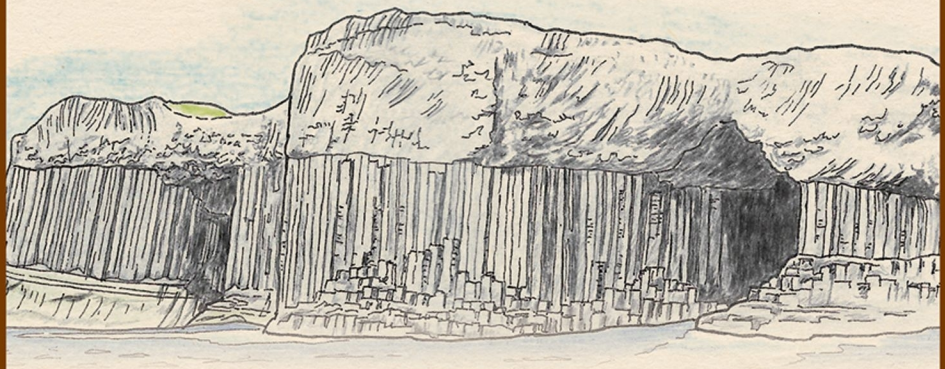
MATTHEW J. GENGE

GEOLOGICAL FIELD SKETCHES AND ILLUSTRATIONS

A Practical Guide



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Details make perfection, and perfection is not a detail—*Leonardo Da Vinci*

This book is dedicated to those who taught me, and those I have taught. In particular amongst my lecturers Paul Garrard, John Cosgrove, and Jack Nolan are thanked for their rigorous field training. The students I have taught are too numerous to mention, but those whom I know continue to espouse the value of drawing in fieldwork are closest to my heart.

Acknowledgements

Special thanks are given to those who encouraged me to write this book. Several of my colleagues including John Cosgrove and Mark Sutton are thanked for useful comments on individual chapters.

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1

Introduction to drawing geology

Natural sciences are observational disciplines and in Earth Science, in particular, excellent observations are the key to rigorous interpretation. Often it has been through careful unbiased observations, rather than spontaneous ideas, that the greatest advancements in Earth Science have occurred. Conversely many of the greatest dead-ends in Earth Science have come about when observations have been overlooked or dismissed since they were not consistent with theory. Excellent observation and recordings are the first step in producing excellent science.

Observing the natural world is challenging since nature is often complex and can seem chaotic and random. Unravelling the chaos requires careful and systematic observation and description. The complexities of the natural world make it difficult to adequately describe in words all but the simplest outcrops of rocks, even when using the brevity of terminology. Pictures, in contrast, provide an excellent medium for recording the spatial variations that makes nature so intricate.

Drawing the structures and lithologies of rocks is a long-standing method of data collection in the field and is practised by all geologists at some stage in their careers. Field sketches are used to record spatially constrained information, whilst maps and cross-sections are used to illustrate the distributions and structures of units above and below ground. Schematic diagrams provide both an aid to interpretation and means of communicating geology to others. Effective use of pictorial representations of Earth Science processes can be transformative in pedagogy. Although drawing is a very useful skill in Earth Science, for students, professionals, and academics, little instruction is often given in the activity, apart from basic guidelines.

This book aims to provide an in-depth training in how and what to draw in Geology. It will introduce techniques that can be used to produce accurate sketches and diagrams as well as tactics to help geologists improve their drawing skills. Since knowing what features are most

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important to draw and emphasize in field diagrams is also important, this book is also a textbook in geology. The fundamental concepts of petrology, mineralogy, structural geology, palaeontology, and field techniques are all described in the context of drawing the features of rocks.

Although this is a book intended for earth scientists it also has useful tips for natural science students and amateur scientists in a wide range of disciplines, such as biology, geography, and environmental science. Any field of science that involves recording spatial relationships benefits from the ability to sketch. This is the book for those who want their notes look amazing as well as being full of technical detail. It is, be warned, no magic pill. Reading this book will not impart a magical ability to draw, but it will provide the tools and methods to draw with confidence, and with practice become an enthusiastic sketcher.

1.1 Why we draw geology

Teachers of Geology will often hear students say 'Why do I have to draw it? Can't I just take a photo?'—a lament that has become more and more common now that all of us carry devices with cameras with us all the time. Drawings, however, are crucial in making excellent field recordings because they are an aid to observation as well as a way of documenting what is seen. There is no substitute for a field sketch, since like the saying goes 'a picture is worth a thousand words'—although that very much depends on the picture. It is certain, however, that whatever the quality of the resulting sketch, taking the time to sit and draw a landscape or an outcrop of rock forces close observation of the most important features and will result in much more to interpret than if just a photograph is taken, as shown in Figure 1.1.

