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INTRODUCTION AND OPERATIONS

Introduction

This report covers the operations and research performed for D.O.E. and the N.R.C. by the University of Washington Geophysics Program on the seismicity and structure of eastern and southern Washington and northern Oregon for the year, July 1, 1983 to June 30, 1984. These contracts help support parts of the Washington state regional seismograph network. There are presently 104 stations in Washington and northern Oregon whose data are telemetered to the University for recording, analysis and interpretation. The Department of Energy supports the stations on the east flank of the Cascades and throughout eastern Washington. The Nuclear Regulatory Commission has supported stations in southern Washington and northern Oregon. Other major parts of the network are supported by the U.S. Geological Survey.

Section I of this report covers the details of the operation of the network in eastern Washington and the Washington-Oregon border area. Details of the past year's seismicity and a description of the catalog is covered in section II. Section III is a preliminary description of our data from the joint USGS-Rockwell-UW refraction experiment carried out this summer. Preliminary examination of these data indicate that useful interpretations will be possible. Section IV summarizes research in vertical seismic profiling which will be useful to study the velocity and attenuation structure of the basalts. The appendices include the earthquake catalog for 1983-1984 and a monthly listing of the station 'up-times' for the eastern Washington network.

Network Operations

As of July, 1984, the University of Washington's seismic telemetry network included 104 stations, 101 of which are operated by the University (see figure I-1). This total includes 34 stations in eastern Washington, 51 stations in Washington west of the Cascade crest, and 19 stations in the northern third of Oregon. Support for stations in eastern Washington is principally derived from the Department of Energy (DOE), while western Washington stations are chiefly funded by the U. S. Geological Survey under two different grants. Operations in northern Oregon have been mainly supported by the Nuclear Regulatory Commission (NRC), but both the USGS and DOE contribute. A number of station resitings and new installations were made during the year, but overall network configuration was not substantially changed. We have made minor changes in operational procedures which have improved data quality. Table I-1 is a list of stations in the eastern and southern Washington and eastern Oregon network.

Operations during the past year were characterized more by resitings and additions of new stations than by equipment changes. Throughout the year, the level of station up-time was high and on occasion reached 100% (see summaries in Appendix II). The efforts of the Stanwyck technician, Mr. Marc Walker, were key to this level of operational success.

In 1984, we have added 3 stations to the eastern Washington/northeastern Oregon network, moved one, and discontinued one. The new stations are Black Rock Valley (BRV), between Yakima and Hanford; Roosevelt Peak (RPK), along the Columbia River between Paterson and Goldendale; and Indian Rock (GL2), north of Goldendale. RPK was formerly operated by Portland General Electric as part of a tripartite network around the proposed Boardman coal-fired generating plant, and was recorded locally. It was the best of the three stations and the only one we have elected to reopen. GL2 is a replacement for the old Goldendale

(GLD) site, which was closed in early 1983 because of excessive telemetry costs and wind generated noise.

In May 1984, the owner of the Badger Mountain site (BDG), demanded an exorbitant lease fee for continued operation. Instead of paying, we moved the equipment. Unfortunately, no nearby site of equivalent quality could be found, and the replacement station, HHW, is about 9 kilometers southwest of BDG. We are evaluating the background noise levels at HHW; another move may be necessary as it seems excessively noisy.

The station SBO, installed and mainly supported through NRC funds, was closed in July 1984. Two years' operation had indicated low seismicity in that area, and difficult maintenance conditions. With NRC support being terminated in late 1984 it seemed that there was little justification for further maintaining the station. The equipment is being used at the GL2 station. Figure I-1 shows the stations of the Eastern Washington network as of July, 1984.

The long-awaited USGS agreement to use Bonneville Power Administration (BPA) microwave circuits for seismic data transmission was being finalized in mid-1984 and arrangements are now underway for shifting telemetry of practically the entire state network to BPA links. Our strategy is to radio individual stations to mixer sites at the BPA facilities; we already have some stations located adjacent to the access points (BRV and VGB east of the Cascades) which will save us a radio pair each when we get access. Some rearrangement of University stations will be required, but it appears that we will be able to do away with all or nearly all of the costly leased lines. The steps taken over the past few years to expand the volume of radio telemetry east of the Cascades have vastly reduced the amount of equipment and personnel time that will be required for the changeover. However, there are a lot of things yet to do. A preliminary review of the network realignment indicates several additional radio links will need to be installed, several stations physically moved at least a short distance, and some stations may be closed with others being opened to keep the network balenced. There will certainly be periods when parts of the network are out of operation for significant periods of time.

The switch to BPA circuits will take place in stages in 1985 starting in March and lasting for about six months. Figure I-2 is a map showing the BPA access points and microwave links we will be using as well as our planned radio links to connect to them. This is still preliminary; requiring yet considerable additional design and testing before our final configuration is solidified.

Automatic Processing

We have been operating a Rex Allen online P-picker since 1981. This monitoring system has the capability to pick earthquake P-wave arrivals from our network stations and obtain a preliminary location within three minutes of the event. The output of the P-picker is directed into the PDP-11/70 where its data is analyzed to determine if an earthquake with damage potential has occurred. If the event is large enough the 11/70 will notify any seismologists logged in that a big earthquake has occurred and will call a seismologist at home.

The station status output of the P-picker has been used for the past two years to detect station problems at an early stage. The P-picker takes 300 second averages of bias and noise level for every station 4 time a day and reports these values to the 11/70. Thresholds for proper station operation are used to tell when a station is not functioning properly. If the bias is too far from zero it can indicate either no subcarrier for that station or a badly drifted VCO. If the noise level is either too small or too large it can indicate a dead seismometer or a dead telemetry link. Of course, some stations will look bad based on these criteria some time since it is possible that it might have a temporary seismic noise which occurs just when the P-picker is sampling each six hours.

We feel that, on the average, it gives a fairly representative indication of station operation and has allowed us to spot troubles earlier than was the case without it. It also gives us a good record of operations. In appendix II we show plots of the P-picker determined station operation "up-time". This should be considered a worst case approximation since the thresholds are set to more likely call good stations bad than the other way around.

Our routine processing is continuing in much the same way as in previous report periods. We are concentrating heavily in the cleanup of old data, in particular that in 1980 and 1981. With the exception of March-May 1980, the rest of that year is in good shape and will be ready for a statewide catalog soon. Parts of 1981 still need some work, but all of 1982 and 1983 are finished. Few changes are being made to the data from eastern Washington. These data have been in pretty good shape all along.

