GEORGIA INSTITUTE OF TECHNOLOGY | **OFFICE OF CONTRACT ADMINISTRATION**

PROJECT ADMINISTRATION DATA SHEET

[X] ORIGINAL [ ] REVISION NO. ______

Project No. G-35-641 (R6095-0A0) GTRC/XXX DATE 2 / 19 / 86

Project Director: Ray E. Habermann School/XXXX Geo. Sci.

Sponsor: U. S. Department of the Interior
U. S. Geological Survey (USGS)

Type Agreement: Grant No. 14-08-0001-G1087

Award Period: From 1/6/86 To 1/5/87 (Performance) 4/5/87 (Reports)

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	This Change	Total to Date
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Funded:	$ 50,000	$ 50,000

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Title: Recognition and Evaluation of Seismicity Anomalies in California

ADMINISTRATIVE DATA OCA Contact Brian J. Lindberg X4820

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Defense Priority Rating: N/A

Military Security Classification: N/A
(or) Company/Industrial Proprietary: N/A

RESTRICTIONS

See Attached N/A Supplemental Information Sheet for Additional Requirements.

Travel: Foreign travel must have prior approval – Contact OCA in each case. Domestic travel requires sponsor approval where total will exceed greater of $500 or 125% of approved proposal budget category.

Equipment: Title vests with GIT on equipment in proposal. No expenditures over $500 for equipment not proposed unless Sponsor approves.

COMMENTS:

Follow-on to project G-35-604 (R5890-0A0)

COPIES TO: SPONSOR'S I. D. NO. 02.111.002.86.001

Project Director	Procurement/EES Supply Services	GTRC
Research Administrative Network	Research Security Services	Library
Research Property Management	Reports Coordinator (OCA)	Project File
Accounting	Research Communications (2)	Other

GEORGIA INSTITUTE OF TECHNOLOGY OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION/CLOSEOUT SHEET

Date 5-26-87

Project No. G-35-641 School/~~Lab~~ Geo. Sci.

Includes Subproject No.(s) N/A

Project Director(s) R.E. Haberman GTRC / ~~GIT~~

Sponsor U.S. Department of the Interior

Title Recognition and Evaluation of Seismicity Anomalies in California

Effective Completion Date: 1/5/87 (Performance) 4/5/87 (Reports)

Grant/Contract Closeout Actions Remaining:

- [ ] None
- [ ] Final Invoice or Final Fiscal Report - Already received.
- [X] Closing Documents
- [X] Final Report of Inventions
- [X] Govt. Property Inventory & Related Certificate
- [ ] Classified Material Certificate
- [ ] Other

Continues Project No. G-35-604 Continued by Project No.

COPIES TO:

Project Director
Research Administrative Network
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~~Research Communications (2)~~
Project File
Other Duane H.
Angela DuBose
Russ Embry

FORM OCA 69.285

Quantitative Determination of the Detection History
of the California Seismicity Catalog

14-08-0001-G-~~992~~ 1087

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We have made progress on several aspects of this work during the last six months. First, we have initiated and made substantial progress on a careful evaluation of the significance levels which we ascribe to changes in seismicity rates. Second, we have nearly finished our comparison of Berkeley and CALNET magnitudes for six regions of Central California. Each of these tasks are described in more detail below.

Significance Levels

Our analysis of seismicity data involves searching for changes in seismicity rates using various statistical tests and windowing schemes. Matthews and Reasenberg recently proposed that the process of searching changes the significance level which is associated with a given statistic. We search for anomalies using the function AS(t) which was designed to answer two questions: 1) When is the most significant rate change between two points in time? and 2) How significant is that change? Matthews and Reasenberg agree that the function finds the times of the most significant change, but they disagree with the interpretation of the significance of those changes.

We have examined this question using several thousand sets of data with uniform, Poisson, and normal distributions. We calculated statistics for these data in the same way as we would for real data and examined the resulting distributions of the statistics. There are two distributions which we are interested in. First, the distribution of all AS(t) values and second, the distribution of maxima of each set of AS(t) values. In addition, there are two lengths that are important. The first is the set length, which is the number of samples in each series. The second is the minimum sample length.

