Bureau of Mineral Resources, Geology & Geophysics

R E C O R D

RECORD NO. 1988/51

THE DISTRIBUTION OF CADOUX AFTERSHOCKS : ADDITIONAL RESULTS FROM TEMPORARY STATIONS NEAR CADOUX, 1983

by

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SUMMARY

Dent & Gregson (1986) presented the first accurate locations of Cadoux aftershocks, showing them to be of shallow depth. New hypocentres presented here, and the relocation of existing ones have helped to define a distinct band of seismicity, trending approximately north-south, on the western side of the Robb Fault. In addition, another band of seismicity of similar orientation may exist south east of the Robb fault. This is near to the preferred location for the large Cadoux earthquake of 2 June, 1979.

INTRODUCTION

A large earthquake occurred near Cadoux in 1979 (Gregson & Paull, 1979). The faulting caused by the earthquake was described by Lewis et al. (1981). However, instrumental location of this event was difficult because of a lack of regional seismographs at the time, and there is a difference of more than 10 km between solutions given by the United States Geological Survey (USGS) and the International Seismological Centre (ISC) (Figure 1). Denham et al. (1987) presented a new location, (Figure 1) based on arrivals at regional Australian stations, which was close to the USGS solution.

Denham et al. (1987) also located 59 fore and aftershocks of the Cadoux earthquake, which occurred during the period January to December, 1979. They recognised that there was a systematic difference of about 5 km between their computer locations and the locations obtained by the Mundaring Geophysical Observatory (MGO), mainly due to the fact that they used an improved earth model. They also observed that aftershocks of the Cadoux earthquake, from 1980 onwards, were occurring at the northern and southern ends of the area affected by the main earthquake.

Because of a lack of precise data, the Mundaring Geophysical Observatory (MGO) had assumed a depth of 10 km for Cadoux events, and indeed for all events in the South West Seismic Zone (SWSZ).

At the completion of a crustal survey of the Yilgarn Block of Western Australia (Drummond & Bracewell, in prep.), a network of temporary stations was set up north of Cadoux between September and December 1983.

The object of this survey was to determine precise locations and depths for earthquakes near Cadoux and was described by Dent & Gregson (1986), where initial results were presented. This report gave the first accurate depth determinations for Cadoux earthquakes, showing them to be much shallower than previously thought. The two largest events (ML 2.4 & 2.1) occurring during the one week life of the inner network had depths of 4 km, and the smaller events had depths of the order of 2 km. Recent work by Langston (1987) , and Fredrich et al. (1988) on Meckering aftershocks has lead further weight to the conclusion that SWSZ earthquakes are usually less than 5 km deep.

I have now extracted more arrival times from data tapes recorded at the temporary stations. Regional stations have also been re-examined for arrival time data to supplement those from the temporary stations. This has enabled the preparation of a fairly complete picture of the seismicity down to ML 1.0 in the Cadoux area during the period of operation of the temporary stations.

THE TEMPORARY SEISMOGRAPHIC STATIONS

The operation of temporary stations near Cadoux can be divided into three distinct and partly overlapping phases.

1. Operation of a station at Manmanning, (MAN), 26 September to 02 November 1983.

2. Operation of a dense network (16 stations) north of Cadoux, 26 October to 02 November, 1983.

3. Operation of a sparse network (4 stations) around Cadoux at a distance of approximately 40 km, from 26 October to 15 December, 1983.

These stations are plotted on Figure 1. Their locations and operational periods are listed in Table 2. The advantage of these stations is that, by replaying data at high speed, arrival times can be scaled with an accuracy of about +/- .02 seconds. Data from regional stations can only be scaled to approximately +/- 0.1 seconds.

Data from the second two phases were presented in Dent & Gregson (1986). In this report, data from the Manmanning station (MAN) are also used, adding four weeks to the period for which small earthquakes in the Cadoux area can be accurately located. These data were not used in the earlier report, because they were not available at the time it was prepared.

EARTHQUAKE LOCATION METHOD

The earthquake solutions presented here were located using the same method as used in the Dent & Gregson (1986) report, - the computer program FASTHYPO (Herrmann, 1979) was used. The earth-model adopted was the same one used by Denham et al. (1987) in their relocations (see Table 1). This model was based on preliminary results from the Yilgarn Crustal Survey and is not the same one as presented by Drummond & Mohamed (1986). The computer outputs are presented in the Appendix.

S phase arrivals were used when available, but were given less weight than the P phase arrivals and a P to S wave velocity ratio of 1.732 was adopted.

EARTHQUAKE DATA

a) Phase 1.

Three earthquakes of ML $\geq$ 2.0 were located by the MGO during this period. These have been relocated using MAN times. Examination of Ballidu and Kellerberrin records has identified a further eight events of ML 1.0 to 1.9, and Manmanning arrival times were readable for five of them. The eight events have been located, and locations for all events which occurred during phase 1 are listed in Table 3(a).

b) Phase 2.

Two events of ML $\geq$ 2.0 and three events between ML 1 and 2 occurred during phase 2. Locations for these events were presented in Dent & Gregson (1986) but they have been relocated in this report using data from MAN where available. These events are presented in Table 3(b), and have more accurate focal depths than events in Tables 3(a) or 3(c), because of the network of close stations operating at the time.

c) Phase 3.

Six events near Cadoux, in the range ML 1.0 - 1.9 were located and presented in Dent & Gregson (1986). New data have been extracted for these events, and they have been relocated. Another five events in the same range have since been identified and located. One event of ML $\geq$ 2.0 occurred in this period (ML 2.3 on 14 Dec.). Locations for all events are listed in Table 3(c).

DISCUSSION OF EARTHQUAKE DISTRIBUTION, OCT - DEC 1983

The events in Table 3 give a complete picture of the distribution of Cadoux earthquakes of ML ≥ 1.0 during the 11 week time period. These events have been plotted on Figure 2, which shows a distinct correlation of seismicity with the Robb Fault - ie, all the events (approximately 20) are within 5 km of the Robb Fault scarp, on the north-western side of its surface trace.

This earthquake distribution supports the conclusion drawn from field mapping and fault plane solutions that the Robb fault has a westerly dip. This is in contrast to the plot of 1979 Cadoux events presented in Denham et al. (1987), which showed almost all events occurring on the eastern side of the fault zone. However, 1979 epicentres are generally of low accuracy because of the inadequate regional seismograph network at the time.

COMPARISON OF EARTHQUAKE SOLUTIONS

One of the significant features of the temporary network is that it has allowed the accurate relocation of six events previously located by the MGO using routine procedures. Two of these were relocated using data from the inner network, and a high degree of confidence can be placed on these two. Three were relocated with the addition of MAN, and one with additional data from the outer network. These events are listed in Table 4.

The effect of relocating the events is shown in Figure 3. While the trend is not particularly consistent, this figure indicates that the MGO solutions are mostly north of their true locations, by about 5 km.

RELOCATION OF OTHER EVENTS IN THE CADOUX AREA

A. July - Sept 1983

It was decided to test the effect of computer relocating some other earthquakes which occurred in 1983. Events which were recorded at the stations BAL, KLB, MUN & MEK from 1 July to 29 Sep were selected, in order to give an idea of earthquake distribution over a 6 month period.

These events and their locations are listed in Table 4, and plotted on Figure 4.

