Lodestone to Martian Blueberries: The Magnetic Lure

Magnetism derives its existence to a naturally occurring form of magnetite, the mineral lodestone. In early days the term loadstone, derived from the old English word load meaning ‘way’ or ‘course’, was literally used for lodestone which showed a traveller the way. Although the Greek philosophers wrote about lodestone around 800 B.C., its properties were known to the Chinese by 300 B.C. who built a rudimentary compass during the Han Dynasty (200 - 300 B.C.). It was only in the 1600's when William Gilbert published his book “De Magnete”, that the concept of earth’s magnetic field and its directional behaviour was given a scientific footing. The first systematic observations of rock magnetic properties are usually attributed to Delesse (1849) and Melloni (1853), who concluded that volcanic rocks acquired a remanent magnetization during cooling. Subsequent work by Giuseppe Folgerhaiter in 1894 (Merill and McElhinny, 1983) suggested that the direction of remanent magnetization was that of the geomagnetic field during cooling. Interest in magnetism has diversified since from studying a rock’s magnetic property to the study of the magnetic field of the planet Earth we live on. The ability of a rock to preserve, for millions of years, the magnetic field it has acquired during or after its formation, has led geophysicists to define a new field of science called Paleomagnetism. This study which relies on the record of the fossil magnetization preserved in rocks, has helped in the development of plate tectonic theories like continental drift and sea-floor spreading. Furthermore, a related study of paleomagnetism is “Archaeomagnetism” which involves deciphering the geomagnetic field record in dateable historic artefacts. The ancient magnetic field of the earth recorded in rocks and the archaeological artefacts is in fact locked by small magnetic mineral grains that act as microscopic compasses. The study of these magnetic minerals in nature and experimentally in lab led to the science of Rock Magnetism. Rock/mineral magnetism has had good scientific recognition in the last decade with its application is not only restricted to a geological/paleomagnetic perspective but also inferring climatic and environmental conditions that prevailed in the past. From the early days of the mere usage of the mineral lodestone in helping a traveller find his way, magnetism is now an important science which dwells with the interests of Geologists, Geographers, Geophysicists, Archaeologists, Biogeochemists, Planetary Scientists and the list goes on. My fascination towards magnetism lies in the field of paleomagnetism applied to dating of mineral deposits and also the application of rock magnetism in environmental studies.

A detailed description of the paleomagnetic methods is given in texts by Merill and McElhinny (1983), Tarling (1983) and Butler (1992). Apart from the application of paleomagnetism to plate tectonics, researchers' also use this tool in apparent polar wander studies and the development of a magneto-stratigraphic timescale for stratigraphic and correlation studies. Recently, this method has been applied in dating (Symons et al., 1996) dolomitization and carbonate-hosted Zn-Pb-Ba ore deposits - "Mississippi Valley-type (MVT)", "Irish-type", "Sherman-type", etc. As Sangster (1986) stated "other than the general definition of MVT deposits given here, a single descriptive or genetic model for all MVT deposits is an unreasonable expectation", and the great diversity among MVT lead-zinc districts is expected because of the wide range in fluid compositions, geological and geochemical conditions, fluid pathways, and precipitation mechanisms possible at the scale of MVT fluid migration (Leach et al., 2001). Also, as Leach et al. (2001) states, "establishing the time of MVT ore formation in a region is, without doubt, the most critical piece of information that can guide the exploration for undiscovered ore". Although direct dating of these carbonate-hosted Zn-Pb ore deposits has also been done radiometrically with varying degrees of success, the paleomagnetic method has proven successful as shown by its excellent track record (Leach et al., 2001). Paleomagnetic dating (Symons et al., 1996) of these ore deposits allows a better understanding of the fluid flow that relates ore deposition and oil migration, if any, related to these specific deposits. The publication of the text “Environmental Magnetism” by Thompson and Oldfield in 1986 revolutionized rock/mineral magnetic methods and gave birth to a new science of magnetism, “Enivronmental Magnetism”. A subsequent publication, “Quaternary Climates, Environments and Magnetism” by Maher and Thompson added thrust to the development of environmental magnetism. Rock/mineral magnetism in the last decade or so has gained significant scientific interest with its application as a interdisciplinary scientific tool in paleoclimatic studies (Dunlop, 1995; Verosub and Roberts, 1995). Major magnetic iron minerals such as magnetite, hematite, maghemite, etc. act as a proxy indicator of (paleo) environmental conditions. Where the individual characteristics of the magnetic mineral reflects the paleoclimatic conditions, the distinguishing characteristics of the minerals provide a better solution of the problem. A recent study on a sediment core from an ancient lake in Indonesia by Crowe et al. (2004) has shown the successful utility of rock/mineral magnetic methods combined with geochemistry to elucidate biogeochemical cycling in aquatic systems. I, being a part of this study, was enthused by the interdisciplinary nature of rock/mineral magnetic methods in addressing issues of environment.

Furthermore, from the usage of mineral lodestone to the study of the magnetic field of Earth, researchers are now trying to understand the magnetic field of other planets in the solar system. One planet of keen interest is Mars, for which extensive exploration programs are designed to investigate the possibility of existence of life. Whereas the active core is believed to be the major source for the magnetic field of Earth, Mars with a suggested stalled core has shown some strong crustal magnetization pattern in a recent solar exploration program (Acuna et al., 1999). Does water exists or existed before on planet mars?, is one of the prime questions researchers are trying to answer. Minerals that could be related to water-driven processes are of primary target in the recent “Rover” and “Opportunity” missions on Mars (see http://science.nasa.gov/headlines/y2001/ast28mar_1.htm). The Mars Exploration Rover Opportunity’s landing site showed rock outcrops, the region being named “Berry Bowl”, with small sphere-like grains or “blueberries”(term used by NASA researchers, see http://marsrovers.jpl.nasa.gov/newsroom/pressreleases/20040318a.html). The Mössbauer spectrometer (one of the instruments on Mars Exploration Rover Opportunity which identifies magnetic minerals) analysis suggests that the major iron bearing minerals in these berries is hematite. This result agrees with the earlier belief of NASA researchers’ that martian spherules are concretions that grew inside water-soaked deposits. Thus, the very wide applicability of magnetism, from merely showing a traveller the way to unfolding the mystery of paleoclimate or inferring the presence of life (or water) on other planets proves the magnetic methods as one of the oldest and the best geophsyical methods to date.

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