LIMA DISASTER PREPAREDNESS REPORT

VOLUME XIII-A

SELECTED AVAILABLE DOCUMENTATION:

THE BRADY EARTHQUAKE PREDICTIONS

BOOK A: Reports, Memoranda, Correspondence and Other Communication

Chronological Collection 1977 - 1980

Office of U. S. Foreign Disaster Assistance

Agency for International Development

October 1982

FOREWORD

This is one of four books which together form a compilation of documentation available to the author concerning the earthquake predictions for Peru in 1981 of Dr. Brian T. Brady. The set of four books together comprise Volume XIII of a fifteen volume report concerning disaster preparedness in Lima, Peru. It was researched in Lima by a team of disaster specialists during the period July - November, 1981, for the Agency for International Development's Office of Foreign Disaster Assistance and USAID Mission in Peru. Further research was conducted in the Office of Foreign Disaster Assistance, Washington, D. C., in Fall, 1982.

October 1982

This work was done under Contract #PDC-0018-0-00-2075-00 by Robert Gersony.

The Lima Disaster Preparedness Report has 15 sections:

Volume I	Methodology Employed
Volume II	Port of Callao Infrastructure Security and Emergency Evacuation Needs
Volume III	Electricity
Volume IV	Water and Sewerage
Volume V	Heavy Equipment Rehabilitation and Maintenance
Volume VI	Airport and Aircraft Resources
Volume VII	Education
Volume VIII	Food Supply and Consumption
Volume IX	Low-Income Housing
Volume X	Emergency Medical Care
Volume XI	International Donor Coordination
Volume XII	Critical Abstracts from the Literature: A Field Perspective on Major Earthquakes Peru, 5-31-70 Nicaragua, 12-23-72 Guatemala, 2-4-76
Volume XIII	Selected Available Documentation: The Brady Earthquake Predictions
Volume XIV	Sewerage and Water: Supplementary Information
Volume XV	Summary

COMMONLY USED ABBREVIATIONS

USGS	U. S. Geological Survey [U. S. Department of the Interior]
USBM	U. S. Bureau of Mines [U. S. Department of the Interior]
DOI/OES	U. S. Department of the Interior/ Office of Earthquake Studies
AID	Agency for International Development
OFDA	Office of U. S. Foreign Disaster Assistance [Agency for International Development]
IGP	Instituto Geofísico Peruano
CERESIS	Centro Regional de Sismología para America del Sur

INTRODUCTION/EXECUTIVE SUMMARY

In 1976, Dr. Brian T. Brady, a theoretical physicist with the U. S. Bureau of Mines who specializes in rock mechanics, applied his deterministic model for predicting rock bursts in silver mines to the prediction of earthquakes. According to Dr. Brady, this model can be used to predict the location of an earthquake, its magnitude and period of occurrence. The Brady model provoked considerable consternation and controversy among the scientific community.

Dr. Brady applied his earthquake prediction model to Peru. He predicted that during mid-1981, a series of earthquakes of unprecedented magnitude -- an event with a recurrence level interval of about 800,000 years -- would occur off the Peruvian coast near Lima. Such earthquakes and accompanying Tsunamis would cause catastrophic damage, probably destroying many of the populated areas of the West Coast of South America, including Lima and its population of about five million.

When the first major predicted event did not occur, Dr. Brady re-evaluated his data and, on July 9, 1981, withdrew his prediction.

In addition to the debate it sparked off in the scientific community, the Brady prediction had considerable impact in Peru itself, where it was sensationalized in the press. Some Peruvians attributed a sharp decline in tourism and a decline in real estate values in some areas to the prediction. Others reported that the prediction has motivated businessmen to renew and

increase insurance coverage against such a contingency. Moreover, the prediction undoubtedly stimulated considerable public sector activity in disaster preparedness (although once the prediction was withdrawn much of it abated).

During the period July - November, 1981, when an OFDA team researched this disaster preparedness report in Lima, one could not help but become interested in the prediction, the process of its consideration, and its public impact. It is clear that these will be of interest to public policy managers, scientists, social psychologists, economists, and professional researchers in the future. Already several studies and activities in this connection have been initiated.

In the context of the foregoing events, it appeared prudent to assure that available documentation concerning the prediction not be lost to the professional public, and the OFDA team determined to include such documentation in its final report. Thus, the purpose of this volume of the Lima Disaster Preparedness Report is a simple one: to present, in chronological order, the documentation available from AID's Office of Foreign Disaster Assistance (OFDA) in Washington, D. C., and from the U. S. Embassy and U. S. AID Mission in Peru, the documentation available in its files concerning the Brady prediction. This information is to be shared with the serious public policy managers and professional researchers who will seek to evaluate the management and impact of the prediction in the future.

This volume (No. XIII) of the report consists of four books:

BOOKS A & B — Reports, Memoranda, Correspondence and Other Communication 1977 - 1980 and 1981 - 1982, respectively.

Each document in these two volumes has an individual sequential identification number on its first page. The series runs from No. 001 to No. 158

BOOK C — Press Clippings and Media Reports - 1979 - 1981

The media reports include transcripts of television presentations, where available.

BOOK D — Published and Unpublished Technical Papers

These papers, relatively small in number, are presented in loose chronological order.

Devoting as much time to this task as possible, I have been able to collect and sort all of the materials, but not to provide a more elaborate cataloguing, indexing or more complete set of materials than those available at the sources which are described later. There remai: much which can be done to improve and complete this effort; again, its purpose is simply to insure that in the meantime the documentation available from these sources is not lost.

Mr. Oliver Davidson, OFDA's Project Officer for this activity, assisted in coordination of the collection effort. Dr. Martin D. Howell, OFDA's Director, recognized the need to preserve these documents and graciously welcomed a review of the pertinent OFDA files. Much of the material in this book was gathered by Mr. Alford Cooley, Economics Officer of the U. S. Embassy in Peru. Mr. Cooley acted as official contact point in Peru for matters related to the prediction and played a vital and constructive role related to the prediction.

The majority of materials in this volume were drawn from the working files of Dr. Paul Krumpe, Science Advisor in OFDA. Dr. Krumpe meticulously collected all kinds of documents related to the prediction and played a central role in its consideration as well.

I am interested in receiving any additional documentation concerning

the Brady prediction and will continue to attempt to make such information generally available.

Robert Gersony
October, 1982

Curriculum Vitae

Dr. Brian T. Brady

Brian Thomas Brady

EDUCATION:

B. Sc. Geology, Physics and Mathematics, University of Dayton, Dayton, Ohio ---- 1961

M. Sc. Geophysics, Applied Mechanics, Massachusetts Institute of Technology ------ 1964

Ph. D. Applied Mathematics, Mining Engineering and Metallurgy, Colorado School of Mines ------ 1969

CAREER:

Supervisory Physicist, United States Bureau of Mines, 1967-present

Geophysicist, Cities Service Oil Company, 1964-1966.

RESEARCH EXPERIENCE:

1. Theoretical and experimental studies of rock fracture development in rock.
2. Rock burst studies in the Coeur d'Alene mining district in Idaho.
3. Development of methods to predict and control structural instabilities in engineering structures in rock.
4. Physical processes involved in earthquake development.
5. Implications of earthquakes and plate tectonics to mining problems.
6. Physical mechanisms involved in producing plate motions.

PUBLICATIONS

1) Brady, B. T. On a Solid Friction Attenuation Scheme for Dry Brittle Rock, in "Status of Practical Rock Mechanics", AIME, New York, pp. 361-377, 1968.

2) Brady, B. T. A Statistical Theory of Brittle Fracture for Rock Materials, Part I - Brittle Fracture Under Homogeneous Axisymmetric States of Stress, Int. J. Rock Mech. Min Sci., vol. 6, pp. 21-42, 1969.

3) Brady, B. T. A Statistical Theory of Brittle Fracture for Rock Materials, Part II - Brittle Fracture Under Homogeneous Triaxial States of Stress, Int. J. Rock Mech. Min Sci., vol. 6, pp 285-300, 1969.

4) Brady, B. T. The Nonlinear Mechanical Behavior of Brittle Rock, Part I - Stress-Strain Behavior During Regions I and II, Int. J. Rock Mech. Min Sci., vol. 6, pp. 211-225, 1969.

5) Brady, B. T. The Nonlinear Mechanical Behavior of Brittle Rock, Part II - Stress-Strain Behavior During Regions III and IV, Int. J. Rock Mech. Min Sci., vol. 6, pp.301, 310, 1969.

6) Brady, B. T. and W. Blake. An Elastic Solution of the Laterally Constrained Circular Cylinder Under Uniaxial Loading, Proceedings of the Tenth Rock Mechanics Symposium, AIME, New York, pp. 199-215, 1972.

7) Brady, B. T. The Effect of Confining Pressure on the Elastic Stress

Distribution in a Radially End-Constrained Circular Cylinder, Int. J. Rock Mech. Min Sci., vol. 8, pp. 153-164, 1971.

8) Brady, B. T. Effect of Inserts on the Elastic Behavior of Cylindrical Materials Loaded Between Rough End-Plates, Int. J. Rock Mech. Min Sci., vol. 8, pp. 357-369, 1971.

9) Brady, B. T. An Exact Solution to the Radially End-Constrained Circular Cylinder Under Triaxial Loading, Int. J. Rock Mech. Min Sci., vol. 8, pp. 165-178, 1971.

10) Brady, B. T. Initiation of Failure in a Radially End-Constrained Circular Cylinder of Brittle Rock, Int. J. Rock Mech. Min Sci., vol. 8 pp. 371-387, 1971.

11) Brady, B. T. Effect of the Intermediate Principal Stress on the Fracture of Brittle Rock, Eleventh Symposium on Rock Mechanics, AIME, New York, pp. 267-279, 1971.

12) Brady, B. T. The Effect of Mechanical Anisotropy on the Transmission of Low-Amplitude Stress Waves in Brittle Rock, Int. J. Rock Mech. Min Sci., vol. 6, pp. 439-452, 1969.

13) Brady, B. T. A Mechanical Equation of State for Brittle Rock, Part I - The Pre-Failure Behavior of Brittle Rock, Int. J. Rock Mech. Min Sci., vol. 7, pp. 385-421, 1970.

14) Brady, B. T. A Mechanical Equation of State for Brittle Rock, Part II - The Pre-Failure Initiation Behavior of Brittle Rock, Int. J. Rock Mech. Min Sci., vol. 10, pp. 291-309, 1973.

15) Brady, B. T., W. I. Duvall and F. G. Horino. A Study of the Post-Failure Characteristics of Brittle Rock, Rock Fracture Symposium Proceedings, ISRM, Nancy, France, 1971.

16) Brady, B. T. and W. I. Duvall. Strengthening of Fractured Rock Pillars by the Use of Small Radial Reinforcement Pressures, U. S. BuMines Report of Investigations 7755, 20 pp., 1973.

17) Brady, B. T., W. I. Duvall and F. G. Horino. An Experimental Determination of the True Uniaxial Stress-Strain Behavior of Brittle Rock Rock Mechanics, vol. 5, 1973.

18) Horino, F. G., W. I. Duvall and B. T. Brady. The Use of Rock Bolts or Wire Rope to Increase the Strengths of Fractured Model Pillars, U. S. BuMines, Report of Investigations 7568, 24 pp., 1971.

19) Horino, F. G., B. T. Brady and W. I. Duvall. A Thousand-Ton Capacity Stiff Testing Machine, U. S. BuMines Report of Investigations 7624, 19 pp., 1972.

20) Leonard Obert, B. T. Brady and F. W. Schmechel. The Effect of Normal Stiffness on the Shear Resistence of Rock, Rock Mechanics, vol. 8, pp. 57-72, 1976.

21) B. T. Brady, V. E. Hooker and J. T. T. Agapito. Laboratory and In-Situ Mechanical Behavior Studies of Fractured Oil Shale Pillars, Rock Mechanics, vol. 7, pp 101-120, 1975.

22) Brady, B. T. Seismic Precursors Before Rock Failures in Mines, Nature, vol. 252, No. 5484, pp. 549-552. 1974.

23) Brady, B. T. Theory of Earthquakes I. A Scale Independent Theory of Rock Failure, Pure and Applied Geophysics, vol. 112, pp. 701-725, 1974.

24) Brady, B. T. Theory of Earthquakes II. Inclusion Theory of Crustal Earthquakes, Pure and Applied Geophysics, vol. 113, pp. 149-168, 1975.

25) Brady, B. T. Theory of Earthquakes III. Inclusion Collapse Theory of Deep Earthquakes, Pure and Applied Geophysics, (in press), 1976.

26) Brady, B. T. Comment on "Diffusionless Dilating Model for Earthquake Precursors", Geophysical Research Letters, vol. 2, May, 1975.

27) Brady, B. T. Dynamics of Fault Growth - A Physical Basis for Aftershock Sequences, Pure and Applied Geophysics, vol. 114, pp. 727-739, 1976.

28) Brady, B. T. Effect of Pressure Overloads Within a Subducting Plate on the Density Contrast Between the Plate and Mantle; Some Geophysical Implications, Pure and Applied Geophysics, vol. 114, pp. 469-477, 1976.

29) Brady, B. T. Inclusion Theory of Shallow Earthquakes: General Implications for Earthquake Predictions, Pure and Applied Geophysics, (in press), 1976.

30) Brady, B. T. Tilt Anomalies Prior to Rock Failure: A Laboratory Investigation, United States Bureau of Mines Report of Investigations RI 8101, 9 pp, 1976.

31) Brady, B. T. Tilt and Seismicity Anomalies in Rock Prior to Failure: A Laboratory Investigation, Nature, vol. 260, pp. 108-111, 1976.

32) Brady, B. T. Theory of Earthquakes IV. General Implications for thquake Prediction, Pure and Applied Geophysics, vol. 114, pp. 1- 1082, 1976.

33) Brady, B. T. and F. W. Leighton. Anomalous Seismicity Prior to a Moderate Rock Burst: A Case Study. Int. Jour. Rock Mech. Min. Sci.,vol 14, pp. 127-132, 1976.

34) Brady, B. T. An Investigation of the Scale Invariant Properties of Failure, Int. Jour. Rock Mech. Min. Sci., vol. 14, pp. 121-126, 1976.

35) Brady, B. T., G. A. Rowell, and L. P. Yoder. Physical Precursors of Rock Failure: A Laboratory Investigation, Jour. Geophys. Res., 1979 (in press)

36) Brady, B. T. Thermodynamics of Failure, to be submitted to Jour. Geophys. Res., 1979.

37) Brady, B. T. and W. Spence. The October 3-November 9, 1974, Peru Earthquake Sequence: Seismological Implications and a Prediction Update, (in preparation).

38) Co-authored with R. F. Holub. The Effect of Stress on Radar Emanation from Rock, Jour. Geophys. Res., (in press) 1979.

39) Brady, B. T. Prediction of Failures in Mines - An Overview, U. S. BuMines Report of Investigations 8285, 22 p., 1978.

40) Brady, B. T. The February 9, 1971, San Fernando Earthquake: An Example of the Possibility of Accurate Long-Range Earthquake Prediction, (in preparation).

List Of

Scientists and Public Policy Administrators

Many of Whose Names Appear in the Documentation

The Brady Earthquake Predictions

Dr. Brian Brady
U. S. Department of Interior
Bureau of Mines
Bldg. 20 Denver Federal Center
Denver, Colorado 80225
(303) 234-3765

Dr. Vernon Hooker
U. S. Department of Interior
Bureau of Mines
Bldg. 20 Denver Federal Center
Denver, Colorado 80225
(303) 234-3765

Dr. Robert Marovelli, Director
Mineral Health and Safety Technology
Bureau of Mines
Columbia Plaza
Washington, D. C. 20241
(202) 634-1210

Dr. John Filson
Acting Director
U. S. Geological Survey
Office of Earthquake Studies
Mail Stop 905
Reston, Virginia 22092
(703) 860-6472

Dr. William Spence
U. S. Geological Survey
Office of Earthquake Studies
Branch of Global Seismology
Box 25046, Mail Stop 967
Denver, Colorado 80225
(303) 234-4041

Dr. Theodore Algermissen
U. S. Geological Survey
Denver Federal Center
Box 25046, Stop 966
Denver, Colorado 80225
(303) 234-4014

Mr. John Purnell
ARA/AND (Peru Desk)
Room 5906
Department of State
Washington, D.C. 20520
(202) 632-3360

Mr. William Rhodes
LAC/SA (Peru Desk)
Room 4917
Agency for International Development
Washington, D.C. 20523
(202) 632-2718

Dr. Clarence Allen Chairman, National Earthquake Prediction Council CALTECH Pasadena, CA 91125	(213) 795-8806
Dr. Keiiti Aki Dept. of Geology & Geophysics Massachusetts Institute of Technology Cambridge, MA	(617) 253-6397
Dr. Harold Loomis Joint Tsunami Research Center NOAA/ERL Honolulu, Hawaii	(808) 948-7895
Dr. John Roberts School of Political Science Wellington, New Zealand	
Mr. Edward Coy Acting Assistant Administrator Bureau for Latin America and the Caribbean Agency for International Development Department of State Washington, D.C. 20523	(202) 632-8246
Dr. Charles Culver Deputy Director Center for Building Technology National Bureau of Standards Washington, D.C. 20234	(202) 921-3375
Mr. Alan Van Egmond Assistant Director for Disaster Preparedness,AID Office of U.S. Foreign Disaster Assistance Washington, D.C. 20523	(202) 632-9755
Mr. Paul F. Krumpe Science Advisor AID Office of U.S. Foreign Disaster Assistance Washington, D.C. 20523	(202) 632-1834
Mr. Fred Cole Disaster Preparedness Officer AID Office of U.S. Foreign Disaster Assistance Washington, D.C. 20523	(202)632-9755

Dr. Masakazu Ohtake
National Research Center for Disaster Prevention
Tennodai Sakura-mura
Ibaraki-Ken
Japan

Dr. Lynn R. Sykes
Lamont-Doherty Geological Observatory (914) 423-0201
Columbia University (914) 359-2900
Palisades, N.Y. 10964

Dr. John A. Kelleher
Woodward-Clyde Consultants (201) 471-2000
1425 Broad St.
Clifton, N.J. 07012

Dr. Bryan L. Isacks
Dept. of Geological Sciences (607) 256-2307
Cornell University
Ithaca, NY 14850

Dr. William Hustrulid
Dept. of Mining Engineering
Colorado School of Mines
Golden, CO 80401

Dr. Z. T. Bieniawski
Dept. of Mining Engineering (814) 723-1645
The Pennsylvania State University
University Park, PA 18042

Mr. Ted Haberman
Cooperative Institute for Environmental (303) 492-5121
Sciences
Boulder, CO 80302

Dr. Charles B. Archambeau
Cooperative Institute for Environmental (303) 492-7943
Sciences
Boulder, CO 80302

Dr. Donald Anderson
Department of Geophysics (213) 795-6811
California Institute of Technology
Pasadena, CA

Dr. Leon Napoff
Department of Geophysics (213) 825-3123
University of California
Los Angeles, CA

Dr. Lou Walter Crustal Dynamics Program NASA Goddard Space Flight Program Greenbelt, MD 20771	(301) 344-9016
Dr. Hiroo Kanamori Prof. Geophysics Seismological Lab/CALTECH Pasadena, CA	(213) 795-6811, Ext. 2914
Dr. Karen C. McNally Program Scientist CALTECH Pasadena, CA	(213) 795-6811
Dr. Leroy Anstead Defense Mapping Agency Washington, D.C.	(202) 254-4501 254-4465
Dr. John Bossler National Ocean Survey Coast & Geodetic Survey Rockville, MD 20852	(301) 443-8710
Dr. E. V. Leyendecker National Bureau of Standards Bldg. 226, Room B-168 Washington, D.C. 20234	(301) 921-3471
Dr. Louis Pakiser 2710 S. Sandy Ridge Road Perry Pines, CO 80135	(303) 688-3022 234-2625
Dr. L. D. Kulm Dept. of Oceanography Oregon State University Corvallis, OR	(503) 425-2296
Dr. William R. McCann Lamont Doherty Geological Observatory Palisades, NY	(914) 359-2900
Dr. Jerry Eaton Office of Earthquake Study U.S. Geological Survey Menlo Park, CA 94025	(415) 856-2575
Dr. Charles Theil Office of Disaster Mitigation Research Federal Emergency Mgmt. Agency Washington, D.C.	(202) 653-7860

Dr. Fred Krimgold Problem Focused Research Program National Science Foundation 18th and G St. Washington, D.C.	(202) 357-7710
Dr. Tom Aldrich Carnegie Institution Dept. Terrestrial Magnetism 5241 Broad Branch Rd., N.W. Washington, D.C. 20015	(202) 966-0863
Dr. John Tomblin United Nations Disaster Relief Office Geneva, Switzerland	
Dr. Brian Isacks Department of Geophysics Kimball Hall Cornell University Ithaca, NY 14853	(607) 256-2307
Mr. William Jones Planning, Analysis, Evaluation Division Federal Emergency Mgmt. Agency Washington, D.C.	(202) 653-7776
Mr. Alex Bacho Division of Mine Safety U.S. Bureau of Mines Washington, D.C.	(202) 634-1245
Dr. M. Finarelli Office of Science & Technology Policy Room 481, New Executive Office Bldg. Washington, D.C. 20500	(202) 395-5636
Dr. Gordon Vaeth NOAA/NESS Room 3301, Suitland Complex Suitland, MD	(301) 763-5166
Mr. Chi-Shing Wang U.S. Bureau of Mines Washington, D.C.	(202) 634-1231
Mr. Ted Kobayashi Bureau of Environmental & Scientific Affairs Department of State Washington, D.C. 20523	(202) 632-1113

Reports, Memoranda, Correspondence
and Other Communication

1977

January 11, 1977

Dr. Enrique Silgado
Asesor
Centro Regional de Sismologia
para America del Sur
Av. Arenales 431 Of. 702
Apartado 3747
Lima, Peru

Dear Dr. Silgado:

Thank you for your letter of 20 December, 1976. I have analysed the 'precursory' seismicity data you generously provided in your letter. I find that your data, for reasons I discuss below, support my earlier hypothesis that the primary inclusion zone (PIZ) which produced the 3 October, 1974, event may have formed within a five-month interval (28 May, 1971 → 3 October, 1971) off the coast of central Peru during 1971.

In my paper "Theory of Earthquakes, Part IV - General Implications for Earthquake Prediction", I was aware that the seismic data taken prior to the 3 October, 1974, mainshock consisted only of teleseismically recorded events. In particular, I was concerned that there appeared to be 'little' seismic activity (recorded teleseismically) within the region that became the aftershock zone of the 3 October, 1974 event. Your data have eliminated some of these earlier concerns.

In the inclusion theory of earthquake mechanics, a region which will contain the aftershock zone (≡ focal region of the PIZ) of an earthquake must approach a condition where the local least principal stress (σ_3, in part IV) attains a state of low compression or tension. In particular, the zone where the PIZ will form must represent a zone where the actual least principal stress has a higher magnitude of tension than its immediate surroundings. In the accompanying figure 1, I am illustrating

qualitatively this precondition. The local tensile stress, σ_3, in figu 1, is assumed for the sake of argument to exist over a region comparabl... size to the focal region of what will become the PIZ of a forthcoming event. I discussed at some length in part IV that the seismic events that occur within the eventual aftershock zone tend to 'soften' this zone; that is, these events serve to decrease the magnitude of the local least principal stress. The region where the PIZ will form will exhibit 'aseismic' behavior, at least in comparison to its surroundings. Thus, as the surroundings soften, the magnitude of the tensile stress within the 'relatively harder' region where the PIZ will form must increase. Consequently, the boundaries of the PIZ will be constrained to lie within this 'relatively harder' region. Geometrically, it will appear that the PIZ will be bracketed in by the earlier seismic events that had been occurring within the region that will become the aftershock zone of a forthcoming event.

I showed in part IV that the seismic events that occur within an evolving PIZ will be characterized by anomalously long rupture lengths--anomalously long because energy that would normally be dissipated by frictional sliding is now available (due to existing tensile stress) to power their growth. These events will, therefore, radiate more long-period energy (than their non-PIZ counterparts) and consequently, should stand a better chance of being detected at large distances from their source. I also emphasized in part IV that it is the zone where the PIZ forms that will be characterized by the dramatic increase in seismicity. This (seismicity) increase may or may not be observable by an obvious change in the regional seismicity pattern. As I discussed in part IV, it appeared that the teleseismically recorded events showed an "apparent" increase in the regional seismicity pattern during 1971. This condition led me to suspect that the PIZ of the 3 October, 1974, event may have formed during 1971.

I have plotted the data you sent (along with all teleseismically recorded events over the interval 1965 - 1974) in the accompanying figures 2 and 3. I have also shown the revised dimensions of the 3 October, 1974, aftershock zone (see Langer et al., 1977). The hypothesized location of the PIZ for this event is included in these figures. I have drawn four observations from this data set that may be of interest to you.

Letter to: Dr. Enrique Stigado, Lima, Peru

1) Your data base clearly shows that the region that was to form the aftershock zone of the 3 October mainshock was active during the period 1965 - 1968. The teleseismically recorded events, while showing some activity in this region, are obviously nowhere as complete. It is interesting that many of the events shown in these figures tend to delineate or conform (e.g., lie within) with the geometry of the aftershock zone.

2) The zone I suspect was the PIZ appears to be bracketed in by the seismicity (see figure 3, 'red' dashed line). The region (PIZ) exhibits 'aseismic' behavior over the time period your data set covers. This behavior is in good agreement with what would be predicted on the basis of the inclusion theory.

3) The events (28 May, 1971 - 3 October, 1971, 6 (six) in total) that I suspect have formed the PIZ lie within the dashed region outlined in figure 3 and appeared to have been of sufficient intensity to be recorded teleseismically. Their m_b values are quite comparable with those events that bracket in this zone. This result is also consistent within the framework of the inclusion theory.

4) If we can assume the depth determinations listed for the 28 May, 1971, - 3 October, 1971, sequence are accurate with respect to one another, then these data show that the depth of the seismic events in the PIZ increases in an easterly direction with a dip angle of approximately 15°. This behavior is essential in my hypothesis that this region formed the PIZ of the 3 October, 1974, mainshock. It is interesting that this calculated slope compares favorably with the dip angle (~20°) Spence et al (1977) calculated for the fault plane of the mainshock.

I am enclosing a copy of a recent manuscript (also to be published in PURE AND APPLIED GEOPHYSICS) which is concerned with seismicity observed prior to rock bursts in a deep silver mine. <u>These bursts were predicted prior to their occurrence</u>. You will see that the seismicity behavior exhibits a number of characteristics common to the seismicity behavior observed prior to some earthquakes (San Fernando, etc.) including, I believe, the 3 October, 1974, earthquake.

Letter to: Dr. Enrique Silgado, Lima, Peru

It is somewhat unfortunate that our data base is not more detailed and complete. However, I believe that there are sufficient data at hand suggesting that my conjectures may have some physical basis. Lastly, it is interesting that all teleseismically reported events (since November 14, 1976) lie outside the aftershock zone. Does your local net show this effect? I have discussed the possible importance of this in part IV. I do hope my notes are of value to you. If you should have any further questions, please feel free to contact me.

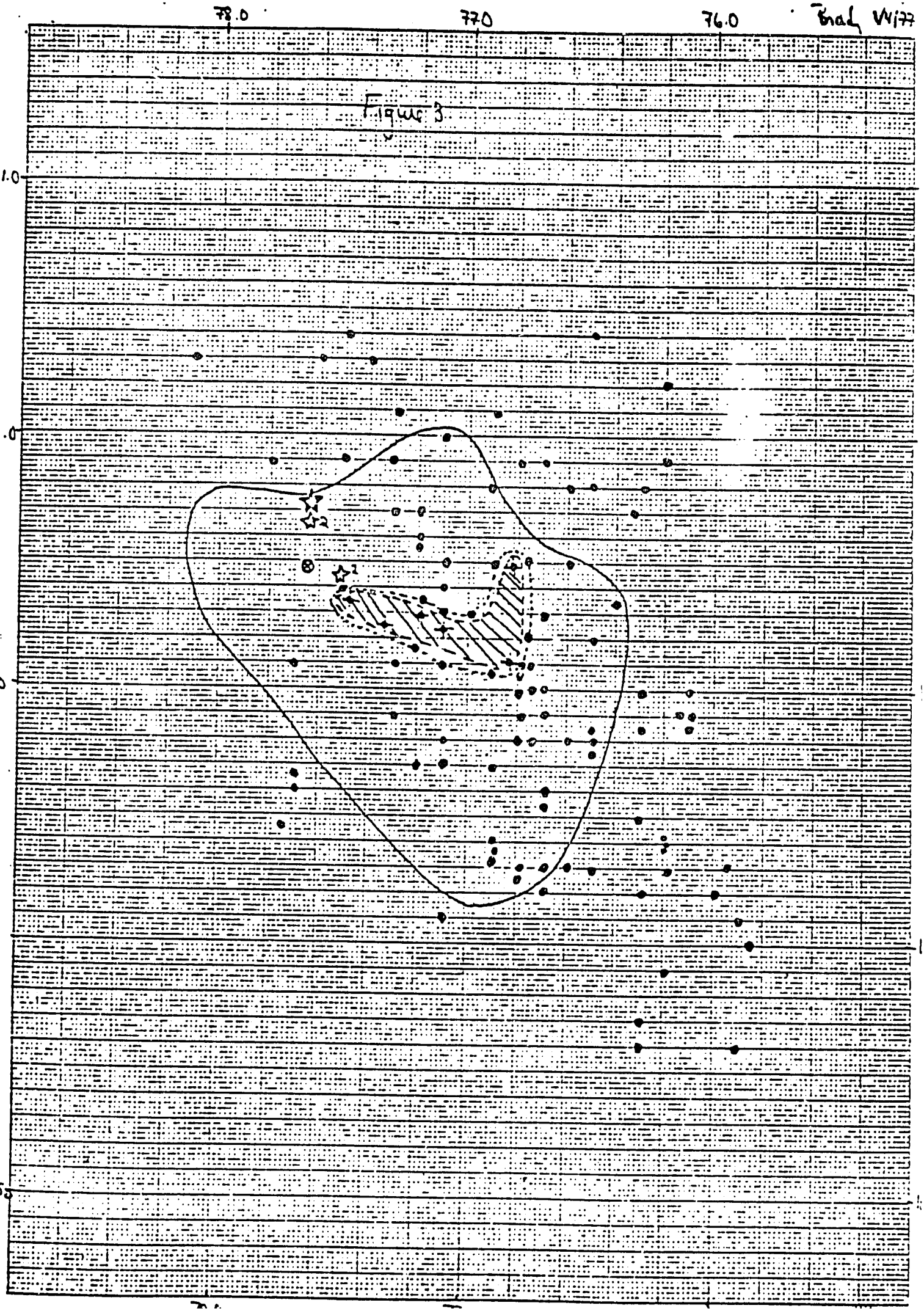
Yours sincerely,

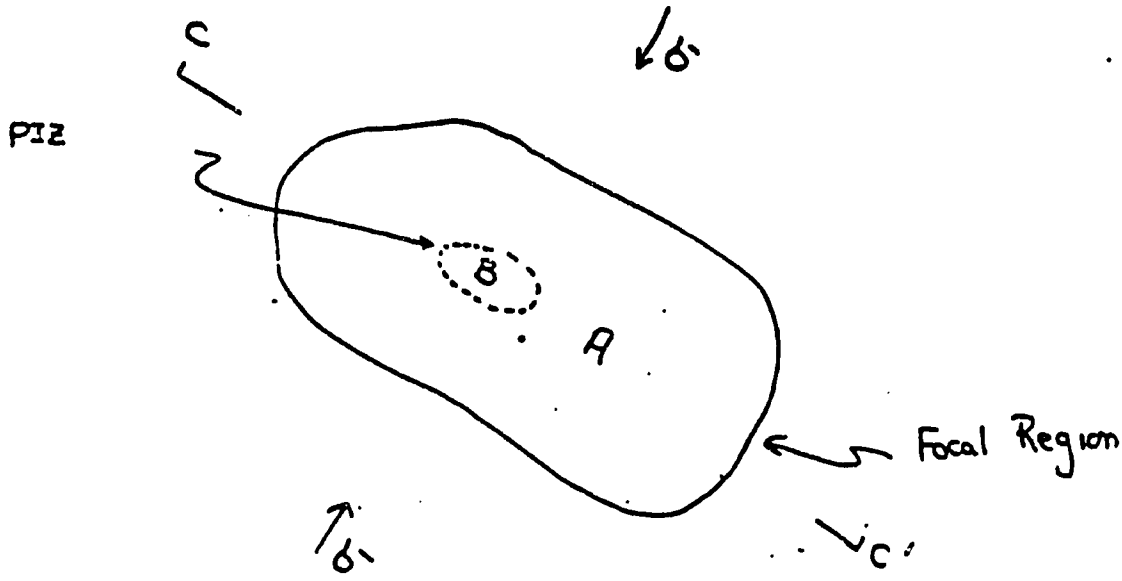
Brian T. Brady
Physicist
Mine Structure Design
Denver Mining Research Center

Enclosures

cc: Special Assistant, International Activities

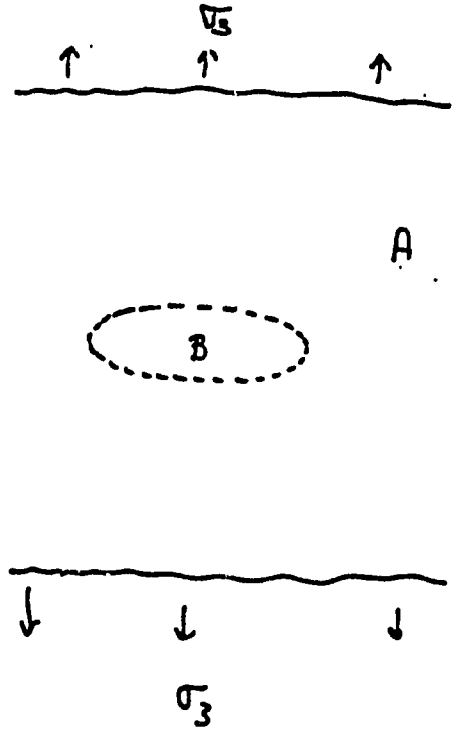
[redacted]
Chron
Res Dir
BTBrady/svw


78.0
77.0
76.0
Thal W/77
Figure 3
11.0
12.0
13.0
1.0
1.5
☆2
☆1



Plan View

Region A is "elastically" soft than region B due to concentration of seismic events within A. This softening results in a concentration tensile stress within B, i.e. is, the local tensile stress within B, say $\sigma_t^{(B)}$, is larger than the tensile stress w A. Note that the cracks (e.g., seismic events within B) will be confined to t region delineated by B

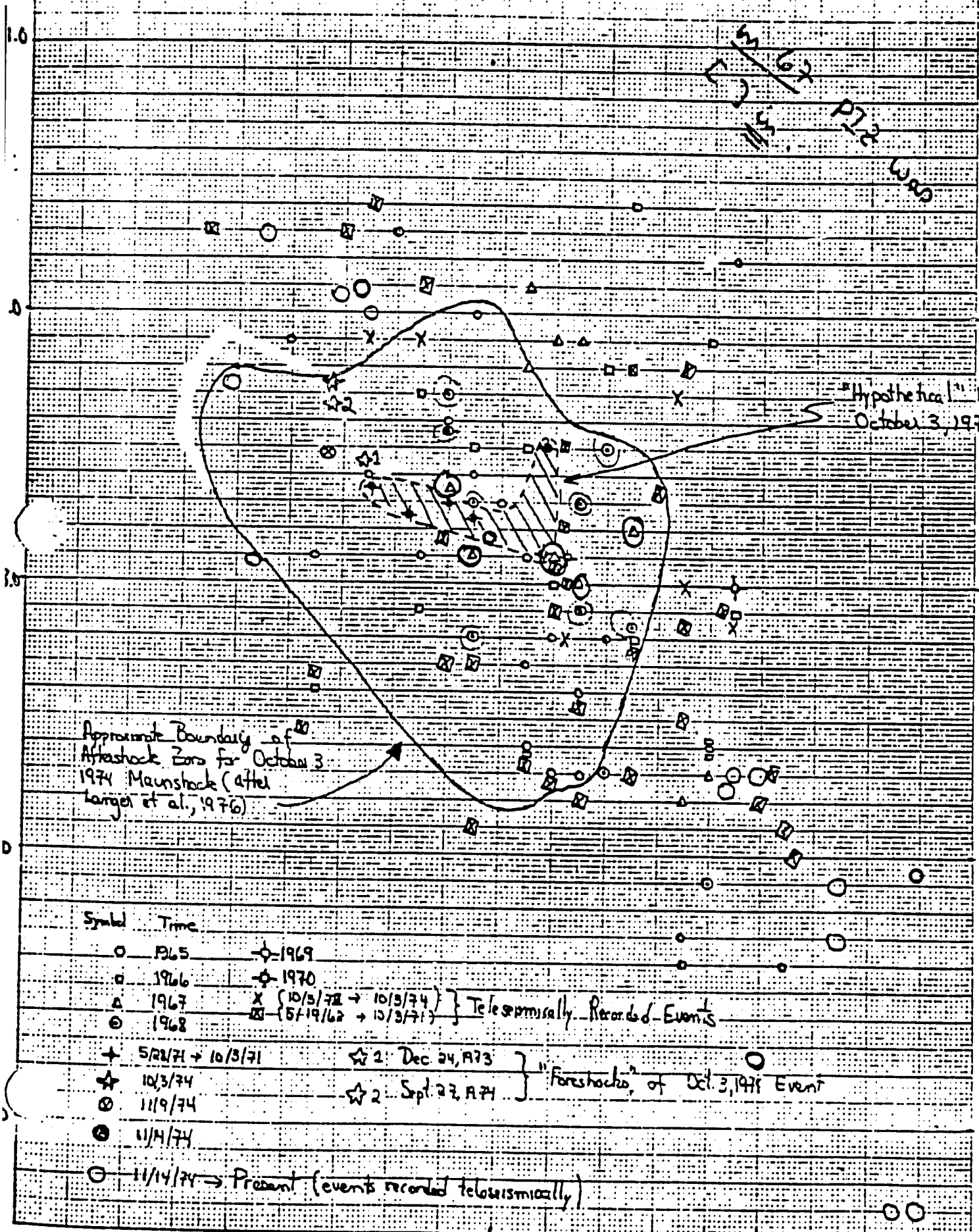


Cross-Section

Figure 1

78.0 77.0 76.0

Figure 2



August 25. 1977

Mr. L. C. Pakiser
Acting Chief
Branch of Seismicity and Earth Structure
United States Geological Survey
Golden, Colorado 80401

Dear Lou:

I am enclosing a summary of my recent studies of the Peru seismicity as you requested. A major portion of this summary has been taken from my Theory of Earthquakes, IV. However, new results such as seismicity since November 14, 1974, and, in particular, aftershock data from the October 3, 1974, mainshock (M_L 7.8) obtained from Bill Spence and Charlie Langer are included and discussed briefly in the summary. Bill and Charlie are preparing a detailed report of the aftershocks and their relationship to the prediction. I am also including in this summary a program to detect short-term precursors of the hypothesized impending event.

Briefly, I believe a serious situation developed near Lima, Peru on November 9, 1974. This situation is that the preparation phase for a great earthquake has begun. Supportive data, including recent theoretical studies by myself, suggest that the magnitude of this event will be approximately $M_s = 8.4 (\pm 0.2)$ and that the minimum time to the event, measured from November 14, 1974, is approximately 5.9 years. This time presumes certain assumptions discussed in the summary are valid for this region. The magnitude estimate arises from observational data. These data indicate the absence of seismicity from November 14, 1974, within a zone whose areal extent is approximately 32,000 k^2m.

I am of the opinion that this prediction has a sound scientific basis and firmly believe that much further study (a portion of which is discussed in the summary) is necessary. The data set at hand clearly indicate that a serious effort to study this region is warranted.

I hope this summary will be of value to you. Please feel free to contact me if I can be of further assistance to you.

REFER TO	INITIAL
HOOKER	
RUSSELL	

Best regards,

Enclosure

Brian T. Brady
Physicist
Mine Structure Design
Denver Mining Research Center

BTBrady/lew
Chron/Subj./Res. Dir.

Ed. Note: For enclosure, see Technical Papers volume, "The 3 October and 9 November 1974 Peru Earthquakes: Seismological Implications" by B. T. Brady

Reports, Memoranda, Correspondence
and Other Communication

1978

VOL. 49 NO. 1 EARTHQUAKE NOTES JANUARY-MARCH 1978

ABSTRACTS OF PAPERS, 73RD ANNUAL MEETING
SEISMOLOGICAL SOCIETY OF AMERICA
APRIL 6-8, 1978 SPARKS, NEVADA

A STUDY OF AFTERSHOCKS OF THE OCTOBER 3, 1974, PERU EARTHQUAKE

LANGER, Charley J. and SPENCE, William, Office of Earthquake Studies, U.S. Geological Survey, Denver, Colorado 80225

Nearly all aftershock hypocenters, determined from regional network data, lie southward of the main shock (M_S = 7.8) and define a 'T'-shaped zone of activity. The two segments of this zone mimic the location and shape of the main shock's inferred inclusion zone (Brady, 1976). The primary, northwest-trending segment includes the main shock, is 80-100 km offshore, and extends subparallel to the coast for a length of about 220 km. The northeast-trending segment is perpendicular to the first at its approximate midpoint, and extends for about 150 km to beneath the coastal town of Chilca. Most hypocenters are confined to a 25-km-thick zone that dips about 20° NE; maximum aftershock depths of approximately 65 km are observed beneath the Chilca region. A composite focal mechanism solution for the aftershocks in the northeast-trending segment is well-constrained and suggests underthrust motion, very similar to that inferred for the main shock. Both segments of the aftershock zone have a 'b'-value of about 0.65; the total data set is thought to be complete above magnitude 3.6. The measured aftershock area is about 10,000 km^2 ($10^{10} cm^2$), implying an equivalent mainshock magnitude of M_S = 7.7 (Utsu relationship: $\log_{10} A = M_S + 6.3$).

A NOTABLE SPACE-TIME DISTRIBUTION FOR THE 1974 PERU AFTERSHOCKS

SPENCE, WILLIAM AND LANGER, CHARLEY J., U.S. Geological Survey, Office of Earthquake Studies, Denver, Colorado 80225

Space-time seismicity studies of the teleseismically- and regionally-located aftershocks of the M_s = 7.8, Oct. 3, 1974, Peru earthquake indicate six distinctive groupings of epicenters. The entire aftershock sequence occurred to the south of the main shock. The first grouping of aftershocks consisted of four teleseismically-located aftershocks that occurred near the extremities of the subsequently developed aftershock zone. The next four groupings show earthquakes to alternate, almost exclusively, between a parallel-to-coast trend of aftershocks and a second trend perpendicular to the first, each grouping lasting 2-3 days. Groupings 3-5 include regionally-located aftershocks, down to the magnitude 3.6 level, and confirm both the gross space-time characteristics and the internal sequencing of earthquakes indicated by teleseismically-located events. In particular the two groups occurring in the offshore limb show a geometrically-regular oscillation of activity between its northern and southern ends, skipping the mid-portion of this zone. The sixth grouping lasted about 3 weeks and showed a more random space-time distribution of epicenters.

United States Department of the Interior

BUREAU OF MINES

BUILDING 20, DENVER FEDERAL CENTER
DENVER, COLORADO 80225

June 5, 1978

Memorandum

To: Robert L. Marovelli, Actg. Assistant Director—Mining, Washington, D.C.

Through: Verne E. Hooker, Research Supervisor, Mine Structure Design
Denver Mining Research Center

Paul L. Russell, Research Director, Denver Mining Research Center

Douglas Bolstad, Staff Engineer, Ground Control, Washington, D.C.

From: Brian T. Brady, Physicist, Mine Structure Design, Denver Mining Research Center

Subject: Background and Summary of Pertinent Data Relating to the Predicted Central Peru Earthquake

BACKGROUND

Over the past several years, I have been developing a theory of failure that appears to have a number of practical applications. Several of these applications include the prediction and, under certain conditions, the control of mine related failures such as rock bursts, coal bumps, coal mine roof falls, gas outbursts, waste dam disposal instabilities, and slope failure in surface mines. In connection with my ongoing Bureau project "Prediction and Control of Failures in Mines," I have found that when certain critical data are available and detected, such as anomalous seismicity patterns, prior to the occurrence of the failure (mainshock), realistic estimates of the magnitude (a measure of the energy released at failure) and the occurrence time of the impending mainshock are possible. The anomalous seismicity pattern refers to an increase of low magnitude seismicity in the immediate vicinity of where the mainshock nucleates. This increase is then followed by a period of 'quiet' (no seismicity) within a region surrounding the eventual location of the mainshock.

My studies have suggested that rock failures are characterized by preparation (precursor) times which are a function of the size of the impending mainshock. The existence of this preparation time is what allows a prediction of failure occurrence to be made. Similarly, the area over which the anomaly

(say the quiescent region) persists allows an estimate to be made of the mainshock magnitude. For example, our studies indicated that laboratory sized failures (failure of hand sized rock specimens) would require preparation times on the order of several hundred microseconds ($\sim 10^{-4}$ seconds); typical mine failures, minutes to hours; and earthquakes, several months to years. I have successfully applied these criteria to several rock bursts that occurred in northern Idaho and to earthquakes. (My reason for using earthquakes is the existence of a large data base not currently available for mine-related failures with which to test the model and our observations in northern Idaho that mining can under certain conditions induce slippage along old fault zones, that is, mining induced earthquakes). These results have been published (for example, "Anomalous Seismicity Prior to Rock Bursts: Implications for Earthquake Prediction," by B. T. Brady, PURE AND APPLIED GEOPHYSICS, v. 115, 1977; "Theory of Earthquakes IV. General Implications for Earthquake Prediction, by B. T. Brady, PURE AND APPLIED GEOPHYSICS, v. 114, 1976; "Prediction of Failures in Mines — An Overview," by B. T. Brady, U.S. BuMines RI 8285, 1978). On the basis of a prediction that anomalous behavior will occur several hundred microseconds prior to failure of laboratory sized rock samples, the Bureau of Mines initiated an experimental laboratory program. This test program was successful, substantiated the prediction, and several papers have been published (for example, "Laboratory Investigation of Tilt and Seismicity Anomalies in Rock Before Failure," by B. T. Brady, NATURE, v. 260, 1976). Additional laboratory results will be published by the JOURNAL OF GEOPHYSICAL RESEARCH.

In these early studies, I stated that the existence of a seismic anomaly (seismicity increase followed by a decrease) provided only necessary conditions for an impending failure. Accurate long-term prediction of impending failure was not possible because of this limitation. The theory has recently been developed to a level which, I believe, will enable accurate long-term prediction of impending failures providing certain data on the characteristics of the seismicity are available. Very briefly, I have found that there is important structure (origin time and magnitude) to the seismicity increase which occurs prior to a mainshock. Recognition of this structure leads to necessary and sufficient conditions for the occurrence of failure. These conditions are that there will be two (short) periods of seismic activity during the preparation time near the hypocenter of the mainshock. The area that will become the aftershock region will have no seismic activity during the preparation time. To test this seismicity hypothesis I have reanalyzed the seismicity data prior to the rock bursts reported earlier by the Bureau and have found that these bursts, including their rupture characteristics, could have been accurately predicted to within one minute of their occurrence. I have also applied these same criteria to several earthquakes, including the last major earthquake (the 9 February, 1971 San Fernando, $M_L = 6.6$) to have occurred in the United States, and

have had similar success. For example, the San Fernando earthquake, using seismicity characteristics (magnitude and occurrence time) could have been predicted on March 21, 1969, to within 1.5 days of its actual occurrence and that its probable magnitude would have been $M_L = 6.5$. In addition, characteristics of this earthquake, such as the direction of greatest energy release and the mechanisms of the dominant aftershocks could have been foreseen nearly 8 years prior to its occurrence. The near failure of the van Norman dam, located near the mainshock epicenter could have been predicted. I presented these results to a seminar of earthquake experts at the U.S. Geological Survey center in Golden, Colorado, on 12 May, 1978. It was generally agreed that the data and analysis are compelling in this case. In addition, an outgrowth of this work is that the so-called Palmdale uplift in southern California, currently the subject of much study by the U.S.G.S., is not the forerunner of a major earthquake, but simply the result of processes that led to the San Fernando earthquake. I also presented this result at a symposium on Global Earthquake Prediction held in Denver, Colo., and sponsored by the U.S.G.S. in late September, 1976.

I am preparing a detailed summary of the rock bursts and San Fernando seismicity data. These data will be included in an article on the energetics of the fracture process in rock. At this time, I am reasonably convinced that the failure theory developed by the Bureau offers promise for accurate, long-term failure prediction. The Bureau's record on this subject supports this statement.

CENTRAL PERU SEISMICITY

I became involved with Peruvian seismicity from an analysis of the seismicity patterns prior to an earthquake sequence that occurred off the coast of central Peru (near Lima) during 3 October – 9 November, 1974. This earthquake sequence began with a magnitude $M_S = 7.8$ event on 3 October and was terminated in a most unusual manner by a $M_S = 7.1$ event on 9 November, 1974.[1]

Dr. William Spence of the U.S.G.S. (Branch of Seismicity and Earth Structure, Golden, Colorado) was instrumental in bringing to my attention several anomalous characteristics of this earthquake sequence. During October 1974, Dr. Spence was in central Peru as a representative of the U.S.G.S. to record and analyze the damage and aftershocks from the 3 October event. As a result of my discussions with Dr. Spence, I noted four observations which suggested that the preparation phase for a much larger earthquake may have begun on 9 November, 1974. First, the spatial and temporal characteristics

---

[1] Magnitude M_S refers to the surface wave magnitude and is measured from the horizontal component displacement of the Rayleigh wave near 20 seconds period. M_S can be viewed as roughly equal to the Richter magnitude (M_L).

of the aftershock sequence and its termination on 9 November, less than 37 days after the mainshock were unusual. Second, no seismic activity has occurred within this region since that time (now approximately 5.5 years). Third, this region was recognized as early as 1970 by most seismologists as being a pronounced seismic gap and capable of sustaining great earthquakes ($M_s > 8.0$). Fourth, the region had not sustained a great earthquake since 28 October 1746.[2] These observations were outlined in the article, "Theory of Earthquakes IV. General Implications for Earthquake Prediction", published in 1976. I suggested in part IV that a potentially great earthquake was in the preparation stage off the coast of central Peru. No precise time or magnitude (except that $M_s > 8$) was made in this article, as I had not developed the necessary and sufficient conditions for seismicity precursors. The prediction was also 'buried' in part IV, so as not to cause alarm and subsequent widespread publication by the press.

The Peruvian government was discretely made aware of this prediction through the offices of Dr. Leonidas Ocoloa, Chief Scientist, Education Sector, Ceresis, (Centro Regional de Sismologia para America del Sur), during his visit to the U.S.G.S. offices in Golden during December 1976. Dr. Spence and I discussed the physical basis for prediction with Dr. Ocola during the latter portions of his visit. Dr. Spence also sent a copy of part IV to Dr. Alberto Giesecke, Director, Ceresis, and Chief, Geophysical Institute of Peru. We have dealt with responsible officials of the Peruvian government at all times during the course of this study.

Mr. L. C. Pakiser, then Acting Chief, Branch of Seismicity and Earth Structure, U.S.G.S., Golden, Colorado, was made aware by Dr. Spence of the prediction, and in particular, of his recent detailed analysis of the physical spacial, and temporal character of the aftershock sequence following the 3 October 1974 event. Mr. Pakiser was impressed with these data and its relationship to the prediction. He requested that I prepare an up-to-date summary of the prediction status. I prepared a detailed memorandum for Mr. Pakiser 25 August 1977, in which I indicated that Dr. Spence's analysis of the temporal character of the aftershocks suggested that the region was in an unusually unstable state. The geometrical characteristics of the aftershock series strongly supported the hypothesis advanced in part IV that the seismicity patterns which developed in early 1970 - late 1971 were precursors of the 3 October 1974 mainshock. Mr. Pakiser forwarded this

---

[2] It is believed that the magnitude of the 1746 event was in the high 8 category. The city of Lima and its environs suffered great damage and loss of life from the mainshock and the subsequent tsunami (e.g. 200 survivors out of 4,000 in the port city of Callao).

Memorandum to: Robert L. Marovelli, Washington, D.C.

memorandum to the Earthquake Prediction Panel of the U.S.G.S. for their evaluation. The panel was also informed by Mr. Pakiser that Dr. Spence and I had new results (not presented in the memorandum) supporting the prediction that the region had entered the preparation phase on 9 November 1974. The panel has not yet responded to Mr. Pakiser's initiative, possibly because the prediction is in a foreign country.

