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Mobile Stones: The Uses and Meanings of Earth Science Teaching Specimens

Résumé

Les échantillons minéralogiques servant au niveau universitaire à enseigner les sciences de la terre ont des origines diverses : certains objets sont collectés spécifiquement à des fins d'enseignement et partent donc du terrain pour entrer aussitôt dans une collection ; pour d'autres, le trajet est bien moins direct. De fait, nombre des échantillons utilisés pour l'enseignement des sciences de la terre ont été en fait recyclés à la suite d'autres activités (la plupart en lien avec la recherche), achetés à des grossistes ou empruntés à des collections muséales, et n'étaient donc pas destinés à l'origine à fonctionner dans ce contexte. Mais comment de tels objets peuvent-ils être utilisables en tant que spécimens d'enseignement ? Qu'arrive-t-il à leurs significations précédentes ? Fonctionnent-ils différemment de ceux qui ont été spécifiquement recueillis à des fins d'enseignement ? En abordant ces questions, cet article révèle que, loin d'être fixes, statiques et stables—loin d'être inscrits « dans la pierre »—ces objets sont polysémiques, flexibles et mobiles.

Abstract

The origins of university earth science teaching specimens are diverse; while some objects are collected specifically for teaching purposes and therefore travel directly from the field into a teaching collection, for others, the journey is less straightforward. Indeed, a considerable amount of the material that is used for teaching in the earth sciences has in fact been recycled from other (mostly research-related) activities, purchased from wholesalers, or borrowed from museum collections, and was therefore not originally intended to function in this context. But how are such objects made to work as teaching specimens? What happens to their previous meanings? Do they function any differently from those objects that have been collected specifically for teaching purposes? In addressing these questions, this paper reveals that, far from being fixed, static, and stable—far from being “set in stone”—these objects are polysemic, flexible, and mobile.

In material culture studies, geological materials appear in various forms, ranging from building stones and gemstones (see Edensor 2009; Kinsey 2009; Plotz 2007; Walsh 2010) to monuments and symbols (see Bender 1998; Bloch 1995; Parker-Pearson 2004; Parker-Pearson et al. 2006; Taçon 1991). The polysemic nature of geological materials is apparent from their consideration by authors writing on themes as diverse as globaliza-

tion, folklore, commodity chains, literature, and mythology (see, respectively, Braun 2000; Duffin 2007; Ferry 2005; Heringman 2004; McNamara 2007). By drawing attention to their cultural significance and values, such work reveals that “stones always have meanings and relationships extending beyond themselves. They are not replete unto themselves. They are always more than themselves, in a process of becoming rather than a static state of being” (Tilley 2004: 222). However, in material culture studies, those who

are interested in the meanings and significance of geological materials and the ways in which they are encountered and experienced have tended to focus on their occurrence either within the landscape (Massey 2006; Tilley 2004; Tilley et al. 2000) or as raw materials from which objects are made (Boivin and Owoc 2004; Brumm, Boivin, and Fullagar 2006; Robb 2009). By contrast, little attention has been paid to geological materials in the form of scientific objects, and while earth sciences provide an abundance of material for material culture studies, rarely does the discipline provide the cultural context (but see Knell 2000).

Outside of material culture studies, there is a tendency to assume that geological materials are both physically and ontologically stable. As Hacking observes, “When thinkers ... want to say that something is real, they resort to rocks,” and, as he goes on to explain, rocks are “what some distinguished thinkers seem to regard as the most unquestionable reality” (1999: 192). Along with their physical hardness and durability that make them both cumbersome and dense, the “impersonal, formal and formulaic” conventions of scientific writing (Fortey 2000: xvi) present earth science objects as passive, inert, and neutral—the “hard facts” of science (Daston 2005; Knell 2007:10). When one thinks of “objects in motion,” it is therefore unlikely that university earth science teaching collections immediately come to mind. Yet, and as I shall reveal using evidence generated through participant observations and interviews carried out at five U.K. university earth science departments, the mobility of these objects—both their physical circulation and their ontological flexibility—is vital to their functionality in the learning setting.¹

