UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

DATA REPORT FOR O-NYNEX THE 1988 GRENVILLE-APPALACHIAN SEISMIC REFRACTION EXPERIMENT IN ONTARIO, NEW YORK AND NEW ENGLAND

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Introduction

In September, 1988, the U.S. Geological Survey (USGS), the U.S. Air Force Geophysics Laboratory (AFGL), and the Geological Survey of Canada (GSC) conducted a seismic refraction/wide angle reflection experiment in southern Ontario, New York, and New England to investigate the crustal and upper mantle velocity structure and inter-relationships of the North American craton, the Adirondack massif, and the northern Appalachians. The primary line of the experiment extended east from Marmora, Ontario, Canada across the Adirondacks in upstate New York, and the northern Appalachians in Vermont and New Hampshire to Waterville, Maine. Portable seismographs were located along this line at intervals of 750-1000 m. Shotpoints were located at intervals ranging from 30 to 40 km. In addition to the linear profile data, three fan shotpoints, located to the south of the recording array, were fired to image deep crustal structures. A subsidiary line acutely transverse to the primary profile in Vermont was recorded at ~3 km spacing by instruments from AFGL and the USGS. A wide-angle reflection experiment was recorded with a modified cross array of 210 instruments recording shots at distances of 0, 70, and 100 km. Instrument spacing in the cross array was 100 meters.

This report is a compilation of the data collected by the USGS, AFGL and the GSC. The data have been archived at the National Geophysical Data Center in Boulder, Colorado. Tapes are available from:

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
325 Broadway
Boulder, CO 80303
(303) 497-6472

Appendix B contains a description of the tape format. Interpretations of these data will be published separately.

Background

USGS/GSC investigations of northern Appalachian crustal structure commenced in 1983 with the collection of magnetic, gravity, seismic reflection and seismic refraction data along a transect from southern Quebec across Maine and the Gulf of Maine to the continental slope [*Stewart* et al., 1986; *Murphy and Luetgert*, 1986, 1987; *Spencer* et al., 1989]. The seismic refraction/wide-angle reflection experiment described here was initiated to further investigate northern Appalachian structure, the transition to the Grenville province and structure within the southern Grenville province. These data provide a partial link between the Quebec-Maine transect and the extensive data collected in the 1986 GLIMPCE experiment in the Great Lakes [*Green* et al., 1989].

Geology

The seismic refraction/wide-angle reflection profiles traverse several different geologic terranes of widely differing age and lithology. From west to east these terranes are the Central Metasedimentary Belt (CMB) of Ontario, the Central Granulite Terrain (CGT) of northern New York, and the Lower Paleozoic terranes of the northern Appalachian orogen in New England (Figure 1). The New England Appalachians are characterized by a series of tectono-stratigraphic terranes, accreted eastwards during multiple episodes of Paleozoic orogenesis [*Osberg*, 1978; *Robinson and Hall*, 1979; *Williams and*

Hatcher, 1982; *Zen*, 1983; *Bradley*, 1983]. Three major tectonic units are identified across the Northern Appalachians; a western Grenville province which is overthrust by lower Paleozoic shelf sediments and deep marine clastics, a central zone typified by island arc volcanics and eugeoclinal lithologies, and an eastern Avalonian block. These terranes represent a complex composite collage of smaller (suspect) terranes.

The survey crosses the eastern CMB and CGT subdivisions of the southeastern Grenville province [*Davidson*, 1986]. Beneath the Ontario segment of the survey, basement rocks are mainly a metaquartzite-metapelite-marble sequence. During the Grenville orogenic cycle, about 1080 Ma, this sequence was pervasively deformed, intruded and metamorphosed to granulite facies. In the New York lowlands, metamorphic grade decreases to amphibolite facies. From northwest to southeast, attitudes change gradually from southeast-dipping through vertical along the St. Lawrence River to northwest-dipping in New York State. On a crustal scale, the area is characterized by a network of continuous, curvilinear zones [*Forsyth* et al., 1990] of highly strained rocks interpreted as tectonic zones formed during deep ductile shearing [*Davidson*, 1984]. At least some of the domains are allochthonous. At the present erosional level, the domains reflect a deep level tectonic interleaving with major displacements occurring by ductile flow, primarily along domain boundary zones [*Davidson*, 1984].

Post-Grenville activity is indicated by a swarm of mafic dykes striking sub-parallel to the refraction line, dated at about 900 Ma, which are in turn cut by finer-grained porphyritic dykes dated at about 575 Ma [*Fahrig and West*, 1986].

Rocks of the CGT division of the Grenville province are exposed at the surface in the Adirondack Massif (Figure 1). Physiographically, the region is divided into the northwest Lowlands, underlain mainly by metasedimentary rocks of the CMB, and the Adirondack Highlands, consisting mainly of metaplutonic rocks with intervening synclines of metasediments [*McLelland and Isachsen*, 1986]. The boundary (Figure 1) is marked by the 110-km-long Carthage-Colton mylonite zone. The Adirondack Massif is a southerly extension of the Grenville province with an isotopic age of 1100 Ma [*McLelland and Isachsen*, 1986]. The Adirondack highlands are composed of a complex assemblage of granulite facies gneisses, schists, marbles and quartzites. Intruding the gneisses are meta-anorthosite bodies, the largest being the Marcy Anorthosite (Figure 1). The Adirondack Massif exposes an oblique section of mid to lower Proterozoic crust [*Selleck*, 1980; *McLelland and Isachsen*, 1986].

The contact between the Grenville and Appalachian provinces lies in the Champlain Valley, where allochthonous lower Paleozoic shelf assemblages and deep marine clastics (Taconic sequence) lie unconformably above the Grenville basement. These sediments have been interpreted as an accretionary complex developed above the eastward subducting Grenville margin in the Ordovician Taconic orogeny [*Stanley and Ratcliffe*, 1985]. Further to the east the Green Mountain massif of central Vermont exposes Grenville basement and Precambrian amphibolitic gneisses which can be correlated to Adirondack exposures further west. The Vermont Ultramafic Belt consists of altered slivers of Ordovician ultramafics imbricated with accretionary prism sediments [*Stanley and Ratcliffe*, 1985; *Bradley*, 1983; *Osberg*, 1978].

The central New England Appalachians are cored by a belt of Ordovician fore-arc sediments and island arc volcanics belonging to the Connecticut Valley trough and the Bronson Hill Anticlinorium, respectively. The

Connecticut Valley trough marks a shallow north-south structural low, where predominant Taconic deformation results in widespread amphibolitic metamorphism. It is widely believed that the Taconic orogeny (Mid to Upper Ordovician) emplaced the Connecticut Valley trough onto the Grenville crust [*Ando* et al., 1984; *Spencer* et al., 1989]. The Bronson Hill Anticlinorium can be traced through the central New England Appalachians as an aligned chain of gneissic domes (Oliverian Plutonic series) mantled by a series of Middle Ordovician meta-volcanics and greenschist to amphibolitic meta-pelites. Calc-Alkaline differentiation trends and rare earth element patterns delineate an eastward subducting Grenville margin beneath the arc in Middle Ordovician times (Taconic orogeny).

Further to the east the Merrimack trough extends through central Maine as a belt of Silurian deep marine clastics. The Merrimack trough has been extensively deformed in the Acadian orogeny (Devonian); metamorphic grades in the region of study typically attain upper amphibolitic facies. Intruded into the Merrimack trough in the early Jurassic, the White Mountain Magma series forms a north-south elongate province [*Creasy and Eby*, 1983; *McHone and Butler*, 1984]. The batholith is a composite of several overlapping caldera complexes composed predominantly of syenite, granite and monzonite. At the eastern end of the seismic profile Acadian granites belonging to the New Hampshire plutonic series are extensively intruded into the Merrimack trough. Gravity modeling of the New Hampshire series plutons indicate that they are thin (< 2.5 km) tabular bodies [*Nielson* et al., 1976; *Hodge*, 1982].

Geophysics

Previous seismic studies have indicated that significant differences in structural and seismic character exist between the Grenville and Appalachian provinces. The Northern Appalachians appear to be composed of a relatively thick (40 km) crust. Two crustal layers, with velocity 6.1 kms and 7.0 km/s for the upper and lower crustal units respectively, were separated by a discontinuity at 15 km depth as interpreted from teleseismic and surface wave dispersion data [*Taylor and Toksoz*, 1982; *Taylor*, 1989]. A major crustal suture separates the Adirondacks from the Appalachians. The Adirondacks are considered to have a somewhat thinner crust (36 km), and high velocities (>6.6 km/s) are observed throughout the crust in this region [*Taylor*, 1989].

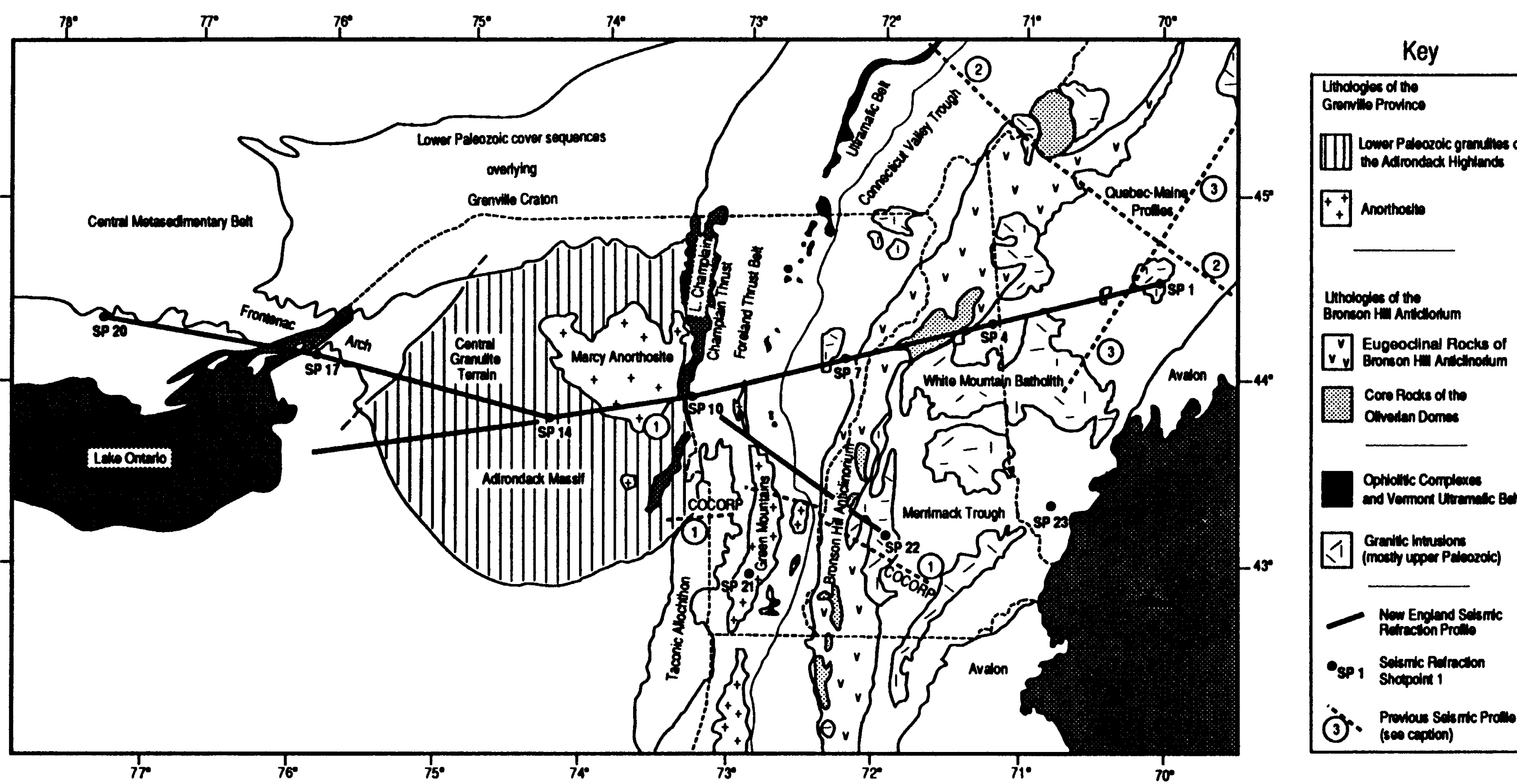
Deep seismic reflection profiling in southern Vermont (Figure 1 - line 1) identified a reflector interpreted as a major décollement over which pre-Taconic shelf sediments, and the Green Mountains were thrust [*Brown* et al.,1983; *Ando* et al., 1984]. The Green Mountains were clearly identified as a large box anticline developed over a lower crustal penetrating ramp. The edge of the Grenville (Taconic suture) was considered to be a highly deformed thrust imbricated zone beneath the Connecticut Valley trough passing eastwards into a transitional lower crust of unknown basement type. Further reflection profiling across the southern Adirondacks revealed a striking band of high reflectivity at mid crustal depths identified as the Tahawus complex [*Brown* et al., 1983; *Klemperer* et al., 1985]. The Tahawus complex consists of a broad band of high reflectivity between 6 and 8 seconds, a non-reflective zone, followed by a thin band of reflections at 9 seconds. This band of high reflectivity was correlated with a highly conductive lower crust at 20 km [*Connerney* et al., 1980].

In 1984 reflection and refraction profiles were obtained by the USGS and GSC across and along strike to the Northern Appalachians in Maine and Quebec (Figure 1 - line 2). A prominent reflector, interpreted as a décollement, was imaged at shallow depths below the St. Lawrence Lowlands extending to around 25 km deep below the Chain Lakes Massif [*Stewart* et al., 1986; *Spencer* et al., 1987; *Spencer* et al., 1989]. This décollement was interpreted to have been the sole thrust over which allochthonous upper crustal units were emplaced. Structures previously believed to be major crustal penetrating high-angle faults were interpreted as shallow imbricated thrusts associated with 120 km of lateral displacement of the allochthonous units. The Connecticut Valley trough was interpreted to be a shallow structure, less than 3 km thick.

Crustal thickening in Maine occurs towards the northwest. An isopach map of crustal thickness based on the 1984 experiment reveals a Moho depression in southwest Maine [*Luetgert* et al., 1987]; the two way travel time of ~11.5 seconds corresponds to a 40 km thick crust. No Moho penetrating structures were observed in wide-angle or vertical reflection data.

A 180 km refraction profile shot along the axis of the Merrimack trough (Figure 1- line 3) identified four major crustal units (*Hennet* et al., in prep.). This line is coincident with shotpoint 2 on the 1988 New England seismic refraction/wide-angle reflection profile. The crust is 40 km thick in the southwest and thins to 36 km in the north. The upper crust has a velocity between 6.0 and 6.3 km/s, and is characterized by strong lateral and vertical variations. The base of the Merrimack trough is considered to lie at around 15 km, and is marked by an increase in velocity to 6.4 km/s. The lower crustal layer is 16 km thick with a velocity of 6.8 km/s. On the basis of laboratory measurements of rock samples at elevated pressures and temperatures the upper crust is interpreted as a thick sequence of metasediments lying above a mafic lower crust (diabase or gabbroic gneiss).

Analyses of gravity data in the northern Appalachians of New England by *Bean* (1953), *Simmons* (1964), *Diment* (1968), and *Simpson* et al. (1980) provide interpretations of gravity anomaly maps of the study area.



New England Seismic Refraction / Wide Angle Reflection Profile

Geology simplified after Hatcher, 1975, and McLeland and Isachsen, 1986

Figure 1 - Generalized geologic map of the region of the experiment. Previous seismic profiles are shown by dashed lines; 1) Southern Vermont and Adirondack reflection profiles (Ando et al., 1984), 2) Quebec-Maine reflection and refraction profiles (Spencer et al., 1989), and 3) 1984 refraction profile along the axis of the Merrimack trough (Hennet et al., in prep).

Description of the Survey

Portable seismic recorders were laid out along the primary profile in a continuous linear pattern (Figure 1). A total of 35 shots were fired at 20 locations along the profile (shotpoints 1-20) and at 3 locations south of the profile (Table 1, Figure 2). To achieve the total profile length of 640 km, instruments were deployed three times.

