I.O.S.

SEASOAR CTD SECTIONS IN THE NORTHEAST ATLANTIC OCEAN COLLECTED DURING RRS DISCOVERY CRUISE 132

BY
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REPORT NO. 200
1985

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

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When citing this document in a bibliography the reference should be given as follows:-

POLLARD, R.T., HOLFORD, D. & SHERROCKS, K. 1985 SeaSoar CTD sections in the northeast Atlantic Ocean collected during RRS *Discovery* Cruise 132. *Institute of Oceanographic Sciences, Report*, No. 200, 61pp.

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WORMLEY

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1. INTRODUCTION

A series of four cruises in 1980 and 1981 (Collins, Pollard and Pu, 1983, referred to as CPP hereafter) in the eastern North Atlantic between the Azores and the U.K. showed large scale frontal features which could be used to describe the upper ocean circulation patterns in that region (Pollard and Pu, 1985). The four cruises were all passage legs, so no time was available to explore the spatial extent of the frontal structure.

Cruise 132 was a physical oceanography cruise (Pollard et al, 1983) whose primary objective was to find and survey frontal structures in the region. It was originally scheduled to take place in October 1982, but was delayed by an industrial dispute, and had to be amalgamated with a second cruise in February 1983, whose objective was to examine spatial variations in the mixed layer in late winter. A third objective was to examine meridional variations of properties on isopycnal surfaces which surface north of 45 N (i.e. 27.0 to 27.2), and thus ventilate the thermocline south of that latitude and beneath the surface layer that is directly modified by seasonal air-sea interaction (McCartney & Tally, 1982).

The cruise programme made some progress on all these objectives, though clearly more limited than originally intended. The major tools used were Neil Brown Instrument Systems CTDs. One, with 6000 m depth capability was used only for normal CTD casts. The second, with 600 m depth capability (limited by its pressure case) was lowered once, at the start of the cruise, before being transferred into the IOS SeaSoar undulating vehicle. The CTD casts and calibration are described in a companion report (Pollard, 1985, referred to as RTP hereafter). The SeaSoar data are presented in this report.

2. INSTRUMENTATION AND DATA ANALYSIS

2.1 SeaSoar

The SeaSoar is described in CPP. Cruise 132 began with completely new Fathom fairing, problems with which limited the initial data. The fairing had been fitted in a single 550 m length with stoppers every few metres along the cable. On the first deployments, it was found that the fairing slid down the cable, seized on the stoppers, and also took many complete turns, particularly near the surface (Pollard et al, 1983). These problems limited the depth penetration that could be achieved. On each subsequent deployment, cuts were made to shorten the continuous fairing runs and seized pieces were cut out, and the response improved.

2.2 Deployments

The SeaSoar was deployed and recovered seven times (Table 1 and Fig. 1); divided into four experiments (Table 2). It may be seen from Table 1 how the maximum yoyo depth increased gradually from 250 m in Run 1 to 360 m in Runs 7 and 8.

2.2.1. Experiment 1

Runs 1 and 2 consisted of three sections across an east-west orientated front (or fronts) which lay between 45.5° and 47° N. Run 1 was terminated to seek the cause of the poor response and a CTD cast (10624) was done before redeploying the SeaSoar. To improve depth penetration on Run 2, deep dives were done every two hours (i.e. every 20-30 km) by taking all way off the ship and putting the SeaSoar into full drive. Eventually it would sink under its own weight to 450-500 m (Table 1). The minimum depth achieved during Run 1 was unsatisfactorily deep, as a new SeaSoar control console had to be gradually adjusted.

2.2.2. Experiment 2

After a CTD section south along 20° W, a second SeaSoar experiment was begun (Run 3), which was intended to zigzag across a frontal system believed to lie east-west along 40°-41° N. Unfortunately, worsening weather conditions caused very slow progress to be made on the initial overnight run. Indeed, speed through the water was insufficient to control the SeaSoar satisfactorily, and minimum depths of only 45-65 m could be achieved. Time constraints forced abandonment of the survey after only the one short (87 km) leg.

2.2.3. Experiment 3

After a CTD section along 41.5°-42° N, a SeaSoar section was run from 42° 20'N, 12° 27'W to 43° 41'N, 15° 17'W. Unfortunately this was terminated a little prematurely, but effectively Run 4 extended Experiment 1 (Runs 1 and 2) southeast to the vicinity of Galicia Bank (fig. 1), which will allow comparison of the water masses near the coast with those found further offshore.

2.2.4. Experiment 4

Timing constraints, and the need to recover moorings and search for drifting buoys allowed only one further SeaSoar section, Runs 5, 6 and 7 east along 38.6°N from 17°W to 11°W. Time was not available for deep dives, but the SeaSoar was near-optimally adjusted to yoyo between the surface and 360m. The section was broken twice for technical reasons (Table 1, Runs 5 and 6), losing about 26 km each time, as Discovery had to steam on during repair, and the SeaSoar was finally recovered within 100 km of shallow water.

2.3 CTD sampling and calibration

Whether a CTD is lowered in the usual way or towed in a SeaSoar, the initial logging, data reduction, editing and calibration procedures are identical, and are fully described by RTP. Note in particular the extensive editing that has had to be done to improve the unusually poor data quality. Data gaps and a few remaining error spikes will be apparent in the plots presented here. Pressure, temperature and oxygen receive no further calibration, but salinity from the SeaSoar CTD requires further work, and calibration of the Chelsea Instruments Fluorometer, which is not fitted to the deep CTD, also needs discussion here.

2.3.1. Salinity calibration

The conductivity cell is prone to fouling (Pollard, 1980) which generally occurs suddenly, and may or may not recover wholly or partially as the fouling material or organism is flushed through the cell. In general, there is a period during which salinity is irrecoverable, as it relaxes back exponentially to a stable calibration. A watch keeper's task is to monitor the salinity for offsets. If they do not recover within a few minutes, the SeaSoar is surfaced, to try to shake off the obstruction in the wave zone. Occasionally even this does not work and the SeaSoar may have to be recovered. While recovery was not necessary on Cruise 132, serious fouling occurred several times, and is documented in Table 2.

Correction of the salinity calibration for offsets after fouling events is achieved by several techniques, refined from the method described by CPP. T/S plots are produced in near real-time for two hour sections of data, with the traces offset after every four profiles (in four different colours). Any sudden offset of the T/S trace indicates a probable fouling event. The size of the salinity offset is measured off the plot, its time of occurrence is pinpointed off time series plots, and a constant offset is added to salinity. This technique mostly ensures temporal stability of the calibration relative to an assumed initial value.

The next step is to compare T/S curves from the SeaSoar with those from any CTD casts in the vicinity of the section, especially those taken at start or end of the tow (Fig. 1 and Table 1). The salinity on the Cruise 132 CTD casts has been calibrated to better than 0.004 psu absolute accuracy (RTP), but great care must be taken to match small features (e.g. fronts) in the T/S curves, as horizontal variations in the salinity of central water at a constant temperature value are typically 0.020 psu over tens of km (see Figs. 2-9). With care, the author believes it is possible to achieve absolute accuracies better than 0.010 psu by this means, with a relative accuracy of perhaps 0.005 psu with occasional jumps.

As a final check, and more critically when there are no suitable comparative CTD casts, surface salinities can be compared with samples drawn off the non-toxic supply (CPP). This method is prone to larger errors, because surface salinity is more variable than the salinity of central water at a fixed temperature. Also the SeaSoar may not reach the surface as in Runs 1 and 3 (Table 1).

On Cruise 132 surface samples were drawn every two hours, and the intercomparison statistics are summarized in Table 3. The statistics have been subjectively rated good (G), moderately good (M) and poor (P). G means that the SeaSoar came within 5-20 m of the surface, salinity was constant within 3 ppm to over 100 m (i.e. about 500 m horizontally along SeaSoar's sawtooth track), and successive near surface values (5-6 km apart along track) were within 10 ppm of each other.

M, in addition to G values, allows values which fail one of the G criteria but are probably okay (e.g. 30 m measurement depth; horizontal difference of 20-30 ppm between successive near-surface values but apparently homogeneous near sampling point). Poor (P) values have been included for Run 3 only because no others were available. The shallowest depths reached by the SeaSoar were in the range 60-80 m and there was still a weak vertical gradient of salinity at those depths. Horizontal differencs between successive minimum depth values were less than 10 ppm, however.

The mean offsets in Table 3 suggest that the Seasoar salinities, after matching to lowered CTD T/S relations, are 0.005-0.007 psu too low for Runs 1-3. However, (a) in our opinion, the T/S fit to CTDs is noticeably degraded if the SeaSoar salinities are increased, (b) the lowered CTD salinities are, if anything too high already by 0.002-0.004 psu (RTP, fig. 5, though admittedly that comparison was at 4000-5000 m) and (c) the Table 3 offset is within our estimated error of 0.010 psu. The calibration has therefore not been adjusted for Runs 1, 2 and 3, and likewise Run 4, for which there is no offset.

The danger of relying on T/S relations is strikingly shown in Experiment 4, Runs 5, 6 and 7 however. As can be seen from fig 1, the final section is over 2° south of all other CTD and SeaSoar data, and time constraints prevented any CTD casts from being made. But the T/S relations fitted well, apparently, to those around 40°N, 20°W and were initially adjusted to fit them. Luckily, a series of ten reasonably good surface sample intercomparisons shows consistently that the SeaSoar values are 0.038±0.004 psu too low, and the data presented in this report have been corrected to fit the surface samples.

Thus the water mass present along 38.5°N is in general quite different from that present along 42°N, though sudden transitions between the two are occasionally observed, for example at 4000-4040 km (p. 28) and at 5760-5800 km (p. 30). The presence of a marked front at around 40°N was inferred by Pollard and Pu (1985) and the southward increase in salinity is reminiscent of the change in T/S relation from the European basin to the North African Basin described by Wright and Worthington (1970).

2.3.2. Fluorometer calibration

Facilities were not available to calibrate the Chelsea Instruments Fluorometer on Cruise 132, but it was felt worthwhile to use it nevertheless. Calibrations for three previous cruises, kindly provided by M.J. Fasham, had been

Cruise 114, October	1980	$\log_e C = 1.430\ V - 4.952$
Cruise 119, April	1981	$\log_e C = 1.344\ V - 5.239$
Cruise 120, May	1981	$\log_e C = 1.481\ V - 5.513$

where V is the measured voltage, and C is the Chlorophyll value in mg m^{-3}. The Cruise 120 values were used on Cruise 132.

To estimate possible errors, we calculate that V=3.0v would have yielded, in chronological order, C=0.52, 0.30 and 0.34 mg m^{-3}. Observed values were generally less than 0.3 mg m^{-3}, reaching 0.45 mg m^{-3} on occasion during Experiment 4. Thus we may conclude

(a) productivity was low, as one would expect in late winter, well under 1 mg m^{-3}

(b) values in this report may be in error by as much as 50%, but that is less than 0.2 mg m^{-3}

(c) the contours of C are still a useful guide to the decay of productivity with depth, and its spatial variations.

2.4 Navigation

At the start of Cruise 132, only satellite fixes could be logged, until commissioning of a new computer system and interfacing of the ship's electromagnetic log was completed. Once this was done, one-minute positions were routinely calculated to interpolate between satellite fixes, after the latter had been checked for quality and poor or suspect fixes discarded. The change from satellite to 1-minute fixes took place after Run 1. Ship positioning is thus as good as the fixes allow, usually estimated to be better than 0.5-1.0 km.

In this report, all data are plotted as functions of Distance Run, which is calculated by integration of the corrected positions. Values of Distance Run are marked on fig. 1 every 100 km.

Navigation and CTD data were merged with TIME as the common variable during processing on shore as described by CPP.

3. DATA PRESENTATION

3.1 Cruise track

Parts of the track plot for Cruise 132 (Falmouth, UK to Lisbon, Portugal) are shown in Fig. 1, and the program which created it is listed in Table 5. Distance Run (section 2.4) is marked on the track every 100 km and correlated with exact latitude and longitude in Table 4. The positions of each of the seven SeaSoar Runs (Table 1) are indicated, and also of all CTD stations. For the full track plot, see Pollard et al (1983).

3.2 Summary of data reduction

The edited, merged (CTD and navigation) data set consists of 1 second averages of time, pressure, temperature, salinity, potential temperature, oxygen, Chlorophyll _a_, sigmatheta, latitude, longitude and distance run along the SeaSoar track. Speed through the water is about 4 m s^{-1}, so that individual points are about 4 m apart horizontally, and 1 m apart vertically. Both down and up traces are used in all plots and there is a profile (down or up) approximately every 1.5 km. For this report, the 1 second data have been further averaged over 7.5 dbar pressure intervals to reduce the number of points plotted on θ/S diagrams and accommodate the maximum number of points contourable in one computer run.

3.3 Potential temperature/salinity diagrams

The 7.5 dbar averages have been plotted on the potential temperature against salinity (θ/S) plots (pages 24-31). The 7.5 dbar averaging causes the plots to be somewhat jerky (obvious straight line sections) in the surface layer where the T/S relation changes rapidly. Data have been overplotted for 40 km (DISTRUN) sections, with an offset of 0.2 psu in salinity between sections. Thus each 40 km plot spans about 3 hours, and consists of about 1000 averaged points in 20-30 vertical profiles. The salinity scale applies to the first plot on a page.

The last 40 km section on each T/S plot is repeated as the first on the following plot so that the along track development of the T/S relation can be followed.

3.4 Contour plots

Contour plots are produced using the SURFACE II software package (CPP). The quadrant gridding process (Table 6, QUAD) further smooths the data prior to contouring, so that the gridded values, which are 7.5 dbar and 2 km apart, are weighted averages about 15 dbar and 10 to 15 km. Most internal waves are effectively removed by the horizontal smoothing.

Potential temperature, salinity, sigmatheta, oxygen and Chlorophyll content are contoured against pressure. The sigmatheta plot, which shows baroclinicity, is placed next to a contour plot of salinity with density as the vertical coordinate, which shows haloclinicity (equivalently thermoclinicity). If the θ/S relation is constant, lines of constant salinity are horizontal on such a plot. It has however been omitted for experiment 1, as the range of densities was too small for density to be useable as an independent variable.

Although oxygen contours have been included in this report, they must be treated with scepticism in view of the calibration problems (RTP). In particular, implausibly large changes in oxygen values occur between experiments. The relative variations may be of some interest, however.

4. ACKNOWLEDGEMENTS

These data were collected on Cruise 132 of RRS *Discovery*. Conditions were difficult, as the cruise was effectively the trial cruise after an extended inport period. The weather was poor, and flooding of the main switchboard nearly brought the cruise to an ignominious end on one occasion. Thanks to the high level of seamanship and professional skill shown by the crew, and especially by Sam Meyl (Master) and David Rowlands (Chief Engineer), the cruise was scientifically very successful.

J. Moorey determined salinities and oxygens and corrected thermometers, J. Smithers calibrated and operated the CTDs, V.A. Lawford was in charge of the SeaSoar, R.J.P. Burnham was in charge of the shipboard computers used to log and archive the data. All members of the scientific party had to work extremely hard to overcome the numerous problems that are described by Pollard et al (1983), and I (RTP) am most grateful to them.

Data reduction and production of this report have been partially supported by the European Economic community through the Commission of the European Community under Contract CL115UK(H).

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TABLE 1 SEASOAR RUNS

Run	Start day/time	Stop day/time	Length (hr)	Depth range (db)	Deep Dives No.	Deep Dives Depth	Comments
1	32/2025	33/0815	12	85-250 25-235	0		Recovered to change wings, found very twisted fairing. Poor depth range. CTD cast 10624 done during repairs.
2	33/1427	35/1139	45	10-275 5-250	21	500	Recovered because erratic depth signal. Fairing very twisted again. CTD 10625 after recovery.
3	39/2131	40/0625	9	45-300 65-300	4	480	Head wind and sea caused poor minimum depth. Terminated by broken conductor where cable enters SeaSoar vehicle. Frontal survey abandoned. CTDs 10638 and 9 before and after section.
4	43/1818	44/1246	18	10-325 5-330	9	450	Terminated by short in cable to plug joint within vehicle. CTD 10647 before section.
5	49/0814	49/1131	3	20-350	0		Vehicle dived out of control during ship's radio transmission. Wings found to be bent on recovery.
6	49/1309	49/2356	11	0-360	0		Recovered because poor depth control. Bridle found to be bent.
7	50/0133	50/1815	17	0-360	0		Recovered as late as possible before docking at Lisbon.

Footnote: There are minor variations between this table and Table 3 in Pollard et al (1983). The values given here span the exact periods for which data were recorded. Slip rings on the cable drum allowed data to be recorded during deployment and recovery, so that typically for the first and last 20-30 minutes of each run the SeaSoar was not in yoyo mode, but rising or falling slowly.

TABLE 2 DATA GAPS

Experiment	Runs	Distance run (km) from – to	length	Distance run gaps (km)	Cause
1	1-2	1250 - 1999	749	1404 - 1416	Gap between runs 1 and 2.
				1544 - 1554	Conductivity cell irrecoverably fouled.
2	3	3026 - 3113	87		
3	4	3802 - 4080	278	3847 - 3864	Conductivity cell irrecoverably fouled. Surfaced to clear at 3864 km so gap in all contoured variables.
				3909 - 3915	Conductivity cell irrecoverably fouled.
4	5-7	5467 - 6025	558	5516 - 5542	Gap between runs 5 and 6, ship had to steam on during repairs.
				5727 - 5754	Gap between runs 6 and 7, ship had to steam on during repairs.
				5886 - 5899	Towed horizontally in a circle during essential radio transmisions. Gap in distance run but not in longitudinal coverage.
				5936 - 5938	Very noisy data, some lost through editing.
		TOTALS	1672	- 113	= 1559 km good data.

