

## Rifting in Eastern North America

by Roy W. Schlische

October 28, 1983. An earthquake registering 7.3 on the Richter scale and centered near Borah Peak shook a large part of south-central Idaho and neighboring states. The earthquake produced a set of fault scarps (offsets of the ground surface) up to 2.7 m in height and 35 km long. The southwestern side of the Lost River fault (which produced the earthquake) moved down 1.5 meters while the northeastern side moved up about a half meter. The Lost River fault is known as a normal fault because the block of rock above the fault plane moved down relative to the block of rock below the fault plane.

Earthquakes similar to 1983 Borah Peak event have repeatedly occurred along the Lost River fault for the last 10 million years. In the process, a large depression about 1.5 km deep formed on the southwestern side of the Lost River fault. This depression, which is known as a basin, became infilled with sediments (mud and sand) and lava flows. The sediments were derived mainly from the Lost River Range, the mountain chain located on the uplifted side of the fault. An identical process has occurred throughout this part of North America, producing a region known as the Basin and Range Province.

About 235 million years ago, in the Triassic period of Earth's history, earthquakes along normal faults affected a wide region of what was to become eastern North America. This faulting produced a series of basins along the eastern seaboard from Nova Scotia to South Carolina. Basins located in Virginia include the Culpeper, Taylorsville, Richmond, and Danville basins.

What caused the faulting and basin formation? To answer that question, we need to know something about plate tectonics. This theory states that the Earth's outer shell consists of a series of rigid plates that move relative to one another. In places where two plates move apart, molten material rises up from within the Earth to fill the void left by the spreading plates. This material then cools to form oceanic crust. In other places, two plates move toward one another. Usually one plate sinks below the other. This is not possible if both

plates contain continental crust, which is not dense enough to sink. In that case, the continents collide and form a large mountain belt in the collision zone. For example, the Himalayas were produced when India slammed into Asia. A third type of plate movement involves two plates that slide past one another. This is currently occurring along the San Andreas fault, where the Pacific plate is shearing past the North American plate.

About 30 million years before basins began to form in eastern North America, the African plate rammed into the North American plate. This was the final stage in both the formation of the Appalachian mountain chain and the assembly of the supercontinent of Pangea. What caused this giant landmass to break apart in a process known as continental rifting? There are two possible explanations.

The first mechanism involves a plume of hot material that ascends from deep within the Earth and accumulates beneath the supercontinent. This hot, buoyant material causes uplift of the supercontinent. Much as the surface of a balloon is stretched as it is inflated with air, the supercontinent is stretched apart by the inflating action of the plume of hot material. As the region is stretched apart, the upper part of the continental crust fractures and forms normal faults and associated basins. In the process, continental crust becomes thinner—similar to a wad of chewing gum that is pulled apart. Eventually, the supercontinent breaks apart completely.

The supercontinent may also be pulled apart by forces generated far away. One way to create these tensional (pulling apart) forces is to surround the supercontinent by subduction zones—regions where one plate dives below another. The place on the Earth's surface where one plate sinks below another is called a trench. In some cases—particularly where the subducting material is old, cold, and very dense—the trench migrates away from the supercontinent. The two plates, however, must remain in contact, so the supercontinent is pulled toward the trench. If these tensional forces are sufficiently large or aided by a thermal plume

from within the Earth, the supercontinent will rift apart.

It is not clear which of these two mechanisms was operating 235 million years ago. Whatever the ultimate cause, the supercontinent experienced tensional forces. Consequently, earthquakes occurred on normal faults, and basins began to form along the entire length of what was to become eastern North America and its counterpart in northwestern Africa.

The rift basins in eastern North America are depressions elongated parallel to the normal faults that formed them and are shaped much like bananas. These faults generally trend in a northeasterly direction. The basins are about five times longer than they are wide. The basins can be quite deep: 2 km for the Danville basin, 3 km for the Richmond basin, and 5 km for the Culpeper basin. We should point out that these depressions are filled with sedimentary and igneous rocks.

In cross section (a vertical slice through the earth), rift basins in eastern North America have a triangular shape. The top leg of the triangle represents the present-day Earth's surface and is approximately horizontal. The other two sides of the triangle are inclined toward one another. The steeper of these two sides is the normal fault that created the basin. Geologists call this type of normal fault a border fault because it forms the boundary of the rift basin. In eastern North America, the border faults commonly occupy older fault surfaces that had formed during continental collision and mountain-building. An example of an older fault that was subsequently reactivated during rifting is the Hylas fault zone that forms the border fault of the Richmond basin.

