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Preparation of Earthquake Catalogs for the National Seismic-Hazard Maps: Contiguous 48 States

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Introduction

Reliable earthquake catalogs are essential for probablistic seismic hazard analysis. Part of the hazard in the new national seismic hazard maps (Frankel *et al,* 1996) comes from smoothed historical seismicity, so it was important for us to find or make a suitable catalog for the contiguous 48 states. Initially, we had access to the following catalogs.

Preliminary Determination of Epicenters (PDE)

We downloaded a PDE catalog for the map area from the National Earthquake Information Center (NEIC) computer in Golden, Colorado, using NEIC's catalog-search software: 23° ≤ latitude ≤ 52°, –127° ≤ longitude ≤ –65°, magnitude ≥ 3.0, time ≥ 1960. It includes offshore earthquakes and earthquakes in southern Canada and northern Mexico. In our version of the PDE catalog each record contains zero to four magnitude entries: m_b and/or M_S determined by NEIC and/or up to two magnitude values (of any type) contributed by other agencies. For contributed magnitudes the magnitude type and contributing agency are listed. This catalog contains approximately 18,000 records from 1960 to June 1995.

Decade of North American Geology (DNAG)

We downloaded a DNAG catalog (Engdahl and Rinehart, 1991) for the map area from the NEIC computer in Golden using NEIC's catalog-search software: 23° ≤ latitude ≤ 52°, –127° ≤ longitude ≤ –65°, magnitude ≥ 3.0. It includes offshore earthquakes and earthquakes in southern Canada and northern Mexico. In our version of the DNAG catalog each record contains one magnitude entry (apparently the largest of all reported magnitude values) of any type. The magnitude type and contributing agency are listed. This catalog contains approximately 24,300 records from 1534 to December 1985.

California Division of Mines and Geology (CDMG)

The CDMG catalog (M. Petersen, personal communication, 1995) covers California (including offshore) and adjacent parts of Nevada, Arizona, and Mexico. In our version each record contains a single M_L-like magnitude (or moment magnitude for some large earthquakes where M_L might have saturated) with magnitude ≥ 4.0. This catalog contains approximately 5,200 records from 1800 to August 1994.

New Mexico Earthquakes 1962-1994 (NEWMEX)

Sanford et al (1995) studied seismicity in New Mexico since 1962, and published a catalog that includes improved hypocentral parameters and magnitudes for earthquakes with duration magnitude ≥ 3.0. They argued that duration gives more reliable magnitudes than amplitudes measured from analog traces converted to equivalent Wood-Anderson traces (the method used for their earlier contribution to the DNAG catalog). This catalog contains 111 records from 1962 to 1994.

National Center for Earthquake Engineering Research (NCEER)

The NCEER catalog (Seeber and Armbruster, 1991) covers the central and eastern United States and southeastern Canada, roughly east of –105° longitude. In our version each record contains a single m_b-like magnitude (or M_n or m_{blg}); there is apparently no lower magnitude cutoff. This catalog contains approximately 3,500 records from 1626 to February 1985.

Seismicity of the United States (USHIS)

We downloaded the entire USHIS catalog (Stover and Coffman, 1993) from the NEIC computer in Golden using NEIC's catalog-search software. It lists United States earthquakes with Modified Mercalli Intensity ≥ 6 or magnitude ≥ 4.5 (magnitude ≥ 5.5 in offshore areas of California, Oregon, and Washington). Earthquakes in Mexico, Canada, or offshore regions are included if they caused damage in the United States. The USHIS catalog is primarily a compilation of published seismicity studies and other catalogs. In our version each record contains zero to four magnitude entries: m_b and/or M_s determined by NEIC and/or up to two magnitude values (of any type) contributed by other agencies. For contributed magnitudes the magnitude type and contributing agency are listed. There are approximately 450 contributed moment magnitudes. The contiguous-48-states part of this catalog contains approximately 2,700 records from 1568 to December 1989.

Stover, Reagor, Algermissen (SRA)

We downloaded the entire SRA catalog (Stover *et al,* 1984) from the NEIC computer in Golden using NEIC's catalog-search software. Like USHIS, SRA lists United States earthquakes, and is primarily a compilation of published seismicity studies and other catalogs. SRA is much larger than USHIS because it lists smaller events, but it is less consistent in completeness and coverage, especially west of –117° longitude. In many cases SRA includes valuable data from local networks. For example, data from the University of Utah network contributes prominently to the Utah part of the SRA catalog. In our version each record contains zero to four magnitude entries: m_b and/or M_s determined by NEIC and/or up to two magnitude values (of any type) contributed by other agencies. For contributed magnitudes the magnitude type and contributing agency are listed. There are approximately 180 contributed moment magnitudes. This catalog contains approximately 17,000 records from 1568 to December 1986.

No single catalog was sufficient for our task. Although PDE and DNAG might claim to be complete, we often favored CDMG, NCEER, NEWMEX, SRA, or USHIS because of the detailed research that went into them. We decided to build a new catalog by combining the original ones, and using our opinions about catalog reliability to eliminate duplicate records when an earthquake was listed in more than one catalog. Since attenuation relations, completeness, and magnitude-conversion rules all vary regionally, we decided to build two catalogs: a moment-magnitude (M_W) catalog for the western United States (WUS) and a body-wave-magnitude (m_b) catalog for the central and eastern United States (CEUS). The WUS/CEUS catalog boundary (Figure 1) is the same as the WUS/CEUS attenuation boundary (Frankel *et al,* 1996).

We used a four-step algorithm to build new catalogs. First, we reformatted the original catalogs, writing each record in a common format that included its catalog provenance. For catalogs with multiple magnitude entries (PDE, DNAG, USHIS, and SRA) a single magnitude value was computed at this step (see below). Second, we concatenated the reformatted catalogs, and sorted the full catalog into chronological order. Third, based on our preferences, we chose a single survivor record when an earthquake was listed in more than one catalog (the provenance information was used here). Earthquakes were considered duplicates when their origin times were within one minute; times seemed more reliable than locations for this purpose. Fourth, we removed aftershocks and foreshocks using the sliding-time-and-distance-window algorithm of Gardner and Knoppoff (1974). An earthquake was declared a "foreshock" when a larger event was encountered in its aftershock window. (For very old earthquakes the origin times reported in different catalogs can differ by more than one minute. In these cases one event is declared an aftershock or a foreshock of another, a somewhat roundabout way to avoid duplication.)

Western United States Catalog

The catalog preference order in WUS was: CDMG (highest preference) > USHIS > SRA > PDE > DNAG. We wanted to combine these lists in such a way that the final WUS catalog would be dominated by CDMG in California, and USHIS, SRA, and PDE elsewhere. The final WUS catalog needed to be complete down to magnitude 4.

During the reformatting step each reported magnitude was converted to an equivalent moment magnitude (called M_W*), and for catalogs with multiple magnitude entries a weighted sum of these was used to compute a single moment magnitude value as follows.

m_b: $M_W^*=0.67*(m_b+2.0)$ for $m_b<3.0$; $=m_b$ otherwise (3.0,4.0,6.8,7.0)
downweight for $m_b<4.0$ (s/n) and $m_b>6.8$ (saturation); downweight for year<1964

M_s: $M_W^*=0.67*(M_s+2.7)$ for $M_s<5.5$; $=M_s$ otherwise (4.0,5.0,8.3,8.5)
downweight for $M_s<5.0$ (s/n) and $M_s>8.3$ (saturation)

M_L: $M_W^*=0.67*(M_L+2.0)$ for $M_L<4.0$; $=M_L$ otherwise (–,–,6.8,7.0)
downweight for $M_L>6.8$ (saturation)

M_n: $M_W^*=0.67*(M_n+2.0)$ for $M_n<3.0$; $=M_n$ otherwise (–,–,6.8,7.0)
downweight for $M_n>6.8$ (saturation)

M_W: $M_W^* = M_W$

M_D: same as M_L, but don't downweight

FeltArea or MaxIntensity: same as m_b, but don't downweight

These conversion rules were generalized from ideas presented by Boore and Joyner (1982), Chung and Bernreuter (1981), and G. Reagor (personal communication, 1995).

The weighting function has a flat top (full weight) and one or two exponential skirts. It has the advantage that the weight is always nonzero, so a single reported value is automatically preserved. The general shape is specified by four values: a lower factor-of-10-down value, a lower full-weight value, an upper full-weight value, and an upper factor-of-10-down value. For example, the weighting function for the M_s-to-M_W* magnitude relationship is specified by magnitude values (4.0,5.0,8.3,8.5). The corresponding weight is 10**((m–5.0)/(5.0–4.0)) for $m < 5.0$, 1 for $5.0 \le m \le 8.3$, and 10**((8.3–m)/(8.5–8.3)) for $m > 8.3$.

Because aftershock and foreshock decisions are based on magnitude, and DNAG records contain the largest of all reported magnitude values, early versions of our algorithm tended to preserve too many DNAG records (at the expense of records from higher-preference catalogs). To fix this, we decided to remove any DNAG record found in the aftershock window of an earthquake from a higher-preference catalog, regardless of magnitude. Also, because our version of the CDMG catalog was cut off below magnitude 4, early versions of our algorithm preserved too many records from lower-preference catalogs in California. (For example, if the CDMG magnitude was 3.8, the earthquake wasn't listed in our version of the CDMG catalog, and we didn't want it in our final WUS catalog. If the corresponding PDE magnitude was 4.1, however, this earthquake would appear as a PDE event. This was especially a problem with the

DNAG catalog.) To fix this, we used only the high-preference CDMG catalog in most of California. Finally, we removed man-made seismic events in the following areas: several coal-mining districts in central Utah since 1900 (Wong *et al,* 1989; W. Arabasz and J. Pechmann, personal communication, 1996) and the Nuclear Test Site in southern Nevada.

The final WUS catalog contained 2896 earthquakes with magnitude ≥ 4.0; the algorithm eliminated approximately 830 "foreshocks" and 4400 aftershocks (Appendix 1). Figure 2 shows the entire WUS catalog (file wmm.cc). FIgure 3 compares the contributions from each original catalog during 1964-1985, a period when all the catalogs were active.

We counted earthquakes on a 0.1°-by-0.1° grid, and normalized by the counting window duration to get a seismicity rate in each grid cell in WUS. In a zone encompassing most of California we counted earthquakes with 4 ≤ magnitude < 5 since 1933, 5 ≤ magnitude < 6 since 1900, and magnitude ≥ 6 since 1850. Considering the poorer catalog completeness in the rest of WUS, we used 1963, 1930, and 1850 for these magnitude ranges, respectively. This scheme is shown in Figure 4. The resulting catalog used for computing the hazard is plotted in Figure 5.

Central and Eastern United States Catalog

We included the Rocky Mountain and Colorado Plateau regions in CEUS, because we assumed that CEUS attenuation rules would be more appropriate there than WUS rules. The catalog preference order in CEUS was: NEWMEX (highest preference) > NCEER > USHIS > SRA > PDE > DNAG. We wanted to combine these lists in such a way that the final CEUS catalog would be dominated by NCEER east of –105° longitude before 1985, and SRA and PDE east of –105° after 1984. SRA and PDE would dominate west of –105°. (Due to late settlement of the western areas, such a western-extended CEUS catalog would not be uniformly complete, something we would need to keep in mind when adjusting seismicity rates for completeness — see below.) The final CEUS catalog needed to be complete down to magnitude 3.

During the reformatting step each magnitude value was converted to an equivalent body-wave magnitude (called m_b*), and for catalogs with multiple magnitude entries a weighted sum of these was used to compute a single body-wave magnitude value as follows.

m_b: $m_b^* = m_b$ (3.0,4.0,6.8,7.0)

downweight for $m_b<4.0$ (s/n) and $m_b>6.8$ (saturation); downweight for year<1975

M_S: $m_b^*=1.0*M_S+1.1$ for $M_S \leq 2.9$; $=0.6*M_S+2.3$ for $2.9<M_S \leq 7.5$; $=6.8$ for $M_S>7.5$ (4.0,5.0,8.3,8.5)

downweight for $M_S<5.0$ (s/n) and $M_S>8.3$ (saturation)

M_L: $m_b^*=M_L$ (–,–,6.8,7.0)

downweight for $M_L>6.8$ (saturation)

M_n: $m_b^*=M_n$ (–,–,6.8,7.0)

doubleweight all M_n (arbitrary decision); downweight for $M_n>6.8$ (saturation)

M_W: $m_b^*=1.5*M_W-2.0$ for $M_W \leq 4.0$; $=M_W$ for $4.0<M_W \leq 6.8$; $=6.8$ for $M_W>6.8$

M_D: same as M_L, but don't downweight

FeltArea or MaxIntensity: same as m_b, but don't downweight

These conversion rules were generalized from ideas presented by Boore and Joyner (1982), Chung and Bernreuter (1981), Veneziano and Van Dyke (1985), and G. Reagor (personal communication, 1995).

The weighting function is described above under the WUS magnitude conversion rules. For the same reasons as WUS, we decided to remove any DNAG record found in the aftershock window of an earthquake from a higher-preference catalog, regardless of magnitude. We moved the 05/26/1909 magnitude-5.0 Illinois earthquake north from the NCEER location to a location that is more consistent with felt reports (Stover and Coffman, 1993). We moved the 02/21/1916 magnitude-5.2 Skyland earthquake west from the NCEER location (M. Chapman, personal communication, 1996). Finally, we removed man-made seismic events in the following areas: Rocky Mountain Arsenal near Denver since 1962 (Hsieh and Bredehoeft, 1981); Rangely oil field in western Colorado since 1957 (Raleigh *et al,* 1976); several coal-mining districts in central Utah since 1900 (Wong *et al,* 1989; W. Arabasz and J. Pechmann, personal communication, 1996); and Cogdell oil field in west Texas since 1974 (Davis and Pennington, 1989).

The final CEUS catalog contained 2750 earthquakes with magnitude ≥ 3.0; the algorithm eliminated approximately 170 “foreshocks” and 600 aftershocks (Appendix 2). Figure 6 shows the entire CEUS catalog (file emb.cc). FIgure 7 compares the contributions from each original catalog during 1964-1985, a period when all the catalogs were active.

