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Body Wave Magnitudes and Locations of Underground Nuclear Explosions at the Nevada Test Site 1971 - 1980

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SUMMARY

The United States of America conducts its underground nuclear tests at the Nevada Test Site (NTS). A maximum likelihood estimate of the seismic magnitude m_b together with announced origin times, locations and depths are presented for explosions at NTS between 1971 and 1980. The amplitude data used to determine m_b are taken from the seismological bulletins of the International Seismological Centre (ISC), Newbury, UK.

1. INTRODUCTION

Basic source information (location, origin time, depth, yield, etc) about underground nuclear explosions is important to seismologists interested in studying the structure of the earth, as well as those interested in discrimination between earthquake and explosion generated seismic signals. Numerous scientists have appealed for the release of epicentral details of explosions to aid research programmes (Bullen, Griggs and Press, Teller, (1-3). In response, Springer and Kinnaman (4,5) published the basic epicentre details for all announced underground nuclear explosions detonated in the USA from 1961 to 1973. Numerous yield estimates were also included. The origin times and precise epicentres of French underground nuclear explosions in the Sahara between 1961 and 1966 have been published by Duclaux and Michaud (6). No comparable data are available for underground explosions in the USSR.

Several international data centres collect seismic wave arrival times from all over the world and compute estimates of the origin time, epicentre, depth and size for seismic disturbances including underground explosions. Bulletins containing these data are published by the US National Earthquake Information Service (NEIS) in Colorado, USA and the International Seismological Centre (ISC) in Newbury, UK. A similar service is provided by the Institute of Physics of the Earth in Moscow, but the Soviet bulletin does not usually report data on nuclear explosions.

From the ISC and NEIS bulletins it is possible to extract either estimates of source parameters of underground explosions or officially announced details for most nuclear tests at NTS. Official announcements are particularly useful for seismological researchers interested in solving some of the outstanding problems of verifying compliance with nuclear test ban treaties since they provide researchers with a list of known explosion sources upon which to develop techniques for the identification of explosion generated signals. The release, by the US Government, of epicentral details of their nuclear tests and the value of this information to the seismological community should be applauded.

The ISC bulletin includes an estimate of the mean magnitude for most explosions. However, the magnitude reported is determined only to one decimal place and takes no account of station magnitude corrections for the seismic stations used. In effect the network used to determine m_b is different for almost every explosion. A useful addition to the officially released data would be reliable estimates of the seismic magnitude m_b of the explosion. To provide this additional information the P-wave amplitude and period data provided by stations reporting to the ISC have been analysed using a maximum likelihood analysis procedure to provide

estimates of the magnitude m_b for all announced explosions for which the amplitude data are available in the bulletins.

This report thus provides the seismological community with a list of announced epicentral details of US nuclear explosions together with an estimate of their magnitude. It is an attempt to extend the work published by Springer and Kinnaman (5) and in addition provide estimates of seismic magnitude.

Estimates of the epicentral parameters and magnitude of explosions at the Soviet test site near Semipalatinsk and of French explosions at Mururoa have been made and published by Marshall et al (7) and Marshall et al (8). Work is already progressing to prepare similar reports on Soviet explosions at Novaya Zemlya and the Caspian sea area to provide seismologists with estimates of the basic source parameters at most of the main nuclear explosion test sites. Reports on several announced US nuclear explosions at test sites other than NTS are already published (see, for example, Gibbs and Blamey (9)).

2. DETERMINATION OF MAGNITUDE

The size of a seismic source is measured by its magnitude. For short period (SP) seismic P wave data the Gutenberg and Richter definition (10) is used:-

$$m_b = \log_{10} A/T + B(\Delta) \qquad \ldots.(1)$$

where A is the amplitude of the P wave in nm, T its predominant period in seconds, $B(\Delta)$ a distance normalising term.

Consider n explosions recorded at some or all of q stations. Then if m_{ij} is the magnitude of the ith explosion recorded at station j, we can write

$$m_{ij} = b_i + s_j + \epsilon_{ij}, \qquad \ldots.(2)$$

where b_i depends on the seismic size of the explosion, s_j is a station correction and ϵ_{ij} is an error term. Least squares can be used to estimate b_i and s_j using the method described by Douglas (11) if it is assumed that

$$\Sigma s_j = 0 \qquad \ldots.(3)$$

Least squares estimates are unbiased if the observed m_{ij} are sampled randomly from a normal population. The latter cannot be assumed however if station amplitude measurement thresholds result in "censoring" of many lower values of m_{ij}. To allow for threshold effects the following "maximum likelihood" estimation technique has been used.

Following Christoffersson et al (12) the distribution of <u>observed</u> station magnitudes m_{ij} can be written as:

$$P\left[\begin{matrix} m_{ij} \\ obs \end{matrix}\middle| b_i, s_j, \sigma..\right] = \frac{\Phi\left[\dfrac{m_{ij} - G_j}{\gamma_j}\right]\theta\left[\dfrac{m_{ij} - s_j - b_i}{\sigma}\right]}{\Phi\left[\dfrac{s_j + b_i - G_j}{\sqrt{\sigma^2 + \gamma_j^2}}\right]} \qquad ....(4)$$

where

$$G_j = g_j + B(\Delta_j) \qquad ....(5)$$

θ is the normal density function of variance σ^2 representing the distribution of "uncensored" values of m_{ij}; Φ the cumulative normal distribution; g_j the mean (50%) amplitude measurement threshold in terms of Log A/T for station j; γ_j^2 the variance of the threshold assumed normally distributed about g_j. If the sources are close together equation 5 enables the mean Log A/T thresholds g_j to be expressed in terms of magnitude thresholds G_j.

Estimates of b_i, S_j and σ can be determined by maximising the likelihood function resulting from the product over the observed values of m_{ij} of terms given by equation 4

$$L(b_i, s_j, \sigma) = \prod_{\substack{\text{observed} \\ m_{ij}}} P(m_{ij}|b_i, s_j....) \qquad ....(6)$$

Maximisation being subject to the constraint equation 3.

When using least squares, the effect of large errors, which deviate from normal law, can be reduced by the application of weighting as in Jeffreys' (13) method of uniform reduction. This method assumes that the random variable ϵ_{ij} is essentially normal but modified by the addition of a low amplitude uniform distribution. In the maximum likelihood estimation described above this is introduced by adding a constant term to the probability density function given by equation 4. Examination of observed distributions away from the mode suggested a value 0.01 times the maximum is appropriate for this term. Its introduction progressively reduces the contribution of observations beyond two to three standard deviations from the mode.

As well as the observations m_{ij} the method requires values for the threshold parameters g_j and γ_j. These are estimated from the overall distribution of Log A/T submitted to the ISC by each station using the method of Kelly and Lacoss (14). Table 3 gives the threshold values used in the analysis and are based on those published by Lilwall (15,16) with some small modifications and additions.

The basic input data are taken from the ISC bulletins in the form of Log A/T readings from stations located in the distance range $\Delta = 8^\circ - 95^\circ$. Resulting magnitude estimates are in table 1 and the station corrections in table 2. Altogether 4633 amplitude readings were used to estimate the 112 magnitudes and 156 station terms. A value of 0.145 was obtained for the station magnitude standard deviation σ.