During late 1977, I had developed the theory to the level discussed in the background of this memorandum. I applied the seismicity precursor criteria to Peru and found the precursory seismicity which occurred in late 1970 and 1971 could have been used to accurately predict (early September 1974) the 3 October 1974 event and that its magnitude would be $M_s = 7.8$. In addition, these data could also have been used to predict that the 3 October 1974 mainshock would be preceded by a secondary foreshock series which would commence in mid-September 1973. The foreshock series began on 6 September 1973.

I now believe the techniques developed for rock bursts and other earthquakes, such as the San Fernando earthquake, apply to Peruvian seismicity. If we had access to these seismicity data and the interpretative power we now possess in late 1971, the 3 October 1974 earthquake could have been predicted well in advance of its occurrence. I have also applied these criteria to the predicted impending event in Peru. I believe the occurrence time of the forthcoming event will be in late October to November 1981 and that the magnitude of the mainshock will be in the range 9.2 ± 0.2. This magnitude represents a measure of the total energy that will be radiated over <u>all</u> frequencies. This earthquake will be comparable to the 22 May 1960 Chile earthquake. The Chile event is the largest earthquake to have occurred since the beginning of instrumental seismology (ca. 1900).

Mr. Pakiser called a meeting on 18 November 1977, at the U.S.G.S. center in Golden to discuss the prediction. Dr. Giesecke was present at this meeting. The concensus of the meeting was that while the prediction had scientific merit, the seismicity used in making the prediction should be relocated using 'modern, up-to-date' techniques. Accordingly, Dr. Spence and several other colleagues in Golden were assigned to this task. This phase of the study is nearing completion. According to Dr. Spence, the pre-3 October 1974 seismicity patterns and the teleseismically reported aftershocks of the 3 October 1974 event show little change from the old located values. Both Dr. Spence and I have examined the relocated pre-seismicity patterns and agree that the new data strengthen the hypothesis that the seismicity discussed in part IV was precursory to the mainshock. The aftershocks recorded only at the local U.S.G.S. network deployed in Peru in October-November 1974 have not been relocated at this time. However, we doubt that any significant changes will occur, as the subset of aftershocks relocated using both regional and teleseismic data have shown only very small location changes.

Memorandum to: Robert L. Marovelli, Washington, D.C.

I am fully aware of the implications of this prediction. The available data indicate this prediction does have a sound scientific basis. The predicted magnitude of this event (9.2 ± 0.2) and the location and size of the primary inclusion zone (PIZ) of this event [∿ 75 km off the coast, 50 km (width) by 190 km (length parallel to the coast)] have not been discussed with Dr. Giesecke at this time. This potential earthquake may have severe tsunamigenic implications for islands of the western Pacific (Hawaiian Islands, Japan, etc.).[3]

Dr. Spence and I plan to write up a detailed summary of these new data and a prediction update in the near future. If possible, we would like to publish these results in the American journal SCIENCE. However, as agreed with Dr. Giesecke at the 18 November, 1977 meeting, publication of these new results in SCIENCE or any other suitable journal will be done only in agreement and close cooperation with the Peruvian government. At some stage in this study, the results should be made public. I am confident the Peruvian government will make the prediction public prior to publication of these new results.

If you require further documentation of this prediction, I will gladly comply.

Brian T. Brady

[3] See note.

Memorandum to: Robert L. Marovelli, Washington, D.C.

[3] Note. The potentially severe tsunamigenic character of this earthquake arises from the predicted large dimensions of the PIZ. The PIZ is a region of low density crustal material and must be associated with uplift (~ several meters) of the ocean bottom in its immediate vicinity. The dimensions of the PIZ and the associated crustal uplift are large enough to have possibly produced a change in ocean currents in its immediate vicinity. Commensurate in time with this predicted uplift, it is well known that the anchovy population along the Peruvian coast has severely diminished. The time frame that this change (in ocean currents?) began is remarkably coincident with the physical processes which I believe began in late 1967 and which produced the 1974 [and possibly the 1981 (?)] event. The decrease in anchovy population appears to have resulted from the combined effects of over-fishing and, interestingly, a change in the movement of ocean currents. The unusually favorable conditions that enable Peruvian anchovies to multiply in vast numbers have been intensively studied. In normal years the cold waters of the Humboldt Current run north from the Antarctic along the Peruvian coast. Trade winds from the southeast drive the current offshore, thereby causing the current to be replaced by upwelling water containing rich nutrients from the depths. These trade winds periodically weaken off the coast and warm currents from the north penetrate south of the Equator, causing the anchovy population to drastically decrease. This decrease is in response to the lack of fertile upwelling and the warm water interferes with the anchovy reproductive cycle. The warm water current is known as El Niño, usually occurs at (approximately) 5-year intervals and lasts for 6 months, after which current patterns return to normal and the anchovy population recovers to its normal strength. The anchovy population rose rapidly during the 1950's and early-to-mid 1960's. However, a pronounced decrease occurred in 1969 and has continued to this day. The anchovy decrease has caused widespread economic problems for both the Peruvians and western nations using fish meal as a food supplement for livestock. Incidentally, I am not implying that the anchovy decrease is a precursor of the 1981 (or 1974) event. However, it is curious that these two phenomena coincide. A possible causal connection should be investigated in more detail.

Reports, Memoranda, Correspondence
and Other Communication

1979

OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

DOCUMENT NO. 005

Memorandum

TO : Rob Wesson

DATE: January 30, 1979

FROM : Ted Algermissen, Jim Jordan, Lou Pakiser, and Bill Spence

SUBJECT: January 19, 1979 letter of Ing. Alberto Giesecke to H. Wm. Menard

Several days ago we became aware of Ing. Alberto Giesecke's letter to the Director requesting assistance in evaluating the prediction of a large earthquake to occur in the next 2-3 years off the coast of Peru near Lima. Since we have been cooperating with Ing. Giesecke and his coworkers in geophysics in Peru for a number of years, we thought that it might be useful to provide some background information about the prediction mentioned in Giesecke's letter and related matters in Peru.

In Peru, the main effort in earthquake seismology is in the Instituto Geofisico del Peru (IGP). Giesecke is Director General of IGP, Director of the Centro Regional de Sismologia para America del Sur (CERESIS) and currently the Chairman of the Geophysics Commission of the Pan-American Institute of Geography and History (PAIGH), a specialized agency of the Organization of American States. CERESIS is a regional seismological center for South America that is supported by Peru, Uruguay, Argentina, Bolivia, Ecuador, Colombia, Venezuela, and Trinidad. It was originally created and funded during its initial years by UNESCO.

The earthquake prediction discussed in Giesecke's letter to Menard was published by Dr. Brian Brady of the Bureau of Mines in Denver in 1976 (Pure and App. Geophys., 114, 1031-1082).

The current elements of Brady's prediction are: 1. Foreshock series beginning in mid-September 1980; 2. Mainshock M_o=5.3x10^{30} dyne-cm (M_w ~ 9.5), on or about July 30, 1981, rupture beginning near 12.3°S x 77.6°W and propagating to include the coastal region from 7.5°-8°S to 15.0°-15.5°S; 3. Normal aftershock series but including a M_w ~ 8.8 event about 1 month following the main shock, occurring near the main shock location. Central to this prediction is a currently-existing seismic 'quiet zone' that has an area of several hundred thousand km^2 and which is rimmed by a large number of earthquakes.

Giesecke requested a meeting with USGS personnel in Golden in late 1977 to discuss the prediction since he knew that Brady was in Denver and that people in Golden were familiar with the technical basis for the prediction. A meeting has held in late November 1977 in Golden at which Brady and Bill Spence made informal presentations of the data and arguments that formed the basis for the prediction. At the meeting were Giesecke, Algermissen, Jordan, Pakiser, Engdahl, Dewey, Langer, Bucknam, and Bob Wallace. No scientific objections were raised although it was pointed

out that Brady's general prediction theory is questioned by some. It was suggested that recomputing the hypocenters of all relevant earthquakes using a relative relocation method would help to clarify the significance of the seismicity data in the prediction. The relocation of hypocenters has been completed by Spence and Dewey using the joint hypocenter model. It appears that the seismicity patterns described by Brady as being significant for the prediction have been enhanced by relocation of the hypocenters.

Peru has encouraged technical programs in seismology. Many of their programs have been cooperative with various foreign agencies and groups. For example:

1932 Installation of Wenner seismograph at Huancayo (upgraded to Benioff in 1951).
1945 Strong motion instruments installed (cooperative program with U.S. Coast and Geodetic Survey, USC&GS*).
1957 Cal Tech installation of a Benioff strain seismograph at Ñaña.
1959 Installation of Wilson-Lamison seismometers at Arequipa (USC&GS*).
1962 WWSSN stations installed at Ñaña and Arequipa (USC&GS*).
1965 Kyoto U. installation of 4-station extensometer networks in the greater Lima and the greater Arequipa regions.
1977 Memorandum of Understanding (MOU) signed between IGP and USGS.
1977 The Peru national seismic network was increased from about 6 to about 32 stations, in direct response to the Brady prediction.

Peru also has had extensive cooperative programs in seismology with the Carnegie Institute over a period of years.

*USC&GS staff now with USGS.

Various OES personnel have had involvement over a long period of time with the seismological program in Peru. For example:

1. Algermissen field investigated and published a paper on the 1970 Peru earthquake. This earthquake was the greatest natural disaster in the western hemisphere with life loss of 60-70,000.
2. Langer, Jordan, Spence, Espinosa and Husid field investigated the 1974 Peru earthquake. A series of papers were given and published by them (together with Algermissen).
3. A Memorandum of Understanding (MOU) between the Instituto Geofisica del Peru, Educacion Sector, Government of Peru, and the U.S. Geological Survey for participation in cooperative projects in Earthquake Hazard Reduction and Engineering Geology was signed in mid-1977. This MOU was developed on the USGS side by Ted Algermissen and Jim Jordan.

The first Project Implementation Plan (PIP) under this MOU was: Seismic Hazard and Zoning of the Bayovar area, Ted Algermissen, USGS Proj. Mgr. The Bayovar area is a coastal zone of Northern Peru slated for development as a new seaport. Under this PIP, Bob Bucknam and Bob Schuster performed field work that was used in the Peru feasibility study of

the Bayovar project. Bucknam was very impressed with the massive, new marine terraces that exist along the central and northern Peruvian coast. Ten seismoscopes, on loan from the USGS, are now installed in the Bayovar area. A report on the seismic risk has been prepared by IGP and published after extensive review by Algermissen and Jordan.

Considerable research on Peru seismicity is currently being done in Golden. Papers that exist in draft form or better are:

1. Seismic gaps in northern Peru, Jim Dewey and Bill Spence: Relocated over 500 teleseismically-recorded earthquakes from the region of central and northern coastal Peru, 1964-1977. Two distinct zones of seismicity in the subduction zone were resolved and precursory seismicity to the 1974 shock was clarified.

2. An instrumental study of aftershocks of the October 3, 1974, Peru earthquake, Charley Langer and Bill Spence: Aftershocks nearly all lie south of the main shock. Aftershocks are distributed in a 'T' shape, with the primary trend parallel to the coast, showing underthrust motion. The other trend is perpendicular to the first at its approximate mid-point, dips about 20°E, and shows a large component of right-lateral strike-slip motion.

3. A notable space-time distribution for the 1974 Peru aftershock series, Bill Spence and Charley Langer: The two trends of aftershocks in the 'T' zone were alternatively active, each period of activity lasting 2-3 days. The offshore periods of activity exhibited an oscillation of activity between the northern and southern ends of the zone, culminating in a M_S=7.1 aftershock on Nov. 9, 1974, near the end of the primary aftershock series.

4. A tectonic study of the Peru earthquakes of October 3 and November 9, 1974: Bill Spence, Charley Langer, Jim Jordan: Both shocks were underthrust events, each consisting of several multiple-ruptures. A minor tsunami accompanied the main shock (M_S=7.8).

In summary, USGS seismologists in Golden have had a long and productive working relationship with the Instituto Geofisico del Peru. Moreover, these seismologists have followed the development of Brady's prediction in detail for the last few years. We feel that USGS seismologists in Golden should have a key role in:

1. Any USGS evaluation of the potential of the earthquake predicted by Brady, including the organization of a meeting where Brady could present the scientific basis of this prediction to a group of critical scientists.

2. Any subsequent development of a scientific program to collect field data in Peru, that could result in studies of near-field precursory and post-earthquake processes.

3. Any development of a scientific program to evaluate the earthquake hazards that could result from the predicted earthquake, due to ground shaking in metropolitan Lima and the surrounding region of northern and central Peru and due to a large tsunami that could be generated by the predicted earthquake.

Attachment

cc: Bob Engdahl
Jim Dewey
Frank McKeown
Charley Langer
Bob Wallace

DOCUMENT NO. 006

UNITED STATES GOVERNMENT

Memorandum

b : E. R. Engdahl and others with apologies for being later than promised

DATE: 6 May 1979

ROM : J. W. Dewey

JBJECT: Analysis of the potential for a massive ($M_w \geq 9.0$) thrust-fault earthquake in the region of central Peru from the seismic gap viewpoint

I. Introduction: This memorandum discusses the hypothesis that a massive ($M_w \geq 9.0$) thrust-fault earthquake will occur in the next few years in the coastal region of central Peru between latitudes 10°S and 15°S. Such an earthquake has been predicted by B. T. Brady and will, I understand, be discussed at a meeting with Peruvian seismologists in late May. I have not seen the current form of Brady's prediction and am unable to consider the prediction in terms of its theoretical basis or in terms of the postulated precursory phenomena. However, analysis of the seismicity of central Peru in terms of the seismic gap hypothesis indicates to me that a massive thrust-fault earthquake is most unlikely to occur in Peru in the next decade.

The massive thrust-fault earthquake I shall consider would be analogous to the 1960 Chile earthquake or the 1964 Alaska earthquake and would be hypothesized to occur at the interface of the subducting Nazca plate and the overriding South American plate. Such an earthquake would have a focal length of about a 1000 km; a focal width of several hundred kilometers, and an average displacement of tens of meters.

The principal conclusion I see, in comparing recent Peruvian seismicity with characteristics of seismicity associated with strong earthquakes elsewhere in the world, is that the coastal region of central Peru is not a likely spot for a great thrust-fault earthquake in the next decade. Most of the interface between the Nazca plate and the South American plate beneath central Peru has experienced major thrust-fault earthquakes in the last few decades. There is probably not sufficiant accumulated elastic strain energy to produce soon a massive earthquake in this region. This conclusion was reached first by Kelleher (1972), who identified the source region of the yet-to-occur 1974 earthquake as the only significant seismic gap in this section of the coastline. More recent work, while differing with details of Kelleher's analysis, supports his overall conclusion.

To postulate that the central Peruvian coastal region will not experience a massive thrust fault earthquake in the next decade, I must make the following assumptions for two pieces of contrary

evidence: (1) that the great 1746 Lima earthquake, which seems to have been larger than any earthquake of the last several decades, involved rupture in a single great event of several fault surfaces that since 1940 have ruptured in separate events and, (2), that much of the motion of the South American plate relative to the Nazca plate is accomodated by aseismic deformation. These assumptions, while "ad hoc" for Peru, are consistent with characteristics of seismicity in some other subduction zones.

II. Observational evidence against the imminent occurrence of a massive underthrust earthquake in the central Peruvian coastal region.

The region of central coastal Peru has recently experienced two great thrust-fault earthquakes, the earthquakes of Oct 17, 1966, and Oct 03, 1974, both with magnitudes about 7.8 and both with aftershock zones about 200 km long (fig 1). The magnitude 7.6 earthquake of May 31, 1970, occurred as the result of normal faulting rather than thrust faulting, and it's implications will be discussed below. The region also experienced great earthquakes (M about 8) on May 24, 1940, and August 24, 1942 (fig 1). If one assumes, as Kelleher (1972) did, that the 1940 and 1942 shocks were both thrust-fault earthquakes on the plate boundary, then most of the plate boundary between 10°S and 15°S has broken since 1940. Considering only the 1966 and 1974 shocks (fig 1), more than half of the plate boundary has broken since 1966, and the remaining seismic gaps are of the order of 100 km or less in length.

It may be hypothesized (and I believe this is part of the Brady prediction) that the 1966 and 1974 earthquakes occurred on the upper edge of a highly-strained focal region and that there are extensive regions down-dip of the 1966 and 1974 earthquakes that remained locked during the earlier earthquakes and are now ready to go in an even greater earthquake. To my knowledge, this phenomenon has never been observed on the scale required by the Brady prediction. Data compiled by Kelleher and his associates (e.g. Kelleher et. al., 1973) suggest that when a thrust-fault earthquake approaches, in size, magnitude 7.8, with a rupture zone hundreds of kilometers in extent, it effectively breaks most of the thrust interface in the arc segment on which it occurs and is not followed in the next two decades by a larger thrust-fault earthquake in the same plate boundary segment.

One may note in fig 1 and fig 2 that the Peruvian earthquake of 1940 occurred further inland and deeper than the 1966 and 1974 shocks. If the 1940 earthquake is taken as a thrust earthquake on the plate interface (although it is not clear that it should be so taken), might not the regions down-dip of the 1966 and 1974 shocks also be accumulating elastic strain and be capable of producing a massive thrust fault earthquake? An insight into this question is provided in the southern Kurile Islands, where the 1958 thrust fault earthquake ($M \simeq 8.2$) occurred inland of and deeper than the adjacent thrust fault earthquakes of 1963 ($M \simeq 8$)

and 1969 (M ≅ 8) (see eg. Kelleher et.al., 1973). However, there has not since been a larger earthquake updip of the 1958 shock or downdip of the 1963 and 1969 shocks, and the historical record (e.g. Kanamori, 1977) does not suggest that there has earlier been a massive (M_W ≅ 9.0) earthquake in this region. Furthermore, whatever the focal mechanism of the 1940 earthquake; focal mechanisms of recent earthquakes imply that the segments of the plate interface landward of the 1966 and 1974 earthquakes are not accumulating significant compressional stresses. The earthquakes inland of the 1966 and 1974 source regions seem to be largely the result of stresses within the decending Nazca plate (e.g. Abe, 1972; Isacks and Barazangi, 1977, Dewey and Spence, 1979). For example, the 1970 earthquake (fig 1) was a normal fault event. Normal faulting implies that the maximum compressive stress is locally oriented nearly vertically. Normal faulting is inconsistent with the horizontal compressive stress that would be present if the interface between the South American and Nazca plates near the 1970 earthquake were locked and accumulating strain for a massive thrust fault earthquake. Normal faulting focal mechanisms are documented downdip of both the 1966 and 1974 earthquakes (summarized by Dewey and Spence, 1979).

III. Alternative explanations for phenomena that may support the occurrence of a massive earthquake in central Peru.

The great Lima earthquake of 1746 seems to have been larger than any earthquake occurring in this century. It may be argued, therefore, that the width of the seismogenic section of the Peruvian subduction zone is significantly greater than the width of the aftershock zones of 1966 and 1974, in order to account for such a great shock. An alternative explanation for the size of the 1746 shock is that it's fault was not much wider than the faults of the 1966 and 1974 earthquakes, but that it was significantly longer. For example, the seismic episode of the mid-eighteenth century, rather than occurring in individual events separated by years (as in 1966 and 1974) may have occurred in a single great earthquake, that of 1746. In that case, the seismicity of the central Peru region would be analogous to that of the thrust interface of the Nankai trough region in Japan, which in 1854 and 1944-1946 has broken in discrete earthquakes but which in 1707 broke in a single massive earthquake (Ando's work, summarized by Kanamori, 1977).

A second observation that may be taken to support the possibility of a massive central Peruvian thrust fault earthquake in the next decade is that the major earthquakes of central Peru in the last two centuries do not seem to have been frequent enough or large enough to account for a large share of relative displacement of the South American and Nazca plates. This discrepency between seismic displacement and displacement estimated from plate tectonics is not unique to central Peru, but is an important problem world-wide (e.g. McCann et.al., 1978). In some regions of great thrust fault earthquakes, such as the South Kurile Islands, the seismic displacement seems to account for only a small percentage of total plate displacement (Kanomori, 1977).

In my view, the evidence is strong against great earthquakes following each other in a period of two decades on the same fault interface, and there is no reason why all relative plate displacement in Peru must occur seismically. Therefore, I prefer to consider that the discrepency between estimated relative plate displacement and historical seismic displacement implies the occurrence of significant aseismic deformation rather than the imminence of a massive earthquake.

In an earlier meeting on his prediction, Brady argued that the 1974 Peru earthquake produced an anomalously low number of aftershocks and that this low number of aftershocks was evidence that elastic strain on the thrust interface had not been substantially relieved by the 1974 earthquake. This hypothesis interests me because the research group with which I am working in Moscow claims success in retroactive long term "prediction" of earthquakes using nearly the opposite hypothesis - that the occurrence of some earthquakes with anomalously high number of aftershocks is a tip-off to the imminence of a strong regional earthquake in the next several years. The main shocks thus retroactively "predicted" do not have unusually high numbers of "aftershocks," as aftershocks are defined by the Soviet group. Because of slightly different definitions and formulation of the problem, the Brady aftershock hypothesis and the Soviet aftershock hypothesis are not necessarily mutually exclusive, but they are nearly so. The Soviet group has gone to considerable effort to test their hypothesis using data sets from many parts of the world and hopefully objective statistical decision making. If the numbers of 1974 aftershocks are hypothesized to be anomalously low and this is taken as evidence for a future great earthquake, supporting evidence from other seismic regions should be presented.

IV. Potentially destructive Peruvian earthquakes which the recent seismicity data do not preclude.

It has been recognized for some time (e.g. Kelleher, 1972) that the region of southernmost Peru is a region with significant seismic potential. It experienced great earthquakes in the 19th century and has been quiet since.

The region of Peru north of 9°S has also been recognized as a seismic gap. Because it has not historically experienced a great earthquake, there is discussion in the literature on whether or not the region experiences great earthquakes with long recurrence times or if instead relative plate motion is completely accomodated aseismically. Bob Bucknam has suggested that study of marine terraces in the coastal region may provide evidence on prehistoric great earthquakes.

The region between the 1966 and 1974 rupture zones (fig 1) is long enough (~ 100 km) to produce a large earthquake. This is particularly the case if the 1940 earthquake is assumed to not

have occurred on the interface between the South American and Nazca plates.

It is worthwhile considering if anomalous seismicity patterns in Peru (which will, I understand, be defined and discussed by Brady) may be precursory to an earthquake of one of the foregoing types. In this connection, I should observe that the Soviet seismologists with whom I am working are convinced that precursory seismicity occurs at very large distances (hundreds of kilometers) from epicenters of the future earthquakes. Obviously, the prediction of a major earthquake by using anomalous seismicity patterns, even for a seismic gap that is widely recognized as dangerous, requires discussion of: (1), why a particular pattern is indeed anomalous and not just a random pattern, and, (2), documentation that the pattern can retroactively "predict" other great earthquakes.

References

Abe, K. (1972), Phys. Earth, Planet. Interiors, 5, 367.

Dewey, J. W. and W. Spence (1979). Seismic Gaps and Source Zones of Recent Large E.Q.'s in Coastal Peru, submitted to PAGEOPH.

Isacks, B. L. and Barazangi, M. (1977), Maurice Ewing Series, 1, 99.

Kanamori, H. (1977), Maurice Ewing Series, 1, 163.

Kelleher, J. (1972), J. Geophys. Res., 77, 2087.

Kelleher, J., Sykes, L., Oliver, J. (1973), J. Geophys. Res., 78, 2547.

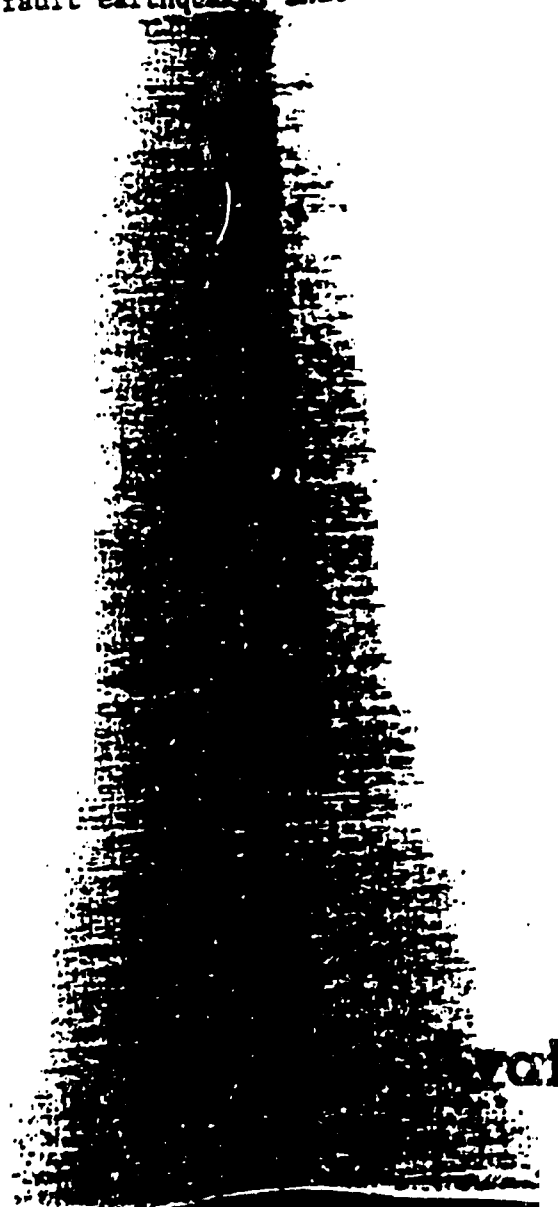
McCann, W. R., Nishenko, S. P., Sykes, L. R., Krause, J. (1978), USGS Open-File Report. 78-943, 441.

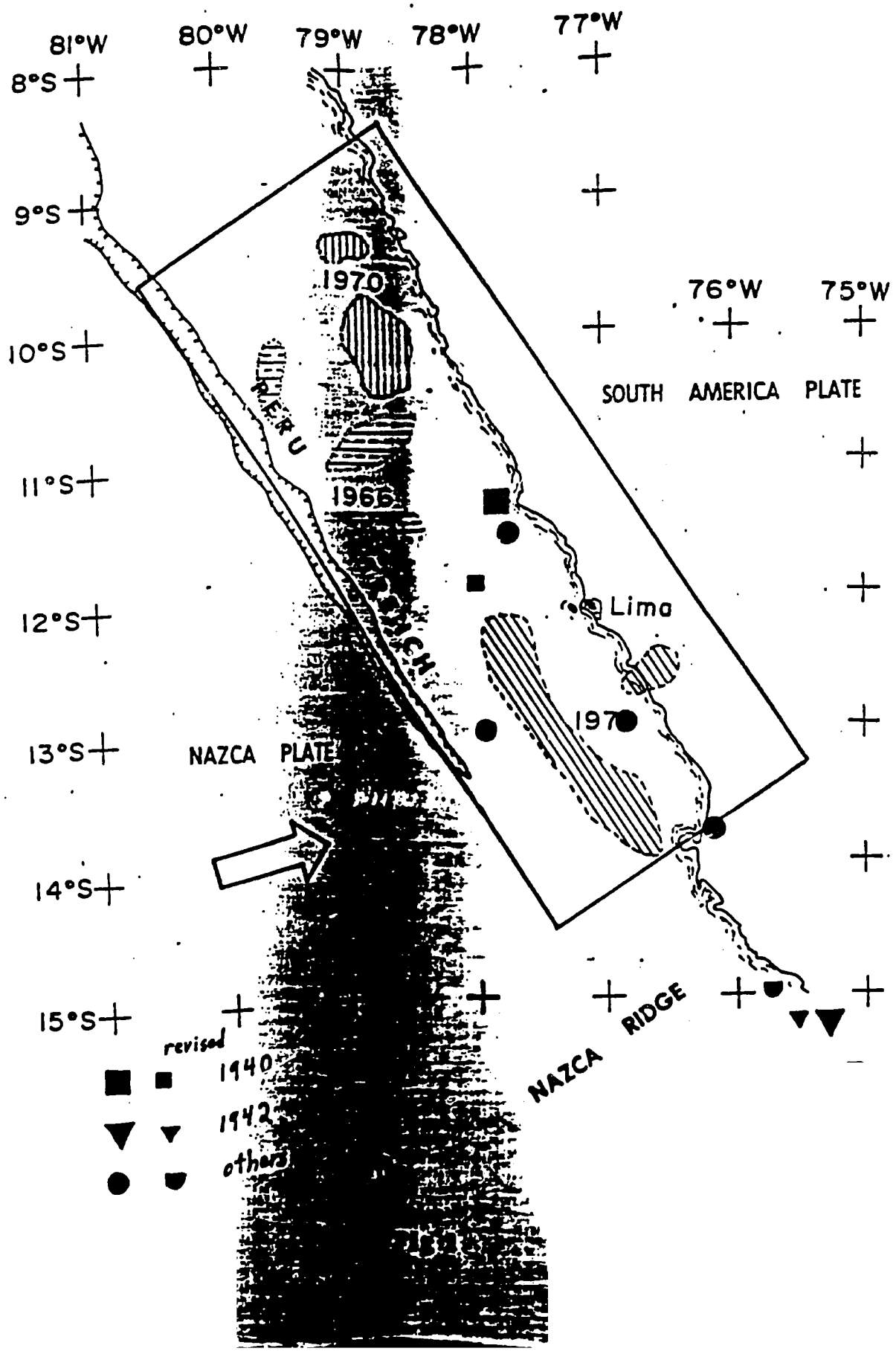
Illustrations

Fig 1. Schematic representation of aftershock zones of three recent (since 1964) great central Peruvian earthquakes. Epicenters of several large shocks since 1940 are also shown. Large square and triangle are epicenters of great 1940 and 1942 shocks, respectively. The aftershocks of the Peruvian earthquakes occurred in distinct clusters, which were outlined here for the purposes of another paper. Such aftershock clustering seems rather common for great earthquakes. To be consistent with conventional seismic gap usage, the "length of aftershock zone" mentioned in this paper is the length of the envelope enclosing all aftershock clusters for that earthquake. Thus the length of the 1966 aftershock zone is the length of the envelope enclosing the three clusters shaded with alternating dashed and solid lines.

USSR

Fig 2. Hypocenters of the central Peruvian coastal region. Pre - 1964 events are the same as Fig 1. 1966 and 1974 earthquakes occurred in interface thrust zone. 1970 normal fault event occurred in coastal plate interior zone, as did four other normal fault earthquakes that were not aftershocks to the 1970 shock.





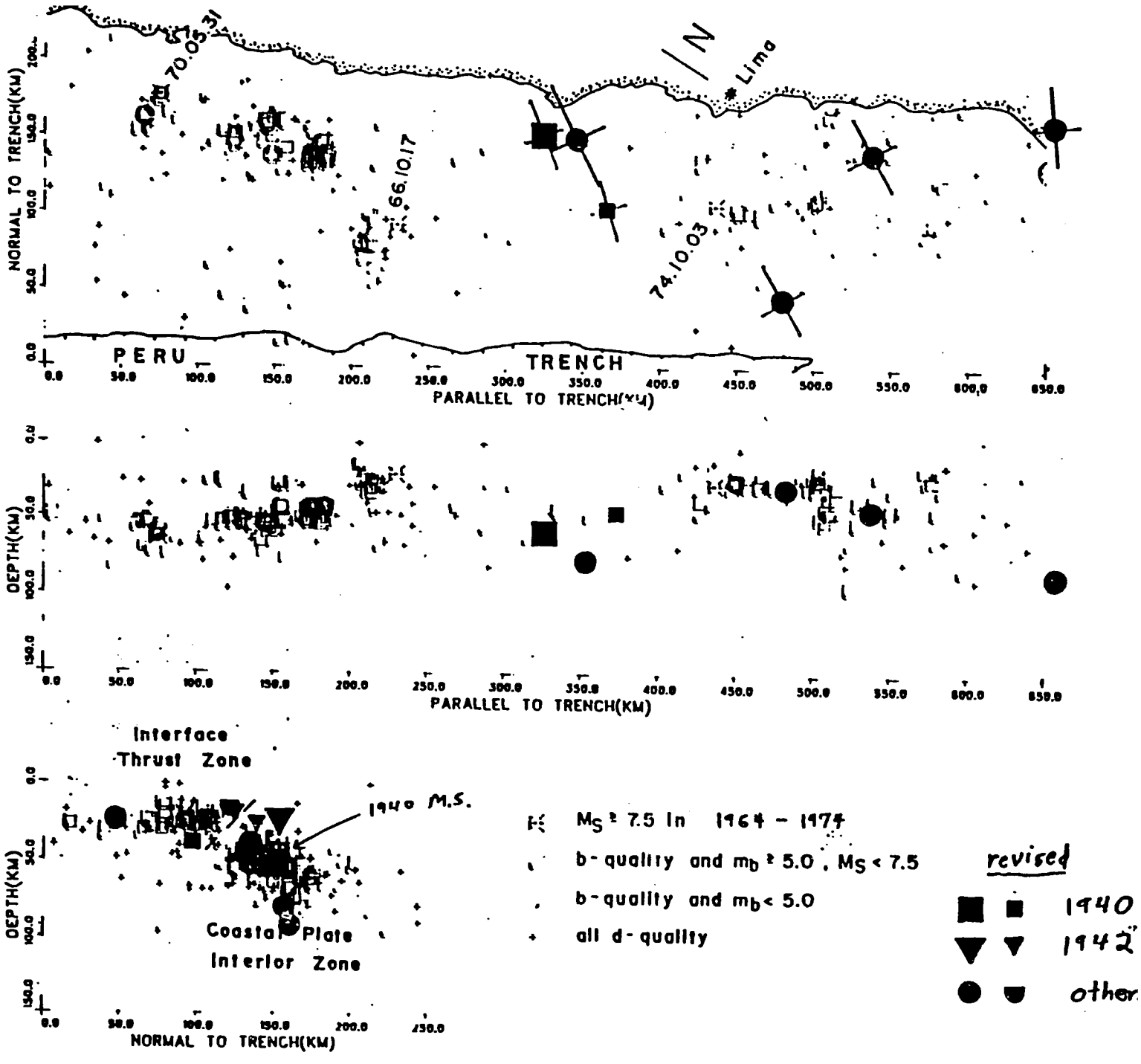

70.05.31
66.10.17
74.10.03
Lima
PERU
TRENCH
NORMAL TO TRENCH(KM)
PARALLEL TO TRENCH(KM)
DEPTH(KM)
PARALLEL TO TRENCH(KM)
Interface
Thrust Zone
1940 M.S.
Coastal Plate
Interior Zone
DEPTH(KM)
NORMAL TO TRENCH(KM)
Ms ≥ 7.5 In 1964 - 1974
b-quality and mb ≥ 5.0 , Ms < 7.5
b-quality and mb < 5.0
all d-quality
revised
1940
1942
other

Fig 2

OPTIONAL FORM NO. 10
JULY 1973 EDITION
GSA FPMR (41 CFR) 101-11.6

DOCUMENT NO. 007

UNITED STATES GOVERNMENT

Memorandum

TO : PDC/OFDA, Anne C. Martindell, Director DATE: June 19,1979

THRU : PDC/OFDA, William R. Dalton, Assistant Director for Preparedness

FROM : PDC/OFDA, Paul F. Krumpe, Science Advisor PFK

SUBJECT: U.S. Geological Survey Meeting Concerning Matters Related to Earthquake Hazards in Peru.

1. On May 24, 1979 I attended a meeting conducted by the U.S. Geological Survey at Golden, Colorado. The meeting purpose was to provide assistance to Dr. Alberto Gieseke and his senior staff of the Geophysical Institute of Peru in the analysis of earthquake hazards potential in Peru. The meeting was attended by seismologists from U.S.G.S., Menlo Park, California and Golden, Colorado offices. Dr. John Filson, Deputy Director, Office of Earthquake Studies, U.S.G.S., Reston, Virginia chaired the meeting.

2. The main objective of the meeting was to provide a forum wherein Dr. Brian Brady, U.S. Bureau of Mines, Department of the Interior, could present his current research work and theoretical basis of earthquake prediction as it relates specifically to earthquake hazard problems in Peru. Dr. William Spence, U.S.G.S. Seismologist, assisted Dr. Brady in the presentation and has contributed significantly to application of Dr. Brady's quantitative prediction methodology to seismic threat in Peru.

3. The meeting constituted the offical U.S.G.S. response to Dr. Gieseke's request to the USG for technical assistance concerning Brady's prediction research as it relates to Peru. The meeting participants did not intend to endorse, condemn, or otherwise evaluate the validity of the scientific work or the technical position presented by Dr. Brady. A request was made by Dr. Filson to keep all comments objective during the day's discussion.

4. The following are participants who attended the meeting:

Brian T. Brady, Bureau of Mines, Golden, Co.
Vernon Hooker, Bureau of Mines, Golden, Co.
John Filson, USGS, Reston, Va.
Ted Algermissen, USGS, Golden, Co.
William Spence, USGS, Golden, Co.
E.R. Engdahl, USGS, Golden, Co.
Humberto Urteaga, Counselor of Embassy of Peru

James Jordan, USGS, Golden, Co.
John Derr, USGS, Golden, Co.
David Hill, USGS, Menlo Park, CA.
Jack Healy, USGS, Menlo Park, CA.
Jerry Eaton, USGS, Menlo Park, CA.
Alberto Giesecke, Geophysics Institute of Peru
Hernan Montes, Geophysics Institute of Peru
Daniel Huaco, Geophysics Institute of Peru
Leo Ocola, Geophysics Institute of Peru
Thomas Aldrich, Carneggie Institute, Washington, D. C.
Paul, F. Krumpe, Agency for International Development, Washington, D. C.

5. Handouts available to attendees at the meeting included:

Physical Precursors of Rock Failure: A laboratory-Investigation (1979) B.T. Brady, G.A. Rowell, and A. Yoder., U.S. Dept. Interior, Bureau of Mines, Denver, Co.

Effect of Stress on Radon Emanation From Rock (1979) R.F. Holub and B. T. Brady, U.S. Dept. Interior, Bureau of Mines, Denver, Co.

Analysis of the potential for a massive (M_W 9.0) Thrust-Fault earthquake in the region of central Peru from the seismic gap view point. (1979) J.W. Dewey, U.S. Geological Survey Memorandum.

Some Personal Experiences with Earthquakes(1915) Rear Admiral L.C. Billings (USN), National Geographic Magazine.

Prediction Parameters for Central Peru (October 3, 1974, M_W=8.7 Event) (1979) B.T. Brady, U.S. Dept. Interior, Bureau of Mines, Denver, Co.

Prediction Parameters for Central Peru 1981, M_W=9.8 Event (1979) B.T. Brady, U.S. Dept. Interior, Bureau of Mines, Denver, Co.

6. The presentation was given in four parts:

A. Physical Basis of the Scale-Invariant Inclusion Theory for the prediction of rock failure (B.T. Brady)

B. Application of the prediction hypothesis to existing earthquake events: San Fernando Earthquake (B.T. Brady)

C. An analysis of the 1974 Peru Earthquake Sequence: Historical perspective, Plausibility arguments, aftershock space-time patterns and tectonic implications. (W.J. Spence)

D. Seismic Risk in Peru: 1981 Earthquake prediction presursor events, experimental design for working hypothesis validation (B.T. Brady).

7. The revised Brady prediction for Peru as of May, 1979 included the following:

September 1980	Initiation of foreshocks(nine months) 13 Foreshocks (M 7 toward end of sequence off the coast of Lima, Peru
July 1981	Mainshock M_w9.8 (7×10^{26}Ergs) Total energy released. Rupture from 12.5°S to 24.5°S off the coast of Peru and Chile
April 1982	Aftershock M8.7 Rupture from 12.5°S to 8.5°S off the coast of Peru.

The mainshock in July, 1981 could generate a tsunami 20 meters high impinging on Hawaii, Japan and other Pacific Islands.

8. The following represents a brief overview of portions of B.T. Brady's Scale Invariant Inclusion Theory.

(1). The physical process leading to rock failure in laboratory controlled stress tests are scale invariant. This means that the same failure parameters that are operative and predictable in laboratory tests can be extrapolated from the microscale to the macroscale to include deep mine failure, rockbursts and earthquakes.

(2). Failure data measured quantitatively in the laboratory include pre-failure (precursor) and post-failure parameters. Precursor data include zone of dilatancy, zone of inclusion, decrease in volume during "preparation time" (i.e. implosion), changes axial in load stress drop, and confining failure process during the time interval when conditions of thermodynamic stability are no longer valid. Conditions for mechanical stability are violated during this time interval, also.

The violation of mechanical, thermal and difussion stability are essential ingredients of the inclusion theory of instability. Their violation is necessary as "set-up" for initiation of the failure process which is irreversible.

(3). Central to Dr. Brady's earthquake prediction model is a complex analysis of the above microscale characteristics of rock failure and a discussion of the energy required to break molecular bonds (thermodynamic instability).

(4). The failure process is independent of scale with precursor time versus fault length data plotting linearly. The failure process leads to conditionsthat force multiple rupture crack growth in rocks.

9. The presentations by Dr. Brady and Dr. Spence were well-planned, comprehensive in scope, illustrated with quality graphics and slides, well-documented with references to the published literature, and provided an excellent overview of very complex subject matter. The presentation ranged from a complete explanation of Dr. Brady's research in rock mechanics and the thermodynamics of rock failure at the microscale, to an explanation of a macroscopic comprehensive physical geometric model (working hypothesis) of earthquake source and prediction parameters relative to South American plate tectonics.

10. Dr. Brady's Scale Invariant Inclusion Theory Model was presented as being capable of predicting occurrence of deep rock mine failure, rock bursts and earthquake precursor phenomena, time intervals between events, magnitude of stress shocks and event location. Dr. Brady contends that each earthquake is unique with the causal mechanism manifesting as precursors equivalent to those observed in controlled laboratory rock fracture experiments Brady demonstrated that certain observed seismic data associated with earthquake events, in retrospect, are consistant with his predictive model. He is currently validating the model by analyzing the 1971 San Fernando earthquake with a view toward proving it's predictability with data available prior to the event. This approach has also been applied to the 1974 Peru earthquake which he concludes is a precursor phenomena, based on postulated seismicity patterns, to a major M9.8 earthquake in July, 1981, 75 miles off the coast of Lima, Peru. Dr. Brady contends that the 1974 earthquake is an irreversible long-term indicator of impending tectonic failure of the Fault System where the Nazca Plate subducts beneath the South American Plate. The working hypothesis dictates periods of active seismicity interspersed with intervals of inactivity, the time intervals being nearly equivalent and, therefore, predictable.

Dr. Brady's hypothesis incorporates modelling of the energetics of rock failure in mines and earthquakes, including models of the deformation zone, rock elasticity, strain, rupture sequence, crack coalescence, feedback processes in tension/compression stress model thermodynamic stability criteria, Tensor Field Equations, Laws of PIZ mechanics and regional geometric analyses.

11. Dr. Brady and Dr. Spence hypothesize that a significant seismic gap exists along the west coast of South America from 7^{o} S to 25^{o} S latitude. The postulated gap exceeds a time period of 60,000 years. Inactivity of volcanos in the region where the Nazca plate subducts

beneath the South American shield evidences the lack of strain energy release which could occur as the predicted mainshock in 1981. The presence of the Andean Mts. range indicates past violent geophysical activity, but in relatively recent geologic times a seismic gap apparently exists with respect to mega-seismic events. According to Dr. Brady the 1974 Peru earthquake represents the key precursor event where the thermodynamic stability of the fault system was violated and preparation time for the mainshock (failure) in 1981 was established. Dr. Brady has computed the energy budget for the rock failure (earthquake) predicted to occur in July, 1981 off the Peruvian Coast.

12. During the course of Dr. Brady's presentation, he was challenged by USGS participants on the following issues:

(1). The scientific community requires publication of his prediction model in detail, with sufficient explanation so that other researchers can replicate his results and derive the same conclusions (predictions) based on equivalent or other data sets. Replication of the results is essential to the prediction model validation, acceptance, and use.

(2).Several USGS participants indicated that Dr. Brady's extrapolation of microscale rock failure criteria (measured in the laboratory and deep mines) to large scale earthquake fault systems (basis of the scale invariant inclusion theory) is not a scientifically valid assumption and that Dr. Brady has not proven the basis for asserting that assumption to date.

(3). Several USGS participants admitted an inability to comprehend the Brady working hypothesis, its theoretical basis, and applicability to earthquake prediction. The mathematical equations are exceptionally complex and very difficult to understand.

(4). Several participants demanded elucidation and publication of the model's constraints, assumptions and physical basis.

(5). Complaints were voiced by several USGS participants concerning the difficulty of understanding the theory, defending it and fostering critical debate on it with respect to evaluation, validation and application of the conclusions. A credibility crisis emerged where the USGS geophysicists felt Brady's work may "discredit the scientific method" unless other scientists are able to relate to Dr. Brady's research and evaluate and comment on it. One USGS scientist stated the following: "I don't understand a thing he is saying..how can you, ask me to join in support of your work?"

(6). Several USGS and Peruvian participants offered to provide constructive assistance in the design of critical tests of the Brady working hypothesis. Dr. Brady was requested to publish the entire theory and prediction in an understandable form as soon as possible.

(7). Several USGS participants indicated that if Dr. Brady's prediction of 1980 foreshocks and main seismic event in 1981 occur in Peru as predicted, this would not necessarily constitute a "proof" or otherwise validate the model.

13. The following is a brief summary of my impression of the meeting, participant discussion and comments.

(1) When challenged by two U.S.G.S. scientists for not making available published professional papers and specifics concerning his earthquake prediction research, Dr. Brady replied that he had published more than 16 technical papers in professional journals since 1973. (see attached reference list). Dr. Brady reiterated that he has not published the details of his Peru prediction because of an agreement with GOP not to go public on the prediction without Dr. Giesekes approval. Dr. Brady stated he would be ready to publish the details in September 1980, following the predicted foreshock series. At that time he assumes the scientific community will be receptive to studying the Scale Invariant Inclusion Theory Model, with a view toward future scientific cooperation in global earthquake prediction research. Dr. Brady indicated his highest priority would be to publish the methodology and details of his theory with respect to the 1971 San Fernando earthquake (retroactive prediction). Dr. Brady indicated he would continue to refine and update his Peru earthquake prediction model as additional data become available.

Dr. Brady provided several handouts at the meeting including a chart of detailed prediction parameters for past (retroactive) and future events occurring in Peru.

(2) Dr. Brady expressed concern that his methodology, theoretical considerations (Tensor Field Equations) and geometric interpretation of the Peruvian inclusion zone, were indeed difficult to comprehend by other reseachers; he nevertheless indicated a continued willingness to work closely with the USGS, Peruvians or others to document his research, predictions, and theoretical assumptions, constraints and and limitations. Dr. Brady stated that to accomplish the above would require time, interagency cooperation and funding.

(3) It appeared to me that several U.S.G.S. participants were not fully aware of the many professional papers published by Dr. Brady in the literature.(see attached Appendix). Therefore,difficulty was experienced by some in understanding portions of the presentation. Dr. referenced a U.S.G.S. memorandum dated 1-30-79 which presumably had been circulated within the U.S.G.S. which explained background information and the general basis (referenced in the literature) upon which he determined the postulated Peruvian earthquake prediction.

(4) Dr. Brady stated clearly that he intends to write-up the details of the predicted M 9.8 earthquake in Peru. The Peruvians agreed to assist Dr. Brady by supplying additional seismic data and working with him to test the hypothesis and design experiments to monitor precursors. Other data needs were discussed and it became clear that the Peru geophysicists consider the possible occurrence of the mid-September, 1980 initiation of the predicted foreshock series to be the major milestone with respect to further validation of working hypothesis.

(5) Dr. Brady emphasized the significance of the occurrence of the last of four "marker events" predicted by the model, which manifested on April 27, 1978 at 1100 GMT, 22 hours following the predicted time of 1300 GMT, April 26, 1978. This last marker event is important in establishing the model's validity because the hypothesis predicts that no teleseismically recorded events will occur in the zone specified by Brady prior to initation of the September 1980 foreshock sequence.

Dr. Brady emphasized at the meeting that from April 1978 to the present time, no teleseismic events have been reported in the zone, indicating the zone is quiescent as predicted.

14. Continuation of Dr. Brady's earthquake prediction research, with emphasis on Peru, will require further investigation and analysis, model testing and validation. In order to meet these objectives in a timely manner, so as to be of assistance to the Peruvian Government in the event the foreshock sequence occurs as predicted, Dr. Brady and Dr. Spence suggest the following actions:

(1) Relocation of Earthquakes in San Fernando, CA region

All unrelocated earthquakes (ca.600) in the San Fernando region of California prior to June 1961 must be relocated and analyzed for consistency with the Brady working hypothesis and his retroactive prediction of the 1971 event. These data, when incorporated in Dr. Brady's published work on the 1971 San Fernando Earthquake prediction, can be analyzed critically with his methodologies replicated (model and tensor field equations) and peer review within the geophysics community can then determine the predictive validity of the Brady model.

(2) Peer Review of Model and Physical, Mathematical Basis for Prediction

Scientific peer review and collaboration concerning Dr. Brady's model and equations by qualified theoretical physicists such as Dr. C. Archambeau (Univ. Colorado), Dr. Leon Napoff (UCLA), Dr. Donald Anderson (Cal Tech), Dr. K. Aki (MIT), H.R. Hardy, Jr. (Pennsylvania State U.) and geophysicists and seismologists

knowledgeable in South American tectonics, earthquake prediction research and rock mechanics should establish a credible basis for either validating and accepting Brady's scale invariant inclusion theory of earthquake prediction, or rejecting the theory as implausible.

(3) Design Critical Tests of Hypothesis

Dr. Brady and Dr. Spence need to design critical tests of the Peru earthquake prediction hypothesis. These tests should be cost-effective, have low visibility, and be performed by the Peruvians with assistance (equipment and technical expertise) provided by the USG. Instrument location should be coordinated by Dr. Brady and Dr. Spence in conjunction with testing the prediction model. The U.S.G.S. may wish to assist in designing other critical tests of the working hypothesis provided they are cost-effective, meaningful and contiguous with Dr. Brady's working hypothesis and Peruvian requirements.

(4) Relocation of Peruvian Earthquakes

The U.S.G.S. needs to assist the Geophysics Institute of Peru in relocating (c.a. 1800)Peru earthquakes. This is necessary to test Dr. Brady's hypothesis further to establish consistency in the data with the prediction parameters.

(5) Examination of Seismic Records and Empirical Data in Peru

It would be advantageous for Dr. Spence and Dr. Brady to visit Peru as soon as possible to examine seismic records, collaborate with the Peruvian geophysicists locate possible instrument sites, assist in seismic network design, determine optimum locations for ocean bottom seismometers, and discuss details concerning the Peru prediction parameters and the model's consistency with observed data. The examination of empirical test data such as sea level changes, ocean bottom uplift, tidal gauge data, and gravity survey data could prove essential in validating or disproving the Brady model.

(6) Modelling of Tsunami Threat

Further analysis and modelling of the tsunamigenic effects resulting from the postulated foreshocks, mainshock and aftershocks associated with the 1981 prediction appears justified according to Dr. Brady and other interested scientists. Investigations of the potential tsunami threat is critical to the safety of U.S. citizens living and travelling in potentially high risk areas such as the South Pacific Islands, Hawaii, New Zealand and possibly the Phillipines.

15. The following represent several options OFDA may persue with respect to further evaluation and application of Dr. Brady's earthquake prediction model:

(1) Include within the scope of work for the CERESIS Andean Mountain Seismic Risk Project (SISRA), the task of relocating the epicenters of c.a. 1800 Peru earthquakes required for refinement of the Brady prediction model parameters. The data acquired will be utilized in the SISPA seismic risk mapping and hazards analyses program in addition to assisting collaboration between the Peruvian geophysicists and the prediction research team.

(2) OFDA consultion with Dr. Brady's peers (theoretical physicists) and others concerning the application of the scale invariant inclusion theory to earthquake prediction could provide substantive evaluation of the scientific basis for the Peru earthquake prediction. Dr. Brady's work demands review by qualified individuals capable of understanding the high levels of complexity inherent in his tensor field equations as well as the comprehensive physical quatitative model he has postulated relative to the Peru case.

This option would necessitate OFDA support of close collaboration among the Peru geophysicists, Dr. Brady and his research team, and consultants OFDA determined were qualified to evaulate the hypothesis. It has been suggested that Dr. Archambeau (Univ. Colorado) would be most qualified and probably willing to submit a proposal to OFDA to provide a comprehensive evaluation of Dr. Brady's earthquake prediction work with special emphasis on the Peru case.

