FINAL TECHNICAL REPORT: 1991

Name of Contractor:	**University of Washington**
Principal Investigator:	**A. I. Qamar** **Geophysics Program AK-50** **University of Washington** **Seattle, WA 98195**
Government Technical Officer:	**Dr. Elaine Padovani** **MS 905** **U.S. Geological Survey** **12201 Sunrise Valley Drive** **Reston, VA 22092**
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CONTENTS

TABLES

APPENDICES

Final Technical Report for USGS Grant

14-08-0001-G1510

Earthquake Intensities

Summary

This is the final technical report for USGS grant 14-08-0001-G1510, "The Effect of Local Geology on Earthquake Intensity in the Seattle to Portland Region of Washington and Oregon". In the final year of this grant, we searched for newspaper and diary accounts of macroseismic effects of Cascadia (Oregon, Washington, and British Columbia) earthquakes prior to 1928 with the idea of improving estimates of location, depth, and magnitude. We rediscovered several moderate sized earthquakes whose magnitudes had been underestimated in current catalogs, and improved our understanding of the uncertainties in location and magnitude of the larger Cascadia earthquakes. We also concluded that historic material describing macroseismic effects should be organized, cataloged, and made more readily available. We designed and are implementing a prototype data base for macroseismic accounts.

Compiling and Reviewing Catalog Entries

We initially proposed to search for newspaper accounts of macroseismic effects of some larger western Washington earthquakes with the idea of seeing whether improved estimates of location, depth, and magnitude might be feasible, particularly for earthquakes prior to 1928, when U.S. Earthquakes began publication. Table 1, from Noson, Qamar, and Thorsen (1988) lists the largest earthquakes in Washington. For each of the earthquakes in Table 1, Noson et al. (1988) reviewed catalogs and other references to determine their preferred locations, magnitudes, depths, etc. Table 2 lists the dozen or so catalogs that cover part or all of the Pacific Northwest, and Table 3 lists some of the other references with useful information on PNW earthquakes. In addition, there are numerous journal articles dealing with specific earthquakes or earthquake sequences, and many other sources of information exist in the "grey literature" of technical

Year	Date	Time (PST)	North latitude	West longitude	Depth (km)	Mag (felt)[1]	Mag (inst)[2]	Maximum Modified Mercalli Intensity	Felt Area (sq km)	Location	References
1872	Dec. 14	2140	48°48'00"	121°24'00"	shallow (2)	7.3 (4)	none	IX (3)	1,010,000(5)	North Cascades	(1) Algermissen, 1983; (2) M. G. Hopper and others 1982; (3) Bechtel, Inc. 1976; (4) Malone and Bor, 1979; (5) Rogers, 1983; (6) Slemmons and others, 1978; (7) Wash. Public Power Supply System, 1977
1877*	Oct. 12	1353	45°30'00"	122°30'00" (8)	shallow (8)	5.3	none	VII (9)	48,000 (9)	Portland, Oregon	(8) Shannon and Wilson, 1975; (9) Thenhaus, 1978
1880	Dec. 12	2040	47°30'00"	122°30'00" (11)	?	?	none	VII (10)	?	Puget Sound	(10) Rasmussen and others, 1974; (11) U.S.Army Corps of Engineers, 1983
1891	Nov. 29	1521	48°00'00"	123°30'00" (10)	?	?	none	VII (10)	?	Puget Sound	(12) Rasmussen, 1967;(10)
1893	Mar. 06	1703	45°54'00"	119°24'00" (8)	shallow	4.7	none	VII (8)	21,000 (8)	Southeastern Washington	(8)
1896	Jan. 03	2215	48°30'00"	122°48'00" (13)	?	5.7 (11)	none	VII (12)	?	Puget Sound	(13) Ruth Ludwin, oral commun., 1987; (11,12)
1904	Mar. 16	2020	47°48'00"	123°00'00" (5)	?	5.3	none	VII (5)	50,000 (5)	Olympic Peninsula, eastside	(5, 12)
1909	Jan. 11	1549	48°42'00"	122°48'00" (5)	deep (5)	6.0	none	VII (5)	150,000 (5)	Puget Sound	(5)
1915	Aug. 18	0605	48°30'00"	121°24'00" (5)	?	5.6	none	VI (5)	77,000 (5)	North Cascades	(5,12)
1918*	Dec. 06	0041	49°37'00"	125°55'00" (5)	?	7.0	7.0 (17)	VIII (5)	650,000 (5)	Vancouver Island	(5)
1920	Jan. 23	2309	48°36'00"	123°00'00" (5)	?	5.5	none	VII (14)	70,000 (5)	Puget Sound	(14) Earthquake History of the United States; (5)
1932	July 17	2201	47°45'00"	121°50'00" (15)	shallow (15)	5.2	none	VII (15)	41,000 (15)	Central Cascades	(15) Bradford and Waters, 1934; (10)
1936	July 15	2308	46°00'00"	118°18'00" (14)	shallow	6.4	5.75 (17)	VII (14)	270,000 (4)	Southeastern Washington	(16) Brown, 1937; (17) Gutenburg and Richter, 1954; (8, 14)
1939	Nov. 12	2346	47°24'00"	122°36'00" (14)	deep	6.2	5.75 (17)	VII (14)	200,000 (5)	Puget Sound	(18) Coombs and Barksdale 1942; (4, 11, 17)
1945	April 29	1216	47°24'00"	121°42'00" (14)		5.9	5.5 (17)	VII (14)	128,000 (14)	Central Cascades	(14)
1946	Feb. 14	1918	47°18'00"	122°54'00" (10)	40 (10)	6.4	6.3 (10)	VII (14)	270,000 (14)	Puget Sound	(19) Barksdale and Coombs, 1946; (10, 14)
1946*	June 23	0913	49°48'00"	125°18'00" (5)	deep (5)	7.4	7.3 (17)	VIII (4)	1,096,000 (5)	Vancouver Island	(5,14)
1949	April 13	1155	47°06'00"	122°42'00"	54 (20)	7.0	7.1 (17)	VIII(22)	594,000 (5)	Puget Sound	(20) Baker and Langston, 1987; (21) Gonen and Hawkins, 1974; (22) Nuttli, 1952; (23) Thorsen, 1986; (24) U.S. Army Corps of Engineers, 1949; (25) Weaver and Baker, 1988; (5, 10, 12, 17)
1949*	Aug. 21	2001	53°37'20"	133°16'20" (5)		7.8	8.1 (17)	VIII	2,220,000 (14)	Queen Charlotte Is., B.C.	
1959	Aug. 05	1944	47°48'00"	120°00'00" (4)	35 (4)	5.5	5.0 (4)	VI (12)	64,000 (14)	North Cascades, east side	(4,10,14)
1959*	Aug. 17	2237	44°49'59"	111°05' (26)	10-12 (27)	7.6	7.5 (26)	X (26)	1,586,000 (26)	Hebgen Lake, Montana	(26) Stein and Bucknam, 1985; (27) U.S. Geological Survey, 1963
1962*	Nov. 05	1936	45°36'30"	122°35'54" (29)	18 (28)	5.3	5.5 (30)	VII (14)	51,000 (14)	Portland, Oregon	(28) Berg and Baker, 1963; (29) Couch and others, 1968; (30) Dehlinger and Berg, 1962; (31) Dehlinger and others, 1963; (14)
1965	April 29	0728	47°24'00"	122°24'00" (32)	63 (35)	6.8	6.5 (32)	VIII (14)	500,000 (5)	Puget Sound	(32) Algermissen and Harding, 1965; (33) Ihnen and Hadley, 1986; (34) Langston, 1981; (35) Langston and Blum, 1977; (36) MacPherson, 1965; (37) Mullineaux and others, 1967; (14)
1981	Feb. 13	2209	46°21'01"	122°14'66" (38)	7 (36)	5.8	5.5 (38)	VII (39)	104,000 (40)	South Cascades	(38) Grant and others, 1984; (39) Qamar and others, 1987; (40) U.S. Earthquakes, 1981
1983*	Oct. 28	0606	44°03'29"	113°51'25" (41)	14 (42)	7.2	7.3 (38)	VII (42)	800,000 (42)	Borah Peak, Idaho	(41) Richins and others, 1987; (42) Stover, 1987

1 Mag (felt) = an estimate of magnitude, based on felt area; unless otherwise indicated, it is calculated from Mag (felt) = -1.88 + 1.53 log A, where A is the total felt area; from Toppozada, 1975.

2 Mag (inst) = instrumentally determined magnitude; refer to references listed in the table for magnitude scale used.

TABLE 1: From Noson et al. (1988) References are given in Noson et al. (1988)

reports (e.g. for dam or power-plant siting, the Hanford Reservation, or the Basalt Waste Isolation Project). and open-file reports. These may be difficult to locate, since they are not included in data bases like the Citation Index or GeoRef. Determining the best selection of summary quantities for an earthquake first requires compiling all the existing information.

TABLE 2
Earthquake Catalogs for the Pacific Northwest

Catalog	Area	Dates	Time Base	Intensity Type
Berg and Baker (1963)	Oregon	1841-1958	"as reported" and GMT	MM
Bradford (1935)	Puget Sound	1833-1934	local	RF
Coombs (1953)	Washington	1930-1951	PST	MM
Coffman and von Hake (1973)	WA-OR	-1970	PST	MM
DNAG (unpublished)	WA + OR	1827-1986	GMT	
Holden (1887)	CA,OR,WA	1769-1887	Local	RF
McAdie	Pacific Coast	1897-1906		
Milne (1956)	Canada W. of 113W	1841-1951	Local	MM
OSU (unpub.)	PNW	1827-1986	GMT?	-
Rasmussen (1967)	Washington	1841-1965	GMT	MM
Smith (1919)	Oregon	1846-1916	local?	RF
Townley and Allen OR (1939)	OR	1846-1928	local PST PDT	RF
Townley and Allen WA (1939)	WA	1833-1928	as above	as above
Woodward-Clyde (unpub.)	PNW	1841-1977	GMT	-

TABLE 3
Some Other Sources for Pacific Northwest earthquake information

Name
Berkeley Clippings (unpublished)
Byerly (1952)
Monthly Weather Review (periodical)
Noson, Qamar and Thorsen (1988)
Reid (unpublished)
Rockwood, C.G., American Journal of Science (periodical)
Rogers (1983)

Because there are so many different catalogs and sources that cover the Pacific Northwest, we began our study by making a scrapbook page for each earthquake, cutting out all the catalog entries for each earthquake and and pasting them onto a page. These pages of information are very useful and informative, but are also hard to interpret; as some investigators use local time, some use Greenwich time; some use the Modified Mercalli Intensity scale, others use the Rossi-Forel scale; some catalogers use square km to describe felt area, others use square miles. While the catalogers always note and describe the units they use, usually at the top of the columns, when the catalogs are cut up the units are not carried along with each event.