In general, differences between the maximum likelihood estimates and those obtained using least squares are small (< 0.2 units) and are negligible above $m_b \simeq 5.5$. A study of these differences will be the subject of a separate report.

3. EPICENTRAL INFORMATION

The basic source information: codename, date, origin time, location and depth are announced for many tests conducted by the US at NTS. These data have been used to compile table 1. The sources of this data are: (A) Springer and Kinnaman (5); (B) US DOE report (17) and (C) Dept. of Energy press releases. In a few cases only the code name and date of the explosion are released. For these explosions the origin time, to the nearest minute, determined by the ISC have been included in table 1 and are indicated by the parenthesis around the origin time.

The epicentres have been plotted (figures 1-3) to illustrate the relative location of the explosions. For presentational purposes the NTS has been divided into three areas; the Yucca Flat, Pahute Mesa and Rainier Mesa.

4. ACKNOWLEDGMENTS

The authors would like to thank the numerous analysts around the world that measure and report P-wave amplitudes to the ISC. Without their contribution this report would never have been prepared.

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TABLE 1

Location, Origin Time, Code Name, Depth and Estimated Magnitude of Underground Explosions at the Nevada Test Site

No	Date	Code Name	Origin Time	Latitude °N	Longitude °W	m_b	Standard Deviation	n	Depth m
1	16.06.71	Embudo	14 50 00.0	37.033	116.014	4.91	0.15	1	303
2	23.06.71	Laguna	15 30 00.0	37.022	116.023	4.73	0.11	5	455
3	24.06.71	Harebell	14 00 00.2	37.147	116.067	4.99	0.10	11	519
4	29.06.71	Camphor	(1830)			4.75	0.06	9	-
5	01.07.71	Diamond Mine	14 00 00.1	37.012	116.203	-	-	-	-
6	08.07.71	Miniata	14 00 00.1	37.110	116.051	5.48	0.03	39	529
7	18.08.71	Algodones	14 00 00.0	37.057	116.036	5.33	0.04	25	528
8	29.09.71	Pedernal	14 00 00.0	37.011	116.007	4.32	0.24	1	
9	08.10.71	Cathay	14 30 00.1	37.114	116.037	4.50	0.12	2	378
10	24.11.71	Diagonal Line	20 15 00.2	36.879	115.935	-	-	-	-
11	14.12.71	Chaenactis	21 09 59.2	37.124	116.096	4.49	0.12	2	331
12	19.04.72	Longchamps	16 32 00.0	37.122	116.083	-	-	-	-
13	02.05.72	Misty North	(1915)			4.71	0.07	10	377
14	17.05.72	Zinnia	14 10 00.2	37.120	116.088	-	-	-	-
15	19.05.72	Monero	17 00 00.0	37.064	116.002	4.48	0.11	2	538
16	20.07.72	Diamond Sculls	17 16 00.2	37.215	116.183	4.90	0.05	17	424
17	21.09.72	Oscuro	15 30 00.2	37.082	116.037	5.66	0.03	42	560
18	26.09.72	Delphinium	14 30 00.2	37.122	116.085	4.07	0.10	3	296
19	21.12.72	Flax	20 15 00.2	37.140	116.083	4.92	0.05	11	688
20	08.03.73	Miera	16 10 00.2	37.103	116.027	5.32	0.03	36	569
21	25.04.73	Angus	22 25 00.0	37.005	116.028	4.57	0.07	5	453
22	26.04.73	Starwort	17 15 00.2	37.123	116.059	5.54	0.03	44	564
23	05.06.73	Dido Queen	17 00 00.2	37.185	116.215	4.94	0.05	19	391
24	06.06.73	Almendro	13 00 00.1	37.245	116.346	6.16	0.02	58	1,064
25	28.06.73	Portulaca	19 15 12.4	37.148	116.086	4.92	0.05	14	466
26	12.10.73	Husky Ace	17 00 00.8	37.200	116.203	4.67	0.06	9	413
27	28.11.73	Bernal	(1530)			4.45	0.09	4	-
28	27.02.74	Latir	17 00 00.1	37.104	116.053	5.62	0.02	54	-
29	23.05.74	Fallon	(1339)			4.79	0.04	18	-
30	19.06.74	Ming Blade	(1600)			4.85	0.05	20	-
31	10.07.74	Escobosa	16 00 00.1	37.068	116.032	5.72	0.02	73	-

TABLE 1 (cont.)

No	Date	Code Name	Origin Time	Latitude °N	Longitude °W	m_b	Standard Deviation	n	Depth m
32	14.08.74	Puye	14 00 00.1	37.023	116.035	4.41	0.10	3	-
33	30.08.74	Portmanteau	15 00 00.2	37.152	116.083	5.76	0.02	57	-
34	26.09.74	Stanyan	15 05 00.2	37.133	116.068	5.51	0.02	46	-
35	28.10.74	Hybla Fair				-	-	-	-
36	28.02.75	Topgallant	15 15 00.0	37.106	116.056	5.69	0.02	67	713
37	07.03.75	Cabrillo	15 00 00.0	37.134	116.084	5.57	0.02	52	600
38	05.04.75	Dining Car	19 45 00.0	37.188	116.214	4.87	0.03	30	305
39	24.04.75	Edam	14 10 00.0	37.116	116.087	4.52	0.05	12	412
40	30.04.75	Obar	15 00 00.0	37.109	116.029	5.08	0.03	28	-
41	14.05.75	Tybo	14 00 00.4	37.221	116.474	6.05	0.02	74	765
42	03.06.75	Stilton	14 20 00.2	37.340	116.523	5.82	0.02	76	731
43	03.06.75	Mizzen	14 40 00.1	37.094	116.036	5.64	0.02	76	637
44	19.06.75	Mast	13 00 00.1	37.350	116.320	6.05	0.02	84	912
45	26.06.75	Camembert	12 30 00.2	37.279	116.369	6.20	0.02	81	1,311
46	06.09.75	Marsh	17 00 00.1	37.024	116.028	4.64	0.07	6	427
47	24.10.75	Husky Pup	17 11 26.1	37.222	116.179	4.76	0.05	15	348
48	28.10.75	Kasseri	14 30 00.2	37.290	116.411	6.30	0.02	68	1,265
49	20.11.75	Inlet	15 00 00.1	37.225	116.368	5.96	0.02	64	817
50	26.11.75	Leyden	15 30 00.2	37.117	116.019	4.37	0.07	6	320
51	20.12.75	Chiberta	20 00 00.2	37.128	116.062	5.69	0.02	62	716
52	03.01.76	Muenster	19 15 00.2	37.297	116.333	6.28	0.02	71	1,451
53	04.02.76	Keelson	14 20 00.1	37.069	116.030	5.65	0.02	61	640
54	04.02.76	Esrom	14 40 00.2	37.107	116.037	5.66	0.02	60	655
55	12.02.76	Fontina	14 45 00.2	37.271	116.488	6.24	0.02	75	1,219
56	14.02.76	Cheshire	11 30 00.2	37.243	116.420	5.92	0.02	62	1,167
57	09.03.76	Estuary	14 00 00.1	37.310	116.364	5.97	0.02	70	869
58	14.03.76	Colby	12 30 00.2	37.306	116.471	6.34	0.02	75	1,273
59	17.03.76	Pool	14 15 00.1	37.256	116.312	6.05	0.03	64	879
60	17.03.76	Strait	14 45 00.1	37.107	116.052	5.87	0.02	62	780
61	12.05.76	Mighty Epic	19 50 00.2	37.209	116.212	4.78	0.05	14	-
62	27.07.76	Billet	20 30 00.1	37.075	116.044	5.35	0.03	29	-
63	26.08.76	Banon	14 30 00.2	37.125	116.082	5.25	0.03	31	-
64	23.11.76	Chevre	15 15 00.2	37.172	116.053	-	-	-	317
65	08.12.76	Redmud	14 49 30.1	37.079	116.002	4.72	0.08	5	427
66	21.12.76	Asiago	15 09 00.2	37.124	116.067	-	-	-	331
67	28.12.76	Rudder	18 00 00.1	37.100	116.036	5.46	0.02	53	640

