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Record No. 1971/75

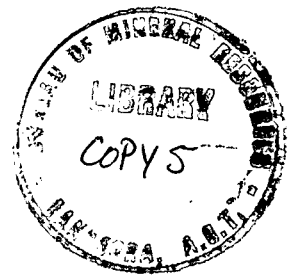
Refraction Recording of Geotraverse Explosions 1969 — Operational Report

by

P. J. Gregson
and
E. P. Paull

RECORD NO. 1971/75

REFRACTION RECORDING OF GEOTRAVERSE EXPLOSIONS 1969 - OPERATIONAL REPORT



By

P.J. GREGSON

and

E.P. PAULL

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SUMMARY

During 1969, the Mundaring Geophysical Observatory collected seismic refraction data from explosions used by the Bureau of Mineral Resources No. 2 seismic party in the southwest of Western Australia.

The seismic party exploded 37 charges up to 4,500 kilograms on a traverse from Balladonia through Kalgoorlie to Perth. Two mobile Willmore seismographs and permanent seismographs at Mundaring and Kalgoorlie recorded the resultant seismic waves.

A brief account is given of the operational aspects of the project; data obtained from the project are listed. They are being analysed in terms of earth structure, and an interpretation will be presented separately.

1. INTRODUCTION

During 1969, the Bureau of Mineral Resources No. 2 Seismic Party carried out seismic reflection probes along the Geotraverse from Balladonia, through Kalgoorlie, to Perth (Branson, 1971). The refracted waves from the explosions were recorded by the Mundaring Geophysical Observatory.

The Seismological stations at Mundaring and Kalgoorlie; a semi-permanent station at Southern Cross, and two roving field stations were used to record these events. The Meekatharra seismograph recorded one event.

The purpose of this record is to describe briefly the operational methods used by the Observatory, and to list the refraction data collected. The scientific interpretations will be presented in a later report.

The personnel engaged in the work and their duties are listed in Appendix A.

2. AIMS OF THE PROJECT

The project of recording refracted waves was to supplement data collected during project FRUMP (Gregson & Woad, 1968) which had the following broad aims:

(a) To investigate the deep structure and thickness of the earth's crust in the region of the south western Precambrian shield. Variations of the earth's crustal thickness occur, particularly near the edges of the continents, where these investigations should assist in determining the nature of the continent.

(b) To investigate parameters of seismic waves in the upper part of the earth's mantle in this region. Geophysicists are interested in the structure of the globe as a whole, and particularly in the mantle beneath a stable shield, such as exists in South Western Australia.

(c) A better knowledge of the structure of the earth's crust, upper mantle, and their parameters will enable the Mundaring Observatory to locate local tremors more accurately.

3. OPERATIONS.

The No. 2 Seismic Party commenced firing shots, suitable for refraction recording by the Observatory, on 3 July, 1969. Up to four suitable shots per week were fired, until the survey was concluded on 27 November 1969.

Communications

Radio communications between Mundaring Observatory Seismic Party, and field units using Traeger transceivers (6.815 MH_2) were generally good except for a few days in September when conditions were disturbed. One of the field Traegers became unreliable in the latter part of the survey, but could still be used for receiving. No record loss resulted from breakdown in communications.

Sufficient warning of the proposed shot times was given by the Seismic Party to allow the observatory staff to set up field recorders.

Radio schedules were arranged for an hour or half hour before the proposed shot time, when revised shot times were broadcast, depending on the readiness of the shooting party and field stations. A final warning five minutes before the shot time was given, after which, the field parties had three minutes in which to stop the shot, if recorders were malfunctioning. The shooter turned off transmitters and receivers two minutes before the shot time, and the shot was then fired within ten minutes of the stated time. The shooter broadcast gave confirmation that the shot had been fired.

Shot sites

The shot sites were selected and their positions determined by the Seismic Party. The Observatory recorded shots from seven sites; at Fraser Range, Boorabbin, Woolgangie, Hines Hill, Doddlakine, Walgoolan, and Wundowie. In addition, a single shot was fired in the abandoned Jubilee Mine Shaft, 60 km east of Kalgoorlie.