When all the information has been compiled, inconsistencies become apparent for almost all of the older events. The events in Table 1 have generally been the subject of fairly detailed study, and the problems associated with these events are often not very amenable to correction; either there is insufficient information, or no consensus exists among investigators. Common problems are related to earthquake origin time or magnitude, or to errors carried forward from previous catalogs. Time problems often arise from the different ways time can be expressed; as A.M. or P.M., local, PDT, PST or GMT. Different catalogs may have different times for the same event, and errors may be introduced when, for example, time is changed from PST to GMT. Magnitude is sometimes estimated directly from maximum intensity, a questionable practice, especially since the information used to estimate the intensity is seldom included. As new catalogs are formulated by compiling and modifying existing catalogs, corrected errors may be reintroduced because of to poor documentation of prior corrections, or because the source of the correction is in "grey literature" unfamiliar to the cataloger. Other substantive problems may occur as well, and are often difficult or impossible to adequately address.

Notes on the largest cataloged earthquakes in Cascadia

We offer here a brief discussion of the earthquakes in Table 1 up to 1932; these events offer a rather complete illustration of the problems encountered in cataloging.

1872 - This is generally agreed to be the largest earthquake in Washington and Oregon but, although it has been extensively studied (Weston Geophysical, 1976; Malone and Bor, 1973), there is no consensus on its depth or location, with both latitude and longitude varying over 1° (Malone and Bor, 1973; History of US Earthquakes, 1992).

1877 - There was some confusion in the catalog entries between two shocks which occurred on a single day, and this earthquake was reevaluated in an open-file report by Thenhaus (1978) who used a single newspaper account from the Portland "Oregonian" to produce an isoseismal map for the larger shock. The correction was in "grey literature", and was not included in the catalog compiled by Woodward-Clyde, (unpublished), which shows two shocks of intensity VIII.

1880 - From the catalog entries this appears to be a very exceptional sequence of nearly a dozen felt earthquakes, including fore, main, and aftershocks. The earthquake listed in Table 1 is the main shock. We sought, but were (mostly) unable to find, additional newspaper accounts. The microfilm of the Seattle Post-Intelligencer is missing all issues from Dec. 1880 through mid-January 1881. Accounts from the Portland Oregonian and Port Townsend papers tended to agree with catalog accounts.

1891 - (Nov. 29) Townley and Allen (1939) apparently quote (without referencing) from the "Oregonian" that "Lake Washington ... was lashed into a foam, water rolled on to the beach ... eight feet above the present stage" If this report is accurate it should be possible to substantiate it with other information.

1893 - The intensity (VI-VII; Coffman and vonHake, 1973) for this earthquake comes from Townley and Allen, who give no reference. In reviewing the newspaper accounts, it may arise from a single newspaper report in the Portland "Oregonian" that one wall of a stone building was thrown down in Umatilla, OR. We sought a confirming damage or felt report in a Walla Walla newspaper, but did not find one. The earthquake was not widely felt; as reflected in the lower magnitude estimate in Table 1. However, if the maximum intensity was used to estimate the magnitude a much larger magnitude would be assigned. Estimating magnitudes on the basis of maximum intensity introduces error.

A time error (due to conversion from PST to GMT) also appears in the catalog listings for this event. The DNAG listing gives the time as March 6, 17:03 GMT, while Earthquake History of the US (Coffman and vonHake, 1973) gives March 6, 17:03 PST.

1896 - The PGC informs us that this earthquake was not much felt in Canada. We found newspaper reports of "severe shaking" (but no damage) in the San Juan Islands. Townley and Allen (1939) report damage in Port Angeles, but we could not confirm this due to a lack of Port Angeles newspapers in the UW collection.

1904 -Some original material reviewed by Garry Rogers (1983), and his interpretation of that material agrees with the newspaper accounts we found. We reviewed quite a few newspapers, (see Table 5) as we were searching for the source of an "overdrawn" (and unreferenced) report included in Townley and Allen indicating extremely high intensities on the Olympic Peninsula. We could locate no supporting evidence for this report.

1909 - Garry Rogers (1983) reviewed this event, and increased the felt area and magnitude estimates based on newspaper accounts. Although he shows an isoseismal map indicating that the earthquake was felt in Portland, the report in the Portland "Oregonian" does not say that the earthquake was felt locally. Rogers gives 150,000 square km (about 60,000 square miles), Coffman and vonHake (1973) give 25,000 square miles, and Townley and Allen (1939) give 100,000 square miles. Although we collected some accounts of this event, we do not yet have enough information to resolve the felt area of this event.

1915 - From catalog accounts, there were clearly two events on this day, one at 6:04 AM, the other at 10:00 AM. There is some confusion amongst the various catalogs as to which is the larger earthquake. We were not able to locate newspapers in the U.W. collection which could resolve the discrepancy. We are still optimistic about finding further information, however. Garry Rogers (1983) has a typographic error on his magnitude estimate for this event (should read 5.6).

1918 -This Vancouver Island earthquake was the subject of a recent article (Cassidy, Ellis and Rogers, 1988) . We currently have no newspaper accounts for this earthquake.

1920 -We have only the catalog entries for this event, a cursory search for newspaper articles from Olympic Peninsula newspapers in the UW collection was fruitless.

1932 -There are large discrepancies in felt area estimates for this earthquake. Coffman and vonHake (1973), give 14,000 square miles, Bradford and Waters (1934), give 70,000 square miles. The 41,000 square km felt area given in Noson et al. is referenced to Bradford and Waters, and appears to be an error.

Within the format of most catalogs, there is no place for the type of observations and discussion given above. This makes it difficult for investigators, and especially new investigators to understand exactly what the state of knowledge about a particular earthquake is. This means that in order to appreciate the capabilities and limitations of the earthquake catalog each investigator goes through the same path of searching through the many catalogs, and the microfilm collection of the University of Washington.

Discovering uncataloged and miscataloged earthquakes

It is possible to find uncataloged or miscataloged earthquakes by compiling material located through indices of newspapers and historical documents, and soliciting historical and genealogical societies, and local libraries for diary, newspaper or other material. These offer a pathway to earthquake information that is independent of the existing catalogs. Newspaper indices in the University of Washington Library are listed in Table 4. There is also an index covering selected PNW periodicals and time periods which is located in the Pacific Northwest Collection (this has been of limited use for this project).

TABLE 4
Newspaper Indices for Pacific Northwest Papers

Name	Dates	Comment
Colville Examiner	1908-1925	Microforms A1128
Early Idaho Newspapers	1863-1912	Microforms A4194
NW Tribune (Spokane)	1887-1895	Microforms Uncat 200
Oregon Journal	1851-1979	Microforms M1244
Oregon Spectator	1846-1854	PNW collection, N 979.505 Os
Oregonian	1851-1979	Microforms A1244
Spokesman Review (Spokane)	1887-1920	Microforms A4194
University of Washington Daily	1893-	PNW collection, N979.705
Wenatchee Republic	1903-1911	Microforms M2031
Wenatchee World	1905-1983	Microforms M2032
Wahkiakum County Newspaper Project	?	Microforms A7289 and A7272

We went systematically through the entries for the Portland "Oregonian" listed in an index covering 1850-1910 compiled by the editor, Leslie M. Scott, and added these articles to our collection of macroseismic accounts by typing them into verbatim ascii files on a portable computer. The "Oregonian" was the leading American paper in the Northwest prior to about 1910. As we began looking up and transcribing the Oregonian articles, we checked the newspaper accounts against earthquake catalogs.

It soon became apparent that newspaper accounts existed for earthquakes that were not included in the catalogs. The most striking example of this was the 1882 April 30 (local time) earthquake, which we have estimated to be close to magnitude 6, based on a comparison of the isoseismal map with that of the 1939 earthquake. Appendix 1 is an extended abstract on the 1882 earthquake. Although this earthquake was referenced in Townley and Allen (1939), only an aftershock is listed in the more recent Berg and Baker (1963), the event is not listed in Rasmussen (1967), nor in other recent catalogs. Rasmussen (1967) does not cite the Oregonian Index, although Berg and Baker (1963) do.

Another type of problem is illustrated by the March 7, 1891 (local time) earthquake, Appendix 2 is an extended abstract on this earthquake. This earthquake was listed in earthquake catalogs, but the listing was based on such limited information that both the location and magnitude estimates were grossly in error. Our attention was called to this event by an 1891 diary entry, which had been sent to the UW seismology lab several years earlier. This loose piece of paper was saved, and was passed on to us. When it was compared to the existing catalogs and the Oregonian account, we conducted a more thorough search of newspaper records and were able to create an isoseismal map, and estimate a magnitude.

Other earthquakes which we will be investigating are on September 17, 1891 (felt from Salem to Portland) and September 11, 1903 (felt from Seattle to Portland). We also discovered several early Canadian earthquakes which were not listed in the Milne (1956) catalog, one on February 17, 1793 (in Vancouver's diary entry on Tuesday, May 21 1793) and another which caused damage at Skidegate in the Queen Charlotte Islands on February 24, 1890 (deBallore, 1906).

In addition to articles in the "Oregonian" index, we also compiled the "Washington Standard" accounts cited by Rasmussen (1967) and we conducted more extensive searches for accounts of certain earthquakes. Table 5 is a list of newspaper, diary, and other accounts which we have compiled. These accounts have been transcribed into computer files. We are collecting other information which has not yet been transcribed; we solicited accounts of earthquakes prior to 1928 from historical societies in Washington and Oregon, and received many replies, some of which concern apparently uncataloged earthquakes. "Washington Geology", published by the Washington State Dept. of Natural Resources is also publishing a request for material on historic earthquakes. We hope to continue compiling macroseismic accounts, as new information is still being found and considerable resource material has yet to be explored.

TABLE 5 - Macroseismal Accounts

1790s

DIARY: George Vancouver; Voyage of discovery to the north Pacific Ocean and Round the World, V. 2, Entry on Tuesday, May 21 1793 regarding earthquake on February 17, 1793.

1820s

DIARY: John McMillan; (diary not yet located) cited in B.A. McKelvie, 1947, Fort Langley; Outpost of Empire, The Vancouver Daily Province.