We counted earthquakes on a 0.1°-by-0.1° grid, and normalized by the counting window duration to get a seismicity rate in each grid cell in CEUS. East of –105° longitude we counted earthquakes with magnitude ≥ 3 since 1924, magnitude ≥ 4 since 1860, and magnitude ≥ 5 since 1700. Considering the poorer catalog completeness in CEUS west of –105°, we used 1976, 1963, and 1860 for these magnitude ranges, respectively. This scheme is shown in Figure 8.

The resulting catalog used for computing the hazard is plotted in Figure 9. We recognized that, in an effort to represent as many sources as possible in CEUS, we had used rather liberal counting time windows east of –105°. To adjust for any resulting incompleteness, we computed average "complete" rates for more recent times (since 1976 for magnitude ≥ 3, 1924 for magnitude ≥ 4, 1860 for magnitude ≥ 5) and "counted" rates (using 1924, 1860, and 1700) in three zones east of –105°, and multiplied the rate in each grid cell by the appropriate "complete" rate / "counted" rate ratio. This scheme is shown in Figure 10. For the New Madrid and Eastern Tennessee seismic zones (NMZ and ETZ in Figure 10) we determined zone-average rates by counting earthquakes with magnitude ≥ 3 since 1976, and then forced these values into each cell in the zone.

Disclaimer

The catalog files can be downloaded from our WWW site at http://gldage.cr.usgs.gov/eq. We understand why others might be interested in obtaining these files, but are concerned they might be misused. We have merged catalogs from several different sources, and used fairly subjective criteria to rank our preferences. We have used simple, automated schemes to compute magnitudes and remove aftershocks. The potential user should read and understand the above documentation, and then ask whether these catalogs suit his or her purpose.

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Appendix 1. Make catalog wmm.cc.

```
$ run CAT2W                                                input file includes
                                                            multiple records, so...
delete DNA eqs in higher-preference catalogs ...
delete PDE eqs in higher-preference catalogs ...
delete SRA eqs in higher-preference catalogs ...
delete USH eqs in higher-preference catalogs ...

catalog1/catalog2 = 53894/8227                             before/after removing m<4,
                                                            multiple records, etc.

1932 12210610 7.2 -> wt= 933.0 wd= 74.4 na=  105    report eqs with
1933 03110154 6.3 -> wt= 678.0 wd= 58.6 na=  126     30 or more aftershocks
1934 12301352 6.5 -> wt= 790.0 wd= 61.0 na=   33    wt= G&K time window (day)
1940 05190436 6.7 -> wt= 840.0 wd= 64.6 na=   33    wd= G&K dist window (km)
1941 09141643 5.8 -> wt= 422.0 wd= 51.8 na=   32    na= no. of aftershocks
1941 09141839 6.0 -> wt= 510.0 wd= 55.0 na=   32
1942 10211622 6.5 -> wt= 790.0 wd= 61.0 na=   48
1946 03151349 6.3 -> wt= 678.0 wd= 58.6 na=   33
1952 07211152 7.7 -> wt= 970.0 wd= 86.2 na=  222
1954 07061113 6.8 -> wt= 865.0 wd= 66.4 na=  197
1954 10172257 5.7 -> wt= 378.0 wd= 50.2 na=   43
1954 10240944 6.0 -> wt= 510.0 wd= 55.0 na=  145
1954 11121226 6.3 -> wt= 678.0 wd= 58.6 na=  170
1954 12161107 7.2 -> wt= 933.0 wd= 74.4 na=  103
1956 02091432 6.8 -> wt= 865.0 wd= 66.4 na=  140
1958 12010321 5.8 -> wt= 422.0 wd= 51.8 na=   56
1966 08161802 5.5 -> wt= 294.4 wd= 47.2 na=   34
1966 12201530 6.3 -> wt= 678.0 wd= 58.6 na=   44
1969 03200816 5.2 -> wt= 209.0 wd= 42.8 na=   52
1969 03200817 5.7 -> wt= 378.0 wd= 50.2 na=   73
1969 03210456 5.8 -> wt= 422.0 wd= 51.8 na=   63
1971 02091400 6.4 -> wt= 734.0 wd= 59.8 na=   55
1975 05141400 5.9 -> wt= 466.0 wd= 53.4 na=   43
1975 06031420 5.9 -> wt= 488.0 wd= 54.2 na=   41
1975 06191300 6.0 -> wt= 510.0 wd= 55.0 na=   45
1975 10281430 6.0 -> wt= 515.6 wd= 55.1 na=   42
1979 10152316 6.4 -> wt= 734.0 wd= 59.8 na=   32
```

```
1980 03202347 4.1 -> wt=  50.2 wd= 31.0 na=   46
1980 03242156 4.2 -> wt=  58.4 wd= 32.0 na=   75
1980 03270226 4.3 -> wt=  66.6 wd= 33.0 na=   63
1980 03272200 4.6 -> wt=  90.2 wd= 35.5 na=   97
1980 03311134 4.6 -> wt=  97.4 wd= 36.0 na=   95
1980 04010424 4.8 -> wt= 132.0 wd= 38.4 na=  120
1980 04011230 4.8 -> wt= 133.4 wd= 38.5 na=  119
1980 04141349 4.9 -> wt= 147.8 wd= 39.5 na=   78
1980 04252320 5.0 -> wt= 155.0 wd= 40.0 na=   49
1980 05170001 4.5 -> wt=  83.0 wd= 35.0 na=   32
1980 05251633 6.1 -> wt= 566.0 wd= 56.2 na=  149
1980 05271450 6.2 -> wt= 622.0 wd= 57.4 na=   82
1982 10252226 5.4 -> wt= 263.0 wd= 45.6 na=   38
1983 05022342 6.7 -> wt= 840.0 wd= 64.6 na=   65
1983 10281406 6.8 -> wt= 870.0 wd= 66.8 na=   30
1984 11231808 6.2 -> wt= 622.0 wd= 57.4 na=   83
1986 07211442 6.4 -> wt= 734.0 wd= 59.8 na=   64
1989 08080813 5.4 -> wt= 263.0 wd= 45.6 na=   58
1989 10180004 7.0 -> wt= 915.0 wd= 70.0 na=   66
1992 04230225 4.6 -> wt=  97.4 wd= 36.0 na=   44
1992 04230450 6.1 -> wt= 566.0 wd= 56.2 na=  113
1992 04251806 6.5 -> wt= 790.0 wd= 61.0 na=   31
1992 06281157 7.3 -> wt= 942.0 wd= 76.6 na=  147
1994 01171230 6.7 -> wt= 840.0 wd= 64.6 na=   51

delete Utah coal-mining events ...                   check special cases
delete NTS events ...

#  mainshocks=         2896
       (CDMG)=         1778
      (USHIS)=          206
        (SRA)=          209
        (PDE)=          470
       (DNAG)=          233
#  foreshocks=          828
# aftershocks=         4365
```

Appendix 2. Make catalog emb.cc.

```
$ run CAT2E                                                  input file includes
                                                              multiple records, so...
delete DNA eqs in higher-preference catalogs ...
delete PDE eqs in higher-preference catalogs ...
delete SRA eqs in higher-preference catalogs ...
delete USH eqs in higher-preference catalogs ...
delete NCE eqs in higher-preference catalogs ...

catalog1/catalog2 = 13173/5512                               before/after removing m<3,
                                                              multiple records, etc.

1886 09010251 6.8 -> wt= 865.0 wd= 66.4 na=   27         report eqs with
1959 08180637 6.8 -> wt= 865.0 wd= 66.4 na=   23          15 or more aftershocks
1966 01230156 4.8 -> wt= 126.2 wd= 38.0 na=   19         wt= G&K time window (day)
1966 07080830 3.6 -> wt=  26.0 wd= 26.8 na=   18         wd= G&K dist window (km)
1966 07090830 3.7 -> wt=  30.0 wd= 27.6 na=   30         na= no. of aftershocks
1966 07100830 3.9 -> wt=  38.0 wd= 29.2 na=   31
1973 03280239 4.3 -> wt=  66.6 wd= 33.0 na=   19
1973 03300032 4.6 -> wt=  97.4 wd= 36.0 na=   16
1974 06090050 4.9 -> wt= 140.6 wd= 39.0 na=   18
1974 07011823 5.1 -> wt= 182.0 wd= 41.4 na=   20
1975 03270448 4.3 -> wt=  66.6 wd= 33.0 na=   41
1975 03280231 6.0 -> wt= 526.8 wd= 55.4 na=   49
1975 06301847 4.7 -> wt= 111.8 wd= 37.0 na=   23
1975 06301854 5.9 -> wt= 488.0 wd= 54.2 na=   42
1976 12081440 5.1 -> wt= 168.5 wd= 40.7 na=   50
1982 01091253 5.7 -> wt= 378.0 wd= 50.2 na=   61
1982 09300227 3.5 -> wt=  22.0 wd= 26.0 na=   15
1982 10081006 3.8 -> wt=  34.0 wd= 28.4 na=   17
1982 10140410 4.7 -> wt= 104.6 wd= 36.5 na=   18
1985 10162001 3.5 -> wt=  22.0 wd= 26.0 na=   29
1985 10162336 3.6 -> wt=  26.0 wd= 26.8 na=   42
1985 10171157 3.8 -> wt=  34.0 wd= 28.4 na=   51
1985 10191534 4.1 -> wt=  50.2 wd= 31.0 na=   68
1985 11091138 4.4 -> wt=  78.9 wd= 34.5 na=   75
1994 01301906 3.2 -> wt=  15.7 wd= 23.9 na=   26
1994 02010958 3.5 -> wt=  21.0 wd= 25.6 na=   48
```

```
1994 02021104 3.8 -> wt=  32.0 wd= 28.0 na=   77
1994 02030714 4.5 -> wt=  80.5 wd= 34.7 na=  125
1994 02030905 5.7 -> wt= 356.0 wd= 49.4 na=  152

delete Rky Mtn Arsenal events ...                  check special cases
delete Rangely events ...
delete Cogdell events ...
delete Utah coal-mining events ...

#  mainshocks=         2750
     (NEWMEX)=           23
      (NCEER)=         2096
      (USHIS)=           40
        (SRA)=          262
        (PDE)=          270
       (DNAG)=           55
#  foreshocks=          169
# aftershocks=          602
```

WUS/CEUS Catalog Boundary

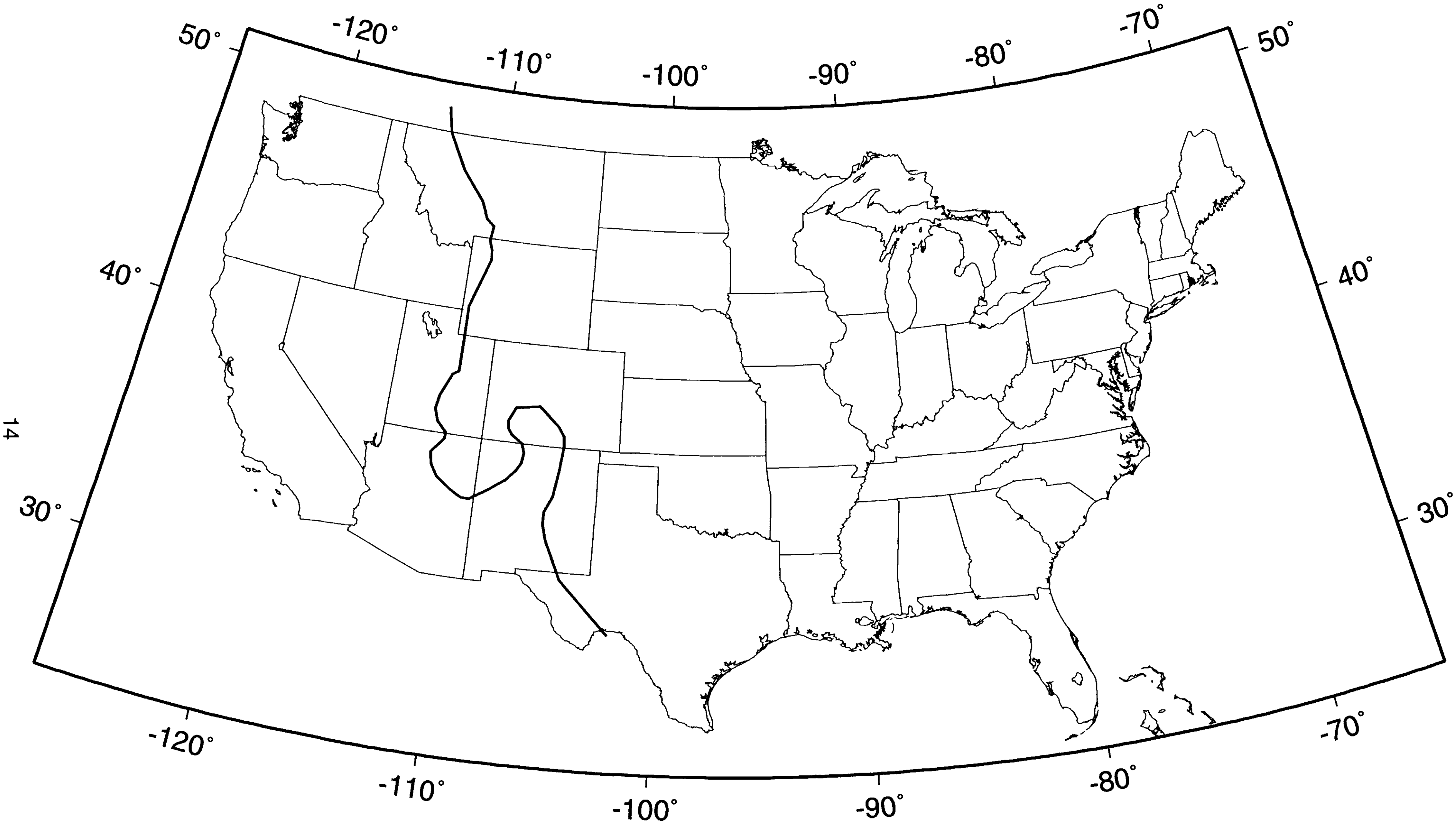

Figure 1. The heavy line shows the boundary between the WUS and CEUS catalog zones.