By extending the existing work in material culture studies to university earth science teaching specimens, this paper examines both the nature and effects of their circulation, and in this sense, I also address a theme that is often associated with museum studies. Over the last decade, interest in the cultural significance of natural science objects and collections in museums has grown significantly.² However, much of this work concentrates specifically on museum objects and therefore emphasises the more passive roles of objects, in particular as they are stored and exhibited (for example Dahlbom 2009; Ferry 2010; Patchett and Foster 2008; Rader and

Cain 2008). This focus, on what Alberti refers to as “nature behind glass” or “museum nature” (2008: 74), tends to consider natural objects in what effectively corresponds to their retirement. Therefore, with a few exceptions (Ellis 2008), the active use of natural science objects and collections as functional scientific specimens has largely been overlooked in museum studies.

By building upon the existing work in both material culture studies and museum studies, I hope to challenge the assumed stability of these things to reveal, instead, that it is precisely their “adaptable, flexible and responsive” qualities (de Laet and Mol 2000: 226)—their mutable mobility (cf. Law and Mol 2001; Law and Singleton 2005; Mol and Law 1994)³—that makes these objects so useful in this context. In what follows, I ask how the origins and uses of these objects affect their meanings and treatment and consider the extent to which their natural origins and scientific status aligns them with or distinguishes them from other forms of material culture.

Before considering the circulation and uses of earth science teaching specimens, it is useful to briefly examine the processes by which these objects come into being (cf. Daston 2000) because no matter how they end up in a learning setting, these objects must all, on account of their natural origins, have been collected at some time.⁴ The subsequent two sections therefore examine the processes of field collecting, firstly for teaching material, and then for research purposes. I then consider how the origins of objects affect their circulation before exploring in detail the “academic lives” of teaching specimens. Following an account of the three distinct ways in which objects may function in a learning setting, I discuss the ways in which different types of objects may be regulated in order to achieve these functions. Finally, I return to my initial questions surrounding the circulation of teaching material, and suggest that, by acknowledging both the intentions and realities of these encounters, it becomes apparent that the value of earth science teaching objects is directly related to their mobility.

The Coming Into Being of Earth Science Objects

Specimens are collected for specific purposes: “You pick your sample because of what you want to do with it” (Robert Finch, interview, November 17, 2008). The ways in which objects are collected, the intentions and expectations of the collector at the time of collecting, and the information that is bound to them when they are collected, influence the specimen’s future career in academia: its use, treatment, authority, credibility, and mobility. If material is being collected specifically for teaching purposes, it is necessary to find a sample that clearly shows the features of interest. Furthermore, the number of samples required will vary according to class size, as is apparent from the following account of a field trip to Skye during which a member of staff from the University of Cambridge was asked to collect samples of Lewisian Gneiss for use in a first-year practical session:

We went to the beach with sledge hammers, and we smashed open some boulders, and we brought back 50 hand specimens.... If you’re collecting material for the first year, you need 50 examples, and it’s actually a really big ask.... You actually have to deliberately set out and say, “I want 50 specimens from here.”... You’d never come back with 50 identical specimens otherwise. (Marian Holness, interview, October 28, 2009).

The size and dimensions of the collected material must also reflect the intended use as well as any techniques and processing to which the specimen will be subjected. If representative samples are required, the size of a hand specimen will depend on the type of material being collected; fine-grained rocks (that are homogeneous at the millimetre to centimetre scale, such as mudstones or slates) require relatively small hand specimens in order to be representative, whereas coarser-grained rocks (that are homogeneous at the decimetre scale, such as granulites and granites) require much larger hand specimens (Kriegsman 2004: 205–206). If, however, thin sections are to be made, the dimensions of the sample must be sufficient to meet the requirements of the particular cutting and grinding equipment available (Marian Holness, interview, October 28, 2009).

