NOTES ON PROCEDURE FOR CONVEYING EARTHQUAKE FORECASTS WITH SPECIAL REFERENCE TO THE PERU PREDICTION FOR 1980-81

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1. INTRODUCTION

This paper deals with certain forecasts made by Dr. B. T. Brady of the U.S. Bureau of Mines and Dr. W. Spence of the U.S. Geological Survey concerning possible events in the subduction zone of the Nazca and Americas plates off the coast of Central Peru. The writer is not a physical scientist and offers no judgement on the validity of the theories developed or observations made by Drs. Brady and Spence. As a student of politics and administration he is concerned only to study the consequences for those public authorities who came to learn of the arguments put forward by the two scientists and from an examination of the response to consider the case for some consistent procedure when scientists who are not resident within a particular country decide that they are in a position to forecast an earthquake at some place in that country within a period sufficiently specified to suggest that some counter-measures should be taken by the community. It is relevant to mention that the author has been actively engaged in the study of political and administrative consequences of earthquake prediction for some ten years. (Cf. Roberts 1973, 1977, 1979, 1979, 1981, 1981.). The author was also present at the audience with the President of Peru when Drs. Brady and Spence officially conveyed their forecast that a series of strong earthquakes would occur near Lima in the second half of 1981. He has had the advantage of several discussions with the American and Peruvian scientists and administrators involved.

2. THE NEED FOR DEFINITIONS

The most cursory acquaintance with earthquake prediction will reveal that there are a number of stages in the process involving an increasing number of actors. The first stage involves the continuing work of the earth science community in gathering information on the phenomena of earthquake causation and frequency. We could call this the hazard evaluation stage. From this data, it is customary to find a response in the technical and politico-administrative community which attempts to assess the exposure of structures and land use to

earthquake risk and to specify standards of construction, land use and civil defence procedures to mitigate risk according to the level at which it is present. We could call this the risk mitigation stage. With the development of enquiry into the scientific possibility of forecasting of time, place and magnitude of events the scientist may be faced with a situation in which his observations convince him that an earthquake may take place at a near date in a given location; this could be called the forecast stage. Naturally, the validity of this forecast will be assessed (if it comes to notice) and the possibility that a prediction should be formally issued will be considered. Several countries (China, Japan, the United States) have evolved machinery for what might be called the prediction evaluation stage. At this point, national authority may have to consider their reaction to the evaluation and decide whether they wish to advance to the prediction stage at which point the possibility of an event is formally put before the community at large. Once a prediction is made the precursory phenomena will come under close scrutiny in what may be termed the hazard monitoring stage Finally, if the sequence of events forecast as precursors to the predicted earthquake occur with sufficient congruity the authorities will be compelled to decide whether or not to advance to the warning stage at which point disaster mitigation programmes would be put in train.

3. FORECASTS FROM FOREIGN SOURCES

Much geological information is international in the sense of availability to earth scientists. The desire to gather information and develop theory takes as little account of national boundaries as do plate tectonics. Naturally, many of those devoted to the cause of scientific enquiry will support a philosophy of open access to data and untramelled analysis. But the sequence of events involved in earthquake prediction is not only a scientific problem. Once given currency, a forecast becomes a matter of intense interest and concern to individuals whose life and property are seen to be at risk and to those private and public institutions which may want to react or are under duty to react. One may expect that in those countries where the geological conditions and historical record indicate a possibility of strong earthquakes, there will be active public institutions for the study of seismic phenomena capable of advising public authorities on such forecasts. It is likely that they will be in touch with the main lines of scientific investigation in this field and will be available for consultation by any scientist who may consider that he has information that the public authorities should consider.

However, the scientist working outside the country may not be in touch with these institutions. Even where the scientist develops scholarly exchanges with colleagues and establishes working relationships with the relevant public agencies, the extent of these contacts will vary with each individual case.

In this exploratory phase of earthquake forecasting, it seems that the greatest care should be employed to avoid undesirable consequences for the community. This depends upon the establishment and maintenance of clear channels of communication between scientist and community but there are difficulties as the forecast made by Drs Brady and Spence demonstrates.