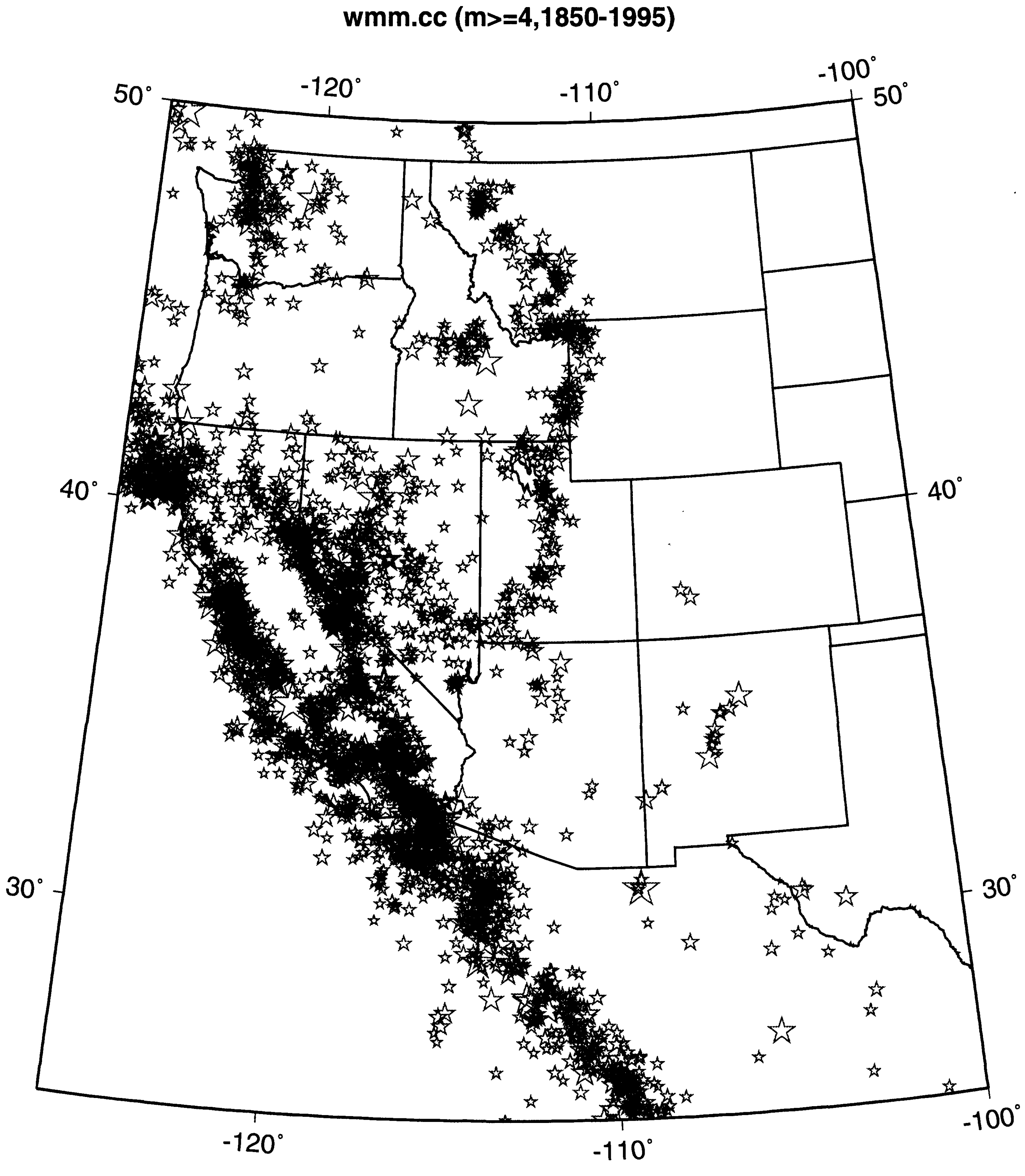

Figure 2. The entire WUS catalog (file wmm.cc).

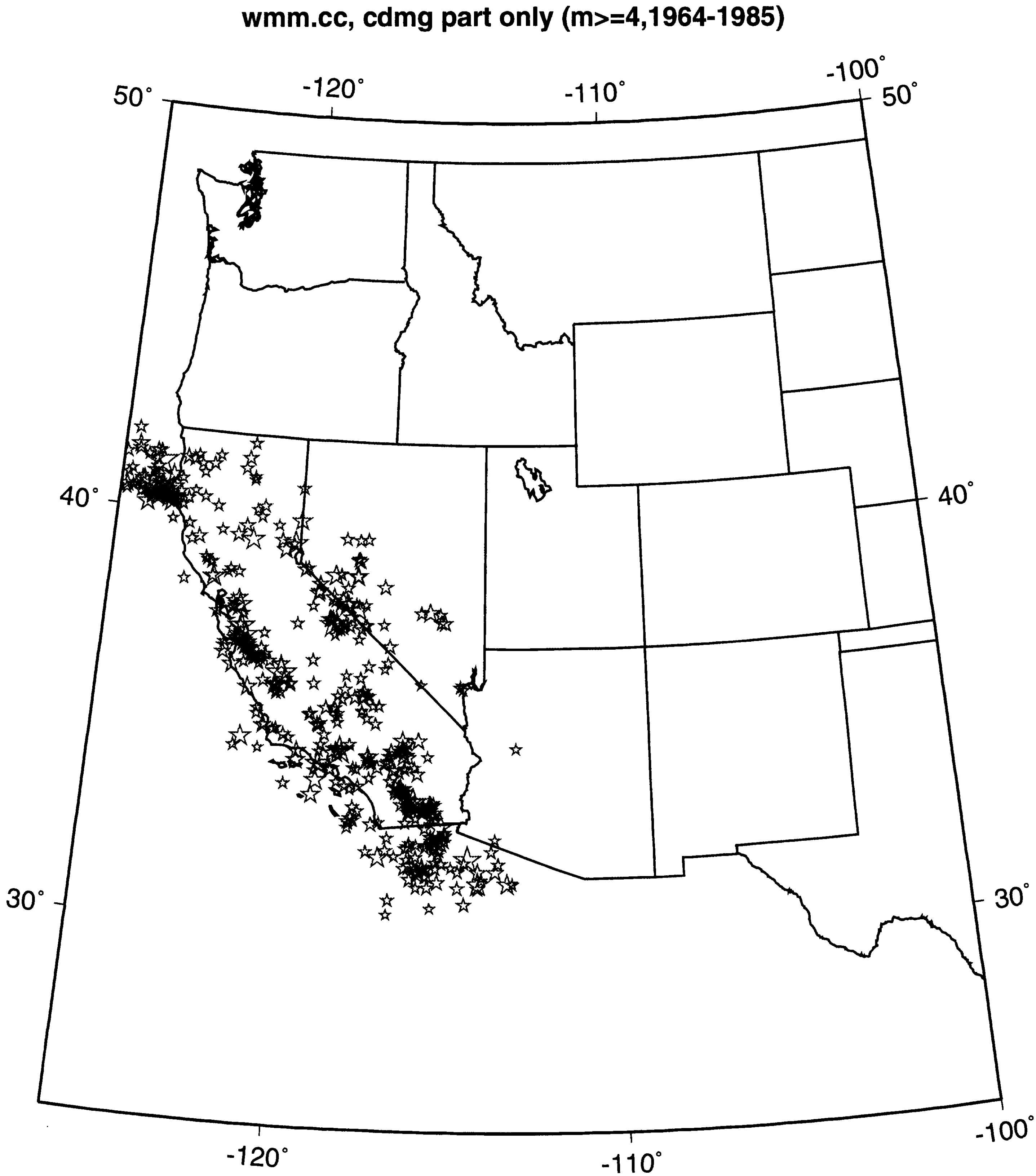

Figure 3a. The CDMG contribution to the WUS catalog during 1964-1985.

wmm.cc, ushis part only (m>=4,1964-1985)

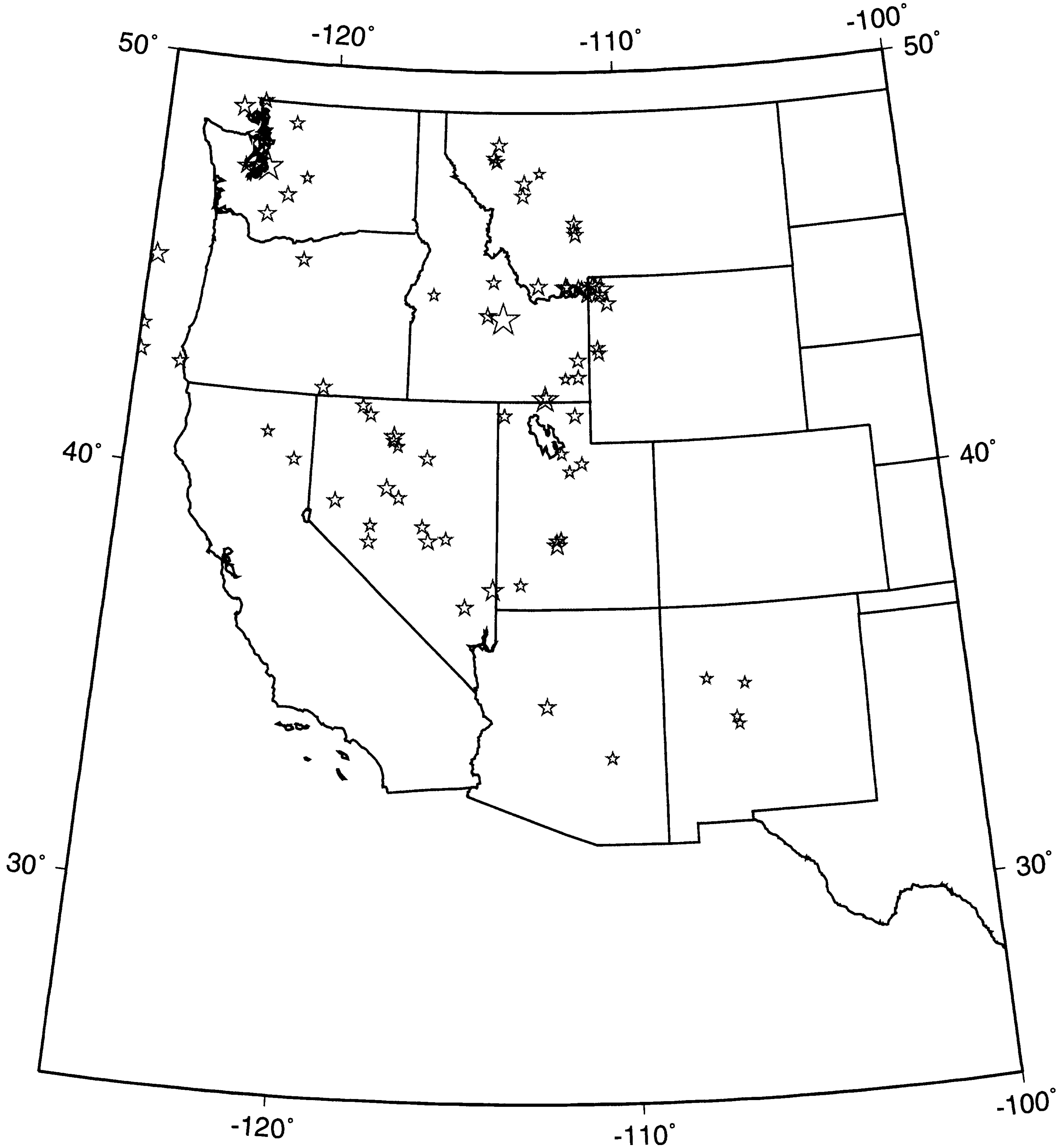

Figure 3b. The USHIS contribution to the WUS catalog during 1964-1985.

wmm.cc, sra part only (m>=4,1964-1985)

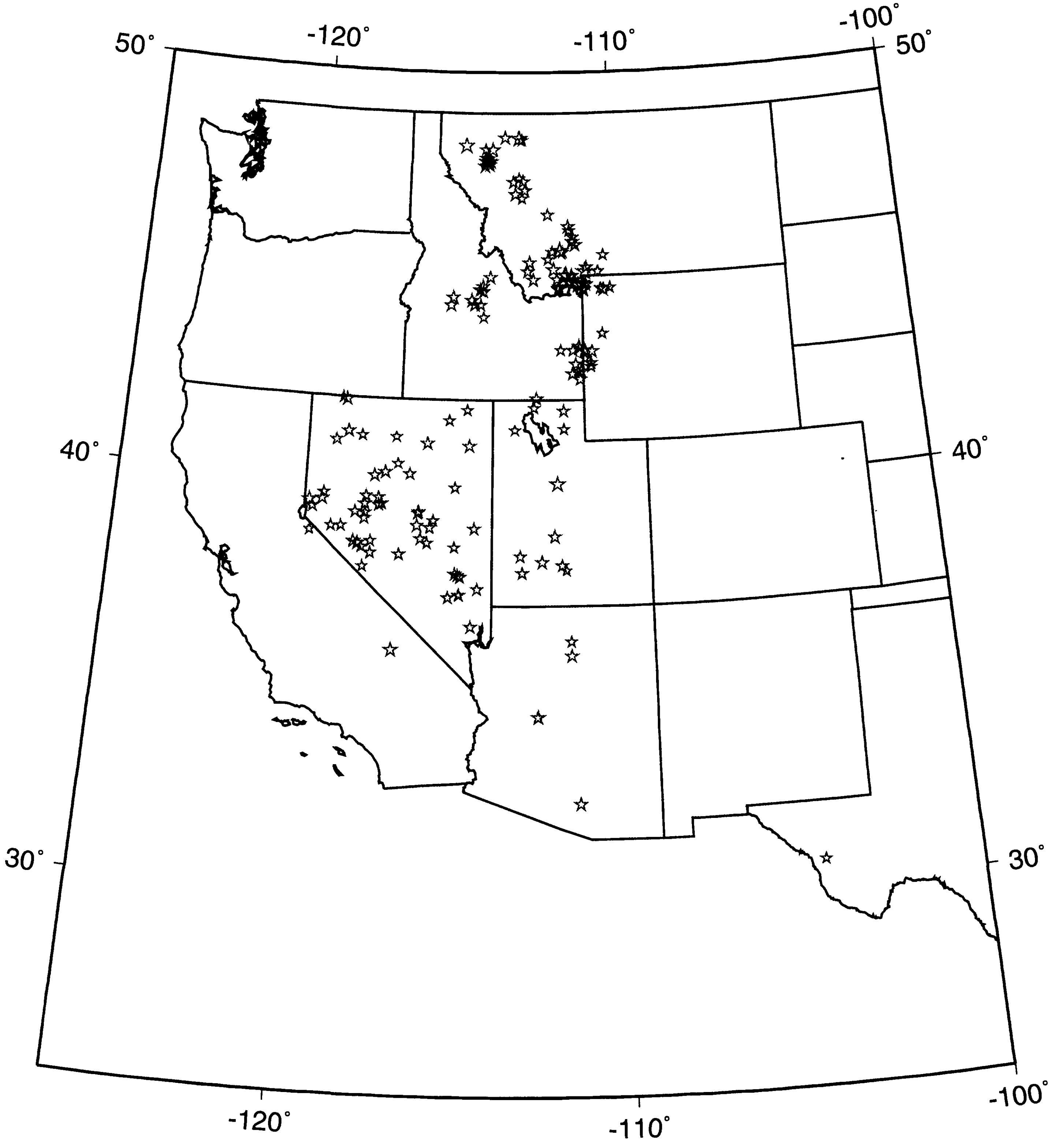

Figure 3c. The SRA contribution to the WUS catalog during 1964-1985.

