other areas; Groddeck continued this work by investigating the lithologic sequences, primarily in the Harz Mountains, as reflected in his booklet *Abriss der Geognosie des Harzes* (1871–1883). His second topic, which historically is probably much more significant and original, was the link between lithology and ore geology. Here he made a major step in a direction that was almost entirely lost for 80 years and which has been rediscovered only recently. It was an observational classification of ore deposits, taking into account the facts of congruence between the host rock and the deposits. In his textbook on economic ore deposits, he came very close to stating that conformable or congruent deposits were contemporaneous, and noncongruent deposits epigenetic. This idea is reflected in his book in the following classification of mineral deposits (p. 84):

I. Bedrock deposits (formed in situ)

Formed with country rock:

- A. Layered deposits
  - 1. massive ore strata
  - 2. coprecipitation ore strata (of disseminated ore matter)
  - 3. lenticular ore layers (or strings)
- B. Massive (nonlayered) deposits

Formed later than enclosing rock:

- C. Cavity fillings
  - 1. fissure fillings or dikes
    - a. dikes in massive rocks
    - b. dikes in layered rocks
  - 2. fillings of caves
- D. Metamorphic mineral deposits

II. Weathering deposits (detrital deposits)

Groddeck's fifty-seven types of ore deposits were classified first according to geometric criteria (layered, vein type, and so on) and second according to composition. In this morphologic trend he was closest of all his contemporaries to the general trend of objectivation, that is, of an introduction of observational as against interpretative criteria in scientific classifications. In botany, zoology, and crystallography, this observational pattern had been followed since the first half of the eighteenth century, whereas in geology, especially in ore geology, old mythologic theories of magic ore sources were still fashionable, and because of Pošepný, had again become accepted dogma in 1890. Consequently, Groddeck was clearly a forerunner of the modern approach, especially the modern French morphological school of thought.

Because of his teaching and administrative duties, his early death, and probably also his less active links with foreign researchers, Groddeck was not very influential in his field, and apparently not nearly as well known in Anglo-Saxon countries as Pošepný, who traveled in North America and whose book on ore deposits was translated into English as early as 1895. Pošepný, and in part also von Cotta, were strong proponents of an almost pan-epigenetic theory of ore genesis, whereas Groddeck showed an independent new approach, linking observations in the country rock with his genetic interpretations. For this independent observation and interpretation of ore features he was rediscovered after 1958; an English translation of his 1879 book on ore deposits is presently being prepared.

His keen scientific mind also led him to propose other new genetic solutions to old problems, thus far explained by complicated hypotheses based more on ideas (projections of ideas) than on observations. For example, he showed with both observation and a sound logic of relations, that the tectonic structure of the Oberharz diabase consists of a simple, compressed saddle-shaped fold. He also proved that the adinole schist of the Oberharz is a normal bed concordant with the siliceous Culm schist, again demonstrating that he was ahead of his time in regard to genetic understanding. He also pioneered observations and interpretations of wall rock alterations. Groddeck's work therefore deserves a more important place in the history of geology than it has up to now been accorded.

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II. Secondary Literature. See A. K. Lossen, "Albrecht von Groddeck," in *Jahrbuch der Preussischen geologischen Landesanstalt u. Bergakademie zu Berlin, 1887* (1888), 109–132; and "Albrecht von Groddeck," in *Neues Jahrbuch für Mineralogie, Geologie und Paläontologie,* **1** (1888), 24.

W. Fischer, *Gesteins- und Lagerstättenbildung im Wandel der wissenschaftlichen Anschauung* (Stuttgart, 1961), refers often to Groddeck's work, but does not fully appreciate the role of his work as compared to that of Cotta and Pošepny.

