Drawing in a Social Science: Lithic Illustration

Dominic McIver Lopes
University of British Columbia

Scientific images represent types or particulars. According to a standard history and epistemology of scientific images, drawings are fit to represent types and machine-made images are fit to represent particulars. The fact that archaeologists use drawings of particulars challenges this standard history and epistemology. It also suggests an account of the epistemic quality of archaeological drawings. This account stresses how images integrate non-conceptual and interepretive content.

A philosophical study of scientific images should complete two tasks. One is to understand imaging as a type of representation with distinctive capabilities (by contrast, in particular, with language). Existing theories of pictorial representation provide a good starting point (e.g. Goodman 1976; Lopes 1996; Hopkins 1998; Kulvicki 2006). The second task is to understand the diversification of different kinds of images across different scientific contexts. Existing theories of pictorial representation also offer some help with this task so long as the two tasks are taken up together. This paper considers selectivity and realism as factors in the epistemic quality of images by addressing itself to a specific kind of image—lithic illustration—used in a relatively less well studied science, archaeology.

Drawing in Archaeology

A teeming variety of scientific images takes in geometrical diagrams, anatomical drawings, Doppler radar scans, bubble chamber photographs, electron micrographs, fMRI scans, molecular models, Feynman diagrams,

Many individuals offered useful suggestions for the improvement of this paper. My thanks to the anonymous referees and to audiences at an on-line conference at interdisciplines.org, the 2006 mini-conference on Scientific Images at the Pacific Division of the American Philosophical Association, and the HPS Collective at the University of British Columbia.

Perspectives on Science 2009, vol. 17, no. 1

topographical maps, and maps of adaptive landscapes. These appear in scientific journals, textbooks, poster boards, powerpoint presentations, and lab notes—where scientists use them to formulate hypotheses, conduct proofs, describe experimental set ups, confirm hypotheses, represent and analyze data, test and calibrate instruments, solve conceptual problems, publicize their work, and teach students. The conspicuous structure of this long list suggests one way to study scientific images. As it happens, a study along the suggested lines should attend to images across the sciences.

Scientific images vary along three dimensions. One is image type, with drawings, pictorial diagrams, and photographs being examples of different image types. A second is imaging task, for images can be used to represent hypotheses, conduct proofs, or present data, for example. The third is context of use, individuated coarsely by discipline (e.g. physics, sociology), more finely by topic (e.g. human immunology, climate change), or by what might be called "working contexts" (e.g. journal articles, lab notes, lectures).

Image type, imaging task, and context of use may be viewed as systematically connected (cf. Gooding 2004a, 551–5). Perhaps, as a matter of fact, they are entirely independent, so that, for example, the type of image that is used in any given context is never determined by any task to be performed in the context. However, this is unlikely, since it appears that at least some tasks are determined by context and that some types of images serve some tasks better than others. At any rate, one approach to scientific images sets out to look for connections between image types, imaging tasks, and contexts of use. It might start out by focusing on a type of image, an imaging task, or a context of use. Thus it might focus on pictorial diagrams as a type of image (e.g. Perini 2005) or deductive proof as a task to be served by images (e.g. Allwein and Etchemendy 1996). Alternatively, it might examine a new context.

One reason this is a good idea is that philosophical writing on scientific images heavily favors the physical and biological sciences. That makes for a biased sample, since images are common in many other sciences, where they seem to make important contributions. At the very least, it would be a mistake to assume that we can generalize from features of physics and biology to features of a science like anthropology (Wylie 2002).

Moreover, the smallish sample of contexts also makes for a biased sample of image types and imaging tasks. Unlike historians of science, philosophers have so far looked mainly at pictorial diagrams used either to represent hypotheses in physics and biology (e.g. Ruse 1996; Cat 2001; Perini 2005) or to conduct proofs in mathematics (e.g. Brown 1999). Machine imaging is only now getting attention. This represents only a small portion of image types serving a wide variety of imaging tasks.

Finally, seen against the backdrop of existing work by philosophers on scientific images, there is something a little surprising about images in archaeology. The use of drawings of artifacts is well entrenched in archaeology, even though photographs are easy to make. True, drawings are used in physics and biology too, but in these sciences they seem not to be used to represent particulars: when particulars are represented, as in telescopy and microscopy, machine imaging is used. Archaeological drawings of objects stand in contrast to machine images of particulars on the one hand and to pictorial diagrams on the other.

Explaining the archaeological use of drawings of particulars means attending to facts about archaeology and also to the nature of drawings. The practice of archaeology consists in performing certain tasks, and archaeological drawings have features that make them effective at performing those tasks.

Realism and Rhetoric in Reconstruction Drawings

A complete account of archaeological drawing should cover the major types of drawing found in archaeology, analyze how drawings are used in combination with other kinds of images like pictorial diagrams and photographs, and consider changes in imaging practice occasioned by new technologies like GIS and digital three-dimensional rendering. That is a book-length enterprise, not least because archaeologists make and use dozens of different kinds of images. For now, a telling case study must suffice. The next section introduces a case study of lithic illustration. However, what is telling about lithic illustration can be brought out by contrast with another kind of drawing, the reconstruction drawing. Reconstruction drawings of paleolithic scenes are well known to non-archaeologists, and they have been studied in some detail by historians. Moreover, a standard account of them embeds an influential conception of the role of realistic drawings in science. The case of lithic illustration will suggest this conception is limited.

Reconstruction drawings either depict sites and structures or scenes of hunting, foraging, campfire life, child-rearing, and other such activities. Sometimes the drawings appear in professional journals, where they illustrate or support a hypothesis, typically about the physical features of a site or structure. For example, an archaeologist might extrapolate from a plan of the foundation of a structure to make drawings of its possible three-dimensional shapes. Far more familiar to non-archaeologists are reconstruction drawings depicting humans engaged in sundry activities. These are usually prepared for museum displays or popular science publications and are intended to serve a largely pedagogical purpose—though, as we shall see, they have also figured in professional debates.

