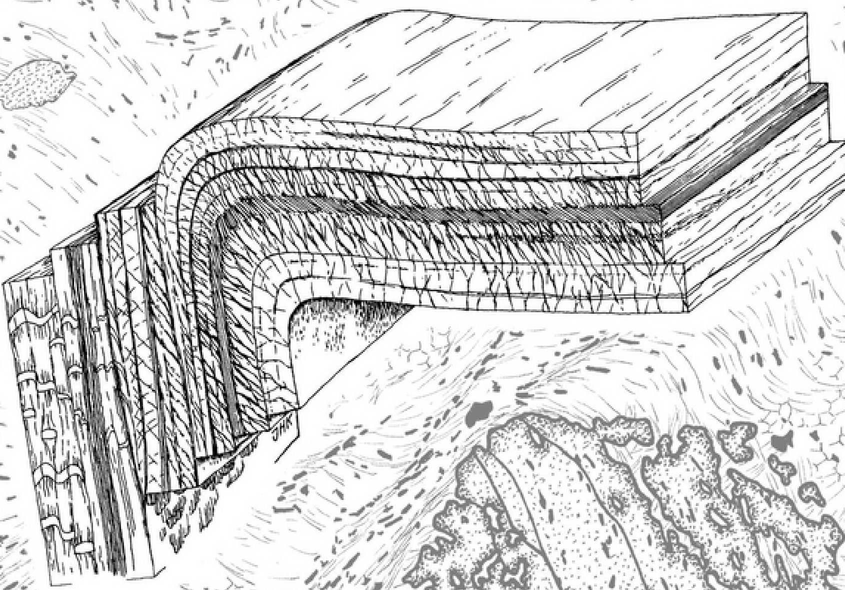
Drawing Geological Structures

THE GEOLOGICAL FIELD GUIDE SERIES

Jörn H. Kruhl



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Translated from the German by Tiana Stute

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ABOUT THE AUTHOR

Jörn H. Kruhl is retired professor of geology at Technische Universität München, Germany. He received his Dr. rer. nat. from Rheinische Friedrich-Wilhelms-Universität Bonn and held appointments in research and teaching at universities in Mainz, Salzburg, Berlin and Frankfurt/M. For decades he worked on rock structures in numerous regions and orogens, from macro to micro, in the fiel and at the microscope.

PREFACE

Drawing is not one of my strengths. My firs attempts at representing rock structures from the fiel on paper ended in disaster, both with regard to the graphic quality as well as the information content of the drawings. It took a long time for me to be able to draw structures halfway precisely and increase their recognition value; to use perspective; to learn to draw symbolically; and to compose larger outcrop drawings and block diagrams. In my early fiel days, Gerhard Voll accompanied me as role model and companion who showed me, by way of his own geologically and artistically sophisticated drawings, how it's done. In later fiel and drawing classes, many of my students were at a higher level from the start than I was when I began. Fortunately, talent is not required for geological drawing—only the willingness to observe and a little practice to acquire the basic rules for drawing geological structures.

A special merit of drawing is that it requires us to look closely. The click of the camera cannot do this. While we are drawing, we must already geologically assess what we are drawing. Therefore, not just the drawing, but also the path to it, is relevant. Graphical representation—manual drawing—is nothing old-fashioned and superfluous or just a nice pastime. In the digital age, it is urgently needed, because it teaches us to observe and reflect and it leads to concentration and mindfulness. This book is about drawing as a language—a language in which geological information can be conveyed precisely and straightforwardly. Contrary to art, a geological drawing is not open for a personal point of view. It is intended to capture a structure's geological message and represent it so that it can be correctly interpreted by the observer. Furthermore, drawings can be used to effectively and quickly store the geological information contained within a structure. Conversely, drawings give us quick and easy access to information while also providing us with a highly informative archive. This book is an exercise book. Nevertheless, it contains only a few, exemplary exercises. This is because, apart from the basics, geological drawing can only be learned to a limited extent with the help of dry training. One learns by observing structures in rocks and under the microscope, and by drawing them directly. For effective practice, one must go out into the field or to the microscope, or, if necessary, search for suitable samples in the geological collection. This is the only way to observe structures in different ways—by walking around the rocks in an outcrop, looking at them up close and from far away, using a hammer and chisel to expose important surfaces, or by varying magnifica tions and other conditions under the microscope.