TABLE 3

Statistics of SeaSoar salinity calibration against surface salinity samples

Experiment	1		2	3	4	
Runs	1	2	3	4	5, 6,	7
No. of samples	14	23	4	7	4	10
quality rating[1]	G	M	P	G	G	M
mean offset[2,3]	7.4	7.1	5.0	-0.7	38.5[4]	37.7[4]
standard deviation[2]	4.3	5.1	4.8	5.3	3.4	4.1

Notes 1) Subjective quality ratings (see text)

G = good intercomparative values
M = good and reasonably good values
P = poor values only.

2) Means and standard deviations are given in p.p.m., where 1 ppm = 1 part per million = 0.001 psu.

3) A positive value means bottle sample value was higher than CTD value.

4) Offsets of calibrations attempted without using surface salinity samples (see text). Reduce these values by 38 ppm to 0.5 and -0.3 for the data presented in this report.

TABLE 4

Timetable of events

Distance Run (km)	Latitude (N)	Longitude (W)	Date in Feb '83	Time (HHMM)	Run	Course	Computer File	Comments
1250	44 20	16 05	1	2025	1	000	1	start of run
1300	44 47	16 00	2	0033			1	
1400	45 41	16 00	2	0729			1	
1404	45 43	16 00	2	0815			1	end of run
1416	45 47	15 57	2	1427	2	000	2	start of run
1500	46 32	15 56	2	2155			2	
1566	47 08	15 50	3	0327		270	3	alter course
1600	47 09	16 16	3	0604			3	
1657	47 10	17 00	3	1029		180	3	alter course
1700	46 47	16 57	3	1347			3	
1800	45 54	16 53	3	2054			4	
1833	45 36	16 54	3	2328		270	5	alter course
1844	45 39	17 02	4	0015		330	5	alter course
1900	46 04	17 22	4	0407			5	
1999	46 45	18 03	4	1139			5	end of run
3026	40 37	20 24	8	2131	3	035	6	start of run
3100	41 07	19 51	9	0514			6	
3113	41 13	19 46	9	0625			6	end of run
3802	42 20	12 27	12	1818	4	303	7	start of run
3900	42 46	13 28	13	0055			8	
4000	43 15	14 30	13	0741			8	
4080	43 41	15 17	13	1246			8	end of run
5467	38 47	17 02	18	0814	5	092	9	start of run
5500	38 46	16 39	18	1032			9	
5516	38 46	16 28	18	1131			9	end of run
5542	38 45	16 14	18	1309	6	093	9	start of run
5600	38 46	15 34	18	1637			10	
5700	38 43	14 25	18	2206			10	
5727	38 39	14 09	18	2356			10	end of run
5754	38 36	13 52	19	0133	7	093	11	start of run
5800	38 34	13 22	19	0431			11	
5900	38 34	12 24	19	1027			12	
6000	38 33	11 15	19	1626			12	
6025	38 31	10 59	19	1815			12	end of run

TABLE 5

Track Plot and Seasoar Runs

```
*#FRN *=(ULIB)LIBRARY/GRAFIX,R;LIBRARY/GESTALT,R;LIBRARY/GEN,R;
*#PEXEC/2/QLIB,R;#OPS/WORMLEY/FLATBED/FJR1"15"
       DIMENSION FILE(10),XLON(320),YLAT(320),DIST(320)
      DIMENSION POS(29),Y1(29),Y2(29),X1(29),X2(29)
      CHARACTER*40 FILNAM
       EXTERNAL SMERC
C..DEFINE DEVICE
       CALL SPOOLB(15,NDEV)
       CALL SWTEXT
C..SPECIFY PAGE SIZE
      CALL DFRAME(NDEV,3)
       CALL FMTLAB(4)
      CALL FMTHRG(20.,20.,10.,25.)
       CALL FMTA(4,1)
       CALL FMTANN(1,0,2)
C..DEFINE DATA AREA
      CALL MAPCEN(345.0,40.2)
      CALL DEFFM2(SMERC,338.,352.,35.,50.)
C..DRAW GRID
      CALL CHLENS(2.5)
      CALL GRISEL(3,3,1)
      CALL ANNGEO(1,-1)
      CALL AXIMAP(SMERC,1)
      CALL AXIFB2(SMERC,10.,10,1)
      CALL AXIMAP(SMERC,2)
      CALL GRISEL(1,3,1)
      CALL AXIFB2(SMERC,10.,10,2)
C..LABEL MAP
      CALL CHLENS(3.0)
      CALL LABEL(2,'ON DISCOVERY CRUISE 132',23)
      CALL LABEL(1,'FIG.1  SEASOAR RUNS AND CTD POSITIONS',37)
      CALL LABEL(4,'MERCATOR PROJECTION',19)
      CALL LABEL(5,'WITH COASTLINE AND',18)
      CALL LABEL(6,'1000 FATHOM DEPTH CONTOUR',25)
      CALL CHLENS(2.5)
C..DRAW COASTLINE
      CALL WORLDM(SMERC)
C..DRAW 1000F CONTOUR
      CALL FATHOM(SMERC,1000.)
C
C
C
C
C..ATTACH FILES
      DO 20 II=1,12
      IF(II.LE.9)ENCODE(FILNAM,550)II
      IF(II.GE.10)ENCODE(FILNAM,560)II
  550 FORMAT('RTP/7/WAV1320',I1,'                           ')
  560 FORMAT('RTP/7/WAV132',I2,'                           ')
      CALL FILBEG(20,FILNAM,1,320,1,2,IERR)
```

```
      PRINT,IERR
      CALL QINITI(20)
      CALL QREADD
      CALL QLSTD(0)
      CALL QINFIL(FILE,NOFLDS,NORECS)
      NSTART=1
      NSTOP=NORECS
      NLEN=320
      DO 30 LL=NSTART,NSTOP,320
      L=LL
      IF((L+NLEN-1).GT.NSTOP)NLEN=NSTOP-L+1
      CALL QINDAT(8,L,NLEN,YLAT)
      CALL QINDAT(9,L,NLEN,XLON)
      CALL QINDAT(10,L,NLEN,DIST)
C...............PLOT
C
      CALL POIBEG
      CALL LINSEL(1)
      CALL MARSEL(0)
      DO 10 NN=1,320
      IF(XLON(NN).EQ.-999.)GOTO 10
      IF(YLAT(NN).EQ.-999.)GOTO 10
      CALL POIFA2(SMERC,(360.+XLON(NN)),YLAT(NN))
   10 CONTINUE
   30 CONTINUE
      CALL POIEND
   20 CONTINUE
      CALL MARSEL(1)
      CALL LINSEL(0)
      CALL POIBEG
      CALL PANLIT(0.)
      CALL POIFC2(SMERC,(360.-16.0),44.78,'1300km',6)
      CALL POIFC2(SMERC,(360.-16.0),45.68,' ',1)
      CALL TEXFA2(SMERC,344.1,45.5,'1400km',1,6,1)
      CALL POIFC2(SMERC,(360.-15.93),46.53,'1500km',6)
      CALL PANLIT(90.)
      CALL POIFC2(SMERC,(360.-16.27),47.15,' ',1)
      CALL TEXFA2(SMERC,343.7,47.25,'1600km',1,6,1)
      CALL POIFC2(SMERC,(360.-16.95),46.78,' ',1)
      CALL POIFC2(SMERC,(360.-16.88),45.90,' ',1)
      CALL POIFC2(SMERC,(360.-17.37),46.07,' ',1)
      CALL TEXFA2(SMERC,341.05,45.97,'1900km',1,6,1)
      CALL TEXFA2(SMERC,338.7,41.1,'3100km',1,6,1)
      CALL POIFC2(SMERC,(360.-19.85),41.12,' ',1)
      CALL PANLIT(45.)
      CALL POIFC2(SMERC,(360.-13.47),42.77,'3900km',6)
      CALL POIFC2(SMERC,(360.-14.50),43.25,'4000km',6)
      CALL PANLIT(270.)
      CALL POIFC2(SMERC,(360.-16.65),38.77,'5500km',6)
      CALL POIFC2(SMERC,(360.-15.57),38.77,'5600km',6)
      CALL POIFC2(SMERC,(360.-14.42),38.72,'5700km',6)
      CALL POIFC2(SMERC,(360.-13.37),38.57,'5800km',6)
      CALL POIFC2(SMERC,(360.-12.40),38.57,'5900km',6)
      CALL POIFC2(SMERC,(360.-11.25),38.55,'6000km',6)
```

```
      CALL POIEND
      CALL TEXFA2(SMERC,344.5,45.,'RUN 1',1,5,1)
      CALL TEXFA2(SMERC,342.75,47.45,'RUN 2',1,5,1)
      CALL TEXFA2(SMERC,339.6,40.3,'RUN 3',1,5,1)
      CALL TEXFA2(SMERC,344.,43.,'RUN 4',1,5,1)
      CALL TEXFA2(SMERC,342.0,39.0,'RUN 5',1,5,1)
      CALL TEXFA2(SMERC,344.,39.0,'RUN 6',1,5,1)
      CALL TEXFA2(SMERC,346.5,38.9,'RUN 7',1,5,1)
C
C......PLOT CTD POSITIONS
C
C......ATTACH FILES
      CALL FILBEG
     &(20,'FJR/TERN/POS132                               ',1,320,1,2,IERR)
      PRINT,IERR
C......READ IN DATA
      READ(20,500)(POS(N),Y1(N),Y2(N),X1(N),X2(N),N=1,29)
  500 FORMAT(A3,1X,F3.0,F5.2,1X,F3.0,F5.2)
      CALL POIBEG
      CALL MARSEL(3)
      DO 50 NN=1,29
      N=30-NN
      YLAT(N)=Y1(N)+(Y2(N)/60)
      XLON(N)=X1(N)+(X2(N)/60)
      IF(N.NE.26)GO TO 100
      CALL POIFA2(SMERC,(360.-XLON(N)),YLAT(N))
      CALL TEXFB2(SMERC,(360.-XLON(N)),YLAT(N),POS(N)
     &,1,3,90.,3.5,0.5,1,0,1)
      GO TO 50
  100 IF(N.NE.17)GO TO 200
      CALL POIFA2(SMERC,(360.-XLON(N)),YLAT(N))
      CALL TEXFB2(SMERC,
     &(360.-XLON(N)),YLAT(N),POS(N),1,3,0.,3.5,0.5,1,0,1)
      GO TO 50
  200 CALL PAHLIQ(1.2,0.5)
      CALL POIFC2(SMERC,(360.-XLON(N)),YLAT(N),POS(N),3)
      CALL PAEOFF
   50 CONTINUE
      CALL POIEND
      CALL GCLOSE
      STOP
      END
```