TABLE I-1 D.O.E. - N.R.C SUPPORTED SEISMIC STATIONS

STA.	LAT	LONG	TIME	NAME
AUG	45 44.17	121 40.83	10/81-	Augspurger Mt.
BDG	46 14.08	119 19.05	7/75-	Badger
BRV	46 29.12	119 59.49	8/84-	Black Rock V
CBW	47 48.42	120 01.96	7/75-	Chelan B
CRF	46 49.51	119 23.09	7/75-	Corfu
DYH	47 57.63	119 46.16	7/75-	Dyer Hill
ELL	46 54.58	120 34.10	7/79-	Ellensburg
EPH	47 21.13	119 35.77	7/75-	Ephrata
EST	47 14.28	121 12.53	7/79-	Easton
ETP	46 27.89	119 03.54	7/75-	Eltopia
ETT	47 39.30	120 17.60	6/77-	Entiat
FPW	47 58.00	120 12.77	7/75-	Fields Pt.
GBL	46 35.86	119 27.59	7/75-	Gable
GL2	45 57.83	120 49.25	7/84-	New Goldendale
JBO	45 27.00	119 51.00	9/82-	Jordan Butte
KMO	45 39.00	123 27.00	9/82-	Kings Mt.
MDW	46 36.80	119 45.65	7/75-	Midway
MFW	45 54.18	118 24.35	7/75-	Milton-Free.
NAC	46 43.98	120 49.47	8/79-	Naches
NEW	48 15.83	117 07.22	/77-	(USGS)
ODS	47 18.40	118 44.70	7/75-	Odessa
OMK	48 28.82	119 33.65	7/75-	Omak
OTH	46 44.34	119 12.99	7/75-	Othello
PAT	45 52.85	119 45.68	6/81-	Paterson
PEN	45 36.72	118 45.78	7/75-	Pendleton
PGO	45 28.00	122 27.17	6/82-	Gresham, Or.
PHO	45 37.14	122 49.80	4/82-	Portland Hills
PLN	47 47.08	120 37.97	6/77-	Plain
PRO	46 12.76	119 41.15	7/75-	Prosser
SAW	47 42.10	119 24.06	7/75-	St. Andrews
RPK	45 45.70	120 13.83	7/84	Roosevelt
RSW	46 23.47	119 35.32	7/75-	Rattlesnake
SYR	46 51.78	119 37.07	7/75-	Smyrna
TBM	47 10.17	120 31.00	7/79-	Table Mt.
TDH	45 17.39	121 47.26	9/82-	Tom,Dick,Harry
VBE	45 03.62	121 35.21	10/79-	Beaver Butte
VFP	45 19.08	121 27.91	10/80-	Flag Point
VGB	45 30.94	120 46.65	4/80-	Gordon Butte
VGT	45 08.09	122 15.92	4/80-	Goat Mt.
VIP	45 13.15	120 37.13	12/79-	Ingram Pt.
VLL	45 27.80	121 40.75	10/80-	Laurance Lk.
VLM	45 32.31	122 02.35	6/80-	Little Larch
VTG	46 57.48	119 59.24	7/75-	Vantage
VTH	45 10.87	120 33.68	3/80-	The Trough
WA2	46 45.40	119 33.76	5/78-	Wahluke2
WAT	47 41.92	119 57.25	11/76-	Waterville
WBW	48 01.07	119 08.23	7/75-	Wilson B
WEN	47 31.77	120 11.65	7/75-	Wenachee
WGW	46 02.68	118 55.96	7/75-	Wallula Gap
WIW	46 25.93	119 17.29	7/75-	Wooded Is.
WRD	46 58.19	119 08.60	7/75-	Warden
YAK	46 31.73	120 31.22	7/79-	Yakima

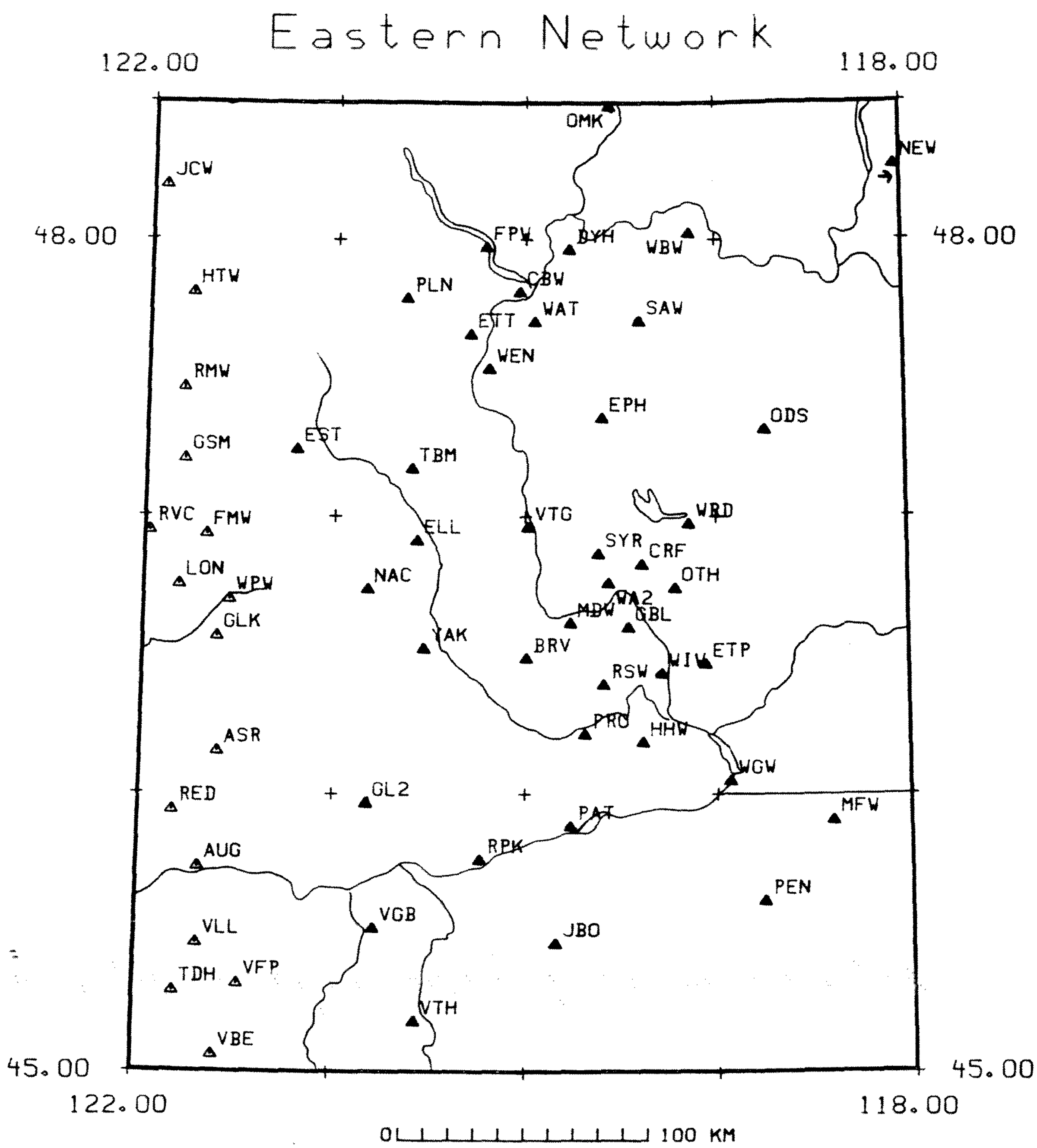

Figure I-1. Map of the Eastern Washington Seismograph network showing the stations supported by either D.O.E. or the N.R.C is filled symbols.

