GAC AGC

The Wit to Distinguish *or* the Role of Physics in Geology

G.V. Middleton
Department of Geology
McMaster University
Hamilton, Ontario L8S 4M1

Address of the retiring President
Geological Association of Canada
Annual Meeting
St. John's, Newfoundland
23 May 1988

Preamble

A unique prerogative of Presidents is that they can spend a few minutes rambling on about whatever comes into their mind. Some Presidents talk about Big Social or Economic Issues, some talk about their own Research, some talk about Philosophy. I want to spend a few minutes talking about the different ways of understanding rocks: so I fall into them last, philosophical, category. My only excuse for doing this is the one offered by Blaise Pascal:

Se moquer de la philosophie,
c'est vraiment philosopher.

Of course, nowadays Pascal is know best for having invented a primitive personal computer. But I assure you that he was also a philosopher.

Geology as History

Consider a typical outcrop (the example shown was of flysch in the Gaspésie): I think that, given the task of studying this group of rocks, many geologists would try first to identify the rocks, that is try to obtain an idea of what they were made of and how they were formed. This would probably not occupy a great deal of our time and once it was done we would settle in to the really serious part of our investigation: what do these rocks tell us about the geological history of this part of Quebec, or to turn the question round, how can we explain our observations historically? Obviously we need to know what age the rocks are, how they correlate with other units in the Gaspésie, what facies are present, what was their sequence of deposition, what sedimentary envirnoments were represented, and so on. Finally, how do we explain the deposition of these rocks in terms of the current paradigms: their relation to plate tectonics, eustatic rises and falls of sea level, impacts of large bolides, and the carbon dioxide level of the Ordovician atmosphere, to name just a few possibilities.

Let me emphasize right away that I have no quarrel with this way of doing geology: a large part of what geologists do is historical reconstruction. Geology's proudest boast as a pure science is that it has changed man's view of himself and his position in the universe by revealing the amazingly long and complex history of events which preceded, accompanied, and followed his appearence on this planet. Not only that, but this historical understanding has proved to be a very valuable guide to geologists in our search for useful minerals and fuels. The better we understand geological history the more closely we are able to define what groups of rocks are most likely to contain coal, petroleum, or metallic minerals.

Geologists rarely pause to reflect how distinctive this search for historical explanation is among the sciences. Many scientists do not bother with such explanations at all. Ask a physicist why a meteorite falls towards the earth and he will begin talking about gravity, not about the evolution of the solar system and the history of the asteroid belt. Most philosophers of science describe the archetypal scientific method in terms of experimental, not historical, science. Indeed, some might claim that "historical science" is a contradiction in terms. History deals with unique events — our reconstructions of what exactly happened and what caused it to happen cannot be verified or falsified in the way that we can test a hypothesis about some physical law. For this reason, I myself prefer the term "scenario" as applied to historical reconstructions, than the more commonly used "model". Some philosophers go so far as to claim that historical explanations cannot be the basis of a true science.

I shall not try to settle the question of what is and is not science in this talk (one must, after all, leave something for future GAC Presidents to take care of!). My own position on the matter is that there is more than one way to carry out a rational enquiry into the origins of things, and therefore there is more than one way of doing science. Scientists who devote themselves to one way only, should resist the temptation to dismiss other ways as "not really scientific". For myself, one of the joys of a life spent doing geology is that it has permitted me to try my hand at several different ways of doing science. I was trained as a historical geologist, and grew up wanting very much to understand the geological history of a small part of England during Mid to Late Devonian times. Had I not emigrated to Canada, I might have continued this type of work for the rest of my life. But the shock of emigration to a new and unfamiliar land caused me to look around for ways of doing geology that were not closely linked to one place or period.

The role of "Physics" in Geology

Let us go back to our outcrop. Instead of seeking a unique historical explanation for these particular sandstone beds, a geologist might enquire what the *general* explanation of such beds might be. This is an important question, whose answer (as it happens) changed radically just before I began my university studies in geology. Before that, geologists knew of no mechanism which could carry sand into deep water. Philip Kuenen discovered that such a mechanism did exist, and that many sandstones previously believed to have been deposited in shallow water by storms and other such events, were better explained as deposited in deep water by high density turbidity currents, that is by gravity or density currents carrying large amounts of sand and mud in suspension.