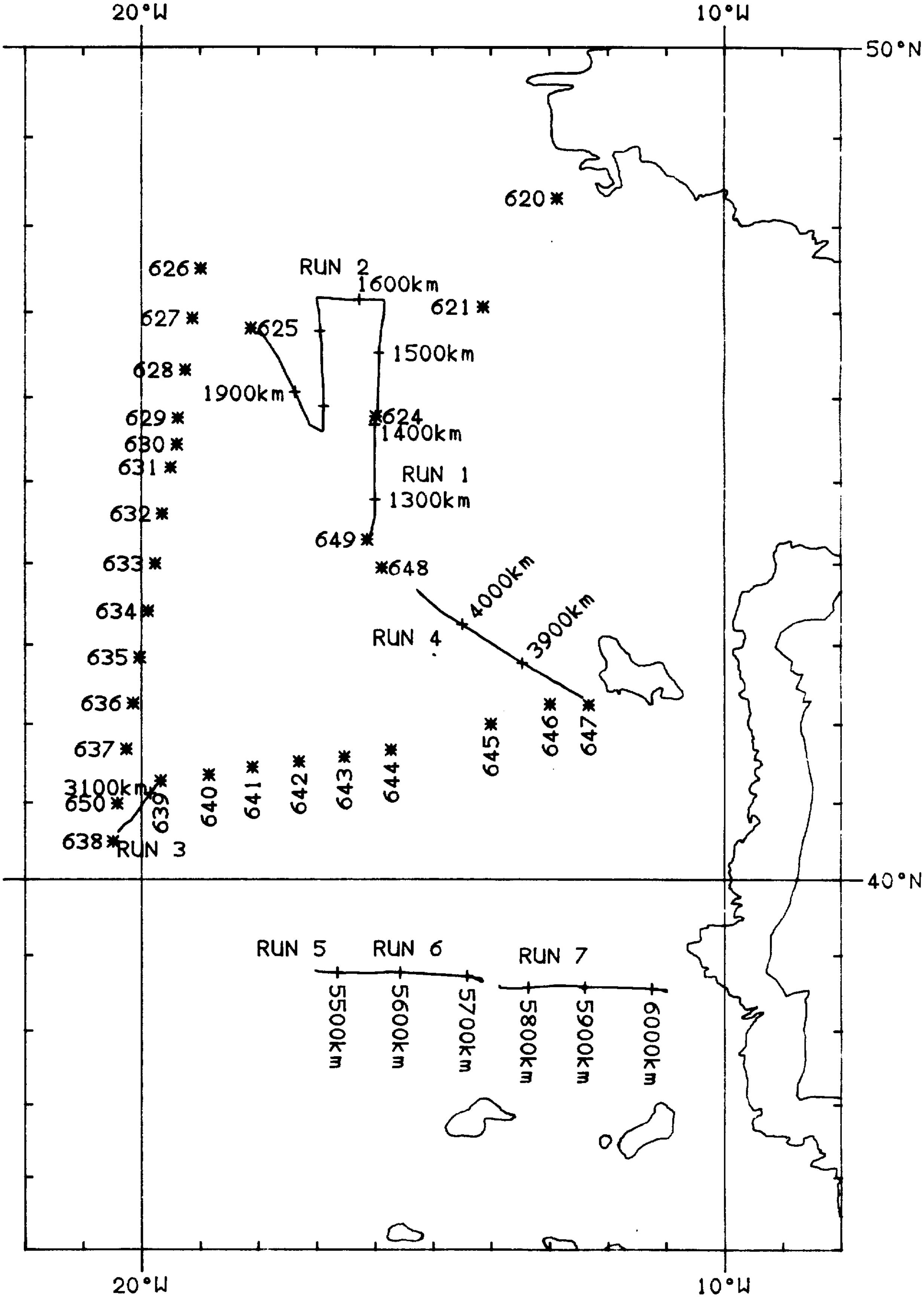
TABLE 6

Production of Contour Plots

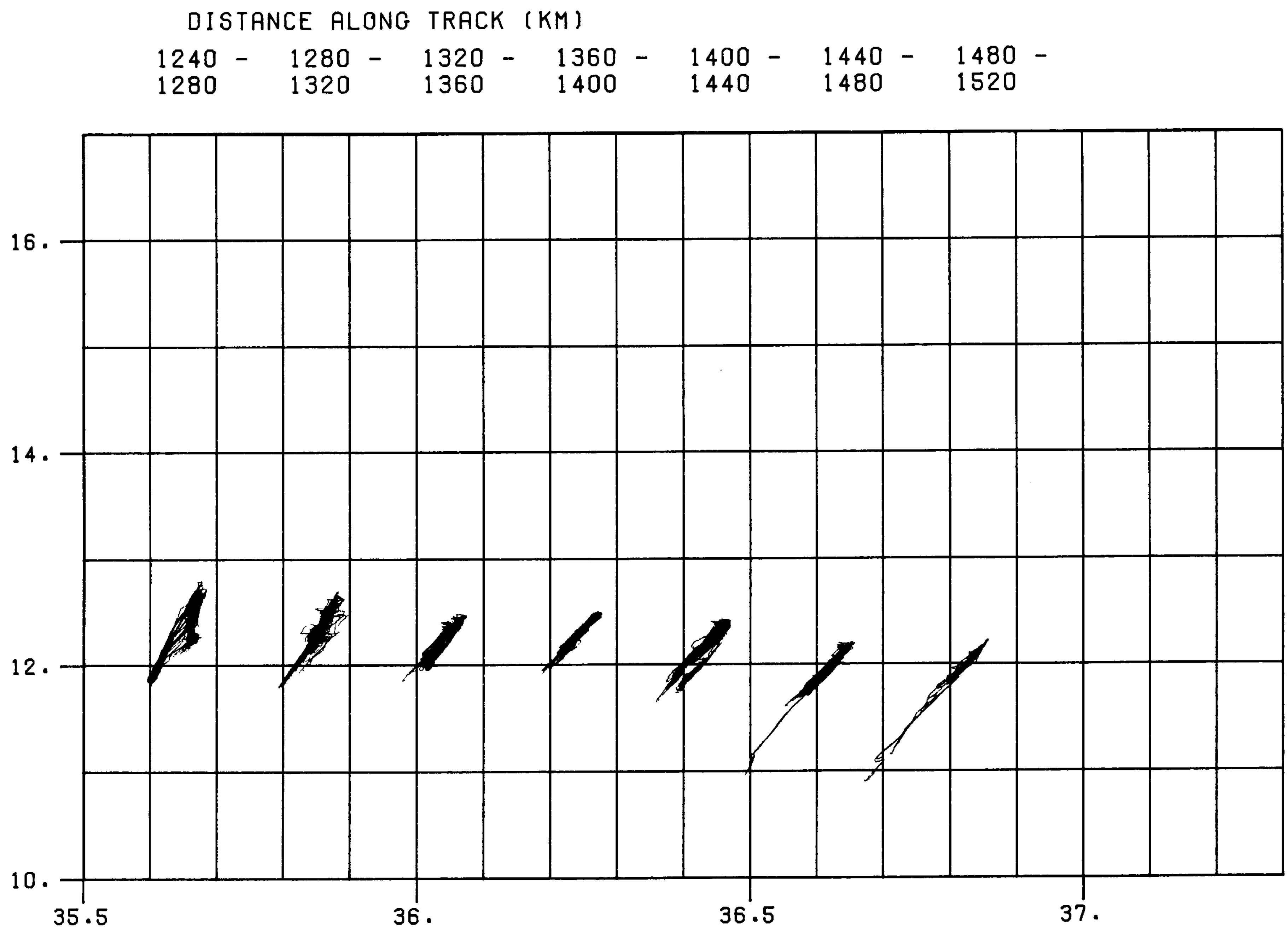
```
DEVI  4,'DAVE',12,10
TITL  DI132:POTEMP,X=DIST(KM),Y=PRES(DB)
IDXY  8000,11,7,1,2,3,,,1,-999.,'(7F8.3)'
EXTR  5850,6050,350,0
GRID  1,2.0,7.5,,2,1
QUAD  2,4
CONT  0,1,,0,1
CINT  0,13.0,0.2,0,5,0.08,1,1.5,5
BOX   5,4,10,5,,,,,0.1
SIZC  1,7.874,2.5984
PERF
CLEAR
TITL  DI132:SALIN:X=DIST(KM),Y=PRES(DB)
IDXY  8000,11,7,1,2,4,,,1,-999.,'(7F8.3)'
EXTR  5850,6050,350,0
GRID  1,2.0,7.5,,2,1
QUAD  2,4
CONT  0,1,,0,1
CINT  0,35.8,0.05,0,2,0.08,2,1.5,2
BOX   5,4,10,5,,,,,0.1
SIZC  1,7.874,2.5984
PERF
CLEAR
TITL  DI132:SIGPOT:X=DIST(KM),Y=PRES(DB)
IDXY  8000,11,7,1,2,5,,,1,-999.,'(7F8.3)'
EXTR  5850,6050,350,0
GRID  1,2.0,7.5,,2,1
QUAD  2,4
CONT  0,1,,0,1
CINT  0,27.0,0.05,0,2,0.08,2,1.5,2
BOX   5,4,10,5,,,,,0.1
SIZC  1,7.874,2.5984
PERF
CLEAR
TITL  DI132:FLOUR:X=DIST(KM),Y=PRES(DB)
IDXY  8000,11,7,1,2,6,,,1,-999.,'(7F8.3)'
EXTR  5850,6050,350,0
GRID  1,2.0,7.5,,2,1
QUAD  2,4
CONT  0,1,,0,1
CINT  0,0.2,0.1,0,1,0.08,2,1.5,2
BOX   5,4,10,5,,,,,0.1
SIZC  1,7.874,2.5984
PERF
CLEAR
TITL  DI132:OXYGEN:X=DIST(KM),Y=PRES(DB)
IDXY  8000,11,7,1,2,7,,,1,-999.,'(7F8.3)'
EXTR  5850,6050,350,0
GRID  1,2.0,7.5,,2,1
QUAD  2,4
```

```
CONT   0,1,,0,1
CINT   0,5.4,0.125,0,2,0.08,2,1.5,4
BOX    5,4,10,5,,,,,0.1
SIZC   1,7.874,2.5984
PERF
CLEAR
TITL   DI132:SALIN:X=DIST(KM),Y=SIGPOT*100
IDXY   8000,11,7,1,5,4,,,1,-999.,'(7F8.3)'
RTXY   0,1.0,100.0
PERF
EXTR   5850,6050,2750,2650
GRID   1,2.0,2.0,,2,1
QUAD   2,4,8,16
CONT   0,1,,0,1
CINT   0,35.8,0.05,0,2,0.08,2,1.5,2
BOX    5,4,5,4,,,,,0.1
SIZC   1,7.874,3.1496
PERF
STOP
```

