

The Lodestone, from Plato to Kircher



D. W. Emerson

Systems Exploration (NSW) Pty Ltd
systemsnsww@gmail.com

Introduction

The natural magnet, the lodestone, exerted a strong fascination in the Mediterranean and Eastern regions during ancient and medieval times. Then it was regarded as a wondrous, marvellous material. It has an interesting history. The lodestone ('loadstone', 'leading' stone, 'course' stone) made possible the development of the magnetic compass, but the lodestone had other roles in the culture of prior generations of humankind. Adams (1954) provides a good introduction, and general information is available in paper and digital format encyclopaedias, but probably not the esoterica herein discussed with a somewhat arbitrary selection of views, over time, from the Mediterranean–European regions. Middle Asia, and the Far East where the Chinese knew of and used the lodestone, are not treated here.

The ancient Greeks located a lodestone supply in the vicinity of the fifth century BC Thessalian colony of Magnesia, ad Sipylum, on the western shore of Asia Minor (~33 km NE of Smyrna, modern Izmir, Turkey). They called it the Magnesian

stone, the magnet. The Greek noun is feminine as it was a special kind of stone, ἡ Μαγνητικὴ λίθος. A variety from one or more of the many places named Heraclea was called Heracleian stone. The Romans called it *magnes* or *magnes lapis*, the magnetic stone (*magnes* functioning both as a masculine noun and an adjective).

What is lodestone? It is locally altered magnetite. It is not stoichiometrically pure magnetite: dark, crystalline or massive, dense, conductive, with high magnetic susceptibility and strong remanence. Such magnetite does not constitute a magnet; it will not pick up nails or support a chain of paper clips or magnetise a needle (try it, see Figure 1). Magnetite is attracted to a magnet; lodestone acts as a magnet.

The nature and genesis of lodestone was discussed, inconclusively, by Newhouse (1929), Gruner (1929) and Bandy (1930). Newhouse invoked oxidation as the means whereby zones in magnetite bodies were converted to lodestone by the formation of a brownish iron oxide. Gruner did not find such material in examined lodestones, rather the effect was ascribed to the concentration of the earth's field at the extremities of magnetic bodies. Bandy rejected both and proposed that the strong magnetic fields from lightning strikes on magnetite outcrops generated lodestone which, in his experience, was an uncommon mineral of erratic occurrence, found more frequently in the higher, more exposed parts of magnetite bodies.

Wasilewski and Kletetschka (1999) proposed lightning as the lodestone charging mechanism, demonstrating that the material struck should comprise magnetite hosting some maghemite, arising from oxidation and exsolution, and also with an assumed concomitant favourable microstructuring. Magnetic hardness was shown to be optimised by large values of coercive force, saturation magnetisation, saturation remanence, and a relatively large ratio of saturation remanence to saturation magnetisation (>0.2 for lodestone, usually <0.05 for coarsely crystalline magnetite).

Lodestone may be found in private and museum collections; local specimens have been curated by the Australian Museum (Figure 2).



Figure 1. A magnet will stick to these collector-grade magnetite octahedra from Bolivia, but they will not pick up a paper clip.



Figure 2. Lodestone from Lionsville NSW. Image by K. Lowe, courtesy of Australian Museum, Sydney ©.



The Greeks

Thales (sixth century BC) was the highly regarded Sage of Miletus (southwest Asia Minor). To him is ascribed the view that the lodestone must have a psyche, the sign of life, ἡ ψυχή, equivalent to the Latin *anima* or breath of life. What he probably meant was that lodestone had a significant essence differing from its material body because it was dynamic with power to attract, repel, and to move to other objects; so it was live. Thales' writings, if any, have not survived.

Plato (427–347 BC) was the disciple of Socrates, and teacher of Aristotle. His works have been the origin or the catalyst of much Western philosophical thought. Plato related Socrates' comments on the rhapsode Ion's recitation histrionics. In a vivid analogy the Muse is likened to a magnet whose mysterious power is clearly manifest in a charged chain of attracted iron rings extending from its (i.e. the lodestone's) surface. Inspiration flows from the Muse, to the poet (Homer), then to the rhapsode, and on to the members of the audience. Ion's skill is not human, it derives from divine possession, beyond reason, like the magnet. In this perspective there are distinct theological overtones reflecting Socrates' belief in divinities. Plato, *Ion* 533D:

ἔστι γὰρ τοῦτο τέχνη μὲν οὐκ ὄν παρὰ σοὶ περὶ Ὀμήρου εὖ λέγειν, ὃ νῦν δὴ ἔλεγον, θεία δὲ δύναμις ἢ σε κινεῖ, ὡσπερ ἐν τῇ λίθῳ ἦν Εὐριπίδης μὲν Μαγνητῶν ὀνόμασεν οἱ δὲ πολλοὶ Ἡρακλείαν. καὶ γὰρ αὕτη ἡ λίθος οὐ μόνον αὐτοὺς τοὺς δακτυλίους ἄγει τοὺς σιδηροῦς, ἀλλὰ καὶ δύναμιν ἐντίθησι τοῖς δακτυλίοις ὥστ' αὐτὸ δύνασθαι ταῦτ' οὗτο ποιεῖν ὅπερ ἡ λίθος, ἄλλους ἄγειν δακτυλίους, ὥστ' ἐνίοτε ὄρμαθὸς μακρὸς πάνυ σιδηρίων καὶ δακτυλίων ἐξ ἀλλήλων ἤρτηται. πᾶσι δὲ τούτοις ἐξ ἐκείνης τῆς λίθου ἡ δύναμις ἀνήρτηται.

Because, as I was just now saying, declaiming Homer well is not your skill; what moves you is divine power like that in the stone which Euripides called a magnet (Magnesian stone) but the majority of people know it as the stone of Hercules. For this stone not only takes iron rings to itself but also puts into them the power to do the same as the stone, and attract other rings in turn. So sometimes there is indeed a long chain of rings and bits of iron hanging one from another; all of them empowered by the stone.

Theophrastus (c370 – c287 BC) was a pupil and colleague of Aristotle. He wrote on a great variety of subjects, including stones. Unfortunately what appears to have survived seems to be an abbreviated version of a larger work on minerals to which Pliny, centuries later, had access. Theophrastus did refer to an Heracleian lodestone in company with the touchstone (black, flinty, siliceous slate or jasper used as comparative streak plates), but seemed more in cautious awe of the possibilities of mineral breeding and propagation. Belief in the supposed regeneration of stones and minerals was not uncommon. Pliny mentioned claims that marble grew in its quarries.

The Romans

The chance discovery of an old manuscript in 1417 saved an outstanding ancient work from oblivion. It was a copy of a

ninth century document (now in Leiden): Lucretius' *De Rerum Natura* (*DRN*) – On the Nature of Things. This great Latin poem, in six books comprising 7415 robust hexameters, expounded post Aristotelian Epicurean technical philosophy and physics: void, atoms, and their motion. It was subsequently printed, circulated and tolerated (nearly ending up in the Index of Prohibited Books during the Inquisition). His work has been studied, and argued about, down to the present day because of its visionary content and uncompromising style. Titus Lucretius Carus (98 – c55 BC) was a great debunker of superstition and myth – no magic or immortality for him. Although a believer in the pagan gods, he did not invoke them to explain physical phenomena.

