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Hanford Quarterly Seismic Report - 97B Seismicity On and Near the Hanford Site, Pasco Basin, Washington, January 1, 1997 Through March 31, 1997

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SUMMARY

Hanford Seismic Monitoring provides an uninterrupted collection of high-quality raw and processed seismic data from the Hanford Seismic Network (HSN) for the U.S. Department of Energy and contractors. The staff also locates and identifies sources of seismic activity and monitors changes in the historical pattern of seismic activity at the Hanford Site. The data are compiled, archived, and published for use by the Hanford Site for activities ranging from waste management, Natural Phenomena Hazards assessments, and engineering design and construction. In addition, the seismic monitoring organization works with the Hanford Site Emergency Services Organization to provide assistance in the event of an earthquake on the Hanford Site.

The HSN and the Eastern Washington Regional Network (EWRN) consist of 41 individual sensor sites and 15 radio relay sites maintained by the Seismic Monitoring staff. Most stations and five relay sites are solar powered. The operational rate for the second quarter of FY97 for stations in the HSN was 97.23% and for stations of the EWRN was 99.93%.

For fiscal year (FY) 1997 second quarter (97B), the acquisition computer triggered two hundred and forth-eight times. Of these triggers three were local earthquakes: one in the pre-basalt sediments, and two in the crystalline basement. The geologic and tectonic environments are discussed in the report.

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Terms

BWIP	Basalt Waste Isolation Project
CRBG	Columbia River Basalt Group
UTC	Universal Time, Coordinated
DOE	U.S. Department of Energy
EWRN	Eastern Washington Regional Network
FY	fiscal year
GPS	Global Positioning System
HSN	Hanford Seismic Network
LIGO	Laser Interferometer Gravitational Wave Observatory
M_c	Coda Length Magnitude
M_L	Local Magnitude
PNNL	Pacific Northwest National Laboratory
RAW	Rattlesnake Mountain-Wallula Alignment
SMART	Seismic Monitoring Analysis and Repair Team
USGS	United States Geological Survey
WHC	Westinghouse Hanford Company

1.0 Introduction

1.1 Background

Seismic monitoring at the Hanford Site was established in 1969 by the United States Geological Survey (USGS) under a contract with the U.S. Atomic Energy Commission. In 1975 the University of Washington assumed responsibility for and expanded the network. In 1979 the Basalt Waste Isolation Program (BWIP) became responsible for collecting seismic data for the Site as part of site characterization. Rockwell Hanford Operations followed by Westinghouse Hanford Company (WHC), Geosciences Group, operated the local network and were the contract technical advisors for the Eastern Washington Regional Network operated by the University of Washington. Funding ended for BWIP in December 1988. Seismic Monitoring and the University of Washington contract were then transferred WHC's Environmental Division. Effective October 1, 1996, all of the Seismic Monitoring workscope, personnel, and associated contracts were transferred to the Pacific Northwest National Laboratory (PNNL[1]).

Seismic Monitoring is part of PNNL's Applied Geology and Geochemistry Group. The Seismic Monitoring Analysis and Repair Team (SMART) operates, maintains, and analyzes data from the Hanford Seismic Network (HSN), extending the site historical seismic database and fulfilling U.S. Department of Energy, Richland Operations Office requirements and orders. The SMART also maintains the Eastern Washington Regional Network (EWRN). The University of Washington uses the data from the EWRN and other seismic networks in the Northwest to provide the SMART with necessary regional input for the seismic hazards analysis at the Hanford Site.

1.2 Purpose

The SMART is tasked to provide an uninterrupted collection of high-quality raw seismic data from the HSN located on and around the Hanford Site. These unprocessed data are permanently archived. SMART also is tasked to locate and identify sources of seismic activity, monitor changes in the historical pattern of seismic activity at the Hanford Site, and build a "local" earthquake database (processed data) that is permanently archived. Local earthquakes are defined as earthquakes that occur within 46 degrees to 47 degrees west longitude and 119 degrees to 120 degrees north latitude. The data are used by the Hanford contractor for waste management activities, Natural Phenomena Hazards assessments and engineering design and construction. In addition, the seismic monitoring organization works with Hanford Site Emergency Services Organization to provide assistance in the event of an earthquake on the Hanford Site.

Pacific Northwest National Laboratory is operated by Battelle for the U.S. Department of Energy.

1.3 Documentation

SMART issues quarterly reports of local activity, an annual catalog of earthquake activity on and near the Site, and bulletins on special-interest local seismic events. The annual catalog includes the final quarterly report for the fiscal year. The SMART also provides information and special reports to other functions as requested. Earthquake information provided in these reports is subject to revisions if new data become available.

2.0 Network Operations

2.1 Monitoring Stations

The HSN and the EWRN combined have 41 sensor sites. Most sites are in remote locations and require solar panels and batteries for power. Sixteen sites are shared by both networks; the HSN uses 21 sites (Table 1 and Figure 1) and the EWRN uses 35 (Table 2 and Figure 2). The networks have 44 combined data channels because Gable Butte and Royal City are three-component sites, each consisting of one vertical, one north-south horizontal, and one east-west horizontal data channel. Both networks use 15 additional telemetry relay sites. All station data links pass through at least one of these relay sites. Some data links transit as many as three relay sites. The last section of the data link for all channels is commercial telephone lines. Three to eight channels are multiplexed per telephone line going to the Seismic Monitoring office in the 337 building. A major outage is considered to be a failure of the HSN data recording computer or three or more data channels.

Table 1. Stations Used for Location of Events

This table lists stations of the Hanford Seismic Network. The first column is the three-letter seismic station designator. This is followed by the latitude-north in degrees, minutes, and hundredth of minutes; the longitude-west in degrees, minutes, and hundredth of minutes; elevation above sea level in meters; and the full station name. An asterisk before the three-letter designator means it is a three-component station. The locations of the stations are all in Washington unless otherwise indicated; locations were derived from a Global Positioning Satellite System (GPS).

