Earth Sciences from the Perspectives of Science and Technology Studies

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Abstract

The discipline of science and technology studies (STS) can provide historians with methodological approaches and theoretical frameworks to access key aspects of the Earth sciences, such as scientific practice, technology, and social values. This chapter outlines these tools as demonstrated by exemplary STS studies of the Earth sciences.

Keywords

Scientific practice · Technology · Social values

1 Introduction

Analyses of how people construct knowledge and the social implications of this scientific work are key elements of histories of the Earth sciences. The discipline of science and technology studies (STS) has a lot to offer historians investigating these

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topics in the form of theoretical frameworks, research methods, and published sources. In this chapter, I discuss examples of STS-informed studies of the Earth sciences to call attention to their usefulness for historians. In particular, studies of scientific practice, technology, and social values in the Earth sciences offer important methodological and theoretical paths for historians to follow. I hope that these studies and other STS research can inspire more historians of Earth sciences to ask questions about labor, tools, and ethics. Embracing these topics enriches the histories of the Earth sciences and helps those histories inform our understanding of today's global problems as well as the realities of scientific work and knowledge.

Many scholars demonstrate the insights gained by applying STS methods and mindsets to interpret the Earth sciences. Specifically, STS relies on reflexive methodologies that encourage critical engagement with scientists, such as participant observation, community-engaged research, and interdisciplinary collaborations to understand, analyze, and – ideally – improve science (e.g., Felt et al. 2016; Sismondo 2010). These methods involve close analysis of relationships among people, things, and ideas, and raise questions about how those relationships could be otherwise, such as more inclusive, more equitable, and more socially beneficial.

As an example of the benefits of this approach, let us consider my study of how people process fragmented, rock-embedded vertebrate fossils to become scientific specimens from which scientists can learn about past life. This question requires close attention to the workers who do this manual, dirty, seemingly simple work. Based on observation and interviews of fossil preparators, I found that they have no formal training. Instead, they rely on their embodied judgment, creativity, and values (e.g., aesthetics, their own control over their work, and the long-term conservation of fossils) to transform a fossil into an irreplaceable research specimen (Wylie 2015, 2018, 2019a, b, 2021). Yet this dynamic and crucial work goes undocumented in scientific papers and specimen records. These workers, like many others who prepare scientific data, are underrecognized for their contributions to knowledge. Institutions and scientists deem them "technicians" and "support staff," rather than researchers, and thereby justify giving them little credit in publications as well as lower pay and prestige than scientists. Furthermore, the invisibility of this work and these workers erases important insights about fossil specimens, limiting how scientists can interpret them as evidence.

This research began as a typical STS study of a scientific community's work of constructing knowledge. As I collected ethnographic data, though, I wanted to say more than what was happening and my interpretations for why. I wanted to make arguments for how research *should* happen based on what I was seeing, specifically, how workers should be treated, how scientific work should be documented, and, more generally, who should be doing scientific work. I relied on theories from STS and other fields to conceptualize power dynamics in scientific workplaces and ethical issues of credit and documentation in scientific work, such as theories of invisible labor (Shapin 1989, 1994; Law 1994), social capital and expertise (Bourdieu 1993; Collins and Evans 2007), communities of practice (Lave and Wenger 1991), and the classic idea of social construction of knowledge (e.g., Latour and Woolgar 1986; Sismondo 1996). This approach made it possible to apply my evidence about vertebrate paleontology laboratory communities to make broader arguments about the hands-on skills that science relies on, the creativity that informs every step of scientific work and not just theory-building, and the context-dependent forms of power and autonomy that workers negotiate in their everyday interactions. Based on these arguments, I raised questions about who *should* count as a researcher, and how to fairly recognize scientific work that is routinely dismissed as menial. These questions have implications for diversity, equity, and inclusion in science, for instance, as well as a richer understanding of how we know what we know about extinct animals. Thanks to STS, I could think about fossil preparators as a revealing case study of data-constructing workers and the challenges they both face and raise for scientific work and knowledge.

Similar to how observers of the Earth have long used specific specimens and landscapes to represent broader phenomena and global systems, I ask here what histories of the Earth sciences can teach us about social systems of work, knowledge, and responsible research in various places and times. STS provides powerful tools to frame these kinds of questions. In this chapter, I discuss the insights that scholars have already provided by applying STS to analyze the Earth sciences, and I point out opportunities for important future work.

2 STS of the Earth Sciences

Here is a tour of STS-informed studies of the Earth sciences to illustrate the most valuable methods and theoretical frameworks. This is not an exhaustive literature review; instead, I highlight studies that I consider exemplars and inspirations for future work. These authors do not necessarily consider themselves to be STS scholars, demonstrating the versatility of STS methods and theories. In particular, I discuss STS studies that investigate scientific practice, technology, and social benefit of the Earth sciences. These sources are primarily about Western contexts, highlighting a need for more studies of Earth sciences based in the rest of the world.