G. C. Amstutz

GROSSETESTE, ROBERT (*b.* Suffolk, England, *ca.* 1168; *d.* Buckden, Buckinghamshire, England, 9 October 1253), *natural philosophy, optics, calendar reform.*

Grosseteste was the central figure in England in the intellectual movement of the first half of the thirteenth century, yet the only evidence for his life before he became bishop of Lincoln in 1235 is to be found in fragmentary references by Matthew of Paris and other chroniclers, by Roger Bacon, and occasionally in charters, deeds and other records.[1] His birth has been variously dated between 1168 and 1175, but since he is described as "Magister Robertus Grosteste" (the first appearance of his name) in a charter of Hugh, bishop of Lincoln, of probably 1186–1190, the earlier date is the more likely. Tradition places his birth in Suffolk, of humble parentage. He may have been educated first at Lincoln, then at Oxford, and was in the household of William de Vere, bishop of Hereford, by 1198, when a reference by Gerald of Wales suggests that he may have had some knowledge of both law and medicine. After that it seems likely that he taught at Oxford in the arts school until the dispersion of masters and scholars during 1209–1214. He must have taken his mastership in theology, probably at Paris, during this period, some time before his appointment as chancellor of the University of Oxford, although with the title *magister scholarum,* probably about 1214–1221, when he must have lectured on theology.

Grosseteste was given a number of ecclesiastical preferments and sinecures, including the archdeaconry of Leicester in 1229; but in 1232 he resigned them all except for a prebend at Lincoln, writing to his sister, a nun: "If I am poorer by my own choice, I am made richer in virtues."[2] From 1229 or 1230 until 1235 he was first lecturer in theology to the Franciscans, who had come to Oxford in 1224. His influence there was profound and continued after he left Oxford in 1235 for the see of Lincoln, within the jurisdiction of which Oxford and its schools came. He contributed largely to directing the interests of the English Franciscans toward the study of the Bible, languages, and mathematics and natural science. Indispensable sources for this later period of his life are his own letters and those of his Franciscan friend Adam Marsh.

Grosseteste's career thus falls into two main parts, the first that of a university scholar and teacher and the second that of a bishop and ecclesiastical statesman. His writings fall roughly into the same periods: to the former belong his commentaries on Aristotle and on the Bible and the bulk of a number of independent treatises, and to the latter his translations from the Greek. Living at a time when the intellectual horizons of Latin Christendom were being greatly extended by the translations into that language of Greek and Arabic philosophical and scientific writings, he took a leading part in introducing this new learning into university teaching. His commentary on Aristotle's *Posterior Analytics* was one of the first and most influential of the medieval commentaries on this fundamental work. Other important writings belonging to the first period are his commentary on Aristotle's *Physics,* likewise one of the first; independent treatises on astronomy and cosmology, the calendar (with intelligent proposals for the reform of the inaccurate calendar then in use), sound, comets, heat, optics (including lenses and the rainbow), and other scientific subjects; and his scriptural commentaries, especially the *Moralitates in evangelica, De cessatione legalium, Hexaëmeron* and commentaries on the Pauline Epistles and the Psalms. Having begun to study Greek in 1230–1231, he used his learning fruitfully during the period of his episcopate by making Latin translations of Aristotle's *Nicomachean Ethics* and *De caelo* (with Simplicius' commentary), of the *De fide orthodoxe* of John of Damascus, of Pseudo-Dionysius and of other theological writings. For this work he brought to Lincoln assistants who knew Greek; he also arranged for a translation of the Psalms to be made from the Hebrew and seems to have learned something of this language.

Although in content a somewhat eclectic blend of Aristotelian and Neoplatonic ideas, Grosseteste's philosophical thinking shows a strong intellect curious about natural things and searching for a consistently rational scheme of things both natural and divine. His search for rational explanations was conducted within the framework of the Aristotelian distinction between "the fact" (*quia*) and "the reason for the fact" (*propter quid*). Essential for the latter in natural philosophy was mathematics, to which Grosseteste gave a role based specifically on his theory, expounded in *De luce seu de inchoatione formarum* and *De motu corporali et luce,* that the fundamental corporeal substance was light (*lux*). He held that light was the first form to be created in prime matter, propagating itself from an original point into a sphere and thus giving rise to spatial dimensions and all else according to immanent laws. Hence his conception of optics as the basis of natural science. *Lux* was the instrument by which God produced the macrocosm of the universe and also the instrument mediating the interaction between soul and body and the bodily senses in the microcosm of man.[3] Grosseteste's rational scheme included revelation as well as reason, and he was one of the first medieval thinkers to attempt to deal with the conflict between the Scriptures and the new Aristotle. Especially interesting are his discussions of the problems of the eternity or creation of the world, of the relation of will to intellect, of angelology, of divine knowledge of particulars, and of the use of allegorical interpretations of Scripture.