Station	Latitude Deg.Min.N	Longitude Deg.Min.W	Elevation (m)	Station Name
BEN	46N31.13	119W43.02	340	Benson Ranch
BRV	46N49.12	119W59.47	920	Black Rock Valley
BVW	46N48.66	119W52.99	670	Beverly
CRF	46N49.50	119W23.22	189	Corfu
ET3	46N34.64	118W56.25	286	Eltopia Three
*GBB	46N36.49	119W37.62	177	Gable Butte
GBL	46N35.92	119W27.58	330	Gable Mountain
H2O	46N23.75	119W25.38	158	Water
LOC	46N43.02	119W25.85	210	Locke Island
MDW	46N36.79	119W45.66	330	Midway
MJ2	46N33.45	119W21.54	146	May Junction Two
OT3	46N40.14	119W13.98	322	Othello Three
PRO	46N12.73	119W41.15	550	Prosser
*RC1	46N56.71	119W26.66	485	Royal City One
RED	46N17.92	119W26.30	366	Red Mountain
RSW	46N23.67	119W35.48	1,045	Rattlesnake Mt.
SNI	46N27.85	119W39.60	312	Snively Ranch
WA2	46N45.32	119W33.94	244	Wahluke Slope
WG4	46N01.85	118W51.34	511	Wallula Gap Four
WIW	46N25.76	119W17.26	128	Wooded Island
WRD	46N58.20	119W08.69	375	Warden

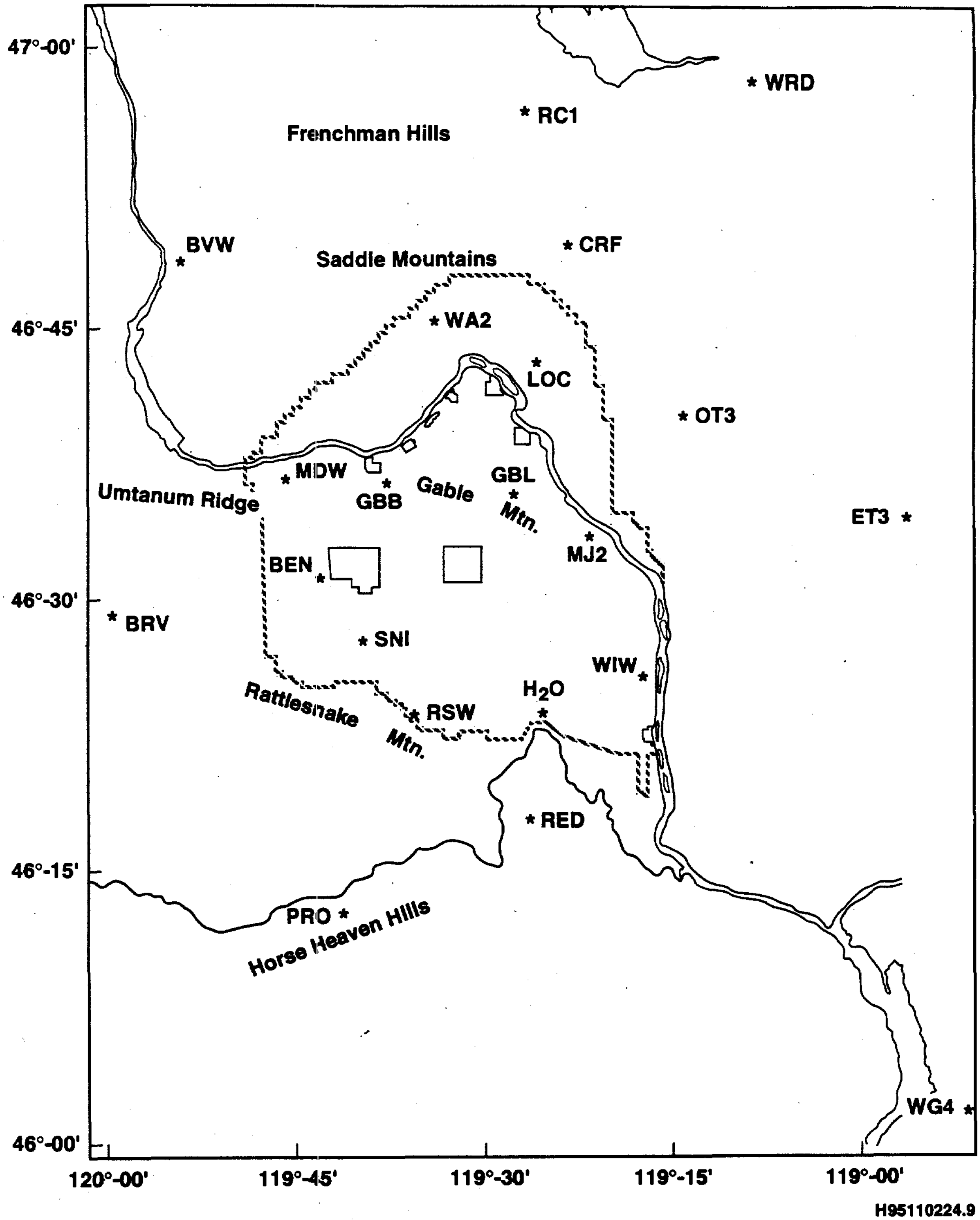

Figure 1. Locations of Seismograph Stations in the Hanford Seismic Network. (See Table 1 for exact locations.)

Table 2. Station Locations for the Eastern Washington Regional Network.

This table lists stations of the Eastern Washington Regional Network. The first column is the three-letter seismic station designator. This is followed by the latitude-north in degrees, minutes, and hundredths of minutes; the longitude-west in degrees, minutes, and hundredths of minutes; elevation above sea level in meters; and the full station name. An asterisk before the three-letter designator means it is a three-component station. The locations of the stations are all in Washington unless otherwise indicated; locations were derived from a Global Positioning Satellite System (GPS).