The distribution of all AS(t) values was found to be normal in all cases, as expected. Table 1 shows the critical levels determined from the distribution of maxima for a series of set lengths ranging from 332 to 900 and for minimum sample lengths ranging from 10 to 100. Each critical level is calculated by examining the cumulative frequency distribution from 1000 sets with the listed lengths and minimum sample sizes. One can make several interesting observations from these data.

First, it is clear that for small minimum sample lengths (10) the critical value is erratic regardless of the set length. The values range from 3.97 to 4.40. For longer minimum sample lengths (100) the range of the critical levels is much smaller and is not dependent on the length of the set. These observations indicate that shorter anomalies are more likely to be random fluctuations and therefore are more difficult to recognize without false alarms, in accordance with our experience. These results indicate that a critical level of 3.5 is appropriate for minimum sample lengths longer than 50.

Table 1. 99% Critical Levels From Sets of 1000 Simulations

Minimum Sample Length	Set Length 332	400	500	600	700	800	900
10	4.27	4.40	4.40	4.00	3.97	4.23	3.98
25	3.60	3.80	3.90	3.56	3.58	3.80	3.67
50	3.75	3.67	3.70	3.65	3.54	3.58	3.60
60	3.47	3.35	3.45	3.50	3.52	3.56	3.56
75	3.40	3.55	3.52	3.48	3.50	3.50	3.50
100	3.43	3.45	3.40	3.50	3.46	3.50	3.50

These preliminary findings suggest that our significance estimates for anomalies shorter than 50 samples may have to be reassessed. Many of these anomalies, however, have z values that are above 3.5, so they remain significant at the 99%+ level. This suggests that while the significance estimates that we made were incorrect, the change in critical level will not strongly influence our conclusions.

Comparison of Berkeley and CALNET Magnitudes.

We have recently completed a comparison of magnitudes in the Berkeley and CALNET catalogs. This comparison is limited to larger events because the Berkeley catalog contains only events which are larger than $ML = 2.5$. We carried out this comparison in seven different regions. The results for six of these regions are shown in Figure 1 (the Northern California region could not be reasonably studied because of the low level of reported activity at these magnitude levels). The differences between USGS and Berkeley magnitudes are shown as a function of time. Changes in the mean difference are thought to reflect changes in the USGS magnitudes because the Berkeley magnitudes are calculated using a stable set of seismometers.

The most obvious observation that can be made from these data is that rather strong systematic changes in USGS magnitudes are apparent in all but the Parkfield region. A common feature appears to be a period of relatively high magnitudes starting during the early 1970's and lasting until 1976 (East Bay), 1977 (N. Calaveras and San Juan Bautista), or 1979 (Bear Valley and S. Calaveras). The decrease in magnitudes at the end of this period is probably associated with decreases in gains in the develocorders at Menlo Park during April, 1977.

We are presently in the process of comparing the information gained from an analysis of these data with that gained from the analysis of magnitude signatures, the technique we developed for examining detection histories and magnitude stability. The primary difference between the two techniques is in the magnitude bands examined, as mentioned above. The ability to include smaller events in the analysis, provided by the magnitude signature approach, gives one a much larger data set to work with and permits one to recognize apparent changes which affect only the smaller events. Good examples of such changes are those associated with the installation and adjustment of the RTP system. In addition, the magnitude difference approach provides less resolution in the time domain because of the scarcity of larger events. Finally, the statistical basis of the magnitude difference approach is weakened by the small number of events which one has to examine. The small number of events also restricts one to examination of relatively large regions using this approach.

ORAL PRESENTATIONS

Consistency of magnitudes in the CALNET catalog, EOS, 67, 1086.

A test of two techniques for identifying systematic errors in magnitudes using data from Parkfield, California, EOS, 67, 1087.

PAPERS PUBLISHED

Man-Made Changes in Seismicity Rates, BSSA, 77, 141, 1987.

A test of two techniques for identifying systematic errors in magnitudes using data from the Parkfield, California region, BSSA, 76, 1660, 1986.

