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Picturing the World of Mining in the Renaissance
The *Schwazer Bergbuch* (1556)

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Among the characteristic inventions of the West that came into being in the age of the Renaissance was a set of languages for picturing the world. The language of perspective is certainly the best known and most studied. Orthogonal plans in architecture, cartographic projections and illustrations in the context of natural history also aroused the interest of historians, as did the pictorial languages used in technical contexts. This communication[1] is intended to contribute further to these studies by considering the technical drawings from the world of mining – a world, as it turns out, where several of these pictorial languages converged. Its focus lies on the images of technical devices contained in the illustrated manuscript "Perkwerch," better known as the *Schwazer Bergbuch* (The Mining Book of Schwaz).[2]

1. The context of the *Schwazer Bergbuch*.

Schwaz is the name of a town in Tyrol, Austria, which, in the 16th century, was the most important center of the Tyrolean mining district. Other centers were located in Hall in Tyrol and in Kitzbühel. In Renaissance Tyrol noble metals were mined; this contrasts with the Industrial Revolution as well as the 19th and 20th centuries, when the mining of iron ores and coal prevailed over all other extractive industries. The most important goal of mining in the Renaissance was to extract the ores of noble metals, above all, those of silver and copper. At that time these metals were of strategic significance for two reasons. The first reason was economic as well as political reasons: silver and copper were the chief mint metals, and money at that time was made exclusively from metal. Moreover, the emergence of political powers of an absolutist character in this period was essentially dependent on money. It

[1] This communication is a revised version of a talk delivered at the Annual Meeting of the Renaissance Society of America in Venice, April 8-11, 2010.

[2] Of the eleven extant manuscripts of the *Schwazer Bergbuch* the most important are (A) Innsbruck Codex Dip(auliana) 856 (Tiroler Landesmuseum); (B) Vienna Codex vindob(onensis) 10.852 (Österreichische Nationalbibliothek), and (C) Bochum Codex Sig. 3313 (Bibliothek des Deutschen Bergbaumuseums). Heinrich Winkelmann has edited a facsimile edition of (A) with a transcription/translation of (B) (Bochum 1956), as well as a facsimile edition of (B) (Essen 1988); a facsimile edition and transcription of (C) together with a transcription of (A) was edited by Christoph Bartels, Andreas Bingener and Rainer Slotta (Bochum 2006).

suffices at this point to remember the renowned and notorious mercenary armies of the Renaissance. The second reason for the strategic significance of noble metals was military: the production of bronze, the metal used to manufacture advanced artillery, required copper.

In the first half of the 16th century, that is, before the Spanish exploitation of South America's noble metals resources created a completely different situation, there were three European mining regions of outstanding importance: the Harz mountains, the Ore Mountains range (*Erzgebirge*) belonging partly to Saxony and partly to Bohemia, and Tyrol. Due to a strange coincidence, we are unusually well informed about the mining and smelting of metals in the latter two of these chief mining districts of the Renaissance, about their technical foundations and achievements, their legal and administrative aspects as well as the economic and social dimensions.

In 1556, the very year that Georgius Agricola's famous *De re metallica* was published by Froben in Basel, the mining authorities of Schwaz produced a richly illustrated manuscript depicting various aspects of the local mining industry – its legal foundations (a very complex issue, as most of these legal regulations derived from the Middle Ages), its economic base and connections, and last but not least its technological constitution at this time.

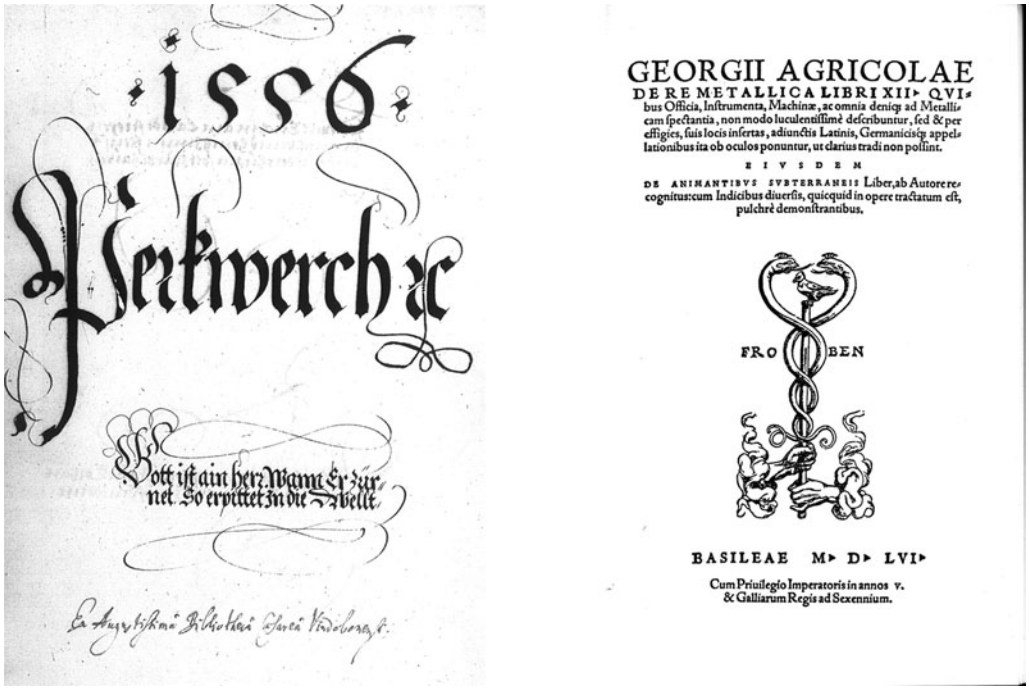

Figure 1. Title pages of the Viennese copy of the *Schwazer Bergbuch* (Vienna, Österreichische Nationalbibliothek, Codex vindob. 10.852) and of Georgius Agricola's *De re metallica*.

The two books came into being for very different reasons. Agricola's book results from the private endeavor of a humanistically educated and knowledgeable physician; it is an attempt to produce a comprehensive and conclusive illustrated record of the most advanced mining and smelting industry of the time. It served generations of mining experts as a guide well into the 18th century.[3] In contrast, the *Schwazer Bergbuch* is a kind of aide-memoire set down by the local mining administrators who wished to exert influence on imminent decisions by the superior political authorities.[4] It is, thus, at the same time a document of a very critical moment in the development of the Tyrolean mining industry, which in the 1550s experienced fundamental changes in its economic structure as well as serious technical limitations.

2. The illustrations of the *Schwazer Bergbuch*.

Regarding the technical illustrations of the *Schwazer Bergbuch*, it seems advisable to take advantage of the fact that Agricola's book is also lavishly illustrated, and thus to compare illustrations in the two books whenever possible.

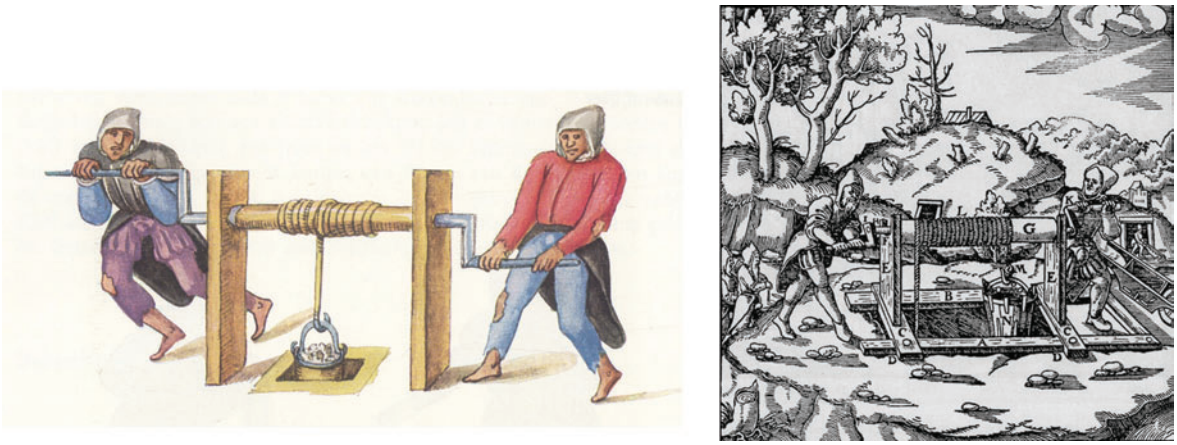

Figure 2. Picture of a winch in (left) the *Schwazer Bergbuch* (Innsbruck, Tiroler Landesmuseum, Codex Dip. 856, f. 123) and (right) Agricola's *De re metallica* (Basel 1556, p. 118).

[3] See Marco Beretta: "Humanism and Chemistry: The Spread of Georgius Agricola's Metallurgical Writings." *Nuncius* 12/1(1997): 17-48.

[4] See Erich Egg: "Der Schwazer Bergbau und sein Bergbuch." In: H. Winkelmann (ed.): *Schwazer Bergbuch : Codex Vindobonensis 10.852*. Essen 1988, pp. i-xxiii; Christoph Bartels, Andreas Bingener and Rainer Slotta: "Die Verfasserschaft des Bergbuchs und der Werdegang des Bilderkodex." In: Christoph Bartels, Andreas Bingener and Rainer Slotta (eds.): *Das Schazer Bergbuch*. Vol. II, Bochum 2006, pp. 197-230; Christoph Bartels and Andreas Bingener: "Der Schwazer Bergbau." In: ibid. vol. III, pp. 701-909.

Figure 2 shows two pictures of the same machine – on the left side from the *Schwazer Bergbuch* and, on the right, from Agricola's *De re metallica*. Depicted is a very simple winch as was in common use at this time. Though the view of the machine and the two workers who operate it is essentially the same, the aesthetic impression of the two images is certainly very different. This is due first of all to the different graphical techniques employed – a colored drawing on the one side and a woodcut print on the other. These different techniques correspond to the different formats of the two books: – an illustrated hand-written manuscript in the case of the *Schwazer Bergbuch* and a printed book in the case of Agricola's *De re metallica*.

