FILE

INTERNAL DOCUMENT 167

I.O.S.

Long Range Acoustic Propagation Trials June-July 1982

RRS DISCOVERY Cr. 130

W.J. Gould

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NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF
OCEANOGRAPHIC
SCIENCES

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Dept. of the Environment
Project No. PECD 7/9/023

INTRODUCTION

The Institute of Oceanographic Sciences are in receipt of a contract from the UK Dept. of the Environment to investigate dispersion in the deep basins of the N. Atlantic. This is to be observed by use of neutrally buoyant floats ballasted for sub-thermocline depths and tracked over periods of the order of 2 years by means of autonomous listening stations (ALS) placed on moorings. Reception of the low frequency (250 Hz) sounds emitted by the floats at at least two ALS permits the float positions to be determined.

Previous use of the technique in the USA has been restricted to thermocline depths (< 2000 m) with the floats ballasted to be neutrally buoyant near the SOFAR axis (the SOFAR channel is marked by a minimum in the vertical profile of sound speed which acts as a wave guide in which sound rays are focussed and which thus permits long range propagation)

The present proposal for use of the floats at depths well away from the SOFAR axis has required two major developments. A float has had to be designed which was capable of working to depths of the order of 4000 m (beyond the 2500 m depth rating of the aluminium tubing used to construct the US floats). It must be demonstrated that reception of signals is possible over horizontal ranges of the order of 1000 km from sound sources at depth.

To these ends an experiment was conducted on RRS DISCOVERY Cr. 130 to test a float design and to measure signal reception over 1000 km-long tracks.

THE SUMMER 1982 EXPERIMENT:

SOUND SOURCE CONSTRUCTION AND DEPLOYMENT

In the sound ranging trials, sound sources were to be moored in the water column and the signal audibility was to be measured by observing signal reception at depths through the water column at a variety of ranges from the sound sources. The sound sources were positioned in the mooring so that they lay at depths near to the SOFAR axis. In the N.E. Atlantic the intrusion of Mediterranean water produces a double minimum (SOFAR channel) in the water column close to 600 and 1900 m. The sound sources were deployed close to these depths.

The sound sources were similar in design to the proposed deep floats (fig. 1), using Benthos 17" dia glass spheres for electronics and battery pack housings but employing the standard sound transducer used in the US floats. (The transducers are manufactured by ACTRAN Corp. Florida, USA and are tuned to the depth of use by D. Webb at Woods Hole Oceanographic Institution). The trial float design will incorporate a second battery pack housing.

The sound signals from each source were transmitted once every 20 minutes, each pulse being an 80 sec-long swept-frequency signal. The two sources on the moorings were synchronised so that the signals occurred close together in time but with a separation of a minute or so to avoid the possibility of overlap. The depths chosen for the sound sources were 600 and 1900 m - close to the minimum in the local sound speed profile (fig. 2).

LISTENING PROCEDURES

The reception of the sound signals was combined on each station with the working of a CTD station. The CTD package consisted of a Neil Brown CTD unit, General Oceanics 12 bottle multisampler, Seatech 1m transmissometer, hydrophone and preamplifier and a 14 m long multielement hydrophone hung below the CTD. On each station the acoustic signals were received during the descent. The winch was stopped at 500 m intervals synchronised with the expected signal arrival times. The signal repetition interval (20 mins) and the 500 m listening interval allowed modest (~ 0.7 m/sec) lowering speeds to be used while still leaving sufficient time at each level to allow the AGC setting on the receiver to respond to the reduced noise level with the winch stopped. Near the bottom of the station the power was switched to the CTD unit and a normal CTD station waited on the ascent.

The acoustic receiving system consisted of two "shore station" receivers loaned by Woods Hole Oceanographic Institution. The outputs of the two receiver correlations were fed to an oscilloscope and to a 2 channel pen recorder. The records from one receiver were recorded on a Sea Data digital cassette.

The signal processing incorporated in the receivers made it impossible to retrieve the actual received signal levels, however, since detectability is the main criterion to assess whether float tracking is feasible the recording of correlation values was sufficient. Perfect correlations resulted in output signal levels of 3 volts, signals of 0.8 v were regarded as marginal and 0.6 v was the typical correlator noise level.

RESULTS

The positions of the sound source moorings and of the listening stations are listed in Table 1 and shown in fig. 3. The listening stations were carried out in two stages. On the first leg of the cruise the southern stations were occupied. After a port call in Madeira the sound source mooring was recovered, the batteries replaced and the mooring relaid period to occupation of the northern stations. The site chosen for the mooring was on top of a ridge in the Gloria fracture zone (running between the Azores and Cape St. Vincent) and gave an uninterrupted aspect to the north and south. During the first deployment of the sound source mooring an accident resulted in a sound source being dropped to the sea bed. The source was undamaged and continued to operate throughout the southern leg while lying on the bottom in 4400 m of water. By the start of the northern leg the battery pack on this source was almost exhausted and no results were obtained. The position of the 4400 m source was 37° 10' 4N 16° 44' 7W.

In the ultimate float deployments the neutrally buoyant floats (sound sources) will be at depth and the receivers (ALS) will be near the local axis of the SOFAR Channel. In this experiment the positions are reversed with the sound sources at the local sound axis and the receiver lowered to depth.

The vertical profiles of sound speed varied considerably over the latitudes covered by this experiment. A sound speed cross section is shown in fig. 4 for the uppermost 3000 m. The figure clearly demonstrates the dominant influence of the Mediterranean water intrusion near 1000 m depth in creating the double sound speed minimum typical of the NE Atlantic. The variations in Mediterranean water influence can also be seen in the individual sound speed profiles for stns 10566 (nearest the sound source mooring) fig. 5, 10568 (southernmost station) fig. 6 and 10574 (northernmost station) fig. 7.

Figure 4 also shows the depth at which the near surface sound speed is encountered at depth i.e. the thickness of the sound channel. Two curves are given, one for the observed summer situation and a second one assuming a mixed layer depth of 100 m as being typical of winter stratification. The difference between these two lines illustrates the significant seasonal effects particularly in the north of the region.

The observed correlation values (3.0 perfect, 0.8 marginal) at the various observed depths are given in tables 2 to 6. They demonstrate that the sound sources near the sound channel axes are detectable in summer over almost all the water column at ranges of up to 1000 km. The uncertainty in any single correlation value is illustrated by the values obtained during seven repeated receptions of signals at a near marginal reception position. The correlation values vary in one case from 0.9 to 1.65 and in the other from 1.0 to 1.55. This suggests that even at positions where signal receptions did not produce significant correlations, reception over extended periods of time might have produced a detectable signal.

A series of ray plots have been produced for the sound speed profiles of the 400 km stations on the southern and northern legs. The sound speed profiles are assumed constant over the entire 1000 km path length (a clearly unrealistic assumption). The rays are terminated at the fifth surface reflection. Eight plots are given (figs. 8-11) for each source depth (600 and 1900 m), for the southern and northern legs, and for winter and summer condition.

Fig. 8 (summer, southern leg) shows refracted rays penetrating to 3600 m from both source depths but for the winter profile (fig. 9) to only 3000 m. The northern leg shows refracted rays penetrating to 3200 m in the summer (fig. 10) but in winter the two sand channels become quite separate with deep channel rays only penetrating to 2700 m.

It is clear that signals in this experiment were detected at depths and ranges to which no refracted rays are predicted to penetrate by the ray tracing program. This suggests that ray tracing may give a somewhat pessimistic view of reception conditions.

