






<https://doi.org/10.48417/technolang.2026.02.16>

Research article

Measuring the Invisible: A Review of Thomas Morel's *Underground Mathematics*

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Abstract

Thomas Morel's *Underground Mathematics* reconstructs subterranean geometry, or *Markscheidekunst*, as a neglected form of practical mathematics developed in the mining regions of the Holy Roman Empire. Morel presents mine surveying as a craft culture in which measurement, legal procedure, manuscript practice, map-making, and administrative record-keeping jointly made the underground knowable. This review reads the book through technical language, representation, and trust. Its central claim is that hidden subterranean space became measurable, legible, and usable through situated procedures and records. Surveying rituals, handwritten manuals, maps, and administrative documents did not merely record technical practice, they helped define what counted as reliable knowledge within mining communities. For readers concerned with technology and language, the book is valuable because it shows how authority emerged through the interplay of vocabularies, instruments, numerical measurement, visual forms, and legal-administrative procedures. The book is therefore important for historians of mathematics, mining, and craft culture, as well as for readers interested in how technical practices generate legibility, authority, and trust. Although Morel could have developed more explicit reflections on technical language, visual mediation, and the geographical boundaries of subterranean geometry, *Underground Mathematics* remains a compelling study of how measurement, inscription, and visualization transformed hidden subterranean spaces into objects of knowledge, judgment, and administration.

Keywords: Subterranean geometry; Practical mathematics; Manuscript culture; Technical representation; Craft knowledge

Citation: Liu, S., & Deng, P. (2026). Measuring the Invisible: A Review of Thomas Morel's *Underground Mathematics*. *Technology and Language*, 7(2), 211-220. <https://doi.org/10.48417/technolang.2026.02.16>



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УДК: 51-7: 622.33

<https://doi.org/10.48417/technolang.2026.02.16>

Научная статья

Измерение невидимого: Рецензия на книгу Томаса Мореля “Underground Mathematics”

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Аннотация

Книга Томаса Мореля *Underground Mathematics* реконструирует подземную геометрию, или *Markscheidekunst*, как забытую форму практической математики, сложившуюся в горнорудных регионах Священной Римской империи. Морель представляет маркшейдерское дело как ремесленную культуру, в которой измерение, правовые процедуры, рукописная практика, составление карт и административное делопроизводство совместно делали подземное пространство познаваемым. В настоящей рецензии книга рассматривается через призму технического языка, репрезентации и доверия. Ее центральный тезис состоит в том, что скрытое подземное пространство становилось измеримым, читаемым и пригодным для использования благодаря ситуативным процедурам и записям. Ритуалы измерения, рукописные руководства, карты и административные документы не просто фиксировали техническую практику, они помогали определять, что считалось надежным знанием внутри горнорудных сообществ. Для читателей, интересующихся технологиями и языком, книга ценна тем, что показывает, как авторитет возникал во взаимодействии словарей, инструментов, числового измерения, визуальных форм и правовых-административных процедур. Поэтому книга важна для историков математики, горного дела и ремесленной культуры, а также для читателей, интересующихся тем, как технические практики порождают читаемость, авторитет и доверие. Хотя Морель мог бы более подробно развить размышления о техническом языке, визуальном посредничестве и географических границах подземной геометрии, *Underground Mathematics* остается убедительным исследованием того, как измерение, запись и визуализация превращали скрытые подземные пространства в объекты знания, суждения и управления.

Ключевые слова: Подземная геометрия; Практическая математика; Рукописная культура; Техническая репрезентация; Ремесленное знание

Для цитирования: Liu, S., Deng, P. Measuring the Invisible: A Review of Thomas Morel's Underground Mathematics // Technology and Language. 2026. № 7(2). P. 211-220.
<https://doi.org/10.48417/technolang.2026.02.16>



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When Johann Wolfgang von Goethe entered the service of the Duchy of Saxe-Weimar in 1776, one of his first administrative charges concerned mining. For years he directed the commission responsible for reviving the abandoned silver and copper mine at Ilmenau, descending its shafts, examining its rocks, and corresponding with surveyors and mining officials. The mineral world never released him: his house on the Frauenplan in Weimar still holds one of the largest private mineral collections of the age, nearly 18,000 specimens, and the iron oxide mineral goethite bears his name. “Rocks are mute teachers,” he reflected in *Wilhelm Meister’s Journeyman Years*; “they render the observer mute, and the best thing one can learn from them is to keep one’s counsel” (Goethe, 1829/1995). The aphorism names a real difficulty: the underground does not speak, and what it teaches resists ordinary communication. Yet the mining administrator in Goethe knew that silence could not be the last word. Mines had to be measured, mapped, recorded, and adjudicated; the muteness of stone had to be converted into numbers, lines, and documents that others could read, check, and trust. How early modern mining communities accomplished this conversion is the question at the heart of the book under review.