Station	Latitude Deg.Min.N.	Longitude Deg.Min.W.	Elevation (m)	Station Name
BRV	46N29.12	119W59.47	920	Black Rock Valley
BVW	46N48.66	119W52.99	670	Beverly Washington
CBS	47N48.26	120W02.50	1,067	Chelan Butte, South
CRF	46N49.50	119W23.22	189	Corfu
DPW	47N52.25	118W12.17	892	Davenport
DY2	47N59.11	119W46.28	890	Dyer Hill Two
ELL	46N54.58	120W33.98	789	Ellensburg
EPH	47N21.38	119W35.76	661	Ephrata
ET3	46N34.64	118W56.25	286	Eltopia Three
ETW	47N36.26	120W19.94	1,477	Entiat
GBL	46N35.92	119W27.58	330	Gable Mountain
LNO	45N52.31	118W17.11	771	Lincton Mt., Oregon
LOC	46N43.02	119W25.85	210	Locke Island
MDW	46N36.79	119W45.66	330	Midway
MJ2	46N33.45	119W21.54	146	May Junction Two
MOX	46N34.64	120W17.89	501	Moxee City
NAC	46N43.99	120W49.42	728	Naches
NEL	48N04.21	120W20.41	1,500	Nelson Butte
OD2	47N23.26	118W42.58	553	Odessa Two
OT3	46N40.14	119W13.98	322	Othello Three
PAT	45N52.92	119W45.14	262	Paterson
PRO	46N12.73	119W41.15	550	Prosser
*RC1	46N56.71	119W26.66	485	Royal City One
RSW	46N23.67	119W35.48	1,045	Rattlesnake Mt.
SAW	47N42.10	119W24.03	701	St. Andrews
SNI	46N27.85	119W39.60	312	Snively Ranch
TBM	47N10.20	120W35.88	1,006	Table Mountain
TRW	46N17.32	120W32.31	723	Toppenish Ridge
TWW	47N08.29	120W52.10	1,027	Teanaway
VT2	46N58.04	119W58.95	1,270	Vantage Two
WA2	46N45.32	119W33.94	244	Wahluke Slope Two
WAT	47N41.92	119W57.24	821	Waterville
WG4	46N01.85	118W51.34	511	Wallula Gap Four
WIW	46N25.76	119W17.26	128	Wooded Island
WRD	46N58.20	119W08.69	375	Warden
YA2	46N31.60	120W31.80	652	Yakima Two

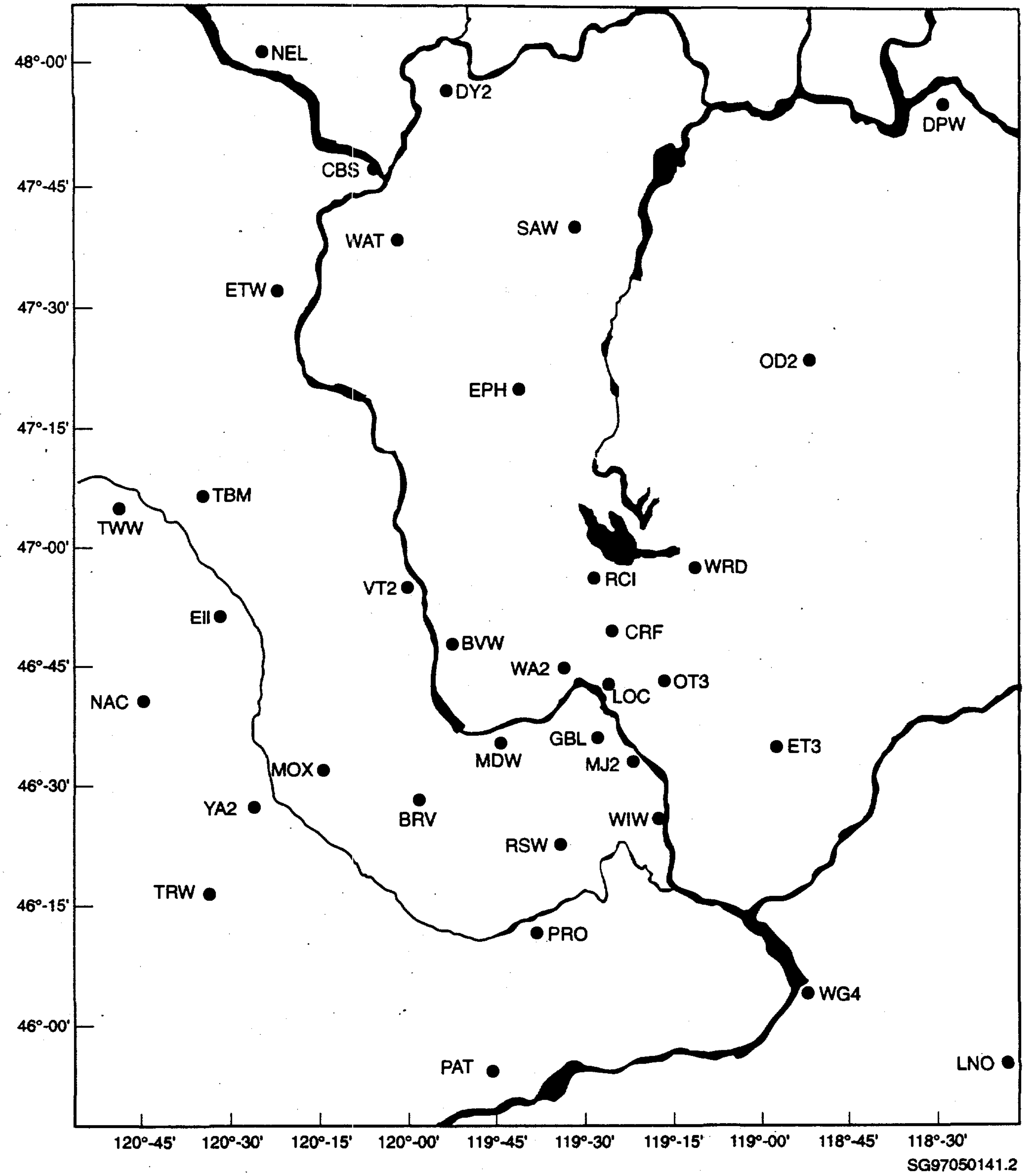

Figure 2. Locations of Seismograph Stations in the Eastern Washington Regional Network. (See Table 2 for exact locations.)

2.2 Station Maintenance

The HSN's maintenance records for the seismic sensor and relay sites are filed in the Seismic Monitoring office. Periods of major outage are addressed in this report. Table 3 shows the operational percentage time for each network. Winter conditions cause malfunctions due to icing of antennas, snow on solar panels, or long periods of heavy overcast. Access to some sites within the EWRN may be impossible during winter months because of travel restrictions or severe damage to access roads.

Table 3. Seismic Channel Operational Time (%).