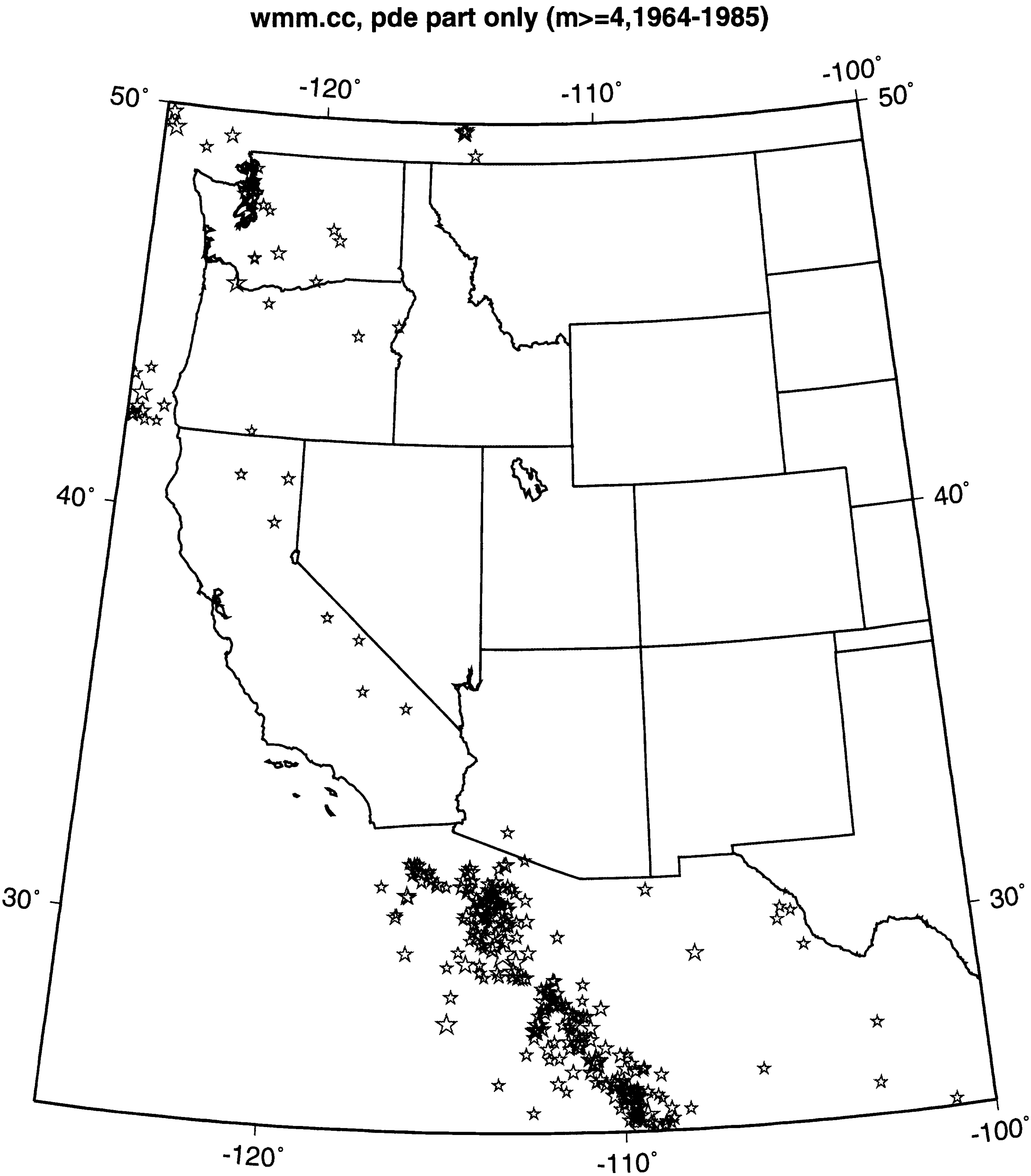

Figure 3d. The PDE contribution to the WUS catalog during 1964-1985.

wmm.cc, dnag part only (m>=4,1964-1985)

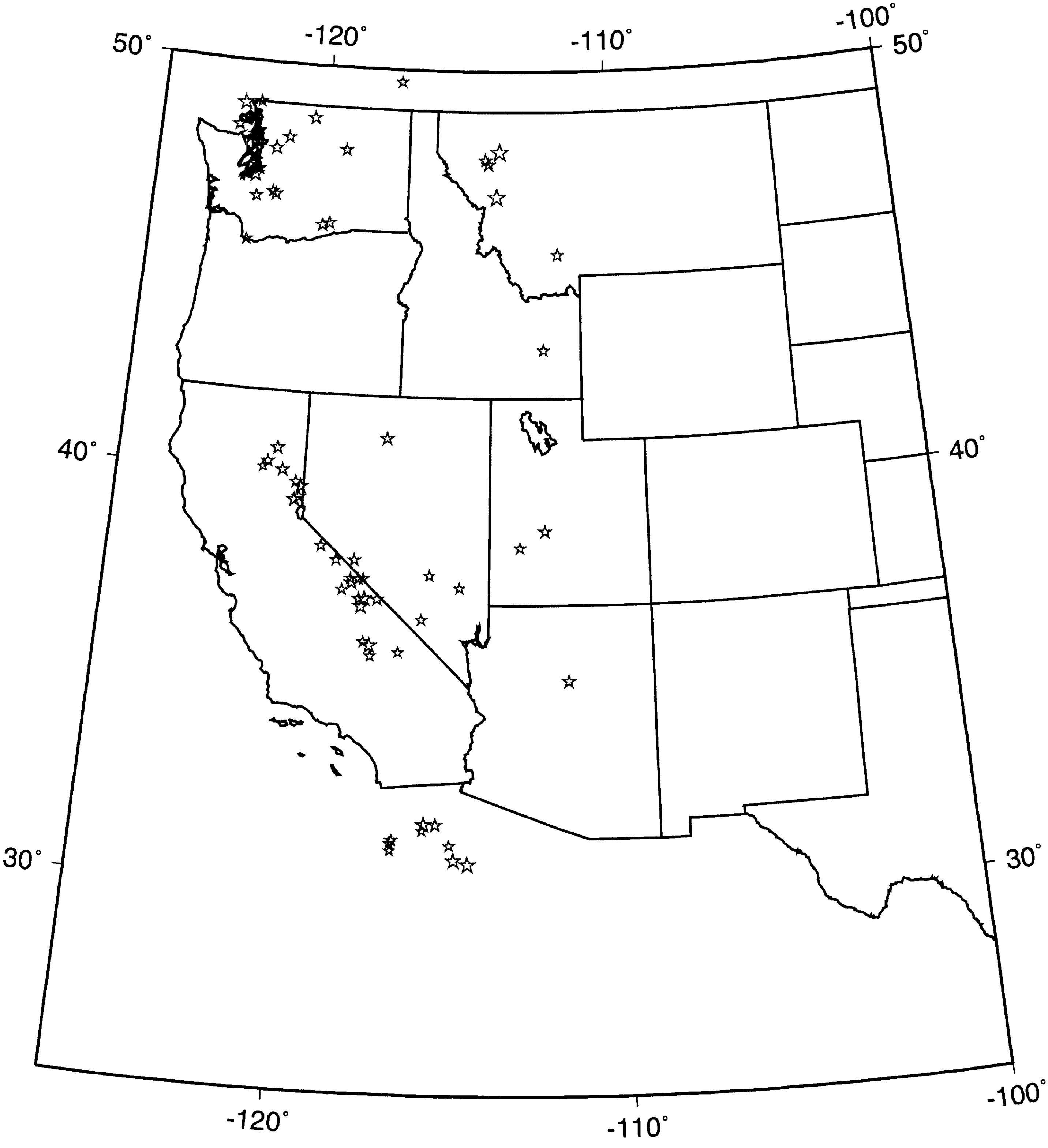

Figure 3e. The DNAG contribution to the WUS catalog during 1964-1985.

Counting Earthquakes in WUS

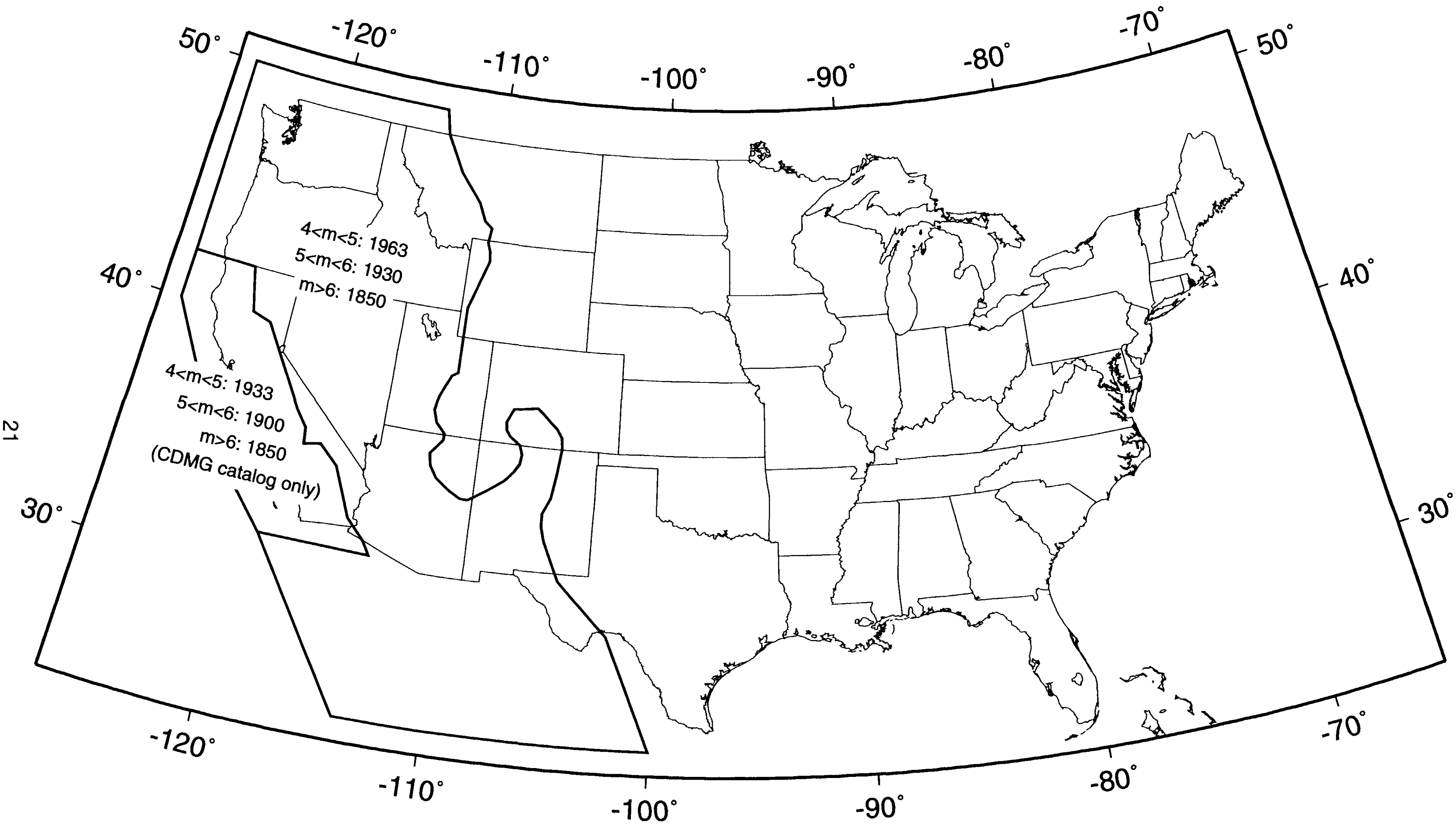

Figure 4. Assumed completeness times for counting earthquakes and computing seismicity rates in WUS.

