UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

National Center for Earthquake Research
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A SURVEY OF PRACTICE IN DETERMINING MAGNITUDE OF NEAR EARTHQUAKES: SUMMARY REPORT FOR NETWORKS IN NORTH, CENTRAL AND SOUTH AMERICA

Compiled By

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for

Working Group on Magnitude of Near Earthquakes
International Association of Seismology
and Physics of the Earth's Interior

U.S. Geological Survey

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This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards and nomenclature.

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CONTENTS

1. INTRODUCTION

At the 1975 meeting of IASPEI's Commission of Practice at Grenoble, France, five working groups were set up to discuss various aspects of the problems of magnitude determinations. These topics and the convenors of Groups are:

1. Homogeneous magnitude system; J. Vanek (Czechoslovakia);
2. Magnitude determination of near earthquakes; R. D. Adams (New Zealand);
3. Magnitude determination of deep earthquakes; S. J. Gibowicz (Poland);
4. Physical basis of magnitude scale; S. Duda (F.R.G.);
5. Magnitudes of historical earthquakes; N. V. Shebalin (U.S.S.R.).

The working group on magnitude determination of near earthquakes has the following membership:

R. D. Adams (New Zealand) Chairman
L. Christoskov (Bulgaria)
V. Karnik (Czechoslovakia)
M. Katsumata (Japan)
W. H. K. Lee (U.S.A.)
T. G. Rautian (U.S.S.R.)
D. J. Sutton (Australia)
R. J. Wetmiller (Canada)

The first task taken up by this working group is to find out what methods are at present being used in the determination of local magnitudes at various seismological centers throughout the world. Following this, an evaluation of the various methods can be undertaken. Dr. R. D. Adams suggested that the world be divided into various geographical areas, and each member write to agencies in these areas to collect the required information. As a result, members W. H. K. Lee and R. J. Wetmiller were assigned to survey North, Central and South America.

2. SURVEY OF MAGNITUDE PRACTICE

In order to collect information uniformly, a survey sheet containing 18 questions was designed. This survey sheet was sent to 50 seismological centers in the Americas in March, 1976. After two months, a second notice was sent to those who did not reply. By late August we have received 30 replies. Three centers indicated that they do not determine magnitudes for near earthquakes and they were excluded from this survey.

The replies from 27 seismological centers contain information for 52 networks/stations. They cover the vast majority of seismic networks in the Americas. We feel that it is best to reproduce the replies here in the Appendix. Minor editing was done to put them in a uniform format. This includes adding headings, typing those replies written by hand, and replacing attachments of reprints by citing references.

In order to have an overall view, we have codified some of the data from the survey replies on punched cards. The results are shown in Table 1.

There are three major methods used in determining the magnitude of near earthquakes: amplitude, amplitude-to-period ratio, and signal duration. In several seismological centers, more than one method is used to determine earthquake magnitudes. Table 1 shows that about one half of the networks uses signal duration; the other half uses amplitude and/or amplitude-to-period ratio.

TABLE 1. SUMMARY OF METHODS TO DETERMINE EARTHQUAKE MAGNITUDE*

COUNTRY	INSTITUTION	NETWORK/STNS.	MAG	INS.	COMP	PHASE	METHOD	REF.	PAGE
BOLIVIA	OB.SAN CALIXTO	LPB, ZLP STNS	ML	BN	Z	,LG	A/T		15
CANADA	DEPT. E. M. R.	CANADIAN NET	M	WL	Z	LG,S	A,A/T	23	16
CANADA	U. BRIT. COL.	MICA ARRAY	MD	WL	Z	NONE	DURATION	9	19
CANADA	UNIV. W. ONT.	LNO ARRAY	M	EV	Z	P,LG	A/T	23	26
CANADA	VICTORIA G.OB.	CANADIAN NET	M	MUL1	Z,H	MAX	AMPLITUDE		27
CHILE	UNIV. CHILE	SANTIAGO STN.	MD	GT	Z,H	NONE	DURATION		28
GUATEMALA	OB.M. NACIONAL	GUAT.CITY STN.	M	WI	H	LG	A/T		29
GUATEMALA	OB.M. NACIONAL	VOLCANO SU.NET	MD	MP	Z	NONE	DURATION	19	30
MEXICO	INST.GEOFISICA	TACUBAYA STN.	ML	WA	H	MAX	AMPLITUDE	25	31
NICARAGUA	INST.I.SISMICA	NICARAGUA NET	MD	MP	Z	NONE	DURATION	19	32
PERU	UNSA INST.GEOF	ARE STN.	MB	BN	Z	P	A/T		33
PERU	UNSA INST.GEOF	AREQUIPA NET	M	WN	Z	P,S	AMPLITUDE		34
U.S.A.	CALIF. D.W.R.	DWR COOP. NET	M	MUL2	H,Z	S	A/T,DURAT.	26,19	36
U.S.A.	CALTECH	S. CALIF. NET	ML	WA	H	MAX	AMPLITUDE	14,21	37
U.S.A.	LAMONT-DOHERTY	NEW YORK NET	M	HS	Z	LG	A/T	23	39
U.S.A.	LAMONT-DOHERTY	NUREK RES. NET	M	HS	Z,H		A/T,DURAT.		40
U.S.A.	LAMONT-DOHERTY	SHUMAGIN I.NET	MD	HP	Z,H		DURATION		41
U.S.A.	LAMONT-DOHERTY	TARBELA D. NET	MD	HS	Z	NONE	DURATION	16	42
U.S.A.	ST.LOUIS UNIV.	ST.LOUIS U.NET	M		Z	LG	A/T	23	43
U.S.A.	U.S.GEOL.SURV.	ALASKA NET	MD	MP	Z	NONE	DURATION	18	44
U.S.A.	U.S.GEOL.SURV.	C.BASIN PLA.A.	MD	MP	Z	NONE	DURATION	19	45
U.S.A.	U.S.GEOL.SURV.	C. CALIF. NET	MD	MP	Z	NONE	DURATION	19,7	46
U.S.A.	U.S.GEOL.SURV.	C. CALIF. NET	ML	WA	H	MAX	AMPLITUDE	26	46
U.S.A.	U.S.GEOL.SURV.	HAWAII NET	ML	WA	H	MAX	AMPLITUDE	26,10	48
U.S.A.	U.S.GEOL.SURV.	IMPERIAL NET	MD	MP	Z	NONE	DURATION	19	49
U.S.A.	U.S.GEOL.SURV.	MOJAVE NET	MD	MP	Z	NONE	DURATION	19	49
U.S.A.	U.S.GEOL.SURV.	OROVILLE NET	M	MP	H,S	S,N	A,DURAT.	26,3	52
U.S.A.	U.S.GEOL.SURV.	PUERTO RI. NET	MD	GT	Z	NONE	DURATION	18	53
U.S.A.	U.S.GEOL.SURV.	S.CAROLINE NET	MD	GT	Z	NONE	DURATION	18	54
U.S.A.	U.S.GEOL.SURV.	YELLOWSTON.NET	MD	MP	Z	NONE	DURATION	19	55
U.S.A.	U.S.GEOL.SURV.	YUMA NET	MD	MP	Z	NONE	DURATION	19	49
U.S.A.	UNIV. ALASKA	C. ALASKA NET	M	GT	Z	P	A/T,DURAT.		56
U.S.A.	UNIV. ALASKA	N. ALASKA NET	M	GS	Z	P	A/T,DURAT.		56
U.S.A.	UNIV. CALIF.	SEISMOGR. STNS	ML	WA,PE	H,Z	MAX	A,A/T	25	58
U.S.A.	UNIV. CALIF.	SEISMOGR. STNS	MS	WA,SP	H,Z	SW	AMPLITUDE	13,14	58
U.S.A.	UNIV. COLORADO	ADAK NET	MD	MP	Z	NONE	DURATION	18	65
U.S.A.	UNIV. COLORADO	AMCHITKA NET	M	MP	Z	P	A/T		66
U.S.A.	UNIV. MONTANA	MSO WWSSN STN.	M	SP	H	MAX	AMPLITUDE	26	67
U.S.A.	UNIV. NEVADA	MINA NET	MD	MP	Z	NONE	DURATION	19	68
U.S.A.	UNIV. NEVADA	NEVADA NET	M	BN	H	S	AMPLITUDE	26.	69
U.S.A.	U.SOUTH.CALIF.	LOS ANG. B.NET	MD	MP	Z	NONE	DURATION	27,24	71
U.S.A.	UNIV. UTAH	TORSION SEISM.	ML	WA	H	S	AMPLITUDE	26,1	74
U.S.A.	UNIV. UTAH	U. UTAH NET	MD	MP	Z	NONE	DURATION	8	77
U.S.A.	UNIV. UTAH	DUG WWSSN STN.	MD	BN	Z	NONE	DURATION	8	78
U.S.A.	U. WASHINGTON	E. WASHING.NET	MD	MP	Z	NONE	DURATION	19	85
U.S.A.	U. WASHINGTON	LON WWSSN STN.	M	BN	Z	P	A/T		86
U.S.A.	U. WASHINGTON	W. WASHING.NET	MD	MP	Z	NONE	DURATION	28	87
U.S.A.	VIRGINIA P.I.	BLA WWSSN STN.	M	BN	Z	LG	A/T	4	88
U.S.A.	VIRGINIA P.I.	BAV STATION	M	BN	Z	LG	A/T	4	88
VENEZUELA	OBS. CAGIGAL	VENEZUELAN NET	M	MUL3	Z	P	A/T		91
W. INDIES	UNIV. W.INDIES	PORTABLE NET	MB	WL	Z	P	A/T	26	94
W. INDIES	UNIV. W.INDIES	TRINIDAD S.NET	M	BN,WL	Z	P	A/T	12	95

*INS: instruments -- BN=Benioff, EV= Electrotech, GS=Geoscience, GT=Geotech, HS=Hall-Sears, MP=Mark Products, MUL=multiple instruments, PE=Press-Ewing, WA=Wood-Anderson, WI=Wiechert, WL=Willmore, WN=Wilson-Lamison.

REF: reference number -- 1. Anderson & Wood, 1925; 2. Bakun & Dratler, 1976; 3. Bakun & Lindh, 1976; 4. Bollinger, 1973; 5. Bolt & Miller, 1975; 6. Bufe, 1976; 7. Bufe et al., 1975; 8. Cook & Smith, 1975; 9. Ellis, 1974; 10. Endo et al., 1974; 11. Freedman, 1967; 12. Gutenberg, 1945; 13. Gutenberg & Richter, 1936; 14. Gutenberg & Richter, 1942; 15. Gutenberg & Richter, 1956; 16. Jacob, 1974; 17. Koyanagi et al., 1971; 18. Lahr et al., 1974; 19. Lee et al., 1972; 20. Lee et al., 1972; 21. Morrison et al., 1976; 22. Nordquist, 1942; 23. Nuttli, 1973; 24. Real & Teng, 1973; 25. Richter, 1935; 26. Richter, 1958; 27. Teng et al., 1975; 28. Crosson, 1972.

3. METHODS TO DETERMINE EARTHQUAKE MAGNITUDE

As originally defined by Richter (1935), the local magnitude, M_L is given by:

$$M_L = \log A - \log A_o \ (\Delta \text{ km}) \tag{1}$$

where A is the maximum amplitude in mm on the Wood-Anderson seismogram for an earthquake at distance Δ km, and A_o is that for a particular earthquake selected as standard. A table of $-\log A_o$ as a function of distance Δ in km is conveniently found in Richter (1958, p. 342). For seismological centers which operate Wood-Anderson instruments, it is relatively simple to follow Richter's definition and measure local magnitude M_L using amplitude.

In the 1940's, Gutenberg and Richter extended this method to more distant earthquakes and defined the surface wave magnitude, M_S, as

$$M_S = \log A - \log A_o \ (\Delta°) \tag{2}$$

where A is the maximum combined horizontal ground amplitude in microns for surface waves with periods of 20 seconds, and A_o refers to the amplitude associated with an $M_S = 0$ earthquake. Table of $-\log A_o$ as a function of distance Δ in degrees is also conveniently found in Richter (1958, p. 346).

The major difficulty in using the M_S scale is that it can only be used for relatively shallow earthquakes which generate observable surface waves. Gutenberg then defined the body wave magnitude M_B to be

$$M_B = \log (A/T) - f\ (\Delta, h) \tag{3}$$

where A/T is the amplitude-to-period ratio (micron/second), and f (Δ,h) is the calibration function of distance Δ and focal depth h. In actual practice equation (3) may be generalized to the form:

$$M = \log (A/T) + C_1 \log (\Delta) + C_2 \quad (4)$$

where M is magnitude (either body wave or surface wave), and C_1 and C_2 are constants. Recent summary of magnitude determinations may be found in Bath (1973), Duda and Nuttli (1974), and Algermissen et al. (1975).

Many local seismic networks have been set up to study small and micro-earthquakes in recent years. Since Wood-Anderson instruments seldom give useful records for earthquakes with magnitude less than 2, we need a convenient method for estimating magnitude of local earthquakes recorded by modern high-gain instruments.

One approach (e.g. Eaton, O'Neill and Murdock, 1970) is to calculate the actual ground motion from the recorded maximum amplitude, and from this calculation, the expected response of the Wood-Anderson seismometer may be computed. As Richter (1958, p. 345) has pointed out, the maximum amplitude on the Wood-Anderson record may not correspond to the wave with maximum amplitude on a different instrument's record. It is also difficult to calibrate and maintain the seismic system so that the actual ground motion may be calculated.

Another approach is to use signal duration. This idea appears to originate from Bisztricsany (1958) who determined the relationship between magnitude (5 to 8) and duration of the surface wave at epicentral distances between 4° and 160°. Solov'ev (1964) applied this technique in the study of seismicity of Sakhalin Island, but used the total duration instead. Tsumura (1967) studied in detail the determination of earthquake magnitude from total duration for local earthquakes recorded by the Wakayama microearthquake network in Japan, and derived an empirical relationship between total duration and magnitude determined by the Japan Meteorological Agency.

Lee et al. (1972) established an empirical formula for estimating magnitude of local earthquakes in Central California by correlating signal duration with Wood-Anderson magnitude or equivalents for 351 earthquakes. In a similar but independent work, Crosson (1972) found a formula for his network in the Puget Sound region using 23 events.

Empirical formulae using signal duration are usually given in the form:

$$M(\tau) = a_1 + a_2 \log (\tau) + a_3 \Delta + a_4 h \quad (5)$$

where τ is signal duration in seconds (different authors may define it slightly differently), Δ is epicentral distance in km, h is focal depth in km, and a_1, a_2, a_3, and a_4 are constants. The use of signal duration to determine magnitude of local earthquakes became widespread since 1972. The readers are referred to works by Real and Tang (1973), Ellis (1974), Jacob (1974), Lahr et al (1974), Cook and Smith (1975), Herrmann (1975), and Bakun and Lindh (1976).

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APPENDIX: Replies from a survey of practice in determining magnitude of near earthquakes.

The replies are arranged alphabetically by country, and within each country alphabatically by institutions. References cited may be found in the Reference section of this report (p. 10-13).

BOLIVIA

OBSERVATORIO SAN CALIXTO: LPB, ZLP STATIONS

1. Name of Network or Station: LPB, ZLP
2. Mailing Address: Observatorio San Calixto, P.O. Box 5939
   La Paz, Bolivia
3. Type of instruments used for local magnitude determination: Standard station
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): Standard station magnification curve
5. Components used (Z or H): Z
6. Specific phase used (P,S,Lg, none): Lg
7. Parameters measured (A,A/T,Duration): A/T
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document):
   $M_L = \log(A/T) + 1.5 \log \Delta + 2$, A, millimicrons, Δ,degrees.
9. Period range over which magnitudes are determined: 1 - 5 sec.
10. Distance range over which magnitudes are determined: less than 1000 km.
11. Tectonic setting (Continental,oceanic,etc.): continental
12. How is magnitude averaged from individual station determinations?
13. What station or source corrections are used if any? standard residuals for LPB calibrated from special study of all azimuthal events.
14. Estimate of consistency of magnitude determinations, and any known errors: very consistent for magnitudes less than 5.
15. Known relationships with local magnitudes determined by other networks:
16. Known relationships between local magnitudes and standard teleseismic magnitudes: This formula is calibrated with standard teleseismic magnitudes.
17. References (Please attach reprint(s) or report(s)):
18. Reply to this Survey is prepared by: Dr. Rene Rodriguez E.
    Date: 8, June, 1976

CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES: CANADIAN SEISMOGRAPH NETWORK

1. Name of Network or Station: Canadian Seismograph Network

2. Mailing Address: Earth Physics Branch, Dept. of E.M.R., 1 Observatory Cres., Ottawa, Ontario, Canada, K1A 0Y3

3. Type of instruments used for local magnitude determination: Mainly Willmores Thirty-seven stations operated in all parts of Canada.

4. Magnification-frequency response curve of instruments (Please cite reference or attach document): Magnifications range from 50K - 500K, generally peaked near 0.5 sec.

5. Components used (Z or H): Z

6. Specific phase used (P,S,Lg, none): Lg

7. Parameters measured (A,A/T,Duration): Amplitude and associated period

8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): Nuttli (1973) equation for $\cdot\cdot$ 4°. Period restriction T $\cdot$ 0.7 sec. not observed

9. Period range over which magnitudes are determined: 0.1 - 1.3 sec

10. Distance range over which magnitudes are determined: 500 - 3000 km

11. Tectonic setting (Continental,oceanic,etc.): Canadian Shield, northern Appalachians

12. How is magnitude averaged from individual station determinations? Average of all readings

13. What station or source corrections are used if any? None

14. Estimate of consistency of magnitude determinations, and any known errors:

15. Known relationships with local magnitudes determined by other networks:

16. Known relationships between local magnitudes and standard teleseismic magnitudes: $m_n \doteq m_b$ in Shield and Appalachians, $M_N \leq m_b$ in northern Yukon, $M_N \geq m_b$ Arctic Archipelago

17. References (Please attach reprint(s) or report(s)):

18. Reply to this Survey is prepared by:

Date:

CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES: CANADIAN SEISMOGRAPH NETWORK

1. Name of Network or Station: Canadian Seismograph Network

2. Mailing Address: Earth Physics Branch, Dept. of E.M.R., 1 Observatory Cres., Ottawa, Ontario, Canada, K1A OY3

3. Type of instruments used for local magnitude determination: Mainly Willmores
Thirty-seven stations operated in all parts of Canada.

4. Magnification-frequency response curve of instruments (Please cite reference or attach document): Magnifications range from 50K - 500K, generally peaked near 0.5 sec.