4. THE BRADY/SPENCE FORECAST

It is not useful to investigate here the scientific background to the forecast of a great earthquake off the coast of Central Peru in August 1981. No doubt other and competent analysis will be available. It is sufficient to point out that in 1976 Dr. Brady concluded a series of four articles on the theory of earthquakes with the deduction that strain building in the subduction zone of the Nazca and Americas plates might result in an earthquake of large magnitude within a period of seven to fourteen years from mid November 1974 (Brady: 1976).

This information reached a journalist in Peru who contacted Dr. Brady and confirmed the general circumstances of the forecast. Wide publication and media comment followed. This was the subject of an analysis by Dr. Alberto Giesecke, Director of the Centro Regional de Sismologia para America del Sur (CERESIS) located in Lima, at a Seminar organised by a number of national and international institutes at San Juan, Argentina, in October 1980. This revealed a reaction ranging from sober commentary on the progress towards a theory of forecasting to somewhat sensationalist condemnation of Drs. Brady and Spence. The latter also presented a paper at San Juan outlining the theory, commenting upon the investigation of empirical data and confirming their forecast.

Subsequent to this seminar Drs. Brady and Spence, Dr. S.T. Algermissen of U.S. Geological Survey and the writer met in Lima at the invitation of Dr. Giesecke. This group joined with officials of the U.S. Government at the U. S. Embassy in Peru to discuss the implications of the forecast on 29 October 1980, and subsequently on the same day, most of this group attended an audience with the President of Peru where Drs. Brady and Spence communicated the substance of their investigations and their forecast of a series of large magnitude earthquakes in the second half of 1981.

It was agreed at the meeting in the U.S. Embassy that data on seismicity in the region should be communicated to Drs. Brady and Spence and there was some discussion on a possible contribution by U.S. sources to the scientific programme. I am not aware that this was forthcoming although it is clear that Peruvian scientists did supply seismic data to Dr. Brady through 1981.

It is of interest to note that Dr. Clarence Allen of the Californian Institute of Technology and Chairman of the U.S. National Earthquake Prediction Evaluation Council (NEPEC) attended the Seminar at San Juan and in conversation with the writer indicated that, in his opinion, the Council would react to the Brady/Spence forecast if requested by the Peruvian Government. Obviously, such a request was made very shortly after the communication of the forecast on 29 October. NEPEC convened at Golden, Colorado and issued the statement on 27 January 1981 appended to this paper. The operational part of their evaluation reads :

> The members of the Council are unconvinced of the scientific validity of the Brady/Spence prediction. The Council has been shown nothing in the observed seismicity data, or in the theory insofar as presented, that lends substance to the predicted times, locations, and magnitudes of the earthquakes.
>
> The Council regrets that an earthquake prediction based on such speculative and vague evidence has received widespread credence outside the scientific community. We recommend that the prediction not be given serious consideration by the Government of Peru.
>
> We cannot say with complete confidence that major earthquakes will not occur at the predicted times but we judge the probability of this happening to be very low indeed. On the basis of the data and interpretation currently available, none of the members of the Council would have serious reservations about being present personally in Lima at the times of the predicted earthquakes.

Notwithstanding this uncompromising rejection, Dr. Brady maintained that his forecast was correct and my information is that as late as early May 1981 Dr. Brady confirmed a forecast that there would be at least three earthquakes on or about July 6, August 18 and September 24, 1981, respectively. His colleague, Dr. Spence, who had looked at "... the prediction that Brady made .... to determine if it was plausible given the region's tectonics" (EOS : 1981) is reported in EOS as follows :

"I think that there's a very small chance of the predictions being correct .... Even if there's a small chance however the risk is extremely great." In light of the prediction "keeping an eye on the zone" to test the prediction would be "very prudent".

"I think scientists should be very careful about issuing predictions because of the social consequences .... predictions should be supported with well documented details".

