What's the Matter with this Compass?

Magnetic Declination as Anomaly in Early Modern Instruments and Thought

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1. Introduction

This article uncovers the «discovery» of geomagnetic phenomena and how some of these phenomena were understood, or misunderstood, since the late Middle Ages. The fifteenth century is of focal importance for this microhistory – yet, textual sources are scarce and must be complemented by material objects, such as instruments, as sources in their own right. These artifacts tell about their makers' and users' conceptual apparatus and presuppositions. While scholastic contributions from the period are virtually absent to deliver insights into geomagnetism, this essay takes a somewhat «scholastic» perspective by targeting the enthymemes of scientific practitioners. These historical actors invoked hidden premises, and instead of taking their conclusions and discoveries at face value, historians should flesh out the very questions, premises, and practices that precede and underpin the documented statements and artifacts.

In 1681, the renowned French naturalist, Melchisédec Thévenot, thought to have unveiled a remarkable revelation buried within a manuscript containing a work dating back to 1269.[1] Crediting a certain Petrus Adsigerius, Thévenot claimed to have unearthed the earliest written evidence of knowledge of magnetic declination. Thévenot already had a clear and distinct understanding

1 M. Thévenot, *Recueil de voyages*, Paris 1681, pp. 29–30: «On a crû jusques à cette heure, que la déclinaison de l'Ayman n'a commencé d'estre observée que vers le commencement du dernier siecle: Cependant j'ay trouvé qu'elle varioit de 5 degrez l'an 1269, c'est dans un manuscript que m'est tombé entre les mains, avec ce titre ‹Epistola Petri Adsigerii in super rationibus naturae Magnetis›. Il y a une Remarque dans cette Lettre que la pointe de l'eguille que l'on suppose marquer exactement le Nord, décline vers l'Orient, et que par plusierus observations cette déclinaison s'est trouvée de 5 degrez.»

of magnetic declination: the angle of deviation between the geographical and magnetic north.[2] He also knew that this declination varied depending on the location and changed over time. Many of his early modern contemporaries had devised grand theories to explain these phenomena, often conceiving the Earth itself as a large magnet.[3] Could medieval scholars have already known about magnetic declination?

As a matter of fact, the author of the treatise from 1269 was Petrus Peregrinus, who wrote his *Epistola de magnete* to a certain Siger – hence the term «ad sigerum» in the Incipit, which the scribe of the codex Thévenot has seen misinterpreted as the author's name, Adsigerius.[4] This groundbreaking short treatise indeed contains the first detailed description of a magnetic compass, which had already appeared in Latin sources around 200 years earlier and had certainly been in use for just as long.[5] However, neither Peregrinus nor his contemporaries were aware of magnetic declination.[6] Instead, he saw the magnet and its alignment to the poles of the world as a perfect representation of the cosmos; such a deviation would have posed a significant problem for his cosmological theory.

Thévenot's supposed discovery was taken up by many, as it predated the historiography of his time – seventeenth-century scholars mostly had

2 On this, see C. Sander, *Magnes: der Magnetstein und der Magnetismus in den Wissenschaften der Frühen Neuzeit*, Leiden/Boston 2020 (Mittellateinische Studien und Texte, 53), pp. 427–453 (https://doi.org/10.1163/9789004419414); A.R.T. Jonkers, *Earth's Magnetism in the Age of Sail*, Baltimore 2003.

3 See Sander, *Magnes*, pp. 478–509, for a comprehensive overview.

4 On Peregrinus, see esp. Petrus Peregrinus, *Opera*, ed. L. Sturlese, R.B. Thomson, Pisa 1995 (Centro di cultura medievale, 5); J.A. Smith, «Precursors to Peregrinus: The Early History of Magnetism and the Mariner's Compass in Europe», *Journal of Medieval History* 18 (1992), pp. 21–74. See also H. Winter, «Petrus Peregrinus von Maricourt und die magnetische Missweisung», *Forschungen und Fortschritte* 11 (1936), pp. 304–306 (p. 305); A.C. Mitchell, «Chapters in the History of Terrestrial Magnetism: Chapter II», *Terrestrial Magnetism and Atmospheric Electricity* 42 (1937), pp. 241–280 (p. 244); H. Balmer, *Beiträge zur Geschichte der Erkenntnis des Erdmagnetismus*, Aarau 1956 (Veröffentlichungen der Schweizerischen Gesellschaft für Geschichte der Medizin und der Naturwissenschaften, 20), pp. 255–260.

5 See esp. Smith, «Precursors to Peregrinus», pp. 21–74.

6 For a discussion, see Sander, *Magnes*, p. 428, n. 294.

agreed that declination had been unknown in the Middle Ages. His blatant mistake was only uncovered in 1835 when Willem Wenckebach, a Dutch physicist and meteorologist, revealed the whole affair to be the result of philological slovenliness:[7]

> Thevenot verzwijgt (volgens eene ook thans nog bij de Franschen zeer gebruikelijke gewoonte, om de bronnen, waaruit zij hunne berigten putten, niet op te geven), waar hij dit handschrift heeft gezien; en daardoor heeft hetzelve de aandacht der natuurkundigen niet getrokken, of ten minste zijn zij niet in staat geweest, er nader onderzoek naar te doen. […] Uit het bovenstaande meen ik te mogen besluiten, dat de naam van Adsigerius geheel uit de geschiedenis der natuurkunde behoort uitgewischt te worden, dat Petrus Peregrinus de afwijking der magneetnaald niet kende, en dat, zoo ver onze berigten gaan, wij geenen grond hebben, om de ontdekking dier zoo belangrijke eigenschap aan de 13° eeuw toe te kennen.[8]

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7 Wenckebach, a self-styled admirer of Alexander von Humboldt, taught at a navigation school and was the first Dutch member of the *Göttinger Magnetischer Verein*, leading to his own magnetic experiments on terrestrial magnetism. See F. van Lunteren, «De oprichting van het Koninklijk Nederlands Meteorologisch Instituut: Humboldtiaanse wetenschap, internationale samenwerking en praktisch nut», *Gewina* 21 (1998), pp. 216–243.

