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Seismicity near the Red Bank, Thomes-Newville, and Colusa Projects recorded by the Northern California Seismic Network

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Introduction

This report briefly discusses the seismicity recorded by the USGS Northern California Seismic Network (NCSN) in the general vicinity of the California Department of Water Resources Red Bank, Thomes-Newville, and Colusa projects. Because of the relatively short monitoring interval (20-25 years) compared to the seismic cycle (100-1000's of years) of many faults in this region, it is very unlikely that most seismogenic structures in the region have been illuminated by the recorded earthquake activity during the interval 1975-1998. The low rate of seismicity in the eastern Coast Ranges, relatively high earthquake detection thresholds (discussed below), and the limited accuracy of the locations makes it difficult to define discrete faults based on alignments of hypocenters. Rather, it appears that most earthquake activity occurs on isolated and independent faults. Assessments of the seismic hazard should not be limited to interpretations of the seismic data and should also consider the strain rates and geologically active faults mapped in the region (Working Group on Northern California Earthquake Potential, 1996).

Because so little seismicity occurs within 25 km radius of the Red Bank or Thomes-Newville projects, the discussion of seismicity is, by necessity, general in nature. The regional seismicity may be considered representative of the type of seismicity that may be expected in the future, subject to the above caveat. Likewise, the minimum magnitude for uniform earthquake detection is based on the analysis of less than 100 earthquakes per region. Comparable analyses of larger regions surrounding the three sites, using hundreds of events, lead to similar minimum detection thresholds within a few tenths of a magnitude unit. All dates discussed in this report are UT.

NCSN operating procedures, station locations, and velocity models are described in Oppenheimer *et. al.* (1993). All hypocenters, focal mechanisms, phase information, waveforms, and station coordinates are available via the World Wide Web from *http://quake.geo.berkeley.edu/ncedc*. Maps of real-time earthquake information are available on *http://quake.wr.usgs.gov/recenteqs.*

Red Bank

Station Distribution and Detection Threshold

In the vicinity of the DWR Red Banks project there were few stations operating until June, 1975. Installation of seismic stations occurred gradually, and the network reached its current configuration by February, 1991, when 4 stations were installed for the California Department of Water Resources (solid squares, Figure 1). Since then, only one additional station west of Cottonwood has been installed in the region. Figure 2a indicates that for the interval 1978 - 1997 earthquakes above *M*2.2 within 25 km of Red Bank could be uniformly detected.

Seismicity

The histogram of earthquakes as a function of time within 25 km of Red Bank (Figure 3a) shows that the number of earthquakes located per month is typically 3 or less and often zero. The map and cross sectional views of seismicity (Figure 1, 4a) image three general features. There are few lineations expressed in this seismicity. In the eastern Coast Ranges scattered earthquake activity occurs within the crust to depths of 15 km. Northeast of Red Bluff at the eastern edge of the Great Valley, earthquake activity occurs at greater depths, approaching 30 km, reflecting the increased thickness of the crust due to the isostatic compensation effect of the Sierra Nevada range.

The earthquakes at depths greater than 30 km west of Red Bank image the subducting Gorda slab. Because of the small numbers of earthquakes during the period of observation and uncertainties in their locations, it is not possible to ascertain whether the earthquakes occur in the slab or on the slab interface. A *M*3.0 earthquake north of Cottonwood (April 3, 1985) that locates at a depth of 70 km also suggests that the slab extends beneath Red Bluff (Cockerham, 1984, Walter, 1986). Though it is unlikely that a mega-thrust earthquake on the Gorda - North America interface would rupture to such depths due to the thermal regime of the plate (Hyndman and Wang, 1995), the seismicity indicates that intraplate Gorda earthquakes are possible.

Thomes-Newville

Station Distribution and Detection Threshold

In the Thomes-Newville region the station coverage is poor. A station at Alder Springs (GAS) was installed in 6/1980, and a station to the north at Round Mt. (GRO) was installed 12/1990. There are no stations to the east within 70 km. The nearest stations is generally greater than 15 km from an epicenter. This degrades the accuracy of the hypocentral data in this region. In particular, the depths are relatively poorly determined compared to other regions of the network. Figure 2b indicates that for the interval 1976 - 1997 earthquakes above *M*2.1 within 25 km of Newville could be uniformly detected. With the installation of additional stations to the north of Newville in 1990-1991, the regional detection threshold decreased slightly to *M*1.9.