Thomas Morel’s *Underground Mathematics: Craft Culture and Knowledge Production in Early Modern Europe* studies a technical practice whose object resisted ordinary visibility (Fig. 1). Subterranean geometry, or *Markscheidekunst*, dealt with shafts, tunnels, ore veins, property boundaries, and underground routes that could not be inspected directly from the surface (Morel, 2023, p. 5). To measure the underground was therefore more than applying geometry to a difficult environment. It meant transforming a hidden and unstable space into relations that could be recorded, communicated, disputed, and administered. This is the sense in which Morel’s book may be read as a history of “measuring the invisible.”

The book makes an important contribution to the history of practical mathematics, early modern mining, and craft knowledge. Its achievement lies in shifting attention away from learned geometry as an abstract discipline. Morel focuses on the situated practices through which miners, surveyors, officials, teachers, and administrators made mathematical knowledge work. Morel shows that underground surveying developed within the legal, ritual, pedagogical, and administrative worlds of mining (Morel, 2023, p. 6). It was embedded in legal procedures, rituals of witnessing, manuscript practice, cartographic representation, and administrative documentation. Geometry, in this account, functioned as a practical means of establishing boundaries, evaluating claims, coordinating work, and producing trust.

The book is especially valuable for showing how technical authority depends on forms of representation. The underground became knowable through a chain of mediations. Instruments converted direction and distance into measurable relations, vocabularies named operations and roles, manuscripts preserved procedures, maps made inaccessible spaces visible, and records turned technical operations into recognized evidence. Morel’s study therefore presents subterranean geometry as a culture of inscription as well as calculation.

Viewed as a study of early modern technical mediation, *Underground Mathematics* shows how mining communities converted physical environments into measurable



relations, preserved procedures and results in written and visual forms, and used these records to support decisions. Measurement, language, image, and record remain concrete practices through which a subterranean world became legible, credible, and administratively usable.

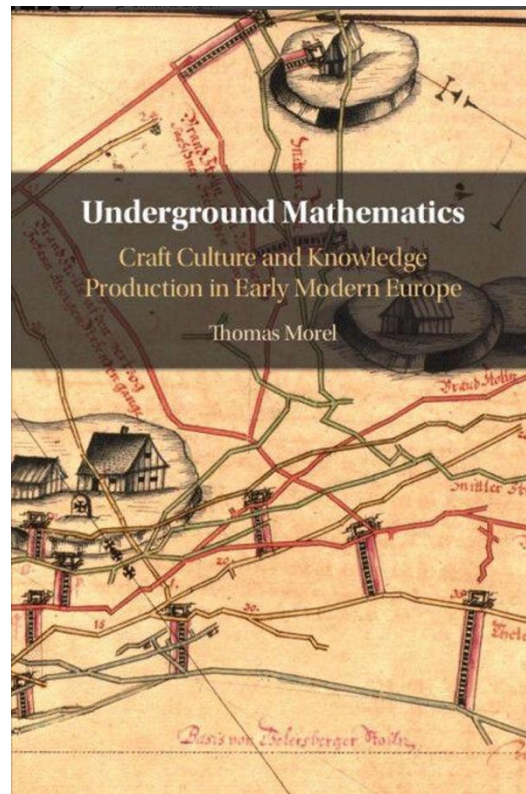


Figure 1. The book's cover of *Underground Mathematics: Craft Culture and Knowledge Production in Early Modern Europe* by Thomas Morel

A central strength of *Underground Mathematics* is its refusal to treat subterranean geometry as a simple application of learned mathematics to mining. The German term *Markscheidekunst*, usually rendered as the “art of setting limits,” already indicates the social and technical work performed by this discipline. It referred to the measurement of mining concessions, the orientation of shafts and galleries, the tracing of underground routes, and the management of spatial uncertainty in metal mines. Morel's account therefore begins from a kind of mathematics whose value lay in use: it helped mining communities establish boundaries, plan underground work, and coordinate operations.

