



Cleaning, sculpting or preparing? Scientific knowledge in Caitlin Wylie's *preparing dinosaurs*

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Abstract

Caitlin Wylie's "Preparing Dinosaurs: the work behind the scenes" (MIT Press 2021) provides a rich ethnographic analysis of the work of fossil preparators. On her account, knowledge in vertebrate paleontology is mediated through a three-way division of labour between paleontologists, preparators and volunteers, each with their own role, expertise and responsibility. In this review, I develop her notion of 'preparation as knowledge', focusing in particular on the nature of objectivity in paleontological knowledge and on the middle-road she indicates between constructivist and realist approaches to epistemology.

Keywords Fossils · Invisibility · Realism · Constructivism · Objectivity

Introduction

An early scene in the original film adaptation of *Jurassic Park* involves what is implied to be an accurate depiction of fossil excavation. The camera swoops overhead as a team of workers sweep away dust and sand, revealing (as John Williams' score swells) a perfectly-articulated theropod fossil ready, but for transport, for museum display. And such is how many of us imagine the construction of paleontological knowledge. Through a remarkable marriage of biology and geology, organismic form is preserved via mineralogical composition, just waiting to be discovered. But fossils are not only the work of biology and geology. They are also the products of skilled human ingenuity and labour. Fossils are extremely rarely as articulated as depicted in the scene, are never that complete, and indeed do not appear to science via the simple clearing of desert dust. Fossils must be painstakingly carved out of their surrounding rock. The removal of fossil from matrix is no trivial task and makes crucial

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differences to how fossils might be deployed as evidence. The scene in Jurassic Park, then, obscures crucial information about how paleontologists generate knowledge: specifically, that of fossil preparation, the central topic of Caitlin Wylie's arresting new book.

Wylie's *Preparing Dinosaurs* is the result of a multi-site ethnographic study examining fossil preparation and is exactly placed to puncture naïve perceptions of fossils as depicted in popular imaginings. The book is the cumulation of Wylie's long-running analysis of fossil preparation, managing a highly-readable combination of sociological analysis, peppered with ethnographic anecdotes through five chapters each covering an aspect of fossil preparation: from the specimens themselves, to their evidential uses, to the communities involved, to public presentation. The reader comes away with a rich understanding of the nature of fossil preparation, how it fits into the generation of paleontological knowledge, and with a set of insights concerning the nature of scientific communities, technological innovation, and the very-human, idiosyncratic nature of science to boot.

Old-hat as it may be, I've a soft-spot for Clifford Geertz's thought that anthropology works by situating Big Questions in mundane, day-to-day circumstances (Geertz 1973). On his view, the anthropologist "confronts Grand Realities... Power, Change, Fate, Oppression, Work, Passion, Authority, Beauty, Violence, Love, Prestige, but he confronts them in contexts obscure enough... to take the capital letters off them" (20). So, one function of ethnographic work is to take these Capitalized Themes and interpret their playing out in down-to-earth contexts: "These all-too-human constancies, "those big words that make us afraid," take a homely form in such homely contexts. But that is exactly the advantage. There are enough profundities in the world already" (20). The best anthropological work, then, provides a rich, ethnographic context to think through larger concepts and questions. Ethnographies situate generalities in local human contexts, and thus makes some sense of them.

Wylie's *Preparing Dinosaurs* is an exemplar of the anthropology of science or science and technological studies. Her Grand Reality is Scientific Knowledge, her mundane circumstances are the work of 'fossil preparators': folks who are not paleontologists, but do the crucial paleontological work of separating fossils from their rock matrix. By examining the human interactions between preparators, paleontologists and volunteers—their varying roles, standing within museums, conflicts, jokes and motivations—Wylie builds a picture of how fossil preparation communities are structured, how they generate knowledge, and how this knowledge is presented to the public.