PAPERS IN PRESS

Reply to Comment by Matthews and Reasenberg (to JGR, with M. Wyss)

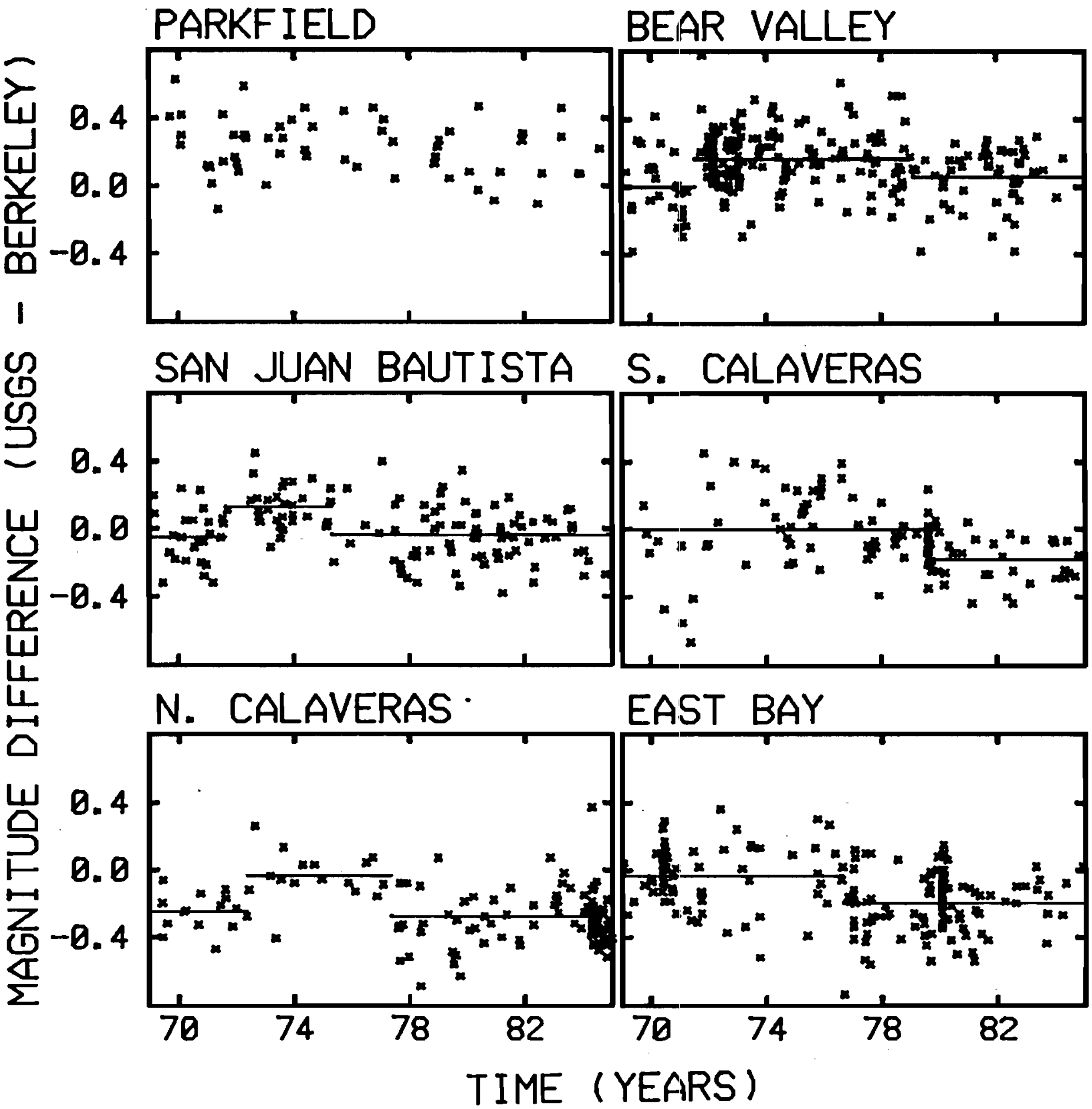

Figure 1. Magnitude differences as a function of time for six regions of California.

Quantitative Determination of the Detection History of the California Seismicity Catalog

14-08-0001-G-~~992~~ 1087

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We have made progress on several aspects of this work during the last six months. We finished our analysis of the detection history in the Bear Valley segment of the San Andreas fault. We are also nearing completion of the Bitterwater segment of the San Andreas. The completion of these segments will bring our coverage to all of the San Andreas from Parkfield to San Juan Bautista as well as all of the Calaveras fault. Work which is currently in progress includes: broadening the statistical framework of our analysis by combining a number of statistical tests proposed by other authors into our programs, examination of the effects of sample duration on the results, synthesis of regional variations, comparisons of Berkeley and CALNET magnitudes for all of Central California since 1969, and integration of station histories into the analysis. Each of these tasks are described in more detail below.

