Chapter 1

# MEASUREMENTS FROM THE BEGINNING THROUGH THE MIDDLE AGES

## Thales of Miletus (640–546 BC)
## Peter Peregrinus (dates unknown)

Over 4 billion years ago, the Earth formed. More than 3 million years ago, primitive people walked the earth. About 10,000 years ago, people began to supplement their hunting of animals by cultivating grain-bearing grasses.

By around 3000 BC historians agree that cities had been established in Mesopotamia, Egypt, and China. The management of land, the construction of buildings, and other group projects required that standards of measurements be established for lengths, areas, volumes, and weights. Each was important in barter, trade, work, government, and religion. Specimens of agreed-upon units were preserved as reference standards of primary authority of the city-state. These standards were inscribed with the king's name and deposited in the principal temples of the kingdom.

The cubit was a commonly used unit of length in many kingdoms; its story illustrates how units developed and were used in ancient times. The Egyptian hieroglyphic symbol for the cubit is a picture of the forearm, indicating its derivation from the human body. It was the distance from the peak of the elbow to the tip of the middle finger, and was the basis of other units based on the human body. The digit was the width of a thumb, and a palm was the width of a hand. In most lands, four digits made a palm, and five palms made a cubit. In time, fractions of a cubit were used extensively. The length of a foot was also used.

The Science Museum in London has a collection of Egyptian wood and stone cubit standards dating from 2400 BC to the first century AD; over that long period of time, the Egyptian cubit varied less than 5 %. The cubit had an extremely long life, and was used in some countries as late as the 1960s before being replaced by metric measures. The foot is still in use today in the United States.

Volume standards were used for measuring grain and liquids, and were based on convenient, arbitrary containers. Weights were probably first used for trade in precious metals, and their standards were initially stones, then a set of carved stones, and later metal castings.

Time is an abstract concept, and measurements of time developed slowly in civilizations. Initially, life was thought to be a succession of recurring cycles, and there was no concept of history. The cycles were based on correlations of natural events: when certain plants bloom, when the heavy rains occur, or when the cry of the migrating cranes are heard. The changes of the moon provided another basis for measuring time: nine moons for the duration of pregnancy, or six moons between sowing and harvest. In sunlight, observing the position of the sun's shadow around a vertical stick indicated the time of the day. As centuries passed, more elaborate solar observations developed. About 2600 BC Stonehenge was built in England, and less elaborate observatories were constructed in France.

The first constant flow water clocks were developed about 250 BC, and began to give the feeling of a continuous flow of time rather than its being a series of recurring events. Mechanical timekeeping devices began to appear in Europe in the 1200s.

In ancient days many combinations of numbers had magical meanings, leading many of today's mathematicians and historians to suspect that the ancients often pursued complexity for its own effect. There are no obvious computational or other benefits in having 60 minutes to an hour, 24 hours in a day, or 360 degrees in a circle. However, having been established in ancient Babylon and used for many years, people have lived with these awkward conventions because it is more difficult to change them than to live with them.

The ancient Greeks were thinkers and philosophers, but not tinkerers, experimenters, or measurers of electricity or magnetism. They observed thunderstorms, lightning, and St. Elmo's fire. They also observed magnetic attraction and repulsion, but their knowledge of science and technology could not explain these phenomena, nor did they investigate them systematically or put them to practical use.

Thales of Miletus (640–546 BC), according to legends, lived in ancient Greece and was of noble birth. He was chief of the "Seven Wise Men" of his time and gained much acclaim by predicting a total eclipse of the sun in May 585 BC. Much of his fame came from introducing geometry from Egypt into Greece, before the time of Euclid, making substantial contributions and communicating the beginnings of many propositions to his successors.

Thales is credited with discovering that amber rubbed with wool or fur attracts light bodies such as pieces of dry leaves or bits of straw, and observing that lodestone attracts iron and other lodestones. None of Thales's manuscripts is known to have survived to modern times. Everything we know about him comes from accounts written by others.

Socrates (470–399 BC) wrote of lodestone "that stone not only attracts iron rings, but imparts to them a similar power of attracting other rings; and sometimes you may see many pieces of iron and rings suspended from one another to form quite a long chain; and all of them derive their power of suspension from the original stone."

