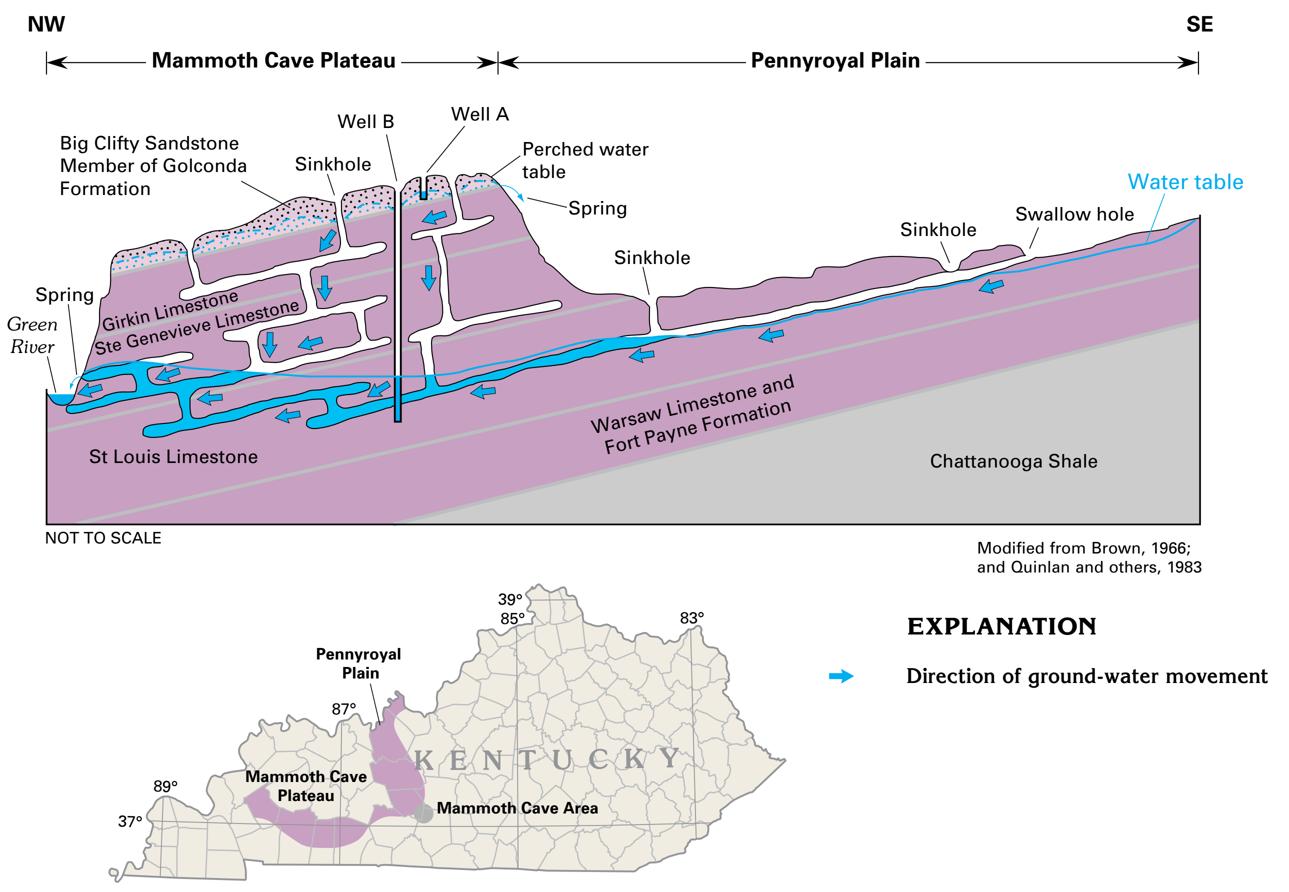
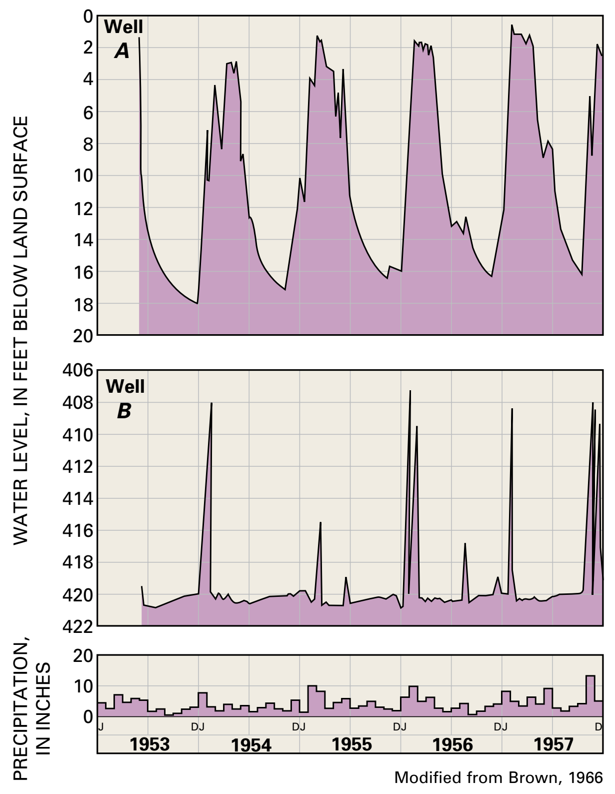
Sandstone and carbonate-rock aquifers