5. Components used (Z or H): Z

6. Specific phase used (P,S,Lg, none): Lg

7. Parameters measured (A,A/T,Duration): A

8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document):
Richter (1958)

9. Period range over which magnitudes are determined: 0.1 - 2.0 sec

10. Distance range over which magnitudes are determined: 0 - 600 km

11. Tectonic setting (Continental,oceanic,etc.): - Continental Cordillera

12. How is magnitude averaged from individual station determinations? average of all readings.

13. What station or source corrections are used if any? None

14. Estimate of consistency of magnitude determinations, and any known errors:

15. Known relationships with local magnitudes determined by other networks:

16. Known relationships between local magnitudes and standard teleseismic magnitudes:
$M_L \geq m_b$ for events on shore
$M_L \leq m_b$ for events west of Vancouver Island

17. References (Please attach reprint(s) or report(s)):

18. Reply to this Survey is prepared by:
Date:

CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES: CANADIAN SEISMOGRAPH NETWORK

1. Name of Network or Station: Canadian Seismograph Network
2. Mailing Address: Earth Physics Branch, Dept. of E.M.R., 1 Observatory Cres., Ottawa, Ontario, Canada, K1A 0Y3
3. Type of instruments used for local magnitude determination: Mainly Willmores Thirty-seven stations operated in all parts of Canada.
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): Magnifications range from 50K - 500K, generally peaked near 0.5 sec.
5. Components used (Z or H): Z
6. Specific phase used (P,S,Lg, none): Sn
7. Parameters measured (A,A/T,Duration): A
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): Richter as extended beyond 600 km
9. Period range over which magnitudes are determined: 0.1 - 2.0
10. Distance range over which magnitudes are determined: 0 - 3000 km
11. Tectonic setting (Continental,oceanic,etc.): Oceanic Continental mixed path
12. How is magnitude averaged from individual station determinations? average of all
13. What station or source corrections are used if any? None
14. Estimate of consistency of magnitude determinations, and any known errors:
15. Known relationships with local magnitudes determined by other networks:
16. Known relationships between local magnitudes and standard teleseismic magnitudes: Reasonable agreement with m_b. Some tendency for $M_L \geq m_b$.
17. References (Please attach reprint(s) or report(s)):
18. Reply to this Survey is prepared by:

    Date:

CANADA

UNIVERSITY OF BRITISH COLUMBIA: MICA ARRAY

1. Name of Network or Station: Mica Array

2. Mailing Address: R.M. Ellis, Dept. of Geophysics & Astronomy
University of B.C., Vancouver, Canada V6T 1W5

3. Type of instruments used for local magnitude determination:
Willmore Mk I, Geotech 42.21 Telemetry amplifier

4. Magnification-frequency response curve of instruments (Please cite reference or attach document):
Attached

5. Components used (Z or H): Z

6. Specific phase used (P,S,Lg, none): none

7. Parameters measured (A,A/T,Duration): Duration

8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document):
1. $\hat{M} = -0.87 + 2.1 \log \tau + .0035\Delta$ (regional events) 2. $\hat{M} = -4.05 + 3.32 \log \tau$ (swarm events)

9. Period range over which magnitudes are determined: .06 - .83 hz

10. Distance range over which magnitudes are determined: 0 - 100 km

11. Tectonic setting (Continental,oceanic,etc.): Continental

12. How is magnitude averaged from individual station determinations?
Only one station used

13. What station or source corrections are used if any?
N/A

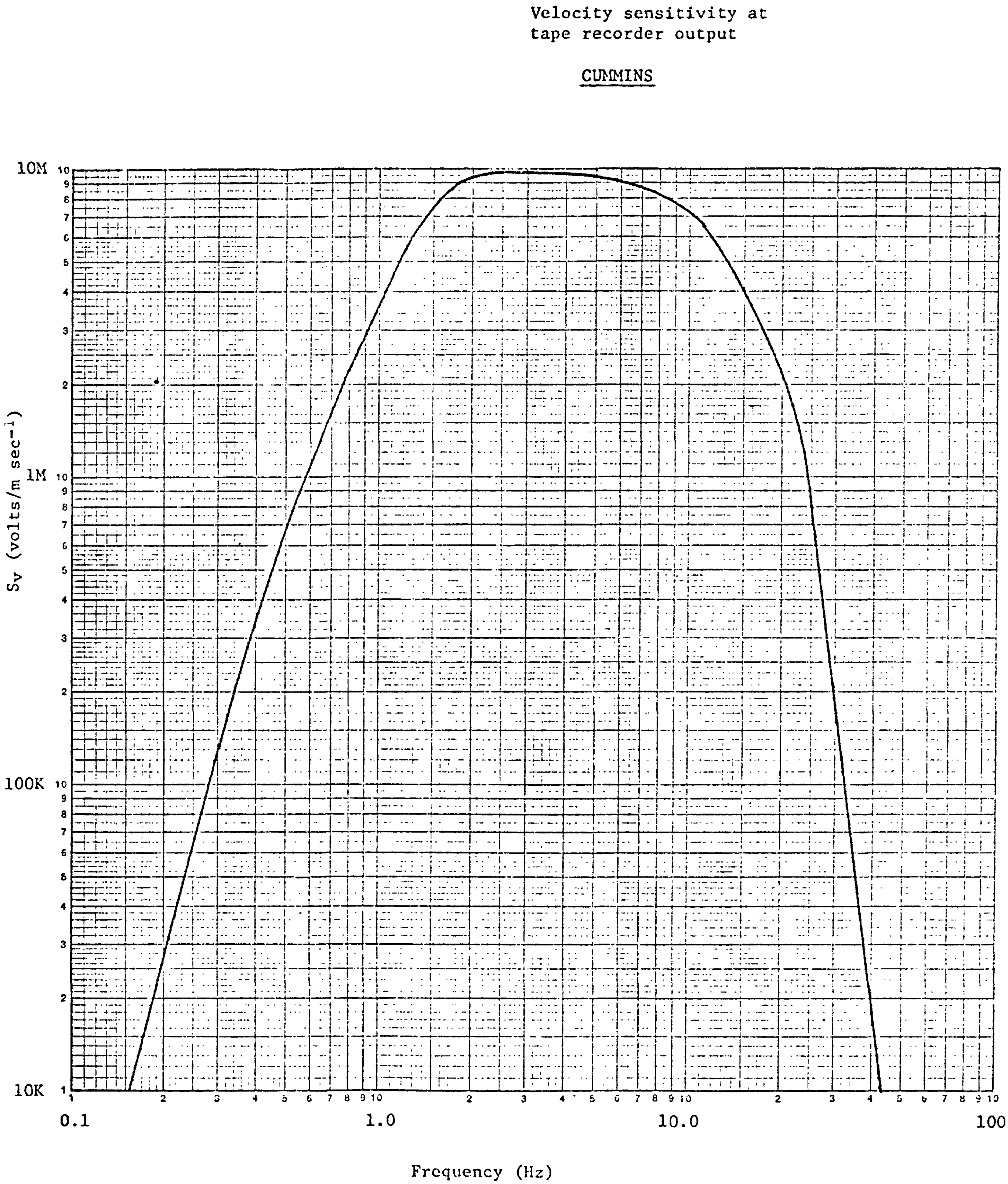
14. Estimate of consistency of magnitude determinations, and any known errors: —

15. Known relationships with local magnitudes determined by other networks:
Formula (2) parameters obtained by regression with Canadian network magnitudes.

16. Known relationships between local magnitudes and standard teleseismic magnitudes:
—

17. References (Please attach reprint(s) or report(s): Ellis, R.M., Monitoring of seismic activity during loading of Mica Reservoir, Rept. for B.C. Hydro & Power Authority, April, 1974.

18. Reply to this Survey is prepared by: R.M. Ellis
Date: 6 April 1976


Velocity sensitivity at
tape recorder output
CUMMINS
10M
1M
100K
10K
Sv (volts/m sec⁻¹)
0.1
1.0
10.0
100
Frequency (Hz)

From: "Monitoring of seismic activity during loading of Mica Reservoir", R.M. Ellis, Apr., 1974 Technical Report to B.C. Hydro and Power Authority.

Data Analysis

The raw data from the Mica array consisted of 7-track FM tapes on which was recorded the output from the five or six (later) seismometers together with the WWVB time code. A helicorder record from either Mt. Dainard or Mt. Cummins station allows a preliminary location in time of the events to be analyzed. From this time, the position of the event on the FM tape is determined.

Due to the non-linear response of our laboratory chart recorders, the data on the original tape is transferred to another 7-track tape which can be played back at one-quarter its original recording speed. This simple frequency dividing system transforms the data into the linear regime thus allowing the direct measurement of the peak-to-peak amplitudes and coda lengths from chart records. The linear signal amplitude at this stage is ± 1 volt corresponding to a recorded amplitude of ± 2.81 volts.

Magnitude Determination

As 'b' depends critically on the magnitude determined for each event, it is necessary to use all available techniques to obtain as accurate a magnitude for each event possible.

For the larger events, local earthquake magnitudes (M_L) (Gutenberg and Richter, 1942) were calculated from the maximum trace amplitudes (normally Lg) and corresponding periods using data from the Canadian Standard Seismic Network Stations EDM, SES, PNT, and FSJ. For M_L>2.7 events were sufficiently well recorded to use these stations.

The amplitudes of these events, and others above magnitude 1.5, were such as to lie in the non-linear regime of the Mica array FM recording system (see Figure 5). For these events, magnitude is determined using the method of coda length duration (Lee et al, 1972). In this method, it is assumed that the logarithm of the coda length is a linear function of the true magnitude, vis:

$$\log D = \alpha + \beta M$$

where D is duration and α,β are measurable constants. The coda length duration is that time increment from the onset of the compressional P phase to the point at which the amplitude drops below a specified level. This time increment varies from station to station for each event due to differences mainly in path propagation and local topography.

In order to obtain the constants (α,β) for each station, the logarithm of the coda length at that station is regressed against local Richter magnitude for events of magnitude greater than 2.7. This allows the normalization of each station against the standard local Richter magnitude (Fig. 12).

For events with magnitudes in the range 0 to 1.5, the signal amplitude is usually in the linear range. For very small events (M_L<0.5 say), the duration technique is not applicable as the coda length is about the same as the S-P time. Where the amplitude and coda length measures overlap, a statistical regression of the logarithm of amplitude against logarithm of coda length is performed i.e. a relationship of the following form is assumed

$$\log A = \gamma + \delta \log D$$

where A is the measured p-p voltage amplitude and γ and δ are constants to be determined for each station (Fig. 13).

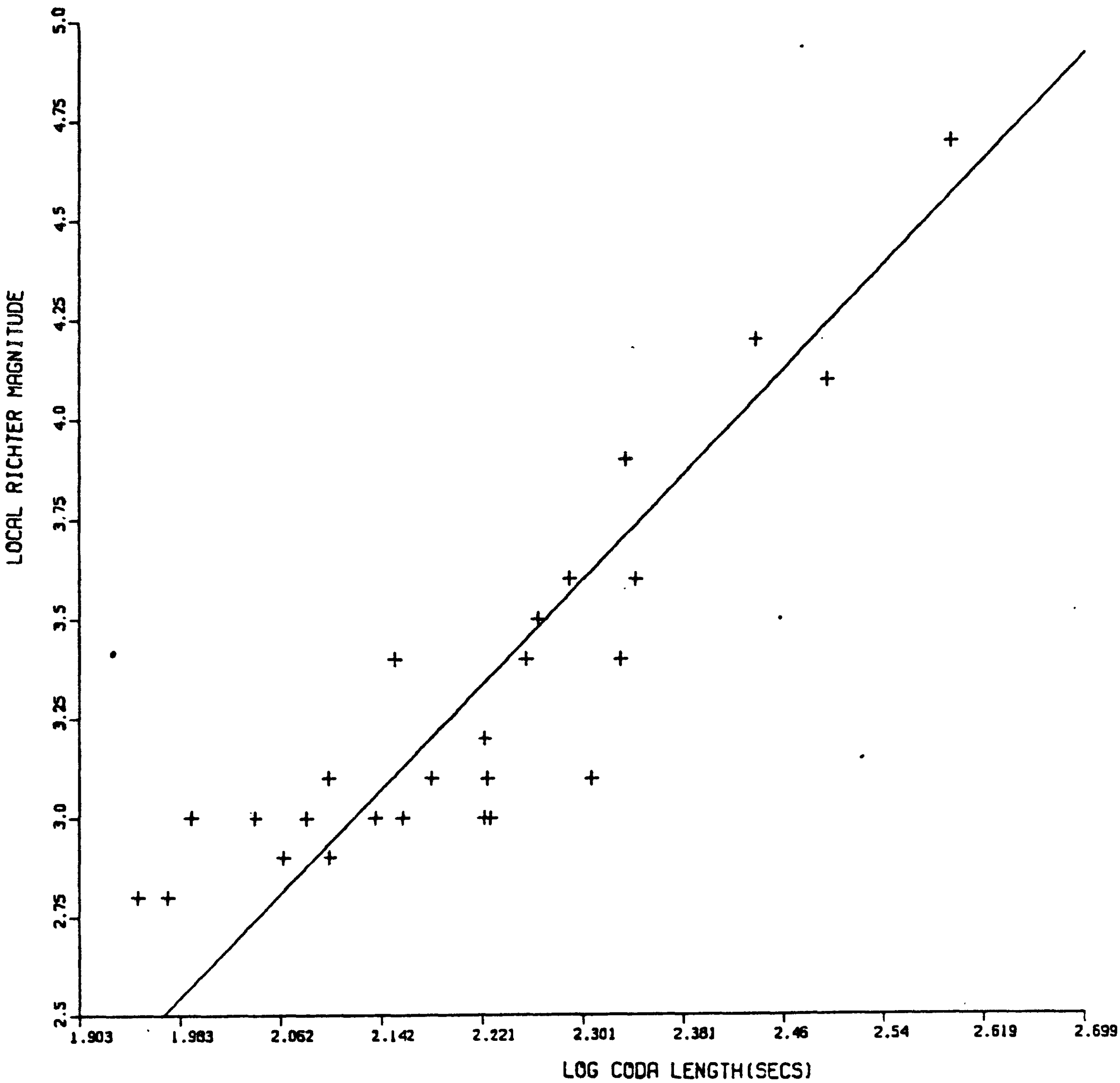


Fig. 12. Local Richter magnitude versus logarithm of coda length for CUM and regression line based on York (1966) technique.

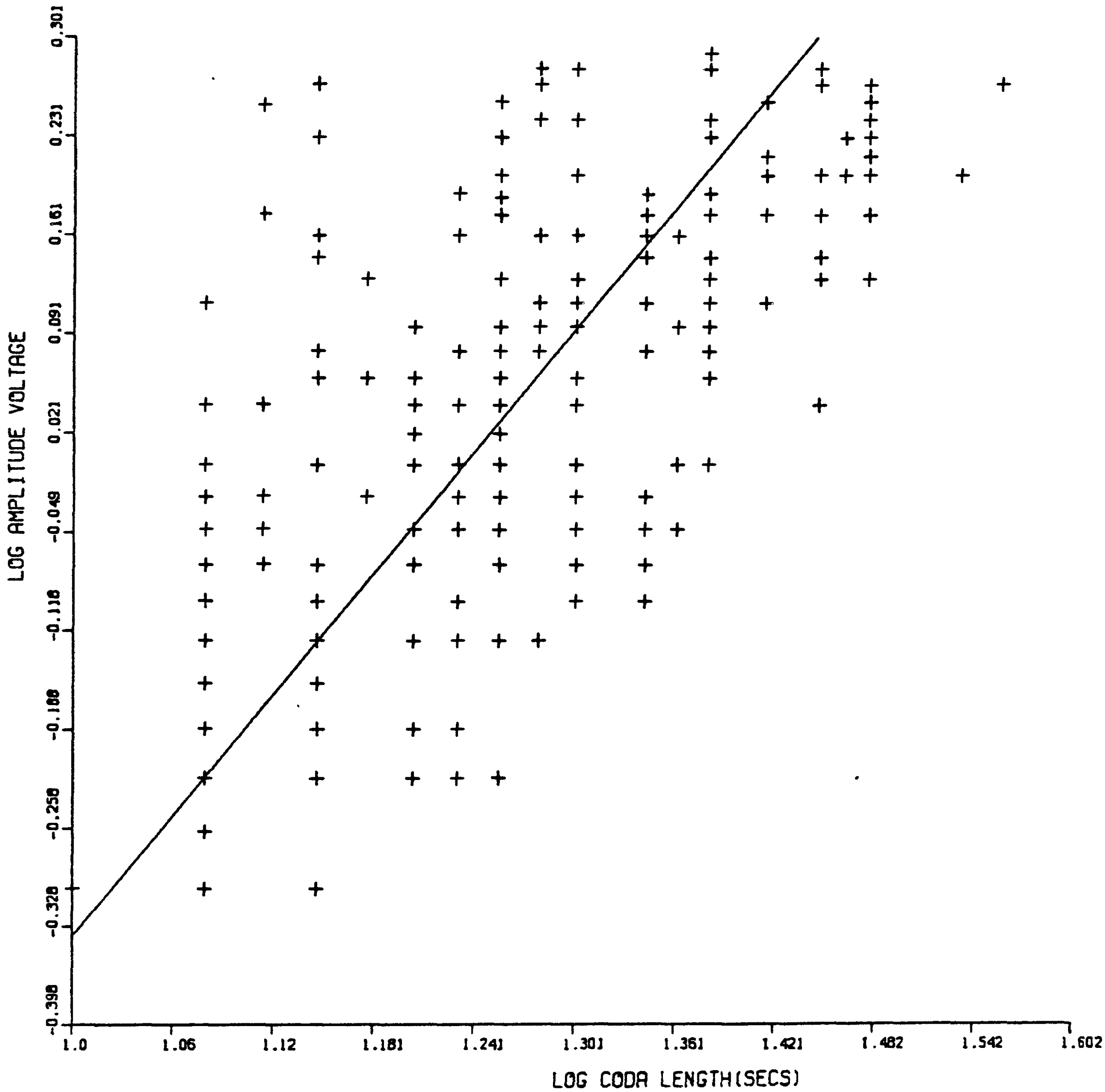


Fig. 13. Logarithm of voltage amplitude versus logarithm of coda length for CUM and regression line based on York (1966) technique.

As coda length can be related to local magnitude using the relation $\log D = \alpha + \beta M$, it is thus possible to related amplitude to local magnitude by substituting for coda length duration to obtain

$$\log A = (\gamma + \delta\alpha) + (\delta\beta) M$$

This yields an equivalent magnitude for each event in the linear amplitude recording range at each station.

Thus by extrapolating the above regressions we are able to make a magnitude estimate for all events greater than zero magnitude at each station. The mean of the magnitude estimate, over all available stations, is the magnitude value used in all subsequent analyses. All the above regressions are based on the unbiased approach of York (1966).

Determination of 'b' value

Having obtained a mean magnitude for each event in the three swarms using the above methods, we now wish to determine a 'b' value for each swarm, the foreshocks and aftershocks of each swarm if applicable, and the 'b' value as it changes through the swarms. As stated above, it is assumed that the logarithm of the number of events (N) greater than a magnitude (M) obey the linear relation: $\log N = a - b M$. The value of 'b' is usually obtained in the seismological literature using maximum-likelihood techniques (Aki, 1965). For this method, we have

$$b = \log_{10} e / (M - M_o)$$

where

M is mean magnitude of sequence

M_o is smallest magnitude of sequence.

In the following discussion, we use $M_o = 1$. This is the normal seismological approach.

CANADA

UNIVERSITY OF WESTERN ONTARIO: LND ARRAY

1. Name of Network or Station: LND (University of Western Ontario Seismic Array)
2. Mailing Address: Dept. of Geophysics, University of Western Ontario
   London, Ontario, Canada
3. Type of instruments used for local magnitude determination:
   Electrotech EV17 1 Hz short period seismometer
4. Magnification-frequency response curve of instruments (Please cite reference or attach document):
5. Components used (Z or H): Z
6. Specific phase used (P,S,Lg, none): P, Lg
7. Parameters measured (A,A/T,Duration): A/T
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document):
   Nuttli 1973 J. Geophys Res. 78 pp.876 - 885
9. Period range over which magnitudes are determined: 1 sec.
10. Distance range over which magnitudes are determined:
11. Tectonic setting (Continental,oceanic,etc.): Continental
12. How is magnitude averaged from individual station determinations?
13. What station or source corrections are used if any? Station Corrections will be determined after further study.
14. Estimate of consistency of magnitude determinations, and any known errors:
    Study is incomplete.
15. Known relationships with local magnitudes determined by other networks:
    Incomplete
16. Known relationships between local magnitudes and standard teleseismic magnitudes:
    Incomplete
17. References (Please attach reprint(s) or report(s)):
18. Reply to this Survey is prepared by: R. F. Mereu
    Date: June 10, 1976

CANADA

VICTORIA GEOPHYSICAL OBSERVATORY: CANADIAN SEISMIC NETWORK IN WESTERN CANADA

1. Name of Network or Station: Canadian Seismic Network in Western Canada
2. Mailing Address: Victoria Geophysical Observatory, RR7, Victoria, Canada
3. Type of instruments used for local magnitude determination: SP Willmores, SP Benioffs, Standard-Wood-Andersons
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): Bulletin of CSN
5. Components used (Z or H): H or Z
6. Specific phase used (P,S,Lg, none): peak amplitudes
7. Parameters measured (A,A/T,Duration): A
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): Richter nomogram adjsuted to fit instruments
9. Period range over which magnitudes are determined: $0.5 - 1.0^s$
10. Distance range over which magnitudes are determined: < 1000 Km
11. Tectonic setting (Continental,oceanic,etc.): Mixture of continental, oceanic
12. How is magnitude averaged from individual station determinations? Simple average unless unusual circumstances
13. What station or source corrections are used if any? None
14. Estimate of consistency of magnitude determinations, and any known errors: ± 0.5
15. Known relationships with local magnitudes determined by other networks: We check with PDE but no statistics determined
16. Known relationships between local magnitudes and standard teleseismic magnitudes: As above
17. References (Please attach reprint(s) or report(s)): Canadian Earthquakes 19XX
18. Reply to this Survey is prepared by: W. G. Milne
    Date: April 14, 1976

CHILE

UNIVERSITY OF CHILE: SANTIAGO STATION

1. Name of Network or Station: Santiago

2. Mailing Address: Dept. of Geophysics, University of Chile
Casilla 2777, Santiago, Chile

3. Type of instruments used for local magnitude determination: Z comp and two HoR components [Geotech S13, AS-330, AR-311, RV-301B]

4. Magnification-frequency response curve of instruments (Please cite reference or attach document): No calibration

5. Components used (Z or H): Z and H

6. Specific phase used (P,S,Lg, none):

7. Parameters measured (A,A/T,Duration): Duration (Total length of record)

8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document):
$M = 2.5 \log t - 1.9$ where $t =$ duration

9. Period range over which magnitudes are determined:

10. Distance range over which magnitudes are determined: 50 - 1000 km

11. Tectonic setting (Continental, oceanic, etc.): Quaternary Sediments

12. How is magnitude averaged from individual station determinations? Only one station used.

13. What station or source corrections are used if any? None

14. Estimate of consistency of magnitude determinations, and any known errors:
$M \pm .5$

15. Known relationships with local magnitudes determined by other networks: None

16. Known relationships between local magnitudes and standard teleseismic magnitudes:
Relation $M = 2.5 \log t - 1.9$ was obtained by comparison with known teleseismic magnitude determinations

17. References (Please attach reprint(s) or report(s)):

18. Reply to this Survey is prepared by: Edgar Kausel
Date: April 20, 1976

GUATEMALA

OBSERVATORIO METEREOLOGICAL NACIONAL: GUATEMALA CITY STATION

1. Name of Network or Station: OBSERVATORIO NACIONAL (Estac ón Sismológi a)
2. Mailing Address: 7a. Avenida Prolongación Zona 13. Guatemala, C. A.
3. Type of instruments used for local magnitude determination: "WIECHERT" (Z & H)
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): - -- -- --
5. Components used (Z or H): Component "H"
6. Specific phase used (P,S,Lg, none): Phase "Lg"
7. Parameters measured (A,A/T,Duration): A/T and Duration
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): GUTENBERG TABULATIONS
9. Period range over which magnitudes are determined: Variable
10. Distance range over which magnitudes are determined: 500 - 700 Kms.
11. Tectonic setting (Continental,oceanic,etc.): Continental
12. How is magnitude averaged from individual station determinations? - - - -
13. What station or source corrections are used if any? None
14. Estimate of consistency of magnitude determinations, and any known errors: - - - -
15. Known relationships with local magnitudes determined by other networks: - - - -
16. Known relationships between local magnitudes and standard teleseismic magnitudes: approximatively
17. References (Please attach reprint(s) or report(s)): - - - -
18. Reply to this Survey is prepared by: J. Vassaux P.