8 W. Wenckebach, «Over Petrus Adsigerius en de oudste waarnemingen van de afwijking der magneetnaald», *Natuur- en Scheikundig Archief* 3 (1835), pp. 267–290 (pp. 270, 285). My own translation: «Thevenot, following a practice still very common among the French of not citing the sources from which they derive their information, does not reveal where he has seen this manuscript; and as a result, it has not caught the attention of naturalists, or at least they have not been able to conduct further research into it. […] From the above, I believe we must conclude that the name of Adsigerius should be completely erased from the history of physics, that Petrus Peregrinus was unaware of the deviation of the magnetic needle, and that, as far as our reports go, we have no basis to attribute the discovery of such an important characteristic to the 13th century.» See also W. Wenckebach, «Sur Petrus Adsigerius et les plus anciennes observations de la declinaison de láiguille aimantée», *Annali di Matematica Pura ed Applicata, Series 1* 7 (1865), pp. 159–168; T. Bertelli, «Intorno a due codici vaticani della epistola de magnete di Pietro Peregrino di Maricourt ed alle prime osservazioni della declinazione magnetica nota», *Bullettino di bibliografia e di storia delle scienze matematiche e fisiche* 4 (1871), pp. 303–331. For a transcription of the addition on fol. 58r, see Petrus Peregrinus, *Opera*, p. 53.

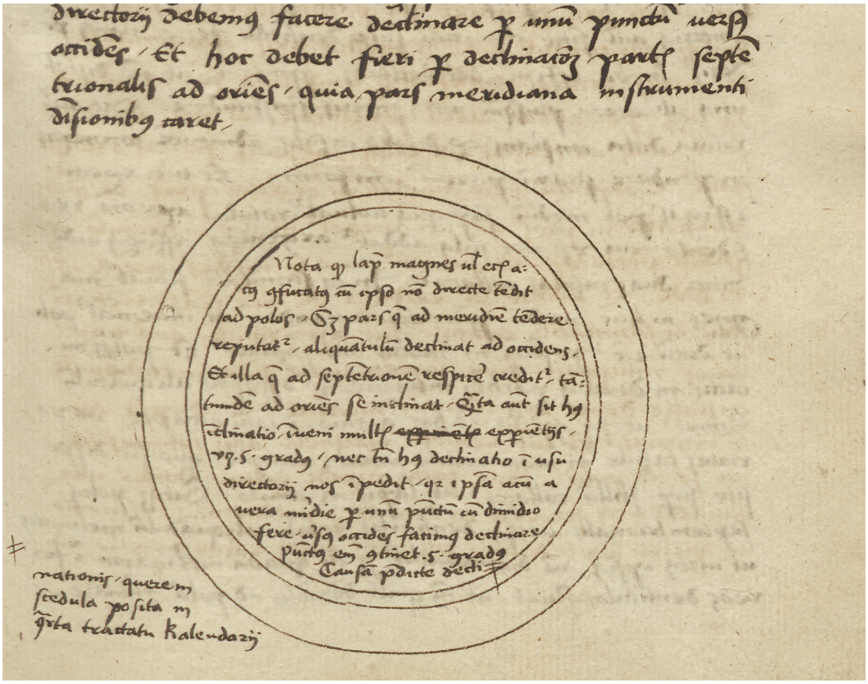

Fig. 1: Leiden, Universiteitsbibliotheek, Voss. Chim. Q 27, fol. 58r.

The respective codex, now known as Leiden Voss. Chim. Q 27, in fact, dates from the sixteenth century. The very passage on which Thévenot based his finding was added to an unfinished diagram by a sixteenth-century scribe, certainly not authored by Peregrinus or any medieval author (see fig. 1).

Scholars like Thévenot and Wenckebach primarily understood the dating of the compass's invention and the discovery of magnetic phenomena as a philological inquiry into the earliest sources mentioning these things.[9] Indeed, this continues to be a major path taken by historical research. However, for the investigation of the first knowledge of the phenomenon of magnetic declination, preserved instruments can also be significant additional primary sources. Nevertheless, instruments and artifacts may struggle to provide insights into the theories and beliefs of past actors making or using them, a role better fulfilled by textual evidence. Particularly intriguing, then,

9 See esp. Sander, *Magnes*, pp. 373–388.

are texts closely related to those instruments, e.g., introducing their use or documenting various measurements in notebooks or letters. In the case of magnetic declination, one might first think of compasses on ships and logbooks. Indeed, from the early modern era, it was believed that the nautical context led to the discovery of magnetic declination, and observations of this phenomenon are frequently found in navigation journals. However, perhaps due to contingent factors related to the transmission of instruments, the earliest objects testifying to an awareness of magnetic declination originate from land. The discerning eye of skilled instrument makers and astronomical experts constructing portable sundials appear to be the pioneers.

However, it is essential to dispel the notion that these practitioners merely stumbled upon magnetic declination as a newly discovered phenomenon.[10] Makers and users of magnetic compasses, at some point must have noticed a discrepancy between astronomical north and the needle's slightly deviating orientation. However, at first they attributed these variations to measurement errors, craftsmanship defects, or to the distinct material properties of the individual iron needles and the magnets used to magnetize the needle. If theorizing at all, these practitioners built on tacit and implicit assumptions about the causes of this effect, without developing «models» or full-fledged theories. It was only with time and meticulous scrutiny that scholars put forward more elaborate and accurate, even predictive hypotheses for magnetic declination.

To begin with, this chapter argues that studying instruments vis-à-vis the incidental and often implicit considerations in related textual sources serves as a rich basis for late medieval and early modern insights and theories on (geo-)magnetism. It will become evident that the realm of timekeeping is where the earliest instruments and descriptions have been preserved, albeit intertwined with the nautical context in which they ostensibly grasped the phenomenon of declination in a similar manner. This constitutes the most intriguing result of this essay: authors did not simply discover a new phenomenon; instead, they initially grappled with a perplexing

10 For a similar point, see also S. Pumfrey, «‹O Tempora, O Magnes!› A Sociological Analysis of the Discovery of Secular Magnetic Variation in 1634», *The British Journal for the History of Science* 22 (1989), pp. 181–214.

measurement that they did, or did not, contextualize. Systematically describing and defining this irritation as a phenomenon in its own right, let alone as a property of geomagnetism, came as a much later development.

While all archaeological and many philological findings for the earliest recognition of magnetic declination presented in the following are already known to scholarship, the related tacit theories and assumptions have not been integrated into a more balanced history of the supposed «discovery». Nevertheless, it is precisely these more implicit and «casual» assumptions concerning a newly explored area of phenomena that provide significant clues for the history of science and philosophy. Naturalists in 1500 did not aim at elevating newly and often accidentally made observations into full-fledged theories of magnetism. Instead, they made sense of these observations, often ad-hoc, as «noise» of a contingent and often only rudimentarily understood nature. Thus, on a more abstract and philosophical level, this addressed the enduring question of how presupposed «upstream» assumptions about reality affect one's experience. As long as, for example, time-keeping and navigation did not need to meet a high demand for precision, slight deviations from expectations went unnoticed, were not reported, or considered unproblematic – and surely did not demand a comprehensive revision of existing assumptions. Moreover, without geomagnetism being a clearly defined phenomenon, why even come up with a causal explanation or theory of declination in the first place? Moreover, from an instrument maker's or user's point of view, a practical coping with this perceived «irregularity» – only later understood as declination –, was more important than any theoretical understanding, it seems. Even for scholars with philosophical aspirations the cause of geomagnetic phenomena at large remained an unsolved puzzle until well into the eighteenth century.