1840s

DIARY: DeMofras; The Quarterly of the Oregon Historical Society, 1925, V. 26, no. 2, p. 158.

Oregon Spectator (Oregon City, Oregon Territory); Thursday, October 18, 1849.

1850s

The Oregonian, Portland; Jan. 27, 1857, p 2, col 3.

1860s

Oregon Statesman (Salem, OR); October 26, 1863, p 2, c4.

Oregon Statesman (Salem, OR); Monday, September 19, 1864, p1, c2.

DIARY: Henry Roeder, Whatcom, WA (Bellingham) Saturday, October 29, 1864

The Daily British Colonist (Victoria, B.C.); Monday (a.m.), October 31, 1864; pg 3, col 3

The British Columbian (Victoria, B.C.); Wednesday, November 2, 1864; pg 3, col 1

The British Columbian (Victoria, B.C.); Saturday, August 26, 1865; pg 3, col 3

The Daily British Colonist (Victoria, B.C.); Saturday morning, August 26, 1865; pg 3, col 1

The Pacific Tribune (weekly) Olympia, WA Terr.; Saturday September 2, 1865; pg 2, col 1

The Washington Standard Olympia, WA Terr.; Saturday September 2, 1865; pg 2, col 3

The Oregonian, Portland; Nov. 27, 1866; pg 2, col 1.

Washington Standard (Olympia); referenced in Rasmussen (1967); Dec 1, 1866, pg 2, col 3. - The identical report from the Oregonian is repeated

Oregon Sentinel (Jacksonville); Saturday, May 18, 1867, p2

1870s

The Oregonian, Portland; Nov 24, 1873

The Oregonian, Portland; Dec. 5, 1873; pg 1 50w.

The Oregonian, Portland; Oct 13, 1877

The Oregonian, Portland; Oct 17, 1877; pg 1, col 6.

The Oregonian, Portland; Dec 1, 1877; pg 6, col 1.

The Oregonian, Portland; found March 20, 1878; p.1, col. 4

The Oregonian, Portland; found July 13, 1879; pg 1, col 3.

1880s

The Oregonian, Portland; Dec 14, 1880; pg 1, col 5.

The Oregonian, Portland; Dec 14, 1880; pg 2, col 2.

The Oregonian, Portland; Dec 14, 1880; pg 3, col 1.

The Oregonian, Portland; Dec 9, 1880; pg 3, col 1.

Democratic Press (Port Townsend); December 16, 1880, Thursday.

Dec. 1880 Weekly Ledger, Tacoma - Checked, no mention

Puget Sound Weekly Courier December 10, 1880, Friday ??

Puget Sound Weekly Courier December 17, 1880, Friday, pg 1, col 2.

Seattle P.I. Dec. 1880 - cannot locate issues - missing for entire time period. Neither the UW library nor the WA State has microfiche.

Vancouver Independent (Vancouver, WA) - Dec. 1880 - Checked, no mention

Washington Standard (Olympia weekly) - Checked, no mention whole month of December, through Jan 7, 1881

REFERENCE: Monthly Weather Review, April 1882; Appendix 83, Report of the Chief Signal Officer of the Army; Report of the Secretary of War, V. 4, part 1, 1883

REFERENCE: Rockwood, C.G., 188?, American Journal of Science, V. 125, p.356
Puget Sound Weekly Courier December 17, 1880; Friday, pg 1, col 2.
Daily Standard" Victoria, British Columbia; May 1, 1882
Seattle Daily Chronicle; Monday, May 1, 1882
Vancouver Independent, Vancouver, WA; Checked no mention found May, 1882
Weekly Ledger, Tacoma; Checked, no mention found May, 1882
The Willamette Farmer; Portland? found May 1882
The Oregonian, Portland; May 1, 1882, pg 3, col 3.
Daily Astorian, Astoria, OR; Tuesday, May 2, 1882 (no edition on Monday, May 1, 1882)
Eugene Weekly Guard, Eugene OR; Searched May-June 1882, not found Issues on 4/30, 5/6
The Oregonian, Portland; May 2, 1882, pg 3, col 3.
The Oregonian, Portland; May 3, 1882, pg 3, col 3.
Puget Sound Weekly Courier (Olympia); Friday May 5, 1882
Weekly Astorian, Astoria, OR; Friday, May 5, 1882
Washington Standard, Olympia (weekly), May 5, 1882, p. 2
Olympia Transcript (Weekly) Saturday, May 6, 1882
The Oregonian, Portland; May 12, 1883; pg 1, col 3.
Washington Standard, Olympia; May 12, 1882
The Oregonian, Portland; Dec 30, 1883.
The Oregonian, Portland; Sept 25, 1884; pg 5, col 4.

1890s

BOOK: Les Tremblements de Terre, Geographie seismologique; Librarie Armand Colin, Paris, 1906 p. 143; Skidegate - February 24, 1890
DIARY: the diary of Helen Margaret Parrish, dated March 8, 1891. (She lived in a canyon near Monitor, between Cashmere and Wenatchee.)
The Oregonian, Portland; Sunday March 8, 1891; pg 6, col 1
Daily Oregon Statesman; Sunday, March 8, 1891; pg 1, col 7
Tacoma Morning Globe; Sunday, March 8, 1891; pg 1, col 3
The Ellensburg Capital; March 12, 1891; pg 3, col 1
The Seattle Post-Intelligencer; March 8, 1891;
The Seattle Telegraph; Sunday, March 8, 1891; pg 6, col 1
The Tacoma Daily Ledger; March 8, 1891; pg 5, col 3
The Tacoma Daily News; March 9, 1891; pg 8, col 2
The Oregonian, Portland; Sept 17, 1891; pg 9, col 2.
The Oregonian, Portland; Feb 4, 1892, pg 1, col 5.
The Oregonian, Portland; March 1, 1892. p3 c3.
The Oregonian, Portland; April 18, 1892; pg 3, col 4.
The Oregonian, Portland; Mar 7, 1893; pg 2, col 2.
The Oregonian, Portland; Aug 29, 1893. p4 c7
The Oregonian, Portland; Jan 15, 1894; pg 3, col 2
The Oregonian, Portland; April 17, 1894; pg 3, col 2
The Oregonian, Portland; Nov 22, 1894, pg 3, col 2.
The Oregonian, Portland; Feb 26, 1895, pg 3, col 2.
The Oregonian, Portland; Feb 26, 1895, pg 5, col 4.
The Oregonian, Portland; April 3, 1896, pg 10, col 3.
The Oregonian, Portland; Jan 28, 1897; pg 3, col 1&2
The Oregonian, Portland; Feb 23, 1898; pg 5, col 1
The Oregonian, Portland; Feb 24, 1898; pg 3, col 5
The Oregonian, Portland; Aug 13, 1898; pg 6, col 5

1900s

The Oregonian, Portland; April 28, 1900; pg 4, col 4
The Oregonian, Portland; Dec 7, 1902; pg 6, col 2
The Oregonian, Portland; March 14, 1903, pg 4, col 3.
The Oregonian, Portland; Sept. 12, 1903, pg 16, col 1.
The Oregonian, Portland; found March 17, 1904, pg 1, col 1&2, Thursday.

Aberdeen Herald (semi-weekly) Thursday March 17, 1904; no account found
Everett Daily Herald, March 17, 1904; p. 1., c. 3; p.8, c. 4
The Tacoma Times - search March 17-31, 1904; no mention found of tidal disturbance on Olympic Peninsula
Hoquiam Washingtonian, Thursday March 17, 1904; p. 1 c. 5
The Tacoma Daily News, Tacoma Washington, March 17, 1904, p. 2, c. 5
The Tacoma Daily News, Tacoma Washington - searched March 17-31, 1904; no mention found of tidal disturbance on Olympic Peninsula
The Seattle Post Intelligencer, Thursday March 17, 1904 V. XLV, N. 124, p. 1 c.1
The Seattle Post Intelligencer, searched March 17-31, 1904; no mention found of tidal disturbance on Olympic Peninsula
Snohomish County Tribune (Weekly) Friday March 18, 1904 and March 25, 1904; no account found
Willapa Harbor Pilot (Weekly) Friday March 18, 1904 - Issue Missing
Kitsap County Herald, Poulsbo (weekly) Friday March 18, 1904, V. 4, N. 12 p. 4 c. 1
Sumner Index (Weekly), Friday March 18, 1904, V. IV, N. 27, p. 2, c. 6
San Juan Islander (Weekly) Saturday March 19. 1904 p. 3, c. 5
The Bremerton News (Weekly) Saturday March 19, 1904; no account found
Seattle Post Intelligencer, Sunday March 20, 1904, p. 1, c.1
The Oregonian, Portland; June 17, 1904, pg 8, col 3.
The Oregonian, Portland; Nov 12, 1905, p 7, c 3
The Oregonian, Portland; April 3, 1906, pg 6, col 5.
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American Reville (Morning Reville), Bellingham; Jan 12, 1909 Front Page; full column, continued on page 3 UW microfilm A4639 (Summary)
Friday Harbor Journal; Jan 14, 1909 - UW microfilm A2358 under "Friday harbor in a nutshell" and subsequent page (Summary)
San Juan Islander, Jan 16, 1909 - UW microfilm A2359, Front Page - half column (Summary)

1910

Anacortes Citizen, Nov. 23, 1916
Concrete Herald, Nov 25, 1916
Sacramento Union, Nov 26, 1916
The Portland Oregonian Aug. 3, 1917 (?)
???? March 23, 1914, pg 16, col 4.

1920s

Oakland, CA Tribune, Jan 31, 1922
Port Townsend Leader. Thursday, April 25, 1929 pg 1, col 4
Port Townsend Weekly Leader. Friday, Feb 13,1925 pg 1, col 2

1930s

The San Francisco Examiner, Nov 14, 1939
University of Washington Daily (University of Washington). Tuesday, November 14, 1939
Morning Oregonian. Monday, July 18, 1932 pg 1, col 7
Port Townsend Leader. Thursday, November 16, 1939 pg 1, col 6-7

1940s

Seattle Times; Monday Aug. 22, 1949; P. 1, C.3
Seattle P.I.; Aug. 22, 1949; p. 2, c. 2
Seattle P.I.; Aug. 22, 1949 p. 2, c. 3
Seattle P.I.; Aug. 22, 1949 p. 1, c.7.