Further, Wylie's book builds a new metaphor for scientific knowledge generally. She presents scientific knowledge as *preparation*, that is, an open-ended, path-dependent and goal-oriented set of processes. As such, her book simultaneously develops a first-order account of how knowledge is generated in fossil preparation and a second-order account of scientific knowledge inspired by analysis of fossil preparation. My aim in this review is to try to capture the central threads of Wylie's rich ideas, and then spend some time reflecting on and developing the notion of 'preparation' as a metaphor for scientific knowledge. So, the next section, 'preparing dinosaurs', describes Wylie's position, while the section following, 'preparing knowledge', aims to highlight and develop Wylie's contribution in a more philosophical vein.

Preparing dinosaurs

Wylie's book is squarely focused on the role of fossil preparators in vertebrate paleontology. Paleontology is a strange beast: despite being easily one of the most-recognised scientific disciplines, it lacks the typical institutional home others enjoy. There are no paleontology departments *per se*, rather, paleontologists are found across geology, biology and archaeology departments, as well as in veterinary schools and—Wylie's focus—museums. Vertebrate Paleontology is also epistemically non-standard in many ways, relying heavily on the analysis of typically incomplete, difficult-to-work-with specimens to wrest knowledge of the lifeways of long-extinct critters (Turner 2011; Currie 2019).

Crucial framing for Wylie's analysis is the notion of *invisibility* as developed by Steven Shapin and others (Shapin 1989; Fara 2011). In short, Shapin noted how the presentation of science—in scientific publications and historical, sociological and philosophical analyses—made prominent, *visible*, some scientific workers but not others. In particular, high-prestige actors, scientists, are given agency, responsibility and credit while others—Shapin emphasized lab technicians—disappear from the scene completely. These standard presentations of science erase the multiple intellectual and material conditions scientists rely on, to say nothing of the various non-scientists whose efforts are necessary for science. In such depictions, scientists stand on the shoulders of giants, not on the shoulders of multitudes. A crucial part of understanding how science really works, then, requires making visible these invisible actors.

This attention to visibility expands who we need to talk about when we talk about scientific knowledge. Wylie adopts the notion of a *research worker*, more-or-less anyone involved in the production of scientific knowledge:

In practice, all research workers—that is, anyone who contributes to research, including scientists, technicians, volunteers and students—do various overlapping, recursive combinations of preparing evidence and interpreting it, making it difficult to extract which tasks count as “science” and therefore which workers deserve scientific recognition (Wylie 2021, 9).

Examining research workers in museums leads Wylie to three crucial players in fossil preparation: paleontologists, preparators and volunteers. These three roles relate in complex ways, with their own areas of responsibility, freedoms and restrictions. This idiosyncratic epistemic and social network is explored through five main chapters, each detailing a different aspect of fossil preparation. These include *preparing evidence* (Chap. 1)—at base, what makes for a good specimen—*preparing communities* (Chap. 2), that is, what makes for a good fossil preparator and their training—*preparing technologies* (Chap. 3), that is, explaining the assemblage of tools and techniques preparators use—*preparing science* (Chap. 4), that is, the social networks that preparators are embedded in and how they underwrite knowledge generation—and *preparing public science* (Chap. 5), that is, how such work is presented in museum contexts. This structure might imply separate topics, but that is misleading: each

chapter bleeds into the others. This isn't a criticism but a consequence of Wylie's focus on research workers and her approach to thinking about knowledge:

Thinking about science as knowledge preparation highlights the interlocking relationship between evidence, communities, technologies, and conceptions of science, and thereby encompasses the entire research community, the variety of work those people do, and the ongoing feedback between research work and knowledge (Wylie 2021, 204).

Making research workers like fossil preparators and volunteers visible involves breaking down various epistemic abstractions. You can't speak of fossils' justificatory roles without considering their journeys as data, from their messy extraction to their laborious preparation to their mounting in museums. But you can't speak of that without considering the social, institutional and pedagogical aspects influencing the various players involved in these activities. Wylie's approach to understanding knowledge (to again refer to Geertz) is thoroughly thick, and as-such resists neat delineation. As she says, "...the process of preparing evidence, communities, technologies, and conceptions of science is one and the same" (Wylie 2021, 166).