wmm.cc, 4<=mag<5 used to compute hazard

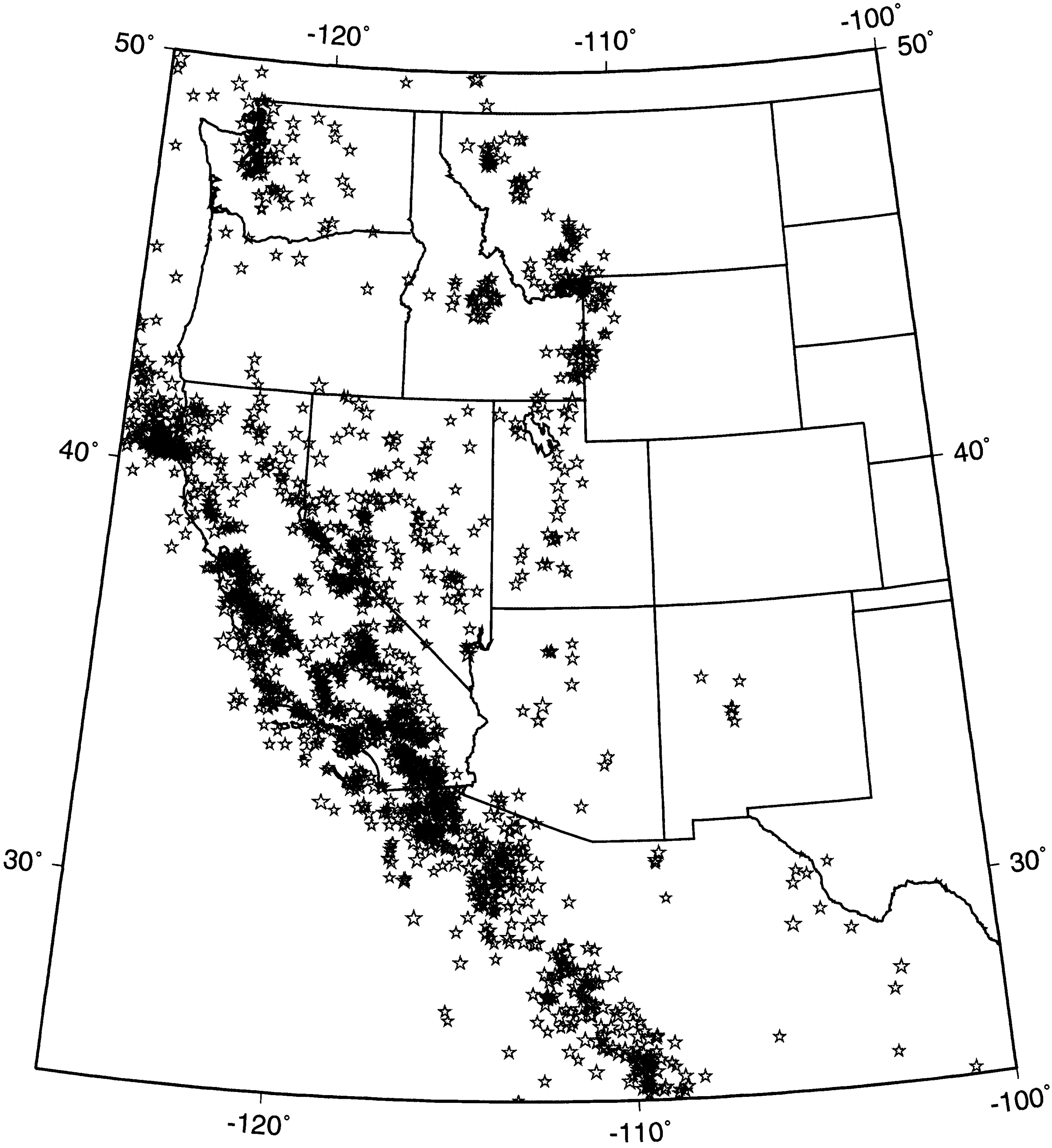

Figure 5a. The WUS catalog used to compute hazard, 4 <= magnitude < 5.

wmm.cc, 5<=mag<6 used to compute hazard

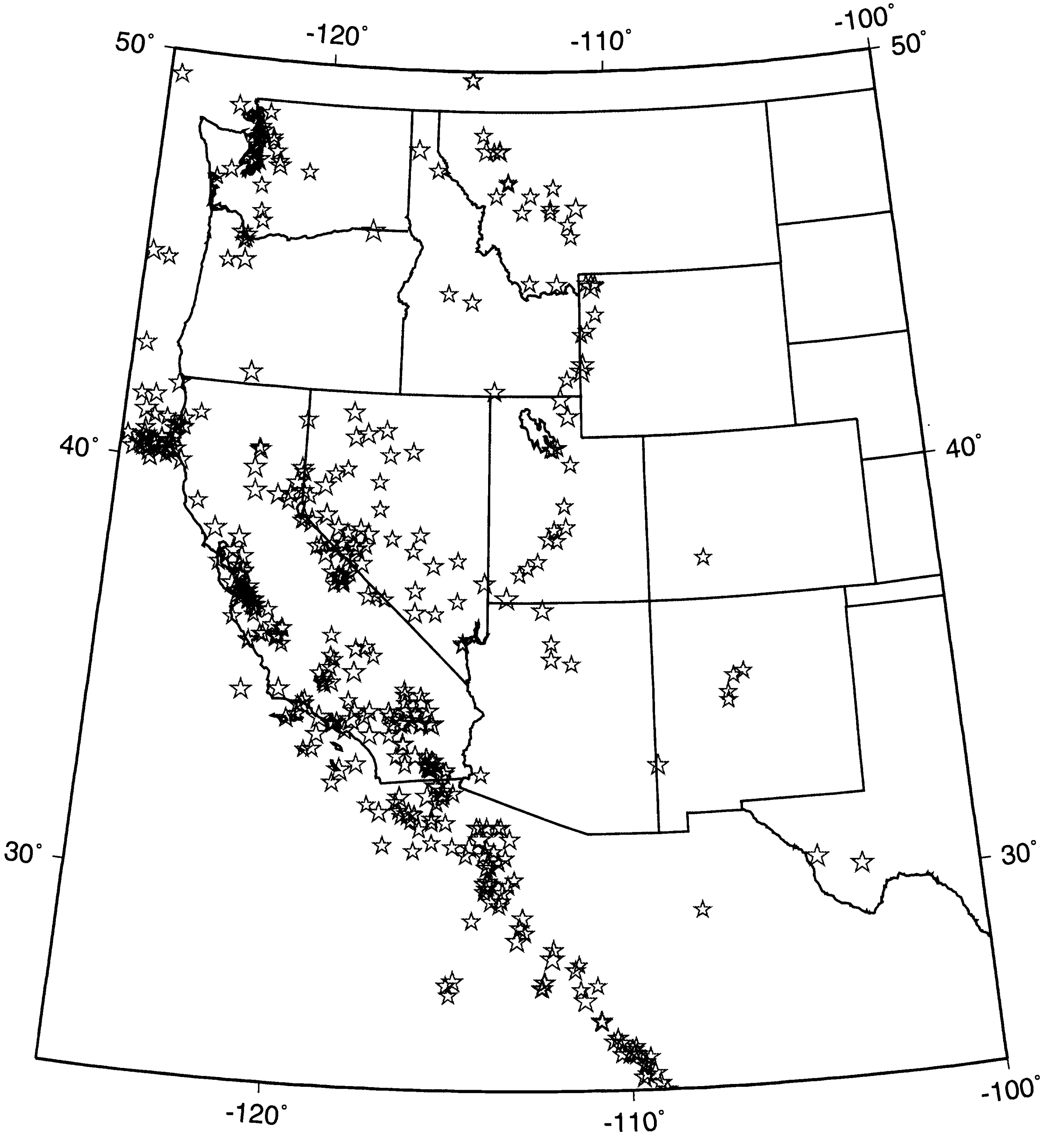

Figure 5b. The WUS catalog used to compute hazard, 5 <= magnitude < 6.

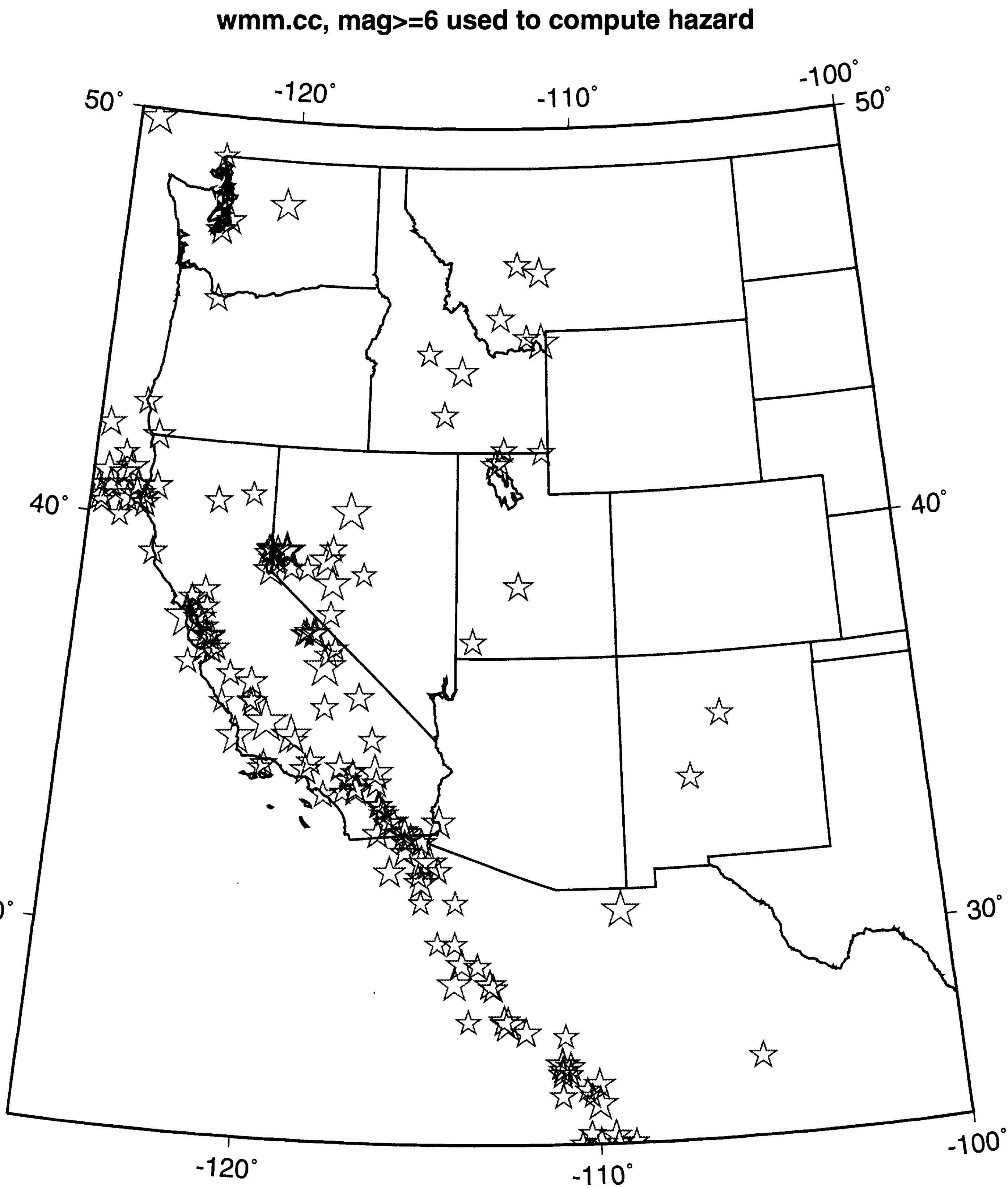

Figure 5c. The WUS catalog used to compute hazard, magnitude >= 6.

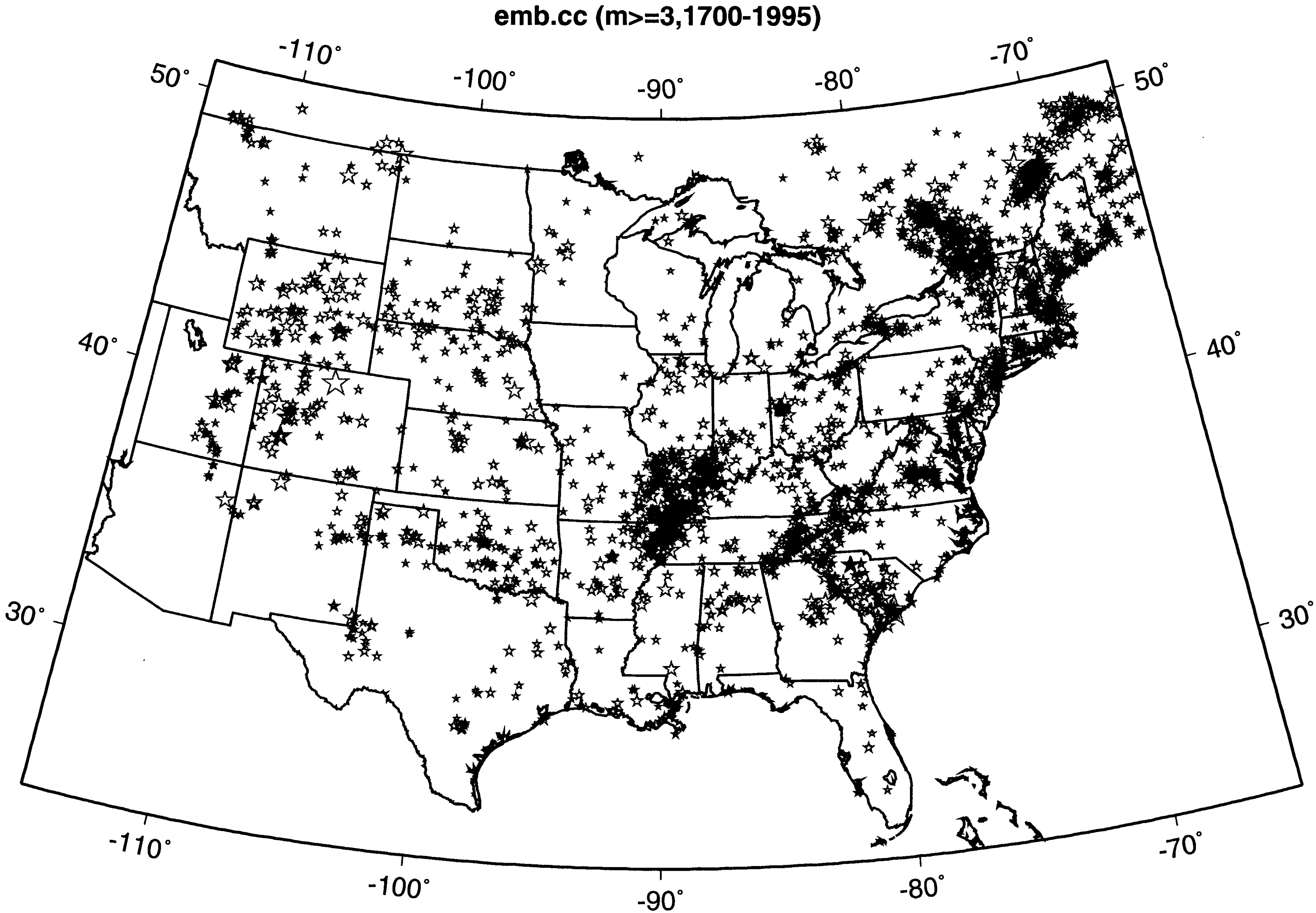

Figure 6. The entire CEUS catalog (file emb.cc).