The Bear Valley Segment of the San Andreas Fault

The segment of the San Andreas between 36.1 and 36.9oN was studied. We found that the northern and southern parts of this segment showed different behaviors, so a division was made at 36.63oN. The principle goal of this study was to determine magnitude corrections for this region. The following corrections were determined for the period from November, 1974 to June of 1980:

South of 36.63

Dates		Mag Min	Mag Max	Corr
211174	130875	0.0	10.0	-.15
140875	240578	0.0	10.0	-.30
250578	220680	0.0	10.0	-.35
230680	140983	0.0	10.0	-.10
150983	290884	0.0	10.0	.10

North of 36.63

Dates		Mag Min	Mag Max	Corr
211174	90476	0.0	10.0	-.11
100476	80278	0.0	10.0	-.23
90278	250680	0.0	10.0	-.10

Addition of New Statistical Tests of Rate Differences

The statistical framework we have used to compare rates relies on a function termed AS(t) which is used to determine the times and significance of rate changes. Several U.S.G.S. scientists have recently proposed that this function overestimates the significance of anomalies by between 4 and 10%. We examined the data that formed the basis of this proposition using statistical tests of rate differences which have been proposed by other authors in the earthquake prediction literature. We found our results to be consistent with the results of all of these tests. We concluded that the criticism was based on incorrect data which was insufficiently tested by the authors of the criticism.

During our examination of these data we incorporated other statistical frameworks into our analysis programs. These include two tests which assume that the seismicity is Poisson (one used by Ohtake et al. and McNally in Mexico and Central America and one described by Veniziano), as well as the Kolmogorov-Smirnov test which is non-parametric. We plan to add the ratios test and the Anderson-Darling statistic described by Frohlich in the near future. Our goal is to provide a general rate analysis program which allows the user to select the statistical test used for rate comparisons, thus making comparison of results of different statistical tests very easy. This goal will be reached by the end of the year.

Effect of Sample Duration on Statistical Tests.

U.S.G.S. scientists also criticized the use of an arbitrary sample duration in our rate calculations. They implied that this selection somehow invalidated our results. This claim was made without any support from actual data analysis. We tested this assertion by calculating the seismicity rates during two time periods using sample bin sizes varying from 42 to 336 hours. We then compared the rates during these two periods using the z test for a difference between two means and examined the resulting z-values. We did this test using data from the Parkfield region. The results of comparisons of rates between December 28, 1983 and November 27, 1984 to those between November 28, 1984 and June 4, 1985 in 52 different magnitude bands are shown in Figure 1. Four sets of comparisons using bin sizes which differ by a factor of eight are shown.

This example comes from a recent study of systematic changes in magnitudes in the Parkfield region (Habermann, 1986). We use it here because of the strong variations in rate changes as a function of magnitude band which should provide a good test of the effects of bin size on the comparisons. Some bands show strong increases in rates (e.g. 1.0 and below), some show strong decreases (e.g. 1.1 and above), and some show little change (e.g. 0.5 and above).

From this test we see that differences in evaluating rate changes which are introduced by varying bin size are extremely small in all magnitude bands. It is clear that the differences between the various sample sizes are not important. We agree that the selection of a bin size is arbitrary, but this example clearly demonstrates that the selection is not crucial to the results. The only practical limitation on bin size would seem to be that it must be small compared to the duration of the changes one is interested in examining.

Regional Variations in Effects of Man-made Changes.

Several man-made changes exist in the CALNET data which everyone involved expects might have an effect on the data. These include the gain change during 1977, the boundary between preliminary and final data during 1978, the installation of the RTP system during late 1980, and modifications to the RTP system since that time. We have recently been able to compare the effects of these changes in different regions.

The RTP system began to be used for coda determinations during the end of 1980 and the beginning of 1981 depending on location. The primary effect of this was a large increase in the number of small events reported, a detection increase. This increase is clear in the Southern Calaveras Fault, Bear Valley, and Bitterwater regions. It is not as strong and occurs later in the Northern Calaveras region. In the Parkfield region the installation of the RTP is mixed with a magnitude decrease caused by the inclusion of Lindh's events in the CALNET catalog so the effect is not as clear.