Diagrams are also an important part of communicating Earth Science to others. Effective use of pictorial representations of geology is valuable as a teaching tool. Enhanced graphics can produce a transformation of pedagogic value in the class-room or in the field. Pictorial learning aids are most effective for visual learners whom can envision imagery easily. For such people diagrams greatly assist in solidifying understanding. Even in the field, when individuals can touch and explore the rocks in front of them, diagrams drawn on a portable whiteboard demonstrate concepts much more clearly than words alone can convey. Photographs, even annotated on a tablet, do not have the same

Figure 1.1 Illustrating how field sketches can provide an enhanced means of recording geology compared to photographs. Showing a view of Ladram Bay in Devon.

impact. The ability to draw is thus just as important for lecturers, as it is for students.

Photographs are nevertheless very useful in field geology and many of them should be taken. There is, however, a tendency with photographs to snap and move on, hardly paying attention to what is being imaged, let alone where the photograph was taken, and in what direction. Photographs of rocks are often also very difficult to interpret. Firstly,

they are in two dimensions, a single view from a single perspective. A sudden change in the orientation of a feature such as a bed of rock could be a fold, or it could be a planar bed seen on a curved surface. When sat in front of the rocks it is easy to move and see which it is. A single photograph doesn't record that three-dimensional (3D) information.

Many academics are now working with aerial drones to generate 3D models of outcrops and landscapes. These are highly useful means of recording the geometries of geological structures; however, they do not encourage careful observation in the field, instead demoting it to a post-field, data-processing, activity. The 3D models of drones also suffer from the same resolution issue as photographs. A single pixel may be 2 cm across, and all the fine-scale information has gone.

Another difficulty with photographs or drone imagery is with colour. The human eye is very sensitive to subtle differences in colour. Often geologists will talk about the colours of rocks as if they are obvious, such as the 'pink rhyolite' and the 'blue andesite', when in fact they are very subtle, more a grey-pink and a grey-blue. In a photograph they are likely to look all the same dull grey colour. Telling the difference between rock types is difficult enough in the field with the aid of a hammer and a hand-lens. It is often not possible from a photograph.

Illumination is also a significant problem in the interpretation of photographs. Our brains are very good at filtering images, thus we can see beyond differences in illumination and trace a feature from brightly lit areas into the shadows. In photographs shadows become deeper, particularly in bright sunshine, and seeing features becomes almost impossible. There is unlikely to be a single geologist who hasn't taken picture of an outcrop, and later wondered why they took it. Photographs make the most imperfect way of recording geology. Therefore we draw.

1.2 Illustration in Natural Science

Pictures have been used to illustrate concepts and provide a visual explanation of text throughout history. In fact, pictures predate writing by a significant period of time and it is likely that they actually predate language. Communication through images is so fundamental that when it finally came to recording language letters evolved from pictographic representations of words.

The modern tradition of illustrated books arguably began with the iconography of medieval religious texts. Ornate and richly coloured

illuminations were hand drawn and painted and the best examples, such as the Book of Kells, held within Trinity College Dublin, are in themselves works of art. Although these illustrations were not technical in nature they provide a context for the scientific illustration that later developed since they were designed to emphasize the information held in text. They demonstrated that pictures have an additional explanatory power that words alone could not convey.

The first scientific illustrations within books came in the sixteenth century with the advent of printing technology that could produce large numbers of copies without laborious and slow illustration by hand. Perhaps the first example of geological illustrations were those of fossils, since these petrified creatures were a peculiar natural oddity that attracted wide interest in the fledgling world of natural science. Diagrams of fossils were included by Conrad Gesner (1516–1565) in his work '*De Rerum Fossilium*', published in 1565. Gesner used diagrams to demonstrate the similarities between modern and fossilized creatures. Thus scientific illustration was born out of the need to prove a controversial hypothesis, that fossils were once alive and are organisms transformed to stone. 'Seeing is believing' is thus a cornerstone of scientific illustration.

