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HISTORICAL PERSPECTIVE

The Evolution of Illustrated Texts and Their Effect on Science: Examples from Early American State Geological Reports

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ABSTRACT

In the 19th century, printing methods made significant advances that allowed mass production of illustrated texts; prior to that time, illustrated texts were expensive and rare. The number of illustrated texts thus rose exponentially, increasing the rate of information transfer among scientists, engineers and the general public. The early American state geological reports, funded by the state legislatures, were among the pioneering volumes that used the new graphic capabilities in the improved printing processes for the advancement of science. They contain thousands of illustrations—woodcuts, etchings, lithographs and hand-painted maps—that may be of interest to historians of science, technology, art and culture.

In the early 19th century the technology became available to produce large print runs of publications with finely detailed woodcuts printed in-line with the text. These books, journals and newspapers often contained illustrations and, like the railroads and later the telegraph, they sped information flow throughout America. Science benefited from the increased speed and capacity for knowledge transfer. The first illustrated geological reports in America were funded by the states, mainly to locate economic resources, in the early 19th century [1]. These reports, many of which are still on library shelves, are richly illustrated compendiums of historic geological thought, images of nature and man, and examples of evolving art and printing processes.

The advances that enabled the mass printing of illustrated texts emerged at the end of the 18th century and became an industry in the early 19th century. These processes included improved woodcut technique, smooth paper, printing presses powered by machines (rather than by men) and stereotyping [2]. This paper uses four of the first state geological reports—Edward Hitchcock's *Final Report on the Geology of Massachusetts* (1841), James Hall's *Geology of New-York, Part IV* (1843), William Kitchell's *Second Annual Report on the Geological Survey of the State of New Jersey for the Year 1855* (1856) and Henry Rogers's *Geology of Pennsylvania* (1858)—to illustrate the explosion of visual communication in the growing printing industry.

Geological publications, in general, were increasing exponentially. In their bibliography of American geological literature, Hazen and Hazen found that between the years 1669 and 1850, "the total number of publications approximately doubled every ten years" [3]. Prior to this time, advances in science had been handicapped by the lack of images with which to clearly illustrate ideas, thus limiting knowledge exchange [4]. After this time the study of geology grew rapidly. Through-

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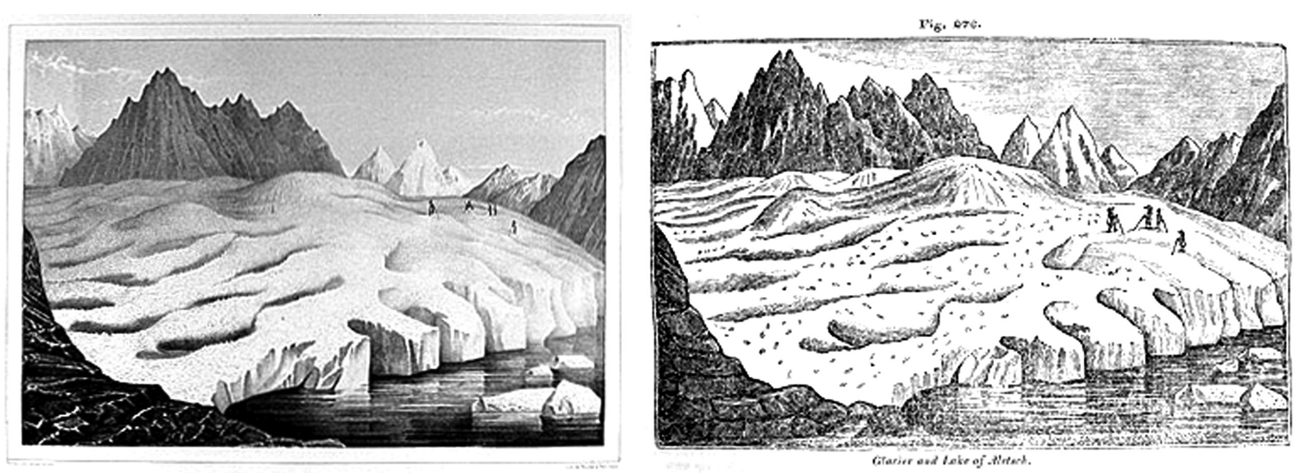
Article Frontispiece. Illustration from Henry Rogers's *Geology of Pennsylvania* (1858, Plate VII, Vol. 2). The drawing was done by a paleobotanist, Leo Lesquereux (1806–1889), and professionally engraved. This drawing appeared, among others, in a separate codex at the end of the second volume.

Fig. 1. A lithograph of a glacier (left) from Louis Agassiz's *Études sur Les Glaciers* (1840) compared to Edward Hitchcock's copy of the image (right) in the *Final Report on the Geology of Massachusetts* (1841, 2a). The Agassiz lithograph was printed in a separate volume from the text and today is hard to find, whereas the hastily woodcut copy appeared in-line with Hitchcock's verbal explanation and is still available in many libraries.