The largest event in this period was an ML 2.7 earthquake on 07 August. Most of the MGO locations only used three stations, BAL, KLB & MUN. Figure 4 shows that the general effect of relocation is a shift of 5 to 10 km to the south. The bias is more consistant for these events than for those of figure 3. This is probably because the events are smaller, and the MGO solutions only used the stations BAL, KLB and MUN, while the computer solutions have included MEK arrival times.

The net effect of this shift is to strongly support the conclusion above that there is a correlation of seismicity with the western side of the Robb fault.

Another significant feature of Figure 4 is a group of earthquake epicentres about 10 km south-east of the southern end of the Robb Fault. As will be seen later, there were a number of large events in this area during January and February, 1982.

B. EVENTS ML ≥ 4.0, 1980 - 1984

As mentioned in the introduction, Denham et al. (1987) observed that energy released during the period 1980-83 occurred principally at the extremities of the fault zone. It was decided to test the effect of computer relocation on some of these events. Events of ML ≥ 4.0 were selected. These events are listed in Table 5 and plotted on figure 5.

Figure 5 shows that the relocation of these events has resulted in shifts of about 5 km, generally with an easterly trend. This trend is different to that noted above. This is possibly because the earthquakes were larger and MGO was therefore able to use a better distribution of recording stations.

The new locations shown in Figure 5 do not refute the observation in Denham et al. (1987). However, it is interesting to note that all of the southern extremity events in Figure 5 occurred between 24 January and 08 February 1982.

There are two events in Figure 5 for which relocations do not fit the general trend; the relocations move to the north, away from the seismically active area. However, these solutions were computed without BAL which was not operational at the time.

CONCLUSIONS

Accurate locations of small Cadoux events using data from temporary stations have helped to demonstrate a correlation of seismic activity with the Robb fault. The conclusion is that earthquakes are occurring on a westerly dipping fault plane. This conclusion is supported by the relocation of other 1983 events using regional stations. A second group of events is also observed, this time to the south east of the Robb fault. Their geological association is not clear.

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TABLE 1

CRUSTAL MODELS

MGO to 1984		MGO from 1985		DENHAM ET AL (1987)	
VEL km/sec	DEPTH km	VEL km/sec	DEPTH km	VEL km/sec	DEPTH km
6.5	0	6.13	0	5.95	0
7.17	19	7.17	19	6.08	1.0
8.11	37	8.11	37	6.17	11
				6.55	15
				6.95	30
				8.10	36
				8.20	50

TABLE 2

LOCATIONS OF TEMPORARY STATIONS

STN	LOCATION	LAT	LONG	OPERATION
BAL	BALLIDU	-30.607	116.707	(PERMANENT STATION)
MAN	MANMANNING	-30.878	117.148	29 SEP - 02 NOV 1983
K01	KONONGORRING	-31.025	116.864	27 OCT - 15 DEC
K02	KOORDA STH	-31.042	117.358	27 OCT - 15 DEC
K03	KOORDA NTH	-30.638	117.513	27 OCT - 15 DEC
K04	KALANNIE	-30.412	117.160	27 OCT - 15 DEC
K05	inner net nw	-30.674	117.086	26 oct - 02 nov
K08	inner net ne	-30.679	117.179	" " "
K17	inner net sw	-30.758	117.076	" " "
K20	inner net se	-30.757	117.183	" " "

TABLE 3(a)

EARTHQUAKES: 29 SEPTEMBER - 25 OCTOBER 1983 (PHASE 1)

date	time	lat	long	ML	depth (km)	COMMENTS
30 Sep	1709	-30.828	117.082	1.4	2G	
03 Oct	1959	-30.834	117.083	1.3	3.1	3 stns (MAN us)
04 Oct	0715	-30.836	117.094	1.6	5G	3 stns (MAN us)
08 Oct	0224	-30.835	117.090	1.2	5G	
12 Oct	1051	-30.762	117.135	1.5	6.4	
19 Oct	0018	-30.850	117.075	1.6	2G	
19 Oct	0137	-30.860	117.096	2.3	2G	-30.80 117.13 10G
20 Oct	1704	-30.761	117.132	1.4	4.2	
20 Oct	1827	-30.851	117.076	2.4	2G	-30.80 117.09 10G
21 Oct	1855	-30.716	117.126	1.8	2.1	3 stns (MAN us)
25 Oct	1455	-30.756	117.093	2.0	8.9	-30.72 117.08 10G

TABLE 3(b)

EARTHQUAKES: 25 OCT - 02 NOV 1983 (PHASE 2)

date	time	lat	long	ML	depth (km)	COMMENTS
25 Oct	2306	-30.730	117.110	2.4	6.3	(30.725 117.106 4.0 km)
27 Oct	1856	-30.740	117.167	2.1	2.1	(30.741 117.190 4.4 km)
28 Oct	2105	-30.735	117.114	1.5	3.6	
30 Oct	0648	-30.733	117.114	1.2	3.8	
30 Oct	1942	-30.798	117.104	1.1	2.2	

TABLE 3(c)

EARTHQUAKES: 02 NOVEMBER - 15 DECEMBER 1983 (PHASE 3)

date	time	lat	long	ML	depth (km)	COMMENTS
04 Nov	0853	-30.733	117.119	1.5	6.0	(30.724 117.118 7.0 km)
05 Nov	2341	-30.823	117.099	1.2	7.8	(30.840 117.081 0 km)
07 Nov	1833	-30.712	117.118	1.0	5G	(30.702 117.132 3.9 km)
09 Nov	1131	-30.769	117.117	1.0	3.3	(30.754 117.130 6.3 km)
10 Nov	1510	-30.845	117.084	1.4	8.3	(30.794 117.102 13.8 km)
12 Nov	0605	-30.829	117.086	1.0	2G	
18 Nov	0717	-30.814	117.075	1.0	5G	
21 Nov	2216	-30.772	117.100	1.0	3.6	(30.779 117.098 0 km)
25 Nov	0423	-30.799	117.099	1.8	1.8	(new)
03 Dec	1148	-30.753	117.138	1.0	3.7	
05 Dec	0210	-30.767	117.139	1.0	6.0	
06 Dec	1447	-30.784	117.034	1.0	7.7	
14 Dec	0200	-30.840	117.099	2.3	6.3	(30.80 117.09 10G MGO)

TABLE 4(a)

COMPARISON OF HYPOCENTRES July to September 1983

DATE	LAT (Fasthypo)	LONG (Fasthypo)	LAT (MGO)	LONG (MGO)	ML	COMMENTS
07 Aug 0038	-30.787	117.099	-30.75	117.10	2.7	
08 Aug 0603	-30.790	117.084	-30.80	117.13	2.6	
15 Aug 1704	-30.87	117.04	-30.81	117.01	2.0	
21 Aug 1804	-30.920	117.124	-30.88	117.14	2.3	
29 Aug 1719	-30.851	117.076	-30.82	117.08	2.6	
02 Sep 1835	-30.764	117.113	-30.67	117.14	2.4	
04 Sep 0312	-30.91	117.15	-30.87	117.15	2.5	
04 Sep 1147	-30.911	117.140	-30.87	117.15	2.6	
04 Sep 1156	-30.895	117.161	-30.87	117.15	2.5	
15 Sep 0713	-30.829	117.081	-30.77	117.07	2.4	
16 Sep 1413	-30.807	117.116	-30.75	117.13	2.4	
17 Sep 1447	-30.746	117.09	-30.67	117.10	2.3	
19 Sep 1203	-30.823	117.085	-30.76	117.10	2.5	

TABLE 4(b)