IMPLICATION FOR FLOAT CONSTRUCTION AND TRACKING

If we assume reciprocity we see that floats will be detectable by listening stations at 1900 m depth over virtually the entire water column in summer both north and south of the Azores/Gibraltar ridge and to ranges of 800-1000 km.

In winter there may be an appreciable reduction in the depth and range of float reception due to the overall thinning of the SOFAR channel. The use of reflected rays could improve the depth limitation but would limit ranges the order of 300 km and would complicate the calculation of float positions. A pessimistic view would be that 2700 m is the lower limit for year-round float reception but in the Madeira basin this lower limit is likely to be closer to 3500 m.

The construction of a sound source employing many float components was successful and its operation demonstrated to a depth of 4400 m. Battery life was as predicted and should ensure a 2 year float life with a signal repetition rate of 3/day.

Overall the trials have shown the feasibility of conducting multi year float dispersion experiments with neutrally buoyant floats at sub-thermocline depths over much of the NE Atlantic.

The construction of floats of similar design to the sound sources appears practicable. The problems of float ballasting and temperature/depth telemetry have yet to be tackled.

TABLE 1

Southern Transect

Station	Latitude	Longitude	Range (km)	Comments
10559	37° 26'.8N	16° 35'.4W	0	SS Mooring
10560	37° 16'.7N	16° 50'.3W	28.8	
10561	37° 03'.9N	17° 09'.9W	66.2	
10562	36° 56'.3N	17° 33'.1W	102.2	
10563	36° 29'.0N	18° 31'.2W	202.0	
10564	37° 16'.4N	19° 38'.8W	270.6	Behind topography
10565	35° 17'.5N	20° 11'.4W	401.3	
10566	33° 54'.0N	21° 46'.5W	611.7	
10567	33° 56'.3N	21° 46'.1W	608.4	Repeat of 10566
10568	30° 49'.3N	24° 11'.3W	1014.3	
10569	31° 29'.7N	21° 50'.7W	818.6	

Northern Transect

Station	Latitude	Longitude	Range (km)	Comments
10570	37° 26'.9N	16° 34'.6W	0	SS Mooring
10571	38° 19'.3N	16° 00'.1W	109.4	
10572	40° 50'.6N	15° 29'.8W	388.5	
10573	44° 18'.9N	13° 43'.6W	799.6	
10574	46° 20'.2N	13° 57'.8W	1010.9	

TABLE 2

Source Depth 1925 m

Southern Leg

Stn. / Range Km. / Depth	10560 28.8	10561 66.2	10562 102.2	10563 202.0	10564 270.6	10565 401.3	10567 608.4	10569 818.6	10568 1014.3
0.5	1.7	2.1	2.5	1.1	2.7	1.8	2.1	2.1	0.8
1.0	2.4	2.3	2.8	2.3	2.4	1.3	2.0	2.6	0.8
1.5	2.5	1.9	1.7	2.5	2.7	2.5	1.2	2.6	1.1
2.0	2.9	2.5	1.8	2.1	2.1	2.5	2.5	2.3	1.0
2.5	2.8	3.1	2.7	3.0	2.7	2.2	2.2	1.6	1.0
3.0	2.4	2.2	2.9	2.5	2.6	2.8	0.9	2.4	0.9
3.5	2.4	2.8	2.8	2.9	1.2	1.3	1.1	1.5	1.0 (1)
4.0	3.1	1.8	2.5	2.4	1.3	No Detect	1.4	1.2	0.8
4.5	2.5	2.4	1.9	1.9	1.2	0.8	1.1	0.9	No Detect
5.0		1.7		1.4	1.5	No Detect			

(1) Repeated correlation values 1.15, 1.0, 1.15, 1.1, 1.1, 1.55, 1.2.

TABLE 3

Southern Leg

Source Depth 669 m

Stn range (km) / Depth	10560 28.8	10561 66.2	10562 102.2	10563 202.0	10564 270.6	10565 401.3	10567 608.4	10569 818.6	10568 1014.3
0.5	2.1	2.1	2.7	1.7	2.1	2.4	2.4	2.3	1.6
1.0	2.4	2.7	2.9	1.9	2.8	0.7*	1.9	2.7	1.1
1.5	2.1	1.9	2.7	2.5	2.6	2.9	2.0	2.3	1.3
2.0	2.7	2.3	2.2	2.5	2.8	2.3	2.5	2.3	1.5
2.5	2.8	2.2	2.5	2.3	3.2	1.8	2.2	1.8	1.1
3.0	2.5	2.2	2.9	2.7	2.5	2.5	2.8	1.5	0.9
3.5	2.7	2.4	2.6	2.7	1.3	1.7	1.7	1.5	1.1 (2)
4.0	3.0	2.0	2.7	2.4	1.0	1.0	1.0	1.3	No Detect
4.5	2.6	2.2	2.0	1.9	1.3	No Detect	No Detect	1.3	No Detect
5.0		1.9		1.4	1.0	No Detect			

*Multiple interfering

(2) Repeated correlation values 1.65, 0.9, 1.54, 1.4, 1.4, 1.7, 1.1

TABLE 4

Southern Leg

Source Depth 4400 m

Stn range km / Depth	10560 28.8	10561 66.2	10562 102.2	10563 202.2	10564 270.6	10565 401.3	10567 608.4	10569 818.6	10568 1014.3
0.5	1.0	1.5	2.2	0.7	No Detect	No Detect	1.0	No Detect	No Detect
1.0	No Data	2.7	2.0	1.1	No Detect	No Detect	No Detect	"	"
1.5	2.0	2.0	1.9	1.0	No Detect	No Detect	No Detect	"	"
2.0	2.8	1.9	2.7	1.6	No Detect	1.3	No Detect	"	"
2.5	2.8	2.4	1.7	1.0	No Detect	0.9	No Detect	"	"
3.0	2.5	2.7	2.2	0.7	No Detect	1.5	No Detect	"	"
3.5	0.8	2.1	1.9	0.8	0.9	No Detect	No Detect	"	"
4.0	1.1	3.0	2.8	2.8	1.7	No Detect	No Detect	"	"
4.5	0.8	2.5	2.7	2.5	No Detect	No Detect	0.9	No Detect	No Detect
5.0		2.9		2.3	1.1	No Detect			

TABLE 5

Northern Leg

Source Depth 635 m

Stn range Depth km			10571 109.4			10572 388.5		10573 799.6	10574 1010.9
0.5			2.8			2.1		0.8	1.5
1.0			2.5			2.4		2.3	0.8
1.5			2.1			1.7		1.4	1.7
2.0			2.6			1.5		1.2	1.3
2.5			2.8			1.7		1.8	1.2
3.0			3.0			2.1		1.4	1.0
3.5			1.7			1.8		1.5	0.6
4.0			1.6			2.3		1.8	0.6
4.5			2.0			0.8		1.1	No Detect
5.0			1.2			1.9		0.6	1.0

TABLE 6

Source Depth 1954 m

Northern Leg

Stn Range Km Depth			10571 109.4			10572 388.5		10573 799.6	10574 1010.9
0.5			2.6			2.4		2.0	1.2
1.0			2.7			2.6		1.5	1.1
1.5			2.6			2.6		1.3	1.5
2.0			3.0			1.8		1.5	1.2
2.5			2.8			2.5		0.8	0.7
3.0			2.5			1.9		1.3	No Detect
3.5			2.7			2.3		0.8	1.2
4.0			2.4			2.7		0.9	1.0
4.5			1.4			1.4		0.9	No Detect
5.0			1.8			1.1		0.6	0.9