Network	January	February	March	Second Quarter[a]	FY-97
Hanford	99.97	91.53	100.0	97.23	97.23
Regional	99.98	99.82	99.98	99.93	99.93

[a] This column is the percentage for the first quarter of FY 1997.

Notes: The Hanford Seismic Network's goal is 98%.
The Eastern Washington Regional Network's goal is 97%.
The quarter period is January 1, 1997 through March 31, 1997.

2.3 Data Acquisition

The data is recorded on a computer located in the 337 building. The Hanford Seismic Network is divided into subnetworks using weighted factors to minimize false triggers but still allows very small seismic events to be recorded. All events that trigger the acquisition computer are analyzed for complex events. Complex events are more than one earthquake or an earthquake contained within a record triggered by another source. Table 4 shows the number of each event type recorded during the second quarter (97B).

Table 4. Acquisition System Recorded Triggers

Event Type	Second Quarter	FY 1997	Remarks
Locals	3	9	Earthquakes within the area 46° - 47° north latitude and 119° - 120° west longitude
Regionals	48	72	Earthquakes surrounding Hanford within the range of 80 to 500 kilometers
Teleseisms	43	118	Earthquakes from around the world greater than 500 km in distance.
Artillery	146	177	Acoustical shock waves from the Yakima Training Center
Explosions	2	6	Confirmed blast, usually in borrow pits
Thunder	0	0	Shock waves and/or lightning induced electrical pulses in telemetry
Sonic Booms	0	3	Shock waves traveling across the array caused by high performance aircraft
False Triggers	3	20	Triggers caused by dataline circuits, maintenance triggers of system for testing, high winds, coincidental noise at multiple sites within a trigger subnet, etc.
Total Triggers	245	405	

3.0 Explanation of Magnitude, Velocity Models, and Quality Factors

3.1 Coda Length Magnitude

Coda-length magnitude (M_c), an estimate of local magnitude (M_L) (Richter 1958), is calculated using the coda-length/magnitude relationship determined for Washington by Crosson (1972).

3.2 Velocity Model

The velocities and layer depths given in Table 5 are used by the program XPED in the SUN operating system. XPED was developed at the University of Washington and the velocity model used in XPED is based on Rohay et al. (1985). XPED is an interactive earthquake seismogram display program used to analyze seismic events.

3.3 Quality Factors (Q)

XPED assigns two **Quality factors** (Table 6) that indicate the general reliability of the solution (**A** is best quality, **D** is worst). Similar quality factors are used by the USGS for events located with the computer program HYPO71. The first letter is a measure of the hypocenter quality based on travel time residuals. For example: **A** quality requires an **RMS** less than 0.15 seconds while an **RMS** of 0.5 seconds or more is **D** quality (estimates of the uncertainty in location also affect this quality parameter). The second letter of the quality code depends on the spatial distribution of stations around the epicenter; i.e., number of stations, their azimuthal distribution, and the minimum distance (**DMIN**) from the epicenter to a station. Quality **A** requires a solution with 8 or more phases, **GAP** $\leq 90°$ and **DMIN** $\leq$ (5 km or depth, whichever is greater). If the number of phases, NP, is 5 or less or GAP $> 180°$ or **DMIN** $>$ 50 km the solution is assigned quality D.

Table 5. Velocity Model (Rohay et al. 1985) for the Columbia Basin (XPED software).

Depth to top of velocity layer (km)	Stratigraphy	Velocity (km/sec)
0.0	Saddle Mountains and Wanapum Basalt and intercalated Ellensburg Sediments	3.7
0.4	Grande Ronde Basalt and Pre-basalt sediments	5.2
8.5	Crystalline Basement, Layer 1	6.1
13.0	Crystalline Basement, Layer 2	6.4
23.0	Sub-basement	7.1
38.0	Mantle	7.9

Table 6. Seismic Event Data. (3 sheets)

EVENT ID: The identification number is created by the analysis program, XPED. XPED uses the year, month, day and time to create a unique number for each event.

DATE: The year and day of the year in Universal Time, Coordinated (UTC). UTC is used throughout this report unless otherwise indicated.

TIME: The origin time of the earthquake given in UTC. To covert UTC to Pacific Standard Time, subtract eight hours; to Pacific Daylight Time, subtract seven hours.

LATITUDE: North latitude, in degrees and minutes, of the earthquake epicenter.

LONGITUDE: West longitude, in degrees and minutes, of the earthquake epicenter.

DEPTH: The depth of the earthquake in kilometers (km).

MAG: The magnitude is expressed as Coda-Length magnitude M_c , an estimate of local magnitude M_L (Richter, 1958).

GAP: Azimuthal gap. The largest angle (relative to the epicenter) containing no stations.

NS/NP: Number of stations/number of phases used in the solutions.

RMS: The root mean square residual (observed P-WAVE arrival time minus the predicted arrival time) at all stations used to locate the earthquake. It is only useful as a measure of quality of the solution when five or more well-distributed stations are used in the solution. Good solutions are normally characterized by RMS values of less than about 0.3 seconds.

Q: The Quality Factors indicate the general reliability of the solution/location (**A** is best quality, **D** is worst). See page 9 of this report: Quality Factors.

TYP: Events flagged in Table 6 use the following code:

- **F** - earthquakes reported to have been felt
- **P** - probable explosion
- **S** - Surficial event (e.g. rockslide, avalanche, sonic boom) not an explosion or tectonic earthquake
- **X** - known explosion
- **blank** - earthquake that was not known to be felt

*Denotes events that occurred during this quarter.

