The Structure and Growth of Evidence about the Earth's Deep Interior

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Integrated history and philosophy of science has its most direct roots in the work of Kuhn, Lakatos, Laudan, and others, whose work was mainly directed towards understanding the large-scale structure of scientific knowledge, at the scale of decades and even centuries. If there is one thing that philosophers of science have come to know since then, however, it is that the growth of scientific knowledge at such scales is an extremely complicated affair.

The aim of this paper is mainly methodological. If we carefully examine the long-term growth of evidence in certain sciences, we see that the structure of this evidence, and its evolution, is extremely complicated–so complicated that it is quite difficult to grasp in its full complexity. Thus, we might be led to examine only manageable bits of it at a time. Yet, we might also think that an overview of the entire structure of evidence and its evolution would be quite useful. One advantage that we now have over Kuhn, Lakatos, and Laudan is that we might have better tools for examining complex phenomena. Whatever the usefulness of the theory of complexity as an explanatory theory, it might provide new resources for representing very complicated phenomena. An examination of such resources, and how they could be applied towards understanding the growth of scientific knowledge in particular cases, is worthwhile from a methodological standpoint.

As an example of the large-scale growth of scientific knowledge, I will consider the growth of evidence about the earth's deep interior. This is a good case to start with because it is limited in scope and its development is relatively easy to understand. Yet, the structure and growth of evidence even here is extremely complicated. Almost all of our knowledge about the earth's deep interior comes from observations of seismic waves that are detected at the earth's surface. An earthquake occurs when a slippage occurs along a fault buried deep within the earth. Seismic waves generated from this seismic source then travel through the earth's interior, and are picked up by seismometers at the earth's surface. The seismic waves that are detected at the earth's surface contain information about both the seismic source and the earth's interior. Seismic waves can thus be used to answer the following questions: (1) What happens at the seismic source? (2) What are the structure and properties of the earth's deep interior? These two questions are intertwined, because a better answer to (1) would give us better means for answering (2), while a better answer to (2) would give us better means for answering (1). The ability to answer these questions is also dependent on developments in the theory of elastic dislocations and elastic waves that would help us formulate models of both the seismic source and propagation. It is also dependent on developments in applications of such theories–ones that, for example, enable the calculation of properties of the earth's deep interior from travel times of seismic waves. It is also, of course, dependent on the development of new observational techniques.

A careful examination of the structure of evidence and its evolution in this particular case shows that there are at least four strands that are intertwined. The first strand is the development of a mathematical theory of waves in elastic media, the foundations of which were established in the mid-ineteenth century. The second strand is the development of applications of this theory to seismic phenomena, such as work on the propagation of waves through elastic media, or the theory of seismic sources. The third strand is the development of what I will call ”constructions from data”. These are idealized models with parameters that have been estimated from data. Paradigm examples of such constructions from data are detailed models of the mechanical properties of the earth's interior. The fourth strand is the development of observational techniques, such as seismometers. We might also include here developments in computing such as the Fast Fourier Transform, which revolutionized the spectral analysis of seismic waves.

These strands are not entirely distinct from each other, and the evolution of each of these strands is interdependent on the others in complicated ways. We might wonder whether there could be ways in which we can represent the growth of evidence about the earth's interior that does justice to the complexity of this evidential structure and its evolution, yet is genuinely informative.

The aim of this paper is to examine some preliminary questions: Exactly what should be represented? What kinds of representations would allow us to accomplish this? What representational resources are available to us from, say, research on complexity? Answers to these questions will be sought through an examination of the growth of evidence about the earth's deep interior. The hope is to take some steps towards new ways in which we might represent, and examine, the structure and growth of evidence in science at a large scale.