Lucretius discussed, at length, in his book 6, features of the natural world and included a lengthy analysis of the lodestone's powers of attracting iron. He was intrigued by action-at-a-distance and made prior mention of the combustion of kindling remote from a flame. Lucretius, *DRN*, 6. 906–916, introduced the magnet:

Quod superest, agere incipiam quo foedere fiat naturae, lapis hic ut ferrum ducere possit, quem Magneta vocant patrio de nomine Grai, Magnetum quia sit patrii in finibus ortus. hunc homines lapidem mirantur quippe catenam saepe ex anellis reddit pendentibus ex se. quinque etenim licet interdum pluresque videre ordine demisso levibus iactarier auris, unus ubi ex uno dependet subter adhaerens ex alioque alius lapidis vim vinclaque noscitur usque adeo permanenter vis pervaleat eius.

Moving on I shall begin to discuss by what law of nature it is that this stone can attract iron. The Greeks call it a magnet, after its fatherland, seeing that it cropped up in the native territory of the Magnesians. Men look at this stone with wonder for time and again it creates a chain of little rings dangling from itself, and as a matter of fact one can see five, sometimes more, serially suspended, swayed by breaths of air, where one hangs from another one, in ever lower attachment, and one from another recognises the connecting force to the extent that it pervasively maintains its power.

Lucretius first established four principles involving relative effects: flux, the continuing emanation of particles from things, e.g. heat from the sun; the disparity of fluxion effects, e.g. sun bakes clay but melts snow; the pervasive porosity in things, e.g. otherwise how could odours pass through a wall; the disparity of porosity to fluxions e.g. sounds traverse stones, but sights don't.

For the lodestone/magnet, he had three agencies. Firstly, strong seeds (current, flux) emanate from the lodestone shifting away air between it and iron (which has unusually tightly bound atoms requiring iron to move as a unit) so the iron is sucked into this vacuum (being loosely structured, wood and rocks don't do this so their emanations simply abrade off and the bulk material does not move). Secondly, the iron is pushed by the thicker air behind it, like wind in a ship's sails. Thirdly, air in the iron's pores, in perpetual restless motion, is an internal engine of movement too.

Thus the lodestone's power is explained, Lucretius, *DRN*, 6. 998–1011:

*Quapropter bene ubi haec confirmata atque locata
omnia constiterint nobis praeposta parata,
quod superest facile hinc ratio reddetur et omnis
causa patefiet quae ferri pelliciat vim.
Principio fluere e lapide hoc permulta necessest
semina sive aestum qui discutit aera plagis
inter qui lapidem ferrumque est cumque locatus.
Hoc ubi inanitur spatium multusque vacefit
in medio locus, extemplo primordia ferri
in vacuum prolapsa cadunt coniuncta fit utque
annulus ipse sequatur eatque ita corpore toto.
Nec res ulla magis primoribus ex elementis
indupedita suis ar(e)te conexas cohaeret
quam validi ferri natura et frigidus horror.*

So that now these principles have been determined for us – all set, established, ready to apply, and authoritative, then next an explanation is readily supplied and the entire reason revealed as to what induces the vigorous movement of iron (to the lodestone). Firstly, it must be the case that very many atoms emanate from this stone, perhaps acting as a surge which by its buffeting displaces whatever air is positioned between iron and stone. When this interval is emptied and plenty of space is unoccupied in the middle, right away the elements of the iron moving as a cohesive unit are launched into the emptiness, and it happens that the (test iron) ring itself in its entirety yields (to the force) and moves. Nor is there anything, comprising primary particles linked and bound, more compactly held together than the structure of iron with its cold rigidity.

In his rugged poetry Lucretius endeavoured to show the way to Epicurus' goal of mental tranquillity by removing fear of the gods and of death. The aim was a mind freed from disturbance, not one wallowing in the self-indulgent hedonism of popular repute. He provided rational explanations of phenomena using Epicurean physics: atoms (*primordia rerum*), void (*inane*), and porosity (*raritas*). His catalogue of explicable marvels included earthquakes, volcanoes, stormy skies, the vastness of seas, and it culminated in the lodestone. Quite an honour for a nondescript rock.

Sextus Propertius (c50 BC – after 16 BC) wrote many poems in a refined style. One of these was devoted to the bawdy witch Acanthis, and her precepts on how women should manage men. Among several instances of her awesome abilities, Propertius, *Elegiae* 4. 5, 9, cited:

illa velit, poterit magnes non ducere ferram
should she wish, lodestone will not attract iron

Pliny the Elder (Gaius Plinius Secundus, AD 23–79) was a prolific writer; he died south of Pompeii, documenting the eruption of Vesuvius. His outstanding achievement was the compilation of thirty seven books of natural history, the *Naturalis Historia* (*NH*), which included information on the lodestone. Regarding its discovery Pliny, *NH*, 36. 127, noted:

*magnes appellatus est ab inventore, ut auctor est Nicander
... invenisse autem fertur clavis crepidarum, baculi cuspidem
haerentibus, cum armenta pasceret.*

Nicander advises that it was called magnes after its finder ... and indeed is reported to have discovered it clinging to his sandal nails and staff tip, when grazing his herds.

To the ancients, rocks could be weird. Nature provided them with a voice (echoes, earthquake rumbling: Pliny, *NH*, 2. 115, 193) but lodestone was really remarkable. Lodestone's strangeness and affinity for iron were emphasised, Pliny, *NH*, 36. 126–127:

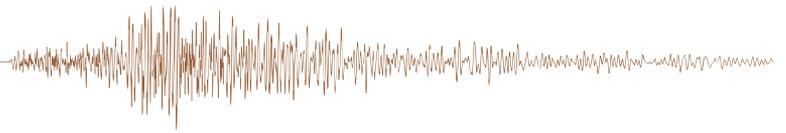
*quid enim mirabilius aut qua in parte naturae maior
inprobitas? dederat vocem saxis, ut diximus, respondentem
homini, immo vero et obloquentem. quid lapidis rigore
pigrius? ecce sensus manusque tribuit illi. quid ferri duritia
pugnacius? pedes ei impertivit et mores. trahitur namque
magnete lapide domitrixque illa rerum omnium materia ad
inane nescio quid currit atque ut propius venit, adsilit
tenetur amplexuque haeret.*

What is more amazing (than this stone) or at least where has nature shown greater devilry? She gave rocks a voice answering, or rather answering back, to man. What is more indolent than the inert character of stone? Yet nature has endowed it with awareness and hooking hands. What is more unyielding than the harshness of iron? On it nature has bestowed feet and a mode of behaviour. For it is drawn by the lodestone, and the all-subduing substance hastens to something like a vacuum, and on its approach it leaps towards the stone, is held and kept there by its embrace.

Pliny (*NH*, 34. 118) mentioned an aborted application of magnetic energy where the third century BC architect Timochares died before he could install lodestone in the vaulted roof of Arsinoë's Temple (Alexandria), so the iron cult image would hang mid-air. Pliny documented various lodestone locations, the best variety being blue and from Ethiopia (Ethiopia, Arabia and India were somewhat indefinite and confused locations in ancient and medieval times). He reckoned that, properly prepared, lodestone was useful in treating eye problems and burns.

In late antiquity the lodestone featured in a poem of pagan praise by Claudius Claudianus (AD fl. 395), and as a contributor to the proof of the reality of hell and damnation by Saint Augustine – Aurelius Augustinus (AD 354–430), Bishop of Hippo.