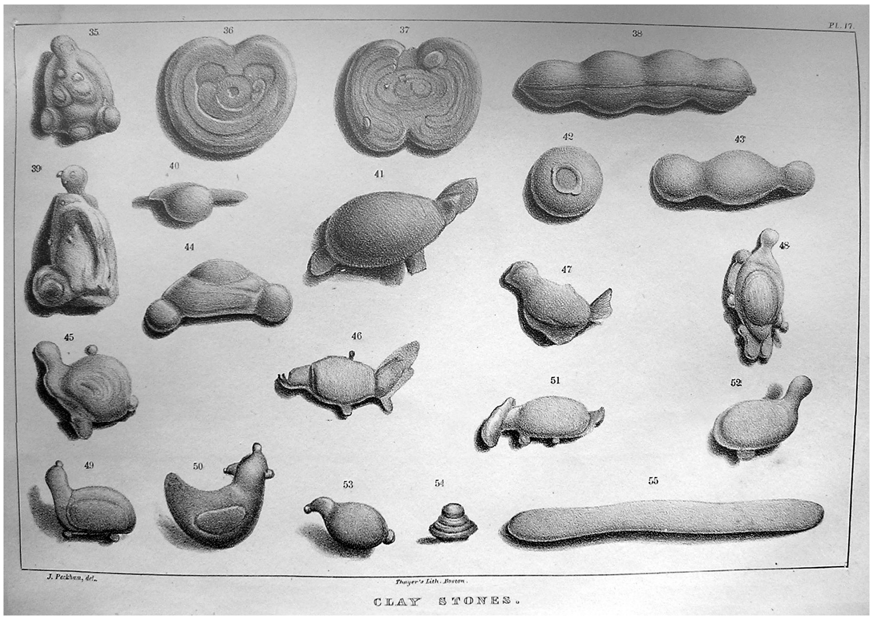


Fig. 2. Lithograph of "Clay Stones" from Hitchcock's *Geology of Massachusetts* (1841, Plate 17). Although these objects appear to be interesting forms of organic life, they are simply clay and sand cemented together with lime, accidental forms found in nature.

out the mid-19th century, most states in the U.S.A. gradually adopted surveys, with varying reports and results. By 1879 the United States Geological Survey took much of the responsibility for surveying the country; photography by then was in wide use, and some of the earliest images of the western states were panoramic photographs taken by Timothy H. O'-Sullivan and William Bell [5]. Today we take the inclusion of such images in scientific texts for granted.

BACKGROUND

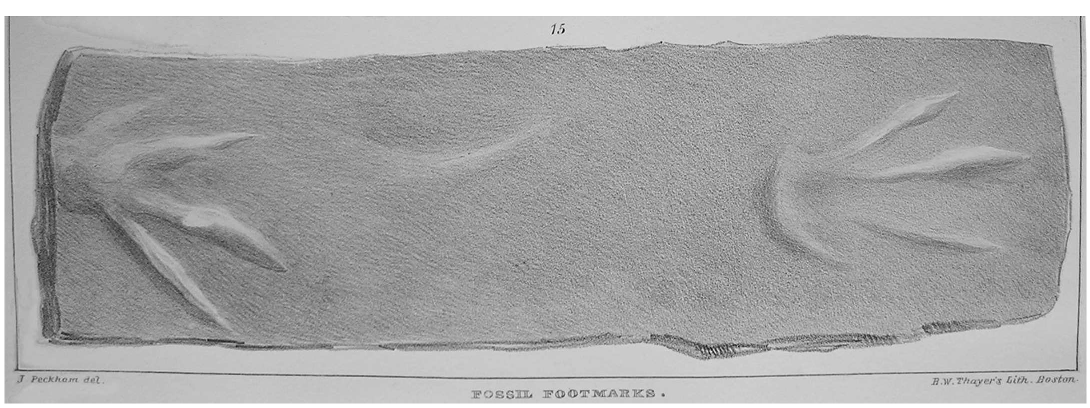
Although the technology of printing images with text was available by the mid-15th century in Europe, it did not reach the masses until certain technological advances were developed in the late 18th century. Prior to that time, woodcuts were carved with a knife and, although they could be set in the press with the type, they did not contain much detail. Copper engraving allowed more detail but slowed the printing process for two reasons: first, the copperplate wore down and had to be frequently re-etched; second, copperplates had to be printed separately from the text, in a secondary run, and then inserted into the text [6]. If a detailed engraving appeared on a page with text, that page had to be run through the press twice. The printing process, prior to the 19th century, was much slower; fewer books were published and those that were either had simple woodcuts or were rare books available only to a few.