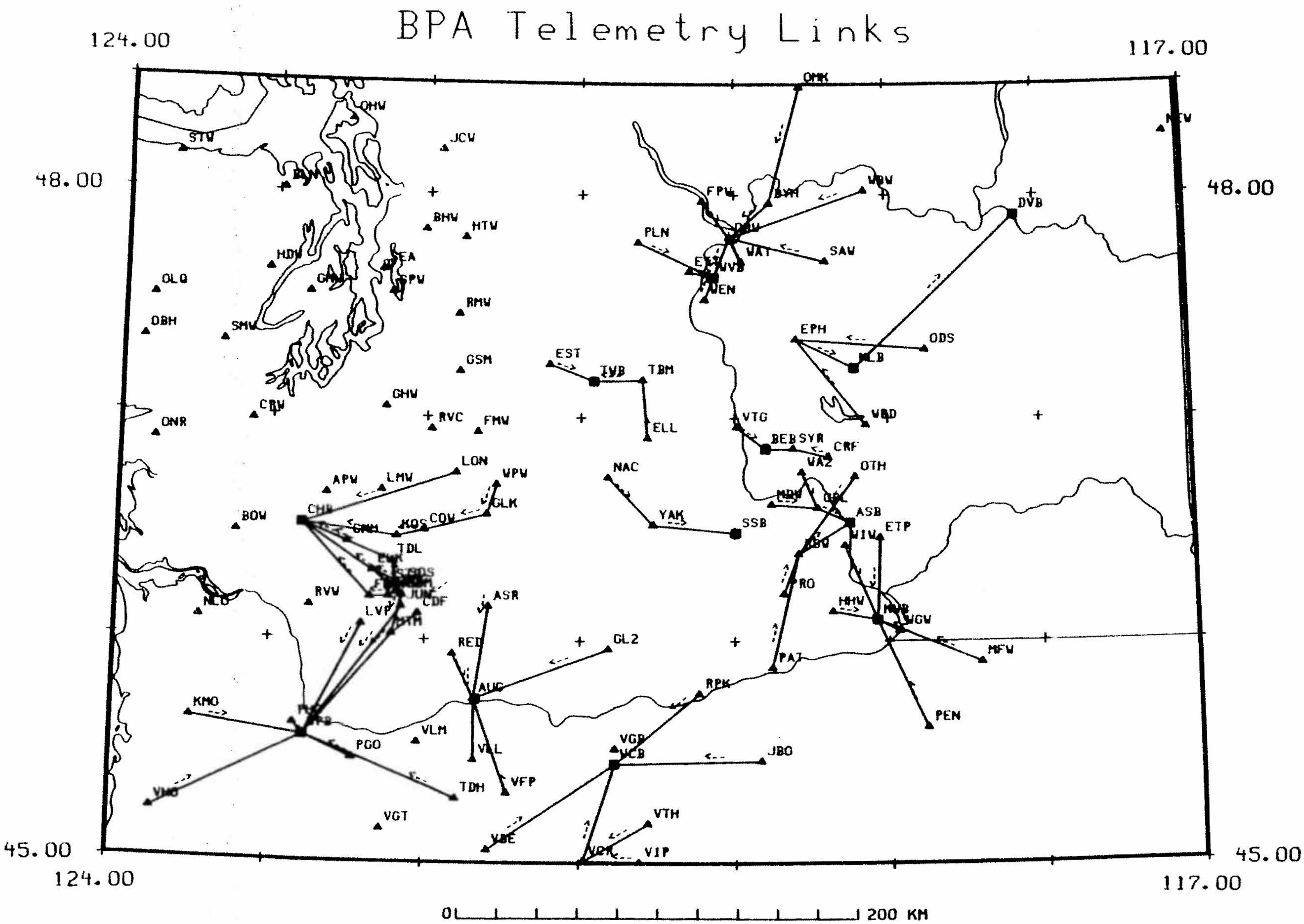

Figure I-2. Washington State Seismograph Network showing the planned telemetry links through the BPA microwave net. Access to their net is at the filled square symbols. Signals at these points will be telemetered to the University of Washington via microwave. Most of the telemetry linnks between our stations and the BPA sites will be via our VHF radios.

SEISMICITY 1983 - 1984

Introduction

During the period July 1,1983 through June 30, 1984, the level of seismicity in Washington state and northern Oregon has been slightly less than many previous years. No significant earthquakes occurred in Washington state or Northern Oregon. The largest magnitude earthquake was a magnitude 4.3 earthquake which occurred in northeastern Washington and was felt from Yakima to Grand Coulee and throughout the southern Lake Chelan area.

Data

There were 3,022 events processed by the online computer system during the past year. We located 1,854 of these events within the state-wide network; 554 of them being in eastern Washington and the Washington-Oregon border area. Of these events 246 were suspected or known blasts and 53 of them were picked from film records because the online system missed them for one reason or another. All of these missed events were less than magnitude 2.3 and most were less than magnitude 1.6 which is our average magnitude threshold for locating 80% of the events over most of eastern Washington. See event detection threshold section below. Our processing system has kept to within a few days of being current during this period.

General Seismicity

Figure II-1 and II-2 show the known and probable blasts in Eastern Washington and Northern Oregon, respectively. Most blasts occurred in areas identified in previous reports as blasts sites; though several new sites began blasting during this report period. The 308 earthquakes are shown on figures II-3 and II-4 for the same areas. Appendix I is the event catalog for this period. We have excluded blasts with a magnitude less than M=2.5 just to reduce the length of the catalog. It may show changes from the preliminary catalogs published in the quarterly technical reports because errors have been found and corrected in the interim.

Seismicity during this period has followed similar patterns as previous years. The area of most intense activity was the southern Entiat-Waterville area which has had consistent located earthquake activity since the network was expanded into this area in 1975, and felt events for most of this century. There were 71 earthquakes located in this area during the past year. The next most active area is that around Yakima which had 39 earthquakes during this report period. There was a small cluster of events south of Portland in the Willamette valley and continuing activity to the southwest of Mount St. Helens. Activity in the central Pasco Basin has remained similar to previous years, with most activity taking place in the Saddle Mountains region in known swarm areas.

Larger Events

An earthquake of some interest during this report period was a M=4.3 earthquake which occurred just north of Wenatchee on April 11, 1984 at 0307 GMT. The event was felt in Yakima, Wenatchee, Leavenworth, Grand Coulee, and the southern Lake Chelan area. Second hand reports of minor damage at Grand Coulee could not be confirmed. The maximum intensity would appear to be MM=IV from Wenatchee. The location for this event (47° 32.5"N, 120° 48"W) is about 20km south of a persistent zone of seismic activity for the past 10+ years. There has been no other activity in the immediate vicinity of this event including aftershocks.

A focal mechanism solution for this event is shown in figure II-5 along with a composite mechanism of 4 smaller events from the area between Waterville and Entiat; the area of continuing seismicity over the past 10+ years. Takeoff angles were calculated assuming a constant velocity gradient with a starting velocity of

5.1 km/sec and a gradient of 0.09 km/sec/km. The first motion data is plotted on an equal area upper hemisphere stereographic projection. The solution for the single large event shows a predominantly strike slip solution with fault planes striking N43°E and N43°W and a maximum compressive stress direction of almost due south. The composite mechanism is similar to this one but more rotated to the west and with more thrust component. The maximum compressive stress direction is S34°E. This mechanism is not as well determined as the former, having several inconsistancies. Focal mechanisms determined previously for events in this area have nodal planes tending to the north-east but have similar maximum compression axies (see *Annual Technical Report*, 1978). This predominantly strike-slip solution of the M=4.3 April 11 earthquake is unique for events in this area.

A sequence of earthquakes just north of Yakima began on November ~~11~~, 14th 1983 with a Magnitude 3.8 event. This event was followed by a short aftershock sequence of 9 events. The main shock was lightly felt throughout the greater Yakima area. A well constrained fault plane solution for this event (see figure II-6) shows a high angle east-west stiking reverse fault mechanism. The aftershocks have first motion distributions consistent with this mechanism but are not well enough recorded to determine a solution uniquely. This mechanism is obviously very different from the strike-slip mechanism determined for a single magnitude 3.8 earthquake near Ellensburg on Dec 5, 1983 (see figure II-6). Previous events in the Ellensburg-Cle Elum area typically show more of a reverse mechanism than this well constrained pure strike-slip one.

Western Idaho - Northeast Oregon Activity

In 1984, earthquake activity has been detected in some unusual areas on the southeast periphery of the Washington State Network. On 31 January, a magnitude 3.5 earthquake occurred near White Bird, Idaho, near the point where the state borders of Idaho, Oregon, and Washington meet. It was felt in the White Bird-Riggins area in Idaho as well as at Clarkston, Washington. Our epicenter should not be concidered very accurate since the earthquake occurred outside our network. The earthquake is of interest chiefly because of its occurrence in an area of extremely sparse seismicity. No focal mechanism is possible using just the Washington network data, and the earthquake's small magnitude makes it unlikely that sufficient regional stations recorded it for a focal mechanism attempt to be successful.

At the time of compilation of this report, an unusual sequence of earthquakes is occurring near Halfway, Oregon, just south of the Wallowa Mountains. Earthquakes of magnitude 3.3 and 3.6 occurred on 10 August 1984 and 19 September 1984 and triggered our on-line system. At least two other shocks in August were seen on helicorder records. The 10 August earthquake was felt at Richland, Oregon; the 19 September event reportedly panicked people at Halfway and was also felt at Richland. On 18 September, a major landslide was reported by the press to have blocked Oregon State route 86. This landslide is alledged to be "a mile long and 700 feet high". Strong local shocks have been reported felt at the landslide site, and the timing of the 19 September earthquake (18 September PDT) may be more than coincidental. Our seismograms do not suggest the shallow focal depth that would be necessary, had the earthquakes been caused by some landslide mechanism. On the other hand, it is a little difficult to believe that such small earthquakes could have generated a major landslide. Strong earthquakes occurred near Halfway in 1927 and 1942, and to the north of Halfway in 1913. Our tentative interpretation is that the earthquakes represent rare but normal tectonic events, but the connection with the landsliding is worthy of investigation. Oregon State University is deploying portable seismographs in the vicinity, and will be assisted by the loan of some of our portable instruments. We will update this very preliminary information when some hard data becomes available. It should be noted that while the White Bird earthquake occurred sufficiently close to our network that it was included in our routine processing and location effort, the Halfway earthquakes were considered to be regionals and were only located upon receipt of information about the unusual circumstances in which they occurred. Therefore, it is unlikely that our routine catalogs have contained information on earthquakes that may have occurred in the Halfway area over the past several years.