COMPARISON OF HYPOCENTRES, Sep to Dec 1983

DATE	LAT (Fasthypo)	LONG (Fasthypo)	LAT (MGO)	LONG (MGO)	ML	COMMENTS
19 Oct 0137	-30.860	117.096	-30.80	117.13	2.3	
20 Oct 1827	-30.851	117.076	-30.80	117.09	2.4	
25 Oct 1455	-30.756	117.093	-30.72	117.08	2.0	
25 Oct 2306	-30.725	117.106	-30.72	117.08	2.4	
27 Oct 1856	-30.741	117.167	-30.71	117.12	2.1	
14 Dec 0200	-30.845	117.098	-30.80	117.09	2.3	

TABLE 5

RELOCATION OF EVENTS ML > 4.0 1980- 1984

DATE	LAT (Fasthypo)	LONG (Fasthypo)	LAT (MGO)	LONG (MGO)	ML	DEP	COMMENTS
02 Jun 19 79	-30.83	117.18	-30.73	117.21	6.2	6G	DEN vs ISC solns
10 Dec 1980	-30.697	117.155	-30.73	117.15	5.0	0.4	BAL, KLB not op
07 Apr 1981	-30.754	117.228	-30.744	117.164	4.5	4.9	BAL, KLB not op
24 Jan 1982	-30.889	117.135	-30.90	117.12	4.3	5G	
25 Jan 1982	-30.842	117.119	-30.91	117.13	4.4	5G	
06 Feb 1982	-30.898	117.157	-30.88	117.15	4.9	16	
06 Feb 1982	-30.911	117.134	-30.87	117.10	4.6	5G	
07 Feb 1982	-30.840	117.150	-30.89	117.09	4.1	5G	BAL U/S
08 Feb 1982	-30.901	117.151	-30.89	117.10	4.1	12	
26 Jan 1983	-30.725	117.150	-30.73	117.13	4.8	13.6	
28 Mar 1984	-30.71	117.10	-30.72	117.08	4.2	14	

figure 1
TEMPORARY STATION DISTRIBUTION

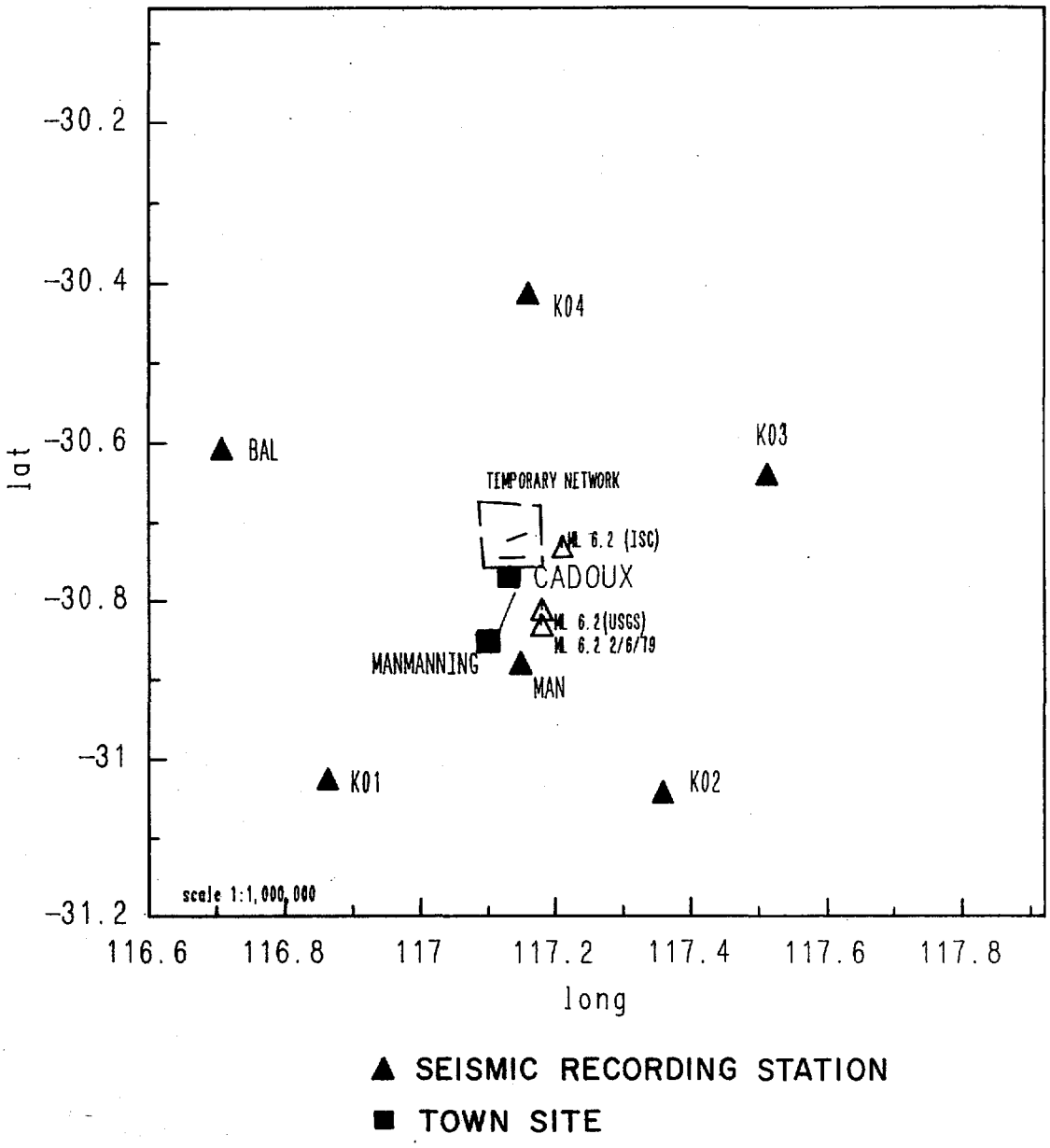
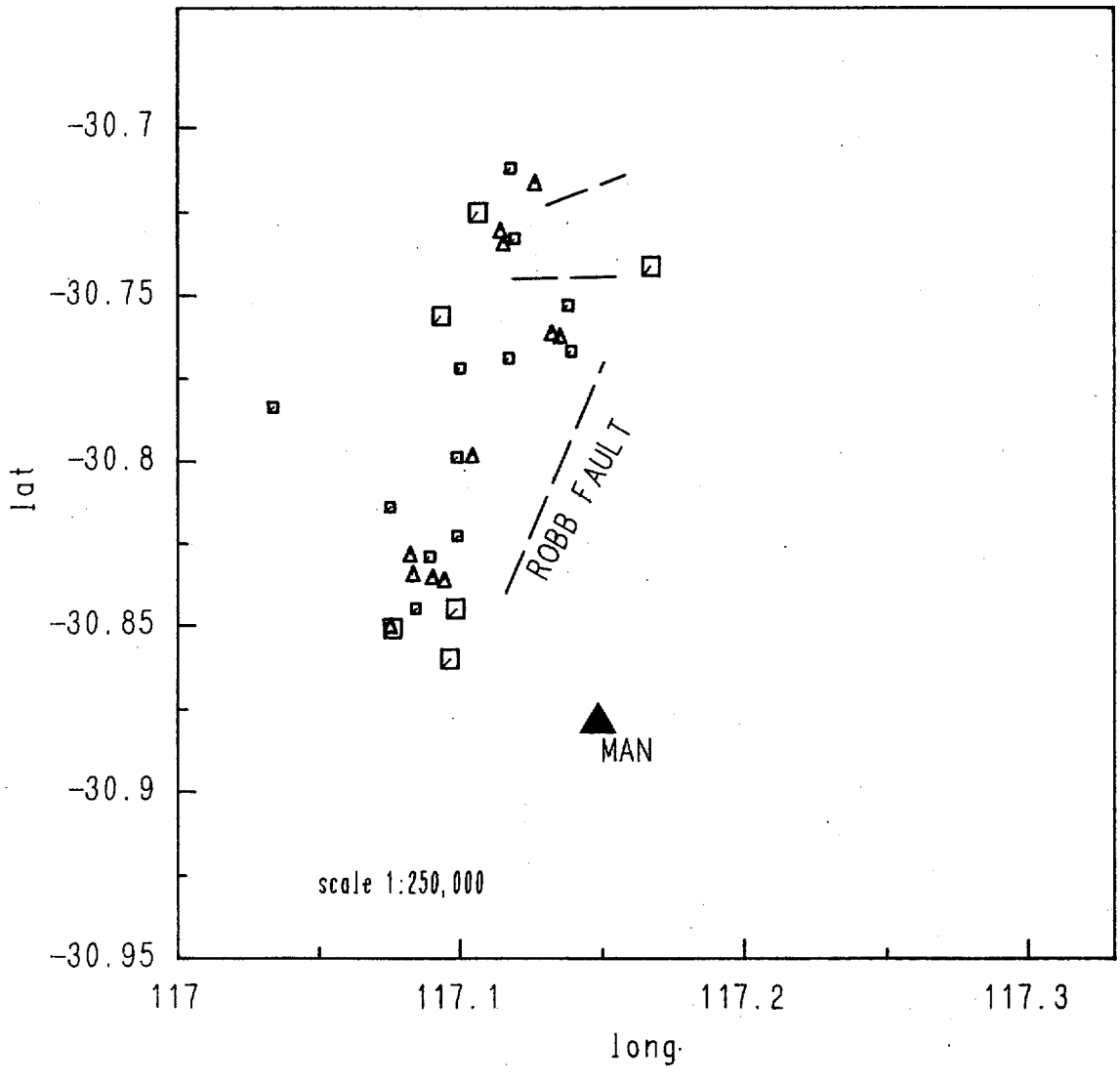