Claudian was Rome's final eminent poet in the classical tradition. He wrote in hexameters on many topics, and showed interest in the world of nature e.g. seven poems on a liquid inclusion in a crystal. His poem on the lodestone is quite instructive, as it gives an indication of the esteem in which it was held by the ancient world and also provides some information on one of the religious ceremonies. Claudian does not seem to have been a Christian even though his emperor Honorius' court was. So we see the lodestone through admiring, terminally pagan eyes.



Claudian, *Magnes* 1–9, classed the lodestone with other major phenomena as requiring clarification by philosophers.

*Quisquis sollicita mundum ratione secutus
semina rimatur rerum, quo luna laborat
defectu, quae causa iubet pallescere solem,
unde rubescentes ferali crine cometae,
unde fluant venti, trepidae quis viscera terrae
concutiat motus, quis fulgura ducat hiatus,
unde tonent nubes, quo lumine floreat arcus,
hoc mihi quaerenti si quid dependere veri
mens valet expediat.*

Whoever, having observed the universe, investigates with anxious consideration the basic principles of physical phenomena and the reasons for the lunar and solar eclipses, the fiery comets with baleful tail, the streaming winds, the movement quaking the earth's interior, the airy cleft drawing lightning along, the thundering clouds, the shining rainbow; if an intellect is capable of discovering some truth, then for me a seeker of truth, let him explain this:

'This' is the lodestone, an unlikely marvel rivalling all others. The worth of lodestone in the ancient world was indicated by its being esteemed above the best pearls (*margaritae*) which were held in very high regard, Claudian, *Magnes* 9–21:

*Lapis est cognomine magnes
decolor obscurus vilis. non ille repexam
caesariem regum non candida virginis ornat
colla nec insigni splendet per cingula morsu,
sed nova si nigri videas miracula saxi
tunc pulchros superat cultus et quidquid Eois
Indus litoribus Rubra scrutatur in alga.
nam ferro meruit vitam ferrique rigore
vescitur, hoc dulces epulas, hoc pabula novit,
hinc proprias renovat vires, hinc fusa per artus
aspera secretum servant alimenta vigorem,
hoc absente perit, tristi morientia torpent
membra fame, venasque sitis consumit apertas.*

There exists a stone called lodestone; discoloured, dingy, nondescript. It does not lend distinction to the combed locks of kings, nor to the fair necks of girls, nor does it gleam on the showy clasps of sword belts. But in fact if you pay due regard to the strange marvels of this dark rock then it outshines elegant adornments and anything, on far eastern shores, that the Indian looks for in the weed of the Red Sea (i.e. pearls). Moreover it sustains itself with iron, feeding on its hardness, recognising such fodder as a fine feast, thereupon refreshing its peculiar power, the harsh nourishment preserves its hidden liveliness. Without iron it wastes away, its withering inner parts grow sluggish from grim hunger, and thirst exhausts its opened arteries. [Red Sea – Mare Rubrum – the Arabian and Persian Gulfs]

Regarding pearls in the ancient world, Pliny, *NH*, 9. 106, remarked:

*principium ergo columnaque omnium rerum pretii
margaritae tenent ... praecipue autem laudantur circa
Arabiam in Persico sinu maris Rubri.*

so pearls hold first place and top rank of all valuable things (from the sea) ... but pearls around Arabia on the Persian Gulf of the Red Sea are particularly esteemed.

Pearls were valued in second spot, above emeralds but below diamonds. Pliny, *NH*, 37. 55, 62:

*maximum in rebus humanis ... pretium habet adamas ...
proximum apud nos Indicis Arabisque margaritis pretium
est.*

diamond is the most valued of human possessions ... next in value in our eyes are Indian and Arabian pearls.

The lodestone is activated by its own warm feelings; iron responds to its beckoning. Claudian, *Magnes*, 40–44:

*Quis calor infudit geminis alterna metallis
foedera, quae duras iungit concordia mentes?
flagrat anhela silex et amicam saucia sentit
materiem placidosque chalybs cognoscit amores.*

What warmth instils the reciprocal bonds in kindred metallics?
What harmony pairs their hardy dispositions?
The stone, afire, sighing, smitten, perceives congenial material,
and the iron finds quiet attachment.

In the rest of the poem Claudian described a religious ceremony mating two deities: a polished iron statue of Mars and a lodestone image of Venus. She is in control, she does the attracting, she subdues his murderous ferocity by giving him peace in her embrace. The lodestone functioned here as a ritual therapeutic agent.

In his *De Civitate Dei Contra Paganos (CD)*, The City of God Against the Pagans, Augustine diligently sought to demonstrate the credibility of hell with its fiery torments for wicked bodies that must yet need to survive an eternity of burning. He noted reports of the salamander living in fire, worms tolerating hot springs, volcanoes burning without being consumed. His approach, *CD*, 21. 5 was:

*quanta sint quorum ratio nequeat agnosci et tamen eadem
vera esse non sit ambiguum*

in what degree there are things whose rationale cannot be identified but are true without doubt.

The lodestone was included as a well-known marvel that existed but was inexplicable. Augustine commented, in words reminiscent of Lucretius and Plato, *CD*, 21. 4:

*Magnetem lapidem novimus mirabilem ferri esse raptorem;
quod cum primum uidi, uehementer inhorruui. Quippe
cernebam a lapide ferreum anulum raptum atque
suspensum; deinde tamquam ferro, quod rapuerat, vim
dedisset suam communemque fecisset, idem annulus alteri
admotus est eundemque suspendit, atque ut ille prior lapidi,
sic alter annulus priori anulo cohaerebat; accessit eodem*

modo tertius, accessit et quartus ... Quis istam virtutem lapidis non stupeat?

We recognise in the lodestone an extraordinary ability to seize iron; I was much perturbed when I first saw it. The reason is that I clearly saw an iron ring grabbed and held up by the stone. Then just as if the stone had given its own power to the attracted iron, and made it communicable, this ring was moved to another and it held it up. And then as the first ring was hanging on the stone so the second held on to the first; a third ring and a fourth ring were added in the same way ... Who would not be amazed at this power of the stone?

Augustine maintained, since such marvels are manifest, the inability to provide explanations did not mean that some things could never have existed or would never exist i.e. his biblical interpretations should be accepted by the faithful. The lodestone's curious role in theological sophistry on the credibility of hell seems not to have been pursued much in later centuries.

Medieval Beliefs

In the early Middle Ages, Marbod (1035–1123) was Bishop of Rennes, ~300 km WSW of Paris. Between 1061–1081, before the printing press, he compiled the first and most popular of all the medieval lapidaries with sixty minerals, gems, stones and their magical and medicinal properties, in 735 Latin hexameters. It included a thirty line poem on the lodestone. Perhaps he believed that the hexameter rhythm helped his students to master the intelligence that follows. Marbod's mineralogy was cited in the prestigious *Laborintus*, Eberhard's 13th century didactic poem, as a curriculum author of importance in those days. Marbod was popular for centuries. Beckmann (1799) gave a listing of the many editions and provided a complete Latin text and commentary. Marbod's poem, *De Magnete*, has some absorbing detail:

*Magnetes lapis est inventus apud Troglodytas,
Quem lapidum genitrix nihilominus India mittit.
Hic ferruginei cognoscitur esse coloris.
Cui natura dedit vicinum tollere ferrum.
Deendor magus hoc primum dicitur vsus,
Consciis in magica nihil esse potentius arte.
Post illum fertur famosa venefica Circe
Hoc in praestigiis magicis specialiter vsa.
Hinc et apud Medos, cum res venisset in vsum,
Detexit lapidis magis experientia vires.
Nam qui scire cupit, sua num sit adultera coniux,
Suppositum capiti lapidem stertentis adaptet;
Mox quae casta manet, petit amplexura maritum,
Non tamen evigilans. Cadit omnis adultera lecto,
Tanquam pulsa manu, subito foetore coacta,
Quem lapis emittit celati criminis index.
Si fur claustra domus spoliis gazisque refertae,
Ingrediens, prunas ardentis per loca ponat,
Et superaspergat magnetis fragmina prunis;
Mox in ea quicunque domo mansere, fugantur,
Vi per tetragonum fumi vapor alta vaporet.
Mentibus eversis, velut impendente ruina,
Diffugient omnes, in ea quicunque manebant,*

*Et fur securus rapiet quaecunque libebit.
Conciliare potest vxoribus ipse maritos,
Et vice conuersa nuptas revocare maritis.
Gratia praestatur simul, et suadela per ipsum,
Sermonisque decor, disceptandique facultas.
Cum mulso datus, hydropem purgando resoluit.
Et combusturas super aspersus medicatur.*

The lodestone was discovered in Ethiopia, Yet India is the source of exports. This stone is known to have dusky colour. Nature gave it the ability to pick up iron nearby. Learned Deendor is reckoned to have made use of it first, Well aware that nothing is mightier in magic. After him Circe the famous sorceress is said To have used it, particularly in occult deceptions. Henceforth in Persia, when its use became customary, Experience revealed more of the stone's power. For anyone who wants to know whether his spouse is unfaithful, Let him position the stone under her head while she snores, Soon, if chaste, she seeks to embrace her husband, Yet she is not awake. But any adulteress falls out of bed, As if pushed by hand, compelled by a sudden stench, Which the stone emits as proof of her secret sin. If a thief overcoming the bolted gate of a richly furnished house. Places glowing coals throughout, And sprinkles fragmented lodestone over the coals, Then any who did stay there would soon be forced to flee As a result of clouds of smoke everywhere filling the house. In panic, as collapse threatens, Any remaining will scatter, all of them, So the untroubled thief will grab whatever he likes. Actually, it is possible for lodestone to win over husbands to wives, And conversely to induce wives to return to husbands. Charisma and the power of persuasion is produced through its agency, Together with elegance of speech and skill in debate. Given with honeyed wine it cures the dropsy by cleansing And in fact it heals when sprinkled on burns.

The Garden of Health, *Hortus Sanitatis (HS)*, was a compilation of facts and factoids, probably from many authors, about the therapeutic virtues of natural tissues (animals etc) and materials (minerals). It was the most popular of the medieval herbals; many editions were printed. The writer has consulted the 1497 edition. In the volume on stones (*Tractatus De Lapidibus, TL*), on the authority of Serapion, the Moor sage, lodestone's deadly effects (see Figure 3) on the unwary are described, *HS, TL 57*:

Magnes. Minera huius lapidis est in maritinis prope terras indie. Et quando naves appropinquant monti minere ipsius non remanet in eis aliquod ferrum quod non egrediatur a navi et volet sicut avis usque ad montem. Et no(n) e(st) aliquis clavus insitus taliter q(uod) possit evelli ... et propter hoc naves illarum partium non clavantur cum clavis ferreis sed cum clavis ligneis. Nam si forent clavata(e) e clavis ferreis quando appropinquare(n)t illi monti dilacerantur.



Figure 3. *The fate of ships with ferrous fixtures venturing foolishly close to a lodestone mountain. Woodcut Hortus Sanitatis.*

The lodestone. There is a deposit of this stone by the coast of India. When ships come near a mountain of this mineral, any iron object not only does not stay on a ship but also quits it and flies off quickly like a bird to the mountain. However, it is not the case that any driven fastening can be plucked out in such a way ... and because of this ships from those parts are not riveted with iron nails, but with wooden ones. For, if fastened with iron nails, when they come close to that mountain, they collapse in pieces.

Perhaps this tale was inspired by Pliny's claim, *NH*, 2. 211:

duo sunt montes juxta flumen Indum quorum alteri natura ut ferrum omne teneat alteri ut respuat, itaque si sint clavi in calciamento vestigia avelli in altero non posse in altero sisti

Near the Indus are two mountains, a feature of one is to hold tight to all iron and of the other to reject it. Accordingly, if there are nails in shoes, on one mountain footsteps are locked to, and on the other repelled from, the ground.

Pre Modern Times

Georgius Agricola (1494–1555), the German Georg Bauer, was born in Saxony during a time of the European revival of classical learning. His mineralogy book *De Natura Fossilium* (*DNF*), published in 1546, surveyed all known minerals of importance. He categorised them by their physical properties i.e. colour, hardness, weight etc. This book earned him a great reputation, the Father of Mineralogy, further enhanced by the posthumous publication in 1556 of *De Re Metallica*, which for the next two centuries was the standard mining textbook. It mentioned that lodestone was found in iron mines. He classified lodestone in his first genera, common stones, pointing out that while it always occurred in iron mines, of which there were many, it was only found in a few. He gave several general locations in Europe, Middle East, Ethiopia and India.

Agricola reviewed the properties of lodestone, *DNF* 5:

different vero Magnetes colore. qui aut niger est, aut in nigro ceruleus, aut in nigro rufus, aut contra, in rufo niger. differunt spissitudine et raritate. nam alii toti densi sunt, & similes smiridi, alii aliqua parte rari, & velut exesi, pumicique similes. differunt pondere, quod partim graves sint, partim leves, mediocres partim. differunt viribus. etenim quidam valide ad se trahunt ferrum, quos mares nominant. aliqui parum valide, quos foeminas. optimus certe magnes non modo ad se trahit & tenet ferrum, sed etiam vim suam in id ita transfundit, ut possit aliud ferrum, quod appositum. fuerit, apprehendere & tenere.

Lodestones differ in colour which is either black or dark bluish black, either reddish brown-black or black-reddish brown. They differ in density and porosity for some are entirely solid and are like emery, others in some degree have an open texture as if hollowed out and are like pumice. They differ in weight with some heavy, some light, some in between. They differ in strength for particular types attract iron strongly, these are called males; some have only a little attraction, these are females. Of course the best lodestone not only attracts and holds iron but also transfuses its own force into it, so that it in turn is able to seize and hold another piece of iron set beside it. [Emery is ferruginous corundum containing some magnetite]

Agricola used the findings of previous authors, presumably supplemented by his own observations. The information on colour has been interpreted rather than translated here. In English it is not easy to represent subtle colour by words because speech is inadequate for what an eye sees. Latin colour words are quite difficult to translate as they often reflect an impression, aspect, radiance, or sheen rather than something recognisable in a modern quantitative colour chart. Agricola's *ceruleus* can mean the blue of the sky, the blue-green of the sea, the grey-green of plants, or a dusky-dark colour. Agricola's *rufus* usually means red, or reddish, but it can mean tawny or chestnut (red brown, golden brown). All this is relevant if one is trying to identify what the documented lithologies actually were.

As to the nature of the lodestone's power, Agricola remarked, *DNF*, 5:

quae res quia vulgo maximam admirationem movet, ferrum, cui lapis ille dedit vim suam, vivum ut scribit Plinius, appellant: quia philosophis Agrigentinus Empedocles magnetem animatum esse affirmavit. certe his eius viribus Theologi actiones diuinas, medici naturales, quarum ratio reddi non potest, confirmant.