One of the advances that allowed more detailed illustration was the development of lithography, which became popular in America after 1820, when artists "saw it as a means of multiplying their own drawings as if by magic and without the intervention of a professional engraver" [7]. After lithographic presses were developed, printing lithographs was faster than printing from copperplates but it, too, required a separate press run, and thus lithographs could not be printed in-line with the text. Lithographs, like copperplate etchings, were often bound separately and attached to a book at the end. Moreover, sometimes the text and the illustrations were printed in separate volumes, which has often led to their being separately catalogued in libraries. In the case of separate volumes, the prints were sometimes lost or, like maps included with books, stolen.

The printing press invented by Gutenberg in the 1450s essentially remained the same for about 300 years. Two or three people operated the press. With each impression there were four steps: remove the printed paper, re-ink the type, place new paper and pull the bar. The output of this process was comparatively slow—approximately 200 impressions per hour. The output increased rapidly in the early 19th century owing to a number of inventions: iron presses that printed larger areas at a single pull; mechanical typesetting that sped the laborious hand process; mechanisms for feeding the paper into the press; and, in 1815, steam-powered presses [8].

The two inventions that led to increased numbers of detailed illustrations were the improvement of the woodcutting process and the industrial production of smooth paper. The improved technology for making woodcuts was one of the simplest. Thomas Bewick (1753–1828) used a different wood and a different tool: Instead of a knife, he used the copperplate engraver's burin and gouge; instead of soft wood cut with the grain, he used boxwood cut against the grain. This innovation rapidly changed woodcutting from a craft into an industry [9]. At the same time, paper-making machines that ran on steam power were being perfected; these produced rolls rather than sheets, and the paper had a woven surface that was smoother than any previous surface, allowing the paper

Fig. 3. Lithograph of "fossil footprints" in Hitchcock's *Geology of Massachusetts* (1841, Plate 34). Hitchcock was the first in America to discover and illustrate dinosaur footprints.



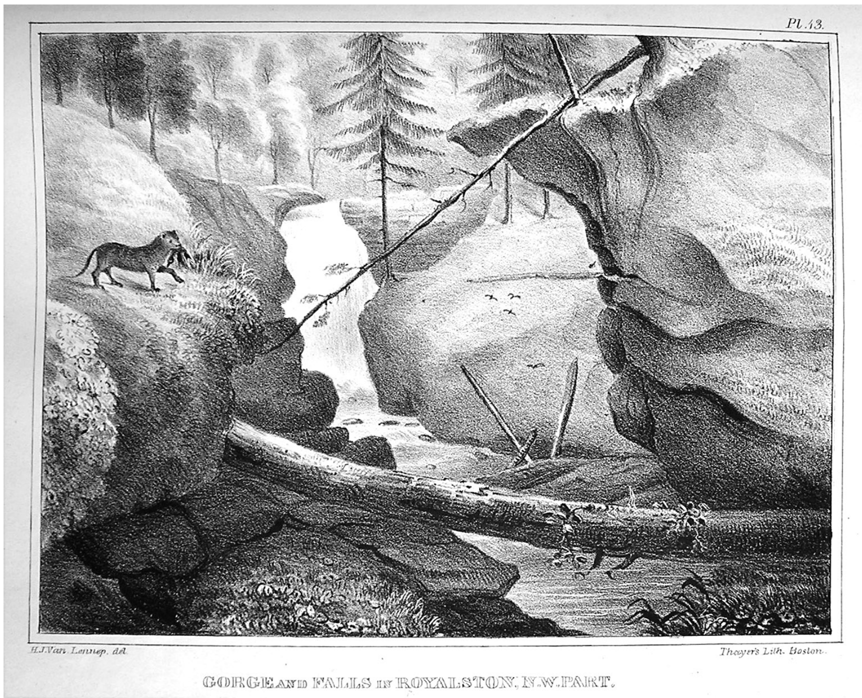


Fig. 4. A full-page plate by Henry Van Lennep in the *Geology of Massachusetts* (1841, Plate 13). Van Lennep met the Hitchcocks while he was a student at Amherst College and later wrote many illustrated travel books about exotic lands.

to capture greater detail. William Ivins wrote, "The historians of printing have devoted their attention to the making of fine and expensive books, and in so doing they have overlooked the great function of books as conveyors of information" [10]. These advances changed the printing of illustrated texts from a craft into an industry and increased the number of readers that they could reach.