The gentler of the inclined sides of the triangle forms the floor of the basin. This surface is the boundary between rocks that are older than the basin and the material infilling the basin. Originally this boundary was located at the Earth's surface, but faulting has progressively tilted it downward. Basins that exhibit the triangular geometry in cross section are termed half grabens. This type of basin is characteristic of regions that have been or are currently being pulled apart, including the Basin and Range, the East African rift system, and the Baikal rift system in Russia.

As we noted above, normal faulting produces a depression next to the downthrown side of the fault. Rivers flowing into these depressions bring sediments with them. These sediments are laid down essentially horizontally within the rift basin.

As faulting continues, these layered sediments are progressively tilted downwards and buried by younger sediments; they also become compacted into rock in the process. This mechanism produces a fan-shaped wedge of rock layers (strata) tilted toward the border fault. The oldest strata are inclined at the highest angle, the youngest at the smallest angle.

In the time interval since the basins formed in eastern North America, the top kilometer or two of rock has been removed by erosion. Because of the tilted nature of the strata, the youngest strata within the basin are exposed next to the border faults, and the rocks get progressively older toward the other side of the basin. Thus, in the Culpeper, Richmond, and Danville basins, the oldest strata are found on the southeastern margins of the basins, and the youngest strata are found next to the border faults on the northwestern edges.

In the first few million years of rifting, the basins were considerably smaller than they are now. During this time, rivers flowed across the floors of these basins, depositing some of their load of sediment and carrying the rest of it outside the basin. In some places, the rivers ponded into small lakes or swamps. In the Richmond basin, a large amount of plant debris accumulated within these swamps. During the Triassic period, the Richmond basin was situated within 200 km of the equator, and the tropical climate allowed extensive plant growth. The plant debris were subsequently buried by sediments and transformed into coal.

As rifting and faulting continued, the basins grew deeper, wider and longer. Eventually, the basins became closed depressions. This means that all sediment and water that flowed into the basin remained there, except for water that was lost to evaporation and seepage into the ground. Large lakes therefore began to form in these basins. In basins located near the Triassic equator, such as the Danville and Richmond basins, the lakes commonly became quite deep. These lakes were similar to the large, deep tropical lakes now filling rift basins in East Africa (Malawi and Tanganyika). In the Fundy basin, which was located farther north of the equator, the lakes were considerably shallower. When these lakes dried out, sand dunes blew across the dry lake bottom.

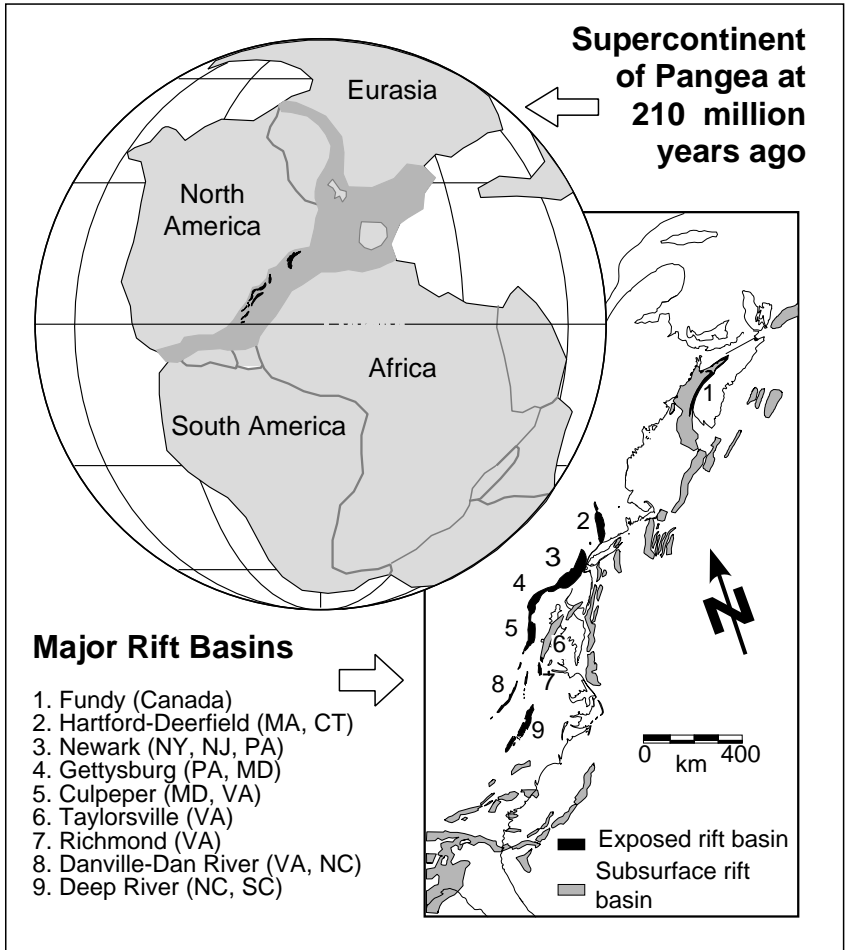
About 35 million years after rifting began, magma (molten rock)—perhaps derived from the plume responsible for rifting—made its way toward the surface along large vertical cracks called fissures. Some of this material squeezed its way

