Consideration on Applied Geophysics[1])

by

J. M. LYSHEDE

It is a great honour to me that the conference of European Exploration Geophysicists has invited me to make the opening address of the conference. On the other hand I have had some trouble in understanding which qualifications I should hold for this task. In trying to realize that, I have found only one small thing, I was trained in modern physics, I worked during 15 years in a field of geophysics, hydrology, and I now try to combine my experiences from both fields. I don't think that this makes me qualified for talking in general about geophysics, but I hope that my consideration on some hydrologic problems will contain something of interest for other geophysicists, too.

Basic *training in physics is—or ought to be—the natural introduction* to any work in geophysics. There is, however, some difference between any branch of modern physics and most of the geophysical subjects, where an all-round knowledge of classical physics, of mathematics, and of modern physics is required in addition to a lot of information on geography and geology. In spite of this difference I hope—and I also believe to be right when I do so—that the methods of experimental physics hold valuable contributions to the methods that are necessary in the fields of geophysics.

Hydrology is one of the youngest of the geophysical subjects and shows many of the features that beforehand characterized several of the other geophysical subjects. I want to mention some of these features by pointing out some concrete problems of practical or scientific art, which I have met, and hope that you will recognize some well-known difficulties in *this geophysical subject so different from your own*, and that, perhaps, the equalities and diversities will throw new light on some old and well-known problems.

Hydrology has as most geophysical subjects been developed from some practical arrangements that were made in order to collect some data that were necessary with respect to some concrete technical problem. The data might for instance be variations in the waterlevel of a river during the seasons, or variations of the water table in some borings at places where the utilization of the groundwater for water-supply was an acute problem for a town.

---

[1]) Opening address at the Seventeenth Meeting of the European Association of Exploration Geophysicists, held in Copenhagen, 9–11 December 1959.

Hydrologic research, consequently, begins with measurements and with the recording of results. The use for practical purposes at first only requires a very simple statistical treatment; the complex character of the conditions under which the well-known physical laws act makes the use of these laws problematic. Gradually, however, the necessity of reliable forecasts gives rise to an even more thorough use of the results in an attempt to find some general hydrologic laws. Three main lines seem to be followed when handling hydrologic problems:

1) Mathematical treatment of the results, hereby regression analysis and other kinds of statistical treatment,
2) Physical evaluation of the variations in the hydrologic results, and
3) Geographical and geological description of the character of the catchment areas in question.

The physical evaluation is, of course, the line I would prefer to follow, but nervertheless I am quite aware of the difficulties in calculating the significance of the multiple physical conditions having great or small influence on the recorded hydrologic data. Take for instance the main source of runoff, the rainfall. The causality seems here beyond doubt, but so many other things influence the rate of runoff that a given amount of rainfall at times gives rise to almost the same amount of runoff, while at other times the same amount of rainfall seems to cause no runoff at all. The reason is that in the first example the pores in the soil and the hollows of the surface of the earth are filled with water so that all the rain must run off at once. In the other case the entire rainfall is absorbed in the pores and hollows. There still remains, that rainfall after all is the cause of runoff and a relation between annual rainfall and annual runoff may give some information of such physical quantities as evaporation and seapage to the sea through the soil. As the relation however expresses no functional dependence, the mathematics to be used must be that of statistics. Supposing that the relation between rainfall and runoff is linear, the first step will be to calculate the regression line connecting rainfall with runoff in a rainfall-runoff-diagram. As the dependence is no functional one, the seperate points will deviate considerably from the regression line calculated, and different methods give different regression lines. The mathematics only tells us that this is the case; but the hydrologist cannot agree that the uncertainty of the regression is as great as that and asks for the best regression line among those possible. It can be shown that the best regression line is the one that uses the row of figures with the smallest mean error as the independent variable. A thorough mathematical treatment of this fact will be of very great value to hydrology and I think for numerous problems, also from other parts of geophysics.

In mentioning this concrete problem I am at the heart of one of the severe questions. How can mathematics be used in geophysics. Very few geophysicists are mathematicians, and fewer mathematicians understand the geophysical problems; the better the calculating machines become the more severe will these problems be. How can the geophysicist translate his problems into mathematical language, and how can the mathematician explain the solved problem in geophysical terms.