2. A Matter of Time

The chronologically earliest recognition of magnetic declination can be inferred from indirect, non-textual evidence. Some historians have claimed that medieval mapmakers and church architects knew about magnetic declination because they adjusted their maps or the alignment of churches accordingly.[11] While this evidence is heavily disputed, a series of movable folding, so-called diptych, sundials provides crucial and undisputed evidence. The earliest of these were made around 1451 by (or within the circle of) the famous astronomer and mathematician Georg von Peuerbach in Vienna (see fig. 2).[12]

These instruments served for timekeeping and were the first movable instruments available. Prior to this, sundials were predominantly affixed to the walls of buildings or to the grounds of squares, in spatial conditions that remained unchanged. A sundial works only when the shadow length and the angle is mapped against the sun's path in a specific geographic latitude.

11 See Sander, *Magnes*, pp. 411 f. and 429, n. 299.

12 The instrument most often discussed, very similar to the one depicted in fig. 2, is held at Innsbruck, Tiroler Landesmuseum Ferdinandeum, Inv.-No. U5. On this, see esp. R. Schewe, J. Goll, «Die Zeit in der Tasche: die älteste in Europa erhaltene hölzerne Klappsonnenuhr aus dem Kloster Müstair, Schweiz», *Zeitschrift für schweizerische Archäologie und Kunstgeschichte* 76 (2019), pp. 5–30; F. Samhaber, *Die Zeitzither: Georg von Peuerbach und das helle Mittelalter*, Raab 2000, p. 188 f. (https://opac.museogalileo.it/imss/resource?uri=000000400183&l=en, accessed 2 August 2023); W. Seipel (ed.), *Mensch und Kosmos: Katalog zur Oberösterreichischen Landesausstellung 1990 «Mensch und Kosmos – Die Heraufkunft des modernen naturwissenschaftlichen Weltbildes»; Schlossmuseum Linz, 7. Mai bis 4. November 1990*, Linz 1990 (Kataloge des Oberösterreichischen Landesmuseums, 33), p. 35, no. 33; Niederösterreichisches Landesmuseum, *Friedrich III Kaiserresidenz Wiener Neustadt. Ausstellung St. Peter an d. Sperr, Wiener Neustadt, 28. Mai – 30. Okt. 1966, Wien*, Wien 1966 (Katalog des Niederösterreichischen Landesmuseums, 436), p. 397, no. 229; E. Zinner, *Deutsche und niederländische astronomische Instrumente des 11.–18. Jahrhunderts*, München 1956, p. 464 f. See also for discussions and further evidence and objects, A. Wolkenhauer, «Der Nürnberger Kartograph Erhart Etzlaub», *Deutsche geographische Blätter* 30 (1907), pp. 55–77 (p. 69); J. Drecker, *Gnomone und Sonnenuhren*, Aachen 1909, pp. 36–38; H.-G. Körber, «On the History of Compass Sundials and Their Makers' Knowledge of Magnetic Declination (15th–18th Century)», in B. Suchodolski (ed.), *Actes du XI^e^ congrès international d'histoire des sciences, Varsovie, Toruń, Kielce, Cracovie, 24–31 Août 1965 / III. Troisième Section: Histoire des sciences exactes (Chimie, sciences geographiques et géologiques)*, Wrocław 1968 (Collection de travaux de l'Académie Internationale d'Histoire des Sciences, 17.4); T. Przypkowski, «On the Magnetic Declination Obtained from Observations by Martin Bylica of Olkusz around 1485», *Acta Geophysica Polonica* 7 (1959), pp. 176–181 (p. 179); M. Mandea, M. Korte, «Ancient Sundials and Maps Reveal Historical Geomagnetic Declination Values», *Eos: Transactions. American Geophysical Union* 88 (2007), p. 310 f.

Fig. 2: Unknown creator, «Klappsonnenuhr mit Kompass, Deutschland, 1451–1500» Vienna, Museum Inv.-No. U 2485, CC BY 4.0, Foto: Birgit und Peter Kainz. (https://sammlung.wienmuseum.at/en/object/389095/).

In practice, this required to know the latitude and the meridian (i. e., geographical south), which could be easily and exactly determined through astronomical observation.[13] However, for a movable sundial, the situation was different. Knowing south while on the move was not always and readily possible, e. g., due to a lack of astronomical knowledge or cloudy weather. Moreover, the earliest movable sundials were designed to be accurate only within a specific latitude range. Expanding their usability to other latitudes was easily achieved through a slightly more complex dial. Yet, the spatial orientation of the sundial towards a cardinal direction had to be addressed differently. For this purpose, a crucial component of these portable sundials was a small magnetic compass. The compass needle pointed towards the

13 See Sander, *Magnes*, pp. 403–411.

north or south, thereby informing the user of the direction in which to hold the instrument.

Consequently, this design posed an immediate challenge for the accurate indication of time in a world in which magnetic and astronomical south differed – governed by magnetic declination. If one did not align the sundial to the true astronomical south, which matched the sun's daily zenith, the shadow would not correctly tell the time. A declination of about 10 degrees between geographical and magnetic north, for instance, corresponds to around 35 to 40 minutes of time difference.[14] The makers or users must have noticed this. For this reason, instrument makers simply and pragmatically marked this difference, a.k.a. magnetic declination, by slightly offsetting a line or the mark for the north in the compass rose for the appropriate compensating angle. As it appears, many of these early portable sundials were not intended for use in vastly different regions of the world, as suggested by their latitude-specific design. Thus, it might have been unproblematic to mark one specific declination angle. This allowed the user to turn the sundial in such a way that the compass needle aligned with the corrected mark or line, indicating the corresponding declination and hence the correct geographic cardinal direction. It is essential to note, however, that this notched line is by no means the material manifestation of the discovery of magnetic declination. Instead, it served as a practical aid to use the instrument correctly. The discrepancy between astronomical and magnetic directions might have stood out during the construction of the sundials, primarily because timekeeping, relying on geographical directions, and the magnetic compass required for mobile use were combined in the same instrument. This compound device afforded epistemic reconciliation.

The first written mention of this correction mark for portable sundials can only be found in a letter from the instrument maker Georg Hartmann

14 See Schewe, Goll, «Die Zeit in der Tasche», p. 12; R.K. Salzer, «Die spätmittelalterliche Burg Grafendorf, Stadtgemeinde Stockerau: eine archäologisch-historische Analyse», unpublished *Diplomarbeit*, Vienna 2012, p. 224, n. 1245.