In the mid-sixteenth century, the prevailing technique for mechanically reproducing images in books was still that of woodcuts. The production of woodcuts requires a rather complicated procedure: First of all, a drawing of the subject at hand has to be made; then a mirror image of the drawing has to be transferred and traced onto the surface of a wooden block; third and finally the space between the lines of the transferred mirror drawing must be carved out. In the case of the woodcuts in Agricola's book,[5] this procedure involved at least two different persons for each and every woodcut, and most probably even three. The drawings of the machines and other subjects from the mining and smelting business were drawn by Basilius Wefring in the mining town Joachimstal in the Ore Mountains of whom we know little, apart from his name. Wefring produced the drawings under the continuous supervision of Agricola himself and facing the technical devices to be represented. These drawings were then sent to the publisher Froben in Basel who commissioned local artists to produce the woodcuts. Of two of these artists we know the names: Rudolf Manuel, known as Deutsch, and Zacharias Specklin. It has been plausibly assumed that these artists were first of all responsible for tracing the mirror drawings on the wooden blocks, whereas the final carving of the majority of the woodcuts may have been the job of other unknown artists. This was a rather complicated procedure which produced outstandingly truthful though somewhat rigid images.

[5] For the following, see Wilhelm Pieper: "Die kunstgeschichtliche Stellung der Holzschnitte in Agricolas *De re metallica*." In: Deutsche Akademie der Wissenschaften (Berlin) (ed.): *Georgius Agricola, 1494 - 1555: zu seinem 400. Todestag, 21. November 1955*. Berlin: 1955, pp. 266-291; Elisabeth Kessler-Slotta: "Die Illustrationen in Agricolas De re metallica." *Der Anschnitt* XLVI/2-3(1994): 55- 67.

Figure 3. Winches in the draft version of the *Schwazer Bergbuch* (Bochum, Deutsches Bergbaumuseum, Codex Sig. 3313, pp. 48f.).

In contrast to these woodcuts, the images in the *Schwazer Bergbuch* appear more spontaneous and less studied. But these images, too, were preceded by drafts (figure 3) as can be seen in the draft version of the book held at the Deutsche Bergbaumuseum, Bochum.[6] Sometimes, the correspondence between draft and final drawing is much closer than in the case of the winch (figure 4).

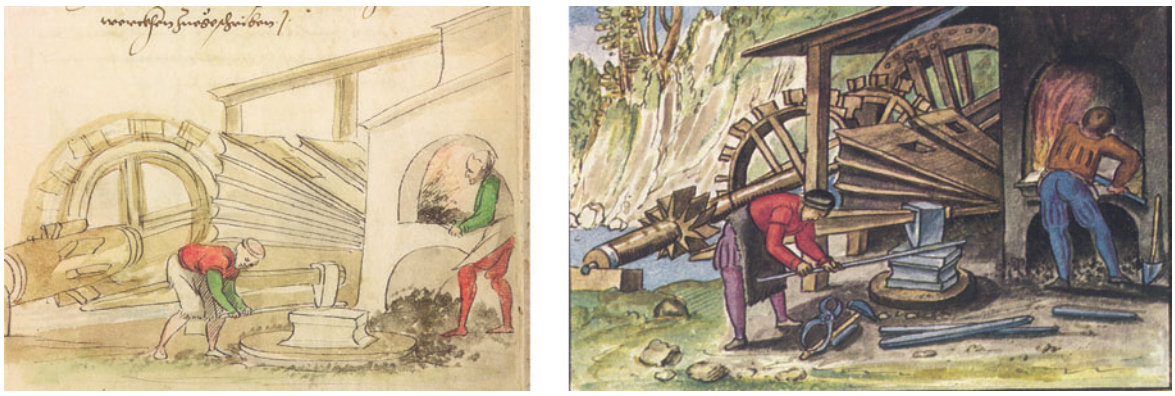

Figure 4. Draft and final version of the picture of a forging hammer (Bochum, Deutsches Bergbaumuseum, Codex Sig. 3313, p. 159 – Innsbruck, Tiroler Landesmuseum, Codex Dip. 856, f. 156).

In the case of the *Schwazer Bergbuch* we do not know who produced the drawings, but it is possible to distinguish different hands at work. And since the surveying undertaken in

[6] See note 2.

connection with mining required skilled drawing abilities, it has been plausibly assumed that the drawings may have been created by local mining officials with surveying expertise.[7]

2.1 The accent does not lie on technical details.

When comparing the illustrations in Agricola's book to those in the *Schwazer Bergbuch*, one can see that they differ considerably with respect to technical details. This holds true even in the case of the depiction of a simple machine like the winch (figure 2). For example, the woodcut depicts how the winch is mounted on a frame that protects the rim of the pit from being damaged by this machine. It also shows how the cranking handles are fastened to the axle of the well. The same could be shown for each and every image in the two books, but it will suffice to demonstrate this for the case of another very simple device, namely the bellows (figure 5).

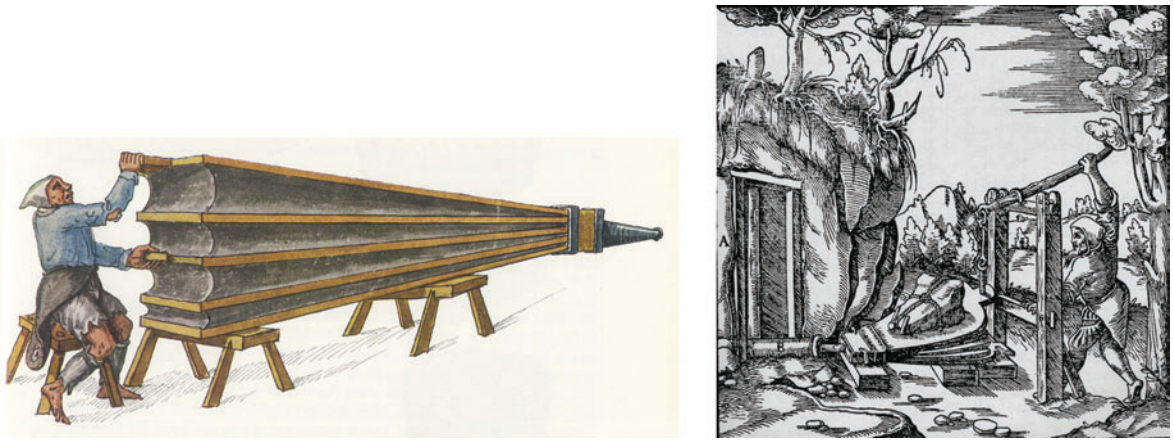

Figure 5. Pictures of bellows in (left) the *Schwazer Bergbuch* (Innsbruck, Tiroler Landesmuseum, Codex Dip. 856, f. 152) and (right) in Agricola's *De re metallica*, (Basel 1556, p. 167).

It is obvious that the draftsman of the colored drawing was less interested in conveying details than were the artists who created the woodcut. This difference is probably due to the different purposes pursued by the authors of the two books: Agricola aimed at a comprehensive, detailed, and instructive report of all aspects of mining and smelting for learned men interested in these issues.

[7] See Rainer Slotta: "Die Illustrationen im Entwurfsexemplar des Schwazer Bergbuchs." In: Bartels et al. (note 4) vol. II, pp. 231-285.

In contrast, addressing the reigning prince and his government, as well as possible investors, the *Schwazer Bergbuch* documents first of all the legal, economic and administrative aspects of the mining center Schwaz; the description of the mining and smelting processes in contrast is confined to an overview. Accordingly, the functions and the organization of the mining administration play a greater role in the *Bergbuch* than in Agricola's book. For this reason, one encounters among its illustrations images of the different kinds of technical professionals and, furthermore, also of the various kinds of administrative officials (figure 6) which one does not find in Agricola' book.

Although these representations of officials and other professionals are certainly of great interest with respect to the social and economic conditions of the Tyrolean mining industry of the age, these issues cannot be addressed in this communication.

Figure 6. Picturing administration in the *Schwazer Bergbuch* (Innsbruck, Tiroler Landesmuseum, Codex Dip. 856, f. 93, 94, 98, and 121): Mining jury (top left), mining court reporters (top right), mining clerk (bottom left), and collectors of duties (bottom right).