TABLE 1 (cont.)

No	Date	Code Name	Origin Time	Latitude °N	Longitude °W	m_b	Standard Deviation	n	Depth m
68	05.04.77	Marsilly	15 00 00.2	37.120	116.062	5.71	0.02	58	690
69	27.04.77	Bulkhead	15 00 00.1	37.095	116.028	5.37	0.02	55	594
70	25.05.77	Crewline	17 00 00.1	37.094	116.045	5.36	0.03	45	564
71	04.08.77	Strake	16 40 00.1	37.087	116.007	5.18	0.03	32	518
72	19.08.77	Scantling	17 55 00.1	37.111	116.055	5.66	0.02	59	701
73	15.09.77	Ebbtide	14 36 30.1	37.033	116.043	4.47	0.09	3	381
74	27.09.77	Coulommiers	14 00 00.2	37.151	116.068	4.87	0.04	22	530
75	26.10.77	Bobstay	14 15 00.1	37.008	116.017	4.35	0.07	5	381
76	01.11.77	Hybla Gold	18 06 00.1	37.188	116.213	-	-	-	385
77	09.11.77	Sandreef	22 00 00.1	37.072	116.050	5.81	0.02	63	701
78	17.11.77	Seamount	19 30 00.1	37.021	116.025	4.68	0.07	6	372
79	14.12.77	Farallones	15 30 00.2	37.136	116.086	5.77	0.02	62	668
80	13.02.78	Campos	(2153)			3.86	0.16	1	-
81	23.02.78	Reblochon	17 00 00.2	37.125	116.064	5.73	0.02	67	658
82	23.03.78	Iceberg	16 30 00.2	37.102	116.051	5.70	0.02	69	640
83	11.04.78	Fondutta	15 30 00.2	37.300	116.327	5.49	0.02	47	633
84	11.04.78	Backbeach	17 45 00.1	37.233	116.367	5.54	0.02	49	611
85	12.07.78	Lowball	17 00 00.1	37.079	116.044	5.67	0.02	69	564
86	31.08.78	Panir	14 00 00.2	37.275	116.357	5.66	0.02	74	681
87	13.09.78	Diablo Hawk	15 15 00.2	37.209	116.211	4.72	0.05	10	388
88	27.09.78	Draughts	17 00 00.0	37.080	116.050	5.10	0.04	26	442
89	27.09.78	Rummy	17 20 00.0	37.070	116.019	5.85	0.02	75	640
90	02.11.78	Emmenthal	15 25 00.2	37.288	116.297	4.25	0.10	3	576
91	18.11.78	Quargel	19 00 00.0	37.126	116.084	5.34	0.03	37	542
92	16.12.78	Farm	15 30 00.2	37.273	116.410	5.63	0.02	58	689
93	24.01.79	Baccarat	18 00 00.1	37.104	116.012	4.52	0.09	3	326
94	08.02.79	Quinella	20 00 00.1	37.102	116.055	5.60	0.02	57	579
95	15.02.79	Kloster	18 05 00.2	37.152	116.072	4.97	0.04	19	536
96	14.03.79	Memory	18 30 00.1	37.028	116.040	4.47	0.09	3	366
97	11.06.79	Pepato	14 00 00.2	37.290	116.455	5.56	0.03	53	681
98	20.06.79	Chess	15 00 13.5	37.108	116.015	4.14	0.16	1	335
99	28.06.79	Fajy	14 44 00.2	37.142	116.088	5.22	0.03	32	537
100	03.08.79	Burzet	15 07 30.2	37.083	116.070	4.85	0.05	14	450

TABLE 1 (cont.)

No	Date	Code Name	Origin Time	Latitude ^{o}N	Longitude ^{o}W	m_b	Standard Deviation	n	Depth m
101	08.08.79	Offshore	15 00 00.1	37.015	116.008	4.82	0.05	16	396
102	29.08.79	Nessel	15 08 00.2	37.121	116.066	4.92	0.04	17	464
103	06.09.79	Hearts	15 00 00.1	37.088	116.053	5.88	0.02	72	640
104	08.09.79	Pera	17 02 00.1	37.154	116.038	-	-	-	200
105	26.09.79	Sheepshead	15 00 00.1	37.229	116.364	5.63	0.02	50	640
106	29.11.79	Backgammon	15 00 00.1	36.994	116.024	3.86	0.16	1	229
107	14.12.79	Azul	18 00 00.1	37.137	116.063	-	-	-	205
108	28.02.80	Tarko	15 00 00.1	37.127	116.089	4.50	0.11	2	369
109	08.03.80	Norbo	15 35 00.1	37.180	116.083	3.93	0.16	1	271
110	03.04.80	Liptauer	14 00 00.1	37.150	116.082	4.86	0.04	17	417
111	16.04.80	Pyramid	20 00 00.1	37.101	116.031	5.41	0.03	40	579
112	26.04.80	Colwick	17 00 00.1	37.248	116.422	5.54	0.02	60	633
113	02.05.80	Canfield	18 46 30.1	37.056	116.019	4.44	0.10	4	351
114	22.05.80	Flora	13 00 00.1	37.003	116.031	-	-	-	335
115	12.06.80	Kash	17 15 00.1	37.282	116.454	5.67	0.02	53	645
116	24.06.80	Huron King	15 10 00.1	37.023	116.034	4.55	0.11	2	320
117	25.07.80	Tafi	19 05 00.1	37.256	116.477	5.57	0.03	55	680
118	31.07.80	Verdello	18 19 00.1	37.013	116.023	4.44	0.16	1	366
119	25.09.80	Bonarda	14 45 00.1	37.056	116.048	4.46	0.07	5	381
120	25.09.80	Riola	15 26 30.1	37.116	116.065	-	-	-	424
121	24.10.80	Dutchess	19 15 00.1	37.075	115.999	4.31	0.12	2	427
122	31.10.80	Miners Iron	18 00 00.1	37.211	116.205	4.91	0.06	12	390
123	14.11.80	Dauphin	16 50 00.1	37.111	116.019	4.51	0.08	4	320
124	17.12.80	Serpa	15 10 00.1	37.325	116.312	5.28	0.03	24	573