As a digression, I might mention that such changes in interpretation are not necessarily irreversible. A paper was recently titled "The Cardium *is* a turbidite", but only a couple of years later, the author changed his mind and is now convinced that most of the Cardium was in fact deposited by storms in shallow water.

The point of the story is to remind ourselves that geology is not *just* a historical science, but a science that investigates the origins of rocks, and other geological phenomena, *in general*. In this respect, it closely resembles physics, chemistry, and the other natural sciences. Geology, however, does not merely make use of the results obtained by other sciences to serve as tools for its historical investigations (rather as an art historian might use neutron activation analysis to help authenticate a disputed painting). Geologists use methods common to all the sciences to understand the general origins of things. In my abstract, mainly as a shock tactic, I called this endeavour "physics", because I think it is practised in its purest form by physicists. But I do not really think it is unique to physics, or that those who do it are physicists practising without a union card.

Kuenen's work on turbidity currents is a nice example of what I believe is the proper role of physics in geology (and incidentally, all his classic experimental studies were carried out by a man who had almost no knowledge at all of mathematics). In general, geologists prefer to observe natural phenomena directly, rather than try to understand them by using laboratory experiments and theoretical models. This is what we mean when we use that well worn expression: "the present is the key to the past". In the case of turbidity currents, it is almost impossible to apply this maxim directly, because turbidity currents are relatively rare events that mostly take place in the deep sea. With apologies to my oceanographic friends, I would claim that most of what we know about turbidity currents is still derived mainly from experiments and theoretical models, not from direct observation of modern events.

Another significant aspect of this subject is that, until recently, almost all the work done specifically on turbidity currents was done by geologists, not by physicists or engineers. Of course, those of us interested in turbidity currents soon discovered that, like all specific geological processes, they are better understood as part of a much larger geophysical spectrum, which includes gravity currents due to salinity and temperature as well as those due to suspended sediment. Salinity intrusion in estuaries, cold fronts in the atmosphere, dust storms in deserts, and snow avalances on mountain slopes, are all closely related phenomena — because, of course, they can be explained in terms of the same fundamental physics. Work on these other phenomena, and on the fundamental mechanics of fluids that is needed to explain them all was largely done by scientists in non-geological fields. Much of my own professional life has been devoted to trying to understand the physics of such flows, and to see how these principles can be used to explain not only turbidity currents, but also the deposits that they and other gravity flows leave behind.

Even where large-scale natural phenomena *can* be directly observed a full understanding of them cannot be obtained by observation alone. So, for example, in an attempt to understand erosion and sedimentation in rivers, geomorphologists and sedimentologists have not only continued to observe modern rivers at all scales, from small creeks to the Mississippi and the Brahmaputra, but have joined with engineers to construct theoretical, numerical, and physical models of sedimentation in rivers.

My conclusion therefore is that though geology is a historical science, it is not *only* a historical science, but shares with other sciences, particularly with the "archetypal" science of physics, the complete range of theoretical, numerical, and experimental methods which scientists have devised in their attempt to understand the natural world. Geologists are interested in explaining general classes of phenomena in terms of general causes, just as they are in explaining particular examples in terms of specific historical events.

Indeed, geologists are driven to develop general theories for the origin of rocks, and even for the progress of geological history, by the abundance and complexity of local evidence. The title of my talk comes from a series of letters written to his daughter by George Savile, Marquess of Halifax, in 1688. Not all of Halifax's pronouncements would evoke an appreciative response from a modern audience, particularly from the more feminist members (he states firmly, for example, that "there is inequality in the sexes, and that ... men, who were to be the lawgivers, had the larger share of reason bestowed upon them ..." In the McMaster library copy, a dissenter has scrawled "haha" in the margin!). But my title was taken from the following striking passage:

"Children and fools want everything, because they want wit to distinguish; there is no stronger evidence of a crazy understanding that the making too large a catalogue of things necessary."

Our sister society to the south, in a noble attempt to put on paper everything that is now known about the geology of North America, is in process of publishing some 40 to 50 fat volumes, which some might perhaps think are the modern equivalent of Halifax's catalogues. In reality, gathering and publishing such lists is not quite the evidence of a "crazy understanding" that Halifax thought it was: the raw material of science is necessarily voluminous, and local geological detail and history can have its own fascination. But Halifax was certainly right that what the wise man seeks is the "wit to distinguish" what is trivial and what is not, what is of local and historical importance only, and what is significant and universal.