Figure 38. *Large volumes of water move rapidly from sinkholes and swallow holes through a well-developed network of solution cavities in the St. Louis and Ste. Genevieve Limestones to discharge at springs or to the Green River. The openings were formed by dissolution of the limestones as water moved along bedding planes and fractures.*



Modified from Brown, 1966; and Quinlan and others, 1983

Figure 39. *Water levels in wells completed in sandstone and carbonate-rock aquifers respond differently to recharge. Changes in the water level in well A, completed in sandstone, show that the sandstone is recharged quickly but drains slowly. In contrast, changes in the water level in well B, open to underlying limestone formations, show that recharge to and discharge from the carbonate-rock aquifer are rapid due to large solution openings in the limestone.*



Modified from Brown, 1966

SANDSTONE AND CARBONATE-ROCK AQUIFERS

Aquifers in sandstone and carbonate rocks are most widespread in the eastern half of the Nation, but also extend over large areas of Texas and smaller areas in Oklahoma, Arkansas, Montana, Wyoming, and South Dakota (**fig. 4**). These aquifers consist of interbedded sandstone and carbonate rocks; the carbonate rocks are the most productive aquifers, whereas the interbedded sandstones yield less water. The aquifers in the Mammoth Cave area of Kentucky are examples of sandstone and carbonate-rock aquifers. The development of solution openings and karst topography in the limestones of the Mammoth Cave area are discussed in the preceding section of this report; the following section discusses the relations of the sandstone and carbonate-rock aquifers in that area.

Movement of water through the unconfined and confined parts of the limestone aquifers that underlie the Pennyroyal Plain and Mammoth Cave Plateau is summarized in **figure 38**. Where the St. Louis Limestone is exposed at the land surface in the Pennyroyal Plain, water from surface streams enters underground solution cavities through swallow holes and sinkholes. Water also enters solution cavities in the Ste. Genevieve and Girkin Limestones through sinkholes that have developed in the Big Clifty Sandstone Member of the Golconda Formation that caps the Mammoth Cave Plateau. The sinkholes on the plateau are collapse sinkholes that developed when the sandstone cap collapsed into caves which formed in the underlying limestone. Many of the solution openings in the Girkin and Ste. Genevieve Limestones are dry because they formed when the erosional base level in the area was at a higher altitude. Water from the saturated solution openings in the Ste. Genevieve and St. Louis Limestones discharges to the Green River from springs in the river channel and valley walls. Large quantities of water move rapidly to the river through the solution openings.

Water moves slowly through intergranular pore spaces and small fractures in the Big Clifty Sandstone Member of the Golconda Formation. Discontinuous layers of shale in the underlying Girkin Limestone (**fig. 38**) impede the downward movement of water and create a perched water table from which small springs discharge at the escarpments bounding the Mammoth Cave Plateau.

The presence or absence of solution openings affects aquifer recharge and discharge and is reflected by the water levels in wells completed in different rock types. The water level in well A (**fig. 39*A***), completed in the Big Clifty Sandstone Member of the Golconda Formation (**fig. 38**), rises quickly in response to seasonal increases in precipitation; after the sudden rise, the water slowly drains from the aquifer and the water level declines slowly. In contrast, the water level in well B (**fig. 39*B***), which is open to the St. Louis and Ste. Genevieve Limestones, rises sharply only in response to heavy rains. Following the abrupt rise, the water level in this well declines quickly as the solution cavities penetrated by the well are drained. The large openings allow rapid recharge and equally rapid discharge during and immediately following periods of intense precipitation. The transmissivity (rate at which water moves through an aquifer) of the part of the rock that contains solution openings is extremely high, whereas that of the undissolved rock between the solution conduits generally is very low.