figure 2
EPICENTRES 29 sep - 15 dec 1983



△ events ML 1 - 2, 29 Sep - 02 Nov 1983

▫ events ML 1 - 2, 02 Nov - 15 Dec 1983

□ events ML ≥ 2.0, 29 Sep - 15 Dec 1983

figure 3
EPICENTRE RELOCATIONS, 29 SEP - 15 DEC 1983

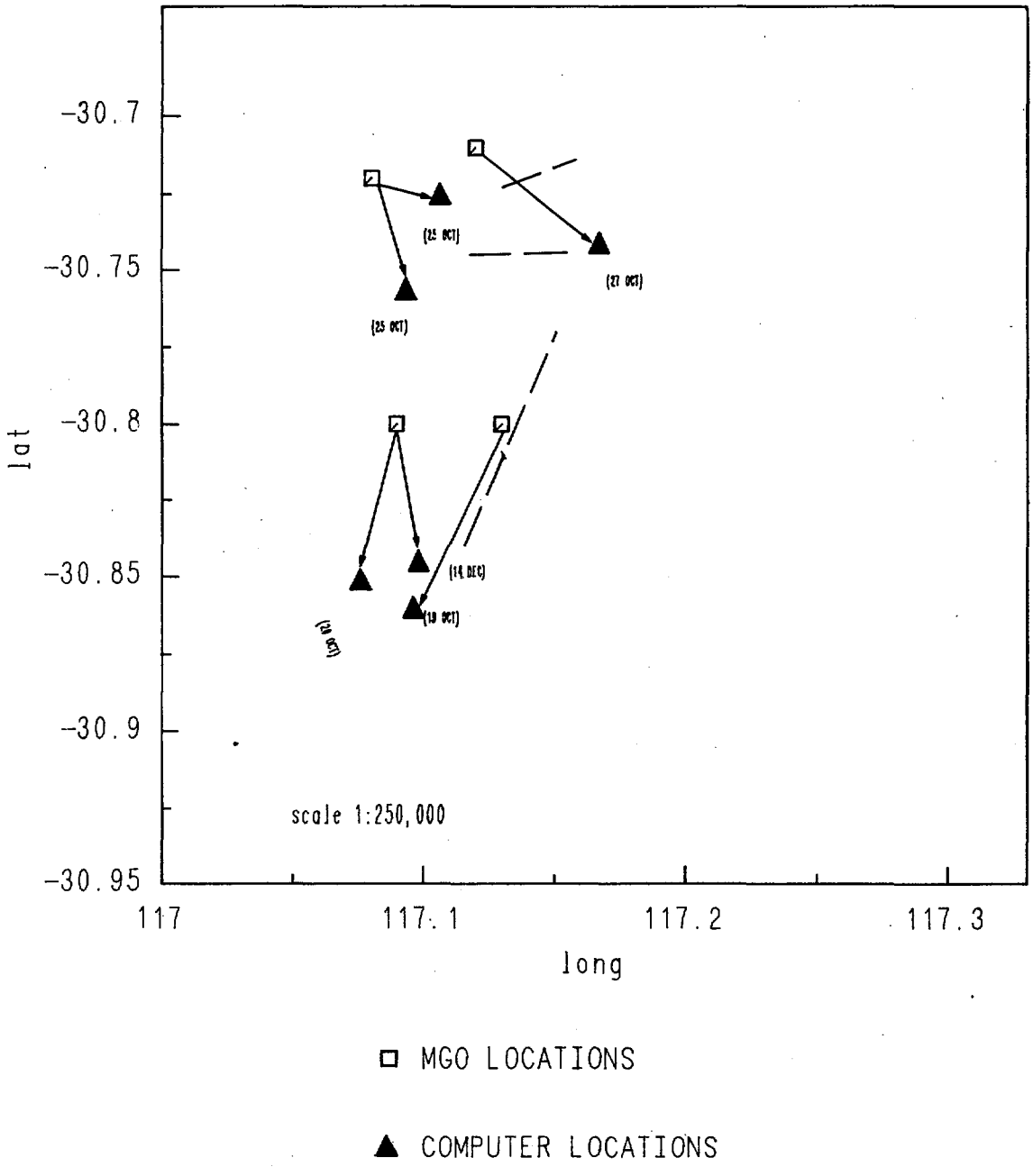


figure 4
EARTHQUAKE RELOCATIONS, 01 JULY - 29 SEP 1983

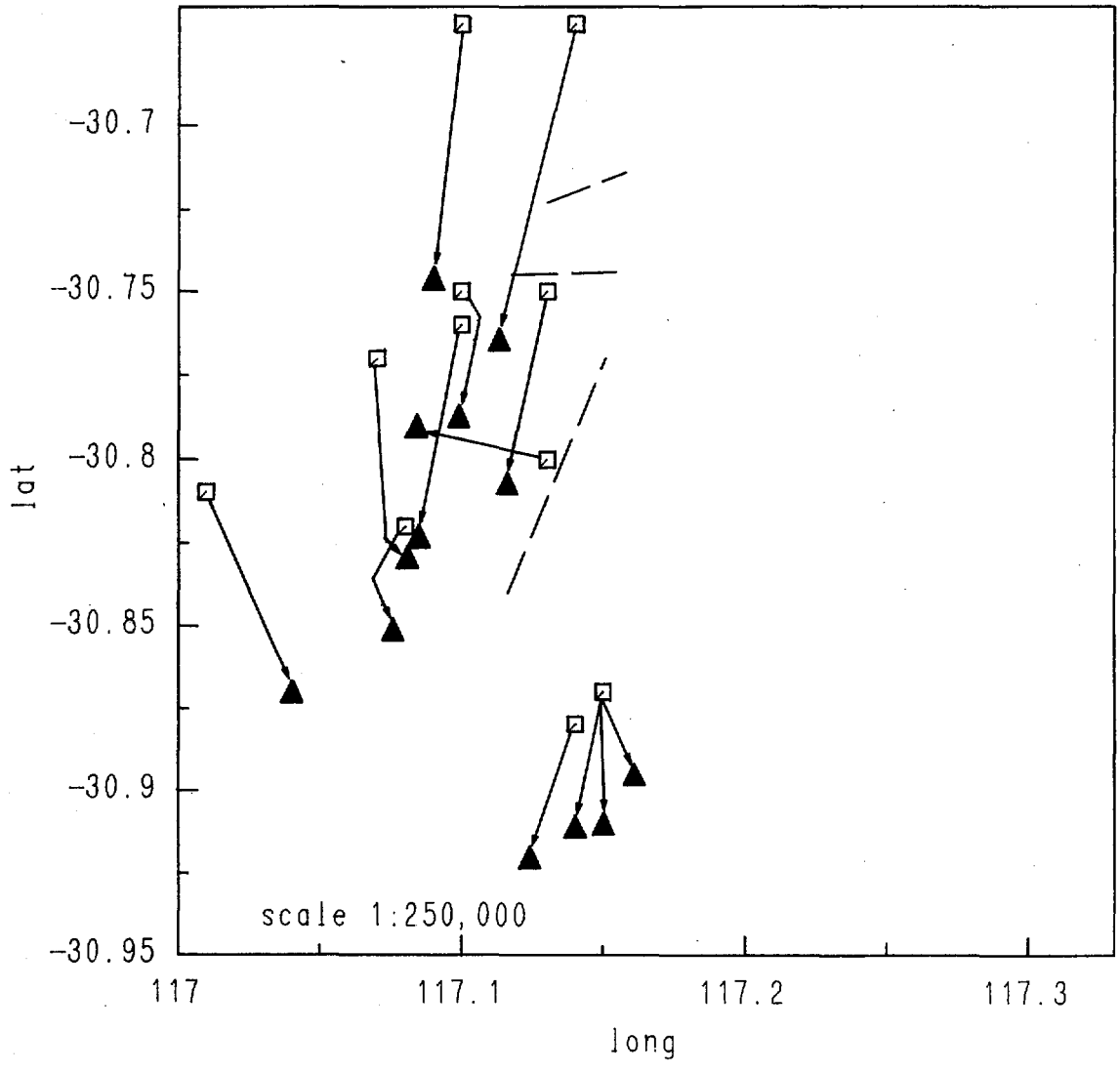