The second strong change which is almost certainly related to the RTP system occurs during July, 1981. This change is a complicated combination of a decrease in the number of small events reported and a strong decrease in the magnitudes for those events. This change is clear in the same regions where the detection of small events is strongly affected by the installation of the RTP system. The cause of the change during July, 1981 is presently unknown, but it likely to be an adjustment to the RTP system in these areas.

The fact that our analysis has included so much of the seismically active region of central California allows us to make regional comparisons of known man-made changes. This will add greatly to the understanding of these changes and to the prevention of them in the future.

Comparison of Berkeley and CALNET Magnitudes.

Some controversy resulted from our finding that the gain change during April, 1977 had little effect on the magnitudes in the Calaveras region. This result was in apparent conflict with preliminary results described in a memo by Bakun. His results were achieved by examining temporal variations in the differences between CALNET and Berkeley magnitudes. We are reexamining these differences to determine the cause of the conflict. We are including all Berkeley events (4000+) from 1969 to 1984. This will extend Bakun's results considerably in time and space.

REPORTS (Available on request)

The Detection History of the Calaveras Fault: A preliminary Assessment

The Detection History of the Parkfield Segment of the San Andreas fault:

A Preliminary Assessment

The Detection History of the Bitterwater Segment of the San Andreas fault: A Preliminary Assessment

Man-made Seismicity Changes

Constructing Synthetic Magnitude Signatures

ORAL PRESENTATIONS

July 26-27 NEPEC Meeting, Menlo Park (Written summaries included in USGS Open-file Report #85-754):

The Detection History of the Calaveras Fault: A preliminary Assessment

The Detection History of the Parkfield Segment of the San Andreas fault: A Preliminary Assessment

AGU meetings:

Recognition and Evaluation of Seismicity Anomalies in California, EOS, 66, 308.

The Central California Seismicity Catalog: Detection and Reporting History, EOS, 66, 971.

Seismic Quiescence at Parkfield: Real or Man-Made?, EOS, 66, 983.

Comparison of Berkeley and CALNET magnitudes for the period 1969-1984 (Fall, 1986)

A test of two techniques for identifying systematic errors in magnitudes using data from the Parkfield, California region (Fall, 1986)

PAPERS SUBMITTED

Man-Made Changes in Seismicity Rates (In Press, BSSA)

A test of two techniques for identifying systematic errors in magnitudes using data from the Parkfield, California region (In Press, BSSA)

Reply to Comment by Matthews and Reasenberg (to JGR, with M. Wyss)