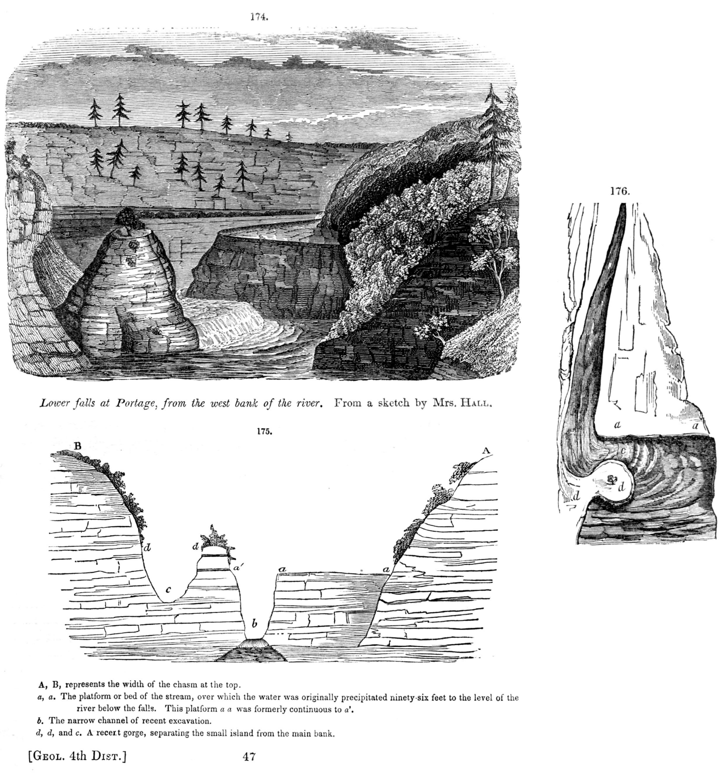
Science is reliant on communication for advancement. It is a social discourse community that creates consensus by sharing and comparing ideas. In the case of geology, its subjects were physical, and thus geology benefited greatly from this increase in illustrated communication. With more accessible, detailed explanations, both visual and verbal, geologists were able to transmit their knowledge about the earth's features more rapidly, create and present hypotheses, and eventually reach consensus. The legislatures first authorized the states to pay geologists to survey the land and then communicate their findings at the same time that these advances in printing were becoming widely used in America. Thus, the state geologists took advantage of the expanded power of the medium to fully illustrate their ideas.

An Example of the Increasing Speed and Scope of Scientific Illustration

Edward Hitchcock (1793–1864), a professor of natural history, was the first geological surveyor for Massachusetts. While Hitchcock was finalizing his 1841 *Final Report on the Geology of Massachusetts*, Louis Agassiz's *Études sur Les Glaciers* (1840) was published in France. *Études* was an important contribution to the ongoing controversy about the formation of the earth. At the time, many geologists believed that the features of the natural landscape, such as the placement of erratics, were due to a flood of Biblical dimensions. Agassiz himself held this view until, during a trip to the Alps, he saw the work of glaciers on the land; and he then put forth the theory that a sea of ice, rather than a flood, had covered the planet. His views were highly controversial [11].

Hitchcock received Agassiz's volume while his own was being typeset and readied for printing. However, he felt that Agassiz's ideas were important. Therefore, he attached a brief summary of *Études* as a preface (but called a postscript) in his *Final Report.* Agassiz's book had been printed in two volumes, with the illustrations separate from the text. Hitchcock must have had access to both volumes because, in order to illustrate the theory for his readers, he had crude woodcuts made from Agassiz's original lithographs (Fig. 1). Since the lithographs in *Études sur Les Glaciers* were bound separately, they are rare collectibles today. However, Hitchcock's hastily copied woodcuts appeared in-line with the text, thus seamlessly and immediately illustrating the ideas for the

Fig. 5. Three river images from *Geology of New-York, Part IV:* a landscape sketch by Mrs. Hall and two annotated sections (1843). These three images appear in-line with the text on three consecutive pages. They are examples of how visual aids mapped to textual explanations aided theoretical explanation.



Fragments of Encrinital columns in Limestone.

Fig. 6. Woodcut of a fossil specimen by Mrs. Brooks in James Hall's *Geology of New-York, Part IV* (1843, 90). Like the other geologists, Hall hired artists, many of them women, to illustrate his volumes. "Del." in the lower left corner stands for *delineavit*, or "he/she drew this."

reader and preserving the visual and textual communication as a unit. Agassiz's volume appeared in 1840, and by 1841 Hitchcock was able to relay Agassiz's ideas to a wide readership in the U.S.A.

Exactly Repeatable Images

While working out in the field, many of the state geologists drew sketches in notebooks as a form of documentation. The lead geologist of each state collected these notebooks and chose which drawings to include in the final report. They were then sent to a professional engraver or lithographer, who prepared them for printing. The more complex illustrations and those that were inserted at the end of the book were sometimes signed by the artist with "Del." in the lower left corner (from the Latin *delineavit*, or he/she drew this) and the name of the printer in the lower right corner. The smaller engravings, printed in-line with the text, were often unsigned. When the geologists collected specimens, such as fossils, they often hired artists to draw them. Most of the landscapes were drawn in the field.