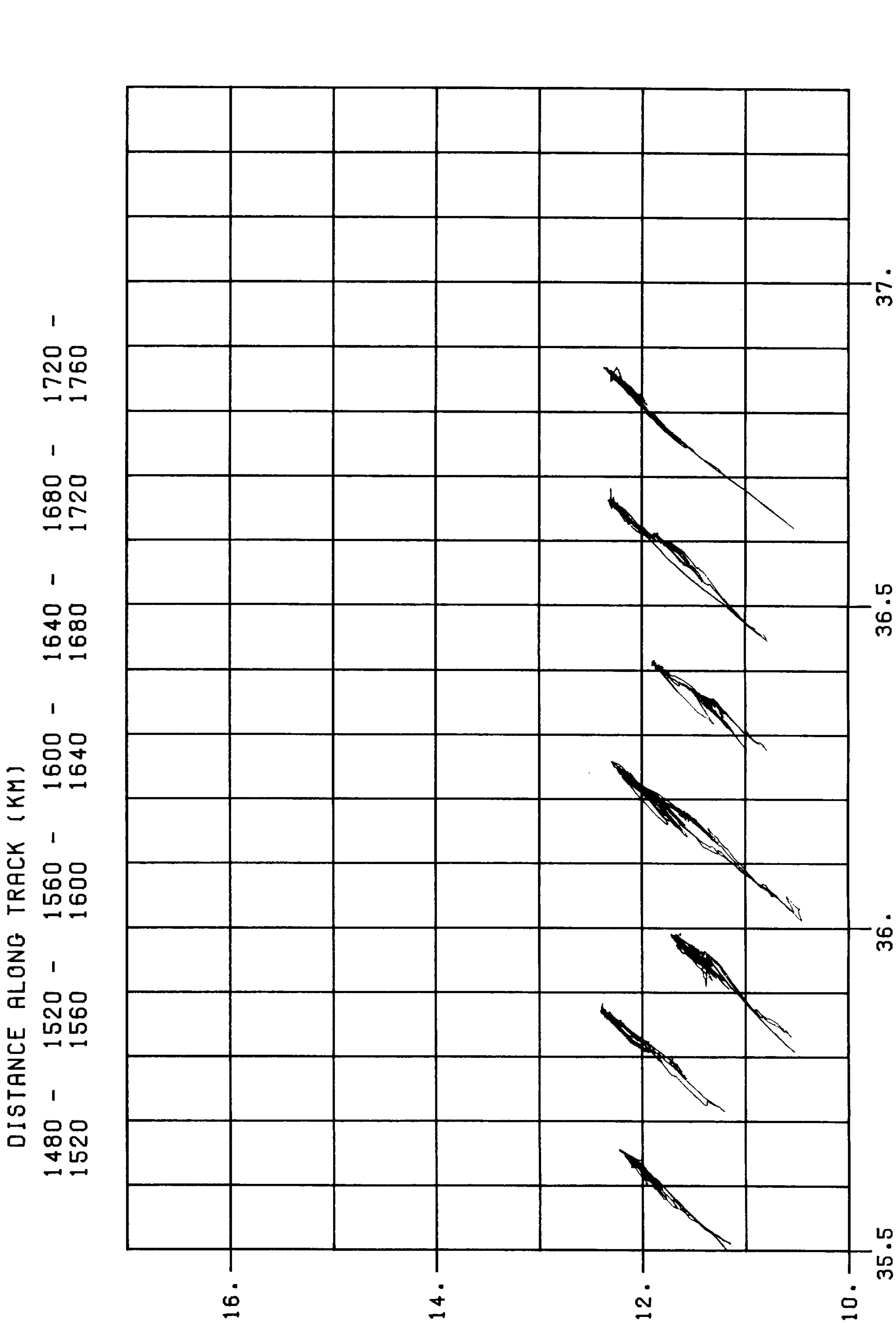
FIG.1 SEASOAR RUNS AND CTD POSITIONS ON DISCOVERY CRUISE 132



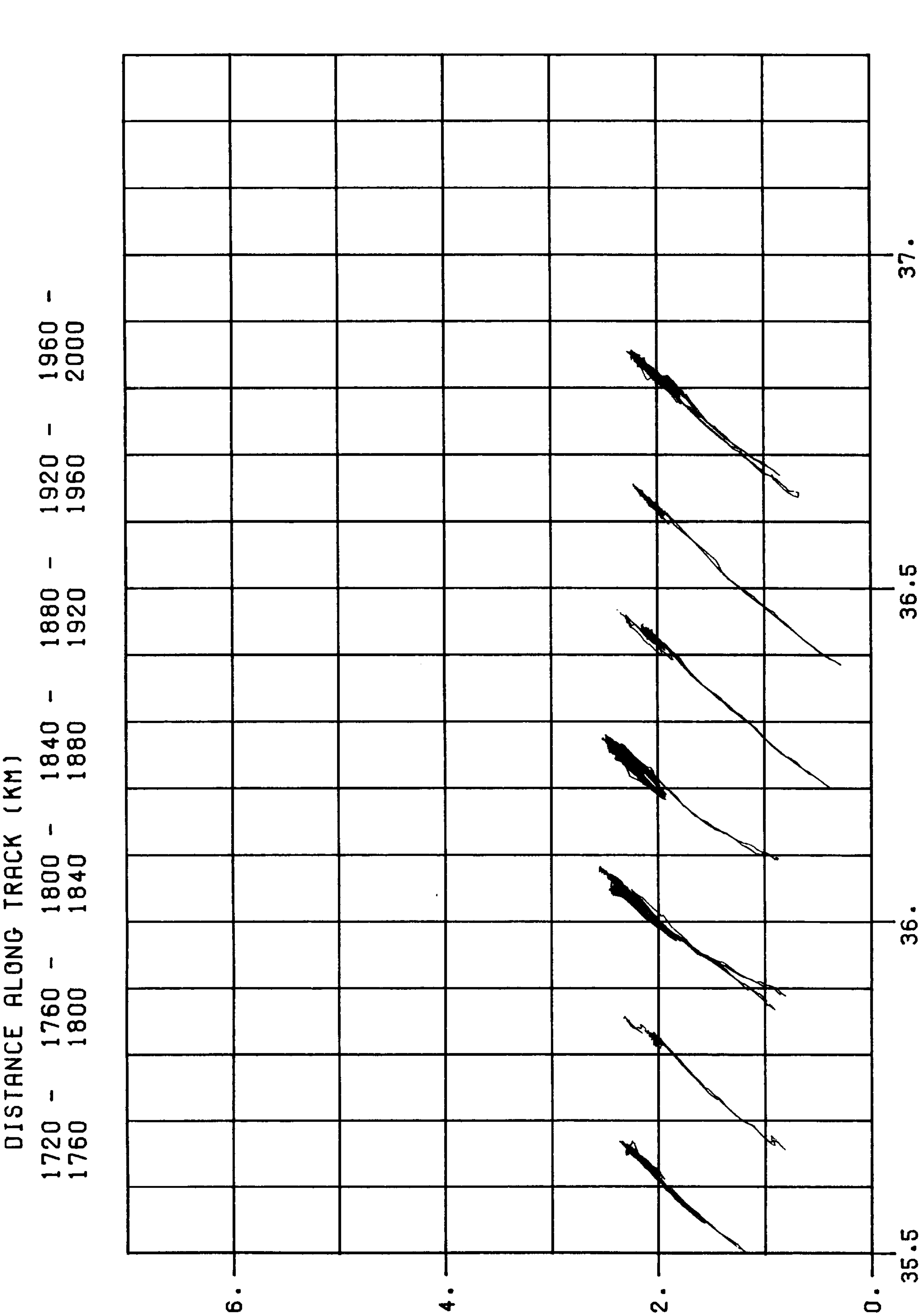
MERCATOR PROJECTION
WITH COASTLINE AND
1000 FATHOM DEPTH CONTOUR



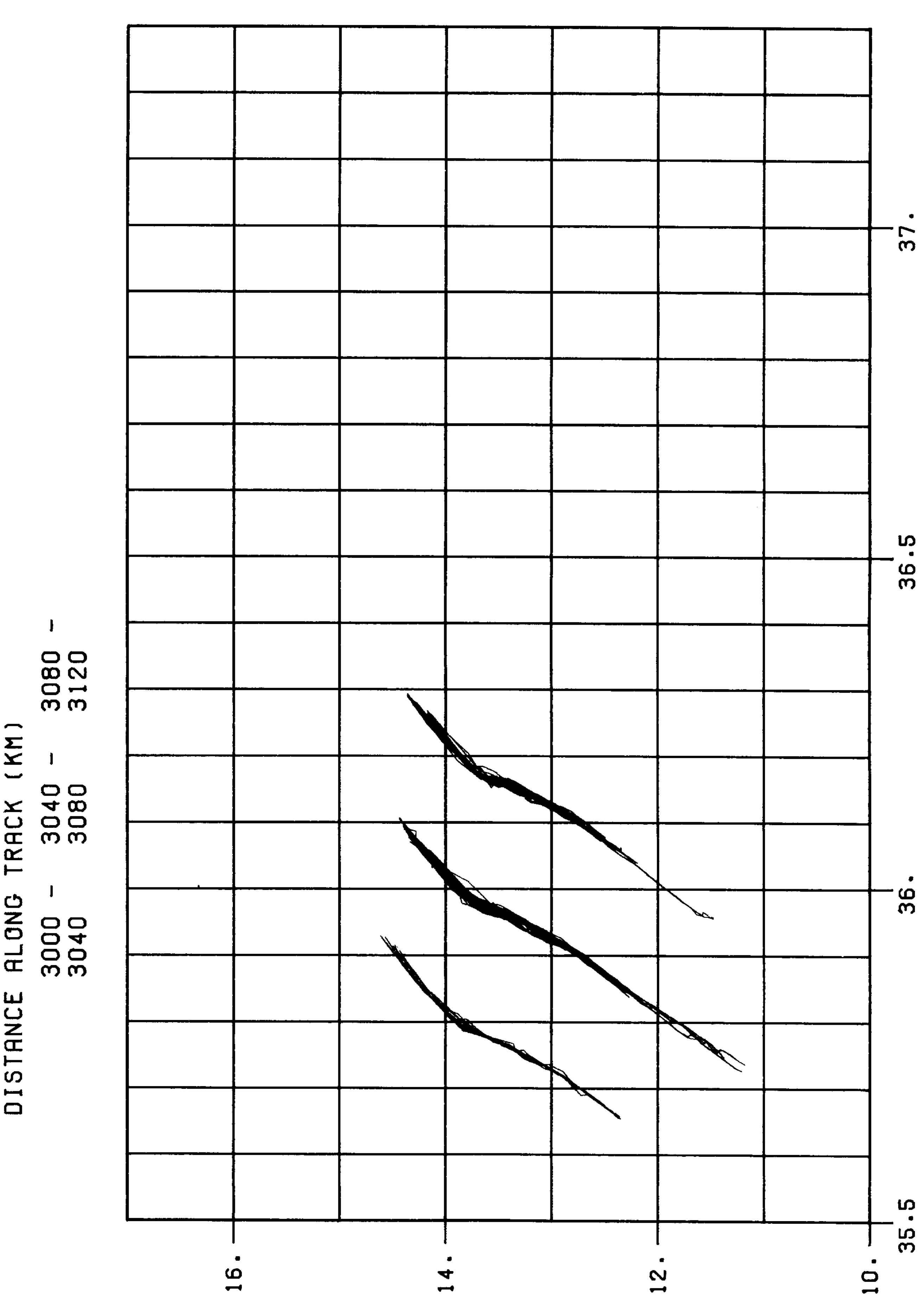
POTENTIAL TEMPERATURE/SALINITY CURVES FOR DISCOVERY CRUISE 132



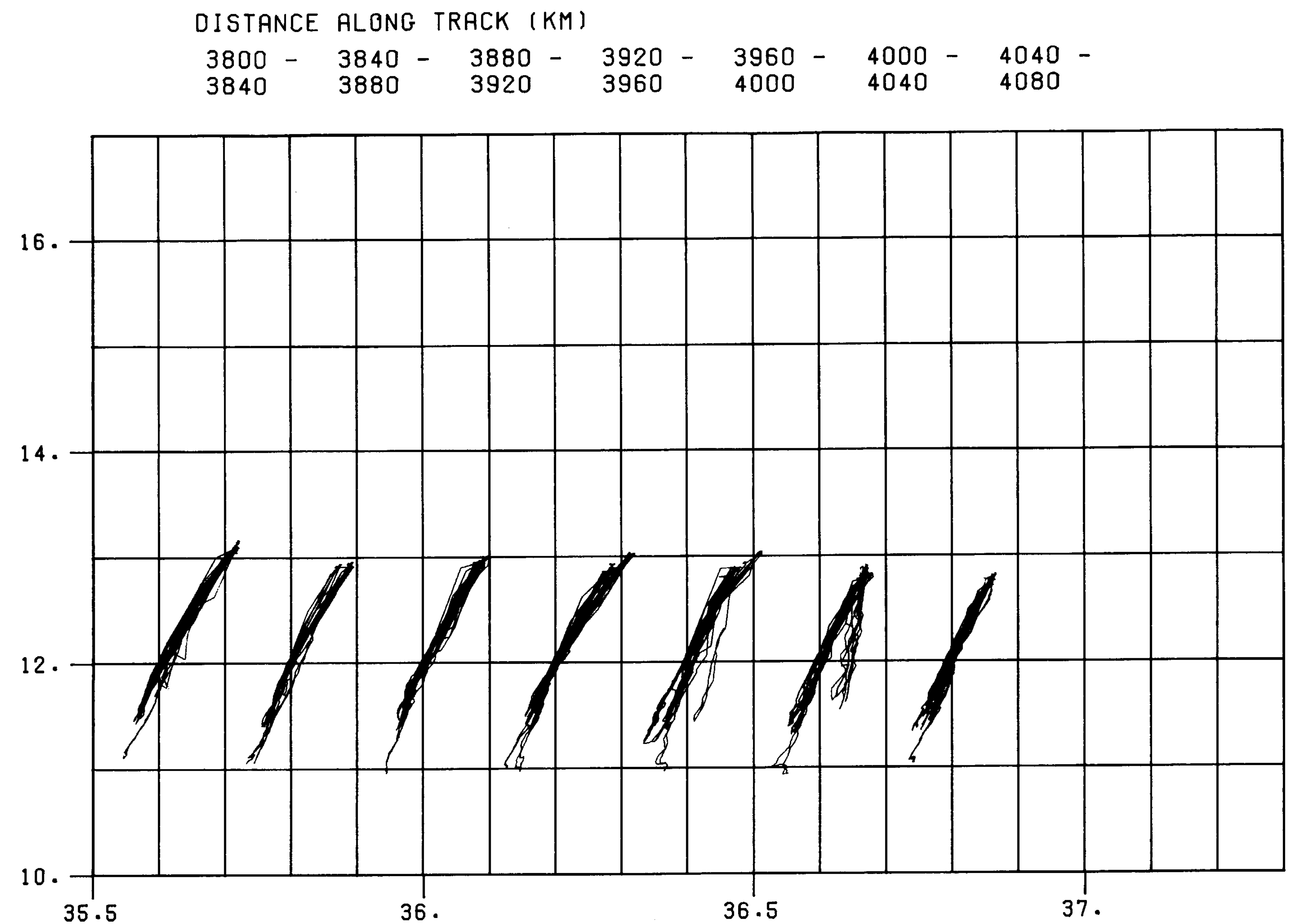
POTENTIAL TEMPERATURE/SALINITY CURVES FOR DISCOVERY CRUISE 132



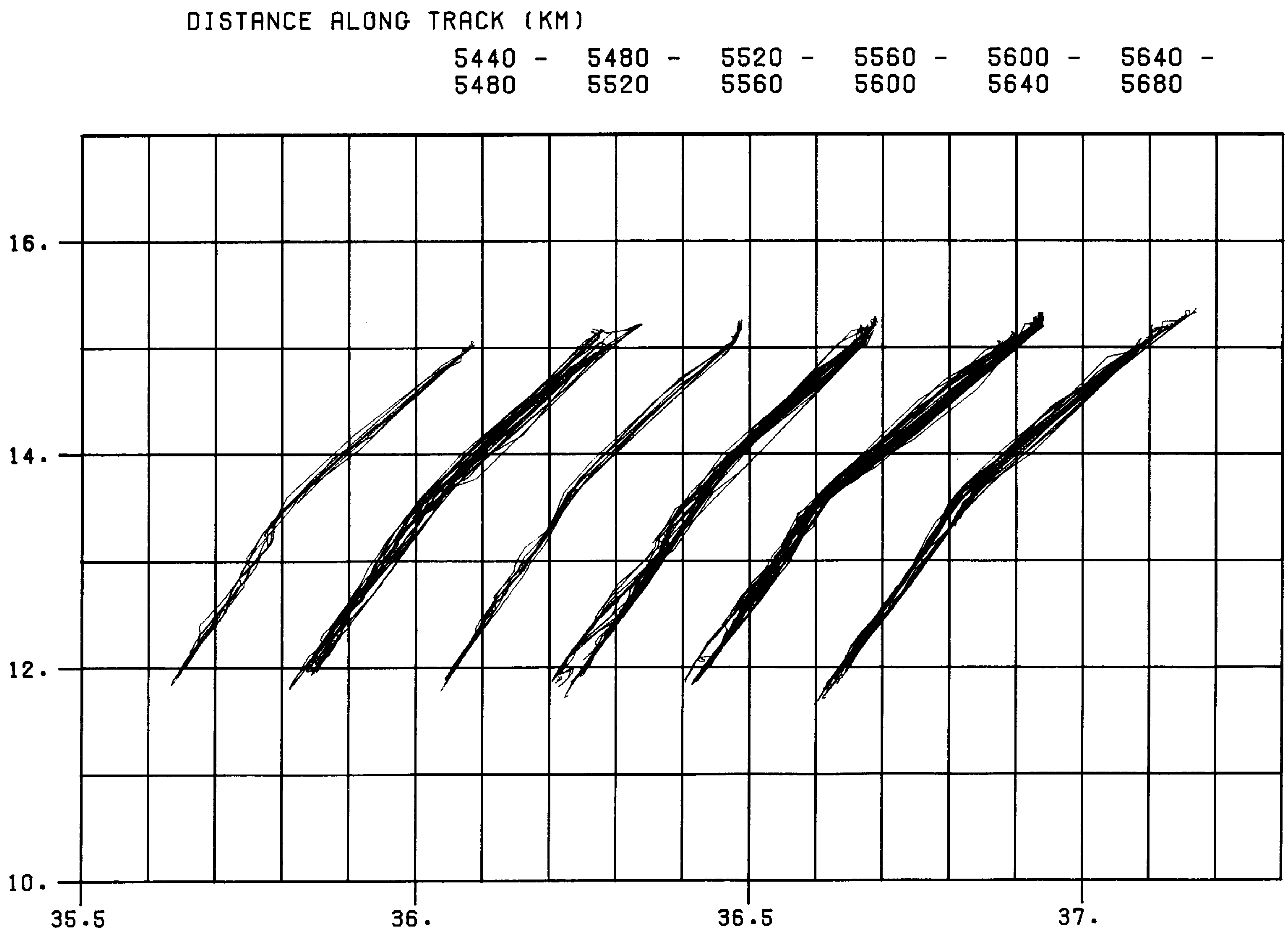
POTENTIAL TEMPERATURE/SALINITY CURVES FOR DISCOVERY CRUISE 132



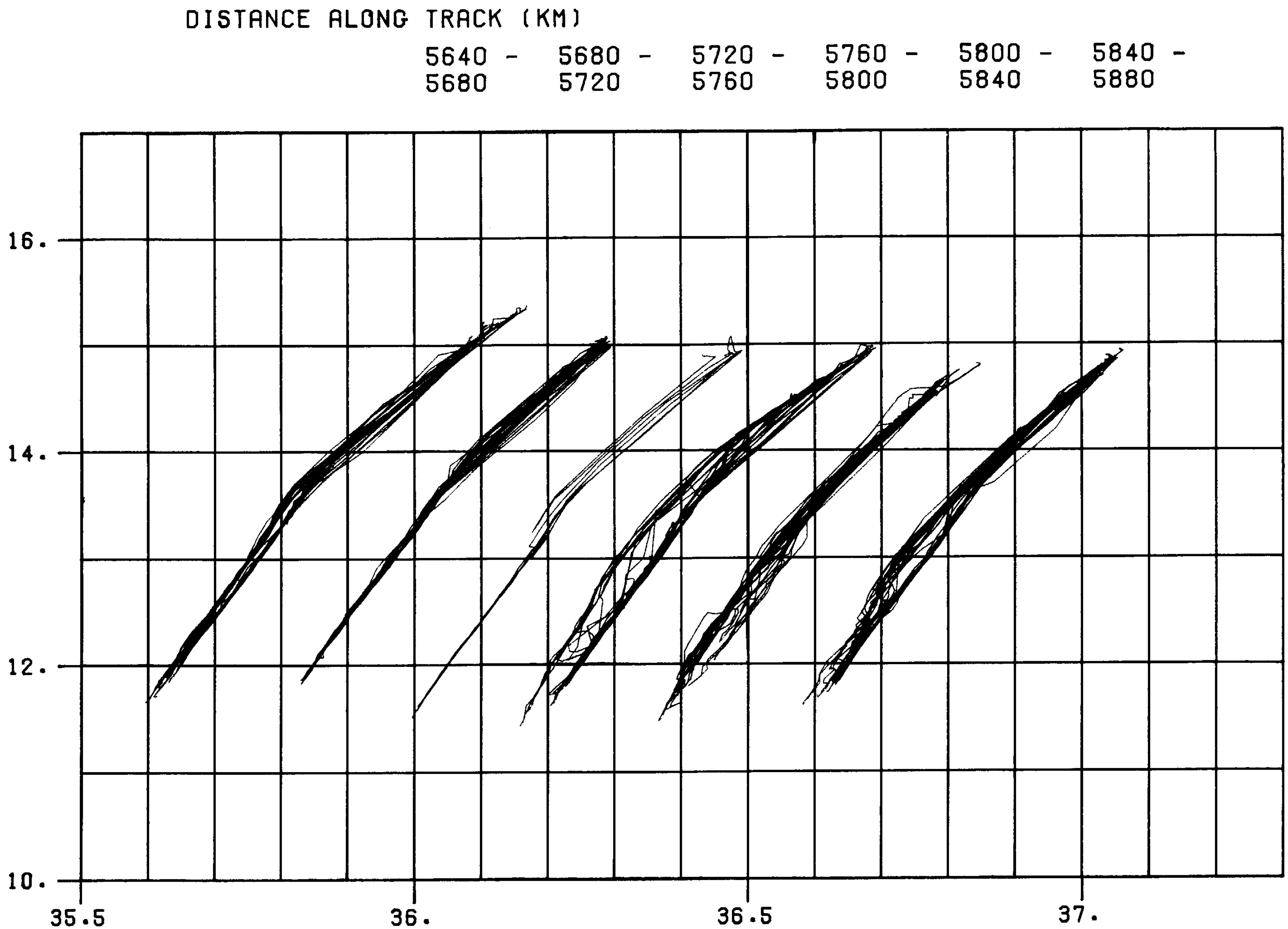
POTENTIAL TEMPERATURE/SALINITY CURVES FOR DISCOVERY CRUISE 132



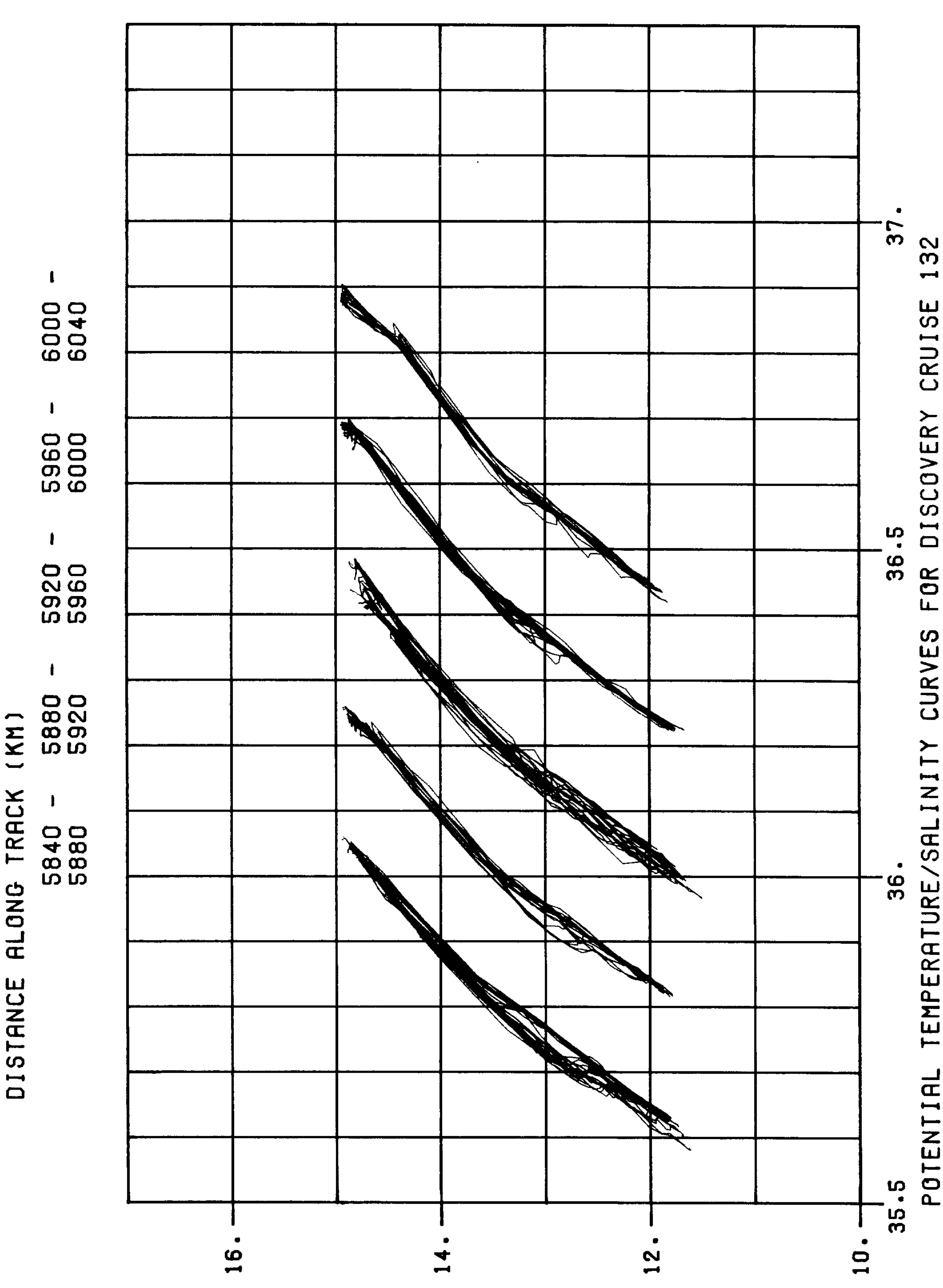
POTENTIAL TEMPERATURE/SALINITY CURVES FOR DISCOVERY CRUISE 132

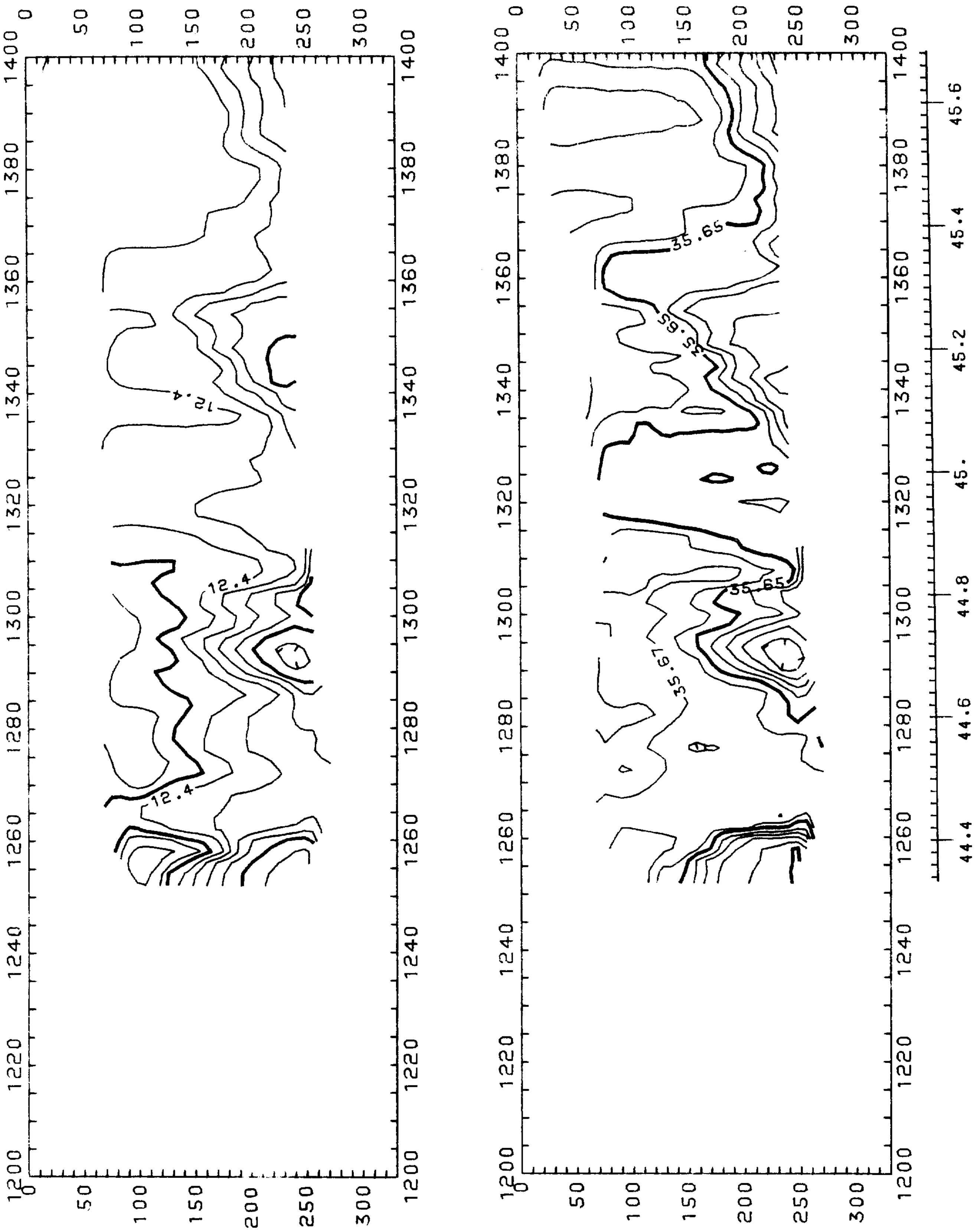