A prototype data base for historical earthquake information

In the process of investigating the "largest" earthquakes and the miscataloged earthquakes, we realized that it would be very useful to compile all the catalog entries along with whatever supporting information could be located for each and every event. The aim is to preserve and organize both catalog entries and supporting information. Making known information accessible should improve the accuracy of earthquake hazards evaluation, and minimize duplication of effort by successive investigators. Searching out newspaper accounts can be a very time consuming process, and the collection of available material varies over time as material is either added or lost. Keeping track of which papers have been searched, and where accounts have been found should allow evaluation of whether more information is likely to be located for an earthquake; and where that information might be sought. We began to experiment to determine what the best format would be to meet these objectives.

We transformed the catalogs listed in Table 2 (except McAdie) into ASCII files on the computer, usually by scanning and proofreading the catalogs. After trying several ways of organizing this data, we came to the conclusion that a data base would provide the best all-around solution. Therefore we designed, and are implementing, a data base to accommodate the information we have collected. We have tried to provide the same kind of one-line summary typical of modern catalogs, while also maintaining the underlying information on which the summary is based, and allowing space for discussion of the problems attending specific events. We believe that a data base for macroseismic observations could be of use to many investigators, and we have prepared an abstract on our prototype data base for the 1992 Seismological Society of America meeting. Appendix 3 is an article describing the prototype data base which has been submitted to TERRA Nova, a British publication of Blackwell Scientific. Because macroseismic accounts are the only source of information for earthquakes prior to the development of seismometers, a tool for compiling and maintaining catalogs based on these accounts should be of interest to catalogers in many countries.

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Acknowledgements

We are grateful for the assistance of librarians at the University of Washington microforms collection, the Pacific Northwest Collection, the University of Washington Archives and Manuscript Collection, the Interlibrary loan Program, Bruce Berney at the Astoria (Oregon) Public Library, The British Museum, and the British Columbia Provincial Archives. Student assistant Teresa Johnson searched for and typed in newspaper reports, scanned and proofread catalogs, and researched the March 7, 1891 earthquake. Kirsten Hampton, another student assistant, reviewed grey literature and searched manuscripts and historical society publications. We appreciate the many authors of the letters we received from historical societies and town offices regarding our search for old earthquake stories. Garry Rogers of the Pacific Geoscience Centre helpfully provided his notes on some events. Linda Noson (Ratti, Swenson, Perbix and Clarke), Chris Trisler (UW), Steve Palmer (DNR), Sherry Oaks (UCLA), Robert Muir-Wood (TERRA Nova), Betsey Detroit, and David Tillson also provided information and advice. Kitty Reed of the DNR kindly edited our extended abstracts, and Washington DNR kindly published them. Rick Ellsbury of Phaedrus Computing has worked with us on the design and implementation of the prototype data base.

APPENDIX 1

R.S. Ludwin and A.I. Qamar, 1991 (extended abstract),

1882 Earthquake Rediscovered,

Washington Geology, V. 19, No. 2, pp. 12-13

1882 Earthquake Rediscovered

by R. S. Ludwin and A. I. Qamar
University of Washington

During a recent review of newspaper accounts of earthquakes in Washington and Oregon, we found several references to an earthquake that occurred on April 30, 1882, at 10:48 p.m. local time (or May 1, 6:48 GMT). This event was widely felt in Oregon and Washington Territory and on southern Vancouver Island. It made a considerable impression on the populace, even though, apart from a few broken chimney tops and window panes in Olympia and damage to crockery and glassware there and elsewhere, no really severe damage was reported.

The following paragraphs were selected from newspapers published within the "felt area".

From the Portland *Oregonian*, May 1, 1882:

> At 12 minutes to 11 o'clock last night a slight earthquake was felt, lasting probably two seconds. This was followed about three seconds later by a more severe shock, accompanied by a low rumbling, which lasted from five to seven seconds. Every building in the city was shaken and sleepers were generally aroused. In the Oregonian office it seemed as though the big press was sinking through the floor, pulling the walls in in its descent. In the larger buildings, particularly the Clarendon hotel, New Market theater and Union block, the shock was more keenly felt, and residences in the western portion of the city shook as though they must fall.

From the Portland *Oregonian*, May 2, 1882:

> It was about the only topic of conversation yesterday. Every one had a very interesting story of how badly he was scared, and the accounts told by three hundred or four hundred paterfamilie of how their wives, snatching the youngest child, rushed en dishabille to the front door, had just sufficient variety to prove that one man had not repeated the other's experience.

From the Olympia *Washington Standard*, May 5, 1882:

> The tall shade trees were violently agitated, their branches thrashing in a manner produced by no other natural means, the buildings creaked like ships at sea, and everything movable swayed to and fro in obedience to a force irresistibly grand and peculiar. The feeling of awe induced by the strange phenomena was dispelled by the scenes which followed immediately afterwards, when half-clad women and crying children poured forth into the streets like bees from a great hive, to be reinforced by stalwart men who showed scarcely less trepidation.

The 1882 earthquake was included in the catalogs of both Holden (1887) and Townley and Allen (1939). Later catalogs, however, generally omitted this earthquake, although mention of its single felt aftershock appeared in reports by Berg and Baker (1963) and Rasmussen (1967).

Descriptions of the effects of the 1882 earthquake in newspaper accounts allow us to sketch approximate intensity contours. (See Table 1 [on following page], Fig. 1). The positions of the intensity 5 and 6 contours

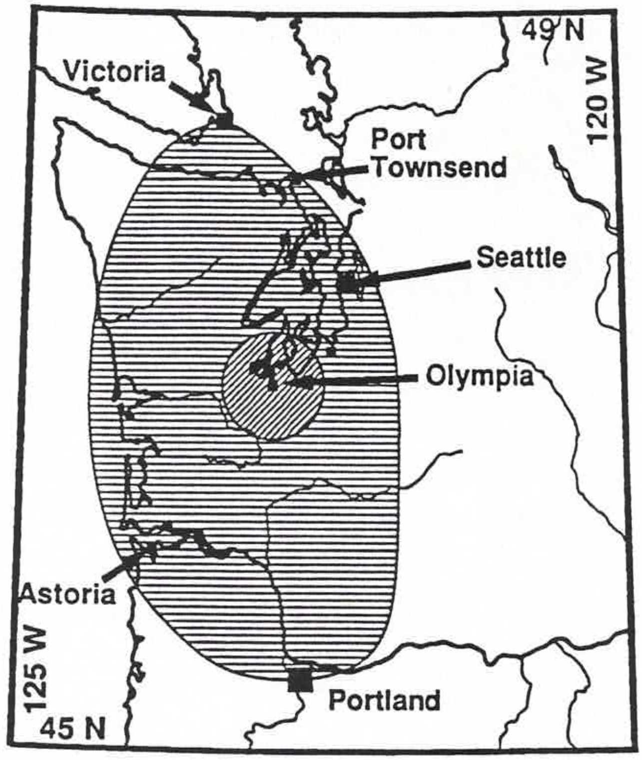

Figure 1. Approximate areas of reported modified Mercalli intensities V (horizontal lines) and VI (diagonal lines) for the April 30, 1882, earthquake. Very few data points were available for constucting this map. The estimated Richter magnitude of this event was ≈6.

for this earthquake appear to be very like those for the 1939 "Olympic" earthquake. This similarity of isoseismal contours suggests that the two earthquakes were of similar magnitude and depth. The 1939 earthquake is considered to have been subcrustal, its epicenter probably at a depth of 40 to 70 km, within the subducting Juan de Fuca plate. The magnitude of the 1939 earthquake, which occurred before instrumentation, has been estimated at from 5.75 to 6.2.

In the southern Puget basin, only three other subcrustal earthquakes of moderate magnitude are known: the 1939 event, the 1949 magnitude (m_s) 7.1 event, and the 1965 magnitude (m_b) 6.5 event. Because all three events were close together in time and space, the potential for recurrence and the recurrence interval for such earthquakes were difficult to estimate. By extending the history of south Puget basin subcrustal events, the 1882 earthquake improves our ability to evaluate the likelihood of similar events in the future.

There are a great number of sources of information on historic Washington earthquakes yet to be studied. Review of other catalogs and data sources will no doubt improve upon our understanding of the 1882 earthquake as well as other historic events.

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Table 1. Extract from the Modified Mercalli Intensity scale developed by Wood and Neumann (1931) with references to the older Rossi-Forel scale. (See p. 9-10.)

IV. Felt indoors by many, outdoors by few.
Awakened few, especially light sleepers. Frightened no one, unless apprehensive from previous experience.
Vibration like that due to passing of heavy, or heavily loaded trucks.
Sensation like heavy body striking building, or falling of heavy objects inside.
Rattling of dishes, windows, doors; glassware and crockery clink and clash.
Creaking of walls, frame, especially in the upper range of this grade.
Hanging objects swung, in numerous instances.
Disturbed liquids in open vessels slightly.
Rocked standing motor cars noticeably.
Equivalent to V on the Rossi-Forel scale.

V. Felt indoors by practically all, outdoors by many or most; outdoors direction estimated.
Awakened many, or most.
Frightened few—slight excitement, a few ran outdoors.
Buildings trembled throughout.
Broke dishes, glassware, to some extent.
Cracked windows—in some cases, but not generally.
Overturned vases, small or unstable objects, in many instances, with occasional fall.
Hanging objects, doors swing generally or considerably.
Knocked pictures against walls, or swung them out of place. Open or closed doors, shutters, abruptly.
Pendulum clocks stopped, started, or ran fast, or slow.
Moved small objects, furnishings, the latter to slight extent.
Spilled liquids in small amounts from well-filled open containers.
Trees, bushes, shaken slightly.
Equivalent to V-VI on the Rossi-Forel scale.

VI. Felt by all, indoors and outdoors.
Frightened many, excitement general, some alarm, many ran outdoors.
Awakened all.
Persons made to move unsteadily.
Trees, bushes, shaken slightly to moderately.
Liquid set in strong motion.
Small bells rang—church, chapel, school, etc.
Damage slight in poorly built buildings.
Fall of plaster in small amount.
Cracked plaster somewhat, especially fine cracks chimneys [sic] in some instances.
Broke dishes, glassware, in considerable quantity, also some windows.
Fall of knick-knacks, books, pictures.
Overturned furniture in many instances.
Moved furnishings of moderately heavy kind.
Equivalent to VI-VII on the Rossi-Forel scale.

VII. Everybody runs outdoors.
Damage negligible in buildings of good construction; slight to moderate in well-built ordinary structures.
Considerable damage in poorly built or badly designed structures. Some chimneys broken.
Noticed by persons driving cars.
Equivalent to VIII⁻ on the Rossi-Forel scale.