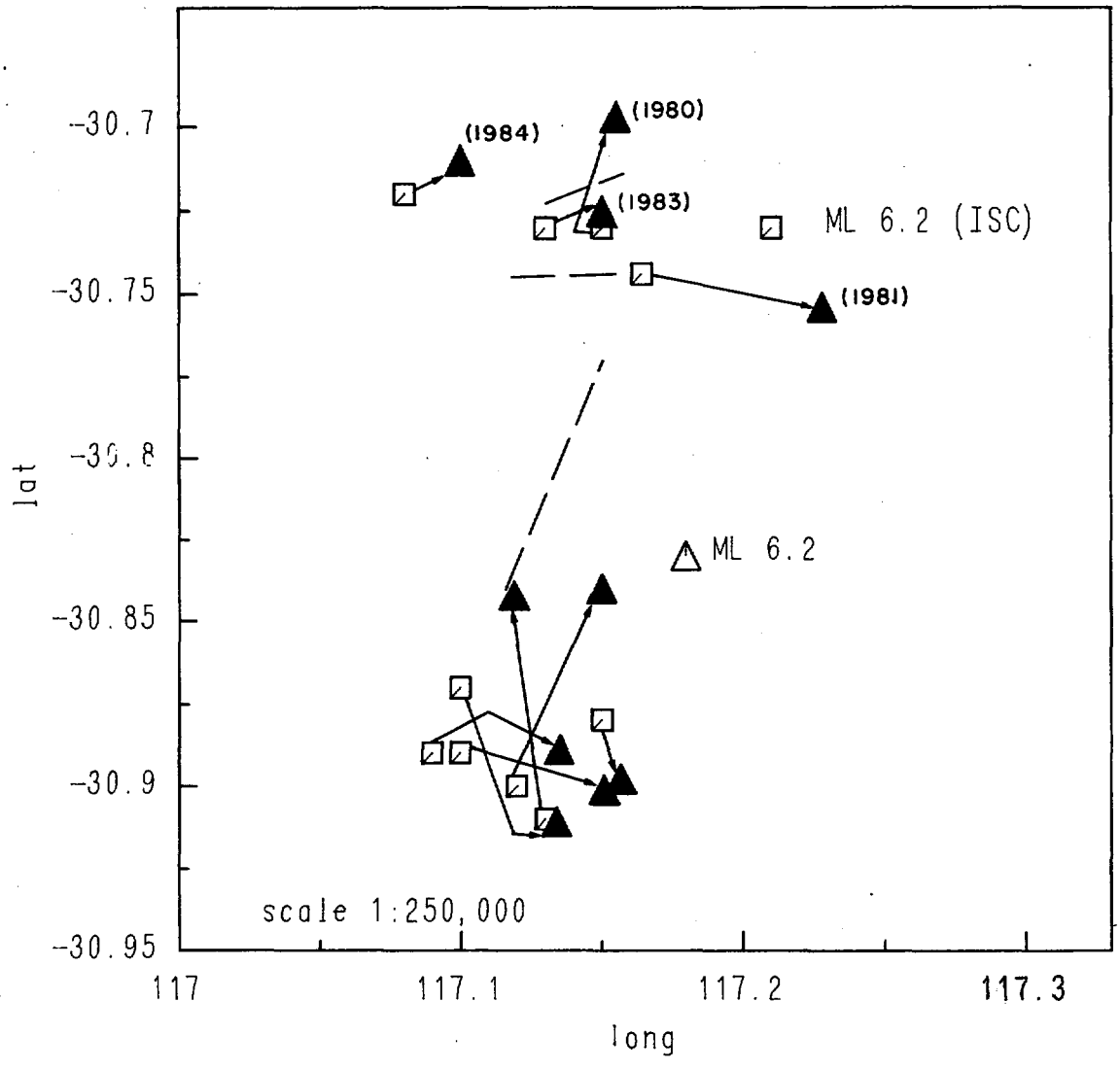


figure 5
epicentre relocations ML≥ 4.0, 1980-84



□ MGO LOCATIONS

▲ COMPUTER LOCATIONS

APPENDIX

FASTHYPO EPICENTRAL DETERMINATIONS

30 SEP 1983 1709 ML 1.4

	MUN	KLB	BAL	MAN
P-ARR	42.50	35.20	25.10	19.10
S-ARR	60.50	47.00	30.20	19.90
DIST=	151.27	105.70	44.10	7.74
P-WT.	2	2	0	0
P-RES	-0.01	0.03	0.05	0.02
S-WT.	4	4	3	3
S-RES	-0.14	-0.92	-0.19	-0.15