In every case, reconstruction drawings show scenes in rich, lifelike detail, employing the illustrator's full compositional and expressive toolkit—the drawings are two dimensional equivalents of the dioramas (once) displayed in museums. As the historian Stephanie Moser puts it, the reconstructions exploit pictorial techniques that "serve to make [them] continuous with our world" so that they "draw on our own human experience" (1996, 213; see also Adkins and Adkins 1989, 145). Their style is, to use a vexed word, "realistic" (Lopes 2006).

In his study of images in E. O. Wilson's *Sociobiology,* Greg Myers describes realism in photographs and drawings as "gratuitous" or "a thicket of irrelevant detail." He writes that,

> the squiggles and splotches that do not seem relevant to the claim the picture illustrates have their own significance, as part of what makes the picture seem continuous with our own world. . . . All this detail carries no relevant information, but it does have a function, making the photo seem to be a document recording an unmediated perception of a particular piece of nature. (1990, 235–7)

For Myers, "irrelevance" is epistemic irrelevance and realism is epistemically irrelevant—it can only serve some non-epistemic purpose.

Moser echoes this view in writing about reconstructions of paleolithic life. The drawings are put forward as explaining a body of material evidence. They represent hypotheses that attribute behavioral capacities to some hominid line so as to explain facts about fossil or artifact finds. Yet many details in these drawings are unsupported by skeletal morphology, material culture, or any other archaeological data. Details of trees and rocks are entirely made up, as are details like the goatee worn by the Leakeys' Zinjanthropus boisei in *National Geographic.*

According to Moser (1996, 1998), the detailed realism of paleolithic reconstruction drawings serves a role in a professional dispute about whether australopithecines were apes or the first hominids. The drawings first embody a conception of the hominid lineage that draws a boundary between humans and apes, and then they show australopithecines as meeting or not meeting that conception. Thus images used to argue that a fossil is hominid show what looks human, whereas images used to argue the contrary show what looks like an ape. Apes do not wear goatees but humans do, so Zinjanthropus is hominid. Reply: unlike humans, apes have little mastery over their environment, and (as this drawing shows) Zinjanthropus hid in the trees from predators, so Zinjanthropus is not hominid. The images contribute to these arguments by establishing a continuity between the paleolithic and our world and by drawing on our own human experience. This contribution exploits their realism. In this way, the drawings "make arguments in a distinctively visual manner" (Moser 1996, 184).

As a historian, Moser is especially interested in paleolithic reconstruction drawings as documenting positions taken in the dispute about hominid status and the difficulties of settling the dispute. She writes that the drawings "reveal how australopithecines were conceptualized as the first ape-like ancestors who exhibited some traits of supposedly human behavior" (1996, 189). So far, so good.

However, Moser (1996, 186–7) goes on to endorse the research agenda of Michael Lynch and Steve Woolgar in *Representation in Scientific Practice* (1990). For Lynch and Woolgar, the proper business of the scholar of scientific images is to expose how scientists use images to "enlist agreement through persuasive appeals" (1990, 3). Here is how Bruno Latour, writing in the same collection, thinks of "holding the focus steady on visualization and cognition:"

> Who will win in an agonistic encounter between two authors and between them and all the others they need to build up a statement S? Answer: the one able to muster on the spot the largest number of well aligned and faithful allies. . . . we should concentrate on those aspects that help in the mustering, the presentation, the increase, the effective alignment, or ensuring the fidelity of new allies (1990, 23–4).

In this "rhetorical or polemical situation," images have a "unique advantage," expressed verbally as, "You doubt what I say? I'll show you" (Latour 1990, 36). Ian Hacking agrees: we should "ask whether the point of [scientific] representations is to convey information at all, or rather to convince us that this is solid stuff, not to be challenged, and not challengeable" (1991, 252).

No doubt images are effective at "consensus formation." Paleolithic reconstruction drawings seem to have been remarkably persuasive, and so make for a rich case study of images in scientific rhetoric (another is Myers 1990). Nevertheless, there is reason not to make too much of this—at least, not to make everything of this.

Skepticism concerning the epistemic quality of images goes back to Plato and is remarkably resilient (Freedberg 1989, Jay 1993). In philosophy, for example, Thomas Kuhn asserted that scientific images "are at best by-products of scientific activity" (1977, 342). In at least some fields, scientists have vigorously debated the propriety of using images to represent experimental results (Galison 1997). The view that images can only be studied as tools of rhetoric accepts without question Platonist skepticism of the epistemic quality of images.

The paleolithic reconstructions that Moser discusses are a special case in archaeological imaging practice. As already noted, some archaeological reconstruction drawings depict structures so as to try out hypotheses about the structures given what remains of them in a dig. In their handbook on archaeological illustration, Lesley and Roy Adkins write that these drawings "require the archaeologist to face up to and even challenge the evidence, since the meaning and function of the surviving evidence has to be examined and interpreted with precision to see whether a reconstruction is plausible" (1989, 131; see also Shelley 1996, 289–93). For this reason, archaeologists sometimes make more than one drawing based on the same evidence, so as to test the plausibility of different scenarios.