The first deployment of 120 USGS instruments and 150 GSC instruments extended from central Maine west to the New Hampshire/Vermont border. Instruments were placed at a nominal spacing of 800 meters. In addition, 31 AFGL portable recorders were placed along the westward extension of the line in upstate New York (Figure 3).

The second deployment of instruments extended from the New Hampshire/Vermont border to the central Adirondacks at Long Lake, NY. During this deployment, AFGL instruments and ten of the USGS instruments were located on a subsidiary 150-km-long profile line between SP10 at Lake Champlain and SP22 in southern New Hampshire (Figure 4).

The third deployment of instruments extended from the central Adirondacks at Long Lake, NY to Marmora, Ontario. During this deployment, AFGL instruments were located near USGS deployment 2 sites in the eastern Adirondacks (Figure 5).

A subsidiary high-density wide-angle reflection experiment was recorded, placing USGS and GSC instruments in a Y-shaped array at 100 meter spacing and recording shots at shotpoints 4, 5, and 7 (Figures 6 and 7).

Recording instrument and shot point locations and elevations in the United States were determined using USGS 1:24000 and 1:62500 topographic maps. Shot point and instrument locations in Canada were determined using Canadian DEMR 1:50000 topographic maps. All the locations (Appendix A) are estimated to be accurate to within 25 meters; elevations within 5 meters.

All shotpoints, except SP20 in Canada, were sited in 20 cm X 45 m drill holes (Table 1). Ammonium nitrate explosive was detonated by electric caps, detonating cord, and boosters. The cap signal and two time-code signals, WWVB and IRIG-E, were recorded on paper strip-chart records, as described by *Healy* et al. (1982). The shots were fired automatically and the origin times were read from the cap break on the paper record. The reported shot times are accurate to within ± 2 milliseconds, assuming that the explosives detonated at the exact time of the cap break. SP20 was located in an abandoned, water filled quarry near Marmora, Ontario. Explosives were lowered to a depth of 195 m, connected to the surface with detonating cord and fired electrically from the shore. Shot instants are corrected for detonating cord delay.

Table 1

SHOT LIST

Shot No.	Shot Point	Date		Shot Time Day:Hr:Mn:Sec	Size (kg)	Latitude (deg, min)	Longitude (deg, min)	Elev. (m)
1	2	1988	9/16	261:04:00:00.006	1011.5	44 33.795N	70 02.672W	122
2	5	1988	9/16	261:04:02:00.009	997.9	44 20.173N	71 23.098W	516
3	7	1988	9/16	261:04:04:00.006	1224.7	44 10.708N	72 14.192W	460
4	22	1988	9/16	261:04:06:00.008	907.2	43 14.165N	71 51.534W	325
5	14	1988	9/16	261:04:08:00.006	1360.8	43 59.969N	74 29.266W	530
6	6	1988	9/16	261:06:00:00.006	907.2	44 16.857N	71 49.785W	329
7	4	1988	9/16	261:06:02:00.010	986.6	44 24.686N	70 58.175W	317
8	1	1988	9/16	261:06:04:00.006	2091.1	44 35.409N	69 44.766W	95
9	3	1988	9/16	261:08:00:00.011	1020.6	44 27.537N	70 31.360W	277
10	23	1988	9/16	261:08:02:00.010	1029.7	43 26.947N	70 40.309W	79
11	10	1988	9/16	261:08:04:00.010	1360.8	44 03.217N	73 23.188W	35
12	4	1988	9/19	264:19:00:00.011	476.3	44 24.686N	70 58.175W	317
13	7	1988	9/19	264:19:04:00.006	158.8	44 10.708N	72 14.192W	460
14	5	1988	9/19	264:20:02:00.007	340.2	44 20.173N	71 23.098W	516
15	8	1988	9/23	268:04:00:00.009	907.2	44 09.047N	72 34.595W	433
16	9	1988	9/23	268:04:02:00.006	907.2	44 04.409N	72 55.955W	671
17	12	1988	9/23	268:04:04:00.007	952.5	43 56.259N	73 58.960W	535
18	22	1988	9/23	268:04:06:00.007	907.2	43 14.165N	71 51.534W	325
19	20	1988	9/23	268:04:07:59.970	1360.8	44 28.661N	77 39.485W	0
20	7	1988	9/23	268:06:00:00.009	1224.7	44 10.708N	72 14.192W	460
21	17	1988	9/23	268:06:02:00.010	1156.7	44 17.825N	75 55.547W	94
22	13	1988	9/23	268:06:04:00.007	1043.3	43 58.078N	74 15.689W	524
23	10	1988	9/23	268:06:06:00.006	907.2	44 03.217N	73 23.188W	35
24	14	1988	9/23	268:08:00:00.007	1247.2	43 59.969N	74 29.266W	530
25	11	1988	9/23	268:08:02:00.006	975.2	43 59.532N	73 39.668W	287
26	21	1988	9/23	268:08:04:00.007	907.2	43 03.415N	72 56.287W	710
27	4	1988	9/23	268:08:06:00.011	1224.7	44 24.686N	70 58.175W	317
28	20	1988	9/29	274:03:59:59.969	907.2	44 28.661N	77 39.485W	0
29	18	1988	9/29	274:04:01:59.990	907.2	44 21.156N	76 41.066W	143
30	17	1988	9/29	274:04:04:00.009	272.2	44 17.825N	75 55.547W	94
31	14	1988	9/29	274:04:06:00.010	1134.0	43 59.969N	74 29.266W	530
32	19	1988	9/29	274:05:59:59.996	907.2	44 25.211N	77 09.508W	180
33	16	1988	9/29	274:06:02:00.007	884.5	44 14.635N	75 31.696W	175
34	15	1988	9/29	274:06:04:00.006	816.5	44 09.337N	75 00.946W	427
35	10	1988	9/29	274:06:06:00.005	1360.8	44 03.217N	73 23.188W	35

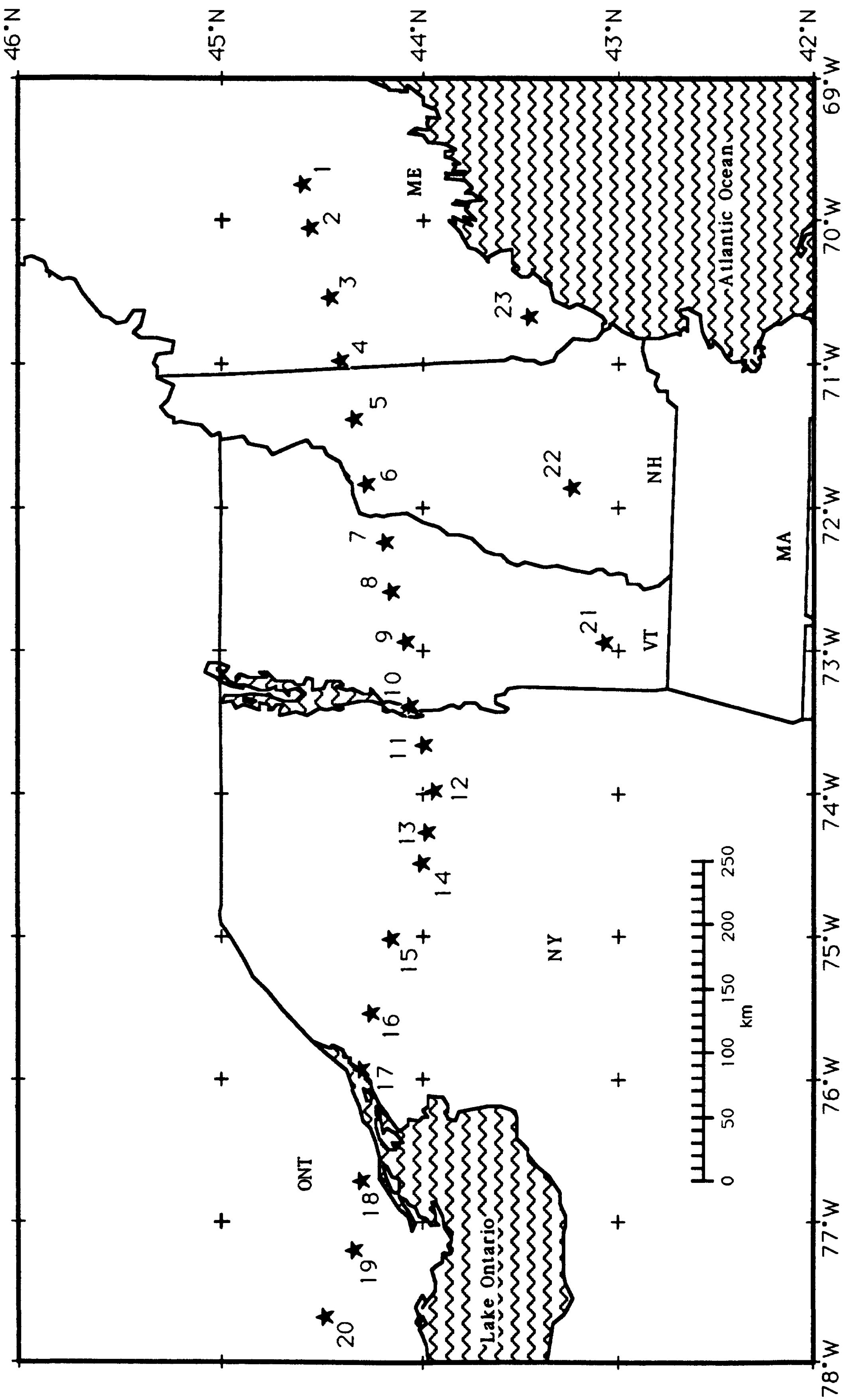


Figure 2 - Shotpoints which were fired during the experiment.

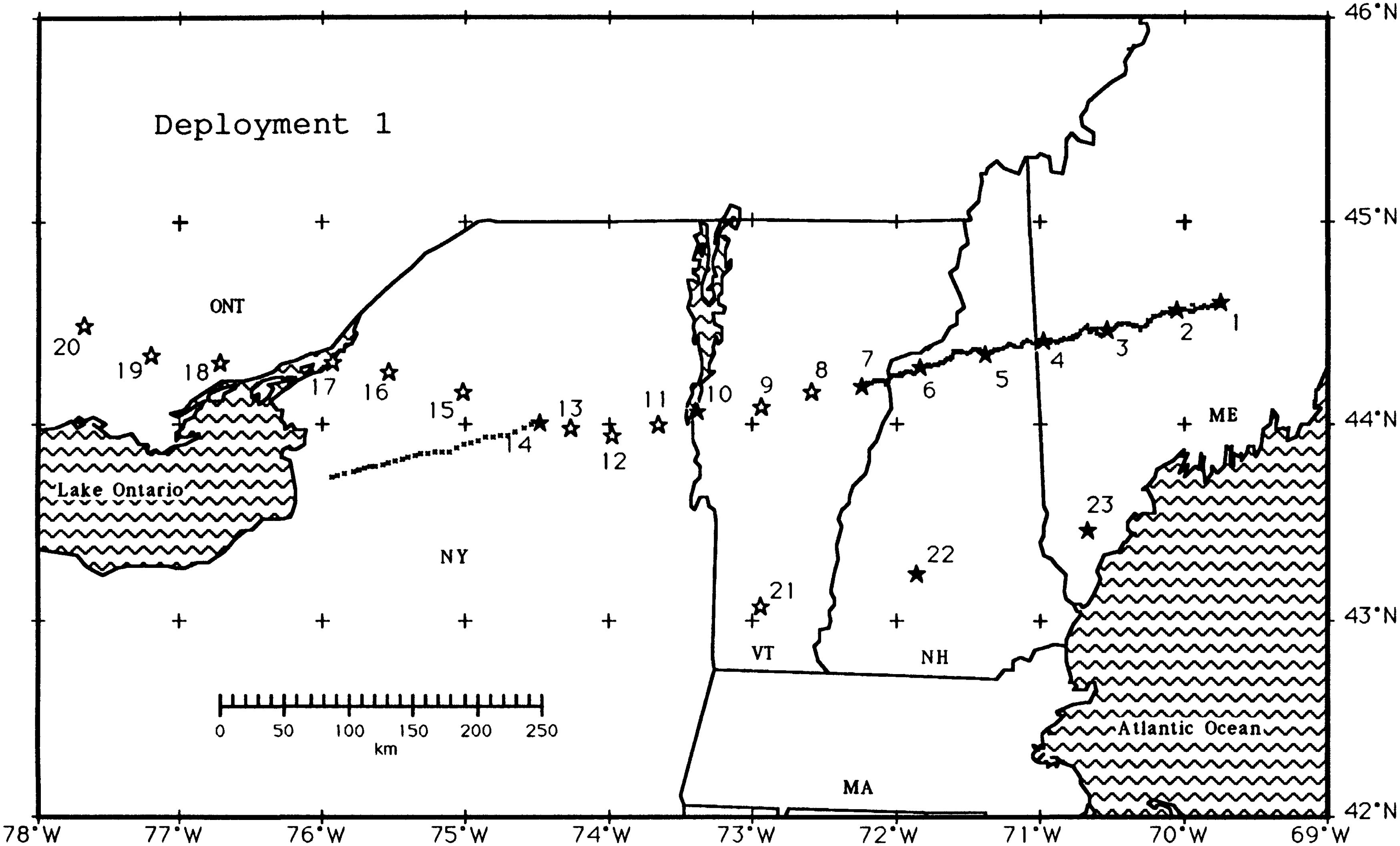


Figure 3 - Recording sites for Deployment 1. Labeled shotpoints were fired during this deployment.

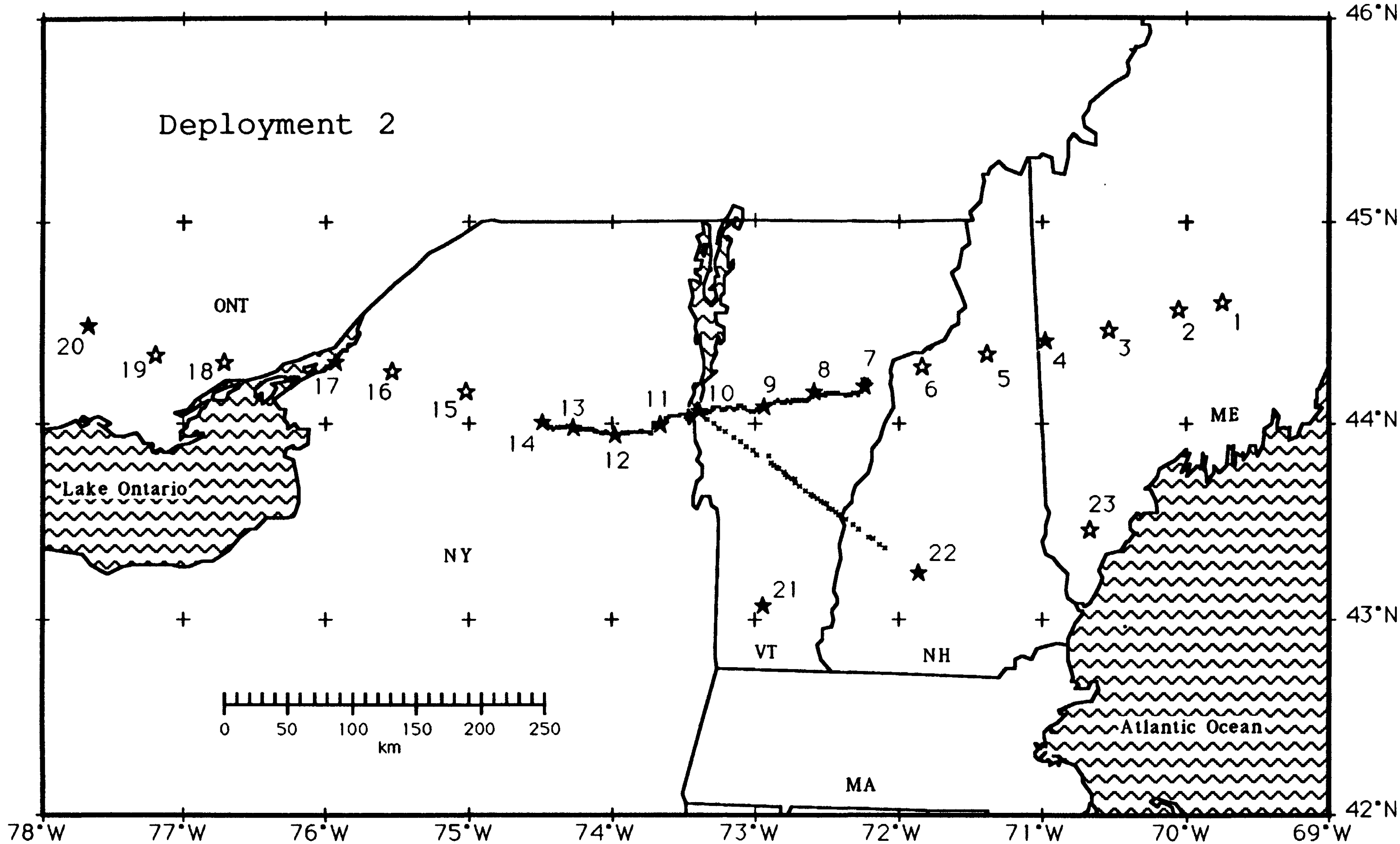


Figure 4 - Recording sites for Deployment 2. Labeled shotpoints were fired during this deployment.