Catalog Completeness

The area within the Washington State seismograph net was evaluated to determine the magnitude levels at which the catalog is complete. The region was divided into one degree quadrangles as shown in Figure II-7, and a magnitude completeness level was determined for each quadrangle where events were located between 1981 and 1983. The number of events per subregion varied from zero (in areas at the edge of the network), to over three thousand, near Mt. St. Helens. Figure II-7 and Table II-1 list the number of events in each quadrangle.

Two methods were used to evaluate magnitude completeness, depending on number of located events. In areas where at least 25 events occurred the linear relation;

$$\log N = A - bM$$

where N is the number of earthquakes of magnitude M or greater (A and b are constants) was used. Reduced network sensitivity to events of small magnitude results in a departure from linearity. By plotting log N versus M; the magnitude level of completeness is determined empirically to be the point where the linear relation no longer holds. Where 25 or fewer events occurred the linear relation is difficult to determine, and another method was used.

TABLE II-1

DATA USED IN FIGURE II-7					
AREA	# OF EVENTS	COMPLETE AT	AREA	# OF EVENTS	COMPLETE AT
A1	13	(1.8)	E1	11	(2.4)
A2	10	(1.9)	E2	199	1.2
A3	3	(2.5)	E3	85	1.3
A4	0	-	E4	15	(2.4)
A5	0	-	E5	2	(3.1)
B1	49	1.7	F1	14	(2.1)
B2	45	1.2	F2	40	1.0
B3	18	(1.7)	F3	188	1.1
B4	5	(2.3)	F4	5	(2.4)
B5	1	(3.8)	F5	0	-
C1	186	1.7	G1	1	(2.9)
C2	415	1.2	G2	10	(2.8)
C3	3532	.7	G3	15	(1.9)
C4	73	1.1	G4	12	(2.8)
C5	2	(2.8)	G5	0	-
D1	117	1.2	H1	0	-
D2	424	1.3	H2	1	(3.5)
D3	422	.8	H3	4	(2.0)
D4	36	(.9)	H4	1	(3.0)
D5	2	(2.1)	H4	0	-

Using regions where the first method applies, the average difference between the magnitude completeness level and the smallest event located in an area was determined. The difference between completeness and smallest located event had a mean (and mode) of 1.3 magnitude units. In the second method, this value was added to the magnitude of the smallest located event in sub-regions where 25 or fewer events occurred to give an estimate of completeness.

Where 25 or fewer events were located, the magnitude completeness is in parenthesis, and was determined by the second method. No magnitude completeness level is given for areas where no earthquakes were located (1981-1983). Where only one event was recorded (e.g. quadrangles B5, G1, H2, and H4) the method used may not be a reliable indicator of completeness. Revision of our magnitude scale may produce a small difference in these magnitude completeness values. Table 3 supersedes a similar table in the 1984 first quarter report. Likewise Figure II-7.

Catalog Summary

Appendix I is a catalog of the located events between July 1, 1983 and June 30, 1984. The locations reported in this catalog have been determined using a location routine obtained from Dr. Bob Herrmann at St. Louis University and extensively modified and tested here at the University of Washington. Obviously bad readings are automatically thrown out and there is a special depth adjustment algorithm for events with poorly controlled shallow depths such as those often found in the central Pasco Basin. Different velocity models are used to locate events in different regions. Table II-2 lists the fundamental parameters used for the standard velocity model for each region. Individual minor station corrections have been determined for each of this models but are not listed in the table.

Most of the columns in the catalog are self explanatory. Times are in coordinated universal time(PST + 8hr). The * sometimes following the depth means that the depth has been fixed. **$** and # mean that the maximum number of iterations has been exceeded without meeting convergence tests and both this and the depth have been fixed respectively. Events flagged with these symbols may be very poorly located even if the quality factors are good. NS/NP is the number of stations and the number of phases used in the location determination. The *types* listed in the catalog are as follows:

X-Known explosion

P-Probable explosion(based on seismogram character)

F-Earthquake reported to have been felt

L-Low frequency earthquake

H-Hand picked event from film records

TABLE II-1 Velocity Structures

North-East (N1)		South-East (S1)	
V (km/sec)	Depth (km)	V (km/sec)	Depth (km)
5.10	0.0	3.70	0.0
6.05	0.5	4.70	0.8
7.2	19.0	5.15	1.2
8.0	24.5	6.05	7.5
		7.20	19.0
		8.00	28.0

Cascades (C1)		St. Helens (S1)	
V (km/sec)	Depth (km)	V (km/sec)	Depth (km)
5.1	0.0	4.8	0.0
6.0	1.0	5.0	1.0
6.6	10.0	6.0	3.0
6.8	18.0	6.4	8.0
7.1	25.0	6.6	10.0
7.9	35.0	6.7	16.0
		6.9	22.0
		7.1	32.0
		7.75	41.0

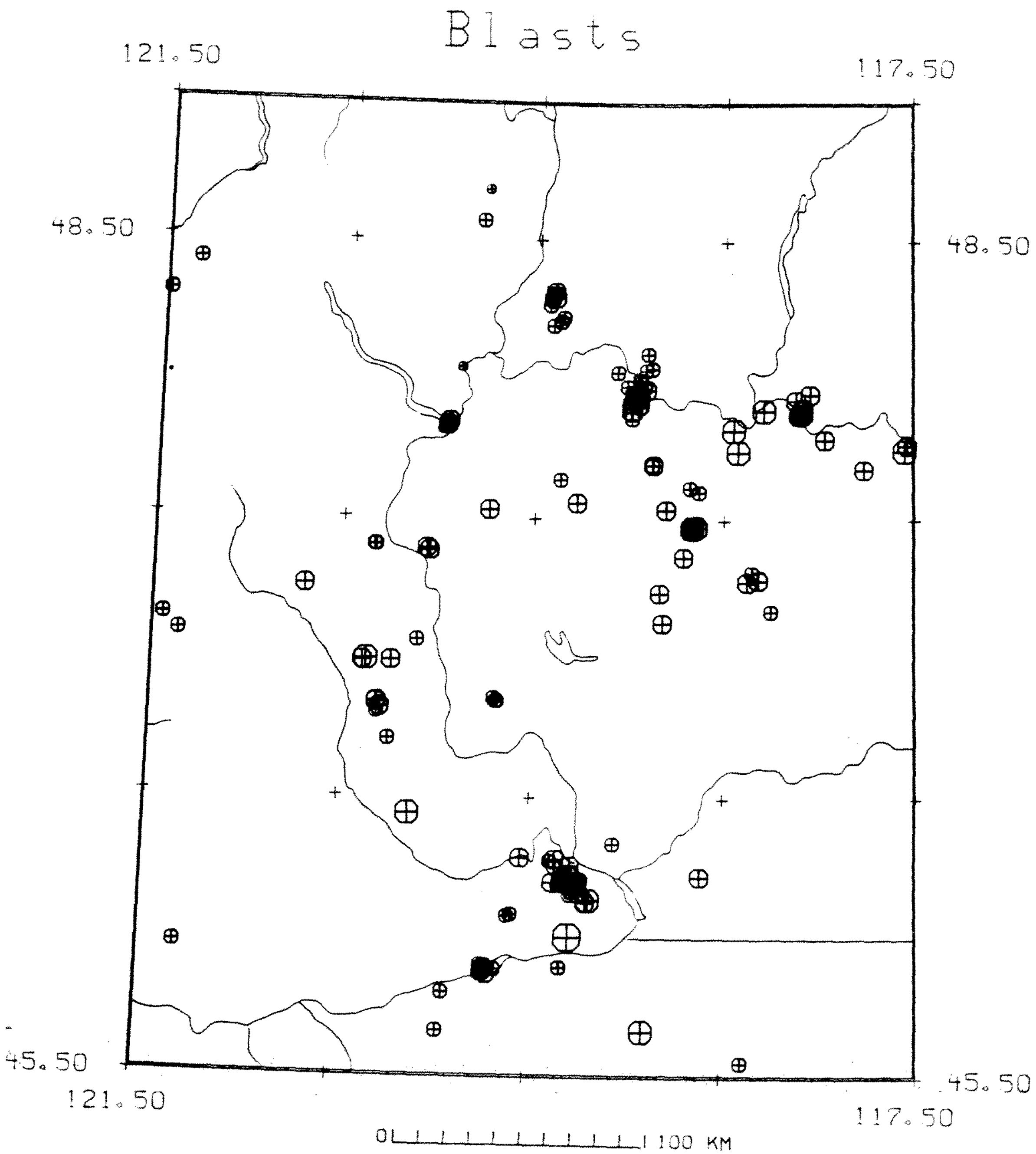

Figure II-1. Eastern Washington known or probable explosions. July 1, 1983 - June 30, 1984