The epistemology of these drawings may well parallel the epistemology of reconstruction drawings in paleontology, which is relatively well studied (Shelley 1996, 285–6). Paleontologists use devices like the camera lucida to make line drawings of two-dimensional fossils, from which they extrapolate drawings of the three-dimensional forms of the fossilized organisms. David Gooding argues that these reconstructions are hypotheses that best explain the two-dimensional fossil imprint (2004a, 561–5; 2004b, 281–6). A reconstruction is adequate if sections taken from it accurately predict features of the two-dimensional fossil and if it can be shown that an organism with the form depicted in the three-dimensional reconstruction would imprint the two-dimensional shape of the fossil given known geological processes.

In sum, the literature on reconstruction drawing makes several assumptions. First, there is a dichotomy between detail, realism, and visuality on one hand and selectivity on the other. Second, realism and visuality serve non-epistemic tasks. Finally, reconstruction drawings do epistemic work only when they represent clear hypotheses for testing.

Lithic Illustration

Archaeological images of stone tools and their byproducts are often drawings: while photographs are taken, they do not predominate. Why? After all, drawings are difficult and expensive to make compared to photographs, and they typically entail a greater loss of information. Solving this puzzle means attending to the role that lithic illustrations play in archaeological practice and also to the specific capabilities of drawing over machine imaging.

In their handbook on archaeological illustration, the Adkins undertake to explain the persistence of lithic drawing. They note that "photography usually gives a good overall realistic impression of the subject, but it has the disadvantage of being unselective," whereas "a drawing can convey much more relevant and comparable information and can be edited more easily than a photograph" (1989, 6). In sum, the advantage of photographs lies in their realism and the advantage of drawings lies in their selective content. Moreover, selectivity is important. First, "the purpose of the illustration is to convey not only information but also an interpretation of that information" (Adkins and Adkins 1989, 5). Second, "a good drawing selectively portrays the details that the reader needs to see and edits out irrelevant details, so that the illustration can be understood much more easily" (Adkins and Adkins 1989, 7). Here, "understanding" cannot be the understanding made available by photographs.

One assumption underlying thinking about reconstruction drawings clearly carries over to thinking about lithic drawings: detail and realism line up against selectivity. Added to this, photography is taken to be unselective, hence detailed and realistic, whereas drawing is taken to be selective.

However, it is a mistake to situate realism and selectivity as complementaries which map onto photography and drawing as disjoint types of representation (Gombrich 1961; Lopes 1996). For one thing, photographs are selective. No image carries full information about its subject. Photography entails a loss of information and allows some room to choose what information to capture and what information to lose. Going a step further, any kind of machine imaging is selective in this way, and machine imaging systems are often built to represent very specific determinables—think of infrared satellite imaging as an example. Moreover, drawings can be realistic in whatever sense of realism represents the thought that they are distinctively visual. The equation of realism with the representation of irrelevant detail is patently inadequate. So is the thought that selectivity defeats realism. A line drawing can be supremely realistic (Lopes 1995; Kulvicki 2006; Lopes 2006; Abell 2007).

The lesson is not that the notions of selectivity and realism should be abandoned. Rather, we should not say that photographs are realistic and drawings are selective . . . end of story. We should raise the question: in what respects are each kind of image realistic and selective? In answering this question, a good place to start is the uses of the images.

To find out what an artifact is for, examine the details of its making: this principle works just as well for drawings of artifacts as it does for any other artifacts. Luckily, the details of lithic drawing are set forth lucidly and systematically in Lucile Addington's manual for archaeological illustrators (1986; see also Dillon 1984). Flaked stone tools are drawn either by an archaeologist or, more often, by a collaborator with specialized training in lithic drawing. Addington is such an illustrator, and her manual is intended to be read by illustrators-in-training and also by archaeologists seeking explicit instruction on the principles of lithic drawing.

As Addington's manual makes clear, lithic drawings must serve two needs. First, a "universal language" is needed to ensure that drawings from any lab can be compared easily and reliably (Addington 1986, ix, xiii–xiv). Note that photography answers this need perfectly well. Second, the drawings should convey all and only relevant information about the objects represented. What is relevant depends on the nature of the object represented and the role of the representation in its context of use. Lithic drawings represent artifacts and they represent them as artifacts—as objects whose shape is largely the outcome of deliberate human activity—in a context where they are objects of study for their artifactual characteristics. As Addington remarks, "properly drawn artifacts are invariably more informative than photographs in illustrating a prehistoric knapper's workmanship as well as an artifact's form and diagnostic features" (1986, ix).

Knapping involves repeatedly striking a stone, usually flint, in order to remove flakes. Either the flakes themselves are knapped further or the stone from which they are taken is knapped to leave behind a pattern of flake scars. The stone is thus "retouched" in order to achieve a finished shape, and it may subsequently be subjected to reuse or weathering that further changes its shape or surface. Flaking stone is not of course a way to pass the time. Stone tools were made for use as knives, cleavers, scrapers, arrowheads, and hammers (Whittaker 1994). Thus a lithic drawing must reveal how a stone was knapped and with what purpose in view. To do this, it must show: scale; the pattern, sequence, direction, and force of blows to the stone; the bulb and platform of percussion; areas of retouch, snapping, and truncation; areas of grinding, battering, or abrasion; fractures caused by heating; the effects of materials; and pitting and sickle sheen. Fossils, variegated coloration, patina, seams, banding, and crystallization are not shown—these features have geological rather than intentional causes.