Grosseteste's public life as bishop of Lincoln was informed by both his outlook on the universe as a scholar and his conception of his duties as a prelate dedicated to the salvation of souls. Analogous to corporeal illumination was the divine illumination of the soul with truth. He extended the luminous analogy to illustrate the relationship between the persons of the Trinity, the operation of divine grace through free will like light shining through a colored glass,[4] and the relation of pope to prelates and of bishops to clergy: as a mirror reflects light into dark places, he said in asserting his episcopal rights against the cathedral chapter of Lincoln, so a bishop reflects power to the clergy.[5]

In practice Grosseteste was governed by three principles: a belief in the supreme importance of the cure of souls; a highly centralized and hierarchical conception of the church, in which the papacy, under God, was the center and source of spiritual life and energy; and a belief in the superiority of the church over the state because its function, the salvation of souls, was more vital. Such views were widely accepted, but Grosseteste was unique in the ruthlessness and thoroughness with which he applied them, for example, in opposing the widespread use of ecclesiastical benefices to endow officials in the service of the crown or the papacy. As a bishop he had attended the First Council of Lyons in 1245, and in a memorandum presented to the pope there in 1250 he expounded his views on the unsuitability of such appointments while accepting the papal right to dispose of all benefices. Likewise, his opposition to the obstruction of the disciplinary work of the church by any ecclesiastical corporation or secular authority brought him into conflict both with his own Lincoln chapter and with the crown over royal writs of prohibition when secular law clashed with church law and when churchmen were employed as judges or in other secular offices. Grosseteste was a close friend of Simon de Montfort and took charge of the education of his sons, but the degree to which he shared in or influenced Montfort's political ideals has probably been exaggerated. Above all he was a bishop with an ideal, an outstanding example of the new type of ecclesiastic trained in the universities.

Scientific Thought. Some of Grosseteste's scientific writings can be dated with reasonable certainty, and most of the others can be related to these in an order based on internal references and on the assumption that the more elaborated version of a common topic is the later.[6] From the evidence for his method of making notes on his reading and thoughts to be worked up into finished essays and commentaries,[7] and from these writings themselves, it may be assumed that many of them arose out of his teaching in the schools. Gerald of Wales's description of Grosseteste at Hereford as a young clerk with a manifold learning "built upon the sure foundation of the liberal arts and an abundant knowledge of literature"[8] is borne out by what is probably his earliest work, *De artibus liberalibus.* In this attractive introduction he described how the seven liberal arts at once acted as a *purgatio erroris* and gave direction to the gaze and inclination of the mind (*mentis aspectus et affectus*). Of particular interest is his treatment of music, of which his love became proverbial, and of astronomy. As for Boethius, music for him comprised the proportion and harmony not only of sounds produced by the human voice and by instruments but also of the movements and times of the celestial bodies and of the composition of bodies made of the four terrestrial elements—hence the power of music to mold human conduct and restore health by restoring the harmony between soul and body and between the bodily elements, and the related power of astronomy through its indication of the appropriate times for such operations and for the transmutation of metals. Related to this essay was his phonetical treatise *De generatione sonorum,* which he introduced with an account of sound as a vibratory motion propagated from the sounding body through the air to the ear, from the motion of which arose a sensation in the soul.

Grosseteste developed his mature natural philosophy through a logic of science based on Aristotle and through his fundamental theory of light. In their present form most of the works concerned were almost certainly written between about 1220 and 1235. *De luce* and *De motu corporali et luce,* with his cosmogony and cosmology of light, seem to date from early in this period. The structure of the universe generated by the original point of *lux* was determined, first, by the supposition that there was a constant proportion between the diffusion or "multiplication" of *lux,* corresponding to the infinite series of natural numbers, and the quantity of matter given cubic dimensions, corresponding to some finite part of that series. Second, the intensity of this activity of *lux* varied directly with distance from the primordial source. The result was a sphere denser and more opaque toward the center. Then from the outermost boundary of the sphere *lumen* emanated inward to produce another sphere inside it, then another, and so on, until all the celestial and elementary spheres of Aristotelian cosmology were complete. Another seemingly early work in this series, *De generatione stellarum,* shows Grosseteste dependent on Aristotle in many things but not in all, for he argued that the stars were composed of the four terrestrial elements. Later, in his commentary on the *Physics,* he contrasted the imprecise and arbitrary way man must measure spaces and times with God's absolute measures through aggregates of infinites.