Date: Marzo 17, de 1,976.

GUATEMALA

OBSERVATORIO METEREOLOGICAL NACIONAL: GUATEMALA VOLCANO SURVEILLANCE NET

1. Name of Network or Station: Guatemala Volcano Surveillance Seismic Net
2. Mailing Address: Ing. Claudio Urrutia, Director, Observatorio Metereological Nacional, 7a Aven. Prol-, Zona 13, Guatemala, Guatemala
3. Type of instruments used for local magnitude determination: Six U.S. Geological Survey type radio telemetered seismic stations.
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): See Endo et al. (1974).
5. Components used (Z or H): Z
6. Specific phase used (P,S,Lg, none): None
7. Parameters measured (A,A/T,Duration): Duration
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): See Lee et al. (1972).
9. Period range over which magnitudes are determined:
10. Distance range over which magnitudes are determined: 0 - 75 km
11. Tectonic setting (Continental,oceanic,etc.): Converging plate margin and left lateral at plate boundary
12. How is magnitude averaged from individual station determinations? simple average
13. What station or source corrections are used if any? None
14. Estimate of consistency of magnitude determinations, and any known errors: about 0.5 unit
15. Known relationships with local magnitudes determined by other networks:
16. Known relationships between local magnitudes and standard teleseismic magnitudes:
17. References (Please attach reprint(s) or report(s)):
18. Reply to this Survey is prepared by: David H. Harlow

Date: Mar. 4, 1976.

MEXICO

INSTITUTO DE GEOFISICA UNAM: TACUBAYA STATION

1. Name of Network or Station: Tacubaya (TAC)
2. Mailing Address: Instituto de Geofisica UNAM
   Mexico 20, D.F. MEXICO
3. Type of instruments used for local magnitude determination: Wood-Anderson (Standard)
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): Lehner-Griffith
5. Components used (Z or H): H
6. Specific phase used (P,S,Lg, none): Max
7. Parameters measured (A,A/T,Duration): A
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document):
   Richter's original nomogram
9. Period range over which magnitudes are determined: about 1500 km
10. Distance range over which magnitudes are determined: about 1500 km
11. Tectonic setting (Continental,oceanic,etc.): Continental
12. How is magnitude averaged from individual station determinations? only TAC gives magnitudes at present
13. What station or source corrections are used if any? none
14. Estimate of consistency of magnitude determinations, and any known errors: unknown
15. Known relationships with local magnitudes determined by other networks: reasonably consistent with M_S from USGS
16. Known relationships between local magnitudes and standard teleseismic magnitudes:
    Reasonably consistent with M_S from USGS
17. References (Please attach reprint(s) or report(s)): Our M_S is regularly reported to Edinburgh and Denver
18. Reply to this Survey is prepared by: C. Lomnitz
    Date: March 11, 1976

NICARAGUA

INSTITUTO DE INVESTIGACIONS SISMICAS: NICARAGUA NET

1. Name of Network or Station: **INSTITUTO DE INVESTIGACIONES SISMICAS**
2. Mailing Address: **P.O. Box 1761 , Managua, D.N., Nicaragua**
3. Type of instruments used for local magnitude determination: **NCER Standard**
4. Magnification-frequency response curve of instruments (Please cite reference or attach document):
5. Components used (Z or H): **Z**
6. Specific phase used (P,S,Lg, none): **P**
7. Parameters measured (A,A/T,Duration): **DURATION**
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): **PROGRAM HYPOC2** (See Lee et al. 1972).
9. Period range over which magnitudes are determined:
10. Distance range over which magnitudes are determined: **0 - 300 Km**
11. Tectonic setting (Continental,oceanic,etc.): **CONTINENTAL**
12. How is magnitude averaged from individual station determinations?
13. What station or source corrections are used if any? **NONE**
14. Estimate of consistency of magnitude determinations, and any known errors: **NOT KNOWN**
15. Known relationships with local magnitudes determined by other networks: **NOT KNOWN**
16. Known relationships between local magnitudes and standard teleseismic magnitudes: **NOT KNOWN**
17. References (Please attach reprint(s) or report(s): **Program HYPOC2 - U.S.G.S. National Center for Earthquake Research** ; Aburto-Quesada (1975).
18. Reply to this Survey is prepared by: **Arturo Aburto Quesada**
    Date: **May 18, 1976**

1. Name of Network or Station: ARE (Arequipa, Perú)
2. Mailing Address: U.N.S.A. Instituto Geofísico
   Casilla 23.- Arequipa, PERU.
3. Type of instruments used for local magnitude determination: Benioff SPZ - To = 1.0 seg.
   Magnification: 50,000 at 1 cps.
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): Standar curves for the World Wide Standardized Seismograph System (WWSSS).
5. Components used (Z or H): Z
6. Specific phase used (P,S,Lg, none): P
7. Parameters measured (A,A/T,Duration): A/T
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document):
   $$M_b = Q + \log \frac{At \times 10^3}{MT} + S$$
9. Period range over which magnitudes are determined: 0.2 - 1.2 seg.
10. Distance range over which magnitudes are determined: 0.1º - 100º
11. Tectonic setting (Continental,oceanic,etc.): Continental border
12. How is magnitude averaged from individual station determinations?
13. What station or source corrections are used if any? Under study, we do not have yet stable values.
14. Estimate of consistency of magnitude determinations, and any known errors:
15. Known relationships with local magnitudes determined by other networks:
16. Known relationships between local magnitudes and standard teleseismic magnitudes:
17. References (Please attach reprint(s) or report(s)):
18. Reply to this Survey is prepared by: A.R. Kosaka Masuno, Seismological Assistant
    Date: June 30, 1976.

PERU

U.N.S.A. INSTITUTO GEOFISICO: AREQUIPA NETWORK

1. Name of Network or Station: AREQUIPA NETWORK

2. Mailing Address: Universidad Nacional de San Agustín de Arequipa.- Instituto Geofísico.- Casilla 23.- Arequipa, PERU.

3. Type of instruments used for local magnitude determination: DTM Wilson-Lamison Type Seismometers (To=1 seg.), with amplifier and pen recording drums.

4. Magnification-frequency response curve of instruments (Please cite reference or attach document): graphs enclosed.

5. Components used (Z or H): Z

6. Specific phase used (P,S,Lg, none): P , S

7. Parameters measured (A,A/T,Duration): A

8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document):
1.- h < 70 Km.: (P) M = log A + 1.37 log D - 0.3.- (S) M=log A + 0.79 log D + 0.57
2.- h > 70 Km.: (P) M = log A + 1.01 log D + 0.96.- (S) M=log A + 0.98 log D + 0.75

9. Period range over which magnitudes are determined: 0.2 - 1.2 seg.

10. Distance range over which magnitudes are determined: 100 - 1000 Km.

11. Tectonic setting (Continental,oceanic,etc.): continental border

12. How is magnitude averaged from individual station determinations? As simple aritmetic mean provisionaly

13. What station or source corrections are used if any?

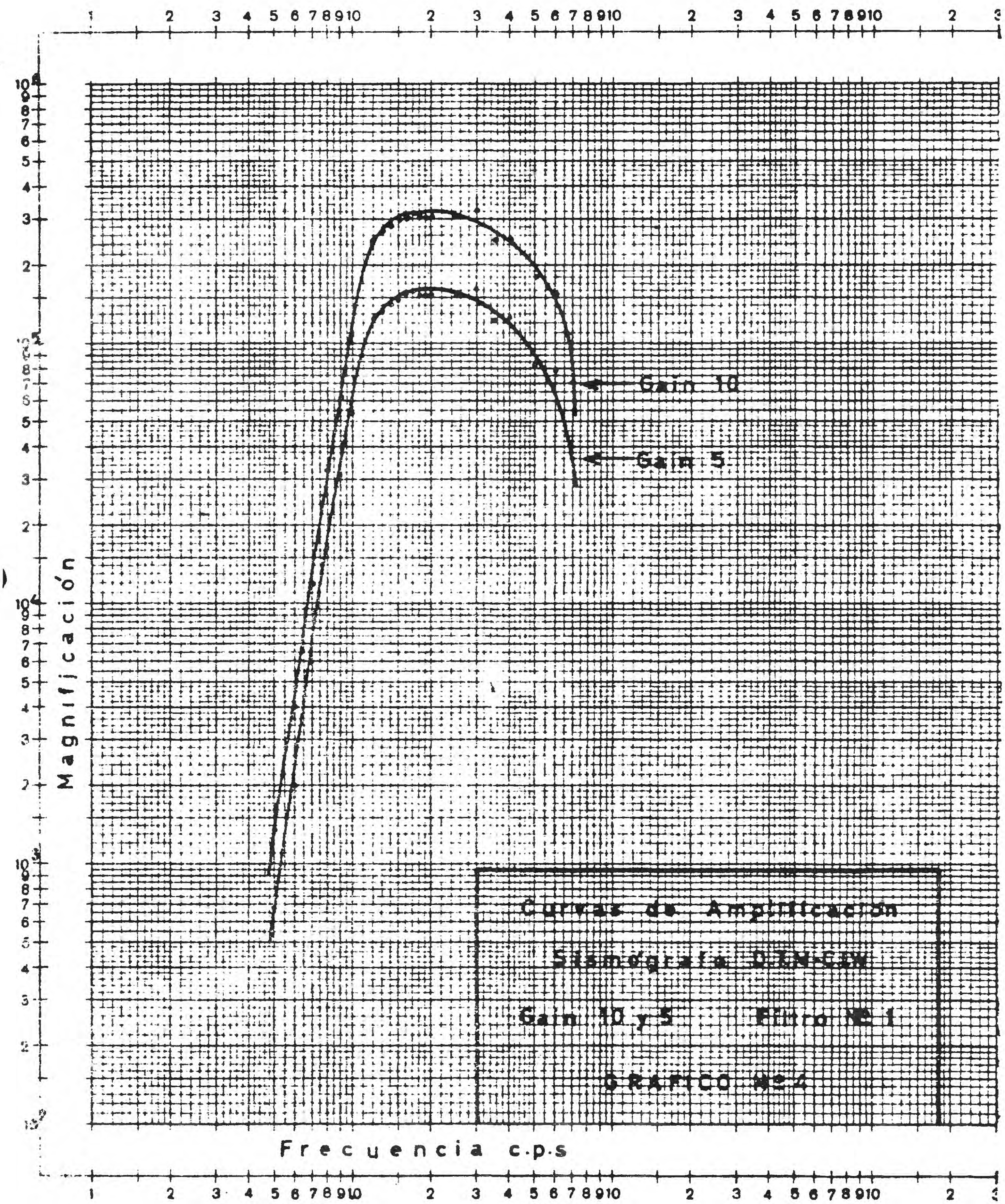
14. Estimate of consistency of magnitude determinations, and any known errors:

15. Known relationships with local magnitudes determined by other networks: There is not other networks in this region

16. Known relationships between local magnitudes and standard teleseismic magnitudes: No great difference, up to 20%

17. References (Please attach reprint(s) or report(s)):

18. Reply to this Survey is prepared by: A.R. Kosaka Masuno, Seismological Assistant
Date: June 30, 1976.


Gain 10
Gain 5
Curvas de Amplificación
Sismógrafo DTN-CIW
Gain 10 y 5 Filtro Nº 1
GRAFICO Nº 4
Magnificación
Frecuencia c.p.s

U. S. A.

CALIFORNIA DEPARTMENT OF WATER RESOURCES: COOPERATIVE NET

1. Name of Network or Station: Department of Water Resources Cooperative Seismographic Network
2. Mailing Address: P. O. Box 388, Sacramento, California 95802
3. Type of instruments used for local magnitude determination: Benioff, Sprengnether 7000's, Teledyne Rangers, T=1.0
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): Mr. Carl Stover, USGS, Branch of Seismicity and Risk Analysis, NEIC, D2, Denver Federal Center, Bldg. 25, Denver, CO 80225
5. Components used (Z or H): H, Z (duration)
6. Specific phase used (P,S,Lg, none): S
7. Parameters measured (A,A/T,Duration): A/T, duration
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): C. F. Richter, 1958 p.340, 342, M_L; A Method of Estimating Magnitude of Local Earthquakes From Signal Duration, by W.H.K.Lee et al, USGS Open File Report.
9. Period range over which magnitudes are determined: 0.1 - 0.5 Sec.
10. Distance range over which magnitudes are determined: 0 - 600 km
11. Tectonic setting (Continental,oceanic,etc.): Continental
12. How is magnitude averaged from individual station determinations? Equal weight to all determinations
13. What station or source corrections are used if any? None
14. Estimate of consistency of magnitude determinations, and any known errors: Not determined
15. Known relationships with local magnitudes determined by other networks: M_L:Good agreement for M_L>2.5, as much as - .7 units off for M_L<2.5. Duration: consistently good agreement.
16. Known relationships between local magnitudes and standard teleseismic magnitudes: Not determined
17. References (Please attach reprint(s) or report(s)):
18. Reply to this Survey is prepared by: Paul Morrison

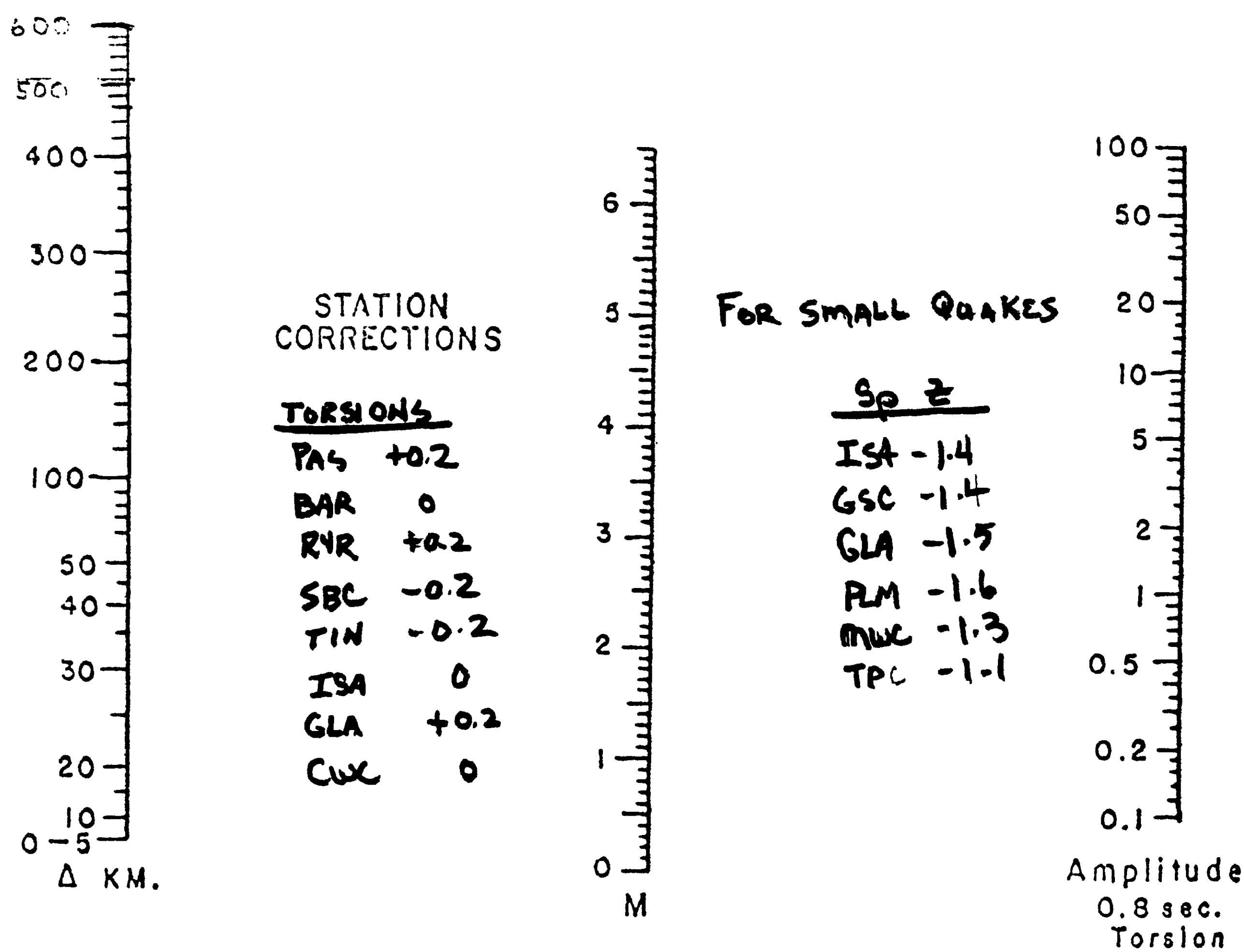
Date: March 8, 1976

U. S. A.

CALIFORNIA INSTITUTE OF TECHNOLOGY: SOUTHERN CALIFORNIA NET

1. Name of Network or Station: Caltech Southern California Seismic Network
2. Mailing Address: Seismological Laboratory, Caltech, mail code 252-21
   Pasadena, CA 91125
3. Type of instruments used for local magnitude determination: Wood-Anderson torsion (for small quakes short period vertical calibrated to torsions used)
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): Anderson and Wood, BSSA vol. 15, no. 1, March 1925, pp. 1-72
5. Components used (Z or H): Wood-Anderson torsions - H, short period - Z
6. Specific phase used (P,S,Lg, none): Largest in coda
7. Parameters measured (A,A/T,Duration): 1/2 maximum peak to peak amplitude
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): Gutenberg and Richter, BSSA, v. 32, no. 3, July 1942, p. 164 (Nordquist nomogram enclosed)
9. Period range over which magnitudes are determined: ~ 0.2 - 2 sec.
10. Distance range over which magnitudes are determined: within 600 km
11. Tectonic setting (Continental,oceanic,etc.): Continental
12. How is magnitude averaged from individual station determinations? Direct average
13. What station or source corrections are used if any? Station correction used to account for varying conditions at station site
14. Estimate of consistency of magnitude determinations, and any known errors: Typical magnitude spread; Torsions ~0.3; Spz ~0.6
15. Known relationships with local magnitudes determined by other networks: -
16. Known relationships between local magnitudes and standard teleseismic magnitudes: Richter, Elementary Seismology, 1958, Chp. 22, Gutenberg and Richter, BSSA, v. 46, no. 2, April 1956, pp. 105-145.
17. References (Please attach reprint(s) or report(s)):
18. Reply to this Survey is prepared by: Martin Friedman, Associate Research Seismologist
    Date: May 28, 1976

CALIFORNIA INSTITUTE OF TECHNOLOGY: SOUTHERN CALIFORNIA NET



U. S. A.

LAMONT-DOHERTY GEOLOGICAL OBSERVATORY: NEW YORK STATE NET

1. Name of Network or Station: New York State Network Lamont-Doherty Geological Observatory of Columbia University
2. Mailing Address: Palisades, N.Y. 10964
3. Type of instruments used for local magnitude determination: HS 10 2 Hz - Develco VCO/Disc Develocorder Mag Tapes
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): Similar to USGS Max Mag-Few Million - recalibration now being done.
5. Components used (Z or H): Z
6. Specific phase used (P,S,Lg, none): Lg
7. Parameters measured (A,A/T,Duration): A/T
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): $m = 3.75 + 0.90 (\log \Delta°) + \log A/T$ Nuttli, O.W.; Seismic Wave Attenuation & Mag. Relations for Eastern North Am. = J. of Geophysical Res. vol. 78 no. 5, 2/10/73, -p. 876-884
9. Period range over which magnitudes are determined: .1 sec to .3 sec
10. Distance range over which magnitudes are determined: 55 km to approx 400 km
11. Tectonic setting (Continental,oceanic,etc.): Continental Eastern U.S.
12. How is magnitude averaged from individual station determinations? Average is taken of consistent stations
13. What station or source corrections are used if any? None
14. Estimate of consistency of magnitude determinations, and any known errors: 80% consistency
15. Known relationships with local magnitudes determined by other networks: Generally higher than Canadian Mag.
16. Known relationships between local magnitudes and standard teleseismic magnitudes:
17. References (Please attach reprint(s) or report(s)):
18. Reply to this Survey is prepared by: Rosemary Schnerk

    Date: 5/17/76

U. S. A.

LAMONT-DOHERTY GEOLOGICAL OBSERVATORY: NUREK RESERVOIR NET

1. Name of Network or Station: Nurek Reservoir Network Tadjikistan USSR (established Aug'75)

2. Mailing Address: c/o D. W. Simpson, Lamont Doherty Geol. Obs.
Palisades, N.Y. 10964

3. Type of instruments used for local magnitude determination:
HS-10-1Hz → Interproducts VCO/DISC → Develocorder & Mag tape

4. Magnification-frequency response curve of instruments (Please cite reference or attach document): similar to USGS response, peak magnification a few million; complete calibration to be done summer '76.

