

Philosophy of earth science; just sloppy physics?

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Introduction

When the philosophy of natural sciences is confronted with the practice of earth science, background insights can be gained why earth science must necessarily be interdisciplinary. The philosophy of science according to the influential Vienna Circle (1920s) can be caricatured as follows (e.g. Klee 1997): "All phenomena consist of physical entities; spirits, souls and essences are either redundant or in principle explainable in physical terms. Thus, all phenomena can in principle be explained with the laws of physics plus a description of initial conditions. Consequently all (real) sciences will eventually be reduced to physics." Despite the normative influence of the Vienna Circle on the practice of science, biology and psychology and others emancipated in the past decennia as their autonomy due to emergent properties (like organisms, evolution and consciousness) was recognised (e.g. Mayr 1985; Figure 1). Organisms and even conscious human beings consist solely of physical entities, but most of their aspects and behaviour cannot be explained by physics.

Earth science on the other hand has largely been neglected by philosophers of science, presumably because it is thought to be reducible in principle to physics and chemistry. Three arguments will be discussed why this view is wrong.

Principal argument

From a number of textbook definitions and from practice, it follows that earth science (environmental science, geology, engineering etc. all including) has biological and societal components. Many examples related to rivers and other systems in highly populated areas can be found. Physics (and chemistry) is a science that causally explains phenomena by physical (or chemical) laws and their boundary conditions. Biology and sociology employ functional (e.g. what is the function of a species in this ecosystem)

and intentional (e.g. what were the motivations of a society for this action) explanation types. The latter two are not reducible to causal explanations without serious loss of explanatory power (e.g. Mayr, 1985). Therefore earth science is not reducible to physics and not just physics.

Practical argument

One specific issue caught much criticism from the physics-oriented: qualitative historical descriptions and 'explanations' of phenomena that have never been observed directly. It can be argued that historical explanation is more than just description, and that it follows the logical scheme of retrodution (inference to the best causal, potential, explanation) (Lipton, 1991), rather than the well known deduction (derivation of instantiations from laws) or induction (construction of generalisations from a limited number of observations). Moreover, it can be argued that even explanations which use highly sophisticated physical computer models, are not deductions but inferences to the best explanation in which deductions play an important but not principal role. In short, we argue that historical explanations are attempts at causal explanations, and the result is not a proof or a theory but a hypothesis of the most likely explanation (Lipton, 1991). This is not necessarily the true explanation, because the true explanation need not have been among the conceived hypotheses, but this most often cannot be verified because of the following point.

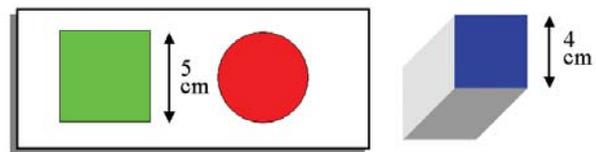


Figure 1. Putnam's Peg: the microscopic (physical and chemical) properties of the peg and plate cannot be used to predict through which hole the peg will fit, but the macroscopic (geometrical) properties can be used, while they cannot be reduced to the microscopic. This is probably true for barchan sand dunes and many other landforms, and is an anti-reductionistic argument.

Fundamental underdetermination problems

The most important reason for using retrodution is the heavy underdetermination of earth-scientific theories by observations. Consequently, the reduction of earth science to physics is hampered in practice by the underdetermination problems. Examples of underdetermination are: a) the evidence of a certain process may have been eroded, or b) various different explanations are possible for a single phenomenon, or c) there are not enough clues or different types of evidence to decide between competing theories or various different models with different concepts converge to the same end result (e.g. Oreskes *et al.*, 1994), or d) a sensitive model needs detailed and highly accurate initial and boundary condition data which cannot be collected in that detail or for the required long period (e.g. Holocene), therefore the model 'runs into a frenzy and crashes', or e) a system is chaotic and the necessary precision of initial conditions for prediction into the future cannot be obtained (Werner, 1999). These are all fundamental underdetermination problems. So earth science is not sloppy physics.

Theory of alternate glaciation as example

An example corroborating the three anti-reductionist arguments is found in the development of the theory of alternate glaciation and deglaciation of the Earth in the past million years. Many hypotheses have been conjectured to explain various phenomena such as relic glacial landforms in a temperate climate, the changed course of the Rhine valley, fluctuations in the oxygen isotope ratios in continental ice cores and deep ocean cores, severe changes of vegetation and so on. A combination of at least two physico-mathematical models provide a hypothetical explanation: a climate model that explains climatic change with irradiation change at high latitudes, and an orbital model that explains irradiation change with orbital fluctuations of the Earth. An alternative model explains global irradiation change with stellar energy fluctuations. However, all the mentioned phenomena cannot directly be deduced from either of these physical theories and much more

steps are needed. Unfortunately most steps cannot be done due to the underdetermination problems. Moreover, vegetation response cannot be modelled physically. Nevertheless, given the evidence and the available hypotheses, it is inferred that the orbital theory is the best explanation of the 'ice ages' of the given hypotheses. This is a retrodution and, as said, a complete reduction to physics is impossible and the ultimate verification of this explanation is not feasible.

Implications for earth science

An important consequence for the practice of earth science is that it is necessary to have different stances at the same time: in (attempts at) causal explanations, deductive and inductive approaches can be combined in an inferred (but ultimately not verifiable) best explanation. To work only deductively means to run the risk of missing the complexity of the real world and excluding seemingly outrageous hypotheses (e.g. such once outrageous hypotheses of glacials and of plate tectonics), and to work only inductively means to run the risk of having hypotheses that conflict with the laws of, e.g., mass conservation. Models may serve heuristically to test for such conflicts, but cannot be used to prove the validity of (physical) theories beyond absolute doubt (Oreskes *et al.*, 1994). Moreover, functional and intentional explanations address very relevant but unphysical aspects of reality (Mayr, 1985). In practice, the researchers in the NCR already cooperate to some extent to join the stances, which is in happy agreement with our philosophical position.

References

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The Genesis Flood narrative is a flood myth found in the Tanakh (chapters 6-9 in the Book of Genesis). The story tells of God's decision to return the Earth to its pre-creation state of watery chaos and then remake it in a reversal of creation. The narrative has very strong similarities to parts of the Epic of Gilgamesh which predates the Book of Genesis. A global flood as described in this myth is inconsistent with the physical findings of geology, paleontology and the global distribution of species. The Genesis flood had to involve a different level of activity than anything seen since that time.

5. What about proposals that the biblical Flood story refers to a local flood somewhere in the Middle East? Another proposal is that the biblical flood story is based on the re-flooding of the Persian Gulf due to rising sea levels as the glaciers melted at the end of the Ice Age. [9] Another great flood in the Black Sea has been claimed as the source of the biblical flood. The Flood of Noah's day (2348 BC) was a year-long global catastrophe that destroyed the pre-Flood world, reshaped the continents, buried billions of creatures, and laid down the rock layers. It was God's judgment on man's wickedness and only eight righteous people, and representatives of every kind of land animal, were spared aboard the Ark. Many critics of the Genesis account of history scoff at the idea of plants and seeds lasting for a year in fresh and salt water, therefore discounting the biblical account of the Flood. The Genesis flood was an event unique to all of history. Neither before, nor since, has the earth seen waters of such force. Scripture indicates the waters rose over 17,000 feet! Not only did the Genesis flood include rain from above, but the "fountains of the great deep" as well. These were the subterranean water reservoirs which had previously watered the world. Rain had not been needed.