Because these phenomena occasion considerable wonder in the populace, they call the iron, to which the lodestone conferred its power, 'living', as Pliny records, in view of the fact that Empedocles of Agrigentum [southern Sicily] maintained that the lodestone was animate. Without any doubt, theologians ascribe divine influences for the lodestone's inexplicable power; doctors declare the causes to be natural.

Agricola himself was a medico; he was Joachimsthal's town physician, having studied philosophy, medicine, and natural science in Italy. Physician (natural) philosophers were

intellectually very influential in those times. They had empirical chemical knowledge (derived from alchemy), and some had proto-scientific interests in minerals, mines, and miners' diseases, e.g. Agricola's famous and contentious contemporary Paracelsus (c.1490–1541).

Additional lodestone features and fancies were noted by Agricola, *DNF*, 5:

Aethiopico autem tam valida(m) vim esse Plinius scribit, ut magnetem alium ad se trahat. sed magnes ad se non allicit ferrum si fuerit rubiginosum, aut impurum, aut oblitum allii cepearum ve succo. nec vero minus adamas eius viribus resistit. si enim iuxta ferrum ponitur, non potest id magnes ad se allicere, aut si iam traxit, quamprimum adamas fuerit appositus, ipsum dimittit. quinetiam magnes si diu ferro aut eius vena careat, aliquam uirum iacturam facit: quod ne fiat, squama ferri est obruendus.

Regarding the Ethiopian type, Pliny writes that it is so strong as to attract another lodestone. However, lodestone does not attract rusty or impure iron or iron coated with the juice of garlic or onions. And no less does diamond resist the lodestone power for if one is placed next to iron the lodestone cannot attract it, or if already attracted, straightaway the lodestone lets it go if a diamond is placed beside it. What is more, if lodestone is kept away from its (parent) vein or iron for a long time it results in some loss of strength. Lest this happen it is necessary to cover the lodestone with a platy fragment of iron.

These observations are a mix of fact and fiction pre-dating the initiation of inductive science by Francis Bacon (1561–1626) and others; their motto was: *plurimis cognita et plurimis probata* – phenomena openly acknowledged and publicly tested.

For the miners in the Magnetum Iron Mine near Eibenstock (Saxony) the lodestone vein therein provided a handy means of tool storage. Agricola, *DNF*, 5:

ita etiam nostris, qui in fodina ferri, quam magnetum vocari supra dixi, operam dederunt. cum enim, definito labore perfuncti, cuneos & malleos de minibus in solo cuniculi, ut sit, deposuissent, aut abiecissent, postero die ad eundem laborem redeuntes, instrumenta non invenerunt in solo cuniculi, in quo deposita errant, sed ad superiorem alterius lateris partem: ex qua lapidis uiribus attracta pendebant: quod operarii, harum rerum rudes, admirati dominis indicarunt. ex quibus cum accepissent magnetis venam esse, vim illam suis facetiis ludentes instrumenta saepenumero de lapide suspenderunt.

So too (the power of lodestone was revealed) to our countrymen who worked in the Magnetum iron mine mentioned above for, having completed their shift, and, as usual, put down their wedge and hammer hand tools on the mine floor, on returning to their labours next day they found the tools not where they had been left on the floor, but in contact with the upper part of the nearby face from which they hung down, drawn up by the power of a particular stone. The surprised workmen, ignorant of such matters, pointed this out to the mine owners. Told that it was a vein of lodestone, they sportively indulged

themselves with the force and oftentimes hung up their tools from the stone.

The lodestone had a key role in the magnetic model of the earth postulated by William Gilbert (1544–1603) the greatest scientist of the reign of Queen Elizabeth I. After original thinking and inspired experimentation and analysis, in 1600 he published his conception of the earth as a great magnet and explained the inclination of magnetic needles. He used a ball of lodestone as a *terrella*, a little earth, and wisps of iron wire to prove his point (see Figure 4). Overall, his work was very controversial then (e.g. his statements about heliocentricity and planet rotation) so the work was condemned during Galileo's 1633 trial. Gilbert's words are simple and direct, *De Magnete* 5. 2:

Ostenditur declinatio ferri magnetici super terrellam, per varia fila ferrea aequalia, longitudinis grani hordei, disposita super meridianum. Fila in aequatore virtute lapidis diriguntur versus polos, & decumbunt super corpus ad horizontis eius planum. Quo propius apponuntur polis, eo magis conuertibili natura eriguntur. In polis ipsis perpendiculariter ad centrum ipsum tendunt. At obeli ferrei non recte eriguntur nisi in vegeto lapide, si fuerint iusto longiores.

The attitude of iron magnetised on a *terrella* is shown by means of several uniform iron strands of the length of a barleycorn distributed above a meridian. The filaments on the equator are directed towards the poles, by the lodestone's power, and lie horizontally on the *terrella*. The nearer they are placed to the poles the more erect they become by an ability to align. At the poles, now perpendicular, they point to the *terrella*'s centre. However, iron points if they be longer than that prescribed do not incline correctly unless placed on a powerful stone. [A barleycorn, *hordeum*, is about 8 mm in length.]

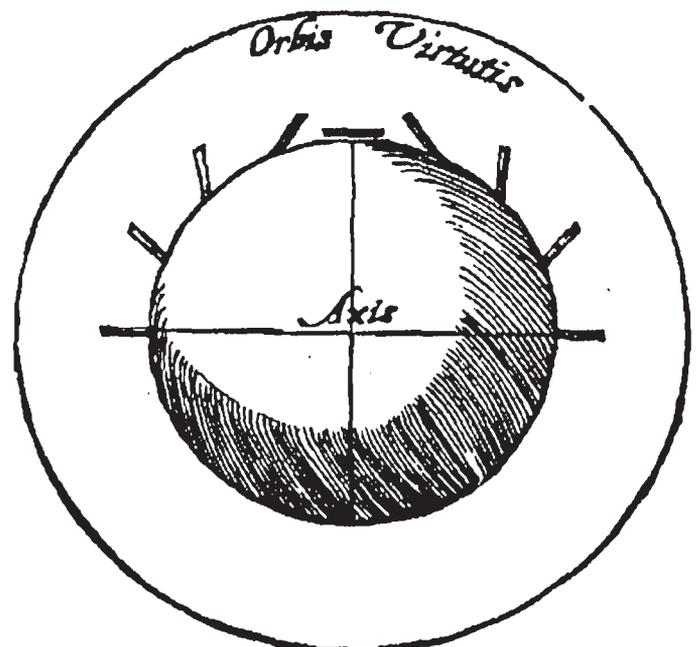
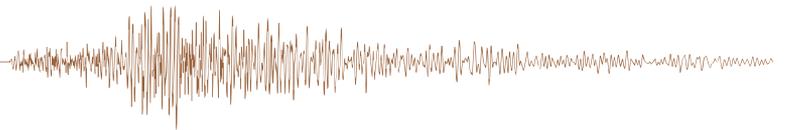


Figure 4. Gilbert's lodestone sphere demonstrating the earth's magnetism by the variation in inclination of fine iron needles. *Orbis virtutis*: sphere of force – limit of *terrella*'s magnetic field.