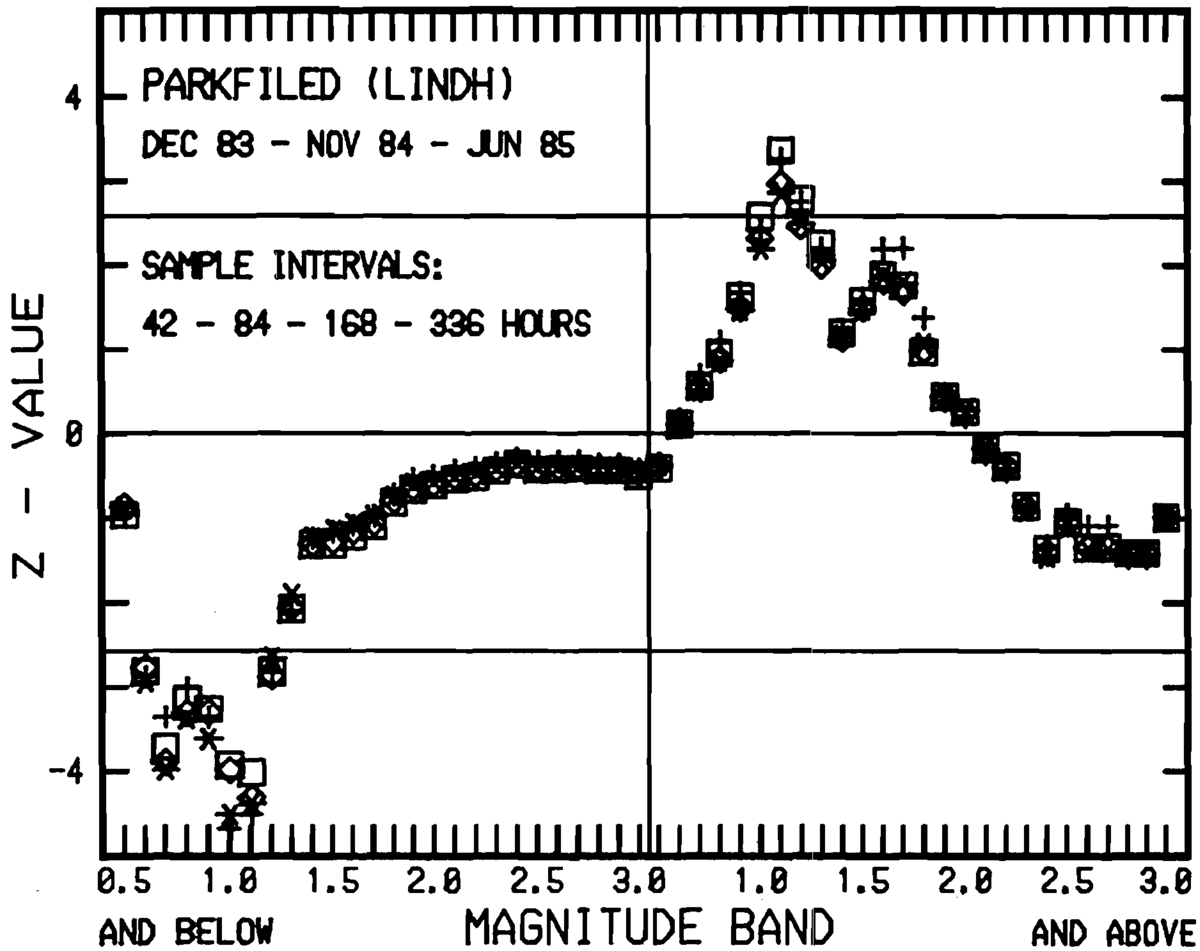

Figure 1. Z-values resulting from comparisons of the seismicity rates in the Parkfield, California region between December 28, 1983 and November 27, 1984 to those between November 28, 1984 and June 4, 1985 in 52 different magnitude bands. The bands on the left side of the plot are bounded by upper magnitude cutoffs and those on the right are bounded by lower cutoffs. Positive z-values indicate that the rate during the second period is lower than during the first, negative z-values indicate that is is higher. The two time periods were divided into samples with durations ranging from 42 to 336 hours (.25 to 2 weeks) and the rates during the two periods were compared. Using this range of sample durations the two time periods being compared contain between 12 and 192 samples each. The z-values which result from this series of comparisons are virtually independent of sample duration for sets with strong rate increases and decreases and for sets which show little change in rates (z-values near zero). The claim by Matthews and Reasenberg that the arbitrary choice of sample duration biases our results is without basis.

Final Report

Recognition and Evaluation of Seismicity Anomalies in California

14-08-0001-G1087

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Seismicity rate variations are presently one of the most promising tools for earthquake prediction. The original goals of this project were to systematically identify seismicity rate changes in the focal regions of larger events in central California and to evaluate the statistical significance and uniqueness of any anomalies which were observed. The major problems involved in achieving these goals are man-made heterogeneities in the seismicity catalog for centeral California (the CALNET catalog). These heterogeneities have two general forms: detection changes, and systematic changes in magnitudes. The level of funding we received for this project neccessitated restricting our studies to developing techniques for identifying these heterogeneities and correcting for them in studies of seismicity rates. We made substantial progress on these techniques.

Magnitude Signatures.

Detection changes and systematic magnitude changes both cause changes in observed seismicity rates. In addition, both of these types of changes have characteristic effects on events of different sizes. One can take advantage of these characteristics in order to identify thecause of an observed change in seismicity rates. We have developed a graphical technique which sheds considerable light on the possible cause of an observed change by displaying the strength of the change in different magnitude bands. If an observed change is due to a change in detection, it will affect the smaller events more strongly than the larger. If a change is due to a systematic change in magnitude, it will affect bands with a lower magnitude cutoff differently than those with a higher cutoff. These characteristics are described in detail in the paper "Man-made Changes in Seismicity Rates" which is attached.