Basaltic and other Volcanic–rock aquifers

R.L. Whitehead 1980

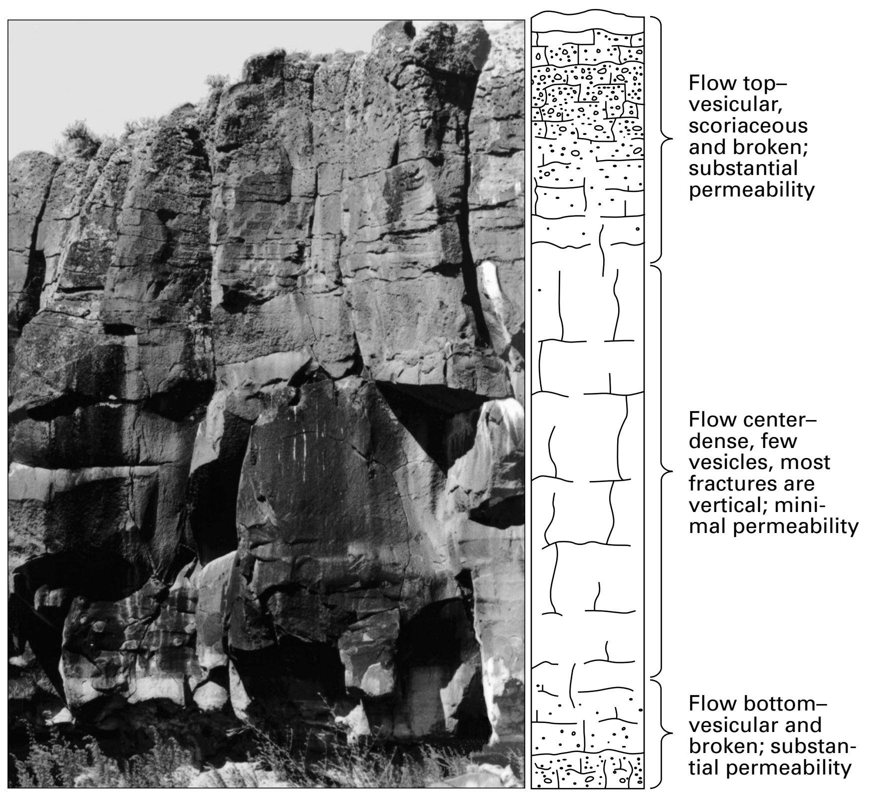
Figure 40. *Pillow basalt forms when basaltic lava enters water and cools quickly. Extensive interconnected pore spaces develop in the flow as the ball-shaped pillows cool.*

BASALTIC- AND OTHER VOLCANIC-ROCK AQUIFERS

Aquifers in basaltic and other volcanic rocks are widespread in Washington, Oregon, Idaho, and Hawaii, and extend over smaller areas in California, Nevada, and Wyoming (**fig. 4**). Volcanic rocks have a wide range of chemical, mineralogic, structural, and hydraulic properties. The variability of these properties is due largely to rock type and the way the rock was ejected and deposited. Pyroclastic rocks, such as tuff and ash deposits, might be emplaced by flowage of a turbulent mixture of gas and pyroclastic material, or might form as windblown deposits of fine-grained ash. Where they are unaltered, pyroclastic deposits have porosity and permeability characteristics like those of poorly sorted sediments; where the rock fragments are very hot as they settle, however, the pyroclastic material might become welded and almost impermeable. Silicic lavas, such as rhyolite or dacite, tend to be extruded as thick, dense flows and have low permeability except where they are fractured. Basaltic lavas tend to be fluid and form thin flows that have a considerable amount of primary pore space at the tops and bottoms of the flows. Numerous basalt flows commonly overlap and the flows commonly are separated by soil zones or alluvial material that form permeable zones. Basalts are the most productive aquifers of all volcanic rock types.