This book is intended to stimulate such practice and be a companion that exemplifies by means of different rocks and structures, the many possibilities of drawing and its development stages from start to completion. A further focus of this book is how drawings can be optimally composed with regard to high information content and quick access to this information. In addition, this book is intended to serve as an encouragement to apply drawing in daily practical work—including areas beyond those discussed here!

This is also important: The geological sign language presented in this book is not an unalterable set of rules. Like every language, it is flexible and open to change. Although the foundation of drawing may stay the same, every person can interpret the rules in their own way, develop new schemas of drawing, and arrive at their own “dialect.”

For didactic reasons, many drawings have been revised or completely redesigned for this book. Several drawings, however, were taken directly from my field books or microscopy notes—with thick lines, mistakes, and corrections. They are unclean and don’t always follow the rules, but reflec the real situation when drawing is a daily work instrument. Whenever possible, these drawings are depicted in their original scale, or at least not greatly reduced. They shall not be made prettier than they are. Even though it is alright and good (and even necessary for certain purposes) to make clean and aesthetic drawings, the hasty and coarse line is the normality when drawing from nature. The quick, rudimentary sketch is the colloquial language of geological scientifi work. This is also covered in this book.

The foundations of this book arose mainly through my own practical work in the fiel and at the microscope, but also through numerous microscopy and several drawing courses for which I could occasionally, despite crammed curricula, fin the time. The interest of the students as well as the colleagues was always motivating. Thank you for that.

In addition, my thanks go to Tom Blenkinsop, who encouraged me to write this book; Herbert Voßmerbäumer, who, as reviewer and with his positive attitude, helped to get the book started; as well quite a few anonymous reviewers who spoke generously and favorably about the project. The book manuscript clearly benefite from the careful inspection by Uwe Altenberger, Annette Huth, and Matthias Nega. I deeply thank you for this. Last but not least, I would like to thank the Wiley-Blackwell staff, who have accompanied the book, with great patience, through its different stages of development over the years—especially Ian Francis, Kelvin Matthews, and Delia Sandford, who accepted, with friendly serenity, my numerous excuses for why the manuscript was still not finished and Sanjith Udayakumar, Ramprasad Jayakumar and Arabella Talbot, who supervised the book in the production phase.

Jörn H. Kruhl
Munich, January 2017

1

INTRODUCTION

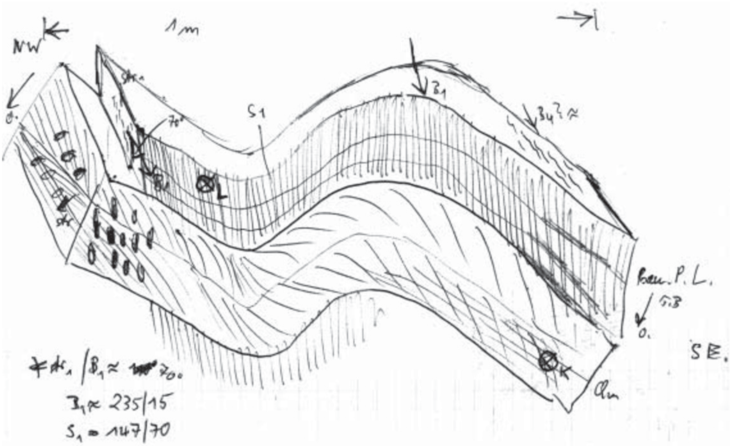
> *"Of course you should draw! You should draw everything that can be drawn . . ."*
>
> *"But, Professor, I have no artistic talent!"—"You do not need it! You aren't supposed to make art, but simply draw as well as you write. Firstly, so that you can learn to better see and observe, because the drawing pencil forces the eye to look closely and give a detailed account of the facts, for drawing is guided seeing; secondly, because drawing is often the shortest and best form of description. For this you need no talent, only diligence and a little guidance . . ."*
>
> (Hans Cloos, 1938)