The position and number of each shot are shown in Plate 1, and listed with shot instant and size in Table 1.

Explosions

The explosives used were either ammonium nitrate or Geophex and were generally between 900 and 4500 kilograms (Geophex equivalent) located in a number of holes drilled to a depth of about 40 metres. Branson (in prep) gives further details relating to the shot pattern, etc. Geophex shots below the water table resulted in recorded amplitudes up to four times those recorded from ammonium nitrate shots.

Shot instants

The shot instant was recorded electrically on the seismic party's recording unit together with one-second radio signals from VNG (12 MH_z). Absolute shot time could then be determined to one millisecond.

Mundaring site

The shots were recorded on a fast-run (240 mm/minute) Willmore recorder with a short-period Benioff seismometer. Eight coils were used in two series of four in parallel. See Table 4 for the details of instrumentation.

Twenty nine of the possible 31 shots were recorded. The two shots missed were caused by operator error.

Kalgoorlie and Meekatharra sites

The seismographs at Kalgoorlie and Meekatharra were operated continuously, during the project, with no special modifications. Kalgoorlie recorded nineteen shots, but all other shots were too far away to record. The seismic waves from only one shot (Boorabbin, No. 1400) were large enough to record at Meekatharra. This shot was 4,500 kg of Geophex and was fired below the water table.

Field stations

Two mobile field units were used as seen in detail in (Table 4). Mobile 1 consisted of a fast-run (200 mm/minute) Willmore seismograph with a Geotech amplifier (Type EA-300) and VNG radio controlled timing.

Mobile 2 consisted of a Willmore seismometer, operational amplifier (about ten times), and Moseley pen recorder (200 mm/minute) with VNG radio controlled timing. As this equipment proved unreliable, and the paper drive speed varied considerably, results were not as accurate as desired. The equipment was replaced after the Boorabbin shots, with a Willmore seismograph similar to Mobile 1, but without an amplifier.

Where possible, stations occupied on previous projects (in particular FRUMP) were used. New stations were selected about a mile from main highways and several hundred yards from secondary roads. In most cases, stations were situated in open fields away from trees, and if possible, where rocks were near the surface and covered only by sandy or gravelly alluvium. The seismometers were preferably buried and well tamped in, but occasionally sites were on large flat rocks. In these instances, the seismometers were placed on the surface, and protected from the wind by small stone cairns, or instrument boxes.

Station positions were plotted accurately to within 0.1 kilometres on Western Australian Government Lands and Survey Lithographs (1 inch = 1 mile). Positions were checked by using Bureau of Mineral Resources magnetic and radiometric maps (1 inch = 2 miles).

Field stations are shown in Plate 1, and listed in Table 2 together with their co-ordinates. The field stations range from 30 to 390 km from the shot-points.

Mobile 1 recorded 27 of a possible 31 shots, and mobile 2 only 11 of a possible 27 shots. The poor return for mobile 2 was mainly caused by equipment failure in the first stage of the project, and operator inexperience with Willmore recorders in the first part of stage 2.

Distance calculations

Distances from shot-points to recording stations were calculated using the formula and tables given by Richter (1958) for the calculation of short distances from their geographical co-ordinates. Calculations were checked by headquarters electronic computer program EPICENT and they agreed to within 0.3 kilometres.

4. TRAVEL TIMES

Seismic phases were read from all seismographs, and travel times calculated. Table 3 lists the distances from shot-point to recording station, and the travel time of each phase recorded. Travel times shown to two decimal places are considered accurate to 0.03 seconds, those to one decimal place accurate to 0.2 seconds, and those without decimals accurate to one second.

To assist with later interpretation of results, Plate 2 diagramatically shows the sections of the geotraverse over which refracted waves were recorded.

5. CONCLUSIONS

The project proved satisfactory considering the small number of staff available for field recording, and carrying out the normal observatory duties.

