Proceedings of the Seminar on the Social and Economic Effects of Earthquake Prediction, 12 October, 1977.

EARTHQUAKE PREDICTION

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SUMMARY

The study of precursory phenomena shows increasing promise as a basis for earthquake prediction. Long-range forecasting can be expected to reduce by a large factor the uncertainty of estimates based on the historical record, and also to facilitate the development of short-range forecasting. The testing of prediction methods for reliability poses special problems. Earthquake forecasting will be much affected in practice by the social and economic implications of forecasts as such, and also by the relative implications of failures and false alarms, as well as successes.

INTRODUCTION

The successful prediction of earthquakes has emerged as a serious possibility in the past few years as a result of advances in knowledge about the processes of earthquake generation. Previously scientists were inclined to leave prediction to students of the occult, and people generally regarding earthquakes, as many still do, as acts of God. This was perfectly understandable in the light of the theory of earthquake generation then current, a theory that was formulated after the great San Francisco earthquake of 1906. Earthquakes were then seen as resulting simply from a slow build-up of stress accompanied by an equally slow build-up of strain, the process continuing until the strength of the rock was reached and sudden fracture occurred. On this concept there was really little hope of predicting earthquakes, which appeared as a cataclysmic sequel to a very gradual and featureless process. Some thought was given to the possibility of measuring the stress and fracture strength in the ground, but these types of measurement are exceedingly difficult to make.

PRECURSORY PHENOMENA

A discovery by the Russian scientists A. M. Kondratenko and I. L. Nersesov, who worked in the Garm region of Tadjikistan and published their results in 1962, showed that the behaviour of the ground in the period before an earthquake was not at all so simple. They found that the velocity of seismic waves (which depends on the elastic properties) was anomalously low before an earthquake, and that the magnitude of the earthquake increased with the duration of the anomaly. This remarkable result went almost unnoticed until attention was drawn to it by the Russian seismologist E. F. Savarensky in a review article in 1968, since when the velocity precursor has become the best known and most widely studied phenomenon relevant to earthquake prediction.

Many other precursory phenomena have also been observed. These include anomalous deformation of the ground surface, changes in the electrical and magnetic properties of the ground, and increases in the amount of the radioactive gas radon in well-water. In New Zealand it has been found that characteristic fluctuations of minor earthquake activity usually precede major earthquakes, and this phenomenon has also been identified in California and Japan. The most encouraging aspect of all this work is that the duration of this wide variety of precursory anomalies is found to be related in the same way to the earthquake magnitude. The duration is quite long - about 1½ years for a magnitude 6 earthquake and about 8 years for magnitude 7. Thus the phenomena are called long-term precursors and they suggest a basis for the long-range forecasting of earthquakes. The Japanese seismologist T. Rikitake in a review article published in 1975 was able to list 110 different observations of long-term precursors by many scientists in several countries.

But more needs to be known about most of these long-term precursors if they are to be used for prediction, and only in the People's Republic of China have major earthquakes been successfully predicted so far. All one can do with the magnitude/duration relationship by itself, assuming that the onset of a precursor has been properly recognised, is to say that the more time passes the larger the earthquake will be. This may be better than nothing from the scientific viewpoint, but not much; from the practical viewpoint it could easily be worse than nothing. The Chinese have been able to collect and use a very large number of amateur observations, including reports of anomalous animal behaviour, as well as studying the usual precursory phenomena.

PREDICTION AND HISTORICAL ESTIMATES

Precursory phenomena provide a deterministic basis for prediction, in contrast to the purely statistical basis provided by past earthquake occurrences. In other words, the precursor gives positive physical evidence that an earthquake is already in preparation in the affected area. Nevertheless both the prediction and

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the statement based on earthquake history specify an area, a timespan and a range of magnitude for the future earthquake occurrence. For example, history shows that on the average New Zealand experiences once every ten years an earthquake of magnitude 7.0 or greater (though the actual interval between such earthquakes is very irregular). Now supposing that a precursor were observed that the best that could be said by way of prediction was that within some rather large part of the country an earthquake of magnitude 7 - 8 should occur within a specified but lengthy future period of years. Such a so-called prediction would have a good chance of success on the purely historical basis and nothing would have been gained by making it out to be anything else.

Thus whether a prediction is meaningful must be judged against the background of historical data. This point has been worth dwelling upon because people interested in prediction are not always aware of it. One amateur observer in the Hamilton district has taken up the very interesting idea that earthquakes may be triggered by changes in atmospheric pressure. But the type of statement made was that "there would be an earthquake down the West Coast some time next week". Now if you go to small enough magnitudes this statement will be abundantly satisfied any week of the year. For a prediction to be worth making it should specify the combination of place, time and magnitude of the earthquake at least twenty times more narrowly than the corresponding statement based on earthquake history.