VIII. Damage slight in specially designed structures, considerable in ordinary substantial buildings with partial collapse, great in poorly built structures.
Panel walls thrown out of frame structures.
Fall of chimneys, factory stacks, columns, monuments, walls.
Heavy furniture overturned.
Sand and mud ejected in small amounts.
Changes in well water.
Persons driving cars disturbed.
Equivalent to $VIII^{+}$-IX on the Rossi-Forel scale.

APPENDIX 2

T.E. Johnson, R.S. Ludwin, and A.I. Qamar, 1992 (in press)

The Central Cascades Earthquake of March 7, 1891

Washington Geology

The central Cascades earthquake of March 7, 1891

by T.E. Johnson, R.S. Ludwin, and A.I. Qamar
Geophysics Program, University of Washington

While reviewing newspaper accounts of earthquakes in Washington and Oregon prior to 1928, we have discovered evidence that an earthquake on March 7, 1891 (7:40 PM local time) was much larger than previously thought. Before our investigation, this earthquake was known to have been felt only at the lighthouses on Smith Island and at Admiralty Head (Bradford, 1935; Townley and Allen, 1939). It is not included in the Earthquake History of the United States (Coffman and vonHake, 1973), which lists earthquakes with Modified Mercalli Intensities (MMI) V or greater. The Modified Mercalli Intensity scale was developed by Wood and Neumann (1931) to measure felt earthquake effects (reprinted in Washington Geology, 1991).

Through old newspaper reports and a diary entry, we have evidence that the earthquake had intensities as high as VI, was felt on both sides of the Cascades, and did some minor damage. Figure 1 shows our estimate of the felt area of the 1891 earthquake, and the distribution of Modified Mercalli intensities (Wood and Neumann, 1931; see also Washington Geology, June 1991) of IV and V-VI were experienced.

The apparent focus of the 1891 earthquake is east of Seattle in the central Cascades, close to Mt. Si, where a number of earthquakes have been located in a tight spatial cluster since instrumental coverage began in 1970, and felt earthquakes of magnitudes 5.6 (Zollweg and Johnson, 1989) and 4.3 (personal commun., Tom Yelin, USGS; coda duration on the Longmire seismic station) occurred in 1945 and 1963, respectively. For the 1891 earthquake, which had a total felt area of approximately 36,000 square kilometers, we estimate a magnitude of 5.0 (Toppozada, 1975).

Acknowledgements

This research was funded under USGS grant 14-08-0001-G1510 on Earthquake Intensities. We thank Betsy Detroit for contributing a copy of her grandmother's diary entry, and Chris Trisler for calling our attention to this earthquake.

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Data for Re-evaluation of the 1891 earthquake:

MODIFIED MERCALLI INTENSITY V-VI

Roslyn

"The shock was severe enough to rock houses, stop clocks and shatter crockery. Disturbance caused vertigo and nausea in several persons. Everybody rushed to the street. (Seattle Post-Intelligencer, March 8, 1891)

Snoqualmie

"heavy shock... The rocks from Mount Si came rolling down and made a loud rumbling noise, which was plainly heard." (Seattle Telegraph, March 8, 1891)

MODIFIED MERCALLI INTENSITY IV

Eagle Gorge

"Eagle Gorge felt three severe shocks." (Seattle Telegraph, March 8, 1891)

Snohomish

"in a number of Snohomish stores the shelves with their contents were given a good shaking up". (Snohomish Daily Sun, March 9, 1891)

Hot Springs

"A lively shock... Things were shaken up, chandeliers swayed and crockery rattled." (Seattle Post-Intelligencer, March 8, 1891)

"The hotel and depot shook lively. No damage done." (Seattle Telegraph, March 8, 1891)

Orting

"People rushed out to find the cause of the disturbance." (Tacoma Daily Ledger, March 8, 1891)

Puyallup

"Light shocks were also felt in ... Puyallup and surrounding villages." (Seattle Telegraph, March 8, 1891)

Seattle

"The effect was felt most severely by those in the upper floors of the six and seven story buildings downtown. There the chandeliers swayed sharply and men standing up found it difficult to keep their feet. (Tacoma Daily Ledger, March 8, 1891)

"a vase in her room nearly fell from the mantle over the fireplace..." "the pencil of a POST-INTELLIGENCER reporter who was writing made a crooked mark, as if someone had pushed his arm..." "the stores and dwellings rocked to and fro, and hanging lamps swung backward and forward like the pendulum of a clock..." (Seattle Post-Intelligencer, March 8, 1891)

Tacoma

"The bookkeeper noticed the lamp moving, then found that his hand was traveling in a wavering line over the paper. Accompanying this was a feeling that he was moving. The rows of hanging lamps which hang on both sides of the room swung quite violently from one side to another. The lighter of the wares jarred against one another." (Tacoma Daily

Ledger, March 8, 1891)

"Several hundred felt the shock but thought it was due to blasting..." (Seattle Post-Intelligencer, March 8, 1891)

"No damage was done, although articles in china and glassware stores rattled a trifle, and occupants of sixth floors rushed from rooms fearing the structures were about to topple" (Oregonian, March 8, 1891)

MODIFIED MERCALLI INTENSITY I-III

Ellensburg

"The shock was light one and a great many failed to notice it." (The Ellensburg Capital, March 12, 1891)

Not reported felt in the "Ellensburg Daily Localizer"

Monitor

"The house trembled and shook" (From the diary of Helen Margaret Parrish, March 8, 1891; copy contributed by her granddaughter, Betsy Detroit)

Admiralty Head Lighthouse

A light shock. (Bradford, 1935)

Smith Island Lighthouse

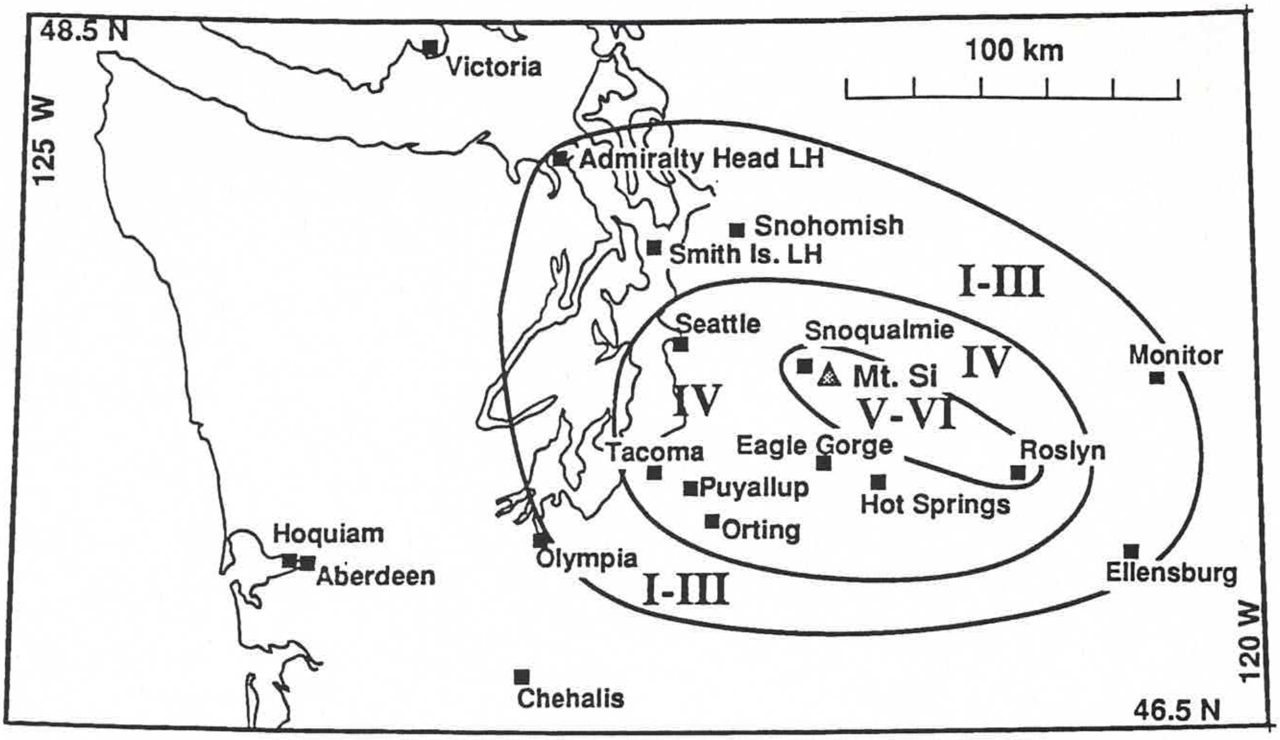
A slight shock. (Bradford, 1935)

NOT REPORTED FELT

The earthquake was not reported felt in the the "Aberdeen Herald", the "Hoquiam Washingtonian", the "Chehalis Bee", or the "Washington Standard", a weekly published in Olympia; nor was it reported felt in the Victoria, British Columbia "Daily Colonist".

FIGURE CAPTION

Figure 1. Estimated isoseismal contours for areas which experienced modified Mercalli intensities V-VI, IV, and I-III in the March 7, 1891 earthquake. Lighthouses are marked "LH", and the location of Mt. Si is indicated as a triangle.


48.5 N
125 W
Victoria
100 km
Admiralty Head LH
Snohomish
Smith Is. LH
I-III
Seattle
Snoqualmie
Mt. Si
IV
Monitor
IV
V-VI
Tacoma
Eagle Gorge
Roslyn
Puyallup
Hot Springs
Orting
Hoquiam
Aberdeen
Olympia
I-III
Ellensburg
120 W
Chehalis
46.5 N

APPENDIX 3

R.S. Ludwin, R. Ellsbury and A.I. Qamar, 1992 (submitted)

Improving and correcting earthquake catalogs using an electronic scrapbook; Rediscovering lost earthquakes, improving estimates of magnitudes and locations, and debunking false reports,

Submitted to TERRA Nova, c/o Blackwell Scientific Publications Ltd., Osney Mead, Oxford, England OX2 0EL

Improving and correcting earthquake catalogs using an electronic scrapbook; Rediscovering lost earthquakes, improving estimates of magnitudes and locations, and debunking false reports

by

R.S. Ludwin, R. Ellsbury, and A.I. Qamar

Abstract

Accurate catalogs of historical seismicity are essential for estimating recurrence intervals and evaluating earthquake hazards. Existing historic catalogs summarize and interpret macroseismic observations based on the limited information available to the cataloger. These catalogs are generally imperfect, and have misinterpretations, errors, and omissions which can only be corrected by review of underlying source materials. The reasons for changes to existing catalogs must be adequately documented to be credible. It is also desirable to compile the original source material in an accessible format both to preserve the information, and to prevent duplication of effort. For these reasons, we have designed and are implementing a prototype PC database which maintains the original historical material, and also provides a catalog of brief event summaries.