In all these writings Grosseteste made it clear that by *lux* and *lumen* he meant not simply the visible light which was one of its manifestations, but a fundamental power (*virtus, species*) varying in its manifestation according to the source from which it was propagated or multiplied and in its effect according to its recipient. Thus he showed in *De impressionibus elementorum* how solar radiation effected the transformation of one of the four terrestrial elements into another and later, in *De natura locorum,* how it caused differences in climate. An explanation of the tides begun in *De accessione et recessione maris* or *De fluxu et refluxu maris* (if this work is by him)[9] was completed in *De natura locorum,* in which he argued that the rays of the rising moon released vapors from the depth of the sea which pushed up the tide until the moon's strength increased so much that it drew the vapors through the water, at which time the tide fell again. The second, smaller monthly tide was caused by the weaker lunar rays reflected back to the opposite side of the earth from the stellar sphere.

In *De cometis et causis ipsarum* Grosseteste gave a good example of his method of falsification in arguing that comets were "sublimated fire" separated from their terrestrial nature by celestial power descending from the stars or planets and drawing up the "fire" as a magnet drew iron. Later, in *De calore solis* (*ca.* 1230–1235), he produced perhaps his most elegant exercise in analysis by reduction to conclusions falsified either by observation or by disagreement with accepted theory, finally leaving a verified explanation. He concluded that all hot bodies generated heat by the scattering of their matter and that the sun generated heat on the earth in direct proportion to the amount of matter incorporated from the transparent medium (air) into its rays.

Grosseteste set out and exemplified the formal structure of his mature scientific method in his *Commentaria in libros posteriorum Aristotelis,* his *Commentarius in viii libros physicorum Aristotelis,*[10] and four related essays giving a geometrical analysis of the natural propagation of power and light. It seems likely that he began the commentary on the *Posterior Analytics* when he was still a master of arts, that is, before 1209, and completed it over a long period, finishing after 1220 and probably nearer the end of the decade. The commentary on the *Physics* was written later, likewise certainly over a period of years, probably around 1230. It has striking parallels with some of the scientific topics of the *Hexaëmeron* but shows less than even the limited knowledge of Greek found in this work, suggesting that it just precedes it.

For Grosseteste, as for Aristotle, a scientific inquiry began with an experienced fact (*quia*), usually a composite phenomenon. The aim of the inquiry was to discover the reason for the fact (*propter quid*), the proximate cause or natural agent from which the phenomenon could be demonstrated:

> Every thing that is to be produced is already described and formed in some way in the agent, whence nature as an agent has the natural things that are to be produced in some way described and formed within itself, so that this description and form itself, in the very nature of things to be produced before they are produced, is called knowledge of nature.[11]

His method of discovering the causal agent was to make first a *resolutio,* or analysis of the complex phenomenon into its principles, and then a *compositio,* or reconstruction and deduction of the phenomenon from hypotheses derived from the discovered principles. He verified or falsified these hypotheses by observation or by theory already verified by observation.

Besides this double method, Grosseteste used in the analysis of the causal agent as the starting-point of demonstration another Aristotelian procedure, that of the subordination of some sciences to others, for example, of astronomy and optics to geometry and of music to arithmetic, in the sense that "the superior science provides the *propter quid* for that thing of which the inferior science provides the *quia.*"[12] But mathematics provided only the formal cause; the material and efficient causes were provided by the physical sciences. Thus "the cause of the equality of the two angles made on a mirror by the incident ray and the reflected ray is not a middle term taken from geometry, but is the nature of the radiation generating itself in a straight path . . . ."[13] The echo belonged formally to the same genus as the reflection of light, but the material and efficient causes of the propagation of sound had to be sought in its fundamental substance: "the substance of sound is *lux* incorporated in the most subtle air . . . ."[14] This introduced a fundamental addition to the very similar discussion of the propagation of sound in *De artibus liberalibus* and *De generatione sonorum.*