Fig. 3: E. Etzlaub, «Das ist der Rom-Weg von meylen zu meylen mit puncten verzeychnet von eyner stat zu der andern durch deutzsche lantt», Nürnberg 1500. Source: Munich, Bayerische Staatsbibliothek, Rar. 287#Bybd. 4.

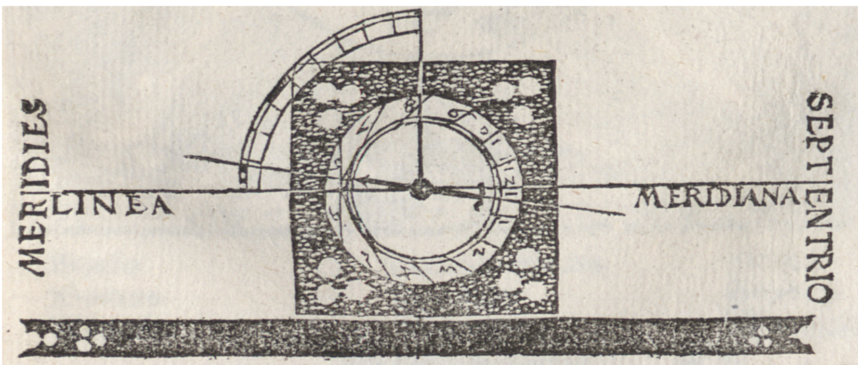

Fig. 4: P. Apian, *Cosmographicus liber*, Landshut 1524, p. 51. Source: Munich, Bayerische Staatsbibliothek, Rar. 271.

from 1544.[15] In the geographical and geodetic context, we find magnetic compasses depicted accordingly (see figures 3 and 4).[16]

15 G. Hellmann (ed.), *Rara Magnetica 1269–1599*, Berlin 1898 (Neudrucke von Schriften und Karten über Meteorologie und Erdmagnetismus, 10), p. 65 f. The manuscript in Vienna, Österreichische Nationalbibliothek, Codex 5203, fol. 79r–86r, «Tractatus de fabrica instrumenti universalis ad inveniendas horas in quocumque climate», often ascribed to Peuerbach, does not seem to mention magnetic declination anywhere.

16 See Sander, *Magnes*, pp. 411–422.

However, these sources do not explain this «declination mark» tweak.[17] A similar modification for compasses was probably also common in nautical compasses, although all available evidence dates from the sixteenth century.[18] In these instruments for navigation, the compass rose was precisely offset by the amount of the difference between magnetic north and geographic north. Another clue for the implicit awareness of the magnetic declination in navigation can be seen in the fact that ships were equipped with different compasses, made at different places, and thus likely calibrated to different magnetic declinations. Christopher Columbus and his crew, puzzled about the changes in declination on the Atlantic Ocean («los marineros y estaban penados»), probably had several compasses on board.[19] The reports also seem to testify to the sailors' awareness that the compass needles changed directions in different places.

While Columbus's (posthumous) travelogue gives some insights, the surviving early instruments from the Viennese milieu and many subsequent ones remain more silent about what their makers truly knew about magnet-

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17 See, however, H. Wagner, «Peter Apians Bestimmung der magnetischen Mißweisung vom Jahre 1532 und die Nürnberger Kompaßmacher: vorgelegt in der Sitzung vom 9. März 1901», *Königliche Gesellschaft der Wissenschaften [zu Göttingen], Philologisch-historische Klasse* 2 (1901), pp. 171–182; A. Wolkenhauer, «Über die ältesten Reisekarten von Deutschland aus dem Ende des 15. und dem Anfange des 16. Jahrhunderts», *Deutsche geographische Blätter* 26 (1903), pp. 120–138 (p. 137); *id.*, «War die magnetische Deklination vor Kolumbus' erster Reise nach Amerika tatsächlich unbekannt?», *Deutsche geographische Blätter* 27 (1904), pp. 158–175 (p. 169).

18 See Balmer, *Beiträge zur Geschichte der Erkenntnis des Erdmagnetismus*, pp. 102–113; D. Waters, *The Art of Navigation in England in Elizabethan and Early Stuart Times*, New Haven 1958, p. 25; U. Lamb, «Science by Litigation: A Cosmographic Feud», *Terrae Incognitae* 1 (1969), pp. 40–57 (p. 45); A. Wolkenhauer, «Der Schiffskompaß im 16. Jahrhundert und die Ausgleichung der magnetischen Deklination», in W. Köberer (ed.), *Das rechte Fundament der Seefahrt: deutsche Beiträge zur Geschichte der Navigation*, Hamburg 1982, pp. 120–130; E.H. Ash, «Navigation Techniques and Practice in the Renaissance», in D. Woodward (ed.), *Cartography in the European Renaissance,* vol. 1, 2 vols., Chicago 2007 (The History of Cartography, 3), pp. 509–527 (p. 520).

19 See Wolkenhauer, «War die magnetische Deklination vor Kolumbus' erster Reise nach Amerika tatsächlich unbekannt?», pp. 158–175; Mitchell, «Chapters in the history of terrestrial magnetism: Chapter II», pp. 241–280 (pp. 252–269). See also note 22 below.

Fig. 5: Marcus Purmann, «Scaphe sundial 1588», Prague, National Technical Museum, Inv. No. 17189.

ic declination or whether they even understood it as such. Importantly, the correction of the instruments does not provide information on whether makers/users assumed the difference between the compass needle's pointing and the astronomical north/south to be identical in any place. There seem to be indications that many of the earliest makers made precisely this (mistaken) assumption of a locally invariant declination. For instance, Etzlaub's famous map for the route from the Holy Roman Empire to Rome (see fig. 3) depicts the magnetic compass with only one fixed declination. A compass used on a ship is required to work in different locations, and large distance navigators, trained in astronomy, are likely to observe the changing magnetic declination in the course of their journey. A portable dial, in contrast, might be designed to tell the correct time in Vienna but not in Lisbon or Copenhagen, or its users might not even notice the inaccuracy. However, a few portable sundials equipped with magnetic compasses take into account the varying declination in different places, e. g., by adding a movable ring to «adjust» the variant declination mark.[20] One sundial made in 1588 by Markus Purmann (fig. 5) accordingly labels this adjusting ring as «Gradus Declinacio Magnetis.»[21] At least later instrument makers of the sixteenth century hence knew about the local declination, as will become evident from the following section.