POTENTIAL TEMPERATURE/SALINITY CURVES FOR DISCOVERY CRUISE 132

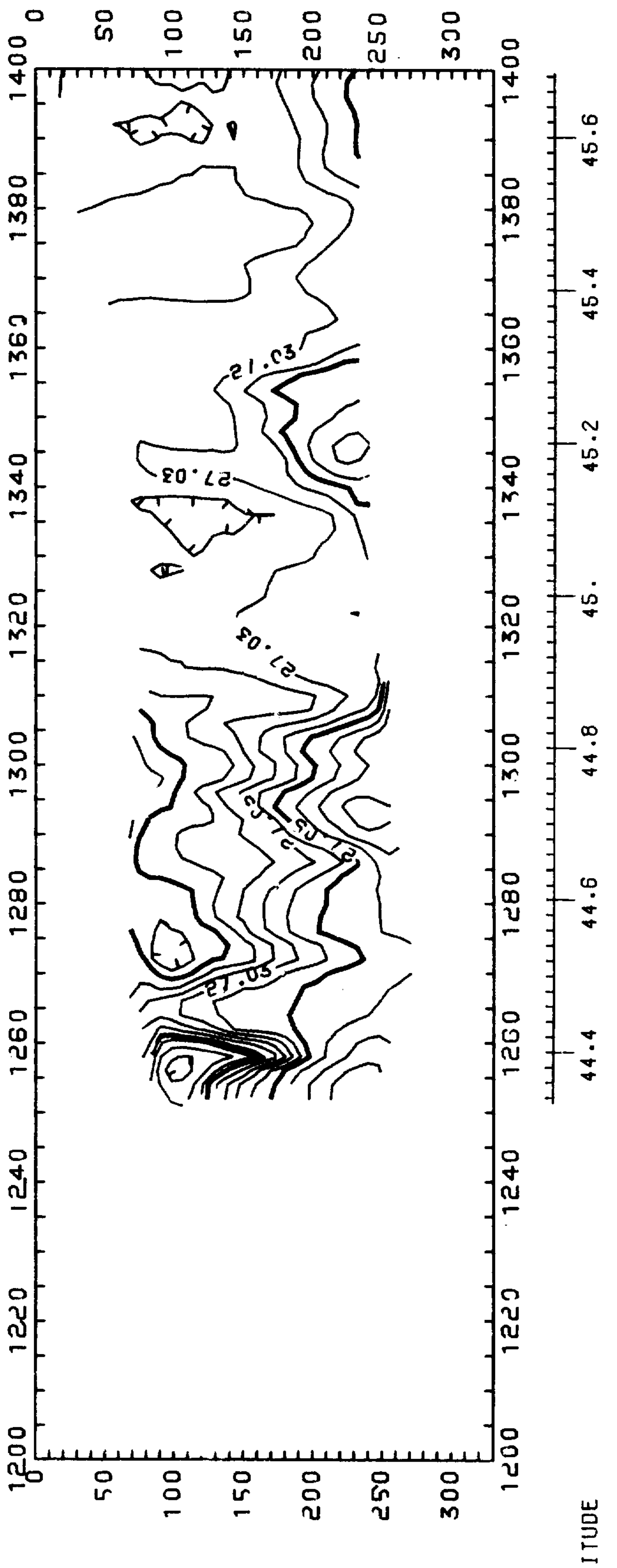


POTENTIAL TEMPERATURE/SALINITY CURVES FOR DISCOVERY CRUISE 132


DISTANCE ALONG TRACK (KM)
5840 - 5880
5880 - 5920
5920 - 5960
5960 - 6000
6000 - 6040
16.
14.
12.
10.
35.5
36.
36.5
37.
POTENTIAL TEMPERATURE/SALINITY CURVES FOR DISCOVERY CRUISE 132

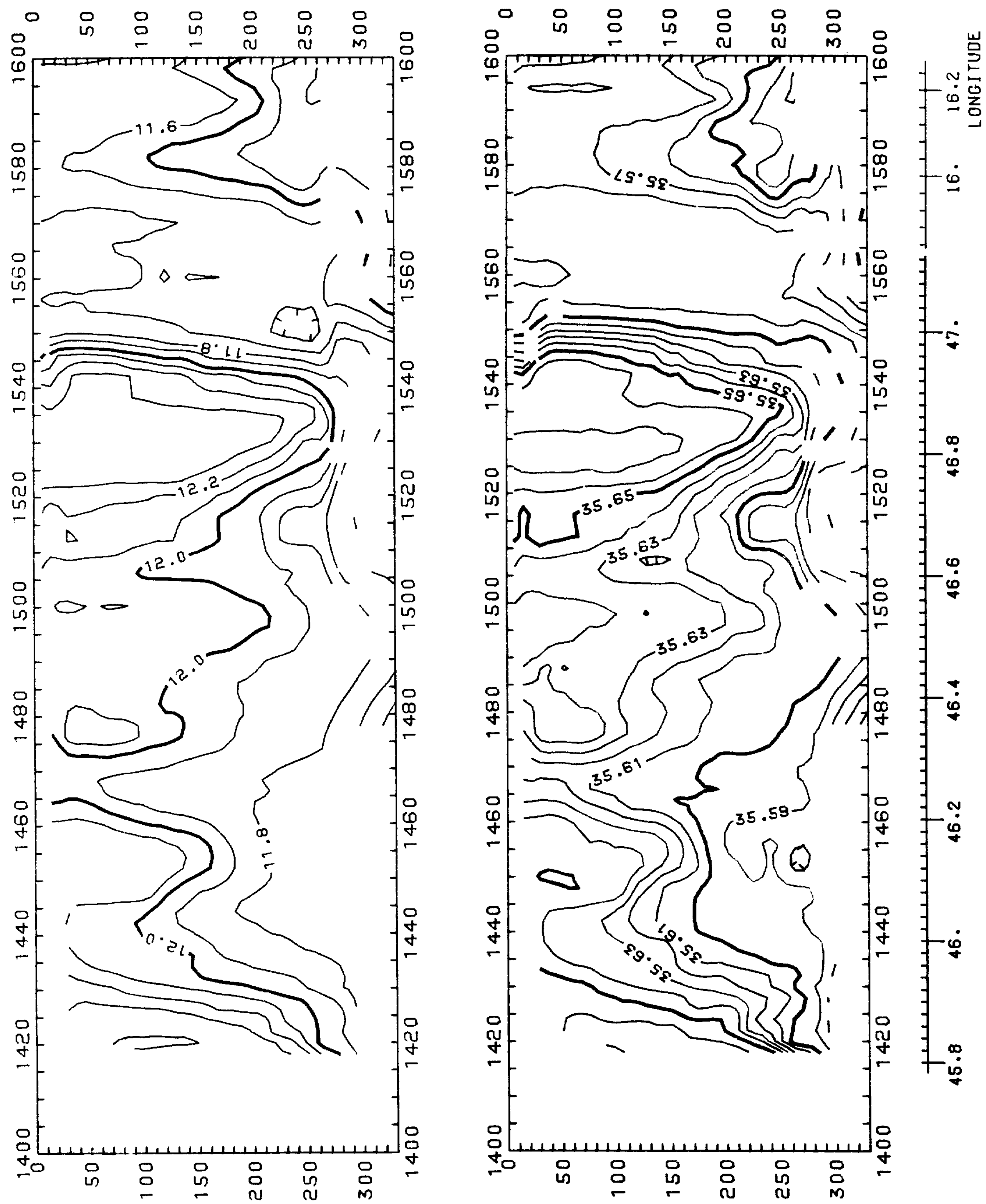


CONTOURS OF POTENTIAL TEMPERATURE(TOP) AND SALINITY(BOTTOM)
X=DISTANCE RUN(KM)   Y=PRESSURE(DB)

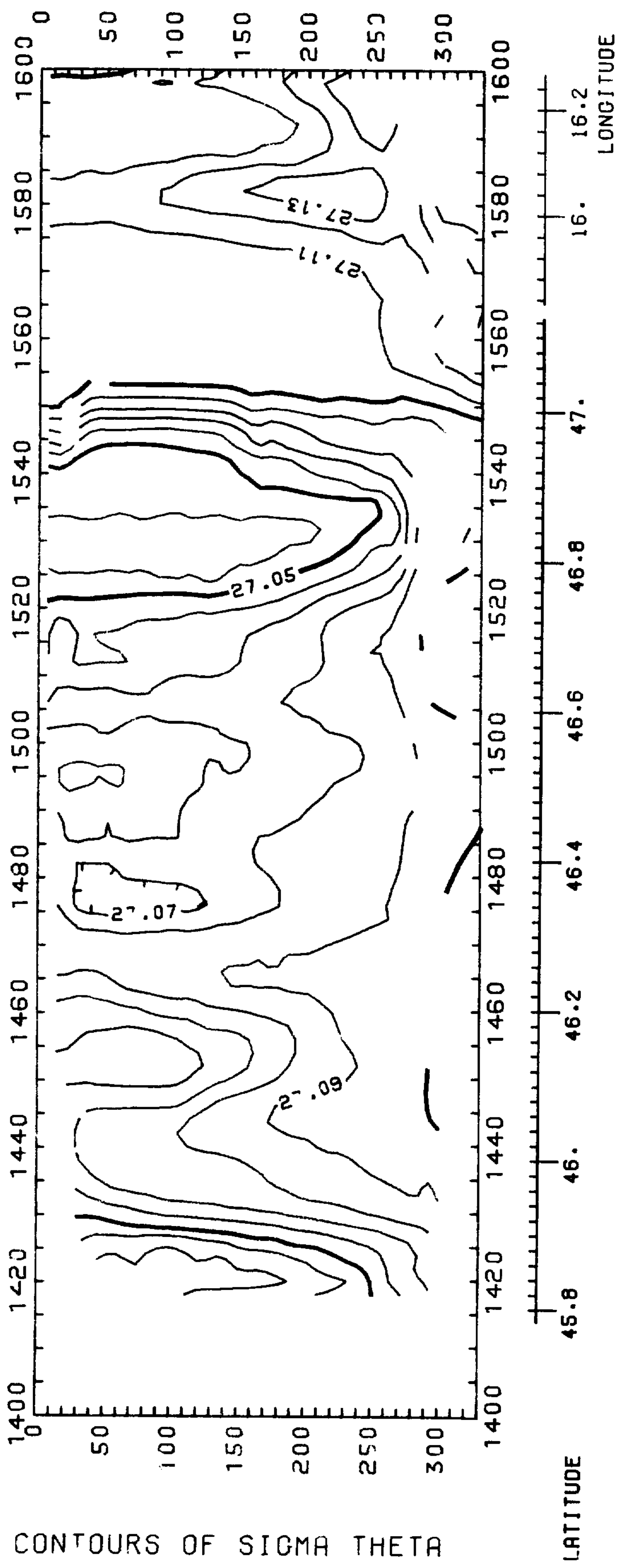


CONTOURS OF SIGMA THETA

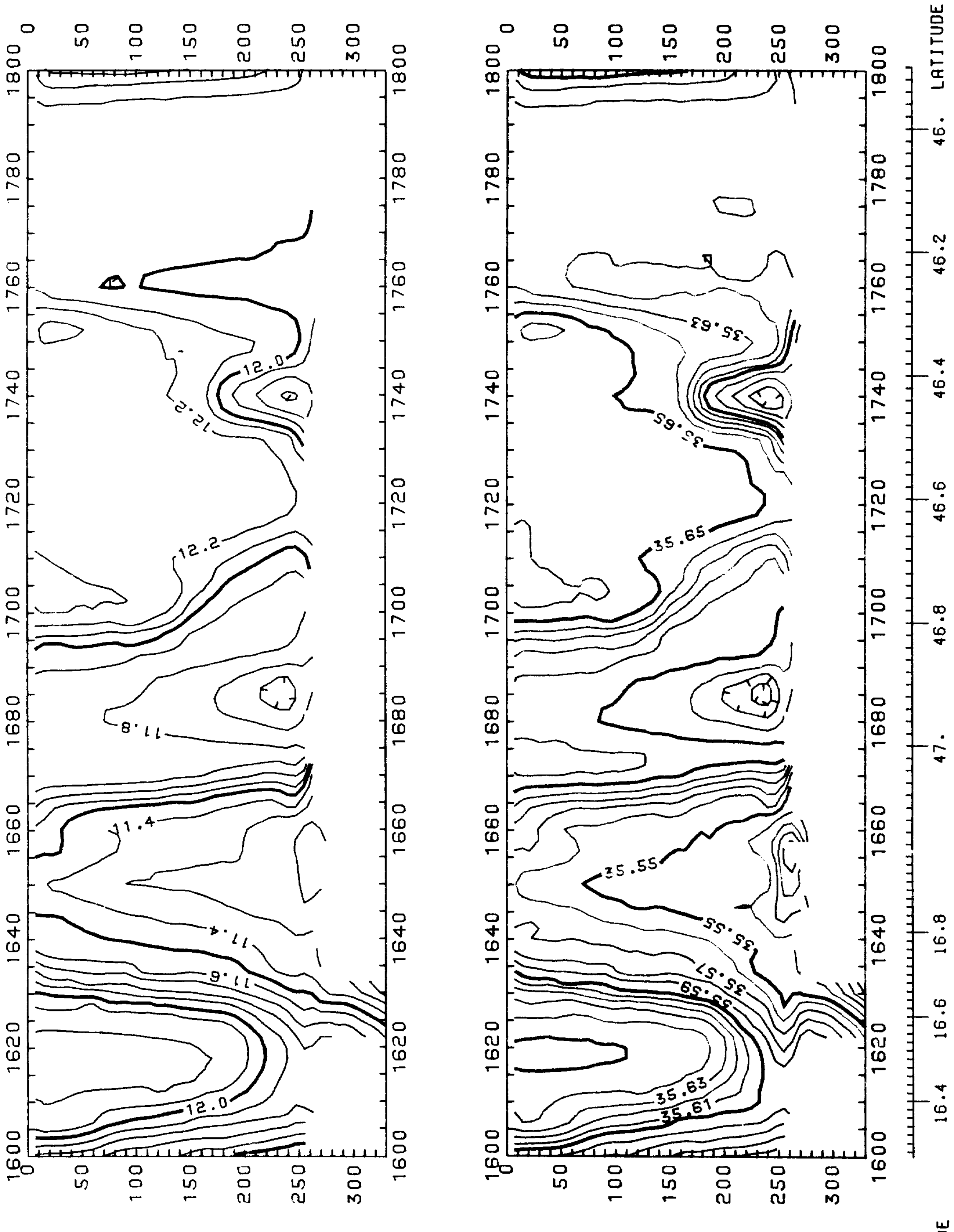
X=DISTANCE RUN(KM)   Y=PRESSURE(DB)



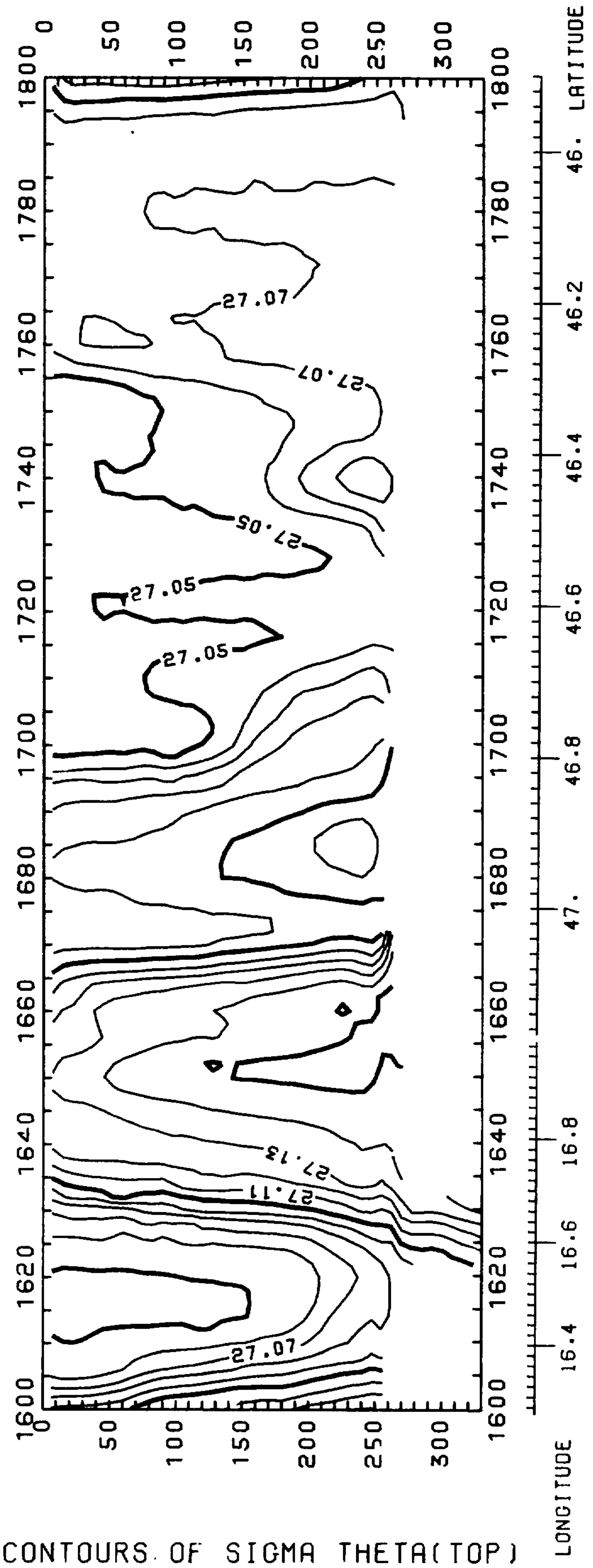
CONTOURS OF POTENTIAL TEMPERATURE(TOP) AND SALINITY(BOTTOM)
X=DISTANCE RUN(KM) Y=PRESSURE(DB)