Seismicity

The histogram of earthquakes as a function of time (Figure 3b) shows that typically only one earthquake per month occurs within 25 km of Newville, but frequently there is no detected earthquake activity. There is scattered seismicity with 25 km of Newville, but no obvious structures defined by the seismicity. Beginning May 16, 1995 a small sequence occurred 18 km west of Newville. The aftershock activity ceased 3 days later. The largest event, which occurred on May 17, had a magnitude of M_D 4.2. The seismicity shown cross section B-B' (Figure 4b) indicates that the earthquakes occur within the crust, as described above in section A-A'.

Colusa/Williams

Station Distribution and Detection Threshold

In the Williams area station coverage is also poor. While station coverage has been uniform since late 1975, the nearest station (on Sutter Butte) is generally greater than 20 km from an epicenter. This degrades the accuracy of the hypocentral data in this region. Figure 2c indicates that for the interval 1976 - 1997 earthquakes above *M*2.3 within 25 km of Colusa could be uniformly detected.

Seismicity

The histogram of earthquakes as a function of time (Figure 3c) shows that earthquake occurrence within 25 km of Newville is rare. However, two separate, north-northwest trending faults are imaged by the alignments of hypocenters near Williams. Two first-motion focal mechanisms for events on Apr 18, 1985 (M_L3.7) and on Nov 26, 1980 (M_D3.2) indicate predominant right-lateral strike-slip motion on a fault plane parallel to the orientation of seismicity (Fig. 5). In cross section C-C' (Fig. 4c) the faults are near-vertical, consistent with the focal mechanisms, and they extend to depths of about 20 km. The April 18, 1985 sequence occurred 11 km southwest of Williams. Minor aftershock activity continued until late September, 1985 (Fig. 3c). The largest event of the sequence, the M_L 3.7 event, occurred on the first day.

References

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Hyndman, R.D., and K. Wang, The rupture zone of Cascadia great earthquakes from current deformation and the thermal regime, *J. Geophys. Res., 100*, 22,133-22,154, 1995.

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Walter. S.R., Intermediate-focus earthquakes associated with Gorda plate subduction in northern California, *Bull. Seism. Soc. Am., 76,* 583-588, 1986.