As I've noted, the core of Wylie's account of knowledge generation is a social network consisting of three major roles, where "... workers differentiate themselves into professional groups that they believe are united by a common purpose: science" (Wylie 2021, 135). At the top of the pile, so to speak, is the paleontologist. The paleontologist is academically trained and is in the business of interpreting and analysing fossils—that is, the paleontologist deploys paleontological data (fossils) to form evidential claims—the paleontologist is also in charge of which fossils get prepared. By contrast, the fossil preparator is not typically trained in paleontology, but is a professional museum employee, highly skilled in removing fossil from its rock matrix. Although deciding which fossils to prepare is the domain of the paleontologist, decisions about how to prepare falls on the preparator. They have control of the techniques, tools and approaches to preparing fossils: often risky decisions given fossils' fragility and the sometimes irreversible processes of preparation. Finally, outnumbering both paleontologists and preparators, are the volunteers. Volunteers differ from fossil preparators sometimes via skill, but always in terms of professionalization and responsibility. Volunteers prepare fossils, but do not make decisions about how.

So, the preparation of fossils relies on a network of paleontologists, who don't know how to prepare but do know how to interpret, preparators, who do not interpret, but prepare and decide how to prepare, and volunteers, who simply prepare, turning to preparators for guidance. This division of labour serves multiple epistemic functions. At base, paleontologists needn't worry much about the vagaries of fossil preparation—they can more-or-less think that specimens are as they should be—and fossil preparators needn't worry about the theories and hypotheses that paleontologists are concerned with. Their differing roles and incentives afford a productive epistemic community.

The distinction between paleontologists and preparators solves a series of trade-offs inherent to working with fossils. Vertebrate fossils as data are typically incomplete, fragile, intransigent and, well, heavy: difficult to work with practically and

epistemically (Currie 2021). But science happens within its own timeframe. Analyses must be carried out, papers drafted and grants sought. As such, paleontologists often want fossils prepared sufficiently for their work as quickly as possible. Preparators, by contrast, care not for the baubles of academic work, and thus are more interested in the fossils in and of themselves. Thus, with different incentives, and with preparators maintaining their own power and autonomy, the two groups can negotiate compromises.

Further, preparators' freedom from analysis and academic incentives leaves their creative juices expendable on preparation itself. A major feature of Wylie's analysis is the *idiosyncrasy* of fossil preparation. In a departure from the paradigm invisible research worker—the lab technician—the ideal preparator does not approach an automated rule-follower. Rather, preparators hone their skills in local groups, trading tips, techniques and practices amongst themselves. Their work is creative, non-standardized and craft-based, and they appeal to this in asserting their roles in paleontology labs (Wylie 2015). This idiosyncrasy is partly underwritten by the idiosyncrasy of vertebrate fossils themselves.

... most technicians can't alter their techniques too much without threatening the reliability of the data they produce, which is supposed to be replicable by other people. In comparison, vertebrate fossils are usually rare, and are stored and restudied over centuries; they are not considered replicable. This view perhaps permits preparators the leeway to select and modify methods to match these diverse specimens, rather than try to standardize the methods or objects. (Wylie 2021, 58–59)

It is tempting—especially as a philosopher—to see the division of labour as a means of tackling issues such as theory-ladenness. If we're worried about the preparation of fossils being infected by paleontological theory, then having a set of folks who do the preparation and another set who do the analysis seems a great solution. As Wylie points out, however, this is at least not supported by paleontological attitudes:

Distancing scientists from evidence production could also promote objectivity by preventing scientists' assumptions from influencing the evidence... Yet paleontologists do not articulate this reason of epistemic defense: rather, they subtly dismiss preparation as merely manual work. (Wylie 2021, 138)

Paleontologists' attitudes do not decide epistemic function alone, but the power relations between high-prestige paleontologists and comparatively low-prestige fossil preparators are crucial for understanding how the negotiation and compromise necessary for fossil preparation plays out.