5. Components used (Z or H): both

6. Specific phase used (P,S,Lg, none): Note: We are in the process of setting up a magnitude scale for this net. Duration and perhaps A/T will be used. Details should be available by late 1976.

7. Parameters measured (A,A/T,Duration):

8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document):

9. Period range over which magnitudes are determined:

10. Distance range over which magnitudes are determined: 0 - 100 km (most in range 0 - 40 km)

11. Tectonic setting (Continental, oceanic, etc.): Continental - tectonic

12. How is magnitude averaged from individual station determinations?

13. What station or source corrections are used if any?

14. Estimate of consistency of magnitude determinations, and any known errors:

15. Known relationships with local magnitudes determined by other networks: Local Soviet Network in Tadjikistan determines magnitudes (Russian energy class, K) for events → K = 6 (approx mag 1) and our scale will be calibrated w.r.t. theirs.

16. Known relationships between local magnitudes and standard teleseismic magnitudes:

17. References (Please attach reprint(s) or report(s)):

18. Reply to this Survey is prepared by: David Simpson
Date: May 14, 1976

U. S. A.

LAMONT-DOHERTY GEOLOGICAL OBSERVATORY: SHUMAGIN ISLAND NET

1. Name of Network or Station: Shumagin Island Seismograph Network
2. Mailing Address: Dr. J. Davies, Seismology, Lamont-Doherty Geol. Obs., Palisades, N.Y. 10964
3. Type of instruments used for local magnitude determination: Mark Products L-4
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): 42db 4.6 db/MICRON
5. Components used (Z or H): Z 8 remote Z 2 local H, 1 Z
6. Specific phase used (P,S,Lg, none): P
7. Parameters measured (A,A/T,Duration): Duration (coda length method)
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): We are currently working on a local magnitude scale. The results should be known soon.
9. Period range over which magnitudes are determined:
10. Distance range over which magnitudes are determined:
11. Tectonic setting (Continental,oceanic,etc.):
12. How is magnitude averaged from individual station determinations?
13. What station or source corrections are used if any?
14. Estimate of consistency of magnitude determinations, and any known errors:
15. Known relationships with local magnitudes determined by other networks:
16. Known relationships between local magnitudes and standard teleseismic magnitudes:
17. References (Please attach reprint(s) or report(s)):
18. Reply to this Survey is prepared by: Philip B. Lelyveld, Seismology

    Date: 5/17/76

U. S. A.

LAMONT-DOHERTY GEOLOGICAL OBSERVATORY: TARBELA DAM NET

1. Name of Network or Station: Tarbela Dam Network
2. Mailing Address: c/o Jacob, Lamont, Palisades, N.Y. 10964 or, c/o TAMS, Tarbela Dam, Dist. Hazara, Pakistan
3. Type of instruments used for local magnitude determination: HS-10 Geophones, Develocorder 16-mm film recordings
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): see attached
5. Components used (Z or H): Z
6. Specific phase used (P,S,Lg, none): Coda Length
7. Parameters measured (A,A/T,Duration): Coda Length
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): See Jacob (1974).
9. Period range over which magnitudes are determined: All
10. Distance range over which magnitudes are determined: 0 - 250 km regularly
11. Tectonic setting (Continental,oceanic,etc.): Shield → Himalayan Bndry
12. How is magnitude averaged from individual station determinations? A few reliable, if possible, measurements are made, extreme values discarded, rest are averaged.
13. What station or source corrections are used if any? None
14. Estimate of consistency of magnitude determinations, and any known errors: some reader's errors lead to large errors (one unit), other errors to less than 1/2 unit or better.
15. Known relationships with local magnitudes determined by other networks: See Jacob (1974).
16. Known relationships between local magnitudes and standard teleseismic magnitudes: see attached presently being checked and revised with more recent events
17. References (Please attach reprint(s) or report(s)): see attached : Jacob (1974).
18. Reply to this Survey is prepared by: Wayne D. Pennington

Date: 17 May 1976

U. S. A.

SAINT LOUIS UNIVERSITY: SAINT LOUIS UNIVERSITY NET

1. Name of Network or Station: Saint Louis University
2. Mailing Address: P.O. Box 8099, Laclede Station, St. Louis, MO 63156
3. Type of instruments used for local magnitude determination: We determine body-wave-magnitude from short-period, vertical component instruments
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): WWSSN 1 - sec instruments or any calibrated system that peaks at about 1 Hz.
5. Components used (Z or H): Z
6. Specific phase used (P,S,Lg, none): Lg
7. Parameters measured (A,A/T,Duration): A/T
8. Formulas or graphs used in local ~~magnitude~~ body-wave magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): See enclosed paper, equation 5 (Nuttli, O.W., J. Geophys. Res., 78, 876-885, 1973).
9. Period range over which magnitudes are determined: 0.7 to 1.3 sec
10. Distance range over which magnitudes are determined: 0.5^{o} to 30^{o}
11. Tectonic setting (Continental,oceanic,etc.): Stable continental
12. How is magnitude averaged from individual station determinations? Average of individual determinations
13. What station or source corrections are used if any? None
14. Estimate of consistency of magnitude determinations, and any known errors: Corresponds well to M_L determined from teleseismic P-waves; ±0.2 M_o units. Can overestimate M_s for very shallow earthquakes (about 1-2 km depth)
15. Known relationships with local magnitudes determined by other networks: I think the term "Local Magnitude" should be reserved for California earthquakes.
16. Known relationships between local magnitudes and standard teleseismic magnitudes: Corresponds to M_b of teleseismic P
17. References (Please attach reprint(s) or report(s): See paper: Nuttli (1973).
18. Reply to this Survey is prepared by: Otto W. Nuttli

    Date: March 4, 1976

U. S. A.

U. S. GEOLOGICAL SURVEY: ALASKA NET

1. Name of Network or Station: USGS Alaska Seismic Network
2. Mailing Address: 345 Middlefield Rd., Menlo Park, CA 94025
3. Type of instruments used for local magnitude determination: Geophone; Mark Products L-4C 1Hz
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): Catalog of Earthquakes in South Central Alaska April - June 1972, USGS Open-File Report, 1974.
5. Components used (Z or H): Z
6. Specific phase used (P,S,Lg, none):
7. Parameters measured (A,A/T,Duration): Duration τ
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): $FMAG = -1.15 + 2.00 \log_{10} T + 0.007Z + 0.0035 \Delta$
9. Period range over which magnitudes are determined: 1 to .05 sec
10. Distance range over which magnitudes are determined: 0 to 400 km
11. Tectonic setting (Continental,oceanic,etc.): Margin of S. Alaska
12. How is magnitude averaged from individual station determinations? Average of all.
13. What station or source corrections are used if any? None
14. Estimate of consistency of magnitude determinations, and any known errors: There is sometimes a distance dependence of up to 1 mag unit!
15. Known relationships with local magnitudes determined by other networks: Close to Palmer Local Magnitude ±.5
16. Known relationships between local magnitudes and standard teleseismic magnitudes: Close to PDE in b magnitude ± .5
17. References (Please attach reprint(s) or report(s): Catalog of earthquakes in South Central Alaska April - June 1972, USGS Open File, 1974.
18. Reply to this Survey is prepared by: John C. Lahr

Date: March 3, 1976

U. S. A.

U. S. GEOLOGICAL SURVEY: CENTRAL BASIN PLATFORM ARRAY

1. Name of Network or Station: Central Basin Platform Array
2. Mailing Address: USGS, Branch of Earthquake Hazards, Mail Stop 978, Box 25046, Denver Federal Center, Denver, CO 80225
3. Type of instruments used for local magnitude determination: L-4C
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): 6K → 50K @ 1 Hz approx
5. Components used (Z or H): Z
6. Specific phase used (P,S,Lg, none): None
7. Parameters measured (A,A/T,Duration): Duration
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document):
   $M = 2.0 \log D - 0.87 + 0.0035\Delta$
9. Period range over which magnitudes are determined:
10. Distance range over which magnitudes are determined: Less than 30 km
11. Tectonic setting (Continental,oceanic,etc.): Continental
12. How is magnitude averaged from individual station determinations? Aug. Durations
13. What station or source corrections are used if any? None presently
14. Estimate of consistency of magnitude determinations, and any known errors: Unknown
15. Known relationships with local magnitudes determined by other networks: For one event we obtain $M_o = 3.9$ whereas $M_L = 3.4$
16. Known relationships between local magnitudes and standard teleseismic magnitudes: Unknown
17. References (Please attach reprint(s) or report(s)): None
18. Reply to this Survey is prepared by: A. M. Rogers
    Date: May 21, 1976

U. S. A.

U. S. GEOLOGICAL SURVEY: CENTRAL CALIFORNIA NET

1. Name of Network or Station: Central California Seismic Network

2. Mailing Address: NCER, 345 Middlefield Rd., Menlo Park, CA 94025

3. Type of instruments used for local magnitude determination: Mark Products Corp. 1 Hz digital grade geophone

4. Magnification-frequency response curve of instruments (Please cite reference or attach document): Displacement rises at 18dB/oct. to 1 Hz, at 6dB/oct to 10 Hz then drops at 18 dB/oct above 10 Hz., Magnification 30K to 250K depend on location, Average 65K (see Bufe and others, 1975).

5. Components used (Z or H): Z and H

6. Specific phase used (P,S,Lg, none): None

7. Parameters measured (A,A/T,Duration): Duration

8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): See Lee and others, 1972

9. Period range over which magnitudes are determined: 2 - 8 Hz (usual dominant frequency content of signals)

10. Distance range over which magnitudes are determined: 0 - 150 kilometers

11. Tectonic setting (Continental,oceanic,etc.): Major transform fault on interplate boundary.

12. How is magnitude averaged from individual station determinations? Unweighted arithmetic mean

13. What station or source corrections are used if any? Empirical coefficients in formula must be determined for different geographic regions; see reference of item 8. In addition station corrections are used for the location process to eliminate effect of local geology on arrival times.

14. Estimate of consistency of magnitude determinations, and any known errors: Duration time magnitudes are known to be systemically too low for values greater than M3.5. See attached summary by C. Bufe.

15. Known relationships with local magnitudes determined by other networks: See C. Bufe

16. Known relationships between local magnitudes and standard teleseismic magnitudes: No known differences

17. References (Please attach reprint(s) or report(s): See Attachments

18. Reply to this Survey is prepared by: J. H. Pfluke

Date:

REFERENCES:

Bufe, C. G., F. W. Lester, K. L. Meagher, and R. L. Wesson, 1975, Catalog of earthquakes along the San Andreas fault system in central California, April-June 1973, U.S. Geol. Sur. Open-File Report.

Bufe, C., 1975, A comparison of amplitude and coda-based magnitudes, personal communication.

Lee, W. H. K., R. E. Bennett and K. L. Meagher, 1972, A method of estimating magnitude of local earthquakes from signal duration, U.S. Geol. Sur. Open-File Report.

A Comparison of Amplitude- and Coda-Based Magnitudes - C. Bufe

In a joint study with K. McNally of the University of California, Berkeley, W. Bakun and C. Bufe have compared USGS central California earthquake magnitudes determined from coda duration with magnitudes computed for the same events by Berkeley (BRK) from peak amplitudes on Wood-Anderson and on short-period vertical seismographs. The linear relationship $M_{CODA} = 0.87 + 0.74\ M_{BRK}$ was found over the range $1 \leq M_{BRK} < 6$. A weak dependence of coda magnitude on focal depth exists, with coda magnitudes of shallow ($h \leq 5$ km) earthquakes averaging 0.15 magnitude units larger than deeper events with the same BRK magnitude. Coda and BRK magnitudes are equivalent at M = 3.5. For larger earthquakes, the USGS publishes the equivalent of the Wood-Anderson BRK magnitude rather than the coda magnitude. Implications of this study are:

1. USGS magnitude 1 earthquakes in central California are about equivalent to BRK magnitude zero.

2. For $M \leq 3.5$, b slopes determined from coda magnitudes will be about 25% higher than those determined from BRK magnitudes. USGS magnitude-frequency plots over a magnitude range using both coda magnitudes and magnitudes based on Wood-Anderson amplitudes will exhibit a change in slope at M = 3.5.

3. A single linear relationship can be used to relate log coda duration to BRK magnitude over the range $1 \leq M_{BRK} \leq 5.5$. Observed data scatter is less than $\pm$ 0.5 magnitude unit.

U. S. A.

1. Name of Network or Station: Hawaii Network
2. Mailing Address: U.S. Geological Survey, Hawaiian Volcano Obs., Hawaii National Park, HI 96718
3. Type of instruments used for local magnitude determination: Wood-Anderson
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): Standard for W-A
5. Components used (Z or H): H
6. Specific phase used (P,S,Lg, none): Body wave
7. Parameters measured (A,A/T,Duration): A
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): ? Richter Formula
9. Period range over which magnitudes are determined: 0.5 -15 Hz
10. Distance range over which magnitudes are determined: 0-500 km
11. Tectonic setting (Continental,oceanic,etc.): Oceanic
12. How is magnitude averaged from individual station determinations? Arithmetically
13. What station or source corrections are used if any? None
14. Estimate of consistency of magnitude determinations, and any known errors: $\approx \pm 0.3$
15. Known relationships with local magnitudes determined by other networks: --
16. Known relationships between local magnitudes and standard teleseismic magnitudes: --
17. References (Please attach reprint(s) or report(s)): HVO Quarterly Summary #61 (Koyanagi et al. , 1971).
18. Reply to this Survey is prepared by: John D. Unger

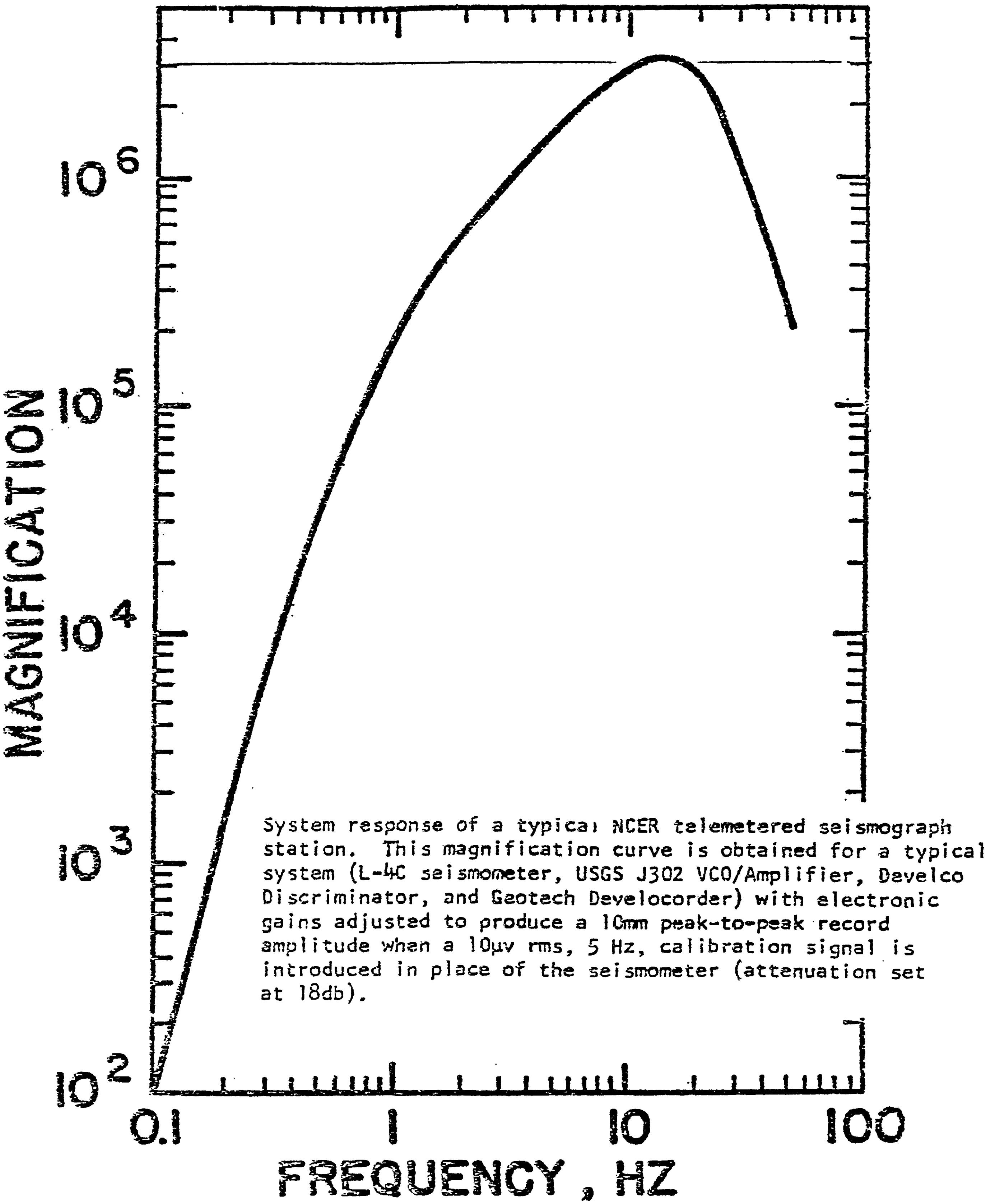
Date: 3/4/76

U. S. A.

U. S. GEOLOGICAL SURVEY: MOJAVE, IMPERIAL VALLEY, & YUMA NETS

1. Name of Network or Station: Mojave, San Bernardino (until 10/1/75), Imperial Valley, Yuma, network.
2. Mailing Address: c/o CIT, Seismo. Lab.
   Pasadena, CA 91125
3. Type of instruments used for local magnitude determination: Short period, vertical seismometers (L-4C Mark Products, T seis = 1.0 sec) recorded on 16 mm films (Geotech develocorders, T galvo = 0.062 sec)
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): attached
5. Components used (Z or H): Z
6. Specific phase used (P,S,Lg, none): none
7. Parameters measured (A,A/T,Duration): signal duration
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): Lee, W.H.K., Bennett, R. E., and Meagher, K. L., 1972, A method for estimating magnitude of local earthquakes from signal duration, open file report, U.S. Geol. Survey, 28 pp.
9. Period range over which magnitudes are determined: 0.1 sec to 1 sec, approximately
10. Distance range over which magnitudes are determined: 100 km approximately
11. Tectonic setting (Continental,oceanic,etc.): continental (Moj.,S.B.,Yuma), oceanic (?) (Imp. Vall.)
12. How is magnitude averaged from individual station determinations? simple average of individual station determinations
13. What station or source corrections are used if any? none, so far
14. Estimate of consistency of magnitude determinations, and any known errors: The standard deviation of individual station determinations for a given quake (commonly 3 to 4 determinations per quake) is about 0.1.
15. Known relationships with local magnitudes determined by other networks: CIT calculates Richter magnitudes or equivalents for local earthquakes. Comparing our (USGS) determinations with theirs (CIT), (See attached)
16. Known relationships between local magnitudes and standard teleseismic magnitudes: unknown
17. References (Please attach reprint(s) or report(s): We are in the process of documenting the Lee *et al*. method for earthquakes in southern California.
18. Reply to this Survey is prepared by: Gary Fuis

Date: 5/25/76



System response of a typical NCER telemetered seismograph station. This magnification curve is obtained for a typical system (L-4C seismometer, USGS J302 VCO/Amplifier, Develco Discriminator, and Geotech Develocorder) with electronic gains adjusted to produce a 10mm peak-to-peak record amplitude when a 10μv rms, 5 Hz, calibration signal is introduced in place of the seismometer (attenuation set at 18db).

7. (continued)

$$\frac{1}{N}\sum_{i=1}^{N}(M_{USGS} - M_{CIT})_i \simeq 0.00 \text{ and } \frac{1}{N}\sum_{i=1}^{N}|(M_{USGS} - M_{CIT})|_i \simeq 0.20$$

over the magnitude range M = 2.5 to 5.0. (There is fair agreement even above M = 4).

U. S. A.

U. S. GEOLOGICAL SURVEY: OROVILLE NET

1. Name of Network or Station: Oroville, California Network
2. Mailing Address: 345 Middlefield Rd., Menlo Park, CA 94025
3. Type of instruments used for local magnitude determination: L-4C Mark Products
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): Empirical Transfer functions for stations in the USGS central California net.; Bakun & Dratler, 1976, Open-File
5. Components used (Z or H): H
6. Specific phase used (P,S,Lg, none): S
7. Parameters measured (A,A/T,Duration): A , Duration
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): Richter, 1956, p. 342. Bakun and Lindh (1976).
9. Period range over which magnitudes are determined: 5 - 15 Hz
10. Distance range over which magnitudes are determined: 0 = 0 to 25 km
11. Tectonic setting (Continental,oceanic,etc.):
12. How is magnitude averaged from individual station determinations? Mean over all available horizontal components.
13. What station or source corrections are used if any? None at present
14. Estimate of consistency of magnitude determinations, and any known errors: ±0.2
15. Known relationships with local magnitudes determined by other networks: Right on BRK WA for larger events.
16. Known relationships between local magnitudes and standard teleseismic magnitudes:
17. References (Please attach reprint(s) or report(s)): Bakun and Lindh, in preparation
18. Reply to this Survey is prepared by: William H. Bakun

Date: 3/5/76

NOTE: Known transfer functions are removed from instruments; in frequency domain (both ampl & phase). Signal is shaped with theoretical Wood-Anderson response and magnitudes computed via Richter, 1956. Relationship to moment and duration in preparation.