Amber was used in antiquity for decoration, often with alloys of gold and silver, and was called "electron," hence our word "electricity." Magnetic iron ore was found near Magnesia in Asia Minor. According to Lucretius (98–55 BC), the term *magnet* is derived from Magnesia.

The magnetic compass is one of the first scientific instruments to have been used extensively. Its origins are not well documented, but legends about its early use abound. The Chinese, Arabs, Greeks, Italians, and other groups have all been credited as the originators. Recent research, however, indicates that the Chinese began to use lodestones to indicate south and north in the early centuries of the Christian era. Ancient documents describe pieces of lodestone, or magnetite, several inches in diameter, with their bottoms rounded and a little tail on top to indicate one of the poles. They called it a spoon, and when placed on a hard, smooth surface and rocked gently, the tail pointed south. Other ancient Chinese manuscripts describe indicators made of a magnetized steel needle floated on a chip of wood or on a reed in a bowl of water, or a needle suspended on a single filament of silk. Since then, compass designers have made many improvements, and much has been learned about terrestrial magnetism. Even today, however, we still have much to learn about magnetism and the dynamics of the earth's magnetic field.

In the Western world, Pierre de Maricourt wrote the earliest known descriptions and discussions of the designs of magnetic compasses in his "Epistola de magnete" (1269). Pierre earned the title of Peregrinus for having traveled to the Holy Land in a Crusade or for having fought the Saracens elsewhere. He is known today as Petrus or Peter Peregrinus.

Peregrinus was in an army camp during a siege of Lucera in southern Italy when he wrote his famous letter to Sigerus de Foucaucort, a soldier and "dearest of friends" back in France. The letter describes the existence of magnetic poles, and the determination of the location of the poles on a spherical piece of lodestone by the following fashion: "Let a needle or elongated piece of iron, slender like a needle, be placed on the stone, and a line be drawn along the length of iron dividing the stone in the middle. Then let the needle or iron be placed in another position on the stone and mark the stone with a line in a similar manner according to that position. All the lines drawn in this fashion will converge in the two opposite points or poles."

Peregrinus described a second method of determining the poles of a spherical lodestone: "Note the place on the above-mentioned spherical lodestone where the point of the needle clings most frequently and most strongly; for this will be one of the poles as discovered by the previous method. . . ." To identify which was the north pole and which was the south, Peregrinus recommended placing the lodestone in a wooden dish with the axis between the poles horizontal: "Float this dish freely in a much larger vessel; the pole which turns toward the north heavens is the north pole, and the south pole faces the southern heavens."

In a similarly clear fashion, Peregrinus explained that unlike poles attract each other, and like ones repel each other: "every fragment of lodestone, however small, is a complete magnet; and a strong pole may neutralize a weaker one of the same polarity, and even reverse its polarity."

Peregrinus ended his letter describing the designs of two compasses. The first was a wood capsule containing a lodestone, not spherical, but with its sides filed so that the equator was substantially reduced. The capsule was to be marked with the north–south axis, plus a line at right angles indicating east and west, and each quarter divided into 90 equal parts. When the capsule was floated, a horizontal ruler could be used to measure the position of the sun with respect to the north–south line, and to determine the azimuths of landmarks.

The second compass Peregrinus described was a better and more efficient instrument in his opinion and did not use water for its suspension. A vertical brass or silver axle rode on pivots top and bottom; the axle had two holes through it at right angles to each other and perpendicular to the axis of the axle. One hole carried a horizontal needle made of iron and was magnetized by a lodestone for north–south indication; the other carried a silver or brass needle indicating east and west. The housing, which had a transparent cover, was marked in four quadrants, each divided into 90 degrees, similar to the first design. In use, the housing was rotated until the north indicator was lined up with the needle. A ruler with a vertical pin at each end served as an alidade.

Little else is known about Peregrinus, but his letter indicates that he was a realist, experimenter, and skilled in instrumentation. He did not speculate why the lodestone behaved as it did, but accepted the fact that it aligned itself with the earth's meridian, possibly by forces from the heavens. The letter is considered the first scientific treatise written and is surprisingly modern in its style.

The original letter from Peregrinus to Sigerus has undoubtedly been lost, although a number of manuscript copies of it remain in European libraries. Interest in the compass continued, but it was almost three hundred years before William Gilbert continued Peregrinus's work with his study of magnetism.