is characterized by greater volcanic activity while the Western Branch is characterized by much deeper basins that contain large lakes and lots of sediment (including Lakes Tanganyika, the 2nd deepest lake in the world, and Malawi).

Recently, basalt eruptions and active crevice formation have been observed in the Ethiopian Rift which permits us to directly observe the initial formation of ocean basins on land. This is one of the reasons why the East African Rift System is so interesting to scientists. Most rifts in other parts of the world have progressed to the point that they are now either under water or have been filled in with sediments and are thus hard to study directly. The East African Rift System however, is an excellent field laboratory to study a modern, actively developing rift system.

This region is also important for understanding the roots of human evolution. Many hominid fossil finds occur within the rift, and it is currently thought that the rift's evolution may have played an integral role in shaping our development. The structure and evolution of the rift may have made East Africa more sensitive to climate changes which lead to many alternations between wet and arid periods. This environmental pressure could have been the drive needed for our ancestors to become bipedal and more brainy as they attempted to adapt to these shifting climates

Conclusions:

The East African Rift System is a complicated system of rift segments which provide a modern analog to help us understand how continents break apart. It is also a great example of how many natural systems can be intertwined - this unique geological setting may have altered the local climate which may have in turn caused our ancestors to develop the skills necessary to walk upright, develop culture and ponder how such a rift came to be. Just like the Grand Canyon, the East African Rift System should be high on any geologist's list of geologic marvels to visit.