Physical Geology is not Geophysics

Discovering what is significant and universal about the earth is certainly not something that geologists want to leave to a different group of scientists.

Other scientists often neglect problems which are crucial to the solution of geological problems. Turbidity currents are a case in point: scientists studying other types of gravity currents saw no reason to make life more complicated for themselves by considering the special case of gravity differences produced by suspended sediment.

Nor can geologists turn over the search for general principles to those disciplines that have been formed with the specific intent of studying general classes of geological phenomena using the classic methods of the non-historical sciences. Such groups rapidly establish their own traditions, which effectively exclude many possible areas of application. Geophysics, as defined by an etymologist or a philospher, may include all applications of physics to understanding the earth. But in sociological reality, geophysicists study only a limited subset of such applications: they are seismologists, geomagnetists, geophysical fluid dynamicists — but not physical geologists. Though most of my professional life has been devoted to trying to apply physics to geology, I doubt that any true geophysicist would regard me as a professional colleague.

This is as it should be: there are some aspects of the earth (*e.g.*, the nature of the deep interior) which can best, or perhaps even only, be studied by classical physical methods. But there is no aspect of the earth that can be fully understood without at least some application of physics, and for almost all problems in geology physics is not enough.

It seems to me particularly important that geologists and geophysicists should not drift apart into relatively isolated scientific communities. Because the members of these communities are often trained in completely different ways, there is the danger that they share few common concepts and techniques, and rarely meet together. Yet both are engaged in the common task of trying to understand the earth.

As you probably all know, this year is the first for the Canadian Geophysical Union as an independent national organization. They have already held their inaugural meeting in Saskatoon. We wish them well, but we hope that this natural evolution towards organizational independence will not lessen the communication between the geological and geophysical community in Canada.

Physics in the Geological Curriculum

Pious hopes are one thing, but as geologists we should ask ourselves what we can actually do to make sure that geology retains close links with geophysics, and for that matter with all the other natural sciences. The practical importance of this is brought home to us if we consider the probable future development of geology as a profession: it is exactly such fields as engineering and hydrogeology, with their strong dependence on physical models and the predictive powers which go with them, which are valued by modern society. Though a rudimentary grasp of physical principles may be all that is necessary to work out geological history, it is generally insufficient to make the kind of practical short-term predictions that are required for the proper development of natural resources and for urban growth.

We are often told that this is an age of specialization, when scientists are separated by barriers of incomprehension from fellow scientists, even those working in closely related subdisciplines. I do not think that this is a correct reading of the general trend of modern science. Of course, there has been a proliferation of jargon, of disciplinary groups, and of the specialist journals which they sponsor. But the physical sciences have also developed a body of knowledge shared by most practising scientists. This knowledge, though it changes fairly rapidly, is summarized in well written introductory textbooks on physics, chemistry, biology and applied mathematics. The personal computer has also recently played a powerful role in disseminating knowledge in applied mathematics.

How do we ensure that the next generation of geologists understand the common language of this growing general community of science? Of course, all universities require some elementary preparation in the basic sciences and mathematics, and in most departments of geology, geophysics and geochemistry and also taught to undergraduates. Nevertheless, it seems clear that geology teachers have to devise better ways to teach more of the common language of the physical sciences within the context of traditional geology courses. It is not enough to depend on a few elementary science prerequisites.

Societies such as the Geological Association of Canada also have a role to play. They exist in part to permit their members to continue throughout their lives as professional geologists the learning experience begun in university. Though Technical Meetings and Journals are one means to this end, they are not the best. Review journals (*Geoscience Canada*, for example), Short Courses, Field Conferences, and small Conferences, such as GAC's newly proposed Nuna Research Conferences, are better ways of maintaining a well informed geological community, one that remains in close touch with the rest of science.

Most of all, let us strive to develop a personal attitude that learning is a life-long experience, one that is not only necessary but fun. We all know that discovering something absolutely new about the earth is the greatest reward that a career in geology can offer, but learning something new (to us) can come a close second.

I close as Halifax closed his letters to his daughter:

"May you so raise your character that you may help make the next age a better thing, and leave posterity in your debt for the advantage it shall receive from your example."

Received 6 June 1988.