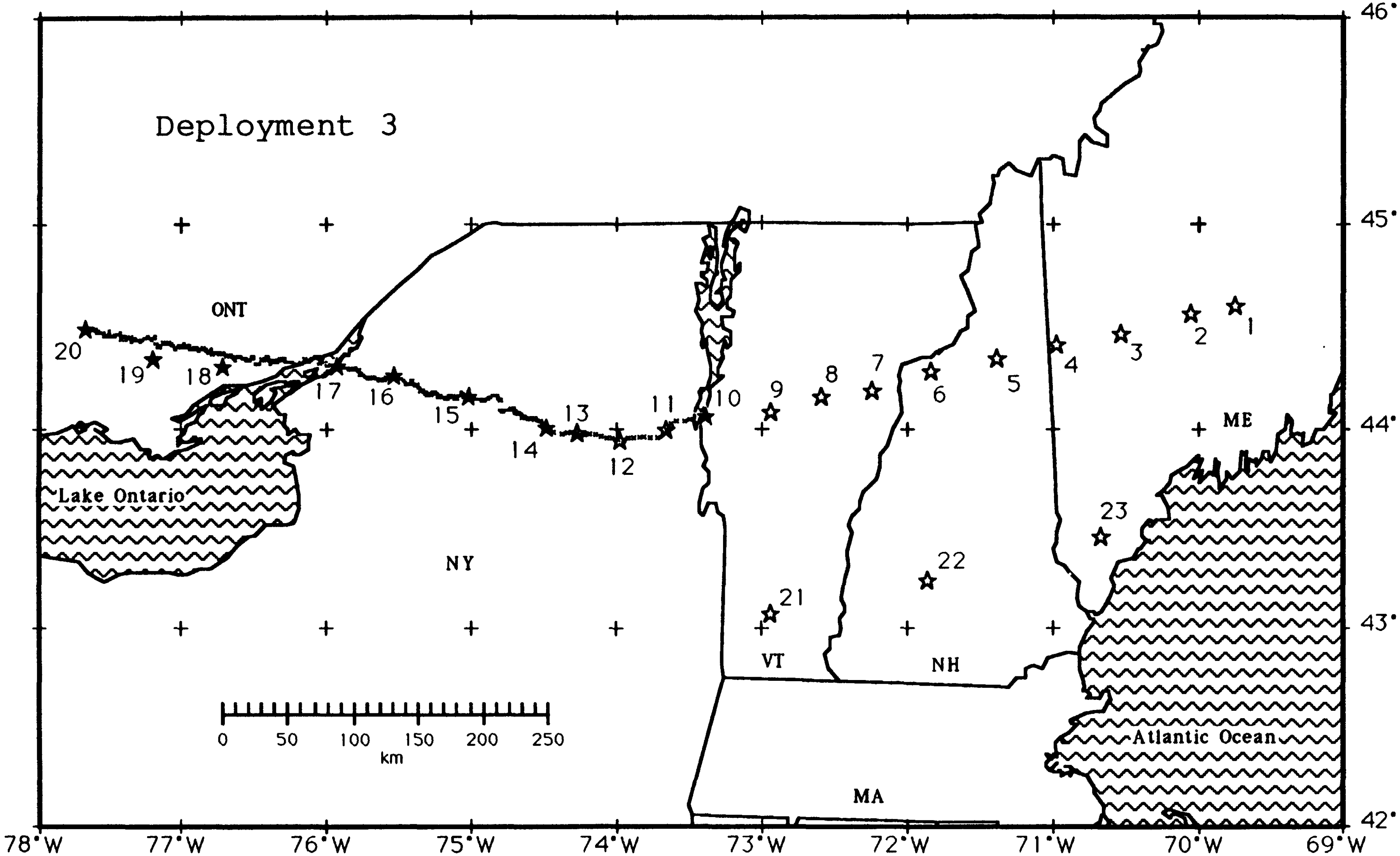


Figure 5 - Recording sites for Deployment 3. Labeled shotpoints were fired during this deployment.

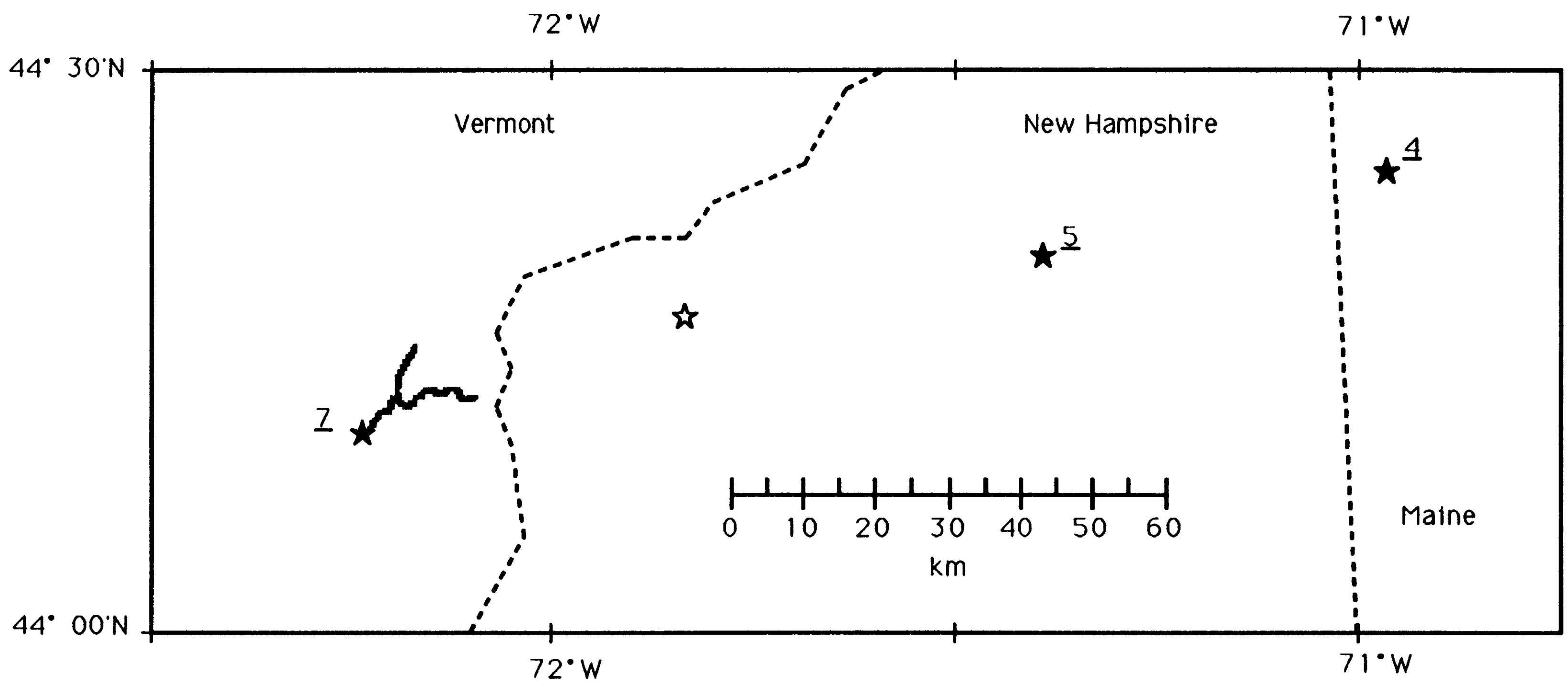


Figure 6 - Recording sites for high-density, wide-angle reflection deployment. Labeled shotpoints were fired during this deployment.

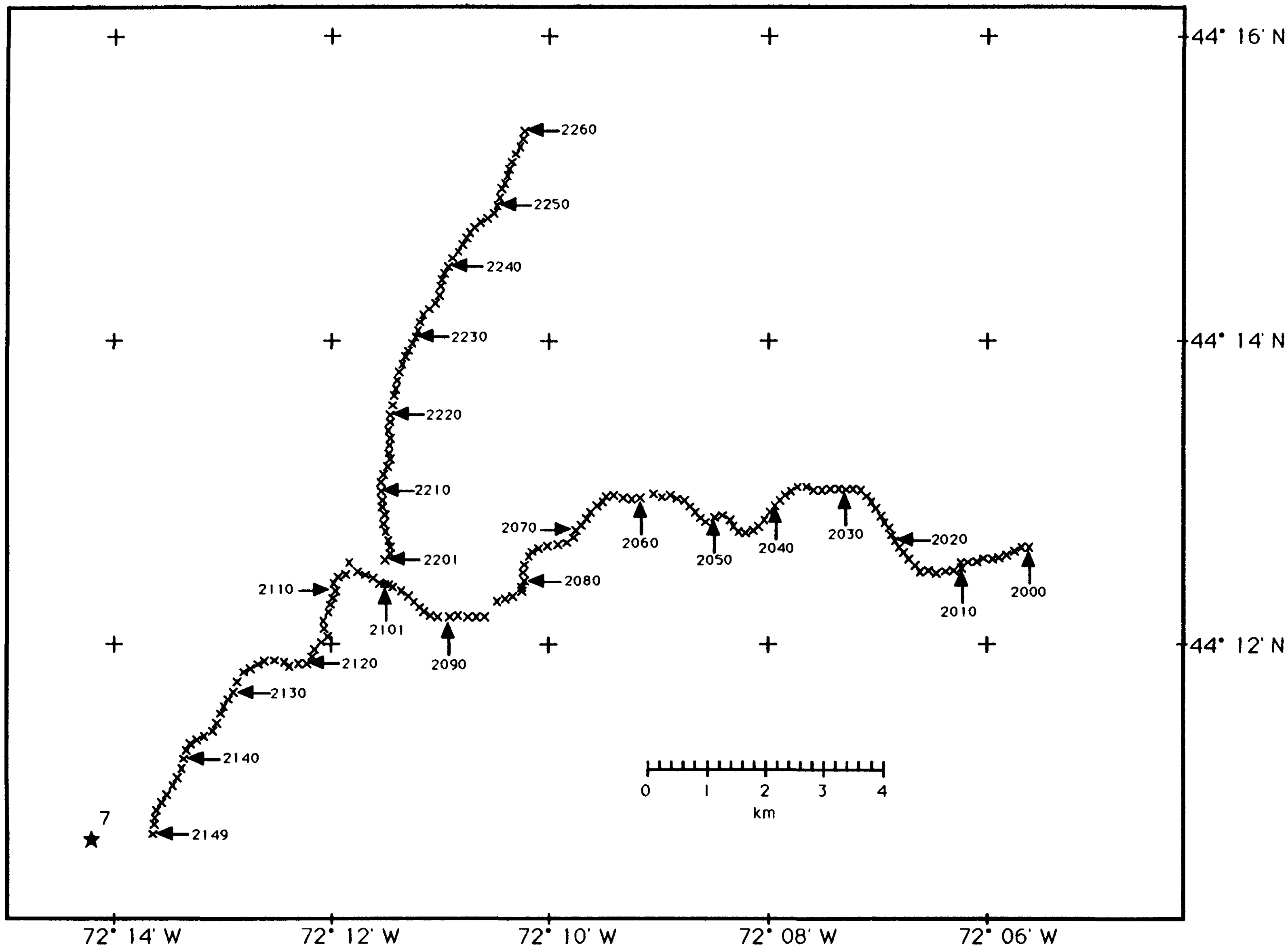


Figure 7 - Recording sites for the high-density, wide-angle reflection experiment.

INSTRUMENTATION AND DATA REDUCTION

Seismic Recorders

The USGS seismic cassette recorders used in this seismic-refraction survey have been described by *Murphy* (1989). Each instrument is connected to a Mark Products L4A 2-Hz vertical-component geophone. The signal from this geophone passes through three parallel amplifiers, each with an adjustable gain setting. The three seismic signals plus an internally generated time code (IRIG-E) and a fixed reference frequency are recorded as a multiplexed signal on analog cassette tape. A programmable memory board in each unit allows data to be recorded during ten predetermined time windows. Prior to recording the seismic data, the instrument records a geophone pulse, an amplification step, and 10-Hz sine-wave calibration signals at 1, 10, 100, and 1000 mv. The displacement frequency response curve for the system peaks at about 20 Hz (Figure 8). Attenuation settings of every instrument have been checked against the calibration signals. Where calibration signals indicated a different dB setting than listed on the field sheets, the correct settings were calculated and entered into the computer. After checking for errors in clock drift and site locations, the analog data were digitized for 50 seconds, starting at (X/8-1) or (X/6-4) seconds prior to shot time, where X is the shot point to recorder distance in km. The sampling rate for digitizing was 200 samples per second.

The PRS-1 system used by the GSC also uses a Mark Products L4A 2-Hz vertical-component geophone. These digitally recording instruments have a total dynamic range of 126 dB. Curves showing displacement versus frequency for this system peak at approximately 17 Hz (Figure 8) (*I. Asudeh*, pers.comm., 1987). The PRS-1 system records data at a sample rate of 125 samples per second. Data from these instruments have been resampled at 200 samples per second for merging with other data.

All AFGL data were recorded on automatic gain ranging Terra Technology DCS-302 portable digital cassette seismographs connected to either a Sprengnether Instruments S-6000, 2 Hz triaxial seismometer, or 3 Hall-Sears HS-10-1B, 1Hz seismometers. In standard configuration each DCS-302 recorded 3 channels of data at 100 sps with a 30 Hz anti-aliasing filter. Some stations were configured to record at 200 sps with a 70 Hz anti-aliasing filter. Calibration pulses for each seismometer were recorded on tape prior to each deployment. Each seismograph also recorded IRIG-H time code from WWVB receivers within each unit. Details of the AFGL instrumentation may be found in *Mangino and Cipar* (1990). While the AFGL data was recorded with three components, only the vertical component has been used in this report for compatibility with the other data. All three components of the AFGL data may be found in *Mangino and Cipar* (1990).

The clocks of each recording unit were initially synchronized to a GOES master clock via a portable base receiver. Each unit was then deployed with programmable timers to initiate recording over the expected shot time window. After each deployment the GOES time signal was compared to the internal clocks for drift measurement. Most data were time corrected using the GOES data assuming a linear drift rate.