CONSTR DEP 2.0 +- 0.0 KM OT= 17.7 +- 0.0 SEC
LOCN IS 30.838 117.082 +/- 1.8 1.7 KM

03 OCT 1959 ML 1.3

	BAL	KLB	MUN
P-ARR	4.00	14.20	21.50
S-ARR	9.00	26.50	39.00
DIST=	44.02	105.95	151.83
P-WT.	0	0	0
P-RES	-0.02	0.01	-0.02
S-WT.	4	4	4
S-RES	-0.35	-0.47	-0.66

FREE DEPTH 3.1 +- 0.0 KM OT= -3.3 +- 0.0 SEC
LOCN IS 30.834 117.083 +/- 0.1 0.1 KM

04 OCT 0715 ML 1.6

	BAL	KLB	MUN
P-ARR	44.00	54.10	61.40
S-ARR	49.30	66.00	79.20
DIST=	44.89	105.22	152.13
P-WT.	0	0	0
P-RES	-0.03	0.16	0.11
S-WT.	3	3	3
S-RES	-0.18	-0.64	-0.17

CONSTR DEP 5.0 +- 0.0 KM OT= 36.6 +- 0.0 SEC
LOCN IS 30.836 117.094 +/- 6.0 5.2 KM

08 OCT 1983 0224 ML 1.2

	MUN	KLB	BAL	MAN
P-ARR	55.50	48.80	38.40	32.33
S-ARR	73.70	61.00	43.40	33.25
DIST=	152.03	105.49	44.57	7.30
P-WT.	3	3	0	0
P-RES	-0.09	0.50	0.10	-0.03
S-WT.	4	4	3	2
S-RES	0.03	-0.04	-0.32	-0.18

CONSTR DEP 5.0 +- 0.0 KM OT= 30.9 +- 0.0 SEC
LOCN IS 30.835 117.090 +/- 2.8 3.1 KM

12 OCT 1983 1051 ML 1.5

	MUN	KLB	BAL	MAN
P-ARR	30.20	22.20	11.50	6.29
S-ARR	49.00	34.00	17.00	8.14
DIST=	160.57	109.37	44.44	12.40
P-WT.	1	1	0	0
P-RES	0.08	0.02	-0.02	-0.07
S-WT.	3	4	3	3
S-RES	-0.14	-1.39	0.07	0.15

FREE DEPTH 5.2 +- 0.0 KM OT= 4.1 +- 0.0 SEC
LOCN IS 30.766 117.133 +/- 0.5 0.6 KM

19 OCT 1983 0018 ut ML 1.6

	MUN	KLB	BAL	MAN
P-ARR	23.50	16.50	6.40	0.35
S-ARR	41.50	28.50	11.30	1.15
DIST=	149.77	104.99	44.42	7.61
P-WT.	2	2	1	0
P-RES	-0.08	0.15	0.01	0.00
S-WT.	4	4	4	3
S-RES	-0.04	-0.51	-0.48	-0.16

CONSTR DEP 2.0 +- 0.0 KM OT= -1.0 +- 0.0 SEC
LOCN IS 30.850 117.075 +/- 1.5 1.4 KM

19 OCT 1983 0137 ML 2.3

	MAN	BAL	KLB	MUN
P-ARR	17.45	24.30	33.60	41.10
S-ARR	0.00	29.30	45.00	58.60
DIST=	5.33	46.67	102.93	150.05
P-WT.	0	0	0	0
P-RES	-0.06	0.02	0.08	-0.04
S-WT.	4	4	4	4
S-RES	-18.20	-0.63	-0.94	-0.53

CONSTR DEP 2.0 +- 0.0 KM OT= 16.6 +- 0.0 SEC
LOCN IS 30.860 117.096 +/- 1.4 1.3 KM

20 OCT 1983 1704 ut ML 1.4

	MUN	KLB	BAL	MAN
P-ARR	56.50	48.50	37.70	32.55
S-ARR	75.00	60.50	43.00	34.13
DIST=	160.43	109.70	44.00	12.58
P-WT.	2	2	0	0
P-RES	0.00	-0.01	0.01	0.00
S-WT.	4	4	3	3
S-RES	-0.60	-1.26	-0.02	0.01

FREE DEPTH 3.1 +- 0.0 KM OT= 30.4 +- 0.0 SEC
LOCN IS 30.765 117.128 +/- 0.1 0.1 KM

OCT 1983 20 1827 ML 2.4

	MAN	BAL	KLB	MUN	NWAO
P-ARR	18.89	25.10	35.10	42.00	54.10
S-ARR	0.00	30.10	0.00	60.00	81.00
DIST=	7.47	44.57	104.85	149.75	230.60
P-WT.	0	0	0	3	4
P-RES	-0.09	0.03	0.12	-0.23	1.33
S-WT.	4	4	4	4	4
S-RES	-19.92	-0.37	-47.62	-0.18	2.56

CONSTR DEP 2.0 +- 0.0 KM OT= 17.7 +- 0.0 SEC
LOCN IS 30.851 117.076 +/- 0.9 0.7 KM

21 OCT 1855 ML 1.8

	BAL	KLB	MUN
P-ARR	8.60	20.50	28.50
S-ARR	13.20	33.70	47.20
DIST=	41.98	114.38	164.96
P-WT.	0	0	0
P-RES	0.00	0.00	0.00
S-WT.	4	4	4
S-RES	-0.49	-0.60	-0.95

FREE DEPTH 2.1 +- 0.0 KM OT= 1.7 +- 0.0 SEC
LOCN IS 30.716 117.126 +/- 0.0 0.0 KM

25 OCT 1983 1455 ML 2.0

	MAN	BAL	KLB	MUN
P-ARR	42.74	46.80	58.50	65.60
S-ARR	44.74	51.60	71.30	0.00
DIST=	14.29	40.55	112.28	159.31
P-WT.	0	0	0	0
P-RES	0.02	-0.01	0.11	0.06
S-WT.	3	3	3	4
S-RES	0.01	-0.21	-0.56	-84.24

FREE DEPTH 8.5 +- 0.0 KM OT= 40.0 +- 0.0 SEC
LOCN IS 30.758 117.092 +/- 2.1 1.9 KM

OCT 1983 26 0706 ML 2.4

	K20	K27	K16	K08	K06	MAN	BAL	KLB	MUN	NWAO	MEK
P-ARR	2.84	2.43	2.87	2.96	2.63	4.29	8.20	20.10	27.30	39.00	67.00
S-ARR	0.00	0.00	0.00	0.00	0.00	6.15	13.00	32.80	46.00	68.00	114.00
DIST=	7.59	3.94	7.38	8.66	6.24	16.77	40.99	113.93	162.87	243.87	477.29
P-WT.	0	0	0	0	0	1	2	2	2	4	4
P-RES	-0.01	-0.02	0.05	-0.03	-0.06	0.11	0.14	0.08	-0.16	1.54	0.77
S-WT.	4	4	4	4	4	3	4	4	4	4	4
S-RES	-4.04	-3.35	-4.00	-4.28	-3.76	-0.19	-0.07	-0.98	-0.67	4.01	0.19

FREE DEPTH 6.3 +- 0.0 KM OT= 1.2 +- 0.0 SEC
LOCN IS 30.730 117.110 +/- 0.2 0.3 KM

02 Jun 1979 ML 6.2

	MUN	NWAO	KLG	MEK	MBL	ASPA	KNA
P-ARR	24.90	34.50	56.00	65.50	138.60	224.20	251.00
S-ARR	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DIST=	158.07	233.03	408.88	485.34	1103.09	1833.86	2047.07
P-WT.	0	0	0	0	4	4	4
P-RES	-0.09	0.13	-0.08	0.04	-2.19	-5.71	-4.91
S-WT.	4	4	4	4	4	4	4
S-RES	-43.70	-59.94	-97.54	-113.79	-244.27	-398.62	-443.65

CONSTR DEP 6.0 +- 0.0 KM OT= -0.6 +- 0.0 SEC
LOCN IS 30.825 117.186 +/- 0.6 1.1 KM
30.82 117.19 DIST. FROM REFERENCE IS 0.7 211.