CONTOURS OF SIGMA THETA
X=DISTANCE RUN(KM) Y=PRESSURE(DB)

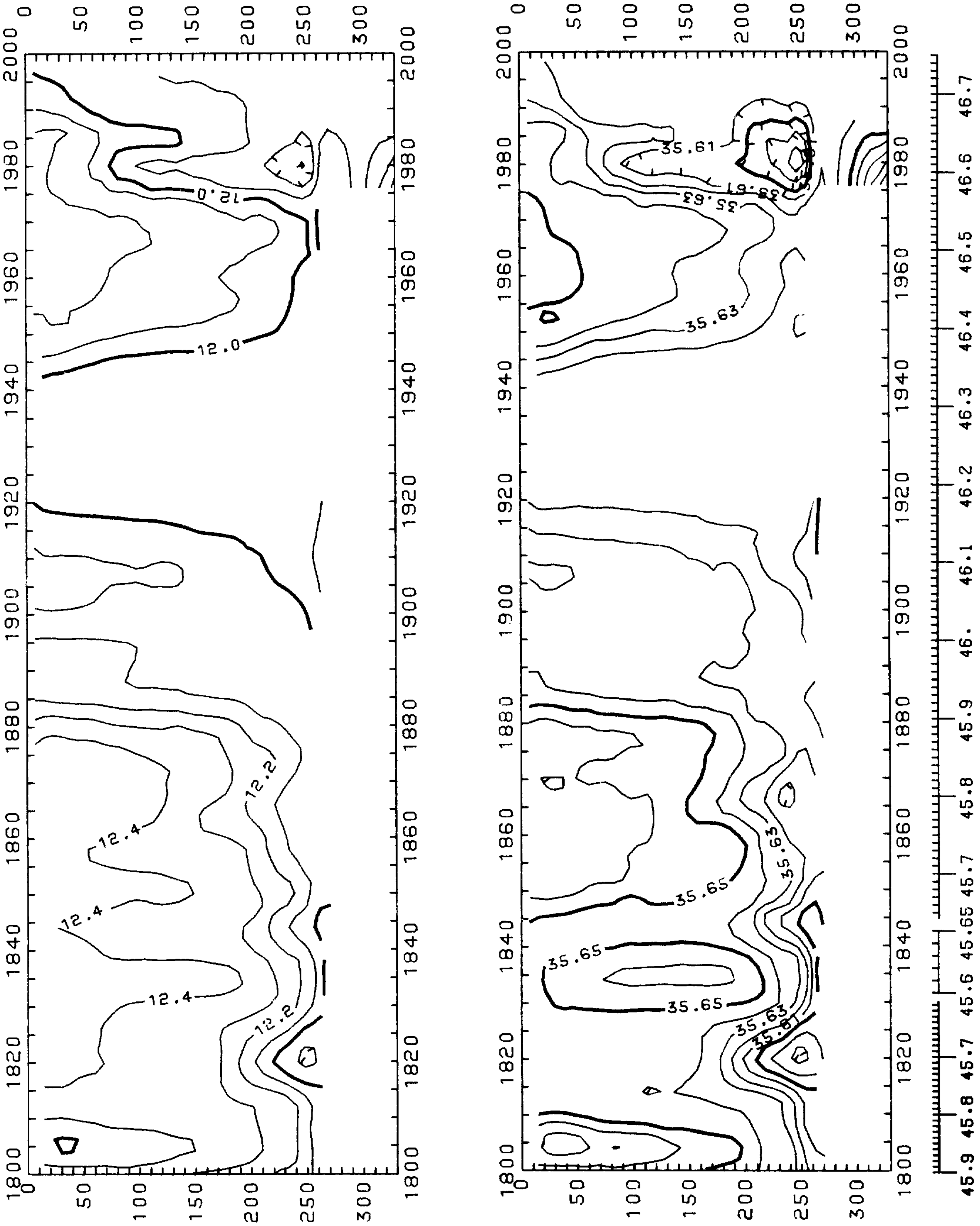


CONTOURS OF POTENTIAL TEMPERATURE(TOP) AND SALINITY(BOTTOM)
X=DISTANCE RUN(KM)   Y=PRESSURE(DB)

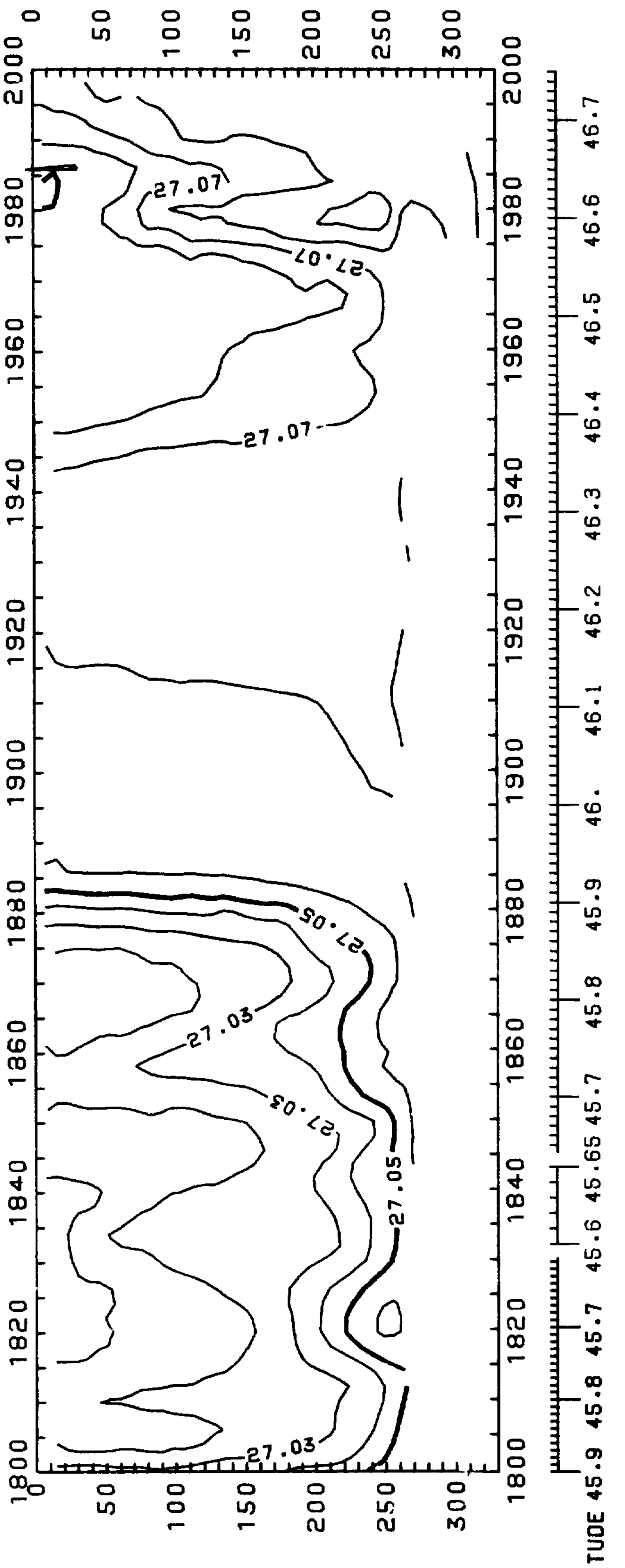


CONTOURS OF SIGMA THETA(TOP)

X=DISTANCE RUN(KM)   Y=PRESSURE(DB)

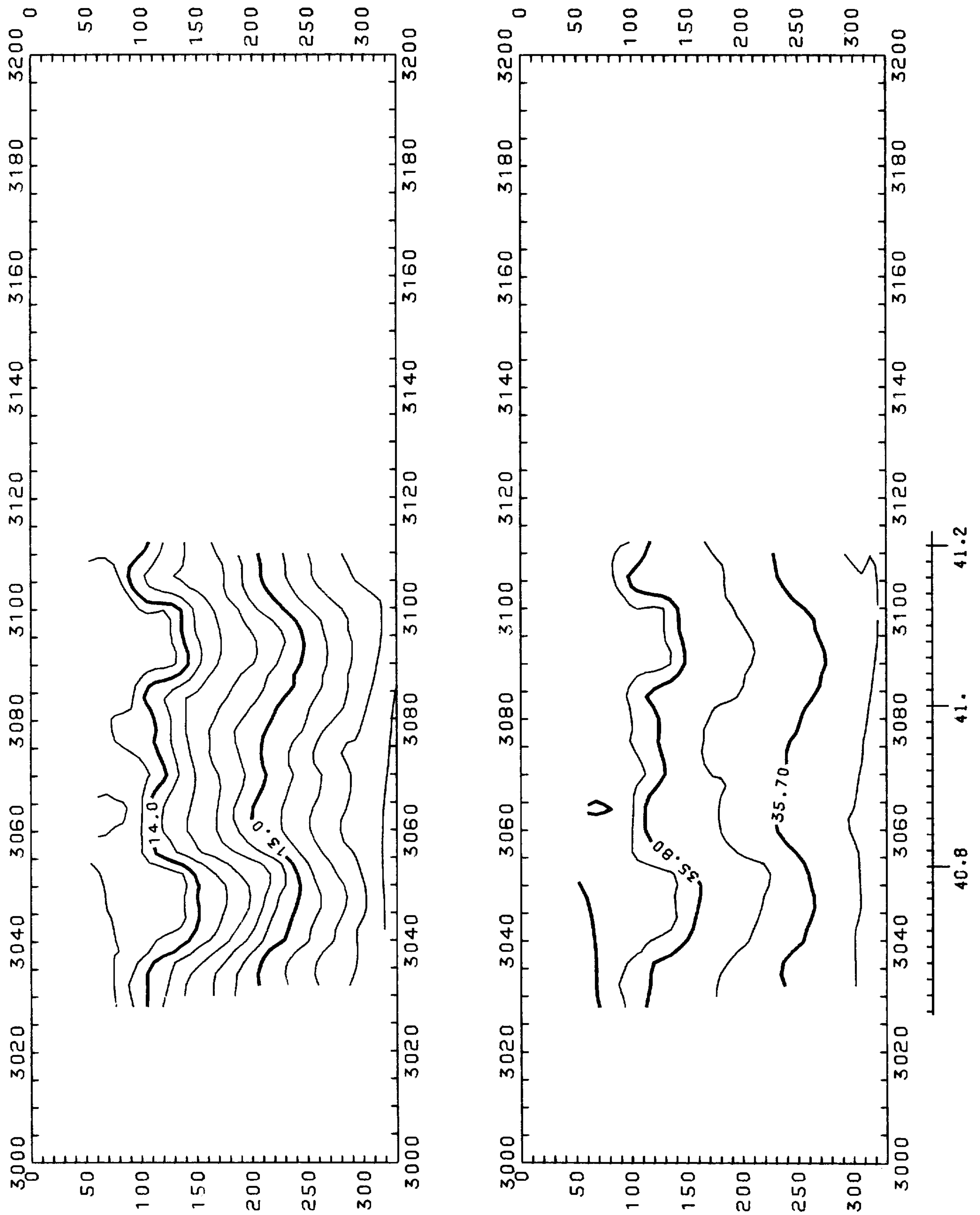


CONTOURS OF POTENTIAL TEMPERATURE(TOP) AND SALINITY(BOTTOM)
X=DISTANCE RUN(KM)   Y=PRESSURE(DB)

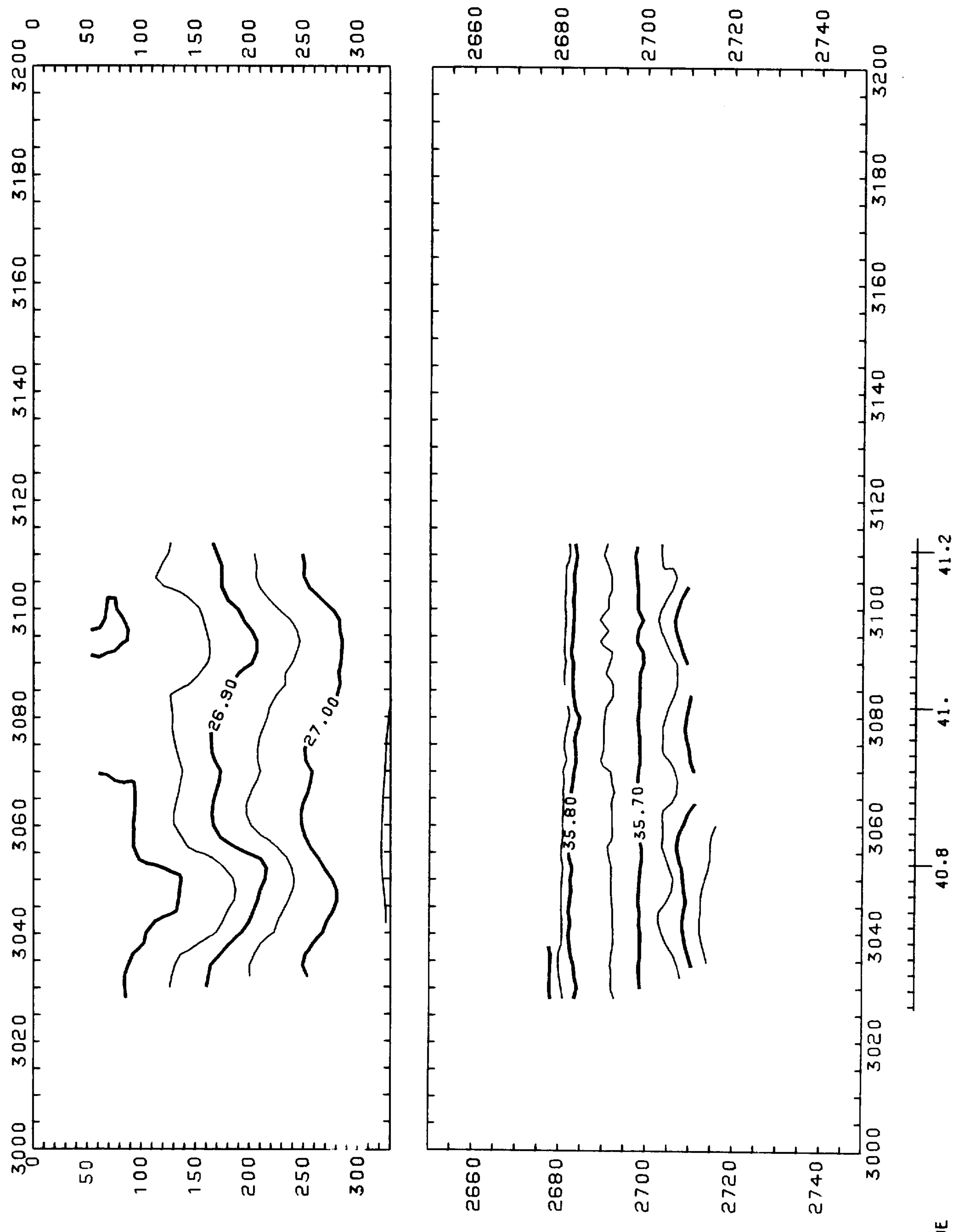


CONTOURS OF SIGMA THETA(TOP)