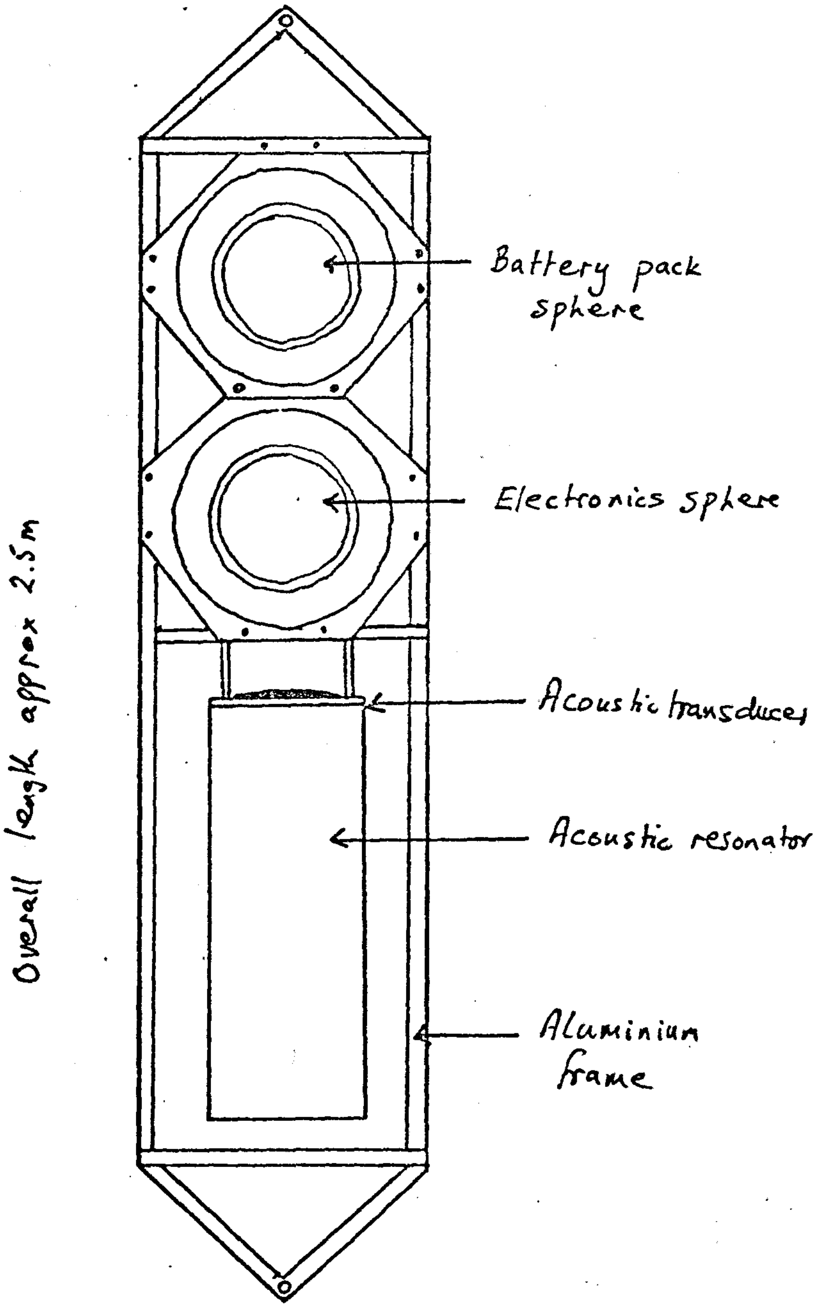

Battery pack sphere
Electronics sphere
Acoustic transducer
Acoustic resonator
Aluminium frame
Overall length approx 2.5m

Fig 1.

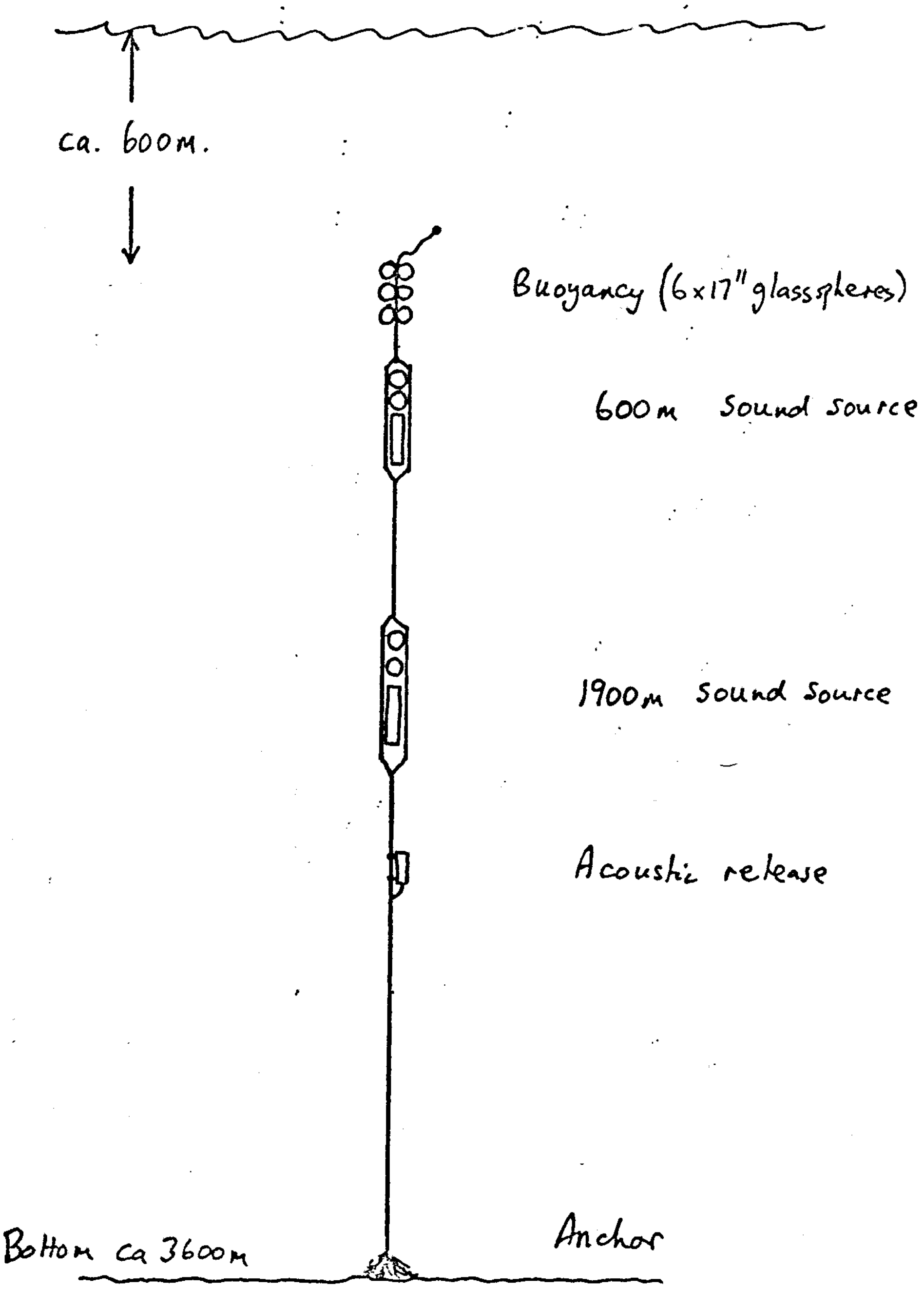
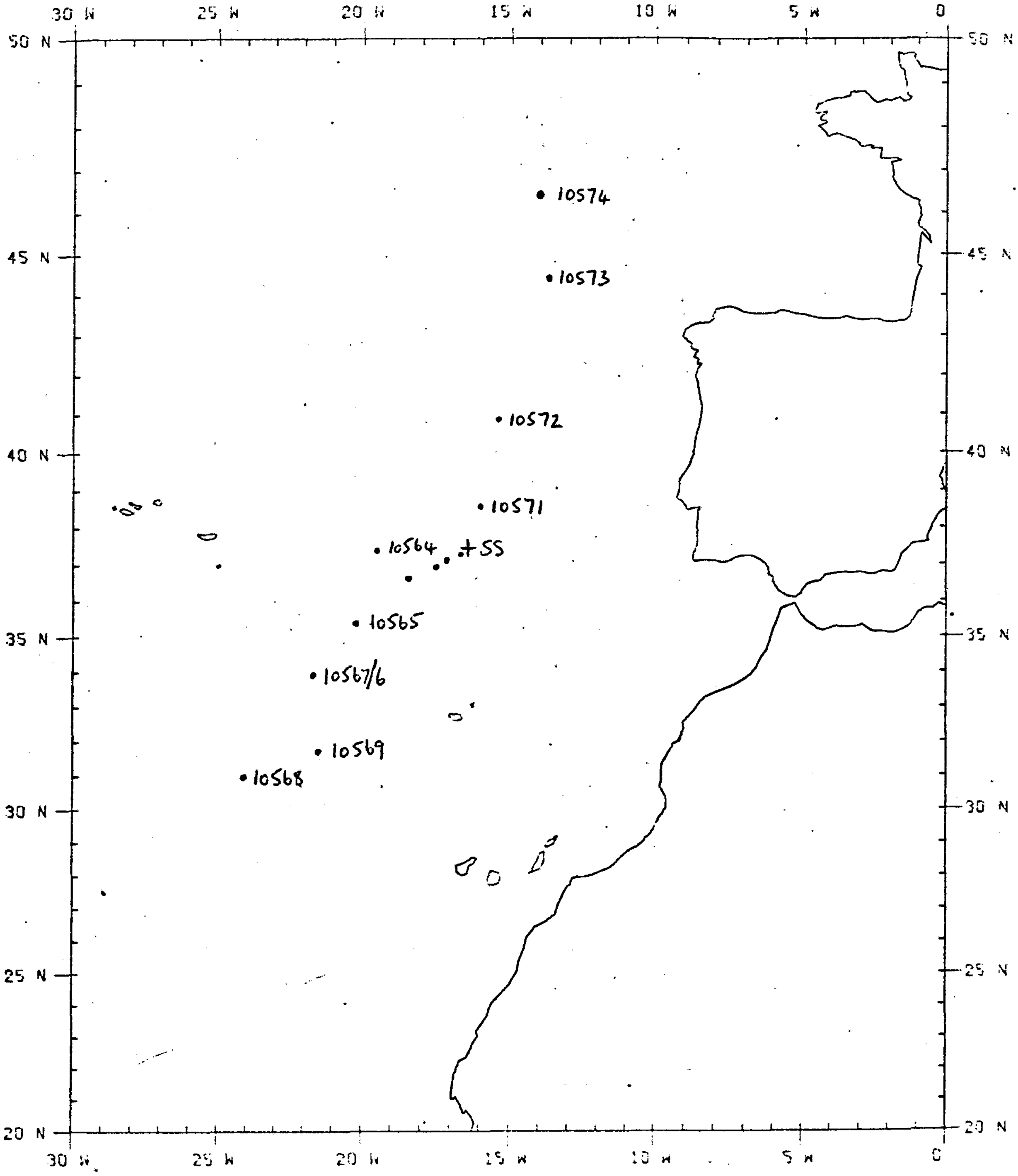

