Compasses Point the Way from Geomancy to Navigation

"How do we get there from here, and how do we get home?" are questions as old as humankind. Today the answer might be with a GPS (Global Positioning System) and a dedicated computer, but for hundreds if not thousands of years the answer was "with a compass." The unusual property of certain rocks to attract each other or pieces of iron was known very early on, at least by the time of Thales, ~600 BC. Such rocks contain the mineral magnetite, mainly Fe_3O_4, often with admixtures of Mg, Zn, Mn, or Ti. These rocks are often strongly magnetized, sometimes possess polarity, and are then known as lodestones, from Old English meaning "leading" or "guiding." We now know that magnetite is a ferrimagnet (one in which the spins of neighboring atoms are antiparallel but unequal resulting in a net magnetization) and that its magnetization is lost at the 580°C Curie point. The magnetization arises from the rock's geologically slow cooling through its Curie point in the earth's magnetic field, hence the directionality, or possibly from the tremendous currents of lightning strikes.

The north-south-orienting capability of lodestone was discovered during the Han dynasty in China sometime between 2nd century BC and 1st century AD. It was first used for divination or geomancy. For the Chinese this meant "the art of adapting the residences of the living and the tombs of the dead so as to cooperate and harmonize with the local currents of the cosmic breath," that is, adopting a north-south orientation. Chinese diviners made use of a board composed of two plates: the square lower plate represented the earth and was inscribed with the cardinal directions; the upper heaven-plate, round and free to rotate, bore a representation of the Big Dipper constellation, the outer rim of which always points to Polaris. Over the years the upper plate was transformed to a three-dimensional representation in the form of a spoon, fashioned from lodestone and pivoted on the polished bronze earth plate so that the spoon handle pointed south (see Needham's text for a figure). The spoon shape was not only a geometric analogue of the constellation, but the long handle acted as a pointer and the large length-diameter ratio counteracted the otherwise demagnetizing effect of poles too close to each other. The spoon-shaped "south pointer" was referred to in Chinese literature nearly 1,400 years before the first European mention of the existence of the directional compass by Alexander of Neckam ~1180 AD.

The Chinese plate-spoon contrivance could hardly have been a very convenient or inexpensive device, and the next improvement in the compass by the Chinese made use of the principle of magnetic induction. Instead of lodestone, small strips of iron were used, sometimes in the shape of a fish or tadpole. Interestingly, the Chinese term for tadpole, "tou," is also the radical for "ladle" or "spoon." Iron needles were also used. These could be magnetized in three ways: by stroking with a lodestone, by hammering a heated strip held in a N-S alignment, or by heating and quenching while in a N-S alignment. Such small compass needles could be made readily rotatable by several means: by flotation on water supported by surface tension, by attachment to a small piece of wood or fiber that easily floated, by suspension from a thread, or by balancing on a fingernail.

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By the 3rd or 4th century AD, Chinese writings speak of "the mysterious needle," "the mysterious fish," and "the shining needle in a bewildering sea," indicating its application for locating directions. In the 3rd century AD it was recorded that "when the people of the State of Zheng go out in search of jade, they carry a south-pointer with them so as not to lose their way in the mountains."

More extensive adoption of the compass by the Chinese was retarded by the national policy of isolation. Most commerce over large distances within the country was by river, canal, and coastal travel, rather than ocean voyages, hence initially the compass was little needed for navigation. Eventually, Chinese seafarers, with the aid of the compass, began to explore and establish routes for ocean navigation to Korea, Cambodia, and elsewhere that they called "needle routes." By the 13th century, China was trading with more than 50 countries in Asia and Africa. The last improvements in the compass by the Chinese were a box, on the bottom of which was a card marked with the 24 Chinese compass points and which enclosed a bowl of water with a floating compass needle, and finally a "dry" compass consisting of a magnetized needle that pivoted on a bamboo pin.

The compass may have made its way from China to Europe via traders from the Middle East. In England in the mid-1300s Nicholas of Lynn, under commission from King Edward III, explored and mapped the regions north of Iceland using an astrolabe and a magnetic compass and discovered the amazing discrepancy between magnetic north and geographic north that the Chinese had known since the work of Shen Kua in 1088. Still later it was realized that the magnetic declination was not only geographically but also time dependent. The only significant European contribution to compass design was the introduction of the gimbal suspension by the Spanish in 1546, enabling the compass to maintain a constant position regardless of outside motion. Actually, this was the reinvention of a Hellenistic toy.

Despite the extensive and well-recorded development and understanding of the magnetic compass by the Chinese, a tantalizing bit of evidence shows that they may have been scooped by a people almost 1,000 years earlier: An archaeological expedition to Veracruz, Mexico in 1967, headed by Michael Coe, discovered an Olmec artifact, dated to 1400–1000 BC, in the form of a carefully shaped, polished bar of hematite. It was a fragment, only $34 \times 9 \times 4$ mm^3, of a piece thought to have been two to three times as long. This bar fragment bore a hemicylindrical groove incised at a small but noticeable angle to the axis of the bar. Several indirect hints show the possibility that the bar was used as a compass. J.B. Carlson has found that the magnetic moment vector is in the floating plane of the artifact. Olmec site alignments are consistently 8° W of N. The Olmecs were sophisticated and knowledgeable workers of iron ore minerals for ornaments, and their culture put a high emphasis on geomancy. The groove might possibly have been a calibration adjustment for magnetic declination so that the artifact could serve as a direction indicator.

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FOR FURTHER READING: J. Needham, *Science and Civilization in China*, vol. 4 (Cambridge University Press, New York, 1962); E. Irving, *Paleomagnetism*, (John Wiley & Sons, New York, 1964); J.B. Carlson, *Science* **189** (1975) p. 753; P. James and N. Thorpe, *Ancient Civilizations*, (Ballatine Books, New York, 1994).