(3) The need to design critical tests of the prediction hypothesis was emphasized by Dr. Gieseke at the meeting. OFDA could provide technical assistance to the Geophysics Institute of Peru through the Carneggie Institution in support of the above task. Dr. Spence (USGS) and Dr. Brady (Bureau of Mines) would work closely with Carneggie Institution geophysicists testing Dr. Brady's prediction hypothesis. Travel to Peru to examine seismic records and empircal data would be included in this technical assistance mission.

(4) The possibility of tsunami threat has been continually emphasized by Dr. Brady in his analysis of the data and the working hypothesis. OFDA is presently collaborating with NOAA (Dr. Gordan Vaeth) and NASA (Mr. Charles Vermillion) concerning a proposed communications satellite based tsunami warning system for the Pacific Ocean area. An OFDA option may include more direct involvement and support of the NASA/NOAA effort and an open exchange of data and information concerning the Peru case. This could result in possibly accelerating development of the tsunami warning system thereby providing a real time reliable early warning capability throughout the region.

APPENDIX

PUBLICATIONS
DR. BRIAN T. BRADY

Brady, B.T. (1974), Seismic Precursors Prior to Rock Failures in Underground Mines, Nature, Vol. 252, No. 5484, pp.544-552

Brady, B.T. (1974), Theory of Earthquakes-I.A Scale Independent Theory of Failure, Pure Appl. Geophys. 112,701-726.

Brady, B.T. (1975), Theory of Earthquakes-II.Inclusion Theory of Crustal Earthquakes, Pure Appl. Geophys. 113, 149-169.

Brady, B.T. (1976), Laboratory Investigation of Tilt and Seismicity Anomalies in Rock Before Failure, Nature, vol. 260, No. 5547, pp. 108-111

Brady, B.T. (1976), Theory of Earthquakes-III. Inclusion Theory of Deep Earthquakes, Pure Appl. Geophys.114, 119-139.

Brady, B. T.(1976), Dynamics of Fault Growth: A Physical Basis for Aftershoc Sequences, Pure Appl. Geophys.

Brady, B.T. (1976), Theory of Earthquakes IV. General Implications for Earthquake Prediciton, Pure and Applied Geophysics, vol. 114, pp. 1031-1082

Brady, B.T. (1977), An Investigation of the Scale Invariant Properties of Failure, Int. J. Rock Mech. Min. Sci., vol. 14, NO. 3, pp. 121-126

Brady, B.T. (1977), Anomalous Seismicity Prior to Rockbursts: Implications for Earthquake Prediction, Pure and Applied Geophysics, vol. 115 Nos. 1-2, pp. 357-375

Brady, B.T. (1977), and F. W. Leighton. Seismicity Anomaly Prior to a Moderate Rock Burst: A case Study, Int. J. Rock Mech. Min. Sci., vol. 14, No. 3, pp. 127-132

Brady, B.T. (1979), The October 3 - November 9, 1974, Peru Earthquake Sequence: Seismological Implications and a Prediction Update, (in preparation).

Brady, B.T. (1979), Thermodynamics of Failure (in preparation)

DOCUMENT NO. 008

United States Department of the Interior

BUREAU OF MINES

BUILDING 20, DENVER FEDERAL CENTER
DENVER, COLORADO 80225

June 19, 1979

Memorandum

To: Robert L. Marovelli, Acting Assistant Director-Mining, Washington, D. C.

Through: Verne E. Hooker, Research Supervisor, Mine Structure Design, Denver Mining Research Center

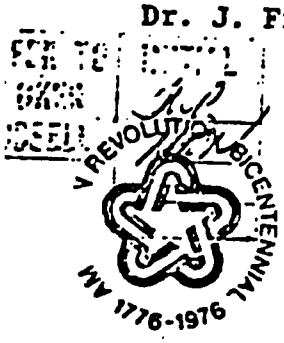
Harry R. Nicholls, Research Director, Denver Mining Research Center

From: Brian T. Brady, Physicist, Mine Structure Design, Denver Mining Research Center

Subject: Summary of meeting on the predicted central Peru earthquake held in Golden, Colorado, May 24, 1979

On January 19, 1979, Dr. Alberto Giesecke, Director, Ceresis, and Chief, Geophysical Institute of Peru, requested Dr. H. W. Menard, Director, USGS, to discuss on a formal basis the earthquake risk potential in central Peru. Accordingly, a meeting on May 24, 1979, was held in Golden, Colorado, with scientists of the United States Government and Peru to discuss the potential of a massive earthquake to initiate off the coast of central Peru in mid-1981. The personnel present at this meeting included:

USGS		USBM	
Dr. J. Eaton Dr. J. Healy Dr. D. Hill	Menlo Park, California	Mr. V. Hooker Dr. B. Brady	Denver, Colorado
Dr. T. Algermissen Dr. W. Spence Dr. J. Derr Dr. R. Engdahl Mr. J. Jorden	Golden, Colorado	CERESIS, IGP Dr. A. Giesecke Dr. D. Huaco Dr. L. Ocolo Dr. H. Montez	Lima, Peru
Dr. J. Filson	Reston, Virginia		



Memorandum to Robert Marovelli, Washington, D. C.

Washington, D. C.

Mr. Humberto Urteaga (Counselor of the Embassy of Peru)
Dr. T. Aldrich (Director, Carnegie Institute)
Dr. P. Krumpe (AID, Department of State)

Dr. John Filson, Deputy Chief, Office of Earthquake Studies, chaired the meeting. I was invited to present results of the Bureau's research on rock burst prediction and control, laboratory studies of rock failure, theoretical studies of the failure process in rock, and the implications of these results to the predicted Peruvian event.

My introductory comments included the current status of the prediction.

1.) Secondary foreshock series commencing on or before 800915[1]. There will be a total of (approximately) thirteen foreshocks, including the possibility of a M7 event prior to the mainshock. I indicated that the theory led to the prediction of a low magnitude event (~M4→M5) on 780426 (last of four marker events in this region) near Chilca (approximately 75 km SE of Lima). The predicted event (M4.8) occurred on 780427. a discrepency of only twenty-two hours.

2.) Mainshock will occur on or before 810731 (M_t9.8, M_t=M_w). The event will initiate a rupture to the S-SE from 12.5°S to approximately 25°S. This event will eliminate the largest known seismic gaps in the world.

3.) A second event will occur approximately nine months later (820502) with a magnitude M_t 8.7. The event will rupture to the north from 12.5°S to approximately 7↔8°S.

4.) Both events are predicted to be shallow underthrust earthquakes. Consequently, they are tsunamigenic events. For example, the mainshock (M_t9.8) is estimated to be capable of generating a sea wave of amplitude of at least 20 meters (≈66 feet) on Hilo island in the Hawaiian Island chain (ca 15 hours following the mainshock). Other islands in the western Pacific are similarly affected.

[1] 800915 - Year/Month/Day

During the following five hours, I described our earlier investigations of rock failure prediction in underground mines, theoretical and laboratory studies and presented the application of these studies to Peruvian seismicity. I discussed in some detail the application of our predictive techniques to the February 9, 1971, San Fernando earthquake (M6.6). I showed that this event could have been predicted on 21 March 1969, to within 1.5 days of its actual occurrence and that its probable magnitude would have been M6.5. In addition, characteristics of this earthquake, such as the direction of greatest energy release and the focal mechanisms of its dominant aftershocks could have been accurately foreseen nearly 8 years prior to its occurrence. For example, the near failure of the van Norman dam, located near the mainshock epicenter could have been predicted. In addition, I discussed that, as outgrowth of this work, the so-called Palmdale uplift in southern California, currently a subject of much study by the U.S.G.S., is not the forerunner of a major earthquake, but simply the result of processes that led to the San Fernando earthquake. I indicated that the subsidence of a major portion of the Palmdale bulge is simply due to the culmination (upper mantle relaxation) of the San Fernando earthquake preparation process. However, the SE portion of the bulge which formed during the early 1970's is not due to the San Fernando event per se, but rather may signify the result that the preparation process of an event (~M7) near the Salton sea region has begun.

Dr. William Spence and I discussed evidence rebutting possible arguments that the earthquake sequence which developed off the coast of central Peru on October 3, November 9, 1977, "destressed" the region or that the subduction process along the coast of Peru is aseismic. No member of the audience refuted our arguments, and the arguments that the subduction process along the Peruvian coast is anomalous. In addition, recent historical earthquakes (16th century - present) along the coast could not have provided the necessary slip between the continental and oceanic lithospheres (convergence rate estimated to be 10→11cm/yr).

I presented observational evidence obtained by seismicity patterns showing that the October 3, 1974, mainshock (M_w8.1) could have been predicted to within 12 hours of its occurrence on July 26, 1974 with a magnitude M_t8.2 and that the sequence would terminate on November 20, 1974. The sequence terminated on November 18, 1974.

Memorandum to Robert Marovelli, Washington, D. C.

The predicted earthquake rests strongly on the hypothesis that the oceanic plate between 7°S and 25°S is "locked", that is, the plate is under horizontal compression normal to the coast. Oceanographic evidence, obtained by Kulm, et al., of the School of Oceanography, Oregon State University for the Nazca Plate Project was presented. Their data indicate that the ocean trench between 6°S and 27°S exhibits reverse faulting (horizontal compression). Ocean trenches are widely recognized as being formed by normal faulting (horizontal "tension"). Focal mechanisms of several recent earthquakes (1960-1973) in the trench obtained by W. Stauder, St. Louis University, show reverse faulting between 6°S and 25°S and normal faulting north of 6°S and south of 25°S. These data were presented to the group as strong evidence that the ocean plate has not been decoupled betweeen 6°S and 25°S. Evidence was put forth showing that the seismicity within these latitude extremes is low and that the "quiet" zone (area ≈ 550,000 km^2) is bounded by an "annulus" of intense seismicity[2]. These types of seismicity patterns have been observed prior to the San Fernando earthquake and numerous earthquakes in Japan and the Aleutians.

It is my belief that evidence for anomalous seismicity patterns, both spacially and temporally, exist which indicate that the oceanic and continental lithospheres along central-southern Peru and northern Chile are "locked" and that this region is in the phase which will culminate in catastrophic failure. The seismicity patterns that I have used for the prediction (time-place-magnitude) of the mainshock and the similarities these patterns show with the retrodicted San Fernando earthquake and predicted rock bursts are striking. These data were presented to the group.

---

[2] Seismic quiescence refers to the overall seismicity prevailing between 7°S and 25°S within a band of approximately several hundred kilometers inland along the coast (the band thins to approximately 100 km south of 16° latitude. There are local regions near Lima (11.6°S 76.5°W; 12°S, 7.8°S) where low magnitude (~M5)events can be expected. These regions and their existence were discussed at the meeting.

Members of the U.S.G.S. (Menlo Park) were invited by Dr. Filson to comment on the presentation. The central themes of their comments were:

1.) The theory is very difficult to understand.

2.) The data (San Fernando and Peru) must be written up and critically evaluated.

3.) The relevance of laboratory and mine failure data to the "real" world of earthquakes requires further study.

4.) The San Fernando data are interesting, but would other independent scientists come to identical conclusions?

5.) If we (U.S.G.S.) comment "officially" or study the prediction and, by doing so, lend credence to Brady's theory, our earthquake prediction program will be placed in jeopardy if the earthquake does not occur. One member of the audience then commented that if the earthquake does occur and the U.S.G.S. had done nothing, members of the U.S.G.S. may be required to provide details to high level government officials as to why there was no response.

We agreed to plan detailed documentation on the San Fernando and Peru earthquakes to critical U.S.G.S. scientists in the near future.

The meeting was adjourned at 4:30 p.m.

V. Hooker, W. Spence and I held discussions with Drs. L. Ocolo and D. Huaco following the meeting on a program to study the prediction. Additional discussions with the Peruvians will be held on an as-needed basis.

Brian T. Brady

United States Department of the Interior
GEOLOGICAL SURVEY
Box 25046
Denver Federal Center
Denver, Colorado 80225

IN REPLY REFER TO:

August 1, 1979

Memorandum

To: Bob Engdahl, Jerry Eaton, and others

From: Bill Spence WJSpence

Subject: Comments on the 24 May 1979 meeting on earthquake hazards in Peru

During this meeting Brian Brady and I made presentations on the prediction of a catastrophic earthquake series to begin about late July 1981 off the west coast of South America, rupturing the coastal zone between 6-8°S and 25-27°S. My comments were largely confined to plausibility arguments for the occurrence of this earthquake, based on the tectonic setting of this zone and on the nature of recent large earthquakes there. After a lengthy review of his work, Brady outlined the actual prediction of the earthquake, based on an interpretation of regional earthquake data in terms of his inclusion theory of earthquakes. This prediction originated as a forecast by Brady (1976).

I found the discussion during the meeting both interesting and useful. Because certain members of the audience were negatively critical of this prediction, I have reexamined the arguments Brady and I presented to see if my position should be retrenched. As a result of this reexamination, I feel more strongly that a very great earthquake could occur in the zone of the predicted earthquake and that geophysical studies there could be of real benefit to general seismic hazards studies and to the understanding of earthquake precursors.

My conclusions are: 1) aseismic slip is not significantly operative along the west coast of South America and that a minimum of 10 m uncompensated slip exists in the zone of the predicted earthquake; 2) horizontal E-W compressive stress exists in this zone, acting across the Peru-Chile Trench and into the shallow South American Plate. This reflects a present-day coupling between the Nazca and South American Plates; and 3) the series of five great coastal earthquakes that have occurred in central Peru since 1940 have not destressed coastal central Peru. The facts germane to my position are given as an appendix to this memo. My conclusions differ substantially from the critical review comments of Dewey (1979), who utilized a blend of published results,

data, and "ad hoc" arguments for Peru tectonics to state that aseismic slip could explain the apparent seismic slip discrepancy in central coastal Peru.

Some of the discussion of the 24 May 1979 meeting touched on fundamental philosophical aspects of the nature of the scientific method. Because there is no accepted physical paradigm for earthquake prediction, the field has seen a succession of attempts at such paradigms. Because those desiring to predict earthquakes do not know exactly what to look for, the field appears to be concerned primarily with a broad range of data collection and hypothesis testing. So it is natural that a precise prediction that is based on a particular one of the available physical theories be dealt with in a very conservative manner. It appears to be easier to accept and investigate vague forecasts such as Cape Yakutaga (USGS press release), Nicaragua (Dave Harlow), Oaxaca (Ohtake, and others, 1977), or even Assam (Khattri and Wyss, 1978), because these forecasts are based on the generally accepted empirical paradigm of the seismic gap. The Appendix presents plausibility arguments for the predicted earthquake series, in terms of the seismic gap paradigm.

I am actively pursuing my research on the earthquake hazard potential in Peru and Chile and am working with Brady in the documentation of the Peru-Chile prediction (Brady and Spence, 1980). critical part of the prediction is a foreshock series to commence in early September, 1980. Independently of these specific foreshocks, it is possible that seismic activity will dramatically increase in the entire zone around what will be the primary aftershock zone of the predicted earthquake, including possibly a very large intermediate-depth, normal-faulting earthquake occurring downdip from the predicted hypocenter. If the predicted foreshock activity does not occur, then the probability of occurrence of the predicted main shock will be lowered considerably, and we will make this revised status a matter of record.

If the predicted earthquake does occur, and if Peru is to have the opportunity of a precise prediction, then the Peruvians will need assistance in processing and interpretation of data obtainable from their networks of seismographs, strain meters, etc. Moreover, they will need assistance in bringing up programs to measure and interpret other important data, such as in situ stress variations, tilt changes, radon emanation, and regional deformation.

Seismic slip discrepancy in Peru and northern Chile

Southern Peru and northern Chile. The bight from southern Peru to northern Chile is the source region of two great tsunami-producing earthquakes, rupturing the coastal zone between about 16°S and 24°S, in 1868 and 1877. According to Abe (1979) these two events were among the largest ten tsunami-producing earthquakes of the circum-Pacific zone to have occurred during the years 1837-1974; he approximates the magnitudes of each of these earthquakes as 9.0, based on wave heights measured at Hakodate, Japan. Figure 1 shows these earthquakes in relation to the most recent major and great earthquakes that have occurred along the west coast of South America and which represent abutting ruptures along this zone. For the coastal zone 9°S-45°S, the zone of these earthquakes has gone the longest without a major earthquake (Kelleher, 1973; Kelleher and McCann, 1976). The convergence rate between the Nazca and South American Plates between 9°S-26°S is about 10 cm/yr and appears to be among the highest present-day convergence rates, globally (Minster and others, 1974; Minster and Jordan, 1978). Because most seismic slip occurs with the very largest earthquakes, there may be about 10-11 m of uncompensated slip in this zone, assuming that aseismic slip is not a major process here and assuming that the 1868 and 1877 earthquakes were decoupling events. McCann and others (1978), in their global compilation of the seismic potential of major plate boundaries, indicate this zone as one of the largest with their rank of 'highest seismic potential.'

Central Peru. This zone, between 9°S and 16°S, has experienced a sequence of five events of $M_S \geq 7.8$ since 1940. Prior to 1940, this zone would have appeared as a major seismic gap. It is fortunate that Silgado (1973) has compiled an authoritative account of the earthquake history of Peru, dating from the first years of Spanish settlement. Central coastal Peru experienced significant earthquakes in 1584, 1586, 1687, 1725, 1746, 1806, 1828, 1904, 1913, 1932, 1940, 1942, 1966, 1970, and 1974. Of these, the great earthquake of 1746 is by far the largest event. Silgado's account of this event, which describes the seismic sea wave and the destruction in Lima and el Callao, is given as Appendix B. Relative plate motions indicate a seismic slip potential of about 23 m for the time interval following the 1746 earthquake to the present. The earthquake series beginning in 1940 (1940, M_S=8.0; 1942, M_S=8.1; 1966, M_S=7 3/4-8; M_S=7.8; and 1974 M_S=7.8) comprises the largest earthquakes in central Peru since the 1746 earthquake and these can directly account for 2-3 m of seismic slip. Thus, assuming that aseismic slip is not significantly operative in central Peru, and that the 1746 earthquake was a decoupling event, there is approximately 20 m of uncompensated slip in this zone.

Northern Peru. This zone extends from 5°S to 9°S. The Carnegie Plateau extends beyond northern Peru, from 5°S to 1°S and is a large shoal region south of the Carnegie Ridge (Anderson and others, 1976).

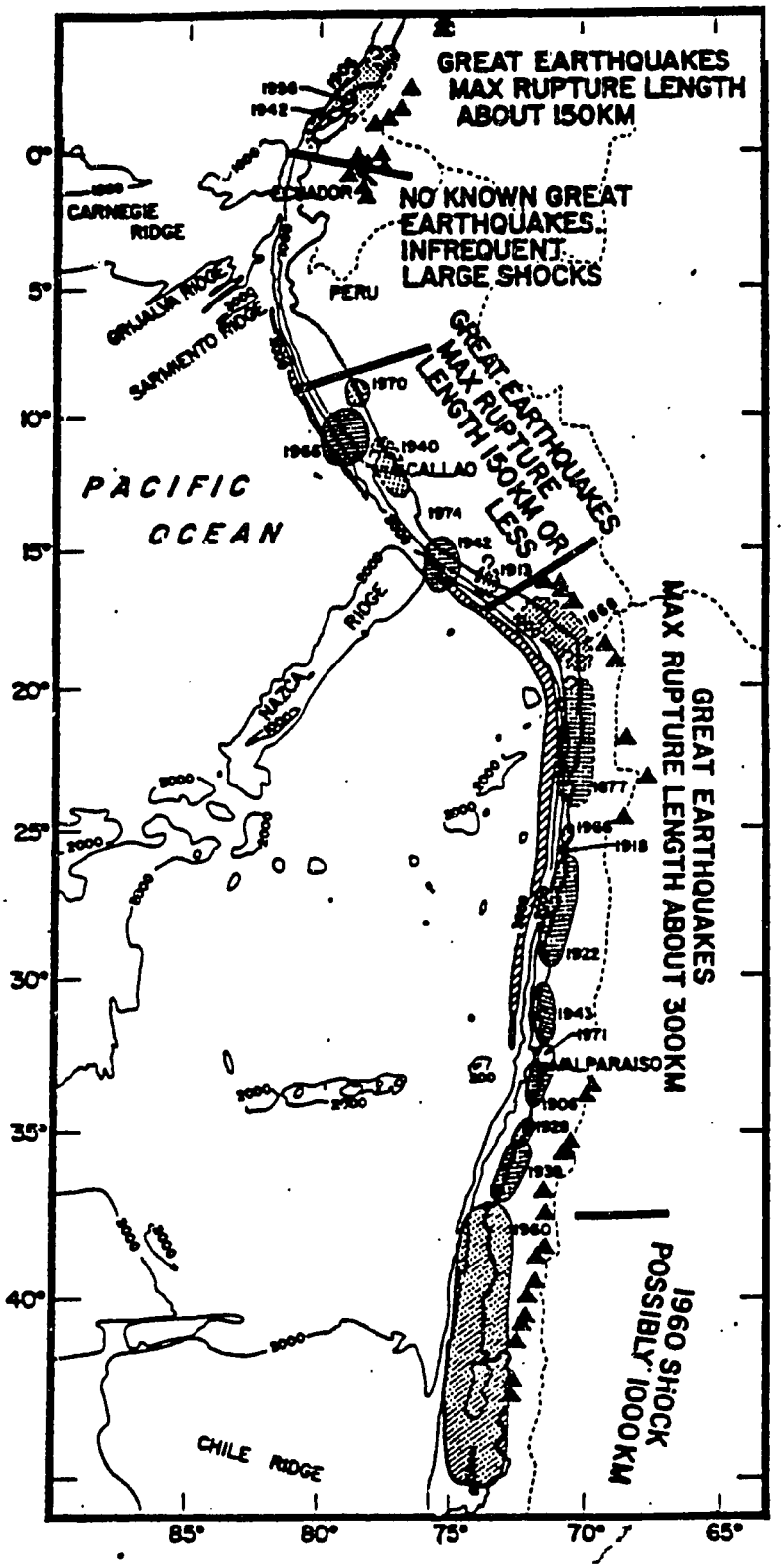


Figure 1. The most recent major and great earthquakes occurring at the west coast of South America, whose rupture zones abut such as to fill most of this plate boundary (Kelleher and McCann, 1976). The largest earthquakes shown here are those of 1868 (M_w=9.0), 1877 (M_w=9.0), and 1960 (M_w=9.5). The 1746 central Peru earthquake was considerably larger than any in the series of five great ($M_s \geq 7\ 3/4$) earthquakes occurring there since 1940. Note the absence of great shocks near the intersection of the massive Carnegie ridge complex with Peru-Ecuador. Solid triangles show active volcanoes and indicate the segmented nature of zones of active volcanism in western South America.

Figure 1 reflects the absence of great historical earthquakes in this zone; moderate-to-large earthquakes have occurred in northern Peru in the years 1759, 1906, 1912, 1917, and 1953 (Silgado, 1973). Mammerickx and others (1975) state that the oceanic crust north of the Mendaña Fracture Zone (located near 9°S at the Peru-Chile Trench) is significantly younger than that in coastal central Peru. It is unknown whether the thinner and more buoyant oceanic crust north of the Mendaña Fracture Zone is capable of storing stresses necessary for the occurrence of a great earthquake.

Evidence against aseismic slip

The following three units present considerable evidence for a strong seismic coupling between the Nazca and South American Plates. In light of this evidence, it is prudent to conclude that the minimum seismic slip discrepancies given in the previous section are uncompensated and represent a potential for future seismic activity.

Shallow horizontal compressive stress in the continental plate. Numerous shallow earthquakes occur in the continental crust of western South America. Focal mechanisms for the larger of these earthquakes in Peru have been determined by Stauder (1975) and these focal mechanisms share the property that the axis of maximum compression is nearly horizontal and parallel to the relative slip vector(E-W) between the Nazca and South American Plates. This suggests that the stress state at the interface between the Nazca and South American Plates is coupled across this boundary into the South American Plate. Mendiguren and Richter (1978), using Stauder's results and their own observations of thrust faulting in the middle of the Nazca Plate and in the eastern South American Plate, conclude that the whole lithosphere between the East Pacific Rise and the Middle Atlantic Ridge is subject to a dominant deviatoric compressional stress.

In a comprehensive survey of the seismic vs. aseismic subduction question, Uyeda and Kanamori (1979) conclude that subduction zones where aseismic slip is a documented phenomenon tend to have back-arc spreading (the shallow crust being under horizontal tension), reflecting a decoupling between the subducting plate and the overriding plate. The type case of Uyeda and Kanamori for totally seismic (coupled) plate motion is southern Chile, where the shallow continental crust is under horizontal compression. A similar tectonic environment exists for Peru and northern Chile.

There is considerable intermediate-depth seismicity inland of the predicted earthquake; focal mechanisms exist for the larger of these earthquakes (Stauder, 1973 and 1975) and indicate shallow-dipping (downdip) extensional stress axes and steeply-dipping compressional stress axes. In Peru those earthquakes lie directly beneath the line of large continental crust earthquakes. The intermediate-depth earthquakes appear to be within subducted plate and are most likely related to the vertical tectonics of the Andean mountain chain, rather than reflecting

insipient back-arc opening in the continent. This stress state at intermediate depths coexists with a pervasive horizontal compressive stress state at shallow depths. Molnar and Atwater (1978) relate the very active cordilleran tectonics of western South America to horizontal compressive stresses acting there, resulting from the particular character of the local subduction process.

These facts argue for the existence of a strong mechanical coupling between the South American Plate and the subducting Nazca Plate and are at odds with contentions that aseismic slip is significantly operative in the zone of the predicted earthquake.

Segmentation of seismic and volcanic zones. Numerous authors have pointed out the segmented nature of the seismic zone and the volcanic arc in Western South America (for example, Barazangi and Isacks, 1976 and 1979; Isacks and Barazangi, 1977; Stauder, 1973 and 1975; Swift and Carr, 1975; Kelleher and McCann, 1976; Sillitoe, 1974). The seismic zone segments are identified by characteristic dips of hypocenters in depth sections taken perpendicular to the axis of the Peru-Chile Trench. Sections of hypocenters that dip about 30°E are found in southern Peru/ extreme northern Chile, and in central Chile. Apparently flat seismic sections beneath the South American Plate are found for northern and central Peru and for northcentral Chile. These two 'flat' sections are anomalous and represent the shallowest dipping Benioff zones in the world (Isacks and Molnar, 1971; Uyeda and Kanamori, 1979), assuming that the spatial distribution of mantle earrthquakes is the best criterion for mapping the location of lithosphere slabs in the upper mantle (for example, Barazangi and Isacks, 1979). Figure 2 shows hypocenter cross-sections for the two flat zones and the intervening zone of 30° dip, with an inset of Benioff-zone dips for other subduction zones. The rapid transitions of depth profiles between adjacent sections are interpreted as zones where the subducting Nazca Plate is highly contorted or actually torn.

Typical subduction zones are characterized by a smooth, narrow lineation of volcanoes, some 110-175 km above the inclined seismic zone. Two extensive sections of the volcanic lineation in western South America no longer have active volcanism. These volcanically nonactive sections closely correspond to the 'flat' seismic sections (Barazangi and Isacks, 1979). If the flat sections of assumed Benioff zones are subducting the South American Plate in their entirety, then these sections are in contact with the bottom of the South American Plate for a width of about 500 km. This degree of contact between plates should offer great resistance to the subduction of the Nazca Plate and in effect increase the coupling between plates. The absence of volcanism above the 'flat' seismic sections may be due to a combination of a lack of aesthenospheric partial melt material above these sections of subducting plate and the high horizontal compressive stesses there which would act to inhibit the production of partial melt material (Sykes, 1972; Brady, 1976; Barazangi and Isacks, 1976; Spence, 1977).

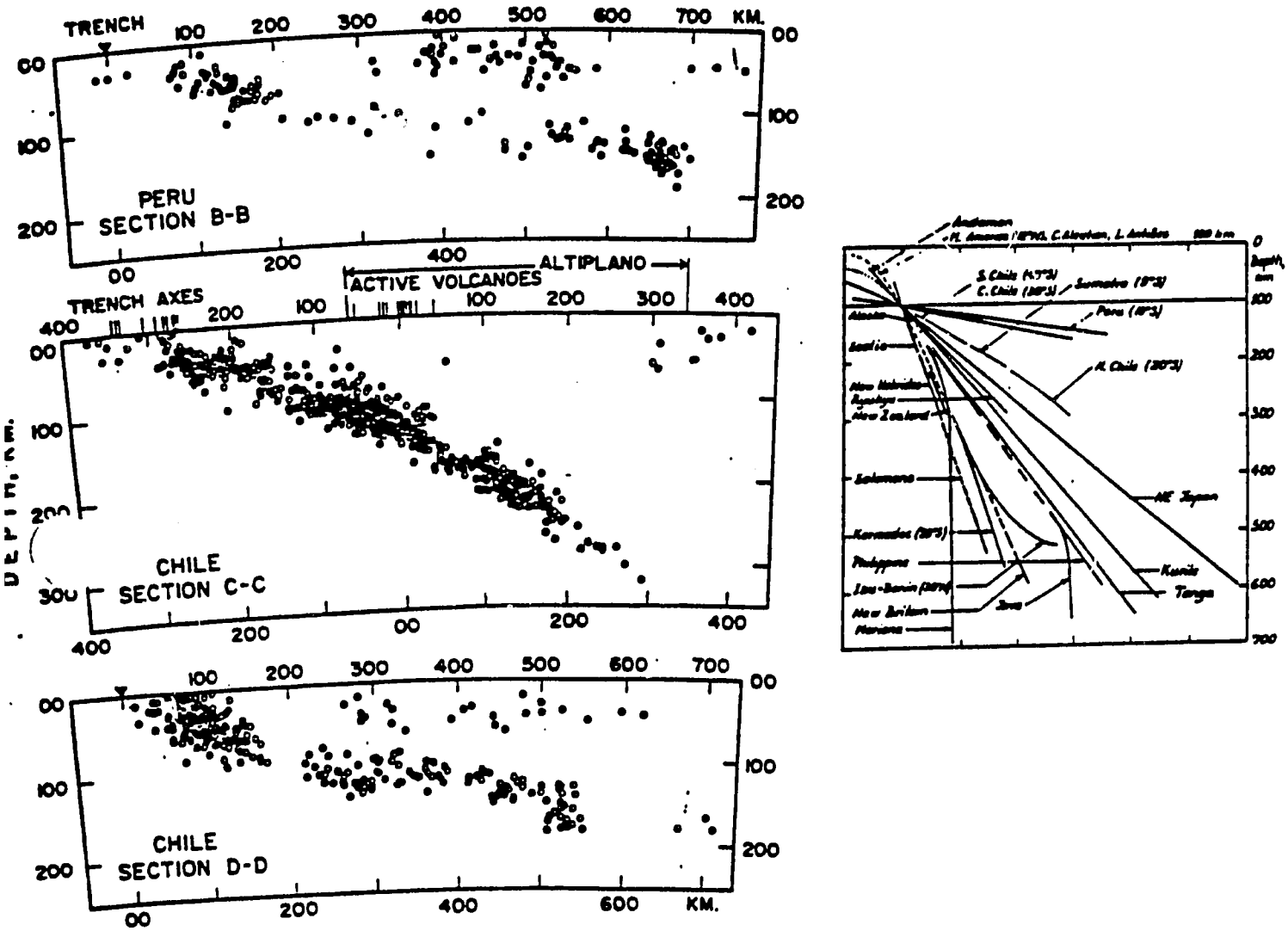


Figure 2. Seismicity cross-sections, taken perpendicular to the axis of the Peru-Chile Trench (Barazangi and Isacks, 1976), for central Peru (Peru section B-B), southern Peru/northern Chile (Chile section C-C), and central Chile (Chile section D-D). Section C-C has a dip of about 30°E and corresponds to the same coastal section of southern Peru and northern Chile for which there is active volcanism (Fig. 1). Sections B-B and D-D have an apparent dip of about 10°E and correspond closely to the zones of Peru and Chile where volcanism is not currently active. Dips of the major global subduction zones (as inferred from mantle seismicity) show that the 10° subduction angle in Peru and central Chile is anomalous (Uyeda and Kanamori, 1979).

The southern terminus of the predicted earthquake (25°-27°S) abuts the northern edge both of the 'flat' seismic section and of the nonactive volcano section of northcentral Chile (Figure 1), possibly near the coastal extension of the Challenger Fracture Zone (Schweller and others, in press; Mammerickx and others, in press). Extensive new bathymetric and seismic reflection coverage of the Peru-Chile Trench shows that a major structural break exists there at about 27°S (Schweller and Kulm, 1978). The northern terminus of the predicted earthquake (6°-8°S) is near the coastal extension of the Mendaña Fracture Zone (Mammerickx and others, 1975; Prince and Kulm, 1975; Hussong and others, 1976).

State of stress at the Peru-Chile Trench. Globally, oceanic trenches appear to be tensional features, marking the zones where plate consumption is initiated. The global association of normal-faulting earthquakes (reflecting an extensional stress condition) near oceanic trenches and pretrench rises is a well-documented phenomenon (summarized in Spence, 1977 and Hanks, 1979). Isacks (see Sykes, 1971) and Stauder (1973) have found normal-faulting mechanisms for a number of earthquakes occurring seaward following the 1960 Chilean earthquake, which was predominently a thrust-faulting earthquake (Plafker and Savage, 1970; Kanamori and Cipar, 1974; Ben-Menahem, 1971). Normal-faulting earthquakes near the Aleutian Trench occurred following the great Aleutian arc thrust faulting earthquakes of 1957, 1964, and 1965; these normal-faulting events have been interpreted as resulting from a decoupling between the oceanic and continental lithospheres and reflecting landward motion of the oceanic plate past the trench position (Spence, 1977; Hanks, 1979). Independent studies at the Aleutian Ridge indicate that following the 1965 Rat Island earthquake, low stess levels existed there and that the overriding continental plate was decoupled from the Pacific plate. These studies were based on strain and seismicity effects of subsequent nuclear explosions (Toksöz and Kehrer, 1972; Engdahl, 1972) and on in situ stress measurements on Amchitka Island (Carr and others, 1971). Aside from the periodic occurrence of great earthquakes at the Aleutian arc, the numerous tectonically formed canyons, that are tranverse to the Aleutian arc and perpendicular to the local relative plate motion vector, provide evidence that high stress levels do periodically occur at the Aleutian Ridge (Spence, 1977; LaForge and Engdahl, 1979).

Stauder (1973 and 1975) shows numerous focal mechanism solutions near the western edge of the South American Plate that indicate horizontal compressive stress but gives solutions for only three earthquakes associated with the Peru-Chile Trench located from about 36°S to 8°S. Two of these, between 26°S and 28°S, show thrust and thrust with strike-slip mechanisms while the event at 10.6°S also had a thrust with strike-slip mechanism. Thus, the seismic evidence on the stess state at the Peru-Chile Trench, between 8°S and 26°S, while scanty, does provide direct seismological evidence for active compressive stress across the trench. The available focal mechanisms for this zone of the Peru-Chile Trench are anomalous with respect to

mechanisms north and south of this zone and with respect to mechanisms determined for trench-associated earthquakes in other subduction zones.

Following the Peru earthquakes of 1966, 1970, and 1974, large zones between the Peru-Chile Trench and the aftershock zones exhibited virtually no teleseismically locatable earthquake activity. Dewey and Spence (1979) interpreted zones as potential sites of future earthquake activity. There is low seismicity near the Peru-Chile Trench for the zone from 6°-8°S to 25°-27°S, except near the intersection of the Nazca Ridge with the trench, at about 15°S. Direct evidence for compression at the Peru-Chile Trench is given by geologic mapping there. Axial ridges in the Peru-Chile Trench, between 6° and 10°S, are suggested as resulting from thrust faulting at the trench axis (Prince and Kulm, 1975). Datable turbidite deposits have been elevated on the seaward wall of the Peru-Chile Trench, at 7.33°-8.50°S; Prince and others (1974) interpret this deformation as resulting from compressional stress there. A 900 m-high basaltic ridge at the trench axis near 9°S. (Kulm and others, 1973; Prince and Kulm, 1975) and apparently analogous but smaller ridges in northern Chile (Schweller and others, 1980) are further evidence for thrusting in the Peru-Chile Trench. Schweller and others (1980) provide evidence for very shallow extensional stresses, seaward of the Peru-Chile Trench, that are interpreted as surficial features due to the initial downbending of the subducting Nazca Plate. Extensive marine terraces in northern Peru provide evidence for recent, rapid uplift in that coastal zone (R. C. Bucknam, personal communication, 1978); similar terraces are believed to exist throughout the zone of the predicted earthquake.

These seismic and geologic indications of compressional stress acting across the Peru-Chile Trench, of segmentation of the seismic and volcanic zones, and of horizontal compressive stress in the shallow continental plate, are evidence for an anomalous subduction mode at the west coast of South America, in that subduction of the Nazca plate is inhibited by the particular tectonic environment that exists there. The very high long-term average convergence rate between the Nazca and South American Plates coupled with the presently inhibited subduction process suggest that high levels of compressive stress have recently (geologically speaking) accumulated in the zone of the predicted earthquake.

Recent large earthquakes in central Peru

The five great earthquakes (M_S>7 3/4) that have occurred in central Peru since 1940 are considered by many to have been a seismic-gap filling episode, even though they can directly account for only 2-3 m of seismic slip. The detailed prediction by Brady and myself considers these earthquakes as part of the tectonic preparation process that will culminate in the 1981 earthquake series and thereby close what appears to be the Earth's largest seismic gap.

We know very little of the 1940 and 1942 central Peru earthquakes, other than their size and location. Figure 3 shows the teleseismically-located aftershocks of Dewey and Spence (1979) that occurred in the 31 days following the main shocks of 1966, 1970, and 1974. One notable result of this study is the "patchy" nature of these three aftershock zones. This suggests that the 2-3 m of slip calculated for these earthquakes is not spread uniformly over the subduction zone interface between 8° and 15° S. The 1966 and 1970 earthquakes generated peak accelerations at Lima that were an order of magnitude greater than would be expected at the corresponding epicentral distances (Cloud and Perez, 1971). The work of Dewey and Spence (1979) suggests that these very anomalous accelerations could be the result of high stress drops during the respective mainshocks. The 1970 mainshock was a normal-faulting earthquake (Abe, 1971; Stauder, 1975) that apparently triggered steeply-dipping thrust activity in a patch that is spatially separate from the initial main shock rupture (Dewey and Spence, 1979). Because the two 1970 earthquake zones are at the same distance from the trench axis and are at the same narrow depth range, it appears that pronounced stress changes may exist along the strike of the subduction zone.

The patchy nature of these three aftershock zones, the lack of aftershocks at the Peru-Chile trench, and the possible high stress drops for the 1966 and 1970 earthquakes suggest that these events were not decoupling earthquakes and that the Nazca and South American plates there remain coupled.

The aftershocks of the 3 October 1974 earthquake are distributed in a T-shaped pattern. As is shown in Figure 4, the main branch of the 'T' is 80-100 km off the coast and parallel to it for a length of about 220 km. The other branch is perpendicular to the first at its approximate mid-point and extends down-dip to beneath the coastal town of Chilca. A well-constrained composite focal mechanism for the largest earthquakes in the perpendicular-to-coast trend indicates predominantly right-lateral faulting with a small thrust component, in contrast to the nearly pure thrust mechanisms for the 3 October 1974 and 9 November 1974 earthquakes (Langer and Spence, 1978). Their investigation also shows that the aftershock series has an anomalously low 'b-value' of 0.65 and, excepting the large aftershock occurring near the end of the primary aftershock series (9 November 1974; M_S=7.1), aftershock magnitudes were smaller than m_b=5.5. Spence and Langer (1978) have studied the space-time seismicity of the aftershock series and observe that the aftershocks of October 3-24, 1974, occurred in four mutually exclusive groups, the activity oscillating from the offshore branch to the perpendicular-to-coast (Chilca) branch. During the two quiet times of the Chilca Branch, even extremely small earthquake activity was greatly diminished, as indicated by seismograms from regional seismographs operated in Chilca. During the two active phases of the offshore branch, aftershocks regularly oscillated between the northern and southern ends, jumping a gap that is 100-150 km long. Since 18 November 1974, there has been active seismicity outside the primary aftershock

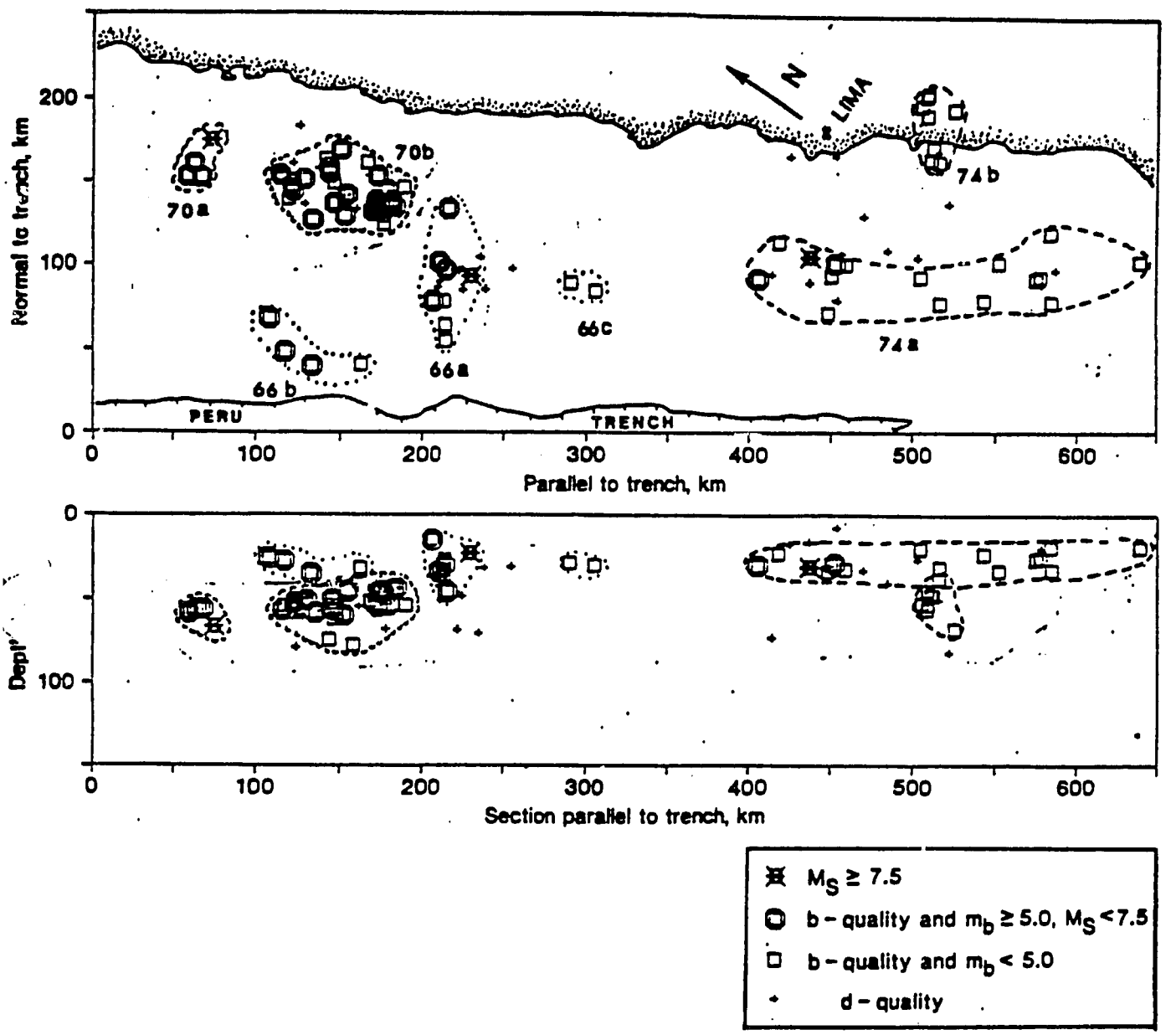


Figure 3. Aftershock zones for the 1966, 1970, and 1974 Peru earthquakes, based on high-quality relocated events occurring during the 31-day period following each main shock (Dewey and Spence, 1979). The 70b and 74b aftershock patches may represent triggered activity as these patches do not contain the corresponding main shocks and focal mechanisms for earthquakes in these patches are distinct from focal mechanisms for the corresponding main shocks (Dewey and Spence, 1979; Langer and Spence, 1978).

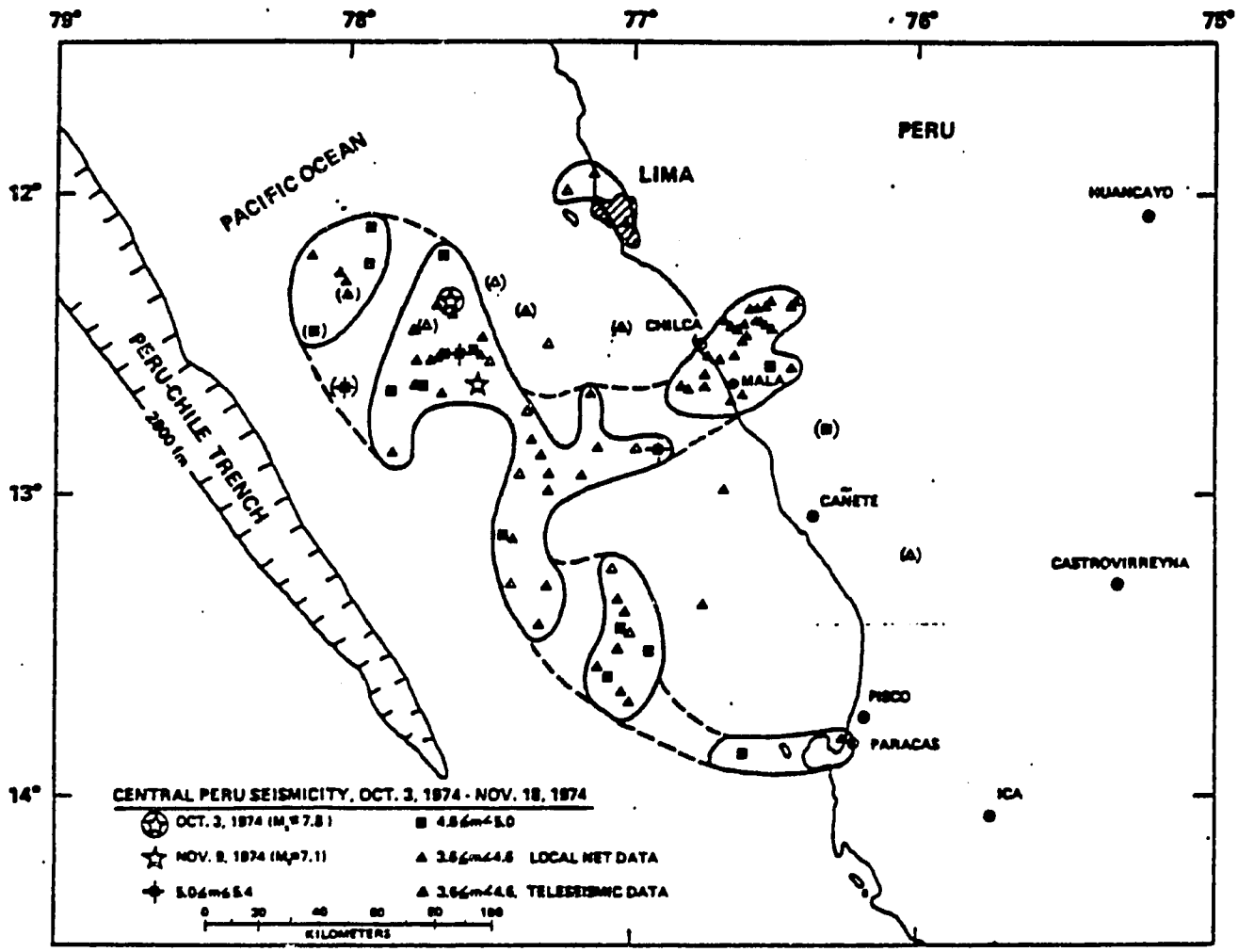


Figure 4. Aftershock zone pf the 1974 Peru earthquake, based on epicenters relocated using a consistent set of station corrections. Epicenters enclosed within parentheses have high standard error.

zone, particularly at or outside the NW, NE, and SE corners of the zone, and well inland of the aftershock zone.

Some aspects of the detailed prediction

This section departs from the data description and plausibility argument format and deals with interpretations of the 1974 earthquake data. The ocurrence of aftershocks in mutually exclusive groups and the oscillation of aftershocks in the offshore group (largely involving events of m_b<5.0 and therefore events of short rupture lengths) may imply that changes in stress at one location must somehow be communicated to other locations, that is, the events are not random. If the offshore zone was largely destressed by the mainshock and aftershocks were due to localized stress concentrations induced by the mainshock, then the aftershocks would essentially be isolated (random) events. However, if the entire zone was in a near-critical compressive stress state, then a small earthquake could result in a weakened patch and the regional stress load would then be supported to a slightly greater degree elsewhere throughout the zone. This could lead to a triggering of an earthquake where the stress was nearest to critical. The contradiction within this explanation is that if the compressive stress state were near-critical, then a rupture initiation would propagate until the regional stress field could no longer sustain crack growth. That is, large aftershocks would soon follow the mainshock (as is normally observed; Utsu, 1969) rather than occurring near the termination of the primary aftershock sequence as in the 1974 Peru series. One could argue that the stress criticality implied by the oscillation of aftershocks was relieved by the occurrence of the 9 November 1974 aftershock, particularly as it was located near the center of the aftershock zone. Indeed, foreshock activity to the disastrous Tangshan earthquake of 27 July 1976 (M_w=7.5, Kanamori, 1977) oscillated in separate NS and EW sequences over the subsequent mainshock epicenter. (Dr. Tan, Chief, Peking Geophysical Institute, PRC, personal communication, May 1979). The essential questions here are not only whether the primary aftershock series of the 3 October 1974 earthquake in fact was also a foreshock series of the 9 November 1974 event, but also whether the entire 1974 earthquake sequence is precursory to the earthquake predicted to nucleate very near the 9 November 1974 hypocenter in July 1981.

As presented at the 24 May 1979 meeting, Brady's analysis leading to the prediction of the 1981 earthquake takes the entire offshore limb of the 1974 earthquake series to be inclusion-zone-forming events for the predicted earthquake. This means that these 1974 aftershocks are contained within an annulus of very high compressional stress that bounds an inner volume of very high and constant tensional stress. The points of occurrence of these 1974 events reflect 'bends' in the annulus of high compressional stress that localized further stress concentrations, whereas the Chilca events reflect triggered activity,.

In this context, the 1974 sequence reflected a process giving the inclusion zone a more regular shape, prepartory to further stress concentration. I feel that this interpretation cannot be discounted, particularly in the light of plausibility evidence for uncompensated slip in the zone of the predicted event. Aside from the predicted 1981 earthquake, a foreshock series is predicted to commence in September 1980 with locations very near the 9 November 1974 hypocenter and with magnitudes in the teleseismic range. It is also likely that pre-1981 seismicity will increase outside the predicted aftershock zone. It is also possible that a large intermediate-depth, normal faulting earthquake could occur downdip from the predicted 1981 hypocenter, as occurred on 5 January 1974 prior to the 3 October 1974 earthquake (Spence and Langer, 1978) and as have occurred prior to great underthrust earthquakes in Japan (Mogi, 1973).

The seismological data that Brady has employed for the precise prediction of the mainshock and foreshocks are distinctive space-time seismicity patterns that began in central Peru on 26 August 1966. These data are specific spatial patterns of seismicity that are alternatively active and quiet. The durations of active and quiet seismicity are simply related to each other and to the overall physics of the evolution of the stress regime that is predicted to lead to catastrophic failure in Peru and northern Chile (Brady, 1980; Brady and Spence, 1980). Brady has used similar data in the successful retrodiction of the 9 February 1971 San Fernando earthquake (M_L=6.6) and of the 26 November 1975 Hawaii earthquake (M_S=7.2); he has also used similar space-time seismicity patterns in successfully predicting low-magnitude rockbursts in Idaho (Brady, 1980).

Concluding Remarks

The preceding evidence for potential seismic slip at the zone of the earthquake predicted by Brady and myself, gives tectonic plausibility to this specific prediction. A complete analysis of the data leading to the prediction, including plausibility arguments and the relationship of current and historical seismicity to the inferred stress regime, is now in preparation by Brady and myself. If the predicted earthquake occurs, then this documentation (Brady and Spence, 1980) should provide a paradigm for future earthquake prediction work. If the predicted earthquake does not occur, then at least a complete documentation of an attempt to predict a significant earthquake, through direct use of Brady's inclusion theory of earthquakes, will be a matter of record. The paper will be complete and ready for publication by the time of the first predicted foreshock (September, 1980). If the predicted foreshock activity does not occur, then the probability of the occurrence of the predicted main shock will be lowered considerably, and we will make the revised status a matter of record.