The model for our database is a **Summary Cardfile** which presents a summary of each earthquake, much like existing earthquake catalogs, together with an underlying **Scrapbook** of information for each event. The historical data we are using to design and develop the prototype database are macroseismic observations of historical earthquakes in Cascadia (Washington, Oregon, and British Columbia) prior to 1930. However, the database should be equally useful for other areas.

Introduction

Earthquakes result from geologic processes which continue over hundreds or thousands of years. These processes give rise to repetitive earthquakes, although recurrence intervals may vary greatly, or be large in terms of human time. An accurate record of approximate locations and magnitudes of past earthquakes provides insight into tectonic processes, and is essential for estimating earthquake hazards and the recurrence intervals of damaging earthquakes. How completely the history of seismic activity can be documented depends largely on the availability of written reports describing macroseismic earthquake effects. The possibility of obtaining such reports depends on the history of the area. The varied and complex, though short, history of Cascadia provides examples of many different cataloging difficulties: macroseismal accounts may be found in many different formats, languages, and locations; accounts may be difficult or impossible to locate; and in the numerous catalogs that may already exist, some earthquakes have certainly been left out, while others have been extensively investigated. Even for well documented earthquakes, there may be a lack of consensus on the earthquake's size and location.

Aside from the apocryphal account of Juan de Fuca, (said to have claimed the discovery (in 1592) of a sea passage, located between 47 and 48 degrees north latitude, joining the Pacific and Atlantic Oceans) and a few brief visits to the coast in the mid 1700s, the first European explorers arrived around 1790 and settlers around 1845. Newspapers began publication around 1850. The native cultures of Cascadia kept no written history, and much of their oral tradition is thought to have been lost with the introduction of European culture and the decimation of the indigenous population by European diseases. Early explorers spoke and wrote in a variety of languages, including English, Spanish, Russian, and French. Cascadia spans an international boundary which was not agreed upon until 1846. The population then expanded rapidly, with a geographic distribution that varied greatly over time, as railroads supplanted overland trails. Prior to 1928, reports of earthquakes were obtained either from newspapers or from weather observers, lighthouse keepers, or other observers or correspondents. Centralized collection of earthquake observations in the United States began in 1928 (Coffman and von Hake, 1973).

A dozen or more catalogs of historic Cascadia earthquakes already exist. These catalogs cover various geographical areas and time periods, and overlap considerably. They usually consist of a brief (one line to one page) commentary on each earthquake. Most catalogers had limited access to original accounts of macroseismic effects, and the original material is seldom included in the catalogs and may not even be directly referenced. The most recent catalogs also include a formatted summary line useful for computer manipulation containing estimates of occurrence time, magnitude, and geographic coordinates of the earthquake. Although these summaries are very useful, they are usually derived from other reports or catalogs which have been selected and interpreted by the author. Not only may interpretations change as understanding of tectonics evolves, but potentially important information may not be known, or may be overlooked or ignored in an interpretation, leading to errors in estimating the size or location of the earthquake. While some catalog errors have been recognized and corrected, errors may also be copied from one catalog to another, and even a corrected error can be reintroduced if the correction is poorly documented. Even when considerable source material is available, opinions may differ on the location or size of the earthquake, and most catalogs offer only the values preferred by the cataloger. By compiling underlying source material with catalog entries, previously unknown earthquakes may come to light, estimates of locations and magnitudes may be an improved or corrected, and differences of opinion between catalogers are more readily appreciated.

Using Original Materials

In Cascadia, newspaper accounts of macroseismic effects are often the original sources of information for a historic earthquake. In some instances a single account contains enough information to produce an isoseismal map (Thenhaus, 1978). Although some original materials have undoubtedly been lost or destroyed, many old newspapers and documents have been preserved on microfilm and are widely available.

The main advantage of original source materials are that they are accounts of the earthquake given by eyewitnesses, and may contain information not previously considered. Macroseismic data, observations of earthquake effects, are the only information for these earthquakes. Prior to about 1900, all information on Cascadia earthquakes is based on accounts of observers, and macroseismic observations remain important at least until the 1960s. Examining the verbatim original material is a check on the interpretations given in existing catalogs. For some events, new material not considered in the existing catalogs can be found which significantly alters the interpretation of that event (Ludwin and Qamar, 1991; Johnson, Ludwin, and Qamar, 1992)

The disadvantages in using original material are that sources may be difficult or impossible to locate, contain errors, or be incomplete. Original manuscripts such as diaries may be handwritten and difficult or impossible to decipher. Once acquired, the original material may be lengthy and possibly unsuitable for photocopying, making it difficult to share or prepare for publication. Also, verbatim accounts of an earthquake must be coordinated with the interpretations of that event in existing catalogs. Organizing the information, maintaining updated lists of summary information, and documenting changes to summary information are time consuming and error-prone tasks.

Scrapbooks and cardfiles were kept by many early investigators of macroseismic observations. The scrapbook format is useful because it accommodates information from any source; either summary cards, catalog entries, or verbatim original accounts; while cardfiles provide useful summaries of the events. While summary cards can usually be adapted to fit into a computer-readable format, they are interpretations of underlying material. The scrapbook format, on the other hand, allows inclusion of all of the underlying material, but may be difficult to interpret. A scrapbook may also be difficult to search for specific information, and difficult to copy or prepare for publication.

The Database as an Electronic Scrapbook and Cardfile

Our prototype electronic **Scrapbook** and **Summary Cardfile** use a PC database, and improve upon their paper counterparts in several respects. Each source retains its unique identity, and is not cut up and spread around as it would be in a paper scrapbook. In addition, all accounts of an earthquake can be grouped together, so that a comprehensive report of all the material for an earthquake can be produced. Preferred summary information can be selected from among the available sources, and stored in an electronic **summary card** which identifies the **source record** which contributed each piece of summary information (location, depth, magnitude). Searches of the electronic scrapbook and cardfile can be readily carried out, and reports can be prepared in formats compatible with word processing programs or electronic mail.

The difficulty in creating a database suitable for macroseismic earthquake observations is that the system must be flexible enough to accommodate a very wide variety of information, while remaining simple enough to be usable. Our concept consists of three parts:

1) A **Scrapbook**, which contains numerous verbatim **Source Records** (newspaper clippings, catalog or diary entries; paragraphs from books, articles, or theses; or any type of original source material); This is supplemented by three subtables; a tabulated source subtable which we call the *Work subtable* which copies information from the **source record** into formatted fields, a *Reference subtable* which includes all references given in the **source record**, and a *Keyword subtable* for tabulating keywords in the **source record**. Table 1 shows the data base field definitions used for the **Scrapbook** (Table 1a) **source records** and *Work, Reference,* and *Keyword subtables* (Table 1b, 1c, and 1d). Throughout the text we refer to the **Scrapbook**, the **Summary cardfile**, and their respective individual records (**source records** and**summary cards**) in bold type, and to particular elements of the data base as given in Table 1 in italic type. Subtables are capitalized, while individual elements are all lower case.

2) A **Summary Cardfile**, which gives summary information for each earthquake. Table 2 shows the data base field definitions used for the **summary card**. A *Related Events subtable* is included for the purpose of cross-referencing earth-

quakes that form part of a sequence.

3) An intermediate section which allows the **Scrapbook source records** to be connected to an earthquake **summary card** in the **Summary Cardfile**, and which allows the best summary information for that earthquake to be selected from the **Scrapbook source record** *Work subtable*.

The Scrapbook

In the **Scrapbook**, each individual earthquake description forms a **source record**. In Cascadia, the basic material for the **Scrapbook** is a dozen or more earthquake catalogs, with each catalog divided into many entries describing individual earthquakes. For these catalogs, each entry becomes a **source record**. Table 1a gives the fields available for the **source record**. For earthquake descriptions that are not from catalogs, the **source record** may hold a piece of independent source material; such as a newspaper article or a diary entry. The main part of each **Scrapbook source record** is the verbatim text of the newspaper account, diary entry, or catalog source. This text is stored in the database in a "Memo" type field, which can be of any length. (We are using a database called "FoxPro 2.0" which allows "Memo" fields of arbitrary length.) The **source record** also gives the source reference and type (e.g. catalog, newspaper, journal article), the *author event number* (i.e. the number given to that event in the original catalog), and some Yes-or-No flags for several types of information. Each **source record** has a unique number (*srec*), used to identify it within the data base.

Selected information from the **source record** is tabulated in the *Work subtable*, which is time-oriented. Table 1b describes the fields defined in the *Work subtable*. Time is a crucial quantity which is usually included in every earthquake description. Each verbatim **source record** is accompanied by one or more time-oriented entries in the *Work subtable*. An important feature of the *Work subtable* is that although many of the **source records**, such as entries from old catalogs, already represent interpreted accounts; no further interpretation takes place within the *Work subtable*. Only information which is explicitly given in the account is used.

For example, intensities are only tabulated if they are expressly given in the account. Each *Work subtable* entry lists a time, plus the location, depth, magnitude, and/or intensity information that is explicitly given with that time in the **source record**. Time may be given on a 12 or 24 hour basis, or as local, standardized, or Greenwich time. No conversions are done when the times are placed in the *Work subtable*. The *Work subtable* is formatted, which makes it easy to index and search, and the format is relatively simple and flexible enough to accommodate the wide variety of information which may be contained in a single **source record**. For example, a **source record** may give multiple times (either many different times for a single shock at different places, or times of several separate shocks), multiple accounts at a single time (such as the earthquake being felt at many places at a single time), or multiple estimates of earthquake intensity. The multiple entries of the *Work subtable* can accommodate all of these cases.

Each entry in the *Work subtable* can be treated as an independent report. However if the verbatim **source record** gives many pieces of information associated with a single time, all referring to the same earthquake, the *entry type* flag allows entries to be grouped together. When the time comes to collect all of the accounts of an earthquake together in the **Summary cardfile**, this reduces the number of entries which have to be sorted through. Example 1 illustrates the use of the *entry type*. This flag which denotes whether a *Work subtable* entry is the first at a given time (*entry type* set to "F"), or has been grouped with other entries at the same time (*entry type* set to "N"). The *entry type* is used at the discretion of the person reviewing the **source record**, depending on its contents; unassociated entries which have identical times can all be assigned *entry type* "F".