2.2 The general style of machine drawings

Notwithstanding the differences as regards the close attention to technical detail, in both books the illustrations of machines conform to the general style of early-modern machine

drawings.[8] They strive to be understandable for non-experts and, at the same time, instructive for experts, conveying to the latter usually only information concerning nontrivial details. To fulfill this twofold task, these images have generally a one-sheet-format, that is, the device at hand is represented not by means of a set of orthogonal plans, as present-day engineers would employ but by means of one more or less perspective view of the subject's appearance. Since this restriction to a perspective-like representation would often thwart the information to be transmitted, several pictorial tricks were invented and employed such as a cut-away view (figure 3), a phantom view (figure 7a), or an exploded view (figure 7b).[9]

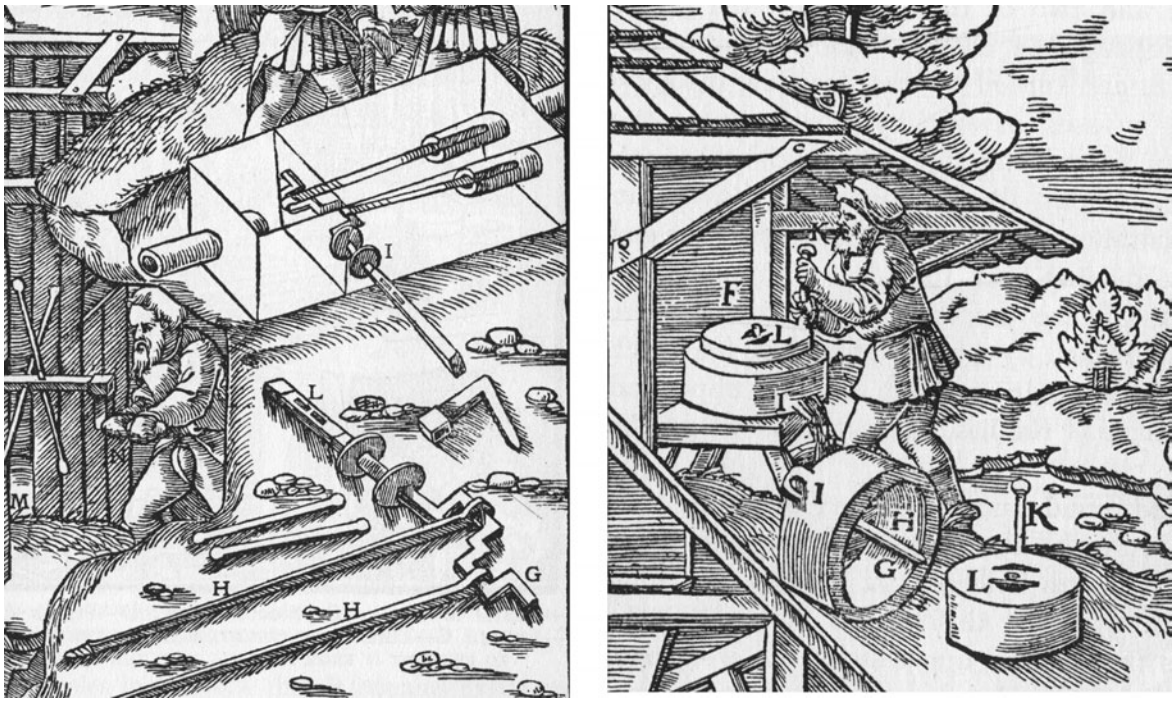

Figure 7. Picturing the invisible. Left: Phantom view showing the inner of a closed wooden box; right: Exploded view of the parts of a mill. (G. Agricola: *De re metallica*. Basel 1556, pp. 139 and 232).

2.3 Generic machines and truthfulness.

What is generally represented in early-modern machine drawings are *generic* machines. That is to say, the depicted subject is, for example, a winch or a pump of a certain type, but not an individual machine with all its peculiarities employed in a certain place at a certain time. There are some exceptions to this, the most prominent being Leonardo da Vinci's and

[8] For this general style, see above all David McGee: "The Origins of the Early Modern Machine Design." In: Wolfgang Lefèvre (ed.): *Picturing Machines –1400-1700*. Cambridge, Mass. 2004, pp.53-84.

[9] See Wolfgang Lefèvre: "The limits of pictures" in: Wolfgang Lefèvre, Jürgen Renn, and Urs Schoepflin (eds.): *The Power of Images in Early Modern Science*. Basel 2003, pp. 69-88, esp. pp. 79ff.

Francesco Giorgio Martini's pictorial records of Brunelleschi's hoisting machines.[10] But these exceptions confirm rather than question the rule that early-modern machine drawings represent generic machines. Of the many interesting implications of this fact, only one will be addressed here, namely the question of whether representing generic machines means representing machines that did not exist in reality, but only in the engineer's imagination.

This question is of particular significance in the case of the *Schwazer Bergbuch* as well as in that of Agricola's *De re metallica*. Can these two books be taken as documents of machines and other technical devices and contrivances employed in Renaissance mining and smelting if only generic devices are depicted? Does the generic character of the images impair their truthfulness? Not necessarily. Like descriptions of a subject in words and by concepts, pictorial representations can concentrate on and stress features of a device which the draftsman regards as essential and omit others he sees as being coincidental or unimportant. Representations, whether pictorial or verbal, are abstractions, and if based on experiences with a wealth of devices of the same kind, they are meaningful and enriched abstractions,. Therefore, a generic style of representation may even be an indispensable prerequisite condition if it concerns truthfulness with respect to the essential features of a machine of a certain type. However, if it is about the question whether machines of the depicted kind really existed in this period, additional evidence is required.

Many of the generic machines one finds depicted in the famous *theaters of machines* from the second half of the 16th century may, indeed, be machines that had no counterpart in reality, but are rather products of an engineer's imagination. In the case of the technical devices depicted in the *Schwazer Bergbuch* and Agricola's *De re metallica*, however, one can be fairly sure that the drawings and woodcuts are pictorial representations of devices that were actually employed on the contemporary mining and smelting sites of continental Europe. All that is known about the processes of how these images were produced corroborates this assumption. And since many of the devices depicted were employed not only in mining and smelting at that time one can usually recourse to other evidences of these devices from independent sources.

In the *Schwazer Bergbuch* as well as in Agricola's *De re metallica* one encounters a few depictions of large machines or systems of machines that may cause one to wonder whether such an extraordinary machine actually did exist in several samples, or whether an individual machine is depicted.

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[10] See Salvatore Di Pasquale: "Leonardo, Brunelleschi and the Machinery of the Construction Site." In: P. Galluzzi (ed.): *Leonardo da Vinci – Engineer and Architect*. [Montreal] 1987, pp. 163-181.

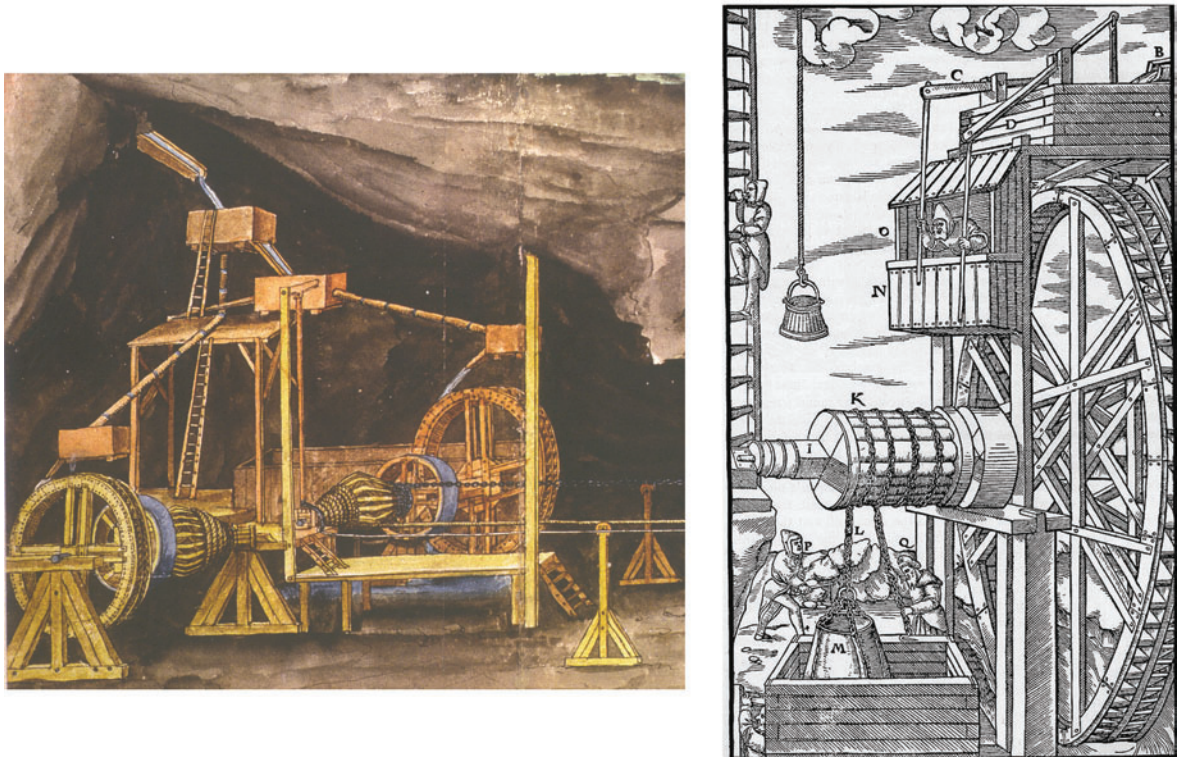

Figure 8. Depictions of individual machines? Machine systems with reversible waterwheels from (left) the *Schwazer Bergbuch* (Innsbruck, Tiroler Landesmuseum, Codex Dip. 856, table XX) and (right) from Agricola's *De re metallica* (Basel 1556, p. 158).

In the case of the pump system depicted in the *Schwazer Bergbuch*, in the manuscript, it is claimed explicitly that this drawing represents the pump system on the floor of a certain mine in the district of Schwaz; historians question this claim, however, pointing out that the pump system in this mine worked with one reversible waterwheel only, and not, as depicted, with two.[11] Thus one has to take into account possible embellishments even when an individual machine is undoubtedly represented.

3. The table "Kitzbühel" of the Innsbruck manuscript.

In one of the extant manuscripts of the *Schwazer Bergbuch* one finds a drawing of particular interest with respect to the question of representing individual machine systems, as well as to a variety of further aspects of drawings of large technical systems (figure 9).

[11] See Bartels et al. (note 4) vol. III, p. 793 The transcription of the text on the drawing ibid., vol. II, p. 527.

Figure 9. The mining district Rerobichl near Kitzbühel in Tyrol (*Schwazer Bergbuch*, Innsbruck, Tiroler Landesmuseum, Codex Dip. 856, table "Kitzbühel")

The drawing depicts a combined and connected system of mine draining facilities conjointly built, used, and maintained by several mines of the mining district of Rerobichl, a locality north of Kitzbühel in Tyrol.