The prospect of an earthquake of the predicted size (M_w=9.8, M_o=7 x 10^{30} dyne-cm) is awesome. Chinnery and North (1975), in their analysis of cumulative frequency of global earthquakes vs. seismic moment, conclude that the possibility exists that extremely large

earthquakes ($M_o \geq 10^{31}$ dyne-cm) may recur from time to time. I believe that the subduction environment off the west coast of South America is more favorable to the occurrence of an extremely large earthquake than that for most other subduction zones, globally. Certainly, our short record of instrumental seismic data (≈80 yrs) is insufficient to preclude the possible occurrence of such an earthquake.

The tectonic environment in the zone of the predicted earthquake is recognized as one of very high seismic potential. The current program for acquisition and interpretation of seismic data for seismic hazard evaluation in this zone is less than optimal, simply in terms of the recognized seismic hazard there. If the predicted foreshocks do occur, beginning about September 1980, then a comprehensive program to gather a wide range of precursory data to permit a refined prediction, in terms of the inclusion theory of earthquakes, is obviously of the highest importance. Because the first of the primary foreshocks gives only a ten-month lead time for the mainshock, such a prediction program should be fully ready to implement before September 1980.

There are many additional studies that could be undertaken to tighten the plausibility arguments given here, such as discussed in Spence and Pakiser (1978). Studies of wave forms of pre-1974 earthquakes relative to wave forms for the many earthquakes now occurring offshore of Chile, at about 25°-28° S, and in continental Peru could provide information on the space-time character of the relevant stress regime. Focal mechanisms should be determined for additional relevant earthquakes. It would be useful to deconvolve the source functions of the 1966, 1970, and 1974 Peru earthquakes. The earthquakes of the study area should be relocated, probably by the joint hypocenter method (Dewey, 1971). A detailed mapping and age-dating of the extensive uplifted marine terraces in the study zone should be accomplished. Other researches would also be enlightening but time constraints dictate that those important to the prediction itself be given first priority.

The predicted earthquake could present an unparalled opportunity to gather precursory data, as the relevant geophysical measurements should be greatly above noise level, thus proving valuable for our own national effort in earthquake prediction. Brady and I have given considerable thought to the overall program that would permit a fine-tuning of the parameters of the predicted event but this is not addressed here. While the predicted earthquake is not located in the United States it is in our "hemisphere" of friends. We have a further national interest in this possible event because the lives of U.S. nationals in Peru and Chile could be jeopardized and, moreover, the accompanying tsunami could generate destructive wave heights at the Hawaiian Islands and throughout the Pacific Basin.

REFERENCES

Abe, K., 1972, Mechanisms and tectonic implications of the 1966 and 1970 Peru earthquakes, Phys. Earth Planet. Int., 5, 367-379.

Abe, K., 1979, Size of great earthquakes, 1837-1974 inferred from tsunami data, J Geophys. Res., 84, 1561-1568.

Anderson, R. N., Langseth, M. G., Vacquier, V., and Francheteau, J., 1976, New terrestrial heat-flow measurements on the Nazca Plate, Earth Planet. Sci. Lett., 29, 243-254.

Barazangi, M., and Isacks, B., 1976, Spatial distribution of earthquakes and subduction of the Nazca Plate beneath South America, Geology, 4, 686-692.

Barazangi, M., and Isacks, B., 1979, Subduction of Nazca Plate beneath Peru: evidence from spatial distribution of earthquakes, Geophys. J. R. astr. Soc., 57, 537-555.

Ben-Menahem, A., 1971, The force system of the Chilean earthquake of May 22, 1960, Geophys. J. Roy. astron. Soc., 25, 407-417.

Brady, B. T., 1976, Theory of earthquakes, IV, General implications for earthquake prediction, Pure Appl. Geophys., 114, 1031-1082.

Brady, B. T., 1976, Theory of earthquakes, 3, Inclusion collapse theory of deep earthquakes, Pure Appl. Geophys., 114, 119-139.

Brady, B. T., 1980, Thermodynamics of failure (in preparation).

Brady, B. T. and Spence, W., 1980, The prediction of a great earthquake off the coast of Peru and northern Chile (in preparation).

Carr, W. J., Gard, L. M., Bath, G. D., and Healey, D. L., 1971, Earth science studies of a nuclear test area in the western Aleutian Islands, Alaska: An interim summary of results, Geol. Soc. Am. Bull., 82, 699-706.

Chinnery, M. A. and North, R. G., 1975, the frequency of very large earthquakes, Science, 190, 1197-1198.

Cloud, W. K., and Perez, V., 1971, Unusual accelerograms recorded at Lima, Peru, Bull. Seism. Soc. Am., 61, 633-640.

Dewey, J. W., 1971, Seismicity studies with the method of joint hypocenter determination, Ph.D. Thesis, Univ. Calif. Berkeley.

Dewey, J. W., 1979, Memorandum to E. R. Engdahl and others, 6 May 1979, Analysis of the potential for a massive (M_w>9.0) thrust-fault earthquake in the region of central Peru from the seismic gap viewpoint, 5 p. (with 2 figs.).

Dewey, J. W., and Spence, W., 1979, Seismic gaps and source zones of recent large earthquakes in coastal Peru, Pure Appl. Geophys. (in press).

Engdahl, E. R., 1972, Seismic effects of the Milrow and Cannikin explosions, Bull. Seism. Soc. Am., 62, 1411-1423.

Hanks, T. C., 1979, Deviatoric stresses and earthquake occurrence at the outer rise, J. Geophys. Res., 84, 2343-2350.

Hussong, D. M., Edwards, P. B., Johnson, S. H., Campbell, J. F., and Sutton, G. H., 1976, Crustal structure of the Peru-Chile trench: 8°-12°S. latitude, in The geophysics of the Pacific Ocean basin and its margin, Am. Geophys. U. Monog. 19, ed. by Sutton, G. H., Manghnani, M. H., and Moberly, R., Wash., D.C., 71-85.

Isacks, B., and Molnar, P., 1971, Distribution of stresses in the descending lithosphere from a global survey of focal-mechanism solutions of mantle earthquakes, Rev. Geophys. Sp. Phys., 9, 103-174.

Isacks, B., and Barazangi, M., 1977, Geometry of Benioff zones: Lateral segmentation and downwards bending of the subducted lithosphere, in Island Arcs, Deep Sea Trenches and Back Arc Basins, 99-114, ed. by Talwani, M. and Pitman, W., Am. Geophys. U., Ewing Series 1.

James, D. E., 1978, Subduction of the Nazca Plate beneath Central Peru, Geology., 6, 174-178

Kanamori, H., 1977, The energy release in great earthquakes, J. Geophys. Res., 82, 2981-2987.

Kanamori, H., and Cipar, J. J., 1974, Focal process of the great Chilean earthquake of May 22, 1960, Phys. Earth Planet. Int., 9, 128-136.

Kelleher, J. A., 1972, Rupture zones of large South American earthquakes and some predictions, J. Geophys. Res., 77, 2087-2103.

Kelleher, J. and McCann, W., 1976, Buoyant zones, great earthquakes, and unstable boundaries of subduction, J. Geophys. Res., 81, 4885-4896.

Khattri, K., and Wyss, M., 1978, Precursory variation of seismicity rate in the Assam area, India, Geology, 6, 685-688.

Kulm, L. D., Scheidegger, K. F., Prince, R. A., Dymond, J., Moore, T. C., Jr., and Hussong, D. M., 1973, Tholeiitic basalt ridge in the Peru Trench, Geology, 1, 11-14.

LaForge, R. and Engdahl, E. R., 1979, Tectonic implications of seismicity in the Adak Canyon region, central Aleutians, Bull. Seism. Soc. Am., 69, (in press).

Langer, C. J., and Spence, W., 1978, a study of the aftershocks of the October 3, 1974, earthquake (abs), Earthquake Notes, 49, 54.

Mammerickx, J., Anderson, R. N., Menard, H. W., Smith, S. M., 1975, Morphology and tectonic evolution of the east-central Pacific, Geol. Soc. Am. Bull., 86, 111-118.

Mammerickx, J., Herron, E., and Dorman, L., 1980, Evidence for two fossil spreading ridges in the southeast Pacific (submitted to Geol. Soc. Am. Bull.).

McCann, W. R., Nishenko, S. P., Sykes, L. R., and Krause, J., 1978, Seismic gaps and plate tectonics: seismic potential for major plate boundaries, in Proceedings of Conference VI, Methodology for identifying seismic gaps and soon-to-break gaps, U.S. Geol. Surv. Open-File Rpt. 78-943, 441-584.

Mendiguren, J. A., 1971, Focal mechanism of a shock in the middle of the Nazca Plate, J. Geophys. Res., 76, 3861-3879.

Mendiguren, J. A., and Richter, F. M., 1978, On the origin of compressional intraplate stresses in South America, Phys. Earth Planet. Int., 16, 318-326.

Minster, J. B., and Jordan, T. H., 1978, Present-day plate motions, J. Geophys. Res., 83, 5531-5354.

Minster, J. B., Jordan, T. H., Molnar, P., and Haines, E., 1974, Numerical modelling of instantaneous plate tectonics, Geophys. J. Roy. astron. Soc., 36, 541-576.

Mogi, K., 1973, Relationship between shallow and deep seismicity in the westrn Pacific region, Tectonophysics, 17, 1-22.

Molnar, P., and Atwater, T., 1978, Interarc spreading and cordilleran tectonics as alternates related to the age of subducted oceanic lithosphere, Earth Planet. Sci. Lett., 41, 330-340.

Ohtake, M., Matumoto, T., and Latham, G. V., 1977, Seismicity gap near Oaxaca, Southern Mexico as a probable precursor to a large earthquake, Pure App. Geophys., 115, 375-385.

Prince, R. A., and Kulm, L. D., 1975, Crustal structure and the initation of imbricate thrusting in the Peru-Chile Trench, Geol. Soc. Am. Bull., 86, 1639-1653.

Prince, R., Resig, J. M., Kulm, L. D., and Moore, T. C., Jr., 1974, Uplifted turbidite basins on the seaward wall of the Peru Trench, Geology, 2, 607-611.

Schweller, W. J. and Kulm, L. D., 1978, Extentional rupture of oceanic crust in the Chile Trench, Mar. Geol., 28, 271-291.

Schweller, W. J., Kulm, L. D., and Prince, R. A., 1980, Tectonics, structure and sedimentary framework of the Peru-Chile Trench, in Geol. Soc. Am. Memoir on the Nazca Plate Project (in press).

Silgado, E., 1973, Historia de los sismos mas notables ocurridos en el Peru (1555-1970), Geofisica Panamerica, 2, 179-243 (USGS translation, 1978).

Sillitoe, R. H., 1974, Tectonic segmentation of the Andes: Implications for magmatism and metallogeny, Nature, 250, 542-545.

Snoke, J. A., Sacks, J. S., and Okada, H., 1977, Determination of the subducting lithosphere boundary by use of converted phases, Bull. Seism. Soc. Am., 67, 1051-1060.

Spence, W., 1977, The Aleutian arc: Tectonic blocks, episodic subduction, strain diffusion, and magma generation, J. Geophys. Res., 82, 213-230.

Spence, W., and Langer, C. J., 1978, A notable space-time distribution for the 1974 Peru aftershocks (abs), Earthquake Notes, 49, 53-54.

Spence, W. and Pakiser, L. C., 1978, Conference report: Toward earthquake prediction on the global scale, EOS, 59, 36-42.

Stauder, W., 1973, Mechanism and spatial distribution of Chilean earthquakes with relation to subduction of the oceanic plate, J. Geophys. Res., 78, 5033-5061.

Stauder, W., 1975, Subduction of the Nazca Plate under Peru as evidenced by focal mechanisms and by seismicity, J. Geophys. Res., 80, 1053-1064.

Swift, S. A., and Carr, M. J., 1975, The segmented nature of the Chilean seismic zone, Phys. Earth Planet. Int., 9, 183-191.

Sykes, L. R., 1971, Aftershock zones of great earthquakes, seismicity gaps, and earthquake prediction for Alaska and the Aleutians, J. Geophys. Res., 76, 8021-8041.

Sykes, L. R., 1972, Seismicity as a guide to global tectonics and earthquake prediction, Tectonophysics, 13, 393-414.

Toksöz, M. N. and Kehrer, H. H., 1972, Tectonic strain release characteristics of Cannikin, Bull. Seism. Soc. Am., 62, 1425-1438.

Utsu, T., 1969, Aftershocks and earthquake statistics (I) — some paremeters which characterize an aftershock sequence and their interrelations, J. Fac. Sci. Hokkaido, Ser. VII, v. III, 129-195.

Uyeda, S., and Kanamori, H., 1979, Back-arc opening and the mode of subduction, J. Geophys. Res., 84, 1049-1061.

APPENDIX B

Description of damage and the seismic sea wave that accompanied the Peru earthquake of 28 October, 1746 (Silgado, 1973).

1725. 6 January, at 23:25. A notable seismic movement caused various damage in Trujillo. In the snow-capped peaks of the Cordillera Blanca a glacial lake was disrupted, overflowing and wiping out the village of Ancash near Yungay, killing 1500 people. The shock was felt in Lima.

27 March. Commotion of [illegible] a great earthquake. The village of Camaná suffered damage, the sea rose.

1739. In that year there was an earthquake which ruined the village of Santa Catalina, in the province of Aymaraes, department of Apurimac. Many of its inhabitants perished.

1746. 28 October, at 22:30. Earthquake in Lima and tsunami in el Callao. Probable intensity, X-XI MM

In a letter written to Father Bruno Morales of the same order, the reverend priest Lozano, a Jesuit, described how Lima before the earthquake "had arrived at the acme of perfection of which

a city of this New World was capable, for the sumptuousity of its buildings, the dwellings which adorned its well laid out streets (Fig. 3), its beautiful fountains, the dignity of its churches, and the construction of the monasteries, which could well compete with the grandest works of this kind in the world. But all this beautiful prospect which had been the object of the care and the loving attention of many years was reduced to dust in an instant." Of the 3,000 houses, distributed in 150 city blocks, only 25 remained standing. The principal and most solid buildings, the Cathedral, the arch at the entrance to the bridge which bore the statue of Philip IV, all fell. Monasteries, convents, hospitals, and many other structures likewise collapsed. According to the official report, 1,141 people perished in Lima, out of a total of 60,000 inhabitants; other chroniclers raised these figures in later days, for various reasons, and because of the epidemics which broke out.

In the harbor of el Callao (Fig. 4) nearly all the buildings lay in ruins, only a few towers and part of the walls remained: 192
a half hour after the spirits of the inhabitants had recovered, the sea rose up and, rising to a great height, burst over the town, inundating a large part of it; the returning sea carried with it everything it encountered in its path. Of the ships which were anchored in the bay, some were sunk, others lifted over the walls and cast ashore; a series of diminishing seismic

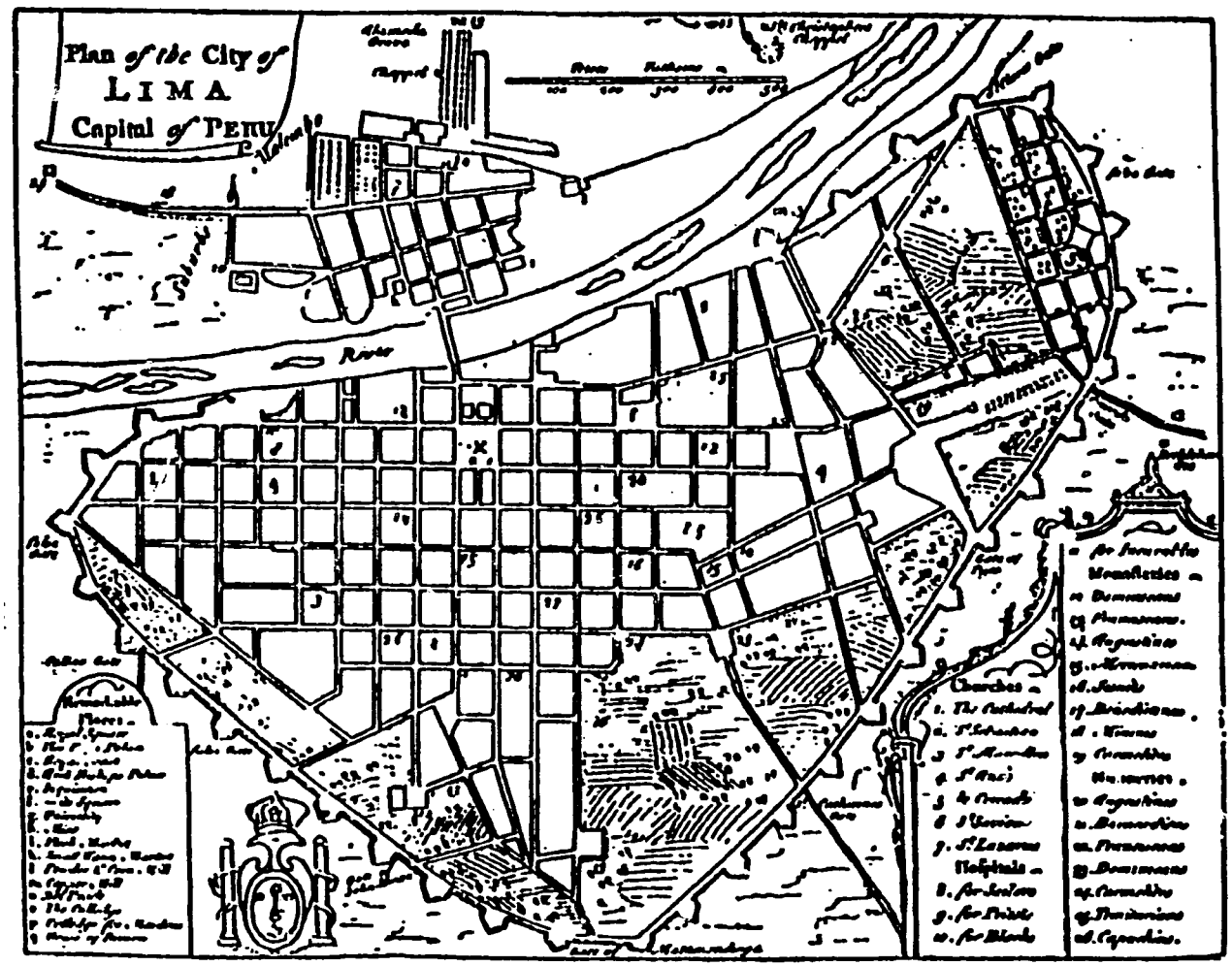


Fig. 3. Plan of the city of Lima before the earthquake of 1746.

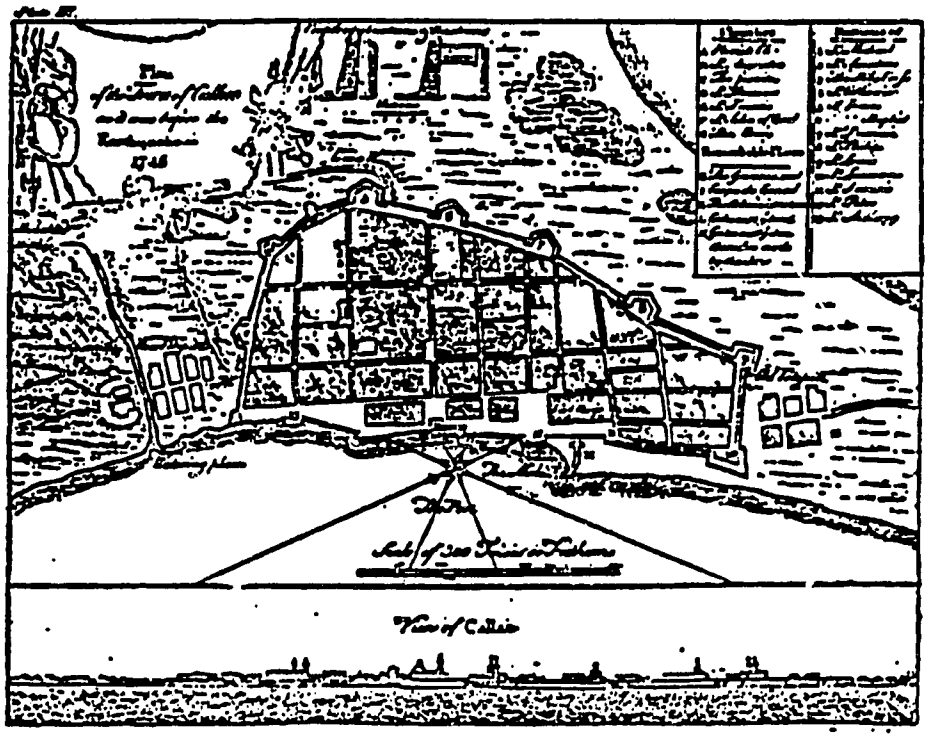


Fig. 4. Plan and profile of the Port of el Callao before the tsunami of 1746.

waves followed. It is reported that the sea advanced as much as a league inland. Of the 4,000 inhabitants who constituted the population of el Callao, only some 200 could be saved. The small coastal villages of Guañape and Caballas were obliterated by the tsunami.

To appreciate the destructive effects, the pleistoseismal area comprised about 44,000 km^2. Within this area, a solid bridge, built over the Huaura river about 120 km north of Lima, collapsed; the access roads to the interior were unusable due to landslides. In the Cerro de la Sal, at Chanchamayo, the

fortress was destroyed; many trees were uprooted, obstructing the access and roads of this mountain. The movement was felt in Guayaquil, 1,100 km NW of el Callao, and at the outpost of the Jesuit Missionaries situated at the confluence of the 193 Marañón river with the Huallaga, and with notable intensity at Huancavelica, SSE of Lima where there were strong ground shaking and noises. In some places in Lucanas (Ayacucho) there occurred fissuring of the ground and landslides. The seismic commotion could be felt at Cuzco and adjacent villages, and at Tacna.

Incursions of the sea were continuous over the whole Peruvian coast.

In the 24 hours which followed this formidable earth movement, some two hundred tremors were counted at Lima.

1747. In that year there occurred a strong shock whose date and month could not be ascertained as it occurred in a remote region of the department of Puno. It is known that it caused great destruction in Ayapata, Carabaya province; muddy water gushed from the earth and many people perished.

1759. 2 September, at 23:15. A strong shock claimed five victims in Trujillo and damaged structures; the cathedral suffered in its vaults, arches, and towers. It was felt along the coast between the village of San Pedro, Lambayeque, and the town of Santa. It was intensive in the villages of the hills of Huamachuco.

APPENDIX A

Plausibility Arguments for the Occurrence of a Catastrophic Earthquake in Coastal Peru and Northern Chile

Introduction

This appendix is a brief synthesis of data and published research on the tectonics of western South America. The subduction of the Nazca Plate beneath the South American Plate is anomalous relative to the other subduction zones of the Earth. This anomalous subduction process may arise from the very high rate of collision between these two plates and from the completely continental nature of the South American Plate. Most zones that are being subducted by an oceanic plate are themselves largely subcontinental, with typical island arc structure. The anomalous features of the subduction process in western South America, such as mapped imbricate thrust faulting in the Peru-Chile Trench or the segmented nature of the line of volcanoes, tend to complicate any treatment of South American tectonics. Indeed the geometry of the subducted Nazca Plate in Peru is the subject of some controversy (for example, James, 1978; Snoke and others, 1977; Barazangi and Isacks, 1979). The synthesis in this appendix provides considerable evidence on the nature of the stress field in western South America and evidence for the non-aseismic nature of the subduction process there. Such evidence is based on observed data and is independent of contemporary tectonic models for the zone of the predicted earthquakes.

The plausibility arguments for the occurrence of a catastrophic earthquake in coastal Peru and northern Chile are given in terms of the theory of plate tectonics and the seismic gap paradigm. A seismic gap is considered to exist when, in a zone of known large historical earthquakes, the time interval since the last large earthquake is sufficient for stresses that result from plate motions to have approached a level sufficient to result in another large earthquake. McCann and others (1978) indicate that this condition can result in gap-filling episodes that range from one earthquake to a complex series of earthquakes and that recurrent rupture sequences of a given gap zone need not occur in a particularly repeatable way. The crux of the plausibility arguments in this appendix centers on whether the apparent gap-filled area of central Peru has left this zone in a destressed state or whether a large degree of uncompensated seismic slip (implying high stress) remains there and that the sequence of five great earthquakes occurring since 1940 can therefore be viewed as preparatory (that is, foreshocks in the broad sense) to still a greater earthquake.

series. One could argue that the stress criticality implied by the oscillation of aftershocks was relieved by the occurrence of the 9 November 1974 aftershock, particularly as it was located near the center of the aftershock zone. Indeed, foreshock activity to the disastrous Tangshan earthquake of 27 July 1976 (M_w=7.5, Kanamori, 1977) oscillated in separate NS and EW sequences over the subsequent mainshock epicenter. (Dr. Tan, Chief, Peking Geophysical Institute, PRC, personal communication, May 1979). The essential questions here are not only whether the primary aftershock series of the 3 October 1974 earthquake in fact was also a foreshock series of the 9 November 1974 event, but also whether the entire 1974 earthquake sequence is precursory to the earthquake predicted to nucleate very near the 9 November 1974 hypocenter in July 1981.

As presented at the 24 May 1979 meeting, Brady's analysis leading to the prediction of the 1981 earthquake takes the entire offshore limb of the 1974 earthquake series to be inclusion-zone-forming events for the predicted earthquake. This means that these 1974 aftershocks are contained within an annulus of very high compressional stress that bounds an inner volume of very high and constant tensional stress. The points of occurrence of these 1974 events reflect 'bends' in the annulus of high compressional stress that localized further stress concentrations, whereas the Chilca events reflect triggered activity.

UNITED STATES GOVERNMENT

DOCUMENT NO. 010

Memorandum

TO : Rob Wesson

DATE: October 17, 1979

FROM : Bill Spence Bill S.

SUBJECT: Forecast of the Southern California earthquake of October 15, 1979

This earthquake apparently was forecast by Brian Brady during an OES Seminar held in Golden on May 11, 1978, and again during a meeting to discuss matters related to earthquake hazards in Peru, held in Golden on May 24, 1979. Copies of his seminar abstract and page 3 of his Bureau of Mines internal memo (dated June 19, 1979) on the Peru meeting, each of which make this forecast a matter of record, are attached. His statement in the Bureau of Mines memo is "...the SE portion of the bulge which formed during the early 1970's is not due to the San Fernando event per se, but rather may signify....that the preparation process of an event (~M7) near the Salton Sea region has begun." Concurrent with the forecast of this earthquake, Brady argued that the primary Palmdale uplift was directly related to the San Fernando earthquake, and as such, was not the forerunner of a major earthquake.

At the May 24, 1979 meeting, Brady applied his inclusion theory to the active elongate uplift zone located near the San Jacinto fault and southward into the Salton Sea region, to forecast the occurrence during the next few years of a magnitude 6.5 - 7.0 strike-slip earthquake in the Salton Sea region. At that time he had no information on the nature of southern terminus of this most recent zone of uplift and subsidence, particularly as it may extend into Mexico. At this meeting, he made a general appeal for access to seismicity data in this zone so that he could attempt a more precise estimate of the earthquake's magnitude, location, and time of occurrence. Eventually, these seismicity data should be analyzed using Brady's model.

This apparently successful forecast lends credibility to the statements of Brady and Spence on the primary topic discussed at the Peru meeting.

cc: J. Eaton
L. Pakiser
B. Wallace
T. Algermissen
B. Raleigh
J. Filson
B. Engdahl
J. Evernden
J. Dewey
J. Devine
H. Spall

Attachments: 2

(Brady, 1980).

Concluding Remarks

The preceding evidence for potential seismic slip at the zone of the earthquake predicted by Brady and myself, gives tectonic plausibility to this specific prediction. A complete analysis of the data leading to the prediction, including plausibility arguments and the relationship of current and historical seismicity to the inferred stress regime, is now in preparation by Brady and myself. If the predicted earthquake occurs, then this documentation (Brady and Spence, 1980) should provide a paradigm for future earthquake prediction work. If the predicted earthquake does not occur, then at least a complete documentation of an attempt to predict a significant earthquake, through direct use of Brady's inclusion theory of earthquakes, will be a matter of record. The paper will be complete and ready for publication by the time of the first predicted foreshock (September, 1980). If the predicted foreshock activity does not occur, then the probability of the occurrence of the predicted main shock will be lowered considerably, and we will make the revised status a matter of record.

The prospect of an earthquake of the predicted size (M_W=9.8, M_o=7 x 10^{30} dyne-cm) is awesome. Chinnery and North (1975), in their analysis of cumulative frequency of global earthquakes vs. seismic moment, conclude that the possibility exists that extremely large

(Please Post)

U.S. DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

BRANCH OF GLOBAL SEISMOLOGY
AND
BRANCH OF EARTHQUAKE TECTONICS AND RISK

JOINT SEMINAR

The 9 February 1971 San Fernando Earthquake:
A Case Study for Accurate Long-term Earthquake Prediction

by BRIAN T. BRADY, U.S. Bureau of Mines, Denver

ABSTRACT

Distinct seismicity patterns prior to and following the 9 February, 1971 San Fernando ...thquake (M_L = 6.4) could have been used to provide an accurate long-term prediction of this earthquake. Two observations can be drawn from the preseismicity data. First, three distinct periods of seismic quiescence each separated by periods of seismic activity, occurred within the eventual aftershock zone. The three quiet periods occurred between 13 May, 1948 and 2 August, 1953 (Q_0, 1908 days); 4 April, 1956 and 7 June, 1961 (Q_1, 1891 days); and 11 February, 1964 and 26 April, 1969 (Q_2, 1901 days). The three active periods occurred between 2 August, 1953 and 4 April, 1956 (A_0, 976 days); 7 June, 1961 and 11 February, 1964 (A_1, 979 days); and 26 April, 1969 and 9 February, 1971 (A_2, 653 days). Second, all seismic activity during the quiet periods occurred outside or along the boundaries of the eventual aftershock region. All seismic activity during the active periods occurred within the aftershock region.

Analysis of these data show four important results. First, a total of fourteen events, termed PIZ forming events, ranging from M_L = 2.0 to 3.0, occurred in the immediate neighborhood of the impending mainshock epicenter during the A_1 active phase. These events mapped out an irregularly-shaped zone that closely mimicked what was to be the aftershock zone. Second, the irregular geometry of the PIZ indicated that the mainshock would be preceded by a foreshock sequence and that this foreshock activity would be confined to a very localized region close to the epicenter of the mainshock. Theoretical calculations, based on data available 11 February, 1964, are used to show this active phase would last approximately 648 days. Third, a reliable first "prediction" that an earthquake (M_L = 6.5) would occur in late January 1971 could have been made any time between 11 February, 1964 and 26 April, 1969 (time of the first foreshock). Fourth, on 21 March, 1970 (occurrence time of fourth foreshock) a "prediction" update of the mainshock to 11 February, 1971 could have been issued.

The theoretical bases for these calculations and their reliability are presented. In addition, rupture characteristics of the mainshock as well as the observed space-time and focal mechanism anomalies of the aftershock sequence are readily understood as a result of the geometrical characteristics of the PIZ that formed during the A_1 phase.

Lastly, evidence will be presented that suggests there will be no major earthquake in the Palmdale region of the well-publicized crustal uplift "anomaly." Theoretical calculations indicate that a major portion of this uplift was associated only with physical processes that produced the San Fernando earthquake. However, the southeastern portion of the uplift which developed in the early-to-mid 1970's was not associated with the San Fernando mainshock and consequently this region should be investigated for its earthquake potential.

COLORADO SCHOOL OF MINES
1711 Illinois Street
Golden, Colorado

May 11, 1978
Thursday, 3:00 p.m.
Conference Room
(Entrance Level, Room 207)

Post-seminar discussion at location to be announced.

For further information please call 303-234-4041

relevant earthquakes. It would be useful to deconvolve the source functions of the 1966, 1970, and 1974 Peru earthquakes. The earthquakes of the study area should be relocated, probably by the joint hypocenter method (Dewey, 1971). A detailed mapping and age-dating of the extensive uplifted marine terraces in the study zone should be accomplished. Other researches would also be enlightening but time constraints dictate that those important to the prediction itself be given first priority.

The predicted earthquake could present an unparalled opportunity to gather precursory data, as the relevant geophysical measurements should be greatly above noise level, thus proving valuable for our own national effort in earthquake prediction. Brady and I have given considerable thought to the overall program that would permit a fine-tuning of the parameters of the predicted event but this is not addressed here. While the predicted earthquake is not located in the United States it is in our "hemisphere" of friends. We have a further national interest in this possible event because the lives of U.S. nationals in Peru and Chile could be jeopardized and, moreover, the accompanying tsunami could generate destructive wave heights at the Hawaiian Islands and throughout the Pacific Basin.

During the following five hours, I described our earlier investigations of rock failure prediction in underground mines, theoretical and laboratory studies and presented the application of these studies to Peruvian seismicity. I discussed in some detail the application of our predictive techniques to the February 9, 1971, San Fernando earthquake (M6.6). I showed that this event could have been predicted on 21 March 1969, to within 1.5 days of its actual occurrence and that its probable magnitude would have been M6.5. In addition, characteristics of this earthquake, such as the direction of greatest energy release and the focal mechanisms of its dominant aftershocks could have been accurately foreseen nearly 8 years prior to its occurrence. For example, the near failure of the van Norman dam, located near the mainshock epicenter could have been predicted. In addition, I discussed that, as outgrowth of this work, the so-called Palmdale uplift in southern California, currently a subject of much study by the U.S.G.S., is not the forerunner of a major earthquake, but simply the result of processes that led to the San Fernando earthquake. I indicated that the subsidence of a major portion of the Palmdale bulge is simply due to the culmination (upper mantle relaxation) of the San Fernando earthquake preparation process. However, the SE portion of the bulge which formed during the early 1970's is not due to the San Fernando event per se, but rather may signify the result that the preparation process of an event (~M7) near the Salton sea region has begun.

Dr. William Spence and I discussed evidence rebutting possible arguments that the earthquake sequence which developed off the coast of central Peru on October 3, November 9, 1977, "destressed" the region or that the subduction process along the coast of Peru is aseismic. No member of the audience refuted our arguments, and the arguments that the subduction process along the Peruvian coast is anomalous. In addition, recent historical earthquakes (16th century - present) along the coast could not have provided the necessary slip between the continental and oceanic lithospheres (convergence rate estimated to be 10+11cm/yr).

I presented observational evidence obtained by seismicity patterns showing that the October 3, 1974, mainshock (M_w8.1) could have been predicted to within 12 hours of its occurrence on July 26, 1974 with a magnitude M_t8.2 and that the sequence could have been predicted to terminate on November 20, 1974. The sequence terminated on November 18, 1974.

Brady, B. T., 1976, Theory of earthquakes, IV, General implications for earthquake prediction, Pure Appl. Geophys., 114, 1031-1082.

Brady, B. T., 1976, Theory of earthquakes, 3, Inclusion collapse theory of deep earthquakes, Pure Appl. Geophys., 114, 119-139.

Brady, B. T., 1980, Thermodynamics of failure (in preparation).

Brady, B. T. and Spence, W., 1980, The prediction of a great earthquake off the coast of Peru and northern Chile (in preparation).

Carr, W. J., Gard, L. M., Bath, G. D., and Healey, D. L., 1971, Earth science studies of a nuclear test area in the western Aleutian Islands, Alaska: An interim summary of results, Geol. Soc. Am. Bull., 82, 699-706.

DOCUMENT NO. 011

United States Department of the Interior

GEOLOGICAL SURVEY
Box 25046
Denver Federal Center
Denver, Colorado 80225

IN REPLY REFER TO:

October 26, 1979

Ing. Alberto A. Giesecke
Jefe del Instituto Geofisico del Peru
Apartado 3747
Lima 100, Peru

Dear Alberto:

This is our preliminary recommended program, per your telephone request of October 23, 1979, to detect possible short-term precursors to the predicted July 1981 main shock. While this program is designed to monitor key geophysical factors relating to the predicted event, it can, of course, be utilized for general seismic hazard studies in Peru. Please understand that this draft represents only a first iteration and the actual location and number of sites, particularly those involved in the in situ stress measurement and the short-baseline geodetic sites, would be chosen only after factors relating to economics and ease of access are considered. These comments and recommendations represent our opinions only and should not be construed as representing official positions of our respective agencies.

We believe that two recent developments increase the probability of occurrence of the predicted earthquake and should increase the general acceptability of the Peru prediction. First, the apparent success of the "El Centro," California earthquake forecast by B. Brady (see accompanying memorandum of W. Spence to R. Wesson). Both this forecast and the Peru prediction have been based on the inclusion theory of earthquake occurrence. Second, here is the independent finding by Dr. V. Kulm of Oregon State University of major subsidence on the Peruvian continental shelf between about 11.8°S and 13.5°S. The amount of subsidence is about 500 m in the central portion of the continental shelf and further westward increases to about 1,000 m; there is no evidence of such anomalous subsidence in the vicinity of the Peru trench (personal communication by Kulm to Spence, September 1979). Kulm further indicated that, for considerable distances both north and south of the subsidence zone, the continental shelf shows no evidence for either subsidence or uplift. Kulm thought that this subsidence has

occurred near the end of the last 5 x 10^6 years, a time consistent with Brady's theoretical preparation time of 8.6 x 10^5 years for the predicted July 1981 earthquake. Dr. Kulm is currently preparing a manuscript wherein the subsidence data are discussed in detail. We believe that this independent finding provides the first direct physical evidence for the existence of the predicted earthquake's inclusion (nucleation) zone (see memorandum of Brady to R. Maravelli, June 5, 1978, p. 6, for inclusion zone location). The volume surrounding the inclusion zone, of course, should have the property of a contracting volume, reflecting a "tightening up" as stress is concentrated there. To maintain the independence of Kulm's findings, we have not yet informed him of our interpretation of his data, particularly in regards to the predicted location and geometry of the hypothesized inclusion zone.

We are of the opinion that the theoretical arguments presented at the May 24, 1979, meeting, the plausibility arguments also presented there (as summarized in Spence's memorandum of August 1, 1979), and the "El Centro" forecast and Peruvian subsidence facts move the status of the prediction significantly forward. A critical part of the prediction is a foreshock series to begin about early September 1980. If earthquakes occur that have the properties of the predicted foreshocks, then we feel that the seismological establishment will view the main shock prediction as having a high enough probability to encourage a thorough search for main shock precursors.

In the recommended program, we have concentrated on five classes of measurements that will permit a continuing evaluation of the prediction status. The elements in this program have differing priorities. Moreover, the highest priority region for all data is 11.5°S-14.0°S. The most important sites for the various measurements are asterisked on the attached sheet.

1. *Seismicity*. We believe seismicity data to be the most important class of data. Ultimately near real-time location of the events offshore of Lima will be needed (this should be implemented when we are sure the foreshocks have begun). The number of seismometers in the zone from 6°S to 12°S should be increased, particularly in the zone that extends to about 100 km north of Lima. The network in the greater Lima region should have hypocenter location resolution to within several kilometers for events of Ml.0. Key stations should be telemetered to a central recording facility; if foreshocks begin then this facility should be earthquake-proofed, and located outside Lima. The addition of at least one ocean bottom seismometer would greatly enhance the detection of very short-term seismicity precursors near the epicenter of the predicted main shock.

foreshocks. Some combination of Peruvian governmental directives and proposals to USAID should allow this to become a reality. We view the seismicity data as critical. Probably U.S. contracted consultants (for example, Woodward and Clyde) should be involved to assure that the key seismic data is reduced on a day-to-day basis. The short baseline geodetic, in situ stress, and radon measurements will have to be taken periodically, say each week, if the final diagnostic variations in these quantities are to be detected. These can be simple-to-make measurements, once the procedures are established. Direct Peruvian government requests through the U.S. Department of State requesting United States assistance in designing and/or setting up radon and in situ stress experiments could permit these experiments to be initiated at cost. Lamont-Doherty (seismic network), Scripps (ocean-bottom seismometers), and Carnegie (strain measurement) may be interested in being involved in the program. Brady and Spence could be requested, through the U.S. Department of State, to assist the Peruvian government on an as-needed basis to help coordinate the experimental design. USAID and Peru should pay for such involvements. Dr. Paul Krumpe is agreeable to such an arrangement.

We do not ourselves want to be involved in data reduction; this must be reliably done by IGP, and their collaborators and consultants. We will need all the time available to interpret the relevant data in making a prediction update; unfortunately, at this time, no other persons are really capable of such an interpretation in terms of the inclusion theory.

Alberto, please rest assured that we wish to help you in whatever way we can. We understand that a prediction such as this is going to be viewed conservatively and, yet, if something constructive is to be done, we have to take certain risks. We would never go out on a professional limb such as we are doing, if we did not objectively conclude that our assessment of the Peruvian situation is a whole lot more right than it is wrong.

Sincerely yours,

Brian T. Brady
U.S. Bureau of Mines
Denver Mining Research Center
Building 20
Denver, CO 80225

William Spence
U.S. Geological Survey
Office of Earthquake Studies
Box 25046, MS 967
Denver, CO 80225

Attachments (table and map)

2. *In situ stress*. These measurements should be made in hard-rock mines located along and near the coastline of central and southern Peru. The measurement device should be the 3-component borehole deformation gauge as developed by the U.S. Bureau of Mines. Once the three principal stresses have been determined at each site, vibrating-wire stress gauges (see D. Kusco for literature finished to IGP by the Bureau of Mines on this gauge) should be inserted into each borehole and long-term monitoring of stress changes at each site begun.

3. *Radon and other geochemical measurements*. These measurements should be taken in sites located in cities along the coast and within the interior. A dense two-dimensional geochemical measuring network should enable a determination of the lateral variations of any geochemical anomalies, such as might be induced during the final preparation process leading to the predicted main shock.

4. *Geodetic measurements*. These measurements are necessary to determine whether horizontal (E-W) contraction is operative along the central and southern Peruvian coast. A positive result here along with a high horizontal (E-W) stress, such as determined from in situ stress measurements, would provide a critical test of our hypothesis that the Nazca and South American plates are tightly coupled.

5. *Miscellaneous measurements*. Other important studies should include analysis of sea level changes from tide gauge data and geologic studies of shoreline elevation changes (including data from Ecuador and Chile), analysis of data from the Kyoto strainmeter network, and detection of possible very short-run electromagnetic anomalies (several hours to several days) prior to the predicted main shock.

—

While the accompanying site list is extensive and correspondingly expensive, we believe its implementation will greatly enhance the collection of geophysical data pertinent to prediction of the main shock. Should economic problems dictate a smaller number of sites, then it will be important to pay particular attention to those sites located between 11.5°S and 14°S (see site list), and we will be glad to advise you accordingly. We also believe sites for all measurements should be considered along the Chilean coast, say to 25-27°S, and that radon/measurements be taken at a few sites throughout the South American continent. In addition, in situ stress and short baseline geodetic measurements should be taken outside the predicted rupture zone ($\leq$7°S, $\geq$25°S). These stations would be invaluable in assessing the relative movements between the predicted "locked" and "unlocked" sections of the Nazca plate.

We feel that a good portion of the program should be operational or at least fully planned and ready to implement by the time of the predicted

Table 1.—Recommended sites for measurements

A. In situ stress measurements; hard rock mines

1. M_1 Salpo
2. M_2 Quiruvilca
3. M_3 Aija
4. M_4 *Nana
5. M_5 *Raul
6. M_6 *Condastable
7. M_7 Rio Seco
8. M_8 Monterrosas
9. M_9 Acari
10. M_{10} Posco

B. Radon and/or other possible geochemical precursors

1. R_1 Piura
2. R_2 Chiclayo
3. R_3 Trujillo
4. R_4 *Callao-Lima
5. R_5 Ica
6. R_6 Camana
7. R_7 Tacna-Arica
8. R_8 Arequipa
9. R_9 Puno
10. R_{10} Cuzco
11. R_{11} Huancavelica
12. R_{12} Huancayo
13. R_{13} Satipo
14. R_{14} Huanuco
15. R_{15} Pucallpa
16. R_{16} Iquitos
17. R_{17} Pto. Maldonado

C. Short baseline geodetic changes

1. Piura region
2. Chiclayo region
3. Trujillo region
4. Chimbote region
5. *Isla San Lorenzo-Callao zone
6. *Isla de Asia zone
7. *Paracas-Pisco (Isla San Gallan) zone
8. Huata-Isla Hormillos zone
9. Arica-Isla Alacran zone

D. Ocean Bottom Seismometer

Near 12.4°S., 77.8°W.

E. Additional seismometers in locations 6°-12°S, particularly in the 100 km north of Lima.

---

* Highest priority sites (located within 11.5°S - 13.5°S)


BRASIL
$M_1 \rightarrow M_{10}$ Possible mine sites for stress measurements
$R_1 \rightarrow R_{17}$ Possible sites for geochemical measurements
$G_1 \rightarrow G_9$ Possible sites for geodetic measurements
OB. Possible location (12.4°S, 77.8°W) for ocean bottom seismometer
INSTITUTO GEOFISICO DEL PERU
ESTACIONES SISMICAS
1976-
LEYENDA
Observatorios Sismicos
Terremoto NU
Glaa
I.G.P. (INIE)
ODECOB

October 30, 1979

DOCUMENT NO. 012

Memorandum

To: James P. Devine, Deputy Director, Office of Earthquake Studies, U. S. Geological Survey, Reston, Virginia

Through: Verne Hooker, Research Supervisor, Mine Structure Design, Denver Research Center

Harry R. Nicholls, Research Director, Denver Research Center

Donald G. Rogich, Director, Research Center Operations, Columbia Plaza, Washington, D. C.

From: Brian T. Brady, Physicist, Mine Structure Design, Denver Research Center

Subject: Seismicity data

Dr. Paul Krumpe, A.I.D./OFDA U. S. State DEPT. recently informed me of your agency's willingness to share seismicity and geodetic data concerning the recent El Centro, California earthquake. I would appreciate receiving, at your convenience, all seismicity data as based on readings from the USGS network and the cooperating Cal Tech seismic network from within a 50-mile radius of the mainshock epicenter from 1932 through 1979 up to the mainshock and including one to two weeks' aftershock data. I would also appreciate receiving results from the recent releveling survey in southern California once they are available.

Brian T. Brady

RES DIR
SUBJ
CHRON
ds

United States Department of the Interior

BUREAU OF MINES DOCUMENT NO. 013

BUILDING 20, DENVER FEDERAL CENTER
DENVER, COLORADO 80225
October 30, 1979

Memorandum

To: Robert L. Marovelli, Director, Mineral Health and Safety Technology, Columbia Plaza, Washington, D. C.

Through: Harry R. Nicholls, Research Director, Denver Research Center

From: Verne E. Hooker, Research Supervisor, Mine Structure Design, Denver Research Center

Subject: Peruvian earthquake studies

Attached is a response letter of comments and recommendations for a program of instrumentation for obtaining geophysical, in situ stress, and other data relevant to the subject for your review.

This letter is also being sent, by Spence, through similar channels in the USGS for their review.

Procedures for approval and mailing of interagency, jointly authored letters such as this is somewhat vague. In any event, the authors would like to have this response reviewed, approved, and mailed as soon as possible.

Verne E. Hooker

Verne E. Hooker

Enclosure

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

OPTIONAL FORM NO. 10
JULY 1973 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

TO : Rob Wesson

DATE: November 2, 1979

FROM : Bill Spence

SUBJECT: Transmittal of letter to Giesecke

For something approaching two years Alberto Gisecke, Director General of the Instituto Geofisico del Peru, has periodically requested that Brian Brady and myself suggest a program that could be implemented to detect precursors to the earthquake predicted to occur in Peru in early July 1981. We have heretofore declined to respond to these requests, even at an informal response level. His most recent request for such a program was on October 23, 1979. I feel that this is a reasonable request and ask that the attached program letter be forwarded to him by the Office.

Because of vague procedural lines for the transmitting of letters authored jointly by Department of Interior employees in different agencies, Brady is transmitting an identical letter on Bureau of Mines stationery through his agency.

Attachment

Ed. Note The letter to Dr. Giesecke which is an attachment hereto can be found under its date, October 26, 1979, in this volume.

DOCUMENT NO. 015

November 13, 1979

MEMORANDUM

TO: PDC/OFDA, Mr. W. R. Dalton, Assistant Director for Preparedness

FROM: PDC/OFDA, P. F. Krumpe, Science Advisor

SUBJECT: Recent Memoranda Concerning Peru Earthquake Prediction by Dr. Brady, U.S. Bureau of Mines (USBM)

Ref: (A) USGS Memo dated November 2, 1979 (Spence to Wesson, with attached letter to Alberto Giesecke, IGP)

(B) USGS Memo dated October 17, 1979 (Spence to Wesson, regarding Dr. Brady's forecast of "El Centro," California earthquake October 15, 1979)

(C) USBM Memo dated October 30, 1979 (Hooker to Marovelli), subject: Peruvian earthquake studies

(D) USBM Memo dated October 30, 1979 (Brady to Devine, USGS/OES), subject: Seismicity data

1. Reference A requests the Director, Office of Earthquake Studies (OES), U.S. Geological Survey (USGS) to forward the attached letter dated October 26, 1979 to Alberto Giesecke. Reference C, with an identical copy of the letter, has been submitted on Bureau of Mines stationery to the Director, Mineral Health and Safety Technology, Bureau of Mines, for transmission to Alberto Giesecke (IGP). The content of the letter, regarding an initial plan to monitor the predicted earthquake precursors, is in response to a request by Alberto Giesecke made at the May 24, 1979 meeting held at Golden, Colorado (see AID memo to Dalton from Krumpe, June 19, 1979).

2. Dr. Brady and Dr. Spence have told me that their participation in further development of a precursor identification and monitoring program will occur only when Giesecke and the Government of Peru (GOP) formally request such action through the Department of State. This action may occur in the near future as indicated in discussions with Giesecke last week.

3. Dr. Brady has officially requested (reference D) that the USGS/OES provide copies of the seismicity data as he has specified for the "El Centro," California earthquake (October 15, 1979) so that he can quantitatively test if (in retrospect) he could have accurately predicted the date, time, location and magnitude of the above event if the data had been available for the SE portion of the Palmdale uplift. James Devine (USGS/OES) is assisting Dr. Brady in obtaining this data which will be sent to him within several weeks. Dr. Spence's memo (reference B) indicates that Dr. Brady forecast (more than a year in advance) the increased likelihood of an event in the M7 range occurring in the Salton Sea area within a few years. This topic was also presented at the May 24 meeting at Golden, Colorado and was met with extreme skepticism. It appears now that Brady's prognostication should have been closely investigated with a view toward

greater understanding of the nucleation mechanism inherent to his inclusion theory. His forecast may well be supported by the seismicity data, in which case significant credibility will be added to the Peru case, although not constituting "a proof" of his theory.

4. Dr. Brady anticipates publication of his analysis of the "El Centro" event based on the inclusion theory (will focus increased attention on the basis for prediction of the September 1980 foreshock series for Peru). Should these events occur, as predicted, then international involvement in an intense, extensive disaster preparedness planning effort and earthquake precursor measurement program will undoubtedly commence. Dr. Brady and Dr. Spence are prepared to publish a comprehensive monograph on the prediction in fall, 1980.

5. The attached letter (October 26, 1979) to Alberto Giesecke from Dr. Spence (USGS) and Dr. Brady (Bureau of Mines) mentions that I have agreed (on behalf of OFDA) to arrangements indicated on page 4. The purpose of this memo is to clarify for the record that I have not (as one reading the memo may mistakenly assume) committed funds in support of Brady and Spence assisting the Peruvian Government on an as-needed basis to help coordinate development of the experimental design to document the predicted earthquake precursors. Rather, I have agreed to entertain proposals in support of efforts to develop a program to monitor and measure the anticipated precursors, and I have agreed to explore and help document every aspect of this prediction with a view toward meeting the objectives of P.L. 94-161 concerning earthquake prediction (Section 491(b)) and assuring continued scientific liaison and inquiry among USGS, Bureau of Mines, DOS, AID, and others as appropriate.

6. No agreements concerning commitment of AID/OFDA funds in this regard will be made without the full knowledge and prior clearance of Mr. Joseph A. Mitchell, Director, Office of U.S. Foreign Disaster Assistance and Mr. William Dalton, Assistant Director for Disaster Prepardeness Planning (OFDA). Additionally, AID/OFDA future action, in conjunction with the USGS and Bureau of Mines concerning proposed development of an experimental design and monitoring program, is currently predicated on a definitive request for technical assistance by the Peruvian Government to the U.S. Government.