ca. 600m.
Buoyancy (6x17" glasspheres)
600m sound source
1900m sound source
Acoustic release
Bottom ca 3600m
Anchor

Fig 2


30 W
25 W
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10 W
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50 N
45 N
40 N
35 N
30 N
25 N
20 N
10574
10573
10572
10571
10564
+55
10565
10567/6
10569
10568

Fig 3

CRUISE 130 SOUND SPEED.

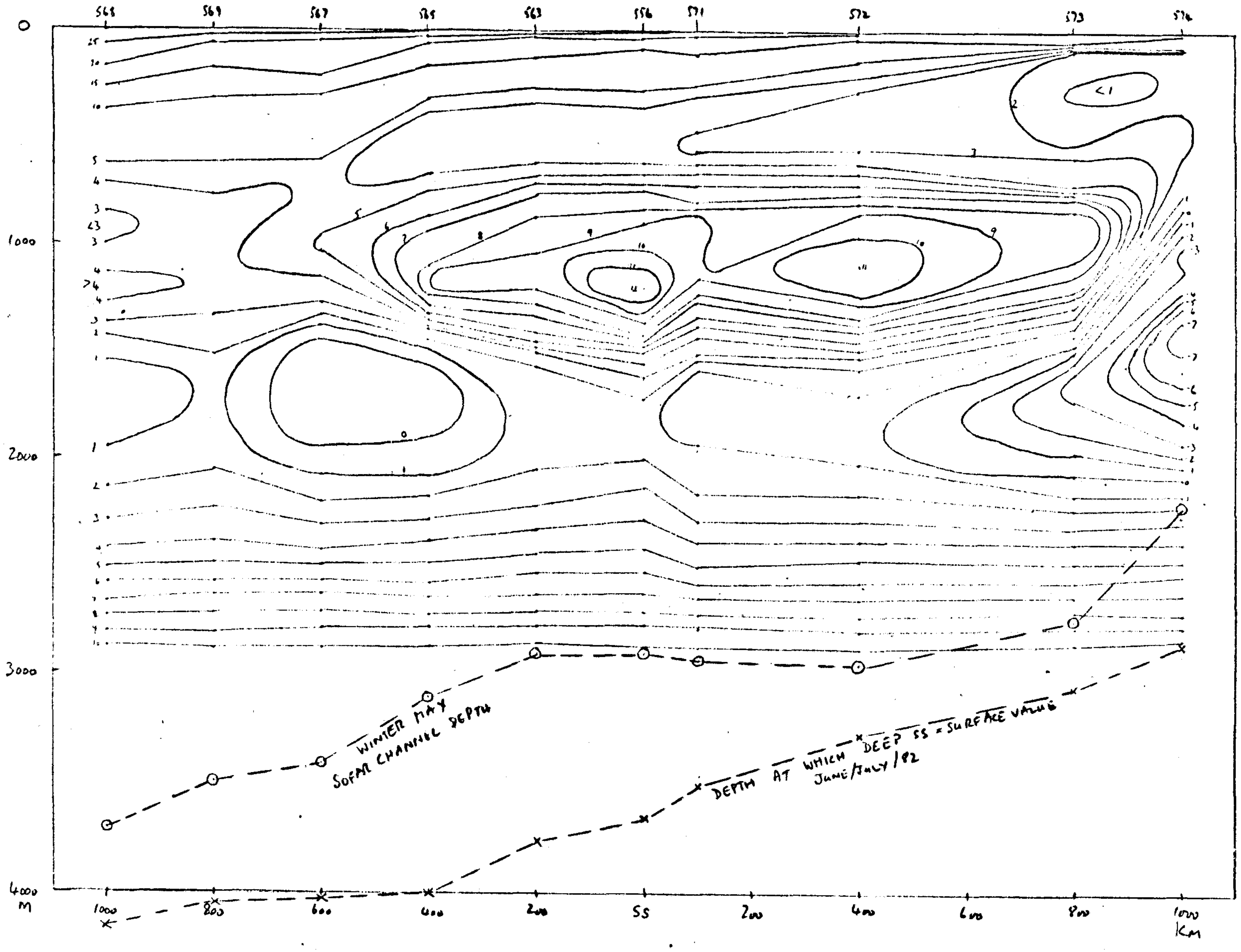