TABLE 2

Station Corrections, Followed by Standard Confidence Limits and Number of Observations

STN	COR			
ABU	-0.279	+OR-	0.061	11
ADQ	0.232	+OR-	0.042	16
ACO	0.751	+OR-	0.147	2
ADK	0.055	+OR-	0.037	20
AFR	0.433	+OR-	0.032	29
AFI	0.006	+OR-	0.071	7
AGM	0.466	+OR-	0.105	2
ALE	-0.140	+OR-	0.021	57
AMN	0.207	+OR-	0.065	6
ANG	0.331	+OR-	0.068	5
APT	-0.134	+OR-	0.049	15
ARE	0.441	+OR-	0.036	19
ALQ	0.452	+OR-	0.097	9
BRA	0.298	+OR-	0.086	4
BLC	-0.380	+OR-	0.031	26
BUD	-0.199	+OR-	0.127	3
BNS	0.082	+OR-	0.033	24
BRG	-0.160	+OR-	0.020	69
BMO	0.044	+OR-	0.176	2
BUB	0.068	+OR-	0.058	10
BNM	-0.589	+OR-	0.076	6
BJI	-0.324	+OR-	0.164	1
BPT	-0.364	+OR-	0.060	10
BMP	-0.208	+OR-	0.107	2
BLA	0.136	+OR-	0.042	17
CBM	-0.220	+OR-	0.067	6
CWF	-0.650	+OR-	0.045	13
CRO	-0.103	+OR-	0.042	13
CUM	0.249	+OR-	0.046	14
CLL	-0.207	+OR-	0.022	57
CPO	-0.212	+OR-	0.033	22
COP	-0.345	+OR-	0.075	5
CAR	0.032	+OR-	0.030	35
COL	0.025	+OR-	0.026	42
DDK	0.318	+OR-	0.156	1
DCN	0.322	+OR-	0.070	5
DNU	0.096	+OR-	0.079	5
DIX	-0.335	+OR-	0.044	22
DAL	-1.358	+OR-	0.089	3
DAG	-0.141	+OR-	0.021	63
EAB	-0.054	+OR-	0.029	32
EBH	0.126	+OR-	0.030	34
EAU	-0.087	+OR-	0.035	31
EDI	0.073	+OR-	0.029	34
EBL	0.021	+OR-	0.036	33
EGL	0.049	+OR-	0.027	35
EDU	-0.150	+OR-	0.036	21
EMM	0.114	+OR-	0.064	6
ECT	-0.230	+OR-	0.082	5
EDM	0.134	+OR-	0.031	32
EKA	-0.358	+OR-	0.026	38
ELO	0.167	+OR-	0.035	19
ESK	-0.098	+OR-	0.059	8
FFC	-0.169	+OR-	0.022	66
FSJ	-0.551	+OR-	0.029	37
FBC	-0.052	+OR-	0.112	2
FUR	0.090	+OR-	0.041	38
FCC	-0.222	+OR-	0.051	17
FRB	-0.069	+OR-	0.035	19
FUM	-0.272	+OR-	0.075	5
FRT	0.064	+OR-	0.081	4
FDA	0.867	+OR-	0.090	4
GUA	0.311	+OR-	0.054	10
GDH	-0.161	+OR-	0.024	44
GOL	0.602	+OR-	0.033	43
GUMO	0.399	+OR-	0.098	3
GRE	-0.075	+OR-	0.059	7
GRF	0.037	+OR-	0.027	34
GIL	0.250	+OR-	0.025	44
HFS	0.163	+OR-	0.018	76
HOF	-0.332	+OR-	0.447	3
HDM	-0.198	+OR-	0.044	23
HNR	0.521	+OR-	0.110	8
INK	-0.052	+OR-	0.045	13
IMA	-0.262	+OR-	0.184	1
JCT	-0.369	+OR-	0.045	15
JOS	-0.189	+OR-	0.030	31
KIR	0.242	+OR-	0.039	21
KMU	0.079	+OR-	0.049	12
KRA	0.392	+OR-	0.023	50
KEW	-0.392	+OR-	0.027	44
KJF	-0.097	+OR-	0.020	71
KJN	-0.101	+OR-	0.083	4
KHC	-0.095	+OR-	0.023	50
KON	0.022	+OR-	0.032	24
KBS	-0.046	+OR-	0.029	34
KTG	0.026	+OR-	0.021	64
LD3	0.160	+OR-	0.056	9
LHC	0.040	+OR-	0.024	44
LJU	-0.093	+OR-	0.051	11
LAO	0.171	+OR-	0.054	11
LPB	0.054	+OR-	0.027	36
LPS	-0.120	+OR-	0.068	15
LON	0.502	+OR-	0.025	55
MUI	0.291	+OR-	0.104	2
MZO	-0.573	+OR-	0.072	5
MIM	-0.362	+OR-	0.050	12
MOX	-0.255	+OR-	0.021	61
MBC	-0.170	+OR-	0.019	77
MNT	0.167	+OR-	0.040	15
MSO	1.083	+OR-	0.025	57
MAT	0.059	+OR-	0.028	31
MB2	-0.255	+OR-	0.035	24
MAE	0.037	+OR-	0.095	3
MBO	-0.239	+OR-	0.093	3
MAO	-0.180	+OR-	0.025	39
MIE	-0.011	+OR-	0.028	38
MEM	0.636	+OR-	0.037	18
NOR	-0.667	+OR-	0.122	2
NUR	-0.102	+OR-	0.025	47
NNA	-0.037	+OR-	0.037	23
OIC	0.043	+OR-	0.050	19
OTT	-0.239	+OR-	0.037	30
OLO	-0.705	+OR-	0.164	1
OTP	0.042	+OR-	0.073	5
PNT	0.495	+OR-	0.027	40
PMR	0.019	+OR-	0.021	63
PRU	0.012	+OR-	0.024	46
PRA	-0.039	+OR-	0.064	10
PHC	-0.514	+OR-	0.033	27
PMO	-0.070	+OR-	0.031	36
PPN	0.097	+OR-	0.028	36
PPT	0.385	+OR-	0.029	35
PAE	0.291	+OR-	0.031	33
PSZ	0.035	+OR-	0.057	10
PCO	-0.132	+OR-	0.114	2
RAB	0.227	+OR-	0.111	2
RES	-0.232	+OR-	0.023	52
ROL	-0.209	+OR-	0.069	5
RUV	0.280	+OR-	0.025	42
RKT	-0.239	+OR-	0.053	11
SES	0.253	+OR-	0.038	18
SHK	0.494	+OR-	0.045	12
SJG	0.566	+OR-	0.035	23
SOP	0.052	+OR-	0.033	30
SFA	0.125	+OR-	0.080	4
SCH	-0.008	+OR-	0.029	30
SKI	0.184	+OR-	0.070	5
STU	-0.206	+OR-	0.046	13
STJ	0.520	+OR-	0.041	17
SUT	0.078	+OR-	0.079	4
SSF	-0.083	+OR-	0.024	44
TRN	-0.043	+OR-	0.027	37
TOL	0.208	+OR-	0.030	36
TUL	-0.543	+OR-	0.022	75
TSK	-0.090	+OR-	0.052	9
TRO	0.185	+OR-	0.115	2
TPT	-0.110	+OR-	0.028	40
TUO	0.281	+OR-	0.030	32
TMT	-0.308	+OR-	0.065	14
TRM	-0.157	+OR-	0.079	4
UAU	0.147	+OR-	0.054	10
UCT	-0.145	+OR-	0.044	21
UPP	0.406	+OR-	0.038	22
VAL	0.043	+OR-	0.053	10
VAH	0.179	+OR-	0.025	43
VIC	0.472	+OR-	0.052	14
VIE	-0.245	+OR-	0.072	5
VAO	-0.304	+OR-	0.115	2
VKA	0.247	+OR-	0.082	4
WOL	0.158	+OR-	0.031	29
WLO	0.256	+OR-	0.079	4
YKC	-0.130	+OR-	0.024	52
ZUL	0.322	+OR-	0.026	48
ZLP	-0.532	+OR-	0.116	5
ZOBO	-0.713	+OR-	0.163	1