2.1 Scientific Practice

A hallmark focus of STS is scientific practice, i.e., the actual work that people do to investigate the world. The idea is that we must understand how people collect, define, analyze, and interpret evidence to understand the knowledge that they propose. I took this approach by studying how vertebrate fossils are chiseled out of rock and reconstructed to be studied and, crucially, who does this expert work. The observations and interviews I did are possible only for recent history, but there are other ways to access scientific work in the archives. Historians Paul Brinkman (2010) and Lukas Rieppel (2019) use field notebooks and museum archives to similarly study the people behind the dinosaurs, particularly fossil collectors and fieldwork assistants in the nineteenth-century United States. Their work illuminates the critical importance of fieldwork and specimens – and thus the people who make them possible – to the Earth sciences. Historian Samantha Muka (2023) likewise draws on archives as well as interviews to reveal the importance of technicians to knowledge about oceans, particularly aquarists who care for live specimen collections in aquariums and who create ingenious technologies of tanks and plumbing systems that sustain "oceans of glass" for research and display. Without these workers' expertise and creativity, scientists' ability to observe and experiment with oceanic ecosystems would be limited to fieldwork.

Amateurs, hobbyists, and volunteers have long contributed their labor and ideas to knowledge about the Earth. Residents guided European naturalists around their homelands, such as working-class men in northern England (Secord 1994) and Indigenous groups in the Americas (e.g., for renowned collectors and theorists Charles Darwin [(1839) 1913] and Hans Sloane [Delbourgo 2017]). These guides provided crucial access to local landscapes, experience-based knowledge, and protection and food. Likewise, volunteer earthquake observers (Coen 2013) and weather-spotters (Daipha 2015) have served for centuries as witnesses of natural phenomena for scientists, who continue today to build observers' report data into their decision-making models and research protocols. In other circumstances, witness accounts are ignored or forgotten. This has been especially true when the witnesses came from marginalized groups, such as the survivors of the 1811–1812 earthquakes in New Madrid, Missouri, who were primarily poor rural residents, tall-tale-telling hunters, Indigenous people, and enslaved people (Valencius 2013). By unearthing this "lost history" thanks to these ignored witnesses' preserved stories, historian Conevery Bolton Valencius (2013) reveals fascinating insights on how race and social class shaped seismic knowledge.

As these studies of ignored collaborators and "lost" histories demonstrate, researchers tend to get the credit for knowledge about nature because their names are on published papers. However, looking more closely at the work required to study nature reveals a much broader cast of characters who have contributed to what we know about the world. These contributors tend to have different education, backgrounds, and identities than scientists do, suggesting that jobs for non-researchers can be a powerful pipeline to include more diverse kinds of people in scientific practice today. A more diverse scientific community will produce scientific knowledge enriched by a wider variety of worldviews and values, which is likely to make that knowledge more comprehensive and socially relevant. Thus, histories of the Earth sciences that consider all contributors enrich our understanding of scientific work and knowledge as well as the social systems that underlie them, such as education, skill, prestige, recognition, and equitable access to participation in knowledge-making. It also awards contributors their due credit for important scientific work that may otherwise be missing from published or archival sources.

Along with discovering *who* is doing scientific work, studying *what* they are doing transports us to a particular time and place, as a powerful reminder that science is human work. Producing knowledge about nature thereby relies on all the creativity, wisdom, skill, failures, and foibles that make us human. For example, historian Martin Rudwick's foundational work on history of geology includes insightful assessments of how eighteenth- and nineteenth-century European researchers represented geological evidence (e.g., 1976a, 1985, 2005, and 2008). A geological feature such as a fault or an anticline cannot be carried home to be analyzed, except as small samples of rocks and minerals. To solve this problem, natural philosophers created a "visual language" for geology, which included conventions for mapping, use of color, and standard indicators of elevation and rock type (Rudwick 1976b). These meticulously drawn diagrams could then be carried home to be analyzed in more depth, compared with othe evidences, and shared with people who had never visited the feature itself. Famous fossilist Georges Cuvier extended this pictorial capture of geology to fossils, thereby building a "paper museum" of drawings of fossil specimens that were much easier to store and share than the heavy, fragile bones (Rudwick 2000). Scientific illustration and representation, like many aspects of scientific practice, are not documented in publications. Rudwick found it in Cuvier's archives, which capture aspects of the creation stories of the images that Cuvier had published without explanations for how they were made. It is easy to overlook the importance of skilled draftsmanship to this approach to research, as well as the complexity of building consensus around standards of representation, particularly when those representations serve as the primary evidence for a knowledge claim (e.g., Lynch and Woolgar 1990; Latour 1999; Coopmans et al. 2014). Rudwick calls attention to these everyday tasks of studying the Earth, alongside his analyses of grand theories and global collaborations among natural philosophers. After all, the skillful, tedious work of making evidence reliable and sharable is what makes theorizing possible, effective, and worthwhile.