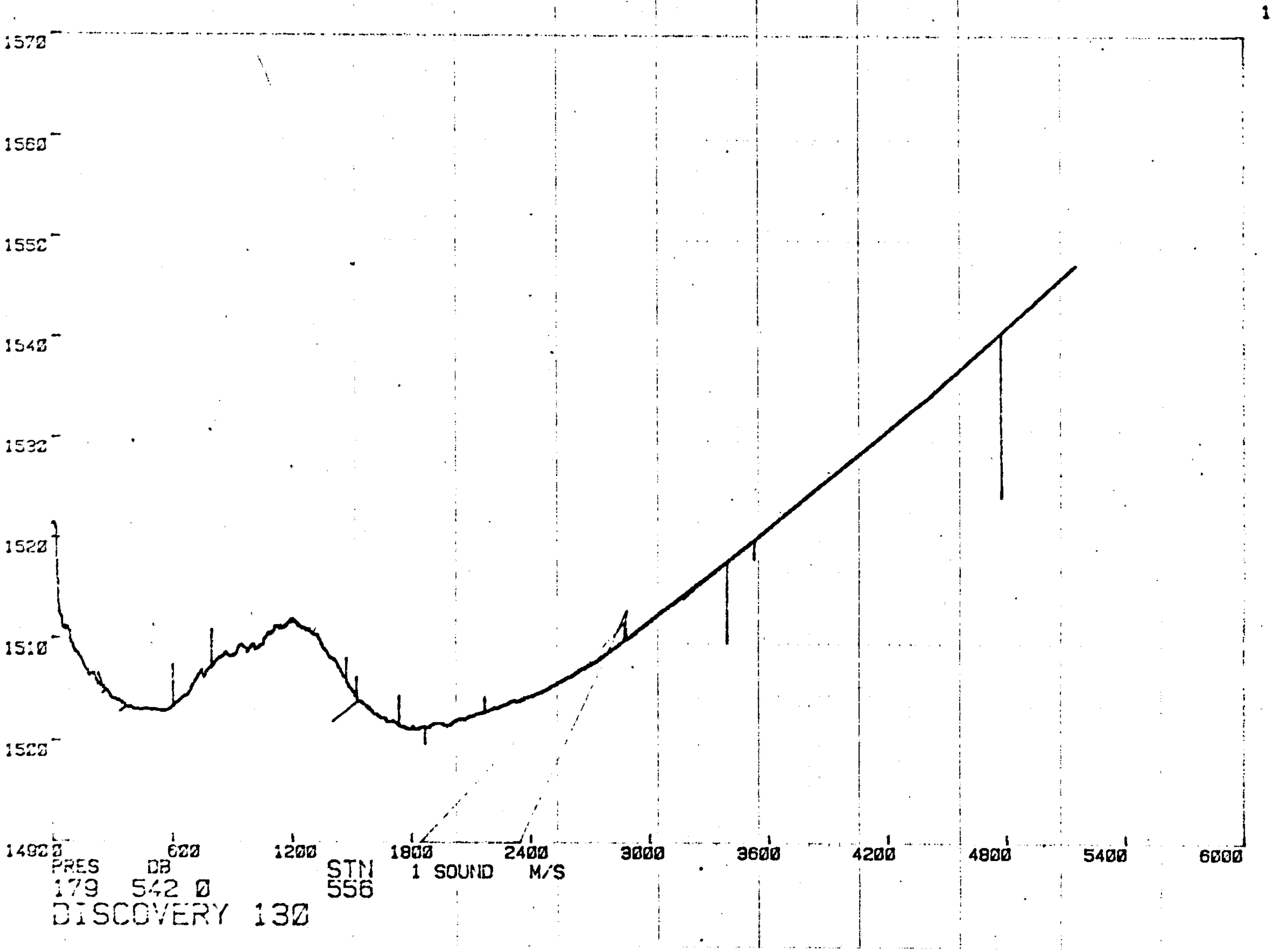


Fig 4

Fig. 5



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1540
1530
1520
1510
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1490
0
600
1200
1800
2400
3000
3600
4200
4800
5400
6000
PRES DB
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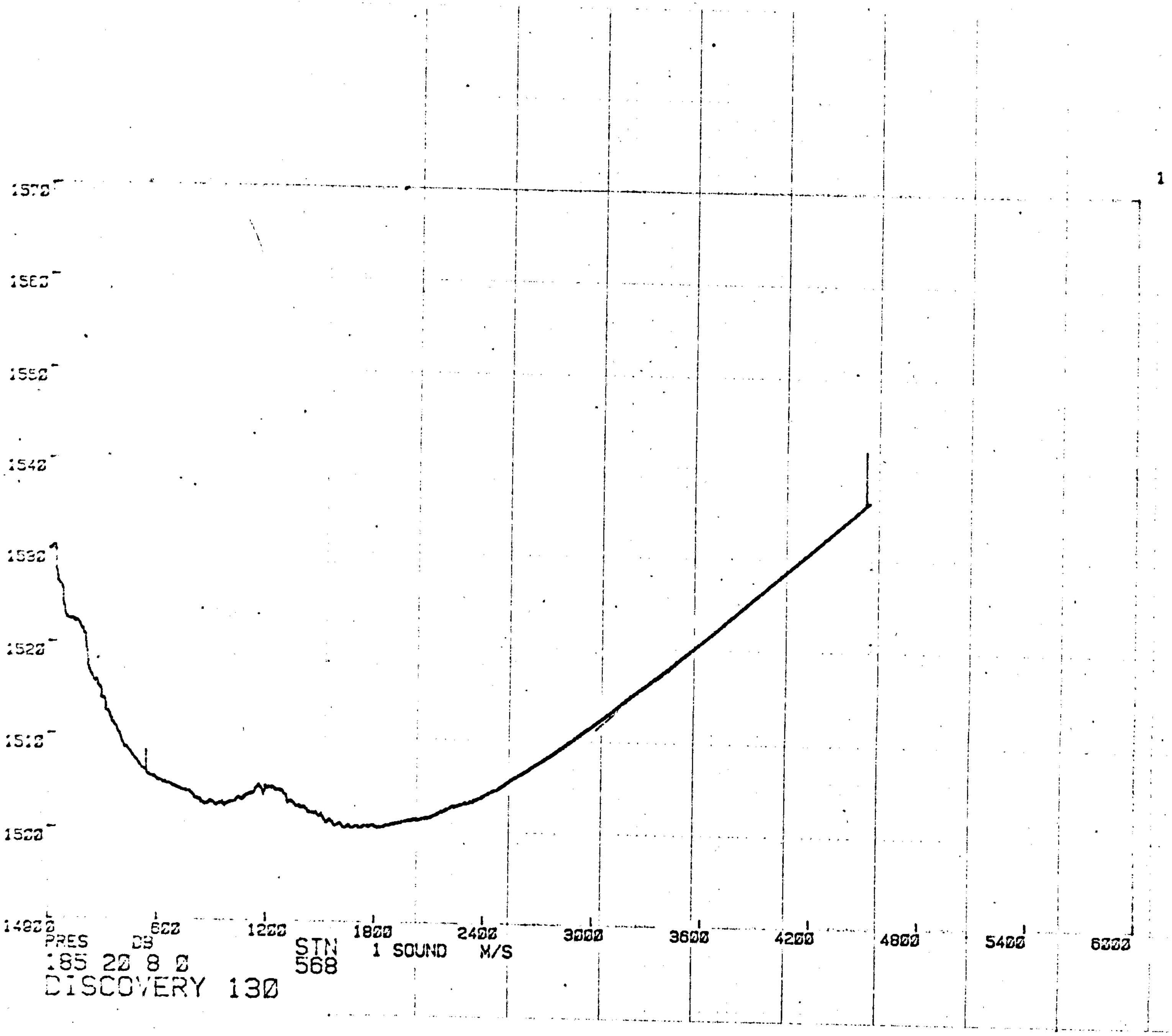
STN 556
1 SOUND M/S
DISCOVERY 130