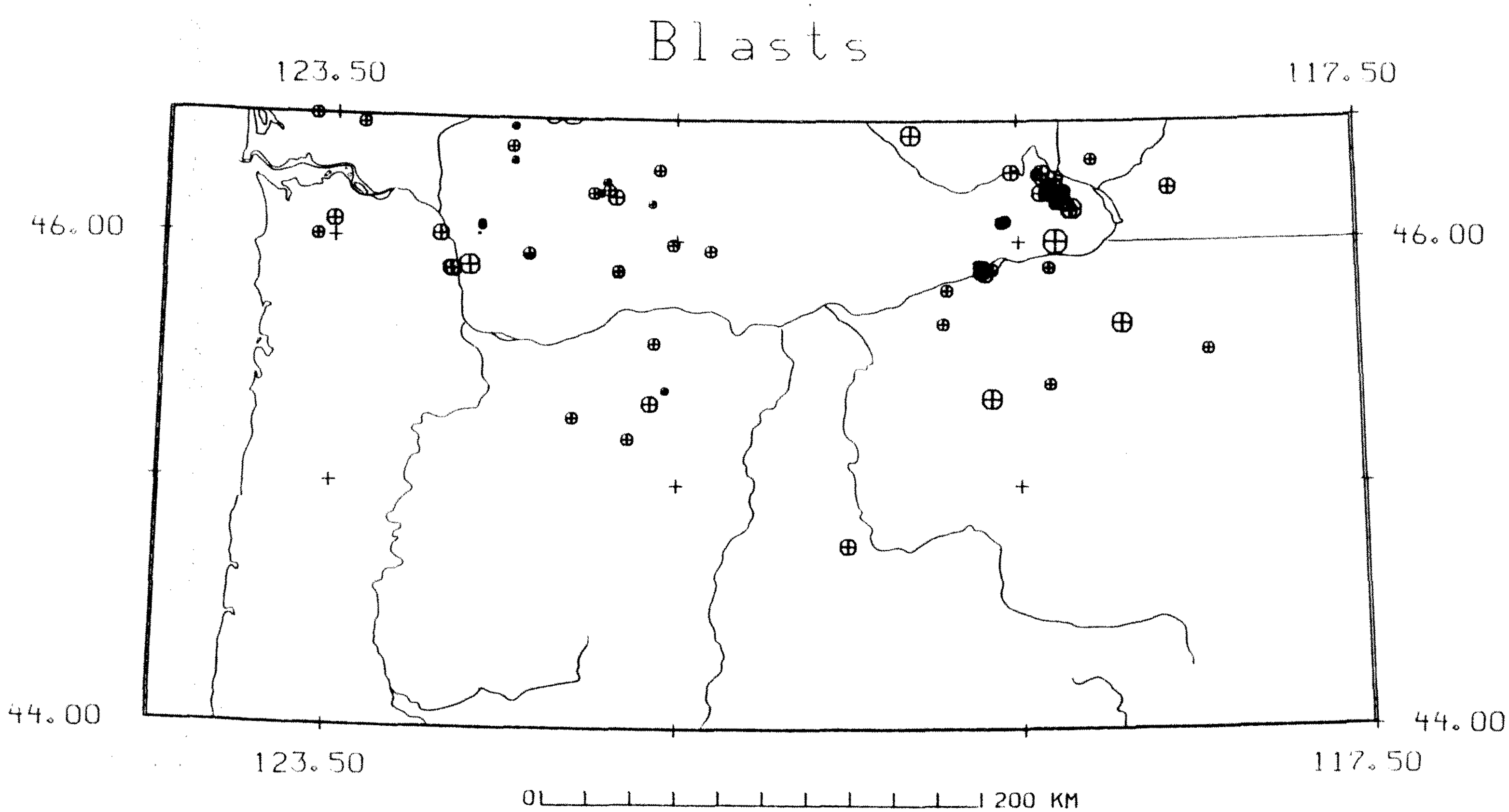

Figure II-2. Southern Washington- Northern Oregon known or probable explosions. July 1, 1983 - June 30, 1984.