Drawing is one of the elementary human abilities. It requires practice. But one must not draw with the skill of a Leonardo da Vinci or an Albrecht Dürer to be able to create drawings that are informative, aesthetic, and a joy to others. The drawing of geological objects is at a level that anyone can reach with a little practice and by following a few rules (Figure 1.1).

When we talk about drawing, we usually mean *artistic drawing*. In the case of Leonardo da Vinci—the brilliant painter, sculptor, architect, naturalist, and engineer of the Renaissance—this includes *technical* or *scientific drawing*. But in later times, the artists were rarely scientists and the scientists rarely artists. The tasks were distributed. Alexander von Humboldt "measured the world" and Aimé Bonpland drew it. Carl von Linné systematized species classification while Maria Sibylla Merian painted insect and flower pictures, and John James Audubon left behind "The Birds of America." Only a few artists sketched geology (apart from the omnipresent Goethe), like Robert Bateman, for example: "I enjoyed painting the rock, a kind of granite called gneiss, using little trickles of turquoise and pink and yellow and gray. When I paint rocks I like to convey their characteristics and to make sure that they belong in the landscape and are recognizable geologically" (Terry, 1981); it is the geoscientists, rather, like Clarence E. Dutton (1882) or Albert Heim (1921), that have seen rocks and their structures with the eyes of artists (Figure 1.2).

Today, constructive drawing is what is meant by the term technical drawing, and that is done almost exclusively by computers. Academic (or scholarly), in particular scientifi and specificall geological, drawing resists automation, because

Drawing Geological Structures, First Edition. Jörn H. Kruhl.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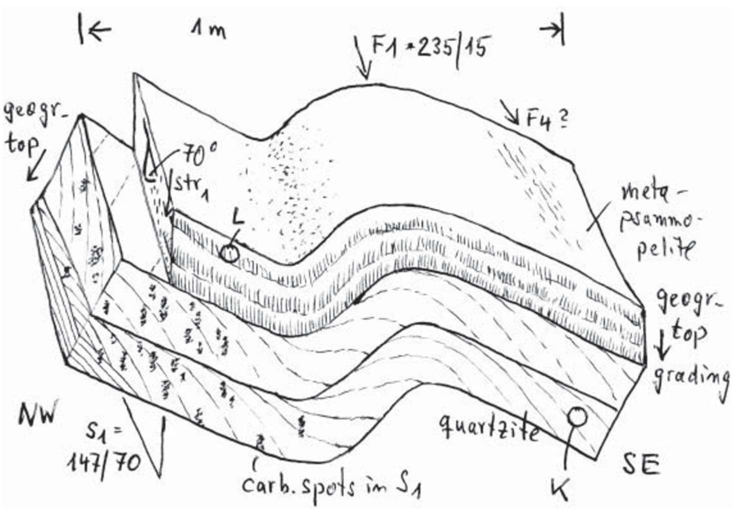
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(b)

Figure 1.1 *One of the author's early, but failed, attempts to draw samples and outcrops in the field, and a better version of the same drawing.* ***(a)*** *Monoclinic fold in psammopelite and quartzite layers of the Moinian (Grampian Highlands at Loch Leven, Scotland); field drawing; outcrop KR513; field book 6 (Kruhl, 1973). The drawing contains numerous shortcomings; above all, imprecise layout of lines, a sloppy perspective, and an incorrect positioning of foliation planes in the metapsammopelitic layers.* ***(b)*** *The same drawing redrawn years later. Cross bedding and S1 foliation planes are more precisely placed; the perspective is correct and, consequently, the 3D appearance of the drawing is better; the carbonate spots are more realistically illustrated; and the labeling is more closely related to the structures. Circles L and K indicate positions of samples. Both drawings ca. A6; black ballpoint pen.*

