Popperian evaluation of earth science

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It has been frequently argued that geology is not a science. Among the reasons given are (a) it is a field dealing with the particular and hence not nomological; (b) it is not a quantitative discipline and (c) it deals with history which is not a science. It is briefly argued here that these are basically prejudices. A definition of science propounded by Popper is new only in terms of a systematic and coherent treatment. Otherwise many earth scientists have had similar attitudes. In spite of the special nature of earth science, it can more readily be a Popperian science, if the educational and research opportunities are more democratic and decentralized.

Is geology disabled?

The title of this article is somewhat inappropriate. It would not be true to describe (say) physics as being entirely a Popperian science and entire sociology (another arbitrary example) as being not. There are theories in physics which are not scientific by the Popperian criterion, just as there would be some in sociology which certainly are. Physics, chemistry, mathematics, earth science, sociology etc. are territorial terms. Popperian demarcation of science operates on individual theories or research programmes, or even more appropriately on individual scientists and their attitudes.

As this is a severely space-limited treatment, the analysis would be suggestive rather than exhaustive. No attempt is made to review or summarize Popper[1-3], nor is the history of earth science systematically scanned.

The question whether physics is a Popperian science has normally never been asked, whereas it has frequently been suggested that Popperian criteria for science are not universal and that for biology, geology, etc. they should not be regarded as appropriate. This indicates that there are significant differences in the territories of physics and geology. Yet what is more important is whether these differences are adequate to disenfranchise geology as a science.

One of the basic differences is that geology is a historical science and there is a widespread misconception that history is not science at least on Popperian criteria. Popper[4] himself has rejected that suggestion.

An attendant notion is that geology is a field dealing with particular events and objects, and that, therefore, there cannot be any laws in it. However, events are caused, form an interconnected sequence and objects evolve. Underlying these, there are processes and therefore laws. As an example, the law of superposition of Steno (1669) is adjudged to have[5] (p. 5) similar sweep and simplicity as is attributed to Newton's law of gravity. Due to this and other laws propounded by Steno, Cloud[5] (p. 9) writes that 'the date of geology's emergence as a distinctive science with principles of its own can be neatly set at the year 1669'. Much later, Bucher[6] formulated 46 laws of structural geology. Obviously, geology cannot be written off as a science of the particular, unamenable to nomological attempts. It is a different matter that earth science has specific nomological constraints requiring what Scriven[7] has called 'normic' statements rather than either universal or statistical[8].

In fact the distinction between the sciences of the particular and the universal, that is, between the concrete and the nomological sciences, is based on a mistaken notion of a reference. Consider the statement, 'Rhodonite is pink'. The existential reference may be presumed to be to all rhodonite samples. A logically equivalent form of this statement is: 'Whatever is not pink is not rhodonite'. Then the reference should be presumed to be to the objects that are not pink. If *all* the logically equivalent statements are to be regarded as having the same reference (otherwise any number of paradoxical situations will arise), then that reference is to everything. The geo in geology should go the way of geo in geometry. The study of the earth necessitates and depends heavily on the study of other planets and astronomy in an essential way[9]. In this sense, there are no sciences of the particular.

Another criticism of earth science is that it is not quantitative enough. This criticism overemphasizes the importance of numbers. The point can be illustrated by drawing an example from geochronology. There is a *relative* time scale derived from the fossil content changes and the collation of sedimentary sections. There is also an *absolute* numerical time scale based on quantitative radiometric methods. On one such scale[10], the boundary between the Triassic and Jurassic periods

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is dated 208 ± 18 my BP, and that between the Early and Middle Jurassic as 176 ± 34 my BP. It has been pointed out[11] that these estimates may permit an absurd suggestion that the Middle Jurassic could be in the Triassic. If numbers come out of observations and experiments, their utility and relevance must be independently judged. The aim of a scientist is not to be *benumbed by numbers*.

Popperian attitudes

Popper is treated here as a representative of a viewpoint, as the one who has most systematically and persistently propounded it. Popperian attitudes can be traced in many of his predecessors and also contemporaries for whom he had plenty of contempt. 'And as to our nihilists and existentialists who bore themselves (and perhaps others). I can only pity them. They must be blind and deaf, poor things, for they speak of the world like a blind man of Perugino's colours or of a deaf man of Mozart's music', he wrote[3] (pp. 194–195). Just as an example, Camus[12], one among the existentialists who called his philosophy 'the absurd', among many other similar things wrote: 'Beginning to think is beginning to be undermined' (p. 12). '... that is certainly a truth – yet an unfruitful one because it is a truism' (p. 15). 'If the only significant history of human thought were to be written, it would have to be the history of its successive regrets and its impotences'(p. 24). 'The absurd creator does not prize his work. He could repudiate it. He does sometimes repudiate it' (p. 90). 'I am not seeking what is universal but what is true. The two may well not coincide' (p. 122).'Thinking is learning all over again to see, to be attentive, to focus consciousness; it is turning every idea and every image....'(pp. 30–31). Popperian resonances can be noticed in these attitudes readily. Yet Camus would hardly classify himself as a scientist. Thus, Popperian attitudes have popped up time and again among rational thinkers concerned with the world, irrespective of whether in the territorial terms they would be regarded as scientists. A synthesis of rationalism and empiricism can naturally point towards Popper.