U. S. A.

U. S. GEOLOGICAL SURVEY: PUERTO RICO NET

1. Name of Network or Station: Puerto Rico Seismic Network
2. Mailing Address: USGS Denver Federal Center, Box 25046, Mail Stop 968
   Denver, CO 80225
3. Type of instruments used for local magnitude determination: Geotech S-13
4. Magnification-frequency response curve of instruments (Please cite reference or attach document):
5. Components used (Z or H): Z
6. Specific phase used (P,S,Lg, none): S
7. Parameters measured (A,A/T,Duration): Duration
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document):
   $M(\tau) = -1.15 + 2.0 * \log(\tau) + .0035 * \Delta + .007 * h$
9. Period range over which magnitudes are determined:
10. Distance range over which magnitudes are determined: 0-100 km
11. Tectonic setting (Continental,oceanic,etc.): Island Arc
12. How is magnitude averaged from individual station determinations?
    Unweighted mean
13. What station or source corrections are used if any?
    None at present
14. Estimate of consistency of magnitude determinations, and any known errors: ± .3 units, new constants under investigation
15. Known relationships with local magnitudes determined by other networks:
    None
16. Known relationships between local magnitudes and standard teleseismic magnitudes:
    None
17. References (Please attach reprint(s) or report(s)):
18. Reply to this Survey is prepared by: A. C. Tarr
    Date: 5/18/76

1. Name of Network or Station: South Carolina Seismic Network
2. Mailing Address: USGS, Denver Federal Center, Box 25046, Mail Stop 968
Denver, CO 80225
3. Type of instruments used for local magnitude determination: Geotech S-13
4. Magnification-frequency response curve of instruments (Please cite reference or attach document):
5. Components used (Z or H): Z
6. Specific phase used (P,S,Lg, none): S
7. Parameters measured (A,A/T,Duration): Duration
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document):
$M(\tau) = -1.15 + 2.0 * \log(\tau) + .0035 * \Delta + .007 * h$
9. Period range over which magnitudes are determined:
10. Distance range over which magnitudes are determined: 0-100 km
11. Tectonic setting (Continental,oceanic,etc.): continental
12. How is magnitude averaged from individual station determinations?
Unweighted mean
13. What station or source corrections are used if any?
None at present
14. Estimate of consistency of magnitude determinations, and any known errors: ± .3 units,
We know Calif. constants do not apply
15. Known relationships with local magnitudes determined by other networks:
16. Known relationships between local magnitudes and standard teleseismic magnitudes:
M_{bhg} from St. Louis seems to be close
17. References (Please attach reprint(s) or report(s)):
18. Reply to this Survey is prepared by: A. C. Tarr
Date: 5/18/76

1. Name of Network or Station: Yellowstone Network (27 stations)
2. Mailing Address: USGS, 345 Middlefield Road, Menlo Park, CA
3. Type of instruments used for local magnitude determination: 1 Hz seismometer with signals recorded on Develecorder
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): Any USGS Central California earthquake catalog (e. g. Lee et al. 1972).
5. Components used (Z or H): Z
6. Specific phase used (P,S,Lg, none): None
7. Parameters measured (A,A/T,Duration): Duration
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): Lee, Bennett, and Meagher, 1972.
9. Period range over which magnitudes are determined: all recorded periods
10. Distance range over which magnitudes are determined: 0 - 150 km
11. Tectonic setting (Continental,oceanic,etc.): continental
12. How is magnitude averaged from individual station determinations? straight averaging
13. What station or source corrections are used if any? none
14. Estimate of consistency of magnitude determinations, and any known errors: consistency very dependent on travel path from earthquake to station.
15. Known relationships with local magnitudes determined by other networks: Similar for magnitudes below 4, lower for magnitudes above 4
16. Known relationships between local magnitudes and standard teleseismic magnitudes: None known so far
17. References (Please attach reprint(s) or report(s)):
18. Reply to this Survey is prepared by: Andrew M. Pitt

    Date: 5/21/76

U. S. A.

UNIVERSITY OF ALASKA: CENTRAL ALASKAN & NORTHERN ALASKAN NETS

1. Name of Network or Station: CENTRAL ALASKAN NETWORK: NORTHERN ALASKAN NETWORK
2. Mailing Address: Attn: N.N. Biswas, Seismological Laboratory, Geophysical Institute, University of Alaska, Fairbanks, Alaska 99701
3. Type of instruments used for local magnitude determination: GEOSPACE HS-10-1/B (Northern Alaska), GEOTECH S-13 (Central Alaska)
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): In preparation.
5. Components used (Z or H): Z
6. Specific phase used (P,S,Lg, none): P
7. Parameters measured (A,A/T,Duration): A/T, Duration
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): See enclosed.
   Note for Points 8 to 17.
9. Period range over which magnitudes are determined:
10. Distance range over which magnitudes are determined:
11. Tectonic setting (Continental,oceanic,etc.):
12. How is magnitude averaged from individual station determinations?
13. What station or source corrections are used if any?
14. Estimate of consistency of magnitude determinations, and any known errors:
15. Known relationships with local magnitudes determined by other networks:
16. Known relationships between local magnitudes and standard teleseismic magnitudes:
17. References (Please attach reprint(s) or report(s)):
18. Reply to this Survey is prepared by: N. N. Biswas
   Date: 19 April, 1976

NOTE

The central Alaskan seismic array is in operation for the last 10 years. During the last five years, a number of new stations have been added. The station calibrations were obtained about 5 years back and recheck of the above could not be carried out due to the shortage of funds. However, during the coming field season, it is planned to obtain the system response curve of each station of the array. After this, a systematic analysis of magnitude determination will be carried out.

The northern Alaskan array has been operational for about 5 months. Each station has been calibrated. The nominal system magnification has been set to 32 K at 1 sec. period. We are in process of analysing the data from this array. As soon as the answers to Points 8 to 17 are ready, we would forward them to you.

U. S. A.

1. Seismographic Stations, U. C. Berkeley

2. Department of Geology and Geophysics
475 Earth Science Bldg.
University of California
Berkeley, California 94720

3. M_L = Wood-Anderson or Press-Ewing and M_s= Wood-Anderson or Springnether

4. See enclosed response curves

References: a) Catalogue of Earthquakes in Northern California and adjoining areas (1January 1910 - 31 December 1972) by Bruce A. Bolt and Roy D. Miller

5. Wood-Anderson & Springnether - Horizontal
Press-Ewing - Vertical

6. M_L: Wood-Anderson & Press-Ewing - maximum amplitude phase
M_s: Wood-Anderson & Springnether - 20 second surface waves

7. Wood-Anderson - amplitude
Press-Ewing - amplitude and period
Springnether - Amplitude of maximum (18-22 second) surface waves

8. M_L: Wood-Anderson and Press-Ewing
M_s: Wood-Anderson and Springnether see enclosed nomograms

References: a) An Instrumental Earthquake Magnitude Scale, Charles F. Richter, BSSA, <u>25</u>, 1, 1-32, January 1935

b) On Seismic Waves, B. Gutenburg and C. F. Richter, Gerlands Beiträge Zur Geophysik, <u>47</u>, 73-131, 1936

c) Earthquake Magnitude, Intensity, Energy, and Acceleration B. Gutenburg and C. F. Richter, BSSA, <u>32</u>, 3, 163-191, July 1942

Notes: 1) The amplitude (B) on the Wood-Anderson nomograph is taken to be the arithmetic mean of one-halfi the largest peak-to-peak excursion of each individual component

9. M_L: Wood-Anderson - period not used and Press-Ewing Period range approx 3-20 sec.
M_s: Wood-Anderson & Springnether - 18 - 22 second period range

10. $0^o < \Delta < 5\frac{1}{2}^o$ mostly and $5\frac{1}{2}^o < \Delta < 20^o$ occasionally

11. Earthquakes in Northern California occur in both continental and oceanic regions - along the San Andreas Fault system, the Gordu Basin, and the Sierra Nevada mountains.

12. $M_L = \frac{1}{n}\sum_{i=1}^{n} M_{L_i}$, $n = 1, \cdots, 4$
For immediate estimation only one station (BKS) is used and for the Bulletin up to four stations are used (BKS, ARC, MIN, and MHC)

13. Station adjustments which we added to the M_L estimate for each station are:
BKS + 0.0; ARC +0.2; MIN - 0.1; and MHC + 0.1

14. Standard error of the mean of the M_L estimate is approximately 0.12 magnitude units (estimated from the August 1975 Oroville sequence)

see next page

14.

Stations Recording	Number of Earthquakes	SEM
2	17	0.12
3	24	0.12
4	8	0.12

Notice that the SEM is not effected by the number of stations used to estimate M_L !

Reference: a) The Oroville Earthquake sequence of August 1975, by P. W. Morrison, Jr., B. W. Stump, and R. Uhrhammer, BSSA 1976 (in press)

15. BKS has a zero magnitude adjustment when referenced to Pasadena (BKS has an adjustment of -0.2 referenced to BRK which has (reference 8b) an adjustment of +0.2 referenced to Pasadena)

16. Analysis of 20 earthquakes in Northern California (1964 - 1972 and $5<M_L<6$) (Reference 4a) indicates that there is a linear relationship between Berkeley M_L and ISC M_b: $M_b = (3.26 \pm 0.36 \text{ SEM}) + (0.32 \pm 0.07 \text{ SEM}) M_L$ $(5 < M_L < 6)$

17. Additional References:

    a) Estimating Earthquake Magnitude, by Helen W. Freedman, BSSA, 57, 4, 747-760, August 1967

    b) Elementary Seismology by Charles F. Richter, W. H. Freeman and Co., San Francisco, 1958

18. Robert Uhrhammer and Bruce A. Bolt

III. RESPONSE CURVES

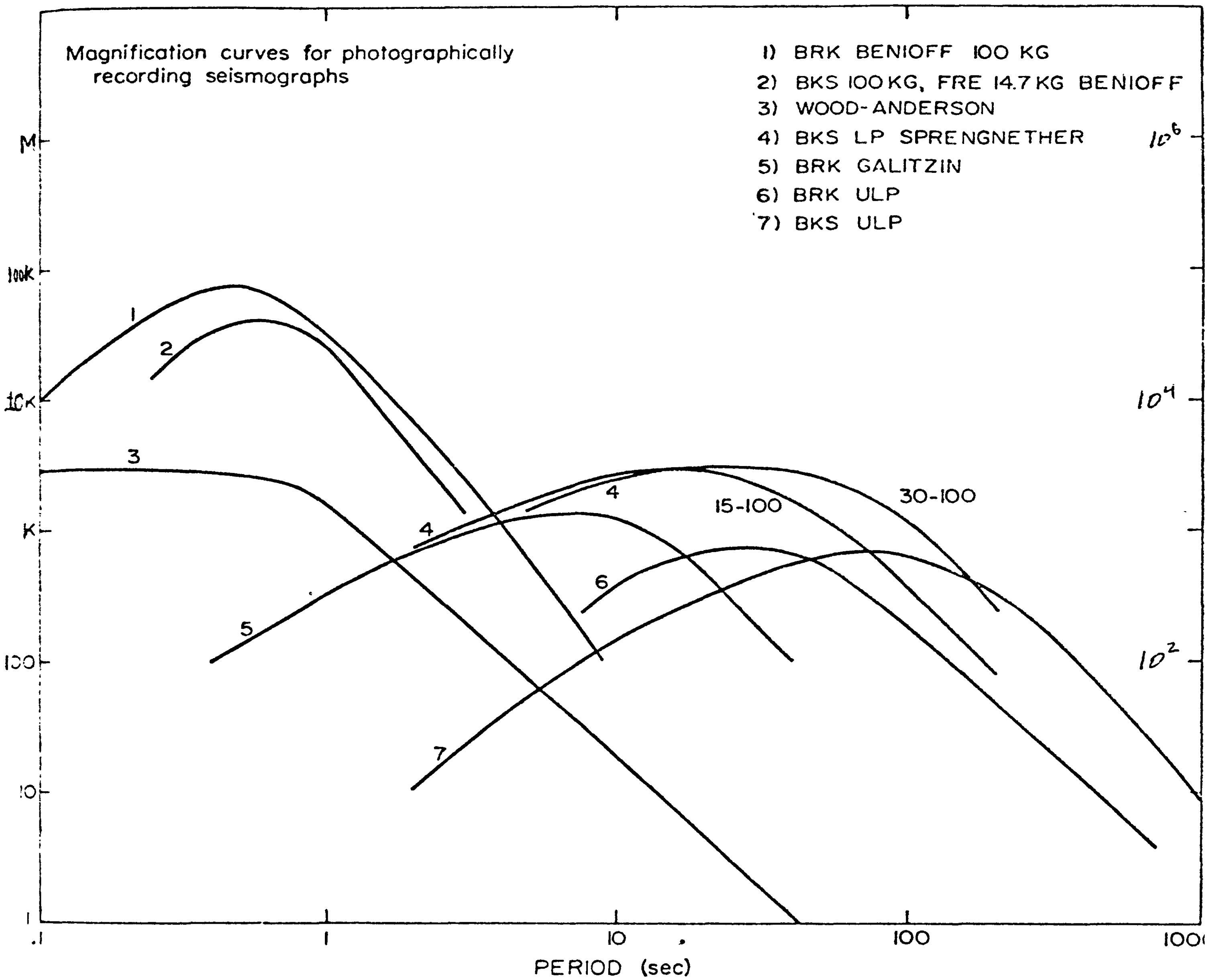


Figure 2 - Response curves for photographically recording seismographs. BKS Benioff and Sprengnether are the WWSSN system. ULP refers to the ultra-long period systems. See Section II.

BRK LP Z PRESS-EWING

$T_o = 15 \quad T_g = 30$

Attenuator Settings: Magnification Cont'l 30db
Helicorder 24db
Cal Pulse 2.5cm 0 to peak

Magnification (K) In thousands	Period (Secs)
1.7	7
1.9	8
2.0	9
2.05	10
2.15	12
2.15	15
2.05	17
1.9	19
1.85	20
1.75	21
1.48	25
1.30	28
1.15	30
1.10	32
0.98	34
0.88	36
0.84	38
0.76	40
0.59	45
0.36	55
0.23	60

Magnitudes of Local Shocks
(Rough Estimate from Press-Ewing)
(Room 565A)

Read: A = maximum (zero to peak) amplitude in mm on helicorder
K = magnification from Table I below
T = period, in seconds, of A
Q = value for Table II below

Thus: Mag = log (A/KT) + Q

Table I

T (sec)	K
3	0.500
4	0.600
5	0.650
6	0.700
7	0.750
8	0.800
9	0.850
10	0.900
11-15	0.950
16-17	0.900
18	0.850
19-20	0.800

Table II

Δ(KM)	Q
0-50	3.9
50-100	4.2
100-200	4.5
200-300	4.7
300-400	5.0
400-500	5.3
500-600	5.5
600-700	5.6
700-800	5.7

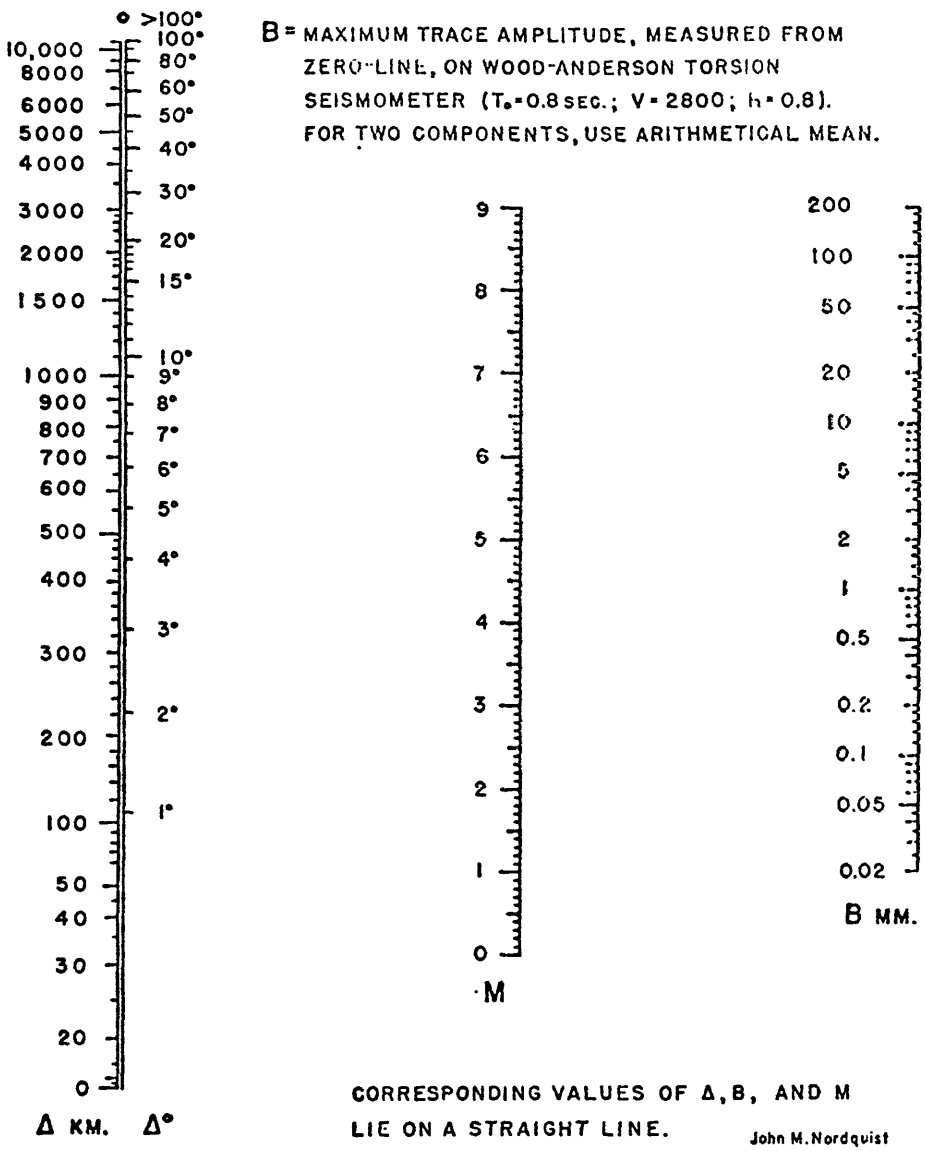


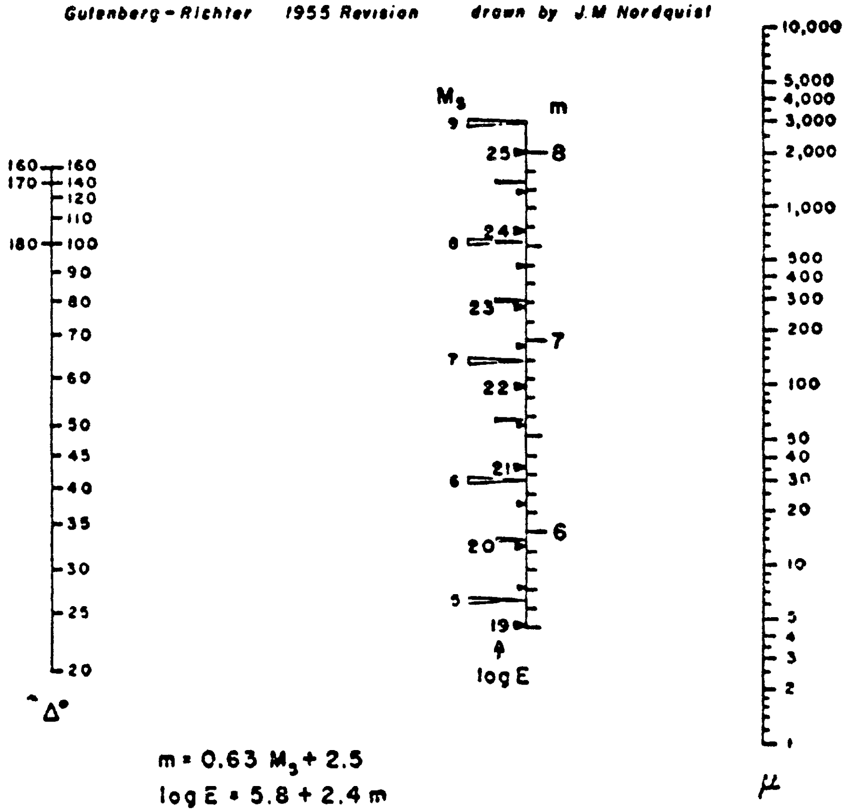
Fig. 1. Nomogram for determining earthquake magnitudes from trace amplitudes in millimeters of a standard-torsion seismogram. For Δ>10° only, the ground amplitude in microns may be substituted, if 2.5 is subtracted from the result for *M*.