Attachments:
as stated in references

Ed. Note The four documents attached hereto and as stated in references can be found under their respective dates in this volume.

cc: USGS: T. Algermissen
USGS: J. Devine
USGS: R. Wesson
USGS: J. Filson
USGS: W. Spence
USGS: A. Marranzino
USBM: B. Brady
USBM: V. Hooker
USBM: R. Marovelli
ARA/AND: J Purnell

November 13, 1979

To: James F. Devine, Deputy Director, Office of Earthquake Studies, U.S. Geological Survey, Reston, Virginia

Through: Fred Leighton, Acting Research Supervisor, Mine Structure Design, Denver Research Center

Verne E. Hooker, Acting Research Director, Denver Research Center

From: Brian T. Brady, Physicist, Mine Structure Design, DRC

Subject: Seismicity and Geodetic Data

As a follow-up to our telephone conversation of October 24, 1979, and my memorandum of October 30, 1979, I would appreciate receiving all seismicity data as based on readings from the U.S.G.S. network and the cooperating Cal Tech seismic network from within a 75 km radius of the October 15, 1979, ("El Centro", M_L = 6.8) mainshock epicenter from 1932 through 1979 up to the mainshock and including several weeks of aftershock data. The seismic data I require at this time include: 1) Origin time, 2) Latitude-Longitude, 3) Magnitude, 4) Source depth, and 5) quality of epicentral determination [(e.g., A - specially investigated (usually with portable seismographs)), B - epicenter probably within 5 km, origin time to nearest second, C - epicenter probably within 15 km, origin time to a few seconds, D - epicenter not known within 15 km, rough location].

I would also appreciate receiving results from the recent releveling survey in southern California once they are available. In particular, the data base used in the "News Release" - U.S.G.S., October 5, 1979, would be of considerable value to me in determining whether my forecast of this earthquake could have been improved to an accurate prediction had these data (seismicity and geodetic) been made available to me earlier

Thank you in advance.

REFER TO	INITIAL
HOOKER	
RUSSELL	

Brian T. Brady

BTBrady/lew
Chron
Subj.
Res. Dir.

Reports, Memoranda, Correspondence
and Other Communication

January - June, 1980

DOCUMENT NO. 017

United States Department of the Interior

GEOLOGICAL SURVEY
RESTON, VA 22092

In Reply Refer To:
Mail Stop 905

January 8, 1980

Mr. W. R. Dalton
Assistant Director for Preparedness
PDC/OFDA/AID
Washington, D.C. 20523

Dear Mr. Dalton:

We have received a copy of a memorandum (with enclosures) dated November 12, 1979, to you from Mr. P. F. Krumpe of your staff regarding the prediction of a major earthquake in Peru and related matters. This matter has caused me some concern and the purpose of this letter is to set down for you our position on the Peru prediction and the issues revolving around it.

The prediction of a catastrophic earthquake off the coast of Peru in the summer of 1981 stems from the work of Dr. Brian Brady of the Bureau of Mines and the ancillary efforts of Dr. William Spence of the U.S. Geological Survey (USGS). Let me clearly state that the USGS does not endorse Dr. Brady's prediction. Moreover, setting aside the question of Government policy toward predicting natural disasters in foreign countries, my office cannot endorse Dr. Brady's prediction because he has yet to write down, for comprehensive study and review, the theoretical basis and interpretative procedure he uses to make his prediction. This is a major point that seems to be lost on several of the people involved. For this reason I have not forwarded the letter dated October 26, 1979, by Drs. Brady and Spence to Alberto Giesecke of Peru. In my opinion this letter would imply an endorsement of Dr. Brady's prediction, an endorsement that cannot presently be justified on scientific grounds and may not be appropriate considering the social and economic effects such a prediction might have on Peru.

There is no doubt that earthquake losses in Peru will occur in the future and that steps can be taken, including the installation of geophysical instrumentation, that may--over the long term--help to mitigate these losses. If you or your staff find the need for advice of consultations on what these mitigative steps may be, we will be happy to cooperate with you and any representatives of the Peruvian government or scientific community you may wish to involve. As I understand it, two members of my staff are presently, at the request of AID, engaged in a review of a CERESIS proposal for earthquake studies in South America.

One Hundred Years of Earth Science in the Public Service

I feel that the USGS has had many mutually beneficial relationships, through AID support, involving earthquake-related studies in foreign countries. It is my strong desire that these exchanges continue on sound scientific bases and with straightforward administrative procedures.

Sincerely yours,

Robert L Wesson

Robert L. Wesson
Chief, Office of Earthquake Studies

UNITED STATES INTERNATIONAL DEVELOPMENT COOPERATION AGENCY
AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON D.C. 20523

DOCUMENT NO. C18

January 15, 1980

Dr. Robert L. Wesson
Chief, Office of Earthquake Studies
U. S. Department of the Interior
Geological Survey
Reston, Virginia 22092

Dear Rob:

Thank you for your letter of January 8, 1980, in which you explain your concern over the recent earthquake predictions for Peru. I certainly understand your concern as I understand the implications of any such prediction, no matter what basis it has in scientific terms.

I am sure that you understand our position as well. It is not our intent to promulgate or attempt to lend credence to Dr. Brady's theory. We sincerely hope that his conclusions are in error. Because we have been offered no scientific evidence to refute his hypothesis, and because of the potential for human suffering if it should be borne out, OFDA would be remiss if we did not remain open to more definitive evidence, pro or con.

We are aware of interest on the part of the U. S. Embassy in Lima in the prediction and possible social and economic consequences. We are relying on the Embassy to offer OFDA guidance as to what role is expected of us or other U. S. Government officials in dealing with this matter. In the meantime, we are remaining open to any qualified source of information which can help define the probabilities we are facing. Toward this end, we may request that the principal proponents and those who may refute Dr. Brady's theory meet with us in an attempt to define a rational approach to resolving the dilemma in which we all find ourselves.

Thank you for your continued cooperation and offer of consultation. We shall keep you fully advised of whatever future activities we may consider.

Sincerely,

William R. Dalton
Assistant Director, Office of U. S.
Foreign Disaster Assistance

DOCUMENT NO. 019

United States Department of the Interior

GEOLOGICAL SURVEY
RESTON, VA. 22092

FEB 12 8 15 AM '80
PDC/OFDA

In Reply Refer To:
Mail Stop 905

January 21, 1980

Mr. W. R. Dalton
Assistant Director for Preparedness
PDC/OFDA/AID
Washington, D.C. 20523

Dear Mr. Dalton:

We have received a copy of a memorandum (with enclosures) dated November 12, 1979, to you from Mr. P. F. Krumpe of your staff regarding the prediction of a major earthquake in Peru and related matters. This matter has caused me some concern and the purpose of this letter is to set down for you our position on the Peru prediction and the issues revolving around it.

The prediction of a catastrophic earthquake off the coast of Peru in the summer of 1981 stems from the work of Dr. Brian Brady of the Bureau of Mines and the ancillary efforts of Dr. William Spence of the U.S. Geological Survey (USGS). Let me clearly state that the USGS does not endorse Dr. Brady's prediction. Moreover, setting aside the question of Government policy toward predicting natural disasters in foreign countries, my office cannot endorse Dr. Brady's prediction because he has yet to write down, for comprehensive study and review, the theoretical basis and interpretative procedure he uses to make his prediction. This is a major point that seems to be lost on several of the people involved. For this reason I have not forwarded the letter dated October 26, 1979, by Drs. Brady and Spence to Alberto Giesecke of Peru. In my opinion this letter would imply an endorsement of Dr. Brady's prediction, an endorsement that cannot presently be justified on scientific grounds and may not be appropriate considering the social and economic effects such a prediction might have on Peru.

There is no doubt that earthquake losses in Peru will occur in the future and that steps can be taken, including the installation of geophysical instrumentation, that may--over the long term--help to mitigate these losses. If you or your staff find the need for advice of consultations on what these mitigative steps may be, we will be happy to cooperate with you and any representatives of the Peruvian government or scientific community you may wish to involve. As I understand it, two members of my staff are presently, at the request of AID, engaged in a review of a CERESIS proposal for earthquake studies in South America.

cresis

AV ARENALES 431 - D° 702
APARTADO 3747
CABLES CERESIS
TELEX: IGPLIM - 25507
TELEFONO: 247421

Centro Regional de Sismología para América del Sur

DOCUMENT NO. 020

January 20, 1980

Dr. Jim Jordan
Branch of Global Seismology
U.S. Geological Survey
Stop 967
Box 15046 DFC
Denver, Colorado 80225
USA

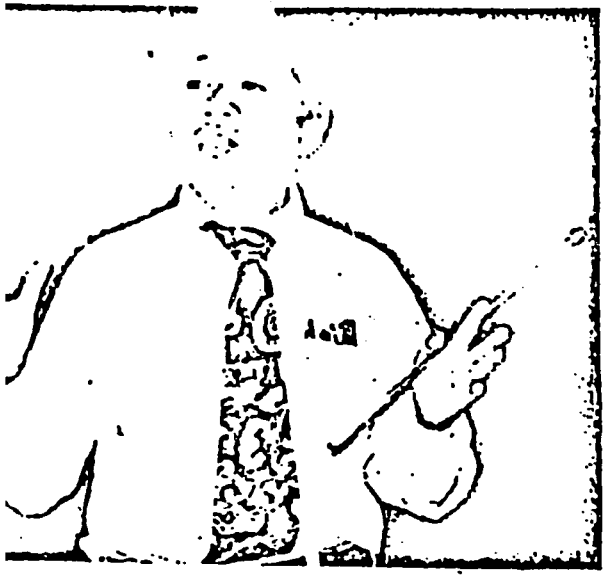
Dear Jim:

I enclose copy of the information which is in the hands of the press and many others. This is not a copy of any document in my files and apparently it has been obtained through a channel other than IGP from USGS. I certainly have never seen this document before. As you can understand, we are quite embarrased we have been handling this whole affair with reservation and at the proper government level and at the same time such key information as that enclosed is being made available by some other means to irresponsible people who are using this for political purposes and also to create panic and unrest. If this information were to motivate the government to providing funds for a program of observations it would be fine but unfortunately all this does is to lower the credibility of the prediction. A memo from Brian to L. C. Pakiser has also been translated and reproduced in the newspapers. This memo is rather old but the date has been deleted in the publication to make it look as if this is the latest information. I hope you can take action to try to find the source of this.

Best regards,

Alberto A. Giesecke M.
Director

AAG/is



geólogo Kuroiwa, miembro del Comité Científico Defensa Civil.

eñor Brady es un científico reputado, una persona ia y algunas veces no se le ha tratado —parece- ebería ser", sostuvo el ingeniero Julio Kuroiwa en ite Seminario de Microzonoficación Sísmica reali- la UNI, que contó con la presencia de una delega- expertos japoneses. Ante la pregunta insistente Nakamura, de LA PRENSA, agregó sobre el pro- de Brady: "Nosotros hemos leído esto de manera El Comité de Ingeniería Sísmica de la UNI tiene s así como los tienen —quizás— también otros or- s. Aquí en la UNI sí que tenemos el informe y lo leído en grupo. Es un informe científico, serio, abíamos dicho anteriormente. El señor Brady ientífico reputado cuyas publicaciones están en de prestigio donde no se admite así nomás cual-

ículo, de tal manera que nosotros no podríamos o de alarmista ni nada de ello.". Luego de apun- sumciones en las cuales reposa el pronóstico con- si bien es cierto que hay una cierta certidumbre to al lugar, en nuestra opinión modesta quizás hay mbre en cuanto al tamaño del terremoto y tam- cuanto a la fecha. Que cada uno tome su respon- ", insistió finalmente.

inión del ingeniero Kuroiwa, experto calificado, no r puesta al servicio de una artificial tranquilidad. e ha de ser cultivar una inquietud razonable. El ngeniero Kuroiwa nos ha invitado a ir a Defensa Ci- ación que aceptamos como un deber, justamente, io.

puesta de la población sea la adecuada, que los medios de comunicación, que el periodismo escrito, radial y televisado, participen activamente y no sólo con avisos oficiales de Defensa Civil o de la Oficina Central de Información que no siempre, por experiencia acumulada, merece fe.

El gran obstáculo para hacer lo que se debe hacer se- que ra imaginarse y frente ual Brady nos alerta.

Para el próximo número de LA CALLE preparamos un informe especial sobre Defensa Civil y las acciones cumplidas en provisión del sismo, así como distintas opiniones y sugerencias que podamos recoger durante el trascurso de la semana.

Traducción de la carta que explica científicamente los riesgos de un sismo de imprevisibles consecuencias en la Costa peruana. Es necesario que se inicie una campaña esclarecedora.

Sr. L.C. Pakiser
Jefe interino
Sección de Sismicidad y Estructura Terrestre
Golden, Colorado 80401

Querido Lou:

Te adjunto un resumen de mis estudios recientes sobre la sismicidad del Perú, tal como me lo solicitaste. Gran parte de este resumen ha sido extraído de mi Teoría de Sismos, IV. No obstante, nuevos resultados tales como la sismicidad a partir del 14 de noviembre de 1974 y, en particular, datos relativos a los temblores post-sismo del 3 de octubre de 1974 (M 7,8) obtenidos de Bill Spence y Charlie Langer están incluidos y se discuten brevemente en el resumen.

Bill y Charlie están preparando un informe detallado sobre los temblores post-sismo y su relación con la predicción. También incluyo en este resumen un programa para detectar precursores a corto plazo de los eventos inminentes supuestos.

En breve, creo que una situación seria se desarrolló cerca de Lima, Perú, el 9 de noviembre de 1974. Esta situación consiste en que la fase preparatoria de un gran terremoto ha comenzado. Datos sustentadores, incluyendo estudios realizados por mí, sugieren que la magnitud de este evento será aproximadamente M = 8.5 (más/menos 0.1) y que el tiempo mínimo hasta el evento, medido a partir del 14 de noviembre de 1974 es, aproximadamente de 5.9 años. Este tiempo presupone que ciertas hipótesis discutidas en el resumen son válidas para esta región. La magnitud estimada se basa en datos provenientes de la observación. Estos datos indican ausencia de sismicidad desde el 14 de noviembre de 1974 dentro de una zona cuya área comprende aproximadamente 32.000 km2.

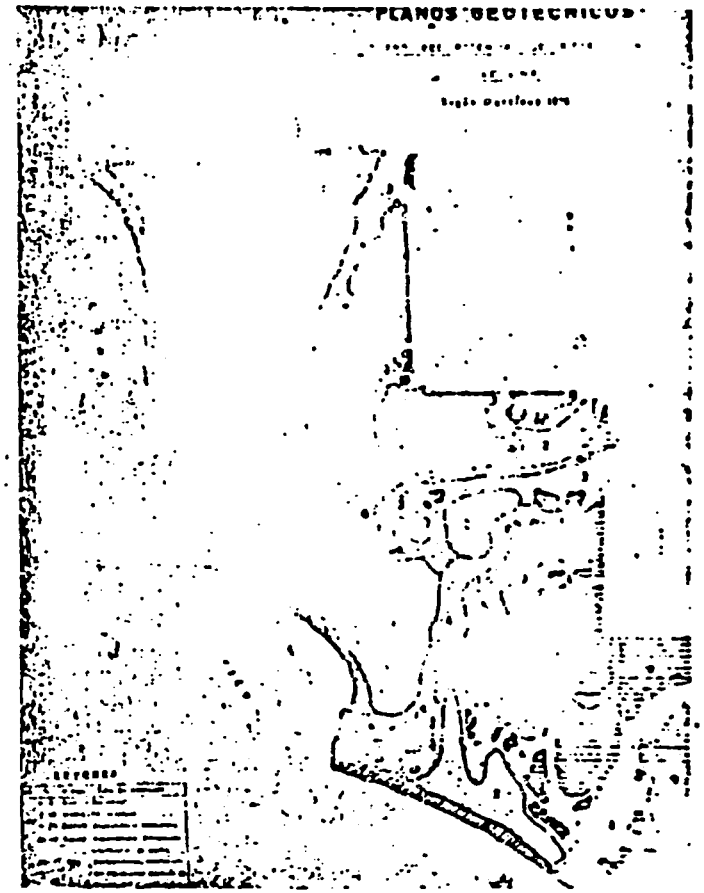
Soy de opinión que esta predicción tiene una base científica sólida, y creo firmemente que un estudio mucho más profundo (parte del cual se discute en el resumen) es necesario. El conjunto de los datos que tenemos al alcance de la mano claramente indican que se justifica un esfuerzo serio para estudiar la región.

Espero que este resumen te sirva. Por favor siéntete libre para ponerte en contacto conmigo si te puedeo ser de más ayuda.

Con mis mejores saludos,
Brian T. Brady
Físico
Diseño de Estructura de Minas
Centro de Investigación Minera de Denver

Gracias a la amable acogida del Inger tartínez Vargas, profesor principal de Geología Aplic y Geotecnia, del Dpto. de Geología de la UNI, ofrecemos una reproducción de su mapa de potencial de riesgo sísmico de Lima, levantado en base a indicadores diversos. La escala va do 1, mínimo potencial de riesgo hasta 5, que representa el más alto potencial de riesgo local. Son zonas de alto riesgo, según el ingeniero Martínez: Callao y La Punta, Chorrillos, La Campiña y La Molina. El efecto diferencial se debe a la naturaleza misma del terreno y factores diversos. Naturalmente que si llegara el 8.4 ó más, el mapa sería de poca utilidad, pues como nos declaró el ingeniero Juan A. Sarmiento, jefe del Dpto. Académico de Estructuras y Construcción de la misma UNI, "nunca se ha pensado en 8.5 para Lima".

El Ministerio de Guerra podría ser una excepción. El mismo techo parabólico del Dpto. de Estructuras, en ese caso, podría colapsar.



Plano del potencial de riesgo sísmico de Lima.

→1976

Portland, Oregon 97219

Telephone (503) 244-1181

Lewis and Clark College
Northwestern School of Law

January 15, 1980

Luis M. Fernandez
Centro Regional de Sismologia
para America del Sur
Apartado 3747
Lima, Peru

Dear Mr. Fernandez:

I am currently developing a research proposal to be submitted to the National Science Foundation of the United States government. The proposed research will address the problem of identifying an analytical framework for the formulation and evaluation of governmental policy on the assignment of responsibility for harm resulting from government involvement in earthquake prediction. The basic method of the study will be to investigate the liability laws of several countries in addition to the United States. A comparative analysis of the various legal regimes will then lead to the development of a general theory of government liability in disaster prediction and warning situations. Based upon this theory and the knowledge of the various national approaches to government responsibility, I will develop an analytical framework for the formulation and evaluation of government policy on liability and responsibility for harm resulting from government involvement in earthquake prediction.

In developing my research plan, I seek to study national legal systems of distinct historic origins in countries with an active concern for earthquakes and earthquake prediction. Peru appears to me to be a good country to include in my research. I am interested in hearing from you on two questions: (1) Do you believe that your government would have any interest in the results of my proposed study? (2) Would you be willing to assist me in identifying the significant agencies and personnel in your government who will be best able to inform me on legal issues and on existing earthquake prediction and mitigation efforts in your country?

Any assistance you can offer will be appreciated very much.

Sincerely,

James L. Huffman
Professor of Law and
Associate Dean for Academic Affairs

JLH:pmk

circular ESTADOS MIEMBROS

CERESIS
AV. ARENALES 431 - OF. 702
APARTADO: 3747
CABLES: CERESIS
TELEX: IGPLIM - 25507
TELEFONO: 247421

Centro Regional de Sismología para América del Sur

January 28, 1980

. James L. Huffman
ofessor of Law and
sociate Dean for Academic Affairs
wis and Clark College
rthwestern School of Law
rtland, Oregon 97219

ar Dr. Huffman:

ur letter to Dr. Fernandez has been received. He is presently South Africa and will not be working with us until late this ar.

RESIS is a regional Center for seismology for all of South erica. It is an autonomous inter-governmental institution, th headquarters in Lima. I enclose a Report of our activities.

are indeed greatly interested in you research proposal; most our countries have to face a significant earthquake hazard d as the "art" of prediction progresses to higher degress of obability with regard to succesful predictions, and on a nger term basis, the handling of the prediction itself poses new and very crucial problem to governments and populations our region. Although one can learn from societies that have perience, such as the chineses, our social and legal structure, r culture and traditions, our economic reality and the fferent levels of risk, make impossible to adopt an effective licy by just copying somebody olso's.

know that the several governments in South America, which we present in the general area of seismology, are very much terested in the problem which you will address in your proposed udy and we will indeed be most happy to assist you in lentifying the significant agencies and personnel who will be le to inform you on the pertinent issues. I am sending copies your letter and this reply to all of our Directive Council mbers and the Liason instituciones in each country. Further- re, there will be many people interested in working with you d participating in your research activities.

hope we will be hearing from you at an early date.

ncerely yours,

Alberto A. Giesecke M.
Director

AG/is

DOCUMENT NO. 021

DOCUMENT NO. 022

ceresis

AV. ARENALES 431 - OF. 702
APARTADO: 3747
CABLES: CERESIS
TELEX: IGPLIM - 25507
TELEFONO: 247421

Centro Regional de Sismología para América del Sur

February 13, 1980.

Dr.
Paul F. Krumpe
Science and Technology Officer
Office of U.S. Foreign Disaster Assistance
U.S. Department of State
Agency for International Development
Washington D.C. 20523
U.S.A.-

Dear Paul:

I enclose copies of recent articles on the predicted Brady earthquake and my letter to Bill Spence. You may want to show the clippings to others and I will also be happy to provide you and others with originals.

I talked with Jim Devine last saturday and he offered to "push" SISRA. I hope to see you next month and that at that time be informed of positive developments (hopefully)

With very best regards,

Alberto A. Giesecke M.
Director

cc. Dr. W. Spence

Ed. Note
Articles enclosed were:
CARETAS - 11 February 1980
MARKA - [aprx.] 11 February 1980
They can be found in PRESS CLIPPINGS volume.

Letter to Dr. William Spence from Dr. Giesecke appears on the following page.

DOCUMENT NO. 023

February 13, 1980.

Dr.
William Spence
U.S. Geological Survey
Denver Federal Center
Building 25
Denver CO 80225
U.S.A.-

Dear Bill:

Enclosed please find copies of recent articles in local magazines; they cover the political spectrum from right to left, but they coincide in their concern over the predicted disaster. Brian, Jin Jordan and others may be interested in the original publications which I can try to get for you if so desired. I have sent a set of copies to Paul Krumpe.

We are still,waiting for a decision on the million dollars which are being considered for a comprehensive program to detect seismic precursors and to analyse and evaluate data. About 1.5 million have apparently been officially approved for Civil Defense for inmediate action. What this means I do not know and I am not sure that C.D. knows either. There are no visible canpaigns to educate people or make them aware of any particular problems. Perhaps the funds are to go to equipment and supplies but although it is justified to have an in-house capability to deal with disaster situations, massive purchases lead to waste and stockpiling has in the past been ineffective because of deterioration,pilferage, canibalization or simple less. Furthermore,in case of great catastrophes,international aid often is more than enough to satisfy requirements. I hope that this fundind is in addition to what we have requested and not "in lieu of".

Very best regards,

Alberto A. Giesecke
Director

UNITED STATES GOVERNMENT

memorandum

DOCUMENT NO. 024

DATE: 2-22-80

REPLY TO ATTN OF: ECOM: J. Jurecky

SUBJECT: Earthquakes and Inspections

TO: DCM - Mr. Preeg

We want to suggest that in light of the likelihood of some seismic disaster occurring in Peru (if not necessarily at Dr. Brady's predicted times and places) the Mission organize under your direction to deal with the requests for assistance from the US which are certain to ensue. We have included such an item at Item 3 on the Inspectors' "Functional Questionnaire" on Science and Technology.

ECOM bjm

Buy U.S. Savings Bonds Regularly on the Payroll Savings Plan

OPTIONAL FORM NO. 10
(REV. 7-76)
GSA FPMR (41 CFR) 101-11.6
5010-112

DOCUMENT NO. 025
February 22, 1980

Mr. W. R. Dalton
Assistant Director for
Disaster Preparedness Planning
Office of Foreign Disaster Assistance
U.S. Agency for International Development
Washington, D.C. 20523

Dear Mr. Dalton:

Reference is made to the issue of United States assistance to the Government of Peru in earthquake studies which was discussed in the memorandum of November 13, 1979, from Mr. P. F. Krumpe of your staff and the letter of January 8, 1980, from Mr. R. L. Wesson of the U.S. Geological Survey to you (copies are attached). It appears that a clarification of the official position of the U.S. Bureau of Mines is in order since the issue is centered on the prediction of a catastrophic earthquake off the coast of Peru in the summer of 1981 by Dr. Brian T. Brady of the Bureau's Denver Research Center.

Since the Bureau of Mines is not authorized by the Congress to conduct earthquake research, we do not intend to develop Dr. Brady's personal interest in the theory of earthquakes into a formal research project. We do, however, consider Dr. Brady's theory of earthquake prediction a logical extension of the research results that have been obtained under the Bureau's continuing research efforts in prediction of rock failures in mines. Nevertheless, we are in general agreement with the cautious position of USGS to withhold any official endorsement of the accuracy of Dr. Brady's earthquake prediction at the present time since his prediction theory, like many other scientific and technologic research products and by-products, must undergo the critical scrutiny of his fellow scientists in the highly sophisticated fields of rock mechanics and seismology and be corroborated with valid field evidence over a substantial period of time before it can mature into a universally acceptable prediction tool for such natural disasters. Therefore, in concert with USGS, the Bureau has not forwarded the joint letter, dated October 26,1979, by Dr. Brady and Dr. W. Spence of USGS to Dr. A. Giesecke of Peru.

Attached also is a copy of the letter, dated February 27, 1979, from the Bureau of Mines Director to the Assistant Secretary of State for Inter-American Affairs of the U.S. Department of State. The Bureau pointed out Dr. Brady's heavy commitment to Bureau programs and expressed the possibility of arranging for a segment of his official working time to assist the

Peruvian government in their earthquake studies on an as-needed basis. We reaffirm our willingness to cooperate with the Peruvian government. However, interagency coordination with the USGS and AID is mandatory.

We note in Mr. Wesson's letter dated January 8, 1980, that USGS personnel are presently engaged in a review of a Peruvian proposal for earthquake studies at the request of AID. Therefore, we plan no further action until we receive information on the outcome of the review and a formal request from your agency for assistance.

Sincerely yours,

Robert L. Marovelli

Robert L. Marovelli
Director, Division of Minerals
Health and Safety Technology

Attachments

cc: Files/MH&ST
Director/MH&ST
Director Reading File
Deputy Director/Minerals Research
Director/RCO
A. Bacho
BR of SR
R.L. Wesson, USGS
P.F. Krumpe, USAID
Research Director/DRC
B.T. Brady/DRC
C.S. Wang
EBM:CSWANG:tlw:2/22/80

ORIGIN ACTION

R	REP	AF	ARA
R	EA	NEA	CU
R	E	P	IO
-	FBO	AID	SY
IL	SCI		
R	COM	FRB	INT
B	TAR	TR	XMB
R	ARMY	NAVY	OSD
A	NSA	CIA	DOT
H	HEW		

GGESTED DISTRIBUTION

DEPARTMENT OF STATE

AIRGRAM

DOCUMENT NO. 026

Original to be Filed in _____ Decentralized Files.

FILE DESIGNATION

UNCLASSIFIED — A-012

HANDLING INDICATOR

TO : SECSTATE WASHDC

E.O.12065: N/A

TAGS: TPHY, PE, CEP

INFO :

DEPT PASS:

FROM : AMEMBASSY LIMA

DATE: March 12, 1980

SUBJECT : Prediction of Major Earthquake in Peru

REF : Lima 1782

Attached are translations of two cover articles which appeared in "Caretas" and "Oiga" magazines on February 11, 1980. Both articles concern the prediction by Dr. Brian T. Brady, US Bureau of Mines, of a major earthquake in Peru in July 1981. For more information on this prediction, Peruvian reactions of it, and embassy involvement, see Lima 1782.

ECON-3 w/encl
AMB "
DCM "
AID "
POL "
ICA "
CHRON "

Ed. Note Both articles appear under their respective dates in the PRESS CLIPPINGS volume.

SHLAUDEMAN

Enclosures: 1.Cover article in "Oiga" Monday, January 11, 1980.
2.Cover article in "Caretas" Monday, February 11, 1980.

FORM 3-70 DS-323

UNCLASSIFIED

Filed by:	Drafting Date:	Phone No.:	Contents and Classification Approved by:
ECON:EPearson:ks	2/27/80	240	DCM:ERPreeg

Clearances:
ECON:AWCooley ADC
ECOM:JJurecky

prediction, we are being cautious in our reaction to it. As the event approaches, we will steps are called for to prevent a dis.., in the context of the international disaster community. whatever

DOCUMENT NO. 027

DRAFT WLE. 5 MAR 80

Preparation for Peru Earthquake 1981

Question: What are you doing to help Peru prepare for the destructive earthquake predicted for 1981?

Answer: Brian Brady, a physicist with the U. S. Bureau of Mines, has predicted a 9.9 Richter earthquake for 31 July 81 about 50 kilometers off the coast of Lima, Peru, using a mathematical method he has developed. Neither the method used in predicting nor the prediction has been endorsed by the U. S. Geological Survey. No one, however, has disproved the prediction method.

REQUESTS FROM GOP FOR ASSISTANCE.

a. S Juan Garland, Pres of Peruvian Red Cross, with Humberto Urteaga, Counselor of Energy, Emb GOP, requested OFDA to coordinate all USG assistance, gave list of goods and services needed. 11 Feb 80. Claim to speak for GOP, as advisor to Minister of Trade.
b. No reports have reached OFDA about requests to other donors, international organizations or voluntary agencies by GOP.

OFFICIAL USG CONTACTS WITH GOP

a. Frank Press, Science Advisor to the President, visited the Prime Minister of Peru 16 Oct 79 on general S&T exchange.
b. President of Peruvian Red Cross called on Director of OFDA to request preparedness assistance and some goods and services. He was accompanied by Energy Counselor Humberto Urteaga of Emb GOP, 11 Feb 80.
c. OFDA knows of no other official contacts.

USAID REQUEST FOR INFORMATION. MDRO Paul Vitale of USAID/Lima requested info on predicted earthquake. He reported that it had been mentioned in Lima in local press.

STEPS TAKEN BY GOP

a. GOP has budgeted $1 million to Peru Inst of Geophysics to study and monitor earthquake precursors. OFDA is in contact with Director, Alberto Gieseke.
b. Thru its Red Cross, GOP has developed initial comprehensive "want list" including assistance in establishing command centers and stockpiles, in developing a national plan, and provision of goods and services. Equipment and services are described.
c. OFDA has no report of request to AmEmbassy Lima.

DRAFT

STEPS TAKEN BY OFDA

a. Regular contact is maintained with Brian Brady and his collaborator, William Spence of USGS.
b. OFDA's Country Profile on Peru is being expanded to accom: many agencies that will be needing key information. Long term job.
c. ??

AID DISASTER ACTIVITIES WITH GOP

a. AID has given relief to Peru after earthquakes, fires, and floods.
b. GOP has participated in preparedness seminars: 6 officials, since 1969.
c. AID-GOP 2-year project in Peru just finished, developing methodology for educating homeowners in earthquake resistant construction, retrofitting.
d. OFDA plans support to project strengthening S.A.Seismology Ctr. Peru member.

UNDRO, LICROSS

a. No preparedness steps have been taken by UNDRO or LICROSS.

United States Department of the Interior
BUREAU OF MINES
BUILDING 20, DENVER FEDERAL CENTER
DENVER, COLORADO 80225

March 7, 1980

Dr. Robert L. Wesson
Assistant Director-Research
U.S. Department of the Interior
Geological Survey
Reston, Virginia 22070

Dear Dr. Wesson:

I have received a copy of your memorandum dated January 8, 1980, (addendum A) to Mr. W. R. Dalton[1] regarding the position of the Office of Earthquake Studies (OES), on my prediction of a large earthquake off the coast of Central Peru in 1981. I plan to state briefly the current status of the prediction and some of the physical bases used to make the prediction. In particular, I wish to build a case that the predicted Peruvian event has immense implications for United States interests, not only in South America, but throughout the western Pacific and, as such, this prediction warrants more attention than given to it by OES.

The status of the prediction is as follows. A foreshock series will commence in mid-September 1980. The time duration of this series will be approximately 328 days. There will be a total of twelve-to-thirteen foreshocks which will be temporally distributed in two active phases, each of whose time durations will be approximately 109 days. The foreshock series will terminate on July 30, 1981, with the occurrence of the mainshock ($M_w \geq 9.8$). This event will nucleate in the vicinity of 12.6°S and 77.6°W and will initiate a rupture to the S-SE from 12.6°S to approximately 26°-28°S. This event will eliminate the largest generally recognized seismic gaps in the world, e.g., the inferred rupture zones of the 1868 and 1877 great earthquakes.[2] The event will be followed by a vigorous aftershock series. My current interpretation of the spacetime seismicity patterns in central Peru also leads me to hypothesize that a second event ($M_w \simeq 8.8$) will nucleate 276 days later (ca May 2, 1982) near 12.5°S and 77.6°W. This event will rupture to the NW from 12.5°S to approximately 8°S. The second event will also be preceded by a foreshock phase with characteristics identical to that preceding the

[1] Mr. W.R. Dalton, Assistant Director for Preparedness, Office of U.S. Foreign Disaster Assistance, U.S. Department of State, Agency for International Development, Washington, D.C. 20523

[2] Kelleher, J., 'Rupture Zones of Large South American Earthquakes and Some Predictions', Jour. Geophys. Res., vol. 77, pp 2087-2103, 1972.

$M_w \geq 9.8$ event. I cannot make more precise predictions of the occurrence times of the mainshocks ($M_w \geq 9.8$, $M_w \simeq 8.8$) until the initiation times of their respective foreshock series are known. I cannot overemphasize that the occurrence of the foreshock phases are necessary and sufficient for the occurrence of the predicted mainshocks. If the foreshocks do not occur, the prediction is invalid.

The predicted mainshocks will be shallow (source depths $\approx$ 20 - 30 km) underthrusting (dip angle $\approx$ 30°NE) events. They will be tsunamigenic events. For example, using Abe's[3] results, I estimate the mainshock ($M_w \geq 9.8$) is capable of generating a sea wave whose maximum amplitude at Hilo will be at least 25 meters (82 feet) approximately 13-14 hours following the mainshock. Other regions throughout the Pacific basin will also be affected, e.g., Aleutian Islands - Honolulu - California, 4 meter (14 feet) wave; Japan, 6.3 meter (21 feet) wave.

The physical basis used in making this prediction has been the occurrence of very specific recent (post 1963) space-time patterns of seismicity which have occurred off the central Peruvian coast and, in particular, the patterns that began August 26, 1966. These patterns have consisted of alternating active and quiet periods of seismicity between 12°S and 13.5°S. The first active period began on August 26, 1966, and ended November 26, 1967. The second active period began September 6, 1973, and terminated on November 18, 1974. There have been no seismic events within the predicted aftershock zones of either predicted event during November 26, 1967 - September 6, 1973, or since November 18, 1974 - present. Teleseismically reported events have occurred in both Peru and northern Chile but only along the boundaries of what will be the predicted aftershock zones. The final active period, the foreshock phase, is predicted to initiate in mid-September 1980. It is of interest that similar behavior has been observed prior to other large earthquakes[4,5,6,7,8].

---

[3] Abe, K., 'Size of Great Earthquakes of 1837-1974 Inferred from Tsunami Data,' Jour. Geophys. Res., vol. 84, pp 1562-1567, 1979.

[4] Kelleher, J., and J. Savino, 'Distribution of Seismicity Before Large Strike Slip and Thrust-Type Earthquakes', Jour. Geophys. Res., vol. 80, pp 260-271, 1975.

[5] Mogi, K., 'Relationship Between Shallow and Deep Seismicity in the Western Pacific Region', Tectonophysics, vol. 17, pp 1-22, 1973.

[6] Spence, W., and L. C. Pakiser, "Conference Report: Toward Earthquake Prediction on the Global Scale", EOS, vol. 59, pp 36-42, 1978 (See Addendum C, this memorandum).

[7] Ohtake, M., Matumoto, T., and G. V. Latham, "Seismicity Gap Near Oaxaca, Southern Mexico as a Probable Precursor to a Large Earthquake", Pure Appl. Geophys., vol. 115, pp 375-385, 1977.

[8] Brady, B. T., "On Accurate Long-Term Prediction of Earthquakes", (in preparation), 1980. See Addendum D, this memorandum).

The theoretical bases for these types of space-time seismicity patterns, e.g., "quiet" periods followed by seismically "active" periods prior to failures, were outlined in some detail by myself at the May 24, 1979, meeting in Golden, Colorado[9]. I presented several applications of the theory to past earthquakes at this meeting as well as to predicted rock bursts in northern Idaho. I went into considerable detail on the seismicity patterns that existed prior to the February 9, 1971, San Fernando, California earthquake (M = 6.6). I presented evidence showing how the space-time seismicity patterns prior to the San Fernando event could have been used to accurately predict the occurrence time as well as the characteristics of aftershock sequence of this event to within several hours of its actual occurrence (See Addendum D). I also applied the theory to the seismicity patterns prior to the October 3, 1974, (M_s = 8.1) and November 9, 1974, (M_s = M_w = 7.1) Peruvian events with identical success at this meeting. Since the May 24 meeting, I have obtained the seismicity data preceding the November 29, 1975, Kalapana (Hawaii) event (M_s = 7.2). I have been able to apply these data to show that this event and the characteristics of its aftershock sequence could have been accurately predicted to within several hours nearly one month prior to its actual occurrence, (Brady, B.T., Unpublished results, 1979). The Bureau of Mines' efforts in successfully predicting low magnitude rock bursts[10] and our studies of precursory behavior several milliseconds prior to failure of rock on the laboratory scale[11] are evidence that our efforts on failure prediction and, in particular, theoretical studies of the physics of failure are noteworthy.

---

[9] Krumpe, P. F., Memorandum to Anne C. Martindell, Director, OFDA, June 19, 1979 (Addendum B, this memorandum).

[10] Brady, B. T., "Anomalous Seismicity Prior to Rock Bursts: Implications for Earthquake Prediction", Pure Appl. Geophys., vol. 115, pp 357-374, 1977.

[11] Brady, B. T., Rowell, G. A., and L. P. Yoder, "Physical Precursors of Rock Failure: A Laboratory Investigation", Inter. Jour. Rock Mech. Min. Sci., (in press), 1980.

Letter to Dr. Wesson, Reston, Virginia

In your letter you have asserted that OES cannot endorse my prediction "because I have yet to write down, for comprehensive study and review, the theoretical basis and interpretative procedure I use to make this prediction" I am including in the attachments (Addendum E) a detailed summary of a forecast update with a copy of my transmittal letter dated August 25, 1977, to Mr. L. C. Pakiser, then acting Chief, Branch of Seismicity and Earth Structure, USGS, Golden, Colorado. Mr. Pakiser was sufficiently impressed with this update and with its possible social and political implications to both the Peruvian and U.S. governments that he distributed the summary to members of the USGS earthquake prediction panel (OES) for their evaluation and study. Despite repeated attempts, Mr. Pakiser did not receive any reply from the panel. We have held nearly 10 hours of meetings (November 18, 1977 - May 24, 1978) with key OES personnel[12,13] (Addendums E and F) during which I discussed in considerable detail the interpretative procedures and their applications to regions where earthquakes have occurred.

I also presented evidence at the May 24, 1979, meeting which suggested that the preparatory phase for a large earthquake ($M \leq 7.0$) along the Imperial fault zone SE of the Salton Sea region in Southern California had begun. Unfortunately, I did not have access to seismicity data from the USGS network and the cooperating Cal Tech seismic network and made an appeal for these data at this time. As you are aware, the forecasted event occurred on October 15, 1979, (El Centro earthquake). The magnitude of the event was $M = 6.8$ and occurred along the Imperial fault system. Additional documentation is provided in addendum F of this memorandum. I am also enclosing several letters to OES in which I requested seismicity data prior to and immediately following the El Centro event. No information has been received.

In your letter, you have termed Dr. Spence's efforts as ancillary. Perhaps that is true, yet Dr. Spence's memorandum (Addendum H) dated August 1, 1979, to you and others in which he clearly and succinctly outlines the plausibility arguments for the occurrence of a large event in Peru and northern Chile as well as our close cooperation on numerous other aspects on Peruvian seismicity are evidence of his intimate role on all aspects of this prediction. Spence's documentation suggests that the tectonic environment off Peru and Chile is anomalous. Spence's arguments and several of my publications indicate that there is a large seismic gap off the coast of central and southern Peru and northern Chile and that recent historical earthquakes have not destressed this region.

---

[12] Brady, B. T., Memorandum to Robert L. Marovelli, June 5, 1978.

[13] Brady, B. T., Memorandum to Robert L. Marovelli, June 19, 1979.

Letter to Dr. Wesson, Reston, Virginia

With regard to the letters of transmittal to Dr. Alberto Giesecke by Dr. Spence and myself, I wish to emphasize that we were acting in regard to a request (unwritten) by Dr. Giesecke to summarize our ideas for a program to monitor possible long-and-short term precursors not only for the predicted event but also for other seismic events which might occur in Peru. Our intention in transmitting these letters through our respective agencies was not to request an endorsement, particularly one from OES. We were simply replying to a request from an official whose government is friendly to the United States and who is concerned with the implications of what the consequences of the predicted earthquake will have on Peru if the event does occur.

I hope my comments will be of value to you in assessing your agency's response to any Peruvian requests for assistance. If there is anything I can do to assist you and your staff, such as a detailed briefing, please do not hesitate to contact me. Copies of this letter will be distributed at the March 18, 1980, interagency meeting at the State Department for further discussion.

Very truly yours,

Brian T. Brady
Physicist
Mine Structure Design
Denver Research Center

Enclosures (Addendums A thru H)

cc: Robert L. Marovelli, Wash., D.C.
Charles B. Kenahan, Wash., D.C.
Donald G. Rogich, Wash., D.C.

DOCUMENT NO. 029

UNITED STATES INTERNATIONAL DEVELOPMENT COOPERATION AGENCY
AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D.C. 20523

March 11, 1980

MEMORANDUM

TO: See distribution below

FROM: AID/PDC/OFDA, William R. Dalton

SUBJECT: Meeting to Review and Discuss the 1981 Peru Earthquake Prediction and Possibility of USG Contingency Planning

The Office of U. S. Foreign Disaster Assistance (OFDA) of the Agency for International Development, will conduct the subject meeting at the following time and place:

Tuesday, March 18, 1980
2:00 p.m. - 4:00 p.m.
Room 1262A, NS
Department of State
21st & C Streets, N.W.
Washington, D.C.

Objectives of this meeting are as follows:

1. Review current status of Dr. Brady's prediction and discuss postulated threat.

2. Clarify current USGS, USBM, State/AID positions concerning the prediction and possible USG responses.

3. Discuss potential for contingency planning for Peru, Western Pacific, Hawaii, and California.

4. Discuss desirability of assisting Peru in conducting a pre-foreshock in situ stress and geodetic measurement program.

5. Discuss alternative responses to possible requests from Peru for scientific studies after foreshocks occur (pre-mainshock).

OFDA contact point is Paul Krumpe, telephone 632-1834.

Distribution:

R. Marovelli (USBM)
J. Filson (USGS)
B. Brady (USBM)
W. Spence (USGS)
J. Purnell (State)
W. Rhodes (AID)
C. Culver (NBS)
E. Coy (AID)
R. Weber (AID)
J. Lutz (State)
T. Algermissen (USGS)
J. Anderson (FEMA)
F. Krimgold (NSF)

Department of State

INCOMING TELEGRAM

7658

PAGE 01 LIMA 02302 151630Z

DOCUMENT NO. 030

ACTION AID-35

INFO OCT-01 /036 W

----------009310 151636Z /34

R 142208Z MAR 80
FM AMEMASSY LIMA
TO SECSTATE WASHDC 081

UNCLAS LIMA 2302

14 March 1980

AIDAC

FOR OFDA

EO 12065: N/A
SUBJ: DISASTER PREPAREDNESS AND PLANNING

REF: STATE 062283

PLEASE KEEP MISSION APPRISED OF CHANGES IN THE BRADEY ET AL PREDICTIONS AS WELL AS PLANS OF PROPOSED REF. INTERAGENCY GROUP.

2. WILL POUCH TO OFDA IN APRIL A COPY OF REVISED MISSION DISASTER RELIEF PLAN.

3. OFDA IS REQUESTED TO PROVIDE MISSION WITH UPDATED PANAMA INVENTORY AS CHANGES OCCUR.
SHLAUDEMAN

MAR 18 9 58 AM '80
PUC/OFDA

CIAO
JM
WD
PK
SG
BK
BK
BK
BK

S/
ACTION
DRC
INFO
EG
PDC.
LASA
LADP
PPALM
PPAID
ES
SER

March 26, 1980

MEMORANDUM

TO: See Distribution

FROM: PDC/OFDA, William R. Dalton

SUBJECT: Seismic Disaster Preparedness Working Group Meeting

There will be a meeting in the Office of U. S. Foreign Disaster Assistance (Room 1262A), Department of State, Thursday, April 3, 10:00 a.m., to discuss the modus operandi of the above subject working group.

Agency designated representative to the working group should contact Joan Sullivan, 632-8746, of name of attendee prior to the date of the meeting and not later than COB Monday, March 31.

Distribution:

M. Finarelli (OSTP)
T. Kobayashi (OES-State)
J. Anderson (FEMA)
F. Krimgold (NSF)
E. Leyendecker (NBS)
J. Purnell (State)
W. Rhodes (AID)

ACTION COPY

UNCLASSIFIED

Department of State

INCOMING TELEGRAM

DOCUMENT NO. 032

PAGE 01 LIMA 02680 2709332 3145 AID3100

'CTION AID-35

26 March 1980

ACTION OFFICE DRC-02

INFO LASA-03 LADP-01 LADR-03 PDC-02 CHS-01 CH9-01 ES-01
AAID-01 SER-01 STA-10 MAST-01 /027 A1

INFO OCT-01 /036 W

098969 2709342 /34

R 261548Z MAR 80
FM AMEMBASSY LIMA
TO SECSTATE WASHDC 258

UNCLAS LIMA 2680

AIDAC

EO 12065: N/A
SUBJ: DISASTER PREPAREDNESS

REF: LIMA 2302

1. MISSION APPRECIATES OFDA EFFORT TO COMPILE BACKGROUND INFORMATION ON BRADEY/SPENCER PREDICTIONS.

2. AS MENTIONED IN REF CABLE, MISSION WILL BE POUCHING TO OFDA REVISED DISASTER RELIEF PLAN SHORTLY FOR YOUR REVIEW AND COMMENT.
HLAUDEMAN

UNITED STATES INTERNATIONAL DEVELOPMENT COOPERATION AGENCY
AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D.C 20523

DOCUMENT NO. 033

March 28, 1980

MEMORANDUM

TO: D/PDC/OFDA, Mr. Joseph A. Mitchell

FROM: PDC/OFDA, William R. Dalton

SUBJECT: Meeting to Review and Discuss the 1981 Peru Earthquake Prediction and Possibility of USG Contingency Planning

On Tuesday, March 18, 1980, the subject meeting was convened in Room 1262-A of the Office of U.S. Foreign Disaster Assistance. Objectives of the meeting included review of the current status of the Brady prediction, clarification of positions concerning appropriate actions in response to the prediction, discussion of possible contingency planning activities and alternative approaches involved in studying the prediction and validating the occurence of the postulated foreshocks.

The meeting was attended by 20 persons representing several agencies (US Geological Survey, National Bureau of Standards, National Science Foundation, FEMA, US Bureau of Mines, AID and Department of State).

Mr. William Dalton, Acting Director (AID/OFDA) chaired the meeting and opened with a brief review of the Peru earthquake prediction. He described the forecasted earthquake as occurring about 75 miles off the coast of Peru in July 1981 with a Mw9+ reading on the Richter scale. Precursors are estimated for September 1980. Although Mr. Dalton surmised that such an event is improbable he determined that the U.S. government (OFDA) cannot ignore the prediction, considering the credentials of the responsible scientist, Dr. B.T. Brady (U.S. Bureau of Mines). After establishing that the purpose of the meeting was not to debate the validity of the prediction or plausibility arguments supporting its possible occurence, Mr. Dalton announced the formation of an ad hoc task force to perform disaster contingency planning for the west coast of South America and the Pacific Basin. He stressed that the topic should for the time being remain classified (i.e. OFFICIAL USE ONLY). He then asked Dr. John Filson, (U.S.G.S.) for his comments on the U.S.G.S. position concerning the Brady prediction.

Dr. Filson stated that he was not prepared to evaluate the prediction, but he did characterize the theory as complicated and therefore difficult to evaluate. In order for the theory to be validated, Dr. Filson indicated that it would have to be published and reviewed by Dr. Brady's peers. According to Dr. Filson, the U.S.G.S. is willing to search their "Determination of Epicenters", data for the forecasted precursors in September. However, he stipulated that the criteria for the precursors must be established by Brady well in advance of the search, so that the analysis will not be biased after the fact. Dr. Marovelli and Dr. Filson agreed that Dr. Brady should write down the foreshock events sequence for the record ASAP.

An exchange followed between Dr. Filson and Mr. Dalton regarding the need for additional instrumentation for premonitory precursor identification. If an earthquake measures Mw5, then the U.S.G.S. can determine the epicenter with a 50-100 kilometer margin of error with current instrumentation. If the earthquake measured less than Mw5, additional instrumentation would be required; and if the measurement was less than Mw4, an especially fine tuned system would have to be set up. After Mr. Dalton referred to the $1.0 million dollar grant from the Peruvian government to the IGP for instrumentation, Dr. Filson expressed concern for Peru's situation and emphasized that regardless of the validity of Brady's prediction, the instrumentation should be installed in Peru to monitor seismicity. Mr. Dalton again stated that OFDA's response should be largely in the area of preparedness unless the Peruvian Government specifically requests OFDA to assist in coordinating technical assistance.

The Bureau of Mines representative, Dr. Robert Marovelli, prefaced his remarks on Brady's prediction by stating that the Bureau of Mines has no mission in earthquake prediction. Rather, one of the Bureau's purpose is to improve mine health and safety. Brian Brady developed his theory and the prediction in the context of "technology transfer", however the USMB has no funds for travel to South America if required to provide techological assistance.

At this point in the meeting, an open discussion occurred on several topics. Mr. Dalton defined the objectives of the working group's task as:

A. to examine the vulnerability and threat to the entire area;
B. to address contingency planning.

The State Desk Officer, Mr. John Purnell, asked for clarification of the magnitude of the foreshocks and Mr. Paul Krumpe (OFDA) responded by describing a series of 13 foreshocks possibly culminating in an event of Mw7 prior to the mainshock (as defined by Brady in recent memoranda). U.S.G.S. representative, Dr. Filson reiterated the need for more data to test the hypothesis. A question was raised as to the extent of the present involvement of Peruvian scientists in the issue, by Dr. Tadao Kobayashi (OES/SCT). Mr. Krumpe responded that over 8 hours of presentation to Dr. Gelsecke (Institute of Geophysics in Lima, Peru) had taken place at the request of the Peruvians in May, 1979.

Dr. Filson referred to an existing memorandum of understanding between the U.S.G.S. and the Government of Peru which could be put into action, however, he did not sense any interest in this area by the GOP. The eventuality of the prediction receiving international attention was raised and discussed by Mr. Dalton and Mr. Richard-Weber (A.I.D.), and Dr. Fred Krimgold (National Science Foundation). Following additional debate on the need to validate the theory, Mr. Dalton resolved that a planning exercise would be carried out by FEMA, NSF, NBS and OFDA. Dr. Krimgold of NSF supported this proposed action with the argument that even though a specific prediction could be questionable in scientific terms, it is still probable that a major earthquake could occur in Peru and the U.S. government (OFDA) should not miss the opportunity to prepare for such an

eventuality. Mr. Fred Cole (OFDA) mentioned that the GOP and Red Cross have adopted precisely this stance.

Mr. Krumpe distributed recent memoranda exchanged among U.S.G.S., A.I.D. and U.S.B.M. concerning the prediction by Brady. In addition, the topic of tsunami threat to countries of the Western Pacific regions was briefly discussed. Mr. Dalton then closed the meeting and called for another meeting to be set up within two weeks.