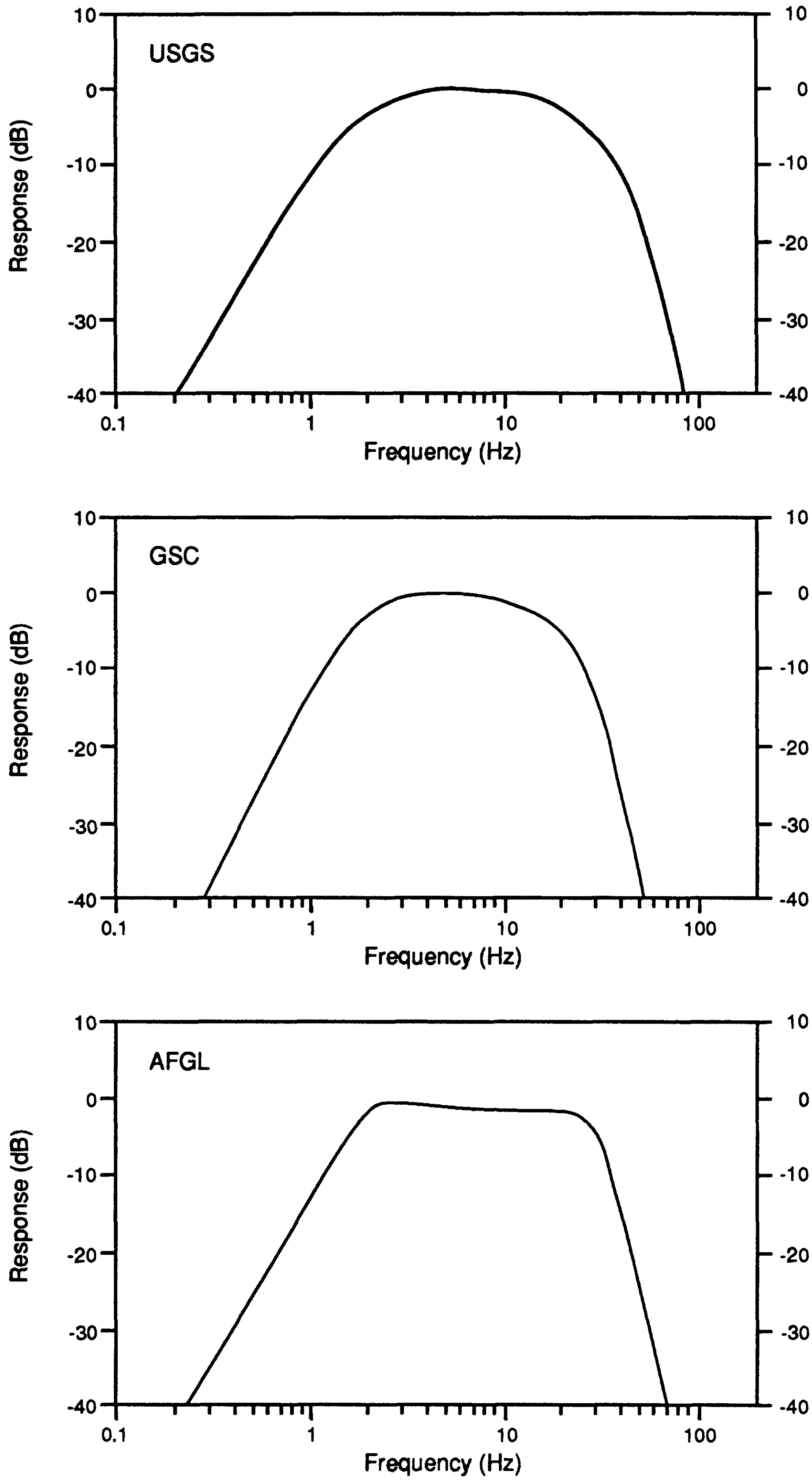


Figure 8 - Theoretical velocity response curves for the three groups of instruments used in this experiment.

Data Reduction

Following the experiment, data from all groups was written in SEGY-LDS format and merged into shot gathers. All data have been resampled (where necessary) to 200 samples per second and header information has been checked for accuracy and consistency.

Record Sections

For each shot a trace-normalized record section is presented (Plates 1-8). Since shots from shotpoints 4, 7, 10, 14, 17, 20 and 22 were recorded during multiple deployments, records from these shotpoints are concatenated to form single record sections.

All traces are normalized to their maximum deflection and plotted using reduced time, with a reduction velocity of 7.0 km/s. A few of the shot gathers were recorded in a fan geometry and, although time reduction is calculated using true offset distance, they are plotted versus distance from the endpoint of the recording array. All traces have been bandpass filtered from 2 to 18 Hz to attenuate high frequency noise bursts and ground roll. A few traces which recorded no data have been removed for clarity.

In order to make the record sections (Plates 1-8) easier to analyze, a few traces were deleted in areas where stations were close together or where a noisy trace obscured surrounding data.

Description of the plates

Plate 1

Shotpoint 1 recorded by AFGL instruments in deployment 1.
Shotpoint 1 recorded by USGS/GSC instruments in deployment 1.
Shotpoint 2 recorded by AFGL instruments in deployment 1.
Shotpoint 2 recorded by USGS/GSC instruments in deployment 1.
Shotpoint 3 recorded by AFGL instruments in deployment 1.
Shotpoint 3 recorded by USGS/GSC instruments in deployment 1.
Shotpoint 4 recorded by AFGL instruments in deployment 1 and
USGS/GSC instruments in deployments 1 & 2.

Plate 2

Shotpoint 5 recorded by AFGL instruments in deployment 1.
Shotpoint 5 recorded by USGS/GSC instruments in deployment 1.
Shotpoint 6 recorded by AFGL instruments in deployment 1.
Shotpoint 6 recorded by USGS/GSC instruments in deployment 1.
Shotpoint 7 recorded by AFGL instruments in deployment 1 and
USGS/GSC instruments in deployments 1 & 2.
Shotpoint 8 recorded by USGS/GSC instruments in deployment 2.
Shotpoint 9 recorded by USGS/GSC instruments in deployment 2.

Plate 3

Shotpoint 10 recorded by USGS/GSC instruments in deployments 1,2 & 3.
Shotpoint 11 recorded by USGS/GSC instruments in deployment 2.
Shotpoint 12 recorded by USGS/GSC instruments in deployment 2.
Shotpoint 13 recorded by USGS/GSC instruments in deployment 2.
Shotpoint 14 recorded by USGS/GSC instruments in deployments 1,2 & 3.
Shotpoint 14 recorded by AFGL instruments in deployments 1 & 3.
Shotpoint 10 recorded by AFGL instruments in deployments 1 & 3.

Plate 4

Shotpoint 15 recorded by AFGL/USGS/GSC instruments in deployment 3.
Shotpoint 16 recorded by AFGL/USGS/GSC instruments in deployment 3.
Shotpoint 17 recorded by USGS/GSC instruments in deployments 2 & 3.
Shotpoint 18 recorded by AFGL/USGS/GSC instruments in deployment 3.

Plate 5

Shotpoint 19 recorded by AFGL/USGS/GSC instruments in deployment 3.
Shotpoint 20 recorded by USGS/GSC instruments in deployments 2 & 3.
Shotpoint 20 recorded by AFGL instruments in deployment 3.
Shotpoint 21 recorded by USGS/GSC instruments in deployment 2 [fan].
Shotpoint 22 recorded by AFGL/USGS/GSC instruments in deployments 1 & 2 [fan].

Plate 6

Shotpoint 23 recorded by AFGL instruments in deployment 1.
Shotpoint 23 recorded by USGS/GSC instruments in deployment 1 [fan].
Shotpoint 4 recorded by AFGL/USGS instruments in deployment 2 [fan].
Shotpoint 7 recorded by AFGL/USGS instruments in deployment 2 [fan].
Shotpoint 8 recorded by AFGL/USGS instruments in deployment 2 [fan].
Shotpoint 9 recorded by AFGL/USGS instruments in deployment 2 [fan].
Shotpoint 10 recorded by AFGL/USGS instruments in deployment 2.
Shotpoint 11 recorded by AFGL/USGS instruments in deployment 2.

Plate 7

Shotpoint 12 recorded by AFGL/USGS instruments in deployment 2.
Shotpoint 13 recorded by AFGL/USGS instruments in deployment 2.
Shotpoint 14 recorded by AFGL/USGS instruments in deployment 2.
Shotpoint 17 recorded by AFGL/USGS instruments in deployment 2.
Shotpoint 20 recorded by AFGL/USGS instruments in deployment 2.
Shotpoint 21 recorded by AFGL/USGS instruments in deployment 2 [fan].
Shotpoint 22 recorded by AFGL/USGS instruments in deployment 2.

Plate 8

Shotpoint 4 recorded by USGS/GSC instruments in reflection experiment [profile].
Shotpoint 4 recorded by USGS/GSC instruments in reflection experiment [fan].
Shotpoint 5 recorded by USGS/GSC instruments in reflection experiment [profile].
Shotpoint 5 recorded by USGS/GSC instruments in reflection experiment [fan].
Shotpoint 7 recorded by USGS/GSC instruments in reflection experiment [profile].
Shotpoint 7 recorded by USGS/GSC instruments in reflection experiment [profile].

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Appendix A

Shot Point Locations

Location	Lat. (N) deg	Lat. (N) min	Long. (W) deg	Long. (W) min	Elev. meters
1	44	35.409	69	44.766	95
2	44	33.795	70	2.672	122
3	44	27.537	70	31.360	277
4	44	24.686	70	58.175	317
5	44	20.172	71	23.098	516
6	44	16.857	71	49.785	329
7	44	10.708	72	14.191	460
8	44	9.047	72	34.595	433
9	44	4.409	72	55.955	671
10	44	3.217	73	23.188	35
11	43	59.532	73	39.668	287
12	43	56.259	73	58.960	535
13	43	58.078	74	15.689	524
14	43	59.969	74	29.266	530
15	44	9.337	75	0.946	427
16	44	14.635	75	31.696	175
17	44	17.824	75	55.547	94
18	44	21.156	76	41.066	143
19	44	25.211	77	09.508	180
20	44	28.661	77	39.485	0
21	43	3.415	72	56.287	710
22	43	14.165	71	51.534	325
23	43	26.947	70	40.309	79

Appendix A

Deployment 1 - USGS & GSC sites

Location	Lat. (N) deg	min	Long. (W) deg	min	Elev. meters	Location	Lat. (N) deg	min	Long. (W) deg	min	Elev. meters
101	44	35.378	69	44.762	95	151	44	32.073	70	12.629	213
102	44	35.449	69	44.965	95	152	44	31.743	70	13.211	152
103	44	35.536	69	45.462	126	153	44	31.331	70	13.662	152
104	44	35.522	69	46.214	94	154	44	30.805	70	14.170	110
105	44	35.302	69	46.756	91	155	44	30.953	70	14.742	110
106	44	35.279	69	47.377	88	156	44	30.698	70	15.299	113
107	44	35.410	69	48.009	78	157	44	29.616	70	15.631	122
108	44	35.401	69	48.627	76	158	44	29.480	70	16.183	102
109	44	35.206	69	49.167	76	159	44	29.197	70	16.685	88
110	44	35.048	69	49.729	103	160	44	29.007	70	17.247	116
111	44	34.891	69	50.245	95	161	44	29.210	70	17.915	128
112	44	35.102	69	50.913	124	162	44	28.108	70	18.212	122
113	44	35.292	69	51.583	98	163	44	29.026	70	19.089	128
114	44	35.071	69	52.139	113	164	44	29.559	70	19.892	128
115	44	34.841	69	52.734	122	165	44	29.444	70	20.466	134
116	44	34.562	69	53.289	78	166	44	29.371	70	21.054	146
117	44	34.664	69	53.922	122	167	44	29.565	70	21.689	134
118	44	34.585	69	54.489	98	168	44	29.766	70	22.335	128
119	44	34.662	69	55.249	143	169	44	30.087	70	23.071	134
120	44	33.971	69	55.504	116	170	44	29.836	70	23.599	140
121	44	35.758	69	56.615	314	171	44	30.318	70	24.391	128
122	44	33.808	69	56.781	314	172	44	30.118	70	24.883	159
123	44	33.432	69	57.156	335	173	44	30.218	70	25.529	183
124	44	33.836	69	57.927	258	174	44	29.889	70	26.059	207
125	44	33.990	69	58.602	250	175	44	29.574	70	26.582	213
126	44	34.138	69	59.276	271	176	44	29.937	70	27.342	207
127	44	34.330	69	59.955	271	177	44	29.519	70	27.771	189
128	44	34.062	70	0.425	268	178	44	29.013	70	28.269	189
129	44	33.877	70	0.870	213	179	44	29.065	70	28.879	159
130	44	33.846	70	1.437	168	180	44	28.590	70	29.387	159
131	44	33.789	70	1.947	171	181	44	28.395	70	29.933	230
132	44	33.711	70	2.349	165	182	44	28.050	70	30.476	232
133	44	33.843	70	2.685	122	183	44	27.956	70	30.986	250
134	44	33.897	70	3.001	104	184	44	27.512	70	31.335	277
135	44	33.746	70	3.398	134	185	44	27.739	70	31.538	280
136	44	33.434	70	3.897	128	186	44	27.588	70	32.152	323
137	44	33.073	70	4.388	116	187	44	27.116	70	32.623	317
138	44	32.950	70	4.980	140	188	44	26.846	70	33.103	317
139	44	33.189	70	5.665	116	189	44	26.532	70	33.640	305
140	44	33.244	70	6.308	122	190	44	26.319	70	34.208	315
141	44	33.450	70	6.999	152	191	44	26.617	70	34.862	308
142	44	33.526	70	7.604	122	192	44	26.910	70	35.634	255
143	44	33.335	70	8.250	183	193	44	26.957	70	36.178	265
144	44	33.279	70	8.987	189	194	44	27.992	70	36.461	215
145	44	32.857	70	9.279	232	195	44	28.312	70	37.127	206
146	44	32.590	70	9.811	195	196	44	28.224	70	37.730	232
147	44	32.374	70	10.329	231	197	44	28.516	70	38.412	192
148	44	32.303	70	10.953	227	198	44	27.847	70	38.867	201
149	44	32.238	70	11.508	201	199	44	27.477	70	39.288	195
150	44	32.157	70	12.083	189	200	44	29.716	70	40.579	195

Appendix A

Location	Lat. (N)		Long. (W)		Elev.	Location	Lat. (N)		Long. (W)		Elev.
	deg	min	deg	min	meters		deg	min	deg	min	meters
201	44	28.703	70	40.901	317	251	44	23.142	71	9.157	232
202	44	28.644	70	41.522	262	252	44	23.117	71	9.757	238
203	44	28.466	70	42.053	207	253	44	23.060	71	10.412	247
204	44	28.158	70	42.633	207	254	44	23.511	71	11.209	241
205	44	27.881	70	43.189	189	255	44	23.685	71	11.879	247
206	44	27.275	70	43.515	207	256	44	23.878	71	12.363	262
207	44	26.949	70	44.080	280	257	44	23.936	71	13.103	279
208	44	26.655	70	44.589	252	258	44	23.503	71	13.461	308
209	44	25.735	70	44.898	207	259	44	23.209	71	14.043	384
210	44	26.223	70	45.656	360	260	44	23.014	71	14.632	418
211	44	26.165	70	46.223	390	261	44	22.813	71	15.188	450
212	44	25.609	70	46.626	280	262	44	22.567	71	15.792	408
213	44	25.764	70	47.371	210	263	44	22.511	71	16.358	384
214	44	25.767	70	47.998	201	264	44	22.503	71	16.948	393
215	44	25.233	70	48.464	198	265	44	22.451	71	17.495	396
216	44	25.276	70	49.102	201	266	44	22.401	71	18.057	402
217	44	25.352	70	49.735	218	267	44	22.219	71	18.705	408
218	44	25.492	70	50.329	203	268	44	22.077	71	19.164	420
219	44	25.283	70	50.920	223	269	44	21.944	71	19.736	432
220	44	24.939	70	51.482	220	270	44	21.645	71	20.280	442
221	44	24.647	70	51.950	216	271	44	21.400	71	20.801	456
222	44	24.485	70	52.483	213	272	44	21.437	71	21.528	456
223	44	24.520	70	53.156	207	273	44	21.478	71	22.081	444
224	44	24.643	70	53.778	204	274	44	21.388	71	22.710	423
225	44	24.733	70	54.374	201	275	44	20.140	71	23.106	510
226	44	24.762	70	55.028	207	276	44	21.036	71	23.441	444
227	44	24.488	70	55.560	205	277	44	20.520	71	23.425	474
228	44	24.313	70	56.099	213	278	44	21.672	71	23.955	408
229	44	24.238	70	56.719	216	279	44	21.934	71	24.657	390
230	44	24.135	70	57.221	207	280	44	22.174	71	25.337	372
231	44	24.101	70	57.849	213	281	44	22.322	71	26.004	360
232	44	24.665	70	58.236	311	282	44	22.429	71	26.743	355
233	44	24.477	70	58.570	284	283	44	22.335	71	27.305	350
234	44	24.151	70	59.065	235	284	44	22.482	71	28.032	334
235	44	24.191	70	59.688	220	285	44	22.169	71	28.422	342
236	44	24.020	71	0.284	213	286	44	21.760	71	28.877	376
237	44	23.613	71	0.741	220	287	44	21.529	71	29.445	397
238	44	23.739	71	1.486	220	288	44	21.367	71	30.042	432
239	44	24.042	71	2.088	220	289	44	21.245	71	30.611	426
240	44	24.219	71	2.785	226	290	44	21.331	71	31.254	396
241	44	24.279	71	3.361	220	291	44	21.412	71	31.859	372
242	44	24.635	71	4.097	232	292	44	21.506	71	32.449	345
243	44	24.774	71	4.728	226	293	44	21.817	71	33.114	318
244	44	24.897	71	5.408	223	294	44	21.842	71	33.846	342
245	44	24.861	71	5.992	232	295	44	21.623	71	34.412	360
246	44	24.684	71	6.544	223	296	44	21.493	71	34.953	348
247	44	24.370	71	7.042	235	297	44	21.731	71	35.614	366
248	44	24.047	71	7.595	232	298	44	21.648	71	36.261	354
249	44	23.249	71	7.906	253	299	44	20.728	71	36.567	366
250	44	23.229	71	8.568	238	300	44	20.065	71	37.004	378