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Figure Captions

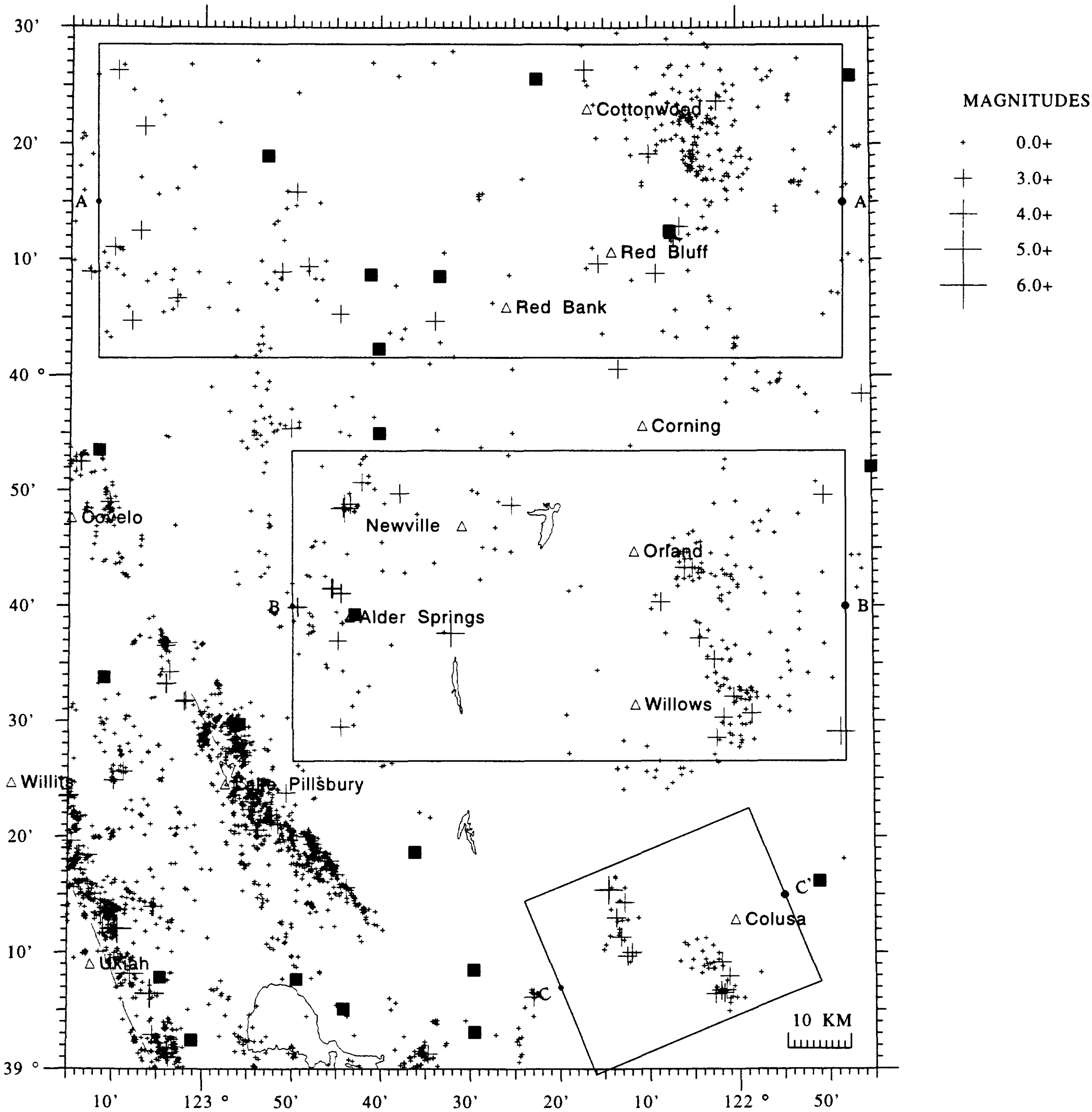
Figure 1. a) Map of well-located seismicity recorded by the Northern California Seismic Network for the period July 24, 1973 through February 7, 1998. Data have been selected with the following typical quality parameters: RMS ≤ 0.3 sec, horizontal uncertainty ≤ 2.5 km, vertical uncertainty ≤ 5.0 km, maximum azimuth gap in station distribution ≤ 180°, # of stations ≥ 8. No magnitude selection were used. Due to sparse station spacing, the above selection criteria eliminated nearly half of possible 6063 earthquakes from the plot. Solid squares depict locations of seismic stations. Open triangles denote locations of labeled cities and towns. Rectangular, labeled boxes depict selection region for cross-sections. Irregular shaped bodies depict lakes and reservoirs. Faults near Ukiah and Lake Pillsbury are Holocene or younger (Jennings, 1992). Symbol size is proportional to magnitude.

Figure 2. Histograms of the *log(N),* where N = number of earthquakes, as a function of magnitude for three areas shown in Fig. 1. The (solid) open squares are the (cumulative) number of earthquakes within 0.1 bins of magnitude. The magnitude detection threshold above which the seismic network is able to uniformly locate all earthquakes is indicated at the top of the plot as "MIN.MAG" and is manually chosen by examination as the point where the slope of the cumulative number of earthquakes departs from a straight line at smaller magnitudes. The line through the cumulative number of earthquakes is a least-squares estimate of the slope ("B" value) of the data greater than the detection threshold; "A" is the M=0 intercept value (*log(N)*). a) Red Bank region (Fig. 1, A-A'), b) Newville region (Fig. 1, B - B'), c) Colusa region (Fig. 1, C - C').

Figure 3. Histograms of earthquakes/month within 25 km of a) Red Bank (40° 06.00', 122° 26.00'), b) Newville (39° 47.00', 122° 31.00'), c) Colusa (39° 12.90', 122° 00.50'). No other selection criteria were used.

Figure 4. Cross sections of seismicity corresponding to earthquakes shown in Fig. 1. a) Red Bank region, b) Newville region, c) Colusa region.