This emphasis allows Morel to move beyond the familiar narrative of mathematics entering technical life from outside, as learned principles later applied to practical problems. In the mining regions of the Central European Holy Roman Empire, geometry emerged within a dense setting of local customs, legal rights, material constraints, and administrative needs. Its authority depended on calculation, procedure, and recognition. Surveying had to be performed in recognizable ways, witnessed by relevant actors,



recorded in appropriate forms, and accepted by the community (Morel, 2023, pp. 53-60). The book is especially persuasive when it shows that mathematical practice acquired force through procedures that made technical results socially and legally recognizable.

Morel's discussion of learned authors such as Agricola and Reinhold is important for this argument. Their printed works helped make mining visible to scholarly readers, yet also reveal the limits of treating textual description as transparent evidence of practice. Morel treats these authors as evidence of the distance between learned reconstruction and craft procedure (Morel, 2023, pp. 22, 46-49). This move redirects attention from mathematics as a formal discipline to situated work, performed with instruments, articulated in miners' language, stabilized through custom, and mobilized in decisions about property, labor, and administration. It also prepares the book's central themes: manuscript practice, cartographic visualization, and measurement as a procedure for producing trust.

A further achievement of *Underground Mathematics* lies in its treatment of craft knowledge as a representational practice. Morel places miners and surveyors at the center of a history too often dominated by scholars. He reconstructs the forms through which their knowledge was inscribed, taught, checked, and authorized: technical vocabularies, measuring procedures, instruments, sketches, manuscripts, maps, and administrative records. The book therefore avoids a narrow opposition between learned theory and tacit practice. Mine surveying was rooted in experience and embodied skill. At the same time, it depended on written, visual, and procedural forms that allowed technical operations to be taught, repeated, inspected, and authorized.

This point matters because craft knowledge is often associated with locality, orality, and resistance to formalization. Morel's surveyors complicate that picture. They worked in mines and on the surface, but their authority also took shape on paper and in drawings. Their expertise had to operate across settings: underground galleries, mining offices, apprenticeship contexts, local disputes, and courtly or state administration. In this movement, knowledge changed form. A measurement became a note, a route became a line, a procedure became an instruction, and a dispute became a record. Morel's account is persuasive because it follows these transformations while keeping them anchored in the material and social conditions of mining.

The book is especially valuable because it shows that representation belonged to technical practice itself. Technical vocabularies named operations and roles, diagrams and plans condensed spatial relations, manuscripts preserved methods, and documents gave measurements institutional weight. In this sense, Morel presents subterranean geometry as a technical culture organized around acts of representation.

This approach gives the book much of its historiographical significance. By placing practitioners at the center, Morel does not romanticize craft knowledge as an alternative to scholarly knowledge. Instead, he shows how practical expertise developed its own standards, forms of inscription, and procedures of validation. The underground surveyor appears neither as an anonymous manual worker nor as a minor version of the learned mathematician. The surveyor appears instead as a technical actor whose authority depended on connecting measurement, language, image, and record. This is where



Underground Mathematics speaks most directly to questions of technology and language: it shows how a craft became a durable technical tradition through forms of representation.

One of the most suggestive parts of *Underground Mathematics* is its treatment of manuscript practice. Morel shows that the handwritten tradition of subterranean geometry was not a marginal survival from a pre-print world. It was one of the principal working forms through which underground surveying developed as a technical practice. In this setting, manuscripts did not merely preserve knowledge after the fact. They shaped how methods were organized, taught, copied, corrected, and authorized.

The central figure here is Balthasar Rösler, through whom Morel reconstructs a seventeenth-century scribal culture of technical instruction (Morel, 2023, pp. 119-123). Rösler and his students did not publish treatises in the manner of learned mathematicians. Their techniques were copied, taught, and maintained through handwritten books that described tasks, instruments, diagrams, and procedures. Morel makes this point concrete through Adam Schneider's Rösler-derived manuscript, in which the apprentice is led from instruments to calculation and then to record-keeping. The measuring chain, suspended compass, and semicircle are not presented as isolated tools, but as parts of a sequence that turns an underground route into measurable data. The right triangle, called the “master of mathematics,” translates the inclined chain into horizontal and vertical components, while the Grubenzug records each pull of the chain as a line of data including length, inclination, and direction (Morel, 2023, pp. 121-128). Even small procedural details are revealing: the surveyor is instructed to check his writing table while the magnetic needle settles, and then to repeat the observation before entering the result. Such manuscripts allowed techniques learned in mines and offices to be passed on to new practitioners while remaining tied to the craft world that gave them meaning.