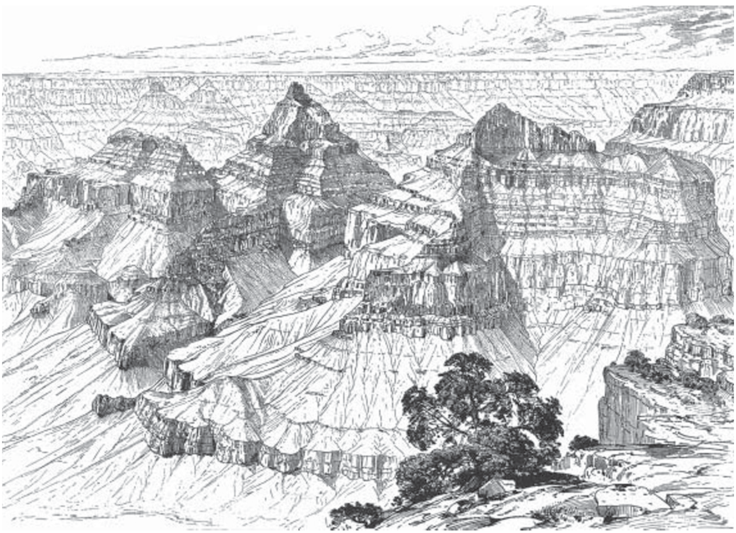


Figure 1.2 *Drawing of part of the Grand Canyon, "Vishnu's Temple" (Dutton, 1882, plate XXXIV): a felicitous combination of artistic, geological, and geomorphological representation.*

nature knows no straight lines. Geological objects, like rock layers, folds, volcanic dykes, foliation planes, joints, and the outlines of crystals cannot be represented using the shapes of Euclidean geometry. This is not a question of precision, since the shapes of all these objects don't just vary by chance from the Euclidean form. We know today that many natural processes are not linear and produce shapes of non-Euclidean, fractal geometry (Mandelbrot, 1983). Many geological shapes appear complex and are usually described qualitatively (*sutured, rounded, amoeboid*) or are represented with the help of picture plates, like the degree of rounding of sand grains, for example. These images are usually paired with specifi names (*angular, subangular, subrounded, rounded*) to ensure the transition to a written description. Complex structures can be captured truly precisely only when they are quantifie using fractal geometry. Using these rules while sketching geological structures is well worthwhile. The gain in naturalness and closeness to reality is big.

While scientifi drawing is based on a number of rules of artistic drawing, it has many of its own laws. Therefore, geological drawing requires different rules, in part, from artistic drawing. However, the principally irregular form of geological objects does not necessarily mean that it must always be drawn "irregularly" or "fractally." There are reasons for schematic, Euclidean drawing. This is why geological drawing must shuttle between lifelike and abstract representation. This is not easy, and the questions of when is it better to draw realistically, when is an abstract representation more effective, and how can a balance be established between the two, will be discussed in detail.

What is drawn must, however, already be technically understood and interpreted. This is the only way to select and distinguish between what is geologically important and unimportant. "It is the theory that determines what we can observe" (Einstein, 1955). Or, in other words: "You only see what you know" (Weizsäcker, 1955). When transferred to the drawing of geological structures, this means: We only see what we already have as a mental model. We only see the geological structures we expect and that already belong to our knowledge base. Although this may seem a little bit strict, it is true that we have difficulty perceiving and often dismiss structures that we do not know and that aren't part of our empirical knowledge.

