SPECIAL SECTION—ASSESSMENT OF SCHEMES FOR EARTHQUAKE PREDICTION

The IASPEI procedure for the evaluation of earthquake precursors

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SUMMARY

Full scientific evaluation of proposed earthquake precursors for earthquake prediction is a problem because independent testing is difficult or impossible. To approach this difficulty, and to assess the current state of the art of earthquake prediction research, IASPEI has devised a peer-review procedure for precursor evaluation. The procedure does not consider predictions of impending earthquakes, but evaluates case histories of proposed precursors for past events according to stated validation criteria, which are specified in terms of guidelines concerning the hypothesized physical model, data quality, anomaly definition, the rules of association of precursor with earthquake, and statistical significance. So far, five precursors have been placed on a preliminary list of significant earthquake precursors, although none has satisfied the validation criteria well enough to ensure that their placement is permanent. Exclusion of a precursor from the list does not mean it is useless, but further work is required if it is to become convincing. The main objectives in producing the list are to establish a consensus on the criteria which a precursor must satisfy to be recognized as validated, and to find case histories which satisfy these criteria. Further nominations of precursor candidates are requested for evaluation by the IASPEI procedure.

Key words: earthquake precursors, earthquake prediction.

1 INTRODUCTION

Scientific earthquake prediction requires the identification of one or more precursors which have a relation to stress or strain or some mechanism leading to earthquakes, and which provide information on the location, time and magnitude of a main shock. Assessment of such a prediction will implicitly involve the assessment of the detection, analysis and interpretation of the precursor on which the prediction is based. In most other branches of science, the precursor would be verified by an independent experiment, which is the vital criterion to prove a claim. However, in seismology such experiments would almost certainly depend on the occurrence of strong earthquakes near an adequately instrumented site. Strong earthquakes are rare, so it could be decades before a rigorous proof could be obtained.

In 1989, the International Association for Seismology and Physics of the Earth’s Interior (IASPEI) recognized that a state-of-the-art assessment of earthquake precursors would be useful even though independent verification was lacking, and called for nominations of geophysical precursors to be evaluated for inclusion in a Preliminary List of Significant Earthquake Precursors, to be updated periodically during the International Decade for International Disaster Reduction (IDNDR). By the attribute ‘significant’, the IASPEI wanted to express the need for some kind of screening, this is carried out by a peer-review process which deals only with case histories of past events, and does not consider predictions of impending earthquakes. The objectives of the procedure are to establish a consensus on (1) the quality criteria which a case history must meet to be considered well substantiated, and (2) which case histories are well substantiated. This brief review summarizes the IASPEI evaluation procedure and the results of the first two rounds of nominations and reviews, and also invites submissions of further precursor candidates for assessment.

2 REQUIREMENTS FOR PRECURSOR CANDIDATES

Researchers nominating a precursor must supply evidence to satisfy as many as possible of IASPEI’s written guidelines for precursor candidates. These guidelines (Wyss 1991) consist of criteria relating to (1) the physical model relating the precursor to the main shock, and the amplitude–distance variation of the anomaly associated with the precursor, including independent evidence for specially sensitive observation sites, (2) the data, such as instrument positions and calibration, associated
environmental conditions, explanations of data gaps, data editing criteria, (3) anomaly definition (so that other data sets can be examined for anomalies), and (4) the rules and reasons for associating a given anomaly with a given earthquake. There is also a requirement to evaluate the probability of the predicted earthquake to occur by chance, and to discuss the frequency of false alarms and failures to predict. The size of precursory anomalies should be compared with the size of any coseismic anomaly, and the relative sizes explained. A complete listing of significant earthquakes near the recording instrument is necessary so that any possible association with other shocks can be assessed.

It follows that detailed nomination papers are required, in which all existing data are shown, all assumptions and sources of error are discussed, the hypothesis is clearly formulated and a plausible physical model is presented to explain the observations. The probability of chance correlation of anomalies with the main shocks should be evaluated, the false-alarm and failure rates estimated as far as possible, and tests of the hypothesis presented. This is the ideal to strive for, and nominations should address as many as possible of these issues in detail.

3 ADMINISTRATION OF THE PROCEDURE

On receipt of nomination papers, the subcommission chairman, with the help of IASPEI members, selects experts in the field of the nomination to review the nomination by mail, which they may do anonymously. A highly qualified panel convened by the chairman then meets, with mail reviews in hand, and discusses the merits and shortcomings of the nomination, and decides whether or not to place it on the List. The panel decision is communicated to the proposer, with the reasons for the decision, and the anonymous reviews. The proposer may then make a reply to the reviewers' and panel's comments. The entire exchange is published: nomination paper, mail reviews, panel opinion and proposer's reply. Proposers have the option to withdraw their nomination at any time. However, the published criticism of a nomination is invariably constructive and thereby advances earthquake prediction research.

4 SUMMARY OF RESULTS

In the first round of nominations, most authors had clearly not realized that the evaluation procedure is more rigorous than journal peer review, and some only supplied a few published papers showing very limited data segments, with no discussion of chance prediction or false alarms. The procedure has to be rigorous, because of the limited opportunity for independent testing of hypotheses, and to justify the pronouncement that they represent the current state of the art. Only 10 per cent of nominations were accepted in the first round; in the second round 14 per cent were accepted, but a mix of detailed and casual nominations persisted.

In the first round, the most common shortcomings cited by the panel were: (1) lack of precise anomaly definition; (2) no statistical evaluation of anomaly significance; (3) lack of detail concerning the experiment; and (4) lack of discussion of other possible sources for claimed anomalies. The second-round evaluations re-emphasized the necessity for examining the probability of chance prediction, as well as requiring a plausible case for the connection between precursor and main shock, and excellent data.

So far, 40 nominations have been evaluated by IASPEI. Out of these, five precursors have been placed on the current Preliminary List of Significant Precursors. Three of these are seismicity patterns, one is based on ground-water chemistry and temperature, and one is a measurement of crustal deformation by ground-water levels. The latter two precursors were each based on single examples, and additional cases of the same precursor will be required before they are firmly accepted as valid. It is not clear that any of these proposed precursors are understood to the point that they can now be used for prediction; they are simply a collection of phenomena which have a better than average chance of becoming useful in earthquake prediction some day.

5 DISCUSSION

It is recognized that evaluation by peer review is flawed in many aspects. For example, it has not been possible to review many publications from some countries with large earthquake-prediction research efforts because they are not in the official languages of the International Union of Geodesy and Geophysics. Inclusion of a precursor on the list is not a guarantee that it can be used for earthquake prediction, while exclusion does not mean that it will never be capable of being used for prediction. Inclusion and exclusion are not 'once and for all'. The cases included have many caveats and there is not a single method on the list which could claim to be universally accepted and by which earthquakes can be predicted reliably. Exclusion only means that in the judgement of several reviewers and panellists the proposed method has not matured enough to be convincing. Nevertheless, IASPEI believes that the List, as well as the published exchanges between authors and reviewers, provides a reasonable evaluation of the state of the art of earthquake prediction research. One of the main purposes in making the list is to stimulate discussion of how earthquake precursors can be best evaluated and earthquake-prediction research improved.

6 CALL FOR SUBMISSIONS

The IASPEI evaluation procedure remains active throughout the IDNDR and additional nominations for earthquake precursor candidates, satisfying as many as possible of the guidelines published in Wyss (1991) and Wyss (1997), are invited to be submitted for assessment to Max Wyss, Chairman of the IASPEI Subcommission on Earthquake Prediction, and coauthor of this paper.

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REFERENCES


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