TABLE 3

Mean 50% Amplitude Reporting Thresholds (q) Followed by Standard Deviations (γ) for Amplitude Data Submitted to the ISC

STATION THRESHOLD DATA AS FUNCTION OF TIME

ABU	6401-8112	2.20	0.30									
ABQ	7401-7712	-.05	0.17									
ACO	7001-8112	1.58	0.33									
ADK	7001-7712	1.89	0.29									
AFR	7001-7712	2.00	0.33	7801-8112	1.92	0.23						
AFI	7001-8112	1.98	0.34									
AGM	7001-8112	1.48	0.34									
ALE	6401-6912	1.53	0.24	7001-7309	1.13	0.14	7310-7712	0.72	0.18	7801-8112	0.72	0.21
AMN	7001-8112	1.98	0.23									
ANG	6401-6912	2.22	0.10	7001-8112	2.41	0.25						
APT	7401-7712	1.50	0.30									
ARE	6401-7012	1.43	0.22	7101-8112	1.66	0.27						
ALQ	6401-6912	0.68	0.22	7001-7312	1.02	0.19	7401-7712	0.93	0.23	7801-8112	0.40	0.16
BRA	7001-8112	2.13	0.30									
BLC	6401-7012	1.90	0.12	7101-7405	2.00	0.26	7406-7706	1.20	0.26			
BUD	7401-7712	1.74	0.32	7801-8112	1.78	0.26						
BNS	6401-6912	1.62	0.19	7001-7312	1.63	0.25	7401-7712	1.63	0.25			
BRG	7001-7312	0.88	0.13	7401-7712	0.89	0.13	7801-8112	0.93	0.08			
BMO	6401-6912	0.04	0.17	7001-7312	0.08	0.17	7401-7712	0.16	0.22			
BUB	7001-8112	1.58	0.19									
BNH	7001-8112	1.20	0.26									
BJI	7001-8112	1.24	0.19									
BPT	7001-8112	1.27	0.28									
BHP	6401-7512	2.00	0.20									
BLA	6401-8112	2.00	0.36									
CBM	7401-8112	1.31	0.26									
CWF	7001-8112	1.27	0.27									
CRO	7001-8112	1.28	0.26									
CUM	7001-8112	2.12	0.18									
CLL	6401-6912	1.57	0.23	7001-7312	1.21	0.12	7401-7712	1.16	0.11	7801-8112	1.18	0.12
CPO	6401-6912	0.49	0.21	7001-7312	0.75	0.15	7401-7712	0.71	0.16			
COP	6401-6912	1.89	0.13	7001-7312	1.81	0.18	7401-7712	1.91	0.18	7801-8112	1.91	0.19
CAR	6401-6912	1.50	0.16	7001-7312	1.54	0.11	7401-7712	1.65	0.16	7801-8112	1.66	0.14
COL	6401-6912	0.83	0.21	7001-7312	0.95	0.14	7401-7712	0.97	0.14	7801-8112	0.93	0.13
DDK	7001-8112	1.68	0.18									
DCN	7801-8112	1.83	0.28									
DMU	7801-8112	1.78	0.27									
DIX	7401-8112	0.81	0.21									
DAL	7803-7904	0.50	0.20									
DAG	7401-7712	0.97	0.20	7801-8112	0.96	0.15						
EAB	7401-7712	1.55	0.28	7801-8112	1.74	0.27						
EBH	7401-7712	1.51	0.31	7801-8112	1.67	0.26						
EAU	7401-7712	1.55	0.28	7801-8112	1.74	0.27						
EDI	7401-7712	1.46	0.25	7801-8112	1.64	0.24						
EBL	7401-7712	1.38	0.27	7801-8112	1.57	0.27						
EGL	7401-7712	1.42	0.28	7801-8112	1.59	0.27						
EDU	7001-8112	1.57	0.30									

TABLE 3 (cont.)