Grosseteste developed his geometrical analysis of the powers propagated from natural agents in the four related essays written most probably in the period 1231–1235. He said in the first, *De lineis, angulis et figuris seu de fractionibus et reflexionibus radiorum:* "All causes of natural effects have to be expressed by means of lines, angles and figures, for otherwise it would be impossible to have knowledge *propter quid* concerning them."[15] The same power produced a physical effect in an inanimate body and a sensation in an animate one. He established rules for the operation of powers: for example, the power was greater the shorter and straighter the line, the smaller the incident angle, the shorter the three-dimensional pyramid or cone; every agent multiplied its power spherically. Grosseteste discussed the laws of reflection and refraction (evidently taken from Ptolemy) and their causes, and went on in *De natura locorum* to use Ptolemy's rules and construction with plane surfaces to explain refraction by a spherical burning glass. "Hence," he resumed, "these rules and principles and fundamentals having been given by the power of geometry, the careful observer of natural things can give the causes of all natural effects by this method." This was clear "first in natural action upon matter and later upon the senses . . . ."[16]

An example of the analysis of a power's producing sensation is provided by Grosseteste's *De colore.* The *resolutio* identified the constituent principles: color was light incorporated by a transparent medium; transparent mediums varied in degree of purity from earthy matter; light varied in brightness and in the multitude of its rays. In the *compositio* he asserted that the sixteen colors ranging from white (bright light, multitudinous rays, in a pure medium) to black were produced by the "intension and remission" of these three variable principles. "That the essence of color and a multitude of the same behaves in the said way," he concluded, "is manifest not only by reason but also by experiment, to those who know the principles of natural science and of optics deeply and inwardly. . . . They can show every kind of color they wish to visibly, by art [*per artificium*]."[17]

The last of these four essays, *De iride seu de iride et speculo,* is the most complete example of Grosseteste's method and his most important contribution to optics. The *resolutio* proceeds through a summary of the principle of subordination and its relation to demonstration *propter quid* into a discussion of the division of optics into the science of direct visual rays, of reflected rays, and of refracted rays, in order to decide to which part the study of the rainbow belonged. It was subordinate to the third part, "untouched and unknown among us until the present time";[18] and it is his treatment of refraction that has the greatest interest.

> This part of optics [*perspectiva*], when well understood, shows us how we may make things a very long distance off appear to be placed very close, and large near things appear very small, and how we may make small things placed at a distance appear as large as we want, so that it is possible for us to read the smallest letters at an incredible distance, or to count sand, or grain, or seeds, or any sort of minute objects.[19]

The reason, as he had learned from Euclid and Ptolemy, was "that the size, position and arrangement according to which a thing is seen depends on the size of the angle through which it is seen and the position and arrangement of the rays, and that a thing is made invisible not by great distance, except by accident, but by the smallness of the angle of vision." Hence "it is perfectly clear from geometrical reasons how, by means of a transparent medium of known size and shape placed at a known distance from the eye, a thing of known distance and known size and position will appear according to place, size and position."[20]

Grosseteste followed this account of magnification and diminution by refracting mediums with an apparently original law of refraction, according to which the refracted ray, on entering a denser medium, bisected the angle between the projection of the incident ray and the perpendicular to the interface. "That the size of the angle in the refraction of a ray may be determined in this way," he concluded, "is shown us by experiments similar to those by which we discovered that the reflection of a ray upon a mirror takes place at an angle equal to the angle of incidence."[21]

It was also evident from the principle that nature always acts in the best and shortest way. Grosseteste went on to use a construction of Ptolemy's to show how to locate the refracted image, claiming again that this "is made clear to us by the same experiment and similar reasonings"[22] as those used in a similar construction for locating the reflected image. The first of these references to experimental verification, since it would have been so inaccurate, may throw doubt on all such references by Grosseteste. As was true for the majority of medieval natural philosophers, most of these references came from books or from everyday experience. Clearly his interest was directed primarily toward theory. Yet he advocated and was guided by the principle of experiment and developed its logic.