3. As a Matter of Fact

Some remarks in texts dealing with the production or use of magnetic instruments are more enlightening than archaeological or visual sources to learn about these actors' conceptions of magnetism. These textual sources are no theoretical or philosophical treatises. They did not propose elaborate causal explanations either, which hardly emerged before the mid-sixteenth century. However, their texts reveal some implicit causal assumptions, when individual declination measurements are suggested to be intrinsically linked to the particular magnet with which the compass needle was magnetized, or to the way a compass was manufactured. Hence, the anomaly of the «inaccurate north-pointing» was interpreted as an anomaly related to the material constitution of the magnet or magnetic iron needle. «Declination» hence was not an effect of geomagnetism but of the compass needle.

These quasi-materialistic assumptions about declination did not perceive the «declination data» to represent a «defined phenomenon» and therefore did not develop any specific explanations. Rather, authors presumed this data was due to handling errors, a flaw in the needle, or some *Schmutzeffekt* of the measurements. The (posthumous) reports of Columbus's expeditions tell us, for example, that the experienced navigator, himself baffled by the odd declination, had to calm down his crew who was

20 See esp. H.-G. Körber, *Zur Geschichte der Konstruktion von Sonnenuhren und Kompassen des 16. bis 18. Jahrhunderts*, Berlin 1965 (Veröffentlichungen des Staatlichen Mathematisch-Physikalischen Salons, 3), pp. 72–75. I thank Antonín Švejda, Michael Korey, and Anthony Turner for sharing their expertise in personal communication.

21 See Z. Horský, M. Plavec, *Poznávání vesmíru*, Prague 1962 (Malá moderní encyklopedie, 37), p. 113; Z. Horský, O. Škopová, *Astronomy, Gnomonics: A Catalogue of Instruments of the 15th to the 19th Centuries*, Prague 1968, p. 108 f.

even frightened by the needle's supposed inaccuracy.[22] To do so, Columbus abstained from acknowledging the phenomenon as «magnetic declination» or distrusting the compasses. Instead, he assumed the Pole Star to move and thereby to redirect the needles, which he believed to have a bond with this heavenly body. This saved the phenomena and was meant to put the crew at ease.

Pedro de Medina's highly influential navigation manual *Arte de navegar* (1545) exemplifies another coping strategy.[23] He did not lend much credibility to sailors' claims of observing a difference between the geographic north and the pointing of the compass. Since these sailors did not provide information about what entity the compass pointed to, according to their opinion, and how significant the alleged deviation was, Medina proposed a test: two compass needles made of identical steel should be manufactured and magnetized with the same magnet – apparently, he deemed this material condition to be relevant. One of the compasses should sail on a ship in the direction of the west, and the other in the direction of the east from the same starting point. Through this *Differenztest*, he aimed to determine whether the alleged declination was related to the pole, the needle, or the path taken by the ship. Medina immediately rules out the pole as a candi-

22 See esp. F. Columbus, *Historie del S.D. Fernando Colombo nelle quali s'ha particolare, & vera relatione della vita, & de' fatti dell'ammiraglio D. Christoforo Colombo, suo padre; et dello scoprimento, ch'egli fece dell'Indie Occidentali, dette Mondo Nuovo, hora possedute dal Sereniss. Re Catolico*, Venice 1571, fols. 41v, 149r; C. Columbus, *Relaciones y cartas de Cristóbal Colón*, ed. C. Varela, Madrid 1892, pp. 8, 10, 46; A. Magnaghi, «Incertezze e contrasti delle fonti tradizionali sulle osservazioni attribuite a C. Colombo intorno ai fenomeni della declinazione magnetica», *Bollettino della Reale società geografica italiana, serie VI* 10 (1933), pp. 595–641; P. de Syria, *Arte de la verdadera navegacion: en que se trata de la machina del mũdo, es a saber, cielos, y elementos: de las mareas, y señales de tẽpestades: del aguja de marear: del modo de hazer cartas de nauegar*, Valencia 1602, p. 54; L. Moscardo, *Note overo memorie del museo*, Padua 1656, p. 141. See also Sander, *Magnes*, pp. 295, 431, 483, and note 19 above.

23 See P. de Medina, *Arte de nauegar en que se contienen todas las reglas, declaraciones, secretos, y auisos, q[ue] a la buena nauegacio[n] son necessarios, y se deuē saber*, ed. F. Fernández de Córdoba, Valladolid 1545, fols. 80r–82r. See also A.R.T. Jonkers, «North by Northwest: Seafaring, Science, and the Earth's Magnetic Field, (1600–1800)», unpublished dissertation, Amsterdam 2000, p. 640 f.

date for being an imaginary immovable point. He also dismisses the needle as a factor: two needles fabricated on two different longitudes could not differ from each other. His argument here is teleological in nature: if the place of manufacture of the compass mattered, there would be an infinite number of compasses oriented differently along an infinite number of meridians, but correct only on their «home meridian» – an oddity not befitting such an excellent instrument as the compass. Medina further notes that it is challenging to observe the alleged declination accurately, which he attributes to the inaccuracy of the required astronomical sighting of the North Star. He then argues that the assumption of magnetic declination would cause considerable harm to navigation – something anyone claiming the existence of declination should be aware of. The declination was flatly rejected by Medina.

Medina's arguments against the existence of magnetic declination may hardly appear convincing and have already been explicitly criticized by his peers.[24] Medina did not take the approach of explaining new observations by a new theory, but rather doubted the new observations to support the old theory. However, his reasoning shows that he sees certain factors as potentially relevant: where was the compass made? what steel was the needle made of? with which magnet was it magnetized?

24 See J. Severt, *De orbis catoptrici seu mapparum mundi principiis descriptione ac usu libri tres*, Paris 1590, p. 55; T. de Bessard, *Dialogue de la longitude est-ouest*, Rouen 1574, p. 23; R. Norman, *The New Attractive; Containing a Short Discourse of the Magnes or Loadstone*, London 1585, p. 8; S. Günther, «Johannes Kepler und der tellurisch-kosmische Magnetismus», *Geographische Abhandlungen* 3 (1888), pp. 1–71 (p. 11); E.G.R. Taylor, *The Mathematical Practitioners of Tudor & Stuart England*, Cambridge 1954, p. 30; Jonkers, *Earth's Magnetism in the Age of Sail*, p. 151 f.; A. Barrera-Osorio, *Experiencing Nature: The Spanish American Empire and the Early Scientific Revolution*, Austin, TX 2006, p. 131; S.D. Gutiérrez, «Failing Myths: Magnetic Variation in Gilbert's de Magnete», in N. Herrán (ed.), *Synergia: Primer Encuentro de Jovenes Investigadores e Historia de La Ciencia*, Madrid 2007, pp. 363–382 (p. 366); A. Sandman, «Spanish Nautical Cartography in the Renaissance», in D. Woodward (ed.), *Cartography in the European Renaissance,* vol. 1, 2 vols., Chicago 2007 (The History of Cartography, 3), pp. 1095–1142 (pp. 1119–1120); E. Collins, «Francisco Faleiro and Scientific Methodology at the Casa de La Contratación in the Sixteenth Century», *Imago Mundi* 65 (2013), pp. 25–36 (p. 31).