STATION THRESHOLD DATA AS FUNCTION OF TIME

EHM	7801-8112	1.50	0.25									
ECT	7001-8112	1.21	0.29									
EDM	6401-6912	1.80	0.20	7001-7312	1.59	0.12	7401-7712	1.69	0.15	7801-8112	1.62	0.09
EKA	6401-6912	1.05	0.26	7001-7312	1.39	0.22	7401-8001	1.17	0.20	8002-8112	0.97	0.28
ELO	7401-7712	1.53	0.30	7801-8112	1.56	0.25						
ESK	6401-6912	1.53	0.19	7401-7712	2.05	0.30	7801-8112	1.85	0.17			
FFC	7001-7309	1.60	0.07	7310-7712	0.99	0.26	7801-8112	1.02	0.25			
FSJ	6401-6912	2.14	0.39	7001-7312	1.55	0.13	7401-8112	1.64	0.28			
FBC	6401-6912	1.65	0.11	7001-7312	1.76	0.14						
FUR	6401-6912	1.52	0.42	7001-7312	1.54	0.31	7401-7908	1.41	0.25	7909-8112	2.10	0.25
FCC	6401-6912	1.71	0.10	7001-7312	1.73	0.09	7401-7712	1.81	0.17	7801-8112	1.93	0.31
FRB	7401-7712	1.82	0.19	7801-8112	1.78	0.16						
FUM	7501-7505	1.00	0.20	7805-8112	2.20	0.20						
FRT	7801-8112	1.92	0.22									
FDA	7001-8112	1.03	0.18									
GUA	7001-7312	2.30	0.20	7401-7712	2.17	0.22	7801-8112	2.28	0.18			
GDH	6401-6912	1.67	0.25	7001-7312	1.43	0.34	7401-7712	1.49	0.36	7801-8112	1.48	0.26
GOL	6401-6912	0.56	0.23	7001-7312	0.83	0.27	7401-7712	0.93	0.24	7801-8112	0.86	0.24
GUMO	7001-8112	2.29	0.20									
GRE	6401-6912	1.76	0.24	7001-8112	1.95	0.24						
GRF	6901-7312	1.53	0.19	7401-7712	1.47	0.23	7801-8112	1.24	0.25			
GIL	6401-6912	0.88	0.23	7001-7312	0.89	0.25	7401-8112	1.11	0.28			
HFS	7001-7312	0.58	0.24	7401-7712	0.68	0.22	7801-8112	0.71	0.23			
HOF	7001-8112	2.07	0.30									
HDM	7401-7712	1.34	0.27	7801-8112	1.54	0.32						
HNR	6401-8112	2.12	0.32									
INK	6901-7312	1.58	0.12	7401-7712	1.53	0.10	7801-8112	1.55	0.13			
IMA	7001-8112	0.79	0.29									
JCT	6401-7312	1.04	0.18	7401-7712	1.17	0.30	7801-8112	0.99	0.20			
JOS	7001-8112	1.30	0.23									
KIR	7401-7712	1.81	0.11	7801-8112	1.83	0.11						
KMU	7001-8112	1.88	0.14									
KRA	6401-6912	1.42	0.16	7001-7312	1.54	0.18	7401-7712	1.49	0.14	7801-8112	1.53	0.10
KEV	6401-6912	1.22	0.16	7001-7312	1.26	0.14	7401-7712	1.18	0.13	7801-8112	1.20	0.13
KJF	7001-7312	1.12	0.14	7401-7712	1.08	0.10	7801-8112	1.19	0.12			
KJN	6401-6912	1.03	0.17	7001-7312	1.02	0.14						
KHC	6401-6912	1.26	0.20	7001-7312	1.15	0.16	7401-7712	1.01	0.16	7801-8112	1.16	0.31
KON	6401-6912	1.34	0.18	7001-7312	1.37	0.16	7401-8112	1.38	0.17			
KBS	6401-6912	1.31	0.19	7001-7312	1.45	0.15	7401-7712	1.64	0.21	7801-8112	1.51	0.18
KTG	6401-6912	1.56	0.28	7001-7312	1.33	0.35	7401-7712	1.10	0.28	7801-8112	1.21	0.22
LD3	7001-8112	1.17	0.28									
LHC	7401-7712	1.79	0.08	7801-8112	1.89	0.15						
LJU	6401-6912	1.59	0.20	7001-7312	1.68	0.22	7401-8112	1.74	0.19			
LPO	6401-6912	0.40	0.27	7001-7312	0.03	0.24	7401-7712	-.08	0.13			
LPB	6401-6912	1.19	0.25	7401-7712	1.41	0.22	7801-8112	1.45	0.28			
LPS	6401-6912	1.35	0.21	7001-7312	1.21	0.16	7401-8112	1.33	0.19			
LON	6401-6912	1.16	0.30	7001-7312	1.18	0.23	7401-8112	1.13	0.14			

TABLE 3 (cont.)

STATION THRESHOLD DATA AS FUNCTION OF TIME

MWI	6401-7612	2.05	0.12									
MZO	7001-8112	1.50	0.27									
MIM	7401-8112	1.26	0.26									
MOX	6401-6912	1.21	0.20	7001-7312	1.03	0.13	7401-7712	1.08	0.13	7801-8112	1.21	0.13
MBC	6401-6912	1.30	0.18	7001-7309	1.43	0.14	7310-7712	0.70	0.22	7801-8112	0.61	0.26
MNT	7001-7312	1.81	0.17	7401-8112	1.91	0.21						
MSO	7001-8112	1.15	0.32									
MAT	7401-7712	1.42	0.31	7801-8112	1.30	0.22						
NBZ	7801-8112	0.20	0.26									
NAE	7001-8112	2.04	0.24									
NBO	7001-8112	0.25	0.28									
NAO	7001-7312	0.16	0.22	7401-8112	0.17	0.28						
NIE	6401-6912	1.20	0.19	7001-7312	1.04	0.14	7401-8112	0.97	0.05			
NEW	6401-6912	1.28	0.21	7001-7312	1.17	0.21	7401-7712	1.43	0.31	7801-8112	1.45	0.33
NOR	6401-6912	1.02	0.19	7001-7312	0.88	0.16						
NUR	6401-6912	1.19	0.18	7001-7312	1.26	0.15	7401-7712	1.11	0.11	7801-8112	1.20	0.12
NNA	7001-8112	1.54	0.16									
OIC	7001-7312	1.29	0.24	7401-8112	1.67	0.33						
OTT	6701-7309	2.10	0.16	7310-7712	1.39	0.16	7801-8112	1.39	0.15			
OLO	7701-7712	1.50	0.20									
OTP	7001-8112	2.10	0.25									
PNT	7001-7309	1.40	0.12	7310-7712	1.19	0.17	7801-8112	1.21	0.14			
PHR	6401-6912	1.04	0.22	7001-7312	1.06	0.26	7401-7712	1.22	0.34	7801-8112	1.15	0.28
PRU	6401-6912	1.24	0.14	7001-7312	1.27	0.12	7401-7712	1.39	0.21	7801-8112	1.33	0.17
PRA	6401-7112	2.36	0.21	7201-7312	1.54	0.12	7401-8112	1.52	0.09			
PHC	7001-8112	2.50	0.32									
PHO	7001-7712	1.76	0.31	7801-8112	1.68	0.26						
PPN	7001-7312	1.57	0.25	7401-7712	1.61	0.27	7801-8112	1.61	0.18			
PPT	7001-7312	1.84	0.29	7401-7712	1.89	0.28	7801-8112	1.90	0.22			
PAE	7001-7712	1.84	0.31	7801-8112	1.80	0.21						
PSZ	7001-8112	1.64	0.31									
PCO	7001-8112	1.95	0.29									
RAB	6401-7106	1.72	0.18	7107-7312	1.84	0.26						
RES	6401-6912	1.50	0.15	7001-7309	1.54	0.15	7310-7712	0.72	0.18	7801-8112	0.68	0.12
ROL	7001-7312	1.30	0.24									
RUU	7401-7712	1.72	0.29	7801-8112	1.74	0.27						
RKT	7401-7712	1.85	0.30	7801-8112	1.79	0.21						
SES	6701-7312	1.65	0.16	7401-7712	1.75	0.15	7801-8112	1.80	0.17			
SHK	6401-6912	1.63	0.26	7001-7312	1.78	0.22	7401-7712	1.88	0.17	7801-8112	2.04	0.16
SJG	6401-6912	1.43	0.26	7001-8112	1.56	0.22						
SOP	7001-7712	1.62	0.25	7801-8112	1.43	0.23						
SFA	6701-7312	2.12	0.13	7401-7712	2.09	0.22						
SCH	7001-7312	1.93	0.17	7401-7712	1.92	0.21	7801-8112	1.56	0.25			
SKI	7001-8112	2.27	0.22									
STU	6401-6912	1.68	0.28	7001-7312	1.86	0.22	7401-7712	1.82	0.22			
STJ	7001-8112	2.33	0.24									
SUT	6401-6912	1.72	0.14	7001-8112	2.23	0.17						

TABLE 3 (cont.)