As well as material collected specifically for teaching purposes, many of the objects that

are used for teaching start their lives as research specimens. While the material collected for research purposes is directly related to its intended use, the information recorded during collection is considered vital for research objects. Indeed, and as I will now briefly explain, this information represents all that has gone before in nature outside; without it, the specimen is just a piece of rock (cf. Griesemer 1990: 18).

The Shape of Things to Come

Earth scientists go out into the field and hammer pieces of rock from outcrops, drill cores out of the ground, or pick up loose pieces of material. No matter how it is done, the process of collecting a natural specimen effectively involves the removal of the object from its original, in situ occurrence. Bringing pieces of outside nature inside constitutes an act of simplification: in selecting objects, scientists reduce nature to a series of “tangible representatives” (Griesemer 1990: 20), which are more easily managed than the “unrefined natural objects that are too quirkily particular to cooperate in generalizations and comparisons” (Daston and Galison 2007: 19). Removed from the complexities of reality, these samples can be investigated at leisure, using equipment and techniques that are not available in a natural environment. The neutral and controlled conditions inside provide objects with both credibility and status, which in turn qualify them to act as “guarantors” (Latour 1999: 38), providing support for the knowledge that has been constructed and bound to them.

Convenience, comfort, credibility, and control, however, come at a price. In extracting these objects from nature, they lose locality, position, and associations; they lose their context (Latour 1987: 225). In order to overcome the losses that occur in bringing pieces of outside nature inside, in order to stabilize these objects, and in order to create “immutable mobiles” (Latour 1990: 44–47), scientists replace the natural context with a new context, through the collection of scientific information. The field notebook is used to record observations, measurements, and other such data about the object and its context, and this information becomes bound to the object through the permanent inscription of a reference onto the specimen (see Jenkins 1994: 253; Latour

1999: 46). The successful transition of earth science objects into the world of academia—their immutable mobility—relies upon both the creation and maintenance of a link between objects and their associated information. While this stability is only temporary, it is usually sufficient to secure the safe passage of these objects into academia. However, it is not the real thing that enters an institution; rather, it is a part thereof; an “abstraction” or “remnant model” (Griesemer 1990: 21). Although the collecting process shapes the ways in which earth science teaching specimens function and circulate in academia, the meanings of these objects are not set in stone. Indeed, and as I shall now consider in more detail, while the coming into being of earth science objects relies upon their stability as immutable mobiles, it is their mutable mobility that allows them to function as teaching specimens.

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While associated information is vital for research specimens, not all functions of earth science objects are as reliant on the quantity or quality of information: “There is a hierarchy of use, in terms of what it [a specimen] can be used for, and it’s all information-based” (Robert Finch, interview, May 6, 2008). The notion of a hierarchy of use is particularly useful for understanding the circulation of earth science objects, as it emphasizes the importance of matching the information requirements of different functions with the amount of information attached to an object.⁵ Thus, as a general rule, research requires the most thorough knowledge about the origins and context of objects, and it therefore follows that research objects tend to have the most information attached to them.

As far as information requirements are concerned, material collected for research purposes may be used for either teaching or display, since these last two functions require the least amount of information. However, there are various other conditions that must be met by research material in order for it to be successfully used for teaching. The transformation of research specimens into teaching objects also requires consideration of factors such as their relevance to the subjects that are being taught and their size or the amount of

material that is available. They must also be stable and safe (i.e., non-hazardous), and they must be sufficiently robust to withstand regular handling. While the movement of material from research to teaching is common, objects rarely circulate in the other direction (unless the material originated from research in the first place). For example, at the University of Leeds, a number of samples of *sillimanite schist* were collected during a departmental fieldtrip to Connemara for the purpose of replenishing a teaching set.⁶ When it came to collecting the material, the collector explained:

Because we knew we were keeping it for a teaching collection we didn’t feel the urge to particularly label it in any way.... So we did some initial field labelling and then as ever I have a book—I have a notebook which I record all my field collecting in—so that gives the locality, the rock type, date, basic information on the rock, what we were intending to use the material for. (Robert Finch, interview, May 6, 2008)

In this case, the potential uses of the collected material have been restricted by the particular information that was recorded by the collector, and, as Robert Finch pointed out, “if you take this into the research realm it would not be good enough” (interview, 6 May 2008). Nonetheless, although the objects could not function as research specimens on account of the lack of detailed information associated with them, this would not prevent the material from functioning as display material.