The numbers of drawings in the early state geological reports were astounding. The *Geology of Massachusetts* had 275 woodcuts within the text and 55 lithographic plates at the end, some of which fold out to three times the width of the book (see Figs 1–4). *Geology of New-York, Part IV* has 193 woodcuts and three etchings within the text, as well as 19 lithographic plates at the end, some of which fold out to five times the width of the book (see Figs 5 and 6). The *Second Annual Report on the Geological Survey of New Jersey* has seven full-page landscapes, three half-page landscapes, a one-page illustration of a hoisting engine and 17 technical drawings and sections, all of which are woodcuts (see Figs 7 and 8). *The Geology of Pennsylvania* has 778 figures and diagrams, 23 full-page copperplate etchings, three color lithographs of landscapes and 18 fold-out etchings at the end (see Figs 7, 9, 10 and the Article Frontispiece). All of these reports included hand-colored maps as well, many of which are now separated from their texts. The geologists were basing their final report format on the Geological Society of London's *Transactions*, the "first specialist periodical for geology [that] had developed a standardized visual language combining maps, sections and landscapes" [12]. Below is a discussion of the drawings organized into sections, specimens and landscapes.

Sections: Exploring Theory

Sections are most often cross-sections that show an interior or conceptual view of a formation. They appeared with the text on the page to illustrate specific strata or concepts and were the most important visual aid to advancing geological understanding, since, unlike specimens and landscapes, they directly portrayed evolving notions about the interior of the earth. There are hundreds of these small images, in-line with textual explanation, in the early geological state reports, and they are all unsigned (5, 7 and 9).

In a chapter entitled "Modern Action of Rivers; Freezing of Water in River Channels," James Hall (1811–1898) demonstrated his theory about how water can sculpt the land. He used the following words, along with images, to illustrate his concept:

> If a river channel can be widened and deepened to the amount of a few inches within the recollection of any individual,

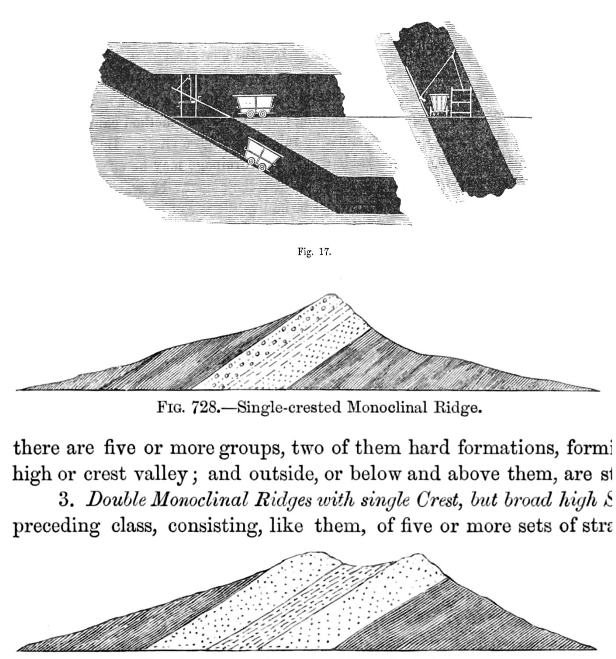


Fig. 7. A section from Kitchell's *Second Annual Report* showing a cross-section of a mine (1856) and two sections from Henry Rogers's *Final Report on the Geology of Pennsylvania* (1858). Cross-sections such as these described features under the surface of the land and thus were useful for illustrating theories about the evolution of topography.

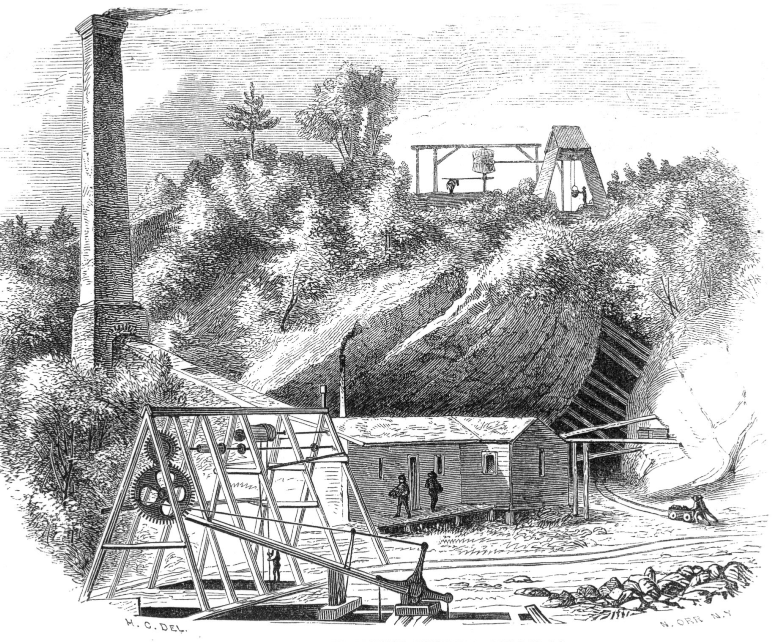


Fig. 8. An etching of an ironworks from William Kitchell's *Second Annual Report on the Geological Survey of the State of New Jersey, for the Year 1855* (1856, 216a). Hired to document economic geology, the Hudson River School painter John Hermann Carmiencke captured rare images of the mid-19th century iron industry.