This division of labour is maintained via specific pedagogical approaches which form a group identity:

Learning how to work and act like a preparator or volunteer is a long-term process of socialization and hands-on experience. Individual practitioners' ongoing learning is a key component of how experts prepare their community—that

is, how they define a shared, collective identity based on often-tacit norms of social and technical behavior. (Wylie 2021, 62)

These collective identities are policed and enacted in the social interactions captured by Wylie's ethnographic anecdotes: preparators use jokes to police paleontological interference with preparation, volunteers gossip about the various hurdles and tests required to access the most prestigious fossils, preparators come into conflict about methods, tools and techniques—particularly pertaining to glue.

At base for Wylie it is the development and maintenance of a set of social roles and their interactions—particularly how trust is maintained across them—that determines how fossil preparation generates knowledge. This is most convincing, I think, in Wylie's discussion of the history of fossil preparation. As opposed to traditional histories of technology which focus on technological innovation, Wylie argues that “The history of fossil preparation is better understood as a history of preparators” (Wylie 2021, 103). The argument is made in two steps.

The first step points to the remarkable stability of the fossil preparator's kit throughout the 20th Century, despite major progress in the quality of prepared fossils. Sandblasting and pneumatic hammers (themselves partly mechanized hammer and chisel) were uniformly in use by the 1920s, but, as Wylie points out, the detail, skill and quality of prepared fossils changed enormously. For Wylie, it is the development of local methods and expertise, underwritten by the emergence of the social networks she describes, that explain this progress against a static technological background.

The second—and for me most interesting—part of the historical argument is the handling of potentially disruptive technologies. Wylie focuses on CT scans, but various new techniques have become increasingly available to paleontology in the last thirty years: from in-silico representations (Sepkoski 2012; Turner 2009), robotics (Tamborini 2020), LiDAR and other scanning techniques, and so on. Such technologies are not treated as replacing fossil preparation. This is partly due to fairly mundane reasons such as the limits and expense of technology, but Wylie also emphasizes how the skill and knowledge of fossil preparators themselves is necessary for paleontological progress. Negotiations and compromise regarding fossil preparation is a necessary part of paleontological reasoning. Further, paleontologists and preparators are socially and physically distant from CT-scanning technicians. The day-to-day interactions between paleontologists and preparators provide social bonds of trust otherwise unavailable.

Workers define their work and roles relative to each other, as opposed to relative to a process of research or specimen care. If CT were to replace preparation and thus preparators, this network of social roles and divided labor in labs would collapse. As merely an additional tool, however, CT does not threaten the status quo (Wylie 2021, 129).

Finally, as a specimen-based science, fossils are where the paleontological buck stops. Even in contexts where a scan might do important evidential work, paleontologists see the fossils themselves as the ultimate epistemic arbiters. This point is

crucial as well for Wylie's discussion of the nature of fossil preparation as displayed in museums:

[Research workers] consider specimens to be a physical defense of scientific knowledge, therefore specimens must be educational but also honest, such as with labelled reconstructions (Wylie 2021, 183).

The increasing practice of placing fossil preparators and volunteers in fishbowl-like displays in museums, Wylie argues, doesn't simply provide some kind of defence of paleontological science, but also somewhat subverts the traditional role of museum exhibits overall:

...they invite visitors to reconsider their knowledge about *science*. A glass-walled lab portrays science as human work that visitors must interpret, thereby somewhat decentralizing museums' typical presentation of finished specimens and knowledge. This approach reverses the role of an exhibit as a source primarily of facts to a source primarily of data... (Wylie 2021, 173, italics in original)

So, Wylie paints fossil preparation as a kind of artistic craft necessary for, and embedded within, vertebrate paleontology. Its idiosyncratic locality of techniques is underwritten by the idiosyncrasy of fossils themselves, and in the place of standardization and homogenization there are local networks of trust. Making fossil preparators visible reveals the messy, human side of scientific knowledge.