PRECISION AND RELIABILITY

The principal elements in a prediction - place, time and magnitude - will each be estimated, in any adequate scientific prediction method, with calculated precision, and the precision should be stated as an integral part of the prediction. In this respect scientific prediction promises less than does the "Old Moore" type of prediction, in which the elements are usually stated with great exactitude. Such statements belong in the realm of the occult and have no basis in science.

The requirements of a prediction have been discussed at length by the U.S. scientist C. R. Allen in his presidential address to the Seismological Society of America in 1976. Besides the requirements mentioned above, Allen states that a valid earthquake prediction must include some indication of its own reliability. This leads us to a paradox which is of great importance when one comes to consider the social implications of earthquake prediction, especially in the present state of the art. The paradox arises because the reliability of a scientific proposition is found by carrying out tests on the hypothesis on which it is based, but it is only by making predictions that one can test a prediction hypothesis. Ordinarily in science the testing exercise is carried out before the hypothesis is announced, let alone applied in practice.

Opinions of eminent scientists and others differ very widely on the question of whether any predictions should be made public before the method used has been fully tested. At one extreme it is asserted that a testing period of ten or twenty years should be successfully completed before the public should be expected to take predictions seriously. At the other extreme is the view that even the earliest tests should be carried out in public so that the public can decide whether to act on a particular prediction or not. This is one question that needs careful consideration from the viewpoint of social and economic implications.

LONG RANGE AND SHORT RANGE FORECASTING

Precusory phenomena have been identified which precede the earthquake by only a few hours or days. The occurrence of such precursors is very unlikely to be recognised in time to be of practical value except when the location of the expected earthquake has already been indicated by a long-range forecast. Thus the first requirement is for effective long-range forecasting. Nevertheless the implications of short-range as well as long-range forecasting need to be studied, since they are very different.

The usefulness of long-range forecasting may not be self-evident to those who have in mind the "Old Moore" type of prediction, and yet in New Zealand conditions greater benefits may accrue from long-range than short-range forecasting. It has been mentioned above that the precision associated with long-range forecasting is superior to that of historical estimates by a large factor. Yet historical estimates have been the basis for a number of far-reaching practical measures. Elaborate provisions for earthquake resistant design in new buildings are included in the New Zealand Standard Model Building By-law. The Municipal Corporations Amendment Act provides for local authorities to be empowered to deal with unsafe old buildings. Much of the work of the Earthquake and War Damage Commission and of the Civil Defence organisation is concerned with earthquake risk as estimated from the historical record. In all these connections the advent of long-range forecasting would have implications needing to be carefully considered.

Thus despite the residual lack of precision that is to be expected in long-range forecasts they will serve to concentrate the attention of the appropriate authorities on the affected area, and also the attention of scientists in search of confirmatory predictive evidence and eventually short-term precursors. The implications of short-range forecasts are very different in countries where the typical dwelling has virtually no strength against earthquake forces, as compared with New Zealand where the typical dwelling is relatively very safe.

SUCCESSES, FAILURES AND FALSE ALARMS

Practical earthquake predictions would assuredly involve some occasions when unpredicted earthquakes occurred, and some when predicted earthquakes did not occur. The relative implications of successes, failures and false alarms are an important subject for study and will have an effect on the prediction process itself. If false alarms are regarded as less undesirable than failures, as they are in China, there

will be a greater readiness to attempt predictions, and this is presumably one of the reasons for the Chinese successes. In one major Chinese earthquake three successive short-range forecasts were issued, of which the first and second turned out to be false alarms, but the population still accepted the third, and this proved successful.

One suspects that in New Zealand false alarms would be regarded as more undesirable than failures. For it may be argued that at present, in the absence of predictions, all earthquake occurrences represent failures to predict, and this is the situation that everyone is adjusted to. But once predictions began to be made there would be a tendency to expect all major earthquakes to be predicted. False alarms, on the other hand, would be regarded as having caused unwarranted expenditure and inconvenience, and would also tend to discredit the making of predictions generally.

CONCLUSION

The future of prediction will depend, apart from the scientific aspects, on the community's ability to take advantage of it. This raises unusual problems at every community level, from the private citizen who needs to adjust both psychologically and in practical life, to the Government which needs to take appropriate political and administrative measures. It has been pointed out that unless these problems are adequately dealt with there is the possibility that a prediction might turn out to be a worse disaster than the earthquake itself.

One could hope that New Zealand might be capable of a pioneering effort in earthquake prediction which would in due course benefit not only this country but those in which the earthquake hazard is much more serious and the resources to cope with it much less abundant.

DISCUSSION

Points raised during the discussion centred on the reliability of prediction, the large number of monitoring measurements required, the various techniques used and the contrast in techniques suitable for use in New Zealand compared to those used in China. Professor Evison emphasised the need for widespread instrumentation and a suitable organisation for the processing of the data.