Table 6. Seismic Event Data. (3 sheets)

EVENT ID	DATE	TIME	LATITUDE	LONGITUDE	DEPTH (KM)	MAG	GAP	NS/NP	RMS	Q	TYP	LOCATION
97022101001*	02/21	01:00:17.52	46N27.33	119W37.90	16.50	1.5	88	16/30	0.07	AA		Near Doke Springs, Snively Basin, on 1200' road. Base of Rattlesnake Mt.
97021020012*	02/10	20:01:20.53	46N13.74	119W45.34	0.05	2.0	218	19/23	0.11	AD	X	Confirmed blast, Benton Co. road department
97020422504*	02/04	22:50:49.74	46N27.00	119W25.78	15.89	1.3	41	21/34	0.10	AA		Cold Creek syncline 2 km west of vertex of LIGO
97012501090*	01/25	01:09:07.00	46N18.77	119W42.68	5.10	1.8	141	16/25	0.05	AC		South flank of Rattlesnake Mt. near Sagebrush Ridge
97011320062*	01/13	20:06:25.91	46N16.89	119W32.49	0.47	1.9	185	14/21	0.08	AD	X	Confirmed blast, Benton Co. Road Department
96111808121	11/18	08:12:14.44	46N31.38	119W49.95	8.63	0.9	260	4/6	0.06	AD		~ 10 km SW of the Yakima Barricade, along the Yakima Ridge
96111706001	11/18	06:00:18.88	46N49.82	119W44.31	3.74	1.6	161	15/24	0.09	AC		~ 14 km E of Beverly, WA in Crab Creek - along the N side of the Saddle Mts.
96110522349#	11/05	22:34:32.92	46N46.93	119W39.93	21.57	0.6	219	7/10	0.09	AD		15 km N of 100-K Area on the south flank of the Saddle Mountains.
96110518051#	11/05	18:05:15.60	46N52.85	119W13.13	13.77	2.2	112	28/31	0.21	BB		7 km NW of Othello, WA.
96102416450	10/24	16:45:05.92	46N16.41	119W33.74	17.46	0.8	285	7/13	0.04	AD		~ 8 km WNW of Benton City, WA along the "Badlands" of the Yakima River
96100508104	10/05	08:10:49.86	46N24.68	119W16.07	1.18	0.8	207	12/21	0.04	AD		~ 2 km N of Johnson Island
96100207245	10/02	07:24:56.98	46N40.54	119W36.51	5.91	1.0	74	12/17	0.07	AB		~ 5.5 km NNE of 100K

4.0 Geology and Tectonic Analysis

4.1 Earthquake Stratigraphy

Studies of seismicity at the Hanford Site have shown that the seismicity is related to crustal stratigraphy (layers of rock types) (Rohay et al., 1985; DOE 1988). The main geologic units at Hanford and the surrounding area are:

- The Miocene Columbia River Basalt Group (CRBG)
- The Paleocene, Eocene, and Oligocene sediments
- The crystalline basement (Precambrian and Paleozoic craton; accreted terranes)

4.1.1 Geologic structure beneath the monitoring area. Since the early 1980s, deep boreholes have been drilled for hydrocarbon exploration. These boreholes have provided accurate measurements of the physical properties of the CRBG and the prebasalt sediments (Reidel et al. 1987, 1994), but the thickness of the prebasalt sediments and nature of the crystalline basement are still poorly understood. The difference between the thicknesses listed in Table 7 and the thicknesses of the crustal layers in the velocity model in Table 5 reflect data specific to the University of Washington's crustal velocity model for eastern Washington. Table 7 is derived from Figure 3 and was developed for the geologic interpretation in Section 4.0. Figure 3 shows a north-south and east-west cross section through the Columbia Basin based on the surface mapping, deep boreholes, geophysical data (including the work of Rohay et al. (1985)), and magnetotelluric data obtained as part of BWIP (DOE 1988). The thicknesses of these units are highly variable across the monitoring area. Table 7 summarizes the approximate thicknesses at the borders of the monitoring area.

Table 7. Thickness of Stratigraphic Units across the Monitoring Area.

Stratigraphy	North	South	East	West
Columbia River Basalt Group (includes suprabasalt sediments)	3.0 km	4.5 km	2.2 km	4.2 km
Pre-basalt Sediments	3.0 km	>4.5 km	0	> 6.0 km

The thickness of the basalt and the pre-basalt sediments varies as a result of different tectonic environments. The western edge of North America (late Precambrian/Paleozoic continental margin and craton) is located in the eastern portion of the monitoring area. The stratigraphy on the craton consists of CRBG overlying crystalline basement; the crystalline basement is continental crustal rocks that underlie much of the western North America. The stratigraphy west

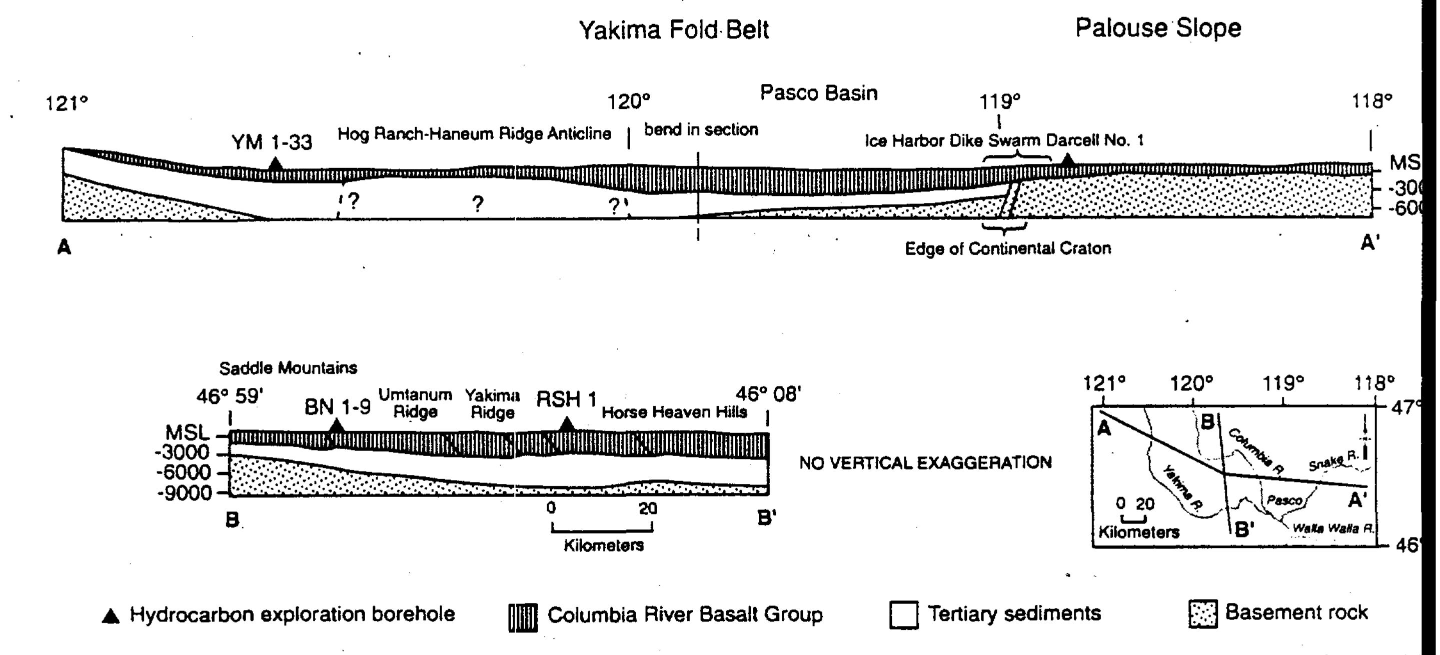

Figure 3. Geologic Cross Sections through the Columbia Basin.