Appendix A

Location	Lat. (N) deg	min	Long. (W) deg	min	Elev. meters	Location	Lat. (N) deg	min	Long. (W) deg	min	Elev. meters
301	44	19.535	71	37.427	426	336	44	15.394	71	56.911	387
302	44	19.728	71	38.169	438	337	44	14.831	71	57.385	341
303	44	19.614	71	38.776	432	338	44	14.576	71	57.917	290
304	44	19.200	71	39.214	384	339	44	15.297	71	58.744	335
305	44	18.658	71	39.764	348	340	44	14.745	71	59.201	341
306	44	18.769	71	40.250	309	341	44	14.726	71	59.890	415
307	44	18.500	71	40.790	372	342	44	15.014	72	0.532	492
308	44	18.414	71	41.372	372	343	44	14.844	72	1.053	427
309	44	18.440	71	41.982	342	344	44	14.584	72	1.324	335
310	44	18.166	71	42.652	330	345	44	14.474	72	1.759	244
311	44	17.621	71	42.909	342	346	44	14.332	72	2.522	152
312	44	18.009	71	43.741	306	347	44	13.709	72	2.789	159
313	44	17.636	71	44.257	312	348	44	13.644	72	3.497	146
314	44	17.769	71	44.807	264	349	44	13.064	72	3.583	159
315	44	17.565	71	45.422	335	350	44	12.645	72	3.703	152
316	44	17.224	71	46.065	360	351	44	12.004	72	4.508	195
317	44	17.870	71	46.817	366	352	44	12.254	72	4.822	232
318	44	17.614	71	47.330	329	353	44	13.028	72	5.567	320
319	44	17.287	71	47.777	293	354	44	13.043	72	6.334	347
320	44	17.418	71	48.463	232	355	44	12.744	72	6.835	378
321	44	17.066	71	48.923	287	356	44	13.020	72	7.264	390
322	44	16.795	71	49.260	329	357	44	13.040	72	7.752	411
323	44	16.785	71	50.047	366	358	44	12.902	72	8.362	360
324	44	16.901	71	50.216	384	359	44	12.963	72	8.832	341
325	44	16.489	71	50.587	329	360	44	12.874	72	9.604	311
326	44	16.327	71	51.136	317	361	44	12.664	72	10.012	271
327	44	15.956	71	51.417	280	362	44	12.177	72	10.533	238
328	44	15.901	71	52.090	287	363	44	12.263	72	11.209	226
329	44	15.199	71	52.613	226	364	44	12.528	72	11.936	250
330	44	15.247	71	53.405	207	365	44	11.848	72	12.316	293
331	44	15.449	71	53.963	213	366	44	11.794	72	12.857	347
332	44	15.919	71	54.687	219	367	44	11.331	72	13.293	393
333	44	15.576	71	55.154	302	368	44	10.788	72	13.840	421
334	44	15.939	71	55.786	299	369	44	10.736	72	14.184	457
335	44	15.830	71	56.467	335	370	44	10.236	72	14.332	549

Appendix A

Deployment 1 - AFGL sites

Location	Lat. (N) deg	Lat. (N) min	Long. (W) deg	Long. (W) min	Elev. meters	Location	Lat. (N) deg	Lat. (N) min	Long. (W) deg	Long. (W) min	Elev. meters
1101	43	43.529	75	56.630	347	1117	43	51.392	75	12.837	460
1102	43	44.036	75	54.471	384	1118	43	51.709	75	9.840	442
1103	43	44.617	75	51.270	442	1119	43	51.726	75	6.979	509
1104	43	45.383	75	47.680	503	1120	43	52.569	75	3.722	387
1105	43	45.727	75	45.487	497	1121	43	53.419	75	0.545	518
1106	43	46.328	75	42.928	503	1122	43	54.111	74	57.672	536
1107	43	46.849	75	40.784	512	1123	43	54.590	74	55.100	517
1108	43	47.271	75	38.031	509	1124	43	55.908	74	51.770	518
1109	43	47.499	75	35.505	512	1125	43	56.026	74	48.737	549
1110	43	48.409	75	32.657	363	1126	43	56.526	74	45.567	556
1111	43	48.802	75	29.646	265	1127	43	56.044	74	42.897	583
1112	43	49.408	75	27.196	250	1128	43	57.701	74	39.563	561
1113	43	49.912	75	23.985	247	1129	43	58.457	74	35.524	549
1114	43	50.261	75	21.611	332	1130	43	59.180	74	33.021	585
1115	43	50.702	75	18.924	334	1131	44	0.001	74	29.414	509
1116	43	50.987	75	15.982	387						

Appendix A

Deployment 2 - USGS & GSC sites

Location	Lat. (N) deg	min	Long. (W) deg	min	Elev. meters	Location	Lat. (N) deg	min	Long. (W) deg	min	Elev. meters
401	44	12.663	72	12.523	250	451	44	7.092	72	39.412	244
402	44	13.133	72	13.181	274	452	44	7.270	72	39.964	238
403	44	13.165	72	13.808	299	453	44	7.108	72	40.686	241
404	44	13.086	72	14.464	335	454	44	6.937	72	41.130	283
405	44	12.915	72	15.049	366	455	44	6.717	72	41.721	256
406	44	10.236	72	14.332	549	456	44	6.986	72	42.431	253
407	44	10.321	72	14.963	576	457	44	6.975	72	43.090	293
408	44	10.109	72	15.469	543	458	44	7.048	72	43.680	311
409	44	9.322	72	15.788	524	459	44	7.276	72	44.339	396
410	44	9.332	72	16.684	504	460	44	6.714	72	44.867	415
411	44	8.513	72	16.804	486	461	44	6.403	72	45.333	427
412	44	8.902	72	17.470	597	462	44	6.782	72	46.013	506
413	44	9.029	72	18.158	536	463	44	6.884	72	46.651	597
414	44	9.094	72	18.735	477	464	44	6.583	72	47.222	719
415	44	9.024	72	19.387	494	465	44	6.289	72	47.717	600
416	44	8.700	72	19.908	479	466	44	6.427	72	48.303	500
417	44	8.498	72	20.398	469	467	44	6.486	72	48.973	436
418	44	8.277	72	21.013	549	468	44	6.692	72	49.633	421
419	44	8.354	72	21.448	536	469	44	6.882	72	50.368	405
420	44	8.669	72	22.217	552	470	44	6.688	72	50.775	323
421	44	8.789	72	22.982	506	471	44	6.629	72	51.400	280
422	44	8.789	72	23.495	475	472	44	6.314	72	51.927	335
423	44	8.831	72	24.198	448	473	44	6.252	72	52.534	378
424	44	8.877	72	24.818	418	474	44	6.128	72	53.142	402
425	44	9.052	72	25.576	355	475	44	6.023	72	53.650	411
426	44	9.273	72	26.343	355	476	44	5.954	72	54.244	408
427	44	9.244	72	26.715	355	477	44	5.505	72	54.724	482
428	44	9.112	72	27.323	396	478	44	5.713	72	55.333	628
429	44	9.476	72	28.015	415	479	44	5.677	72	55.955	693
430	44	9.307	72	28.537	482	480	44	5.483	72	56.546	524
431	44	9.163	72	29.130	411	481	44	4.401	72	55.973	671
432	44	9.187	72	29.778	384	482	44	4.918	72	56.405	640
433	44	9.200	72	30.365	343	483	44	5.432	72	57.136	470
434	44	8.424	72	30.738	351	484	44	5.564	72	57.771	427
435	44	8.754	72	31.359	238	485	44	4.519	72	58.083	427
436	44	8.821	72	32.122	293	486	44	4.189	72	58.565	399
437	44	8.565	72	32.563	311	487	44	4.300	72	59.198	378
438	44	8.876	72	33.295	378	488	44	4.026	72	59.713	396
439	44	10.026	72	34.387	430	489	44	3.797	73	0.228	475
440	44	9.541	72	34.412	443	490	44	3.564	73	0.810	543
441	44	9.085	72	34.615	436	491	44	3.442	73	1.405	573
442	44	9.042	72	35.334	457	492	44	3.679	73	2.052	524
443	44	8.415	72	35.577	518	493	44	3.855	73	2.711	463
444	44	8.480	72	36.247	381	494	44	4.048	73	3.414	378
445	44	7.988	72	36.318	427	495	44	4.858	73	4.237	244
446	44	7.738	72	36.914	506	496	44	4.875	73	4.795	162
447	44	7.634	72	37.484	451	497	44	5.383	73	5.552	119
448	44	7.506	72	37.707	399	498	44	5.458	73	6.205	98
449	44	7.353	72	38.184	366	499	44	5.474	73	6.851	128
450	44	6.826	72	38.584	311	500	44	4.876	73	7.247	91

Appendix A

Location	Lat. (N) deg	Lat. (N) min	Long. (W) deg	Long. (W) min	Elev. meters	Location	Lat. (N) deg	Lat. (N) min	Long. (W) deg	Long. (W) min	Elev. meters
501	44	4.586	73	7.793	91	551	44	1.819	73	36.713	360
502	44	4.523	73	8.351	91	552	44	1.536	73	37.238	360
503	44	4.180	73	8.847	90	553	44	1.162	73	37.744	352
504	44	4.556	73	9.574	122	554	44	0.674	73	38.217	370
505	44	5.166	73	10.352	125	555	44	0.250	73	38.758	350
506	44	5.137	73	10.943	101	556	43	59.919	73	39.261	323
507	44	4.980	73	11.499	113	557	43	59.516	73	39.621	287
508	44	4.522	73	11.987	94	558	43	59.510	73	39.755	290
509	44	4.269	73	12.540	70	559	43	59.633	73	40.477	296
510	44	4.243	73	13.168	73	560	43	59.458	73	40.968	299
511	44	3.931	73	13.706	50	561	43	59.441	73	41.610	296
512	44	5.096	73	14.573	55	562	43	59.299	73	42.133	287
513	44	5.040	73	15.155	63	563	43	59.271	73	42.749	290
514	44	4.979	73	15.663	88	564	43	58.438	73	43.130	265
515	44	5.007	73	16.370	95	565	43	57.516	73	43.497	268
516	44	5.111	73	17.027	57	566	43	57.080	73	43.990	262
517	44	4.709	73	17.453	67	567	43	57.085	73	44.527	274
518	44	4.149	73	17.953	67	568	43	57.288	73	45.197	274
519	44	3.765	73	18.467	60	569	43	57.403	73	45.829	296
520	44	3.703	73	19.003	50	570	43	57.384	73	46.504	299
521	44	3.600	73	19.575	42	571	43	57.398	73	47.108	329
522	44	3.265	73	20.130	45	572	43	57.690	73	47.730	366
523	44	3.029	73	20.636	45	573	43	57.666	73	48.284	363
524	44	2.951	73	21.228	35	574	43	57.427	73	48.885	372
525	44	3.161	73	21.879	37	575	43	57.409	73	49.503	375
526	44	3.205	73	22.481	35	576	43	57.284	73	50.063	379
527	44	3.264	73	22.932	37	577	43	57.267	73	50.681	390
528	44	3.233	73	23.162	35	578	43	57.260	73	51.341	418
529	44	3.177	73	23.709	40	579	43	57.328	73	51.884	466
530	44	3.065	73	24.223	46	580	43	57.273	73	52.483	518
531	44	2.968	73	24.889	41	581	43	57.262	73	53.059	549
532	44	2.169	73	25.234	35	582	43	57.201	73	53.710	607
533	44	1.461	73	25.569	45	583	43	57.084	73	54.287	610
534	44	1.893	73	26.053	33	584	43	57.086	73	54.713	573
535	44	3.110	73	27.148	30	585	43	57.011	73	55.393	570
536	44	1.379	73	27.410	35	586	43	56.946	73	55.978	604
537	44	1.265	73	28.055	155	587	43	56.894	73	56.572	573
538	44	2.035	73	28.903	175	588	43	56.713	73	57.084	537
539	44	2.826	73	29.630	208	589	43	56.474	73	57.657	573
540	44	2.769	73	30.231	255	590	43	56.669	73	58.276	588
541	44	2.728	73	30.884	270	591	43	56.559	73	58.871	598
542	44	2.595	73	31.426	317	592	43	56.856	73	59.564	570
543	44	2.420	73	32.000	365	593	43	56.690	74	0.094	604
544	44	2.375	73	32.612	355	594	43	56.299	73	58.960	536
545	44	2.410	73	33.233	338	595	43	56.715	74	0.724	543
546	44	2.400	73	33.799	328	596	43	56.858	74	1.396	604
547	44	2.336	73	34.384	330	597	43	57.113	74	2.067	598
548	44	2.262	73	35.014	355	598	43	57.564	74	2.752	558
549	44	2.187	73	35.592	370	599	43	57.390	74	3.365	524
550	44	2.079	73	36.137	370	600	43	57.131	74	3.988	515

Appendix A

Location	Lat. (N) deg	min	Long. (W) deg	min	Elev. meters	Location	Lat. (N) deg	min	Long. (W) deg	min	Elev. meters
601	43	57.010	74	4.451	497	621	43	58.565	74	16.298	512
602	43	56.963	74	4.966	500	622	43	58.678	74	16.943	530
603	43	57.228	74	5.716	500	623	43	59.012	74	17.616	537
604	43	57.445	74	6.345	516	624	43	59.179	74	18.219	563
605	43	57.734	74	6.964	492	625	43	58.933	74	18.829	556
606	43	57.926	74	7.672	476	626	43	58.708	74	19.415	549
607	43	58.148	74	8.365	479	627	43	58.719	74	20.077	548
608	43	58.306	74	9.027	499	628	43	58.795	74	20.587	557
609	43	58.177	74	9.637	518	629	43	58.657	74	21.230	585
610	43	58.102	74	10.190	482	630	43	58.537	74	21.731	552
611	43	58.351	74	10.873	486	631	43	58.568	74	22.439	566
612	43	58.296	74	11.502	494	632	43	58.676	74	22.926	561
613	43	58.235	74	12.017	486	633	43	58.552	74	23.563	543
614	43	58.226	74	12.641	488	634	43	58.373	74	24.112	537
615	43	58.236	74	13.212	498	635	43	58.079	74	24.801	527
616	43	58.259	74	13.845	488	636	43	58.847	74	25.419	512
617	43	58.225	74	14.449	491	637	43	58.773	74	26.127	500
618	43	57.982	74	14.492	488	638	43	58.745	74	26.601	524
619	43	58.221	74	15.040	506	639	43	59.244	74	27.395	546
620	43	58.236	74	15.653	512	640	43	59.812	74	28.184	543
						641	43	59.756	74	28.682	521