BSSA, 32, 3, Page 164 (July 1942)

EARTHQUAKE MAGNITUDE AND ENERGY

CALCULATED FROM MAXIMUM GROUND AMPLITUDE IN MICRONS (COMBINED HORIZONTAL COMPONENTS) FOR SURFACE WAVES OF 20-SECOND PERIOD.

Gutenberg-Richter 1955 Revision drawn by J.M Nordquist



$m = 0.63\ M_s + 2.5$

$\log E = 5.8 + 2.4\ m$

GUTENBERG & RICHTER MAGNITUDE REVISION 1955

1. Name of Network or Station: ADAK
2. Mailing Address: CIRES, University of Colorado
   Boulder, CO 80309
3. Type of instruments used for local magnitude determination: high-frequency microearthquake (USGS)
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): USGS (with 15 cps galvo on Develocorder)
5. Components used (Z or H): Z
6. Specific phase used (P,S,Lg, none): None
7. Parameters measured (A,A/T,Duration): Duration (Onset to 1 cm peak-to-peak)
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): Magnitude = $-1.15 + 2.00 \text{ Log (Duration)} + 0.007 \text{ (Depth)}_{km} + 0.0035 \text{ (Delta)}_{km}$
9. Period range over which magnitudes are determined: 0.1-0.5 sec
10. Distance range over which magnitudes are determined: 0 - 150 km
11. Tectonic setting (Continental,oceanic,etc.): Island Arc
12. How is magnitude averaged from individual station determinations? Linearly
13. What station or source corrections are used if any? None
14. Estimate of consistency of magnitude determinations, and any known errors: ±1/4 magnitude
15. Known relationships with local magnitudes determined by other networks: None
16. Known relationships between local magnitudes and standard teleseismic magnitudes: Seems to agree with teleseismic M_B
17. References (Please attach reprint(s) or report(s): None
18. Reply to this Survey is prepared by: E. R. Engdahl
    Date: 4/19/76

U. S. A.

UNIVERSITY OF COLORADO: AMCHITKA NET

1. Name of Network or Station: AMCHITKA

2. Mailing Address: CIRES, University of Colorado
Boulder, CO 80309

3. Type of instruments used for local magnitude determination: high-frequency microearthquake (similar to USGS)

4. Magnification-frequency response curve of instruments (Please cite reference or attach document): similar to USGS (with 15 cps galvo on Develocorder)

5. Components used (Z or H): Z

6. Specific phase used (P,S,Lg, none): P

7. Parameters measured (A,A/T,Duration): A/T

8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): Magnitude = -0.76 + Log (A/T) + 0.91 Log S, A ≡ amplitude of max P in mμ TZ period in sec S ≡slant distan in Km

9. Period range over which magnitudes are determined: 0.1-0.5 sec

10. Distance range over which magnitudes are determined: 0-150 km

11. Tectonic setting (Continental,oceanic,etc.): Island Arc

12. How is magnitude averaged from individual station determinations? Linearly

13. What station or source corrections are used if any? None

14. Estimate of consistency of magnitude determinations, and any known errors: ± 1/4 magnitude

15. Known relationships with local magnitudes determined by other networks:

16. Known relationships between local magnitudes and standard teleseismic magnitudes:
Constants adjusted to agree with teleseismic M_B

17. References (Please attach reprint(s) or report(s): None

18. Reply to this Survey is prepared by: E. R. Engdahl
Date: 4/19/76

U. S. A.

UNIVERSITY OF MONTANA: MSO (WWSSN) STATION

1. Name of Network or Station: MSO (WWSSN)
2. Mailing Address: Anthony Qamar, Geology Dept., University of Montana
   Missoula, Mt. 59801
3. Type of instruments used for local magnitude determination: SP N, SPE of WWSN station MSO
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): SEE WWSSN Manual
5. Components used (Z or H): H (NS) and H (EW)
6. Specific phase used (P,S,Lg, none): None (largest amplitude)
7. Parameters measured (A,A/T,Duration): A
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): Amplitude is normalized to that of "equiv Wood-Anderson" and Richter's formula used for near distance
9. Period range over which magnitudes are determined: 0.5-1.5 Hz
10. Distance range over which magnitudes are determined: x<1000 km
11. Tectonic setting (Continental,oceanic,etc.): Continental
12. How is magnitude averaged from individual station determinations? only MSO used
13. What station or source corrections are used if any? None
14. Estimate of consistency of magnitude determinations, and any known errors: No detailed study. Fairly good correlation with USGS for M in range 3.0-4.0
15. Known relationships with local magnitudes determined by other networks: --
16. Known relationships between local magnitudes and standard teleseismic magnitudes: --
17. References (Please attach reprint(s) or report(s)): --
18. Reply to this Survey is prepared by: Anthony Qamar
    Date: March 8, 1976

U. S. A.

UNIVERSITY OF NEVADA: MINA NET

1. Name of Network or Station: Mina Network
2. Mailing Address: Seismological Laboratory, Mackay School of Mines, University of Nevada, Reno, Nevada 89507
3. Type of instruments used for local magnitude determination: USGS equipment, recorded on magnetic tape, see USGS reports for descriptions.
4. Magnification-frequency response curve of instruments (Please cite reference or attach document):
5. Components used (Z or H): Z
6. Specific phase used (P,S,Lg, none): none
7. Parameters measured (A,A/T,Duration): duration
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document):
   $FMAG = -.87 + 2LogF + .0035D$ Open File Rpt. 75-311
9. Period range over which magnitudes are determined: 0.05 - 1.0
10. Distance range over which magnitudes are determined: to 100km
11. Tectonic setting (Continental, oceanic, etc.): Basin and Range Province
12. How is magnitude averaged from individual station determinations? HYPO71
13. What station or source corrections are used if any? None yet
14. Estimate of consistency of magnitude determinations, and any known errors:
    undetermined
15. Known relationships with local magnitudes determined by other networks:
    undetermined
16. Known relationships between local magnitudes and standard teleseismic magnitudes:
    undetermined
17. References (Please attach reprint(s) or report(s)):
18. Reply to this Survey is prepared by: Doug VanWormer
    Date: 4 March 1976

U. S. A.

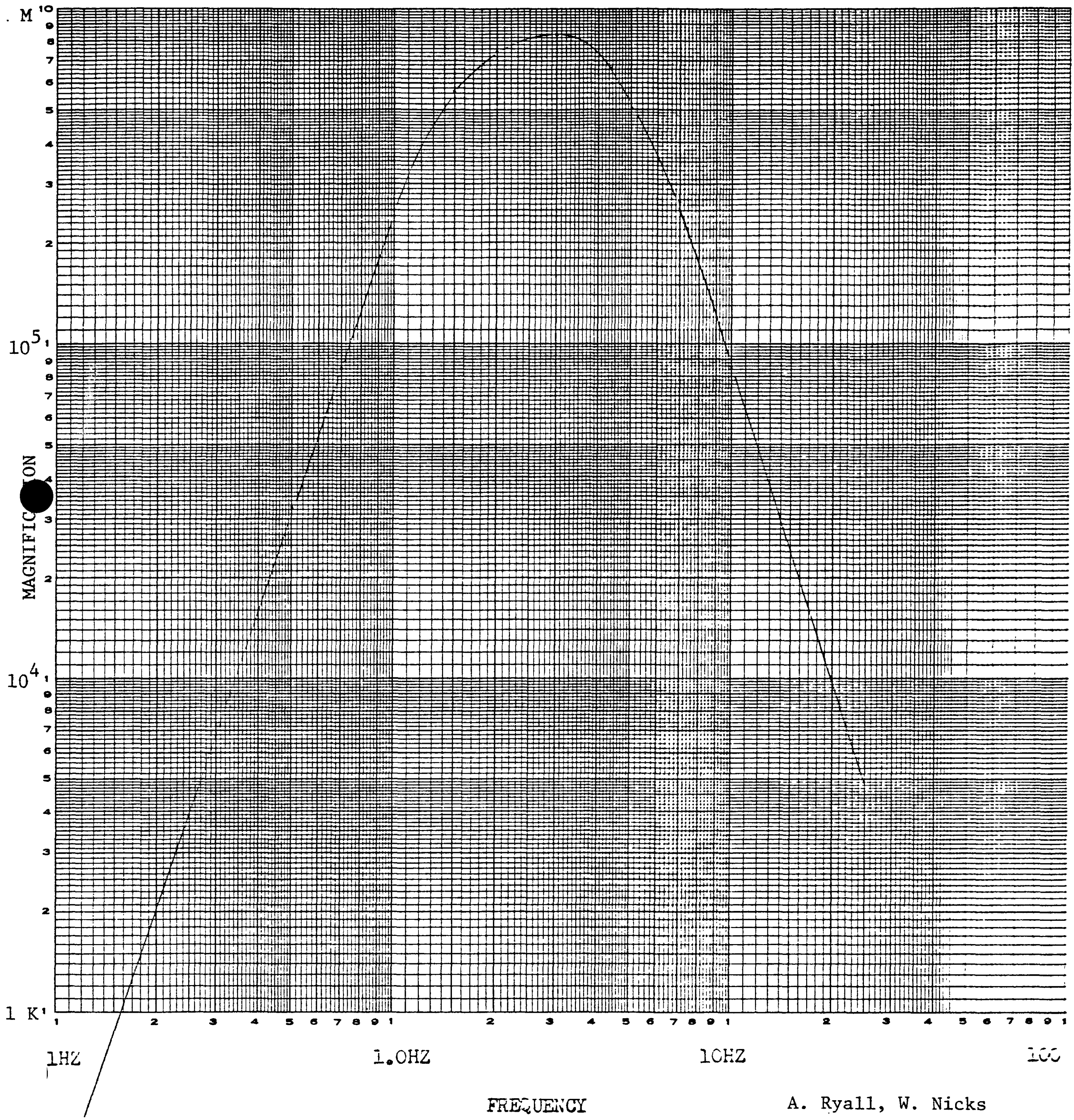
UNIVERSITY OF NEVADA: NEVADA NET

1. Name of Network or Station: Nevada
2. Mailing Address: Seismological Laboratory, Mackay School of Mines University of Nevada, Reno, Nevada 89507
3. Type of instruments used for local magnitude determination: Benioff, short period
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): typical curve attached - magnification varies
5. Components used (Z or H): H
6. Specific phase used (P,S,Lg, none): S
7. Parameters measured (A,A/T,Duration): A
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): Convert to equivalent Wood-Anderson amplitude and use Richter's Table 22-1, p 342, Elem. Seis.
9. Period range over which magnitudes are determined: 0.2 - 0.6 sec.
10. Distance range over which magnitudes are determined: to 500km
11. Tectonic setting (Continental, oceanic, etc.): Basin and Range Province
12. How is magnitude averaged from individual station determinations? simple average -- each H-component is one observation; observations are summed, divided by N
13. What station or source corrections are used if any? TNP -0.16, BMN +0.05 corrections from comparison of Wood-Andersons
14. Estimate of consistency of magnitude determinations, and any known errors: probably about ± 0.2. We know that attenuation varies in the region
15. Known relationships with local magnitudes determined by other networks: Fair agreement with UC Berkelely
16. Known relationships between local magnitudes and standard teleseismic magnitudes: not known
17. References (Please attach reprint(s) or report(s)):
18. Reply to this Survey is prepared by: Doug VanWormer
    Date: 4 March 1976

U. S. A.

UNIVERSITY OF NEVADA: NEVADA NET

TNP SPE 25 Feb. 71

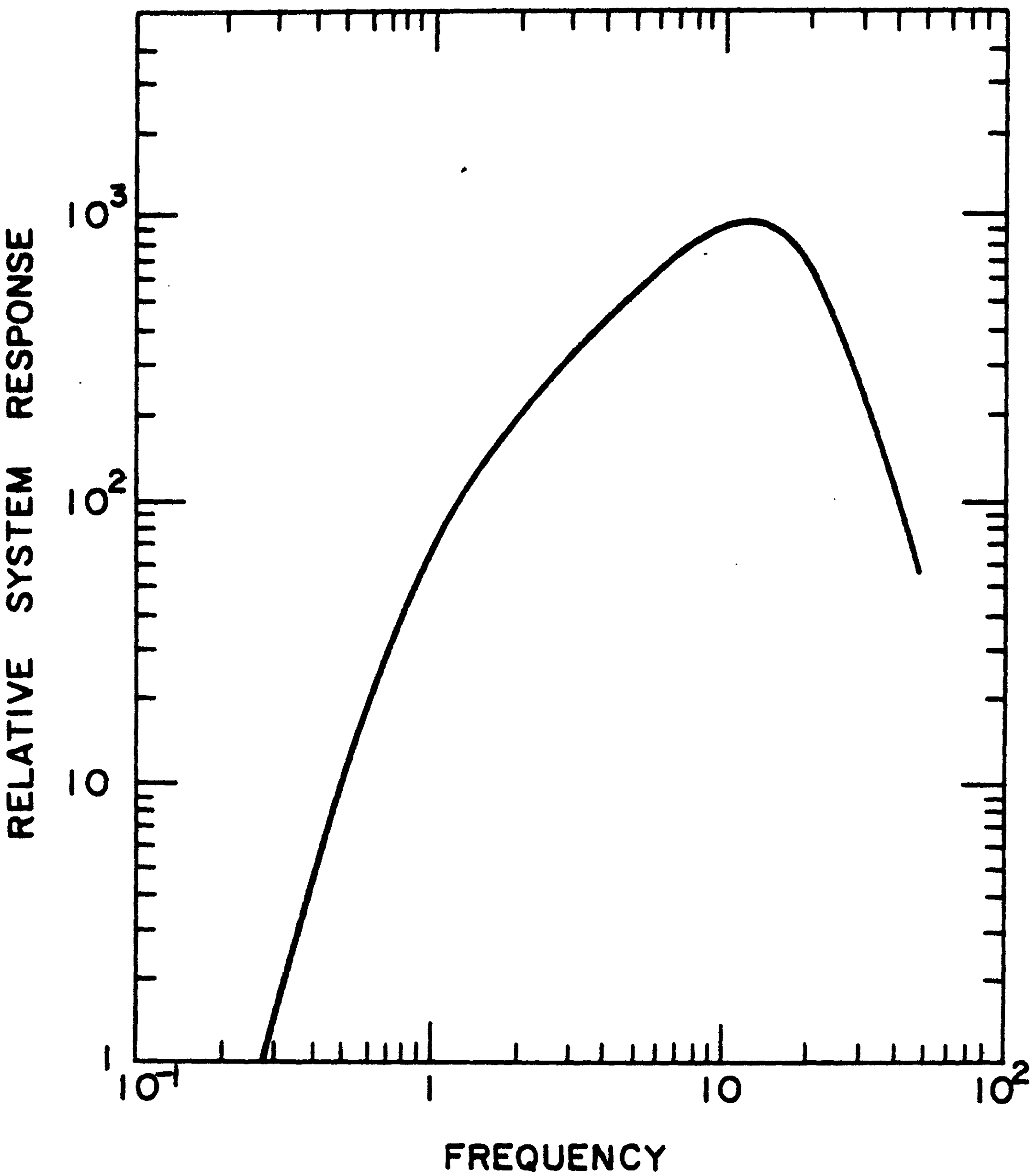


A. Ryall, W. Nicks

U. S. A.

UNIVERSITY OF SOUTHERN CALIFORNIA: LOS ANGELES BASIN NET

1. Name of Network or Station: Los Angeles Basin Seismic Network
2. Mailing Address: Dr. T. L. Teng, Dept. of Geological Sciences, University of Southern California, Los Angeles, Calif. 90007
3. Type of instruments used for local magnitude determination: Mark Products L4-3 and Develco VCO/Pre Amp.
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): See Attached
5. Components used (Z or H): Z
6. Specific phase used (P,S,Lg, none): Entire seismogram (Total Duration)
7. Parameters measured (A,A/T,Duration): Total Duration (Onset to the time when S/N = 1.)
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): NONE
9. Period range over which magnitudes are determined: 1 - 20 Hz
10. Distance range over which magnitudes are determined: < 100 km
11. Tectonic setting (Continental,oceanic,etc.): Continental
12. How is magnitude averaged from individual station determinations? Simple Average Unweighted
13. What station or source corrections are used if any? None
14. Estimate of consistency of magnitude determinations, and any known errors: ± 0.1 magnetic unit.
15. Known relationships with local magnitudes determined by other networks: Consistent with Richter Local Magnitude (cf: BSSA, 63, pp. 1809-1827, 1973, Real & Teng Paper)
16. Known relationships between local magnitudes and standard teleseismic magnitudes:
17. References (Please attach reprint(s) or report(s): Teng et al. (1975).
18. Reply to this Survey is prepared by: Ta-liang Teng
    Date: 3/17/76


RELATIVE SYSTEM RESPONSE
10³
10²
10
1
10⁻¹
1
10
10²
FREQUENCY

UTAH LOCAL MAGNITUDES

General Statement

Prior to 1974, seismicity catalogs compiled by the University of Utah unfortunately included mixtures of m_b and variously-determined estimates of M_L for "magnitude."

A complete revision of Utah local magnitude scales is under way; currently, local magnitudes are estimated by the following methods:

1) Measurement of amplitudes on Wood-Anderson or Wood-Anderson-type torsion seismographs that now operate in pairs at 5 sites in Utah (see p. 2, Table 1).
2) Measurement of total signal duration on Geotech develocorders that record telemetered signals from approximately 30 USGS-type vertical-component seismic systems (see p. 5).
3) Measurement of total signal duration on short-period vertical-component Benioff seismograms recorded at Dugway (DUG)--a WWSSN station (see p. 6).

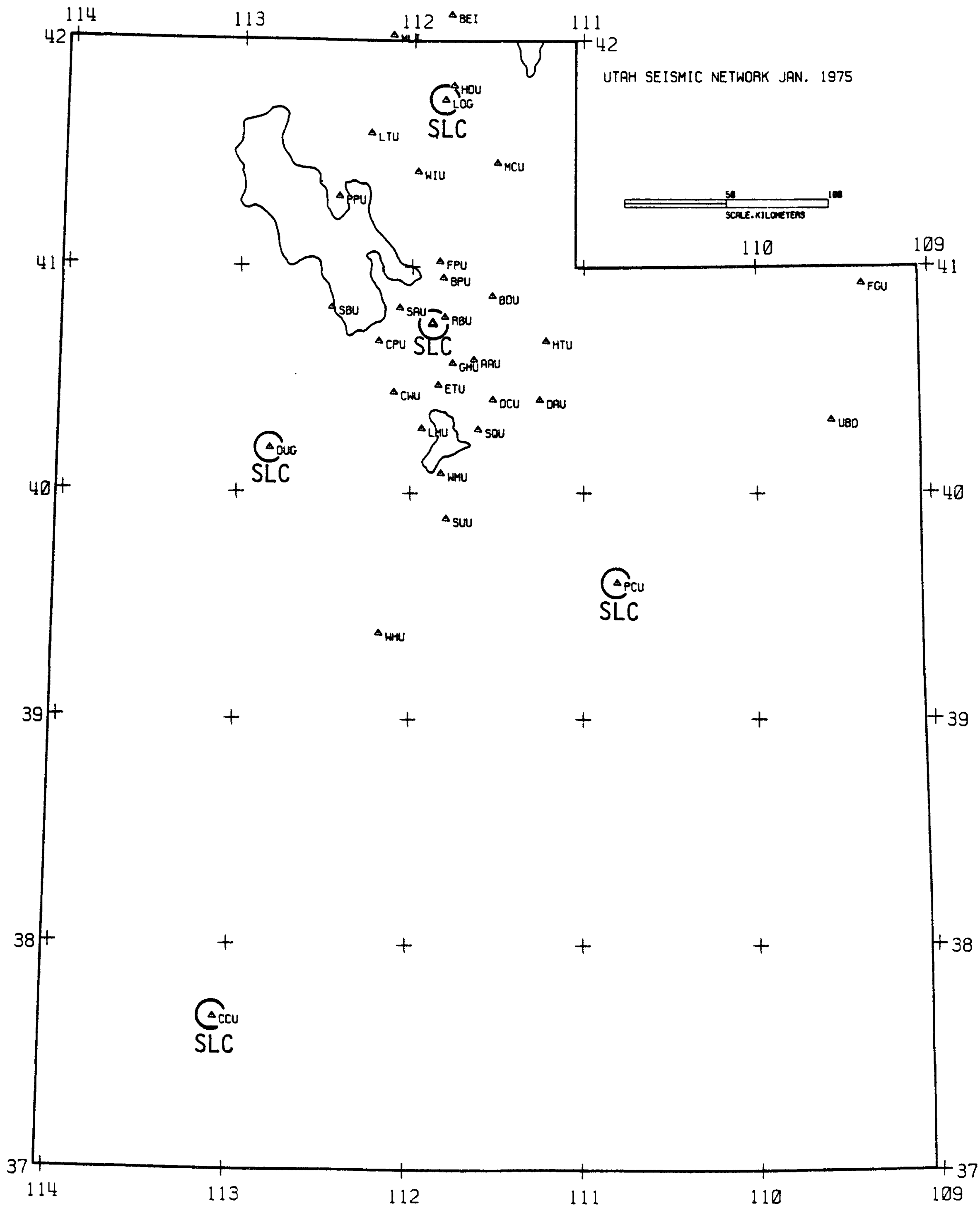
Methods 1 and 3 have been used for preliminary revision of earlier earthquake catalogs. Methods 1 and 2 are used to determine magnitudes for current listings of Utah earthquakes; Wood-Anderson magnitudes are generally determined for all local earthquakes of M 2.5 or greater.