Polydore Vergil (1470–1555) in his *De Inventoribus Rerum*, 1499, gave an account of many inventions from antiquity to his day. He greatly admired the magnetic compass but had no idea who invented it or when it was invented. Magnetic compasses in Europe were first mentioned in the 12th century, and were probably in use before then. Mariners came to rely on the lodestone-magnetised needle for direction in the day, when the sun was hidden by clouds, and in the night, whenever the polestar was obscured. The poem *La Bible Guiot* by Guiot de Provins (c1206) stated that a needle touched by an ugly brown stone and floated by a stick or straw on water turns its end to the polestar.

The possible medical benefits of lodestone still seem to have been taken seriously in the seventeenth century. Richard Burton (1577–1640) was an Oxford scholar and author of the massive and popular *Anatomy of Melancholy* (AM). He wrote it in English, after considering and deciding against Latin. Burton, AM 2. 4. 1. 4 noted: ‘Nicholas Cabeus, a Jesuit of Ferrara, in the first book of his *Magnetical Philosophy*, cap.3, speaking of the virtues of a loadstone, recited many several opinions; some say that if it be taken in parcels inward, *si quis per frusta voret, juventutem restituet*, it will, like viper’s wine, restore one to his youth; and yet if carried about them, others will have it to cause melancholy; let experience determine.’ So, if ingested (*frustum*: ‘bit’) it may do good; if carried about in a pocket it may cause harm. Lodestone pills seem not to have survived as a rejuvenating medicine, even in rustic and folk remedies. It is interesting that Aulus Cornelius Celsus (AD 14–37) who, in elegant Latin, surveyed, quite impressively, the whole field of ancient professional medicine, did not mention lodestone in his list of medicaments, although hematite, lead, sulphur, nitre, and other minerals were included.

After Gilbert, matters magnetic continued to occupy the minds of the 17th century intelligentsia. Burton took a break from his mournful compilation and allowed himself a digression. Burton, AM 2. 2. 3:

... concerning those northern parts under the Pole ... whether there be ... a great rock of lodestones which may cause the needle in the compass to bend that way, and what should be the true cause of the variations of the compass, is it a magnetised rock, or the polestar, as Cardan will; or some other star in the bear ... *vel situs in vena terrae* [or situated in a vein/extended mass of the earth] as Agricola; or the nearness of the next continent, as Cabeus will; or some other cause ... till we have better intelligence let our Dr Gilbert and Nicholas Cabeus the Jesuit, that have both written great volumes of this subject, satisfy these inquisitors.

The Jesuit Athanasius Kircher (1601/2–1680) was an extraordinary, erudite, polymath based in Rome from 1638. His views on many subjects, sometimes contentious, were very influential throughout Europe. He revered antiquity and embraced occult philosophy. His extensive treatises on earth science (*Mundus Subterraneus*, and *Magnes*) were a blend of the esoteric and the empiric. He climbed Mt Vesuvius and proposed that eruptions resulted from subterranean cyclic events rather than the displeasure of deities. This was an important geological insight, remarkable for its time. Yet Kircher was very much a 17th century natural philosopher. The bases of natural bodies were believed to be Aristotle’s four elements, fire, earth,

air, water. These elements were not concrete matter but represented certain properties which, in mediated combination, resulted in the production of materials (Adams 1954). Furthermore, celestial forces impinging on the earth, and on the elements, were regarded as causative agents for minerals and stones, both common and exotic. The sun’s heat baked clay; Venus’ creative influences led to the development of copper, Mars’ to iron, Jupiter’s to tin, Saturn’s to lead. The theory of the lapidifying juice (mineral bearing solutions) was also current, although its nature was controversial. This juice operating through the earth’s porosity and permeability produced minerals and stones (e.g. stalactites in limestone caves). Following Seneca (~4 BC – AD 65), these macrocosmic events were regarded as analogous to the microcosm, the human body, where fluids circulated and materials formed (e.g. kidney stones). All these perceptions were to change completely in the 18th century.

Kircher accepted the notion of an essential lapidifying agency, *Causa Formalis, Magnes* 1.1.2:

Causa porro formalis lapidum nihil aliud est, quam vis quaedam lapidifica, quae vel materiae praeparatae insidet, vel efficienti causae accedere debet.

Furthermore the essential cause of stones is nothing other than a kind of lapidifying force: be it intrinsic to the readied material, or necessarily added to the efficient cause [The heavenly ‘general worker’ driving terrestrial activity].

Lithological variety could be explained, *Lapidum Generatio, Magnes* 1.1.2 :

Dum enim materia succum lapidificum ducens, terrae partes intrat, atque aqua e massa iterum exstillat, vel ab exhalatione calida expellitur atque absumitur: massa illa paulatim expulso humido indurescit, donec in lapidem formam massae servantem abeat. Hinc pro diversitate succi terrestres, massae, aut etiam matricis, in qua formantur constitutione, variae quoque lapidum species nascuntur.

For when the material cause guiding the lapidifying juice enters parts of the earth, and, next, water trickles out of the (intruded) mass, or is expelled by warm vapor and taken away, that dewatered mass gradually hardens until it is changed into stone, preserving the form of the mass. Regarding this: on account of the diversity in lapidifying juice, the mass, or even its interstitial texture in which substances are structured, so too are various kinds of stone produced.

Addressing lodestone magnetite directly, Kircher acknowledged its importance and global reach, *Magnetis Generatio, Magnes* 1.1.2:

si in terrestri materia, vera, genuina & homogenea telluris portione, seu matrice Magnetica, fuligo dicta Magnetica recepta inibi varia decoctione, ab omni humido superfluo fuerit vindicata, ea vi lapidifica ibidem latente in lapidem formam virtutesque; massae, matricisque; seruantem videlicet Magnetem, convertetur, cuiusmodi Magnetis saxorum fibris totius telluris compagem certo ordine a polo ad polum, non secus, ac quandam veluti mundani dorsi

spinam, qua partes partibus firmiss solidiusque; connecterentur, mirabili sane sagacissimae naturae consilio constitutam esse in sequentibus fusius declarabitur

if in terrestrial material, a natural and homogeneous portion of the earth, that is to say the host for magnetic matter, dark thick magnetic vapour has been accepted, there freed from all excess moisture by changing heating events, it will be altered to lodestone in that very place, hidden in the subsurface, by the lapidifying force, preserving the form and properties of mass and internal structure. It will be amply shown in the following discussion that the framework of the whole earth has been established, in a remarkable plan of very clever nature, by magnetic veining of rocks of whatever kind, in specific arrangement from pole to pole just like what might be called the backbone of the world whereby parts are quite strongly and extensively linked together.

Kircher, for geological reasons, objected to Gilbert's simple model of the earth as a magnetic continuum, *Tellus non est magnus Magnes, Magnes* 1.1.3:

nemo me terram propterea cum Gilberto Magnetem magnum asserere existimet, dum enim venarum Magneticarum mentionem facio, non eas ita accipi volo, quasi ex perfecto & formato Magnete omnes consent; sed quod pleraeque inchoatae quaedam ad Magnetica corpora venae sint, quae etsi ob externo malo foedatas partes, & heterogenearum materialium variam misturam in perfectum Magnetem, utpote verioribus & magis genuinis terrae partibus nimium dispersis & disunitis non excrescant.

no one should think, with Gilbert, I claim, that the earth is a huge magnet, for, while I do make mention of magnetic veins, I do not propose such observations to be thus accepted as if all such comprise perfectly produced magnetic material. On the contrary, the fact is that very many kinds of veins have originated in the neighbourhood of lodestone occurrences, and yet these do not increase in their extent to a full mass of lodestone owing to contamination of their parts by extraneous impairment, and because they are an inconstant mixture of different materials; as one might expect. These are very much distributed in scattered fashion in the actual regions of the earth.