In Figure 1.2, an illustration from '*De Rerum Fossilium*' shows the morphology of an echinoid. The drawings are of a remarkable quality considering they were printed by woodcut. They resemble modern line drawings and are accurate simplified representations of the main features of echinoids showing the pentaradial symmetry, the ambulacra with spine attachments, and the interambulacra areas. Gesner uses different line widths within the drawings to emphasize features, a technique that will be used throughout this book. He also uses shading to impress volume upon the reader, which is a sophisticated technique that can be difficult to achieve well.

Although Gesner's book provides the first published illustrations of this type, there were earlier representations of geology. German scholar Georgius Agricola (1494–1555) included illustrations to show the locations of mineral deposits in his book '*De Re Metallica*', published in 1556. The diagrams, such as that shown in Figure 1.3, however, were schematic by comparison with those of Gesner and clearly were not drawn as sketches of real objects, but as exaggerated illustrations. In particular features are not draw to scale. Shading and differing line with, however, is used to provide an illusion of depth. The exaggeration is typical of

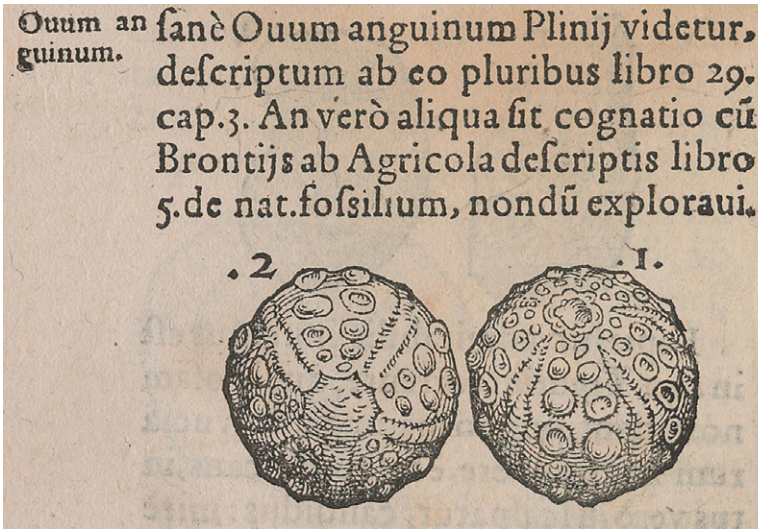
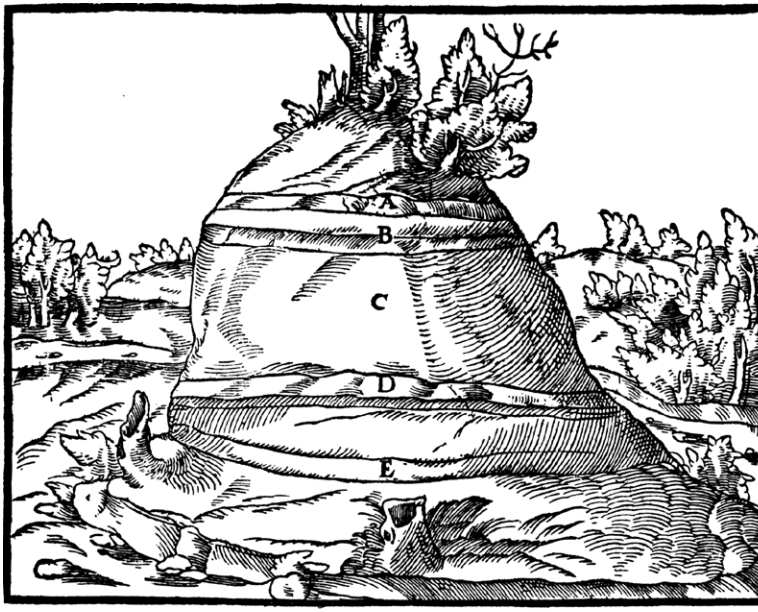


Figure 1.2 Illustration of an echinoid in Conrad Gesner's *De Rerum Fossilium.*



A & B—*Venae dilatatae.* C—*Intervenium.* D & E—Other *venae dilatatae.*

Figure 1.3 An illustration of ore deposits in Giorgios Agricola's *De Re Metallica.*

early renaissance illustrations and similar examples can be seen in '*Mundus Subterraneus*' by Athanasius Kirchur (1602–1680) published in 1665.