Besides these works related to optics, Grosseteste wrote important treatises on astronomical subjects. In *De sphaera,* of uncertain date between perhaps 1215 and 1230, and *De motu supercaelestium,* possibly after 1230, he expounded elements of both Aristotelian and Ptolemaic theoretical astronomy. In a later work, *De impressionibus aëris seu de prognosticatione,* dating apparently from 1249, he discussed astrological influences and, again, his mature explanation of the tides.

GROSSETESTE

More original were Grosseteste's four separate treatises on the calendar: *Canon in kalendarium* and *Compotus;* correcting these, *Compotus correctorius,* probably between 1215 and 1219; and *Compotus minor,* with further corrections, in 1244. He showed that with the system long in use, according to which nineteen solar years were considered equal to 235 lunar months, in every 304 years the moon would be one day, six minutes, and forty seconds older than the calendar indicated. He pointed out in the *Compotus correctorius* (cap. 10) that by his time the moon was never full when the calendar said it should be and that this was especially obvious during an eclipse. The error in the reckoning of Easter came from the inaccuracy both of the year of 365.25 days and of the nineteen-year lunar cycle.

Grosseteste's plan for reforming the calendar was threefold. First, he said that an accurate measure must be made of the length of the solar year. He knew of three estimates of this: that of Hipparchus and Ptolemy, accepted by the Latin computists; that of al-Battānī; and that of Thābit ibn Qurra. He discussed in detail the systems of adjustments that would have to be made in each case to make the solstice and equinox occur in the calendar at the times they were observed. Al-Battānī's estimate, he said in the *Compotus correctorius* (cap. 1), "agrees best with what we find by observation on the advance of the solstice in our time." The next stage of the reform was to calculate the relationship between this and the mean lunar month. For the new-moon tables of the *Kalendarium,* Grosseteste had used a multiple nineteen-year cycle of seventy-six years. In the *Compotus correctorius* he calculated the error this involved and proposed the novel idea of using a much more accurate cycle of thirty Arab lunar years, each of twelve equal months, the whole occupying 10,631 days. This was the shortest time in which the cycle of whole lunations came back to the start. Grosseteste gave a method of combining this Arab cycle with the Christian solar calendar and of calculating true lunations. The third stage of the reform was to use these results for an accurate reckoning of Easter. In the *Compotus correctorius* (cap. 10), he said that even without an accurate measure of the length of the solar year, the spring equinox, on which the date of Easter depended, could be discovered "by observation with instruments or from verified astronomical tables."[23]

As with Grosseteste's optics, it was Roger Bacon who first took up his work on the calendar; and Albertus Magnus first made serious use of his commentary on the *Posterior Analytics,* as did John Duns Scotus of that on the *Physics.* These attentions marked the beginning of a European reputation that continued into the early printing of his writings at Venice, the collecting of his scientific manuscripts by John Dee, and interest in them by Thomas Hobbes.[24]