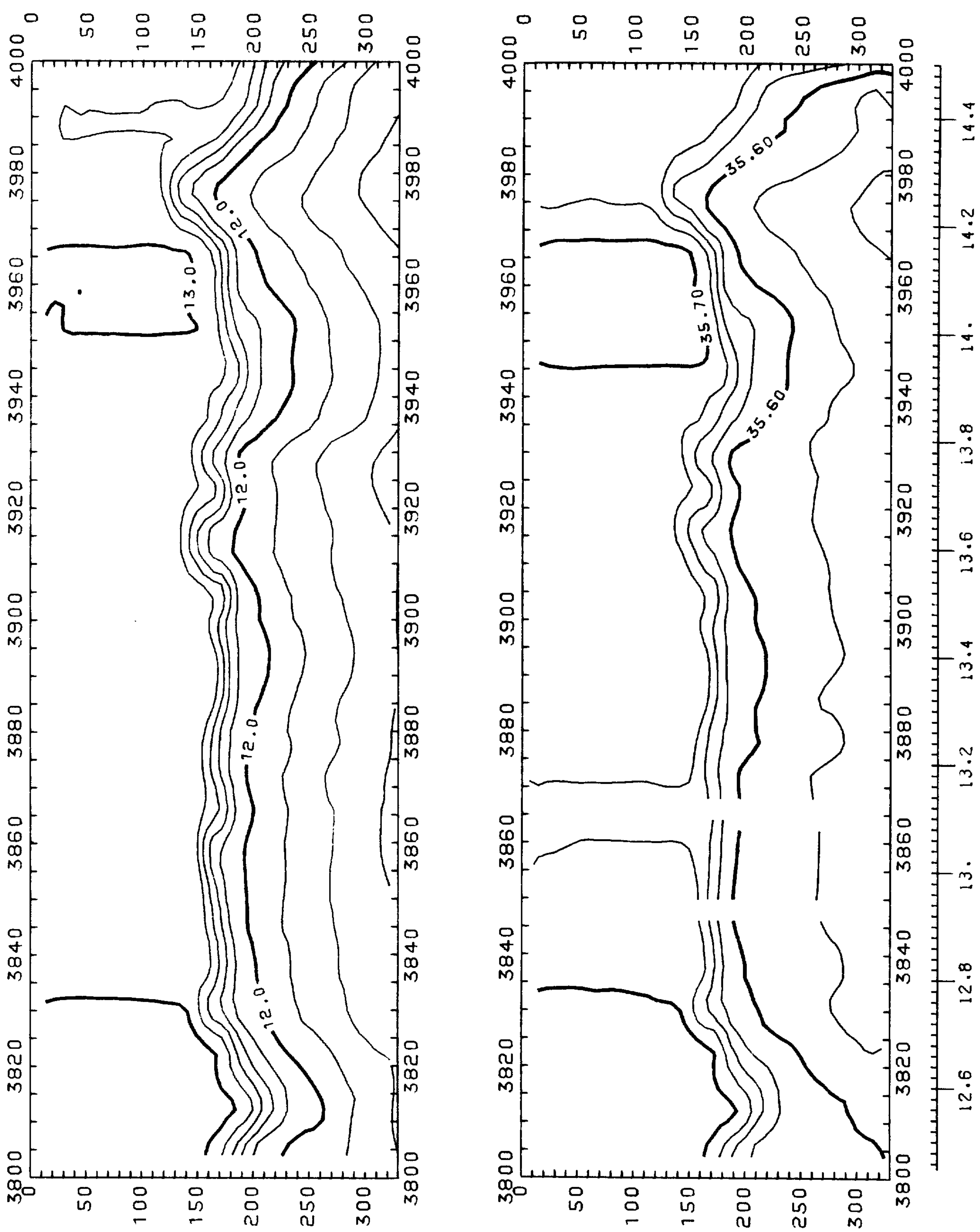
X=DISTANCE RUN(KM) Y=PRESSURE(DB)



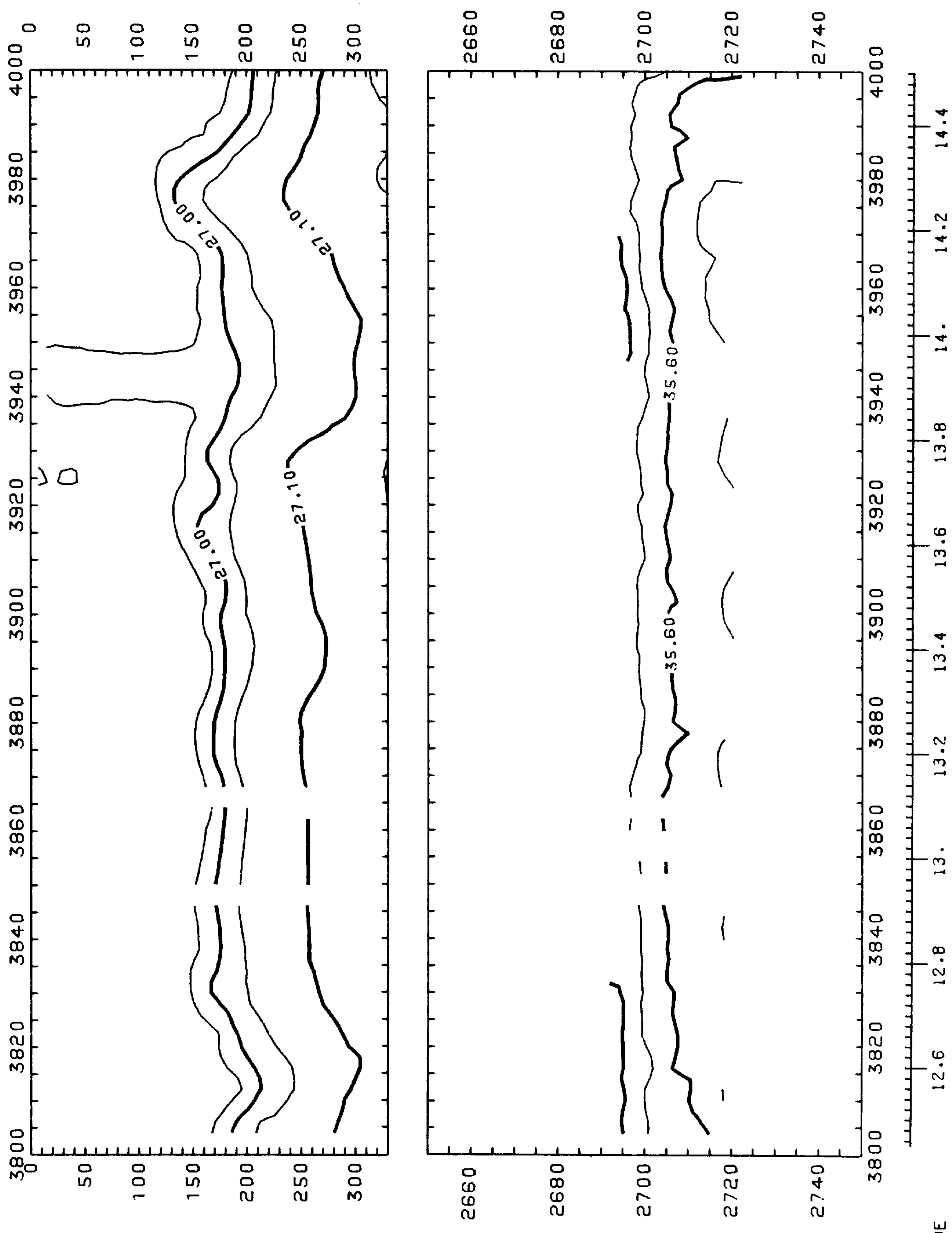
CONTOURS OF POTENTIAL TEMPERATURE(TOP) AND SALINITY(BOTTOM)
X=DISTANCE RUN(KM)   Y=PRESSURE(DB)



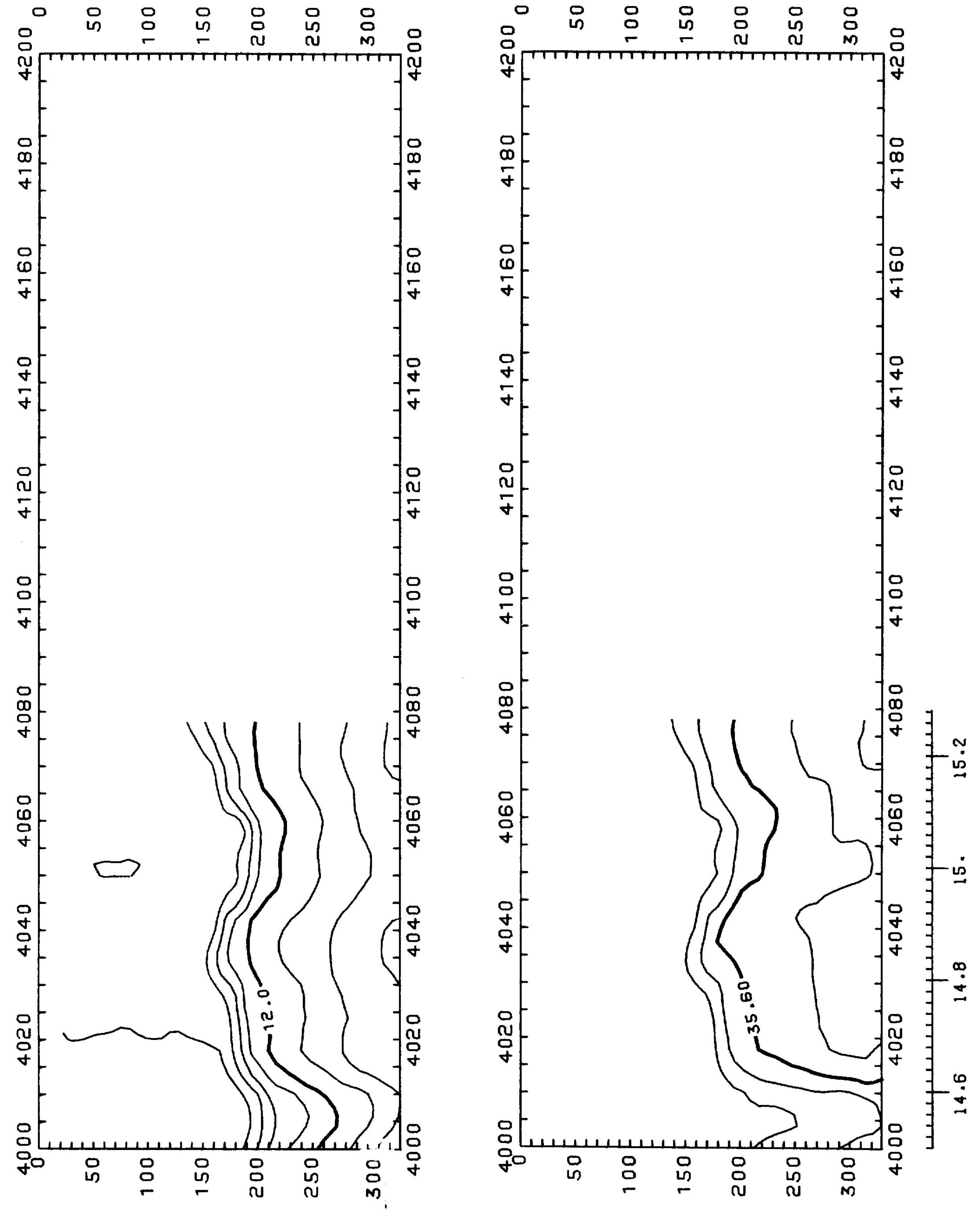
CONTOURS OF SIGMA THETA(TOP) AND SALINITY(BOTTOM)
X=DISTANCE RUN(KM) Y=PRESSURE(DB) OR SIGMA THETA*100(CGS)



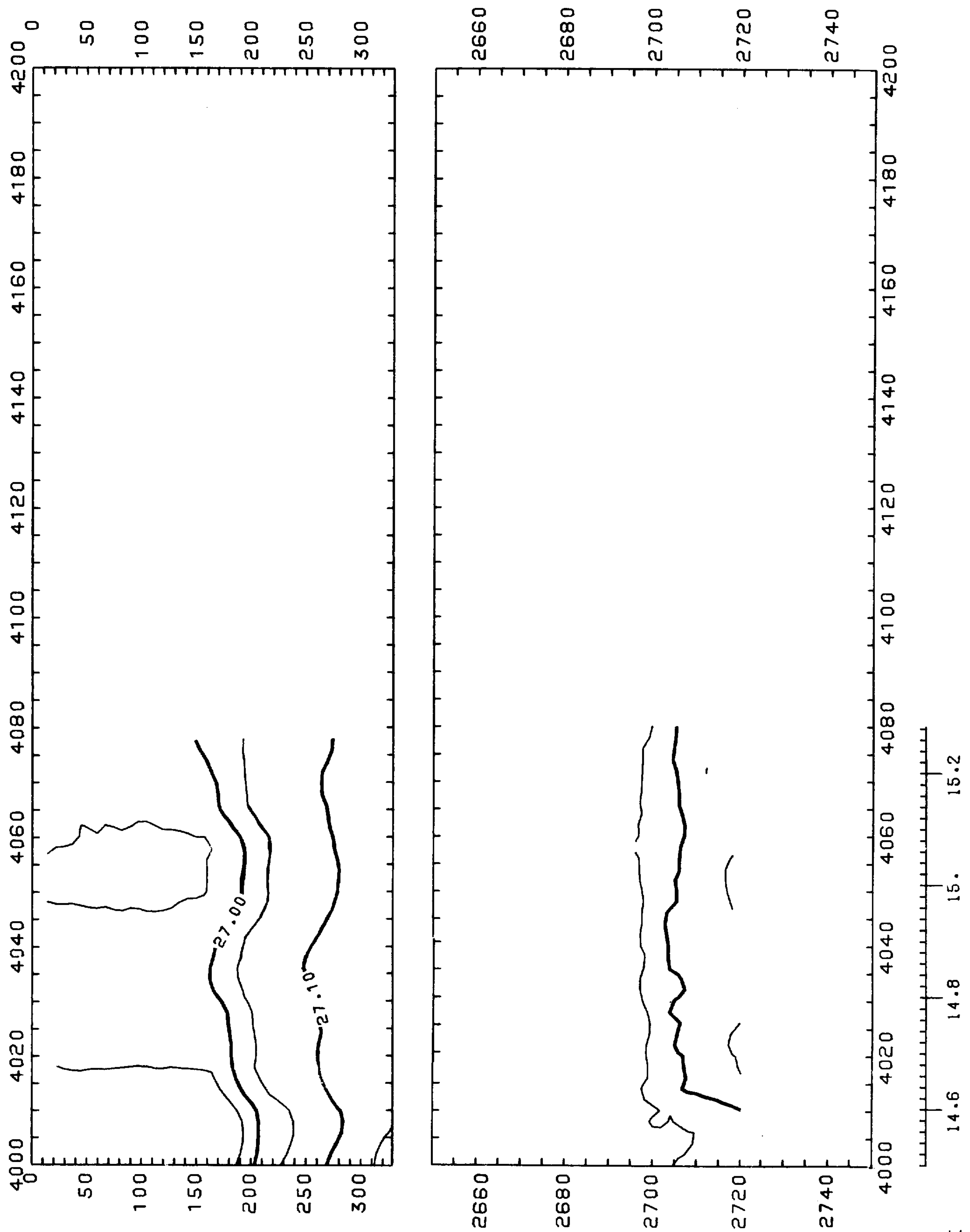
CONTOURS OF POTENTIAL TEMPERATURE(TOP) AND SALINITY(BOTTOM)
X=DISTANCE RUN(KM)   Y=PRESSURE(DB)



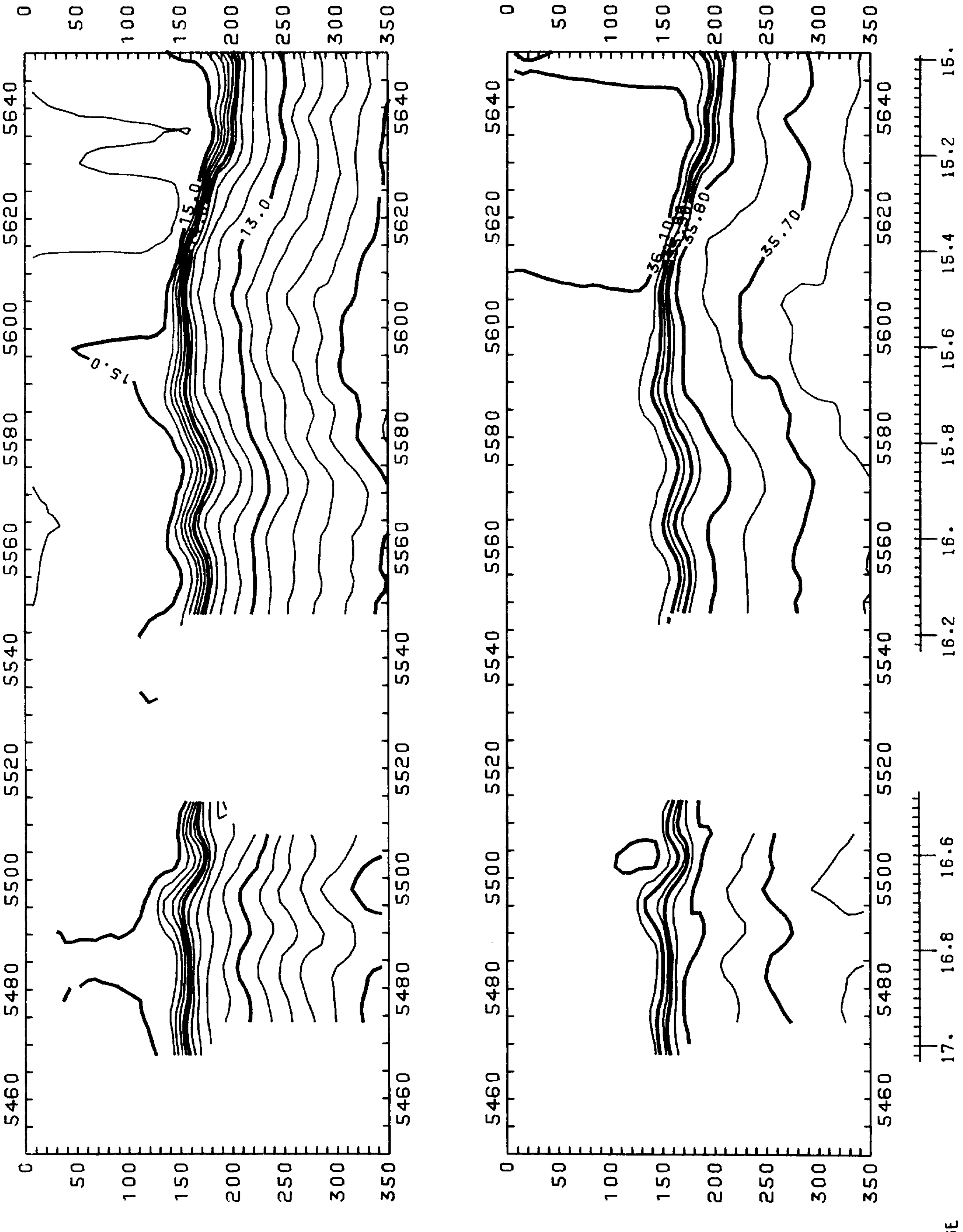
CONTOURS OF SIGMA THETA(TOP) AND SALINITY(BOTTOM)
X=DISTANCE RUN(KM)   Y=PRESSURE(DB) OR SIGMA THETA*100(CGS)