Evidence exists that natural scientists had made use of drawing in recording observations before their appearance in print. The Italian polymath Leonardo da Vinci (1453–1519) kept detailed notes (his Codex) that were full of detailed sketches and diagrams—used principally to record observations that were too complex to be sufficiently described in words. In addition to anatomy, cartography, mathematics, and engineering, Leonardo da Vinci had a keen interest in geology, perhaps born out of his landscape painting. His drawing of a Tuscany landscape (Figure 1.4, dated 1473) shows his attention to detail and appreciation of realistic perspective, which was unusual amongst his contemporary artists. In particular in this sketch da Vinci includes realistic bedding in the sedimentary rocks near the waterfall that emphasizes the lower bedding planes. These are probably turbidite packets with erosional lower contacts. Although not a geological sketch as such, since the geological features are not the subject, it does illustrate many of the principles of a good geological sketch that will be discussed later in the book.

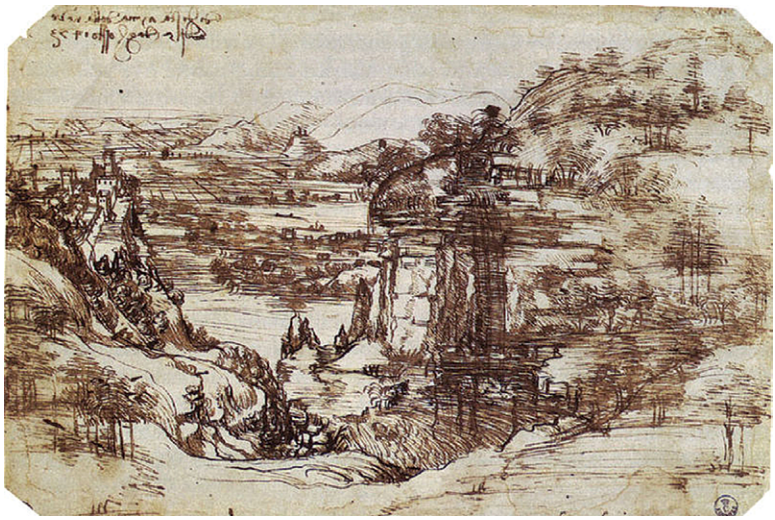


Figure 1.4 The Arno Valley by Leonardo da Vinci (1473).

Considering his fame as an artist, Leonardo da Vinci doesn't provide an ideal example of a field sketch achievable by most people. However, not all his sketches were as detailed or as accurate. In folia 25r of his codex I, he includes sketches of fossils brought to him by peasants whilst he was working in Milan probably around 1499 (Figure 1.5). These clearly show brachiopods and the trace fossil paleodictyon; however, they are rough drawings with some issues with symmetry and accuracy. Even da Vinci it seems would sometimes sketch objects quickly as a reminder of their form but without adequate detail.

A specific focus on drawing natural objects in order to make more accurate and detailed observations was championed by Italian naturalist Ulisse Aldrovandi (1522–1602). In his posthumous work '*Museaeum Metallicum*', published in 1648 he says:

to understand plants and animals there is no better way than to depict them from life

Figure 1.5 A reproduction of Leonardo da Vinci's sketch of fossils from *Codex Leicester Hammer*.

The concept of drawing nature as a means of study, rather than just as a way of illustration, was also championed by Italian botanist and geologist Fredrico Angelo Cesi (1585–1630). Cesi founded the Accademia dei Lincei (the Academy of the Lynx) in 1602, a scientific academy based in Rome dedicated to scientific investigation free from political or religious control—a dangerous endeavour next door to the Vatican. The academy was named after the cover illustration on the book '*Magia naturalis*' (1558) by Giambattista della Porta (1535–1615), who had established a similar academy in Naples, which showed a Lynx with the words:

> *. . . with lynx like eyes, examining those things which manifest themselves, so that having observed them, he may zealously use them*

The academy encouraged its members to record the natural world in pictorial representations and accumulated over 7000 drawings and paintings of natural objects, landscapes and phenomena.

The first verifiable sketches of geology made in the field can be attributed to Fredrico Cesi. His work was of sufficient quality to be used after his death in 1637 in Francesco Stelluti's (1577–1652) book on fossilized wood '*Trattato Del Legno Fossile Minerale Nuouamente Scoperto*'. Cesi's sketches were used by Stelluti to construct a locality diagrams in his book, as shown in Figure 1.6. Stelluti's book also included many hand specimen

Figure 1.6 Fossil wood locality at Rosaro in Italy.

images of fossil wood that are also high quality and the first microscope images to appear in print.