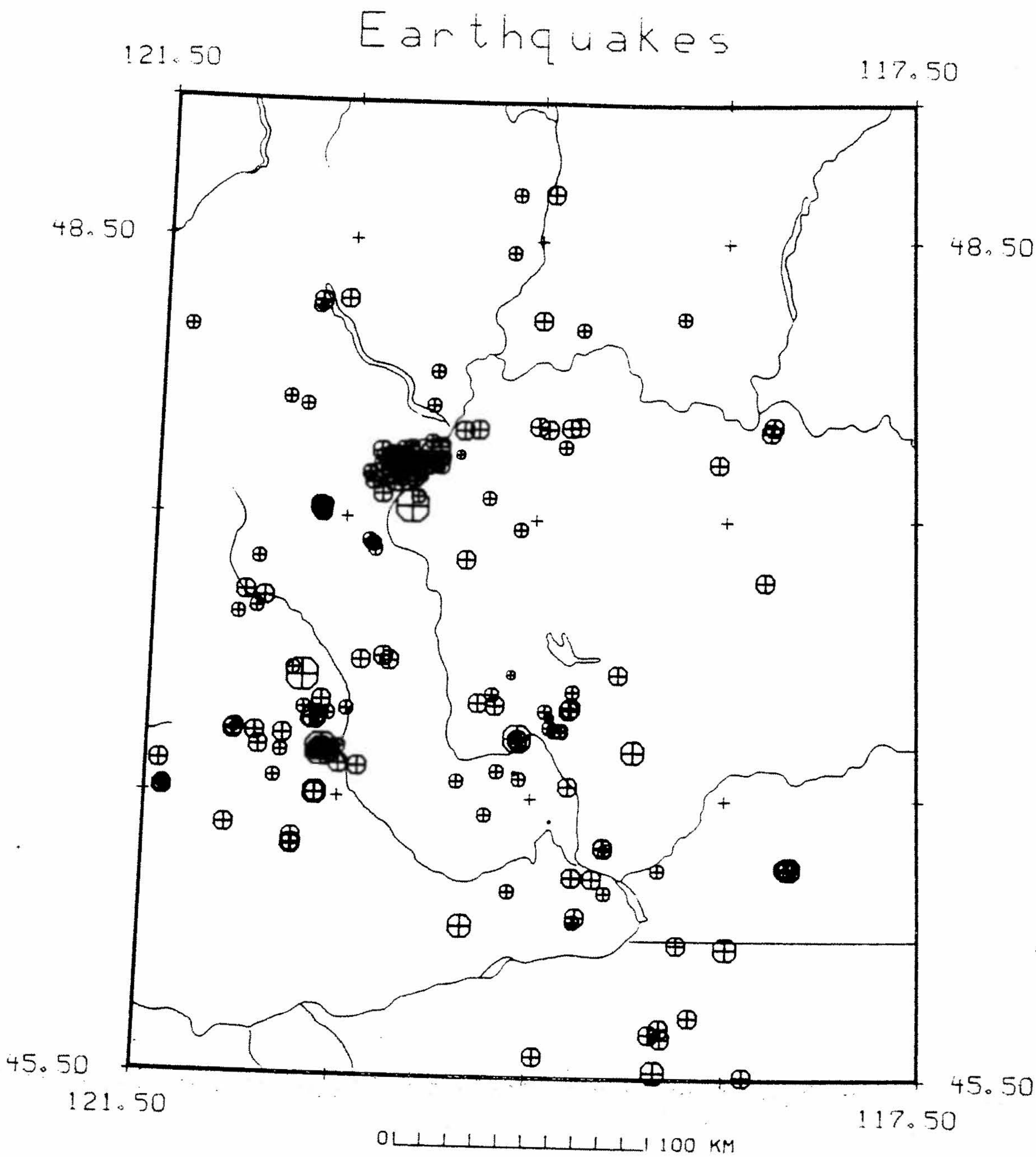

Figure II-3 Eastern Washington earthquakes. July 1, 1983 - June 30, 1984

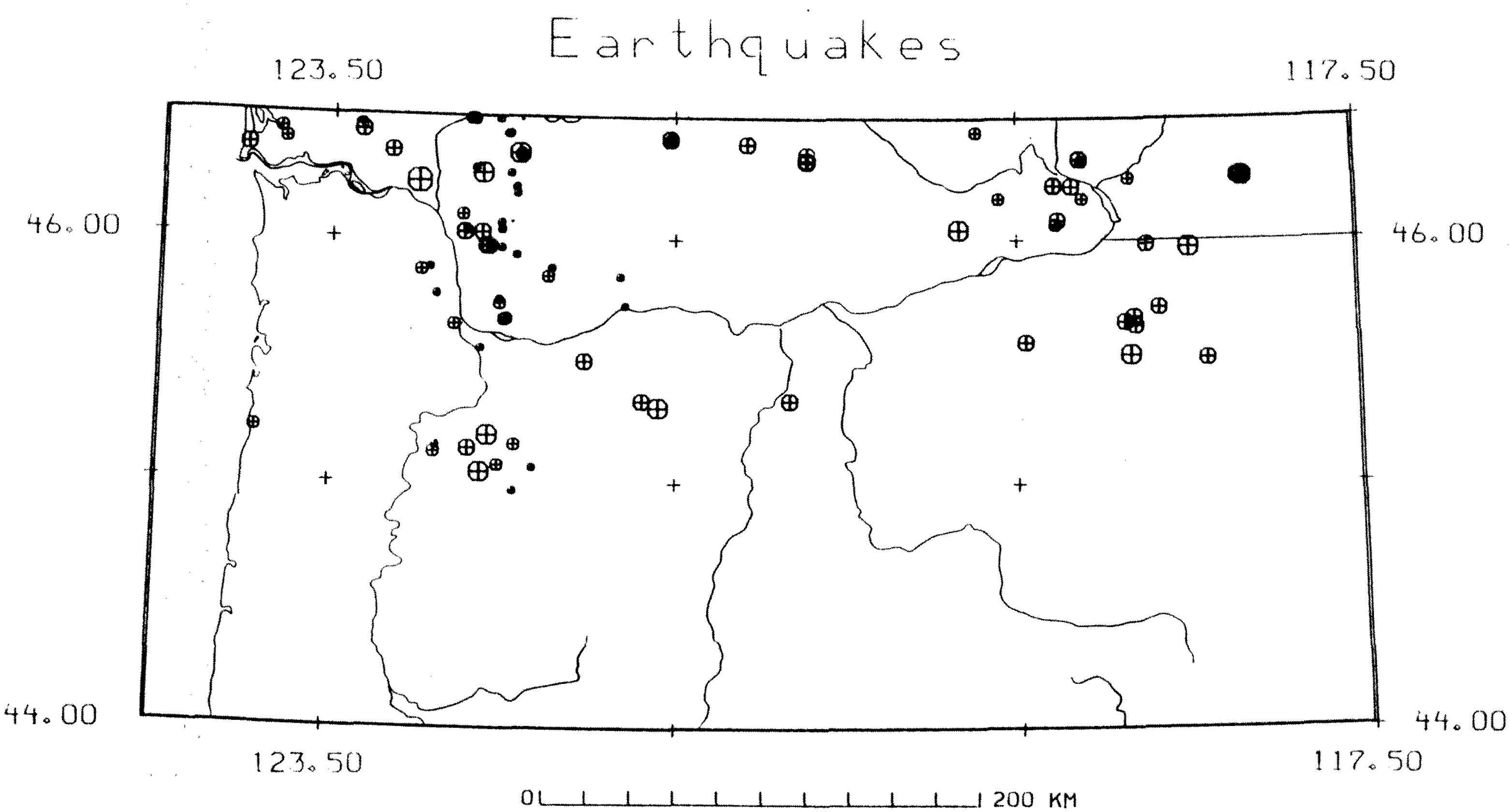

Figure II-4 Southern Washington-Northern Oregon earthquakes. July 1, 1983 - June 30, 1984.

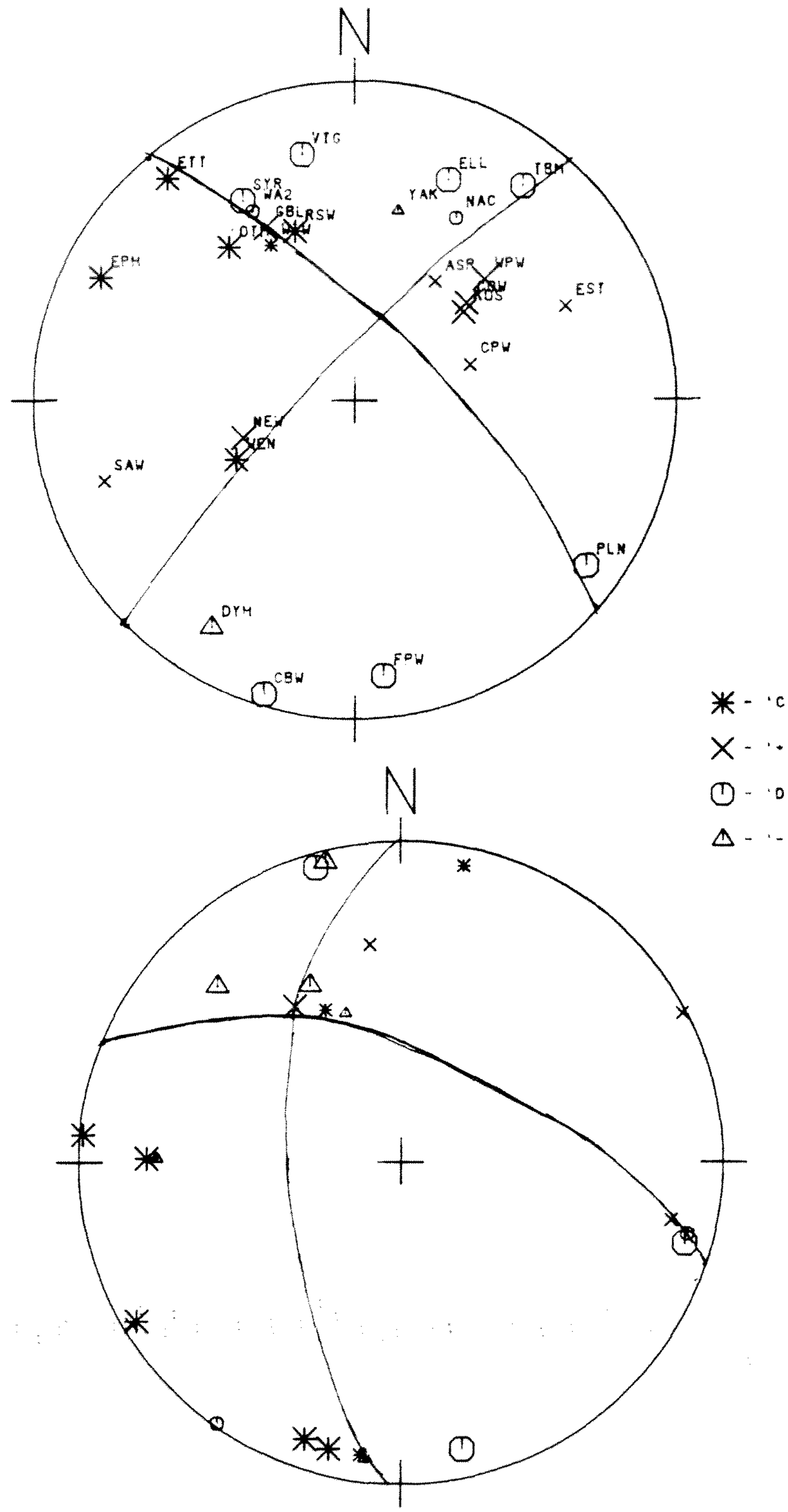

Figure II-5. A) Focal mechanism plot of magnitude 4.3 earthquake just north of Wenatchee on April 11, 1983. B) Composite focal mechanism plot of three earthquakes from the Entiat seismic zone.