Deployment 2 - AFGL sites

Location	Lat. (N) deg	min	Long. (W) deg	min	Elev. meters	Location	Lat. (N) deg	min	Long. (W) deg	min	Elev. meters
1211	44	2.310	73	22.226	38	1231	43	35.950	72	31.505	296
1212	44	1.063	73	19.781	50	1232	43	34.288	72	28.971	451
1213	43	59.858	73	17.215	87	1233	43	33.164	72	26.614	305
1214	43	58.610	73	14.676	107	1234	43	32.145	72	24.427	189
1215	43	57.483	73	12.543	110	1235	43	30.968	72	22.344	140
1216	43	55.875	73	9.197	132	1236	43	29.323	72	19.308	329
1217	43	54.312	73	6.182	140	1237	43	27.811	72	17.164	396
1218	43	52.966	73	3.848	184	1238	43	25.441	72	12.962	335
1219	43	51.768	73	0.951	372	1239	43	24.655	72	10.874	305
1220	43	50.548	72	59.400	463	1240	43	23.230	72	8.200	338
1221	43	49.904	72	54.344	549	1241	43	21.995	72	5.811	396
1222	43	48.007	72	53.532	494	1270	43	47.072	72	52.306	439
1223	43	46.724	72	51.250	396	1271	43	46.463	72	49.944	335
1224	43	45.272	72	48.299	396	1272	43	44.434	72	47.385	585
1225	43	43.400	72	44.814	418	1273	43	43.760	72	46.776	610
1226	43	42.052	72	43.161	372	1274	43	42.942	72	43.812	475
1227	43	40.863	72	41.251	582	1276	43	37.932	72	35.564	457
1228	43	39.416	72	39.147	460	1277	43	36.553	72	32.727	223
1229	43	38.264	72	36.803	536	1278	43	35.606	72	30.367	332
1230	43	37.211	72	33.953	314	1279	43	33.989	72	28.095	396
						1280	43	32.305	72	25.293	238

Appendix A

Deployment 3 - USGS & GSC sites

Location	Lat. (N) deg	Lat. (N) min	Long. (W) deg	Long. (W) min	Elev. meters
701	43	59.959	74	29.243	530
702	44	0.825	74	30.049	533
703	44	1.223	74	30.344	549
704	44	1.404	74	30.610	564
705	44	1.734	74	30.747	573
706	44	2.101	74	30.986	610
707	44	2.421	74	31.678	588
708	44	2.538	74	32.367	602
709	44	3.064	74	32.929	578
710	44	3.268	74	33.599	527
711	44	3.091	74	34.529	530
712	44	3.076	74	35.329	524
713	44	3.175	74	35.930	550
714	44	3.194	74	36.648	549
715	44	3.486	74	37.329	536
716	44	3.590	74	38.108	549
717	44	3.837	74	38.714	561
718	44	4.415	74	39.321	585
719	44	4.719	74	40.010	558
720	44	4.902	74	40.681	555
721	44	4.775	74	41.416	567
722	44	5.410	74	42.029	555
723	44	5.991	74	42.601	552
724	44	5.810	74	43.517	549
725	44	5.706	74	44.233	549
726	44	5.516	74	45.057	549
727	44	5.575	74	45.725	549
728	44	5.161	74	46.627	546
729	44	4.995	74	47.433	546
730	44	5.724	74	48.003	546
731	44	8.600	74	47.881	457
732	44	8.929	74	48.398	457
733	44	9.275	74	49.101	457
734	44	9.931	74	49.632	457
735	44	9.880	74	50.384	457
736	44	10.004	74	51.132	457
737	44	9.571	74	51.992	457
738	44	9.260	74	52.815	457
739	44	9.016	74	53.658	457
740	44	8.630	74	54.491	459
741	44	8.285	74	55.424	457
742	44	8.674	74	56.037	460
743	44	8.755	74	56.743	472
744	44	9.025	74	57.375	457
745	44	8.771	74	58.199	509
746	44	8.965	74	58.996	466
747	44	9.937	74	59.391	436
748	44	9.956	75	0.107	427
749	44	9.424	75	0.950	427
750	44	8.948	75	1.909	436
751	44	9.035	75	2.618	451
752	44	9.385	75	3.251	448
753	44	10.268	75	3.738	439
754	44	10.964	75	4.285	418
755	44	10.062	75	5.306	457
756	44	9.117	75	6.300	405
757	44	9.057	75	7.119	433
758	44	10.023	75	7.577	479
759	44	9.890	75	8.461	427
760	44	9.730	75	9.418	408
761	44	9.063	75	10.122	402
762	44	8.919	75	10.680	396
763	44	9.510	75	11.284	341
764	44	9.533	75	12.246	344
765	44	9.674	75	12.961	340
766	44	9.636	75	13.709	317
767	44	10.195	75	14.280	314
768	44	10.740	75	14.846	296
769	44	10.875	75	15.393	283
770	44	10.902	75	16.318	271
771	44	10.379	75	16.911	273
772	44	10.405	75	17.797	235
773	44	10.339	75	18.566	226
774	44	10.819	75	19.099	232
775	44	11.111	75	19.863	229
776	44	11.336	75	20.488	235
777	44	11.309	75	21.342	235
778	44	12.197	75	21.773	238
779	44	12.477	75	22.490	242
780	44	13.039	75	23.090	229
781	44	13.093	75	23.950	232
782	44	13.372	75	24.462	229
783	44	14.123	75	25.005	201
784	44	13.997	75	25.789	210
785	44	13.406	75	26.617	189
786	44	13.398	75	27.498	192
787	44	13.938	75	28.052	192
788	44	14.392	75	28.675	189
789	44	14.828	75	29.301	183
790	44	14.863	75	30.727	168
791	44	15.145	75	31.341	165
792	44	14.677	75	31.826	174
793	44	14.955	75	33.000	168
794	44	14.846	75	33.718	158
795	44	14.910	75	34.443	162
796	44	14.886	75	35.200	162
797	44	15.147	75	35.948	158
798	44	14.650	75	36.730	168
799	44	14.360	75	37.682	154
800	44	14.817	75	38.296	149

Appendix A

Location	Lat. (N) deg	min	Long. (W) deg	min	Elev. meters	Location	Lat. (N) deg	min	Long. (W) deg	min	Elev. meters
801	44	14.705	75	39.087	162	851	44	19.786	76	15.726	101
802	44	15.015	75	39.717	143	852	44	19.717	76	16.484	93
803	44	15.030	75	40.459	116	853	44	19.690	76	17.193	98
804	44	15.512	75	41.067	113	854	44	20.824	76	17.719	118
805	44	15.314	75	41.902	116	855	44	20.737	76	18.507	117
806	44	15.078	75	42.717	122	856	44	20.664	76	19.182	118
807	44	15.247	75	43.396	128	857	44	20.457	76	20.039	112
808	44	15.514	75	44.062	125	858	44	20.136	76	20.908	119
809	44	15.479	75	44.750	125	859	44	20.120	76	21.605	110
810	44	15.867	75	45.460	93	860	44	19.931	76	22.405	108
811	44	16.485	75	45.983	107	861	44	19.597	76	23.233	106
812	44	16.395	75	46.706	107	862	44	20.360	76	23.807	94
813	44	17.272	75	47.209	98	863	44	21.277	76	24.244	95
814	44	17.637	75	47.868	125	864	44	21.187	76	24.991	98
815	44	18.008	75	48.527	116	865	44	20.707	76	25.827	120
816	44	17.941	75	49.264	105	866	44	20.669	76	26.694	128
817	44	17.805	75	50.132	101	867	44	19.261	76	27.862	125
818	44	17.697	75	50.830	110	868	44	19.257	76	28.623	124
819	44	17.987	75	51.534	113	869	44	19.216	76	29.355	117
820	44	18.265	75	52.194	113	870	44	20.516	76	29.810	130
821	44	18.040	75	52.985	110	871	44	21.150	76	30.350	141
822	44	18.294	75	53.607	107	872	44	21.336	76	31.009	140
823	44	17.948	75	54.365	94	873	44	20.435	76	32.042	123
824	44	17.936	75	55.116	109	874	44	20.348	76	32.761	129
825	44	17.798	75	55.475	109	875	44	20.768	76	33.398	141
826	44	17.859	75	56.574	96	876	44	20.905	76	34.205	134
827	44	18.613	75	57.366	76	877	44	20.774	76	34.891	130
828	44	18.744	75	58.004	79	878	44	21.389	76	35.459	150
829	44	18.755	75	58.755	82	879	44	21.358	76	36.188	143
830	44	18.602	75	59.534	88	880	44	21.346	76	36.978	142
831	44	18.887	76	0.226	79	881	44	20.618	76	37.933	145
832	44	19.528	76	0.776	96	882	44	21.033	76	38.507	140
833	44	19.652	76	1.667	98	883	44	21.496	76	39.141	140
834	44	19.808	76	2.377	87	884	44	21.910	76	39.850	153
835	44	20.996	76	3.353	85	885	44	21.957	76	40.575	153
836	44	21.083	76	4.029	76	886	44	21.739	76	41.326	138
837	44	21.214	76	4.838	90	887	44	21.880	76	42.047	150
838	44	21.039	76	5.554	84	888	44	22.640	76	42.576	167
839	44	20.548	76	6.468	79	889	44	22.597	76	43.355	160
840	44	20.155	76	7.397	72	890	44	22.197	76	44.216	169
841	44	20.195	76	8.152	93	891	44	22.528	76	44.821	151
842	44	20.263	76	8.952	90	892	44	22.441	76	45.633	149
843	44	20.668	76	9.471	96	893	44	22.644	76	46.362	138
844	44	19.544	76	10.740	95	894	44	22.074	76	47.232	144
845	44	19.250	76	11.427	89	895	44	23.320	76	47.617	151
846	44	19.350	76	12.120	87	896	44	23.060	76	48.432	149
847	44	19.394	76	12.897	79	897	44	22.556	76	49.320	147
848	44	19.232	76	13.655	80	898	44	23.141	76	49.907	151
849	44	19.953	76	14.198	94	899	44	23.747	76	50.512	154
850	44	19.863	76	14.937	91	900	44	23.883	76	51.166	151

Appendix A

Location	Lat. (N) deg	Lat. (N) min	Long. (W) deg	Long. (W) min	Elev. meters	Location	Lat. (N) deg	Lat. (N) min	Long. (W) deg	Long. (W) min	Elev. meters
901	44	23.633	76	52.038	148	941	44	26.205	77	21.161	188
902	44	23.261	76	52.911	160	942	44	27.147	77	21.656	176
903	44	23.619	76	53.541	135	943	44	26.926	77	22.446	179
904	44	23.984	76	54.202	149	944	44	26.457	77	23.395	185
905	44	24.082	76	54.928	149	945	44	27.518	77	23.868	189
906	44	23.713	76	55.756	160	946	44	27.323	77	24.590	195
907	44	23.654	76	56.445	159	947	44	26.672	77	25.509	188
908	44	24.377	76	57.048	168	948	44	28.291	77	25.807	200
909	44	24.754	76	57.800	157	949	44	28.045	77	26.848	192
910	44	24.536	76	58.556	155	950	44	27.861	77	27.459	178
911	44	24.923	76	59.097	139	951	44	27.685	77	28.266	186
912	44	24.379	77	0.053	165	952	44	27.509	77	29.036	191
913	44	24.789	77	0.695	182	953	44	27.343	77	29.680	185
914	44	24.477	77	1.522	177	954	44	28.816	77	30.135	177
915	44	24.055	77	2.338	175	955	44	27.714	77	31.467	178
916	44	23.752	77	3.131	169	956	44	27.582	77	31.994	163
917	44	24.812	77	3.689	169	957	44	27.668	77	32.671	172
918	44	24.860	77	4.382	174	958	44	28.614	77	33.150	198
919	44	25.340	77	5.001	167	959	44	28.574	77	33.944	183
920	44	25.663	77	5.650	172	960	44	28.533	77	34.583	174
921	44	25.158	77	6.506	159	961	44	28.837	77	35.302	175
922	44	25.214	77	7.175	173	962	44	29.352	77	36.109	173
923	44	25.641	77	7.943	185	963	44	29.630	77	36.617	172
924	44	24.536	77	8.928	166	964	44	29.340	77	37.501	181
925	44	24.366	77	9.696	170	965	44	29.665	77	38.217	182
926	44	24.126	77	10.516	166	966	44	29.029	77	38.747	193
927	44	25.273	77	10.932	165	967	44	28.938	77	39.534	201
928	44	25.327	77	12.125	183	980	44	23.812	77	8.678	161
929	44	25.164	77	12.891	184	981	44	23.551	77	8.217	165
930	44	25.777	77	13.292	180	982	44	22.310	77	7.418	163
931	44	26.510	77	13.791	150	983	44	20.819	77	6.875	165
932	44	26.248	77	14.742	180	984	44	20.416	77	6.748	164
933	44	26.016	77	15.562	160	985	44	19.737	77	6.366	161
934	44	25.925	77	16.086	155	986	44	19.347	77	6.145	159
935	44	25.719	77	16.889	145	987	44	18.612	77	5.856	140
936	44	25.727	77	17.591	145	988	44	18.289	77	5.637	141
937	44	26.329	77	18.206	150	989	44	21.123	76	41.479	145
938	44	26.313	77	18.960	158	999	44	21.141	76	2.609	79
939	44	26.623	77	19.507	147						
940	44	26.383	77	20.420	167						

Appendix A

Deployment 3 - AFGL sites

Location	Lat. (N) deg	Lat. (N) min	Long. (W) deg	Long. (W) min	Elev. meters	Location	Lat. (N) deg	Lat. (N) min	Long. (W) deg	Long. (W) min	Elev. meters
1301	44	2.855	73	29.526	354	1317	43	58.245	74	8.805	503
1302	44	2.360	73	32.026	369	1318	43	58.317	74	11.074	488
1303	44	2.240	73	35.148	384	1319	43	58.224	74	13.539	497
1304	44	1.429	73	37.408	354	1320	43	58.521	74	16.355	518
1305	43	59.560	73	39.628	293	1321	43	59.119	74	18.185	564
1306	43	57.436	73	43.334	271	1322	43	58.711	74	20.074	547
1307	43	57.407	73	46.393	323	1323	43	58.592	74	22.495	573
1308	43	57.554	73	48.831	378	1324	43	58.897	74	25.806	524
1309	43	57.261	73	50.515	390	1325	43	59.287	74	27.757	561
1310	43	57.261	73	53.184	567	1326	44	0.548	74	30.079	552
1311	43	57.022	73	55.337	567	1327	44	2.251	74	31.306	597
1312	43	56.537	73	57.308	530	1328	44	2.836	74	33.852	543
1313	43	56.892	73	59.595	573	1329	44	3.227	74	35.884	539
1314	43	57.175	74	2.060	594	1330	44	3.425	74	38.914	579
1315	43	57.024	74	4.241	512	1331	44	4.712	74	41.647	555
1316	43	57.574	74	6.341	506						

