LETTERS TO THE EDITORS

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The Theory of Magnetic Storms and Auroras

Under the above title, Dr. D. F. Martyn has published an article in *Nature* of January 20, 1951, which is of much interest.

Dr. Martyn's treatment is founded on Chapman–Ferraro's theory of magnetic storms. It is not my intention to review here the objections to this theory —objections which I believe to be fatal—nor is it worth while to discuss the curious superstructure which Dr. Martyn tries to erect on this weak ground. It is much more interesting to recall Dr. Martyn's statement that "the strength of the Chapman–Ferraro theory lies in the extreme care with which each necessarily occurring process has been analysed". This brings up the question in what parts of geophysics it is possible to analyse a phenomenon so carefully that really "each necessarily occurring process" could be found. In some rather simple cases it probably *is* possible. In more complicated cases, however, it is a very dangerous method which should be used with great care and only when no other way is possible. The theoretical geophysicist should learn from the physicists that a topic can be developed only by intimate contact with experiment.

These remarks may appear to be trivial, but Dr. Martyn's article has demonstrated the necessity of stressing them for the field of electric currents in gases. This is a subject on which very much laboratory work has been done during this century. Many theories have been formulated with much care ; but even if they have started from correct assumptions about the properties of atoms and electrons, it has again and again been shown that many of them were not tenable. This is due to the fact that the field is very complicated, because so many different factors may enter. However carefully a theoretical worker has selected what factors should be of importance for a certain phenomenon, he will very often find from experiment that Nature has another opinion about what factors are essential. Nobody who has studied the present theory of spark breakdown or the streamer mechanism of a flash of lightning will believe that any theoretician, however skilful, would have been able to give an *ab ovo* theory of it starting from general principles without knowing anything of the experimental results.

The theoretical geophysicist has no greater chance than the theoretical physicist of making a correct guess about the important factors. Moreover, he has much less chance of being quickly corrected when he has started on a wrong road. The only remedy for this seems to be a much better contact with laboratory experiments. Many of the formulæ which have been worked out for application to geophysical problems might, and should, be checked in the laboratory. For example, even Chapman–Cowling's formula for the electric conductivity in an ionized gas should be used with some hesitation, not because any fault has been made in the admirable calculations leading to it, but because there is no experimental check. It would not be at all astonishing if in some cases it were wrong by several orders of magnitude, because factors which have not been included in the calculations turn out to be more important than those which have been included. In fact, measurements of the diffusion of a plasma across a magnetic field have shown that in some cases this is some hundred times more rapid than expected, presumably due to plasma oscillations[1].

It is very annoying to all theoreticians in this field that we know so little about plasma oscillations except that they are very important. So far no real theory of them exists. In this respect they may be considered as analogous to turbulent phenomena, which upon the whole can be treated only in a semi-empirical way. Applying empirical criteria for the occurrence of plasma oscillations to the problems in Chapman–Ferraro's theory, there are indications that such oscillations may be of decisive importance. If this is so, the claim that "each necessarily occurring process has been analysed" seems exaggerated.

My conclusion is that in many fields of geophysics we should not attempt to go directly from our writing-desk to cosmical phenomena. It is much better to call at the laboratory on our way out. If our theoretically derived results are found in the laboratory to be in error, there is little chance that they will be right when applied to the geophysical phenomena.

This stresses the importance of scale-model experiments, which indeed was fully realized by Birkeland, the founder of the electromagnetic part of geophysics. In order to find what electrical phenomena occurred during a magnetic storm, he put up a 'terrella' imitating the earth with its magnetic field in as good a vacuum as was attainable at that time and started an electric discharge. He observed luminous rings around the poles, similar to the aurora. Unfortunately, the theory of discharges in gases was quite undeveloped at that time so it was impossible for him to interpret the phenomenon. Dr. Malmfors's repetition of this experiment under much better controlled conditions has demonstrated how important experiments of this type are for the understanding of geophysical phenomena.

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[1] Cf. Bohm, D., Burhop, E. H. S., Massey, H. S. W., and Williams, R. M., Chapter 9 of "The Characteristics of Electrical Discharges in Magnetic Fields", p. 173 (National Nuclear Energy Series, 1 : 5 : 1949).

No one will disagree with Prof. Alfvén when he stresses the desirability of attempting scale-model experiments of geophysical phenomena in the laboratory. Unfortunately, experience shows that unambiguous experiments of this type are hard to make : a recent study of such an experiment devised by Chapman[1] to test theories of magnetic storms reveals some of the difficulties. It would seem that in the field of low-pressure physics, Nature still provides the laboratory best suited for illustrating fundamental principles in action. Certainly, to date, all scale-model attempts to illustrate theories of magnetic storms have yielded ambiguous results : in Alfvén's own recent words[2], "we ought to be careful in applying a result from a scale-model experiment to Nature".

Prof. Alfvén considers that Chapman and Ferraro's work cannot be thorough since it apparently takes no account of plasma oscillations. It is unfortunate that these authors' long series of papers on magnetic storm theory have not been more widely read, possibly because of their mathematical difficulty and the modesty of their claims. In point of fact, Chap-