Preparing knowledge

It is when we recognise science as the actions of distinct groups of actors, with varying values, goals, expertise, and forms of power, that we can fully understand knowledge as the hard-won outcome of compromise and cooperation (Wylie 2021, 208).

Wylie provides a rich and plausible story about the nature of scientific knowledge in vertebrate paleontology as it pertains to fossil preparation. However, this is not her only aim: she also wants to explore the notion of 'preparation' as a metaphor for science generally. Here, understanding which aspects of fossil preparation should or might be understood as a model for science is to some extent left up to the reader. This needn't be a criticism, however: returning to the Geertzian approach, we're using the mundane world of fossil preparation to take the capital letters off of 'scientific knowledge', and this needn't involve (in fact, we might think it somewhat in opposition to) some kind of Grand Theorizing. Regardless, I want to here suggest a few ways of understanding knowledge as preparation, taking Wylie's work as a jumping-off point.

In the opening chapter, Wylie presents the notion of ‘preparation’ as a contrast, or perhaps corrective, to the more familiar notion of ‘construction’. I won’t here attempt to differentiate these two ideas: the notion of knowledge being constructed has been used in many ways and I doubt there is a strict way of differentiating them. Instead, we should think of preparation as providing a different kind of emphasis. As Wylie puts it,

I suggest that we think about knowledge as the intersection of many interlocking and iterative processes of preparation, namely preparing evidence, communities of workers, technologies, and private and public conceptions of science. Thinking about science as all these kinds of work, done by scientists and non-scientists alike, offers a more comprehensive model of how we learn about the world (Wylie 2021, 20).

So, part of understanding scientific knowledge as being prepared is seeing it as an open-ended process. The preparation of a fossil, in principle at least, never ends: old fossils are re-prepared according to new techniques and towards differing evidential, pedagogical or display purposes. There is no ‘final’ fossil. Is this true of scientific knowledge overall? Certainly in principle: that scientific knowledge is revisable is an old-hat truism if anything is. But fossil preparation isn’t open-ended in merely this sense: changes to fossils are often permanent, moves in one direction close off other approaches. So too with scientific knowledge: it is path-dependent, relying on what went before it. The preparation of knowledge involves various decision points which potentially close off a set of avenues even as others open. Knowledge-production is scaffolded (Chapman and Wylie 2018, Caporael, Griesemer & Wimsatt 2014, Routledge 2021).

Further, as fossil preparation demands a holistic, broad understanding of the epistemic, so too does scientific knowledge more generally. Science is the product of an array of different actors performing differing roles, embedded in complex institutions using a variety of theoretical and technical machinery while managing a variety of relationships and perceptions both within and without science. This doesn’t mean our focuses cannot be narrowed—Wylie’s own work leaves open a variety of other actors we might care about in understanding paleontology—but it does warn against over-reliance on too-abstract, reified conceptions of knowledge or justification (an important reminder for philosophers...).

One lesson I take from Wylie’s account of the role of technology and trust in science is her expert puncturing of the idea that anything in science is, as it were, *off the shelf*. By that, I mean that scientific technologies and techniques should be understood in more-or-less automated, by rote terms. Technologies such as CT-scans—just like fossil preparation—require highly specific and tailored skills to use effectively. Paleontologists and fossil preparators have a somewhat fraught relationship with CT-scans in part because they don’t have the right social relationships with CT-scan experts. Paleontologists can black-box fossil preparation not because those details don’t matter to the knowledge they generate but because long-standing social relationships and roles underwrite their trust in what fossil preparators do. So, we might say that all scientific technologies and techniques rely upon local, trained—dare I say

artisanal—expertise, and as such ‘black-boxing’ on the basis of the details of knowledge-generation techniques not mattering is never justified. Instead, black-boxing can occur because of institutional structures which underwrite trust between experts (see also Chapman & Wylie’s 2018 discussion of carbon dating).