Example 1 is edited real information for a Cascadia felt event. Six separate **source records** (*srec* numbered 1 to 6) were found for this earthquake. This example does not reflect the usual data entry procedure, in that it is multiple entries for a single earthquake. A more likely procedure would be to enter and tabulate all earthquake data from each catalog before beginning another catalog One problem with catalogs is that the intensity scale used (e.g. Modified Mercalli or Rossi-Forel) is usually the same throughout the catalog, but is often not referenced in each individual entry. Likewise, time may consistently given as GMT without individual labeling. References are often given in an abbreviated or coded form. The lack of complete information with each entry is a serious drawback in paper scrapbooks; the electronic version addresses this by providing fields to label each entry. Entering each catalog in its entirety ensures that the fields are filled out correctly.

The structure of the first section of Example 1 corresponds to the definitions given in Table 1a; verbatim entries are given in the *smem* field, source reference short name and type in the *sid* and *stype* fields, and the reference citation in the *pub* fields. Accounts 1 and 4 are formatted summaries; while accounts 2, 3, 5, and 6 are descriptive. The second part of Example 1 corresponds to the fields defined in Table 1b, and shows how the information given in the **source records** is tabulated in the *Work subtable.*

Discussing each entry in order: Account 1 is in an abbreviated format and includes two magnitudes and two abbreviated references "EQH" and "RAS2"; the full references can be entered in the *Reference subtable* (not included in this example). Because the two magnitudes are quoted in the **source record**, we provide two entries in the *Work subtable* which share a date, time, and location and are linked by the *entry type.* In Example 1 Part 2 we have placed quote marks in the date and fields of those entries where the *entry type* is set to "N" (not-first). This is to highlight the accounts that are grouped together; within the data base the fields contain a date and time identical to the linked entry where the *entry type* is set to "F" (first). The second account gives three different times; each time is given as a first or "F" *entry type.* The second paragraph of this account gives multiple felt places at a single time; in part 2 of the example, each felt place is provided a separate entry in the *Work subtable*, and after the first entry each has the *entry type* set to "N". The third account mentions three earthquakes which occurred at other times, and these are entered into the *Work subtable* and flagged as "M" for "mentioned only" in the *qcom* field. This field is potentially useful for locating uncataloged events. The fourth **source record**, from a catalog, gives an intensity, V, and a cryptic reference, 1, which actually represents the "EQH" source given in Account 1. The full reference can be entered into the *Reference subtable* and is more informative. The intensity scale used by this author is Modified Mercalli, although it is not explicitly given. Accounts 5 and 6 give intensities in the Rossi-Forel scale, as described in the source articles, and less-cryptic references. Account 5 mentions two places; the first is assigned *entry type* "F", while the second becomes *entry type* "N" and will be carried along with the first.

The final field in each *entry type* "F" entry in part 2 of the example (see also Table 1b) is the *event number.* This field links the *Work subtable* entries to individual **Summary Cardfile** events. Although the event number is actually part of the **Summary Cardfile** (because it is an interpretation), it is stored in the *Work subtable.* This allows us to easily locate entries in the *Work subtable* that are not assigned to events. In practice, event numbers would be assigned after *Work subtable* entries had been filled out for every **source record,** and sorted into time order. Keywords may be entered in the *Keyword subtable* (not included in the example).

The Summary Cardfile

The **Summary Cardfile** is the cataloger's interpretation of the **Scrapbook source records** and the *Work subtable* entries. Table 2 gives the field specifications for the **Summary Cardfile.** Each **summary card** gives the best estimate of the time, location and magnitude of one event. In addition the **summary card** contains a comment field, an event type specifier, and a *Related events subtable* which is a cross-reference index to related events. The **source records** underlying the **summary card** can be accessed through the *event number* field in the *Work subtable.*

Creating the **Summary Cardfile** requires at least three passes through the data. The first pass is to identify *Work subtable* entries pertinent to each event. Each earthquake will usually have several **source records** associated with it;

perhaps representing a mixture of catalog entries and newspaper accounts. The *Work subtable* entries can be sorted into consecutive time order according to time, and presented to the cataloger on the computer screen with each time labeled with the **source record** name and number. By looking at the times and sources, a decision can be made as to which times should be referenced to a particular earthquake. This is not always completely straightforward, since the times reported for a single earthquake may be based on when the earthquake was felt at different locations (discrepancies of half an hour or more are not uncommon, especially for earthquakes before the establishment of standardized time). In addition, discrepancies between different sources occur, and errors exist in both catalogs and newspaper accounts. Sorting out which time goes with which earthquake is an interpretive process. The purpose of the *entry type* "F" or "N" (Example 1, part 2; discussed above) is to minimize the number of separate pieces of information. When all of the **source records** have been entered into the *Work subtable*, and the *Work subtable* entries are sorted by time and presented in the **Summary Cardfile** for grouping by event, only *Work subtable* entries which have *entry type* "F" are shown; "N" entries follow their associated "F" entry.

The second pass is to select a preferred time, location, magnitude, and depth from among those offered in the source subtables for the times specified for that event, and to enter an *event comment* if desired. The *event comment* can be used for any sort of commentary on the event; for example to justify the selection of the preferred earthquake time, location, or magnitude, to comment on discrepancies or errors in the original entries, or to suggest additional information which might be sought. The *event type specifier* is useful for flagging accounts of non-seismic phenomena (e.g. meteorites, volcanic activity, and explosions) or undocumented events (where an event summary card has been introduced in a modern catalog, but is undocumented in earlier catalogs, suggesting that original material should be sought to confirm the event.

If the earthquake time, location, or magnitude given in the existing **Scrapbook source records** are unsatisfactory, and the cataloger believes that better estimates can be made, a new **Scrapbook source record** can be created which gives a new location, magnitude or depth. In the case of Example 1, the newspaper accounts give information sufficient for the assignment of intensities at several new sites. An additional **source record** might be added to assign intensities, at those places, and to compute a new magnitude based on an estimate of the felt area of the earthquake. The "verbatim" **source record** memo field in this case is a commentary stating the time of the earthquake and the new magnitude estimate, stating the newly assigned intensities, explaining how the magnitude and intensity were obtained, and referencing the newspaper accounts. The time subtable is filled out using this information, and then the new magnitude estimate is available for selection as the preferred magnitude in the **Summary Cardfile**. The new source record must be properly identified (by investigator) in the appropriate fields *sid*, *stype*, *pub*, (Table 1a). Only information tabulated from **source records** can be referenced in the **Summary cardfile.**

The final pass is to select and specify any related events: foreshocks, aftershocks etc. After the database has been filled, a search can be done on any quantity which has been entered in a formatted field, and a wide variety of reports can be generated. Reports can be generated by source, either with or without subtables; by event, in a **summary card** format with a list of **source record** references, or with the full verbatim text of the **source records**, or as one-line summaries for maps.

Discussion

Compiling and storing original macroseismic accounts will reduce duplication of effort by succeeding generations of seismologists. The existence of a centralized place to store macroseismic accounts makes it worthwhile to go to greater lengths to discover such accounts, for example to canvass libraries for newspaper indices, or to ask historical and genealogical societies for diaries or other material.

In any practical cataloging effort, the temporal and geographical limits of the catalog must be restricted. These may reflect the tectonic setting, or be limited by political boundaries. Ideally, one cataloger will be responsible for each area, and catalogers from adjacent areas will cooperate to provide the best coverage of events near the boundaries. Our prototype database will cover earthquakes with epicenters in Washington, Oregon, and southern British Columbia prior to 1930. Other events are also included if they were felt within the area.

Because the database is capable of continuous evolution, it is advisable not to distribute the database until it is in a stable and moderately complete version, and then to distribute an unchangeable version which can be properly referenced. The cataloger should accumulate corrections and new material until the next version is issued.

For Cascadia, many old newspapers are available on microfilm. We have easier access, and in many cases a broader selection of material available to us today than did earlier catalogers. At the same time, we have found indices which cite issues of newspapers that are missing from the microfilmed records; evidence that some earlier material has been lost or destroyed. Using another modern technology, published catalogs can be readily converted into computer files by scanning. Although a considerable amount of preparation is required to put the source material into the data base, and to formulate the **summary cards**, much of the work can be done by students or hourly workers. Any meticulous person, with a small amount of training, can enter newspaper accounts and old catalogs into the computer and proofread. We have used undergraduate students for this work. Even filling out the time-oriented subtable is a simple task, as no interpretation is required. A student or hourly worker, particularly after the experience of entering in the source material, can even do a credible first pass at making the **Cardfile** by linking together all accounts of an earthquake. A greater degree of familiarity with seismology and seismicity is required to select a preferred time, location, magnitude, etc. In many cases an appreciation for the historical setting is also required.

Conclusions

Improvements in data base software, in particular the availability of character fields of unlimited length, make this earthquake database concept feasible; while the implementation of powerful databases on personal computers has lowered hardware and software costs. Scanning technology has allowed us to convert printed catalogs into computer files. The limitation of the database is that all pertinent information must be tabulated. Only tabulated information can be searched. The **Electronic Scrapbook and Cardfile** prototype attempts to provide enough structure so that information can be consistently and correctly tabulated, while remaining reasonably simple and flexible enough to accommodate the wide variety of information contained in catalog entries and macroseismic accounts.

Using a database to store and index earthquake catalogs and macroseismic descriptions has many advantages. The original material is retained unaltered, but is far more accessible, and can be searched for a wide variety of information. With microfilming of newspapers, and indexing of both newspapers and other historical materials we may actually have better access to original macroseismic accounts than earlier investigators. However, old documents deteriorate, and some have been lost. Timely compilation and indexing will preserve existing macroseismic information, expose substantive differences of opinion, help locate uncataloged earthquakes, correct catalog errors, and prevent duplication of effort by subsequent generations of researchers. A more accurate catalog will provide improved estimates of recurrence intervals and better earthquake hazard evaluation.