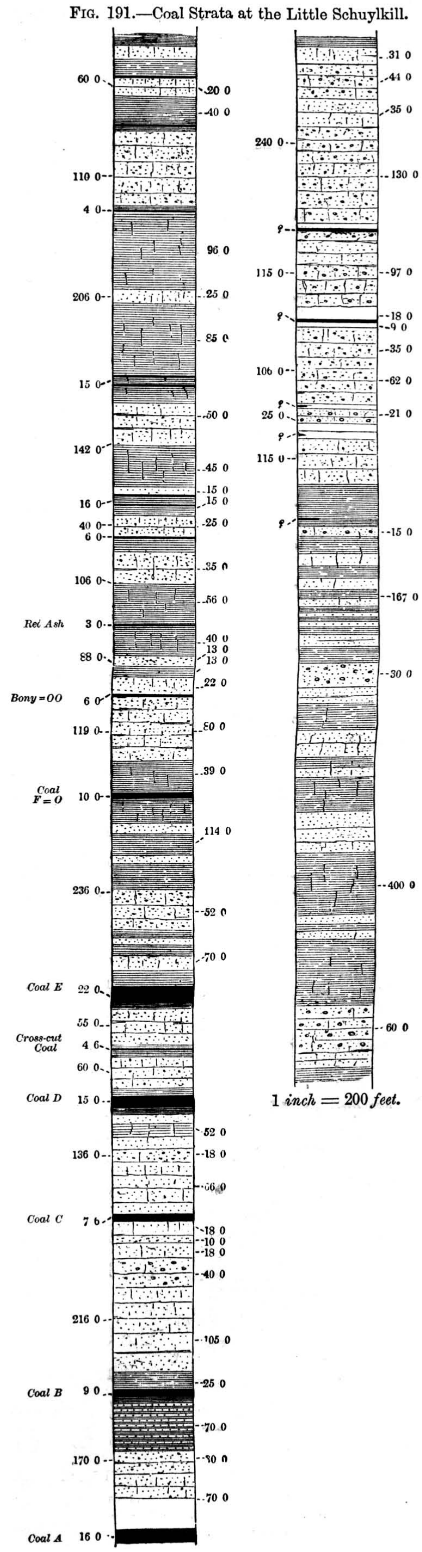


Fig. 9. A section from the *Geology of Pennsylvania* showing the layers of a coal-bed (1858). Although today coring is commonplace, these drawings were made before that technology was available. According to J. Peter Lesley, these drawings were unique for their time [13].

> may not a gorge of one or two hundred feet be formed by the same process? Our theories of modern operations make provision for wide sweeping deluges, for immense excavating waves, for hemispheres of ice . . . but we have almost forgotten the quiet operation of running streams, and the freezing of water in fissures of hardened rocks [14].

At the time, there was still controversy about how the surface features of Earth had been formed. Here Hall is advancing a theory that the continual motion of water was powerful enough to form a gorge. His meaning is further explained by the accompanying illustrations (Fig. 5). The top drawing represents the formation as a landscape, thus providing the visual context. The second drawing is a cross-section with letters mapped to descriptions. The third view (at the right), adds another theoretical dimension from above, since it shows the movement of the water within the channel and suggests that its motion could gradually carve bedrock. Martin Rudwick notes that the visuals "developed in the course of time towards greater abstraction and formalization, and thereby became able to bear an increasing load of theoretical meaning" [15].

Specimens: Printing as Reification

In these early state reports, specimens were a standard inclusion. Like the cross-sections, specimens existed to communicate details about data—they could be shared, compared and evolve into a consensus regarding strata and theory. However, they also reified objects and formations, making them real in a culture that had never seen the original, and catalogued them for the future. Specimens, therefore, had an additional cultural dimension within this relatively new process of mass and rapid printing: they were exotic collectibles (indeed images of specimens are still printed, framed and sold today). Sometimes the specimens did not signify a formation that would ultimately enhance geological understanding, such as Hitchcock's "clay stones" (Fig. 2). Sometimes, however, the specimens did signify significant discoveries with lasting importance to geological theory, such as Hitchcock's "fossil footprints," which were from dinosaurs (Fig. 3).