Like Rudwick's oeuvre, the best histories of the Earth sciences link developments in scientific knowledge and practice to their social and political contexts. Rudwick's analyses of the French Revolution's epistemic repercussions in geology are masterful (e.g., Rudwick 2005). Historian Jim Secord (1986) uses a rather obscure controversy among nineteenth-century British natural philosophers to powerfully reveal the social values underlying the stratification of Victorian science, society, and imperialism. Historians have also long situated twentieth-century Earth sciences as a key geopolitical tool, from monitoring countries' geological resources to searching oceans for military craft to applying seismological tools to surveil nuclear tests (Turchetti and Roberts 2014). Historian David Sepkoski (2020) traces theories about extinction to their accompanying social milieu, such as by arguing that the previously rejected idea of mass extinction gained support in the 1980s alongside the "asteroid bomb" theory of the dinosaurs' extinction due to widespread fears of nuclear warfare. Studies of polar sciences in particular reveal complex social and political dynamics among scientists and among nations. Historian Michael Bravo (2018) traces a centuries-long history of how people have thought about the North Pole, as a reflection of their own cultures' beliefs and values about nature and society. Anthropologist Jessica O'Reilly (2017) examines Antarctic science as a site of performing global politics and environmental policies through the everyday work of ecological, geological, and climate research. These authors demonstrate that taking far-reaching perspectives on Earth sciences' methods and knowledge can yield insights into global politics, including the social, epistemic, and ethical values that underlie them.

Strikingly, Earth sciences are closely linked with beyond-Earth sciences. Studying how scientists study outer space offers insights into how they see themselves and their own planet (see ► "Planets: A History of Observing Worlds and Changing Worldviews"). STS scholar Valentina Marcheselli, anthropologist Lisa Messeri, and sociologist Janet Vertesi, respectively, conducted ethnographic studies of researchers as they searched for extraterrestrial microbes (Marcheselli 2020), explored exoplanets and Martian geology (Messeri 2016), and designed vehicles to explore Mars (Vertesi 2015, 2020), all *by studying Earth*. Earth thus serves as an analog or a testbed for investigating otherworldly phenomena. Likewise, knowledge these scientists produce about other worlds reveals insights about Earth. By asking what these researchers are really learning, Marcheselli, Messeri, and Vertesi flip the narrative from studying planets to studying those who study planets. Their insights illuminate the human side of seemingly inhuman topics. For example, Vertesi (2015) analyzes the "Rover dance" that NASA engineers unconsciously perform as they use their bodies to imitate the robot rover on Mars during their planning sessions for where to next move the machine. They are imagining themselves as the rover as a strategy to understand the machine and its Martian environment so that they can better control the rover and thus produce better research data. Classifying body movements as a component of research broadens the typical notion of scientific practice and reveals the many kinds of knowing that researchers rely on to make sense of this world through the study of other worlds.

2.2 Technology

Technology is a critical component of scientific practice and thus a primary focus of STS research and theories (e.g., Bijker et al. 2012; Wyatt 2008). Technologies in the Earth sciences range from stonemasons' hammers and Cuvier's paper fossils to precise measurement instruments and digital models that inform complex systems of simulation and prediction. For example, sociologist Phaedra Daipha (2015) highlights the embodied judgments of meteorologists as they work to advise governments and the public about future weather. Based on an ethnography of US National Weather Service staff, Daipha demonstrates how those workers' skillful judgments become incorporated into automated systems of weather prediction and public alerts – or not. Her study examines the linked constructions of knowledge about weather, technical systems to monitor and manage weather's effects on society, and social and professional roles of meteorologists, amateur weather trackers, and policymakers.

Simulation and prediction technologies are powerful and revealing sites of interaction between science and society, as scientists try to translate knowledge about natural processes into recommendations to help protect people and infrastructure. For example, sociologist Benjamin Sims (1999) followed a team of scientists, engineers, and construction workers trying to create machines to simulate earthquakes and thus provide testing scenarios for building designs for earthquake-vulnerable communities. Anthropologist Elizabeth Reddy (2023) followed Mexico's earthquake prediction system to illuminate its sociotechnical and socioecological foundations of citizen trust, scientific credibility, and political support for disaster planning. In these cases, studies of people studying earthquakes provide insights about the everyday teamwork, knowledge integration, individual skill, political and social values, and luck that underlie the epically important scientific and social knowledge of how to protect communities from geological disasters.