A Popperian scientist must follow a critical approach to everything that he studies. William Buckland (1784–1856) once visited a cathedral[13] (p. 62) and was shown what was purportedly martyr's blood frozen on the pavement. He immediately kneeled down, licked the stain with his tongue and testified that it was bat's urine. This compulsion not to take anything on faith and to put everything to test for veridicality is Popperian. It can lead to the desired deconvolution or unscrambling of geological arguments and those of divine design and purpose hinted at by Müller *et al.*[14] (p x i).

Sedgwick in his presidential address[15] to the Geological Society (1831) recanted his belief in the Mosaic flood quite explicitly. 'Having been myself a believer, and, to the best of my power a propagator of what I now regard as philosophical heresy ... I think it right, as one of my last acts before I quit this Chair, thus publicly to read my recantation', he said. This readiness to retract from one's own past beliefs in the light of newer empirical observations rather than to maintain consistency is certainly Popperian. A scientist is not a *believer* but a tester.

Sengor[16] has shown how 'Hutton was a Popperian in the full sense of the word'. 'Prior to Hutton, geology did not exist, and I think it is generally agreed that the science was created in the fifty years between 1775 and 1825', wrote McIntyre[17]. Thus, geology came out of the Popperian stock.

Popperian ideas have to contend with two very different sets of ideas. One is represented by Kuhn[18] and the other by Bacon. For want of space, it is assumed that the readers are familiar with these alternatives.

While criticizing Wegener, the propounder of the continental drift theory, before plate tectonics became generally accepted, Lake[19] wrote, 'Whatever his own attitude may have been originally, in his book he is not seeking truth; he is advocating a cause, and is blind to every fact and argument that tells against it'. This is a charge against an opponent to be an advocate rather than a scientist, who according to Popper should subject his ideas to strict empirical tests rather than shield them. Wegener wrote to Koppen about some professor in the following terms[20]: 'Such men will have nothing to do with a reorientation of ideas. If they had learned the displacement theory at school they would uphold it uncritically with the same lack of understanding as they now do with the sinking of the continents into the oceans...'. This is an accusation that an opponent was following a Kuhnian model of normal science rather than keep an open mind about theories and continually judge them in the light of empirical observations. Thus, as proper expectations begin at the opponent's home, earth scientists are publicly Popperians.

Consider a passage from Gilbert[21], who was a practising methodologist. 'Scientific observation, or the observation of the investigator endeavours to discriminate the phenomena observed from the observer's inference in regard to them, and to record the phenomena pure and simple. I say "endeavours", for in my judgement he does not ordinarily succeed. His failure is primarily due to subjective conditions, perception and inference are so intimately associated that a body of inferences has become incorporated in the constitution of the mind. And the record of an unattained fact is obstructed not only directly by the constitution of the mind, but indirectly through the constitution of language, the creature and imitator of the mind But while the investigation does not succeed in his effort to obtain pure facts, his effort creates a tendency, and that tendency gives scientific observation and its record a distinctive character'. This concern to carefully scrutinize all the effects of subjective traps and an effort to stay clear of them is quite Popperian. On the other hand, Kuhn's formula of normal science, which seems to have many adherents, is unduly Maginot-minded, and not really objective, and even less scientific.

At one place Popper[2] (pp. 140–141) has listed what a scientist (S) does. Let h and H be hypotheses and p a problem. Then the activities of S are listed as an effort to understand h, thinking of alternatives to h, criticisms of h, proposing empirical tests for h, attempts to axiomatize h, deriving h from H, proving that h is not derivable from H, proposing a new problem p suggested by h, developing a solution of p and criticizing that solution. To pun, the Popperian formula is to *p*ropose, *o*bserve, *p*onder, *p*redict, *e*xperiment and *r*efute. Eventually, every hypothesis will be refuted by the empirical evidence. The inductivist notions of the probability of a theory being true and the balance of evidence cannot be sustained against any proper definition of truth. The argument, that as the theory survives more and more empirical tests, its probability of being true goes up, is just as bad as the belief that as the age of a living creature increases, the probability of its being immortal increases. To quote Popper[3] (p. 103): 'The realization that natural science is not indubitable *episteme* (*scientia*) has led to the view that it is *techne* (technique, art, technology); but the proper view I believe, is that it consists of *doxai* (opinions, conjectures), controlled by critical discussion as well as experimental *techne*'. There is no reason to believe that geology cannot be a Popperian science.