28 OCT 1983 0256 lt ML 2.1

	BAL	K01	K02	K03	K04	K20	K17	K16	K15	K14	K13	K11	K07	MAN	K05
P-ARR	28.50	28.10	27.30	26.78	26.89	21.37	22.40	21.51	21.46	21.83	22.27	21.69	22.28	23.50	22.81
S-ARR	33.30	32.80	0.00	30.70	30.90	0.00	0.00	0.00	22.46	23.20	0.00	0.00	23.24	25.37	23.90
DIST=	46.45	42.86	38.15	35.03	36.38	2.45	8.86	2.53	2.05	4.60	7.49	4.06	7.66	15.35	10.67
P-WT.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P-RES	-0.12	0.07	0.04	0.04	-0.08	-0.10	-0.05	0.03	0.04	0.05	0.04	-0.01	0.02	-0.01	0.06
S-WT.	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
S-RES	-0.95	-0.43	-31.88	-0.29	-0.48	-21.86	-23.56	-21.88	0.68	0.81	-23.18	-22.26	0.02	-0.02	-0.17

FREE DEPTH 2.1 +- 0.0 KM OT= 20.9 +- 0.0 SEC
LOCN IS 30.740 117.167 +/- 0.1 0.1 KM

OCT 1983 29 0505 ML 1.5

	K20	K04	K17	K16	K15	K13	K11	K10	MAN	K08	K06	K05	K01	K02	K03
P-ARR	31.90	36.51	31.57	32.03	31.55	31.47	31.60	31.57	33.36	32.23	31.83	31.97	37.36	37.52	37.32
S-ARR	32.80	0.00	0.00	33.06	31.92	0.00	0.00	0.00	35.30	0.00	0.00	32.75	0.00	42.15	0.00
DIST=	7.04	36.05	4.46	7.05	3.83	2.63	4.52	3.45	16.17	8.73	6.75	7.29	40.13	41.27	39.64
P-WT.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P-RES	-0.05	-0.11	-0.02	0.08	0.04	0.09	0.00	0.10	-0.02	0.02	-0.08	-0.02	0.06	0.04	0.11
S-WT.	3	4	4	3	3	4	4	4	3	4	4	3	4	3	4
S-RES	-0.11	-41.00	-32.29	0.14	-0.23	-31.93	-32.30	-32.08	-0.09	-33.35	-32.84	-0.23	-42.17	-0.34	-42.03

FREE DEPTH 3.6 +- 0.0 KM OT= 30.6 +- 0.0 SEC
LOCN IS 30.735 117.114 +/- 0.2 0.2 KM

30 OCT 1983 1448 ML 1.2

	K20	K17	K16	K15	K14	K13	K11	K08	K07	K06	K05	K04	K03	K02	K01
P-ARR	43.84	43.49	44.03	43.46	43.21	43.33	43.58	44.17	44.12	43.81	44.00	48.40	49.19	49.44	49.35
S-ARR	0.00	0.00	44.90	44.18	0.00	0.00	0.00	0.00	45.05	44.51	44.87	0.00	53.70	0.00	0.00
DIST=	7.15	4.55	7.06	3.82	0.59	2.49	4.40	8.61	7.33	6.54	7.07	35.84	39.62	41.47	40.28
P-WT.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
P-RES	-0.09	-0.08	0.11	-0.02	-0.02	-0.01	0.03	0.02	0.16	-0.03	0.08	-0.14	0.03	-0.03	0.08
S-WT.	4	4	3	3	4	4	4	4	3	3	3	4	3	4	4
S-RES	-44.91	-44.29	0.01	0.04	-43.70	-43.90	-44.26	-45.29	0.09	-0.25	-0.02	-52.90	-0.27	-54.50	-54.16

FREE DEPTH 3.8 +- 0.0 KM OT= 42.6 +- 0.0 SEC
LOCN IS 30.733 117.114 +/- 0.2 0.2 KM

31 OCT 1983 0342 ML 1.1

	BAL	KLB	K01	K03	K04	MAN	K20	K17	K10	K09	K05
P-ARR	14.90	25.60	13.54	14.90	14.82	9.36	9.08	8.57	9.68	9.69	10.12
S-ARR	19.50	37.50	19.80	19.50	0.00	10.50	0.00	0.00	0.00	0.00	11.75
DIST=	43.55	107.98	34.04	43.00	43.19	9.75	8.89	5.21	10.58	10.71	13.92
P-WT.	0	0	0	0	0	0	4	4	4	4	4
P-RES	0.01	0.12	0.21	0.10	-0.01	0.01	-0.13	-0.06	0.20	0.19	0.09
S-WT.	3	3	4	4	4	3	4	4	4	4	4
S-RES	-0.67	-1.01	2.35	-0.51	-20.06	-0.06	-10.32	-9.32	-10.79	-10.83	0.01

FREE DEPTH 2.2 +- 0.0 KM OT= 7.7 +- 0.0 SEC
LOCN IS 30.798 117.104 +/- 0.6 0.6 KM

04 NOV 1983 0853 ML 1.5

	BAL	K02	K03	K04	KLB	MUN
P-ARR	6.50	6.65	6.28	5.53	18.40	26.20
S-ARR	11.50	11.35	10.30	0.00	31.10	44.30
DIST=	41.89	41.19	39.13	35.78	113.21	163.05
P-WT.	0	0	0	0	0	0
P-RES	-0.08	0.19	0.15	-0.05	0.13	0.31
S-WT.	3	3	3	4	3	3
S-RES	-0.18	-0.14	-0.61	-9.96	-0.84	-0.84

FREE DEPTH 6.0 +- 0.0 KM OT= -0.4 +- 0.0 SEC
LOCN IS 30.733 117.119 +/- 1.1 1.0 KM

05 NOV 1983 2341 ut ML 1.2

	BAL	K02	K03	K04	KLB	MUN
P-ARR	45.80	44.28	46.00	46.07	56.00	63.30
S-ARR	50.90	48.30	51.00	51.60	68.00	81.00
DIST=	44.52	34.69	44.67	45.98	106.05	153.54
P-WT.	0	0	0	0	0	0
P-RES	-0.02	0.05	0.15	0.01	0.12	0.17
S-WT.	3	3	3	3	3	3
S-RES	-0.38	-0.22	-0.32	-0.09	-0.69	-0.25

FREE DEPTH 7.8 +- 0.0 KM OT= 38.4 +- 0.0 SEC
LOCN IS 30.823 117.099 +/- 0.7 0.6 KM

07 NOV 1983 1833 ML 1.0

	BAL	K02	K03	K04
P-ARR	9.20	9.60	8.80	7.90
S-ARR	14.10	14.60	12.80	10.90
DIST=	41.06	43.16	38.72	33.55
P-WT.	2	0	0	0
P-RES	0.04	0.09	0.02	-0.04
S-WT.	3	2	4	4
S-RES	-0.06	-0.16	-0.70	-1.14