In the case of climate science, the need for long-term data calls into action a variety of technologies, including centuries of salt-soaked ships' logbooks containing daily weather notes, local and global measurements of temperature and greenhouse gases, and satellite images of polar ice cover. These diverse data inform many kinds of models to simulate and predict current and future climate scenarios and thereby inform policy and social responses (Edwards 2010; Oreskes and Conway 2010; Bokulich and Oreskes 2017). Historian Deborah Coen (2018) argues that today's climate science derives from a long history of "scaling," i.e., the skillful and fraught practice of fitting together various paradigms of understanding the Earth. This combination of simple and complex technologies that have originated in various time periods and places – as well as the ongoing negotiation of the "scale" of data, natural phenomena, and knowledge – may be signature components of the Earth sciences, which span local to global features, events, and patterns and which range from the deep past to the teeming present.

2.3 Earth Sciences for a Better World

STS prides itself on critical engagement with science and society (e.g., Downey and Zuiderent-Jerak 2021), a commitment that is present among historians and, I hope, growing. This engagement includes STS scholars facilitating public outreach and engagement in knowledge-making, and participating on research teams as a way of directly intervening in scientific practice and knowledge production while also studying it. Another method – one that may be more accessible to historians – involves interpreting evidence about science and technology to make normative arguments about the way science, technology, and/or society *should* be. This work includes, for example, calls for social justice, environmental sustainability, and more inclusive participation in science. We have already seen that the Earth sciences can be a very productive site for thinking about how nonscientists contribute to scientific work and knowledge, thanks to the field's reliance on a variety of expertise and skill. Furthermore, the Earth sciences' explanatory and predictive power about natural and anthropogenic phenomena makes them supremely relevant to many communities, as does their attention to a wide range of times and places. After all, where better to seek justice, equity, and social benefit than in a planet-level collective of sciences?

Social studies of mining are a powerful example of calls for social justice. Literature scholar Allison Bigelow (2020) examines sixteenth- and seventeenth-century Spanish texts about mining as evidence of how Spanish colonists assimilated Indigenous and African knowledges about minerals in the Americas, even as they oppressed the Indigenous peoples and enslaved Africans they were learning from. Bigelow's study of technical mining language offers fascinating insights into colonialism, racism, and power. Likewise, anthropologist Jessica Smith's (2021) study of the relationships between today's petrochemical companies, engineers, and mining communities raises crucial questions about the many meanings of "corporate social responsibility" and, in response, recommends new approaches in engineering education to better equip future mining engineers to serve society. To support the growing field of justice-centered studies of geological resources, Smith, sociologist Abby Kinchy, and environmental studies scholar Roopali Phadke created STS Underground, a network of scholars studying mining and the energy industry as a site of scientific practice, community participation, and ethical planning for the future (see the special issue introduced by Kinchy et al. 2018). Their approach is an admirable example of the importance of understanding scientific practice and knowledge in the Earth sciences in order to propose ways to make those systems more socially beneficial, such as for environmental conservation, climate change mitigation, economic well-being, and safety. It is also an excellent model for bringing together interdisciplinary scholars to think through a topic collaboratively. Historians could adopt the same approach to make histories of the Earth sciences more comprehensive, broader in geographic and temporal scope, more willing to recommend ways to do science otherwise, and, perhaps, more socially relevant and beneficial.

3 A Concluding Call for Future Histories

Here I have discussed three topics – scientific practice, technology, and social good – through which STS methods and studies can inform historians' investigations of the Earth sciences. There are many more. These three are merely helpful starting points because they apply well to the Earth sciences and there are already excellent examples of studies to demonstrate the value of these approaches for historians.

Other STS topics that deserve more development in histories of the Earth sciences include expertise, power (e.g., feminism, critical race theory, and decolonialism), policy and governance, relationships between science and the public, knowledge infrastructures, and ethics (for more ideas, see Felt et al. 2016 and ► "History of the Earth Sciences from the South"). Furthermore, historians of the Earth sciences can serve as experts for the scientific community, the communities of STS scholars and historians of science, and for us as citizens of the Earth, to help achieve trustworthy knowledge about how our planet works, how we can enable equitable access to natural resources and disaster protection, and how to pursue environmental and climate justice. For example, we need spokespeople to help us all understand conflicted knowledges and policies surrounding natural disasters, fossil fuel production, pollution, remote sensing, and the global socioecological systems of weather, climate, and natural resources. As sciences that have been practiced for so long and about such a wide variety of places and time periods, the Earth sciences can serve both as an informative precedent for current social and scientific problems and as a model for how to integrate diverse kinds of knowledge and practitioners to address global social and scientific problems.

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