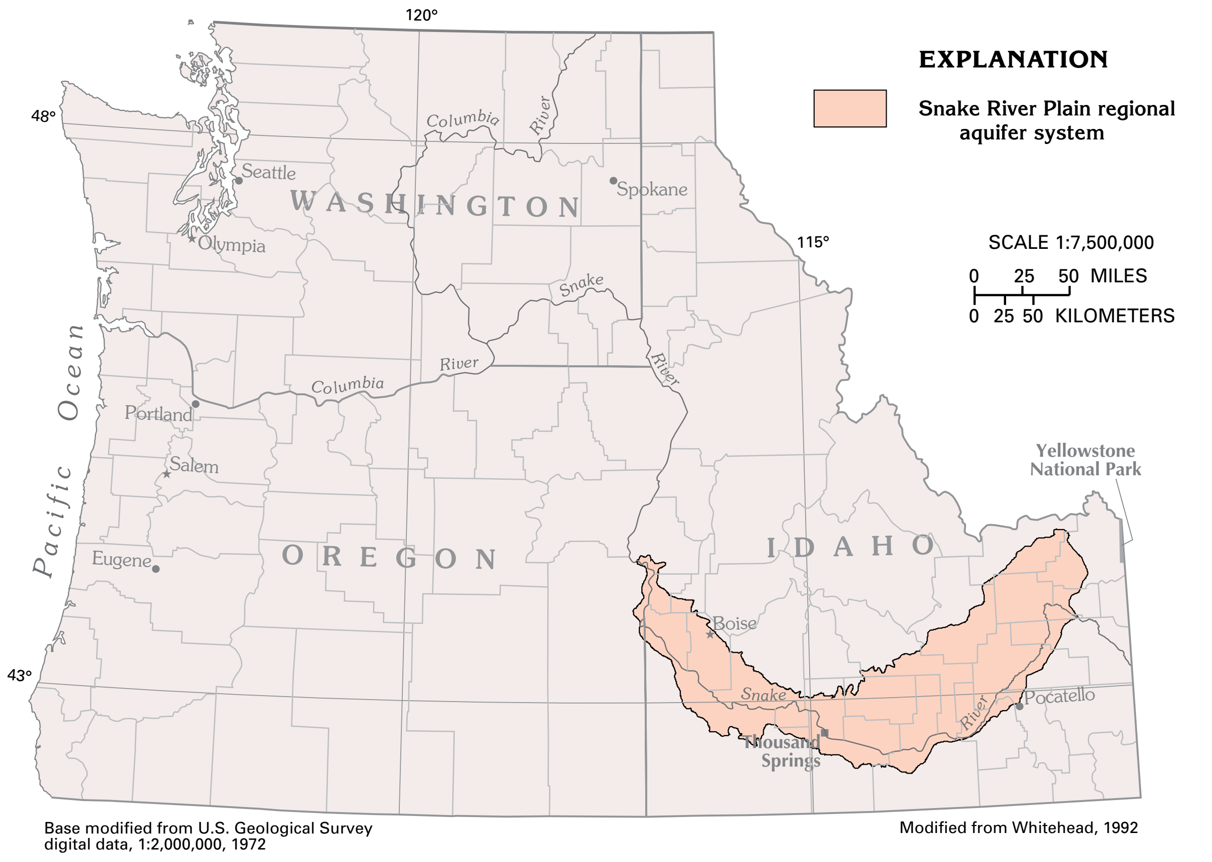
The permeability of basaltic rocks is highly variable and depends largely on the following factors: the cooling rate of the basaltic lava flow, the number and character of interflow zones, and the thickness of the flow. The cooling rate is most rapid when a basaltic lava flow enters water. The rapid cooling results in pillow basalt (**fig. 40**), in which ball-shaped masses of basalt form, with numerous interconnected open spaces at the tops and bottoms of the balls. Large springs that discharge thousands of gallons per minute issue from pillow basalt in the wall of the Snake River Canyon at Thousand Springs, Idaho. Interflow zones are permeable zones that develop at the tops and bottoms of basalt flows (**fig. 41**). Fractures and joints develop in the upper and lower parts of each flow, as the top and bottom of the flow cool while the center of the flow remains fluid and continues to move, and some vesicles that result from escaping gases develop at the top of the flow. Few open spaces develop in the center of the flow because it cools slowly. Thus, the flow center forms a dense, low-permeability zone between two more permeable zones. Thin flows cool more quickly than thick flows, and accordingly the centers of thin flows commonly are broken and vesicular like the tops and bottoms of the flows.

The Snake River Plain regional aquifer system in southern Idaho and southeastern Oregon (**fig. 42**) is an example of an aquifer system in basaltic rocks. The Snake River Plain is a large graben-like structure that is filled with basalt of Miocene and younger age (**fig. 43**). The basalt consists of a large number of flows, the youngest of which was extruded about 2,000 years ago. The maximum thickness of the basalt, as estimated by using electrical resistivity surveys, is about 5,500 feet. The basalt is bounded at the margins of the plain by silicic volcanic and intrusive rocks that are downwarped toward the plain.



Modified from Whitehead, 1992

Figure 41. *A typical basalt flow contains zones of varying permeability. Vesicular, broken zones at the top and bottom of the flow are highly permeable, whereas the dense center of the flow has minimal permeability.*



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1972

Modified from Whitehead, 1992

Figure 42. *The Snake River Plain, which is located in southern Idaho and southeastern Oregon, is underlain by basalt aquifers.*