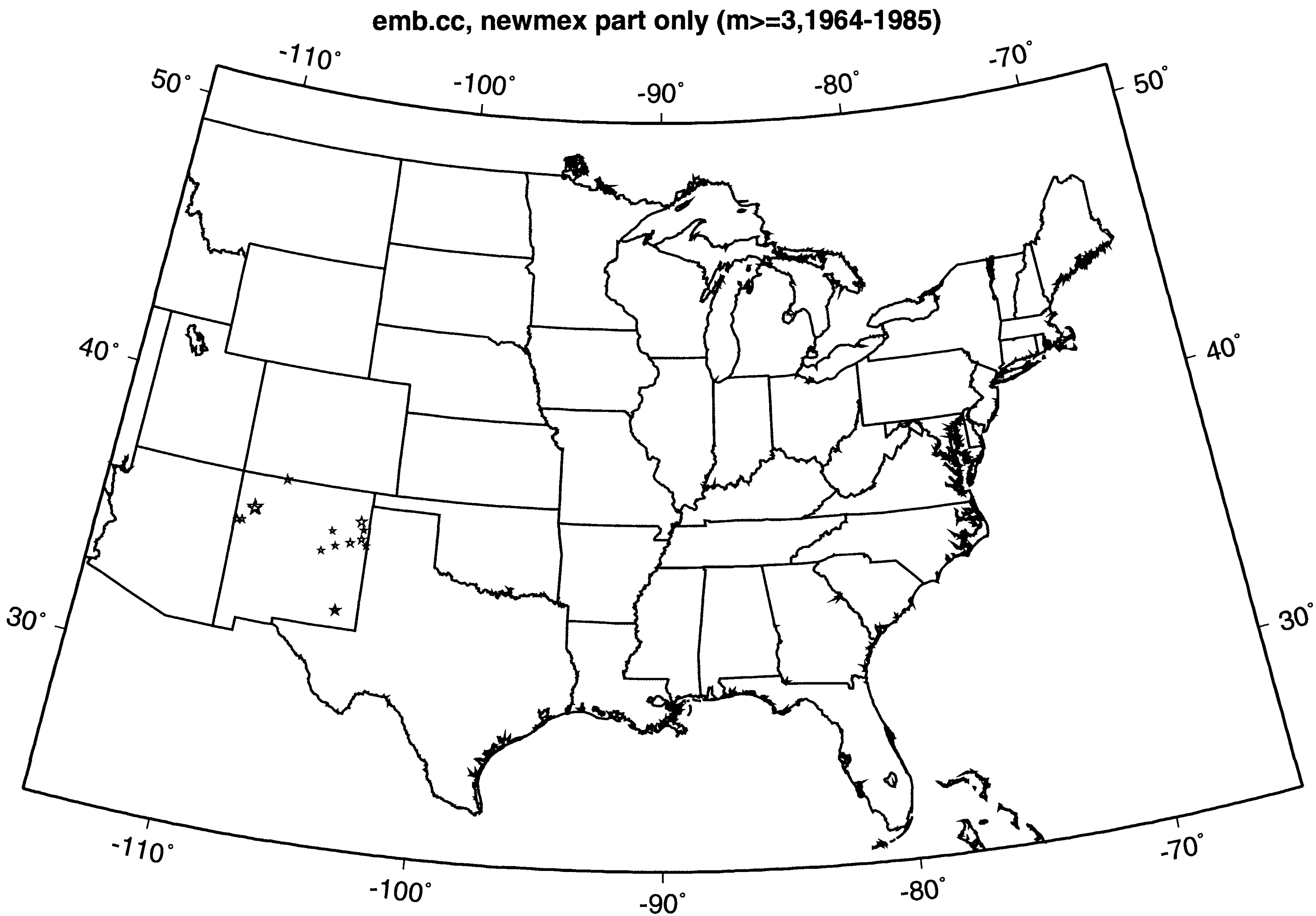

Figure 7a. The NEWMEX contribution to the CEUS catalog during 1964-1985.

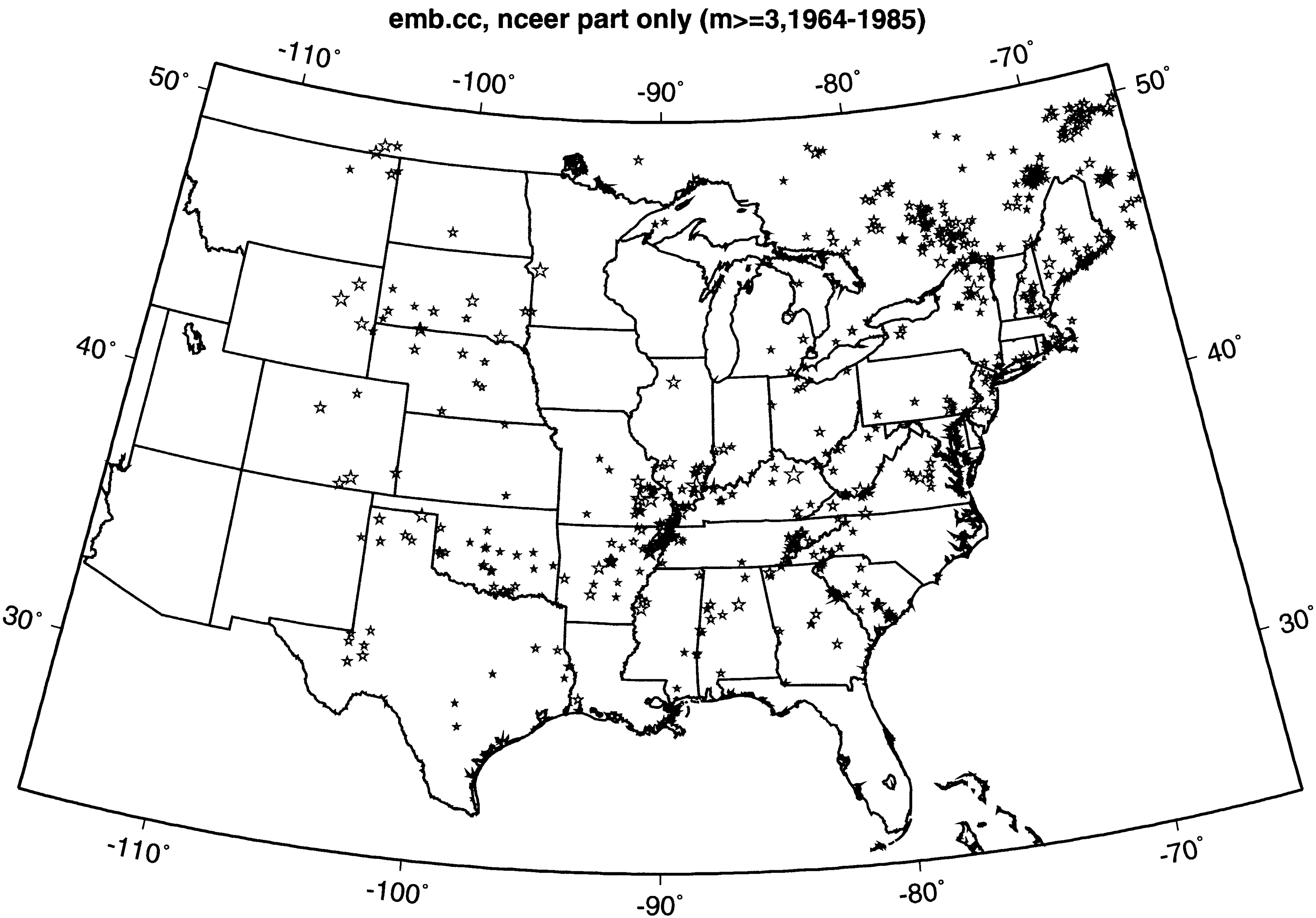

Figure 7b. The NCEER contribution to the CEUS catalog during 1964-1985.

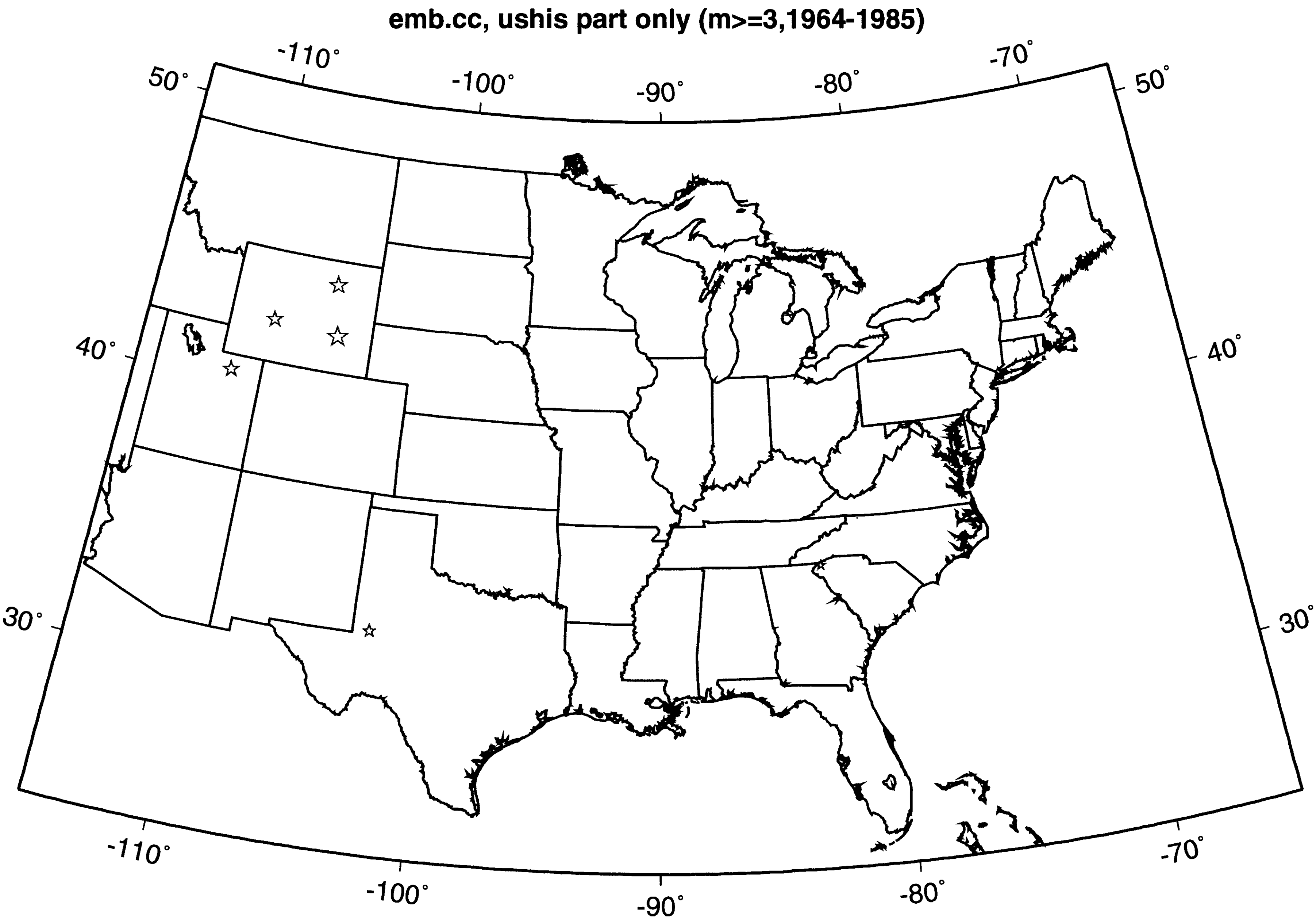

Figure 7c. The USHIS contribution to the CEUS catalog during 1964-1985.

emb.cc, sra part only (m>=3,1964-1985)

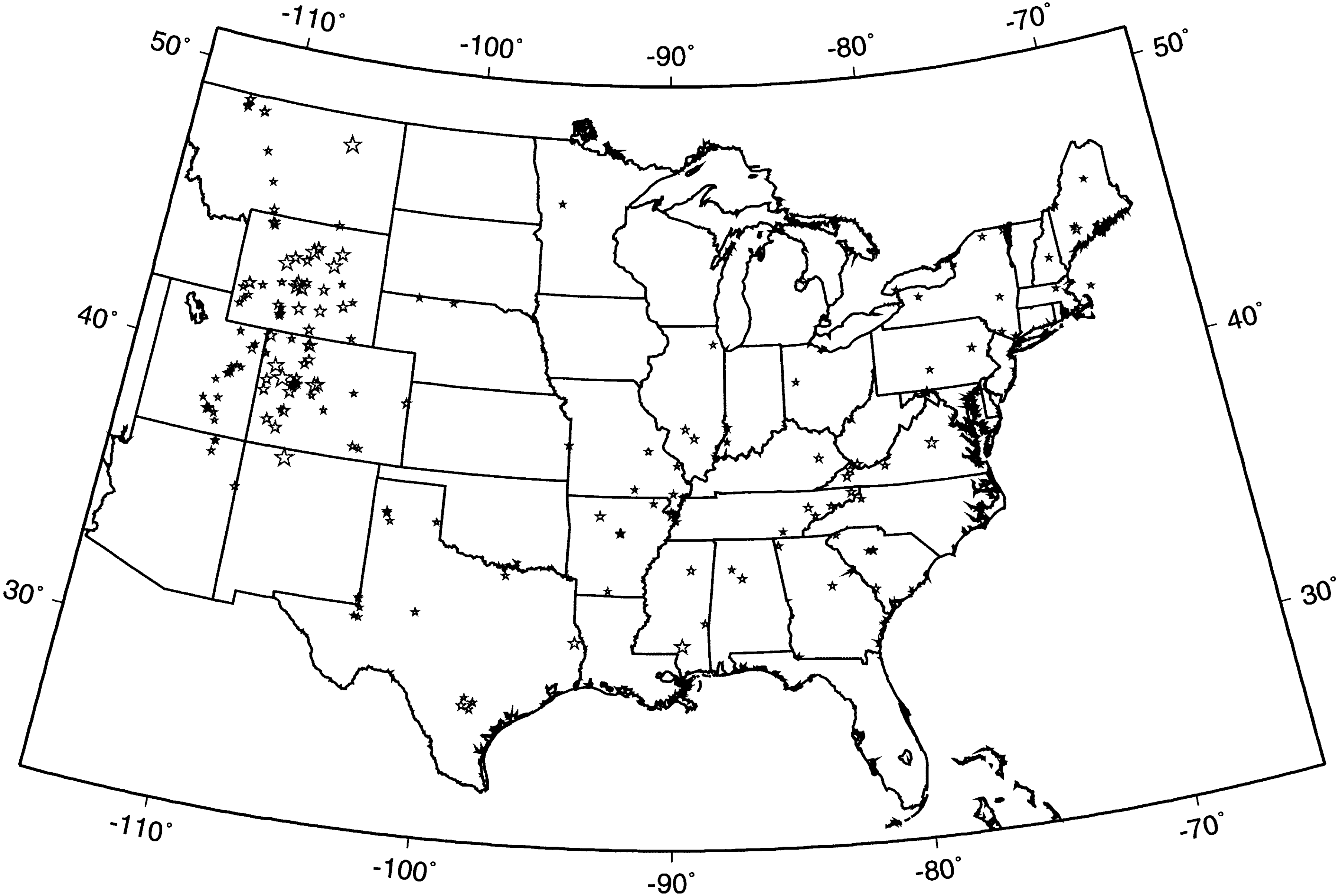

Figure 7d. The SRA contribution to the CEUS catalog during 1964-1985.