Geological illustration became increasingly used through the eighteenth century. Scottish geologist James Hutton (1726–1797), who established some of the most important principles of geology, demonstrated his theory of plutonism using a geological map of Glen Tilt in Scotland. A map by John MacCulloch of Glen Tilt published in 1815 and incorporated in to later editions of Hutton's book *Theory of the Earth* is shown in Figure 1.7. The map demonstrates how observations recorded in the field allow complex information to be conveyed and interpreted. These sketch maps will be considered later in this book.

Hutton also used sketches collected in the field to record and interpret geology. He included many drawings in *The Theory of the Earth*. The drawing of the unconformity at Jedburgh in Scotland shown in

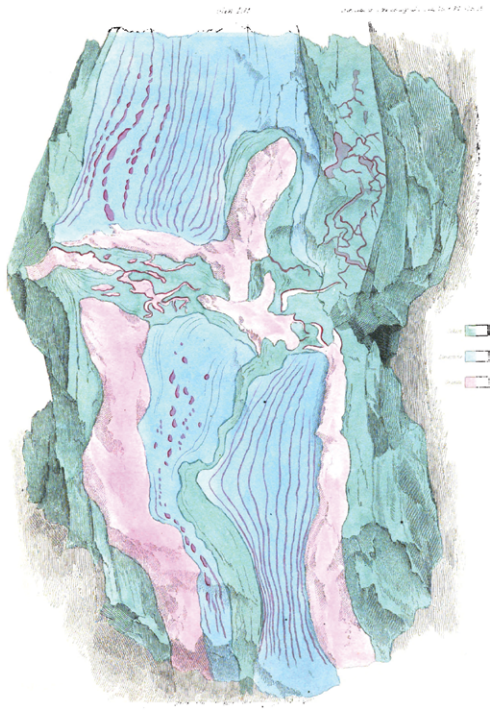


Figure 1.7 John MacCulloch's map of Glen Tilt published in 1815 in the *Transactions of the Geological Society*, volume iii.

Figure 1.8 was used to demonstrate the concept of geological time and was based on field observations.

Hutton employed an artist, John Clerk to accompany him in the field to record the geology. The same artist produced impressive hand specimen diagrams for Hutton's book such as a sketch of a granophyre (Figure 1.9). This diagram provides a high level of detail that illustrates very well the nature of the graphic texture, showing the intergrowth of alkali feldspar and quartz. Part of the reason for the sketch is to allow others to recognize similar samples, and in this respect the diagram achieves its aim. Such detailed illustrations, however, are rarely feasible in the field and best created afterwards. Today a photograph would provide a more than adequate recording of such a specimen.

Hutton also used cross-sections to extend geological relations into the subterranean realm. His cross-section of the isle of Arran, showing its central intrusion deforming the surrounding Dalradian and onlapping later Devonian strata, is an excellent early example of this type of diagram (Figure 1.10). In a later section in this book the creation of sketch cross-sections will be described as a semi-schematic means of interpreting the spatial relationships of between geological units.

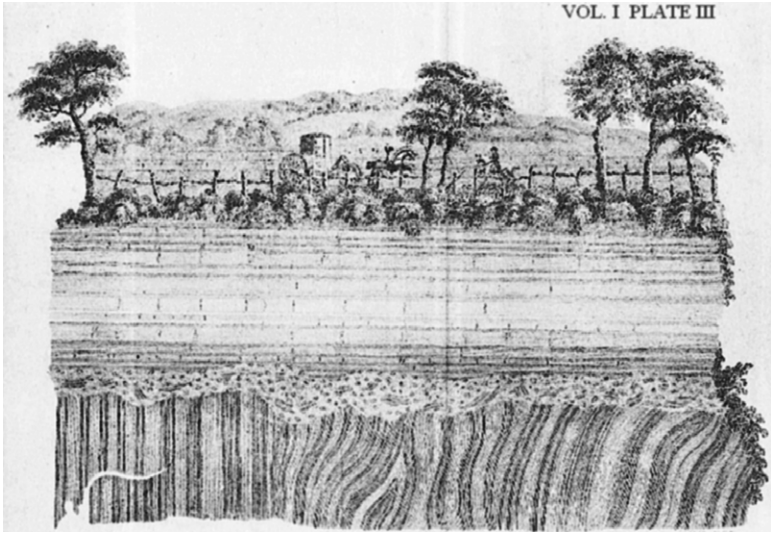


Figure 1.8 An illustration of Hutton's unconformity at Jedburgh in Scotland for his book *Theory of the Earth*.