1. Name of Network or Station: University of Utah Seismograph Stations
2. Mailing Address: 611 Mineral Science Building, University of Utah
   Salt Lake City, Utah 84112
3. Type of instruments used for local magnitude determination: Wood-Anderson and Wood-Anderson-type torsion seismographs (see table 1).
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): Anderson, J. A., and Wood, H. O. (1925). Description and theory of the torsion seismometer: B.S.S.A. 15, 1-72.
5. Components used (Z or H): H
6. Specific phase used (P,S,Lg, none): S
7. Parameters measured (A,A/T,Duration): 1/2 maximum peak-to-peak amplitude
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document):
   Richter's "$-\log A_0$ versus distance" corrections are assumed
9. Period range over which magnitudes are determined: ca. 0.3-1.0 sec.
10. Distance range over which magnitudes are determined: 0-500 km.
11. Tectonic setting (Continental,oceanic,etc.): Continental
12. How is magnitude averaged from individual station determinations?
    Simple arithmetic averaging.
13. What station or source corrections are used if any? station corrections
    (M_L corrected = M_L computed + station correction)
    ~~DUG : + 0.13 PCU : - 0.24 LOG : - 0.07 [SLC & CCU not calibrated yet]~~
14. Estimate of consistency of magnitude determinations, and any known errors:
    Std. dev. of M_L at a single station from $\bar{M}_L \cong 0.25$ (N = 79)
15. Known relationships with local magnitudes determined by other networks:
    (See Table 3. in Attachment No. 1)
16. Known relationships between local magnitudes and standard teleseismic magnitudes:
    (See Table 3 in Attachment No. 1)
17. References (Please attach reprint(s) or report(s): See Attachment No. 1
18. Reply to this Survey is prepared by: W. J. Arabasz & W. D. Richins
    Date: May 18, 1976

Table 1. Outline of Wood-Anderson Instrumentation in Utah

Station	Lat. - N	Long. - W	Instrument Specification	Component	Displacement Magnification	Date Operational	Station* Correction
DUG	40-11.70	112-48.80	Lehner-Griffith Model TS-220	N-S E-W	2800 2800	20 SEPT 1963 20 SEPT 1963	+0.13
			Lehner-Griffith Model TS-220 (w/35-mm film recorder)	N-S E-W	1400 1400	(27 AUG 1966) (to 7 JAN 1976)	- -
PCU	39-36.40	110-48.30	Lehner-Griffith Model TS-220	N-S E-W	2800 2800	16 MAY 1962 16 MAY 1962	-0.24
LOG	41-44.50	111-48.80	Wood-Anderson	N-S E-W	2800 2800	1 FEB 1964 1 FEB 1964	-0.07
SLC	40-45.83	111-50.87	Kinemetrics system with simulated Wood-Anderson response	N-S E-W	5600 5600	2 JAN 1976 2 JAN 1976	- -
CCU	37-40.52	113-04.11	Lehner-Griffith Model TS-220 (w/35-mm film recorder)	N-S E-W	1400 1400	21 JAN 1976 21 JAN 1976	- -

*additive constant (in units of M_L)


UTAH SEISMIC NETWORK JAN. 1975
SCALE, KILOMETERS
114
113
112
111
110
109
42
41
40
39
38
37
BEI
HOU
LOG
SLC
LTU
MCU
WIU
PPU
FPU
BPU
BDU
SBU
SAU
RBU
SLC
CPU
HTU
GMU
AAU
CWU
ETU
DCU
DAU
LMU
SQU
WMU
SUU
DUG
SLC
FGU
UBO
PCU
SLC
WHU
CCU
SLC

1. Name of Network or Station: University of Utah Seismograph Stations
2. Mailing Address: 611 Mineral Science Building, University of Utah
   Salt Lake City, Utah 84112
3. Type of instruments used for local magnitude determination: Most common instrument package consists of: Interproducts J302 VCO, Mark Products L4 seismometer, Interproducts J101 Discriminator, Motorola HT200 radio, Geotech develocorder.
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): Same as for standard USGS telemetered seismograph station-- (e.g. Lee et al, 1972, Fig. 2)
5. Components used (Z or H): Z
6. Specific phase used (P,S,Lg, none): None
7. Parameters measured (A,A/T,Duration): Total signal duration (measured from onset to point where signal decays to pre-onset level)= τ_{F-P}
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document):
   $M_L = -2.96 + 2.66 \log \tau_{F-P}$
9. Period range over which magnitudes are determined: (not applicable)
10. Distance range over which magnitudes are determined: 0-150 km
11. Tectonic setting (Continental, oceanic, etc.): Continental
12. How is magnitude averaged from individual station determinations? mean magnitude computed from determinations of M_L at individual stations
13. What station or source corrections are used if any? None, at present
14. Estimate of consistency of magnitude determinations, and any known errors: Std. dev. = 0.13 (N=99); provisional formula does not incorporate distance correction
15. Known relationships with local magnitudes determined by other networks: --
16. Known relationships between local magnitudes and standard teleseismic magnitudes: --
17. References (Please attach reprint(s) or report(s)): --
18. Reply to this Survey is prepared by: W. J. Arabasz & W. D. Richins
    Date: May 18, 1976

1. Name of Network or Station: University of Utah Seismograph Stations

2. Mailing Address: 611 Mineral Science Building, University of Utah, Salt Lake City, Utah 84112

3. Type of instruments used for local magnitude determination: WWSS, large Benioff short period seismometer, magnification of 200 K.

4. Magnification-frequency response curve of instruments (Please cite reference or attach document): See Attachment No. 2

5. Components used (Z or H): SP - Z at DUG

6. Specific phase used (P,S,Lg, none): None

7. Parameters measured (A,A/T,Duration): Total signal duration (measured from onset to point where signal decays to pre-onset level)

8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document):
$M(\tau_\Delta) = -3.26 + 2.60 \log(\tau_\Delta) + 5.0 \times 10^{-4} \Delta_x$, See attachment No. 1

9. Period range over which magnitudes are determined: Not applicable

10. Distance range over which magnitudes are determined: 0-300 km

11. Tectonic setting (Continental,oceanic,etc.): continental

12. How is magnitude averaged from individual station determinations?
single-station determination, DUG

13. What station or source corrections are used if any? None

14. Estimate of consistency of magnitude determinations, and any known errors:
Std. dev. = 0.22 (N=35)

15. Known relationships with local magnitudes determined by other networks: --

16. Known relationships between local magnitudes and standard teleseismic magnitudes:
--

17. References (Please attach reprint(s) or report(s)): See attachment No. 1

18. Reply to this Survey is prepared by: W. J. Arabasz & W. D. Richins
Date:

Attachment No. 1*

Utah local magnitudes.--Wood-Anderson seismographs in Utah have been operating at Dugway (since Sept., 1963), at Price (since May, 1962), and at Logan (since Feb., 1964). All three stations have both N-S and E-W components and operate at a magnification of 2800. All measureable Wood-Anderson amplitudes for the calibration earthquakes were re-read by one observer in order to evaluate station corrections and to make a comparison with magnitudes determined elsewhere.

Table 3 lists all the events for which local Wood-Anderson measurements could be made, and for which CGS/NOAA magnitudes had been published in an Earthquake Data Report (EDR) or an earlier counterpart. For determinations of m_b, the number of observations (NO) is tabulated, together with an equivalent Richter or local magnitude (ML*). The latter is based on Gutenberg's relation (Richter, 1958, p. 366):

$$m_b = 1.7 + 0.8 M_L - 0.01 M_L^2$$

To derive an average value of M_L (AVML) for the events in Table 3, full weight was given to Utah values of M_L and to values of M_L given by CGS/NOAA. Estimates of Richter magnitude based on m_b were given full weight if NO > 3, ½ weight if NO = 2, and ¼ weight if NO = 1.

Comparison of Richter magnitudes at DUG, PCU, and LOG with the weighted average values indicates mean corrections of +0.13 at DUG, -0.24 at PCU, and -0.07 at LOG. This information represents one of the first evaluations of local magnitudes in Utah. Magnitudes listed in earlier seismicity catalogs compiled by the University of Utah unfortunately include mixtures of m_b, and variously determined estimates of M_L.

*From Progress Report No. 1 on USGS research contract to University of Utah (Contract No. 14-08-0001-14585), Feb. 7, 1975.

Table 3

COMPARISON OF UTAH LOCAL MAGNITUDES

		EDR MAGNITUDES				ML UTAH			
DATE	TIME	MB	NO	ML*	ML	DUG	PCU	LOG	AVML
630415	2218	4.2	1	3.3			3.4		3.4
630424	1333	4.6	1	3.8			3.5		3.6
630619	0838	4.2	2	3.3			3.9		3.7
630707	1920	4.9	8	4.2			4.6		4.4
630709	2025	4.1	3	3.1			4.2		3.7
630710	1832	4.2	4	3.3			3.9		3.6
630930	0917	4.5	3	3.7		4.0	4.6		4.1
631224	1451	4.1	2	3.1		2.9	3.1		3.0
631229	0415	4.0	4	3.0		3.7			3.4
641018	1833	4.3	4	3.4		3.4	4.8		3.9
650114	1230	4.5	3	3.7			3.7		3.7
650321	2256	4.0	3	3.0		2.5	3.0		2.8
650326	0051	4.3	4	3.4		2.6	3.2		3.1
650511	0150	4.1	1	3.1		2.5			2.6
650627	1924	4.1	2	3.1		2.6	3.5		3.1
650629	0746	4.4	2	3.5		2.7	3.6		3.2
660317	1147	4.5	5	3.7		4.2	5.0		4.3
660816	1802	6.1	5	5.9			5.4		5.7
661021	0713	4.9	1	4.2		3.9	4.5		3.9
670215	0328	4.4	7	3.5		3.6	4.2	4.3	3.9
670216	1921	4.0	1	3.0		3.9	4.1	4.0	3.9
670722	2151	4.2	1	3.3		3.6			3.5
671004	1020	5.2	11	4.7			5.2	5.4	5.1
671207	1333	4.3	3	3.4		3.5	4.4	3.3	3.7
680116	0858	4.1	2	3.1		3.5			3.4
680116	0942	4.0	1	3.0		3.9	4.1	3.8	3.9
680804	0623	4.0	1	3.0		2.5	3.2		2.9
680924	0210	4.0	1	3.0		3.4			3.3
681117	1433	4.6	5	3.8		3.3	3.4	3.7	3.6
700329	1240	4.6	2	3.8		4.6	4.8	4.6	4.5
710224	0708				3.6(NOS)		3.0		3.3
710422	2301				3.4(NOS)	2.6	3.6		3.2
711110	1114				3.0(ERL)	2.9			3.0
711110	1124				2.9(ERL)	2.9			2.9
711110	1338				2.6(ERL)	2.9			2.8
711110	1346				2.2(ERL)	2.4			2.3
711110	1410	4.5	1	3.7	4.0(ERL)	3.7	3.7		3.8
711110	1443				3.5(ERL)	3.3	3.5		3.4
711110	1608				3.0(ERL)	2.9			3.0
711110	1907				2.3(ERL)	2.7			2.5

COMPARISON OF UTAH LOCAL MAGNITUDES

		EDR MAGNITUDES				ML UTAH			
DATE	TIME	MB	NO	ML*	ML	DUG	PCU	LOG	AVML
711110	1941				3.5(ERL)	3.3			3.4
720103	1129	4.6	2	3.8	4.3(ERL)	4.3			4.2
720306	1333	4.6	2	3.8		3.1		3.1	3.2
720602	0315	4.6	2	3.8		3.6	4.4		4.0
721001	1942	4.7	3	3.9		4.0	4.5		4.1
730414	645	4.4	5	3.5	4.75(ERL)	3.9	4.4	4.4	4.2
730716	0636	4.2	1	3.3		2.7	2.7		2.8

The average values of M_L in Table 3 were useful in calibrating provisional formulas for duration magnitudes--directly for state stations recording on photographic paper, and indirectly for the new develocorder traces. The formula used to determine magnitudes for nearly all the smaller shocks of the Wasatch Front 12-year seismicity sample (Appendix C) was a duration-magnitude formula for DUG:

$$M(\tau_\Delta) = -3.26 + 2.60 \log_{10} (\tau_\Delta) + 5.0 \times 10^{-4} \Delta_x \qquad (1)$$

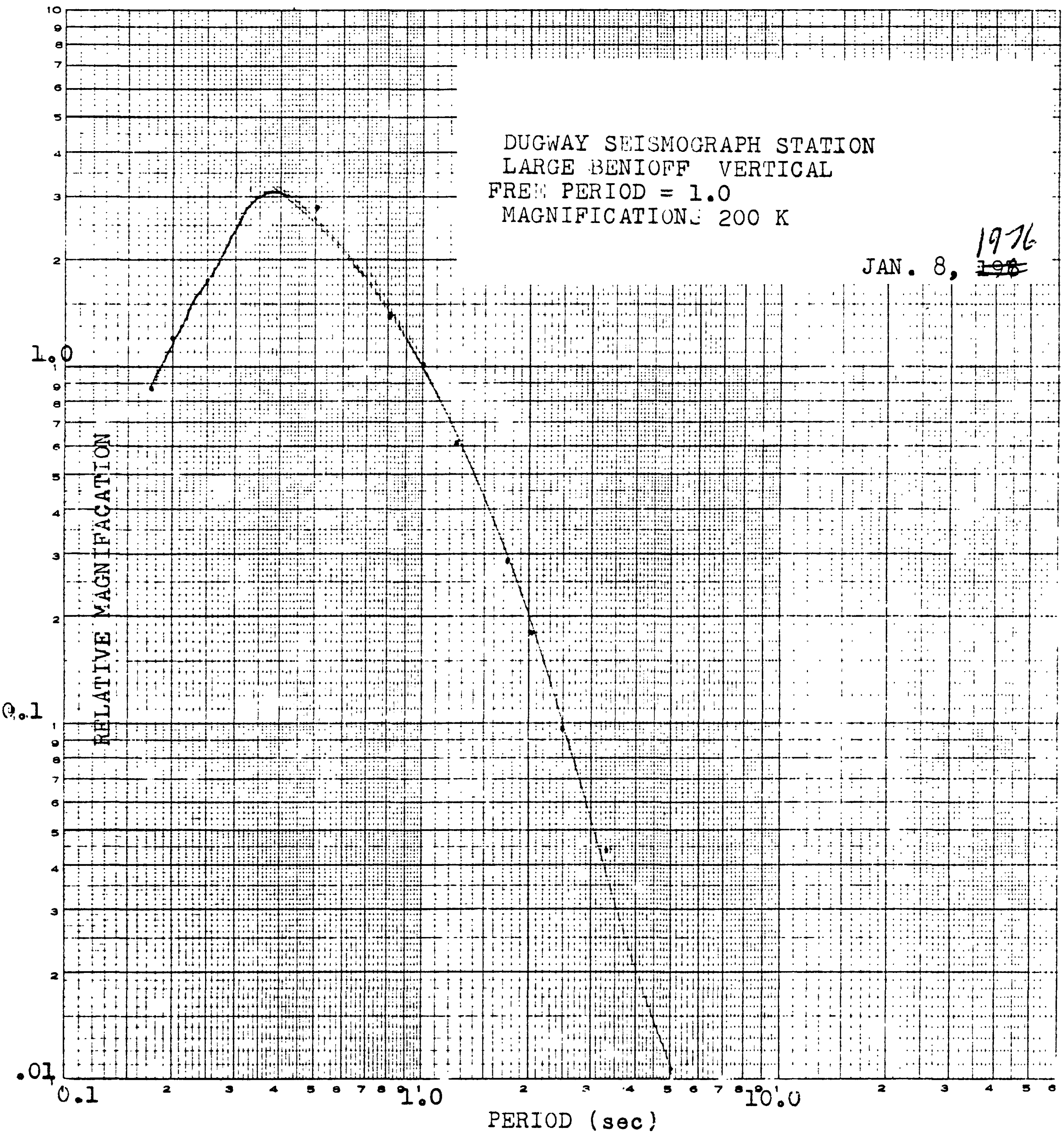
where τ_Δ is the total duration of signal in seconds at an epicentral distance Δ(km), $\Delta_x = \Delta - 200$ km, and $M(\tau_\Delta)$ is the Richter magnitude estimated from signal duration at an epicentral distance Δ(km). Using techniques similar to those described by Lee _et_. _al_. (1972), the formula is based on a fit of average values of M_L less than 4.0 in Table 3 to signal durations at DUG adjusted to a 200 km distance. The standard deviation of M_L for 35 observations was 0.22.

Attachment No. 2

Dugway Calibrations
Done by Steve Bellon and Bill Richins
January 8, 1976

Motor Constant Calibrations

(Z)	Wt. lift amplitude	= 32.0 mm
	EM Cal amplitude	= 35.2
	X_2 amplitude	= 1.5
	Damping ratio	= 23.6/1
	EM Cal driving force	= 2650 microamps
	18 db attenuation	
	Wt. used	= .5 gram
	G = 1.94 Newtons/ampere	
	D.B. setting	= 18
	Free period	= 60 h.p.m.
	Magnification	= 205k at 6 db
(N/S)	Wt. lift amplitude	= 31.5
	EM Cal amplitude	= 36.2
	X_2 amplitude	= 1.2
	Damping ratio	= 30.1/1
	EM Cal driving force	= 2650 microamps
	18 db attenuation	
	Wt. used	= 1.0 gram
	G = 1.85 Newtons/ampere	
	D.B. setting	= 18
	Free period	= 59.5
	Magnification	= 202k at 6 db
(E/W)	Wt. lift amplitude	= 34.0 microamps
	EM Cal amplitude	= 36.0
	X_2 amplitude	= 1.3
	Damping ratio	= 26/1
	EM Cal driving force	= 2650 microamps
	18 db attenuation	
	Wt. used	= 1.0 gram
	G = 1.96 Newtons/ampere	
	D.B. setting	= 18
	Free period	= 610 h.p.m.
	Magnification	= 210k at 6 db


DUGWAY SEISMOGRAPH STATION
LARGE BENIOFF VERTICAL
FREE PERIOD = 1.0
MAGNIFICATION 200 K
JAN. 8, 1976
RELATIVE MAGNIFACATION
1.0
0.1
.01
0.1
1.0
10.0
PERIOD (sec)

U. S. A.

UNIVERSITY OF WASHINGTON: EASTERN WASHINGTON NET

1. Name of Network or Station: Eastern Washington

2. Mailing Address: Geophysics Program, AK-50, University of Washington, Seattle, Washington 98195

3. Type of instruments used for local magnitude determination: Mark 4, Mark Product Ranger (Kinemetrics)

4. Magnification-frequency response curve of instruments (Please cite reference or attach document): not known

5. Components used (Z or H): SPZ

6. Specific phase used (P,S,Lg, none): none

7. Parameters measured (A,A/T,Duration): coda length

8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document):
m = -.87 + 2.0 log (coda length in seconds) + 0.0035 (epicenter distance in kilometers)

9. Period range over which magnitudes are determined: not applicable

10. Distance range over which magnitudes are determined: 3 degrees

11. Tectonic setting (Continental,oceanic,etc.): Continental, basaltic shield

12. How is magnitude averaged from individual station determinations? arithmetic average

13. What station or source corrections are used if any? none

14. Estimate of consistency of magnitude determinations, and any known errors: There are errors, depending on person picking coda length (± 0.5).

15. Known relationships with local magnitudes determined by other networks: We have problems and are in the process of reevaluating and refining our present method of magnitude determination.