Three recommendations are made for future projects:

(a) The Geotech type EA-300 amplifier proved a useful and reliable addition to the Willmore field seismographs. It increased the recording range from about 200 to 350 kilometres and was limited only by background noise. Further units should be purchased for use in the field.

(b) The Moseley 680 pen recorder is unsatisfactory for seismic recording.

(c) Where possible, field operators should have prior experience in operating Willmore recorders.

6. REFERENCES

BRANSON, J.C. (in prep) - Deep Crustal Seismic Investigations along the Geotraverse, W.A., 1969. Bur. Miner. Resour. Aust. Rec.

GREGSON, P.J. and WOAD, G. 1968 - Fremantle Region Upper Mantle Project 1967, Operational Report. Bur. Miner. Resour. Aust. Rec. 1968/6. (unpubl.).

RICHTER, R.F. 1958 - ELEMENTARY SEISMOLOGY. San Francisco. W.H. Freeman & Co.

APPENDIX A

PERSONNEL AND DUTIES

P.J. Gregson	Mundaring Base Co-ordinator.
J.C. Branson	Party Leader, Seismic Party No. 2.
A. Parkes	Mundaring Seismic Station
G. Woad	Mundaring Seismic Station
E.P. Paull)	Mobile Field Station No. 1.
I.B. Everingham)	
P. Harrison)	Mobile Field Station No. 2.
J.B. Connelly)	

TABLE 1

SHOT DATA

Date	Shot No.	Latitude °S	Longitude °E	Shot Time 120° EMT	Size Kilograms
BOORABBIN					
1969					
9 Sep	1106/1	31° 24.6'	120° 00.4'	14 44 47.149	900
9	1106/2	31° 24.6'	120° 00.4'	16 30 50.108	4500
10	1105	31° 25.9'	120° 00.4'	16 29 53.097	2700
16	1107	31° 23.3'	120° 00.4'	12 03 54.476	4500
18	1303/1	31° 14.0'	120° 09.6'	14 37 51.770	3700
23	1303/2	31° 14.0'	120° 09.6'	13 05 52.157	3900
24	1305/1	31° 13.4'	120° 12.5'	13 06 50.386	4400
26	1305/2	31° 13.4'	120° 12.5'	11 45 53.789	4900
29	1304	31° 13.7'	120° 11.1'	15 24 54.757	3600
1 Oct	1400	31° 16.1'	120° 11.5'	14 31 50.420	4500
3	1306	31° 13.0'	120° 13.9'	12 14 52.190	2000
8	1591	31° 10.9'	120° 26.7'	11 34 51.583	3000
8	1301	31° 14.6'	120° 06.7'	16 07 53.914	1300
HINES HILL					
17 Oct	1616/1	31° 39.4'	118° 05.8'	16 16 53.654	2700
21	1616/2	31° 39.4'	118° 05.8'	14 20 50.024	1800
23	1715/1	31° 49.0'	118° 08.4'	13 09 48.055	4500
24	1715/2	31° 49.0'	118° 08.4'	15 24 51.158	4500
27	1713/1	31° 49.5'	118° 05.5'	14 07 51.628	2800
28	1616/3	31° 39.4'	118° 05.8'	14 50 50.048	1800
29	1615	31° 40.5'	118° 06.0'	14 44 49.762	1800
31	1614/1	31° 41.7'	118° 06.3'	10 14 50.912	1500
4 Nov	1613/1	31° 42.8'	118° 06.6'	12 34 49.704	1400
5	1612	31° 44.0'	118° 06.9'	11 54 51.690	1300
7	1617	31° 38.2'	118° 05.4'	15 31 49.122	900

TABLE 1 (Continued)

