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SPECIFIC FEATURES OF MODELING IN GEOLOGY

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Mining geologists use modeling to determine the geometry and placement of mineral deposits in the earth crust. They then determine the concentration and volumes of the minerals investigated. Economic constraints are applied to the model determining the value of mineralization. Plans for mineral extraction are determined by the ability of the miner to make an economic extraction of the defined ore.

Models are of central importance in many scientific contexts. The centrality of models such as the billiard ball model of a gas, the Bohr model of the atom, the MIT bag model of the nucleon, the Gaussian-chain model of a polymer, the Lorenz model of the atmosphere, the Lotka-Volterra model of predator-prey interaction, the double helix model of DNA, agent-based and evolutionary models in the social sciences, or general equilibrium models of markets in their respective domains are cases in point. Scientists spend a great deal of time designing, testing, comparing and revising models, and much journal space is dedicated to introducing, applying and interpreting these valuable tools. In short, models are one of the principal instruments in modern science. Major parts of current research in the natural and social sciences can no longer be imagined without simulations, especially those implemented on a computer, being a most effective methodological tool. Natural scientists simulate the formation and development of stars and whole galaxies, the detailed dynamics of violent high-energy nuclear reactions as well as aspects of the intricate process of the evolution of life, while their colleagues in the social science departments simulate the outbreak of wars, the progression of economy and decision making procedures in an organization – to mention only a few.

Recently, computer simulations have even proved useful in moral philosophy. In fact, there is almost no academic discipline without at least a little use of simulations.

Simulations may help scientists to explore situations that cannot be investigated by experimental means yet. The performance of an experiment might be impossible for pragmatic, theoretical or ethical reasons. An example of a pragmatically impossible experiment is the study of the formation of galaxies; we simply cannot do much to manipulate galaxies. An example of an ethically impossible experiment is to predict the long-term consequences of raising, say, the income tax by a factor of 1.5. In many cases an appropriate simulation is the best scientists can do. In fact, simulations help us to theoretically approach regions in a parameter space that are inaccessible by standard experiments.

Numerical experimentation is much more founded in natural than in social sciences. What reasons do we have to believe in numerical extrapolations? In the natural sciences models are (often) well confirmed in a certain parameter space and, furthermore, embedded in strong theories. Starting thus from such “solid ground” makes extrapolations in realms beyond experimental reach more trustworthy. In the social sciences, on the other hand, there often is no such “solid ground” to start with; this makes it much harder to trust numerical experiments.

Philosophers are acknowledging the importance of models with increasing attention and are probing the assorted roles that models play in scientific practice. The result has been an incredible proliferation of model-types in the philosophical literature. Probing models, phenomenological models, computational models, developmental models, explanatory models, impoverished models, testing models, idealized models, theoretical models, scale models, heuristic models, caricature models, didactic models, fantasy models, toy models, imaginary models, mathematical models, substitute models, iconic models, formal models, analogue models and instrumental models are but some of the notions that are used to categorize models.

Models in geology can be determined as so-called ‘models of data’. A model of data is a corrected, rectified, regimented, and in many instances idealized version of the data we gain from immediate observation, the so-called raw data. Characteristically, the model eliminates errors (e.g. removes points from the record that are due to faulty observation) and then presents data in a ‘neat’ way, for instance by drawing a smooth curve through a set of points. These two steps are commonly referred to as ‘data reduction’ and ‘curve fitting’. When we investigate the trajectory of a certain planet, for instance, we first eliminate points that are fallacious from the observation records and then fit a smooth curve to the remaining ones. Models of data play a crucial role in confirming theories because it is the model of data and not the often messy and complex raw data that we compare to a theoretical prediction.

The construction of a data model can be extremely complicated. It requires sophisticated statistical techniques and raises serious methodological as well as philosophical questions. How do we decide which points on the record need to be removed? And given a clean set of data, what curve do we fit to it? The first question has been dealt with mainly within the context of the philosophy of experiment. The core of the latter question is the so-called curve fitting problem, which is that the data themselves do not indicate what form the fitted curve should take. Traditional discussions of theory choice suggest that this issue is settled by background theory, considerations of simplicity, prior probabilities, or a combination of these.

Geological models can be described as straightforward physical objects. These are commonly referred to as ‘material models’. The class of material models comprises anything that is a physical entity and that serves as a scientific representation of something else. Among the members of this class we find stock examples like wooden models of bridges, planes, or ships, analogue models like electric circuit models of neural systems or pipe models of an economy, or Watson and Crick's model of DNA.

Also models of ore bodies can be considered as equations (which are also termed ‘mathematical models’). The problem with this suggestion is that equations are syntactic items and as such they face objections similar to the ones put forward against descriptions. First, one can describe the same situation using different co-ordinates and as a result obtain different equations; but we do not seem to obtain a different model. Second, the model has properties different from the equation. An oscillator is three-dimensional but the equation describing its motion is not. Equally, an equation may be inhomogeneous but the system it describes is not.

An important part of geologic modeling is related to geostatistics. In order to represent the observed data, often not on regular grids, we have to use certain interpolation techniques. The most widely used technique is kriging (group of geostatistical techniques to interpolate the value of a random field (e.g., the elevation, z, of the landscape as a function of the geographic location) at an unobserved location from observations of its value at nearby locations) which uses the spatial correlation among data and intends to construct the intepolation via semi-variograms.

Modeling in geology, a difficult and complicated task, which includes a number of features, is a rapidly developing method of mineral deposit exploration, and on the basis of progress that the chair of Mining, Geology and Geotechnology has achieved, it is considered to be the main tool of success.