A few words regarding the background :[12] The district Rerobichl was the Klondyke of the 1540s. After its rich veins of silver ore had been discovered in the late 1530s, a rush of entrepreneurs of all kinds – small local ones as well as major capitalists like the Fuggers, tried to exploit these spectacular resources. Within ten years, the Rerobichl district had become a high-tech mining district exhibiting the deepest mines ever heard-of in Europe.[13] Accordingly, major technical problems had to be mastered, in particular the problem of effective mine-draining facilities.

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[12] See Max Reichsritter von Wolfstrigl-Wolfskorn: *Der Tiroler Erzbergbaue 1301-1665*. Innsbruck 1903, p. 185f.; Georg Mutschlechner: "Kitzbüheler Bergbaugeschichte." In: Eduard Widmoser (ed.): *Vorgeschichte und Bergbau* (= Stadtbuch Kitzbühel vol. 2). Kitzbühel 1968, pp. 139-238; Manfred Rupert: "Beiträge zur spätmittelalterlichen und frühneuzeitlichen Hüttengeschichte von Kitzbühel und Umgebung." *Archäologia Austriaca* LIV(1973): 1-154, LVII(1975): 21-103, and ILX/LX: 273-437; esp. vol. LVII: 22-27.

[13] Wolfstrigl-Wolfskorn (note 12) p. 195.

Figure 10. The joint water system of mines in the Rerobichl mining district (detail of figure 9).

The system of water pipes depicted in this table (figures 9 and 10) connects five mines: it begins at the mine on the right side which is situated a bit above the others and ends near the river on the left. It is more than one kilometer in length. There is no question that it is extremely challenging to depict technical facilities of this scale when using the general style of machine drawings of the early-modern period, that is, to depict such an extensive system in a manner that combines information on its structural whereabouts with the rendering of the systems' appearance. Such a drawing has furthermore to convey information about – and to some degree also an idea – of the appearance of the locality. It is thus worthwhile to consider in a step-by-step process the different functions and dimensions of this drawing.

First, the drawing records the topographic configuration of the mines connected by the pipe system. Being a view from the south, the mines are arranged correctly according to their location from west on the left-hand side to the east on the right.[14] Second, the pipe system itself is rendered more or less schematically and yet in a pictorial manner since the supports are indicated and also the fact that the pipe system consists, naturally, of a set of pipes joined together. Third, as regards the system's connection with and function for each of the mines, the drawing is confined to depicting the mines as round buildings with a conical roof and a waterwheel situated above the aperture of the shaft. Presumably, the water pumped out from one mine powers the waterwheel of the next mine in the row. The conical roof, however, may indicate that also a hauling device driven by a horse whim is employed. But more information on the single mines themselves cannot be expected from a drawing that attempts to depict an entire system.

[14] A geographical reconstruction of this mining site can be found on a web-site of the Austrian society for folklife studies "Sagen" produced by the engineer Gerd Kohler: http://www.sagen.at/doku/bergbau/Roehrerbuehel_Kitzbuehel_Gerd_Kohler.html

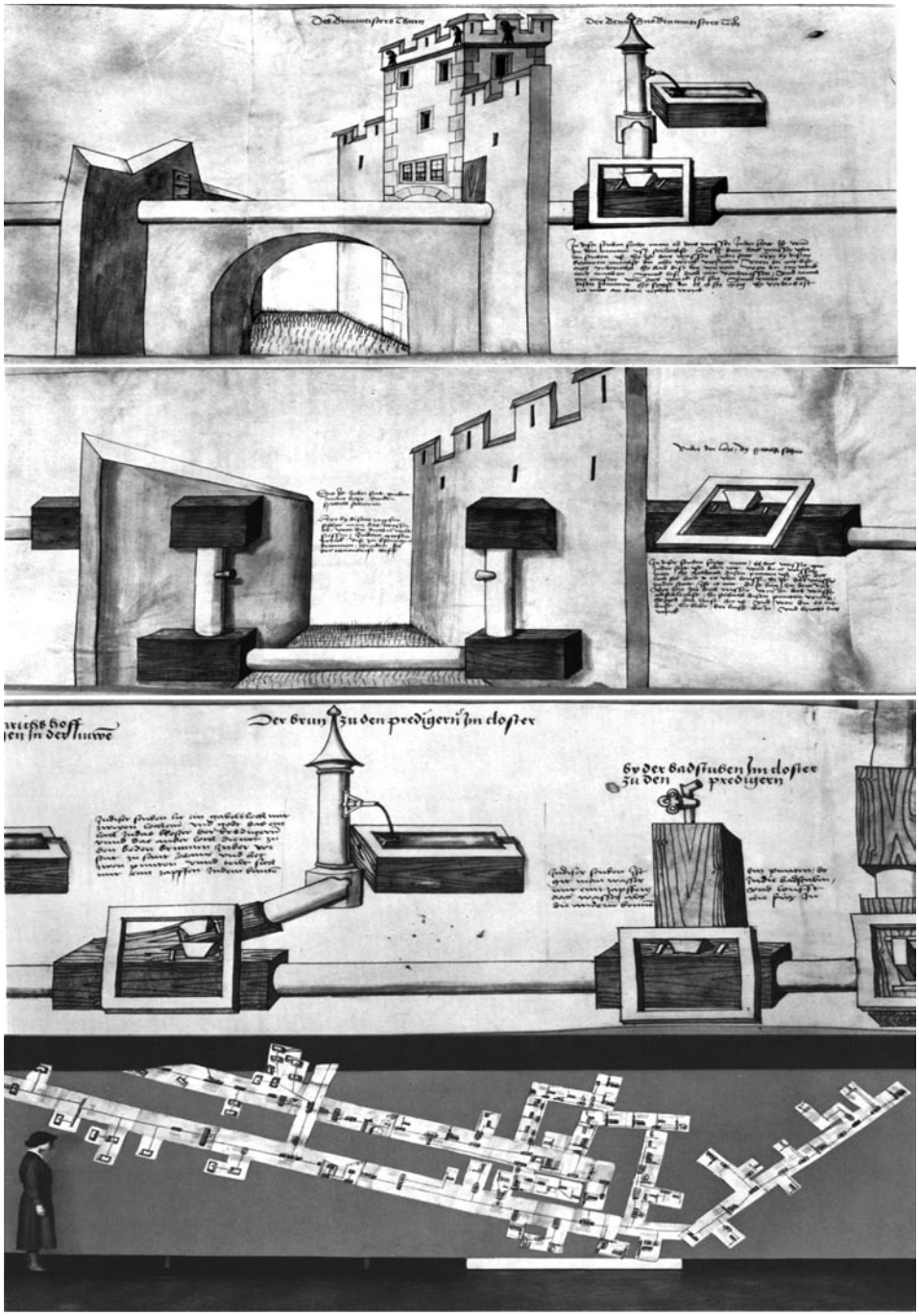

Figure 11. Three single sheets and the assembled sheets of Hans Tschan's 1502 plan of the city of Basel's water system.[15]

3.1 Schematic rendering

The schematic rendering of this system's overall structure must be taken as a special feature of this drawing and deserves further attention. It seems appropriate to connect this drawing

[15] Since the original could not be scanned due to conservational considerations recourse must be taken to the figures in Karl Albert Huber: "Die Basler Wasserversorgung von den Anfängen bis heute." *Basler Zeitschrift für Geschichte und Altertumskunde* 54(1955).

with other contemporary schematic renderings of large technical systems of which a specific pictorial language is characteristic. Therefore, some examples of contemporary schematic drawings of large water systems may be welcome.

The first example is Hans Tschan's plan of the water system of the city of Basel from 1502 (figure 11). The drawings on the single sheets are in good conformity with the general style of machine drawings of the age. But when connected – see the photo at the bottom – they represent the water supply net schematically.

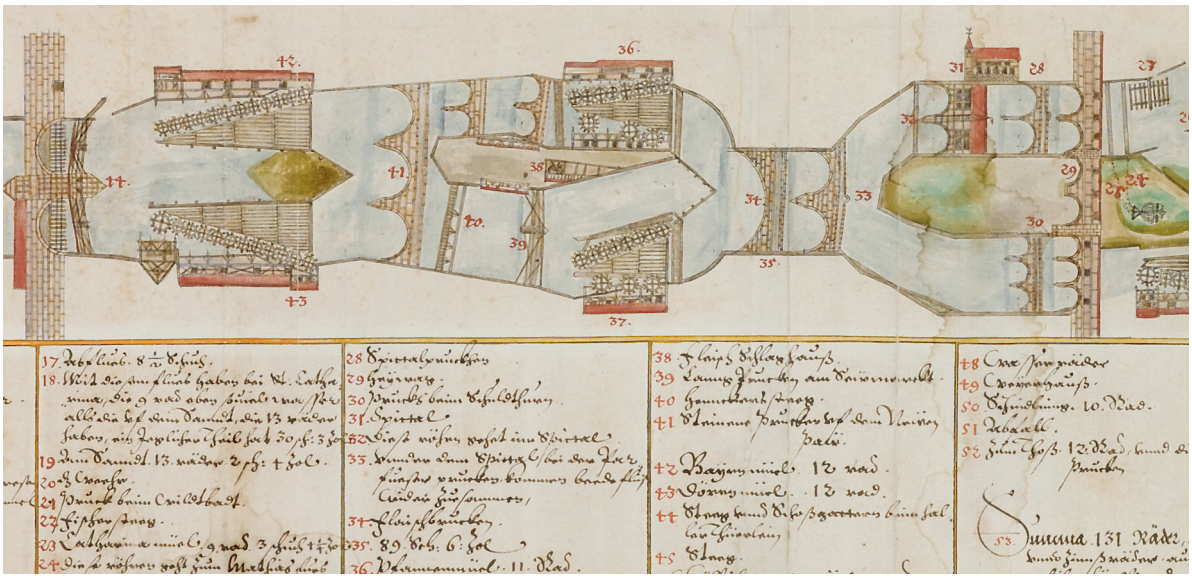

Figure 12. Detail of a schematic plan of the 16th-century canal system that distributed water from the river Pegnitz to the mills in the city of Nuremberg. (Nuremberg Germanisches Nationalmuseum, HB 3089, Kaps 1055h.)