Of course it is fundamentally possible to perceive even the unexpected or unusual, but it's hard, and we therefore do well to look at structures exactly before drawing them. If we interpret first, it will be easier to perceive the unexpected and unusual, and incorporate it into our knowledge and experience. This can be time consuming, and causes difficulties Nevertheless, drawing itself, the physical process of seeing and sketching geological objects, is on a level of craftsmanship that anyone can achieve with a little practice, and, in any case, a "bad" drawing is still better than no drawing!

There are some aspects of geological drawing relating to geological maps and the construction of profile that we will not touch upon, because they veer too much into the fiel of technical drawing. For this, there are a sufficien number of good books and, above all, websites where these techniques can be trained online. Furthermore, this book is not about drawing fossils. Although the drawing of fossils coincides in many ways with the drawing of geological structures, there are still some fundamental differences, like the object fidelit , which is essential to the drawing of fossils but more of a hindrance when drawing geological structures. The present book is mainly about:

- the way in which one must represent geological objects at different scales,
- how the purpose of the representation affects the nature of the representation,
- the way in which a balance between detailed and symbolic representation must be maintained in such drawings, and
- how one can practice all of this.

We will go from small to large, from thin section to outcrop, especially the ensemble of outcrops, and from the two-dimensional representation to the three-dimensional. This order has been chosen in part because two-dimensional representations are technically and in their principles easier, and because the two-dimensional surfaces of three-dimensional objects are seen first Secondly, big geological objects are made up of many small pieces, and the bigger picture is best understood, if we understand the details.

This book is intended as an exercise book for the purpose of self-study. It should encourage the playful retention of structures, the anchoring of one's own geological data collection in the form of graphic representations, and the occasional replacement of the camera with paper and pen in the field In addition, this book is meant to encourage the use of the benefit of exact drawings especially when it comes to precision and conciseness (e.g., in publications). Finally, I would like the representations in this book to show that geological structures have not only scientifi value but also deserve our attention for their complexity and aesthetics.

1.1 Why Do We Need Drawings?

Anyone who has tried to describe a thin section, a rock sample, or an outcrop without the help of drawings (or photos), would probably not pose such a question. Compared to the expressiveness and the rich detail of graphic representations, the spoken or written word is an inadequate tool. Drawings and photos can document things that would otherwise take much more time to describe, in no time. And since graphics can be digitized, the electronic storage and processing of graphic information is not a problem.

There is no strong conflict between drawing and photo. Photography is a quick and easy type of documentation. When taking pictures, one can be sure that all the details in the range of resolution are preserved. Even on a small scale, subtleties, which would not be accessible in a drawing or which would cost a lot of time to include, can be captured. Those who have participated in a field trip with an eager leader racing through a packed itinerary have learned to appreciate the camera. If 20 minutes are allotted to an outcrop with nice sedimentary structures or complex folds, one can leave the fiel book or the sketch pad in one's pocket, unless of course one belongs to the small, gifted group of precise fast-drawers.

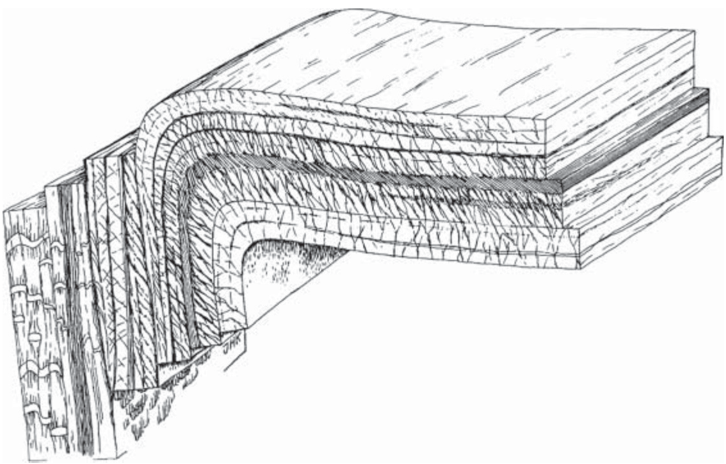
On the other hand, the photograph reaches its limits when it comes to filtering out the essentials from a jumble of small details. Who hasn't photographed an outcrop that appeared clear and impressive to the eye, or even a rock thin section, that then, in black and white or in color, on paper or on the screen, appeared only as an indissoluble mixture of details distorting the essentials? In addition, the photo also captures the unimportant surrounding and provides information that we do not need and that we must carry with us as interfering ballast. Computer-aided photography provides opportunities to smooth surfaces and thus to convert photographs overloaded with details into sketch-like representations (Hayes, 2008). This development, however, is still in its early phases and it remains to be seen how useful it will be for geological objects with complex, detailed structures, and, especially, if the effort of editing the photographs exceeds that of sketching.