The New York geological survey, begun in 1836, hired four geologists, each assigned to a district. James Hall surveyed the 4th district and collected many fossils, which he had drawn by various artists (Fig. 6). These illustrations were essential to geological understanding because they allowed the fossils from one location to be compared to those from another, and thus strata could be defined. Publishing illustrations of fossils allowed detailed information about them to be communicated across space and time. As the geologists of New York worked together, they provisionally created names for the beds, or formations, that they discovered, including such diverse terms as

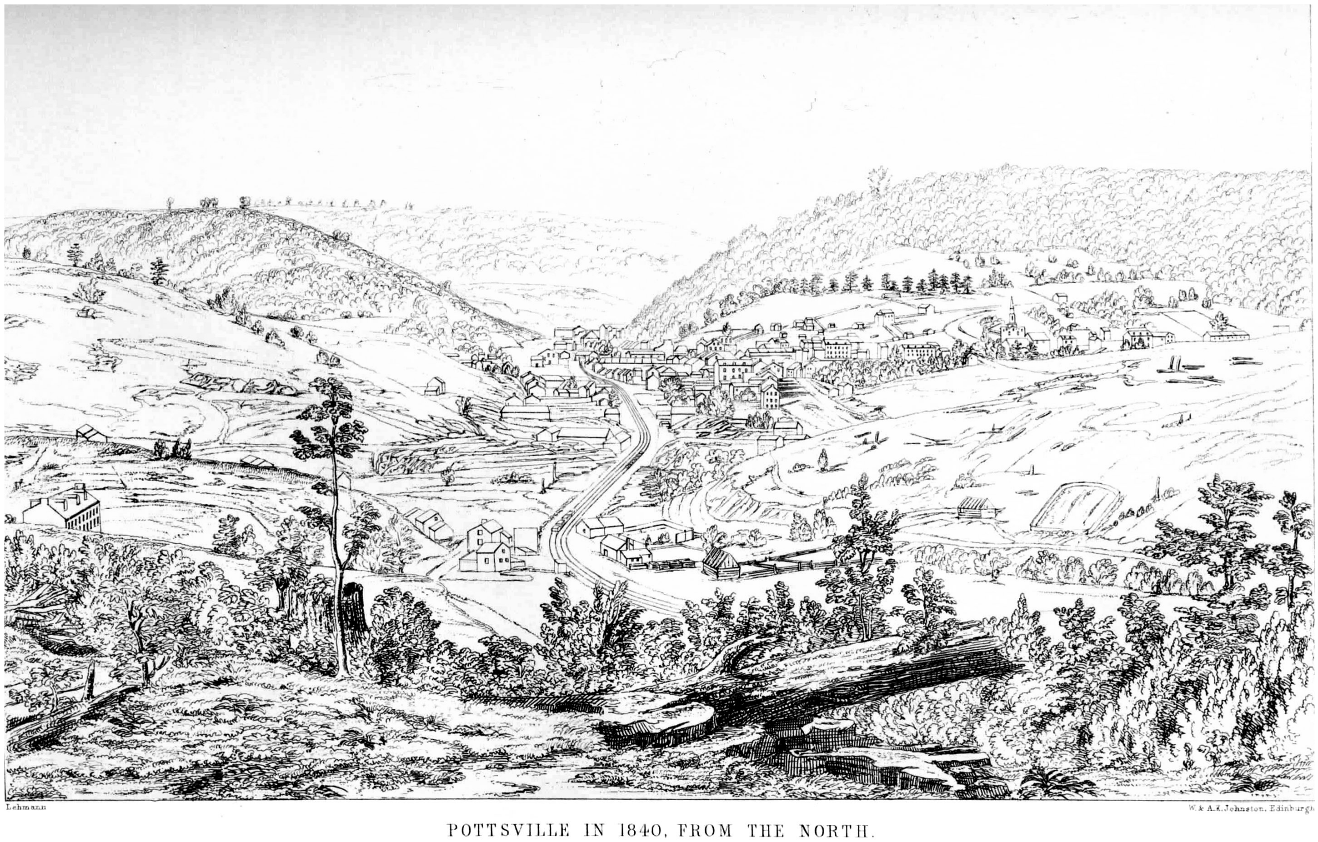


Fig. 10. A field drawing by George Lehman etched on copperplate for the *Geology of Pennsylvania* (1858, facing p. 37). The 23 drawings and three lithographs (taken from watercolors) included in this book represent only a small number of the drawings and paintings that Lehman had done for the survey [20].

Chemung, Genesee, Portage and Coal Measures. Hall's publications, with their drawings, contributed to the fact that the New York naming standards for geological strata eventually became the established norm in 19th-century geology [16].