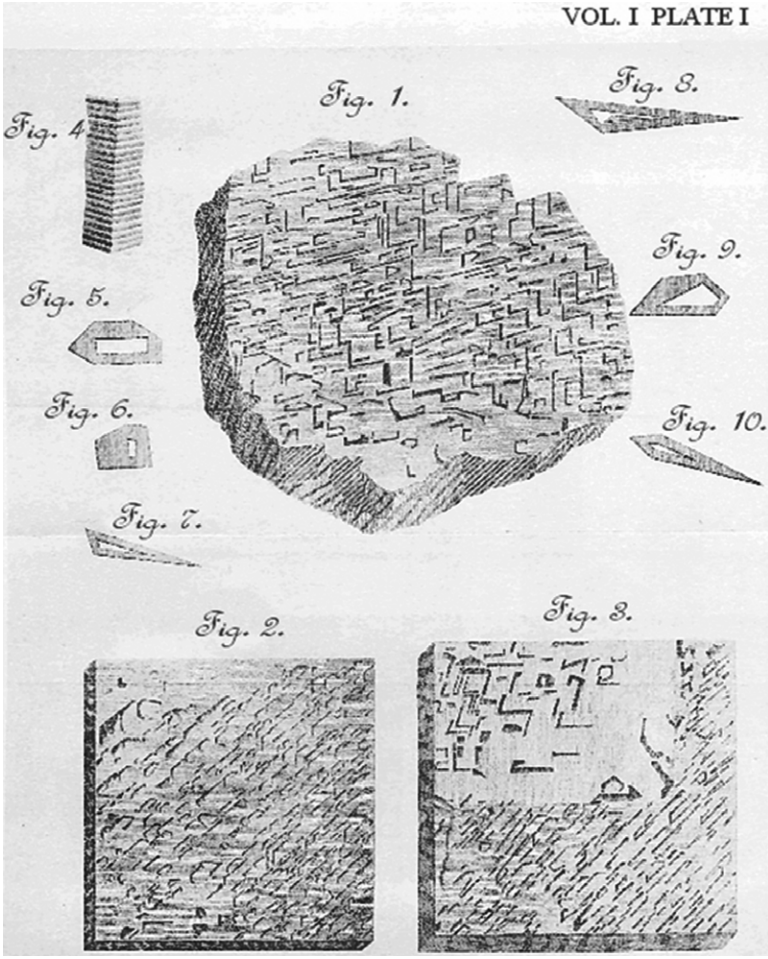


Figure 1.9 Graphic granite from Hutton's *Theory of the Earth.*

Improvements in printing technology, with the development of the chemolithograph in the 1790s, allowed reproduction of colourful detailed images. Increasingly geological illustrations became more elaborate with finer drafting lines and realistic colours. Illustrations of fossils within William Smith's (1769–1839) monograph entitled '*Strata Identified by Organized Fossils*' published in 1816 made full use of these developments and played a crucial role in popularizing his methods amongst

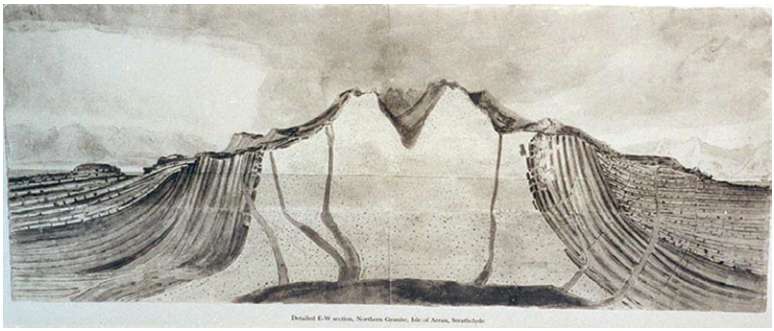


Figure 1.10 Cross-section of Goat's Fell on the Isle of Arran by James Hutton (Credit: U.S. Geological Survey, Department of the Interior/USGS).