of the craton is 4-5 km of CRBG overlying greater than 6 km of pre-basalt sediments which in turn overlie accreted terranes of Mesozoic age. The area west of the craton was subsiding during the Eocene and Oligocene accumulating great thicknesses of pre-basalt sediments. Continued subsidence in this area during the Miocene resulted in thicker CRBG compared to that on the craton. Subsidence continues today but at a greatly reduced rate (Reidel et al. 1994).

4.1.2 Depth of Earthquakes. Since records have been kept, about 75 percent of the earthquakes at the Hanford Site have originated in the CRBG layer. The prebasalt sediments have had about 7 percent of the events and the crystalline basement has had 18 percent.

For the second quarter of FY 1997, three events were located (Table 6); no events in the basalt, one event (33.3 percent) in the pre-basalt sediments, and two events (66.7 percent) in the crystalline basement.

For FY 1997 to date, ten events were located (Table 6); two events (20.0 percent) in the basalt, three event (30 percent) in the pre-basalt sediments, and five events (50 percent) in the crystalline basement.

4.2 Tectonic Pattern

Studies at the Hanford Site have concluded that earthquakes that can affect the Hanford Site can occur in the following six different tectonic environments (earthquake sources) at the Hanford Site (Geomatrix 1996).

- **Reverse thrust faults.** Reverse/thrust faults in the CRBG associated with major anticlinal ridges such as Rattlesnake Mountain, Yakima Ridge, and Umtanum Ridge could produce some of the largest earthquakes.

- **Secondary faults.** These are associated with the major anticlinal ridges.

- **Swarm areas.** Small geographic areas of unknown geologic structure produce clusters of events (swarms), usually in the CRBG in synclinal valleys. These clusters consist of a series of small shocks with no one outstanding principal event. Swarms occur over a period of days or months and the events may number into the hundreds and then quit, only to start again at a later date. This differs from the sequence of foreshocks, mainshock, and trailing-off aftershocks that have the same epicenter or are associated with the same fault system. Three principal swarm areas are known at the Hanford Site. One is the Wooded Island Swarm Area along the Columbia River near the 300 Area. The second area, the Coyote Rapids Swarm Area, extends from the vicinity of the 100 K Area north-northeast along the Columbia River Horn to the vicinity of the 100 N Area. The third major swarm area is along the Saddle Mountains on the northern boundary of the Hanford Site. Other earthquake swarm areas are present, but activity is less frequent.

- **The entire Columbia Basin.** The entire basin, including the Hanford Site, could produce a "floating" earthquake. A floating earthquake is one that, for seismic design purposes, can happen anywhere in a tectonic province and is not associated with any known geologic structure. It is classified as a random event by Seismic Monitoring for purposes of seismic design and vibratory ground motion studies.

- **Basement source structures**. Studies (Geomatrix 1996) suggest that major earthquakes can originate in tectonic structures in the crystalline basement. Because little is known about geologic structures in the crystalline basement beneath the Hanford Site, earthquakes cannot be directly tied to a mapped fault. Earthquakes occurring in the crystalline basement without known sources are treated as random events for seismic hazards analysis and seismic design.

- **The Cascadia Subduction Zone**. This source recently has been postulated to be capable of producing a magnitude 9 earthquake. Because this source is along the western boundary of Washington State and outside the HSN, the Cascadia Subduction Zone is not an earthquake source that is monitored at the Hanford Site, so subduction zone earthquakes are not reported here. Because any earthquake along the Cascadia Subduction zone can have a significant impact on the Hanford Site (Geomatrix 1996), the University of Washington monitors and reports on this earthquake source for the U.S. Department of Energy (DOE). Ground motion from any moderate or larger Cascadia Subduction Zone earthquake is detected by seismometers in the HSN.

4.3 Current Tectonic Activity

The locations of all events with M_c greater than 0.5 for January 1, 1997 to March 30, 1997 are shown on Figure 4. The locations of all seismic events for the preceeding three quarters and this quarter (October 1, 1997 to March 30, 1997) are shown in Figure 5. Local events on Figure 5 that occurred between April 1, 1997 and September 30, 1997 are listed in Hartshorn and Reidel (1996). Figure 6 is a tectonic map of the Yakima Fold Belt and Hanford Site. The Yakima Fold Belt is the main tectonic province of concern for the Hanford Site. The figure shows all the major mapped ridges and faults that are potential seismic sources. These figures should be referred to for the following discussions.

4.3.1 Reverse/Thrust Faults on Major Anticlinal Ridges

During the period from January 1, 1997 to March 30, 1997 no events appear to have occurred on any major anticlinal ridges.

4.3.2 Secondary Structures on Main Anticlinal Ridges

During the reporting period, no events appear to have occurred on any secondary structures that are part of major anticlinal fold in the area.

4.3.3 Swarm Area Activity

During the reporting period, no events were located in earthquake swarm areas.