The second example is the plan of Nuremberg's canal system in the mid-16th century (figure 12). This plan departs from the usual style of machine drawings and embarks on a specific schematic style of rendering. Notice the toothed wheels that symbolize rather than depict the various mills on the canals.

Such schemes, however, were no completely new inventions of the Renaissance. Rather, the engineers who created them were able to draw on a tradition of rendering infrastructural features on architectural plans that went back to the Middle Ages; one needs only recall, for example, the famous plan of the water system of the Canterbury Cathedral, attributed to Prior Wilbert who flourished in the mid-12th century.[16] But the Renaissance did indeed develop such plans further towards what we call schematics, that is, plans that render

[16] See R.A. Skelton and P.D.A. Harvey (eds.): *Local Maps and Plans from Medieval England*. Oxford 1986, color plates 1A and 1B. A reproduction to scale of plan 1A can be found in: Frontinus-Gesellschaft (ed): *Die Wasserversorgung im Mittelalter*. Mainz 1991.

spatial relations among entities without care for fidelity as regards distances or angles. The plan of 1619 of the system of wells of the town Ravensburg is a good example (figure 13).

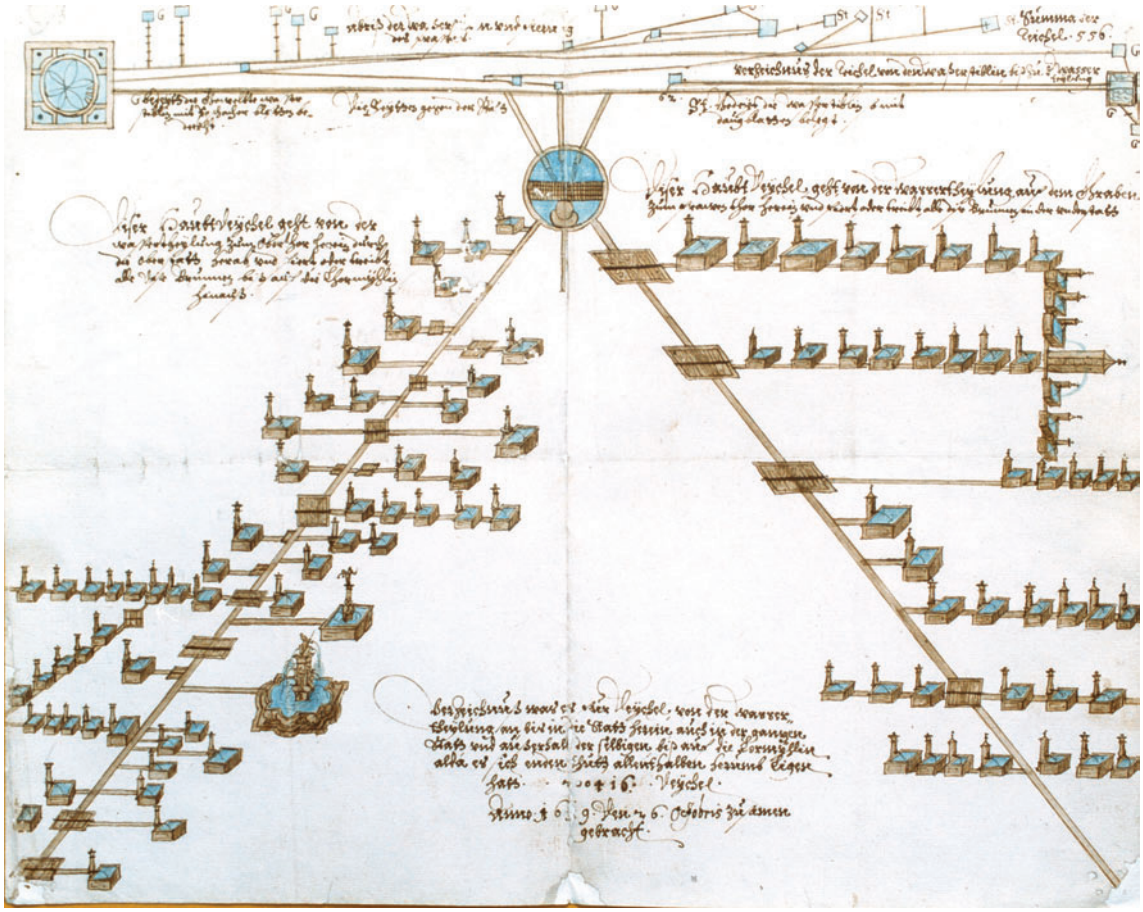

Figure 13. Plan of the system of wells in Ravensburg (1619).

Plans of this kind have been in common use up to the present day, for instance, as network maps of traffic systems (figure 14).

Figure 14. Detail of the network map of London's Tube lines.

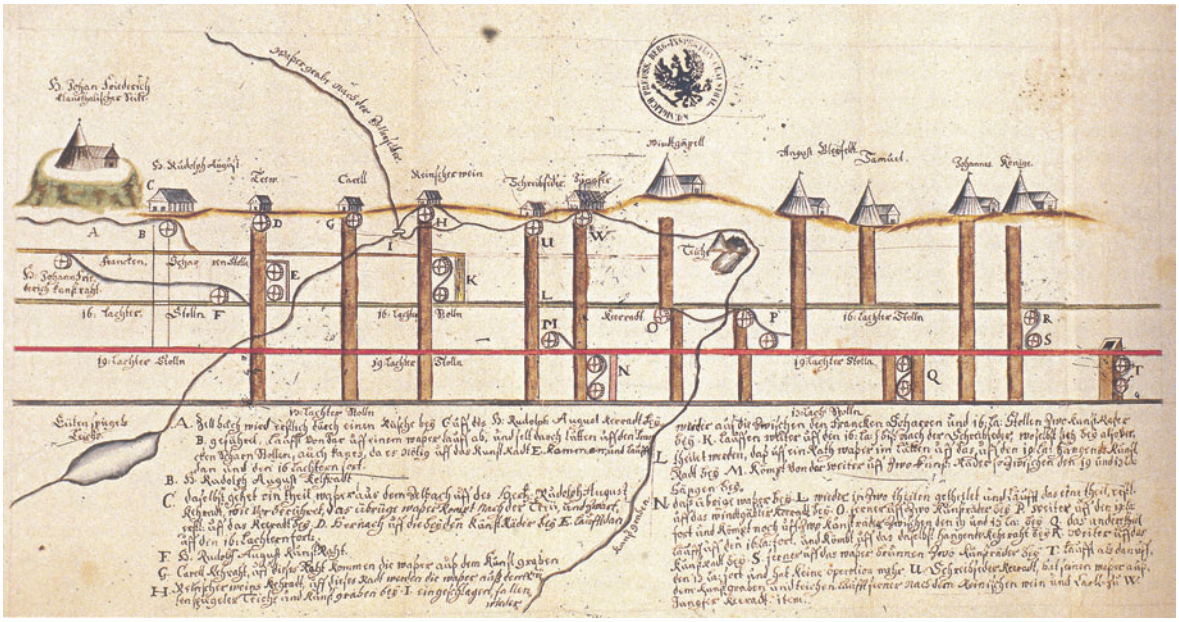

Figure 15. Schematic and map of the water system of the mining district of Clausthal in the Harz mountains (17th-century).

The last example is a 17th-century representation of the water system of a mining district in the Harz mountains (figure 15) that combines the schematic rendering of the mines' shafts, galleries, and waterwheels that power the pumps with a map that indicates how this system takes advantage of the water from small local rivers. Regarding this schematic, it may be appropriate to raise the question of how the underground world of mining was depicted in this early modern period.

Figure 16. Depiction of veins of silver ore in the *Schwazer Bergbuch* (Innsbruck, Tiroler Landesmuseum, Codex Dip. 856, f.131 and 132).

3.2 Excursus*: Rendering the underground world of mining*

There is a group of images in the *Schazer Bergbuch* which attempts a representation of ore deposits (*Lagerstaetten*), that is, the location of veins of silver ore within the rocks (figure 16). These images are of special interest since they are at the same time of both a technical and a learned or, in this case, a scientific character. They should be taken as pictorial representations of facts and circumstances that pertain to the mining business and, at the same time, to geology.

The blue lines or blue ribbons in these drawings represent veins of ore. However, in the *Schwazer Bergbuch,* the immediate function of these illustrations is limited to supporting the explication of the meaning of particular names for the different kinds of ore veins used by the local miners.