For three-dimensional objects, it may prove especially hindering that a photo only delivers a two-dimensional view of structures that in small form, even at the two-dimensional outcrop face, appear three-dimensionally and contain much more information in three dimensions than in two (Figure 1.3). We can

→

Figure 1.3 (a) *Photo of the "Spitznack" Fold (near the Loreley, Middle-Rhine region, Rhenish Massif, Germany). Centimeter- to decimeter-thick metapsammopelitic layers are bent to an open, monoclinic fold. The boundaries of bedding are represented by strong fractures in the horizontal fold limb and by weak fractures and differences in brightness in the vertical limb. In addition, a schistosity can be recognized. It is represented by narrow-spaced, nearly parallel fractures. The schistosity is pronounced and steep in the horizontal limb, fan-shaped in the fold crest, and is barely visible in the steep limb. Additional fabric details cannot be recognized. Hammer as scale.* ***(b)*** *Schematic drawing of the same fold. Based on the small protrusions and the fabrics that can be recognized on them, the planar, 2D view has been supplemented to form a 3D block. Highlighted are (i) the partitioning of the schistosity to two different sets of foliation planes in metapsammitic layers, (ii) the pile shape of the schistosity in metapelitic layers, (iii) the stretching lineation on an obviously bedding-parallel foliation plane, (iv) the compressed and sheared quartz veins in the steep limb, and (v) the slickensides on steep bedding-parallel shear planes. All these structures are not visible in the photo and are only revealed by close observation of the fold. Modified after Zurru and Kruhl (2000, Figure 33); size of original drawing ca. B4. A more comprehensive drawing is shown in Figure 4.27.*

(a)



(b)

(interpretatively!) capture three-dimensional structures more clearly and comprehensibly on two-dimensional paper when drawing perspectively. This also applies during microscopy: The brain can better distinguish between important and unimportant, and filte out the structures in question. How aesthetically and clearly identifiable the deformation and metamorphic fabrics could be, were it not for the retrograde influence that transform aesthetic plagioclase twins into an "ugly" mix of small mineral grains or that superimpose all the striking quartz deformation structures with an iron-plated net of micro fractures.

This means: Drawings are important when it comes down to emphasizing details or omitting the unessential, and when representing the three-dimensional three-dimensionally. This is a scientifi decision! The strengths of the sketch are highlighting, omitting, and combining things that were not together in the original. One composes an image so that it meets the necessary requirements. This may seen "unscientific at firs glance. But fidelity is not most important; what is worth striving for is the scientifi documentation and the interpretation of structures. Of course, structures that do not belong together should not be put together in such visual compositions, and no other, or even false, interpretations may emerge. But a drawing is not purely for documentation; it communicates beliefs and ideas. From this follows: Drawings must always contain an interpretation. Strictly speaking, one can hardly draw without interpreting, because even an omission is an interpretation. The geological stereogram (Chapter 5) is one of the most impressive forms of interpretation. In it, detailed pictures from individual outcrops are combined into one image that is neither to scale nor must show things next to one another as they occur in nature. The point of a stereogram is to represent the principle of the large-scale structure of geological area. The stereogram is therefore the model that a processor makes of a given area.