Wylie’s analysis is focused on people, a social network centered on a division of labor that is delineated by forms of authority, differing incentives and differing kinds of visibility. While the importance of incentives and divided labour is nothing new, the way that differing visibility plays out in fossil preparation is fascinating. Where typically invisibility—the erasure of various research workers’ contributions—is taken as a negative, in Wylie’s analysis the notion becomes significantly more ambivalent. The invisibility engendered by fossil preparator’s being cut-off from academic recognition is crucial for their role in helping negotiate various trade-offs involving paleontological data. Further, it is hard to imagine the flexible, idiosyncratic problem-solving and artistry of fossil preparation without the shield of invisibility. Making fossil preparators more visible would likely involve standardizing their practices, putting their various creative works to potentially quashing scrutiny. Indeed, given the idiosyncrasy of fossils and their evidential uses, a standardized preparation procedure would be ineffective. If we take this element of Wylie’s analysis as part of a metaphor concerning scientific knowledge, we see it as the product of complex negotiations between many different actors, one where trust plays a crucial role.

Trust underlies their collaborative compromises across fields, even during controversies. It gives credence to preparators’ skillfully crafted specimens and creatively designed technologies. It leads museum visitors to respect and admire displays of scientific knowledge, specimens, and sometimes workers. It encourages amateur fossilists to swap expertise with research workers. Crucially, trust allows us all to see a rock not as a rock but instead a fossilized relic of an unfamiliar animal in an alien environment, and therefore as one fragment of a grand narrative about life on Earth (Wylie 2021, 221).

Although Wylie’s account emphasizes the social side of epistemology, its ambivalence concerning invisibility creates interesting potential tensions with notions of objectivity which emphasize social exchange and openness. For instance, consider Helen Longino’s classic account:

As long as background beliefs can be articulated and subjected to criticism from the scientific community, they can be defended, modified or abandoned in response to such criticism. As long as this kind of response is possible, the incorporation of hypotheses into the canon of scientific knowledge can be independent of any individual’s subjective preferences. Their incorporation is, instead, a function in part of the assessment of evidential support. (Longino 1990, 73)

Views like Longino’s boil scientific objectivity down to the object of knowledge being subject to the relevant expert scrutiny. A background belief’s running the gauntlet of scientific debate is the bulwark against wishful thinking. As such, sci-

entific knowledge should be made as accessible as possible to the relevant communities. We needn't read these accounts of objectivity in terms of maximally naïve concepts of 'open science', but nonetheless on such views an easy connection is there to be made between openness and good science. But fossil preparation, on Wylie's view, seems to only very rarely be put to this kind of scrutiny. Metadata concerning fossil preparation is not gathered, techniques are traded in idiosyncratic ways, work is explicitly—and proudly—non-standardized, with only a few telling exceptions fossil preparators do not appear in publications as authors nor are their techniques described in methods sections.

On views emphasizing the public accessibility of knowledge, the invisibility of fossil preparation could very well undermine the objectivity of vertebrate paleontology. And yet, as we've seen, that very invisibility underwrites the crucial epistemic roles that fossil preparators play. Without that, they could be subject to different incentives—and thus less well-placed to balance the paleontologists' desire for quick fossil data—and less able to adopt the idiosyncratic, creative approach that is so crucial to Wylie's account. We might be tempted to *say so much the worse for paleontological knowledge*, but I think that is too quick. A science like paleontology, one based in epistemic scarcity and with deep focus on specimens, requires individual, non-standard data preparation, and to some extent at least invisibility enables the social conditions underwriting that preparation. No doubt—we might think—the lack of scrutiny on fossil preparation is a mark against paleontological knowledge, but we might also argue that the more intimate social relationships in paleontological labs foster a different kind of trust and objectivity¹.