These questions in fact mattered much in Medina's epistemic community. As early as 1535, Francisco Faleiro wrote in his navigation manual that the declination was due to the «difference in steel (of the needles) and the (magnetic) stones used for magnetization» («la diversidad de los azeros y delas piedras de cevar»).[25] And the navigator João de Castro seemed to share similar assumptions.[26] When he lost the needle belonging to a magnetic instrument in 1538, he replaced it with a German sundial needle but expressed his skepticism: The German needle, made in a different place, probably had different properties («das regiões serem tam diferentes a propiadade das pedras parece ser huma mesma»), as the declination of the needle resulted from the material of the iron («causada da materia do ferro») and the nature of the magnetic stone («da natureza do manhete»).

If the deviation of the compass needle indeed depended on the magnet or loadstone used for magnetization, it is not surprising that a heated dispute erupted in Seville in the 1550s over the specimen found in the estate of a compass maker.[27] The reliability of a tradition of compass manufacturing was at stake, as all compasses should exhibit the same magnetic north-south calibration. This matter-specific declination, however, is not limited to explicitly navigational contexts. Joachim Rheticus reported in 1541 that the declination of sundials sometimes depended on the craftsmanship of their makers, referring to the varying-declination magnets owned by his friends,

25 See F. Faleiro, *Tratado del esphera y del arte del marear con el regimieto [sic] de las alturas*, Sevilla 1535, ch. 8. See also P. Radelet-de Grave, «Le magnétisme et la localisation en mer», in M. Watelet, J. Babicz, H. Weckx, M. Wollecamp (eds.), *Gérard Mercator cosmographe: le temps et l'espace*, Antwerpen 1994, pp. 208–219 (p. 210); Gutiérrez, «Failing myths: magnetic variation in Gilbert's de Magnete», p. 366.

26 See J. de Castro, *Primeiro roteiro da costa da India: desde Goa até Dio: narrando a viagem que fez o vice-rei, D. Garcia de Noronha, em soccorro desta ultima cidade, 1538–1539*, ed. D. Köpke, Porto 1843, pp. 87, 102. See also E.G.R. Taylor, «The South-Pointing Needle», *Imago Mundi* 8 (1951), pp. 1–7, here p. 6.

27 See U. Lamb, «The Sevillian Lodestone: Science and Circumstance», in *ead.*, *Cosmographers and Pilots of the Spanish Maritime Empire*, Brookfield (Vt.)/Aldershot 1995 (Variorum Collected Studies Series, 499), ch. VII, pp. 29–39.

Georg Tannstetter (4°), Peter Apian (10°), and Georg Hartmann (11°).[28] Similarly, Johannes Mathesius reported in 1562:

> Ich hab von Kauffleuten gehöret/ das man zu wasser noch Orientische und Arabische Magneten brauchet/ da einer ein Apoteker spaten auffhebet. Die sollen auch etwas gewisser sein/ unnd die Mittagslinien richtiger zeigen/ denn die Orientischen/ welche gemeiniglich ire declinationes und abweichen haben/ einer auff mehr grad als der ander. Der Magnet im Nürnbergischen Compassen/ sol bis inn zehen grad vom Mittag in Morgen sich lencken [...].[29]

Under these conditions, it is not surprising that the idea of a material cause for declination was repeatedly taken up. A large number of authors of the sixteenth century suspected the elemental mixture of iron and magnetic stone («la mezcla que hacen el hierro y la piedra»),[30] the difference in magnetic stones («differenza della calamita»),[31] different types of magnetic stones («tale diversità più tosto provenga da diverse sorti di calamite»),[32] the geological origin of the magnetic stone («ex elementariae regionis pro-

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28 See F. Hipler, «Die Chorographie des Joachim Rheticus», *Zeitschrift für Mathematik und Physik* 21 (1876), pp. 125–150, here p. 45. See also G. Hellmann, «Die Anfänge der magnetischen Beobachtungen», *Zeitschrift der Gesellschaft für Erdkunde zu Berlin* 32 (1897), pp. 112–136, here p. 120.

29 J. Mathesius, *Sarepta, oder, Bergpostill sampt der Jochimssthalischen kurtzen Chroniken*, Nürnberg 1562, fol. 202v. My own translation: «I have heard from merchants that for navigation at sea, Oriental and Arabic magnets are still needed, where one lifts an apothecary's spade. These are also said to be more reliable and show the meridian lines more accurately than the Oriental ones, which usually have their declinations and deviations, one more degrees than the other. The magnet in compasses from Nuremberg is said to deviate ten degrees from South towards East.»

30 See F. López de Gómara, *La historia general de las Indias: y todo lo acaescido enellas dende que se ganaron hasta agora y La conquista de Mexico, y de la nueua España*, Anvers 1554, fol. 10r.

31 See Columbus, *Historie*, fol. 149r.

32 See L. Garzoni, *Trattati della calamita*, ed. M. Ugaglia, Milan 2005 (Filosofia e scienza nell'età moderna, 3), p. 158.

prietatibus ibi dominantibus»),[33] the skill of the compass constructor,[34] believed that the pointer «dothe varie according unto the nature of some kinde of mineraltes»,[35] or that the influence of winds on the magnetic stone led to its alignment with the cardinal directions.[36]

While some sailors saw the compass's declination simply as a defect, Richard Polter still adhered to the intrinsic quasi-materialist position in 1605, writing: «when Robert Norman dyed (who had a good Stone) Seamen had a great losse […]. The Variations delivered by many stones are different.»[37] Although a rare opinion in the seventeenth century, the Portuguese Luis de Fonseca also promoted controlled declination with his secret technique of needle magnetization («las operaciones de la piedra yman responden a la vazon del secreta que consiste en como se deuen tocar las agujas»).[38]

It is noteworthy that the idea of a dependence of magnetic declination on the unique material constitution of the magnet or needle was still not abandoned in the first half of the seventeenth century. In 1640, a member of

33 See Collegium Conimbricense, *Aristotle, In octo libros Physicorum Aristotelis Stagiritae*, Coimbra 1592, p. 673. L. Forer, *Viridarium philosophicum: hoc est disputationes aliquot de selectis […] in philosophia materiis*, Dillingen 1624, p. 242, refers for this local dependency to wine, which is still drinkable in Spain, but begins to smell at sea. Similar ideas are found also in Severt, *De orbis*, p. 57. See also in the manuscript in Oxford, Bodleian Library, Ms. No. 313, edited in J.O. Halliwell-Phillipps (ed.), *A Collection of Letters Illustrative of the Progress of Science in England from the Reign of Queen Elizabeth to That of Charles the Second*, London 1841, pp. 122–124.