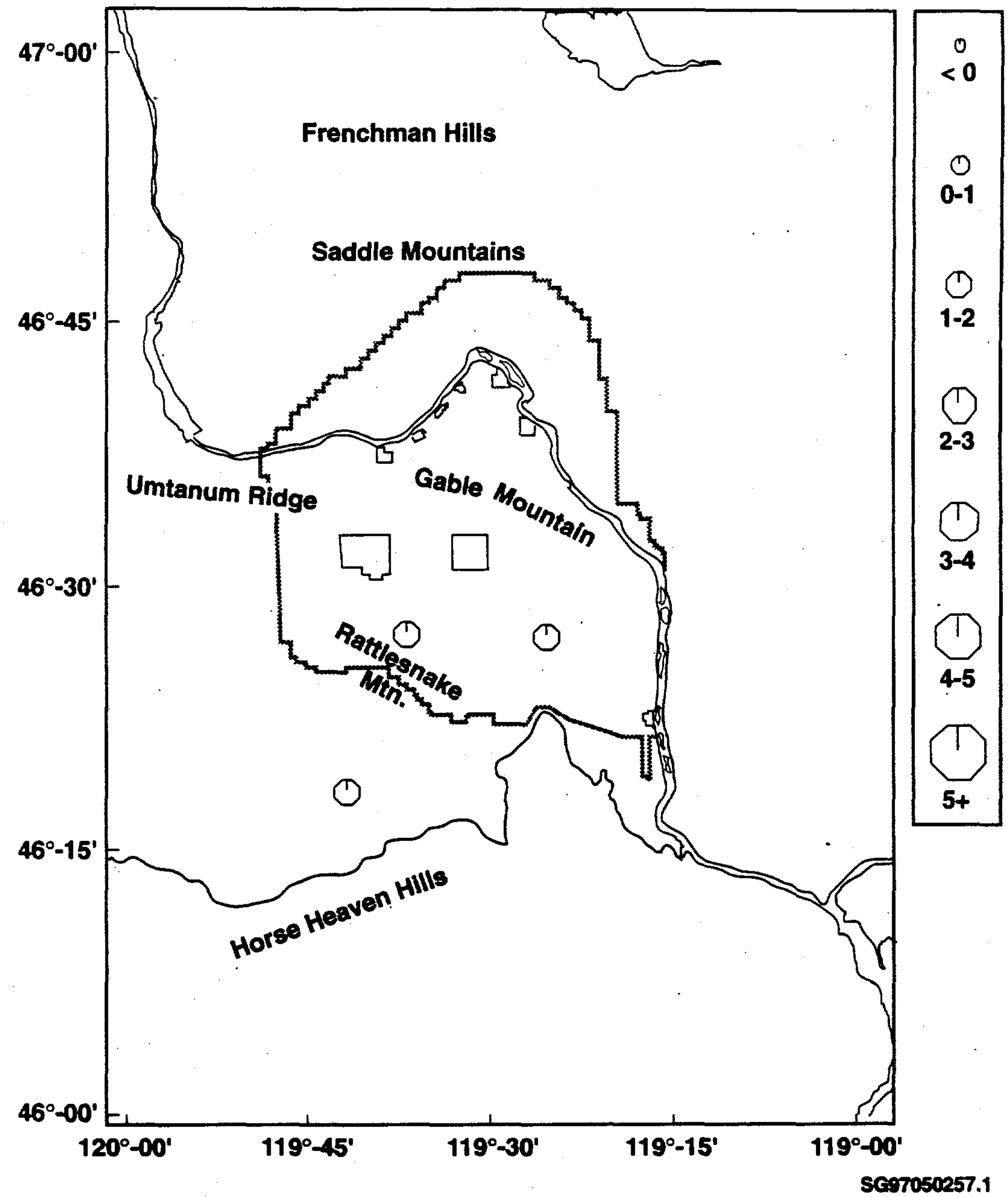

Figure 4. All Located Earthquakes: January 1, 1997 and March 31, 1997. (Coda Length Magnitude (M_c). Scale is shown at the side of the Map.)