This account is important because it challenges the assumption that print necessarily represented a more advanced form of technical instruction. In Morel's narrative, manuscript culture appears as flexible, selective, and closely adapted to practice-bound instruction. A manuscript could be copied for a student, adjusted to local circumstances, supplemented by drawings, and kept within a circle of trusted users. Its authority rested less on public authorship than on recognized training, experience, and use. It depended on the reputation of teachers, the credibility of experience, and the ability of the text to guide recognizable operations.

The case of Nicolaus Voigtel further clarifies this point. His *Geometria subterranea* gave printed visibility to material that had long been shaped by manuscript practice (Morel, 2023, pp. 138-143). Yet Morel avoids a simple story in which print replaces manuscript or secrecy gives way to openness. Even after Voigtel's book, becoming a competent surveyor still required training, practice, and access to a professional culture that could not be fully captured by print. The issue is not that manuscripts were more “authentic” than printed books, but that manuscript and print supported different forms of technical authority.

Morel's discussion of manuscript culture deepens the book's larger argument about knowledge production. Technical knowledge became stable when writing was embedded in practices of teaching, copying, correction, authorization, and use. Handwritten manuals, copied diagrams, and administrative registers made technical operations durable



without making them fully public. In this sense, manuscripts were working instruments of instruction and authorization rather than passive containers of subterranean geometry.

If manuscript practice made subterranean geometry teachable, maps made the underground visually available for comparison, planning, and judgment. Chapter 5 is therefore central to the argument of *Underground Mathematics*. Morel treats mining maps as instruments for rendering the underground intelligible, rather than as illustrations appended to technical practice. Shafts, galleries, veins, concessions, and drainage works were transformed into lines, sections, scales, labels, and spatial relations. The result was a visual language capable of making hidden structures available to people who could not inspect them directly.

The example of Johann Berger's Freiberga subterranea is especially important. Morel presents it as an ambitious cartographic undertaking grounded in subterranean geometry and shaped by Abraham von Schönberg's administrative ambitions. Berger's drafts make the technical work of mapping unusually visible. Before the map became a pictorial representation of underground space, the path of a gallery was constructed from numbered data points; in the draft plan of the Holy Father gallery, for instance, the "angles of this gallery" were listed and points such as 5, 10, and 15 were marked for clarity, while figurative lines indicating the gallery, hut, and winch were added afterwards (Morel, 2023, pp. 167-168). This example shows that the map was not simply an image of the mine, but a working surface on which measured data could be organized, checked, and used. Its significance therefore lies not only in its detail, but in the work it was meant to perform. It allowed routes, pits, and prospective works to be compared within a coherent view of a mining district. The map was both a representation of underground space and a tool for planning and administrative judgment.

Morel is particularly good at showing how such visual forms acquired authority. Mining communities had long relied on direct inspection, local testimony, written reports, and repeated measurements. A map acquired force only when it could be read alongside these older practices. It required conventions of reading, confidence in surveying procedures, and administrative support. This is why the political setting of Chapter 5 matters. The rise of mining cartography was linked to efforts to reform, supervise, and finance mining operations. Visualization was therefore closely connected to administrative supervision.

The force of Morel's analysis lies in his refusal to treat maps as transparent windows onto the underground. They were selective constructions designed for use. Their value depended on what they made visible and what they simplified. A technical map condensed complex underground relations into a form readable by surveyors, officials, investors, and rulers. It organized the mine as an object of judgment, rather than merely reproducing it. This makes the chapter one of the strongest parts of the book: it shows with particular clarity how visual representation could transform uncertainty into a basis for decision.

There is, however, a small tension here. Morel's discussion makes clear that maps were crucial to the history he reconstructs, yet the visual materials themselves are not always easy for readers to examine in detail. Since the argument depends heavily on cartographic mediation, larger or more legible reproductions would have helped readers



follow the technical work performed by these images. This does not weaken the argument, but it does show how much a history of visual knowledge depends on the visibility of its own evidence.

Overall, the chapter on mapping gives the phrase “measuring the invisible” its most concrete form. The underground became knowable because it could be drawn, scaled, annotated, compared, and used in planning. Maps converted subterranean space into a visual field of relations, linking measurement to administration and representation to decision-making. In Morel’s account, mapping created a form through which hidden space could be inspected, trusted, and administered.

A further strength of *Underground Mathematics* is its treatment of measurement as both technical operation and social procedure. In this context, accuracy was not a purely internal mathematical value. It mattered because underground surveying was tied to property, labor, investment, safety, and jurisdiction. A measurement could determine where a concession began, whether a gallery crossed a boundary, how underground work should proceed, or whether a technical claim could receive administrative recognition. Numbers acquired force when they were produced and received through recognizable procedures.