Fig. 6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6000
PRES DB
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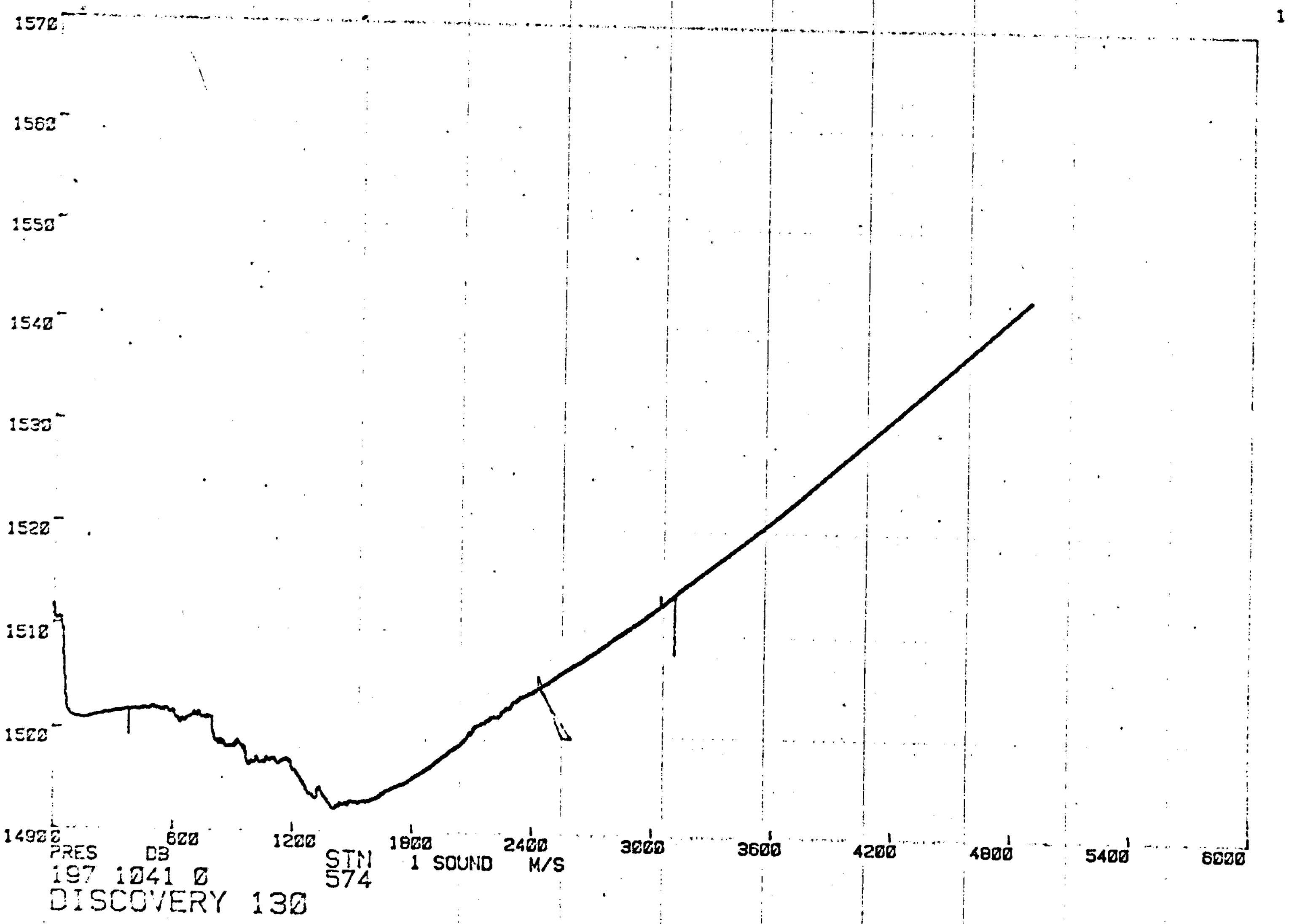
DISCOVERY 130
STN 568
1 SOUND M/S

Fig. 7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1 SOUND M/S
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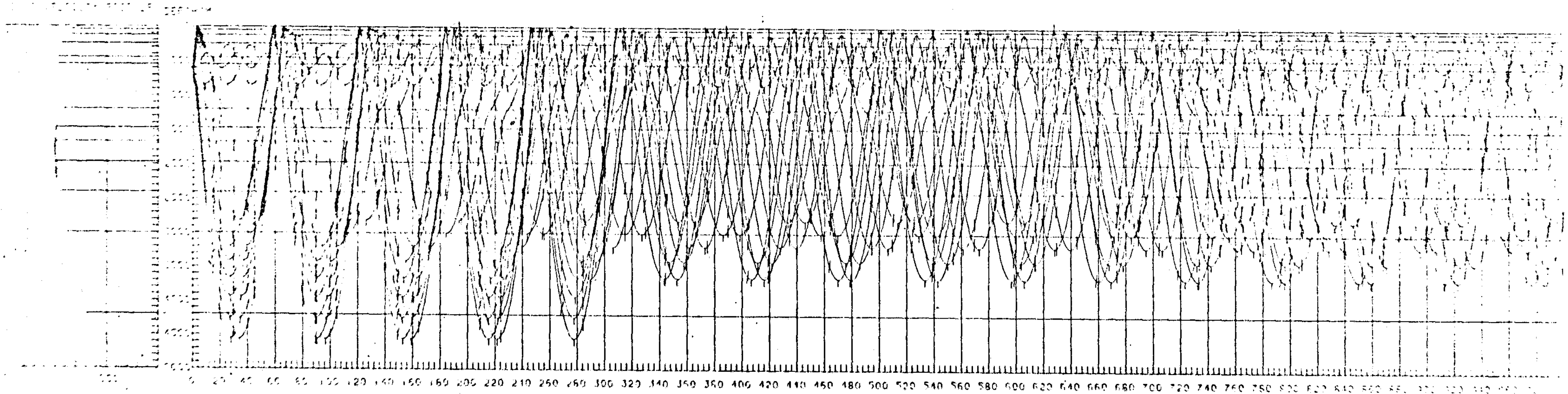
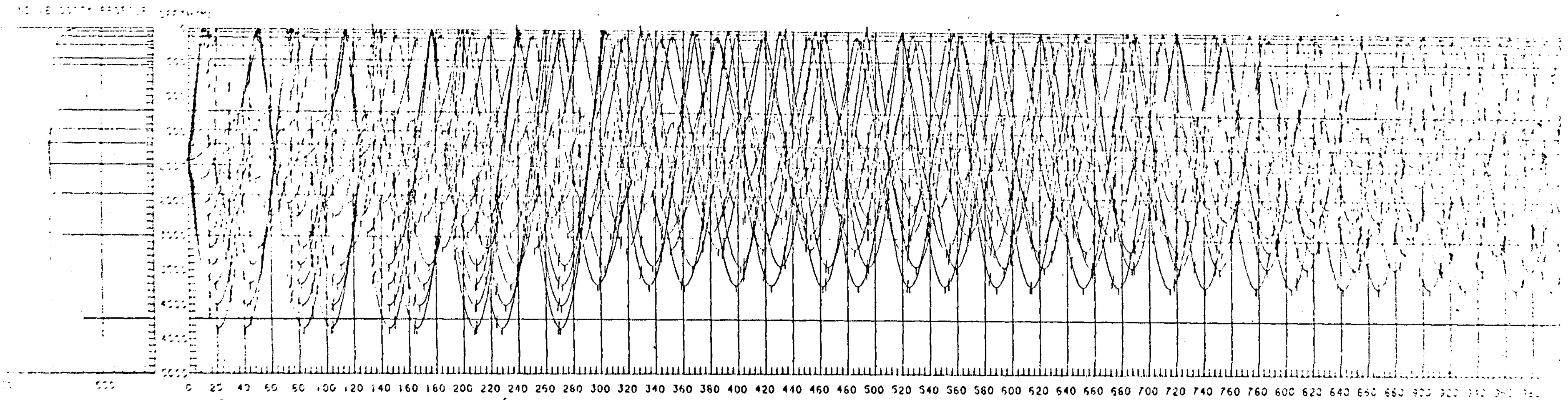
DISCOVERY 130