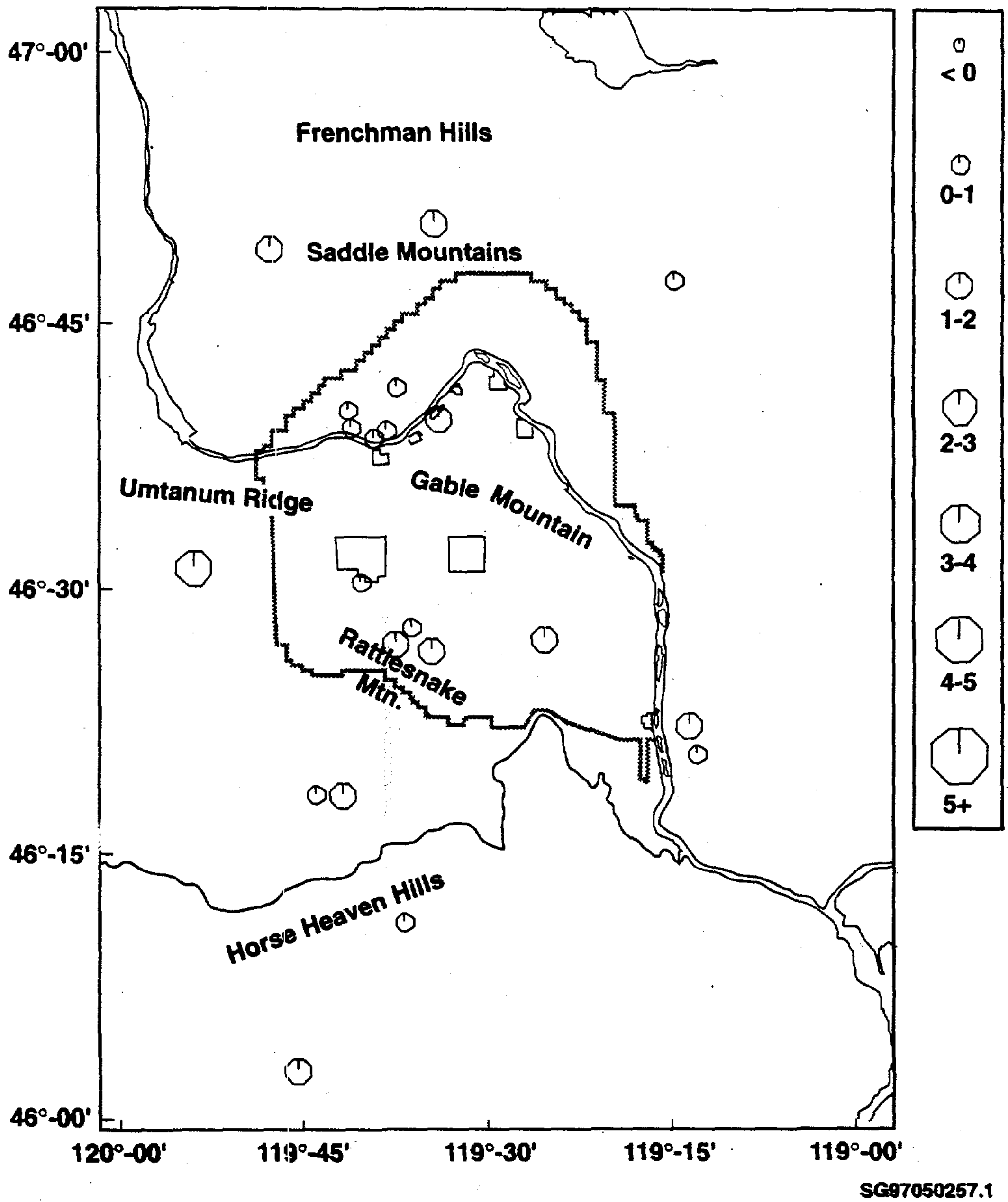

Figure 5. Locations of All Events between April 1, 1997 and March 31, 1997: (Coda Length Magnitude (M_c). Scale is shown at the side of the map.)

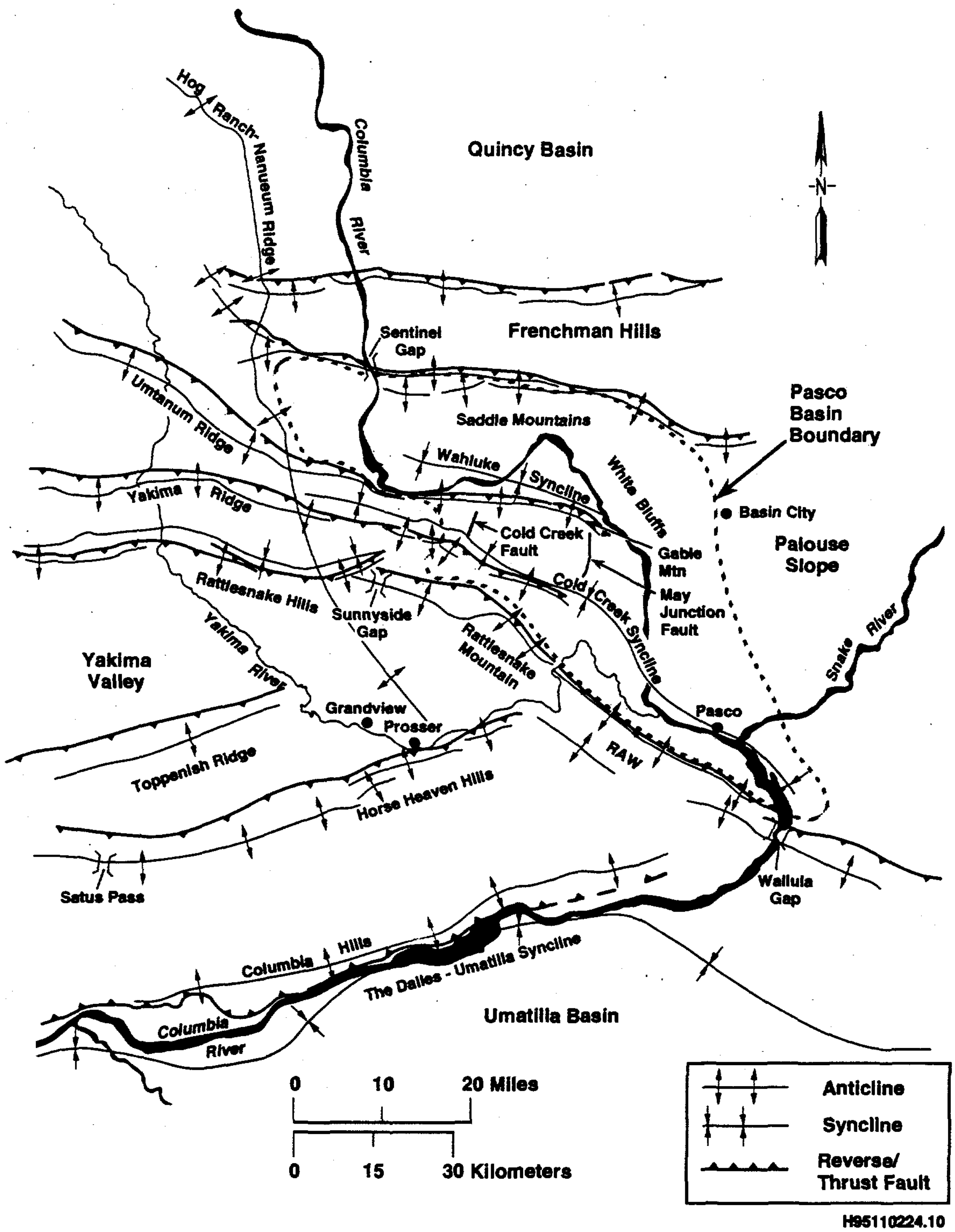

Figure 6. Structural and Tectonic Map of Columbia Basin Showing Major Seismic Source Structures.

4.3.4 Random or Floating Event Areas

Three events that occurred during this reporting period (100 percent of all events located) are classified as random events.

One event (<2 M_c) occurred on the southern flank of Rattlesnake Mountain where it joins the Yakima Valley syncline. This event occurred on January 25, 1997 at a depth of over 5 km. This depth places it in the prebasalt sediments near the contact with the overlying CRBG. The earthquake can not be related to any known geologic feature so it is classified as a random event.

An event (1.3 M_c) occurred on February 4, 1997 in the Cold Creek syncline near the LIGO. This earthquake occurred in the crystalline basement at a depth of nearly 16 km. Because this event can not be related to any known geologic structure it is classified as a random event.

The third event (1.5 M_c) for the quarter occurred on February 21, on the north side of Rattlesnake Mountain where it joins Snively Basin. This event occurred in the crystalline basement at a depth of 16.5 km. Although this event occurred near the Rattlesnake Mountain fault, it is classified as a random event because previous studies have interpreted the Rattlesnake Mountain fault to be confined primary to the CRBG. This event occurred along the Olympic-Wallowa lineament (OWL) which may be controlled by geologic structures in the crystalline basement. However, very little is known about the OWL and any structural control on the crystalline basement is speculative at this point. This location is not an historic area of earthquakes.

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