SHOT DATA

Date	Shot No.	Latitude °S	Longitude °E	Shot Time 120° EMT	Size Kilograms
DOODLAKINE					
11 Nov	1813/2	31° 27.3'	117° 50.4'	15 54 51.841	4000
12	1813/3	31° 27.3'	117° 50.4'	15 06 51.908	3400
13	1813/4	31° 27.3'	117° 50.4'	14 07 51.598	3400
WUNDOWIE					
21 Nov	2012	31° 42.7'	116° 23.5'	15 04 52.676	1800
25	2014	31° 40.3'	116° 23.5'	15 09 47.00	4600
27	2010	31° 45.1'	116° 23.5'	15 09 52.608	1900
JUBILEE					
7 Oct	JUB	30° 31.0'	122° 02.5'	13 05 00.582	4500
WALGOOLAN					
14 Nov	WGL	31° 22.2'	118° 37.4'	14 30 00.0**	3200
FRASER RANGE					
26 Jun	502	32° 05.0'	123° 05.0'	12 08 51.642	1400
27	501	32° 04.4'	123° 03.8'	10 44 53.297	1400
1 Jul	505	32° 06.9'	123° 08.7'	12 15 55.570	4500
2	509	32° 09.3'	123° 13.7'	10 41 53.126	900
3	508/1	32° 09.0'	123° 13.1'	11 16 54.503	

NOTE: ** Shot exploded manually on radio pip.

TABLE 2

RECORDING STATIONS

Station	Code	Latitude °S	Longitude °E	Litho No
Gosnells Pool	GOP	32° 03.8'	116° 02.0'	341/80
Gleneagle North	GLN	32° 16.4'	116° 09.9'	341/80
Mundaring	MUN	31° 58.7'	116° 12.5'	-
The Lakes "A"	LAA	31° 53.1'	116° 24.5'	2/80
Avon	AVO	31° 52.1'	116° 35.4'	2/80
York	YOR	31° 48.7'	116° 49.6'	2/80
Meckering West	MEW	31° 36.7'	116° 58.2'	26/80
Cunderdin	CUN	31° 41.7'	117° 16.4'	26/80
Tammin	TAM	31° 36.4'	117° 29.9'	26/80
Kellerberin	KEL	31° 39.7'	117° 41.6'	26/80
Doodlakine	DOO	31° 37.7'	117° 54.4'	25/80
Hines Hill	HHL	31° 46.1'	118° 07.5'	25/80
Merredin	MRD	31° 31.1'	118° 16.4'	24/80
Carrabin	CAR	31° 22.0'	118° 40.2'	35/80
Moorine Rock	MOO	31° 23.0'	119° 06.2'	36/80
Southern Cross	SXC	31° 13.9'	119° 19.4'	36/80
Yellowdine	YEW	31° 19.1'	119° 39.6'	24/240
Boorabbin Probe	BRP	31° 25.9'	120° 00.4'	24/240
Boorabbin	BOO	31° 13.4'	120° 18.2'	24/240
Woolgangie	WOO	31° 10.9'	120° 26.7'	24/240
Coolgardie	COO	30° 51.4'	121° 17.3'	50/80
Kalgoorlie	KLG	30° 47.0'	121° 27.5'	-
Curtin	CUR	30° 54.7'	121° 59.3'	49/80
Karonie	KAR	30° 58.4'	122° 32.4'	41/80
Chifley	CHY	30° 59.7'	122° 50.1'	26/240
Pinjarra	PIB	32° 42.2'	115° 57.9'	380/80
Marradong T.O. "B"	MTB	32° 55.9'	116° 41.4'	384/80
Tarwongup	TAR	33° 11.3'	116° 59.0	409/80
Boscabel South "B"	BSB	33° 41.8'	117° 09.4'	416/80
Cranbrook West	CRW	34° 18.2'	117° 28.0'	444/80
Mt Barker	MBR	34° 35.1'	117° 41.8'	445/80
Yallingup	YAL	33° 43.2'	115° 02.2'	413/80