34 See A. Calderini, *Modo d'vsar il bossolo per pigliar piante de luoghi murati, e non murati*, Milan 1598, p. 8.

35 See W. Bourne, *A Regiment for the Sea*, London 1574, fol. 61v.

36 See Sander, *Magnes*, pp. 308–312.

37 See R. Polter, *The Pathway to Perfect Sayling: Being a Deliuerie in as Breefe Mannera as May Bee, of the Sixe Principall Pointes or Groundes, Concerning Nauigation: Written by Mr. Richard Polter, One of the Late Principall Maisters of the Nauie Royall. And Now Published for the Common Good of All Maisters, Pilots, and Other Seamen Whatsoeuer*, London 1605, fol. D1r; Waters, *The Art of Navigation in England in Elizabethan and Early Stuart Times*, p. 307; Taylor, *The Mathematical Practitioners of Tudor & Stuart England*, p. 57; Pumfrey, «O tempora», pp. 181–214, here p. 186f.

38 See Jonkers, *Earth's Magnetism in the Age of Sail*, p. 52f.; Jonkers, «North by Northwest», p. 492.

the Jesuits reported to Athanasius Kircher about a measurement of the declination with different needles at the same place and time, but all the measurements supposedly differed from each other («omnes inter se dissentiebant»).[39] In 1631, Kircher himself considered the cause of declination to be a combination of the geological disposition of the Earth and the disposition of the magnetic needle, before formulating a completely geological cause in 1641.[40]

Similar speculations started anew in response to Henry Gellibrand's landmark «discovery» of the temporal variation of declination, or «secular declination» (1634).[41] Until then, researchers agreed that declination changes with position, without questioning whether it changes at a particular location over time. After recording and compiling various declination measurements for London over a long period of time, Gellibrand hypothesized that there was also a temporal aspect to declination. Initially skeptical of this assumption, Marin Mersenne informed Christophe Villiers about the supposed finding and received a more precise analysis of the connection between matter and declination in 1640.[42] Villiers explained that this *variatio variationis*, as Kircher would call it, could indeed be related to external factors such as weather affecting the magnet or the needle.[43] Not all magnets

39 See Rome, Archivio della Pontificia Università Gregoriana, APUG 567, fol. 177r. This letter by Jakob Imhofer of 15 January 1640 is also mentioned in M.J. Gorman, «The Angel and the Compass: Athanasius Kircher's Magnetic Geography», in P. Findlen (ed.), *Athanasius Kircher: The Last Man Who Knew Everything*, New York 2004, pp. 239–259, here p. 247. See APUG 567, fol. 44r, in a letter from Johann Grothaus to Kircher, dated 1 March 1640, for a similar observation.

40 A. Kircher, J.J. Schweigkhard von Freihausen, *Ars magnesia: hoc est disquisitio bipartita empeirica seu experimentalis, physico-mathematica de natura, viribus et prodigiosis effectibus magnetis*, Würzburg 1631, p. 14. See also Sander, *Magnes*, p. 160 f.; *id.*, «Der Magnetstein in geologischen Theorien der Vormoderne», *Der Anschnitt* 74 (2022), pp. 98–108.

41 See Pumfrey, «O tempora», pp. 181–214; Sander, *Magnes*, pp. 450–453; H. Gellibrand, *A Discourse Mathematical on the Variation of the Magneticall Needle Together with Its Admirable Diminution Lately Discovered*, London 1635.

42 See M. Mersenne, *Correspondance du P. Marin Mersenne, religieux minime*, ed. P. Tannery, C. de Waard, 17 vols., Paris 1932–1988, vol. 9, p. 28 f.

43 A. Kircher, *Magnes; sive, De arte magnetica opus tripartitum*, Rome 1641, p. 479.

were equally good («ne sont egalement bonnes»), and some would deviate more than others («les une auront une declinaison plus ou moins grande que l'autre»). The nature of the mineral was highly variable, as chemists had observed through experiments involving heating the magnet and analyzing the rising vapors («les achemins qui s'elevent»). Experimenting with compass needles magnetized with different magnetic stones and made from different types of iron, therefore, posed significant challenges («tres dificile à experimenter à cause des aiguilles diversement aymantees et qui sont de divers fer»).

On the same day Villiers was writing to Mersenne, January 20, 1640, Mersenne also informed Kircher about Gellibrand's discovery of the temporal variation of declination.[44] This letter shows traces of subsequent editing. In the modern edited version, Mersenne simply noted that the declination in Paris was 4°30', but in the manuscript, he had written this on the margin and crossed out a different observation in the text: two needles did not deviate by the same amount at the same location, which could be attributed to the diversity of the deviations resulting from the diversity of the magnets («lapidum diversitatem diversam declinationem inducere»). Thomas White rationalized Gellibrand's observation in his work *De mundo* (1642) by considering the temporal variation at the same location arising from the instability of the nature of the magnetic stone («ex ea magnetis instabilitate naturae secutura foret varietas»).[45] Pierre Petit reported after 1660 that he had observed the declination to vary over time, and he wondered if this might be due to the use of different magnets («ut mihi liqueret an ex illa diversitate lapidum et contactuum, aliqua in declinatione varietas emergeret»).[46]

The diversity of individual specimens of loadstone used to make magnetic iron needles was relevant not only in matters of declination. Georges Fournier (1643) attaches almost methodological importance to this diversity:

> Avant toutes choses ie prie le Lecteur que toutesfois et quantes qu'il trouvera en ce Traicté ces paroles universelles, «tous», ou bien d'autres indefinies, de ne les prendre que pour une universalité non absolute, mai fondée seulement sur les opera-

44 See Mersenne, *Correspondance*, vol. 9, p. 34.

45 See T. White, *De mundo dialogi tres*, Paris 1642, p. 200.

46 See Mersenne, *Correspondance*, vol. 8, p. 634.

tions que j'ay veu, car l'experience m'a appris qu'il y a fort peu de choses qui soit en l'aymant absolument universel; ainsi qu'il n'y a rien au monde de si irregulier.[47]