16. Known relationships between local magnitudes and standard teleseismic magnitudes: not known

17. References (Please attach reprint(s) or report(s)):

18. Reply to this Survey is prepared by: Norman Rasmussen
Date: 3/15/76

U. S. A.

UNIVERSITY OF WASHINGTON: LON (WWSSN) STATION

1. Name of Network or Station: LON, WWSSN, Longmire
2. Mailing Address: Geophysics Program, AK-50, University of Washington, Seattle, Washington 98195
3. Type of instruments used for local magnitude determination: SPZ Benioff
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): WWSSN (100K at 1.0 sec.)
5. Components used (Z or H): Z
6. Specific phase used (P,S,Lg, none): P
7. Parameters measured (A,A/T,Duration): A/T
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): We compute local Richter magnitude from other instruments. A/T data is sent to USGS, NEIS and ICS, Scotland.
9. Period range over which magnitudes are determined: 0.5 - 1.5
10. Distance range over which magnitudes are determined: all, except small local shocks
11. Tectonic setting (Continental,oceanic,etc.): N.W., U.S. coastal
12. How is magnitude averaged from individual station determinations? see #8
13. What station or source corrections are used if any? none
14. Estimate of consistency of magnitude determinations, and any known errors: see #8
15. Known relationships with local magnitudes determined by other networks: none
16. Known relationships between local magnitudes and standard teleseismic magnitudes: not known
17. References (Please attach reprint(s) or report(s)): none
18. Reply to this Survey is prepared by: Norman Rasmussen
Date: 3/15/76

U. S. A.

UNIVERSITY OF WASHINGTON: WESTERN WASHINGTON REGIONAL NETWORK

1. Name of Network or Station: Western Washington Regional Network
2. Mailing Address: Geophysics Program, AK-50 / University of Washington, Seattle, Washington
3. Type of instruments used for local magnitude determination: Short-period 1 Hz vertical seismometers (Mark Products L4-c)
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): See Crosson, R. S., Bull. Seis. Soc. Am., v. 62, no. 5, p. 1133, 1972
5. Components used (Z or H): Z
6. Specific phase used (P,S,Lg, none): none
7. Parameters measured (A,A/T,Duration): Duration
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document):
   $m = -2.46 + 2.82 \log \overline{(F-P)}$; $\overline{(F-P)}$ = average duration
9. Period range over which magnitudes are determined: NA (pass band of instruments)
10. Distance range over which magnitudes are determined: 0 - 400 km from array center
11. Tectonic setting (Continental,oceanic,etc.): Continental (near margin)
12. How is magnitude averaged from individual station determinations? Duration of individual stations read is averaged, then formula applied.
13. What station or source corrections are used if any? No station or source corrections for distance applied. Weak stations deleted at discretion of observer.
14. Estimate of consistency of magnitude determinations, and any known errors: Standard error for suite of estimates ≈ 0.2 mag. unit.
15. Known relationships with local magnitudes determined by other networks: none / note calibration of method accomplished using Wood / Anderson magnitudes determined at University of Washington and LON stations.
16. Known relationships between local magnitudes and standard teleseismic magnitudes: none examined in detail to date
17. References (Please attach reprint(s) or report(s): see 4 above
18. Reply to this Survey is prepared by: Robert S. Crosson
    Date: Aug. 16, 1976

U. S. A.

VIRGINIA POLYTECHNIC INSTITUTE: BLA (WWSSN), BAV, & CPO STATIONS

1. Name of Network or Station: BLA (WWSSN); BAV; CPO

2. Mailing Address: Dept. of Geological Sciences, Virginia Polytechnic Institute & State University, Blacksburg, Virginia 24061

3. Type of instruments used for local magnitude determination: Benioff SPZ; Geotech S-13; Johnson-Matheson

4. Magnification-frequency response curve of instruments (Please cite reference or attach document): WWSSN; Attached for BAV; CPO not yet calibrated (just began telemetry to Blacksburg)

5. Components used (Z or H): Z

6. Specific phase used (P,S,Lg, none): Lg

7. Parameters measured (A,A/T,Duration): A/T

8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): Lg formula by Bollinger (BSSA, 63, 1973, pp. 1785-1808) Agrees with Nuttli's $M_b(Lg)$*

9. Period range over which magnitudes are determined: 0.4 to 1.2 sec.

10. Distance range over which magnitudes are determined: 100 km to 1000 km

11. Tectonic setting (Continental,oceanic,etc.): Continental margin

12. How is magnitude averaged from individual station determinations? BLA and BAV are averaged

13. What station or source corrections are used if any? None used

14. Estimate of consistency of magnitude determinations, and any known errors:

15. Known relationships with local magnitudes determined by other networks:
 * Agrees with St. Louis University network within ± 0.2 units

16. Known relationships between local magnitudes and standard teleseismic magnitudes:
 Adjusted to m_b

17. References (Please attach reprint(s) or report(s)):

18. Reply to this Survey is prepared by: G.A. Bollinger GAB
 Date: March 5, 1976

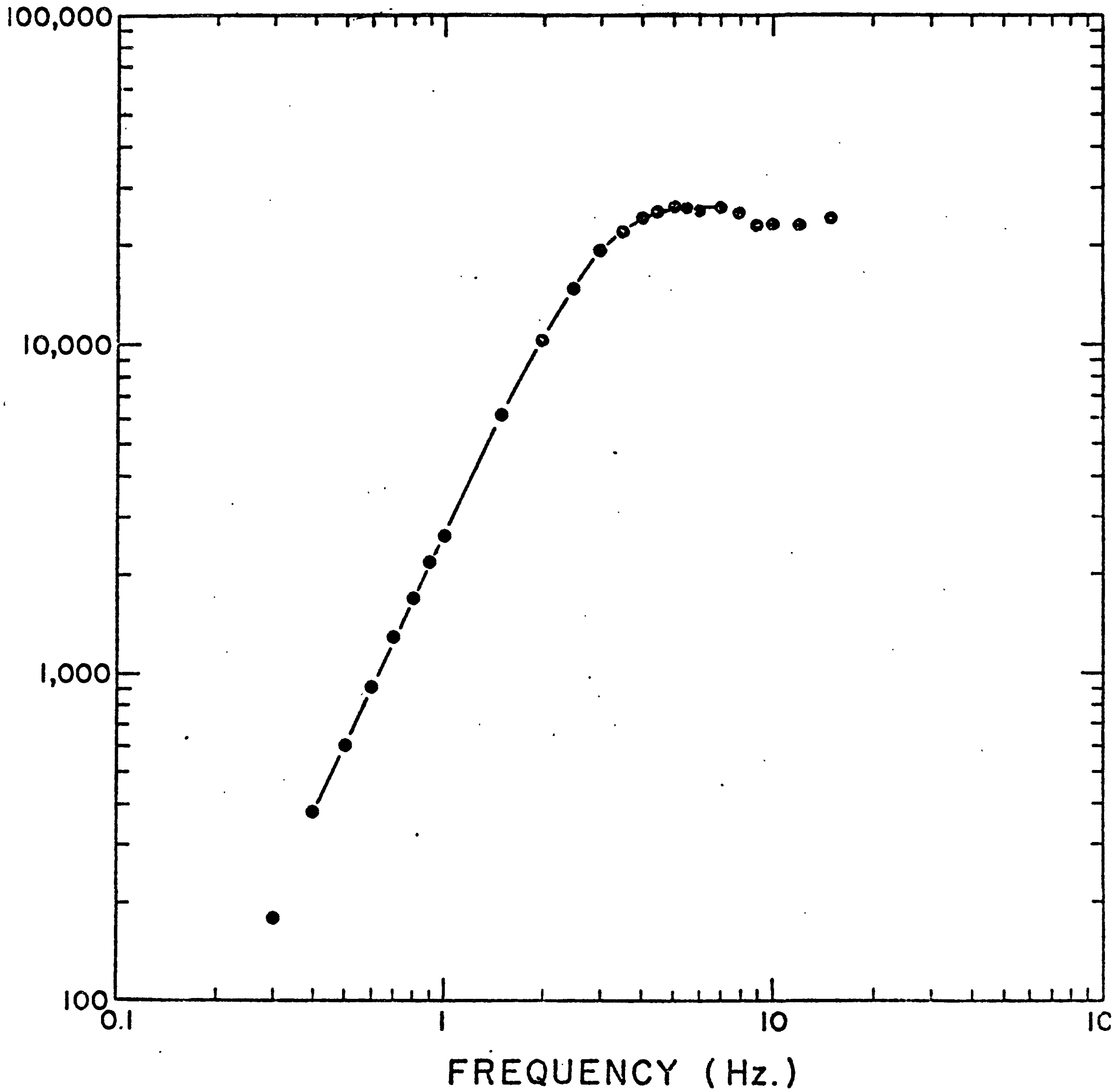
STATION BAV

VPI SS-80 SEISMOGRAPH

Geotech S15 Seismometer (1 Hz) With Sprengnether SS-80 Recorder and Chronometer.

Filters: Low-Out, High-5 Hz.

Location: 37.222° N - 80.425° W; elev. - 622 m.



BAV

VIRGINIA POLYTECHNIC INSTITUTE & STATE UNIVERSITY

Department of Geological Sciences

SS - 80 SEISMOGRAPH - Room 1040-A Derring Hall
Filters: Out and 5 Hz.

Frequency (Hz.)	Period (sec.)	Magnification (96dB)	(102dB)	(90db)
0.1	10.0	5	7	2
0.2	5.0	55	85	30
0.3	3.33	180	270	90
0.4	2.50	380	580	190
0.5	2.00	610	920	300
0.6	1.66	930	1400	460
0.7	1.43	1300	2000	660
0.8	1.25	1700	2600	860
0.9	1.11	2200	3300	1100
1.0	1.0	2600	4000	1300
1.5	0.66	6200	9400	3100
2.0	0.50	10,300	15,600	5200
2.5	0.40	14,800	22,400	7400
3.0	0.33	19,200	29,000	9600
3.5	0.28	22,200	33,600	11,100
4.0	0.25	24,200	26,600	12,100
5.0	0.20	25,600	38,600	12,800
6.0	0.17	25,400	38,300	12,700
8.0	0.12	24,800	37,400	12,400
10.0	0.10	22,900	34,600	11,500

System: Teledyne-Geotech S13 Seismometer (1 Hz.) with Sprengnether SS-80 Recorder and Chronometer

Location: 37° - 13' - 19.4"N (37.222) Elev. 622m. 80° - 25' - 30"W (80.425)

Direction of motion: Up on the ground = Down on the record

Magnification: Set at 96dB unless otherwise specified

Note: This seismograph is not located in the BLA WWSSN vault.

1. Name of Network or Station: **VENEZUELAN SEISMIC NETWORK:CAR,SIR,CUM,LGN,UAV,TOV,SDV**

2. Mailing Address: **Dr.Günther Fiedler B. Head Seismic Institute, Observatorio Cagigal, DHN/COMGEMAR, apartado 6745, Caracas, Venezuela.**

3. Type of instruments used for local magnitude determination: **CAR: WWSSS-SPZ,GEOTECH S-13,KINEMETRICS RANGER SS1.UAV,TOV,SDV:GEOTECH S-13,CUM,LGN:Sprengnether SPZ.SIR SS1.**

4. Magnification-frequency response curve of instruments (Please cite reference or attach document): **See annexed RESPONSE CURVES for CAR,SIR,LGN,CUM Due to re-installations in SDV,UAV,TOV response curves unknown at the moment.**

5. Components used (Z or H): **Short period vertical**

6. Specific phase used (P,S,Lg, none): **P-waves (P, Pg,Pb,Pn,PкP under test.)**

7. Parameters measured (A,A/T,Duration): **Ground amplitude and period**

8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): **see annexed formula and Q-values for CAR**

9. Period range over which magnitudes are determined: **.1 sec. to 3 sec. and 20 sec.**

10. Distance range over which magnitudes are determined: **0 to 1000 Km by MC,-also Mb**

11. Tectonic setting (Continental,oceanic,etc.): **continental**

12. How is magnitude averaged from individual station determinations? **No avarage made for national network.PDE-Magnitude should give standard deviations etc.**

13. What station or source corrections are used if any? **The factor(!) 0,82 in formula for MC (that "C" stands for Caracas).**

14. Estimate of consistency of magnitude determinations, and any known errors: **Errors due to nodal planes, - not all P-waves are the same P-waves, it depends on epicentral distances and instrumental sensitivities etc.**

15. Known relationships with local magnitudes determined by other networks: **-**

16. Known relationships between local magnitudes and standard teleseismic magnitudes:

17. References (Please attach reprint(s) or report(s)):

18. Reply to this Survey is prepared by: **Dr.Günther Fiedler B., CAR**

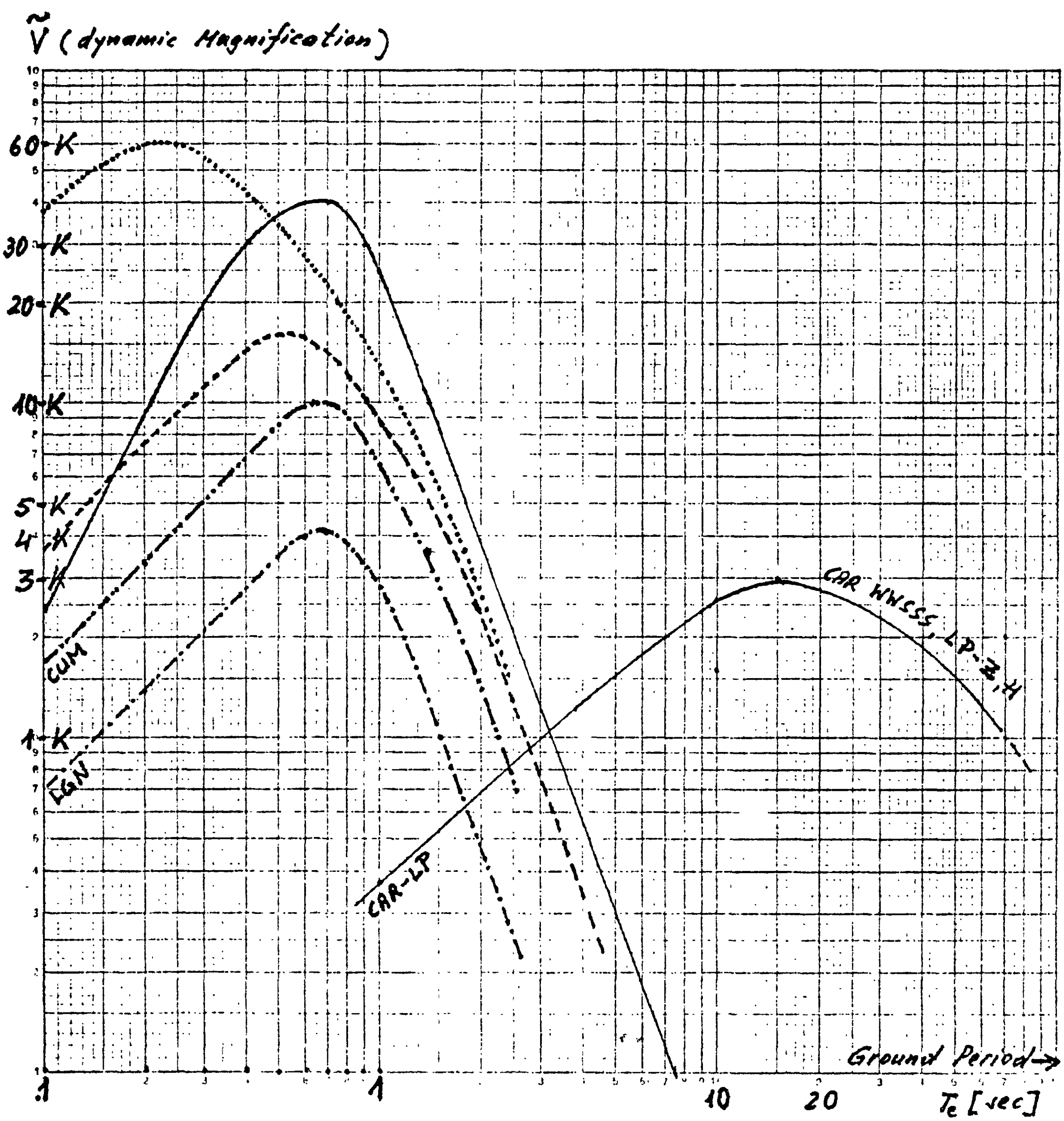
Date: **8-VI-1976**

2 annexes.

—— CAR, WWSSS-SPZ, T_n = 1sec., T_g = 0.8 sec., $\tilde{V}$ 25K for 1sec; WWSSS-LPZ, H.
- - - - CAR, (OEA) RANGER-VA1 Kinemetrics, T_n = 1sec, Potentiometer 1.0
.... CAR, Geotech S-13-Helicorder, T_n = 1sec, Potentiom. in 0 dB
- - - - SIR, same as CAR-OEA-Ranger, variable Gain-settings.
-.-.-. LGN, SPRENGNETHER SPZ - 1sec, Galvo 0.8 sec.

UAV, SPZ
TOV, SPZ
SDV, SPZ
} not well calibrated, instrumental interchanges made by others.

-..-..- CUM, SPRENGNETHER SPZ, 1sec, Galvo 0.8 sec.



Dr. Günther Fiedler S.
Caracas, 8-VI-1976

VALORES Q_v PARA EL CALCULO DE MAGNITUD MC = mb de ONDAS "P" para SISMOS CERCANOS, con Δ entre 0 hasta 1.000 KMS

$$MC = Mb = 0.82 \ (Q_v + \log_{10} (v_z))$$
$$= 0.82 \ (Q_v + \log_{10} (\frac{2\pi A}{\tilde{V} \cdot T_e}))$$

en donde : Q_v es un factor de distancia

v_z es velocidad vertical de particulas del suelo, del sismograma SPZ

"A" es la amplitud traza single, en <u>cms</u> , del SPZ

$\tilde{V}$ es la magnificación del SPZ para T_e

T_e es el PERIODO de la onda sísmica registrada y usada para la medición de la amplitud "A",- en general una de las primeras ondas longitudinales.

Dist. Kms → / Prof. (depth) Kms ↓	25	50	75	100	200	300	400	500	600	700	800	900	1.000 Kms Δ
0-25	6.2	6.5	7.2	7.7	8.3	9.0	9.3	9.5	9.7	9.9	10.0	10.3	10.4
50	7.2	7.3	7.5	7.7	8.1	8.6	9.2	9.3	9.3	9.4	9.5	9.6	9.7
75	6.9	7.0	7.1	7.2	7.6	8.0	8.4	8.9	9.2	9.4	9.7	9.7	9.7
100	6.9	7.0	7.1	7.2	7.5	7.7	8.2	8.8	9.1	9.5	9.7	9.8	9.9
125	7.2	7.3	7.3	7.4	7.7	8.2	8.2	8.5	8.7	9.4	9.7	9.7	9.7
150	7.7	7.9	8.0	8.2	8.4	8.6	8.8	9.1	9.2	9.3	9.4	9.4	9.4
175	7.9	8.0	8.1	8.2	8.5	8.9	9.1	9.2	9.3	9.4	9.5	9.5	9.4
200	8.0	8.1	8.1	8.2	8.7	9.0	9.2	9.3	9.4	9.4	9.3	9.2	9.1

[illegible]

CAR

P. VI. 1976

WEST INDIES

UNIVERSITY OF WEST INDIES: PORTABLE NET

1. Name of Network or Station: Portable network used in a volcanic island at times of seismic crises.
2. Mailing Address: Seismic Research Unit, University of the West Indies, St. Augustine, Trinidad, W.I.
3. Type of instruments used for local magnitude determination: Willmore Mk II & Racal-Thermionic multichannel magnetic tape system, V.H.F. radio links. Events played out on Ningograph 800 jet for oscillograph.
4. Magnification-frequency response curve of instruments (Please cite reference or attach document): Will send this later
5. Components used (Z or H): Z
6. Specific phase used (P,S,Lg, none): P
7. Parameters measured (A,A/T,Duration): $\frac{A}{T}$ We are investigating the use of duration.
8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): $M_B = \log \frac{A}{T} + Q$. We do not know the value of Q, so use the amount of increase in $-\log A_o$ from the value at Δ = 0 km (Richter's "Elementary Seismology", Table 22-1 p. 342 (1958 edition))
9. Period range over which magnitudes are determined: Approx. 0.06 - 0.20 sec.
10. Distance range over which magnitudes are determined: 0 - 20 km
11. Tectonic setting (Continental,oceanic,etc.): Volcanic island arc
12. How is magnitude averaged from individual station determinations? Arithmetic mean of all station determinations for a particular event.
13. What station or source corrections are used if any? None
14. Estimate of consistency of magnitude determinations, and any known errors: We don't know the value of Q for short distances.
15. Known relationships with local magnitudes determined by other networks: We have a Wood-Anderson Seismograph and we will eventually calibrate our equipment with this so that we can determine more meaningful local magnitudes.
16. Known relationships between local magnitudes and standard teleseismic magnitudes:
17. References (Please attach reprint(s) or report(s)):
18. Reply to this Survey is prepared by: Marion Michael Leiba
    Date: May 13, 1976

WEST INDIES

UNIVERSITY OF WEST INDIES: TRINIDAD NET

1. Name of Network or Station: Trinidad, Seismic Research Unit

2. Mailing Address: Seismic Research Unit, University of the West Indies
St. Augustine, Trinidad, W.I.

3. Type of instruments used for local magnitude determination: (1) Vela Uniform (WWSS)
(2) Willmore-Watts SPZ only. To 0.8 sec. Tg 0.25 sec.

4. Magnification-frequency response curve of instruments (Please cite reference or attach document):

5. Components used (Z or H): Z

6. Specific phase used (P,S,Lg, none): P

7. Parameters measured (A,A/T,Duration): A/T

8. Formulas or graphs used in local magnitude determinations including calibration functions for distance and depth (Please cite reference or attach document): $M_B = \log (A/_T) + Q - \frac{(\log A/_T + Q - 0.7)}{9}$ Q is obtained from Gutenberg BSSA Vol 35 (1945) p 126 and p 123
(N.B. Q = A - 3.0)

9. Period range over which magnitudes are determined: 0.1 - 1.0 sec.

10. Distance range over which magnitudes are determined: 0° - 30°

11. Tectonic setting (Continental,oceanic,etc.):

12. How is magnitude averaged from individual station determinations? Average of individual station values.

13. What station or source corrections are used if any? $- \frac{(\log A/_T + Q - 0.7)}{9}$

14. Estimate of consistency of magnitude determinations, and any known errors:

15. Known relationships with local magnitudes determined by other networks:

16. Known relationships between local magnitudes and standard teleseismic magnitudes:

17. References (Please attach reprint(s) or report(s)):

18. Reply to this Survey is prepared by: [signature]
Date: 20 May 1976