Drawings assist geologists in their everyday work. Sketches preserve the memory of details that would've been impossible or too complicated to photograph in the first place (poor lighting conditions, too many details, vegetative coverage, etc.). Drawings become indispensable when it comes to defending one's hypotheses in discussions and when trying to directly convey impressions of outcrops to discussion partners who are unfamiliar with them. Even in a cartoon-like presentation of how structures develop, drawings are well suited. In any case, the apparatus of geological drawing must be mastered in order to draw accurately and powerfully.

In microscopy, drawings serve as a memory aid. They help record the otherwise fleetin impressions that arise during the examination of thin sections. Here, in contrast to laborious photography, drawing is an effective form of documentation. It does, however, require its own style that is different from the style of outcrop, sample, or exact thin section drawing.

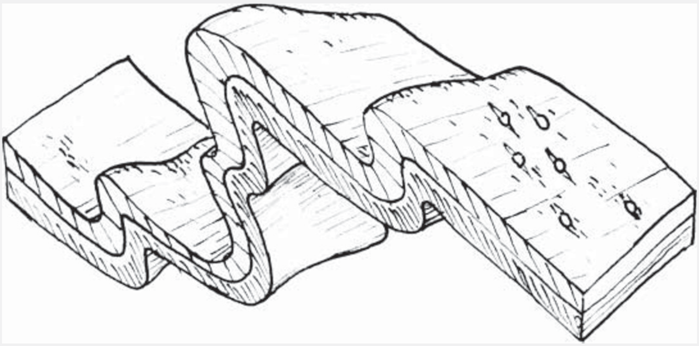
Even the processing of data is facilitated by drawing. If one wants to evaluate, on the basis of one's fiel book, how often and where certain geological structures (e.g., foliations or shear zones) occur in a given area, even just rapidly flipping through the drawings in a fiel book can give a rough idea. Searching for this information in texts can be extremely time-consuming. Additionally, the close connection between drawing and text (labeling) increases the informational content. It is even possible to obtain certain information (e.g., spatial relationships of lineations to foliation planes, the orientation of joints to layering) from careful drawings that one did not pay attention to or write down in the field

Perhaps the most outstanding feature of drawings is that they are an important tool for thinking (Larkin & Simon, 1987). Experiments provide evidence of the "analog," that is: the visual processing of information in the brain (Brooks, 1968, Shepard & Metzler, 1971—cited in Metzig & Schuster, 1993). "One technique for avoiding the rigidity of words is to think in terms of visual images and not use words at all. It is perfectly possible to think coherently in this way ... The visual language of thought makes use of lines, diagrams, colors, graphs and many other devices to illustrate relationships that would be very cumbersome to describe in ordinary language" (De Bono, 1990, p. 73).

Drawing, like writing, is suitable—in many cases even more so!—for sorting and bundling thoughts. While drawing, the unimportant can be separated from the important, new ideas can form, and old ideas can be specified It can also be resolved whether ideas are even usable and can be translated into logical and consistent models. Therefore, we should draw as often as possible while discussing, explaining, or even while thinking; what we are talking or thinking about should always be conceptualized with simple sketches or accompanied by schematic drawings. Such drawings can stretch our imagination (and that of others) and help to fin the mental entry into a topic.

Finally, the circumstantial information can be more effectively saved with the help of drawings. "Pictorially presented material or visual representations [can] be stored particularly easily and permanently," and "descriptions of many creative thinkers specificall [reference] the course of pictorial ideas and the resulting creative act (like Poincaree, Kekule, Heisenberg, and others)" (Metzig & Schuster, 1993). The advantage of the schematic sketch versus an artistic, detailed, and extensive drawing has also been highlighted in investigations. "And so the development of details compared to outlined images leads not to an improvement of memory (e.g., Angin & Levie 1985). In fact, insignifican image details are forgotten shortly after being presented" (Rock *et al.*, 1972—cited in Metzer & Schuster, 1993). Although the brain is well suited for processing visual information, a photographic reproduction of individual details is not saved, "but rather, stored visual prototypes are resorted to for a mental image ... " (Metzig & Schuster, 1993).