Since selected features of each stone must be shown in a way that allows for reliable comparisons, lithic drawing conforms to several conventions. The object is illuminated from 45° in the upper left. The ventral surface of the stone is placed at the bottom of the drawing and, when multiple views are shown, profile views are shown next to the edges they display. The scale is fixed at 1:1. Paper types, drawing instruments, and techniques of pencilling and inking are standardized. Finally, a well-defined representational vocabulary is strictly followed. Stippling indicates the cortex of the stone, with greater density indicating greater roughness. Outlines show flake scars in their sequence of making. Lines imitating the ripples caused by flaking indicate the direction of a blow and, by their thickness, its approximate force. They are shown as attached to only one side of a flake scar and to two sides of a bulbar surface. Curved direction lines indicate snapped surfaces and thermal fractures are shown by spider lines, spoked lines, or swirls. Moreover, stippling and direction lines are dual purpose, since they convey the volume of the stone as well as its surface details. This vocabulary of marks replicates the look of the object. It is supplemented by a non-mimetic vocabulary. Arrows point to bulbs of percussion. Dashed lines show where broken fragments of a stone fit together. Tick marks coordinate multiple views so that key features of the stone can be matched up.

In order to make a drawing complying with these rules, an illustrator must "read an artifact's surfaces" (Addington 1986, 2). He or she must have an eye for flake scars and what they indicate about how they were made and in what order; for the different types of flaking, including retouch, snapping, truncation, grinding, and cleaving; for the effects of materials (flint is most common but other stones are also knapped); for the effects of weathering and reuse, which must be distinguished from the effects of knapping; and finally for the practical challenges facing a knapper who is knapping a particular stone, since every stone is different and not all "readings" of a stone are consistent with what a knapper can do with it. An archaeologist who is not also an illustrator is capable of the same reading, but only an illustrator is able to embody the reading in a drawing.

Selectivity serves many ends. Bill Wimsatt contends that some scientific tasks are "at least virtually impossible to do without visualization" (1990, 112). In these, images serve to reduce informational overload. Some set off similarities against a background of difference, some set off differences against a background of similarity, and some factor global similarities and differences into local similarities and differences (Wimsatt 1990, 117). Wimsatt proposes that images are good for reducing informational overload because "the visual system has been selected for efficient, reliable, and rapid solution" of these tasks (1990, 117). However, the selectivity of lithic drawings serves another function that is otherwise virtually impossible: to isolate features of artifacts as intentionally made.

Lithic drawing challenges all three assumptions underlying conceptions of archaeological imaging that focus on reconstruction drawings. There is no real dichotomy between detail, realism, and visuality on one hand and selectivity on the other: lithic drawings beautifully illustrate a concourse between detail, realism, visuality, and selectivity. Realism is not only an instrument of persuasion, for lithic drawings are realistic and yet do honest epistemic work. And this work does not consist in presenting hypotheses, for the drawings represent particulars rather than general types.

Drawing in History

According to a simple history of images in science, machine imaging technologies, as they are invented, supplant drawing. Clearly this simple history needs refinement, since drawing persists in many scientific contexts, presumably because it serves tasks that are hard to carry out by machine imaging. Peter Galison and David Topper have suggested refinements to the simple history which combine to form a powerful hypothesis. Since this hypothesis predicts that drawings are not normally used to represent particulars, lithic illustration challenges the hypothesis.

According to Galison, the history of scientific images has three major phases. In the first phase, from the mid-seventeenth to mid-nineteenth centuries, scientific images are made by hand in order to standardize observed phenomena by eliminating idiosyncrasies (Daston and Galison 1992, 84). That is, they are made to represent types. Thus Goethe described his skeleton as “a general picture containing the forms of all animals as potential, one which will guide us to an orderly description of each animal” (quoted in Daston and Galison 1992, 87). In order to make such a drawing, the scientist must exercise judgement in selecting typical, characteristic, ideal, or average features to be represented.

The second phase comes with the invention and adoption of technologies such as photography and x-ray imaging beginning in the nineteenth century. For Galison, the invention of these technologies did not determine their adoption. Instead he proposes that they were adopted to eliminate interpretation from the imaging process. As one scientist put it, “we are able to employ new processes that reproduce the drawings of the original object without error of interpretation” (William Anderson quoted in Daston and Galison 1992, 100). On this view, interpretation diminishes objectivity and so should be minimized in science (Daston and Galison 1992, 117–23; Galison 1998). Machine imaging was thought to eliminate interpretation and ensure objectivity, breaking the “dreaded circle of art, interpretation, and personal predilection” (Galison 1998, 331).

In Galison’s third phase, beginning in the early twentieth century, scientists reconcile machine imaging with interpretation. For example, the authors of an atlas of encephalography published in 1941 declare that “a ‘seeing eye’ which comes from complete familiarity with the material is the most valuable instrument which an electroencephalographer can possess” and “no objective index can equal the accuracy of subjective evaluation” (quoted in Galison 1998, 335). Galison attributes this phase to a growing trust in the judgement of scientists.

If this history is correct, then one should expect to see a resurgence of drawing in phase three. Yet nothing like this happens. Although drawings are common in science, they rarely supplant an adopted machine imaging technology. Galison's history is incomplete.

Topper (1996) argues that early scientific images are by and large drawings that represent types—botanical and anatomical drawings are prime examples. In many cases, what is represented has features never found in a particular specimen—it is an idealization. In other cases, the object represented has the features of a particular specimen, but we are to abstract from its particularity and take it to stand for a type. When machine imaging comes along, we see an explosion of images, made mechanically, that represent particulars and not types. (We are not to abstract from their particularized features since they present evidence about the particulars themselves). These images fix observations for later examination.

Like Galison, Topper refines the simple history. History does not show drawing entirely replaced by machine imaging. Instead, only drawings of particulars are replaced by machine-made images, so there is still a place for drawing in representing types. As Topper writes, "despite the invention of photography . . . the artist still has a role to play in illustration, for the camera captures an individual specimen (the particular) whereas an artist can depict the archetype" (1996, 234). Michael Lynch (1990) explains why. In an account of drawings paired with photographs in cell biology, he observes that the photograph shows the "unique, situationally specific, perspectival, instantaneous, and particular aspects of the thing under examination while the [drawing] puts into relief the essential, synthetic, constant, veridical, and universally present aspects of the thing 'itself'" (1990, 163). Drawing is used to represent types because it is selective.