Appendix A

Reflection Experiment - USGS & GSC sites

Location	Lat. (N) deg	min	Long. (W) deg	min	Elev. meters	Location	Lat. (N) deg	min	Long. (W) deg	min	Elev. meters
2000	44	12.645	72	5.611	293	2050	44	12.842	72	8.496	347
2001	44	12.645	72	5.682	294	2051	44	12.809	72	8.574	347
2002	44	12.618	72	5.752	296	2052	44	12.835	72	8.623	351
2003	44	12.594	72	5.819	295	2053	44	12.873	72	8.668	347
2004	44	12.576	72	5.891	296	2054	44	12.911	72	8.720	344
2005	44	12.566	72	5.948	297	2055	44	12.950	72	8.767	341
2006	44	12.570	72	6.029	299	2056	44	12.964	72	8.841	341
2007	44	12.552	72	6.096	305	2057	44	12.983	72	8.899	347
2008	44	12.544	72	6.173	311	2058	44	12.972	72	8.975	358
2009	44	12.542	72	6.242	317	2059	44	12.992	72	9.056	366
2010	44	12.505	72	6.235	319	2060	44	12.968	72	9.171	360
2011	44	12.490	72	6.309	323	2061	44	12.961	72	9.247	351
2012	44	12.484	72	6.379	329	2062	44	12.967	72	9.326	338
2013	44	12.475	72	6.463	335	2063	44	12.984	72	9.406	329
2014	44	12.488	72	6.528	341	2064	44	12.977	72	9.480	320
2015	44	12.479	72	6.609	344	2065	44	12.943	72	9.508	317
2016	44	12.526	72	6.656	349	2066	44	12.914	72	9.562	311
2017	44	12.565	72	6.708	360	2067	44	12.877	72	9.620	311
2018	44	12.607	72	6.755	366	2068	44	12.829	72	9.656	302
2019	44	12.644	72	6.792	372	2069	44	12.788	72	9.707	299
2020	44	12.683	72	6.835	372	2070	44	12.757	72	9.752	294
2021	44	12.725	72	6.864	375	2071	44	12.707	72	9.779	290
2022	44	12.769	72	6.893	378	2072	44	12.673	72	9.837	283
2023	44	12.808	72	6.930	378	2073	44	12.663	72	9.920	277
2024	44	12.850	72	6.963	381	2074	44	12.648	72	10.014	268
2025	44	12.896	72	7.004	384	2075	44	12.634	72	10.102	265
2026	44	12.941	72	7.049	390	2076	44	12.613	72	10.159	268
2027	44	12.981	72	7.094	393	2077	44	12.585	72	10.186	265
2028	44	13.019	72	7.146	393	2078	44	12.528	72	10.227	265
2029	44	13.025	72	7.216	393	2079	44	12.476	72	10.238	262
2030	44	13.023	72	7.284	619	2080	44	12.418	72	10.227	250
2031	44	13.027	72	7.347	384	2081	44	12.376	72	10.253	244
2032	44	13.027	72	7.425	384	2082	44	12.350	72	10.250	236
2033	44	13.019	72	7.500	390	2083	44	12.317	72	10.334	239
2034	44	13.018	72	7.580	402	2084	44	12.301	72	10.408	239
2035	44	13.041	72	7.643	405	2085	44	12.284	72	10.483	238
2036	44	13.041	72	7.726	408	2086	44	12.184	72	10.594	226
2037	44	13.012	72	7.787	404	2087	44	12.181	72	10.674	224
2038	44	12.988	72	7.841	401	2088	44	12.178	72	10.749	224
2039	44	12.950	72	7.890	396	2089	44	12.191	72	10.840	226
2040	44	12.913	72	7.935	390	2090	44	12.183	72	10.921	229
2041	44	12.871	72	7.979	384	2091	44	12.180	72	11.023	229
2042	44	12.822	72	8.035	378	2092	44	12.190	72	11.094	229
2043	44	12.783	72	8.087	369	2093	44	12.215	72	11.152	229
2044	44	12.752	72	8.134	360	2094	44	12.246	72	11.190	229
2045	44	12.740	72	8.209	357	2095	44	12.279	72	11.244	229
2046	44	12.745	72	8.273	352	2096	44	12.321	72	11.295	229
2047	44	12.782	72	8.322	354	2097	44	12.351	72	11.364	229
2048	44	12.825	72	8.354	357	2098	44	12.377	72	11.436	229
2049	44	12.852	72	8.423	351	2099	44	12.398	72	11.511	232

Appendix A

Location	Lat. (N) deg	min	Long. (W) deg	min	Elev. meters	Location	Lat. (N) deg	min	Long. (W) deg	min	Elev. meters
2101	44	12.392	72	11.476	238	2126	44	11.869	72	12.677	317
2102	44	12.401	72	11.557	239	2127	44	11.841	72	12.748	332
2103	44	12.438	72	11.619	244	2128	44	11.817	72	12.810	343
2104	44	12.459	72	11.686	245	2129	44	11.754	72	12.867	352
2105	44	12.484	72	11.758	245	2130	44	11.688	72	12.906	360
2106	44	12.538	72	11.840	244	2131	44	11.639	72	12.951	366
2107	44	12.466	72	11.872	250	2132	44	11.593	72	12.992	370
2108	44	12.449	72	11.937	258	2133	44	11.545	72	13.021	375
2109	44	12.403	72	11.980	265	2134	44	11.482	72	13.058	381
2110	44	12.355	72	11.965	265	2135	44	11.429	72	13.096	387
2111	44	12.305	72	11.983	265	2136	44	11.396	72	13.169	390
2112	44	12.262	72	12.014	267	2137	44	11.367	72	13.240	390
2113	44	12.210	72	12.029	268	2138	44	11.342	72	13.291	390
2114	44	12.157	72	12.076	265	2139	44	11.298	72	13.329	392
2115	44	12.106	72	12.066	265	2140	44	11.246	72	13.352	393
2116	44	12.056	72	12.037	268	2141	44	11.180	72	13.372	396
2117	44	12.014	72	12.093	271	2142	44	11.121	72	13.409	393
2118	44	11.969	72	12.156	274	2143	44	11.067	72	13.456	396
2119	44	11.921	72	12.175	280	2144	44	11.007	72	13.513	389
2120	44	11.872	72	12.227	287	2145	44	10.959	72	13.556	389
2121	44	11.873	72	12.303	291	2146	44	10.906	72	13.601	392
2122	44	11.858	72	12.385	299	2147	44	10.859	72	13.620	389
2123	44	11.882	72	12.432	299	2148	44	10.813	72	13.627	389
2124	44	11.895	72	12.520	299	2149	44	10.748	72	13.638	399
2125	44	11.889	72	12.614	305						

Location	Lat. (N) deg	min	Long. (W) deg	min	Elev. meters	Location	Lat. (N) deg	min	Long. (W) deg	min	Elev. meters
2201	44	12.560	72	11.515	247	2221	44	13.578	72	11.445	326
2202	44	12.598	72	11.463	258	2222	44	13.641	72	11.427	326
2203	44	12.642	72	11.462	271	2223	44	13.684	72	11.411	325
2204	44	12.687	72	11.482	274	2224	44	13.740	72	11.399	329
2205	44	12.748	72	11.506	280	2225	44	13.794	72	11.381	332
2206	44	12.796	72	11.522	290	2226	44	13.846	72	11.353	335
2207	44	12.857	72	11.516	293	2227	44	13.899	72	11.326	338
2208	44	12.909	72	11.538	296	2228	44	13.937	72	11.301	341
2209	44	12.953	72	11.536	296	2229	44	13.984	72	11.264	341
2210	44	13.008	72	11.547	299	2230	44	14.029	72	11.233	341
2211	44	13.069	72	11.548	302	2231	44	14.067	72	11.208	344
2212	44	13.124	72	11.523	302	2232	44	14.125	72	11.189	347
2213	44	13.172	72	11.487	299	2233	44	14.170	72	11.162	351
2214	44	13.223	72	11.468	305	2234	44	14.210	72	11.105	357
2215	44	13.262	72	11.480	306	2235	44	14.249	72	11.045	357
2216	44	13.314	72	11.470	311	2236	44	14.299	72	11.017	360
2217	44	13.362	72	11.469	314	2237	44	14.357	72	11.005	360
2218	44	13.412	72	11.484	320	2238	44	14.400	72	10.989	360
2219	44	13.468	72	11.466	320	2239	44	14.447	72	10.965	360
2220	44	13.515	72	11.461	326	2240	44	14.486	72	10.932	361

Appendix A

Location	Lat. (N) deg	min	Long. (W) deg	min	Elev. meters	Location	Lat. (N) deg	min	Long. (W) deg	min	Elev. meters
2241	44	14.544	72	10.892	369	2251	44	14.944	72	10.460	399
2242	44	14.587	72	10.842	370	2252	44	14.999	72	10.439	405
2243	44	14.632	72	10.795	372	2253	44	15.035	72	10.414	408
2244	44	14.675	72	10.760	378	2254	44	15.084	72	10.390	408
2245	44	14.708	72	10.733	379	2255	44	15.132	72	10.372	408
2246	44	14.746	72	10.695	381	2256	44	15.176	72	10.348	412
2247	44	14.781	72	10.638	384	2257	44	15.227	72	10.313	414
2248	44	14.806	72	10.571	387	2258	44	15.274	72	10.270	418
2249	44	14.840	72	10.512	390	2259	44	15.326	72	10.237	418
2250	44	14.888	72	10.485	393	2260	44	15.380	72	10.226	422

Appendix B - SEGY Data File Format

The data from this experiment are archived in an extended version of the standard SEGY seismic data format. Data is organized by shotgathers; one SEGY file per shotpoint. SEGY data files are sequentially written to tape with intervening End-Of-File marks.

```
c
c    INCLUDE FILE FOR FORTRAN PROGRAMS TO READ SEGY DATA FILES
c
c This file is an implicit definition of SEGY format with additions
c for refraction work. It is the SEGY standard of Barry et al
c Geophysics (1975) with extensions labelled LDS USE and USGS use
c for refraction work. When used as an include file for a FORTRAN
c program, all variables will be set after reading arrays SEGY1A,
c SEGY1B, and SEGYDB.
c
c Character code is EBCDIC unless IEEE data format (see variable icode)
c If IEEE, then the character code is ASCII.
c
c Written by Carl Spencer and Isa Asudeh  4/2/86 original specification
c This version is compatible with the final Lithoprobe version dated 5/12/87.
c
c
c Maximum number of bytes allowed in a trace (system dependent)
c MAXLEN = ((max trace length) * (sample rate) * (bytes per sample)) + 240
c
      parameter (MAXLEN=16620)
c
c
c SEGY REEL IDENTIFICATION HEADER PART 1
        byte  segy1a(3200)
c SEGY REEL IDENTIFICATION HEADER PART 2
        byte  segy1b(400)
c SEGY TRACE DATA BLOCK
        byte  segydb(MAXLEN)
        common/segycom/iiopen,segy1a,segy1b,segydb
c
c EBCDIC CARDS
        character*80  cards(40)
        equivalence  (segy1a(1),cards(1))
c
c TRACE IDENTIFICATION HEADER
        byte  thead(240)
        equivalence  (segydb(1),thead(1))
c
c DATA WORDS
        integer*2     iidata((MAXLEN-240)/2)
        integer*4     jdata((MAXLEN-240)/4)
        real*4        rdata((MAXLEN-240)/4)
        equivalence  (segydb(241),iidata(1),jdata(1),rdata(1))
c
```

Appendix B

```
c
c------------------------------------------------------------------
c Binary area of file (or reel) Identification Header starts here
c------------------------------------------------------------------
c
c
c
c Job Identification number                          SEGY STANDARD
      integer*4  jobid
      equivalence  (segy1b(1),jobid)
c
c Line number                                        SEGY STANDARD
      integer*4  lineno
      equivalence  (segy1b(5),lineno)
c
c Reel number                                        SEGY STANDARD
      integer*4  reelno
      equivalence  (segy1b(9),reelno)
c
c Number of data traces per record                   SEGY STANDARD
      integer*2  ntrace
      equivalence  (segy1b(13),ntrace)
c
c Number of auxiliary traces per record              SEGY STANDARD
      integer*2  nauxt
      equivalence  (segy1b(15),nauxt)
c
c Sample interval in microseconds - this data        SEGY STANDARD
      integer*2  sint
      equivalence  (segy1b(17),sint)
c
c Sample interval in microseconds (in field)         SEGY STANDARD
      integer*2  sint2
      equivalence  (segy1b(19),sint2)
c
c No of samples per trace - this data                SEGY STANDARD
      integer*2  nsam
      equivalence  (segy1b(21),nsam)
c
c No of samples per trace (in field)                 SEGY STANDARD
      integer*2  nsam2
      equivalence  (segy1b(23),nsam2)
c
```

Appendix B

```
c Data sample format code                                  SEGY STANDARD
c  icode=0001   (1)     IBM FLOATING POINT                 SEGY STANDARD
c  icode=0002   (2)     FIXED POINT (4 bytes)              SEGY STANDARD
c  icode=0003   (3)     FIXED POINT (2 bytes)              SEGY STANDARD
c  icode=0004   (4)     FIXED POINT WITH GAIN              SEGY STANDARD
c  icode=0100   (256)   FLOATING POINT - IEEE              VERITAS STANDARD
c  icode=0200   (512)   FIXED POINT (4 bytes) - IEEE
c  icode=0300   (768)   FIXED POINT (2 bytes) - IEEE
c  icode=0500   (1280)  LUNCHBOX FORMAT                    LDS USE
c  icode=0600   (1536)  VAX R*4 FORMAT                     LDS USE
      integer*2  icode
      equivalence  (segy1b(25),icode)
c
c Number of traces in CDP ensemble                         SEGY STANDARD
      integer*2  ncdp
      equivalence  (segy1b(27),ncdp)
c
c Trace sorting code                                       SEGY STANDARD
c  itsort=1   as recorded                                  SEGY STANDARD
c  itsort=2   CDP ensemble                                 SEGY STANDARD
c  itsort=3   Single fold continuous                       SEGY STANDARD
c  itsort=4   Horizontal stack                             SEGY STANDARD
c  No LDS or USGS use.
      integer*2  itsort
      equivalence  (segy1b(29),itsort)
c
c Vertical sum code                                        SEGY STANDARD
c   vcode=n sum on n traces
      integer*2  vcode
      equivalence  (segy1b(31),vcode)
c
c Start sweep frequency (hz)                               SEGY STANDARD
      integer*2  ssweep
      equivalence  (segy1b(33),ssweep)
c
c End sweep frequency (hz)                                 SEGY STANDARD
      integer*2  esweep
      equivalence  (segy1b(35),esweep)
c
c Sweep length in milliseconds                             SEGY STANDARD
      integer*2  sleng
      equivalence  (segy1b(37),sleng)
c
c Sweep type                                               SEGY STANDARD
c  stype=1    Linear                                       SEGY STANDARD
c  stype=2    Parabolic                                    SEGY STANDARD
c  stype=3    Exponential                                  SEGY STANDARD
c  stype=4    Other                                        SEGY STANDARD
c  stype=5    Borehole source                              LDS USE
c  stype=6    Water explosive source                       LDS USE
c  stype=7    Airgun source                                LDS USE
      integer*2  stype
      equivalence  (segy1b(39),stype)
```

Appendix B

```
c
c Trace number of sweep channel                         SEGY STANDARD
      integer*2 nts
      equivalence (segy1b(41),nts)
c
c Sweep trace taper in milliseconds at start            SEGY STANDARD
      integer*2 stts
      equivalence (segy1b(43),stts)
c
c Sweep trace taper in milliseconds at end              SEGY STANDARD
      integer*2 stte
      equivalence (segy1b(45),stte)
c
c Taper type                                            SEGY STANDARD
c  ttype=1   Linear                                     SEGY STANDARD
c  ttype=2   cos**2                                     SEGY STANDARD
c  ttype=3   Other                                      SEGY STANDARD
      integer*2 ttype
      equivalence (segy1b(47),ttype)
c
c Correlated data traces                                SEGY STANDARD
c  cort=1 no  2 yes
      integer*2 cort
      equivalence (segy1b(49),cort)
c
c Binary gain recovered                                 SEGY STANDARD
c   bgr=1  Yes. For USGS data, the data has also been demeaned.
c   bgr=2  No
      integer*2 bgr
      equivalence (segy1b(51),bgr)
c
c Amplitude recovery methods                            SEGY STANDARD
c  arm=1 none  2 spherical  3 AGC  4 other
      integer*2 arm
      equivalence (segy1b(53),arm)
c
c Measurement system                                    SEGY STANDARD
c  isys=1 meters  2 feet
      integer*2 isys
      equivalence (segy1b(55),isys)
c
c Polarity                                              SEGY STANDARD
c  ipol=1 Upward movement gives neg. number             SEGY STANDARD
c  ipol=2 Upward movement gives pos. number             SEGY STANDARD
      integer*2 ipol
      equivalence (segy1b(57),ipol)
c
c Vibrator polarity code                                SEGY STANDARD
      integer*2 vpc
      equivalence (segy1b(59),vpc)
c
```