The material used for teaching undergraduate students may originate from a number of sources other than from research. The nature of undergraduate teaching often requires large numbers of duplicate specimens, and, in such cases, it is common for departments to purchase material in bulk. For example, most departments purchase their basic teaching sets of minerals, as it is cheaper to do so than it would be to collect them themselves. However, and in direct contrast to the permanent movement of purchased objects into teaching collections, material may also enter the teaching realm temporarily. Such temporary movements tend to involve material that does not belong to a department, such as items taken from personal collections belonging to members of staff, or, more commonly, accessioned museum specimens. For example, at the University of

Cambridge, the Department of Earth Sciences regularly borrows material from the Sedgwick Museum's collections for use in undergraduate practicals.

The origins of teaching material are clearly diverse, ranging from purposefully collected objects and former research specimens, to purchased items and material borrowed from museum collections. But how do such different types of material actually function in a learning setting? How do students encounter them and how are their meanings and uses affected by the trajectories along which they have travelled? In order to answer these questions it is necessary to explore the uses of earth science teaching objects in more detail.

The Academic Lives of Teaching Objects

In the earth sciences, specimens are vital for teaching students the “fundamentals” (Dott 1998: 17) of their discipline. Despite the emergence of fields such as geophysics and geochemistry and the resulting shift from the field to the lab and from description to experiment, and despite the changes in academic instruction that have occurred alongside these developments (de Clercq 2003: 27; Wyse Jackson 1999: 419), collections remain essential tools for teaching and learning in the earth sciences. The visual and interpretive nature of the earth sciences requires students to develop what Frodeman describes as “the practiced geologic eye” (2004: 212), and objects provide the means to do this.

In addition to functioning as tools for developing “trained judgement” (Kitts 1977: 35) and “intuitive awareness” (Frodeman 2003: 155), in the earth sciences objects also provide a means of socializing students into the academic community as they learn which questions to ask and how to go about answering them (Livingstone 2003: 18). Contact with objects can therefore be seen as a way of naturalizing students, or “stripping away the contingencies of an object's creation” (Bowker and Star 1999: 299). For example, during a practical at the University of Leeds concerned with mineral testing, the interaction between students and specimens extended beyond that required in order to carry out each test. Having carried out a test, students often continued to handle

specimens (particularly the more tactile minerals such as the cubic pyrite and fluorite crystals, or the sheets of mica), while writing up their results or talking to their peers. Such casual—yet careful—interactions with specimens suggest that the students were becoming more familiar and comfortable with the objects, or, in Bowker and Star's terms, for the students, the objects had lost their “anthropological strangeness” (1999: 299).

The ways in which objects may function in the teaching context are diverse; materials range from real specimens to casts, and may also include thin sections, models, diagrams, reconstructions, and maps. Specimens may be used in isolation, in carefully designed sets, or alongside resources such as images or data. They may be used to train students to identify key features or characteristics, to develop skills (such as scientific drawing), or as a source of evidence for interpretation. This diversity is demonstrated by a typical first-year palaeontology practical at the University of Cambridge in which students learn how to describe, compare, and identify trilobites (Glynis Caruana, interview, August 12, 2009). During this practical, students observe hand specimens in order to make detailed drawings of a trilobite head and to determine the variation in growth vectors (by plotting equivalent points on their drawing against an existing diagram drawn on a grid). Students also identify unknown trilobite fossils using the British Palaeozoic Fossils booklet (a standard tool for the palaeontologist) and observe a horseshoe crab preserved in spirit in order to familiarize themselves with the features of trilobite appendages (which are rarely preserved in fossils). Finally, building on their knowledge of trilobite morphology, students interpret, among other things, the direction of movement, from casts of trace fossils.