April 1, 1980 DOCUMENT NO. 034

MEMORANDUM

TO: Mr. William R. Dalton, Assistant Director for Preparedness, OFDA

FROM: Weston W. Emery, Senior Planning Officer, OFDA/P

SUBJECT: Peru earthquake of July 31, 1981

1. I strongly recommend that the National Science Foundation be tasked to form a panel of scientists to evaluate the reliability of Brian Brady's prediction of a 9.8 Richter earthquake in Peru in July, 1981.

2. A copy of the request to NSF, which must be couched in terms of OFDA responsibility only, should be sent to USGS, USBM, OSTP Frank Press, NAS and State. It should be channeled up through the Administrator before it is divulged to the public.

3. A panel picked by Brady, or even approved by Brady, would be counter-productive for two reasons:

A. It would go against AID policy of evaluation by objectively verifiable indicators and, in fact, could indicate that we are not overly concerned with scientific investigation; and

B. It would indicate to the people in the government who are responsible for earthquake prediction that we are supporting Brady in his prediction, in spite of your statement at the inter-agency meeting on the subject last week that OFDA believes that the predicted earthquake will not occur.

4. I believe that our responsibility is to assist in preventing and relieving suffering. I believe that economic losses are not our direct concern. There are many other agencies which are involved in preventing or lessening, or recuperating from, economic catastrophes.

5. The panel should be instructed to limit its efforts to the reliability of the prediction, and not be permitted to deliberate on preparedness measures, warning systems and policies, contingency planning, or the sociological dynamics surrounding the prediction.

6. The Government of Peru, the private agencies there, and the Peruvian inhabitants have already begun to react to the Brady prediction. Without some scientific evaluation which is independent of the work being performed by Brady and Spence, the Peruvians have no reason not to believe that the United States Government supports the prediction. As long as the USGS makes no public statement about the prediction, I believe that the world will perceive government endorsement -- since, in fact, Brady is a career scientist working for the government.

7. The NBS should be instructed in the tasking document to provide a preliminary finding within 30 days of accepting the task, and a final position within 60 days of accepting the task. This sense of urgency is the result of two factors:

A. A great deal of actions must be put into motion, actions which may require from 3 to 16 months to achieve desired results. For example, if half a million tents are going to be needed, then tent specifications must be drawn up specifically for the Peruvian families they will serve, material must be accounted for and obtained by the Peruvian government, manufacturing facilities must be contracted and put into production, testing and inspection procedures laid out, and warehousing and stockpile systems must be designed and implemented. To wait until after the earthquake to request tents is a waste of resources.

B. The P ruvian Red Cross formally requested OFDA's assistance on 11 February 1980, specifically to coordinate all foreign efforts related to the predicted earthquake, and also to coordinate the U.S. efforts. D/OFDA replied that we would be happy to do so. Although this request has not been reported to AmEmbassy/Lima, we have received one report from the Embassy of increasing GOP and Peruvian public reaction to Brady's prediction. Otherwise, we have done very little to respond directly to the GOP (as in most Latin American countries, the Red Cross of Peru is so strongly interlinked with the GOP that it should be perceived as a government entity).

8. I recommend that OFDA establish a position vis-a-vis the predicted earthquak and inform interested agencies, including UNDRO, exactly what our position is. Such a position should have the concurrence of AA/LAC and GC.

Seismic Disaster Preparedness
Working Group Meeting
April 3, 1980 10:00 a.m.
AGENDA

1. Review of meeting on March 18, 1980
   (Memorandum)

2. Purposes of Preparedness Planning Working Group:
   - .Contingency planning and coordination
   - .Definition of potential responsibilities
   - .Collection of information/data/
   - .Organization of U. S. elements
   - .Interagency and intergovernmental communication
   - .Voluntary Agency participation

3. What is the U.S. role?
   - .Before precursors (September 1980)
   - .After precursors

4. How should we proceed?
   - .With local embassy officials?
   - .Action items to pursue?

5. Discussion macrozonation task,
   - .Compilation of information/data
   - .Suggested sources
   - .Threat parameters (Peru)
   - .Regional vulnerability (i.e. Pacific ring of fire)

April 3, 1980

DOCUMENT NO. 036

To: Bill Dalton

From: Joyce

Subj: Meeting on Earthquake Preparedness

Following are the highlights of today's meeting on earthquake preparedness.

According to Peggy Finarelli, Bill Maynard intends to write a letter to Frank Press stating the U.S. position on the Brady Peru prediction. That position being that the prediction is not an official U.S. prediction. Another letter, same subject, will then go from Frank Press to Alberto Gesiecke The purpose of these exercises is to (1) document and disclaim any responsibili and association with Brady's prediction and (2) separate any proposed planning efforts from it. This would help pave the way for conducting a generic study of that seismically-active area; a general study until credibility in the prediction and the theory behind it is significantly improved. At that time, it will be up to the USGS to make it an official U.S. prediction.

It was decided that a task force with a planning group component consistin of representatives of NSF, FEMA, and OFDA be established. Its purpose would be to put together an outline of proposed steps to take for earthquake predicti contingency planning purposes. It was suggested that the role of the U.S. coul be that of methodology transfer. Fred Cole is to arrange the group's initial meeting. State expects only to participate in the first meeting and be included in the clearing process. OSTP sees no need to participate in the planning group but will be kept informed.

Fred Krimgold said that studies on response to earthquake prediction have been conducted in California and that the planning group may want to draw upon them. NSF could be the point of contact with the persons knowledgeab of these studies. The experience of the Chinese could also be a useful source.

Querying whether or not the international community is doing any contingency planning as a result of the Brady prediction was discounted as hazardous.

DOCUMENT NO. 037

DEFENSE MAPPING AGENCY
BUILDING 56, U S NAVAL OBSERVATORY
WASHINGTON D C 20305

PA

APR 11 1980

Mr. Paul Krumpe
Agency for International Development
Office of Foreign Disaster Assistance
Department of State
Washington, D. C. 20523

Dear Mr. Krumpe:

This is to confirm our numerous telephone conversations regarding microfilm of old survey data of Peru.

Per your request last week, we have located in the archives at the DMA Hydrographic/Topographic Center nine roles of microfilm. They contain information on surveys tying into early Peruvian surveys, including stations established in 1927, 1930's and the 1940's when the Inter American Geodetic Survey (IAGS) began work in Peru. They contain mainly horizontal control. In the 1950's, IAGS established basic vertical control in Peru and that data is also on the films.

The IAGS has a project officer in Peru to whom we will send copies of the microfilmed data and indexes. Dr. Alberto Geisicke, Director of Geophysics in Peru, can then request the data through our project officer in the Peruvian Instituto Geografico Militar. We believe this is the most efficient way to get the information to Dr. Geisicke without compromising our MC&G agreement with Peru.

We do not have a bibliography of thematic maps of Peru showing features such as mines, highways, railroads, etc. You may be able to obtain this from State's map coordinator, Doug Dixon, Tel: 362-9674.

I trust the above satisfies your requirements.

Sincerely,

Tacy S. Cook

TACY S. COOK
Public Affairs Officer

UNCLASSIFIED

Department of State

APRIL 19, 1980

OUTGOING TELEGRAM

DOCUMENT NO. 038

PAGE 01 STATE 103001 0125 AID2267
ORIGIN AID-35

ORIGIN OFFICE DRC-02
INFO AALA-01 LASA-03 PPCE-01 PPPB-02 PDEA-01 AADS-01 DIU-04
DSST-01 ENGR-02 CH8-01 CH4-01 INT-04 RELO-01 PDPR-01
/026 A3

INFO OCT-00 /035 R

DRAFTED BY PDC/OFDA:PKRUMPE:PS
APPROVED BY PDC/OFDA:JAMITCHELL
PDC/OFDA:WDALTON
LAC/SA:WRHODES (PHONE)
ARA/AND:RBLOHM (PHONE)
ONE)
DESIRED DISTRIBUTION

19 April 1980

IH ACTION DRC CHRON 9 INFO AALA LASA PDC
017511 191554Z /34

P 191204Z APR 80
FM SECSTATE WASHDC
TO AMEMBASSY LIMA PRIORITY

UNCLAS STATE 103001

AIDAC

E.O. 12065: N/A

TAGS:

SUBJECT: IGP REQUEST FOR GEODETIC DATA SEARCH

1. AT THE REQUEST OF DR. ALBERTO GIESECKE AND DR. LEO OCOLA (IGP) OFDA CONTACTED THE DMA HYDROGRAPHIC/TOPOGRAPHIC CENTER IN WASHINGTON, D.C. TO SEARCH THE ARCHIVES FOR ORIGINAL MICROFILMED GEODETIC DATA OF PERU. THE FOLLOWING REPLY WAS RECEIVED 11 APRIL: QUOTE

PER YOUR REQUEST LAST WEEK, WE HAVE LOCATED IN THE ARCHIVES AT THE DMA HYDROGRAPHIC/TOPOGRAPHIC CENTER NINE ROLLS OF MICROFILM. THEY CONTAIN INFORMATION ON SURVEYS TYING INTO EARLY PERUVIAN SURVEYS, INCLUDING STATIONS ESTABLISHED IN 1927, 1930'S AND THE 1940'S WHEN THE INTER AMERICAN GEODETIC SURVEY (IAGS) BEGAN WORK IN PERU. THEY CONTAIN MAINLY HORIZONTAL CONTROL. IN THE 1950'S IAGS ESTABLISHED BASIC VERTICAL CONTROL IN PERU AND THAT DATA IS ALSO ON THE FILMS.

THE IAGS HAS A PROJECT OFFICER IN PERU TO WHOM WE WILL SEND COPIES OF THE MICROFILMED DATA AND INDICES. DR. ALBERTO GIESECKE, DIRECTOR OF GEOPHYSICS IN PERU, CAN THEN REQUEST THIS DATA THROUGH OUR PROJECT OFFICER IN THE PERUVIAN INSTITUTO GEOGRAFICO MILITAR. WE BELIEVE THIS IS THE MOST EFFICIENT WAY TO GET THE INFORMATION TO DR. GIESECKE WITHOUT COMPROMISING OUR MC AND G AGREEMENT WITH PERU. UNQUOTE.

2. PLEASE CONTACT DR. GIESECKE AND DR. OCOLA (GEOPHYSICS INSTITUTE OF PERU) WITH THE SPECIFIC INFORMATION PROVIDED IN PARA 1 ABOVE. VANCE

FDC/OFDA

APR 22 2 03 PM '80

UNCLASSIFIED

DOCUMENT NO. 039

April 28, 1980

MEMORANDUM

TO: Distribution

FROM: AID/PDC/OFDA, Frederick Cole

SUBJECT: Earthquake Contingency Planning

On Friday, May 2 at 3:00, there will be a meeting in OFDA's Coordination Center (Room 1262A, State Department) to renew our discussion of the U.S. Government's role in contingency planning for earthquakes which may affect Latin America. The attached outline reflects our initial thoughts on the planning components which should be included. We hope at this meeting to reach a concensus on which elements deserve priority attention and to identify U.S. resources which can be brought to bear.

Distribution:
James Anderson, FEMA
Joseph Massa, FEMA
E. V. Leyendecker, NBS
Tadayo Kobayaski, OES/SCT
Frederick Krimgold, NSF
Joseph Mitchell, OFDA
William Rhodes, LAC/SA
John Purnell, ARA/AND

Contingency Planning Elements
Earthquake

1. Hazard Analysis
   a) Historical Incidence
   b) Tectonics and Seismicity
   c) Residual Effects (e.g. Landslides, Tsunami)

2. Vulnerability Analysis
   a) Population Patterns
   b) Soil Conditions
   c) Structural Vulnerability
      (1) Shelters
      (2) Lifelines
      (3) Public buildings
      (4) Industrial/Commercial
      (5) Transportation
      (6) Communications

3. Preparedness
   a) Disaster Plans
   b) Legislation and Regulations
   c) Organization
   d) Public Awareness

4. Prevention
   a) Land Use
   b) Building Standards
   c) Condemnation
   d) Evacuation

5. Warning
   a) Source
   b) Evaluation
   c) Communications
   d) Response

6. Response Capabilities
   a) Damage Assessment
   b) Needs Assessment
   c) Resource Analysis (Goods and Service)
      (1) Critical Stockpiles
      (2) Local Markets
      (3) National Resources
      (4) Foreign Donors
   d) Logistics
   e) Communications
   f) Distribution
   g) Accountability

7. Reconstruction

DOCUMENT NO. 040

United States Department of the Interior

BUREAU OF MINES

BUILDING 20, DENVER FEDERAL CENTER
DENVER, COLORADO 80225

May 1, 1980

Memorandum

To: Robert L. Marovelli, Director, Minerals Health and Safety Technology, Bureau of Mines, Columbia Plaza, Washington, DC

Through: Verne Hooker, Research Supervisor, Mine Design, Denver Research Center

Galen G. Waddell, Research Director, Denver Research Center

From: Brian T. Brady, Physicist, Mine Design, Denver Research Center

Subject: General locations and approximate physical characteristics of the predicted foreshock sequence off the central Peruvian coast

The status of the foreshock series for the predicted July 1981 central Peruvian event is as follows: the foreshock series will commence in mid-September 1980. The time duration of this series will be approximately 328 days. There will be a total of twelve or more events in this series which will be temporally distributed in two active phases at the beginning and end of the series, each of whose time durations will be approximately 109 days. The magnitude range of these events will be greater than m_b 4.5. Their general locations will be along the boundaries of the inclusion zone shown in figure 1 (red). I expect that the majority of the foreshocks will cluster in the vicinity of the predicted mainshock locations (stars in figure 1). The foreshock series will terminate on or about July 30, 1981. The exact time will depend on the initiation time and length of the active phases of the foreshock series, with the occurrence of the mainshock ($M_W \geq 9.8$). This event will nucleate in the vicinity of 12.6° S and 77.6° W ("star" in figure 1) and will initiate a rupture to the S-SE from 12.6° S to approximately 26° - 28° S (yellow zone).

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

My current interpretation of the space time seismicity patterns in central Peru also leads me to hypothesize that a second event (M_W = 8.8) will nucleate 276 days later, the exact date depending on the initiation and characteristics of its own foreshock series, near 12.5° S and 77.6° W (ca May 2, 1982). This event will rupture to the NW from 12.5°S (Y_2 in figure 1) to approximately 8° S. This second event will have a foreshock phase with characteristics identical to that preceding the $M_W \geq 9.8$ mainshock. I cannot make more precise predictions of the occurrence times of the mainshocks until the initiation times of their respective foreshock series are known. Please understand that the occurrences of the foreshocks are necessary and sufficient for the occurrence of the predicted mainshocks. If the foreshocks do not occur, the prediction is invalid.

The exact locations and magnitudes of the predicted foreshocks cannot be predicted until their respective preseismicity data are known. Unfortunately, the preseismicity patterns preceding each foreshock will not be reported teleseismically because of their low magnitude range (= M=1 → M=2). The Peruvian local network could detect these events.

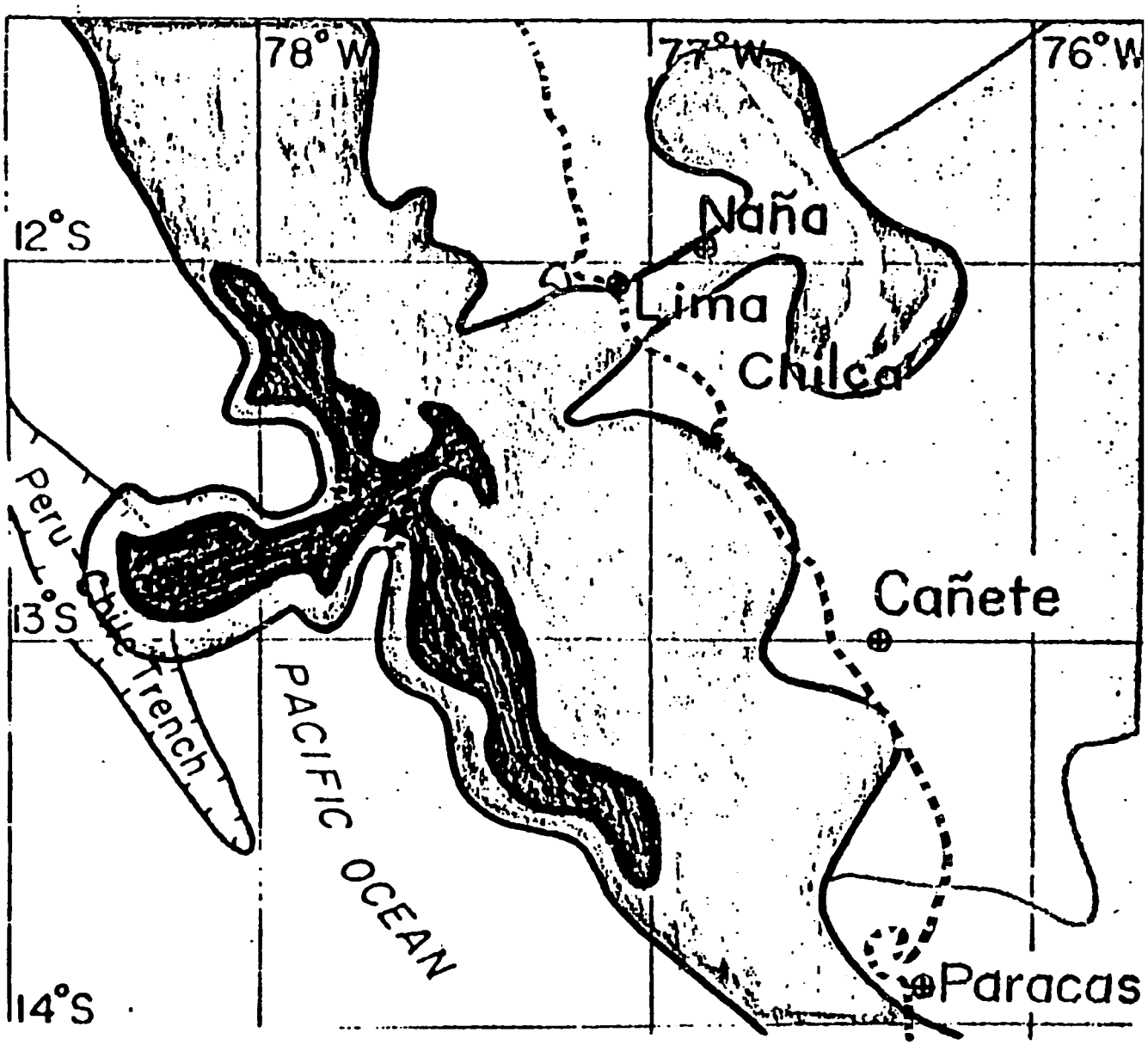
Dr. Spence and I are in agreement with the predicted foreshock characteristics. We are also of the opinion that the possibility exists for the occurrence prior to the mainshock of a large ($\geq M_S$=7.5) nominal faulting event downdip of the predicted July 1981 event.

I hope these comments will be of value to you. I should also mention that Dr. Spence and Mr. Langer of the USGS have determined that the "aftershocks" of the October 3, 1974, mainshock (M_W = 8.1) display a remarkable depth distribution along the boundaries of the predicted nucleation (red) zone in figure 1. Briefly, the seismological evidence is now strong that not only are the boundaries of the nucleation zone shown in figure 1 clearly delineated by seismic events immediately following the October 3, 1974, mainshock, but also the cross-section (depth) view shows that the zone is delineated both on the top and bottom. There is a "null" zone of approximately 7 km thickness where no seismic activity occurred. The seismic activity developed only along the boundaries of the predicted nucleation zone. Exactly this behavior was predicted by the theory nearly five years ago.

Brian T. Brady

Brian T. Brady
Physicist
Mine Design
Denver Research Center

Enclosure


78°W
77°W
76°W
12°S
13°S
14°S
Naña
Lima
Chilca
Cañete
Paracas
Peru-Chile Trench
PACIFIC OCEAN

DOCUMENT NO. 041

Goddard Space Flight Center
Greenbelt, Maryland 20771

NASA National Aeronautics an Space Administration

SCIENTIFIC COLLOQUIUM

Speaker: ROBERT L. WESSON

OFFICE OF THE DIRECTOR
U.S. GEOLOGICAL SURVEY
RESTON, VA

Subject: EARTHQUAKE PREDICTION

Date/Time: FRIDAY, MAY 2, 1980 - *3:30 P.M.

Place: BUILDING 3 AUDITORIUM

Advances in understanding the processes of deformation in the Earth's crust have led earth scientists to the brink of earthquake prediction. A routine capability to predict earthquakes does not yet exist, but successful predictions of damaging earthquakes have been made in the People's Republic of China and perhaps in the Soviet Union. The Chinese, however, are particularly mindful of their failure to predict the disasterous Tangshan earthquake of July 1976, in which several hundred thousand people were killed.

Optimism about the attainment of earthquake prediction arises from understanding of the relative motion of the large tectonic plates making up the Earth's surface, from understanding of the mechanisms of elastic strain accumulation and release in the Earth's crust and from technological advances in instrumentation enabling the monitoring of these processes. Unanswere questions about the technical aspects of earthquake prediction involve the processes of material failure leading up to and at the instant of the earthquake.

The capability to predict earthquakes raises a variety of ethical, social, economic, and political questions which must be addressed by earth scientists and Government. Some progress is being made to develop means for the evaluation and communication of predictions, and to enable the constructive use of this information, but much remains to be done.

"Though it be honest, it is never good to bring bad news...," William Shakespeare.

*COFFEE AND TEA SERVED FROM 3:00, COMPLIMENTS OF GEWA.

DOCUMENT NO. 042

MEMORANDUM

May 12, 1981

TO: PDC/OFDA, Dr. Martin D. Howell, Director

THRU: PDC/OFDA, Alan Van Egmond, Assistant Director for Disaster Preparedness

FROM: PDC/OFDA, Paul F. Krumpe, Science Advisor

SUBJECT: Update on the Status of the Peru Earthquake Prediction by Dr. Brady

REF: OFDA Memorandum (4/15/81) from Krumpe to Van Egmond on comparative analysis of Brady prediction statements and the occurrence of events.

This memorandum is the third addendum (update) to my April 15, 1981 memo to Mr. Van Egmond concerning recent occurrence of seismic events in Peru which tend to correlate with prediction statements made by Dr. Brady since 1977.

The attached U.S. Bureau of Mines memorandum from Dr. Brady to his Division Director, Mr. Robert Marovelli provides, in detail, the past and current seismicity patterns in central Peru which Brady contends support his prediction of a series of catastophic events to occur this summer in Peru.

The attached status report of the Peru earthquake predictions of Dr. Brady will be discussed and explained at the Technical Briefing to be held on May 13 in the OFDA Operations Center. Copies of the report are being provided to OFDA Senior Staff in preparation for the meeting.

The first event predicted by Dr. Brady as of this status report is July 6, 1981. The predicted magnitude is M_W = 8.1 - 8.3 with a rupture zone from 12.2°S to 13.7°S. The following events remain on schedule for mid-August and mid-September according to Dr. Brady. Dr. Brady considers these dates preliminary and subject to change as data from the Peru local network become available for further interpretation and analysis. The attached memo explains elements of Dr. Brady's analysis technique. He does not elaborate on his theory (subject of previous memoranda) but does provide some explanation of the physical basis for rock failure and the preparation process which he contends is predictable regardless of scale.

DOCUMENT NO. 043

United States Department of the Interior

BUREAU OF MINES
2401 E STREET, NW.
WASHINGTON, D.C. 20241

IN REPLY REFER TO:

May 14, 1980

Mr. John R. Filson
Acting Chief
Office of Earthquake Studies
U.S. Geological Survey
Mail Stop 905
12201 Sunrise Valley Drive
Reston, VA. 22092

Dear Mr. Filson:

At the meeting on Peruvian earthquake prediction convened by the U.S. Agency for International Development on March 18, 1980, you mentioned that if Dr. B.T. Brady could produce a list of the series of foreshocks that he predicted to occur in Peru beginning September 1980, giving the time, location, and magnitude of each predicted event, the U.S. Geological Survey would be able to use the existing worldwide earthquake monitoring network to check Dr. Brady's prediction. Accordingly, we have advised Dr. Brady to respond to your suggestion. Enclosed for your review is a copy of Dr. Brady's memorandum of May 1, 1980, giving the general locations and approximate physical characteristics of the predicted foreshock sequence. We would like to call your attention to the statement in the second papagraph on page 2 of the memorandum, "the exact locations and magnitudes of the predicted foreshocks cannot be predicted until their respective preseismicity data are known." Although his response is not as specific as you wish to have, we hope it can be of some help in your effort to verify his prediction. Please let us know if you have any comments, or if we can be of any further help to you in earthquake studies.

Sincerely,

Robert L. Marovelli
Director, Division of Minerals
Health and Safety Technology

Enclosures

U.S. Geological Survey
Office of Earthquake Studies
Reston, Virginia

MAY 22 A.M.

RECEIVED

DOCUMENT NO. 044

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20500

May 15, 1980

Dear Bill:

In our earlier conversations about Brian T. Brady's prediction of a massive earthquake off the coast of Peru, I indicated to you that Bill Menard had told Frank Press that this prediction is not an official USG position. I am enclosing for your records a letter which Menard has written Press explaining USGS's position on this issue. You will note in the final paragraph, however, that USGS does encourage general disaster planning exercises of the type you are now conducting.

Sincerely,

Peggy

Margaret G. Finarelli
Senior Policy Analyst for
International Science & Technology

Mr. William Dalton
Assistant Director for
Preparedness and Planning
Office of Foreign Disaster
Assistance
Agency for International
Development
320 21st Street, NW
Washington, DC 20523

(LETTER OF MAY 6 1980 ATTACHED)

United States Department of the Interior

GEOLOGICAL SURVEY
RESTON, VA. 22092

In Reply Refer To:
Mail Stop 905

MAY 6 1980

Dr. Frank Press, Director
Office of Science and Technology Policy
Executive Office of the President
Washington, D.C. 20500

Dear Frank:

We are writing in response to your request for information concerning the prediction of a large earthquake off the coast of Peru to occur on July 30, 1981. This prediction is based principally upon the work of Dr. Brian T. Brady of the Bureau of Mines. Dr. Brady is predicting an earthquake associated with fault rupture initiating just off the coast of Lima and extending over 1,000 km to the south-southeast along the bend in the western South American coastline. The predicted magnitude of the earthquake is $M_w = 9.8$ or greater.

Against the background of the work on seismic gaps done by the Lamont group, the predicted earthquake would initiate in a previously identified gap filled by a magnitude 8.1 event in 1974. However, the southern portion of the rupture would extend into a region designated as one of highest seismic potential by the Lamont group. The northern portion of this zone of highest seismic potential previously experienced a great earthquake in 1886; the southern portion last experienced a great earthquake in 1877. The latter event generated a destructive tsunami.

The basis for the Peruvian prediction is a scale invariant theory of failure developed by Dr. Brady from his work on mine failure and rock bursts. The application of Dr. Brady's theory to earthquake prediction requires the recognition of various seismicity patterns (zones of increased and decreased seismicity) in the vicinity of the impending earthquake. Although descriptions of Dr. Brady's theories have been in the literature since 1976, they have not gained wide acceptance nor recognition from the seismological or rock physics communities.

In January of 1979 the Geological Survey was asked by Alberto Giesecke of the Institute of Geophysics of Peru to have members of our staff meet with him to discuss the potential for a catastrophic earthquake off Peru. Dr. Giesecke's concern was based, apparently, on Dr. Brady's prediction. In May 1979, a meeting was held in Golden, Colorado, between members of the Survey's Office of Earthquake Studies, Dr. Giesecke and his staff, representatives from the Office of Foreign Disaster Assistance, and a representative of the Peruvian Embassy in Washington. At this meeting Dr. Brady presented his case, and it was opened for discussion and question. Although the general reception of the

theory by scientists of the Geological Survey was skeptical, Dr. Brady was urged to set down in rigorous detail the basis for his Peruvian prediction so that it could be evaluated and verified by others.

Because Dr. Brady has yet to do this, we do not, indeed we cannot, endorse his prediction at this time. For the same reason we do not feel it merits review by the National Earthquake Prediction Evaluation Council.

As you may be aware, the Brady prediction has recently been given wide publicity in Peru. Apparently it is also being used by the Office of Foreign Disaster Assistance to provide the focus for a disaster-planning exercise. In our opinion there is no doubt there is a serious threat to lives and property in Peru due to the earthquake hazard. We encourage all efforts that will better prepare the country of Peru to mitigate the hazard of and reduce losses from large earthquakes that will continue to affect that country. However, at this time we do not, indeed we cannot, endorse Dr. Brady's prediction because of a lack of a well-accepted empirical or theoretical basis. Despite our misgivings, however, we are willing to search for any precursory seismicity patterns described by Dr. Brady using the data routinely available from our worldwide epicenter location efforts.

Sincerely yours,

H. William Menard
Director

DOCUMENT NO. 045

United States Department of the Interior

GEOLOGICAL SURVEY
RESTON, VIRGINIA 22092

In Reply Refer To:
Mail Stop 905

May 27, 1980

Memorandum

To: Chief, Global Seismology Branch

From: Acting Chief, Office of Earthquake Studies

Subject: Prediction of earthquakes off Peru

Enclosed is a letter from Robert Marovelli transmitting a memorandum from Dr. Brian Brady. In the memorandum Dr. Brady sets down the details of the foreshock-mainshock sequence he has predicted to begin off the coast of Peru in mid-September 1980.

You are directed to use the facilities and data available to the National Earthquake Information Service (NEIS) in efforts to detect the foreshock sequence predicted by Dr. Brady. Beginning in October 1980, you should submit to me a written report at the end of each month reviewing the detected seismicity in the region of the predicted earthquake sequence. In these reports you should include a statement, based on your best scientific judgment, on whether or not the seismicity is following the pattern predicted by Dr. Brady. This statement should also include an estimate of the uncertainties associated with your evaluation and the uniqueness of the seismicity patterns observed, if any.

Your reports will form the basis for any further comment by this Office on teleseismic evidence relevant to the prediction by Dr. Brady.

John R. Filson

Enclosure

Copy to: R. Marovelli
R. Wesson
D. Peck

Ed. Note
Memo from Brady to Marovelli of May 1, 1980; and letter from Marovelli to Filson of May 14, 1980; both referenced in this letter can be found under their respective dates in this volume.

June 5, 1980

Memorandum to the Files

From: Fred Cole FMC

Subject: Meeting on S.A. Contingency Planning with NSF

On June 4, Bill Dalton and I met with Fred Krimgold and Bill Anderson, Program Managers of NSF's Earthquake Hazard Mitigation Program, Problem Focused Research Division.

The following points were brought up during the meeting:

There is a good deal of Congressional interest in "Post Prediction Response" to disasters, largely mobilized by Congressman Brown of California.

Although that interest is directed toward domestic problems, a parallel is easily drawn between the U.S. and Peru; research for both cases can be seen as mutually supportive.

Chuck Thiel coordinates activities of "Federal Programs" in this area to insure minimum overlapping. He has "mission responsibility" at FEMA, meaning his purpose is to produce written materials to foster the cause of mitigation.

NSF gets involved in prototypical research; FEMA is responsible for extrapolating that research for federal, state and local mitigation purposes.

NSF, like USGS and NOAA, can work in the international arena only when such research can be proven to be of direct benefit to the U.S. Krimgold sees the Peru situation as fitting these guidelines and sees their potential role in this exercise as:

1. Providing relevant research material and data
2. Providing guidance for and access to U.S. experts
3. Managing components of the overall program such as analysis of structural vulnerability.

The methodology which has been developed to date suggests that an early component of the contingency planning program should be aerial reconnaiscance of the threatened area (Coastal and Sierra Regions) to get an inventory of population concentrations, building types, potential transportation and communications failures, etc.

The U.S. scientific community is fast backing off from optimistic projections for long term earthquake prediction. Speculation on 4 - 6 week warning is currently in vogue.

Of relevance to Peru, Krimgold mentioned:

- The Dutch have installed a materials testing program in Peru

- A guy named Kitely, structural engineer, has a testing program at Montana State which deals with Peruvian structure vulnerability.

- Herez Shaw, at Stanford's John Bloom Research Center has created hazard maps for Central America, Algeria, etc. which methodology could be valuable for Peru.

- The University of Florida Peru reconstruction analysis program should be considered for our purposes as should Volker Hartkopf's Peru shelter study at Carnegie Mellon University.

Krimgold had copies of "A Study of Earthquake Losses..." series which represents the basis for existing vulnerability analysis methodology. These have been done for San Francisco, Los Angeles, Puget Sound and Salt Lake City. Originally does for OEP, the series is to be continued by FEMA.

In summary, the NSF stands ready and willing to help us pull together the scientific expertise we will need to create a sound basis for contingency planning in Peru. Although they may have some money they could put into the project, I don't think we should count on it. We can determine how best to enlist NSF's services once we've met with FEMA and others.

J. Mitchell

cc: P. Krumpe –
J. Clark

Clearance:
PDC/OFDA:WRDalton

PDC/OFDA:FCole:ps:6/5/80:28746

UNITED STATES INTERNATIONAL DEVELOPMENT COOPERATION AGENCY
AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D.C 20523

DOCUMENT NO. 047

June 6, 1980

Margaret G. Finarelli
Senior Policy Analyst for
International Science & Technology
Executive Office of the President
Office of Science and Technology Policy
Washington, D.C. 20600

Dear Peggy:

Forgive the delay in acknowledging your letter of May 15th which transmitted Director Menard's letter to Dr. Frank Press on the subject of the Peru prediction.

During the past few weeks we have been hard at work putting on a Pan-Caribbean working meeting of disaster responsible officials from most of the islands of the Caribbean which was designed to produce a comprehensive disaster preparedness and prevention program for the islands of the Caribbean and Belize and Guyana. That effort which really started two years ago culminated in a five day meeting in Santo Domingo. 55 projects were developed by the participants in such fields as seismology, meteorology, engineering, health, national planning and the like. I mention this effort not as an explanation alone of the reason for our not acknowledging your letter but also on the probability that your office might be interested in this unique regional approach being taken in the area of disaster preparedness.

Director Menard's letter nicely summarizes the situation relative to the Brady prediction. We, Fred Krimgold and Chuck Thiel are moving now with others to develop a schematic for a planning exercise based upon heavy seismicity anticipated in the area in future years. We will keep you informed of significant developments.

I appreciate your support in what we are trying to do.

Sincerely,

William R. Dalton
Assistant Director
Office of U.S. Foreign Disaster
Assistance

Reports, Memoranda, Correspondence and Other Communication

June - December, 1980

DOCUMENT NO. 048

UNCLASSIFIED

Department of State

OUTGOING TELEGRAM

17 July 1980

PAGE 01 OF 02 STATE 188396 4824 STATE 188396
ORIGIN AID-35

INFO OCT-00 /035 R

DRAFTED BY AID/PDC/OFDA:FCOLF/PKRUMPE:ED
APPROVED BY AID/PDC/OFDA:JAMITCHELL
AID/PDC/OFDA:WRDALTON
ARA/AND:JPURNELL (PHONE)
AID/LAC/SA:WRHODES
AID/PDC/OFDA:ODAVIDSON
OES/SCT:TKOBAYASHI
OSTP:PFINARELLI (PHONE)
ARA/AND:WKNEPPER (PHONE)
ARA/AND:PWHITNEY (PHONE)
AID/PDC/OFDA:JACLARK
USGS/OES:RSTEWART (PHONE)
DESIRED DISTRIBUTION
ORGIN DRC CH 8 CH 9 INFO AALA LACA LASA LADR PPEA PPCE PDPR PPPB PD
STA OL=00 END

----------030305 172113Z /34

P 171813Z JUL 80
FM SECSTATE WASHDC
TO AMEMBASSY LIMA PRIORITY
AMEMBASSY BOGOTA
AMEMBASSY CARACAS
AMEMBASSY LA PAZ
AMEMBASSY QUITO
AMEMBASSY SANTIAGO

UNCLAS STATE 188396

AIDAC GENEVA,PASS TO UNDRO, LORCS

E.O. 12065: N/A

TAGS:

SUBJECT: ANDEAN REGIONAL DISASTER PREPAREDNESS

1. WHEN PERUVIAN RED CROSS PRESIDENT JUAN GARLAND WAS IN WASHINGTON IN FEBRUARY, 1980, OFDA AGREED TO COORDINATE U.S.G. ELEMENTS WHICH COULD ASSIST PERU AND OTHER ANDEAN COUNTRIES IN PREPARING FOR LARGE-SCALE EARTHQUAKES WHICH MAY AFFECT THE REGION IN THE FUTURE. TOWARD THIS END, WE HAVE HELD TWO INTER-AGENCY MEETINGS TO DISCUSS OPTIONS OPEN FOR CONTINGENCY PLANNING. U.S. GEOLOGICAL SURVEY, BUREAU OF MINES, NATIONAL BUREAU OF STANDARDS, OFFICE OF S/T POLICY, NATIONAL SCIENCE FOUNDATION, FEDERAL EMERGENCY MANAGEMENT AGENCY, STATE AND AID HAVE BEEN REPRESENTED. THE CONCLUSIONS OF THESE EXPLORATORY SESSIONS CAN BE SUMMARIZED AS FOLLOWS:

(A) PERU'S INITIATIVES AND REGIONAL N R S N D DISASTER PREPAREDNESS PRESENT A SIGNIFICANT OPPORTUNITY TO FURTHER DEVELOP THE METHODOLOGY AND TECHNIQUES OF CONTINGENCY PLANNING FOR DISASTERS. SUCH TECHNIQUES INCLUDE THE ANALYSIS OF VULNERABILITY OF THREATENED POPULATIONS, CREATING SCENARIOS FOR PROBABLE GEOPHYSICAL EVENTS AND DEVELOPING REMEDIAL COUNTERMEASURES. THESE ACTIVITIES ARE SPECIFIED IN OFDA'S INTERNATIONAL DISASTER ASSISTANCE MANDATE AND ARE CLEARLY OF PARALLEL INTEREST TO NATIONAL SCIENCE FOUNDATION, FEDERAL EMERGENCY MANAGEMENT AGENCY AND OTHERS WITH DOMESTIC U.S. RESPONSIBILITIES.

(B) OFDA IS PREPARED TO COORDINATE U.S.G. ACTIVITIES IN CONTINGENCY PLANNING FOR EARTHQUAKE THREAT TO ANDEAN COUNTRIES AS REQUESTED TO THE EXTENT THAT SUCH ASSISTANCE IS MISSION APPROVED, APPROPRIATE AND COMPLEMENTARY TO THE EFFORTS OF THE GOX, OTHER NATIONS AND INTERNATIONAL ORGANIZATIONS.

2. THE FOLLOWING APPROACHES ARE RECOMMENDED BY OFDA FOR EARTHQUAKE CONTINGENCY PLANNING PURPOSES:

(A) HAZARD ANALYSIS: DESCRIPTION OF THE PROBABILITY THAT A GIVEN EVENT WILL OCCUR WITHIN A SPECIFIED AREA. FOR OFDA PLANNING PURPOSES, WE PROPOSE SELECTION OF MULTIPLE SITES CHOSEN AS LIKELY EPICENTERS ALONG THE WEST COAST OF SOUTH AMERICA BASED ON KNOWN SEISMIC GAP DATA. MAGNITUDES, FOCAL DEPTHS, TIMES OF DAY, ETC. WOULD BE ASSIGNED ON A WORST CASE BASIS.

(B) VULNERABILITY ANALYSIS: GIVEN A PREDETERMINED EVENT, THE THREAT TO SPECIFIC POPULATIONS CAN BE ESTIMATED ON THE BASIS OF PREDICTABLE GROUND MOTION, LOCATION, SOIL, CONDITIONS, BUILDING PRACTICES, ETC.

(C) SCENARIO ANALYSIS: PRIOR EXPERIENCE, ORGANIZATIONAL RESPONSIBILITIES, DISASTER PREPAREDNESS AND RELIEF PLANS, STATUS OF COMMUNICATIONS AND LOGISTICS, RESPONSE CHARACTERISTICS OF OUTSIDE DONORS AND OTHER FACTORS CAN BE INTERPRETED THROUGH CASE STUDIES TO DETERMINE PROBABLE REACTIVE MECHANISM AND PARTICULARLY TO IDENTIFY CONSTRAINTS TO PRODUCTIVE RELIEF MEASURES.

(D) REMEDIAL ACTIONS: RECOMMENDATIONS FOR STRENGTHENING SYSTEMS CAN BE FORMULATED ON THE BASIS OF ASSUMED WEAKNESSES IN CRITICAL PHYSICAL, ADMINISTRATIVE, EDUCATIONAL OR LOGISTICAL COMPONENTS.

3. TO DATE, WE HAVE BEEN REQUESTED (BY JUAN GARLAND) ONLY TO COORDINATE U.S.G. RESOURCES TO BE BROUGHT TO BEAR IN MITIGATING THE EFFECTS OF A FUTURE HYPOTHETICAL GREAT EARTHQUAKE IN PERU. WHILE IN WASHINGTON, MR. GARLAND PRESENTED A COPY OF THE PERU RED CROSS SOCIETY'S PROPOSAL FOR STOCKPILING CRITICAL SUPPLIES. IT HAS NOT BEEN MADE CLEAR WHAT RESPONSE HAS BEEN OFFERED BY THE LEAGUE OF RED CROSS SOCIETIES, UNDRO OR OTHER NATIONS TO WHOM THE PROPOSAL HAS ALSO BEEN SUBMITTED. FYI, WE DO NOT CONSIDER THE PROCUREMENT AND PREPOSITIONING OF NATIONAL DISASTER RELIEF ASSETS TO BE AN APPROPRIATE ACTIVITY OF OFDA BECAUSE WE DO MAINTAIN OUR OWN REGIONAL STOCKPILE IN PANAMA. END FYI.

4. WE ARE INCREASINGLY MADE AWARE THAT PERU AND OTHER ANDEAN COUNTRIES ENJOY A SOPHISTICATED, SCIENTIFIC AND ADMINISTRATIVE DISASTER PREPAREDNESS PROGRAM, VIS-A-VIS SEISMOLOGICAL INVESTIGATION, RISK ANALYSIS, LAND USE PLANNING AND PREPAREDNESS PLANNING. ALTHOUGH THE CONTINGENCY PLANNING EFFORT OUTLINED ABOVE IS USEFUL FOR OUR OWN PURPOSES AND IS VALUABLE FOR DEVELOPMENT OF PROTOTYPICAL PLANS, WE DO NOT WANT TO DUPLICATE THE EFFORTS OF HOST GOVERNMENTS. WE ARE THEREFORE SEEKING MISSION ADVICE ON WHAT WILL BE OFDA'S MOST PRODUCTIVE AND APPROPRIATE ROLE IN ASSISTING GOX IN THEIR PREPARATIONS FOR POSSIBLE FUTURE MAJOR EARTHQUAKES.

5. RE DR. BRADY'S PREDICTION (65 KM SW OF LIMA, PERU) FOR A SEVERE EARTHQUAKE TO OCCUR IN JULY, 1981, THE U.S.G.S. DOES NOT HAVE SUFFICIENT EVIDENCE EITHER TO ENDORSE OR REFUTE THE HYPOTHESIS AT THIS TIME. ACCORDING TO THE U.S.G.S.; DR. BRADY HAS NOT YET SET DOWN IN RIGOROUS DETAIL THE BASIS FOR HIS PERUVIAN PREDICTION SO THAT IT CAN BE EVALUATED AND VERIFIED BY OTHER MEMBERS OF THE SEISMOLOGICAL OR ROCK PHYSICS COMMUNITIES. USGS'S NATIONAL EARTHQUAKE INFORMATION SERVICE WILL HOWEVER MONITOR POSTULATED FORESHOCK SEQUENCE PERIOD, PROJECTED FOR LATE SEPTEMBER, 1980, IN AN ATTEMPT TO VERIFY OR DISCOUNT THE SEISMICITY

UNCLASSIFIED

PATTERN UPON WHICH DR. BRADY BASES HIS PREDICTION. F.Y.I., IF THE FORESHOCK SEQUENCE DOES NOT OCCUR AS PREDICTED, DR. BRADY STATES THAT THE MAINSHOCK PREDICTION WOULD BECOME INVALID. WE SHALL KEEP YOU INFORMED OF ANY FURTHER DEVELOPMENTS WHICH COME TO OUR ATTENTION. END FYI.

6. OFDA IS IN THE INITIAL STAGES OF PLANNING AN ANDEAN DISASTER PREPAREDNESS ACTIVITY TO BE HELD IN THE REGION HOPEFULLY WITHIN A YEAR. THE FORUM, SITE AND AGENDA ARE STILL OPEN, BUT IT PRESUMABLY WILL SERVE AS A FOCAL POINT FOR SEVERAL OF OUR ACTIVITIES INCLUDING CONTINGENCY PLANNING. SEPTEL TO ALL INTERESTED MISSIONS WILL ADVISE YOU FURTHER ON THIS PROSPECT AND VARIOUS DISASTER HAZARDS TO BE CONSIDERED.

7. PLEASE ADVISE US OF YOUR MISSION'S VIEW PER RECOMMENDATIONS PARA. 2 AND APPROPRIATE MEANS OF OFDA ASSISTANCE IN PLANNING FOR EARTHQUAKES IN GOX PER PARA. 1-B. ALSO KEEP US INFORMED OF PREPAREDNESS ACTIONS BY THE GOX, INTERNATIONAL ORGANIZATIONS AND OTHER DONORS. MUSKIE

Report to the Agency for International Development on a trip to Peru from Aug 17 to Sept 1, 1980 by Jerry P. Eaton, Geophysicist of the United States Geological Survey

From August 17 to September 1, 1980, I travelled to Peru at the request of Dr. Alberto Gieseke, Director of the Instituto Geofisico del Peru, and with the support of AID to discuss problems raised by the prediction of a catastrophic earthquake near Lima in the fall of 1980. My activities in Peru can be divided into four topical areas, the last two of which were pursued more or less concurrently throughout the visit:

1) discussion with Dr. Giesecke and the Executive Secretary of the National Security Council of Peru on
   a. the scientific merit of the Brady-Spence prediction,
   b. the long-term threat to Peru of major earthquakes in the country,
   c. the importance and appropriateness of the earthquake studies program carried out by the Instituto Geofisico del Peru;
2) discussions with Ambassador Scleuderman and with Mr. Leonard Yaeger (and others) of USAID in Lima on the three topics listed under #1, above;
3) field trips to several field study areas to examine facilities and discuss IGP work in those areas and to become acquainted with working conditions and support facilities in those areas--
   a. Talara-Piura region of north coastal Peru, with Dr. Daniel Huaco,
   b. Lima-Ica region of central coastal Peru, with Dr. Giesecke and Mr. Deza,
   c. Cuzco-Machupicchu region of the Peruvian altiplano, by myself but with instructions from IGP staff;

4) discussions with principal members of the IGP staff on current seismological studies of IGP and on plans to augment those studies to provide a more adequate basis for efforts to reduce loss of life and economic disruption from future earthquakes in Peru.

In accordance with recent telephone conversations with Mr. William Rhodes, USAID Washington, this report will address itself primarily to an evaluation of the senior staff, current program, plans for an expanded program, and principal difficulties facing IGP, based on items 3 and 4 above.

The modern Instituto Geofisico del Peru has developed partly out of a long-continuing series of Peruvian-Foreign (chiefly US) cooperative scientific studies of global importance that have been carried out in Peru. A partial list of these cooperative studies related to the solid earth includes:

1) the Huancayo Observatory for magnetic and seismic observations--established in the 1930's in cooperation with the Carnegie Institution of Washington, I believe, and continued with some support from the US Coast and Geodetic Survey (later NOAA);
2) the Nana Observatory for seismic and strain observations--established in the 1950's in cooperation with the California Institute of Technology, I believe;
3) establishment in the early 1960's of worldwide standard seismograph stations at Nana and Huancayo in cooperation with NOAA, and continued operation of those stations in cooperation with first NOAA, then the USGS;

4) collaboration with the Carnegie Institution of Washington in a study of earthquakes in the Peruvian Andes by means of a sparse short-period seismic network from the 1960's to the present time;

5) collaboration with Kyoto University in a study of crustal deformation in central coastal Peru by means of several sets of "invar wire" strain meters during the last 5 years or so.

In addition to the solid earth studies indicated above, IGP operates a sophisticated electronic facility at Jicamarca, I believe in cooperation with a US agency (NASA or NOAA?) and for the purpose of low-lattitude ionospheric sounding studies.

The steady development of the apparently fragile IGP during at least the last 10 years is due largely to the remarkable energy, insight, and skill of its current director, Dr. Alberto Gieseke, who occupies a leading (perhaps unique) position in the Peruvian government/scientific community. Dr. Giesecke has strong personal contacts within the Peruvian leadership and enjoys the respect of his scientific associates and foreign scientific cooperators. He has wisely used the opportunities provided by the cooperative programs to develop a Peruvian competence in the topical areas of the programs. This effort has resulted in several promising Peruvian students being sent to the US for higher degrees in geophysics. Two of these men, Dr. Leonidas Ocola (PhD, Univ. of Wisc.) and Dr. Daniel Huaco (PhD, St. Louis Univ.), are current leaders of the two principal seismology Divisions of IGP.

The arousal of scientific, governmental, and public concern over earthquakes in Peru that has resulted from the long-continuing (and

changing) Brady-Spence predictions of a catastrophic earthquake near Lima has led the Peruvian government to authorize, somewhat tentatively, a substantial increase in the IGP seismological program. Two draft proposals for an expanded program have been produced within IGP, one by Huaco and one by Ocola. These proposals differ in the emphasis and priority placed on various types of studies that should be undertaken: seismic network studies of seismicity, crustal structure, and tectonic processes; long-base-line and "point" measurements of crustal strain, etc. Both proposals were developed with an awareness of similar work now under way in the US and elsewhere. The document by Ocola is particularly useful because it is based on a recent fact-finding trip made by Ocola to the US and because it summarizes the status of current studies in Peru. It is an extremely well-thought-out document that proposes a plan of organization of the work as well as an outline of the work that should be undertaken and a list of equipment and facilities that would be required.

The proposed program is a long-term one, and I believe that in its full version it would require considerably higher funding levels than appear to be available as well as a considerable increase in the size and level of training of the staff now available for maintenance and operation of equipment and for the analysis and interpretation of data. It is therefore extremely important that initial efforts to implement such a plan be scaled at an appropriate level, concentrated on the most urgent tasks, and undertaken by the institution (or group) best prepared to carry them out. Extension of the work to other groups (and/or regions) and to other tasks could then be carried out with the help of a trained Peruvian staff that had proven its ability to do the work.

I am enclosing a copy of the Ocola report, "Prediccion Sismica en el Peru: Parametros Importantes, Programa General, y Equipamiento", although I am not certain of its status within IGP, because it contains the features noted above. In a general way it presents views on the sort of program that should be undertaken in Peru that are very similar to my own. As stated in its introduction:

> In the present report the results are summarized in three parts. The first is concerned principally with the degree of importance of the physical and chemical "parameters" presently being used in prediction. The second suggests a program of work. The third presents a recommendation on the equipment to be acquired.

In its summary, Part I concludes (page 8):

> From the foregoing description it is evident that the order of importance of the different observable parameters for earthquake prediction at a national level is: i) seismicity, ii) geodetic deformation, iii) neotectonic phenomena, iv) "point" deformations, v) variations in the flux of radon, vi) variations in the magnetic field, and vii) variation in the level of groundwater, viii) variations in the electric field

In accordance with this order of importance, I find the sections of Part II that deal with the present and proposed seismic networks to be the most important: pages 9-16, pages 21-23, and page 25. These sections are of particular importance because they deal with the central problem of developing, operating, and analyzing data from the national seismic network, which will play a leading role in the study of the causes and effects of earthquakes in Peru.

Part III presents recommendations on the acquisition of equipment. This whole section is very important because it deals with approaches, priorities, and equipment choices that will determine the ultimate form of the studies based upon them as well as the likelihood of success of those studies.

Within the general framework of studies outlined in the Ocola report, I believe that the most crucial and urgently needed element is the portion of the national seismic network that will cover central Peru and will be recorded and analyzed at IGP in Lima. This is the region involved in the Brady-Spence prediction and the region that is most readily accessible to IGP for installing and testing the proposed network. In addition to the seismic and telemetry equipment required in the field, facilities for recording, processing, and analyzing the network data at IGP in Lima will also be needed. I believe that some further consideration of the recording and analysis equipment is needed to decide just what combination of several possible choices would be most effective and reliable.

In the design, selection of specific equipment items, installation, and testing of the system suggested above, I believe that IGP would be aided greatly by collaboration with some group in the US, like the USGS or one of several university groups, that is a already operating such a system. Such collaboration could also provide a means of training selected Peruvian technicians in the maintenance and operation of the equipment before it is installed and of expediting the acquisition and shipping of repair parts after the system is operating.