Figure 5. Lower hemisphere, equal-area projection of fault plane solutions for earthquakes near Williams on a) 02:33 UTC, Nov 26, 1980 (M_D3.2) and b) 16:29 UTC Apr 18, 1985 (M_L3.7). Compressional and dilatational first-motion directions are indicated by circles and +'s, respectively. P and T symbols denote P-axis and T-axis, respectively. Three numbers adjacent to nodal planes correspond to strike, dip, and rake.



MAGNITUDES
0.0+
3.0+
4.0+
5.0+
6.0+
Cottonwood
Red Bluff
Red Bank
Corning
Covelo
Newville
Orland
Alder Springs
Willows
Willits
Lake Pillsbury
Colusa
Ukiah
A
A'
B
B'
C
C'
10 KM
30'
20'
10'
40 °
50'
40'
30'
20'
10'
39 °
10'
123 °
50'
40'
30'
20'
10'
122 °
50'

Figure 1

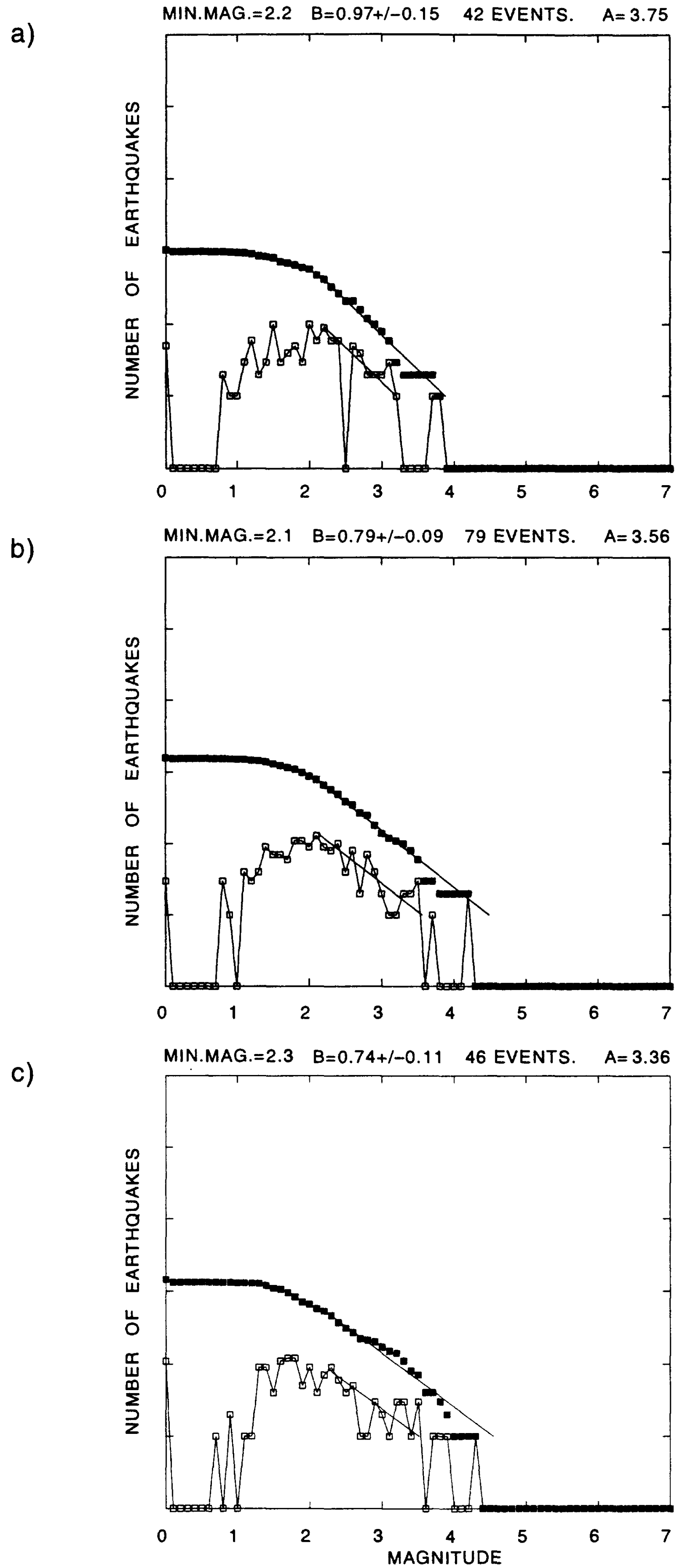
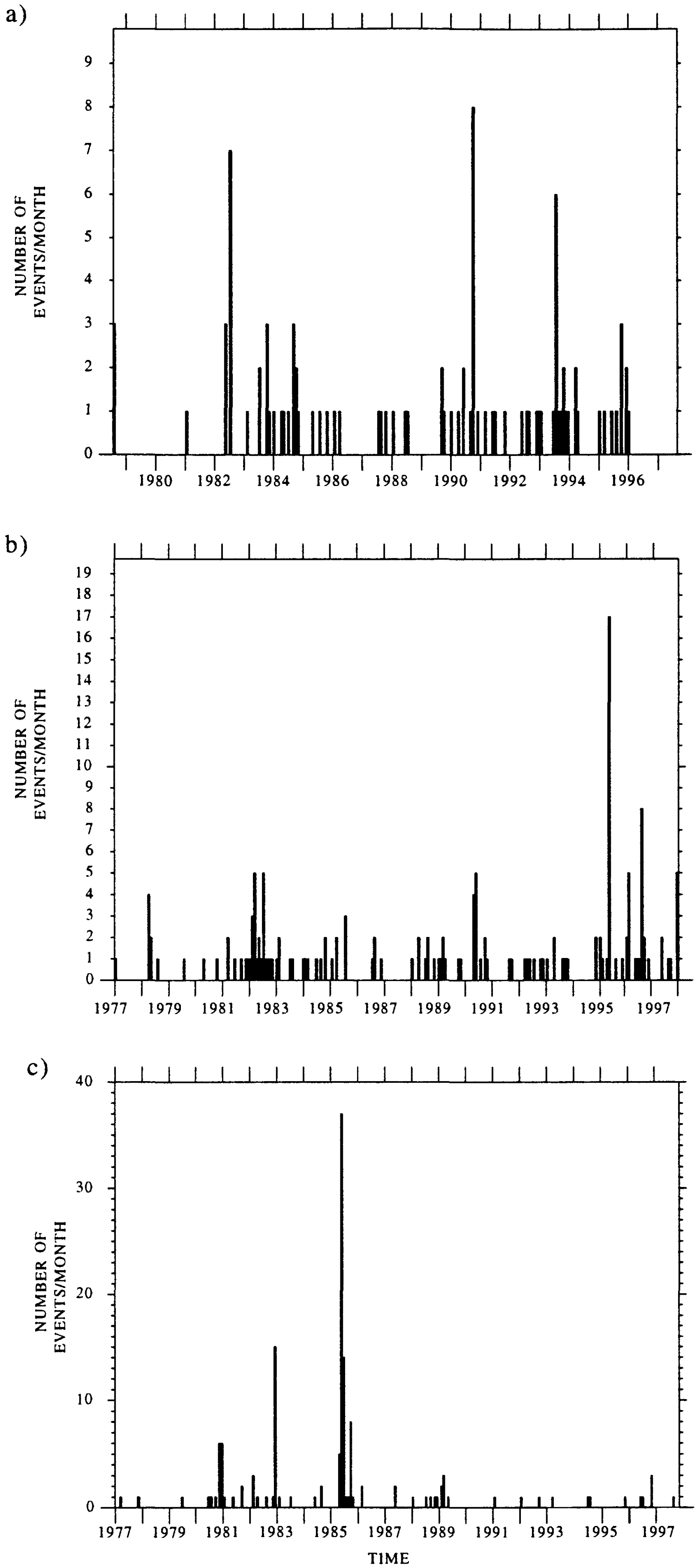
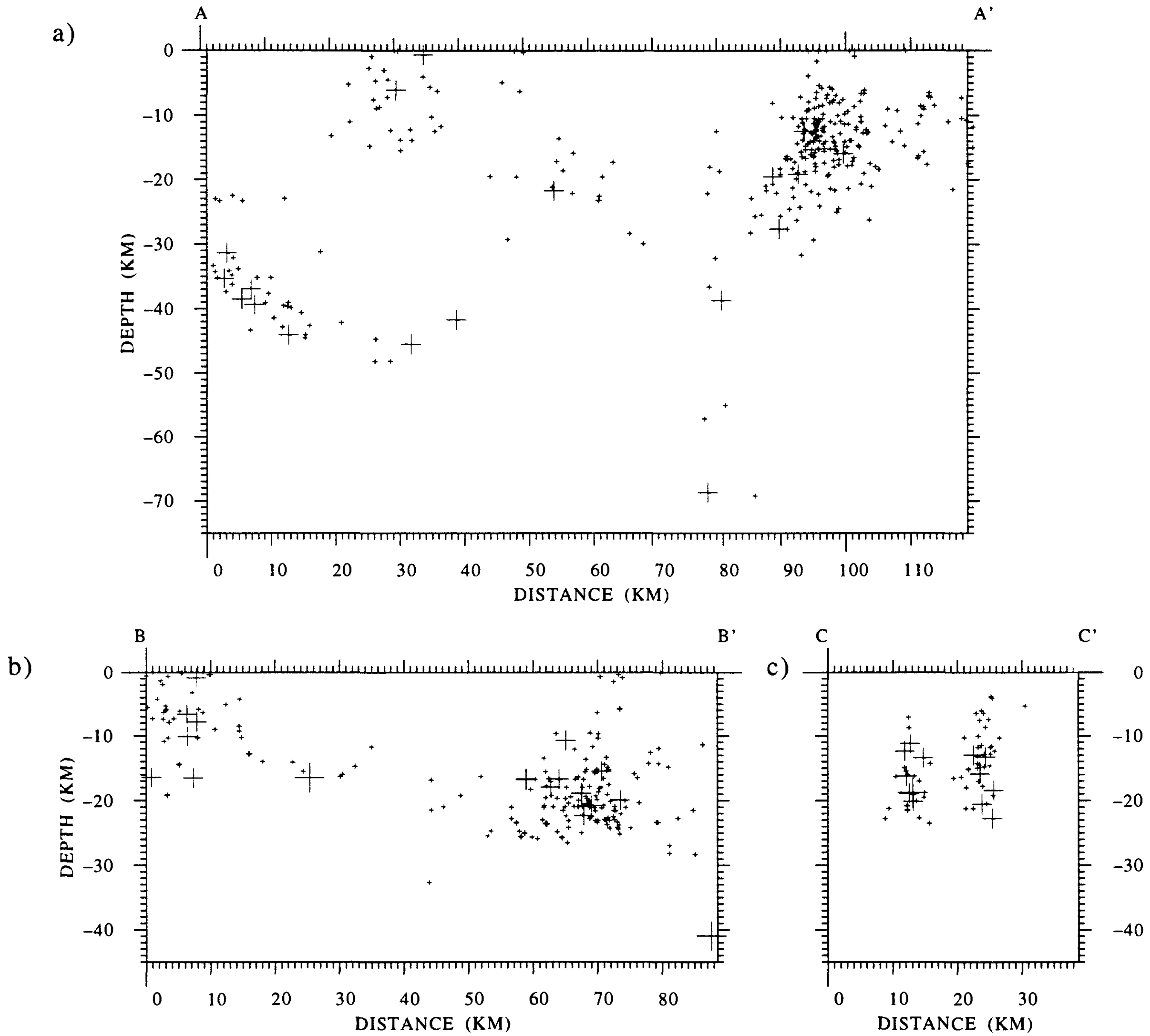