The two histories are consistent. Galison claims that machine imaging is first adopted in order to ensure objectivity defined as freedom from interpretation. This dovetails with Topper's view that machine imaging is preferred for representing particulars if interpretation is acknowledged to be needed in representing types. Galison also claims that in the twentieth century scientists acknowledge that interpretation should play a role in imaging. However, the images that he surveys in making this point are images of types—the atlas of encephalography, for example. That is why we do not see a return to drawing of particulars. In sum, Galison's epistemic explanation of the history—objectivity is a virtue of machine imaging—nicely fits Topper's semantic explanation of the history—machine imaging is ideal for representing particulars.

Conjoining the two views amplifies the strengths of each. According to the Galison–Topper Hypothesis, machine imaging technologies are used to represent particulars, which must be represented objectively, whereas drawing, which relies on the judgement and knowledge of the scientist, is used to represent types. Scientists do represent types, so drawing persists in the age of mechanical imaging.

Obviously the Galison–Topper Hypothesis needs qualification. Machine imaging is only used to represent particulars when technologically feasible—otherwise drawing is used. Particulars are drawn before the age of mechanical imaging—examples are Galileo's lunar drawings and Wegener's drawings of the continental plates. The hypothesis implies only that, had they been available, machine-made images would have been preferred by Galileo and Wegener. A striking example is Percival Lowell's switch from drawing to photography in his studies of the canals of Mars (Galison 1998, 329–30). The same point applies to images made earlier than the time frame considered by Galison and Topper. Lorraine Daston and Katharine Park (1998) argue that a strand of science from the twelfth to the eighteenth centuries distrusted attempts to extract invariable features of types from the fluctuating variety of nature and concerned itself instead with documenting oddities, monsters, and other "wonders." The documentation included drawings as well as texts. This is not inconsistent with the Galison–Topper Hypothesis if scientists would have used machine images were they available.

The Galison–Topper Hypothesis predicts that drawings are not used in science to represent particulars when machine imaging is available. The trouble is that drawing is commonly used in lithic illustration despite the availability of photography. The counterexample also points to the sources of the trouble. According to the Galison–Topper Hypothesis, drawing is used to represent types because it is selective; but the evidence shows that drawing is also used to represent flaked stones and their byproducts because it is selective. Moreover, an epistemology underlies the Galison–Topper Hypothesis: machine imaging is thought to ensure the objective representation of particulars. But there is no worry in archaeology about the objectivity of lithic drawing.

An Epistemology of Lithic Drawing

Several threads have spun from the discussion so far. Standard accounts of reconstruction drawings assume a dichotomy between detail, realism, and visuality on one hand and selectivity on the other, associating the former with non-epistemic tasks and the latter with representing hypotheses. Contra Moser, Hacking, and others, lithic drawings are realistic and yet they seem to do honest epistemic work. Contra the Galison–Topper Hypothesis, they do honest epistemic work even though they are drawings of particulars and involve interpretation. Perhaps these negative conclusions are conclusions enough; or perhaps a study of lithic drawing can suggest how to think about the epistemic work done by some drawings in so far as they represent particulars at once realistically and selectively.

What Galison calls "objectivity" scarcely helps appreciate the epistemic work done by lithic drawings. If drawing is selective, selection involves interpretation, interpretation diminishes objectivity, and representations of particulars should be objective, then photography should dominate in lithic illustration. Yet drawing has secured a place in lithic illustration that we should assume to be deserved. No epistemic standard should be applied to a scientific task if it renders the task impossible, and this principle is defeasible only given strong arguments. Many tasks in archaeology depend on interpretation because intentional features of finds support archaeological generalizations and explanations (Shelley 1996, 282–4), whether the generalizations and explanations appeal to intentions (e.g. a population made weapons) or not (e.g. a population acquired a new cognitive capacity). It is reasonable to query any epistemic standard that makes the evidence needed for these generalizations and explanations unobtainable. (Of course, Galison does not endorse the objectivity standard. He claims merely that its adoption at a certain point in time fueled the drive to machine imaging.)

Here is an alternative framework to help in appreciating the epistemic work done by lithic drawings. The framework does imply a norm: any image type used to perform an imaging task should be informative, where what counts as informativeness depends on the task at hand. This norm is almost a truism, but not quite, and so it ultimately requires independent defense (see Lopes 1992, 1995; Kulvicki 2006; Abell 2007). For now, it is enough if the norm helps to make sense of the use of image types for imaging tasks—particularly the use of drawing in lithic illustration. Achieving this kind of understanding might indeed provide some defense of the norm. First, though, "informativeness" needs unpacking.

Assume that images belong to systems, each individuated by an image-making process or by determinable features that are represented. Images belong to different systems if they are made differently—for example, digital and film photography are different systems. Systems also differ by representing different determinables. Color and monochrome photography are different systems because images in the systems represent different determinables. Thus systems may be hierarchically nested. Color photography is nested within black and white photography, since color photography is black and white photography with the addition of resources for representing hue and saturation. (By the way, there is no requirement that represented determinables be visible to the naked eye—infrared images represent radiation that is otherwise invisible.) Stopping at this point, of course, leaves us with a very coarse-grained conception of imaging systems, and a great deal more could be and has been said (e.g. Goodman 1976; Lopes 1996; Kulvicki 2006). But this is enough for now.