To indicate an appropriate level of effort for the proposed system, I shall list the major equipment items that it might include:

1) 20 single-component seismic stations for installation along the coast and in the Andean foothills with appropriate radio telemetry equipment,

2) 10 single component seismic stations with onsite recorders for installation in the Andes and on the altiplano,

3) seismic recorders (film or paper type) for recording the telemetered stations at IGP,

4) tabletop digitizer for reading seismograms,

5) minicomputer (or guaranteed access to a convenient general-purpose computer) and associated input/output devides suitable for processing seismic data to determine earthquake hypocenters and to prepare plots of epicenter maps, cross sections, etc.

6) 6 self-recording portable seismograph stations for temporary deployment to study regions of unusual short-lived interest: aftershock sequences, regions with unusual changes in seismicity, etc. At least half of these should be 3-component systems, preferably recording digitally on tape, supported by an appropriate playback facility at IGP.

The foregoing list is not necessarily balanced or complete, but it may help to fix ideas.

The most serious problems that IGP will face in carrying out an expanded earthquake program are those that are common to most of Central and South America. They include:

1) salaries, particularly for all but the highest level personnel, are very low: morale among the technicians is therefore rather low and the most able are likely to leave government employment for higher paid jobs in industry;

2) the general level of technology is low, so local facilities for the support of electronic and computer systems are inadequate;

3) foreign mail service is extremely slow; so other provisions must be made for rapid access to foreign suppliers of critical parts and materials.

I see no good way around the first of these difficulties. The second two could be ameliorated (as they have been for earthquake studies in Central America) by close collaboration between IGP and a US cooperating project or agency.

IGP's principal assets are:

1) dedicated, determined leadership at the highest level,
2) excellent preparation and experience of its principal earth scientists,
3) broad institutional background and long history in the conduct of scientific studies in Peru,
4) electronic expertise developed through its operation of the Jicamarca observatory and its present seismic network.

I believe that the focused program sketched above would have a very high probability of success

PAGE 01 LIMA 08389 160204Z 061711 AID3330
ACTION AID-35

ACTION OFFICE DRC-02
INFO LASA-03 LADP-03 LADR-03 PPCE-01 PDPR-01 PPPB-02 PPEA-01
STA-10 PDC-02 CHS-01 INT-04 RELO-01 MAST-01 /035 A4 S

INFO OCT-01 /036 W

------------------064709 160208Z /34

P 151930Z SEP 80
FM AMEMBASSY LIMA
TO SECSTATE WASHDC PRIORITY 2682

UNCLAS LIMA 8389

AIDAC

FOR P KRUMPE, OFDA

EO 12065: N/A
SUBJ: DISASTER PREDICTION AND PREPAREDNESS PLANNING

REF: (A) STATE 231436, (B) STATE 156228; (C) STATE 195456, (D) STATE 192175, (E) STATE 186396

1. AT THE REQUEST OF THE DIRECTOR OF THE GEOPHYSICAL INSTITUTE OF PERU, THE USAID FINANCED A RECENT VISIT (AUGUST 14-31) TO PERU BY DR JERRY EATON OF THE US GEOLOGICAL SURVEY. THE PURPOSE OF EATON'S VISIT WAS TO PROVIDE TECHNICAL ASSISTANCE TO THE GEOPHYSICAL INSTITUTE IN THE AREA OF EART HQUAKE PREDICTION.
BEFORE DEPARTING PERU, EATON DISCUSSED WITH USAID THE POSSIBILITY OF ESTABLISHING A COOPERATIVE ARRANGEMENT BETWEEN THE USGS AND THE PERUVIAN GEOPHYSICAL INSTITUTE, IN WHICH THE USGS WOULD PROVIDE LIMITED SHORT-TERM TA, SIMILAR TO AN ON-GOING ARRANGEMENT IN OTHER COUNTRIES, EG., NICARAGUA. EATON WILL KEEP USAID INFORMED OF ANY ACTIONS TAKEN BY THE USGS ON THE MATTER.

2. HAVE SUBSEQUENTLY LEARNED FROM DR ALBERTO GIESECKE THAT USGS ON BEHALF OF THE REGIONAL CENTER FOR SEISMOLOGY FOR SOUTH AMERICA (CERESIS), HAS SUBMITTED A PROPOSAL TO OFDA ENTITLED "SEISMIC RISK IN THE ANDEAN REGION". SUCH A PROPOSAL WOULD INVOLVE USGS IN FUTURE TA IN THE REGION. ALSO, REVIEW OF PROPOSAL SUGGESTS THAT OFDA REGIONAL SEMINAR TIES-IN WITH PROJECT'S REGIONAL INTEREST IN DISASTER PREDICTION AND PREPAREDNESS PLANNING.

3. DR GIESECKE PROPOSES THAT OFDA SEND REPRESENTATIVE (S) TO REGIONAL SEMINAR ON "SEISMIC PREDICTION AND EVALUATION OF THE DANGERS OF EARTHQUAKES" TO BE HELD IN SAN JUAN, ARGENTINA, OCTOBER 20-24, 1980. DR GIESECKE REGRETS DELAY IN FORWARDING THIS INVITATION, HE WAS BEEN CAUGHT UP IN A SERIES OF PROBLEMS AT THE INSTITUTE.

4. MISSION POUCHING COPIES OF OUTLINE OF SEMINAR, PROJECT SISRA AND SEISMIC PLAN FOR METROPOLITAN AREA OF LIMA. OUR REVIEW OF SISRA NOTES STRONG INTEREST IN PREDICTION WORK AND IDENTIFICATION OF PROBLEM AREAS. BUT LITTLE ATTENTION DIRECTED TO PREPAREDNESS AND RELIEF PLANNING.

5. MISSION ENCOURAGES OFDA PARTICIPATION IN SEMINAR IN SAN JUAN, FOLLOWED BY SHORT VISIT TO LIMA TO DISCUSS WITH CIVIL DEFENSE FEASIBILITY OF HOLDING REGIONAL PREPAREDNESS SEMINAR IN PERU.

6. REGARDING REF (A) MISSION DIRECTOR TO MEET NEW DIRECTOR OF CIVIL DEFENSE. WILL DISCUSS OFDA INTEREST IN REGIONAL SEMINAR.

7. FYI, MISSION TO UPDATE DISASTER RELIEF PLAN, INCLUDING

LIMA 08389 160204Z 061711 AID3330
A REVISED ROLE FOR PVOC AND THE LIST OF KEY OFFICIALS INVOLVED IN RELIEF PLANNING. REVISED PLAN TO BE POUCHED TO OFDA ASAP. DOES OFDA HAVE ANY OBSERVATIONS ON MISSION PLAN FORWARDED TO OFDA IN MAY OF 1980.
SHLAUDEMAN

15 September 1980

Last AK SG GM GB FC OD

SEP 16 1 55 PM '80
PDC/OFDA

Department of State

INCOMING TELEGRAM

Peru

Ref.

PAGE 01 LIMA 08479 1801592 DOCUMENT NO. 051 8368 AIL5002

ACTION AID-35

ACTION OFFICE DRC-02
INFO LASA-03 LADP-03 LADR-03 PDC-02 CH9-01 REL0-01 MAST-01
0-00 /016 A2 X

INFO OCT-01 /036 W

080419 1801592 /34

R 171348Z SEP 80
FM AMEMBASSY LIMA
TO SECSTATE WASHDC 2923

UNCLAS LIMA 8479

17 September 1980

AIDAC

FOR PAUL KRUMPE, OFDA/AID

EO 12065: N/A
SUBJ: EARTHQUAKE PREDICTION MEETING SAN JUAN, ARGENTINA, OCTOBER 15-24, 1980

REF: (A) CERESIS LETTER 9/12/80, (B) LIMA 8389

1. MISSION POUCHED COPY OF REF (A) IN WHICH GIESECKE INVITES TWO REPRESENTATIVES FROM OFDA TO PARTICIPATE IN ARGENTINA SEMINAR. THE LETTER REFERS TO DR ALGERMISSEN WHO COULD DISCUSS THE STATUS OF THE SIRSA PROPOSAL FOR OFDA FUNDING; A SECOND PERSON COULD DISCUSS THE PROPOSED OFDA REGIONAL MEETING ON DISASTER PREPAREDNESS.

2. MISSION DIRECTOR MET WITH GENERAL VILLA FUERTE, NEW DIRECTOR GENERAL OF THE NATIONAL CIVIL DFENSE, COMMITTEE, AND MENTIONED THE POSSIBILITY OF A REGIONAL SEMINAR ON DISASTER PREPAREDNESS. GENERAL VILLA FUERTE INDICATED INTEREST IN THE IDEA. SHOULD OFDA PARTICIPATE IN MEETING IN ARGENTINA, SUGGEST YOUR REPRESENTATIVE STOP IN LIMA TO DISCUSS DETAILS OF SEMINAR WITH THE NATIONAL COMMITTEE.

3. PLEASE ADVISE BY CABLE OFDA INTEREST IN PARTICIPATING IN SAN JUAN MEETING. MISSION WILL ADVISE GIESECKE.
HLAUDEMAN

SEP 19 3 44 PM '80

FDO/OFDA

Department of State

INCOMING
TELEGRAM

PAGE 01 LIMA 09325 111845Z 079319 AID2409

ACTION AID-35

10 October 1980

ACTION OFFICE DRC-02
INFO LAEM-02 LASA-03 LADP-03 LADR-03 PDC-02 CH9-01 RELO-01
MAST-01 /018 A4 3

INFO OCT-01 /036 W

000112 111851Z /34

R 102149Z OCT 80
FM AMEMBASSY LIMA
TO SECSTATE WASHDC 3310

UNCLAS LIMA 9325

AIDAC

EO 12065: N/A
SUBJ: OFDA VISIT TO LIMA

REF: FRED COLE, OFDA TELCON 10/9/80

MISSION CONCURS IN PROPOSED COLE AND KRUMPE TDY OCTOBER 25-31.
HOTEL RESERVATIONS MADE AT SHERATON.
LAMBERTY

MEMORANDUM

TO: PDC/OFDA, Mr. Alan Van Egmond, Assistant Director

FROM: PDC/OFDA, Paul F. Krumpe, Science Advisor
PDC/OFDA, Fred Cole, Disaster Preparedness Officer

SUBJECT: Trip Report on the International Seminar on Earthquake Prediction and Evaluation of Seismic Hazard, October 20-24, 1980, San Juan, Argentina

1. Subject Conference was held at the Instituto Nacional de Prevencion Sismica (INPRES) in San Juan, Argentina. It was jointly sponsored by UNESCO, UNEP, UNDRO, CERESIS and INPRES. The organizing committee consisted of the following members:

Dr. Ramon Cabre, S. J., Presidente
Observatorio San Calixto
Apartado Postal N 5939
La Paz, Bolivia

Ing. Juan Carlos Castano, Secretario
Secretaria Cientifica del Seminario
Instituto Nacional de Prevencion
Sismica - INPRES
Roger Balet 47 - Note
San Juan, Argentina

Dr. John Filson
Office of Earthquake Studies
U.S. Geological Survey
Mail Stop 905
Reston, Virginia 22092

Ing. Alberto A. Giesecke M.
Director, CERESIS
Apartado 3747
Lima, Peru

Dr. Stephan Mueller
Institut fur Geophysik
ETH-Honggerberg
CH-8093 Zurich
Switzerland

Dr. Lautaro Ponce
Instituto de Geofisica
UNAM - Universidad Autonoma de Mexico
Torre de Ciencias, 3er. Piso
Mexico 20, D.F.

early November 1980

2. The purpose of the seminar was to review advances in the field of earthquake prediction, particularly with respect to South America, and to study means of reducing the death toll and property losses resulting from earthquakes, through risk analysis and mitigative actions. The seminar was divided into five thematic sessions as follows, with a theme each day and one 3 hour session Thursday evening, October 23:

Monday, October 20	- South American Earthquake Prediction: Physical Basis
Tuesday, October 21	- Earthquake Prediction Case Histories
Wednesday, October 22	- Induced Seismicity
Thursday, October 23	- Evaluation of Seismic Risk
Friday, October 24	- Response to Earthquake Prediction

3. Seminar participants included geophysicists, planning, and civil defense experts, economists, sociologists, disaster preparedness experts, seismologists, insurance specialists, physicists and applied mathematicians. There were more than 100 participants, including INPRES scientists and students from the National University. Twenty-one countries were represented including South American countries, New Zealand, China, U.S.A., Switzerland, Germany, USSR, Spain, Mexico, Italy, Indonesia, Honduras, Panama, and Dominican Republic. (Japan was not represented). A list of participants is attached.

4. The seminar was unique for the following reasons:

a. The subject was particularly timely inasmuch as a catastrophic earthquake has been predicted to occur off the west coast of South America (Peru-Chile) in August of 1981 by U. S. Scientists, Drs. Brady and Spence.

b. The CERESIS Council met before the Conference to formulate priorities and discuss programs relative to the outcome of the seminar. Specifically CERESIS prepared their final proposal for the SISRA Project (Seismic Risk Study of the Andean Region) to be funded by AID/OFDA and coordinated by the U.S. Geological Survey.

c. The Chinese delegation was chaired by the Deputy Director of the National Bureau of Seismology, Peking, China and included the seismologist who predicted the Haichieng Earthquake in 1976.

d. This conference was the first internationally recognized and significant earthquake prediction seminar held outside Europe or the U.S.A.

5. The following scientific papers were presented during the five day conference:

October 20:

Brady, B. and W. Spence: Hypothesis for the prediction of the occurence of an earthquake in the Peruvian and northern Chilean coast.

Fernandez L.: The inclusion theory and the prediction of a strong earthquake near Lima, Peru for 1981.

Kelleher, J.: Summary of earthquake forecasts for major plate boundaries near Latin America.

Hays, W.: Earthquake Prediction: An opportunity to improve ground-shaking hazard maps for Latin American cities.

Minaya, E. and R. Cabre: Interplate earthquakes precursors of interplate earthquakes.

Gou Ximing: The effect of the stress tensor of the earth tide on the triggering of earthquakes.

Figueroa, M.: Space-time approach to seismic fluctuations.

October 21:

Xingyuan, Ma: Intracontinental seismicity and earthquake prediction in China.

Ponce, L.: The November 29, 1978 earthquake of Oaxaca: A historical case.

Fengming Zhu: Study on characters of Haicheng earthquake anomalies in the short and impending period.

Ramierez, J. E.: The Columbian earthquakes of November 23 and December 12, 1979.

Zonjin, M.: Prediction problems of nine strong shocks in China.

Gvishiani, A.: Pattern recognition investigations of earthquake prone areas of the South Pacific Coast.

Anshu, J.: Seismicity and variations of Seismic velocity in the Beijing Region.

October 22:

Aparicio, J.: Induced Seismicity: a local and regional problem.

Aparicio, J.: Induced Seismicity: a special case.

Allen, C. R.: Seismic risk from reservoir induced earthquakes.

Huaco, D.: Induced seismicity in South America.

Yuliang, H.: Reservior induced seismicity in China.

October 23:

Vega, A.: Seismic Risk in Bolivia.

Castano, J.: Seismic tectontical analysis and its application to the estimation of seismic hazard in Argentina.

Riuscetti, M.: Italian Geodynamic Project

Riuscetti, M. and V. Petrini: Geodynamic Project: activity and research related with earthquake hazard reduction.

Barrientos, S. and E. Kausel: Seismic regionalization of Chile.

Kausel E. and S. Barrientos: Seismic intensity attenuation in Chile.

Patwardhan, A.: An application of seismic gap theory to seismic risk in various earthquake environments.

Ocola, L.: Seismicity and seismic hazard in Peru.

Mueller, S. and D. Mayer-Rosa: An exchange of earthquake hazard evaluation: the new seismic risk maps for Switzerland.

Hall, M. and H. Yepes: Faulting and microseismicity activity in the Anders valley of Ecuador.

Fiedler, G. R.: Some observations in the occurence of multiple seismic events.

Isacks, B. L.: Crustal earthquakes in the Andes.

October 24:

Roberts, J. L.: Political and administrative consequences of earthquake prediction.

Allen, C. R. and J. R. Filson: The National Earthquake Prediction Evaluation Council of the United States.

Giesecke, A. A.: The response to the prediction of an earthquake in Peru.

6. The following is a brief summary of each round table discussion conducted during the five-day seminar.

October 20 and 22:

Topic: Spatial Techniques Applied to Earthquake Prediction

- seismic gap and recognition techniques include the use of math models, recurrence interval analysis, statistical probabilities of specified magnitude events, historical seismicity, ten-year test intervals and hypocenter depth and source mechanism definition and epicenteral concentrations.

- the interpretation of seismic gaps to make earthquake forecasts is based on morphology and structure of trench slope in island areas, seafloor morphology and underthrusting plate tectonics, plate interface spatial geometry, prominent coastal contours, and thrust-fault mechanisms

- study of continental, regional and localized fractures and lineaments is invaluable to developing spatial prediction/forecast models and defining past and current fault zones

- development of seismic intensity zone (isoseismal) maps and seismic attenuation zone base maps are essential to the application of spatial techniques to prediction analysis.

October 23:

Topic: Seismic Risk Evaluation

- site response is a principle component of seismic hazard

- definition of mainshock spectral variability is necessary to seismic risk evaluation

- earthquake risk assessment is based on prediction of ground motion

- Dr. McCann has prepared a global map of seismic potential (gap theory)

- the principle components of seismic risk analysis include,
  1) definition of hazard parameter (ground motion)
  2) spatial distribution of vulnerable population and
  3) estimate of damage factors (hazard vs. loss potential)

- Seismic hazards are physical phenomena associated with the ocurrence of earthquakes which may lead to economic loss. Seismic risk are those entities which are subject to economic loss, i.e. that which is vulnerable and at risk to seismic hazards.

- Elements of seismic hazard evaluation includes:
  1) Seismicity data analysis
  2) earthquake mechanism (fault length)
  3) attenuation (energy transfer)
  4) site response (ground vibrations)
  5) geological hazards (landslides etc. caused by ground shaking).

- Estimation of seismic hazard includes:
  1) ground motion measurements (acceleration, attenuation, etc.)
  2) liquifaction potential
  3) landlside potential
  4) active fault zone definition

- One of the most useful end products of seismic risk evaluation is the preparation of contour maps for effective peak acceleration.

October 24:

Topic: Response to Earthquake Prediction

- increased analysis of seismicity and other parameters will lead to seismic risk analysis and prediction of earthquakes and improved building design criteria and analysis

- when foreshocks are associated with a predicted event, increased lead-time (weeks before mainshock) can enable orderly mitigation response to prediction, i.e. Oaxaca, Mexico 1978.

- why predict an earthquake based on laboratory (micro-scale) data when it is not necessary to do so? (based on assumptions that cannot be proven!).

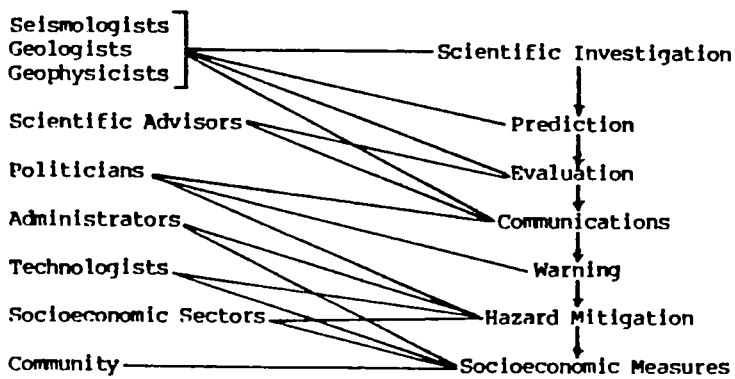
- Giesecke indicated he would be willing to write the U. S. National Earthquake Prediction Evaluation Council for a review of the Brady Prediction.

- the Government of Chile has been informed about the Brady Prediction but is not interested in any reaction ... unless earthquake is imminent ... in which case Civil Defense is prepared to take mitigative action.

- Dr. Allen spoke of the great problems as well as the opportunities presented by advances in earthquake prediction, not the least of which is the awesome responsibility which must be assumed by predictors. They must respond to social values and act responsibly. A prediction reflects not only on the individual, but also on the entire profession. With this caveat in mind, the scientific community needs to encourage young scientists in pursuing innovative ideas.

- the following responsibilities were defined and examined by Dr. Tomblin (UNDRO) with respect to earthquake prediction response:
  1) Monitoring Phenomena (Scientist)
  2) Interpretation of Hazard (Scientist)
  3) Communication of Hazard (Interdisciplinary)
  4) Evaluation of Risk (Engineer/Economist)
  5) Identify Protective Measures (Engineer/Civil Defense
  6) Decisions to take action (Engineers, C.D., Politicians)
  7) Implementation of Protective Measures (Engineers/Civil Defense)

- Dr. Roberts (New Zealand) outlined and discussed the following interactions among experts and phases of action leading to effective mitigative response to earthquke prediction:



- Dr. Giesecke provided a detailed description of events and published articles concerning the public reaction to the Brady Prediction. These meetings, requests, events and media articles are a matter of record.

October 24:

Topic: Final Evaluation and Conclusions

- Dr. Kelleher (USA) indicated he was not pessimistic concerning advances in the state-of-the-art in earthquake prediction and called for increased development and testing of physical

models and math models. He recognized the significant need for increased observational data (as in the Chinese case) world wide to enchance national earthquake prediction and forecasting programs.

- Dr. Isacks (USA) commented on the importance of studying induced seismicity before dam construction using 3-component instrumentation and also obtaining data on soil pore pressures and movement of water before dam filling.

- Dr. De Vaccino (Venezuela) called for increased use and exchange of computer software, data reduction techniques, and regional seismicity data in the future to improve the geophysical community understanding of South American earthquake and tectonic processess.

- Dr. Fernandez (Peru) called for increased regional emphasis on seismic hazards evaluation, preparation of preliminary maps of seismic hazards and risks, and the need for a follow-up regional multidisciplinary conference under UNESCO auspices to bring together seismologists, engineers, and geophysicists to examine continental and national needs to augment current seismic risk analysis programs.

- Dr. Algermisson (USA) discussed the CERESIS/SISRA program recently funded by AID/OFDA. The Seismic Risk Study for the Andean Region includes the following tasks:

  1. Preliminary regional seismic risk mapping
  2. Historical compilation and catalogue of regional seismicity
  3. Review of needs and state-of-the-art for satellite relay of seismic data
  4. Education and training program in Seismic risk analysis.

7. Conclusions:

- The Seminar was well planned, adequately staffed, properly staged and conducted with simultaneous translation in English or Spanish. The meeting facilities at INPRES were excellent. Receptions at State Governor's estate, evening cocktails, afternoon luncheon and closing dinner were well-catered and fostered continued goodwill among all participants regardless of nationality. Social activities afforded excellent opportunities for exchange of ideas on seminar topics as well as solidifying professional ties.

- The Brady Prediction was discussed informally among participants as well as in the media during the five-day conference period. The hypothesis was genereally understood as applicable to predicting rock-bursts in mines but

assumptions for extrapolation to earthquake prediction remained questionable. Participants accepted the high probability of a large earthquake occurring off the coast of southern Peru (known seismic gap) but were highly skeptical that such an event could be predicted inasmuch as no one has ever done so.

- The CERESIS Seismic Risk Study for the Andean was considered by participants to be a major advance in meeting regional needs and could provide the impetus for additional funding of national programs and "spin-off" activities in earthquake hazards evaluation and mitigation.

- The papers presented by seismologists from Argentina and Chile demonstrated an excellent understanding of classical seismological analysis coupled with advanced computer processing techniques.

- The papers presented by Dr. Isacks, Dr. Kelleher, Dr. Algermisson, Dr. Roberts, Dr. Allen, Dr. Mueller, Dr. Castano, Dr. Gieseke, Dr. Fielder, Dr. Ocola were the most comprehensive and understandable. The U.S.S.R. participant's paper on pattern recognition was unseemingly complex with no comparative analysis of congruent South American Seismic gap data.

DOCUMENT NO. 054

MEMORANDUM

2 November 1980

TO: The Director, USAID/Peru

THRU: Paul Vitale, USAID/Peru/Housing and Urban Development Office

FROM: Frederick Cole, OFDA/Preparedness
Paul Krumpe, OFDA/Preparedness
Paul F. Krumpe

SUBJECT: Disaster Preparedness Meetings in Lima

The following narrative summarizes the substance of the meetings held in Lima, October 27-30, 1980, on matters of disaster preparedness. Further detail will be supplied for the record via our OFDA trip report.

October 27, Monday

9:30 am - USAID: Paul Vitale, Rudolfo Salinas, Mario Quiroga

Discussed the San Juan, Argentina, seminar on Earthquake Prediction and Seismic Risk. Conveyed the status of the "Brady Prediction" and indicated additional credibility had been gained in San Juan. Discussed status of SISRA program, Mission Disaster Plan, OFDA/NOAA Agro meteorological program for Andean Region, tsunami threat analysis for Pacific basin. Learned that Edilberto Alarcon, chief of the engineering section, had been designated MDRO and said that Ollie Davidson was to be OFDA point of contact for disaster preparedness (new LA disaster operations officer to be appointed in next few weeks). Discussed Volag liaison for disaster assistance and was referred to FFPO. Indicated possibility of Ministerial level round table discussion on earthquake prediction to be coordinated by Dr. Giesecke. Requested appointment with Civil Defense Officials to discuss cooperation potential. Meeting arranged with Alf Cooley, Embassy Economic Officer. Inquired about any recommendations made by Dr. Jerry Eaton (USGS) on recent technical assistance mission (mission has not received end-of-tour report).

11:00 am - Embassy: John Jurecky, Alf Cooley, Bruce Pearson

Explained purpose of OFDA trip. Provided background and status of "Brady Prediction" from 1978 to present. Discussed sensitivity of pending arrival of Brady and Spence and mentioned their stopover in Santiago to conduct Seminar. Mentioned possibility of Ministerial level meeting re earthquake prediction. Jurecky suggested he would coordinate with Giesecke. Discussed USGS official position vis-a-vis prediction. Discussed possibility of further definition of system for monitoring precursory seismic activity for testing Brady hypothesis. Mentioned possibility of U.S. National Earthquake Prediction Council reviewing "Brady Prediction", and suggested Giesecke should initiate if appropriate. Discussed media sensitivity of Brady/Spence visit.

2:00 am - USAID/FFP: Jerry Foucher

Discussed possibility of involving U.S. Volags more effectively in disaster preparedness and relief. Mentioned upcoming Volag Conference in Washington in which new directions for cooperative Volag/OFDA/Peace Corps and other initiatives would be discussed. Confirmed FFPO as liaison with Volags. Discussed importance of major Volags in disaster programs. Received information regarding infrastructure and programs of CRS/CARITAS, OFASA (Seventh Day Adventists), CWS and CARE. Provided overview of OFDA/NOAA agromet program and suggested value of program in forecasting food deficits resulting from drought.

4:00 pm - Civil Defense: General Julio Villa Fuerte Jurgens, Col. Cesar Ramires Perez, , Engr. Radl Flores Sosi, Engr. Cesar Arguedas Madrid; Mario Quiroga (USAID).

Initial going slow — Engr. Flores initiated the discussion by presenting a proposal to provide training for technical people in planning for disasters (3 months course) and to receive expertise in tsunami modeling. It was stated that Flores had originally planned this program following his attendance at an OFDA International Disaster Preparedness Seminar in Washington in 1977. Seems to have been some confusion here, since proposal we received was addressed to UNDRO and the subject matter, we had been told in San Juan, had been suggested to Civil Defense by UNDRO's John Tomblin, who was in Lima a few weeks ago. Training in Emergency Operating Center (EOC) operations was also desired. Most interest was shown in possibility of 3 month public awareness campaign combined with seminar, for which materials (films, videotape, publications) and public relation expertise would be required from outside Peru. Possibility of short-term exchange of personnel was discussed. California State and local Civil Defense functionaries and FEMA Washington, D. C., advice would be desirable. TV/Radio campaign was considered primary media. It was mentioned that media and material costs would exceed Civil Defense budget. We described ongoing OFDA tsunami threat analysis project with possible collaboration by Peru Civil Defense consultants. We were asked what was mechanism for OFDA post disaster assistance and replied that appropriate vehicle was U. S. Mission via USAID and American Ambassador. Civil Defense indicated no interest in regional training or other activities — national only. Meeting adjourned with OFDA requesting follow-up meeting on Wednesday or Thursday.

October 28, Tuesday

9:00 am - USAID, Paul Vitale

Presented OFDA Illustrative National Disaster Plan which was provided to Civil Defense for their consideration. Discussed USAID housing program, urban planning objectives and related developmental issues.

Vitale requested OFDA assistance in acquiring Landsat imagery of Peruvian coastal urban areas and suggested possible Washington contacts concerning urban vulnerability analysis. Meeting terminated to attend Embassy executive session.

10:30 am - Embassy (Watch Committee), Jerry Lamberty, Paul Vitale and Embassy Officers.

Reviewed revised mission disaster plan. Discussed strengths and weaknesses of Warden System, E & E plan, communications reliability, and personnel safety in time of disaster. Presented current status of "Brady Prediction", discussed fundamental weakness of mission plan in the event of communications breakdown in Lima disaster. Reviewed media options regarding awareness of Brady/Spence presence in Lima.

1:00 pm - Geophysical Institute of Peru: Daniel Huaco, Leo Ocola, U. S. Team.

Discussed U. S. Team's review of recent data and possible implications. Examined map data, IGP facilities, and data handling techniques.

7:00 pm - Attended meeting with South American fire protection officials and civil defense counterparts at Municipality Building. Discussed OFDA role in foreign disaster assistance.

9:00 pm - Met with Dr. John Roberts (Conference participant from New Zealand) on matters concerning socio-political implications of earthquake prediction.

October 29, Wednesday

11:00 am - Embassy: Jerry Lamberty, John Jurecky, Alf Cooley, Dan Cleary, John Roberts (New Zeland), Ted Algermisson, Bill Spence (USGS), Brian Brady (USBM), Luis Fernandez (South African T.A. consultant), Alberto Giesecke, Leo Ocola, Daniel Huaco (IGP)

Discussed upcoming meeting with President of Peru. Items included:

- Need for list of priority project options.
- Desirability of divorcing program from prediction. Linking it rather to long-term inevitability of "a major earthquake in Peru."
- Project areas include stress and geodetic measurements, tiltmeter implantation, ocean bottom seismometers, tide gauge equipment, radon measurement, computer analysis, additional terrestial seismographs and telemetry.

- Importance of interpreting scientific data in terms of risk to population.

- Importance of real time interpretation of seismic data.

- Significance of crustal deformation in Lima basin.

- "Agonizing political appraisal" required of Peruvian authorities.

- Importance of hazard mitigation program.

- Strategy re press inquiries was addressed. All present were to defer to Dr. Giececke, who had already drafted press release for approval of President's office. Idea was to readily admit Brady/ Spence presence in country and indicate it was in public interest to discuss prediction more fully.

- Status of IGP and current reorganization thru Presidential Commission recommendations was addressed by Dr. Giesecke.

5:00 pm - Presidential Palace: Lamberty, Jurecky, Giesecke, Fernandez, Huaco, Ccola, Brady, Spence, Roberts, Algermisson.

Met with President Belaunde. Giesecke introduced subject by indicating international exposure to the prediction. It has not been endorsed nor denied. Introduced Brian Brady who presented brief overview of theoretical basis and current status of prediction. Bill Spence presented the historical context of predicted earthquake with respect to regional geo-tectonics. The President inquired as to possible options. Brady and Spence discussed possible precursor monitoring program. Giesecke placed all within context of IGP proposed earthquake prediction program. The President suggested Civil Defense and public awareness as potential mitigation factors. Lamberty offered possible U. S. assistance in support of priority initiatives identified by meeting participants. Lamberty suggested quid pro quo Peruvian support. President replied, "We offer the environment." Giesecke was designated Peruvian scientific contact for program development. Following official visit, Lamberty requested Brady, Spence and Algermisson provide list of priority projects regarding above for transmittal to Washington.

October 30, Thursday

10:00 am - USAID Senior Staff Briefing - Howard Lusk, Paul Vitale and Senior Staff. Interest in specifics regarding Brady Prediction was minimal. Meeting on general preparedness activities/options and linkage to development objectives were discussed.

11:30 am - Embassy - Delivered cable input regarding possible Civil Defense related initiatives to Embassy per Lamberty request. Discussed contents of State cable to be prepared by Jurecky.

3:00 pm - Civil Defense - Col. Ramirez, Engr. Flores, Engr. Arguedas, etal.

Follow-up meeting which explored Peruvian priorities in greater detail. Received Civil Defense organization chart, presented Illustrative National Disaster Plan. Viewed EOC, Communications gear, etc.

Department of State Peru INCOMING TELEGRAM Nov 3/80

PAGE 01 LIMA 10117 040414Z DOCUMENT NO. 055 012932 AIDS743
ACTION AID-35

ACTION OFFICE LASA-03
INFO AALA-01 LAEM-02 STA-10 DRC-02 CH9-01 INT-04 RELO-01
TELE-01 MAST-01 /026 A2 X

INFO OCT-01 /036 W

041582 040421Z /34

R 032117Z NOV 80
FM AMEMBASSY LIMA
TO SECSTATE WASHDC 3688

UNCLAS LIMA 10117

AIDAC

3 November 1980

EO 12065: N/A
SUBJ: REQUEST FOR TRIP REPORT

TO: DR. JERRY EATON
DEPARTMENT OF INTERIOR
GEOLOGICAL SURVEY
OFFICE OF EARTHQUAKE STUDIES
345 MIDDLE FIELD ROAD MS-77
MENLO PARK, CALIFORNIA 94025

1. MISSION WOULD APPRECIATE RECEIVING COPY OF JERRY EATON'S PERU TRIP REPORT THAT COVERS PERSONS CONTACTED AND OBSERVATIONS ON PERU'S CAPABILITY TO MONITOR SEISMIC ACTIVITY.

2. EATON ALSO REQUESTED TO PASS A COPY OF HIS REPORT TO PAUL KRUMPE, SCIENCE ADVISOR, OFFICE OF FOREIGN DISASTER ASSISTANCE, AID/W.
CORR

PASSED BY AID/W SER/MO/TEL 11/4/80

Action
PK
Duffo
11/5 ~~BT~~
MM
RH
~~GB~~

DOCUMENT NO. 056

Peru

AV
FC
GB
BN
OD
PK

DRAFT

November 5, 1980

AIDE-MEMOIRE

The Aide-Memoire of the Embassy of Peru, dated July 22, 1980, has reaffirmed the dedication of the Government of Peru toward protecting the Peruvian people from the potentially disastrous effects of future earthquakes. The Department of State is pleased to take this opportunity to reiterate the United States Government's readiness to cooperate with the Government of Peru in such programs.

It is the United States Government's intent to continue cooperation in all areas of geophysical scientific interest as they pertain to the threat posed by earthquakes. The Agency for International Development (A.I.D.) has recently made a commitment of funds to cooperate in the Survey of Seismic Risk in the Andean Region. This program will be supported by the United States Geological Survey. A.I.D. has also begun a comprehensive program to analyze the potential for seismic sea wave generation in the Eastern Pacific Basin.

Both governments share an interest in improving the effectivness of civil emergency planning organizations. Toward this end both countries can benefit by increasing cooperation in the many aspects of civil preparedness in response to the threat of earthquakes. Because of the complexity of this issue and the need to determine priorities for accelerated action, discussions could

profitably take place both in Washington and Lima. Representatives of A.I.D.'s Office of U.S. Foreign Disaster Assistance expect to meet with key Peruvian officials in Lima as soon as possible to discuss the practicalities of cooperation.

It is hoped that the Embassy will feel free to call directly upon the Office of U.S. Foreign Disaster Assistance, of which Mr. Stanley Guth (telephone number 202/632-8924) is Acting Director, to discuss matters of disaster preparedness, which are of interest to both governments.

The United States Government believes that this is an important opportunity to strengthen the bonds of friendship and cooperation between the two nations and looks forward to a mutually rewarding relationship pertaining to civil defense and the protection of both populations against natural disasters.

Department of State, November 5, 1980
Washington,

Drafted: ODC/OFDA - FCole:lee
X28477:11/3/80

Cleared: PDC/OFDA - SWGuth
PDC/OFDA - AVanEgmond
PDC/OFDA - GMcCloskey
PDC/OFDA - JClark
PDC/OFDA - ODavidson
ARA/AND/P - JAPurnell
LAC/SA - WRhodes
OES/SCT - TKobayashi
PDC/OFDA - PKrumpe
S/S-S - EDenham

OPTIONAL FORM NO. 10 JULY 1973 EDITION GSA FPMR (41 CFR) 101-11.6

DOCUMENT NO. 057

U.S. Geological Survey
Office of Earthquake Studies
Reston, Virginia

File: Peru

UNITED STATES GOVERNMENT

Memorandum

NOV 7 3 31.

TO : Acting Chief, Office of Earthquake Studies RECEIVED DATE November 3, 1980

FROM : Chief, Branch of Global Seismology

SUBJECT: Prediction of Earthquakes Off Peru

A foreshock-mainshock sequence has been predicted by Brian Brady to begin off the coast of Peru in mid-September 1980. We have been directed to use the facilities and data available to the National Earthquake Information Service (NEIS) in efforts to detect the foreshock sequence predicted by Brady. This is the first monthly report on seismicity detected in the region of the predicted earthquake sequence.

For purposes of this exercise we define the region of interest to be described by figure 1 of the Brady letter to Marovelli dated May 1, 1980. This region has approximate geographic boundaries of 11.5° to 14.0° south latitude and 75.5° to 79.0° west longitude. In the year preceding September, 1980, four earthquakes, at least three of which were greater than m_b 4.5, were detected in this region. For purposes of comparison these can be considered as normal background for seismicity detected in the region by NEIS. On the basis of these data and earlier studies we conclude that the NEIS threshold magnitude for the region lies between m_b 4.5 and 5.0. This suggests that data provided to NEIS will not ordinarily permit us to locate <u>all</u> earthquakes above m_b 4.5 that <u>might</u> have occurred in the region. However, the Peruvian local network appears to have been making recent special efforts to provide NEIS with data from small magnitude events in the region so that this condition may no longer be valid.

Summary for September, 1980—only one earthquake was detected by NEIS in the region of interest. The hypocentral parameters for this event are:
September 20, 1980, origin time = 4h 42m 23.5s (GMT), latitude = 12.475°S, longitude = 77.718°W, depth = 33 longitude M_L = 3.2. This earthquake was detected solely on the basis of data reported from six stations of the Peruvian local network. An examination of the seismogram from our Albuquerque, New Mexico, station revealed no detection for this event, which meant that it was at least less than m_b 3.8 (about one milimicron of ground motion at that station). On the basis of this report on detectable seismicity in the region of interest for September, 1980, we must conclude that the pattern of seismicity predicted by Brady has not commenced.

E R Engdahl

5010-110

DOCUMENT NO. 058

November 12, 1980

MEMORANDUM

TO: PDC/OFDA, Alan Van Egmond, Assistant Director for Preparedness

FROM: PDC/OFDA, Paul F. Krumpe, Science Advisor Paul F. Krumpe
Fred Cole, Disaster Preparedness Officer

SUBJECT: Predicted Peru Earthquake, August-October 1981: Disaster Preparedness Conclusions and Recommendations

The trip report dated November 7, 1980 was originally prepared in Lima at the request of the A.I.D. Mission. This addendum offers conclusions and recommendations based on the findings in Peru.

1. Conclusions

A. Significant segments of the Peruvian population are at risk from earthquake hazards.

(1) Within the context of forecasting the likely occurrence of a major earthquake in the region, it is generally accepted among the geophysical and seismological scientific community that the probability for such an event is relatively high as evidenced by an existing geo-tetonic seismic gap. The time frame, magnitude and exact location cannot be determined using existing forecasting techniques. In contrast to this approach, prediction of an earthquake is deterministic, i.e., it specifies date, time, place and magnitude well in advance of an event, and is based on a physical model as opposed to empirical or strictly observational data immediately preceding an event. In light of the above, the "Brady Prediction" is a deterministic prediction that can be verified or denied based on scientific investigation of the occurrence of precursory phenomena which are clearly necessary and sufficient to validate or invalidate the prediction and hypothesis upon which it is based.

(2) The historical incidence of destructive seismicity along the west coast of South America indicates that high vulnerability exists which could result in catastrophic loss of life and property in the event of a great earthquake and possible tsunami. From 0 degrees South to 10 degrees South along the continental coast, no known great earthquakes have occurred. However, from 10 degrees South to 16 degrees South, great earthquakes with maximum rupture lengths of 150 km or less

have occurred (1970, Northern Peru; 1940, Callao; 1974 and 1942, Central Peru). From 16 degrees South to 37 degrees South, great earthquakes with maximum rupture lengths of about 300 km have occurred (1922 and 1868, Northern Chile; 1943, 1971, 1939, Central Chile). From 37 degrees South to 45 degrees South, the possible rupture zone of the 1960 Southern Chile earthquake was about 1000 km. Selected earthquakes of the largest magnitudes recorded occurring in South America are as follows: Chile, 1960, Mw 9.5; Ecuador, 1906, Mw 8.8; Chile, 1922, Mw 8.5; Chile, 1906, Mw 8.2; Peru, 1940 and 1942, Mw 8.2; Chile, 1943, Mw 8.2; Peru, 1966, Mw 8.1; Peru, 1974, Mw 8.1; and Peru, 1970, Mw 7.9.

(3) The "Brady Prediction" currently (November 1980) is "on schedule" (preliminary data suggest seismicity has occurred in the predicted zone) according to Drs. Brady and Spence (following their examination of local seismicity and rock strain data obtained by the regional Peruvian network (IGP)). The status of the prediction is as follows: low magnitude foreshocks occurring in the inclusion zone August 14 and September 20 indicate initiation of the first active foreshock phase (low magnitude events, some teleseismic, occurring at the specified time (August-September 1980) within the specified region (inclusion zone, 65 Km SW of Lima, Peru)). Additional seismic activity may occur in the inclusion zone until mid-December, at which time no seismicity is expected again until April-May in the inclusion zone. At that time, the second active foreshock phase would begin and would culminate in the mainshock Mw 9.9 and rupture to the South (24 degrees South) to be followed 35 days later with another shock, Mw 9.2 to rupture 700 Km to the North along the Peru-Chile trench. The "prediction" will be revised by Brady as deterministic "marker" events occur and establish the sequence, timing and pattern of future events leading to the occurrence of the mainshock. Examination of the IGP rock strain data by Brady and Spence indicated that the elasticity of rock within the coastal region follows the predictive model and therefore supports the seismicity data analysis. Geotectonic anomalies are apparently occurring in the region, as evidenced by seismicity patterns, unusual rock strain data, geodetic data (uplift is continuing), and other "phenomena" (submarine light emanations are reported near Chilca).

(4) There is a clear need for additional, accurate, timely, formatted, and consolidated seismic, rock strain, radon and geodetic data to establish a meaningful Peruvian earthquake monitoring, prediction and early warning capability. The relatively high probability of the occurrence of a major

or even catastrophic earthquake looms over the scientific seismological establishment and Government of Peru. The threat of devastation due to any possible earthquake is ever present in Lima, Peru. Without adequate seismic data reduction computer software and hardware, digital recorders for automatic data collection (seismic and rock strain data) and examination of geodetic control (rate of uplift), there will be no way of validating or invalidating the "Brady Prediction" in real time such that credible warning and logistical response are possible (even based on prior preparedness planning). Without a program of scientific data collection and analysis, preparedness activities and logistical planning take on marginal significance in this context.

(5) There is an immediate need to define the dimensions of the threat posed by the possible occurrence of these postulated catastrophic earthquakes, their aftershock sequence, seismic sea wave inundation, landslides, river diversions and other geo-morphological consequences both within the region and the circum-pacific area. Once the threat of these large magnitude earthquakes is better understood, more meaningful planning and risk analysis is possible. The threat can be studied as a hypothesis, i.e., hypothetical parameters are used to drive a model which generates possible outcomes upon which appropriate responses are made. The need to translate scientific data into risk, hazard, and threat analyses for implementation of disaster mitigation programs and decision-making is clear. The probability distributions of different levels and kinds of damage caused by these (or other) earthquakes as a function of geophysical, engineering, economic and social factors is an area in need of further assistance in Peru. Results derived from these studies should be used in decision-making concerning mitigation of earthquake hazard to all types of construction (including traditional adobe housing), lifelines, evacuation routes, stockpiles, etc.

B. The Peruvian Civil Defense Office has proved effective in reacting to small and medium-scale disasters. They are not equipped to prepare the population for or respond to the magnitude of earthquake which is forecast for Peru.

(1) Considerable effort was made to beef up the organization following their poor showing in the 1970 earthquake relief program. In the earthquake of 1974, they are said to have done a much better job. Currently they are staffed at the level of about 70 officials, some of whom man the few field offices they maintain. Their connection with the public is through the local constabularies.

(2) Civil Defense has three principal functions in regard to natural disasters. They translate scientific data (accumulated by the IGP) into risk and vulnerability analyses, primarily through mapping techniques; they are responsible for preparing the population for the threat of disasters; and they coordinate the relevant sectors of government in response to disasters. Apparently, their major thrust in developing their capabilities has been long on methodology and short on implementation of plans. They have defined the problem well but have not grabbed hold of potential solutions. They are better at producing paper than attacking problems.

(3) It is evident that the spector of a major natural disaster is intimidating. They are loath to admit that a significant disaster relief effort is beyond their grasp and are wary of asking for assistance they know they need. They are conscious of being deficient in preparing the public for an emergency and seem not to know how to get started. There is an aura of inertia which stems the will to proceed with an active preparedness and response program.

(4) Civil Defense has a clear mandate to define the disaster threat to Peru, prepare the public and respond to disasters once disasters occur. They need help in the following:

(a) Determining the specific populations which are threatened by earthquake, tsunami and flood hazards.

(b) Defining the threat in terms of the vulnerability of those populations.

(c) Informing the populations of pragmatic means of protecting themselves from and mitigating disasters' effects.

(d) Training Lima and Field C.D. personnel in disaster management techniques and procedures.

(e) Planning for contingencies (scenario analysis, simulation).

(f) Decision-making processes for alerts and warnings.

(g) Mobilization procedures.

(h) Communications.

(i) Evacuation and logistics planning.

2. Recommendations

Whether or not the Brady prediction is valid, it may pose a severe threat to the social, economic and political fabrics of Peru. The public has been exposed to the prediction through the media. The public has been relatively quiescent in recent months, but this is not to say that renewed interest and fear will not be generated as the projected date draws nearer. Added to the constant concern of Peruvians to the general threat of earthquakes, the specific prediction is a severe worry which has the potential for inducing depression, panic or precipitate action. This worry will be aggravated by vagueness of the parameters of the predicted event and by perceptions on the part of the public that mitigative actions are not being taken. If a catastrophic event does take place, countless lives will needlessly be lost if the government of Peru is unable to warn the population and respond to the threat. The U.S. Government should offer cooperation and assistance, as appropriate and in coordination with International Organizations and other donors, in the following areas:

A. Scientific Instrumentation and Technical Assistance

(1) Immediately implement a program in real-time seismic data collection, reduction and analysis, concentrating on the inclusion zone, to monitor the hypothesized foreshocks and precursory events. Program priorities and estimated costs are as follows:

First Priority:	Install Data Processing Computer System	$200,000
Second Priority:	Install Telemetry for Seismicity Data Collection (15 stations, spare parts, test equipment, vehicle)	460,000
Third Priority:	Install Strain Meter Telemetry Transducers and Recorder at four Stations	190,000
Fourth Priority:	Investigate Geodesy Data and Tide Gauge Program	80,000
Fifth Priority:	Conduct Seismic Risk and Hazard Analysis to Define Threat Dimensions	200,000

(2) Provide immediately the best possible means for rapid transmission of seismic and other geophysical data to Golden Co. for review and analysis by Drs. Brady and Spence.

(3) Accelerate funding and modify scope of work with S.A.I. to conduct a detailed Tsunami threat analysis for the South American coast and Lima region. This work would incorporate NOAA and the Peruvians in data analysis and scenario development for hypothesized threat parameters. Program should be funded by mid-December as an amendment to S.A.I.'s existing contract.

(4) Accelerate NOAA's program utilizing the GOES satellite for Tsunami Early Warning dissemination throughout the Pacific region. This system should be in place by June 1981.

(5) Implement immediately a program in threat definition, hazard and risk analysis and isoseismal intensity mapping based on postulated earthquake parameters. Peruvian cooperation and participation would be essential in this program. A USGS proposal is in preparation to accomplish the above.

(6) Develop a fail-safe communications network and pre-position equipment to ensure viable transmissions from Lima region in the event of total destruction. This should be accomplished by April 1981.

B. Civil Preparedness Assistance

(1) Cooperation in Public Awareness Campaign: Within three months transfer communication skills and technologies in mounting a sensitive media campaign to inform Peruvian public of earthquake threat, protective measures to be taken and procedures to be followed in the event of a disaster, to include technical assistance, written materials, video-tapes, film strips and possibly financial aid for television time. Possible resources include FEMA, ANRC, state and local civil defense organizations (California), NSF. Campaign should be completed by June 1981.

(2) Disaster Management Training: Short-term cooperative ventures to give Peru Civil Defense officials exposure to U.S. Civil Defense installations (probably California) and training of officials in Peru by U.S. counterparts and OFDA. This effort should begin as soon as possible. Serious

consideration should be given to involving Philippine Civil Defense in such a program. Peru's Civil Defense has had prior experience with PAGASA (Philippine Atmospheric and Geophysical Agency); communications and logistics problems are analagous; Philippines has an excellent public awareness and response program which would be of benefit to Peru.

(3) Tsunami Threat Analysis and Contingency Planning: A follow-on program to OFDA's tsunami modeling effort which would describe the effect of randomly generated tsunami conditions on specific shore areas of Peru, with indicated scenario analysis. Could be supported by FEMA and Hawaii and California Civil Defense systems. UNDRO is interested in this prospect and should be included as planner/sponsor to the extent their resources permit. This effort should be contiguous with the S.A.I. tsunami modelling program and should begin by January 1981.

(4) Communications Upgrade: The Civil Defense Office in Lima boasts an outdated HF transceiver and a CB for local use. The network extends only to three field posts between which transmission is dicey. First step would have to be requirements survey to indicate who would be communicating with whom, what repeaters/relays needed, type of data to be transmitted, maintenance constraints, relevance of emergency utilization to administrative needs, etc. Some 15 field locations are in question for C.D. installations, State/A.I.D. communications, FEMA and local U.S. CD offices, ANRC, ITU and contractors are potential resources for feasibility study and specifications. This study should begin January 1981 and be completed within three months.

(5) Lima Lifeline Analysis and Strategy: Water systems, sanitation, fuel and power systems are considered very vulnerable. UNDRO has suggested analysis of potable water availability in aftermath of disaster and presumably has resources to support such a project. Other lifelines should be analyzed as well. Earthquake Engineering Research Institute, FEMA, NSF and City of San Francisco could probably mount such a study in conjunction with UNDRO resources. This effort should be initiated as soon as possible and be completed by May 1981.

(6) American Community: Using appropriate resources and channels, the specific needs of the American community should be addressed in terms of communications, shelter protection, procedures, stockpiled materials and access to information. At the discretion of the Ambassador, this effort should be ongoing and will necessarily be implemented by American Embassy and military logistics experts.

FINAL

DOCUMENT NO. 059

November 12, 1980

INFORMATION MEMORANDUM FOR THE ADMINISTRATOR

THRU: ES
AA/PDC, Calvin H. Raullerson

FROM: PDC/OFDA, George McCloskey

SUBJECT: Earthquake Alert for Peru and Neighboring Coastal States of South America

In 1976, Dr. Brian Brady, a theoretical physicist specializing in rock mechanics with the U.S. Bureau of Mines, applied his deterministic model for predicting rock bursts in silver mines to the prediction of earthquakes. According to Dr. Brady, this model can be used to predict the location of an earthquake, its magnitude, and period of occurrence. The Brady model has provoked consternation and controversy among the scientific community. The Office of U.S. Foreign Disaster Assistance has been aware of Dr. Brady's theory since December 1978 and has encouraged further analysis and testing of the hypothesis.

Dr. Brady has applied his earthquake prediction model to Peru and three areas in the U.S. as "test cases." Dr. Brady's prediction for Peru posits that between August and October 1981 an earthquake of unprecedented magnitude (Mw 9.9^{+} on the Richter Scale) will occur about 65 kilometers southwest of Lima, off Peru's coast. This is to be followed in April-May 1982, by a second quake with a magnitude of Mw 9.2. According to Brady, such a geophysical event has a recurrence interval of about 800,000 years. Such an earthquake's aftershock events, and accompanying seismic sea waves, would cause catastrophic damage, probably destroying many of the populated areas along the West Coast of South America (including Lima with a population of four million) and severely affecting the islands in the South Pacific region, including Hawaii (due to seismic sea waves).