NOTES

1. See D. A. Callus, ed., *Robert Grosseteste.*
2. *Epistolae,* H. R. Luard, ed., p. 44.
3. E.g., *Hexaëmeron,* British Museum MS Royal 6.E.V (14 cent.), fols. 147v–150v; L. Baur, "Das Licht in der Naturphilosophie des Robert Grosseteste," in *Abhandlungen aus dem Gebiete der Philosophie und ihrer Geschichte. Eine Festgabe zum 70. Geburtstag Georg Freiherrn von Hertling* (Freiburg im Breisgau, 1913), pp. 41–55.
4. *De libero arbitrio,* caps. 8 and 10, in L. Baur, *Die philosophischen Werke des Robert Grosseteste,* pp. 179, 202.
5. *Epistolae,* pp. 360, 364, 389.
6. For the basic work on this question, see Baur, *Die philosophischen Werke;* and S. H. Thomson, *The Writings of Robert Grosseteste*—with the revisions by Callus, "The Oxford Career of Robert Grossetest," *Robert Grosseteste;* A. C. Crombie, *Robert Grosseteste and the Origins of Experimental Science* (1953, 1971); and R. C. Dales, "Robert Grosseteste's Scientific Works," *Commentarius in viii libros.*
7. From William of Alnwick, as first noticed by A. Pelzer. See Callus, "The Oxford Career of Robert Grosseteste," pp. 45–47.
8. Giraldus Cambrensis, *Opera,* J. S. Brewer, ed., I (London, 1861), 249.
9. See R. C. Dales, "The Authorship of the *Questio de fluxu et refluxu maris* Attributed to Robert Grosseteste," in *Speculum,* **37** (1962), 582–588.
10. See the ed. by Dales. Grosseteste wrote probably about 1230 a summary of Aristotle's views in his *Summa super octo libros physicorum Aristotelis.*
11. *Commentarius in viii libros physicorum Aristotelis,* lib. I, Dales, ed., pp. 3–4.
12. *Commentaria in libros posteriorum Aristotelis,* I, 12 (1494), fols. 11r–12r.
13. *Ibid.,* I, 8, fol. 8r.
14. *Ibid.,* II, 4, fol. 29v.
15. *De lineis, angulis et figuris,* in Baur, *Die philosophischen Werke,* pp. 59–60.
16. *De natura locorum, ibid.,* pp. 65–66.
17. *De colore, ibid.,* pp. 78–79.
18. *De iride, ibid.,* p. 73. See L. Baur, *Die Philosophie des Robert Grosseteste,* pp. 117–118; Crombie, *Robert Grosseteste* (1971), pp. 117–124.
19. *De iride,* in Baur, *Die philosophischen Werke,* p. 74.
20. *Ibid.,* p. 75.
21. *Ibid.,* pp. 74–75.
22. *Ibid.,* p. 75.
23. *Compotus,* R. Steele, ed., pp. 215, 259.
24. See Crombie, *Robert Grosseteste* (1971); A. Pacchi, "Ruggero Bacone e Roberto Grossetesta in un inedito hobbesiano del 1634," in *Rivista critica di storia della filosofia,* **20** (1965), 499–502; and *Convenzione e ipotesi nella formazione della filosofia naturale di Thomas Hobbes* (Florence, 1965).

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I. ORIGINAL WORKS. The earliest-dated printed ed. of a work by Grosseteste is *Commentaria in libros posteriorum Aristotelis* (Venice, 1494; 8th ed., 1552). It was followed by his *Summa super octo libros physicorum Aristotelis* (Venice, 1498; 9th ed., 1637); *Libellus de phisicis lineis angulis et figuris per quas omnes actiones naturales com-*

plentur (Nuremburg, 1503); *De sphaera,* pub. as *Sphaerae compendium* (Venice, 1508; 5th ed., 1531); and *Compotus correctorius* (Venice, 1518). His *Opuscula* (Venice, 1514; London, 1690) includes *De artibus liberalibus, De generatione sonorum, De calore solis, De generatione stellarum, De colore, De impressionibus elementorum, De motu corporali, De finitate motus et temporis* (appearing first as the concluding section of his commentary on the *Physics*), *De lineis, angulis et figuris, De natura locorum, De luce, De motu supercaelestium,* and *De differentiis localibus.* All these essays, with *De sphaera* and the hitherto unprinted *De cometis, De impressionibus aëris* and *De iride,* were published by L. Baur in *Die philosophischen Werke des Robert Grosseteste* (see below). For further modern texts see *Canon in Kalendarium,* ed. by A. Lindhagen as "Die Neumondtafel des Robertus Lincolniensis," in *Archiv för matematik, astronomi och fysik* (Uppsala), **11**, no. 2 (1916); *Compotus, factus ad correctionem communis kalendarii nostri,* R. Steele, ed., in Roger Bacon, *Opera hactenus inedita,* VI (Oxford, 1926), 212 ff.; S. H. Thomson, "The Text of Grosseteste's *De cometis,*" in *Isis,* **19** (1933), 19–25; and "Grosseteste's *Questio de calore, de cometis* and *De operacionibus solis,*" in *Medievalia et humanistica,* **11** (1957), 34–43; *Commentarius in viii libros physicorum Aristotelis* . . ., R. C. Dales, ed. (Boulder, Colo., 1963); and R. C. Dales, "The Text of Robert Grosseteste's *Questio de fluxu et refluxu maris* with an English Translation," in *Isis,* **57** (1966), 455–474. See also *Roberti Grosseteste episcopi quondam Lincolniensis epistolae,* H. R. Luard, ed. (London, 1861).