Stipulate also that a system tracks a determinable property just in case images in the system represent the determinable and their contents depend counterfactually on determinates of that determinable. An image's content depends counterfactually on trajectories just in case it represents its subject's trajectories and would also represent its trajectory were it different. An image's content depends counterfactually on the outline shape of a stone just in case it represents its outline and would also represent the outline were the stone a different shape. Systems of images whose contents counterfactually depend on determinates of the determinables that the system represents track those determinables.

The notions of an imaging system and tracking articulate the required conception of informativeness. An imaging system is informative relative to a task just in case the system tracks the very determinables that the task requires. The idea is that informative systems are made up of images whose contents counterfactually depend on the right features of objects. Doppler radar imaging is informative in forecasting rain because Doppler radar images represent intensity of precipitation at a time and place and would represent the intensity were it higher or lower. Topographical maps are informative in identifying erosion patterns because they track landscape contours. Certainly this conception of informativeness is but one among many. The point is not to give it any kind of priority over other conceptions. The point is to see if it helps makes sense of the epistemic work done by lithic drawings.

One way to ensure that an imaging system tracks a determinable is to build a device to make images mechanically. Film-based photography tracks many determinables; Doppler radar imaging tracks others. However, tracking does not in principle require machine imaging. A drawing system tracks shape, for example, so long as drawings in the system represent objects' shapes and would have represented them as having a different shape were their shapes different.

Do any drawing systems meet that condition? The deeply ingrained answer is that they do not. Maybe the culprit is Dürer's rhinoceros, or Gombrich's discussion of it; maybe it is a staple diet of New Yorker cartoons showing such scenarios as cubist artists drawing what they see because they see the world cubistically. Neither justifies the ingrained answer, though they suggest the source of misgiving. Nothing in the drawing process seems to ensure that the drawing tracks the determinables that the system represents. Drawings represent shape, for example, but the contents of individual drawings do not depend counterfactually on the determinate shapes of represented objects (cf. Walton 1984). In a word, drawings too easily lie.

The key to a reply is the role of the conventions and techniques of lithic drawing. These function to ensure the tracking of selected determinables, such as scale, overall shape, shape and location of flake scars and retouch, and location of features like thermal fractures. That is, an illustrator who follows the rules will produce drawings that show the relevant features and that would also have shown those features as different, were they different. This counterfactual dependence is not a fluke; it is a consequence of compliance with the conventions and techniques of lithic drawing.

This makes sense of why lithic drawings are used instead of or in addition to photographs. Lithic drawing taps the illustrator's expert judgement, ensuring that the system tracks the determinables needed to test hypotheses for which the stones are evidence. The illustrator's judgement comes in applying visual concepts such as "flake scar," "retouch," and "thermal fracture." This is why lithic illustrators must know some archaeology and why they are often closely associated with archaeological labs. No matter what our drafting abilities, you and I would make poor lithic illustrators as long as we lack the required visual concepts (and the same goes for a camera). The virtue of drawing is not that it is more selective than photography, as is often said. The virtue of drawing is that its selectivity taps human judgement. Illustrators "read" stones and accordingly render them on paper. Their judgement is anything but gratuitous: lithic drawing is useful precisely because it allows the illustrator's expert input. Given the need for the illustrator's input, regulating lithic drawing ensures that it tracks determinables informatively.

However, while this is part of the story, it is not the whole story. The explanation of why lithic drawing is informative, given the task context, raises a new question about why lithic drawings are made at all. Surely expert judgements can be expressed non-imagistically, in text or in tables, so why go to all the trouble of making drawings? Or, less radically, surely expert judgement can be expressed in schematic drawings, so why make richly detailed, realistic drawings? If what matters is expert judgement, then why not count any further detail as gratuitous? Put another way, the conventions regulate and so ensure the informativeness of lithic drawings in so far as they are selective. Are the drawings also informative in so far as they are realistic images?

Consider what is involved in lithic drawing. Illustrators read stones' surfaces, as can any archaeologists familiar with flint knapping. But illustrators do something that archaeologists who are not illustrators cannot do. They use their eyes and hands to make marks on paper that capture the finely detailed contours and textures of stones. They draw the stone. The question is what is involved in drawing, apart from selectivity.

One answer comes straight to mind. Illustrators draw the looks of stones so as to make their readings visible. This answer assigns a role to vision in drawing by implying that drawings show how things look. Even so, the answer falls short in two ways. First, it is not clear what epistemic role is played by showing how things look. Showing how things look in pictures serves many useful and serious tasks, such as teaching ("see, here is what thermal fractures look like"). That granted, when it comes to testing a claim, seeing through a picture how a stone with certain features looks adds nothing to knowing that it has the features. Second, the answer does not explain why lithic drawings show any more detail than is needed to show the look of the interpreted features.

Fred Dretske (1981, 135–41) distinguishes between what he calls the digital and analog content of information signals, including representations. Dretske's distinction is not the traditional one: for one thing all representations have both kinds of content in Dretske's sense. A representation carries the information that x is F in digital form just in case the representation carries no more specific information about x (that is not analytically or nomologically nested in x's being F). A representation carries the information that x is F in analog form just in case it carries more specific, more determinate information about x than that it is F. In Dretske's example, the sentence "the cup contains coffee" carries the information that the cup contains coffee in digital form. It says nothing more specific than that. However, it carries the information that the cup contains a liquid in analog form.

The digital–analog distinction brings out a characteristic feature of images (Dretske 1981: 137; Lopes 1996). A description expressing a reading of a stone carries the content of the reading in digital form—it says nothing more specific than the reading. By contrast, a drawing expressing the reading typically carries the content of the reading in analog form, since it typically carries more specific information than is given in the reading. Why "typically"? The drawing may be very schematic. However, realistic drawings are not like this. Such a drawing will represent in analog form that the stone has a flake scar 1.3 centimeters wide because it also shows the precise shape of the scar.