between bedding planes within the rift basins. There it cooled below the Earth's surface to form large sheets of igneous rock known as diabase. These sheets are common in the Culpeper basin. Some of the molten rock flowed out of the fissures and formed large lava lakes within the basins. The cooled lava became basalt. The Mount Zion Church Basalt, Hickory Grove Basalt, and Sander Basalt of the Culpeper basin formed in this manner. Magma that cooled within the vertical fissures formed diabase dikes, which are common in all rift basins in Virginia.

Approximately 175 million years ago (55 million years after faulting began), rifting had decreased the thickness of the crust sufficiently to cause North America and Africa to split apart. This rupturing of the former supercontinent relieved the tensional forces. Normal faulting and basin formation therefore ceased at this time. As North America and Africa drifted apart, magma rose up between the separating plates to form oceanic crust. In this process known as seafloor spreading, which is still continuing today, the Atlantic Ocean has grown progressively wider, and North America has drifted northward.

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**Figure 1**

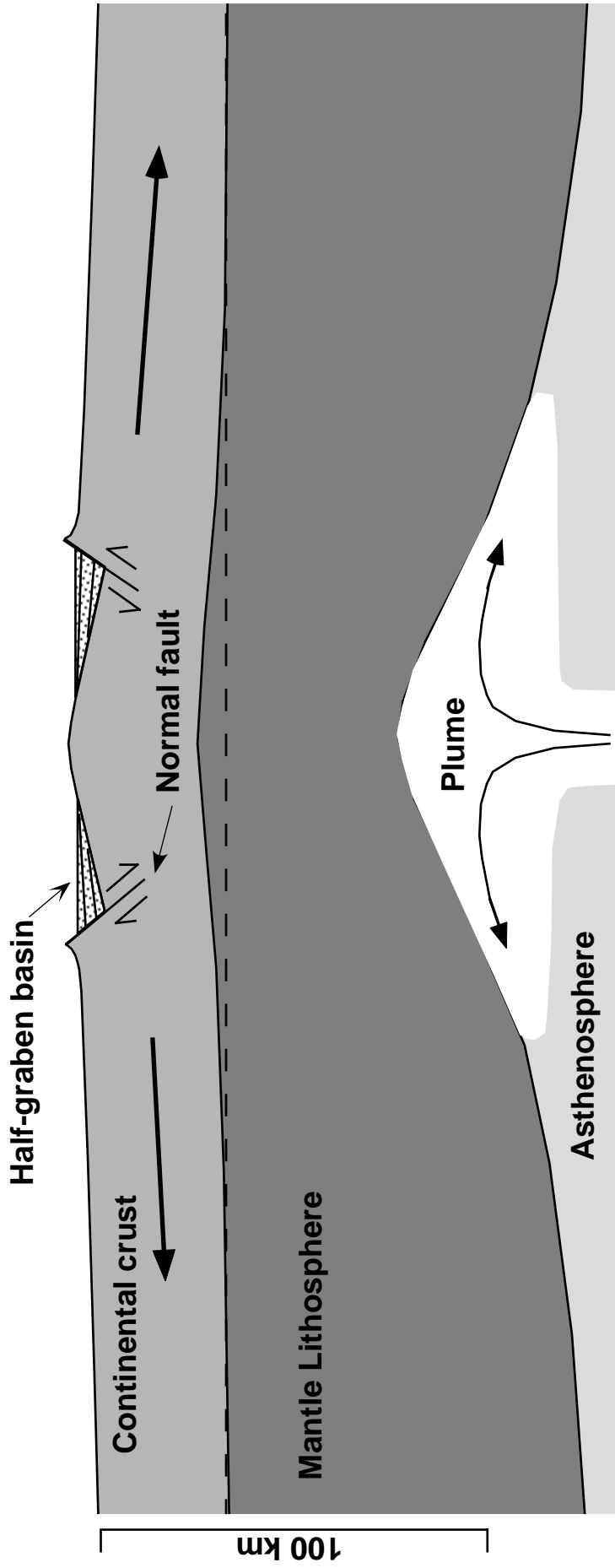
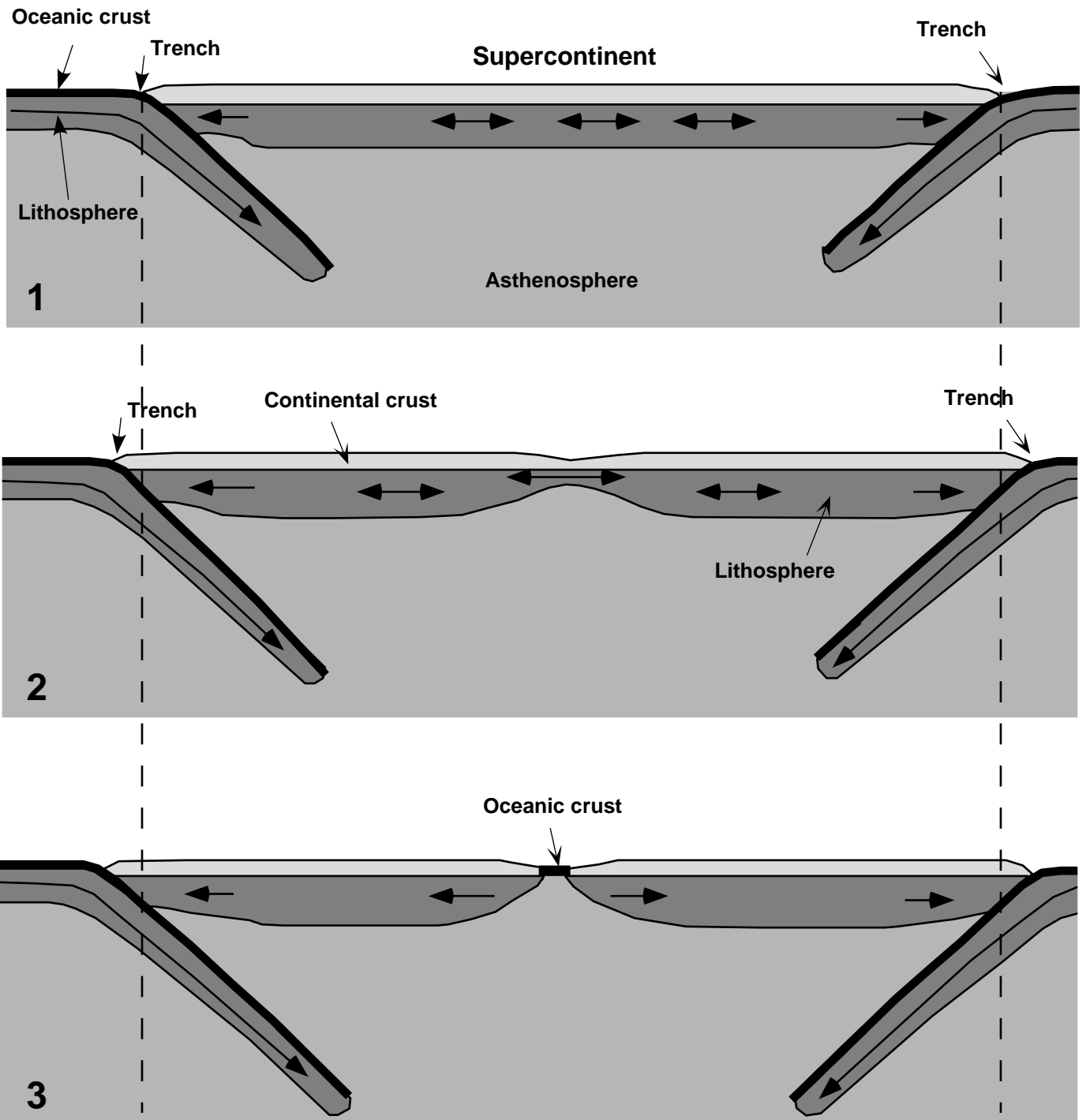