Magnitude signatures provide a powerful tool for examining seismicity catalogs and for determination of neccessary magnitude cutoffs and average corrections for systematic changes in magnitudes. An opportunity to test these average corrections was provided by a study carried out by U.S.G.S. scientists working on seismicity in the Parkfield region. This study involved the determination of station magnitude corrections and the redetermination of magnitudes for many events from this region. This provided a completely independent estimate of systematic changes in the magnitudes of these events. The results of that study were in very good agreement with our results. The comparison is described in detail in the paper "A Test of Two Techniques for Identifying Systematic Errors in Magnitude Estimates Using Data from the Parkfield, California Region" which is attached.

Magnitude Comparisons.

Another method for testing magnitude involves comparison of suspect magnitudes to a temporally consistent standard. We have recently completed such a comparison of magnitudes in the Berkeley and CALNET catalogs. This comparison is limited to larger events because the Berkeley catalog contains only events which are larger than ML = 2.5. We carried out this comparison in seven different regions. The results for six of these regions are shown in Figure 1 (the Northern California region could not be reasonably studied because of the low level of reported activity at these magnitude levels). The differences between USGS and Berkeley magnitudes are shown as a function of time. Changes in the mean difference are thought to reflect changes in the USGS magnitudes because the Berkeley magnitudes are calculated using a stable set of seismometers.

The most obvious observation that can be made from these data is that rather strong systematic changes in USGS magnitudes are apparent in all but the Parkfield region. A common feature appears to be a period of relatively high magnitudes starting during the early 1970's and lasting until 1976 (East Bay), 1977 (N. Calaveras and San Juan Bautista), or 1979 (Bear Valley and S. Calaveras). The decrease in magnitudes at the end of this period is probably associated with decreases in gains in the develocorders at Menlo Park during April, 1977.

We are presently in the process of comparing the information gained from an analysis of these data with that gained from the analysis of magnitude signatures, the technique we developed for examining detection histories and magnitude stability. The primary difference between the two techniques is in the magnitude bands examined, as mentioned above. The ability to include smaller events in the analysis, provided by the magnitude signature approach, gives one a much larger data set to work with and permits one to recognize apparent changes which affect only the smaller events. Good examples of such changes are those associated with the installation and adjustment of the RTP system. In addition, the magnitude difference approach provides less resolution in the time domain because of the scarcity of larger events. Finally, the statistical basis of the magnitude difference approach is weakened by the small number of events which one has to examine. The small number of events also restricts one to examination of relatively large regions using this approach.

Statistical Approach.

Matthews and Reasenberg (from the U.S.G.S.) have recently questioned several aspects of our statistical approach to recognition of seismicity rate changes. They have submitted a comment on these techniques to the Journal of Geophysical Research. We have completed a preliminary study examining their findings which is in press at JGR. A preprint of our reply is attached.

Reports (Available on request):

The Detection History of the Calaveras Fault: A preliminary Assessment

The Detection History of the Parkfield Segment of the San Andreas fault: A Preliminary Assessment

The Detection History of the Bitterwater Segment of the San Andreas fault: A Preliminary Assessment

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Oral Presentations:

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U.S. Geological Survey Redbook Conference on Intermediate-Term Earthquake Prediction, November 1986, Monterey, Ca.:

Precursory Seismic Quiescence: Past, Present, and Future

The Prediction of the May 7, 1986 Andreanof Islands Earthquake

AGU meetings:

Recognition and Evaluation of Seismicity Anomalies in California, EOS, 66, 308.

The Central California Seismicity Catalog: Detection and Reporting History, EOS, 66, 971.

Seismic Quiescence at Parkfield: Real or Man-Made?, EOS, 66, 983.

Consistency of magnitudes in the CALNET catalog, EOS, 67, 1086.

A test of two techniques for identifying systematic errors in magnitudes using data from Parkfield, California, EOS, 67, 1087.

Papers Published:

Man-Made Changes in Seismicity Rates (BSSA, 77, 141-159, 1987).

A test of two techniques for identifying systematic errors in magnitudes using data from the Parkfield, California region (BSSA, 76, 1660 - 1667, 1986).

Reply to Comment by Matthews and Reasenberg (JGR in press, with M. Wyss)

Papers Submitted:

Precursory Seismic Quiescence: Past, Present, and Future, submitted to U.S.G.S. Redbook and special issue of PAGEOPH on intermediate-term earthquake prediction.