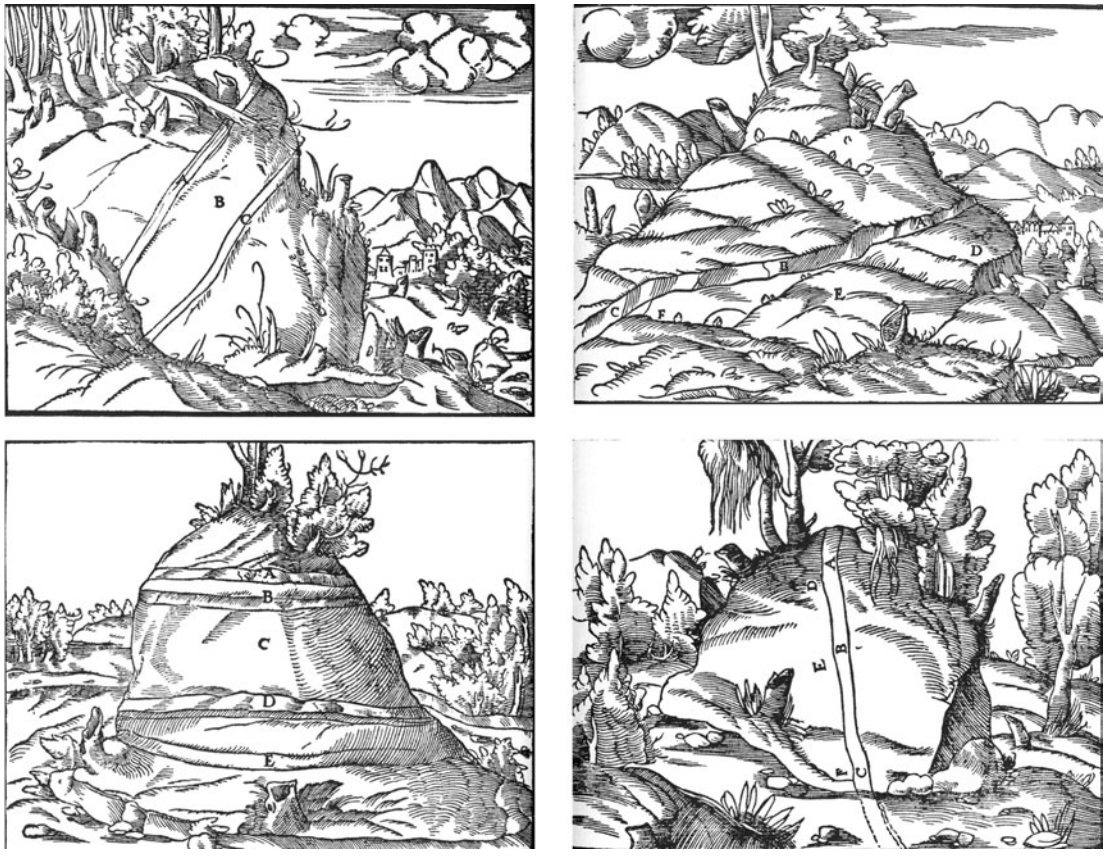

Figure 17. Depiction of veins of silver ore in Agricola's *De re metallica*, (Basel 1556, pp. 32 and 35).

In contrast to this, Agricola dedicates an entire book (Book III) of his *De re metallica* to the issue of deposits. Here the illustrations not only contribute to the clarification of certain terms used by local miners, but are also intended as illustrations of the notions Agricola had developed on this issue (figure 17),. Using woodcuts that should impart information without using coloration, white ribbons or strips of cloth were laid over hills or mountains to represent

the veins. Agricola thus appears to take up and to modify a pictorial language that was introduced by the first printed mining booklet we know of, namely the mining booklet by Ulrich Rülein von Calw that appeared around 1500 (figure 18).[17]

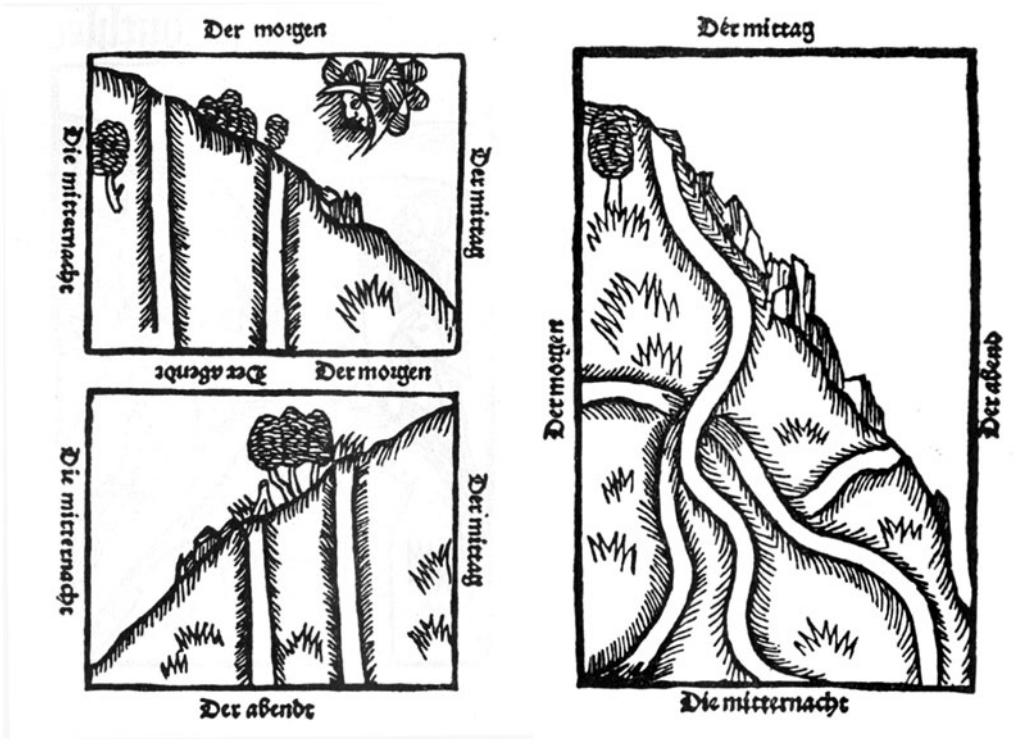

Figure 18. Depiction of veins of ore in Rülein von Calw's *Bergbüchlein* (c. 1500). The words that are printed all around the four sides of each picture are German words for the cardinal directions east, south, west, and north.

Agricola's manner of rendering veins of ore was taken up by other authors of books on mining and metallurgy well into the 17th century.[18] Yet, as regards the pictorial language of these drawings, its unsuitability for conveying information about the veins' position within the rocks is rather obvious. The format of a more or less perspective representation of the particular elements and items of a landscape does not allow to clarifying understandably what is beneath the surface of the depicted elements.

[17] A facsimile edition of the "Urtext" was edited by Wilhelm Pieper ("Ulrich Rülein von Calw und sein Bergbüchlein") with the Akademie Verlag (Berlin 1955).

[18] Representations of veins of ore by means of ribbons running through the landscape or over hills can still be found in the first decades of the 17th century. See for instance Georg Engelhard Löhneyss: *Bericht vom Bergwerck* (1617); a digitalization of the 1650 edition of the *Bericht* can be found via http://digital.slub-dresden.de/ppn266601863 (pictures on pp. 419 and 421).

Figure 19. Incorporating geometric schemata into perspective views. (G. Agricola: *De re metallica*. Basel 1556, p. 46).

As can be observed in other technical drawings of the age, too, and particularly, as mentioned, in machine drawings, the draftsmen tried to gloss over such problems by using tricks. In this case, Agricola's draftsman, possibly advised by Agricola himself, attempted to clarify the spatial relations of different veins by inserting geometric schemata into the pictures (figure 19). It is doubtful if this actually worked. In any case, in geology as well as in mining, this manner of representing veins of minerals or deposit strata was not pursued further. Instead, the pictorial language for this purpose, which became standard, was one that employed imaginary orthogonal sections through the rocks (figure 20).

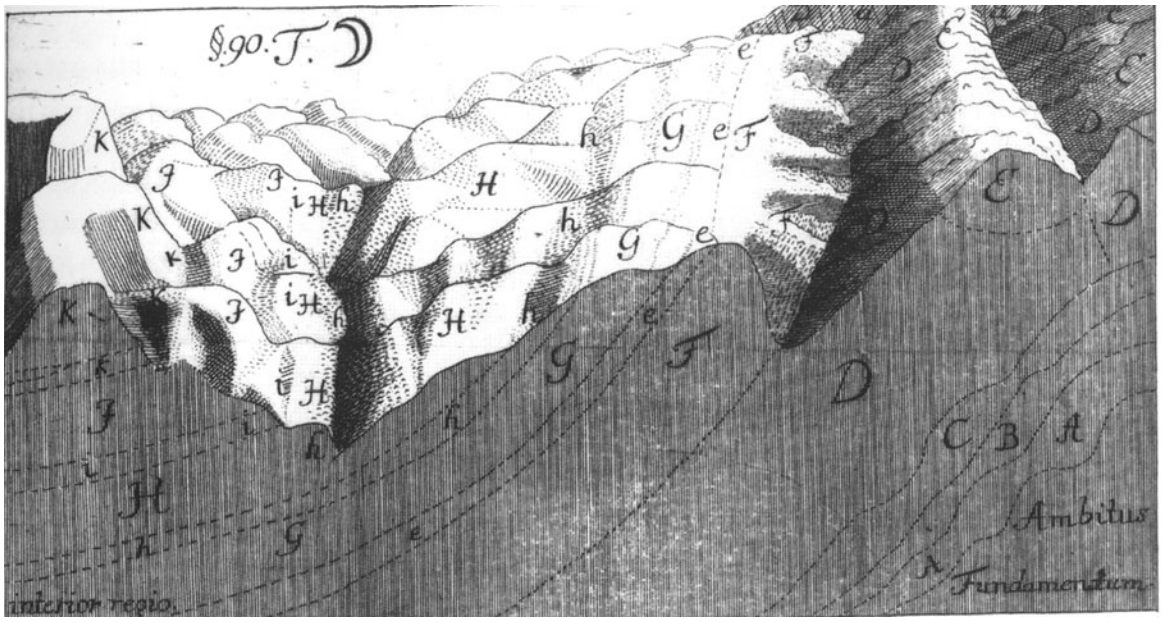

Figure 20. Representation of strata in 18th-century texts on geology. (Georg Christian Füchsel: "Historia terrae et maris." *Acta Academiae electoralis moguntinae scientiarum utilium, quae Erfordiae est*, 2(1761): plate 5.

The section from Georg Christian Füchsel's *Historia terrae et maris* (figure 20) shows that such a section could be combined with perspective views of the surface of the rock formation at hand. This could be accomplished in a virtuous and very impressive manner, as the following engraving from the 18th century shows (figure 21).

Figure 21. Section and view of a quarry. (Friedrich von Trebra: *Erfahrungen vom Inneren der Gebirge*. Dessau 1785, plate I picture 2).

