GEOLOGIC TIME

During the middle Ages, the intellectual climate in Europe was ruled by the clergy, who tried to explain natural history by a literal interpretation of the Bible. In the middle 1600s, Archbishop James Ussher calculated the Earth's age from the Book of Genesis in the Old Testament. He concluded that the moment of creation occurred at noon on October 23, 4004 B.C.

Hutton refuted this biblical logic and deduced that the Earth was infinitely old. Today, geologists estimate that the Earth is about 4.6 billion years old. In his book *Basin and Range*, about the geology of western North America, John McPhee offers us a metaphor for the magnitude of geologic time. If the history of the Earth were represented by the old English measure of a yard, the distance from the king's nose to the end of his outstretched hand, all of human history could be erased by a single stroke of a file on his middle fingernail.

THE GEOLOGIC TIME SCALE

Geologists have divided Earth history into units displayed in the **geologic time scale**. The units are called eons, eras, periods, and epochs and are identified primarily by the types of life that existed at the various times. The two earliest eons, the Hadean and Archean, cover the first 2.5 billion years of Earth history. Life originated during Archean time. Living organisms then evolved and proliferated during the Proterozoic Eon (*protero* is from a Greek root meaning "earlier" or "before" and *zoon* is from the Greek word meaning "life"). However, most Proterozoic organisms had no hard parts such as shells and bones. Most were single celled, although some multicellular organisms existed. The Proterozoic Eon ended about 538 million years ago.

Then, within an astonishingly short time—perhaps as little as 5 million years—many new species evolved. These organisms were biologically more complex than their Proterozoic ancestors, and many had shells and skeletons. The most recent 13 percent of geologic time, from 538 million years ago to the present, is called the Phanerozoic Eon (*phaneros* is Greek for "evident"). The Phanerozoic Eon is subdivided into the Paleozoic Era ("ancient life"), the Mesozoic Era ("middle life"), and the Cenozoic Era ("recent life") (Fig. 1).

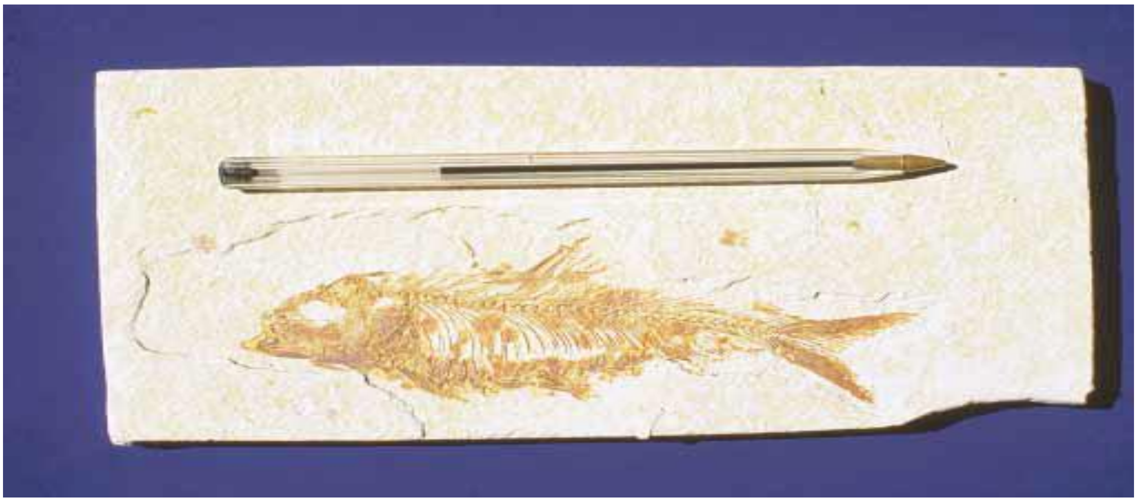

Figure 1 This 50-million-year-old fossil fish once swam in a huge landlocked lake that covered parts of Wyoming, Utah, and Colorado.

THE EARTH'S ORIGIN

THE EARLY SOLAR SYSTEM

No one can go back in time to view the formation of the Solar System and the Earth. Therefore, scientists will never be able to describe the sequence of events with certaintyThe hypothesis given here is based on calculations about the behavior of dust and gas in space and on observations of stars and dust clouds in our galaxy. Refer to the "Focus On" box on page 12 for a discussion of how scientists formulate a hypothesis.