Precursory Seismic Quiescence, submitted to U.S.G.S. Redbook on intermediate-term earthquake prediction, (with M. Wyss).

Precursory Quiescence before the May, 1982 Stone Canyon, San Andreas fault earthquake, submitted to U.S.G.S. Redbook and special issue of PAGEOPH on intermediate-term earthquake prediction.

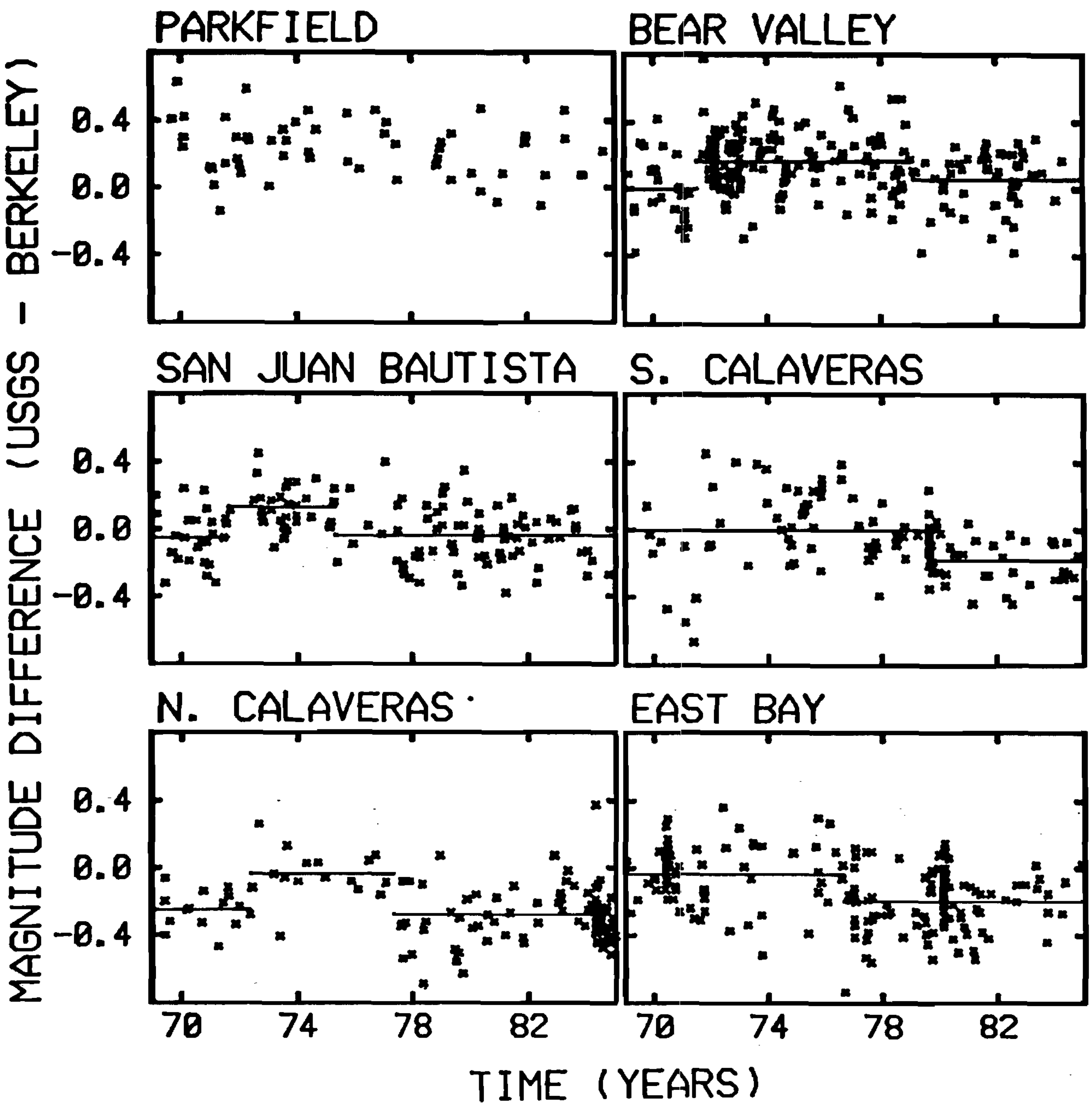

Figure 1. Magnitude differences as a function of time for six regions of California.