Exercise 1.1:



Exercise 1.1 ***(a)*** *Describe the fold structure in all of its geologically relevant details.* ***(b)*** *Give your description of the folds to a fellow student or colleague and have them draw the fold. Compare this drawing to the supplied sketch of the fold.*

Notes on Exercise 1.1:

What is geologically relevant? Certainly the monoclinic form of the fold. It refers to a movement of the "top" to the left (in the sketch). Furthermore, parts of the sketch and their geometries can be linked with geological structures and processes as follows:

- The angle of ~50-70° between the fold limbs with a "moderate" shortening,
- the "light" layering with its fan-shaped, wide-spaced foliation planes with a more quartz-rich, mica-poor composition,
- the "dark" layering with its slightly pile-shaped, narrow-spaced foliation planes with mica-rich composition,
- the foliation-free upper margin of the lower layer with a grading (mica-free versus mica-rich) and the resulting "stratigraphic up" that points, geographically, down,
- the slightly thinned fold limbs and thickened fold crests, also in the quartz-rich layer, with crystal-plastic deformation of the quartz and, consequently, with deformation temperatures of >300°C,
- the slightly curved shape of the fold axes with clearly crystal-plastic behavior of the rock layers.

- Additionally, the lineation on the layering (mica and feldspar- and garnet-blasts with preferred orientations) attests to the fact that (i) the foliation of the firs deformation event (D1) already lies parallel to it, and, with that, the fold already represents a second fold and the sketched foliation a second foliation, and (ii) the extension of the first deformation event (D1) lies approximately perpendicular to the D2-fold axes, and that, therefore, the kinematic system during D1 and D2 was probably oriented the same way.

Probably, you will notice a difference between the present fold drawing and the fold drawing based on the description.

1.2 The Tools

When drawing in the field the only drawing materials we need are a pen and paper. It is important that the pen leaves clean lines. The paper should be smooth (but not too smooth) and blank. Smooth paper has poor moisture retention, which gives a clean line. If the paper is too smooth, however, the pen will slip easily. Lined or graph paper interferes with drawing and scanning. Of all utensils used for artistic drawing, the ones that are most practical for geological drawing in the fiel are pencils, felt-tip pens, and ballpoint pens. The pencil is often recommended for drawing in the field I, however, fin it not particularly useful in most cases. If one doesn't want to keep sharpening it to avoid thick, inaccurate strokes, one must work with a hard pencil. This, however, generates pale, low-contrast drawings that require great effort by the brain to grasp and decrypt. Even when rapidly flipping through a fiel book, the higher-contrast drawings can be identifie and compared more quickly.

A black ballpoint pen or a waterproof felt-tipped pen with a thin line offers better services compared to a pencil. Ballpoint pens also have the advantage that, depending on the pressure, lines of different weights can be generated without having to continuously sharpen the pen. The lines of waterproof felt-tipped pens can bleed on rough or wet paper. Waterproof paper is expensive or only available in fiel books ("rite-in-the-rain") whose layouts aren't always favorable for drawing. Damp paper, however, can be avoided with a large umbrella (the most important piece of equipment for any field geologist), for example. But if it's pouring, fiel work beyond just mapping is not useful, because fin structures are poorly visible in wet rocks. It is better to stay at the inn, prepare for the next field day, evaluate the drawings from the previous days, or enjoy some of the local culinary specialties. Not being able to simply erase strokes also breeds precision and thinking ahead. The pencil tempts especially beginners to draw blurredly to conceal an inaccurate observation with hatchings and the like, or to indulge their own artistic talent. Even the knowledge that "wrong" lines can be deleted leads to unconcentrated work.