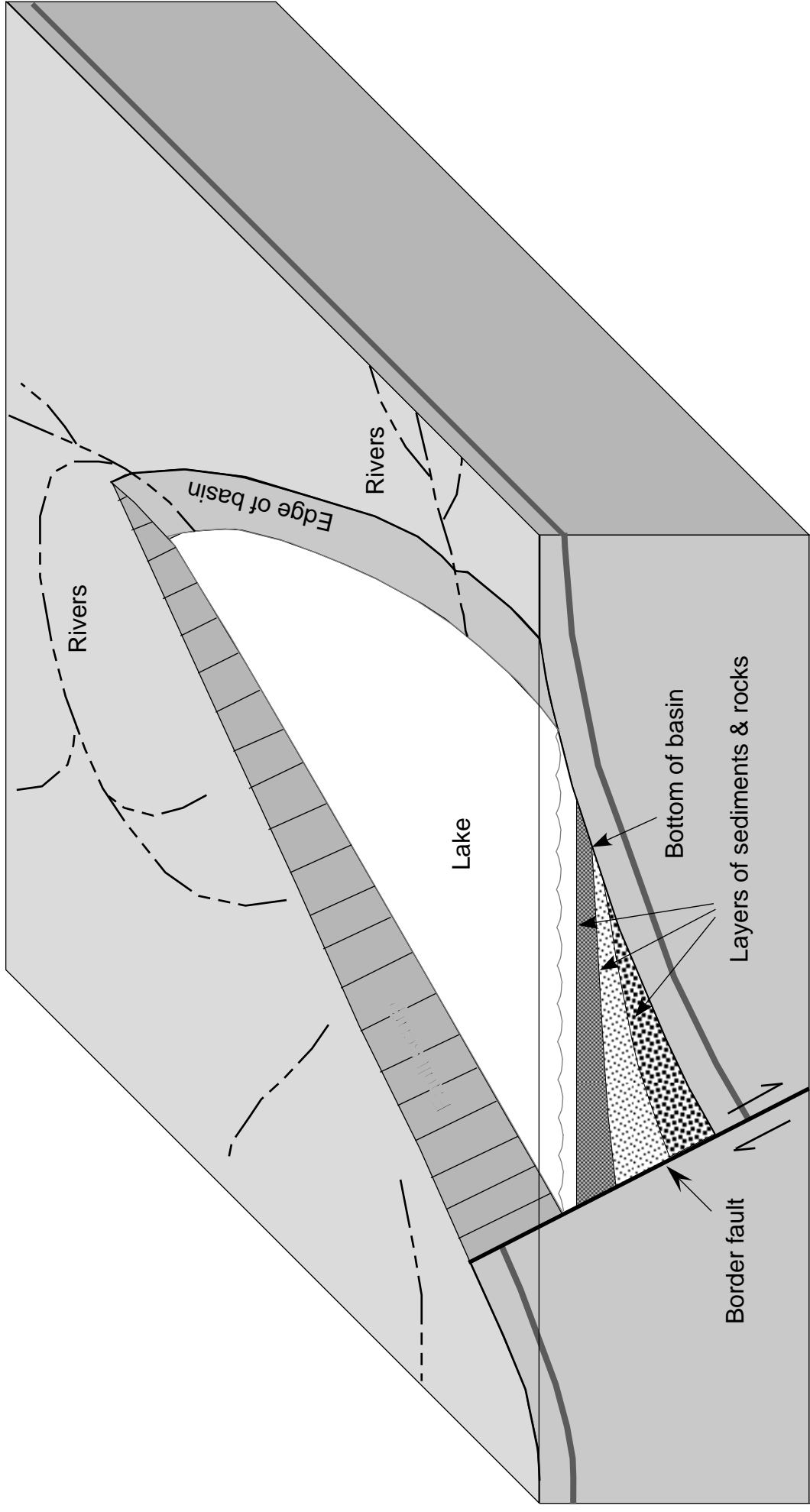
Figure 2

Vertical slice through the Earth showing how a rising plume of hot material uplifts the continental crust, causing tension (arrows) and the formation of normal faults and basins.



**Figure 3**

**Mechanism of continental splitting (as seen in vertical slices through the Earth) shown in three time steps. The trenches migrate away from the supercontinent, causing tension (double-headed arrows) which thins and ultimately ruptures the supercontinent. Dashed lines indicate original position of trenches.**



**Figure 4**

Cutaway block diagram of a rift basin. Note the half-graben geometry (triangular) in the cross section view (front panel).