TABLE 3

TRAVEL TIMES

Station	Shot	Distance (km)	P Travel Times (Sec) 1	2	3	4	S Travel Times (Sec) 1	2	3	4
BOORABBIN SHOTS (WEST)										
YEW	1106/1	34.5	5.73				10.09			
YEW(M)	1301	43.8	13.2							
MOO	1106/2	86.0	14.13							
SXC	1591	107.1	17.59							
CAR	1400	145.4	23.61				40.6			
CAR (M)	1591	170.4	27.6				47.8			
DOO	1105/1	200.8	32.26	32.8	35.1		55.7	59.8		
MRD	1591	210.2	31.84	32.22						
KEL	1306	246.5	36.09	38.9			((62.8))	67		
TAM	1305/1	261.4	40.61		54.21		72.4			
CUN	1305/2	284.1	((40.54))	44.45			76.8			
YOR	1303/2	323.3	45.09	50.17	52.74		88.75	94.84		
AVO	1304	348.9	49.0							
MUN	1105	365.5	50.2	50.90	58.90					
MUN	1106/2	365.9	50.2	50.88	58.92					
MUN	1107	366.4	50.1	50.84	58.80					
MUN	1303/1	384.3	52.43	61.2						
MUN	1303/2	384.3	52.58	61.26						
MUN	1400	386.4	52.62	55.08	62.3		92.6			
MUN	1304	386.8	52.82	61.64						
MUN	1306	391.4	53.30	62.4			93.6			
BOORABBIN SHOTS (EAST)										
KLG	1591	106.5	17.72				33.8			
KLG	1306	126.7	21.01				36.0			
KLG	1305/1	129.1	21.51				36.5			
KLG	1305/2	129.1	21.61				36.8			
KLG	1304	131.4	22.04				38.0			

TABLE 3 (continued)

TRAVEL TIMES

Station	Shot	Distance (km)	P Travel Times (Sec) 1	2	3	4	S Travel Times (Sec) 1	2	3	4
KLG	1400	132.5	21.98				37.9			
KLG	1303/1	133.8	22.13				38.1			
KLG	1303/2	133.8	22.34				38.0			
KLG	1107	154.0	24.82				43.8			
KLG	1106/2	155.1	25.09				43.1			
KLG	1105	156.2	25.40				44.2			
CUR	1107	196.4	((29.8))	31.65						
KAR	1303/1	229.1	35.56	36.96			67.6			
CHY (M)	1303/2	256.8	36.3							
BOORABBIN SHOTS	(NORTHWEST)									
MEK	1400	540.7	72.4	78.7	84.6		123.4	127.6	149	
HINES HILL	(WEST)									
KEL	1617	37.7	6.28							
TAM	1713/1	59.1	9.56							
MEW	1713/1	109.0	18.01				31.0			
YOR	1616/1	121.7	19.96				33.7			
AVO	1616/2	144.7	23.58	23.91			40.8			
LAA	1613/1	162.4	25.80				45.05			
MUN	1713/1	179.1	28.06	31.32			49.16			
MUN	1615	182.4	28.35	28.63						
MUN	1616/1	182.5	28.35	28.67			50.5			
MUN	1616/2	182.5	28.39	28.74			50.3			
MUN	1616/3	182.5	28.35	28.60						
MUN	1613/1	182.6	28.40				49.9			
MUN	1715/1	183.8	28.46	29.06			51.6			
MUN	1715/2	183.8	27.9				51.8			
GLN	1715/2	193.5	((29.7))	30.07			53.7			
GOP	1616/2	200.6	((30.95))	31.23	31.53		54.2			

TABLE 3 (continued)

TRAVEL TIMES

Station	Shot	Distance (km)	P Travel Times (Sec) 1	2	3	4	S Travel Times (Sec) 1	2	3	4
JUBILEE SHOT										
KLG	JUB	63.3	10.4				16.2			
BOO (M)	JUB	183.9	30.0							
BRP (S)	JUB	219.5	35.0							
CAR	JUB	336.0	((52.5))	81.8			90.9			
MUN	JUB	579.3	((77.5))							
WALGOOLAN SHOT										
MUN	WGL	239.0	((38.0))	39.9			75.9			
PIB	WGL	291.7	42.1	43.2			71	73	78.5	
KLG	WGL	278.5	((39.9))				75.9			
FRASER RANGE SHOTS										
KLG	502	211.2	33.5				58.5			
KLG	501	208.9	32.1				56.4			
KLG	505	217.1	34.1				58.7	60.6		
KLG	509	226.4	((33.4))				59.7			
KLG	508/1	225.6	36.2				62.2			