Fig 8



SOUTHERN LEG SUMMER (600m SOURCE)

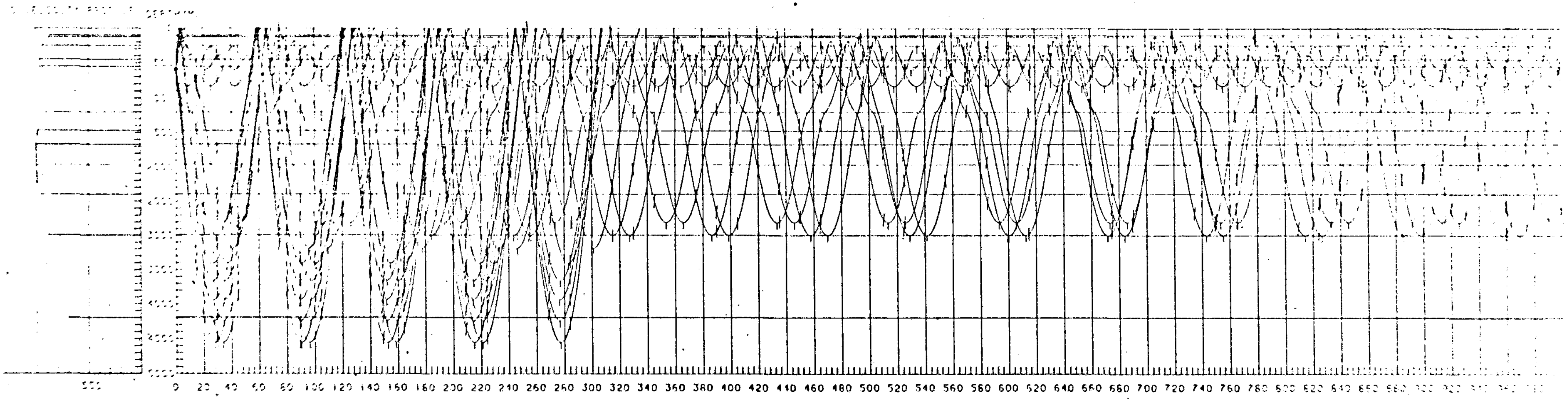
A



SOUTHERN LEG SUMMER (1900m SOURCE)

B

Fig 9



SOUTHERN LEG WINTER (600m SOURCE)

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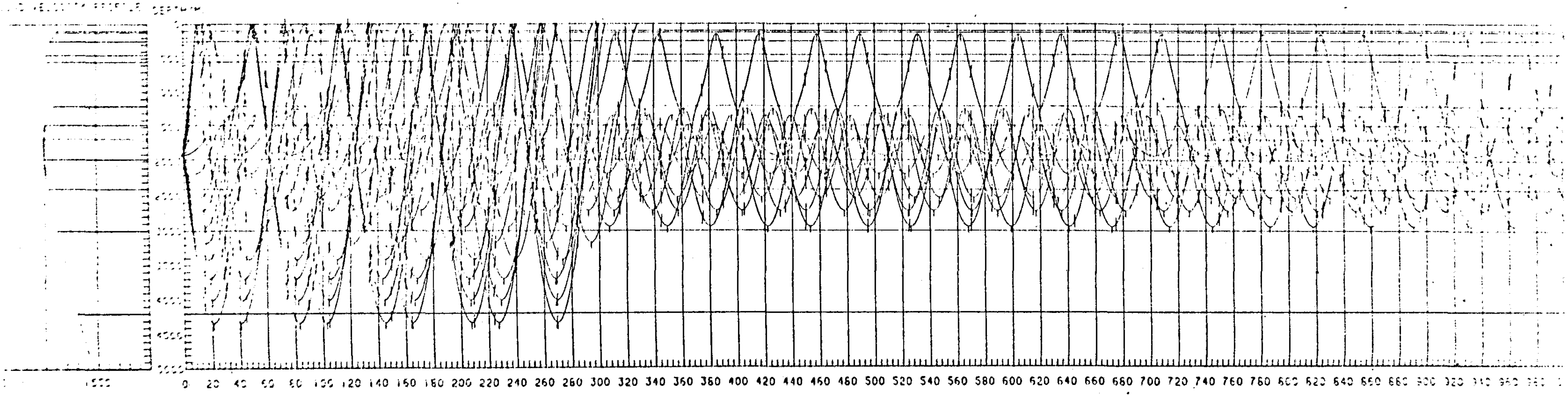
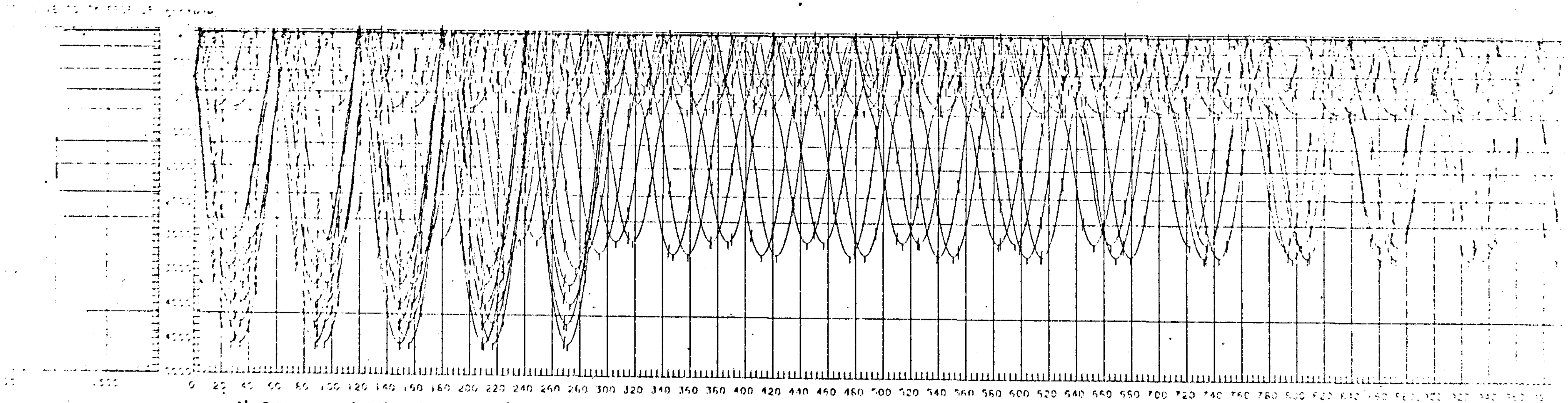