Figure 21 depicts the stratigraphical situation of a quarry near the mining center Clausthal in the Harz mountains. It was published by the mining official Friedrich von Trebra, who graduated from the famous mining academy in Freiberg (Saxony).

Miners employed the technique of orthogonal sections, which was first developed in architecture, not just for representations of mineral deposits beneath the surface of the earth; presumably, such sections were first employed by miners for constructing plans of mines. Figures 22 through 24 show some examples of mine plans from the 16th to the 18th centuries.

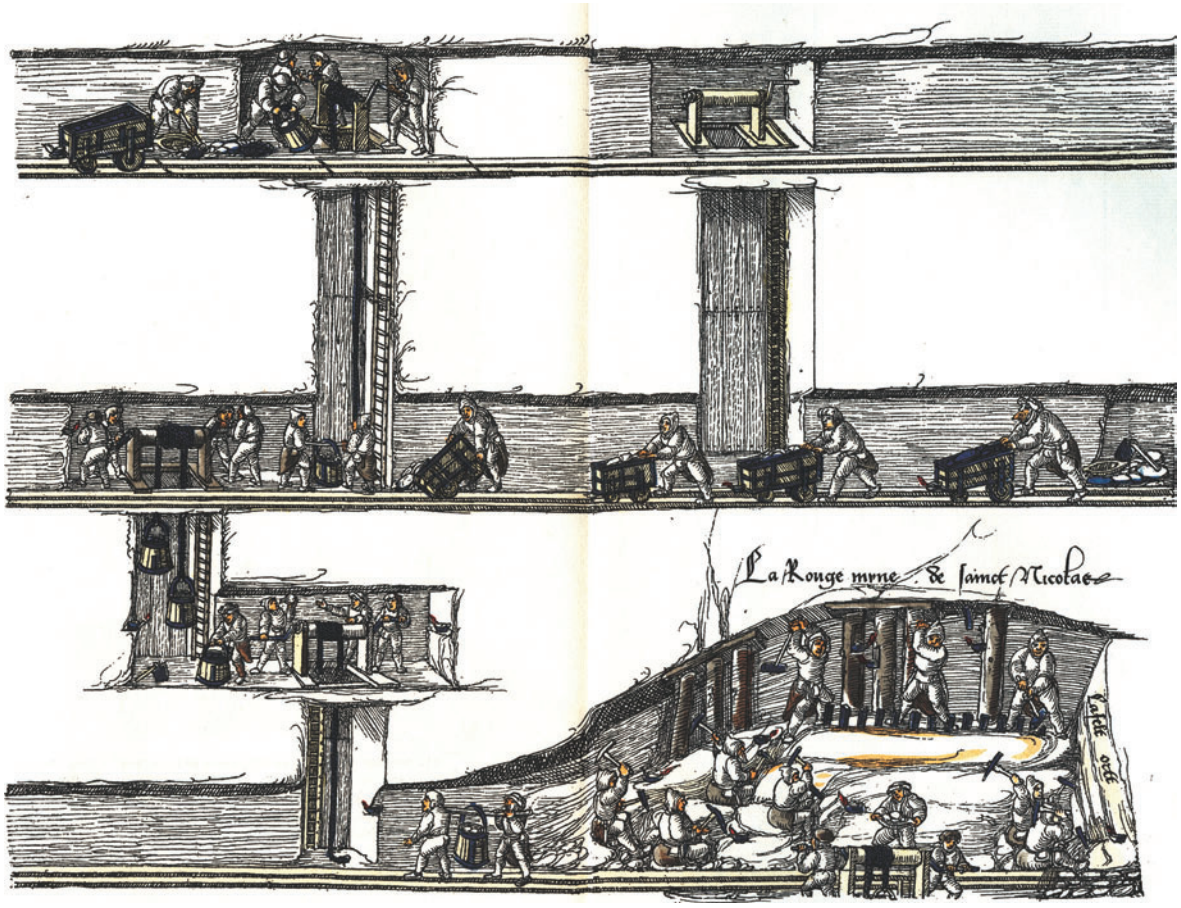

Figure 22. Section through *La rouge myne de Sainct Nicolas* in La Croix-aux-Mines (Alsac). Pen and ink drawing by Heinrich Gross (1550?).[19]

Figure 24 shows an orthogonal mine plan from the late 18th century which is both perfectly architectural and geological at the same time. This section, too, was published by the mining official Friedrich von Trebra and demonstrates the high quality of pictorial representations in 18th-century mining.

[19] It is not entirely sure whether the drawing can be dated to the mid-16th century. See Heinrich Winkelmann: *Bergbuch des Lebertals*. Wethmar 1962, pp. 157ff. Reproduction from ibid., plate XIV.

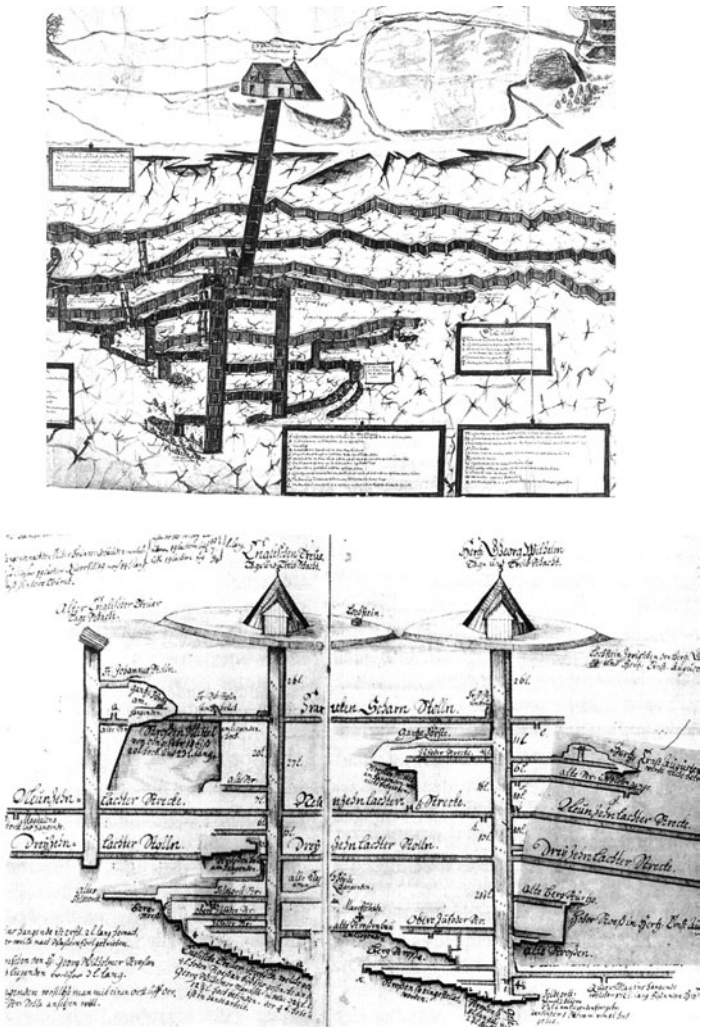

Figure 23. Two 17th-century sections through mines in the mining district of the Harz mountains.[20]

3.3 Rendering topographic situations

Coming back to the "Kitzbühel" table (figure 9), our attention should be turned to a further aspect. This drawing combines the schematic rendering of a water drainage system with a topographic rendering of the geographical situation of the same system. The drawing is thus not only a machine drawing, but must be taken as a geographical drawing at the same time. More precisely, it is a chorography as geographical views of landscapes and cities were called at that time.

[20] Reproduction of figures in Christoph Bartels: *Vom frühneuzeitlichen Montangewerbe zur Bergbauindustrie*. Bochum 1992.