Appendix B

```
c Number of traces in the file                          LDS USE
c   Used for disk files.
      integer*2  notif
      equivalence  (segy1b(61),notif)
c
c  Attribute  information                               LDS USE
c   attri=0   velocity/displacement  data
c   attri=1   instantaneous  amplitude
c   attri=2   instantaneous  frequency
c   attri=3   instantaneous  phase
c   attri=4   slowness  (m/ms)
c   attri=5   semblance  (0-1000)
      integer*2  attri
      equivalence  (segy1b(63),attri)
c
c Mean amplitude of all samples                         LDS USE
c    in all traces in file     Used for disk files.
      real*4  meanas
      equivalence  (segy1b(65),meanas)
c
c Domain of data                                        LDS USE
c   domain=0 Time - distance domain
c    domain=1 Frequency - wavenumber domain
c    domain=2 Intercept time - slowness domain
      integer*2  domain
      equivalence  (segy1b(69),domain)
c
c     Bytes 71, 72 unused to align four byte boundaries.
c
c Reduction velocity meters/sec if data is reduced      LDS USE
      integer*4  vred
      equivalence  (segy1b(73),vred)
c
c Minimum of all samples in file.                       LDS USE
      real*4  minass
      equivalence  (segy1b(77),minass)
c
c Maximum of all samples in file.                       LDS USE
      real*4  maxass
      equivalence  (segy1b(81),maxass)
c
c  Recording  instrument  type                          USGS USE
c  iinstr=1    EDA  lunchbox  recorder
c  iinstr=2    USGS  seismic  cassette  recorder
c  iinstr=3    GEOS
c  iinstr=99   Mixed
      integer*2  iinstr
      equivalence  (segy1b(85),iinstr)
c
c File creation date - Last two digits of year          USGS USE
      integer*2  cryear
      equivalence  (segy1b(87),cryear)
c
```

Appendix B

```
c File creation date - Month of year                    USGS USE
      integer*2  crmnth
      equivalence  (segy1b(89),crmnth)
c
c File creation date - Day of month                     USGS USE
      integer*2  crday
      equivalence  (segy1b(91),crday)
c
c   Bytes 93-398 of the binary File Identification Header are not used
c
c  Format  version  number (x100)
c  Version 0.99       "Discussion version", October 1986.
c  Version 1.00       "Final version", December 5, 1987
      integer*2  fvn
      equivalence  (segy1b(399),fvn)
c
```

Appendix B

```
c----------------------------------------------------------------
c Trace Identification Header (total of 240 bytes) starts here
c----------------------------------------------------------------
c
c Trace sequence number within line                    SEGY STANDARD
      integer*4  tsnl
      equivalence  (thead(1),tsnl)
c
c Trace sequence number within file                    SEGY STANDARD
      integer*4  tsnt
      equivalence  (thead(5),tsnt)
c
c Original field record number                         SEGY STANDARD
c For LDS use this will be sequential shot number      LDS USE
      integer*4  ofrn
      equivalence  (thead(9),ofrn)
c
c Trace number within original field record            SEGY STANDARD
      integer*4  tnofr
      equivalence  (thead(13),tnofr)
c
c Energy source point number                           SEGY STANDARD
      integer*4  espn
      equivalence  (thead(17),espn)
c
c CDP number                                           SEGY STANDARD
      integer*4  cdp
      equivalence  (thead(21),cdp)
c
c Trace number within CDP                              SEGY STANDARD
      integer*4  tncdp
      equivalence  (thead(25),tncdp)
c
c Trace identification code                            SEGY STANDARD
c  1 = Seismic data,    2 = Dead,     3 = Dummy        SEGY STANDARD
c  4 = Time break,      5 = Uphole,   6 = Sweep        SEGY STANDARD
c  7 = Timing,          8 = Water break                SEGY STANDARD
c  9 = Deleted trace                                   USGS USE
c  10 = Long Period data (see thead(117),isi)          USGS USE
      integer*2  tic
      equivalence  (thead(29),tic)
c
c Number of vertically summed traces
c       yielding this trace                            SEGY STANDARD
      integer*2  nvs
      equivalence  (thead(31),nvs)
c
c Number of horizontally stacked traces
c       yielding this trace                            SEGY STANDARD
      integer*2  nhs
      equivalence  (thead(33),nhs)
c
```

Appendix B

```
c Data use (1=production 2=test)                        SEGY STANDARD
      integer*2  duse
      equivalence  (thead(35),duse)
c
c Distance from source to receiver                      SEGY STANDARD
      integer*4  idist
      equivalence  (thead(37),idist)
c
c Receiver group elevation                              SEGY STANDARD
      integer*4  irel
      equivalence  (thead(41),irel)
c
c Surface elevation of source                           SEGY STANDARD
      integer*4  ishe
      equivalence  (thead(45),ishe)
c
c Shot depth                                            SEGY STANDARD
      integer*4  ishd
      equivalence  (thead(49),ishd)
c
c Datum elevation at receiver                           SEGY STANDARD
      integer*4  delr
      equivalence  (thead(53),delr)
c
c Datum elevation at source                             SEGY STANDARD
      integer*4  dels
      equivalence  (thead(57),dels)
c
c Water depth at source                                 SEGY STANDARD
      integer*4  wds
      equivalence  (thead(61),wds)
c
c Water depth at receiver                               SEGY STANDARD
      integer*4  wdr
      equivalence  (thead(65),wdr)
c
c Scalar multiplier/divisor for bytes 41-68             SEGY STANDARD
      integer*2  smul1
      equivalence  (thead(69),smul1)
c
c Scalar multiplier/divisor for bytes 73-88             SEGY STANDARD
      integer*2  smul2
      equivalence  (thead(71),smul2)
c
c Source coordinate X or longitude (East positive)      SEGY STANDARD
      integer*4  ishlo
      equivalence  (thead(73),ishlo)
c
c Source coordinate Y or latitude (North positive)      SEGY STANDARD
      integer*4  ishla
      equivalence  (thead(77),ishla)
c
```

Appendix B

```
c Group coordinate X or longitude (East positive)          SEGY STANDARD
      integer*4  irlo
      equivalence  (thead(81),irlo)
c
c Group coordinate Y or latitude (North positive)          SEGY STANDARD
      integer*4  irla
      equivalence  (thead(85),irla)
c
c Coordinate units                                         SEGY STANDARD
c  1:   meters/feet
c  2:   seconds of arc (smul2 holds multiplier)
c  N:   mod   100 = TX zone
c       div   100 = RX zone
      integer*2  cunits
      equivalence  (thead(89),cunits)
c
c Weathering velocity (m/s?)                               SEGY STANDARD
      integer*2  wvel
      equivalence  (thead(91),wvel)
c
c Subweathering velocity (m/s?)                            SEGY STANDARD
      integer*2  swvel
      equivalence  (thead(93),swvel)
c
c Uphole time at source                                    SEGY STANDARD
      integer*2  utimes
      equivalence  (thead(95),utimes)
c
c Uphole time at group                                     SEGY STANDARD
      integer*2  utimeg
      equivalence  (thead(97),utimeg)
c
c Source static correction (ms?)                           SEGY STANDARD
      integer*2  sstati
      equivalence  (thead(99),sstati)
c
c Group static                                             SEGY STANDARD
      integer*2  gstati
      equivalence  (thead(101),gstati)
c
c Total static                                             SEGY STANDARD
      integer*2  tstati
      equivalence  (thead(103),tstati)
c
c Lag time A                                               SEGY STANDARD
      integer*2  istime
      equivalence  (thead(105),istime)
c
c Lag time B                                               SEGY STANDARD
      integer*2  ibtime
      equivalence  (thead(107),ibtime)
c
```

Appendix B

```
c Delay recording time (reduced start time) (msec)      SEGY STANDARD
      integer*2  ictime
      equivalence  (thead(109),ictime)
c
c Mute start time                                        SEGY STANDARD
      integer*2  mtimes
      equivalence  (thead(111),mtimes)
c
c Mute end time                                          SEGY STANDARD
      integer*2  mtimee
      equivalence  (thead(113),mtimee)
c
c No of samples in this trace                            SEGY STANDARD
      integer*2  length
      equivalence  (thead(115),length)
c
c Sampling interval in microseconds                      SEGY STANDARD
c If (thead(29),itic) = 10, in milliseconds              USGS STANDARD
      integer*2  isi
      equivalence  (thead(117),isi)
c
c Gain type (1=fixed 2=binary 3=floating)                SEGY STANDARD
      integer*2  gaint
      equivalence  (thead(119),gaint)
c
c Gain constant                                          SEGY STANDARD
      integer*2  gc
      equivalence  (thead(121),gc)
c
c Instrument or initial gain in DB                       SEGY STANDARD
      integer*2  gidb
      equivalence  (thead(123),gidb)
c
c Correlated 1=no 2=yes                                  SEGY STANDARD
      integer*2  tcorr
      equivalence  (thead(125),tcorr)
c
c Start sweep frequency (hz)                             SEGY STANDARD
      integer*2  tsswee
      equivalence  (thead(127),tsswee)
c
c End sweep frequency (hz)                               SEGY STANDARD
      integer*2  teswee
      equivalence  (thead(129),teswee)
c
c Sweep length in milliseconds                           SEGY STANDARD
      integer*2  tsleng
      equivalence  (thead(131),tsleng)
c
```

```
c Sweep type                                      SEGY STANDARD
c  stype=1    Linear                              SEGY STANDARD
c  stype=2    Parabolic                           SEGY STANDARD
c  stype=3    Exponential                         SEGY STANDARD
c  stype=4    Other                               SEGY STANDARD
c  stype=5    Borehole source                     LDS USE
c  stype=6    Water explosive source              LDS USE
c  stype=7    Airgun source                       LDS USE
      integer*2  tstype
      equivalence  (thead(133),tstype)
c
c Sweep trace taper in milliseconds at start      SEGY STANDARD
      integer*2  tstts
      equivalence  (thead(135),tstts)
c
c Sweep trace taper in milliseconds at end        SEGY STANDARD
      integer*2  tstte
      equivalence  (thead(137),tstte)
c
c Taper type                                      SEGY STANDARD
c  ttype=1   Linear                               SEGY STANDARD
c  ttype=2   Cos**2                               SEGY STANDARD
c  ttype=3   Other                                SEGY STANDARD
      integer*2  tttype
      equivalence  (thead(139),tttype)
c
c Antialias filter frequency                      SEGY STANDARD
      integer*2  aif
      equivalence  (thead(141),aif)
c
c Alias filter slope                              SEGY STANDARD
      integer*2  ais
      equivalence  (thead(143),ais)
c
c Notch filter frequency                          SEGY STANDARD
      integer*2  nif
      equivalence  (thead(145),nif)
c
c Notch filter slope                              SEGY STANDARD
      integer*2  nis
      equivalence  (thead(147),nis)
c
c Low cut frequency                               SEGY STANDARD
      integer*2  flc
      equivalence  (thead(149),flc)
c
c High cut frequency                              SEGY STANDARD
      integer*2  fhc
      equivalence  (thead(151),fhc)
c
c Low cut slope                                   SEGY STANDARD
      integer*2  slc
      equivalence  (thead(153),slc)
```

Appendix B

```
c
c High cut slope                                         SEGY STANDARD
      integer*2   shc
      equivalence  (thead(155),shc)
c
c Year of start of trace                                 SEGY STANDARD
      integer*2   tyear
      equivalence  (thead(157),tyear)
c
c Day of start of trace                                  SEGY STANDARD
      integer*2   tday
      equivalence  (thead(159),tday)
c
c Hour of start of trace                                 SEGY STANDARD
      integer*2   thour
      equivalence  (thead(161),thour)
c
c Minute of start of trace                               SEGY STANDARD
      integer*2   tmin
      equivalence  (thead(163),tmin)
c
c Second of start of trace                               SEGY STANDARD
      integer*2   tsec
      equivalence  (thead(165),tsec)
c
c Time basis code  1=local 2=GMT                         SEGY STANDARD
      integer*2   tbcode
      equivalence  (thead(167),tbcode)
c
c Trace weighting factor                                 SEGY STANDARD
      integer*2   twf
      equivalence  (thead(169),twf)
c
c Geophone group no. on roll switch first position       SEGY STANDARD
      integer*2   ggrp1
      equivalence  (thead(171),ggrp1)
c
c Geophone group no. trace position 1                    SEGY STANDARD
c    on field record
      integer*2   ggtp
      equivalence  (thead(173),ggtp)
c
c Time code translator error light                       USGS USE
c   1=No error  2=Error
      integer*2   errlt
      equivalence  (thead(175),errlt)
c
c Distance-azimuth calculation algorithm                 USGS USE
c    1 = Sodano algorithm.  The program utilizes the Sodano and Robinson
c        (1963) direct solution of geodesics (Army Map Service, Tech Rep
c       #7, Section IV).
      integer*2   daca
      equivalence  (thead(177),daca)
```

Appendix B

```
c
c Earth dimension code                          USGS USE
c   1 = Fischer spheroid (1960),
c          OMEGA & NASA datums                  6378166.      298.30
c   2 = Clark ellipsoid (1866),
c          N. American datum 1927               6378206.4     294.98
c   3 = Ref ellipsoid (1967), S. American datum 6378160       298.25
c   4 = Hayford International Ellipsoid (1910)  6378388.      297.00
c   5 = World Geodetic Survey Ellipsoid (1972)  6378135.      298.26
c   6 = Bessel (1841), Tokyo datum              6377397.      299.15
c   7 = Everest (1830), India datum             6377276.      300.80
c   8 = Airy (1936),
c          Ordnance survey of Great Britain     6377563.      299.32
c   9 = Hough (1960), Wake-Eniwetok             6378270.      297.00
c  10 = Fischer (1968), Modified Mercury        6378150.      298.30
c  11 = Clarke (1880)                           6378249.      293.47
      integer*2  edc
      equivalence  (thead(179),edc)
c
c Microseconds of trace start time              LDS USE
      integer*4  mst
      equivalence  (thead(181),mst)
c
c Millisecond of timing correction              LDS USE
      integer*2  cor
      equivalence  (thead(185),cor)
c
c Charge size in kg                             LDS USE
      integer*2  charge
      equivalence  (thead(187),charge)
c
c Shot time - Year                              LDS USE
      integer*2  syear
      equivalence  (thead(189),syear)
c
c Shot time - Day                               LDS USE
      integer*2  sday
      equivalence  (thead(191),sday)
c
c Shot time - Hour                              LDS USE
      integer*2  shour
      equivalence  (thead(193),shour)
c
c Shot time - Minute                            LDS USE
      integer*2  shmin
      equivalence  (thead(195),shmin)
c
c Shot time - Second                            LDS USE
      integer*2  sseco
      equivalence  (thead(197),sseco)
c
```

Appendix B

```
c Shot time - Microsecond                                LDS USE
      integer*4  ssmic
      equivalence  (thead(199),ssmic)
c
c Azimuth of receiver from shot (minutes of arc)         LDS USE
      integer*2  azimut
      equivalence  (thead(203),azimut)
c
c Azimuth of geophone orientation axis with
c respect to true north in minutes of arc                LDS USE
      integer*2  geoazi
      equivalence  (thead(205),geoazi)
c
c Angle between geophone orientation axis and
c vertical in minutes of arc                             LDS USE
      integer*2  geover
      equivalence  (thead(207),geover)
c
c Time to be added to recorded trace time to get
c actual trace start time.  To be used when data
c has been reduced but start time is not updated
c so that the actual time can be recovered even if
c distance and shot time have changed
c (microseconds)                                         LDS USE
      integer*4  ttrace
      equivalence  (thead(209),ttrace)
c
c Recording instrument number                            LDS USE
      character*4  scrs
      equivalence  (thead(213),scrs)
c
c Deployment name                                        LDS USE
      character*4  deploy
      equivalence  (thead(217),deploy)
c
c Shotpoint name (shotpoint number)                      LDS USE
      character*4  spname
      equivalence  (thead(221),spname)
c
c Receiver site name (station number)                    LDS USE
      character*4  rstnam
      equivalence  (thead(225),rstnam)
c
c Shot name (shot number)                                LDS USE
      character*4  shotid
      equivalence  (thead(229),shotid)
c
```

Appendix B

```
c Line name                                        LDS USE
      character*4   lineid
      equivalence   (thead(233),lineid)
c
c Geophone orientation eg R40,Z                    LDS USE
      character*4   geoor
      equivalence   (thead(237),geoor)
c
c   End of Trace Identification Header
```