SOUTHERN LEG WINTER (1900m SOURCE)

D

Fig 10



NORTHERN LEG SUMMER (600m SOURCE)

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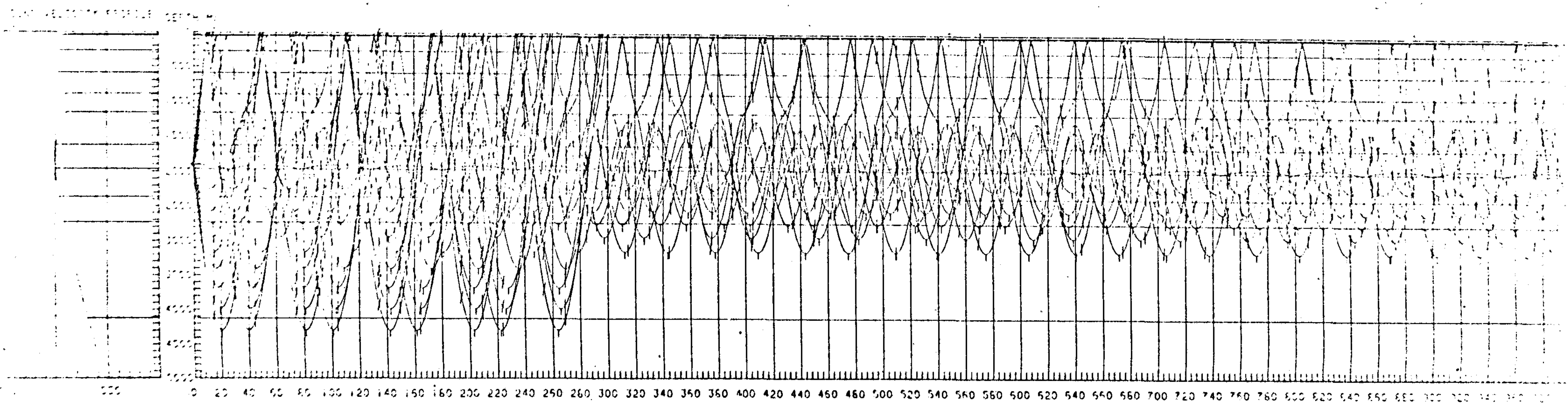

NORTHERN LEG SUMMER (1900m SOURCE)

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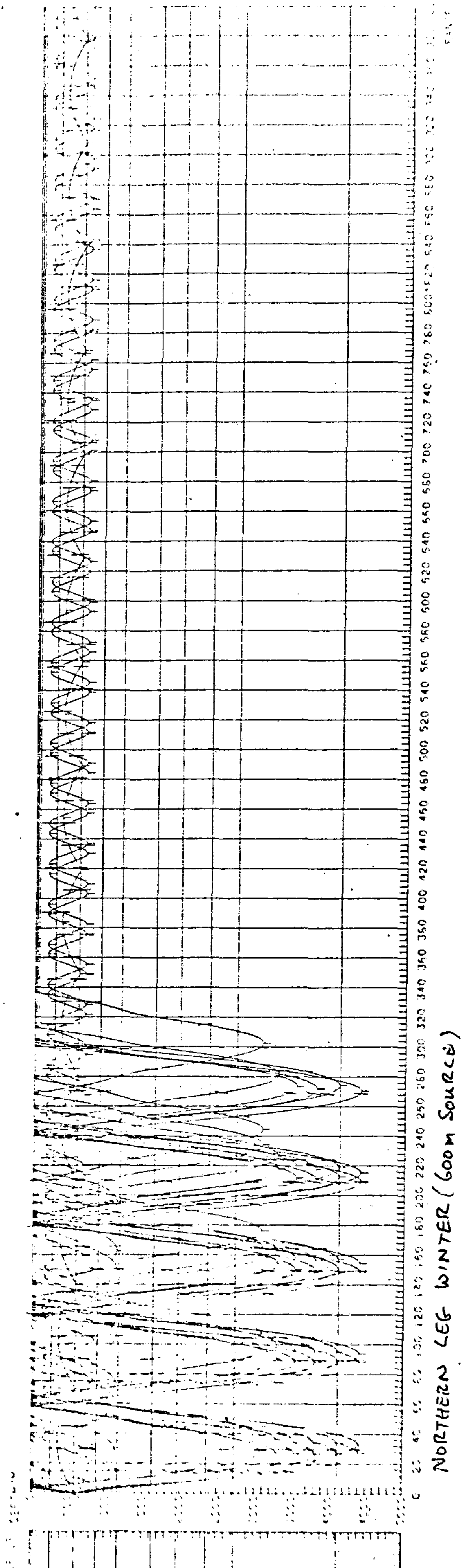
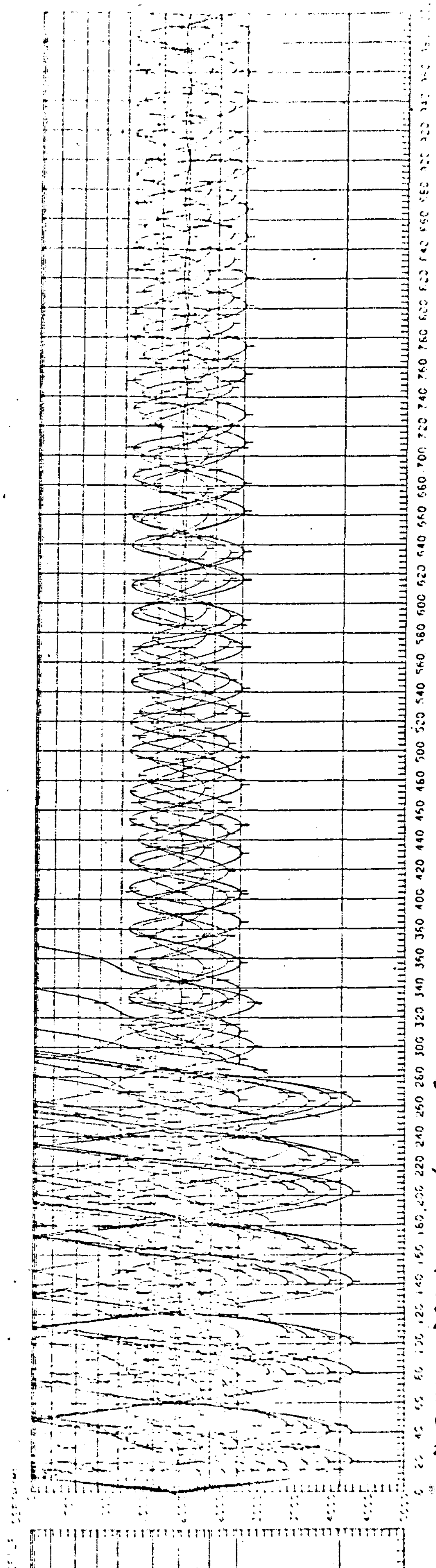


NORTHERN LEG WINTER (600m SOURCE)

G



NORTHERN LEG WINTER (1900m SOURCE)

H

Fig 11