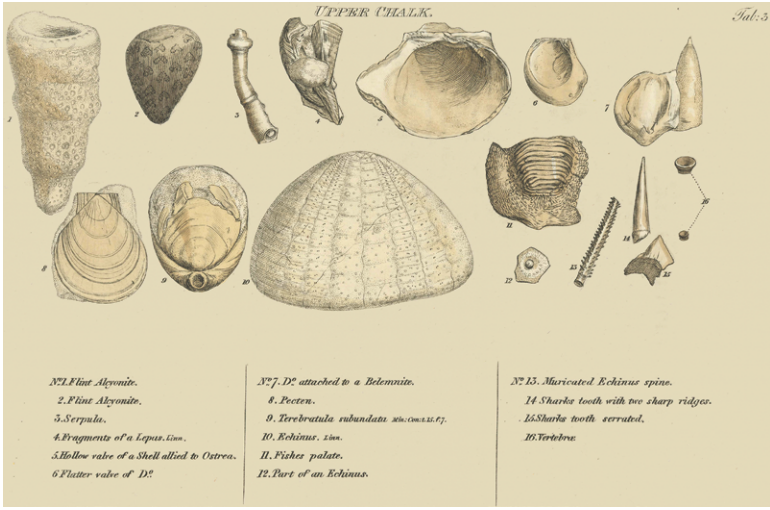


Figure 1.11 Fossils from the upper chalk from William Smith's monograph *Stata Identified by Organized Fossils* published in 1816.

other geologists. Smith maintained that particular stratum contained specific fossils that differed from other layers allowing them to be identified. The detailed illustrations (Figure 1.11) enabled other geologists to test and confirm his findings, establishing new important tools in stratigraphy. These concepts would be later be crucial in the discovery of the theory of evolution.

The new printing techniques also coincided with the publication of Smith's famous geological map of the United Kingdom—the first large-scale, national map of geology (Figure 1.12). Its publication revolutionized Earth Science and propelled it into the industrial era. Using Smith's stratigraphic techniques, together with those already established by Hutton, the geology could be traced across the landscape. The application of geology as a natural science to mining, civil engineering and agriculture became apparent just at the time when the industrial revolution was beginning.

Perhaps the zenith in geological illustration came when the boundary between utilitarian diagrams and art became blurred. Sketches by the naturalist Richard Waller (d. 1715) of Robert Hooke's collections of fossils published in '*Posthumous Works*' in 1705 are clearly designed with an aesthetic empiricism in mind. The sketch shown in Figure 1.13 illustrates 'snake-stones', now termed ammonites, which Hooke proposed

Figure 1.12 William Smith's 1819 map of Sussex.

Figure 1.13 Illustrations of snake stones by Richard Waller published in Robert Hooke's 'posthumous works', 1705 (Credit: Wellcome Collection).

were the petrified remains of ancient creatures. The sketches convey the taxonomic characteristics of ammonites but are also beautiful pieces of art. Elements such as the shadows cast by specimens, which partially obscure parts of the annotation, would not normally be

included in geological sketches, but in this case provide the specimens with the impression of volume. Such realism in art is suited to science since it represents the subject without artefact and stylistic convention. This contrasts strongly with the conventional art world of early eighteenth century that was dominated by the exaggerated and grandiose Baroque movement.

The advent of new scientific techniques has influenced the nature of geological drawings. In Earth Science the development of polarizing microscopy and thin-section preparation was momentous. For the first time it was possible to see a whole new world of petrology at microscopic scales and to identify minerals with little uncertainty. The new technique demanded a new type of illustration.

The petrographic microscope first became possible in 1828 when Scottish physicist William Nicol (1770–1851) discovered that polarized light could be generated by passing light through a crystal of Iceland spar, a variety of calcite. At first only individual mineral grains could be observed with such microscopes, however, in the 1840s the preparation of optically thin-slices of rocks through polishing was developed and the petrology of entire specimens could be recorded. Illustration techniques adapted to this two-dimensional world.

Some particularly interesting examples of sketches of petrology in thin-section were used by Prof John Wesley Judd (1840–1916), from the Royal School of Mines, within '*The eruption of Krakatoa and subsequent phenomena*' published in 1888 by the Royal Society. The samples comprised of pumice ejected in the 1883 eruption of Krakatau and lavas collected on the island. The diagrams illustrate that a degree of simplification best gives optimal results, since in thin-section the detail can overwhelm the important elements of the petrology. Using these techniques Judd demonstrated that the Krakatau pumice changed in character from the beginning of the eruption to its intense climax. He showed that the pumice records the flow of magma and the all-important formation of vesicles in abundant glass with relatively few crystals present. He also examined samples of older lavas present on the island and these thin-sections are shown here in beautifully detailed images (Figure 1.14).