emb.cc, pde part only (m>=3,1964-1985)

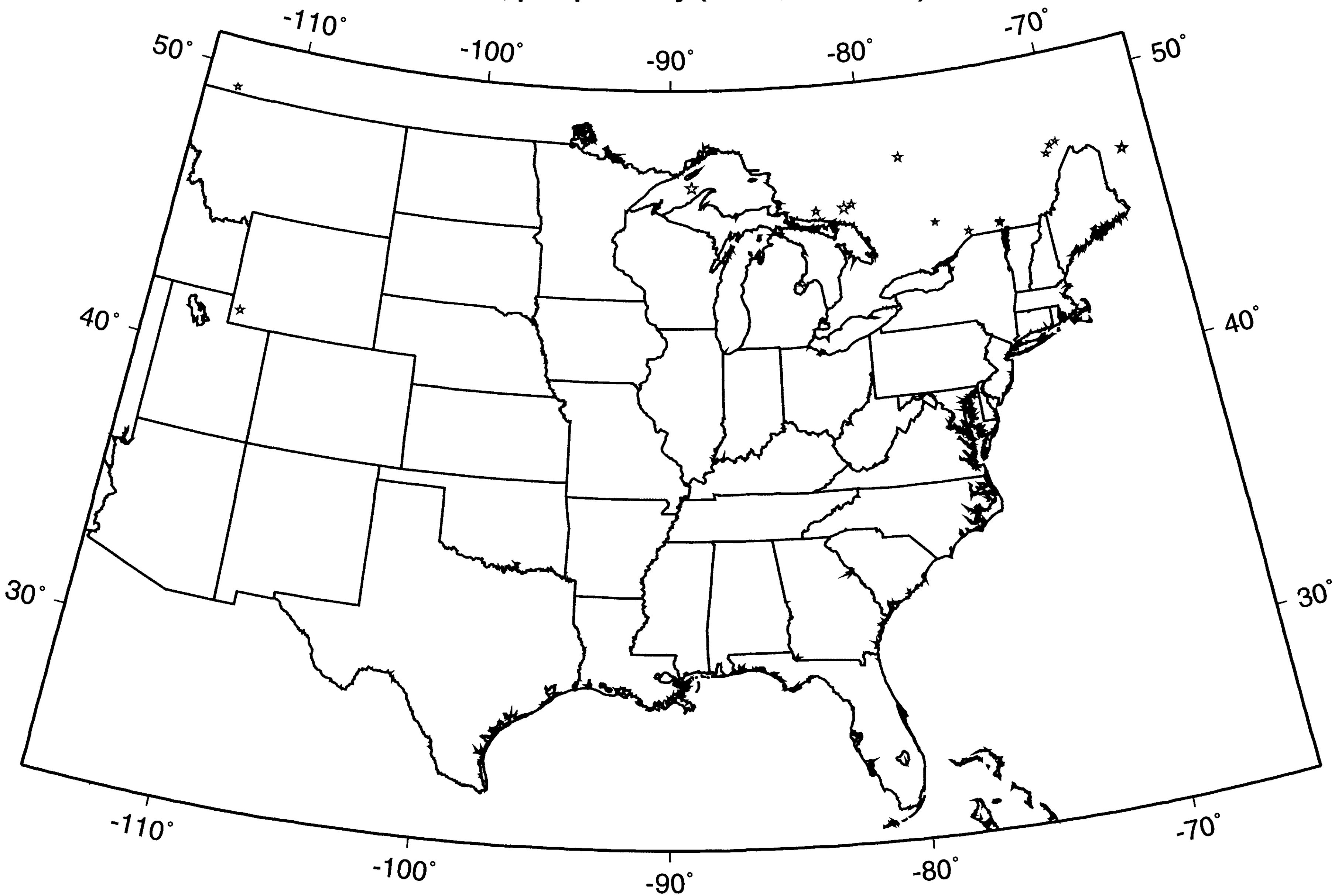

Figure 7e. The PDE contribution to the CEUS catalog during 1964-1985.

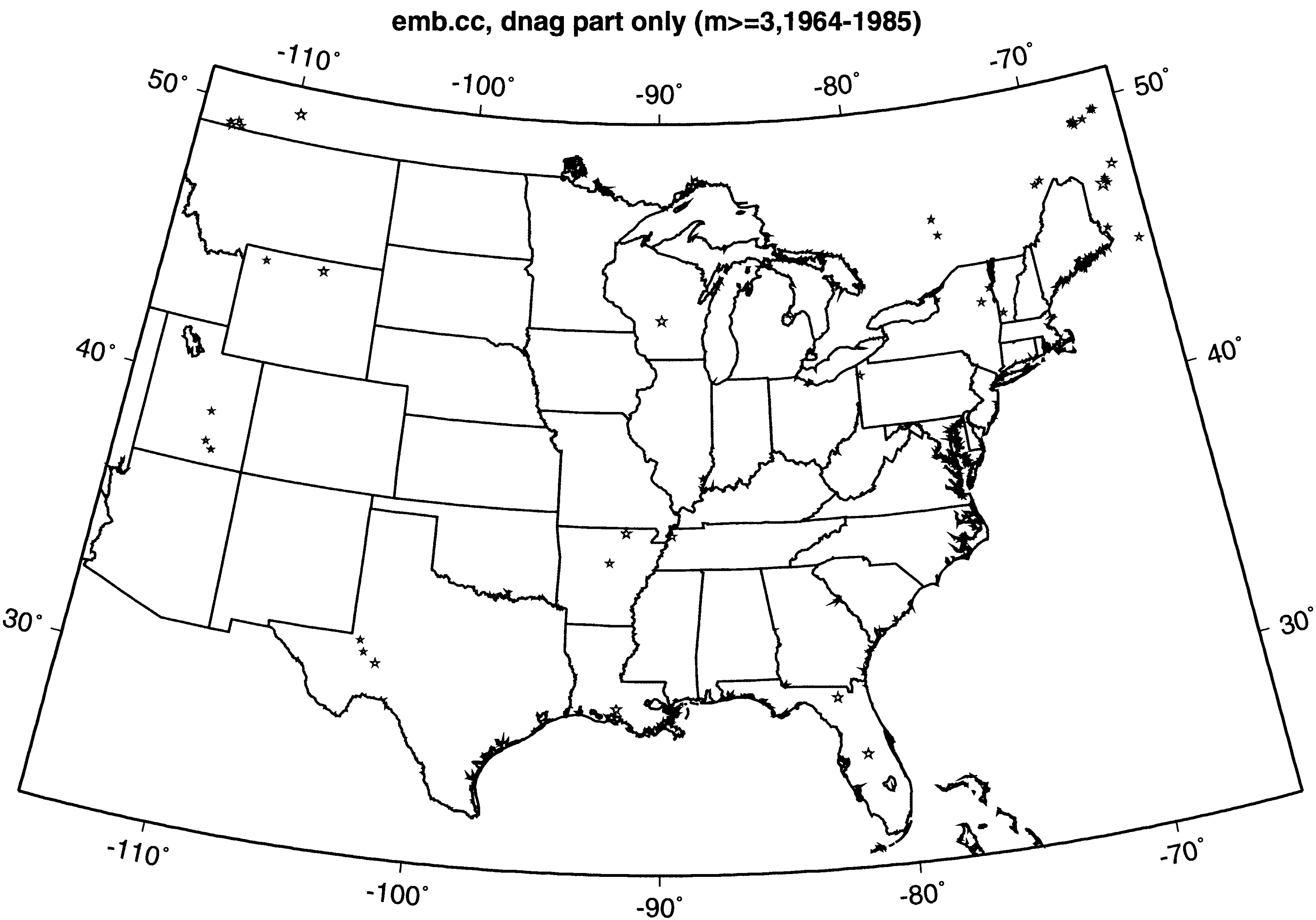

Figure 7f. The DNAG contribution to the CEUS catalog during 1964-1985.

Counting Earthquakes in CEUS

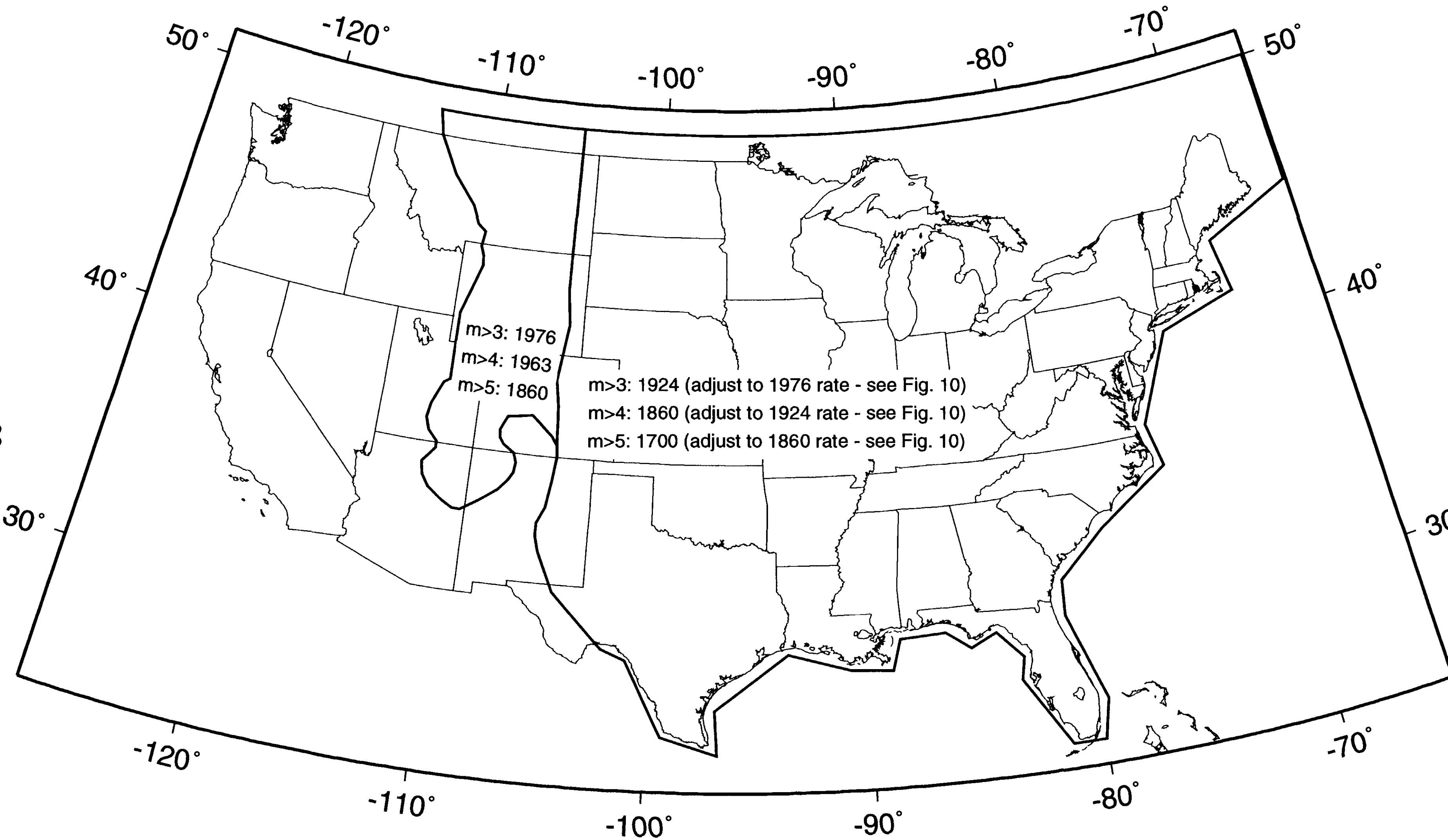

Figure 8. Assumed completeness times for counting earthquakes and computing seismicity rates in CEUS.