NOTE: (M) Moseley Recorder used - accuracy $\pm$0.3 seconds
(S) Geophone spread
(( )) Doubtful phase

TABLE 3 (continued)

TRAVEL TIMES

Station	Shot	Distance (km)	P Travel Times (Sec) 1	2	3	4	S Travel Times (Sec) 1	2	3	4
YAL	1617	368.3	((57.4))							
HINES HILL	(EAST)									
MRD	1615	24.0	4.22							
CAR (M)	1715	71.0	11.8							
SXC	1616/1	125.9	20.5							
SXC	1616/2	125.9	20.6	21.4			35.4	37.8		
SXC	1616/3	125.9	20.9	21.2			35.7	38.3		
KLG	1616/1	334.9	54.4				91.3			
SXC	1715/2	129.9	21.4				36.3	36.6	39.3	
DOODLAKINE SHOTS	(WEST)									
YOR	1813/3	104.0	17.19	17.86						
MUN	1813/2	165.4	26.18				45.75	46.63		
MUN	1813/3	165.4	26.11	26.89	27.38		45.79	46.56		
PIB	1813/4	224.9	33.74	34.6			59.8	60.8	61.5	
WUNDOWIE SHOTS										
MUN	2010	30.5	5.00							
MUN	2012	34.3	5.57							
MUN	2014	38.2	6.17							
PIB	2010	112.9	18.39	18.8			30.9	36.4		
MTB	2014	142.5	22.32	22.78			39.6	41.9		
TAR	2012	172.9	26.62	27.47			47.3	48.5		
BSB	2010	227.3	34.28	34.65	35.11	36.00	60.4	62.0		
CRW	2012	304.5	((44.15))	44.25	49.1		68.1	69.0		
MBR	2014	345.6	48.83	49.6	54.0		((82.0))	86.2	96	

TABLE 4

INSTRUMENTS

	Mundaring	Kalgoorlie	Meekatharra
Seismometer	Benioff vertical To = 1.0s.	Willmore Mk I vertical To = 0.7s.	Willmore vertical To = 1.0s.
Galvanometer	Willmore Tg - 0.04s.	Benioff Tg = 0.25s.	Benioff Tg = 0.25s.
Recorder	Willmore	Benioff	Benioff
Paper speed	240 mm/min	60 mm/min	60 mm/min
Time marks	Relay mirror deflection, 10 second, minute, and hour marks controlled by WWSSN programmer.	Relay mirror deflection, chronometer minute mark controlled by radio pips each hour.	Relay mirror deflection, 10 second and minute marks from E.M.I. crystal clock controlled by radio pips each hour.
Operator	A. Parkes G. Woad	D.C. Allen	B. Wharton

TABLE 4 (continued)

	Mobile 1	Mobile 2 (1st stage)	Mobile 2 (2nd stage)
Seismometer	Willmore Mk II, To = 1.0s.	Willmore Mk Im To = 1.0s.	Willmore Mk II, To = 1.0s.
Galvanometer	Willmore, Tg = 0.25s.	-	Willmore, Tg = 0.25s.
Amplifier	Geotech, type EA-300 Low output 30 or 36 db	Operational amplifier Approx. amplification X10	-
Recorder	Willmore, gain 1/100	Moseley 680	Willmore, gain direct
Paper speed	200-240 mm/min.	200 mm/min.	240 mm/min.
Time marks	Relay mirror deflection. Second pips from VNG and chronometer minute marks through B.M.R. seismic timing unit.	Relay deflection. Second pips from VNG using Labtronics receiver direct onto recorder.	Relay mirror deflection. Second pips from VNG through B.M.R. seismic timing unit.
Operators	E.P. Paull P.J. Gregson I.B. Everingham	P. Harrison	P. Harrison J.B. Connelly