By using earth science objects (whether collected, transferred, purchased, or borrowed) for teaching, nature is literally being brought inside for convenience, allowing students to learn from the real thing in the controlled and detached conditions of academia. Due to the complexity of nature, students are taught through simplified versions of reality and there are three key scenarios in which objects are used to achieve this simplification, which I refer to as “specimens to observe,” “samples to test,” and “sets for interpretation,” and which I will now outline briefly,

before considering how the origins of teaching specimens may impact their uses and meanings.

Specimens to Observe

Perhaps the most common use of objects for teaching purposes (particularly in lower-level courses) requires them to function as “specimens to observe.” This strategy provides an effective means of familiarizing students with both their disciplinary objects and some basic tools of the trade, such as hand lenses, microscopes, and grain-size charts. Here, students are taught to recognize characteristic traits of particular types of objects (rocks, minerals, or fossils) by observing key features, and it is therefore essential that specimens clearly display the particular features of interest. Because students encounter objects on a one-to-one basis, large numbers of duplicate specimens are often required. However, by its very nature, the observation scenario emphasizes visual information, and, therefore, proxies (such as casts or virtual objects) may be used in place of the real thing; objects may represent something that is either intrinsically part of them (such as the texture of a rock) or not (such as a fossil cast). In a similar way, unlabelled objects remain potentially useful as “specimens to observe,” as the following description suggests:

There’s a lot of things in the first year [teaching collection] that just have an ancient specimen number on that doesn’t relate to anything. And you’ve got no idea where they’re from or anything. But as an object, you just think “well, this is a big feldspar crystal” and that’s enough; it’s all they need to know. (Marian Holness, interview, October 28, 2009)

As “specimens to observe,” the role of the object is to display a particular feature and the role of the student is to observe that feature, with the aim of making a link between that particular feature and information such as a name or process. In order to ensure that students observe the correct feature and make the correct link, objects are “purified to single meanings” (cf. Edensor 2005: 312) using practices of modification (temporary or permanent). However, the strategies that are used to achieve this purification may vary depending on an object’s origins, and this may limit the potential meanings of certain types of material. Techniques such as cleaning, reshaping,

resizing, highlighting, annotating, or enhancing may be used to modify collected or purchased objects. Such techniques would not, however, be used to modify accessioned museum objects because of the importance that is placed on their long-term preservation. Unnecessary information such as compositional detail, history, circumstances of collection, previous uses, owners, or classifications, often associated with ex-research material and museum objects, may also be omitted or erased. Again, for museum objects, only reversible techniques would be permitted—for example, a label may be concealed but would not be permanently removed. It is therefore not the whole object itself that is of interest; rather, it is a particular selected element that is used to transmit a pre-decided message.

Samples for Testing

The use of objects as “samples for testing” actively engages students in discovering information for themselves, rather than simply presenting them with facts. In this scenario, students follow instructions in order to carry out tests on objects with the aim of discovering particular physical properties. For example, at the University of Leeds, first-year students were required to carry out a number of tests on mineral specimens in order to determine relative hardness (using the “scratch test”), streak or powder-colour (using the “streak test”), cleavage (which was determined by creating a fresh surface with a hammer), and carbonate content (using the “acid test”).

As “samples for testing,” objects necessarily function as individuals and, again, this requires numerous duplicate specimens. However, while the observation scenario focuses on the visual qualities of objects, in the testing scenario, the physical and chemical properties of objects must be consistent and typical. Therefore, unlike the observation scenario described above, it is essential to have “the real thing,” and as a result of the emphasis placed on the intrinsic properties of the physical objects, replicas and virtual objects cannot be used in their place. Furthermore, the very nature of testing means that the physical integrity of these objects is ultimately sacrificed—they are consumables—and, as a result, “samples for testing” are commonly purchased in bulk or

collected specifically for this purpose but would never be borrowed from a museum collection.