The lodestone was employed by Kircher (1654) to illustrate, by analogy, his technique of deciphering Egyptian hieroglyphics, using the *impresa* of the Jesuit Parthenian Academy in Rome (Figure 5). An *impresa* is a cryptic emblematic device, of fanciful design, which includes a motto, but no explanatory text. The image needs to be studied together with the motto to elicit its meaning; each is insufficient without the other. Kircher, *Oed. Aegypt.* 3.1:

... in Impresia quavis duo continentur, symbolum, & sententia, quarum coniunctione in abdita tandem eius, quod praesert, symboli significationem deuenimus; Verbi gratia in hoc Phrenoschemate praesente Magnetem vides, a quo concatenata annulorum series trahitur; vidisti symbolum, considera gnomen, quae est, 'arcanis nodis':

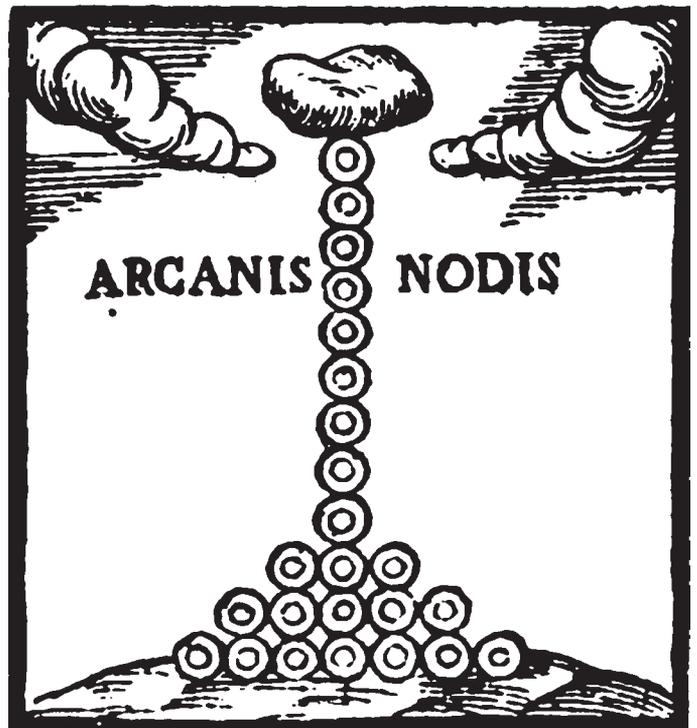


Figure 5. Kircher's (1654) *impresa* showing Plato's lodestone, iron rings and the key words 'by mysterious bonds' or 'by secret knots'.

quae verba nisi apposita fuissent, nihil in symbolo certi innotuisset ...

... in any *impresa* you like to consider two things are included, the depiction and the sentiment. After time and effort we arrive at the hidden meaning of this depiction to the extent exhibited. For instance in this informative pictorial presentation you see the Lodestone which attracts a series of rings linked together. Having seen the device, consider the label which is 'by mysterious bonds'. If these words had not been put on, nothing definite in relation to the depiction would have been intelligible ...

The lodestone and Plato's rings inspired the enigmatic *impresa*, a tribute to and reminder of the mysterious and marvellous.

Kircher's extensive earth science works warrant translation and study, for their inherent historical value, and for the information, attitudes, and insights they contain.

Concluding remarks

A curiosity now, famed for two millennia at least, the lodestone has been discussed here from several perspectives. Lodestone, while not rare, is not common in its occurrence as a special variety of magnetite that has a natural power of attracting iron. Magnetite is very familiar as one of the most common terrestrial oxides and one with salient physical features of great benefit to modern geoscience. Lodestone, being very unusual, greatly impressed previous generations. Despite its unattractive appearance it was an admired mineral type more precious than pearls, it was celebrated in persuasive Latin hexameters, it was an analogue for the power of deities, it took a witch to subdue



Figure 6. Tennant Creek Ironstone core showing the magnet effect which is patchy and not manifest on all the core surfaces.

it, it was deemed explicable by Epicurean atomic theory, it was involved in a rather tenuous argument for eternal punishment of wicked persons, it meant doom for unwary mariners, it furnished fodder for folk lore, it resided in the arsenal of the apothecary, it helped to demonstrate the earth's magnetism, and it assisted navigation. What other mineral has such a record? The lodestone was quite a remarkable rock; it still is, and oddly, yet to be completely studied and documented.

Previous generations had attitudes to nature quite different from current viewpoints. Belief in the four elements endured well into the 1600s. In 1650 the Old Testament chronologist Archbishop Ussher proposed 4004 BC as the date of all creation, which the scriptural literalist, and alchemical devotee, the great Sir Isaac Newton accepted. The review of lodestone given here very much pertains to earlier worlds. It seems strange that they appeared to know, at least in a general and empirical sense, more about lodestone than current geoscience. Where are the lodestone deposits? None are shown on the Barrington Atlas of the Greek and Roman World. What is their geometry? Can they be sampled and tested? What is the reason for the reported remarkable variations in colour and appearance? To what depth(s) does lightning charging extend? Are there other mechanisms for lodestone generation? The writer has observed unexplained, patchy, magnet effects in Tennant Creek Ironstone, (magnetite with ~5% hematite content), drilled at depth (Figure 6). Is the lodestone effect important in the bulk magnetisation of some geological bodies? The mineralogy, petrophysics, and petrochemistry of lodestones are worthy of more attention.

Acknowledgements

Dr D. F. Branagan introduced the writer to the wealth of geoscience information in Latin literature. Figure 2 was kindly provided by Mr Ross Pogson, Collections Manager Geosciences, Australian Museum Sydney and the photo was taken by Ms Kate Lowe; copyright is held by the Australian Museum. Dr. Phil Schmidt assisted with advice on lodestone's magnetisation characteristics and carried out some saturation magnetisation experiments on magnetite (these did not yield a magnet). Mrs S Franks, Mrs L Kalnins, and Mr D Kalnins prepared the manuscript. Many thanks to all.

This contribution on lodestone arose from the writer's continuing translation work on Marbod's Lapidary for which

Beckmann's summary edition of 1799 has been used, but Beckmann's footnotes in Latin and Greek have not been included here. All the translations herein are the writer's. Formal translations with scholarly introductions and commentaries may be found in the Loeb Classical Library (LCL) and other editions in Bibliography, except for Marbod, Hortus Sanitatis, and Kircher; as far as the writer is aware there are no English translations of these works. The discussion of the compass in medieval Europe is based on an entry in the Encyclopaedia Britannica, vol. 6, 1968 edition.

The Lionsville lodestone (Figure 2) seems to come from magnetite lenses within a probable pendant of volcanics and sediments in granitoids of the Dumbudgery Creek Granodiorite in the New England Fold Belt NSW (The Mineral Deposits of NSW, 1974, see Ch. 5 by N. L. Markham – fig. 5.20, location no. 86).