PLATE I

MOORA
WONGAN HILLS
GOOMALLING
MEW
MECKERING
TAM
CUN
KEL
DOO
MERREDIN
WGL
CAR
MOO
SXC
SOUTHERN CROSS
YEW
BRP
BOO
WOO
COO
KLG
KALGOORLIE
COOLGARDIE
CUR
KAR
CHY
ZANTHUS
JUB
LAKE LEFROY
LAKE COWAN
NORSEMAN
BALLADONIA
THE JOHNSTON LAKES
GNANGARA
MUNDARING
AVO
YOR
YORK
LAA
MUN
PERTH
GOP
ARMADALE
GLN
MRD
HHL
CORRIGIN
HYDEN
MANDURAH
PIB
MTB
NARROGIN
LAKE GRACE
LAKE KING
TAR
COLLIE
BUNBURY
BUSSELTON
YAL
BSB
KATANNING
RAVENSTHORPE
ESPERANCE
ONGERUP
MANJIMUP
CRW
MBR
MT BARKER
AUGUSTA
ALBANY

SHOT-POINTS AND STATION LOCATIONS

LEGEND

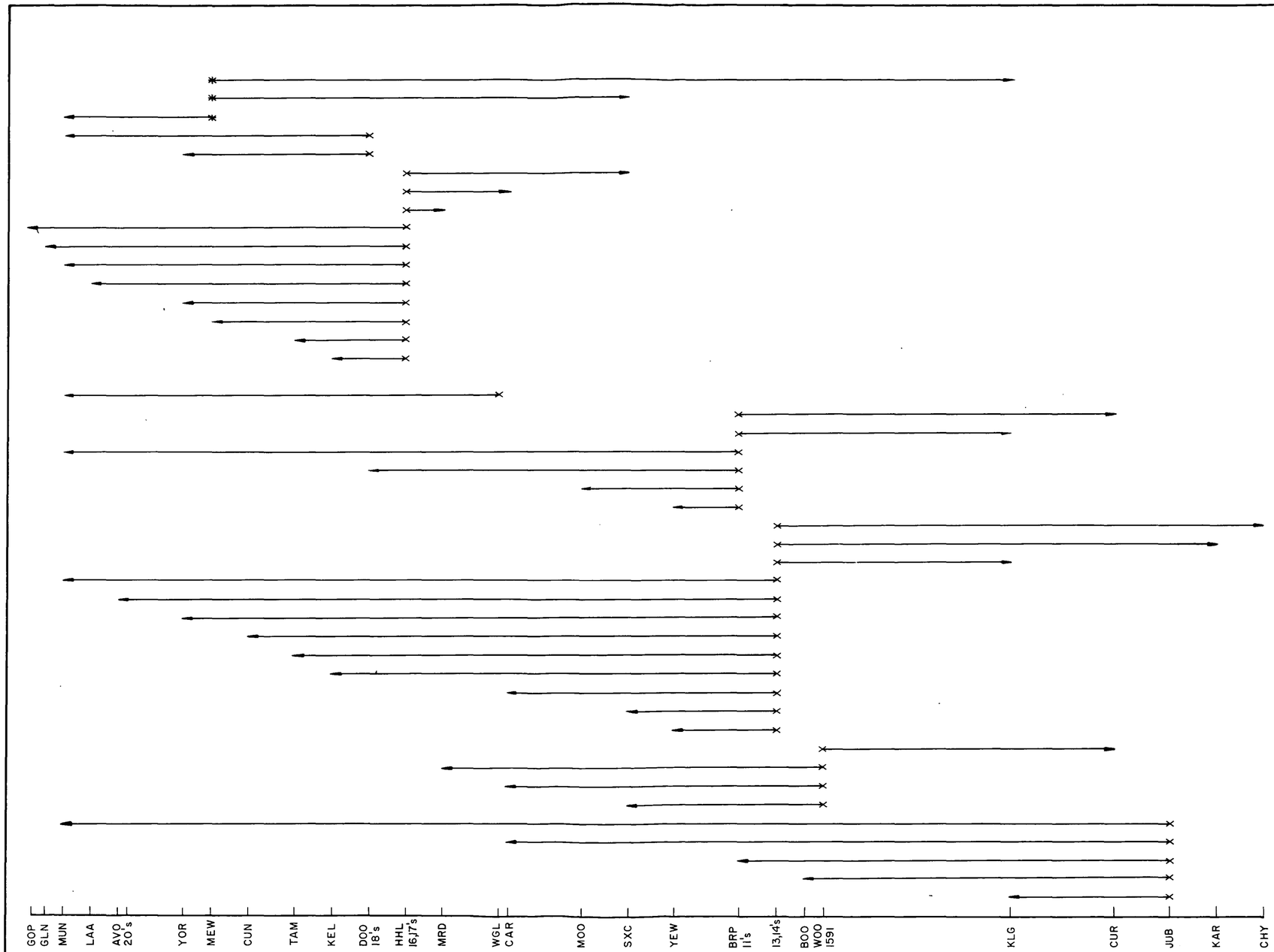
- FIELD STATION
- FIXED STATION
- 2014 SHOT-POINT
- HIGHWAY
- RAILWAY

50 0 50 100
KILOMETRES

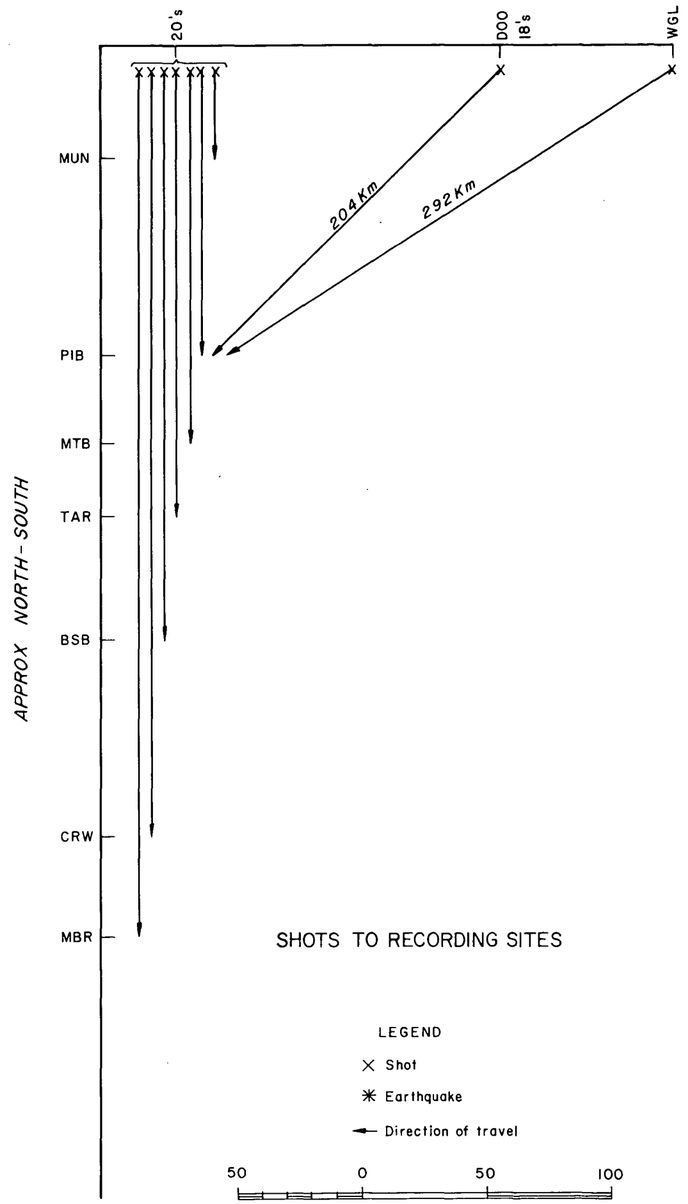
(Based on G96-328 & G96-329)

TO ACCOMPANY RECORD No. 1971/75

WA/B3-12



APPROX EAST-WEST



SHOTS TO RECORDING SITES

LEGEND

× Shot

✳ Earthquake

← Direction of travel

50 0 50 100

Kilometres

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