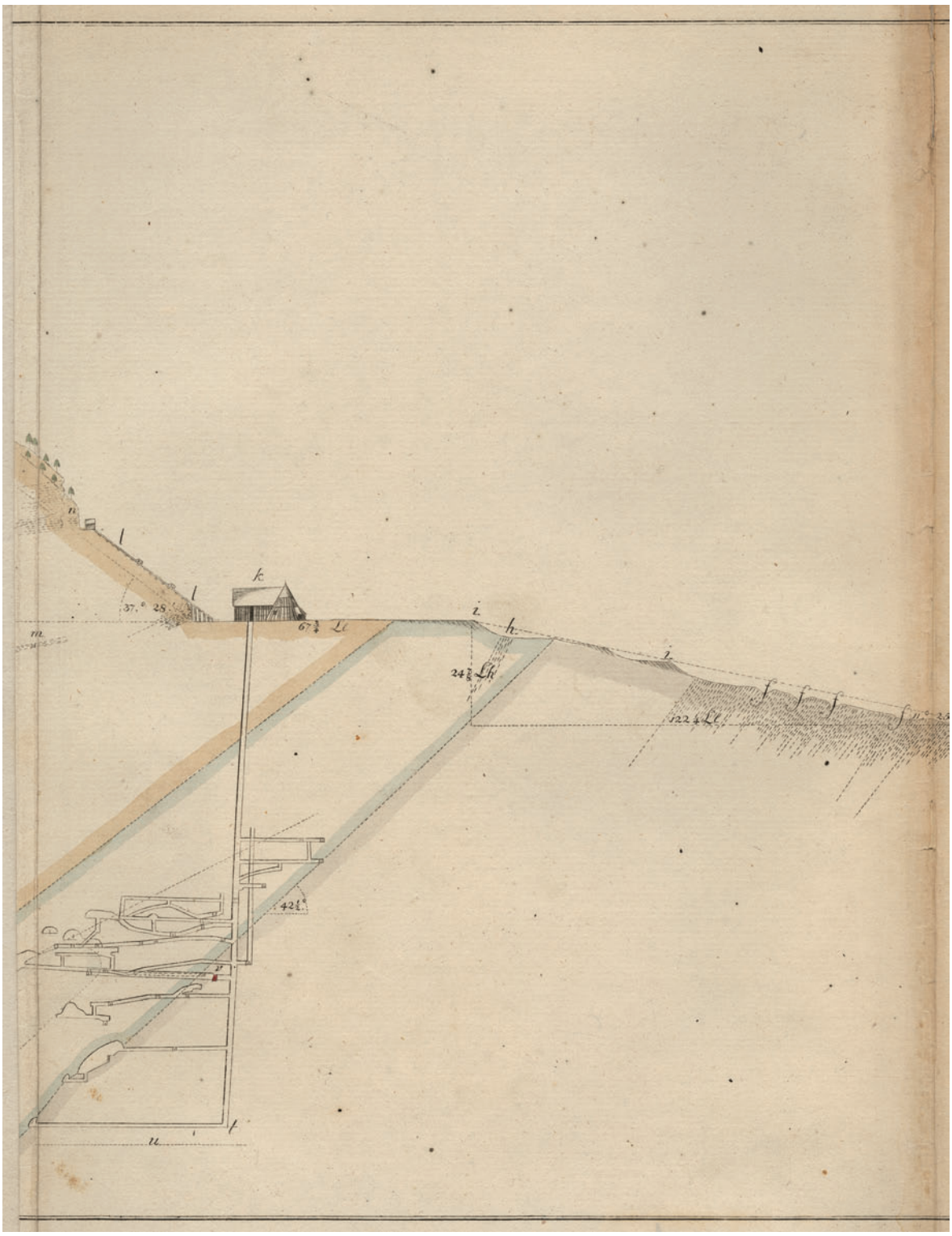

Figure 24. An 18th-century section through a mine. (Friedrich von Trebra: *Erfahrungen vom Inneren der Gebirge*. Dessau: 1785, plate VI).

Chorographic views – the term goes back to Ptolemy – were a new kind of graphical representation of geographic facts and circumstances, employed and developed above all by cosmographers in the Renaissance age. At the turn of the 15th century, cosmographers did not have an established pictorial language for such chorographical views at their disposal, but had to develop one. An account of the development of chorographic languages in the Renaissance is beyond the scope of this communication,[21] but a few of its aspects will be addressed very briefly here.

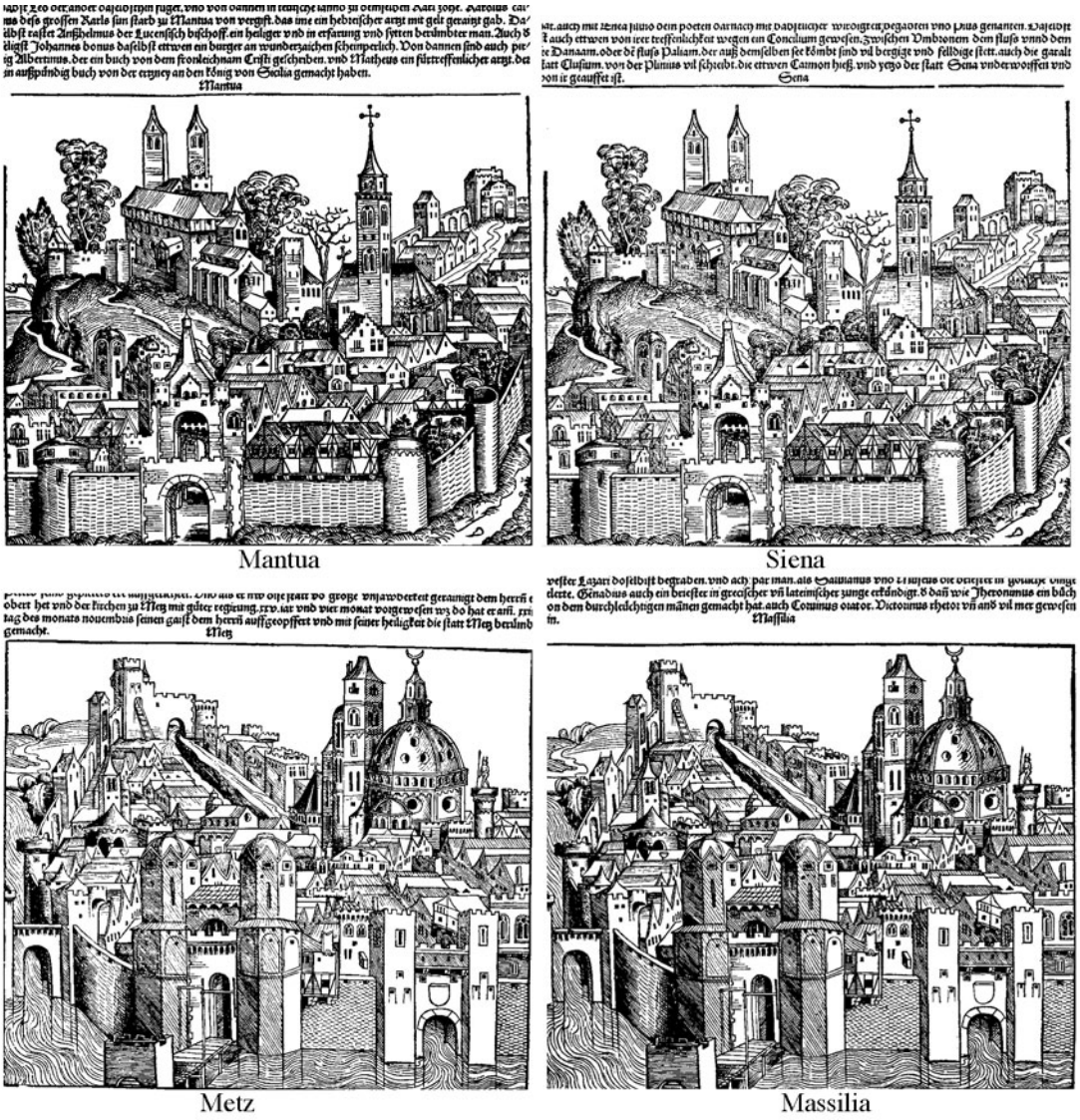

Figure 25. City icons from Schedel's *Weltchronik* (1493).

[21] For this development, see above all Lucia Nuti: "The Perspective Plan in the Sixteenth Century: The Invention of a Representational Language." *The Art Bulletin* LXXVI/1(1994): 105-128.

First of all, the cosmographers attempted to overcome and replace the fictive and usually also stereotypic city views of the 15th century, as are well known, for instance, from the famous *Weltchronik* of Hartmann Schedel (figure 25). In many cases, Schedel used the same woodcut of an imaginary image of a city for iconic representations of different cities (both of the two examples of woodcuts are used not only for representing these two different cities, but for several other cities as well). City images of this kind are icons rather than depictions, and such iconic representations of cities were common in medieval cartography, and are particularly characteristic of portolan charts.

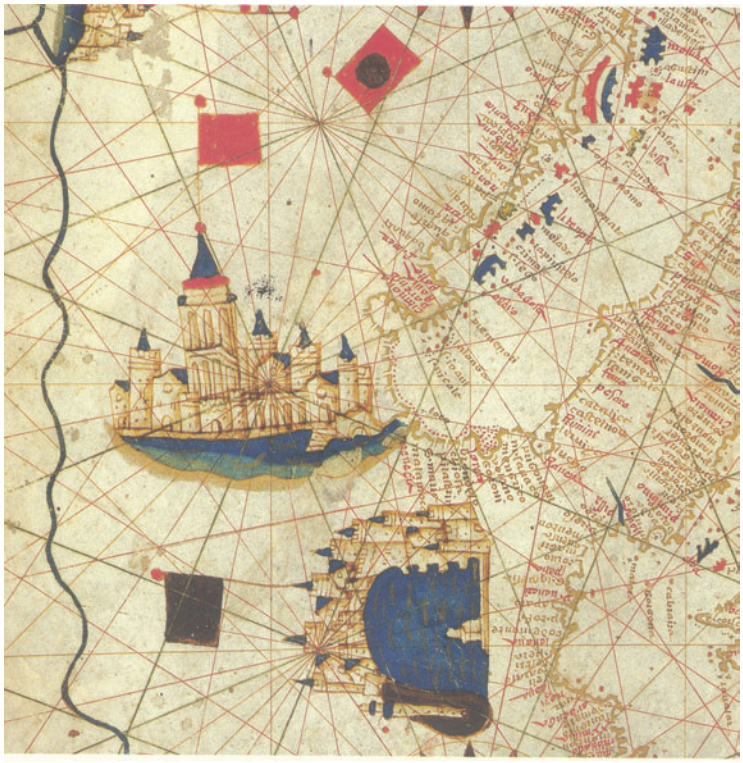

Figure 26. Representation of cities on a portolan chart.[22]

Secondly, such charts are of special interest in this context since one of the pictorial languages explored for use in chorographic views at the time also came from nautical charts. *Pilots* (navigational handbooks of the age) used the pictorial language of silhouettes for representing views of coasts. This language of silhouetted views was employed for chorography as late as the mid-16th century in Sebastian Münster's *Cosmographia* (figure 27).

[22] Reproduction from A. Hernando Rico et al. (ed.): *Cartografía mallorquina*. Barcelona 2000, p. 84.

Figure 27. View of Speyer in Sebastian Münster's *Cosmographia* (1544).

Thirdly, the pictorial language that became the standard language of early-modern chorographic views took shape in the course of the 16th century and was employed exemplarily by Matthäus Merian in the first half of the 17th century (figure 28). The decisive feature of this pictorial language is the choice of an imaginary viewpoint above the city or landscape at hand. By showing the subject as if seen from a balloon, this language enables information that only a map could provide to be combined with that of elevations in perspective that represent the subject's appearance.

Figure 28. View of Biel (Switzerland) by Matthäus Merian (1654).

Against this background, it is absolutely remarkable that the draftsman of the chorographic tables in the Innsbruck manuscript of the *Schwazer Bergbuch* created landscape views that indicate a mastery of this new pictorial language.

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