The latest transition and freedom

In earth science the transition to the concepts of plate tectonics is regarded by many[22] as a Kuhnian paradigmatic revolution. Carey[23] believed that he was initiating another Kuhnian revolution towards the paradigm of the expanding earth from that of plate tectonics. But these revolutions and their possibilities signify a paradigm-shift away from Kuhn as suggested by Naess[24] and Kuhn can be complimented for permitting in his model such a paradigm-shift away from his conceptions of history. In a recent festchrift volume[14] the editors have argued how the transition has been cultural (pp ix–xv): from the 'tradition virus' that infected almost everyone in the former elitist social and scientific structure to the modern free (at least in tendency) environment wherein even a student can refute his teachers' theories. Formerly, Kuhnian normal science held sway, juniors and students had to strengthen the 'school of thought' presided over by some authority. In the modern environment, educational and research facilities are more democratic. Those outside the elite class or caste and those younger in age can also succeed in having facilities, grants and rewards of their own without subscribing to the established 'school of thought'. That is how the 'festschriftee' K. J Hsü has matured from a Kuhnian to a Popperian. An obvious corollary is that the better and more democratic a funding and recognition system in a scientific field, more Popperian can the liberated scientists be. Those who stand for Popperian science must support democratization and decentralization of educational and research opportunities. Kuhnian normal science basically can be viewed as an aberration which was strengthened by the pre-democratic era in education. Popper's[25] concern for an open society can be understood in this light.

The festchrift volume[14] can be read as a documentation of how earth science has progressed by utilizing the opportunities of devising critical experiments and adopting critical Popperain attitude to the theories. It also records many degenerating problem shifts in historical perspective, which can be understood as lost Popperian opportunities Opportunities are countably infinite. Under more democratic and freer research set-up, if they are seized more frequently by earth scientists, their field has a potential to be Popperian science

Sengör[16] has conducted a highly enlightening Popperian analysis of the temporal aspects of orogeny. This field has had a persistent unresolved controversy between Kober-Stille and Wegener-Argand schools. He has shown that the theories locked in debate are metaphysical and not scientific. The supporting frameworks of those theories constitute *Leitbilder* and hence the controversy could not be resolved scientifically. The importance of Popper separating science from metaphysics by his demarcation criterion can now be appreciated in the light of a relevant geological context. So does Sengör's paper illustrate that Popperian notions are guiding the work of some contemporary earth scientists.

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Molecular modelling and graphics of polymers

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Molecular modelling and graphics studies of polymers have developed as an important tool to predict the performance and design of new polymers. This article reviews the work reported in the literature and compares various commercial packages available in the market. The article also describes modelling studies carried out on styrene–butylmethacrylate copolymer, and the attempts made to predict the physical properties of the product from the molecular structure.

COMPUTER-AIDED molecular modelling and graphic visualization of small and large molecules have become a part of chemical research, mainly due to drop in the cost of computing technology, availability of sophisticated graphics software and rapid increase in the cost of conducting laboratory experiments[1]. Modelling and simulation techniques are fairly well established in fields such as biological chemistry and pharmaceuticals. It is now being extended in other areas of chemistry like polymers, materials science and inorganic chemistry.

Polymer molecules are very complex and large, and modelling them invokes a staggering number of variables. This has become feasible over the last few years owing to the increase in available and affordable computer power in the form of graphics work stations and fast parallel processors. Interest in predicting polymer properties has risen dramatically, especially in industrial laboratories, as the cost of industrial research has increased and as polymers have moved into specialized high-performance areas, named as 'specialty polymers'. Industries are busy creating new 'designer polymers' to meet customer-specific needs. Chemists at Hoechst Celanese are searching for new high-performance polymer blends using modelling and simulation[2]. This approach reduced the number of polymer pairs that needed to be experimentally tested in the laboratory from 300 to 30.

Several companies have joined polymer-modelling consortium established by Biosym Technologies, a software company based in California, to act as a focus for developing new methods in polymer modelling and to distribute them in the form of rigorous software pacakges[1]. The consortium has about 50 members, including Hoechst Celanese, BASF, Ciba-Geigy and Eastmann Kodak. They have released six modules

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