CONSTR DEP 5.0 +- 0.0 KM OT= 2.3 +- 0.0 SEC
LOCN IS 30.712 117.118 +/- 0.3 0.3 KM

09 NOV 1983 1131 ut ML 1.0

	BAL	K02	K03	K04	KLB	MUN
P-ARR	19.40	18.60	19.10	18.97	0.00	38.50
S-ARR	24.20	23.00	23.40	22.90	43.00	56.00
DIST=	43.23	37.98	40.61	39.87	109.90	159.49
P-WT.	0	0	0	0	0	0
P-RES	0.04	0.10	0.17	0.16	-30.33	0.39
S-WT.	3	3	3	3	3	3
S-RES	-0.41	-0.12	-0.46	-0.75	-0.60	-1.08

FREE DEPTH 3.7 +- 0.0 KM OT= 12.2 +- 0.0 SEC
LOCN IS 30.769 117.117 +/- 1.2 1.2 KM

NOV 10 1510

	BAL	K02	K03	K04	KLB	MUN
P-ARR	21.10	19.38	21.45	21.60	31.20	38.20
S-ARR	26.30	23.40	25.00	0.00	43.00	56.20
DIST=	44.73	34.11	47.06	48.59	104.95	150.73
P-WT.	1	0	0	0	2	2
P-RES	0.06	0.09	0.03	-0.07	0.25	-0.01
S-WT.	3	3	4	4	3	3
S-RES	-0.16	-0.04	-2.13	-27.56	-0.62	0.00

FREE DEPTH 3.6 +- 0.0 KM OT= 13.6 +- 0.0 SEC
LOCN IS 30.845 117.084 +/- 0.6 0.7 KM

12 NOV 1983 0605

	BAL	KLB	K02	K03	K04
P-ARR	18.60	29.00	17.19	18.82	19.35
S-ARR	23.70	41.00	21.20	23.70	24.00
DIST=	43.85	106.26	35.14	46.07	46.81
P-WT.	0	3	0	2	3
P-RES	0.02	0.16	0.04	-0.13	0.28
S-WT.	3	4	3	4	4
S-RES	-0.20	-0.66	-0.21	-0.83	-0.74

CONSTR DEP 2.0 +- 0.0 KM OT= 11.3 +- 0.0 SEC
LOCN IS 30.829 117.086 +/- 0.6 0.5 KM

18 NOV 1983 0717

	BAL	KLB	MUN	K02
P-ARR	40.20	0.00	58.20	39.52
S-ARR	45.00	63.20	76.20	43.66
DIST=	42.02	108.27	153.19	37.08
P-WT.	0	4	0	0
P-RES	-0.04	-51.12	0.07	0.08
S-WT.	4	4	3	3
S-RES	-0.36	-0.99	-0.14	-0.30

CONSTR DEP 5.0 +- 0.0 KM OT= 33.3 +- 0.0 SEC
LOCN IS 30.814 117.075 +/- 2.9 2.5 KM

NOV 21 2216 z

	BAL	K02	KLB	MUN
P-ARR	36.00	35.46	47.40	54.80
S-ARR	40.70	39.80	60.00	73.50
DIST=	41.89	38.75	110.56	158.38
P-WT.	0	0	3	0
P-RES	0.00	-0.02	0.11	0.00
S-WT.	4	4	4	4
S-RES	-0.38	-0.39	-0.65	-0.15

FREE DEPTH 3.6 +- 0.0 KM OT= 29.1 +- 0.0 SEC
LOCN IS 30.772 117.100 +/- 0.2 0.2 KM

25 NOV 1983 1224 lt ML 1.8

	BAL	K01	K02	K03	K04	MUN
P-ARR	21.50	20.16	20.49	21.58	21.53	39.80
S-ARR	26.50	24.00	24.60	26.60	0.00	0.00
DIST=	43.19	34.15	36.72	43.06	42.87	156.30
P-WT.	0	0	0	0	0	0
P-RES	-0.04	0.11	0.02	0.07	0.05	-0.02
S-WT.	3	4	3	3	4	4
S-RES	-0.27	-0.20	-0.33	-0.14	-26.68	-58.44

FREE DEPTH 3.5 +- 0.0 KM OT= 14.4 +- 0.0 SEC
LOCN IS 30.795 117.102 +/- 0.4 0.3 KM

DEC 03 1148

	BAL	K02	K03	K04	KLB	MUN
P-ARR	59.30	58.42	58.29	58.27	70.10	78.30
S-ARR	64.50	62.50	62.40	0.00	82.70	96.50
DIST=	44.31	38.36	38.12	37.86	110.39	162.11
P-WT.	0	0	0	0	0	0
P-RES	-0.01	0.08	-0.01	0.02	-0.08	0.01
S-WT.	4	4	4	4	4	4
S-RES	-0.19	-0.50	-0.53	-62.85	-0.81	-1.05

FREE DEPTH 3.7 +- 0.0 KM OT= 52.0 +- 0.0 SEC
LOCN IS 30.753 117.138 +/- 0.2 0.2 KM

05 DEC 1983 0210 ut

	K01	K02	K03	K04	BAL	KLB	MUN
P-ARR	13.76	13.28	12.95	13.02	14.60	0.00	0.00
S-ARR	0.00	17.55	17.40	17.20	19.40	37.50	52.00
DIST=	41.69	38.03	36.19	37.07	45.74	110.06	163.70
P-WT.	0	0	0	0	0	4	4
P-RES	-0.08	0.04	0.01	-0.06	0.09	-25.09	-33.70
S-WT.	4	4	4	4	4	4	4
S-RES	-18.91	-0.32	0.06	-0.39	-0.66	-0.88	-1.31

FREE DEPTH 0.1 +- 0.0 KM OT= 6.9 +- 0.0 SEC
LOCN IS 30.746 117.156 +/- 0.2 0.2 KM

DEC 06 1447 ML 1.0

	K01	K02	K03	K04	BAL	KLB	MUN
P-ARR	26.80	28.52	29.60	28.67	27.70	0.00	46.30
S-ARR	0.00	0.00	0.00	33.46	0.00	56.20	64.00
DIST=	31.30	42.14	48.60	42.99	37.00	113.21	153.98
P-WT.	0	0	0	0	0	4	0
P-RES	0.01	-0.02	0.02	0.00	-0.01	-40.08	0.00
S-WT.	4	4	4	4	4	4	4
S-RES	-30.68	-33.71	-35.52	-0.48	-32.27	2.51	-0.47

FREE DEPTH 7.7 +- 0.0 KM OT= 21.5 +- 0.0 SEC
LOCN IS 30.784 117.034 +/- 0.0 0.0 KM

DEC 14 0200 ML 2.3

	K01	K02	K03	K04	BAL	MUN
P-ARR	38.04	38.28	40.41	40.79	40.40	57.40
S-ARR	0.00	0.00	0.00	0.00	45.60	0.00
DIST=	30.48	33.36	45.47	47.81	45.62	152.04
P-WT.	0	0	0	0	0	0
P-RES	0.11	-0.11	0.05	0.04	0.01	-0.01
S-WT.	4	4	4	4	3	4
S-RES	-41.69	-42.49	-45.91	-46.57	-0.35	-75.43

FREE DEPTH 6.3 +- 0.0 KM OT= 32.8 +- 0.0 SEC
LOCN IS 30.840 117.099 +/- 0.5 0.5 KM