(EOS : 1981)

In July 1981 Richard A. Kerr, writing in Science, reported that Brian Brady of the U. S. Bureau of Mines in Golden, Colorado, has formally withdrawn his predictions of two mammoth earthquakes off the coast of Peru. Because the prerequisite seismic activity had not occured "The probability of the last two [large] events occuring is extremely small" he said (Kerr: 1981). Kerr also reports that despite the evaluation by NEPEC many Peruvians had continued to take the Brady forecast "very seriously" according to Dr. John Filson of U. S. Geological Survey and Vice Chairman of NEPEC. Not until the first event forecast by Dr. Brady had failed to occur were they relieved of their anxiety (Kerr: 1981).

5. ASSESSMENT

This narrative raises several important questions about the nature of scientific and public obligation. To take the scientific aspect first, it could be said that a scientist has a right to be wrong and a duty to make every effort to be right. That is, no condemnation should fall upon a scientist who publishes an hypothesis which he has earnestly, and in a professional manner, endeavoured to verify but which subsequently proves to be false. It is not for a layman to judge whether Dr. Brady had attained that standard of verification when be published his paper in the Journal of Pure and Applied Geophysics but it is not unreasonable to assume that the editor or editorial board of that Journal made the usual efforts to ensure that qualified authority considered the paper worthy of publication. It is my understanding that Dr. Brady continued to publicise his conclusions before the San Juan meeting but so far as I am aware no systematic refutation appeared in public prior to the prediction evaluation of NEPEC in January 1981. Since Dr. Brady had made in 1976 and subsequently a specific forecast of a series of large and probably devastating earthquakes, public anxiety was to be expected. Independent scientific comment could have guided lay assessment of the forecast. The problem is one of time; to coin a phrase scientia longa vita brevis.

No doubt in time, the scientific community in its ordinary process of examining hypotheses would have got round to Dr. Brady's theory and forecast. But one may doubt that this would have occured soon enough to be of much use to the Peruvian community.

This raises the second problem of obligation. When a scientific hypothesis is likely to cause anxiety, economic loss and, perhaps, public disorder, has the scientist a duty to modify his method of proceeding by accomodating his scientific activity in some way to the requirements of community interest ?

It would be misleading to dodge the underlying individual moral dilemma in this. If one has information whose release it is sincerely believed may increase the chances of life for others there must be an ethical duty to make the information available, other things being equal. Suppose the possessor of the information believes that to resign this duty to some independent body may lead to neglect, misinterpretation or even the suppression of the information. The establishment of NEPEC is one answer to this dilemma since the Council is composed of qualified scientists, meets in public and issues a public evaluation. Yet in the case under consideration, Dr. Brady did not accept the NEPEC evaluation. To the contrary he persisted with his forecast for nearly six months after the NEPEC pronouncement. May we say that this is his proper privilege taking into account both the cause of promoting scientific advances and his duty to fellow human beings in Peru ?

I know of no unqualified answer to these questions but I believe that a special set of considerations should apply to a scientist who makes forecasts for a community in which he does not live and to which he feels no more responsibility than may be evoked by common humanity.

It is obvious that a scientist living in the community must feel a greater weight of local opinion than a foreigner. Dr. Clarence Allen, then President of the Geological Society of America, speaking to his fellow American scientists suggested "The next ten years are going to be tough ones.... We're going to have to work hard to maintain public support" (Spall: 1978). Dr. Allen speaks of the great interest of the media in prediction and the determination of reporters to pursue any and all rumours. A prudent scientist, realising this, will be fully alive to the need for caution in publishing a forecast affecting the area where he lives. One can expect that he will take every precaution to consult with colleagues and, where scientific support is forthcoming, advise the civil authorities if only to avoid personal harassment or even liability.

This pressures may not be felt by a non-resident. An excess of enthusiasm may tempt him to publish without considering the implications for the society affected by his forecast. While it is not suggested that Drs. Brady and Spence succumbed to such temptation it is relevant to point out that foreign predictions have been issued for areas other than Peru. A telegram from the United States was received in Mexico predicting an earthquake at Pinotepa Nacional on 23 April 1978. The municipal authorities made the contents of the telegram known and there was widespread anxiety in the region. The forecast, whose source is still not known as far as the writer is aware, turned out to be false. Clearly it was also irresponsible (Sosa Ordono: 1979). G.A. Eiby records that an English academic following a theory of causation forecast a large event in New Zealand. This reached New Zealand from press sources but fortunately the local journalists sought expert comment before publishing the story and any disturbance of public calm was avoided. According to Mr. Eiby "New Zealands's displeasure was conveyed to the prophet, who is understood to have muttered darkly about intereference with academic freedom" (Eiby: 1980).