STATION THRESHOLD DATA AS FUNCTION OF TIME

SSF	7401-7712	0.93	0.18	7801-8112	0.99	0.23						
TRN	6401-6912	1.55	0.19	7001-7312	1.56	0.15	7401-7712	1.57	0.15	7801-8112	1.67	0.18
TOL	7001-8112	2.00	0.33									
TUL	6907-7312	1.24	0.30	7401-7712	1.09	0.27	7801-8112	1.03	0.25			
TSK	6401-6912	1.48	0.35	7001-8112	1.38	0.27						
TRO	6401-6912	1.41	0.20	7001-7312	1.44	0.20						
TPT	7001-7312	1.68	0.25	7401-7712	1.68	0.28	7801-8112	1.67	0.25			
TVO	7001-7312	1.78	0.25	7401-7712	1.87	0.25	7801-8112	1.89	0.21			
TMT	7001-8112	1.42	0.26									
TRM	7001-8112	1.50	0.30									
UAU	7001-8112	2.08	0.21									
UCT	7401-7712	1.35	0.26	7801-8112	1.42	0.23						
UPP	7604-8112	1.83	0.11									
UAL	6401-6912	2.30	0.29	7001-7312	2.17	0.28	7401-7712	2.07	0.23	7801-8112	2.09	0.29
UAH	7001-7312	1.64	0.25	7401-7712	1.67	0.31	7801-8112	1.65	0.26			
UIC	7001-8112	1.56	0.24									
UIE	7001-7312	2.17	0.19	7401-7712	2.09	0.31						
UAO	7806-7812	1.00	0.20									
UKA	7001-8112	1.85	0.22									
UOL	7001-8112	1.53	0.17									
ULO	7001-8112	1.93	0.33									
YKC	6901-7309	1.75	0.15	7310-7712	1.15	0.20	7801-8112	1.24	0.24			
ZUL	7401-7712	1.38	0.20	7801-8112	1.50	0.18						
ZLP	7001-8112	0.95	0.19									
ZOBO	7001-8112	0.95	0.20									

Time periods (year followed by month) are intended to bracket overall intervals during which the thresholds are thought appropriate and are not intended to indicate station operation periods.