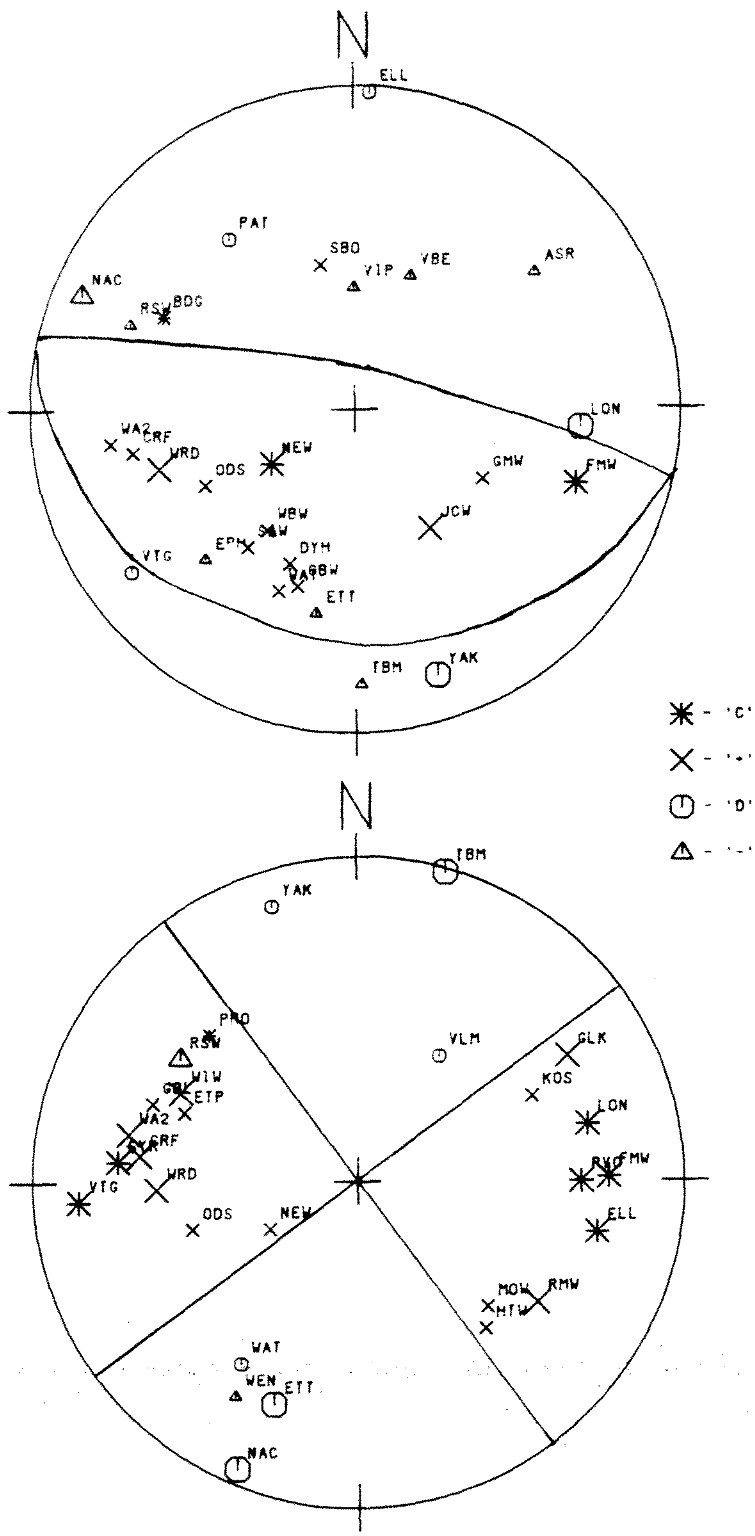

Figure II-6. A) Focal mechanism plot of the magnitude 3.8 earthquake near Yakima on November 14, 1983. B) Focal mechanism plot of the magnitude 3.8 earthquake just south of Ellensburg on December 5, 1983.

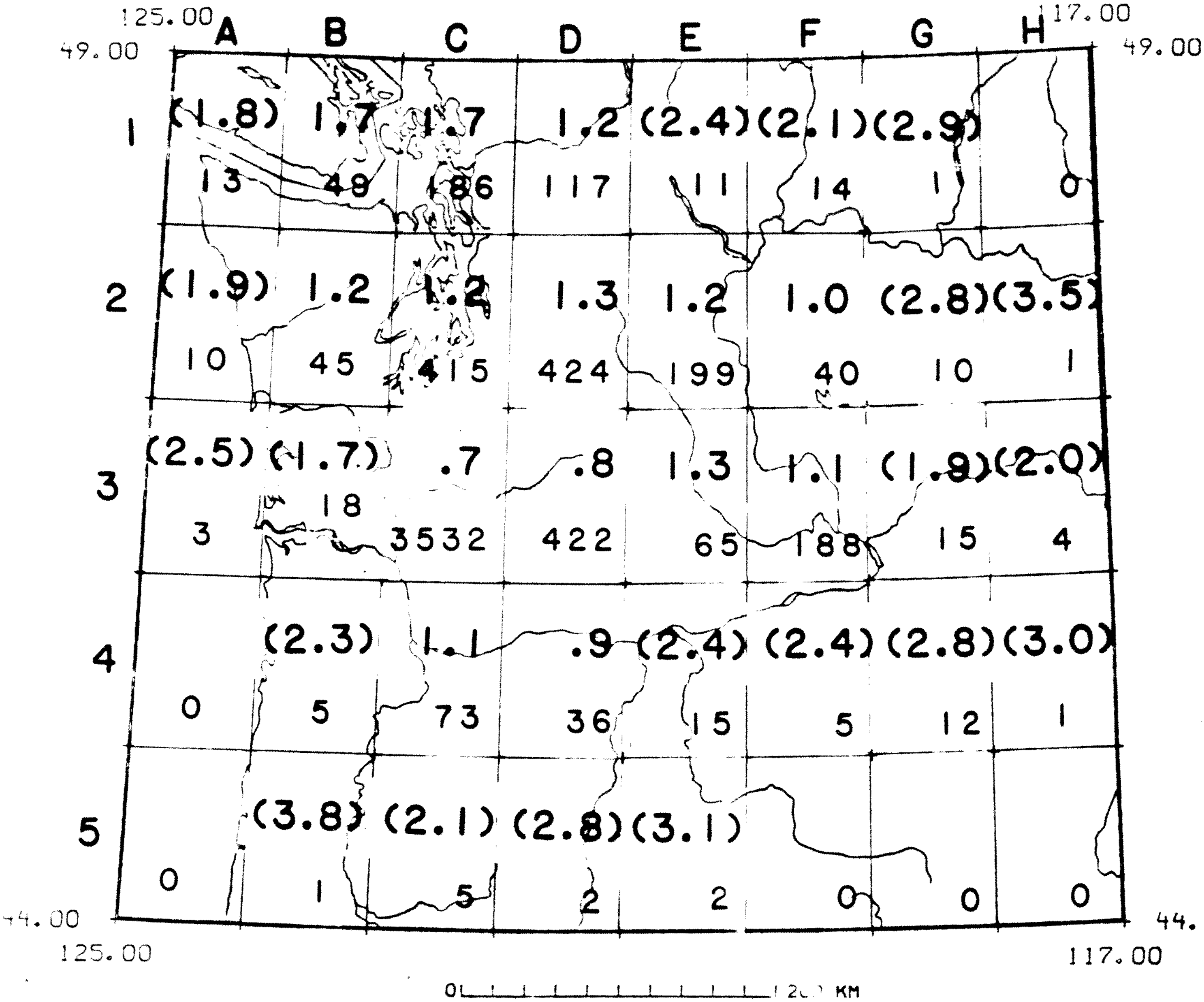

Figure II-7. Estimated magnitude completeness levels (large numbers), and number of located events 1981 through 1983 (small numbers). Magnitude completeness levels were estimated on the basis of linearity of log N vs. M plots when 25 or more events were located in an area. Where less than 25 events occurred, 1.3 magnitude units were added to the smallest located event in the area, and the magnitude completeness level is shown in parentheses.