a)
MIN.MAG.=2.2 B=0.97+/-0.15 42 EVENTS. A= 3.75
NUMBER OF EARTHQUAKES
0 1 2 3 4 5 6 7
b)
MIN.MAG.=2.1 B=0.79+/-0.09 79 EVENTS. A= 3.56
NUMBER OF EARTHQUAKES
0 1 2 3 4 5 6 7
c)
MIN.MAG.=2.3 B=0.74+/-0.11 46 EVENTS. A= 3.36
NUMBER OF EARTHQUAKES
0 1 2 3 4 5 6 7
MAGNITUDE

Figure 2



a)
NUMBER OF EVENTS/MONTH
0 1 2 3 4 5 6 7 8 9
1980 1982 1984 1986 1988 1990 1992 1994 1996
b)
NUMBER OF EVENTS/MONTH
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997
c)
NUMBER OF EVENTS/MONTH
0 10 20 30 40
1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997
TIME

Figure 3



a)
A
A'
DEPTH (KM)
0
-10
-20
-30
-40
-50
-60
-70
0 10 20 30 40 50 60 70 80 90 100 110
DISTANCE (KM)
b)
B
B'
DEPTH (KM)
0
-10
-20
-30
-40
0 10 20 30 40 50 60 70 80
DISTANCE (KM)
c)
C
C'
0
-10
-20
-30
-40
0 10 20 30
DISTANCE (KM)

Figure 4

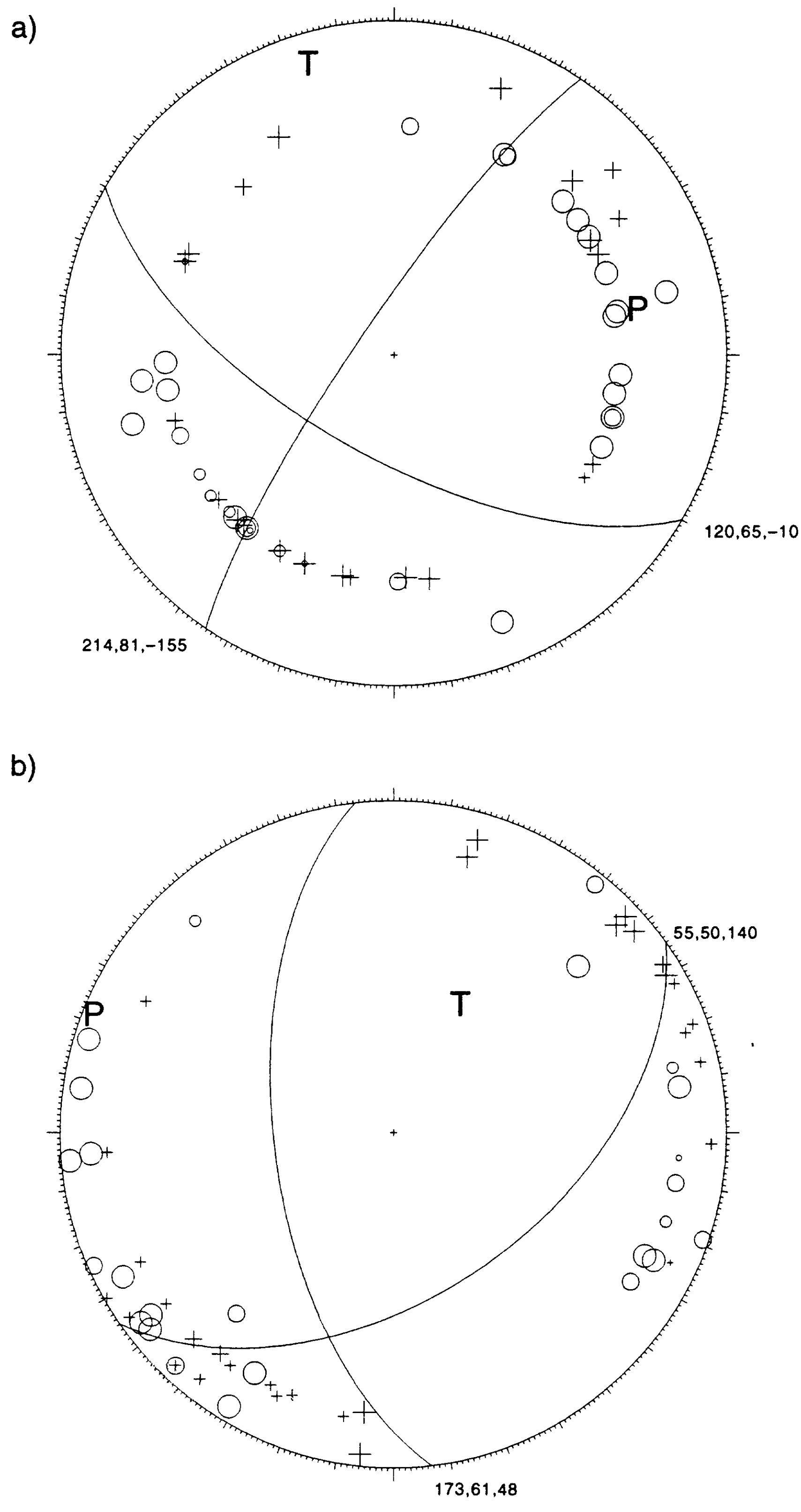


Figure 5