II. Secondary Literature. For the fundamental work of identifying and listing Grosseteste's writings see L. Baur, *Die philosophischen Werke des Robert Grosseteste, Bishop von Lincoln,* vol. IX of Beiträge zur Geschichte der Philosophie des Mittelalters (Münster, 1912); and S. H. Thomson, *The Writings of Robert Grosseteste Bishop of Lincoln 1235–1253* (Cambridge, 1940). For further discussions of his scientific writings with references to additional items, see D. A. Callus, "The Oxford Career of Robert Grosseteste," in *Oxoniensia,* **10** (1945), 42–72; D. A. Callus, ed., *Robert Grosseteste, Scholar and Bishop* (Oxford, 1955); A. C. Crombie, *Robert Grosseteste and the Origins of Experimental Science, 1100–1700* (Oxford, 1953; 3rd ed., 1971) and the comprehensive bibliography therein; and R. C. Dales, "Robert Grosseteste's Scientific Works," in *Isis,* **52** (1961), 381–402. The basic modern biography is still F. S. Stevenson, *Robert Grosseteste, Bishop of Lincoln* (London, 1899), while Callus, *Robert Grosseteste,* judiciously sums up more recent scholarship. The pioneering account of his scientific thought is L. Baur, *Die Philosophie des Robert Grosseteste, Bischofs von Lincoln,* XVIII, nos. 4–6 of Beiträge zur Geschichte der Philosophie des Mittelalters (Münster, 1917).

A. C. Crombie

GROSSMANN, ERNST A. F. W. (*b.* Rothenburg, near Bremen, Germany, 16 February 1863; *d.* Munich, Germany, 17 March 1933), *astronomy.*

Grossmann began to study astronomy in 1884 at Göttingen, where he took his doctorate under A. C. W. Schur and Leopold Ambronn in 1891. He was assistant at the Göttingen observatory from 1891 to 1896, at Moritz Kuffner's observatory in Vienna from 1896 to 1898, at the Leipzig observatory from 1898 to 1902, and at the Kiel observatory from 1902 to 1905. In 1905 he became observer at Munich, where he lived for the rest of his life. He retired in 1928.

Grossmann was an enthusiastic and important worker with meridian instruments. All of his work was devoted to questions concerning fundamental astrometric measurements. After examining systematic errors in measurements of double stars in his dissertation, he made careful observations with the meridian circles of all the observatories where he worked. One main area of his research was the theory of atmospheric refraction; his very important examination of existing observations resulted in a value for the constant of refraction of 60.15″, which is still used.

Grossmann's observations of fundamental right ascensions near the celestial pole indicated clearly that the values adopted at that time were affected by systematic errors. Although his attempts to measure stellar parallaxes by a meridian circle were unsuccessful, they convinced astronomers that the photographic method is better. In 1921 he showed that existing observations of the planet Mercury were not sufficiently accurate to permit determination of a reliable value of the relativistic motion of its perihelion. It was more than twenty years later that a new comprehensive discussion of all observations of Mercury made between 1765 and 1937, which was undertaken by the U.S. Naval Observatory at Washington, showed convincingly that the observed value of the motion of perihelion was in agreement with the theory of relativity.

BIBLIOGRAPHY

Grossmann's major works are "Untersuchungen über die astronomische Refraktion," in *Abhandlungen der K. Bayerischen Akademie der Wissenschaften,* Math.-phys. Kl., **28**, no. 9 (1917), 1–72; "Die Bewegung des Merkurperihels nach den Arbeiten Newcombs," in *Astronomische Nachrichten,* **214** (1921), 41–54; and "Parallaxenbestimmungen am Meridiankreise," in *Neue Annalen der K. Sternwarte in München,* **5**, no. 1 (1926), 1–173.

There is no secondary literature.

F. Schmeidler

GROSSMANN, MARCEL (*b.* Budapest, Hungary, 9 April 1878; *d.* Zurich, Switzerland, 7 September 1936), *mathematics.*