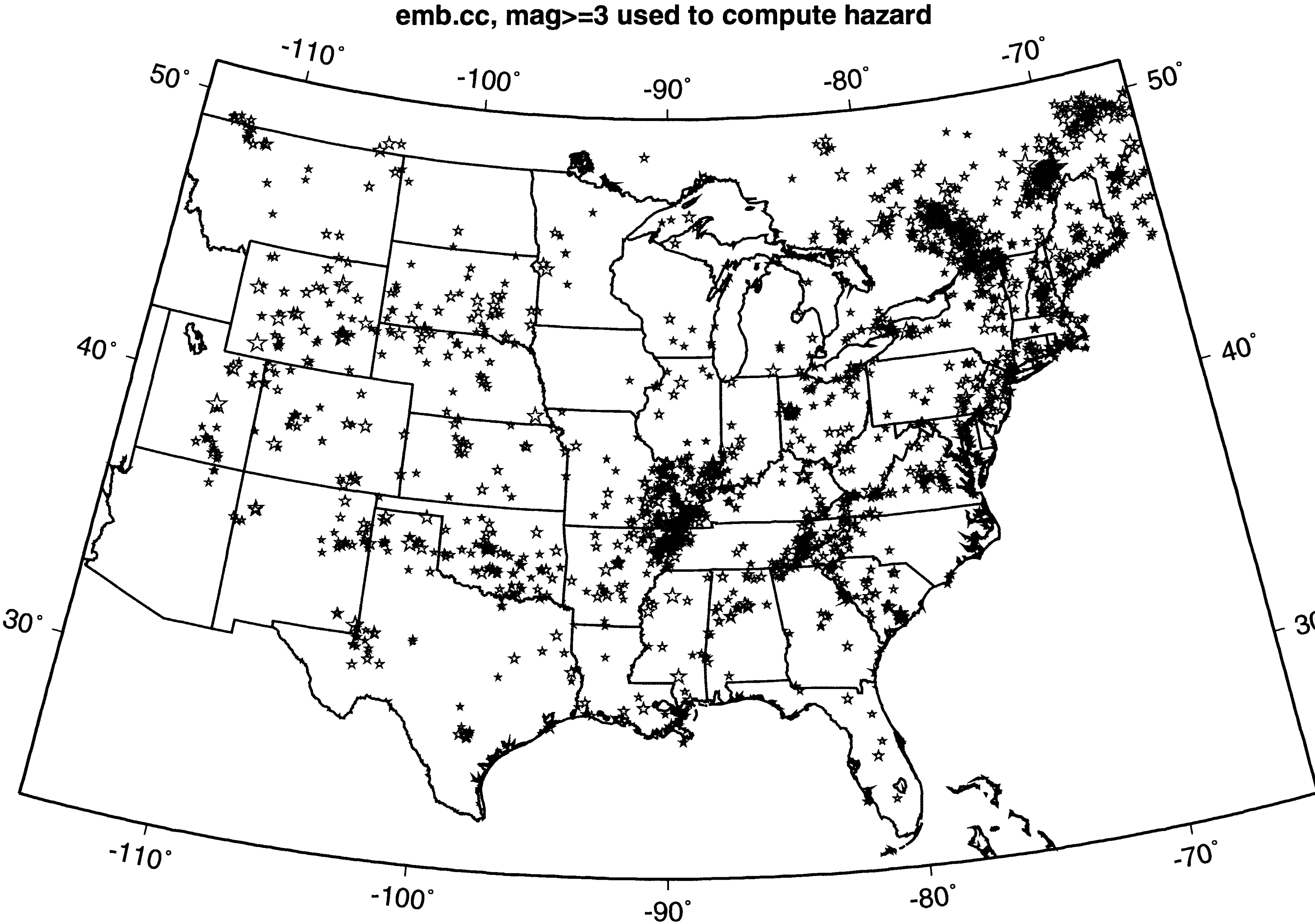

Figure 9a. The CEUS catalog used to compute hazard, magnitude >= 3.

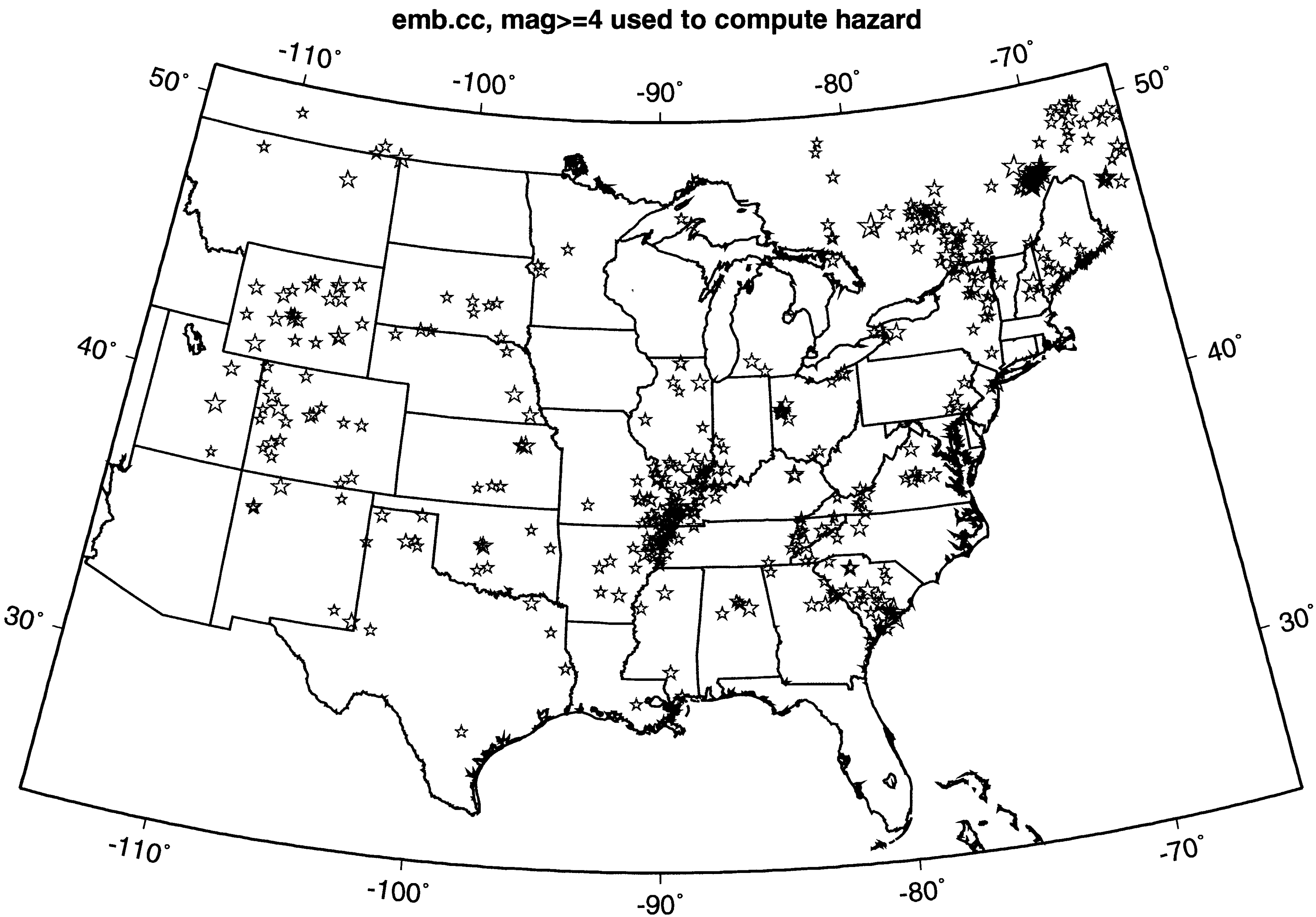

Figure 9b. The CEUS catalog used to compute hazard, magnitude >= 4.

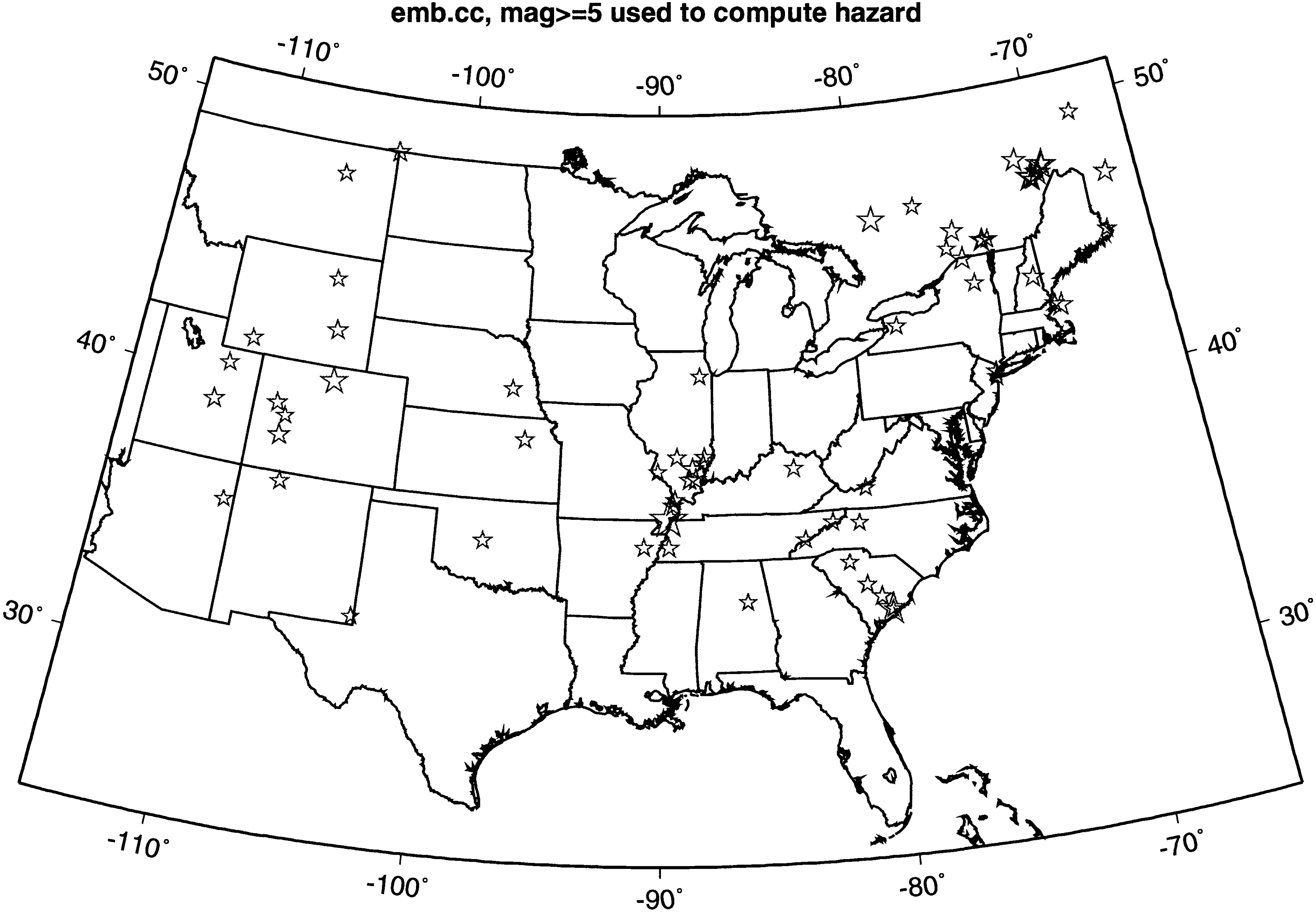

Figure 9c. The CEUS catalog used to compute hazard, magnitude >= 5.

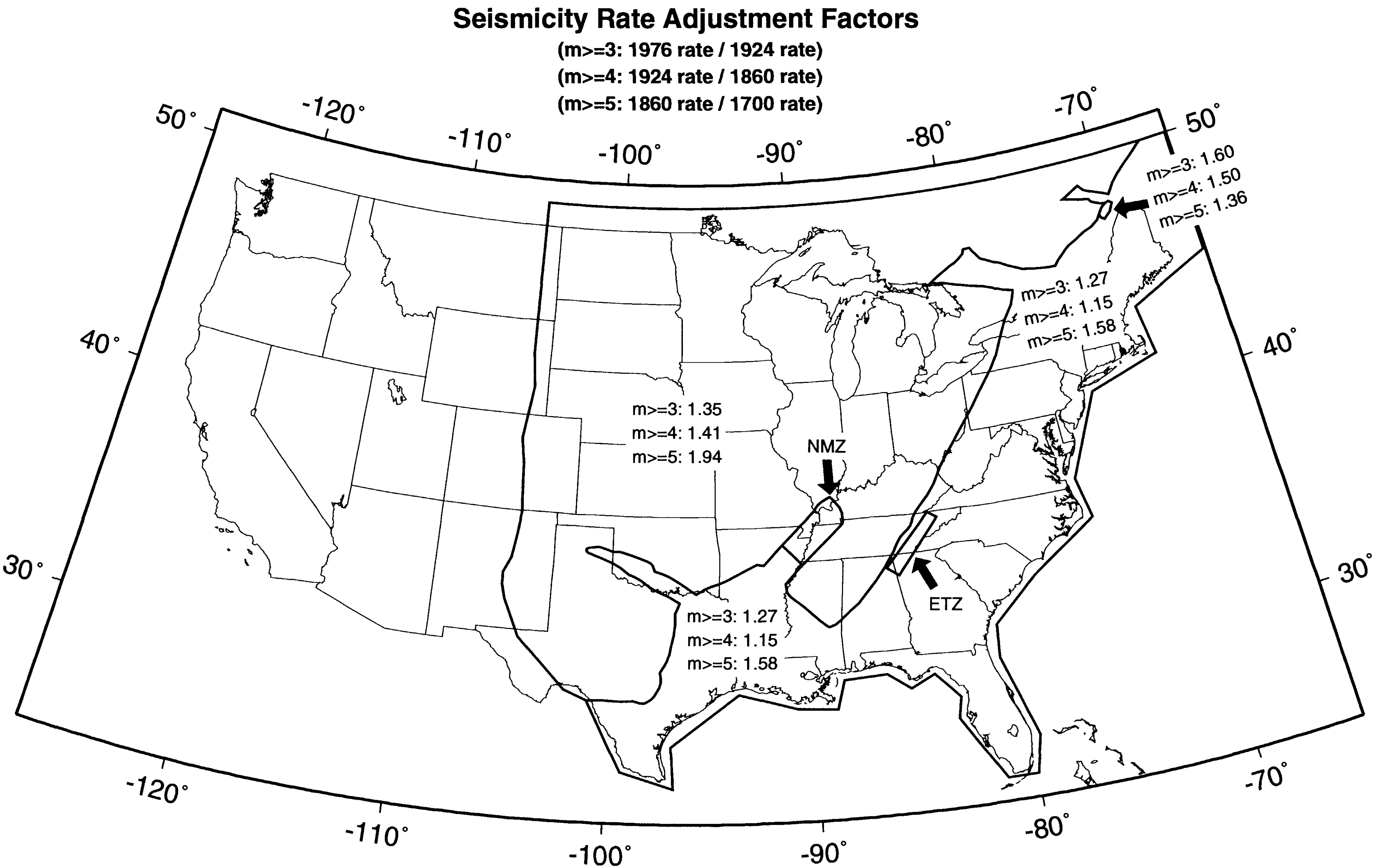

Figure 10. Multiply the "counted" rate in each cell by the appropriate zone-average "complete" rate / "counted" rate ratio. For New Madrid (NMZ) and Eastern Tennessee (ETZ) force a zone-average rate (m>=3 since 1976) into each cell.