Historically, the Andean region has been a zone of major earthquake activity. In 1970, Peru experienced an earthquake (7.7 on the Richter Scale) which resulted in the loss of 67,000 lives and about $530 million in physical damage.

About 65 kilometers off the coast of Ecuador, Peru and Chile, an oceanic tectonic plate is pushing against the continental plate of South America. The movement of these plates generates intense pressures which are being released through a series of "seismic events," some of which are barely detectable, others which have been forecast have the potential to cause mass destruction.

An international conference was convened in San Juan, Argentina, from October 20-24, 1980, to explore among other things the scientific validity of Dr. Brady's prediction. Two officers from the OFDA preparedness staff were present at the conference as observers. Dr. Brady was accompanied by a collaborator, Dr. William Spence, from the U.S. Geological Survey (USGS). Scientists at the conference could not confirm nor disprove Brady's hypothesis. Generally, they remained somewhat skeptical concerning the plausibility of Brady's prediction, yet it was established that a highly destructive earthquake could occur in the region at any time.

Following the San Juan Conference, Drs. Brady and Spence travelled to Lima, Peru where they conferred with Peruvian officials, U.S. Embassy and USAID/ Peru personnel, and the two OFDA officers. Upon examination of certain foreshock and rockstrain data derived locally, Brady claimed that the quake he is predicting "is on schedule." A key caveat, however, is that these data were derived from less than satisfactory scientific sources than would be necessary to form fully reliable conclusions. Small seismic events occurred in the Inclusion Zone in August and September as predicted by Dr. Brady. Follow-on "marker events" are predicted to occur as early as mid-December of this year and at specified intervals during the first half of calendar year 1981.

While in Peru, Drs. Brady and Spence, in the presence of U.S. Embassy, OFDA and USGS officials, briefed Peruvian President Belaunde on the Brady prediction and their preliminary conclusions. During this meeting, the President of Peru requested assistance from the U.S. government to help detect seismicity in the region and prepare for a major earthquake.

It is imperative that we ascertain the credibility of the Brady prediction and, if it is likely to be correct, attempt to assure that adequate surveillance is in place to record the next predicted precursor in mid-December. OFDA is now seeking to obtain the views of the U.S. scientific community regarding the plausibility of the prediction, and to identify possible additional sources of funding to support surveillance and analysis activities. OFDA would appreciate your intervention with Dr. Frank Press, the Presidential Science and Technology Advisor, to obtain additional judgments concerning the Brady prediction. Time is of the essence; any additional seismic monitoring capability which is needed should be in place and functioning within the next month.

If the consensus of the scientific community is that the Brady prediction has merit and, if sufficient resources are not immediately available elsewhere, OFDA should be prepared to commit up to $200,000-500,000 in the coming days in an attempt to assure adequate observation of the predicted precursor in mid-December. OFDA should also stand ready in this case to make an all-out effort in support of Peru's initiatives to prepare for the earthquake next summer or fall.

PDC/OFDA:AVanEgmond:ja:11/10/80:X29755

DOCUMENT NO. 060

November 13, 1980

MEMORANDUM

TO: PDC/OFDA, Alan Van Egmond

FROM: PDC/OFDA, Paul F. Krumpe

SUBJECT: Interagency Committee Meeting on the Peru Earthquake Prediction Program

Participants scheduled to attend the subject meeting at 2:30 p.m. November 14, 1980, are as follows:

- Dr. John Filson (USGS)
- Mr. Alex Bacho (USBM)
- Mr. Ted Kobayashi (OES)
- Mr. Edward Coy (AA/LAC)
- Mr. John Purnell (ARA/AND)
- Mr. William Rhodes (LAC/SA)
- Mr. Leroy Anstead (DMA)
- Dr. John Bossler (NOAA/NOS)
- Dr. Ted Flinn (NASA)
- Dr. Charles Thiel (FEMA)
- Dr. Margaret Finarelli (OSTP)

Mr. William Jones (FEMA)
Dr. Charles Culver (NBS)
Dr. Tom Aldrich (Carnegie Institution)

DOCUMENT NO. 061

November 18, 1980

MEMORANDUM

TO: PDC/OFDA, Alan Van Egmond

FROM: PDC/OFDA, Paul F. Krumpe PFK

SUBJECT: Interagency Committee Meeting on the Peru Earthquake Prediction Program

Subject meeting held November 14, 1980, from 2:30-4:30 p.m. was attended by the following agency representatives:

Dr. John Filson (USGS)
Mr. Alex Bacho (USBM)
Mr. Mike Gaus (NSF)
Mr. Donald Rogich (USBM)
Mr. Edward Coy (AA/LAC)
Mr. John Purnell (ARA/AND)
Mr. William Rhodes (LAC/SA)
Mr. Leroy Anstead (DMA)
Mr. Ted Kobayashi (OES)
Dr. C. S. Wang (USBM)
Mr. Ugo Morelli (FEMA)
Mr. George Beauchamp (AID/OFDA)
Mr. William Kelly (AID/OFDA)
Mr. George McCloskey (AID/OFDA)
Ms. Denny Avignone (FEMA/IA)
Dr. Margaret Finarelli (OSTP)
Dr. Ted Flinn (NASA)
Mr. William E. Strange (NGS)
Mr. Alan Van Egmond (AID/OFDA)
Mr. Paul F. Krumpe (AID/OFDA)
Mr. Fred Cole (AID/OFDA)

The meeting was convened to discuss the incoming State cable, Lima 10336 (LOU), dated November 10, 1980. Alan Van Egmond (AID/OFDA) chaired the meeting and initiated discussions by asking for comments on the prediction, background info from participants as appropriate, current attitudes and roles or positions of agencies represented, and appropriate USG response to requests and recommendations in the cable.

Mr. J. A. Purnell, State Desk Officer, mentioned that he had talked with Ambassador Corr earlier in the day and that a "sense of doom" prevailed in the American community in Lima due to the recent Brady/Spence visit. Purnell questioned how and why the Embassy could have permitted a visit to President Belaunde by the U.S. contingent visiting Lima inasmuch as Brady's prediction is not USG endorsed nor sanctioned in any way. Corr was apparently unaware that Brady and Spence were not on official travel, rather were funded by CERESIS to visit Peru (Ref. State 277382). Purnell was unaware that Cole/Krumpe specifically informed Embassy staff that Brady/Spence visit was funded by CERESIS and that Brady prediction was not endorsed by the USG. Purnell expressed considerable consternation concerning the Brady prediction and its implications for Lima due to recent publicity.

Dr. Margaret Finarelli (OSTP) indicated that Dr. Frank Press, White House Science Advisor, maintains same USG official position as stated in Menard (USGS) to Press (OSTP) letter dated May 8, 1980, i.e., the U.S. Government does not endorse the Brady Prediction for Peru nor the hypothesis upon which it is based. Dr. Brady must set down, in writing, in rigorous detail, the basis for his Peruvian prediction if it is to be evaluated by others in the scientific community. The National Earthquake Prediction council cannot review the prediction unless the Peruvian Government requests such review and not until the prediction and its basis are written down for peer review.

Dr. John Filson (USGS) stated that the USGS has reviewed Brady's prediction and hypothesis to the extent to which personnel and time have been available to do so. The USGS remains highly skeptical and finds no scientific basis for further evaluation of the prediction or further dedication of scarce USGS resources to examine it. Filson stated that Dr. W. Spence could not be made available to work full time on the Brady prediction hypothesis or related seismic monitoring program. For Spence to do so would constitute a tacit USGS endorsement of the Brady hypothesis which would be contrary to USG policy as established by OSTP. Dr. Filson stated a more useful allocation of A.I.D. resources should be in establishing an earthquake hazards mitigation program in Peru, one which is not based on Brady's prediction but rather directed toward the earthquake hazard in general. He mentioned development of the California Building Codes Act (1933) as a model for such a development program.

Dr. Ted Flinn (NASA) stated that the Brady prediction theory is not credible, has not been written down for peer review and is, in its present state, unscientific, regardless of Dr. Brady's status as USBM scientist. Dr. Flinn indicated that allocation of A.I.D. resources in support of the program requested by Amembassy would not be advisable based solely on the Brady hypothesis, i.e., scare tactic to conduct crash monitoring program would set bad precedent, be poor policy, etc. Dr. Flinn did consider a seismic monitoring program of the highest priority for Peru as long as no linkages were established to the Brady prediction. He stated that NASA (Crustal Dynamics Program) would not change its scheduled program for South America, nor contribute any research funds in any effort to monitor the Brady prediction or its outcome.

Mr. Rogich (U.S. Bureau of Mines) stated the USBM position, that it has allowed Brady to work on the hypothesis without advocacy by the USBM. He stated that Dr. Brady is a credible, capable, competent scientist, well published and able to work on the problem to a greater degree if so requested and permitted by USG policy. Rogich stated that Dr. Brady requires a quality, real-time seismic data stream to enable him to either maintain or relinquish his own confidence in the application of his theory to the prediction of the catastrophic Peru earthquake in August 1981. According to Dr. Brady, the prediction is deterministic, i.e., either certain events will occur, in sequence and of certain specificity, or they will not. If events occur as specified, then the main event is absolute (and predictable).

Dr. Filson indicated USGS is extremely reluctant to direct William Spence to continue working on the Peru case when, in fact, Southern California situation is lacking adequate instrumentation and manpower to study earthquake danger and prediction there.

Mr. Paul Krumpe (OFDA) described the current status of the Brady prediction as stated at the October 20, 1980 San Juan, Argentina Conference. He further stated details of recent events in the "inclusion zone" as reported by Peruvian seismologists. Krumpe indicated that events of Mb = 3.5-3.7 occurred in "inclusion zone" on August 14 and September 20 as generally predicted by Brady in his memorandum to Marovelli (USBM) dated May 1, 1980. The magnitude of these events was slightly smaller than that stated in the May 1 memorandum. On October 25 an earthquake swarm Mb = 3.4-4.0 occurred in the inclusion zone which appears consistent with Brady's foreshock prognostication. These events do not constitute proof of Brady's hypothesis, rather the preliminary analysis of the data indicates that the foreshock sequence may have begun as predicted (stated by Brady to the President of Peru on October 29, 1980).

Mr. Van Egmond asked for agency collaboration to further study the Brady hypothesis and its implications for disaster preparedness planning and operations.

Dr. Filson restated that USGS "has no confidence in the Brady hypothesis to warrant further consideration of testing it at this stage." Dr. Flinn (NASA) indicated that perhaps the National Academy of Sciences (NAS) Committee on Seismology might consider reviewing the Brady hypothesis as a case study, provided he writes down for critical review the basis of his Peru predictions.

The meeting adjourned with agency positions remaining as originally stated by the principal participants as outlined in Dalton/Mitchell memo dated March 28, 1980. USGS representative, John Filson, did not provide the current results of the Office of Earthquake Studies review of events in the inclusion zone as monitored by NEIS personnel in Golden, Co. It was apparent that no events had occurred which supported Brady's predicted foreshock hypothesis as stated in the May 1 USBM memo. Dr. Filson

indicated that USGS would have no objections to establishing a sensible seismic monitoring program in Peru providing it was apart from the Brady prediction.

It was suggested that the $200,000 estimate for a Peruvian seismic data processing system to be installed at IGP was a reasonable request given the high seismicity of the region. However, it was indicated by Dr. Filson and Dr. Flinn that a seismic telemetry network of seven stations would be adequate to establish a reasonable program. Any program would be useful to augment IGP capabilities but should not be linked to the Brady hypothesis. Meeting participants agreed that the Embassy should disengage the "Brady Prediction" from future requests for assistance to the IGP. It was deemed unwarranted to assign Brady or Spence full time to work on the Peru case inasmuch as Brady's prediction has no proponents in the scientific community except Dr. William Spence (USGS).

November 18, 1980

MEMORANDUM

TO: PDC/OFDA, Joseph A. Mitchell, Director

FROM: PDC/OFDA, Alan Van Egmond, Assistant Director for Preparedness and Planning

SUBJECT: Recommendations Concerning the Earthquake Hazard in Peru

I. General Comments

Basic information on the earthquake hazard and the Brady prediction was presented in a memo to the A.I.D. Administrator which is attached. Initial recommendations for assistance from the U.S. Mission in Peru are contained in Lima 10336 which you have already seen.

Obviously, Dr. Brady has touched a very sensitive nerve in the American scientific community. Earthquake prediction is in its infant stages; anyone purporting to be able to predict earthquakes with some accuracy is likely to be regarded as a kook. The problem from OFDA's standpoint is that there is a chance, however slim, that Dr. Brady may be right. Even if he is only half-right, OFDA must exercise its responsibility to help Peru prepare for disasters.

II. Recommended Preparedness Strategy

Regardless of whether Dr. Brady's prediction is creditable, there is a consensus that Peru, and the Andean region generally, is ripe for another major earthquake. Paul Krumpe and Fred Cole's trip report reveals that appropriate institutions in Peru are woefully unprepared for the inevitable earthquake which is to occur.

OFDA's focus therefore should be on assisting the Government of Peru to prepare for the overall threat with no direct linkage to the specific events predicted by Dr. Brady. However, OFDA's preparedness program can be pursued in a fashion which complements a goal shared by all earthquake prone countries in improving the science of earthquake prediction generally.

III. Recommended OFDA/Preparedness Actions

A. Recommendation 1: OFDA Should Help the Peruvians Improve Their Seismic Surveillance and Data Reduction Capability

According to experts present at a meeting hosted by OFDA on Peru, the Peruvians do not have the necessary equipment to properly monitor and synthesize data on seismic activity in a manner which permits timely analysis and action. Rough estimates suggest that $300,000 to $400,000 would be sufficient to upgrade Peruvian capabilities to an adequate level in this area. Accordingly, OFDA should initiate a program immediately with preparedness funds available. A program of this magnitude has already been contemplated in the FY 81 preparedness budget, but other entities in A.I.D. and the U.S. Government should be encouraged to contribute time and resources as well. Technical specialists from USGS and other agencies have already indicated their willingness to cooperate with OFDA in selecting appropriate equipment for this program.

B. Recommendation 2: OFDA Should Help the Peruvians Improve Their Capability to Respond to Major Disasters

While Lima 10336 did not address this item, from OFDA's standpoint, one of the most troubling aspects of the earthquake threat is the rudimentary state of disaster planning and preparedness in Peru. OFDA should encourage a preparedness program which does not assume Lima will be operational in the event of a major disaster, and which significantly upgrades the capabilities of the Peruvian civil defense agency in disaster preparedness. Other relevant agencies of the USG should also be encouraged to make resources and personnel available in connection with this effort.

C. Recommendation 3: OFDA Should Encourage Other Appropriate USG Agencies to Scientifically Evaluate and Test Dr. Brady's Hypothesis

OFDA should encourage the U.S. Bureau of Mines and the USGS to make Drs. Brady and Spence available to fully set forth their hypothesis in writing. At the same time, the USGS should be encouraged to convene a panel of appropriate experts in seismology and earthquake prediction to evaluate and test the Brady hypothesis. Information collected through OFDA's program in Peru should be made available in support of this effort.

Attachment:
Info Memo for the Administrator
Dated November 12, 1980

Department of State

OUTGOING TELEGRAM

DOCUMENT NO. 063

021045 AID4005

PAGE 01 STATE 306472
ORIGIN AID-35

ORIGIN OFFICE DRC-22
INFO LASA-03 LADR-03 STA-10 PDC-02 AADS-01 DSST-01 CH8-01
CH9-01 COM-02 INT-04 NASA-02 NSC-05 RELO-01 .038 A4 8

INFO OCT-00 ARA-15 OES-09 .060 R

DRAFTED BY AID/PDC/OFDA: AVANEGMOND: ED
APPROVED BY AID/PDC/OFDA: JAMITCHELL
AID/PDC/OFDA: GMCCLOSKEY
AID/PDC/OFDA: JCLARK
AID/LAC/SA: WRHODES (INFO)
ARA/AND: JPURNELL (PHONE)
USGS: JFILSON (INFO)
OSTP: MFINARELLI (SUBS)
DESIRED DISTRIBUTION
ORIGIN DRC CH 8 CH 9 INFO LASA LADR PDC AADS DSST COM INT NASA NSC
STA 98-00 END

18 November 1980

---------- 024266 180416Z /60

O 180305Z NOV 80
FM SECSTATE WASHDC
TO AMEMBASSY LIMA IMMEDIATE

UNCLAS STATE 306472

AIDAC

E.O. 12065: N/A

TAGS:

SUBJECT: EARTHQUAKE HAZARD IN PERU

REF: LIMA 10336

1. REGRET DELAY IN RESPONSE TO REFTEL. REFTEL RECEIVED BY OFDA 13 NOVEMBER.

2. INFORMAL MEETING WAS CONVENED BY OFDA TO DISCUSS BRADY PREDICTION AND REVIEW PROPOSED EARTHQUAKE HAZARD PROGRAM FOR PERU. AMONG THOSE IN ATTENDANCE WERE REPRESENTATIVES FROM STATE, AID, U.S. GEOLOGICAL SURVEY, NOAA, NASA, U.S. BUREAU OF MINES AND OSTP/WHITE HOUSE. DESPITE GENERAL UNDERSTANDING OF SEVERE SEISMIC RISK IN THE AREA, SKEPTICI WAS EXPRESSED REGARDING THE BRADY PREDICTION.

3. FULL REPORT FOLLOWS BY STATETEL. MUSKIE

Peru

DOCUMENT NO. 064

Memo of Conversation

November 21, 1980

Participants: Ollie Davidson, OFDA
John Filson, USGS

Subject: OFDA - USGS Collaboration on Peru

The Prediction:

Filson said that he and three other USGS seismologists met with the Director of USGS today. They listened to Bill Spence's explanation of the Brady prediction. According to Filson, the Director was not particularly impressed with the prediction.
It was decided that USGS should inform the the Peruvian Government through the U.S. Embassy, Lima that the Earthquake Prediction Council was available and would evaluate the Brady prediction if requested by the GOP.

Filson is drafting a paragraph(s) to be included in the cable to Lima. I gave him OFDA's telecopier number. I indicated that we wanted the paragraphs tonight, he hedged.

The Equipment:

I told Filson that I understood that the USGS agreed in the meeting with Van Egmond and Pierson to review the equipment necessary to better prepare Peru for any seismic event. He had not discussed that aspect with the Director. He has not started this activity.

Filson agreed that he and other USGS staff could review the list of equipment proposed by Peru. I expressed a sense of urgency and Filson agreed that he could have the review completed within 4-5 days. He asked what funding level might be available for this activity. I said that from $200,000$400,000 had been suggested.

O Davidson 11/21/80

DOCUMENT NO. 065

November 25, 1980

MEMORANDUM OF CONVERSATION

FROM: PDC/OFDA, Alan Van Egmond, Assistant Director for Preparedness and Planning

SUBJECT: Meeting Concerning U.S. Government Response to Peruvian Earthquake Hazard

The meeting was convened at 10:00 a.m. on Wednesday, November 19, 1980, at the request of Mr. Gordon Pierson, Deputy Assistant Administrator, Bureau for Private and Development Cooperation, who also served as host. Other persons present were:

Mr. Edward Coy
Acting Assistant Administrator
Bureau for Latin America and the Caribbean/A.I.D.

Mr. Alan Van Egmond, PDC/OFDA

Dr. Robert Wesson, USGS

Dr. John Filson, Acting Director
Office of Earthquake Studies, USGS

Mr. Pierson began the discussion by summarizing how A.I.D. has reacted to the Peruvian earthquake hazard recommendations set forth in Lima 10336. He also described a conversation the A.I.D. Administrator, Mr. Douglas J. Bennet, Jr., had with Dr. Frank Press, OSTP/White House, concerning the USG reaction to the Brady Prediction.

Mr. Pierson emphasized that A.I.D.'s focus is on the overall threat posed by the earthquake hazard to the Andean region generally. However, Pierson suggested that A.I.D.'s response to requests from Peru for assistance might perhaps be helpful in generating seismic data which could be used to test the Brady Prediction. Pierson said that Bennet had asked him to ascertain what USGS' position was on the Brady Prediction and why thus far USGS has apparently pursued a non-responsive approach.

Dr. Wesson described USGS' perspective on earthquake prediction generally. He then reacted to specific suggestions for action which were made by the U.S. Embassy in Peru. Wesson stated that it is generally accepted among

Key U.S. scientists that the Andean region is facing a major seismic threat, not just Peru. According to Wesson, the science of earthquake prediction is in its infancy. Significant USG resources have supported research in this field following a major earthquake in Alaska in 1964. USGS now has an earthquake prediction research program involving upwards of 400-500 scientists with a budget of around $20 million annually.

China, the Soviet Union and Japan are the only other countries conducting noteworthy research in earthquake prediction. Thus far, only the Chinese have been able to successfully predict an earthquake--one which occurred in 1975. At present, the USGS is sponsoring pure research rather than seeking to develop and test specific predictive models.

According to Wesson, in 1976 Dr. Brady of the U.S. Bureau of Mines published some articles in a European journal outlining his prediction for a major earthquake to occur off the West Coast of Peru in 1981. These papers received no attention in the U.S. scientific community except fo Dr. William Spence, who works with USGS' Office of Earthquake Studies in Denver, Colorado. According to Wesson, Brady has no standing among U.S. seismologists. He is a professional in the field of rock mechanics. Up to the present, U.S. seismologists have been focusing on data derived from "seismic gaps" in the Pacific Ocean, and historical data on earthquake occurrences in Japan and Southern California. (A lay person could conclude from this that rock mechanics is generally extraneous to areas seismologists perceive appropriate for their research.)

Wesson stated that in 1978, Drs. Brady and Spence recommended that more monies be used for research in Peru to investigate Brady's predictive model. The USGS declined this recommendation and urged that Dr. Spence devote his time and attention to other areas, as the Brady prediction was not deemed worthy of testing.

According to Wesson, earlier this year the Director of USGS was given the responsibility of making earthquake predictions on behalf of the U.S. Government. A National Earthquake Prediction Council chaired by Dr. Clarence Allen (a scientist at Cal Tech) was established to assist and advise the head of USGS in performance of this task. The Council is comprised of six USGS officials and six U.S. scientists from outside the federal government. The Council established a policy of not reviewing earthquake predictions pertaining to other countries unless requested to do so by the governments concerned. Meanwhile, USGS has expressed concern to the U.S. Bureau of Mines about Dr. Brady's persistence in advocating his prediction. So far the Bureau has been rather lenient in allowing Brady to continue his work on this subject, much to the chagrin of USGS. USGS has allowed Dr. Spence to cooperate with Dr. Brady so long as his other tasks were performed adequately.

Earlier this year Dr. Alberto Giesecke, acting in his capacity as head of CERESIS (a regional Andean seismological network) invited Drs. Brady and Spence to attend a conference in San Juan, Argentina in October 1980, with funds supplied by the U.N. Wesson stated that USGS thought the focus

of the conference was on regional seismic programs. Dr, Spence was allowed to attend as a private U.S. citizen with funds paid for by Conference sponsors. The U.S. Bureau of Mines allowed Dr, Brady to attend, apparently on the same basis. The USGS also sent Dr. Ted Algermissen from Denver, Colorado as a "voice of reason." Dr. Allen of Cal Tech also attended the conference.

Subsequently, according to Wesson, the USGS was shocked to learn that much of the attention of the conference was centered on the Brady prediction. Furthermore, to their horror, Drs. Brady and Spence stopped in Lima, and at Dr. Giesecke's initiative met with the President of Peru.

Wesson related that in USGS' view, they are being leveraged by Dr. Giesecke to provide more assistance to the Peruvian Geophysical Institute (IGP) which he heads. In Wesson's judgment, Dr. Giesecke is a highly capable geophysicist, but has ulterior motives in seeking to expand his program and personal position. Wesson also stated the USGS was very disappointed in Dr. Spence's conduct, who perhaps went beyond reasonable bounds in creating the impression of tacit USG endorsement for the Brady model. Finally, Wesson stated that the Peruvian Government has yet to request USG assistance in evaluating the Brady prediction, nor has Brady set forth his hypothesis in a manner conducive to scientific review and testing.

Mr. Van Egmond stated that OFDA's focus was on disaster preparedness relating to the general earthquake hazard facing the Andean region, as stressed earlier by Pierson. Van Egmond then asked about the advisability of providing assistance to IGP in upgrading Peru's seismic monitoring and surveillance capability. He also commented that the Peruvian Government may not have asked for the USG to test the Brady prediction because they were either unfamiliar with the procedures for activating the Earthquake Prediction Council or feared local public reaction to further public discussion of the Brady prediction.

Mr. Coy expressed the opinion that scarce A.I.D. resources could best be used by analyzing the various levels of risk associated with quakes at different magnitudes, and upgrading Peru's disaster preparedness capability. Coy questioned the advisability of using funds to purchase additional seismic equipment, since without a valid working model for earthquake prediction, adequate early warning was not possible. Also, Coy stated his concern about unnecessarily raising local fears further with additional data that would inevitably be generated through improved seismic detection.

Both Coy and the USGS officials felt strongly that before any money is used in connection with the Brady prediction (i.e., purchasing additional seismic equipment) the Earthquake Prediction Council should first evaluate the hypothesis underlying the prediction. Wesson estimated that once assistance was requested by the GOP, it would take two to three weeks to scientifically assess the Brady prediction upon activation of the Council. Also, Wesson and Filson said their initial judgment was that USGS and the IGP already had sufficient capability to detect the precursor events which

Brady predicted for December 1980 and early 1981. However, they are going to check again with their staff and confirm this judgment within a few days.

During the final stages of the meeting, it was decided that:

1. OFDA would be responsible for coordinating the drafting of a cable to Lima in response to Lima 10336.

2. OFDA would be responsible for drafting sections of the cable dealing with risk analysis, preparedness and public awareness. OFDA would also determine whether certain activities sponsored under CERESIS could be accelerated.

3. USGS would be responsible for drafting a section on procedures for convening the Earthquake Prediction Council. The USGS will see if the Council can act in a manner which protects the sensitivity of the information it considers and conclusions it reaches. USGS will also determine if adequate seismic detection capability exists in the U.S. and in Peru to monitor events predicted by Brady.

Finally, it was decided that the cable would be subject to the policy guidance of the State Department, but that A.I.D. and USGS have primary roles in responding to requests set forth in Lima 10336. The meeting adjourned at 11:45 a.m.

DOCUMENT NO. 066

United States Department of the Interior

GEOLOGICAL SURVEY
BOX 25046 M.S. 967
DENVER FEDERAL CENTER
DENVER, COLORADO 80225

IN REPLY REFER TO:

Branch of Global Seismology

Nov. 24, 1980

Memorandum

cat N. 26

To: John Filson

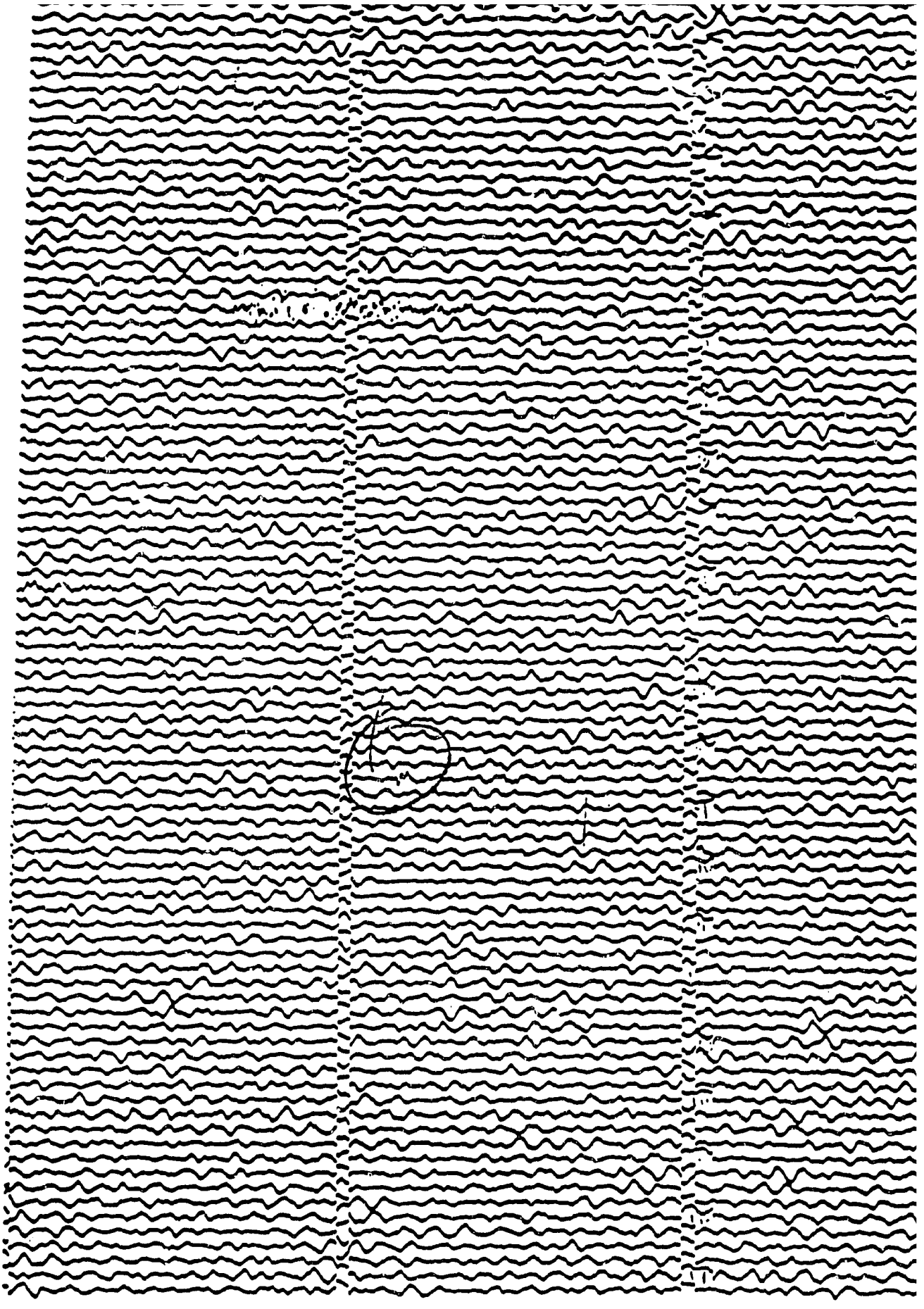
Through: Bob Engdahl

From: Bill Spence Bill Spence

Subject: The Peru-Chile prediction

The end of the first phase of foreshocks to the main predicted earthquake should occur by January 10, 1981. It appears that low magnitude earthquakes ($3.8 > m_b > 2.5$) have occurred in the delimited Brady target zone during the stipulated time frame of first phase foreshocks. Peruvian sources claim that this sequence of events, beginning August 14, 1980, is the only such activity to have occurred in the last few years in the delimited target zone. However, apparently there is no reliable data base with which to compare this activity and thus permit me or Brady to conclude beyond a reasonable doubt that this activity definitively corresponds to the predicted sequence of first phase foreshocks. Therefore, if no teleseismically locatable earthquake of $m_b \geq 4.5$ occurs in the delimited Brady target zone by January 10, 1981, I shall view the probability of the predicted earthquake to be significantly lowered, withdraw my immediate endorsement for the Peru-Chile prediction, and would be unwilling to present my arguments to the National Earthquake Prediction Evaluation Council.

On the other hand, if a teleseismically locatable earthquake of $m_b \geq 4.5$ does occur within the delimited Brady target zone by January 10, 1981, then it would lend credence to the interpretation of the current low magnitude earthquake series in the delimited Brady target zone as first phase foreshocks. In this case I shall hold to the opinion that the possibility of the predicted catastrophic Peru-Chile earthquake should be considered further. Under this circumstance, I would be willing to present my tectonic arguments to an open meeting of the National Earthquake Prediction Evaluation Council, as integrated with a presentation by Brian Brady. In this eventuality we would need 1½ days for presentation and perhaps ½ day for discussion. Brian Brady concurs with all points in this memo and would be glad to discuss with you or your staff this or other aspects of the prediction.



ec. 26, 1980
08h 19m
2.99°S x 77.32°W
h ~ normal (33)
m ~ 4.5
(= 52 PDE

learned of this
event Jan 23, 1981
~1230 MST
W/S.

STATION AGG COMP E MAG 2004 CALCUR 0.75 G 2.0
DATE ON 12-25-80 TIME ON 1832 CORR -5.10 MS @ 173.0G
DATE OFF 12-26-80 TIME OFF 1724 CORR -5.10 MS @ 173.0G
To 1.0 Tg 0.75 Remarks:

DOCUMENT NO. 067

United States Department of the Interior
GEOLOGICAL SURVEY
BOX 25046 M.S. 967
DENVER FEDERAL CENTER
DENVER, COLORADO 80225
Branch of Global Seismology

November 26, 1980

Memorandum

To : John Filson

From : Bill Spence BWSpence

Subject: Recommendations for Geophysical Program in Peru

My view on the best way to spend $200-400K in Peru is to provide a means for instant access and subsequent processing at some central facility, to the strain, tilt and seismographic data now recorded in that country.

It would make sense to assure that the central recording facility and the data links are not susceptible to operational difficulties in the case of a significant earthquake.

The strain and tilt instruments at Nana, the 3-station strain and tilt array south of Lima, and the similar array near Arequipa should be modified to record digitally on magnetic tape. These data should be obtainable at any time through an interrogation capability, via telephone or satellite. In this way, completely up-to-date data would be available in a format suitable for signal processing. Then any apparent anomalies, such as 'S-bend tilt' or a possible strain pulse, can be correlated and interpreted in the context of phenomena that could be precursory to a significant earthquake. A specific mechanism for processing of these data should be an element of this program.

The seismographic data should be telemetered to a central recording facility. It is my understanding that outputs from four (perhaps five) seismometers are now centrally recorded. It is recommended to include stations from an expanded telemetry network (including I. Hormigas) to achieve a more homogeneous coverage of Peru seismicity and to achieve increase in the precision of calculated hypocentral data. The seismographic data should be processed routinely and a monthly bulletin prepared.

DEPARTMENT OF DEFENSE
UNITED STATES SOUTHERN COMMAND
APO MIAMI 34003

Jacome 12/10/80

DOCUMENT NO. 068

SCRM-L

2 December 1980

Mr. George Beauchamp
c/o Office of Foreign Disaster Assistance
Room 1262A, New State Building
Washington, D.C. 20523

Dear ~~George~~ George:

Enclosed find the stockpile inventory report of 6 November 1980. There have been no significant changes although under field cooking outfits (Comm Code 511001) please note that repair parts for three unserviceable stoves cannot be replaced. Recommend these stoves be cannibalized for their remaining serviceable parts. Please advise.

The SecState message with the FY81 appropriated fund cite has arrived. A return message from the 193d Infantry Brigade will provide you with update addresses. The monthly inventory reports should continue to come to my office.

The Bill of Lading for the plastic water containers and caps for water containers has arrived in the Brigade. Though the cargo is probably located in the port of Balboa, Panama, it has not yet been picked up by the Brigade. Balboa port operations are now under Panamanian control and delays are regularly encountered regarding notice of receipt of inbound cargo. We will report receipt in next report.

The Brady Prediction continues to draw interest in SOUTHCOM. We have a copy of the AmEmbassy Lima message (AmEmbassy, Lima 102224Z Nov 80) and the Miami Herald of 10 Nov 1980 carried a complete article regarding the prediction. A copy of the article is enclosed. Any additional information your office may have and any additional reports that may be generated by the SecState and the AmEmbassy, Lima that can be sent to this Headquarters would be appreciated. This Headquarters should be on regular distribution for Brady Prediction reports.

During the disaster relief conference in Norfolk, the possibility of a SecState sponsored conference in the Spring of 1981 was briefly discussed. If

SCRM-L
Mr. George Beauchamp

the meeting is still scheduled, the status of the Brady Prediction must be a meeting agenda item.

Best regards,

J. A. LINNEMANN
LtCol, USMC
Chief, Logistics Division

2 Incls
as

CF:
193d Inf Bde
(ATTN: Ms Pat Coleman)
DIO, Corozal

DOCUMENT NO. 069

United States Department of the Interior

GEOLOGICAL SURVEY
BOX 25046 M.S. 967
DENVER FEDERAL CENTER
DENVER, COLORADO 80225

December 2, 1980

Branch of Global Seismology

U.S. Geological Survey
Office of Earthquake Studies
Reston, Virginia

DEC 2 PM

RECEIVED

Memorandum

To: John Filson

Through: Bob Engdahl RE

From: Bill Spence Bill Spence

Subject: The Peru-Chile prediction

The end of the first phase of foreshocks to the main predicted earthquake should occur by January 10, 1981. It appears that low magnitude earthquakes ($3.8 > m_b > 2.5$) have occurred in the delimited Brady target zone during the stipulated time frame of first phase foreshocks. Peruvian sources claim that this sequence of events, beginning August 14, 1980, is the only such activity to have occurred in the last few years in the delimited target zone. However, apparently there is no reliable data base with which to compare this activity and thus permit me or Brady to conclude beyond a reasonable doubt that this activity definitively corresponds to the predicted sequence of first phase foreshocks. Therefore, if no teleseismically locatable earthquake of $m_b \geq 4.5$ occurs in the delimited Brady target zone by January 10, 1981, I shall view the probability of the predicted earthquake to be significantly lowered, withdraw my immediate endorsement for the Peru-Chile prediction, and would be unwilling to present my arguments to the National Earthquake Prediction Evaluation Council.

On the other hand, if a teleseismically locatable earthquake of $m_b \geq 4.5$ does occur within the delimited Brady target zone by January 10, 1981, then it would lend credence to the interpretation of the current low magnitude earthquake series in the delimited Brady target zone as first phase foreshocks. In this case I shall hold to the opinion that the possibility of the predicted catastrophic Peru-Chile earthquake should be considered further. Under this circumstance, I would be willing to present my tectonic arguments to an open meeting of the National Earthquake Prediction Evaluation Council, as integrated with a presentation by Brian Brady. In this eventuality we would need 1½ days for presentation and perhaps ½ day for discussion. Brian Brady concurs with all points in this memo and would be glad to discuss with you or your staff this or other aspects of the predi tion.

OPTIONAL FORM NO. 10
MAY 1962 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

DOCUMENT NO. 070

Memorandum

TO : Chief, Office of Earthquake Studies

DATE: December 3, 1980

FROM : Chief, Branch of Global Seismology

SUBJECT: Prediction of Earthquakes Off Peru

A foreshock-mainshock sequence has been predicted by Brian Brady to begin off the coast of Peru in mid-September 1980. We have been directed to use the facilities and data available to the National Earthquake Information Service (NEIS) in efforts to detect the foreshock sequence predicted by Brady. This is the second monthly report on seismicity detected in the region of the predicted earthquake sequence.

For purposes of this exercise we define the region of interest to be described by figure 1 of the Brady letter to Marovelli dated May 1, 1980. This region has approximate geographic boundaries of 11.5° to 14.0° south latitude and 75.5° to 79.0° west longitude. In the year preceding September, 1980, four earthquakes, at least three of which were greater than m_b 4.5, were detected in this region. For purposes of comparison these can be considered as normal background for seismicity detected in the region by NEIS. On the basis of these data and earlier studies we conclude that the NEIS threshold magnitude for the region lies between m_b 4.5 and 5.0. This suggests that data provided to NEIS will not ordinarily permit us to locate all earthquakes above m_b 4.5 that might have occurred in the region. However, the Peruvian local network appears to have been making recent special efforts to provide NEIS with data from small magnitude events in the region so that this condition may no longer be valid.

Summary for October, 1980—with the exception of the September 20, 1980, ML = 3.2 earthquake previously reported, no activity in the region of interest has been detected and reported by NEIS through PDE No. 45-80, dated December 3, 1980.

DOCUMENT NO. 071

United States Department of the Interior

GEOLOGICAL SURVEY
RESTON, VIRGINIA 22092

In Reply Refer To:
Mail Stop 905

December 11, 1980

Memorandum

To: Members, National Earthquake Prediction Evaluation Council

From: Chief, Office of Earthquake Studies

Subject: Evaluation of prediction of a major earthquake off Peru in 1981

Drs. Brian Brady of the Bureau of Mines and William Spence of the Geological Survey have predicted the occurrence of a major earthquake off the coast of Peru. The Peruvian government has requested an authoritative assessment of the prediction by the United States Government. Specifically, we have been asked to convene the National Earthquake Prediction Evaluation Council to review the prediction.

In order to fulfill promptly the request of the Peruvian government, and in consultation with Director Menard and Clarence Allen, we have decided to convene the National Earthquake Prediction Evaluation Council during 26-27 January 1981 in Golden, Colorado.

Please let us know by phone (703/860-6471) if you will be able to attend the meeting. We urge you to attend if at all possible so that we will be able to give the prediction a fair and thorough evaluation. We will provide additional information on the meeting as it becomes available.

John R. Filson

DOCUMENT NO. 072

UNCLASSIFIED FDR670

PAGE 01 STATE 328210
ORIGIN ARA-16

11 December 1980

INFO OCT-00 ADS-00 OES-09 AID-07 FDRE-00 INT-05 /037 R

DRAFTED BY ARA/AND/P - JAPURNELL:LEE
APPROVED BY ARA/AND - SHART
USGS - JFILSON (PHONE)
OES - TKOBAYASHI
AID/OFDA - PKRUMPE

----------061734 112100Z /15

O 112015Z DEC 80
FM SECSTATE WASHDC
TO AMEMBASSY LIMA IMMEDIATE

UNCLAS STATE 328210

E.O. 12065: N/A

TAGS: TRHY, PE

SUBJECT: EARTHQUAKE HAZARD IN PERU

REF: STATE 324986

1. EMBASSY MAY PROVIDE PRESIDENT BELAUNDE AND GIESECKE ENTIRE CABLE IF IT WOULD BE USEFUL TO DO SO. PARA 7 AND SUMMARY WERE MARKED LOU ONLY TO ALLOW EMBASSY SOME DISCRETION IN CONSULTING WITH GOP ON POSSIBLE USG ASSISTANCE IN THE AREA OF DISASTER PREPAREDNESS.

2. FYI: USGS PLANS TO CONVENE NATIONAL EARTHQUAKE PREDICTION EVALUATION COUNCIL IN GOLDEN, COLORADO, NEXT JANUARY 26. NATIONAL EARTHQUAKE INFORMATION SERVICE, WHOSE CONSIDERABLE DATA BANK COULD BE USEFUL TO THE COUNCIL, IS LOCATED IN GOLDEN. DEPARTMENT WILL CONFIRM DATES ASAP. GIESECKE AND/OR HIS COLLEAGUES PRESUMABLY WILL WISH TO ATTEND. CHRISTOPHER

UNCLASSIFIED

DOCUMENT NO. 073

EMBASSY OF THE
UNITED STATES OF AMERICA
Lima, Peru

December 17, 1980

Mr. William Spence
U.S. Geological Survey
Box 25046
Federal Center
Denver, Colorado 80225

Dear Bill:

The attached paper consitute a test run of a system for expediting materials to you. The materials have just been received from Dr. Giesecke's Instituto Geofisico del Peru.

I am sending the same to you via APO mail and would like you to let us know which way is faster. Later we'll inquire about how fast this batch would take to process telegraphically using our embassy facilities.

It may be of interest to you to know that I offered this facilitative service to Dr. Giesecke seven days ago.

Sincerely,

Alford Cooley
Economic Officer

Attachment:
12 pages of Seismic data for several stations, period Oct.25-Dec.11 (with code to stations)

cc: Mr. Paul Krumpe, AID/OFDA

You wouldn't want the attachments, Paul.

UNITED STATES INTERNATIONAL DEVELOPMENT COOPERATION AGENCY
AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D C 20523

DOCUMENT NO. 074
December 21, 1980

MEMORANDUM

TO: PDC/OFDA, Alan Van Egmond, Director for Preparedness and Planning

FROM: PDC/OFDA, Paul Krumpe, Science Advisor PFK

SUBJECT: Meeting of National Earthquake Prediction Evaluation Council on Peru

On Jaunary 26-28, 1981 the subject Council will convene in Golden, Colorado under the Chairmanship of Dr. Clarence Allen (CALTECH Seismological Laboratory) to review and evaluate the Peru earthquake prediction (August 1981) made by Dr. Brian Brady, U.S. Bureau of Mines. The meeting will be open and should be attended by other scientists concerned with the Brady Prediction credibility.

I propose to attend subject proceedings as an observer and to report to you and the Director on the following:

1) Current status of prediction for Peru
2) Revisions in methodology and interpretation based on recently acquired data;
3) Reaction of Council participants to Brady presentation analysis and conclusions;
4) Summary review of plausibility agruments (to be presented by Dr. Willian Spence, U.S.G.S.);
5) Review of formal challenges (questions/answers) and exchanges between Brady, Spence and Council members;
6) Summarization of recommendations, conclusions, agruments and actions taken by the council concerning the Peru prediction.

As you know, the Council meeting will be convened at the request of the GOP to formally evaluate the prediction and reach conclusions regarding its technical basis, scientific credibility, prediction early warning capability as well as determine if there is, in fact, a physical basis or reason upon which GOP should initiate mitigative actions. This meeting is the first of its kind (i.e. specific prediction alledgedly based on physical model for a foreign location). The meeting will establish precedents with respect to format, deliberations, documentation procedures, timing, conduct and information dissemination.

As OFDA Science Advisor I have been closely monitoring the "Brady Prediction" and its ramifications since December 1978. In May 1979 I attended a closed meeting at Golden, Colorado convened by the U.S.G.S. to informally review the Brady Prediction. Questions of a technical nature posed to Drs. Brady and Spence were answered, however, those scientists in attendance admittedly did not understand the presentation and following explanations. Hence, no real technical challenge to Brady's hypothesis

or his data interpretation developed as a result of the meeting. He was requested to "write it down for critical review". This action Brady has resisted until now because (1) he lacked the time, staff, and funding to do so to the degree necessary to publish in the open geophysical literature, (2) he agreed not to publish to date to protect the GOP from adverse effects of the prediction itself, (3) he did not want to publish just the Peru case study alone inasmuch as there are four other case studies in final preparation which support the hypothesis, (4) he lacks all the seismic data and precursory data (strain data, geodetic data, etc.) necessary to fully verify the prediction based on the associated plausibility agruments, (5) his collaborator, Dr. William Spence has found it increasingly difficult to assist him in "writing it up" due to a difficult working environment and pressure from USGS management, (6) he had hoped to "write up" the San Fernando case study including physical basis of model before the Peru event, but USBM committments have thus far precluded final manuscript preparation and final editing necessary to publish findings.

However, Dr. Brady has nevertheless continued to prepare his analysis and interpretation of data in his possession specific to the Peru case. His recent visit to the IGP in Peru has resulted in acquisition of additional data (strain meter records) which convincingly support his hypothesis and Spence's tectonic interpretation. These arguments and analysis of current Peru data, as well as the physical basis of the model will be provided, in part, in writing, at the January 26th meeting. In fact, Dr. Brady may publish this paper as well as council questions/challenges and his answers (provided as a matter of record) before the possible earthquake event.

My attendance as an observer at the subject meeting is extremely important to ensure that OFDA obtains an objective detailed scientific analysis of the proceedings and conclusions derived therefrom.

This determination is based on the following:

1) All reports, memos, record of communications and cables prepared by me on the prediction since early 1979 are a matter of record and reflect an objective analysis of the Brady prediction. They include balanced recommendations based on the potential severity of possible outcomes, and an honest attempt to avoid both error by omission and commission through sharing all pertinent facts and data with those concerned.

2) The Prediction Council meeting is a real precedent in the history of disaster mitigation research and represents possibly the last real opportunity to understand Brady's predictive assumptions, physical hypothesis and methodology of prediction. As such, with a written paper provided, this meeting may prove to be the turning point in many scientists' and understanding of Brady's research hypothesis. The scientific bases of the prediction will be challenged. If Brady's assumptions are invalid then the prediction will be negated; however, if the scientists assembled cannot invalidate Brady's assumptions, then the outcome

of the meeting will take on new diminsions and perhaps lead to further cooperation, assistance and sharing of information and data between Brady, IGP, and possible emergent proponents of further analysis and data collection.

3) Inasmuch as I have intensely studied, monitored, attended all meetings, and provided scientific liaison and continual detailed updates on all aspects of the prediction to OFDA since early 1979, it is certainly appropriate that I observe the Council Proceedings to be assured that their objective deliberations and potential nullification of the Brady Prediction is based on all available facts and documents (which I have meticulously assembled for internal OFDA/AID/STATE use). More importantly, if Brady and Spence are scientifically challenged and cannot or do not respond or meet the challenge (i.e. their assumptions are proven incorrect) then it would certainly lead to a termination of my interest (for and on behalf of OFDA) in the prediction and its possible outcomes.

The Council meeting outcome has several possible scenarios, all of which would affect OFDA responses and activities in the next eight months with respect to South American preparedness.

These scenarios are:

1) Council resolves they cannot reach a conclusion concerning the physical basis of the Brady hypothesis, i.e. too complex to understand and judge in its current form, therefore Council recommends no statement, conclusions, or warning be issued by USGS concerning Brady Prediction, rather, Council resolves that region is prone to earthquakes and all prudent mitigation measures should be implemented regardless on any specific prediction or implied immediacy.

2) Council resolves that Brady hypothesis, assumptions and conclusions are incorrect, invalid and therefore recommends issuing a U.S.G.S. statement publicly nullifying prediction and publicly declaring prediction to be totally false, leading to absolute disassociation of prediction from U.S.G. pervue and any other consideration.

3) Council resolves that Brady hypothesis, assumptions, plausibility agruments and conclusions may have possible scientific validity yet to be tested and proven true (or false). Council recommends U.S.G.S. coordinate an immediate program to either validate or invalidate Brady's data interpretation and prediction conclusions. Brady/USGS and IGP initiate program to monitor precursors to provide Council additional data upon which to make more definite statements in the near future.

4) Council is convinced, based on presentation of data and its interpretation by Brady and Spence, that a "prediction warning"

should be issued by U.S.G.S. to GOP, pending further investigation of new data per para 3 above. Should the data (presursor phenomena) negate the prediction in May 1981, then U.S.G.S. would formally withdraw the "warning" to GOP. Any mitigative actions taken by GOP or others could be reduced in May if precursors do not occur as prescribed. However, level of preparedness re: general threat would have been substantially raised (in the GOP national interest).

5) None of the above but some permutation thereof.

Recommendations:

1) That my TDY travel to Denver/Golden, Colorado, January 25-29, 1981 be approved/authorized so that I can attend the Council meeting as an OFDA observer and provide report as appropriate.

2) That American Embassy (Lima) be encouraged to send a representative to Golden, Colorado to attend meeting.

DOCUMENT NO. 075

Lima, Peru

December 30, 1980

Dr. Brian Brady
U.S. Department of Interior
Bureau of Mines
Bldg. 20 Denver Federal Center
Denver, Colorado 80225

Dear Brian,

I am sending you a copy of an article which appeared recently in the left-wing weekly "Marka" featuring an interview with your dinner guest of earlier this year, Engineer Kuroiwa. He appears to be focusing more on the tidal wave aspect of the earthquake than have other observers.

Sincerely,

Alford W. Cooley

Enc. As Stated

cc: Paul Krumpe

In Reply Refer To:

Mail Stop 905 December 31, 1980

Mr. William Rhodes
Agency for International Development
Room 4917 LAC/SA
State Department Building
2201 C Street, N.W.
Washington, D.C. 20520

Dear Mr. Rhodes:

Please find enclosed the following materials related to earthquake hazards in Peru and Brady-Spence prediction of a major earthquake off the coast of Peru:

1. Trip report of Dr. Jerry P. Eaton, Geophysicist, U.S. Geological Survey.

2. Pre-print of a paper by Professor Keiiti Aki of the Massachusetts Institute of Technology. On page 12 Professor Aki discusses a fundamental point in the theory used by Brady to develop his earthquake prediction. In Aki's opinion Brady has made an "unacceptable assumption" and in reaching the conclusion that the length of time in which precursory phenomena should be observed is dependent on earthquake size. This conclusion is crucial to Brady's prediction.

3. Memorandum sent to members of the National Earthquake Studies Advisory Panel.

Sincerely yours,

John R. Filson
Chief, Office of Earthquake Studies

Enclosures

Copy to: A. Furnell
E. Coy
A. Van Egmond