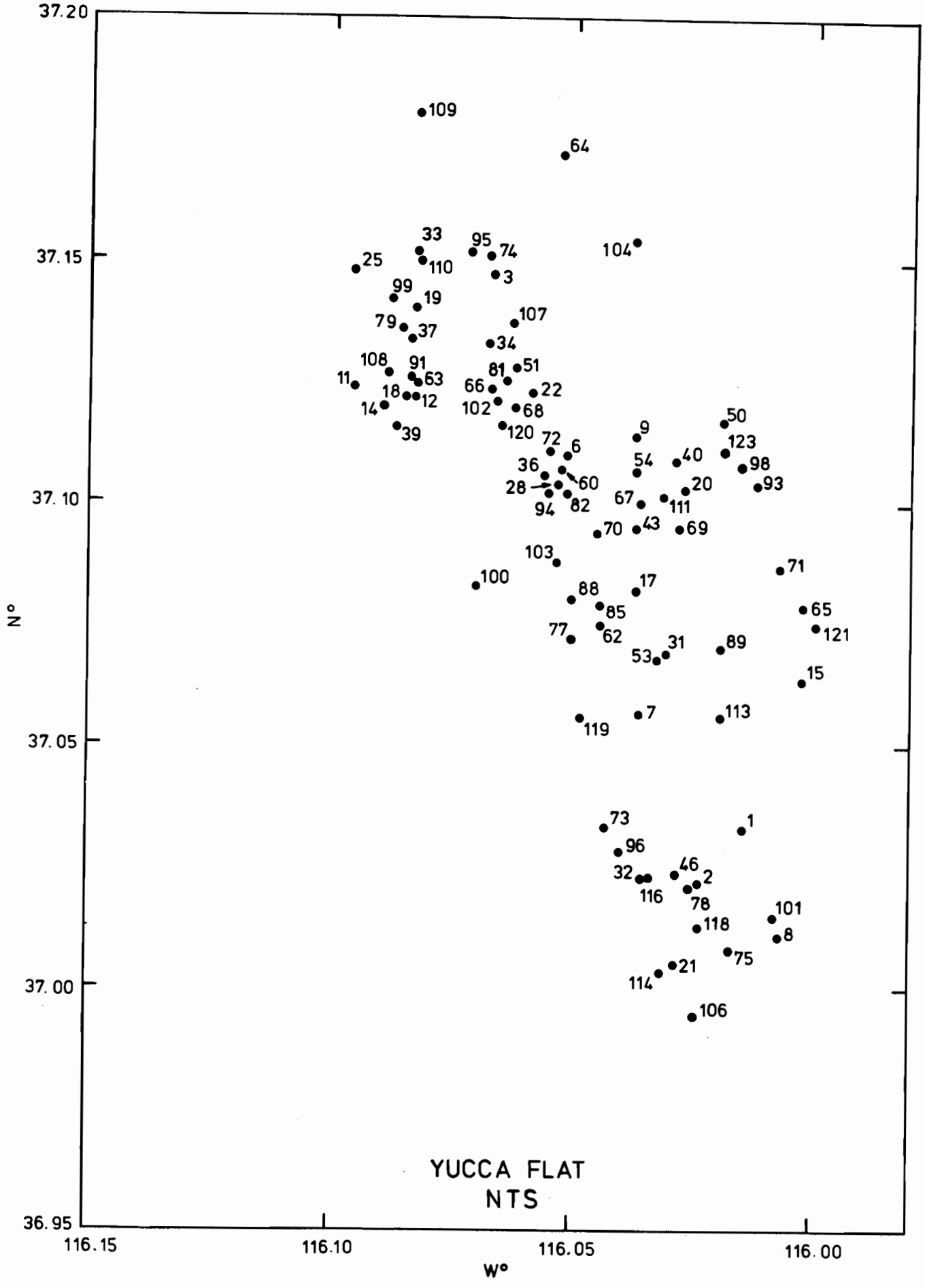

FIGURE 1. LOCATION OF EXPLOSIONS AT YUCCA FLATS NTS

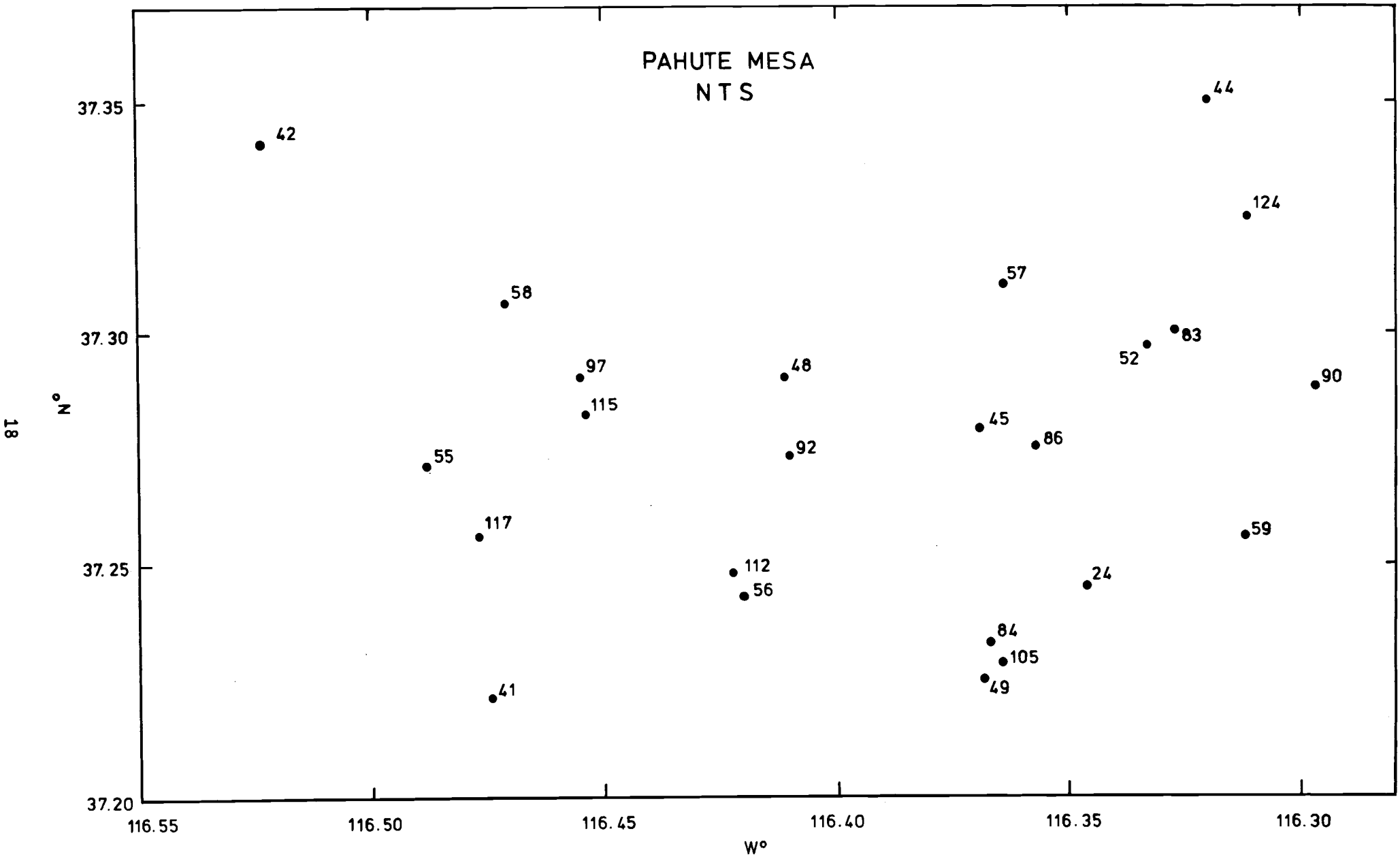

FIGURE 2. LOCATION OF EXPLOSIONS AT PAHUTE MESA NTS

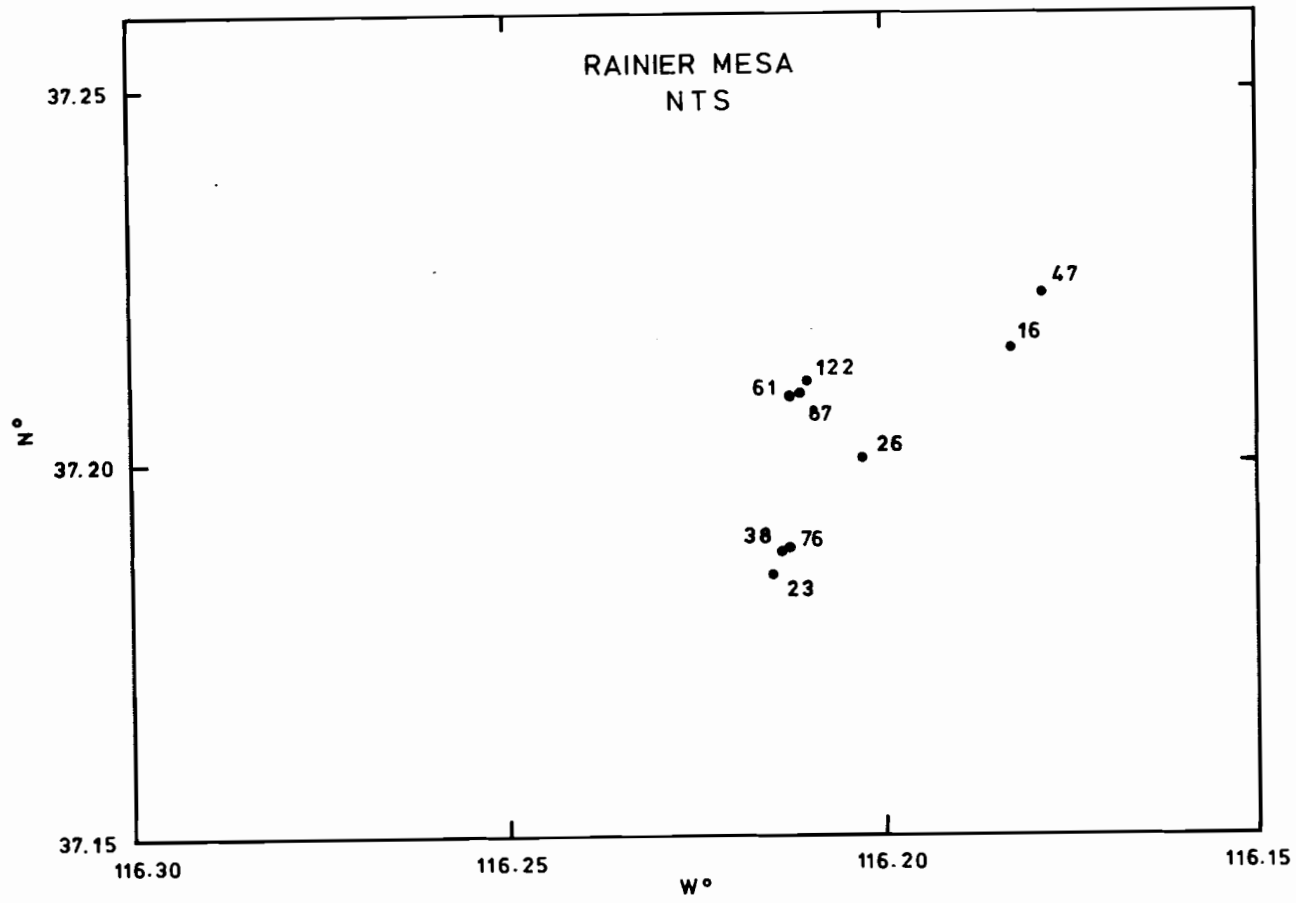

FIGURE 3. LOCATION OF EXPLOSIONS AT RAINIER MESA NTS

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Abstract

The United States of America conducts its underground nuclear tests at the Nevada Test Site (NTS). A maximum likelihood estimate of the seismic magnitude m_b together with announced origin times, locations and depths are presented for explosions at NTS between 1971 and 1980. The amplitude data used to determine m_b are taken from the seismological bulletins of the International Seismological Centre (ISC), Newbury, UK.