While this scenario (also commonly used in lower-level courses) gives students more control of their learning experience, it is still rather contrived; students are not discovering unknowns; instead, they are discovering specific, predetermined, and unambiguous information for themselves. In this way, the function of objects as “samples for testing” is based on the same underlying principles as the observation scenario, and the difference lies simply in the level of physical engagement with the object. At the University of Leeds, for example, students were asked to carry out the streak test on colourful minerals (such as hematite, pyrite, and chalcopyrite) that would generate a streak, rather than on colourless minerals that would not, thus guaranteeing clear, unequivocal, and useful results.

The destructive nature of the testing scenario limits the range of objects that may perform this function. As “samples for testing,” the physical integrity of an object is ultimately sacrificed and, therefore, only certain types of objects may be suitable. However, equally significant are the effects of testing on the mobility of objects that *have* been used for testing: in most cases, objects that function as “samples for testing” are no longer suitable for any other uses, thus preventing the subsequent circulation of such material.

Sets for Interpretation

The use of objects as “sets for interpretation” is a typical method of approaching problem-based learning and combines a number of objects with resources such as maps, diagrams and data. This use of objects is concerned with fabricated or simplified scenarios that are constructed through the careful selection, arrangement, and combination of particular objects, in order to make a particular point or develop particular skills. For example, at the University of Leeds, second-year students use a set containing hand specimens, thin sections, and a map in order to determine both the relationships between a suite of rocks and the processes leading to their formation (Robert Finch, interview, May 6, 2008). In this case, the various resources are combined in order to encourage students to appreciate the different

scales on which metamorphic processes operate and may be observed, from the mineralogical (using thin sections) to the lithological (using hand specimens) to the regional scale (using maps).

Because interpretation begins with observation, these objects function in much the same way as those used in the observation scenario described above—namely, through visual interaction with the particular features of objects that are of interest. The difference between the observation and interpretation scenarios relates to the complexity of information that students must work with; this scenario effectively requires students to construct an interpretive framework using their own observations and knowledge. Therefore, in addition to tactile and visual engagement, students must engage mentally with the objects and resources.

The Uses and Meanings of Teaching Specimens

In all three scenarios, the ways in which the students encounter objects is closely regulated, both directly through instructions and indirectly through various visual clues and spatial arrangements, in order to both guide the learning process and ensure that objects are treated appropriately. Direct instructions may be provided verbally by the course leader or may be written into worksheets or guidance notes. A number of subtler, indirect clues may also be employed, such as the presentation of objects and their position in the room. At the University of Cambridge, for example, the course workbook provides students with clear instructions about the objects featured in each practical and how they should be treated (Glynis Caruana, interview, August 12, 2009). With reference to a “magnificent sample of fossil crinoids” borrowed from the Sedgwick Museum, students are given the following instructions: “It is heavy and fragile; please keep the sponge base beneath the slab at all times.... Please do not annotate the slab with any marks: inadvertent or deliberate” (Handbook: Part 1A Palaeobiology Practicals 2009). The spatial arrangement of objects is also used to regulate the ways in which students treat objects; museum specimens are placed on benches around the edge of the teaching lab, effectively separating them from the teaching sets of hand specimens which students

handle regularly. Placement on plastezote mats or under glass provides additional clues that objects are to be treated carefully, and these strategies are, again, often used to distinguish the Sedgwick Museum's objects from those taken from the department's teaching collections (Glynis Caruana, interview, August 12, 2009).

In the context of a practical, while students do engage with the objects, they have little control over their meanings; in all three scenarios, information and meanings are decided in advance. By manipulating, physically and conceptually, the objects, using various techniques of modification, presentation, and arrangement, background noise, ambiguities, and alternative meanings are deleted, allowing objects to communicate particular messages and meanings. Thus, for teaching objects that originated as research specimens, for example, it may be necessary to modify them both physically, through resizing or reshaping, and conceptually, by concealing their complex and detailed research histories. The use of museum objects is, however, less flexible, as their physical integrity must remain intact, and, therefore, although associated information may be concealed, keeping it intact may prove more difficult, especially if it is physically attached to the surface of an object on a label, for example.