With the development of photography in the late nineteenth century, illustration through drawing began to decline in its role as a means of presenting evidence in geological research. Geologists, however, continued to draw in the field as an aid to interpretation. Schematic diagrams also became popular in textbooks to demonstrate concepts,

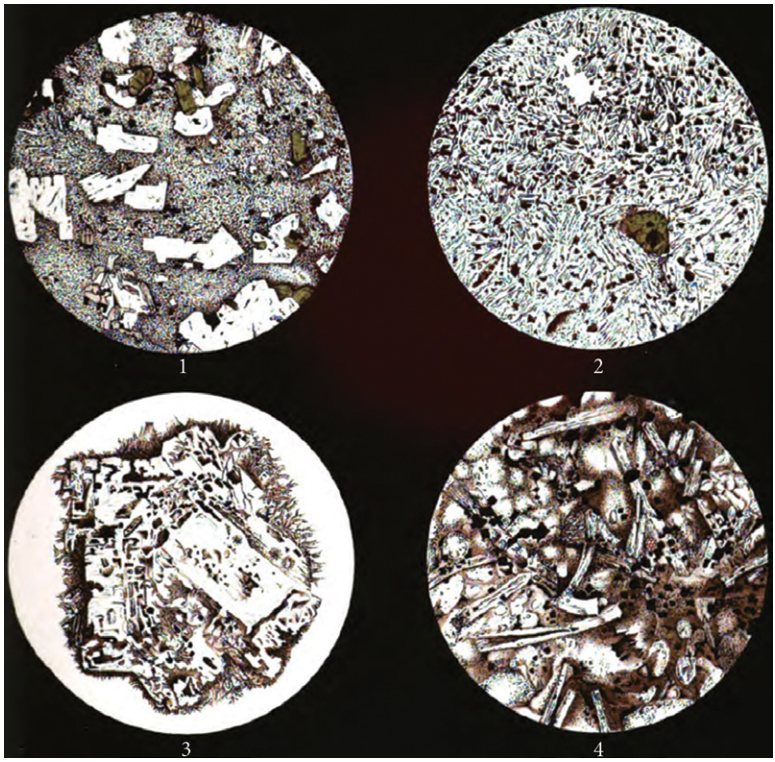


Figure 1.14 Thin-section diagrams of lavas from Krakatau from the Royal Society Report on Krakatau, 1888.

and in the field to guide the process of interpretation. Certain schematic diagrams, such as the sedimentary log, however, have more technical uses in the recording of scientific information and remain widely used. Schematic diagrams are also included throughout this book as a means of illustrating the spatial relationships of geological structures and the terminology that describes them. These diagrams are often more difficult to draw than field sketches since their subjects stem from the imagination and their perspective must be constructed rather than observed.

Today many professional geologists do not draw in the field and rely on the imperfect medium of the photograph to record geology. The opinion that sketching is an activity that is not worth the time, unless you are sufficiently 'artistic', is widespread. The history of geological

illustration, with its focus on famous artists and those geologists of legendary reputation perhaps dissuades those who are not confident of their abilities. A geological sketch, however, is not art and its aesthetic qualities are not important. It is the ability of a geological sketch to record information that defines its quality.

1.3 Everyone can draw

The commonest explanation for not wanting to create a sketch of an outcrop is 'I can't draw'—it is also not true, everyone can draw. What people mean when they say they cannot draw, is they can't draw as well as those they consider 'artistically gifted'. However, most people can draw a stick person to approximately the same level of proficiency. Of course, the stick person is easy to draw well because it is so simple, and there's not really any way for the 'artistic' person to do any better than the 'I can't draw' person. This does show a very important point. We are all capable of drawing simplified sketches of familiar objects at a minimum level of competency.

Often people who can draw pictures are considered as 'naturally talented'. The implication is that being able to draw is a talent people are born with, something genetic, such as height or hair-colour. This is, however, not exactly true. No one has the immediate ability to draw, it is a learnt ability, albeit one most natural to those with the best hand to eye coordination. The reason that some people seem to be able to draw and others not is mainly the result of practice. At some point most people give up drawing and do something else they find more rewarding. The point is those who keep drawing, have far more practice than those who stopped.

There is a general rule of competence in anything, the more the activity is practised, the better we become at it. To be an expert in something, whether it is playing the trombone, woodwork or cooking, around 10,000 hours of practice is required to be an expert. The 'artistic' person has been drawing all their life, they've practised and perfected their technique, so it seems like they can naturally draw, but their inherent ability may not be much more than anyone else. Everyone, of course, has a plateau of ability in any particular activity; the objective is to reach it.

It is not necessary practice for 10,000 hours to draw, a few hundred will suffice to become good, and after maybe 40 hours of practice a