STRUCTURAL STUDIES

In late August of this year, the USGS, in conjunction with the Basalt Waste Isolation Project of Rockwell Hanford Operations and the University of Washington, conducted a large-scale seismic refraction experiment in eastern Washington. In addition to the permanent networks operated by the University of Washington and Rockwell Hanford Operations, many portable instruments were deployed for this experiment. The USGS set up a line through the Hanford Reservation and Rockwell Hanford Operations set up a temporary network just to the east of the Hanford site. The University of Washington concentrated on the area just west of the Hanford Reservation.

Data Acquisition

Blasts were set off at four different locations on two separate nights. The first night shot #1 was a large blast while shot #'s 2, 3, and 4 were about half the size as shot #1. On the second night shot #4 was the large blast. The blast locations are given in Table III-1.

TABLE III-1 Blast Sites

Name	Latitude	Longitude
Shot #1	46 58 14	119 11 44
Shot #2	46 40 34	119 27 58
Shot #3	46 20 52	119 50 18
Shot #4	45 56 26	120 14 46

The USGS set up a refraction line 260km long that ran between the blasts and extended 60km past shot #'s 1 and 4 (Figure III-1). They used a 0.9km station spacing between the shots and a 1.3km station spacing northeast and southwest of shot #'s 1 and 4, respectively.

The Basalt Waste Isolation Project of Rockwell Hanford Operations set up a temporary network consisting of thirteen stations just east of the USGS deployment. A list of their temporary stations follows in Table III-2.

TABLE III-2 BWIP-RHO Temporary Network

Name	Latitude	Longitude
RYD	46 05 21	119 37 19
PTN	45 58 31	119 29 48
HAT	45 55 03	119 10 12
BUT	45 35 26	119 24 47
CSP	45 51 58	119 02 22
MFC	45 49 56	118 51 45
WRM	45 57 24	118 41 09
JON	46 07 25	118 39 34
GRN	46 18 05	118 32 43
MUR	46 20 40	118 46 03
SRR	46 28 34	118 45 47
DLY	46 37 54	118 39 03
PSC	46 20 44	118 57 11

The University of Washington set up refraction lines by using the stations in the area from our permanent network as a guide. These stations involved in the planning are VTG, ELL, TBM, NAC, YAK, GL2, and AUG. AUG, however, did not supply any useable data. Twenty-two stations were set up for the temporary network. Three of these stations (KIT, SLH, and WNS) were telemetered to our on-line system. The remaining sites were occupied by a variety of portable instruments. The temporary stations operated by the University of Washington are listed in Table 3.

Our on-line system triggered for seven of the eight blasts. The system did not trigger for shot #4 on the first night; however, it did trigger the second night when shot #4 was the large blast. We, therefore, have very good records from the stations that were telemetered to the university except for AUG. Our portable instruments recorded the blasts fairly well with the exceptions of N01, N08, and N09. We deployed portable digital recorders at these sites. First arrivals from these instruments could not be read from the output of the playback unit. But within the next couple of months we plan to obtain the capability of putting the digital data directly into the computer. With this in mind, we remain optimistic for the retrieval of some of this data.

TABLE III-3 University of Washington Temporary Network

Name	Latitude	Longitude	Shot #'s well recorded
NE1	46 58 21	119 34 41	1,2
NE2	46 57 56	119 43 42	1
NE4	46 45 42	119 56 16	1
N01	46 53 55	120 10 23	*
N02	46 55 30	120 21 58	2,4
N03	46 48 19	120 38 48	1,3,4
N08	46 54 45	120 43 51	*
N09	47 04 42	120 35 57	*
WNS	46 42 37	120 34 30	1,2,3,4
SLH	46 37 55	120 32 28	1,2,3,4
KIT	46 37 13	120 21 25	1,2,3,4
S01	46 29 18	120 31 04	4
S02	46 22 56	120 30 38	1,2,3,4
S03	46 17 06	120 31 36	1,2,3,4
S04	46 13 36	120 30 45	1,2,3,4
S06	46 09 17	120 27 20	1,2,3,4
S05	46 04 57	120 26 09	1,2,3,4
SW1	45 55 40	120 27 56	1,2,4
SW2	45 54 42	120 37 55	1,2,4
SW3	45 51 00	120 59 20	2,4
SW6	45 49 56	121 05 45	2,3,4
SW8	45 45 30	121 29 37	2,4

* We may be able to use secondary arrivals from these stations.

Analysis and Discussion

We have five main refraction lines to interpret. Our best line is s4-ELL. This line starts at shot #4 and trends northward through the Yakima Indian Reservation up to ELL (See Figure III-2). Another line beginning at shot #4 trends west towards Goldendale to SW8 (Figure III-3). A line from shot #3 extends northwest up to NAC (Figure III-4). We also have two lines starting at shot #1. The first, s1-YAK, trends southwest through YAK (Figure III-5) and the second, s1-N08, trends due west (Figure III-6). s1-N08 is the line most affected by our data retrieval problem mentioned earlier.

An initial look at the record section of s4-ELL indicates a first layer with an apparent refractor velocity of about 5.0 km/s (Figure III-2). There then appears to be a basement refractor with apparent velocity of about 7.4 km/s. This seems to be quite high. A possible explanation for this high velocity could be that the seismic energy is traveling up-dip along the refractor. The crossover distance is approximately 68km, which is very close to YAK.

The initial analysis of s4-SW8 is inconclusive. This line runs almost due west into the Cascades. Unfortunately the sampling sites are not as dense as we had hoped. Nevertheless, we may be seeing a basement refractor with a high apparent velocity (Figure III-3). Again this could be due to the wave traveling up-dip from shot #4. According to last year's annual report the area near shot #4 has a deep basement in comparison to the rest of the region. Therefore the up-dip hypothesis is reasonable since the Columbia River Basalts are absent at the far western end of the line.

The data for refraction line s3-NAC are a little sparse (Figure III-4). We may be seeing a first refractor at 5.0 km/s with the basement refractor near 6.0 km/s. This puts the crossover distance around 55km.

The data for line s1-YAK are not yet complete. We have just received the data from the Rockwell Hanford Operations network and this data has not been merged with the data from our network yet. We will have another station, RC2, on this line. An initial observation yields a 6.3 km/s basement refractor (Figure III-5). s1-N08 is the line in which we are trying to retrieve more data (Figure III-6).

One line from the Rockwell Hanford Operations temporary network begins at shot #4 and extends eastward (Figure III-7). This line has a first refractor with an apparent velocity of around 5.2 km/s and a basement refractor with an apparent velocity of about 7.5 km/s. This puts the crossover distance at 72km. Again we see a high apparent velocity from the basement refractor and therefore, a more shallow depth to basement as we proceed away from shot #4.

The high apparent velocities for refractors seen from shot #4 are consistent with a great depth to the 6.0 km/sec layer under this shot. Further evaluation for all of the lines is upcoming once we have all of the data digitized and into the computer. Complete record sections can then be played out for analysis. We plan further analysis of this kind as well as two dimensional ray tracing and synthetic seismogram generation based on trial models. We hope that these data, and perhaps other refraction data from additional quarry blasts, along with careful use of geologic controls based on maps and well data, will significantly improve our understanding of the structure in this region.