4. Does It Matter?

The idea of an «irregular magnet» was welcomed and widely adopted in accounting for the earliest observations of irregularities in magnetic north-pointing. However, not knowing they experienced a phenomenon in its own right, early scientific practitioners considered it an anomaly and strange irregularity. Interpreting this irregularity by assuming an irregularity within the object, i. e., the magnet/needle itself, does not appear irrational from a contextualist point of view. Thus, these observations were «raw» in the sense of not being perceived as an instance of some phenomenon or structure of physical reality, such as a codified «magnetic declination». «Matter», philosophically understood, has been contingency's entry point into nature in much of premodern metaphysics.[48] So it was the magnet's matter, its principle of individuation, which led to these supposed individual disruptions of the harmony between the magnetic north-pointing and the structure of the cosmos. Moreover, the connection between matter and declination seems to fit well within the broader context of early modern theories of magnetism. For instance, natural historians since Pliny the Elder paid much attention to distinguishing various different types of magnets and identifying them based on their different properties and powers.[49] Such

47 G. Fournier, *Hydrographie contenant la théorie et la practiqve de tovtes les parties de la navigation*, Paris 1643, p. 531. My own translation: «Before anything else, I beg the Reader that whenever and wherever he finds in this Treatise these universal words, ‹all›, or other indefinite ones, to take them only for a non-absolute universality, but based only on the operations I have seen, for experience has taught me that there are very few things in the magnet that are absolutely universal; and that there is nothing in the world so irregular.»

48 See P.D. Omodeo, R. Garau (eds.), *Contingency and Natural Order in Early Modern Science*, Cham 2019 (Boston Studies in the Philosophy and History of Science, 232).

49 See Sander, *Magnes*, pp. 19–24; *id.*, «Magnetismus und Theamedismus. Eine Fallstudie zur Kenntnis der magnetischen Abstoßung in der Naturkunde der Frühen Neuzeit», *Sudhoffs Archiv* 101 (2017), pp. 42–72.

types were often associated with various places where a particular type of loadstone has formed naturally in the earth.[50] Alchemists described magnets as a mixture of different substances whose different proportions affected the properties and powers of the stone.[51] Others even linked the north-pointing to the spatial position or orientation in which the stone was found in the earth or related magnetic polarity to polar weather phenomena.[52] The theories of the seventeenth century turned this materialistic view on its head when they blamed the irregularities of the magnetic Earth itself, its underground iron ores, its mountains and seas as the cause of declination.[53] This theory proved highly successful because it «predicted unpredictable variations.»[54]

The magnet was considered a product of its environment, and its powers were often seen just as contingent as those of its surroundings. The observation of «magnetic declination», which at first appeared as an anomaly, could thus be mirrored in a seemingly anomalous material disposition of the magnet itself. Matter was all that mattered in this regard. Before Edmond Halley's 1701 map of so-called «isogones» showing magnetic declination, there was – somewhat simplified – no formal principle to account for magnetic declination.[55] None of the numerous models and hypotheses to predict and explain this phenomenon could (convincingly) address the irregularities of geomagnetism until then.

50 See Sander, *Magnes*, pp. 140–143; Sander, «Der Magnetstein in geologischen Theorien», pp. 98–108.

51 See Sander, *Magnes*, pp. 71–75.

52 See Sander, *Magnes*, pp. 155–173, 242–245, 304–312. See also G. della Porta, *Magiae naturalis libri XX*, Naples 1589, p. 130; O. Worm, *Museum Wormianum: seu historia rerum rariorum, tam naturalium, quam artificialium, tam domesticarum, quam exoticarum, quæ Hafniæ Danorum in ædibus authoris fervantur*, Leiden 1655, p. 62.

53 See Sander, «Der Magnetstein in geologischen Theorien», pp. 98–108.

54 S. Pumfrey, «William Gilbert's Magnetic Philosophy, 1580–1684: The Creation and Dissolution of a Discipline», unpublished dissertation, London 1987, p. 268.

55 On Halley's map, see L.L. Murray, D.R. Bellhouse, «How Was Edmond Halley's Map of Magnetic Declination (1701) Constructed?», *Imago Mundi* 69 (2017), pp. 72–84. See also A. Udías Vallina, «Athanasius Kircher and Terrestrial Magnetism: The Magnetic Map», *Journal of Jesuit Studies* 7 (2020), pp. 166–184.

Reconstructing the earliest observations of what later came to be called «magnetic declination» is challenging because the historical actors themselves did not fully understand what they were observing. To approach these fragile testimonies historically and phenomenologically, it seems particularly helpful to consider a combination of practical and theoretical knowledge of the actors. This includes the archaeological study of instruments that codify practical knowledge, as well as the first verbal descriptions of what was found remarkable in the use of these instruments and the interpretation of certain measurements.

In a nutshell, by the year 1700, the scientific community not only had more, or more accurate, empirical knowledge about magnetic declination than in 1500, but the very object of this knowledge differed.[56] In 1500, the concept of magnetic declination was outside the conceptual horizon of the scientific community. The creation or first use/instance of this concept – an event that cannot be precisely dated – is not only the result of the accumulation of empirical data; rather, it is the creative result of conceptual integration and reinterpretation of a critical mass of observations made possible within a specific and dynamic conceptual framework. This historiographical account is by no means postmodern or relativistic. In both 1500 and 1700, the same laws of terrestrial magnetism applied. Researchers in different years observed the same type of phenomenon governed by these exact laws of nature. The measuring instruments and compasses they used were sufficiently similar as well. The epistemic-historical difference is rather on the conceptual level. The observations were considered as tokens of different types of natural forces: first as a kind of anomaly of a measurement or the instrument used, and later as an essential effect of terrestrial magnetism. This difference also informs the empirical framework and apparatus: the observations were made against the backdrop of different expectations of measurement. Seventeenth-century authors expected a declination and only had to detect and record it. In 1450, Peuerbach might have been highly irritated. Moreover, the demands placed on the measurement differed. Later authors recorded declinations more precisely, because they used them, e. g.,

56 See also, following Ian Hacking and making a similar argument, D. Lehoux, *What Did the Romans Know? An Inquiry into Science and Worldmaking*, Chicago/London 2012.

to roughly determine the geographical longitude. In 1500, a declination measurement had no instrumental value – it needed rather to be corrected than to be recorded.

Thus, the proposition «The magnetic needle points to 10 degrees East from astronomical north» has – in a somewhat pointed manner – a different meaning in 1500 and 1700, even though the underlying observed physical phenomenon is of the same type. This sentence relates, from the perspective of the actors in their historical context, to two ultimately different implicit questions: «Where does the magnetic needle of one specific instrument exactly point to?» vs. «How big is the magnetic declination in one specific location?» Or, how R.G. Collingwood has greatly put it: «If you cannot tell what a proposition means unless you know what question it is meant to answer, you will mistake its meaning if you make a mistake about that question.»[57]

57 R.G. Collingwood, *An Autobiography*, London 1939, p. 33. See also P.R. Blum, «How to Think with the Head of Another? The Historical Dimension of Philosophical Problems», *Intellectual History Review* 26 (2016), pp. 153–161.