In the final analysis this is the issue. Academic freedom is a central principle of scientific advance. It is also breached constantly for commercial reasons, for reasons of state and to maintain civil order. A scientist must always weigh his scientific obligation against his obligation as a member of a local, national or international community. The Peru case suggests that some scientists will find it difficult to maintain equilibrium and that they need a reliable, independent and qualified consultative mechanism to help them in reaching a decision to publish a forecast.

6. PREDICTION EVALUATION

At some point a forecast may become a prediction. This will follow upon an assessment process which this paper calls the prediction evaluation stage. This terminology seems to be useful in signifying a possible change of status for the forecast. The evaluation of a forecast is not only concerned with its scientific validity but also with the question of a potential response of the public authorities and the community. Thus NEPEC in evaluating the Brady/Spence forecast not only stated that the members were 'unconvinced of the scientific validity of the Brady/Spence prediction' but also recommended that it should 'not be given serious consideration by the Government of Peru'. That evaluation having passed to the government of Peru, it was up to the Government to decide whether to issue a "prediction" - that is a formal notification to the community that responsible public authorities accept the

the possibility that an earthquake will or will not occur in accordance with the terms of the evaluation. It would be naive to imagine that this will relieve a forecaster entirely of any further burdens but, at least, he may reasonably claim that a defensible procedure has been followed.

In the writer's opinion, the discussion of 'earthquake prediction' has now reached the point where responsible national and international bodies should consider encouraging the establishment of prediction evaluation procedures and advising those scientists who may develop forecasts to submit their findings to the relevant national evaluation procedure. This should not be read as an endorsement of the NEPEC form of evaluation. While NEPEC may suit the particular conditions of the United States, it may be inappropriate for other societies. As the experience of the People's Republic of China and of Japan demonstrates, there are other valuable precedents to assist in the development of a procedure adapted to the scientific and political conditions of each country. To venture briefly into an area beyond the writer's proper competence, it seems that in this palaeotechnic period of earthquake forecasting we have been misled by the drama of a possible prediction certain in time, place and magnitude - a sort of one shot scenario of disaster, to which the NEPEC procedure with its open theatre of conflict lends some support. The writer is much impressed by the reasoning of two colleagues at Victoria University of Wellington who in a paper on the subject of what they term 'synoptic forecasting' argue that

> earthquake forecasting is essentially an estimation of probabilities - a statement of hazard - and this represents things as they really are.
>
> Up to the present, most thinking about earthquake prediction has been based on the concept of the isolated prediction of a single earthquake - what might be called (to borrow a word from oil prospecting) a wildcat prediction.
>
> (Evison and Rhoades : 1981).

While probablistic forecasts may pose problems for the public authorities responsible for risk mitigation programmes, it does seem that both in testing hypotheses and in establishing operating estimates of risk, they offer opportunities for sensible policy development. Clearly the NEPEC procedure would not be appropriate to probablistic evaluation and its associated monitoring.

The writer is well aware that there is nothing new in these suggestions for evaluation procedures. An Ad hoc Working Group convened under Unesco auspices in 1981 to consider the selection of international experimental sites for research on earthquake prediction pointed out that 'guidelines for the formulation, evaluation and communication of such predictions should have previously been drawn up, to which host countries and participating institutions would already have signified their agreement'. (Unesco : 1981).
Earlier in 1979 a Panel of Experts convened to review aspects of earthquake prediction recognized 'that scientific observations pertaining to earthquake predictions may have an immediate impact on society' and recommended that 'Unesco encourage the development of guidelines to assist individual scientists, scientific institutions and governments in the presentation of such information' (Unesco: 1979). Last year the General Assembly of the International Association of Seismology and Physics of the Earth's Interior resolved as follows :

> Noting the valuable past contributions of Unesco, UNEP and UNDRO towards the development of multidisciplinary studies of earthquake prediction and its social implications.
>
> Recognizing the need for the world seismological community to develop a code of practice on the formulation, assessment and communication of earthquake predictions, especially when the crossing of international boundaries is involved.
>
> Recommends that ICSU be invited to encourage these United Nations Agencies to address this need in implementing their work programmes related to seismology and the mitigation of earthquake risk.