Landscapes: Aestheticism and Science

Landscape illustrations ostensibly provided a visual context for the sections and specimens as well as a view of the surface of the land. Like the specimens, however, which had value outside of geology as collectible popular objects, landscapes were very popular in the 19th century. Thus, all of the geological reports contain many more landscapes than they needed for geological explanation. Some of them depict towns and lakes, romantic settings and dramatic formations. Interest in landscapes was so pervasive in the 19th century that Hitchcock titled one of the parts of his report "Sceneographical Geology." Hitchcock conducted his geological surveys by traveling with several artists, such as his wife, Orra White Hitchcock, and Henry John Van Lennep (1815–1889), who later wrote illustrated books such as *The Oriental Album: Twenty Illustrations in Oil Colors of the People and Scenery of Turkey* (1862) and *Travels in Little-Known Parts of Asia Minor* (1870) (Fig. 4). Travel, geology, drawing and an interest in the exotic were all part of the cultural environment that surrounded the discourse community of geology. An interest in the exotic contributed to the landscapes in these reports. Scott Montgomery wrote:

> On the one hand, surveyors, map-makers, mining engineers, and other men of more practical mind began recording their observations, and this may well have contributed toward the idea of the field sketch as a potential source of essential information. But even more important was the great burgeoning of travel literature during this period, buoyed by continued colonial expansion and interest in exotic lands, sights, and information-based tales [17].

William Kitchell (1827–1861) wrote the *Second Annual Report on the Geological Survey of the State of New Jersey for the Year 1855*, which was mainly focused on the mineral industry. His surveyors located and documented iron mines and ironworks, describing processes and machinery, and produced images of the mines and the miners. Kitchell hired John Hermann Carmiencke (1810–1867), a Hudson River School painter who was trained in Europe and had been Court Painter to the King of Denmark, as the artist for the survey. Since the survey was required to document economic geology, Carmiencke turned his artistic eye to charcoal iron-making, thus providing rare views of a largely undocumented industry (Fig. 8).

Henry Darwin Rogers (1808–1866), geologist for the state of Pennsylvania, also hired an artist, George Lehman (d. 1870), who was a professional engraver and lithographer. Lehman is remembered today for the approximately 40 backgrounds he painted for Audubon's *Birds of America*. The *Geology of Pennsylvania* (1858) was a monumental work, and it included 26 images drawn or painted by Lehman of local and industrial landscapes (Fig. 10). Although some of the landscapes may have aided geological understanding by furnishing a general overview of the land or, in some cases, depicting mines and rock formations, there were far more than absolutely necessary. Geology was a science "steeped in aesthetics" [18]; it seemed that art and geology went hand-in-hand. An understanding of artistic perspective in drawing contributed to geological understanding [19].

CONCLUSION

Images were central to the emerging language of geology. Rudwick wrote:

> An essential part of this complex historical process was the construction of a visual language that was appropriate to the subject-matter of the science, and which could complement verbal descriptions and theories by communicating observations and ideas that could not be expressed in words [21].

The "exactly repeatable image" that Ivins describes is what allowed visual communication to take place on a wide scale; prior to the 19th century, exactly repeatable images were limited to rare and expensive volumes. The 19th-century advances in printing made ongoing scientific dialogue visible to a wide audience. This increased communication aided the advancement of science. Ivins wrote, "There have been many revolutions in thought and philosophy, in science and religion, but I believe that never in the history of men has there been a more complete revolution than that which has taken place since the middle of the 19th century in seeing and visual recording" [22]. The change is in both quantity and quality: more publications appeared, more images appeared in them and the detail in the images continually improved.

In the 19th century, the separation between art and science was not as distinct as it is today. Many geologists were artists as well, and they thought like artists. In the first paragraph of Rogers's 1,631-page report, he wrote:

> The contour of the ground is the sculpture which guides to the anatomy within; and it is as needful to note the slopes, projections, and wavy outlines of the surface, while studying the mineral masses beneath it, as it is for the anatomist to employ the perceptions of the artist [23].

In the passage above, Rogers thought like a sculptor. J. Peter Lesley (1819–1903), who later became the state geologist for Pennsylvania, thought like a painter. He wrote, "The face of the earth is the face of a great angel, with infinite smiles and anguish-lines, and profound sympathies with peace and suffering stamped upon its features" [24]. Their artistic understanding of the earth was central to their scientific understanding of the theories used to understand it. As Cyril Stanley Smith wrote, "One must conclude that creative discovery in any field is a matter for the whole man, not his intellect alone" [25]. The creative mind uses all of its senses in order to understand the world.

Acknowledgments

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Glossary

codex—a set of folded sheets held together by stitching.
engraving—using sharp tools to draw on metal, stone or wood. Etching and engraving were often used in combination.
etching—engraving with acid. The plate is coated with an acid-resistant substance that forms the surface for the drawing.
lithography—a printing process using oiled stone, discovered in 1798.

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