One of the main problems in hydrology is that of water balance or as it is often named, the hydrologic cycle; the water comes from the clouds, penetrates the pores of the soil, the surplus running off through the underground or more often through the valleys to the rivers. A large part of the water evaporates or transpires. Physics cannot distinguish between these verbs and must regard the phenomenon as evaporation, because no water can become vapour unless the energy necessary for vaporization is available. Most of the energy comes from the sun, and a smaller part may be supplied as heat. This obvious view-point had not penetrated until ten or twenty years ago, to some degree because meteorological data could not give any information on the evaporation. The most reliable data for evaporation came from the meteorological records of rainfall and the hydrological records of runoff. With those undisputable results as background, a successfull calculation of evaporation on the basis of sunshine was established after several attempts. Once the physical character of the evaporation was established, this fact became a source of inspiration to botanists, agriculturists and plant physiologists. New view-points may subsequently occur in these sciences, and that kind of application of geophysics seems to me to be extremely valuable. New knowledge is often a result of interaction between different sciences.

May I mention another concrete point. Between rainfall and runoff there is a time lag, the size of which follows from the magnitude and the character of the reservoirs in the soil pores and at the earth's surface. If the sizes and the runoff conditions of the reservoirs were known in detail, the time lag could be handled mathematically or at least numerically. This is of course seldom the case, but some approach may often be reached by simple means. If the rate of runoff is proportional to the reservoir content an exponential decay curve may be computed. As there usually are several reservoirs of different characters the resulting runoff may be described by sums of decay curves of the kind mentioned before. When nothing is known of the number of reservoirs, series of a simple mathematical character may be introduced and happen to give a suitable curve to describe the runoff phenomena. It must, however, be said that this line of action is a substitute for the correct introduction of the real reservoirs in the computation.

Here, I think, is the real problem in hydrology, and the way to the solution of it must be the co-operation of physics and mathematics with geology in an approach to this the third line of the hydrologic research. Without physics and mathematics hydrology will stagnate in description; without geology it will miss the connection with the earth and the right to be named geophysics. The common interest in co-operation is obvious, and it must be hoped that all categories of hydrologists can agree with that. In addition to the better knowledge of hydrologic problems new methods may result for the geological as well as for the physical hydrologist, also to other parts of their science. As an example of the profitable use of physical methods in geology I might mention the geoelectric survey that has been so successfull in geologic research with a reacting inspiration on the theory of the method.

A thing of newer date must be mentioned, the use of radioisotopes in geological survey, which is just at the beginning of its development. The methods may show to be of the greatest importance also for the future hydrology. Perhaps we may be anxious for an evolution of such methods, and I cannot say that there is no cause for such anxiety; but it seems to me that the sooner the co-operation in this field progresses satisfactorily, the more help hydrology will be able to contribute to diminuishing the dangers of the radioactive waste, one of the great problems of the future, to the solution of which problem I expect that also other geophysicists must contribute.

I have not said much about the general contents in the title, which was given me for my address, but only spoken on hydrology, of which I have some first-hand knowledge. I now feel obliged to say something of a more general character. Applied geophysics is in some way related to geophysics as geophysics is to physics. But in the word applied is something else, namely the utilization of knowledge in the service of humanity, where pure science finds its main purpose in itself. I will not deny that occupation in pure science is attractive because of the independency of any objective; but the fact is that the demands for applied sciences are ever increasing as the technical problems of the community increase, leaving less and less time for anybody to do scientific work for its own sake. We may regret that, but must feel relieved in the fact that also pure science will benefit from the evolution of the applied sciences. Having said so I must add there is a serious danger in applied sciences because of the given objective. I have had that feeling, and surely nobody working in applied science can quite free themselves from thoughts of that kind. In applied sciences results are often required before the investigations can be concluded. To some extent the demands for scientific care contrast to the demands of the community for rapid results. But if this danger does not kill the scientific care, the contrast mentioned may be a most significant source to a sound mental development, the broad plane af touch with the community preventing the scientist from getting too narrow-minded regarding his own scientific problems. May I conclude with these words as my greeting and welcome to the conference on exploration geophysics. I hope that the conference will give you the scientific advantage you want and that you at the same time will enjoy being together for a couple of days with colleagues having the same or familiar interests as yourself.