The ways in which earth science teaching specimens are interpreted depends upon both the physical context of the object and the mental context of the interpreter (Bauer 2002: 46), and, although it is possible to regulate both the objects themselves and the ways in which they are encountered, the mental context of the interpreter is perhaps more challenging. For example, during a first-year practical at Liverpool John Moores University, a student was attempting to identify a piece of breccia.⁷ Having carefully observed the hand-specimen, the student attempted to determine the rock's identity using a flowchart. Starting at the top of the chart, the student used his finger to trace a route through a series of questions: "Is the rock mainly made of calcite? No. Are the grains visible with the naked eye? Yes. Does it contain pebbles? Yes," leading him to identify the rock as a conglomerate. The student had, however, already identified another rock as a conglomerate, so asked the student sitting next to him for help. The other student explained that

it was a breccia and, using the flowchart, demonstrated how he had reached this conclusion: "Does it contain pebbles? No. Does it contain angular pieces of rock? Yes. It's a breccia." After a brief discussion about the difference between pebbles and angular pieces of rock, the student still seemed unsatisfied with the identification, explaining, "but I thought that breccia would be much darker than that."

This example clearly demonstrates the significance of "mental context" in interpreting objects. As Dant explains, "interpretation ... is, at least in part, determined from what the interpreter already knows" (2008: 17), and in the case described above, it is likely that it was a previous encounter with a dark-coloured breccia had led the student to associate the rock with its colour. Thus, by acknowledging that these objects function as signs, their transient and polysemic nature becomes clear. Indeed, the purpose of teaching specimens is to present a simplified version of reality and that is only achieved through the selective regulation and framing of objects. How, then, does this affect the circulation of earth science teaching specimens?

Discussion

Throughout this paper, it has become increasingly apparent that even the most stable scientific objects have multiple meanings, and these may vary both within and between different functions. For example, as a "specimen to observe," a sample of crinoidal limestone may be handled, observed, and described by a student in a particular context, leading to its interpretation as a sedimentary rock that formed in a shallow marine environment (as in the practical session at Liverpool John Moores University). However, the same object may be used as a "sample for testing," and if a drop of diluted hydrochloric acid is added to its surface (as in the practical session at the University of Leeds), the fizzing reaction between the acid and the limestone may be interpreted as evidence that the rock contains calcium carbonate cement. Likewise, placed alongside other sedimentary rocks and maps, as part of a "set for interpretation," students may describe and test the same object in order to calculate the catchment area of a river basin.⁸

Depending on the context in which it is encountered, a single object may be capable of generating a variety of different interpretations. This is not, however, to suggest that these meanings are arbitrary, that they are simply made up, or that any one meaning is more “correct” than the others. Rather, and as Schinkel argues, objects define practice as much as practice defines objects (2004: 401), and this is particularly apparent when it comes to museum objects. For example, the placement of a glass barrier between a student and an object limits the possible meanings of that object to those relating to its observable features, and if we return to the example of crinoidal limestone mentioned above, while a glass barrier would not necessarily interfere with its interpretation as a sedimentary rock that formed in a shallow marine environment, it would prevent a student from discovering that the rock contained calcium carbonate. The strategies used to regulate objects and the particular contexts (physical and mental) in which the objects are encountered include the instructions and worksheets that direct students to interact with objects in particular ways and the presentation of objects and their arrangement in a teaching laboratory. It is possible for these strategies to have multiple meanings and therefore to circulate between different functions, without implying that their meanings are simply “socially constructed” and arbitrary; to borrow from Dewsbury and Naylor, the meanings of these objects are made, but they are not simply made up (2002: 254).

Conclusions

This paper has treated university earth science teaching specimens as “objects in motion” and in so doing has revealed that, despite their weighty and cumbersome qualities, these objects are surprisingly mobile. The origins of teaching objects are diverse, ranging from those collected specifically for teaching purposes to those originally collected for research and from purchased specimens to accessioned museum items. However, this paper has also demonstrated that the origins of objects may affect their meanings and their ability to perform certain functions; the mobility of these objects is not unlimited. Attention to the physical mobility of earth sci-

ence specimens has also called into question their assumed ontological stability: while their meanings are neither unlimited nor arbitrary, they may nonetheless vary. By exploring the different scenarios in which earth science teaching objects may function—as “specimens to observe,” “samples to test” and “sets for interpretation”—this paper has identified some of the strategies that are used to regulate the meanings of these polysemic objects and acknowledges the cultures of the earth sciences.