The ritual and legal dimensions of *Markscheidkunst* are therefore central to Morel’s account. Morel shows that mine surveying combined instruments and calculation with public acts, witnesses, local customs, written confirmation, and institutional acceptance. A mathematically correct measurement became trusted only when it was performed in a recognizable and accepted manner. The authority of subterranean geometry thus depended on a sequence of actions through which technical results became socially recognizable.

Measurement produced trust through procedure. Instruments generated readings, surveyors interpreted them, witnesses and officials confirmed the act, and documents preserved the result. Maps and records then allowed measurements to be checked, recognized, and used. Morel’s point is that reliability in early modern mining was built through linked technical, social, and documentary operations.

The book’s larger significance lies in showing how technical authority emerged where measurement, documentation, and institutional recognition met. Mining communities needed reliable numbers, but they also needed shared vocabularies, accepted forms of documentation, and procedures for resolving disagreement. Subterranean geometry became powerful because it transformed uncertain spatial relations into claims that could be checked, disputed, certified, and used.

This also explains the significance of the book’s religious and ceremonial materials. Sermons, rituals, and public acts of witnessing might seem peripheral to mathematics. Morel shows that they belonged to the moral and social world in which mathematical practice gained legitimacy. Geometry was associated with precision, fairness, order, and legitimate procedure. In mining communities where economic interests and spatial uncertainty were deeply intertwined, measurement became part of the broader moral and social order of mining.

Seen from this angle, one of the book’s most valuable achievements is to make trust visible as an achievement of procedure, documentation, and institutional judgment. The



underground became knowable through the coordination of instruments, maps, manuscripts, testimony, and administrative judgment. It became credible through procedures that connected measurement to testimony, inscription, visualization, and administrative judgment. Morel's history of subterranean geometry is therefore also a history of how technical evidence became acceptable within a community.

The strengths of *Underground Mathematics* also suggest a few further questions. The first concerns technical language. Morel repeatedly shows that subterranean geometry depended on specialized terms, practitioners' vocabularies, and forms of communication that were not easily accessible to outsiders. These linguistic practices mattered because they shaped who could learn, explain, authorize, and challenge surveying practices. Yet the book might have developed this dimension more explicitly. A more explicit account of technical vocabulary would have strengthened the connection between language and authority in the history Morel reconstructs.

This is less a criticism of omission than a response to the richness of the materials Morel presents. Morel gives readers many materials through which language can be seen at work: the naming of roles and procedures, the translation of craft practice into written instruction, the tension between learned terminology and practitioners' speech, and the movement from local expression to administrative record. These materials invite more sustained reflection on how technical words stabilized practice and authority. In a culture where hidden space had to be measured, described, copied, mapped, and certified, language was part of the practical apparatus through which knowledge became usable.

A second question concerns visual mediation. Morel's treatment of mining maps is one of the strongest parts of the book, although the visual evidence is not always easy for the reader to examine. Since the argument depends on plans, sections, diagrams, and cartographic detail, larger reproductions or more extensive visual commentary would have helped readers follow the technical work performed by these images. This does not weaken Morel's analysis; it reflects the difficulty of writing a history in which images are themselves central to the argument.

A third question concerns the conceptual and geographical boundaries of subterranean geometry. Morel's decision to focus on the mining regions of the Holy Roman Empire gives the book its depth and coherence. At the same time, the category of subterranean geometry remains somewhat difficult to delimit as a historical object. Was it primarily a German artisanal tradition rooted in *Markscheidekunst*, or can it also describe a broader family of quantitative mining practices across regions? Morel's study does not need to answer this question exhaustively, but the issue matters because it affects how we understand the portability of technical vocabularies, procedures, and evidentiary forms beyond the settings in which they acquired authority.

These questions are modest in comparison with the book's achievement. They arise because Morel has recovered a technical culture rich enough to support further inquiry. A book that reduced subterranean geometry to calculation alone would not raise such questions. *Underground Mathematics* raises them because it shows measurement, language, image, and record working together. Its remaining open questions therefore point less to weakness than to the generative character of the study. Morel has made a



once-obscure mathematical practice visible. The book also shows why its vocabularies, images, procedures, and boundaries deserve further attention.

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<https://doi.org/10.1017/9781009267274>

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Статья поступила 19 марта 2026
одобрена после рецензирования 29 апреля 2026
принята к публикации 1 июня 2026

Received: 19 March 2026
Revised: 29 April 2026
Accepted: 1 June 2026