Taken as a metaphor, we can understand scientific knowledge as preparation, then, as involving many differing components. Nothing is off-the-shelf. The components of knowledge—data, evidence, specimens, theories, etc.—are path-dependent. Understanding justification requires a holistic conception of actors, roles, techniques and institutions. Trust is built from divisions of labour policed by social interactions and incentives, themselves often requiring differing levels of visibility. Although these are common themes in both STS and the philosophy of science, Wylie makes these a particularly compelling package. It is an open question how widely the package might apply: science is complex, diverse and resistant to too-general treatments. Perhaps we could think of what I've drawn from Wylie here as the *preparation hypothesis*: namely, scientific knowledge is generated via open-ended, path dependent generative processes relying on networks of power, responsibility and trust embedded in social institutions. To see if the hypothesis holds out across science, we need to go and look.

There's a final element to the notion of knowledge as preparation, which Wylie makes explicit in the introduction, but disappears throughout the rest of the book. As mentioned, Wylie contrasts 'preparation' with 'construction', that is, it is a kind of alternative to the social-construction of knowledge. But in what sense exactly? Social constructivists would likely agree with much in the preparation hypothesis, so, where's the difference? Wylie takes language from fossil preparators and scientists to

¹ We shouldn't take this thought too far: paleontologists recognise the importance of specimens being available for scrutiny.

recast the familiar categories of constructivism and realism. For the latter, we have the notion of *cleaning* fossils:

Cleaning implies preexisting evidence waiting to be revealed. The work therefore sounds clean in the sense of free from values, theories, and individuals' biases as well as simple, straightforward, and quotidian. In this view, practitioners' actions respond to reality alone. (Wylie 2021, 14).

On this view, fossil preparation merely involves 'wiping away' the matrix to reveal the fossil, much as the fieldworkers appear to in Jurassic Park. However, this cannot be the whole picture. For the constructivist, we have the notion of *sculpting*:

Preparators subtly embrace constructivism more often than scientists do, such as by talking about their work as "creative" and, occasionally, "sculpting." This kind of language emphasizes the complexity of their work as well as their own power in defining fossils. (Wylie 2021, 14)

If fossil preparators are sculpting fossils, they might find themselves with some constraints from the materials they work with (just as an artistic sculpture is restricted by their materials), but it is they who decide what the fossil looks like. Wylie's notion of preparation claims that fossil preparation sits somewhere in between cleaning and sculpting.

... supposed cleaners also make decisions that influence evidence (e.g., fossils' appearance, completeness, and stability; taxidermied animal skins' shapes and type of preservation; and data sets' selected information and organization). They thus constitute what that evidence is by altering its form. The cleaning and sculpting (and hence the realist and constructivist claims) are inseparable and simultaneous. (Wylie 2021, 14).

To *prepare* a specimen, then, is to engage expert, trained—and potentially creative, opportunistic and artistic—agency in making some part of the world amenable to scientific study. Fossils are not only the products of collaboration between biology and geology—human skill is crucial—but neither are they merely the product of human skill. They are co-produced by ourselves and nature. Of course, realists don't deny the role of human ingenuity and intervention in revealing nature, and constructivists needn't deny that there are natural process that we study, but overemphasizing and sometimes forgetting these aspects are occupational hazards that perhaps the metaphor guards against.

So, by making fossil preparators visible—bringing them from the background to the foreground—Wylie undercuts a particular source of paleontological objectivity. Namely, one that sees fossils as 'raw' natural objects, incomplete but nonetheless 'readable' as is. However, she doesn't at all leave us with skepticism. Rather, we're invited to understand how through social interactions, tacit skill and trust a variety of research workers are able—with great effort and many cracked fossils along the way—to wrest some rich knowledge of the past from its scant material remains.

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