The content of drawings characteristically outstrips our conceptual repertoire: drawings have non-conceptual content. A representation has non-conceptual content just in case its having the content it has does not require possession of concepts of the properties represented. The fact that a drawing carries a piece of information in analog form does not imply that it has non-conceptual content. Recall that "the cup contains coffee" carries the information that the cup contains a liquid in analog form, yet the content of the sentence is conceptual. However, if a drawing has non-conceptual content, then a standard interpretation of the drawing stating its content is in analogue form. So, why think that drawings have non-conceptual contents? An argument for this claim (just sketched here—see Lopes 1996) derives from an account of drawing.

Here is one description of drawing a curve. To draw the curve, you recognize it as a curve of a determinate kind, applying a determinate curve concept to it, and then exercise the very same determinate curve concept in moving your hand to mark the surface of a drawing. Here is another description. To draw a curve, you look at the curve and the surface you mark, as you mark it, and let feedback from the look of the surface join with the look of the curve to control the movement of your hand. Drawing, so characterized, does not exclude the exercise of a determinate curve concept, but it does not require it either. Both descriptions are coherent, but there is evidence that the second more accurately describes many acts of drawing (e.g. Humphrey 1999; cf. Gaut forthcoming).

Suppose the second account of drawing is correct. If it is correct, then drawing a feature does not require having a concept of the feature, so the drawing has non-conceptual content. Admittedly, many features of items drawn are conceptualized as such, but some may not be. Thus drawings represent the features that are conceptualized in the drawing process in analog form. If the illustrator applies the concept of a curve but not of that determinate curve, then the drawing represents that the item is curved in analog form—it carries more specific, non-nested information about the curve. Only a specification of the digital content of a drawing (the thousand words that the drawing is worth) will include features not conceptualized.

What follows from this is that lithic drawings represent more than the illustrator knows, if what the illustrator knows lies in her reading of a stone which attributes conceptualized features—like having thermal fractures. Making use of these concepts, she prepares a drawing that represents the stone as having the interpreted features—as having thermal fractures, for instance. There is more to the drawing than this however. If her eye and hand operate without conceptual guidance—under the guidance of the stone instead—then she will prepare a drawing that expresses her reading in analog form. The drawing will show more than is contained in her reading.

Realism cuts two ways now. In paleolithic reconstruction drawings, realism, detail, and visuality are not tied to features of represented particulars. The goatee worn by Zinjanthropus is made up. In lithic illustration, realism, detail, and visuality are tied to features of represented particulars. The realism–selectivity dichotomy misses this distinction. Just as there are different kinds of selectivity, there are different kinds of realism. Just as the epistemic quality of lithic drawings depends on the kind of selectivity they have, their epistemic quality also depends on their kind of realism.

How, then, does the realism of lithic drawings contribute to their informativeness in context? Since informativeness has to do with what determinables the task context requires to be tracked, the question is not one that can be answered definitively in a few words. Nevertheless, here are two suggestions, offered to illustrate the idea that the non-conceptual contents of lithic drawings interact with their interpreted contents in support of informativeness.

Preparing a lithic drawing involves non-conceptual drawing as well as interpretation, and when not every reading is consistent with the act of non-conceptual drawing, then the process of non-conceptual drawing constrains the reading. Only readings that are consistent with the digital content of a drawing can be depicted. A drawing cannot embody the judgement that a feature is a thermal fracture and also carry more specific non-nested information about the feature that is inconsistent with its being a thermal fracture. It is one thing to look at a stone and offer a reading—expressed in a description, for example—and it is another thing to look at a stone and offer a reading by means of drawing it. Both involve looking at the stone, but only one involves drawing it. Drawing is a check on reading. Moreover, the informativeness of the drawing piggybacks on the informativeness of the reading.

A suitably trained person inspecting a lithic drawing can distinguish what in the drawing is due to the reading and what is due to non-conceptual drawing. Indeed, the conventions of lithic drawing demarcate interpreted from non-interpreted elements. One consequence of this is that a trained eye can find in the drawing itself a basis for alternative readings. Topper comments that "on the one hand, concepts aid us in seeing what may otherwise be missed; on the other hand, they can also impede us in recognizing something that does not fit the given categories but which may, in fact, be sitting in front of our noses" (1996, 223). Lithic drawings get the benefits of conceptualization without all of their costs. By expressing a reading, they aid us to see what would otherwise be missed, but they convey enough additional information in a format that allows us to recognize alternative readings. They embody interpretations without eliminating alternatives. As drawings, they are informative in this distinctive way.

Only the first steps have been taken here towards a full account of the epistemic work done by lithic drawings, both as expressions of expert judgment and images with a relatively high degree of realism, detail, and visuality. The sketch of a theory of informativeness needs filling in, and the accounts of drawing and the non-conceptual contents of images are controversial. However, we can now see how an epistemology of lithic drawing and of scientific images in general might profit from nuanced conceptions of selectivity, realism, detail, and visuality, given a framework in which image types are viewed as serving context-relative imaging tasks. Getting the nuances right means taking seriously the variety of image types, imaging tasks, and task contexts.

References

Abell, Catharine. 2007. "Pictorial Realism." *Australasian Journal of Philosophy* 85: 1–17.

Addington, Lucile R. 1986. *Lithic Illustration: Drawing Flaked Stone Artifacts for Publication.* Chicago: University of Chicago Press.

Adkins, Lesley and Roy A. Adkins. 1989. *Archaeological Illustration.* Cambridge: Cambridge University Press.

Allwein, Gerard and John Etchemendy, eds. 1996. *Logical Reasoning with Diagrams.* Oxford: Oxford University Press.