Suppose that the professional association and government organisations to which Drs. Brady and Spence belong had promoted discussion of the need for caution in publishing specific forecasts and wide dissemination of information on the procedures available for referring any forecasts to, inter alia, Peruvian authorities for testing and, if necessary, evaluation, would it have been reasonable for Dr. Brady to have refrained from incorporating in his 1976 publication the specific forecast referred to above and to have submitted this information in confidence to the specified procedure in Peru ? The answer to this question depends upon the confidence the individual scientist has in the response to his submission. This is a matter of some moment. The whole purpose of an evaluation procedure is to prevent unofficial prediction.

If scientists believe that their findings have not received thoroughly professional and sympathetic examination they may decide to publicise them whatever conclusion may be reached in the evaluation process. It seems to me that standards of evaluation including the process of consultation with the forecasting scientist deserve the closest attention by national and international associations. If anyone doubts that forecasts may remain current against sustained criticism it would be wise to consider the experience of U.S. authorities in the Brady/Spence case.

> A lesson learned from the experience, some scientists say, is that the federal government's handling of earthquake predictions can still be improved. In particular, scientists have censured the Agency for International Development's Office of Foreign Disaster Assistance (OFDA); Filson notes that for 2 years the USGS had emphasized to OFDA that Brady's predictions totally lacked support in the scientific community, outside of Spence's feasibility arguments. These "early informal reviews by the Survey were not taken as seriously as we would have liked". Clarence Allen says "Many of us were upset with OFDA's handling of this". In spite of the lack of scientific support, OFDA continued to place credence in Brady's prediction and even promoted the idea, he says. (Kerr: 1981).

It is of interest to note that officials of AID/OFDA were present in Lima at the meetings of 29 October 1980.

The lesson seems to be that "early informal reviews" in a foreign country are not enough. Reason suggests that Lima should have been the appropriate place and the Peruvian scientific establishment the proper authority to consider the Brady/Spence forecast. From observation, it seems to the writer that having no precedent to refer to and no canons of judgement, the Peruvians were not equipped for this task. They tended to feel that as Drs. Brady and Spence were U.S. nationals and employees of the U.S. Federal Government it was largely up to the United States to dispose of the matter. While the writer accepts that this was inevitable in the given circumstances, steps should be taken to see that a similar situation does not recur.

7. CONCLUSION

Discussions on earthquake prediction so far convinces the writer that a prediction which is given wide currency and is generally believed will be a disaster for the affected community whether or not the predicted events occur. In the Brady/Spence case it was fortunate that NEPEC existed and was able to refute the prediction sufficiently early to avoid the worst consequences. That may not always be the case and the circumstances reveal an urgent need for an authoritative evaluation process in countries vulnerable to strong earthquakes. Although it is possible to argue that scientific freedom may be inhibited by such procedures, it is clear that such freedoms are frequently subject to constraints of a national or commercial interest, and in any event compulsion is not contemplated as an element in the procedures. National and international bodies concerned to promote responsible scientific activity should consider their duty to propose and assist in the establishment of evaluation procedures and to encourage the scientific community to submit their findings to the appropriate institutions. In the specific case of forecasts developed by scientists not resident in the country to which the forecast refers, the need for caution and for early and confidential consultation should be strongly emphasized.

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DISCUSSION

Prof. Lomnitz commented that geoscientists are being challenged to do more socially relevant work. To do so, they must become more concerned about political communication. He asked whether geoscientists should communicate "immature" results to society.

Dr. Fournier d'Albe and Prof. Roberts discussed the need to determine what is an acceptable risk. Prof. Roberts raised the issue of how to convey a probability to a politician in order to make an administrative decision.

Prof. Lomnitz suggested that the probability threshold will depend on the society.