Earth science teaching specimens are both polysemic and mobile. By focusing on the use of objects for teaching purposes, it has been possible to observe some of the conventions and assumptions that contribute to the cultures of the earth sciences. It has become apparent that in order to function in a learning setting, the mobility and flexibility of objects that makes them so *useful* is precisely what must be regulated in order to make them *useable*.

While this paper has revealed the similarities that exist between the material contained in university earth science collections and the more typical objects that constitute material culture, I believe that there are also some fundamental differences that set them apart. Although teaching objects in university earth science collections (with the exception of casts and replicas) originate in nature, the processes and practices involved in collecting and using objects affect them in various ways. While the selection and removal of samples during the collection process, and the strategies that are used to regulate teaching objects, do not change the fact that these objects came from nature, their impact cannot be ignored. If artifacts are understood as “entities with intentionally modified properties” (Siipi 2003: 415), then it follows that these things are artifacts. This is not to suggest, however, that these objects are no longer natural; as Siipi explains, “the lines between natural and unnatural may be drawn differently from the ones between artefacts and non-artefacts” (2003: 420). In this way, it is possible to acknowledge that these things are both natural and man-made; the two are not mutually exclusive.

The intentionality embedded in these natural artifacts as a result of both the collecting process and their subsequent modification and regulation, is not, however, the same as the intentionality

that is “designed into” man-made objects (Dant 2008: 28) that are constructed from scratch. This is because no matter how much effort and work are put into stabilizing and regulating these objects, their natural origins make them essentially unruly. In this way, they seem to differ from other forms of material culture because these objects are selected and collected *because* they are natural, in order to function as evidence or illustrations of geological processes, evolution,

or ancient environments, for example. As natural objects, however, their possible meanings are varied, and, in spite of the work that goes into regulating these things, those objects that are used for teaching purposes remain flexible and mobile; containment merely “tames” them (Edensor 2005: 312); as this paper has revealed, they retain their transience, despite the best efforts of scientists to pin them down.

Notes

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1. This paper focuses on an element of my doctoral research (Chalk 2012) that is concerned with extending the theories and methods of material culture studies to university earth science objects and collections, exploring the larger lives of these objects, from their initial collection, use (for teaching, research, or display), and circulation, through to their eventual fate. The case study institutions on which my research has focused are: University of Leeds, Liverpool John Moores University, University of Cambridge, University College London, and University of Manchester.
2. For a review of this work, see Alberti (2008).
3. A “mutable mobile” is described as: “An object or a class of objects [that] may be understood as a set of relations that gradually shifts and adapts itself rather than one that holds itself rigid” (Law and Singleton 2005: 339). In this sense, the “mutable mobile” stands in contrast to Latour’s “immutable mobiles” (1986, 1990: 44-47), for which mobility is dependent upon the maintenance of stable networks of relations (cf. Law and Singleton 2005: 347).
4. The exception occurs when casts and replica objects are used, and I mention these in the Academic Lives section.
5. This account of the hierarchy of use has been simplified for the purpose of this paper. I do, however, acknowledge that in practice, there are various factors that complicate the model presented here. They are not considered in detail as they add little to the purpose of this paper.
6. *Sillimanite schist* is a particular type of metamorphic rock with a high content of the mineral sillimanite. The material was collected from a field site in Connemara, Ireland. This particular example has been considered in more detail in Chalk (2011).
7. All classroom observations taken from Understanding the Earth practical 3 (sedimentary rocks) on October 6, 2009.
8. This example is taken from Plymouth University’s “Labplus” website: http://www.ssb.plymouth.ac.uk/labplus/projects/KS_cheddar.htm

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