Brown, James Robert. 1999. *Philosophy of Mathematics: An Introduction to a World of Proofs and Pictures.* London: Routledge.

Cat, Jordi. 2001. "On Understanding: Maxwell on the Methods of Illustration and Scientific Metaphor." *Studies in History and Philosophy of Modern Physics* 32: 395–442.

Daston, Lorraine and Peter Galison. 1992. "The Image of Objectivity." *Representations* 40: 81–128.

——— and Katharine Park. 1998. *Wonders and the Order of Nature: 1150–1750.* New York: Zone Books.

Dillon, Brian D. 1985. *The Student's Guide to Archaeological Illustrating.* 2nd ed. Berkeley: University of California Press.

Dretske, Fred. 1981. *Knowledge and the Flow of Information.* Oxford: Blackwell.

Freedberg, David. 1989. *The Power of Images.* Chicago: University of Chicago Press.

Galison, Peter. 1997. *Image and Logic: A Material Culture of Microphysics.* Chicago: University of Chicago Press.

———. 1998. "Judgement Against Objectivity." Pp. 327–59 in *Picturing Science, Producing Art.* Edited by Caroline Jones and Peter Galison. London: Routledge.

Gaut, Berys. Forthcoming. "Opaque Pictures." *Revue Internationale de Philosophie.*

Gombrich, E. H. 1961. *Art and Illusion.* Princeton: Princeton University Press.

Gooding, David. 2004a. "Cognition, Construction, and Culture: Visual Theories in the Sciences." *Journal of Cognition and Culture* 4: 551–93.

———. 2004b. "Envisioning Explanations: The Art in Science." *Interdisciplinary Science Reviews* 29: 278–93.

Goodman, Nelson. 1976. *Languages of Art.* 2nd ed. Indianapolis: Hackett.

Hacking, Ian. 1991. "Matters of Graphics." *Science* 252: 978–9.

Hartley, Beryl. 1996. "The Living Academies of Nature: Scientific Experiment in Learning and Communicating the New Skills of Early Nineteenth-Century Landscape Painting." *Studies in the History and Philosophy of Science* 27: 149–80.

Hopkins, Robert. 1998. *Picture, Image, and Experience.* Cambridge: Cambridge University Press.

Humphrey, Nicholas. 1999. "Cave Art, Autism, and the Evolution of the Human Mind." *Journal of Consciousness Studies* 6: 116–43.

Jay, Martin. 1993. *Downcast Eyes: The Denigration of Vision in Twentieth-century French Thought.* Berkeley: University of California Press.

Kuhn, Thomas. 1977. *The Essential Tension.* Chicago: University of Chicago Press.

Kulvicki, John. 2006. *On Images.* Oxford: Oxford University Press.

Latour, Bruno. 1990. "Drawing Things Together." Pp. 19–68 in *Representation in Scientific Practice.* Edited by Michael Lynch and Steve Woolgar. Cambridge: MIT Press.

Lopes, Dominic McIver. 1992. "Pictures, Styles, and Purposes." *British Journal of Aesthetics* 32: 330–41.

———. 1995. "Pictorial Realism." *Journal of Aesthetics and Art Criticism* 53: 277–85.

———. 1996. *Understanding Pictures.* Oxford: Oxford University Press.

———. 2006. "The Special and General Theory of Realism." *Contemporary Aesthetics* 4: n.p.

Lynch, Michael. 1990. "The Externalized Retina: Selection and Mathematization in the Documentation of Objects in the Life Sciences." Pp. 153–86 in *Representation in Scientific Practice.* Edited by Michael Lynch and Steve Woolgar. Cambridge: MIT Press.

——— and Steve Woolgar, eds. 1990. *Representation in Scientific Practice.* Cambridge: MIT Press.

Moser, Stephanie. 1996. "Visual Representation in Archaeology: Depicting the Missing Link in Human Origins." Pp. 184–214 in *Picturing Knowledge.* Edited by Brian Baigrie. Toronto: University of Toronto Press.

———. 1998. *Ancestral Images: The Iconography of Human Origins.* Ithaca: Cornell University Press.

Myers, Greg. 1990. "Every Picture Tells a Story: Illustrations in E. O. Wilson's Sociobiology." Pp. 231–66 in *Representation in Scientific Practice.* Edited by Michael Lynch and Steve Woolgar. Cambridge: MIT Press.

Perini, Laura. 2005. "Explanation in Two Dimensions: Diagrams and Biological Models." *Biology and Philosophy* 20: 257–69.

Piggott, Stuart. 1978. *Antiquity Depicted: Aspects of Archaeological Illustration.* London and New York: Thames and Hudson.

Ruse, Michael. 1996. "Are Pictures Really Necessary? The Case of Sewall Wright's 'Adaptive Landscapes,'" Pp. 303–37 in *Picturing Knowledge.* Edited by Brian Baigrie. Toronto: University of Toronto Press.

Shelley, Cameron. 1996. "Visual Abductive Reasoning in Archaeology." *Philosophy of Science* 63: 278–301.

Topper, David. 1996. "Towards an Epistemology of Scientific Illustration." Pp. 215–49 in *Picturing Knowledge.* Edited by Brian Baigrie. Toronto: University of Toronto Press.

Walton, Kendall. 1984. "Transparent Pictures." *Critical Inquiry* 11: 246–77.

Whittaker, John C. 1994. *Flintknapping: Making and Understanding Stone Tools.* Austin: University of Texas Press.

Wimsatt, William. 1990. "Taming the Dimensions: Visualization in Science." *Proceedings of the Biennial Meeting of the Philosophy of Science Association* 2: 111–35.

Wylie, Alison. 2002. *Thinking from Things: Essays in the Philosophy of Archaeology.* Berkeley: University of California Press.