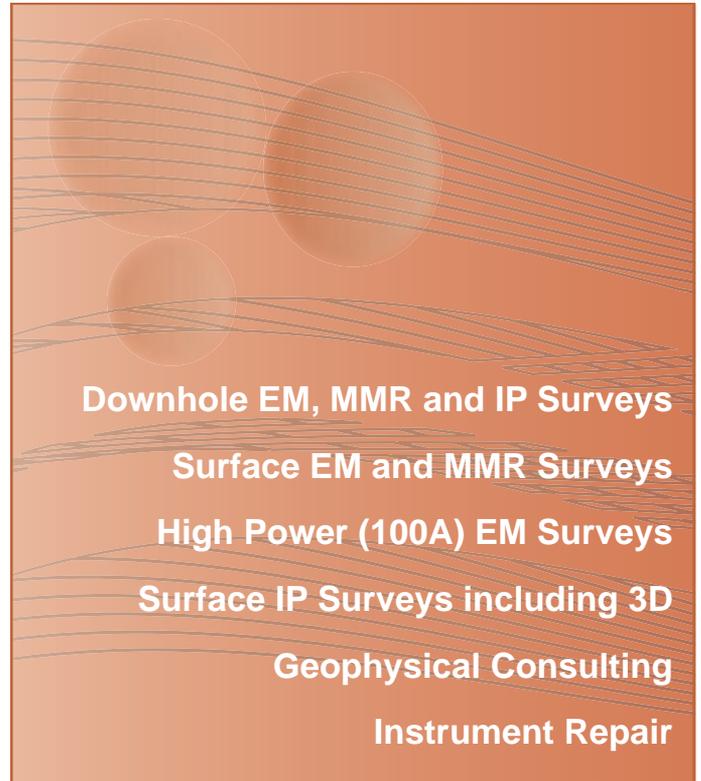
The Tennant Creek Ironstone with the patchy magnet effect was one of a suite of magnetite samples, from the Proterozoic Tennant Creek Inlier in the Northern Territory studied in the Emerson & Yang Australian Mineral Industries Research Association (AMIRA) Project P416: Electrical properties of magnetite rich rocks and ores (1994). The sample shown in Figure 6 is microcrystalline, spongy textured magnetite with minor hematite, chlorite and quartz occurring as veinlets or clusters. Maghaemite, if present, was not identified in routine thin section analysis. The physical properties are: 4.91 g/cc density, 11 SI magnetic susceptibility, 0.6 S/m DC galvanic conductivity, 3.3 S/m electromagnetic (induced) conductivity. The EM and galvanic responses differ on account of texture, which is also responsible for the quite low conductivities (compared to magnetite's single crystal conductivity of ~20 000 S/m). The sample came from 150m depth, below the zone of oxidation.

Bibliography

- [LCL refers to the Loeb Classical Library]
 Adams, F. D., 1954, *The birth and development of the geological sciences*: Dover Publ.
 Agricola, G., 1546, *De natura fossilium*: Froben, Basel [Georg Bauer's Mineralogy].
 Anon, 1497, *Hortus Sanitatis, De lapidibus et in terre venis nascentibus*: medieval compilation, publ. in Mainz, author not known with any certainty, (copy, University of Madrid Library).
 Bandy, M. C., 1930, *The genesis of lodestone: Econ. Geol.*, 25, 871–875.
 Bandy, M. C. & Bandy, J. A., 2004, *De natura fossilium*: Dover Publ. [Agricola's Mineralogy]
 Beckmann, J., 1799, *Marbodi liber lapidum seu de gemmis* [Marbod's book of stones and on gems]: J.C. Dieterich, Göttingen.
 Burton, R., (Democritus Junior), 1628, *The anatomy of melancholy*: H. Cripps, Oxford.
 Caley, E. R., and Richards, J. F. C., 1956, *Theophrastus on stones*: The Ohio State University.
 Copenhaver, B. P., 2002, *Polydore Vergil, On Discovery*: Harvard Uni Press.
 Corcoran, T. H., 1976, *Seneca – naturales questiones (3, 15 : earth-body analogy)*: William Heinemann Ltd. [LCL #450]
 Eicholz, D. E., 1971, *Pliny natural history, 36–37*: Harvard Uni. Press. [LCL #419]

- Gilbert, W., 1600, *De magnete, magneticisque corporibus, et de magnete tellure*: P. Short, London.
- Godwin, J., 1991, *Lucretius de rerum natura*, 6: Aris & Phillips.
- Goold, G. P., 1999, *Propertius elegies*: Harvard Uni. Press. [LCL #18]
- Green, W. H., 1972, *Augustine, the city of god against the pagans*: Harvard Uni. Press. [LCL #417]
- Greenblatt, S., 2011, *The swerve, how the world became modern*: Norton [On Lucretius' manuscript rediscovery].
- Gruner, J. W., 1929, The identity and genesis of lodestone magnetite: *Econ. Geol.*, 24, 771–775.
- Hoover, H. C. & Hoover L. H., 1950, *De re metallica*: Dover Publs. [Agricola on mining]
- Kircher, A., 1643, *Magnes*, 2nd edn.: Jodocus Kalcones.
- Kircher, A., 1654, *Oedipi Aegyptiaci tomus III*: Typograph, Vitalis Mascardi.
- Kircher, A., 1678, *Mundus subterraneus*, 3rd ed.: Janssonius, Amsterdam.
- Lamb, W. R. M., *Plato, vol.8, Ion 533 D*: William Heinemann. [LCL #164]
- Newhouse, W. H., 1929, *The identity and genesis of lodestone magnetite*: *Econ. Geol.*, 24, 62–67.
- Platnauer, M., 1998, *Claudian, v.2*: Harvard Uni. Press. [LCL #136]
- Rackham, H., 1949, *Pliny natural history*, 2: Harvard Uni. Press [LCL #330]
- Rackham, H., 1952, *Pliny natural history*, 9: Harvard Uni. Press. [LCL #353]
- Rackham, H., 1984, *Pliny natural history*, 33–35: Harvard Uni. Press. [LCL #394]
- Rouse, W. H. D., 1992, *Lucretius, on the nature of things (revised by Smith, M.F.)*: Harvard Uni. Press. [LCL #181]
- Sinker, A. P., 1962, *Introduction to Lucretius*: Cambridge Uni Press.
- Spencer, W. G., 1938, *Celsus de medicina, vol. 2*: Harvard Uni Press. [LCL #304]
- Stallings, A. E., 2007, *Lucretius the nature of things*: Penguin Classics.
- Stolzenberg, D., 2013, *Egyptian Oedipus, Athanasius Kircher and the secrets of antiquity*: Uni. Chicago Press.
- Talbert, R. J. A. ed., 2000. *Barrington Atlas of the Greek and Roman World*: Princeton Uni. Press.
- Wasilewski, P., and Kletetschka, G., 1999, Lodestone: nature's only permanent magnet – what it is and how it gets charged: *Geophysical Research Letters*, 26, 2275–2278.

Don Emerson is a geophysical consultant specialising in hard rock petrophysics. For a long time he has been interested in the mineralogical and geological information contained in ancient and medieval Latin and Greek texts.



Downhole EM, MMR and IP Surveys
Surface EM and MMR Surveys
High Power (100A) EM Surveys
Surface IP Surveys including 3D
Geophysical Consulting
Instrument Repair



4/133 Kelvin Rd, Maddington
Western Australia 6109

PO Box 3215, Lesmurdie
Western Australia 6076

p. (08) 9291 7733
f. (08) 9459 3953

e. sales@vortexgeophysics.com.au



VORTEX GEOPHYSICS
www.vortexgeophysics.com.au