The hypothesis states that about 5 billion years ago the matter that became our Solar System was an immense, diffuse, frozen cloud of dust and gas rotating slowly in space. This cloud formed from matter ejected from an exploding star. More than 99 percent of the cloud consisted of hydrogen and helium, the most abundant elements in the Universe. The temperature of this cloud was about _270ºC. Small gravitational attractions among the dust and gas particles caused the cloud to condense into a sphere (Figs. 2–a and 2–b). As condensation continued, the cloud rotated more rapidly, and the sphere spread into a disk, as shown in Figure 2–c. Some scientists have suggested that a nearby star exploded and the shock wave triggered the condensation. More than 90 percent of the matter in the cloud collapsed toward the center of the disk under the influence of gravity, forming the **protosun**. Collisions among highspeed particles released heat within this early version of the Sun, but it was not a true star because it did not yet generate energy by nuclear fusion. Heat from the protosun warmed the inner region of the disk. Then, after the gravitational collapse was nearly complete, the disk cooled. Gases in the outer part of the disk condensed to form small aggregates, much as snowflakes form when moist air cools in the Earth's atmosphere. Over time, the aggregates stuck together as snowflakes sometimes do. As they increased in size and developed stronger gravitational forces, they attracted additional particles. This growth continued until a number of small rocky spheres, called **planetesimals**, formed, ranging from a few kilometers to about 100 km in diameter. The entire process, from the disk to the planetesimals, occurred quickly in geologic terms, over a period of 10,000 to 100,000 years. The planetesimals then coalesced to form a few large planets, including Earth.

At the same time that planets were forming, gravitational attraction pulled the gases in the protosun inward, creating extremely high pressure and temperature. The core became so hot that hydrogen nuclei combined to form the nucleus of the next heavier element, helium, in a process called **nuclear fusion**. Nuclear fusion releases vast amounts of energy. The onset of nuclear fusion marked the birth of the modern Sun, which still generates its energy by hydrogen fusion.

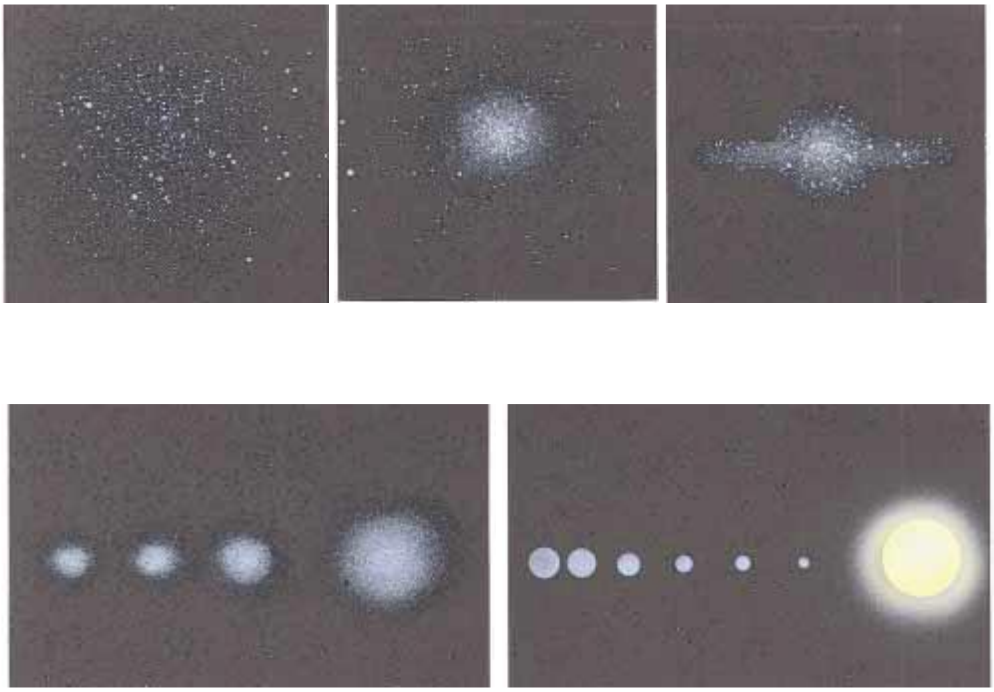

Figure 2 Formation of the Solar System. (a) The Solar System was originally a diffuse cloud of dust and gas. (b) This dust and gas began to coalesce due to gravity. (c) The shrinking mass began to rotate and formed a disk. (d) The mass broke up into a discrete protosun orbited by large protoplanets. (e) The Sun heated until fusion temperatures were reached.The heat from the Sun drove most of the hydrogen and helium away from the closest planets, leaving small, solid cores behind.The massive outer planets are still composed mostly of hydrogen and helium.