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TABLE 1A: VERBATIM SOURCE RECORD- INFORMATION FROM SOURCE

FIELD	NAME	TYPE	DESCRIPTION
* **Source memo**	smem	memo	**Verbatim Account**
Source record number	srec	n6	
Source ID	sid	c5	Short Name for Source
Source type	stype	c1	C: Catalog, J: Journal, N: Newspaper, D: Diary, L: Letter, O: Other Sources, T: Thesis, F: Open file report, R: Technical report, P: Personal communication I: Investigation (cataloger's research)
Instrumental location	inst	L	Y or N
Extensive intensity Infor.	int	L	Y or N
Author event number	autherno	n5	(If given)
Foreshocks	fore	L	Y or N
Aftershocks	aft	L	Y or N
Isoseismal map	iso	L	Y or N
References to other events	ref	L	Y or N
Publication	pub	c255	Book Reference, Newspaper Name, etc.
Pub. Place	pubpl	c25	for Newspapers
Pub. details	pubde	c50	Issue, Vol., Pg. Column, etc.
Pub. date	pubda	date	Year, Month, Day

TABLE 1B: TIME-ORIENTED WORK SUBTABLE

FIELD	NAME	TYPE	DESCRIPTION
Table record number	strec	n6	
Source record number	srec	n6	
Source type	stype	c1	C: Catalog, J: Journal, N: Newspaper, D: Diary, L: Letter, O: Other Sources, T: Thesis, F: Open file report, R: Technical report, P: Personal communication.
Entry Type	entype	c1	F-first at this time; N-not first at this time
Mention Type	qcom	c1	M: mentioned only
Year	yr	c4	
Month	mo	c2	
Day	da	c2	
Hour	hr	c2	
Minute	mi	c2	
Second	se	c6	
AMPM	ap	c1	Blank, A or P
Time type	tt	c1	G: GMT, P: PST, D: DST, L:.Local, U: Unknown
Latitude	lat	n6.3	
Latitude type	lattype	c1	N or S
Longitude	long	n6.3	
Longitude type	longtype	c1	E or W
Lat./Long. precision	prec	n3.1	
Depth	depth	n6.2	
Depth units	depthu	c1	K or M
Depth Precision	depthprec	n3.1	
Felt place name	feltpl	c40	
Felt place state, province	feltst	c4	
Intensity	Int	c5	0: not felt, I, II, III, IV, V, VI, VII, VIII, IX, X, XI, XII
Intensity type	Inttype	c2	MM or RF
Felt Area	far	c7	
Felt area intensity	fari	c5	I, II, III, IV, V, VI, VII, VIII, IX, X, XI, XII
Felt area units	faru	c1	K or M
Magnitude	mag	n6.2	
Magnitude type	magtype	c5	FAR: Felt Area, IFR: Intensity Falloff Rate, MXI:Maximum intensity, ICO:Instrumantal Coda, Ims: Instrumental Ms: Imb: Instrumental Mb, Iml: Instrumental Ml
Magnitude comment	magcom	memo	

CARDFILE EVENT NUMBER FIELD:

Relating Tine-Oriented Subtable Entries To The Catalog Of Events

FIELD	NAME	TYPE	DESCRIPTION
Event Number	evrec	n6	

TABLE 2A: THE CARDFILE- A COMBINED AND CORRECTED CATALOG

FIELD	NAME	TYPE	DESCRIPTION
Event Number	evrec	n6	
Comments	evcom	memo	
Event type	evtype	c1	C: confirmed, U:Unreferenced, N: Non-earthquake, S: Spurious Event: D: Duplication S: Suspected Duplication
Sequence flag	sequ	c1	N: No, F: Foreshocks, A: Aftershocks,S: Sequence
Selections from the time-oreiented Work Subtable			
Source and Table record #s			
pref. time	**evtms**	**n6**	**srec:**Source record number for preferred time
	evtmst	**n6**	**strec:**-Table record number for preferred time
Source and Table record #s			
pref. lat./long.	**evlocs**	**n6**	**srec:**Source record number for pref. location
	evlocst	**n6**	**strec:**Table record number for pref. location
Source and Table record #s			
pref. depth	**evdeps**	**n6**	**srec:**Source record number for pref. depth
	evdepst	**n6**	**strec:**Table record number for pref. depth
Source and Table record #s			
pref. magnitude	**evmgs**	**n6**	**srec:**Source record number for pref. magnitude
	evmgst	**n6**	**strec:**Table record number for pref. magnitude
Source and Table record #s			
pref. intensity	**evins**	**n6**	**srec:**Source rec. number for pref. max.inten.
	evinst	**n6**	**strec:**Table rec. number for pref. max. inten.
Source and Table record #s			
pref. felt area	**evfas**	**n6**	**srec:**Source rec.number for pref. inten. area
	evfast	**n6**	**strec:**Table rec. number for pref. inten. area

TABLE 2B: RELATED CARDFILE EVENTS SUBTABLE (FORESHOCKS, AFTERSHOCKS)

FIELD	NAME	TYPE	DESCRIPTION
Event Number	evrec	n6	
Related Event Number	relrec	n6	

Example 1: Part 1: Six accounts of an earthquake in 1895

ACCOUNT 1: srec: 1
smem:
18950225124700.00 46.500-122.400 0.0, 4.33 EQH 4.30__RAS2
sid: DNAG
stype: C
pub: Decade of North American Geophysics, GSA, unpublished catalog of seismicity in Washington and Oregon, 1986.

ACCOUNT 2: srec: 2
smem: FELT AT OLYMPIA

Olympia, Wash., Feb. 25.-- The earthquake shock was felt here at 4:45 this morning. It was more remarkable for length of duration than for its severity.

Tacoma, Feb. 25.-- This morning's earthquake shock was plainly felt in Tacoma, on top of the hill, and at Edison, Sumner, Puyallup and Steilacoom a few minutes before 5 AM. The shock was felt at the insane asylum at Steilacoom more plainly that anywhere else. At Sumner and Puyallup people were awakened from sleep. A woman living in the north end was awakened by the second shock, which aroused her thoroughly, and made her feel seasick.

Oregon City, Feb. 25.-- The earthquake was distinctly felt here this morning at 4:46 o'clock. A number of people were awakened at that time without knowing what disturbed them, but many clearly recognized the shock as an earthquake. The shaking continued lively about six seconds, and then gradually ceased. No damage from it has been reported.

sid: Oreg
stype: N
pub: Oregonian
pubpl: Portland
pubda:02/26/1895
pubde: p. 3, col 2.

ACCOUNT 3: srec: 3
smem: THE EARTH TREMBLED.

A Slight Quake Visits Portland At 4:47 o'clock in the morning a slight earthquake shock was felt, and those who were awakened, or are light sleepers, experienced the tremor. The first shock was quickly followed by two others, each about three seconds in duration. Portland has several times been visited by earthquake shocks. The most severe one was on the afternoon of October 12, 1877, when several shocks followed each other in rapid succession. On February 21, 1892, several slight shocks were experienced in the evening, and on the afternoon of April 17, in the same year, three distinct shocks were also felt. The earthquake of yesterday is the first experienced in Portland for three years.

sid: Oreg
stype: N
pub: Oregonian
pubpl: Portland
pubda:02/26/1895
pubde: p. 5, col 4.

ACCOUNT 4: srec: 4
smem:
82 1895 Feb. 25 12:47 46.5 N, 122.4 W V 1
sid: RAS
stype: C
pub: Rasmussen, N.H., 1967, Washington State earthquakes 1840 1965, BSSA, V. 57, pp. 463-476.

ACCOUNT 5: srec: 5
smem: 1895 February 25. 4:47 a.m.
Tacoma, and points to the southward. Three shocks, intensity III; Green River Mines, intensity V.-F. G. Plummer, Tacoma. [See also Oregon.]
sid: T&AWA
stype: C
pub: Townley and Allen, 1939, Descriptive catalog of earthquakes of the Pacific coast of the U. S. 1769-1928, BSSA, V. 20, pp. 1-297.

ACCOUNT 6:srec: 6
smem: 1895 February 25. 4:47 a.m., standard time. III. Portland.
Portland: Three distinct shocks of earthquake were felt here early this morning.Each shock lasted about three seconds. The first occurred at 4:47.-San Jose Mercury, February 26, 1895. [See also earthquakes in Washington.
sid: T&AOR
stype: C
pub: Townley and Allen, 1939, Descriptive catalog of earthquakes of the Pacific coast of the U. S. 1769-1928, BSSA, V. 20, pp. 1-297.

Example 1: Part 2. Time -oriented *Work Subtable* for accounts in Part 1

SREC	STREC	STTYPE	ENTYPE	YR	MO	DA	HR	MI	AMPM	TT	SEC	LAT	LONG	FELTPL	FELTST	QCOM	INT	INTTYPE	MAG	MAGTYPE	EVNO
1	1	C	F	1895	02	25	12	47		G	00.00	46.5	122.4						4.33	MXI	78
1	2	C	N	•		•	•	•		•	00.00	46.5	122.4						4.30	MXI	•
2	1	N	F	1895	02	25	04	45	A	L				Olympia	WA						78
2	2	N	F	1895	02	25	04		A	L				Tacoma	WA						78
2	3	N	N	•	•	•	•		•	•				Edison	WA						•
2	4	N	N	•	•	•	•		•	•				Sumner	WA						•
2	5	N	N	•	•	•	•		•	•				Puyallup	WA						•
2	6	N	N	•		•	•	•	•	•				Steilacoom	WA						•
2	7	N	F	1895	02	25	04	46	A	L				Oregon City	OR						•
3	1	N	F	1895	02	25	04	47	A	L				Portland	OR						78
3	2	N	F	1877	10	12			P	L				Portland	OR	M					65
3	3	N	F	1892	02	21			P	L				Portland	OR	M					70
3	4	N	F	1892	04	17			P	L				Portland	OR	M					71
4	1	C	F	1895	02	25	12	47		G		46.5	122.4				V	MM			78
5	1	C	F	1895	02	25	04	47	A	L				Tacoma	WA		III	RF			78
5	2	C	N	•		•	•	•	•	•				Green River Mines	WA		V	RF			78
6	1	C	F	1895	02	25	04	47	A	P				Portland	OR		III	RF			78

- EVNO: Event Number
- MAGTYPE: Magnitude Type (MXI=Max. Intensity)
- MAG: Magnitude
- INTTYPE: Intensity Scale (MM=Modified Mercalli, RF=Rossi-Forel)
- INT: Intensity
- QCOM: Mention flag (M=mentioned only)
- FELTST: State where felt
- FELTPL: Place felt
- LONG: Longitude
- LAT: Latitude
- SEC: Seconds (if available)
- TT: Time Type (G=GMT, P=PST, L=Local, etc.)
- AMPM: A=AM, P=PM, or blank
- YR MO DA HR MI: Date: Year, month, day hour, minute
- ENTYPE: Entry Type: F=first at this time, N=not first
- STTYPE: Source Type: N=newspaper, C=catalog
- STREC: Table Record number: each source record can generate many *Work subtable* records
- SREC: Source Record Number: Identifies the six source records for this earthquake