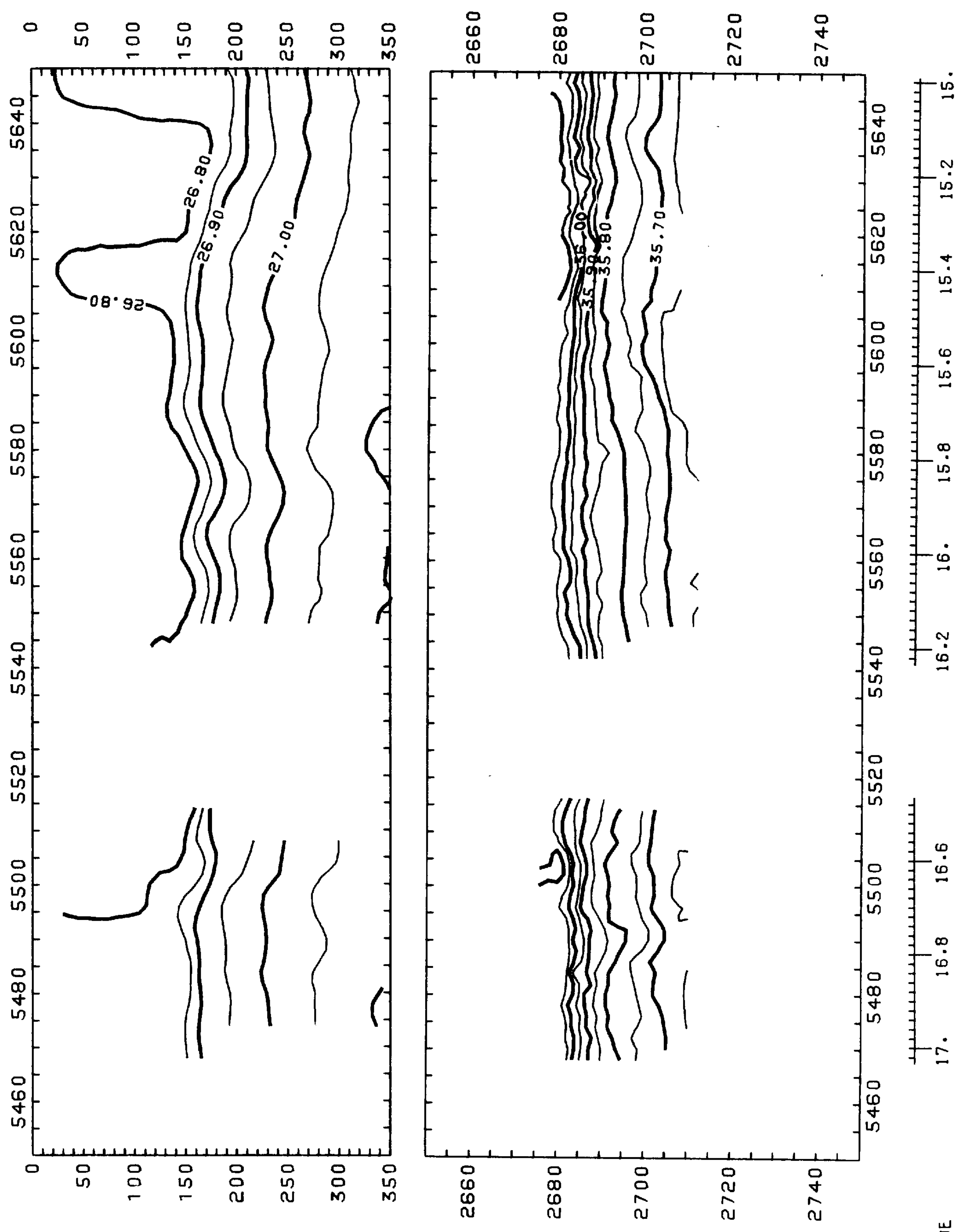
CONTOURS OF POTENTIAL TEMPERATURE(TOP) AND SALINITY(BOTTOM)
X=DISTANCE RUN(KM)   Y=PRESSURE(DB)



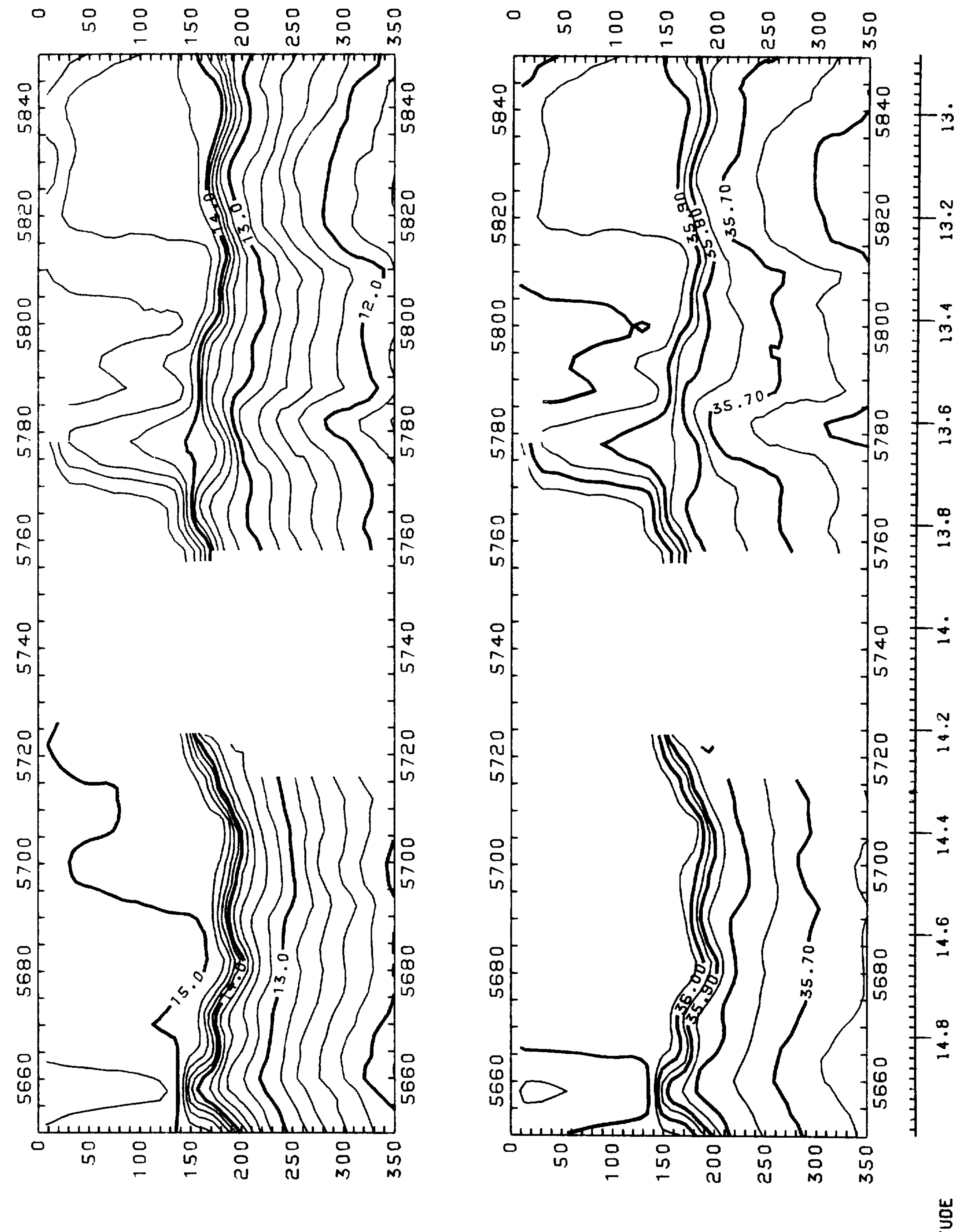
CONTOURS OF SIGMA THETA(TOP) AND SALINITY(BOTTOM)
X=DISTANCE RUN(KM)   Y=PRESSURE(DB) OR SIGMA THETA*100(CGS)



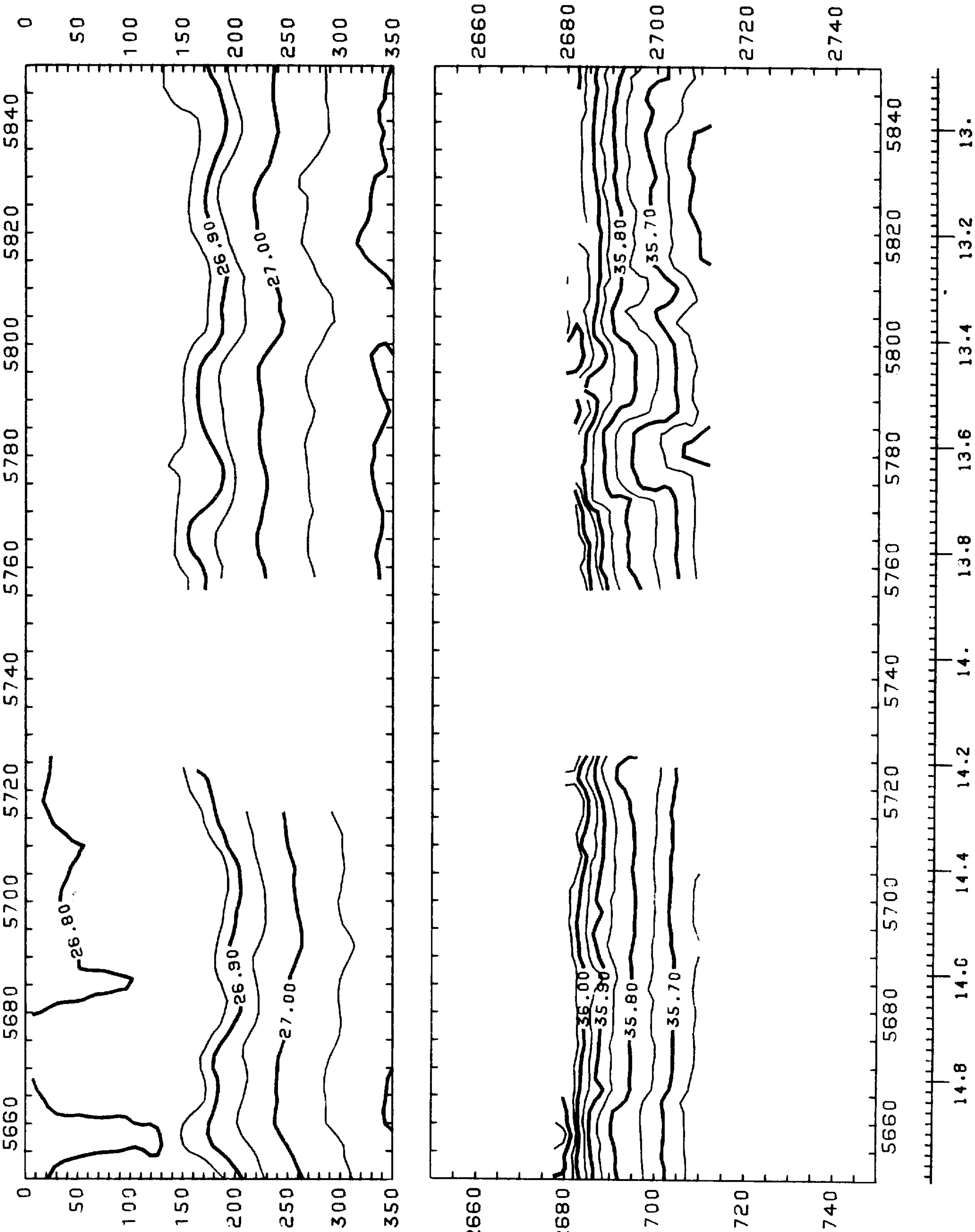
CONTOURS OF POTENTIAL TEMPERATURE(TOP) AND SALINITY(BOTTOM)
X=DISTANCE RUN(KM)   Y=PRESSURE(DB)



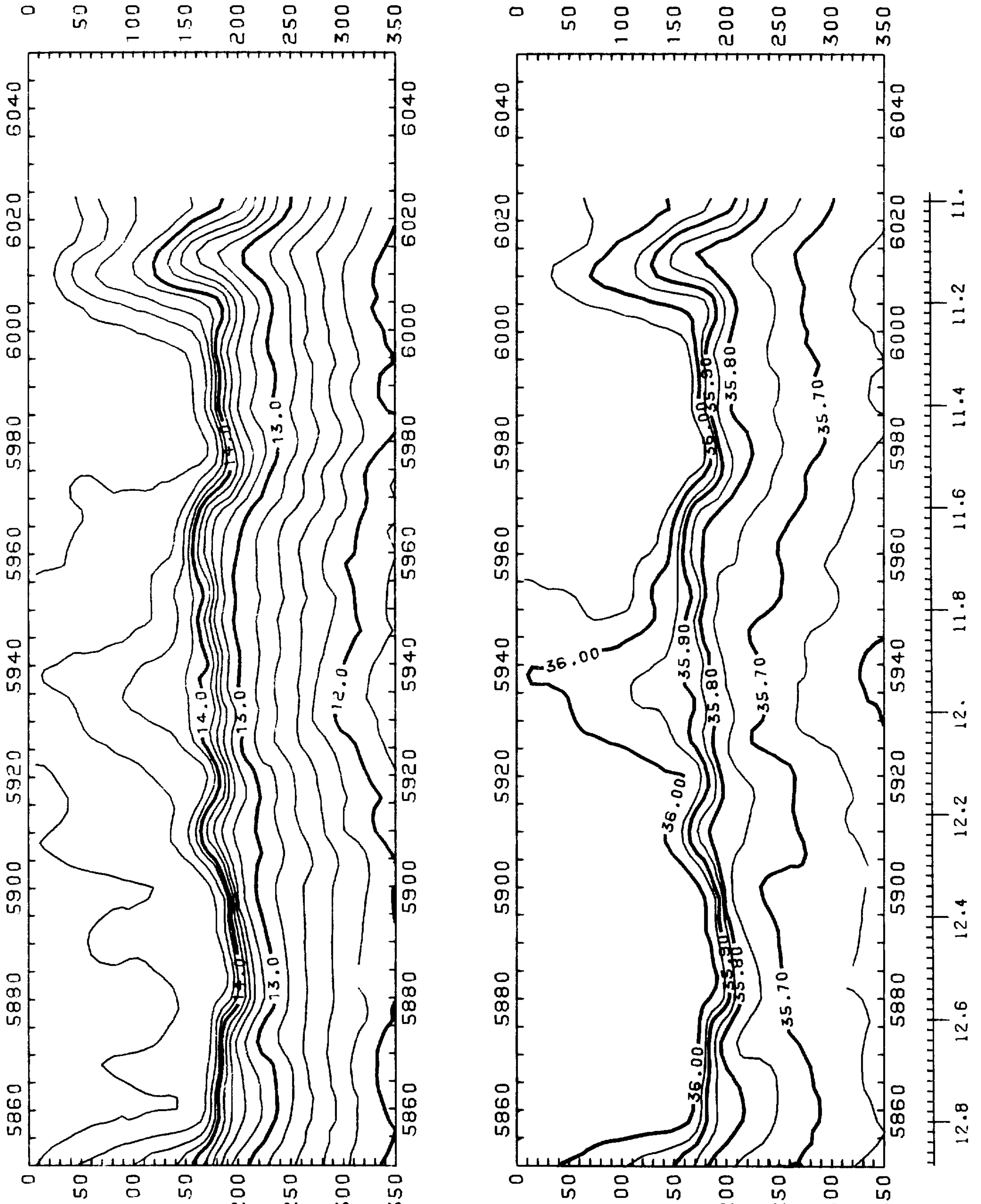
CONTOURS OF SIGMA THETA(TOP) AND SALINITY(BOTTOM).
X=DISTANCE RUN(KM) Y=PRESSURE(DB) OR SIGMA THETA*100(CGS)



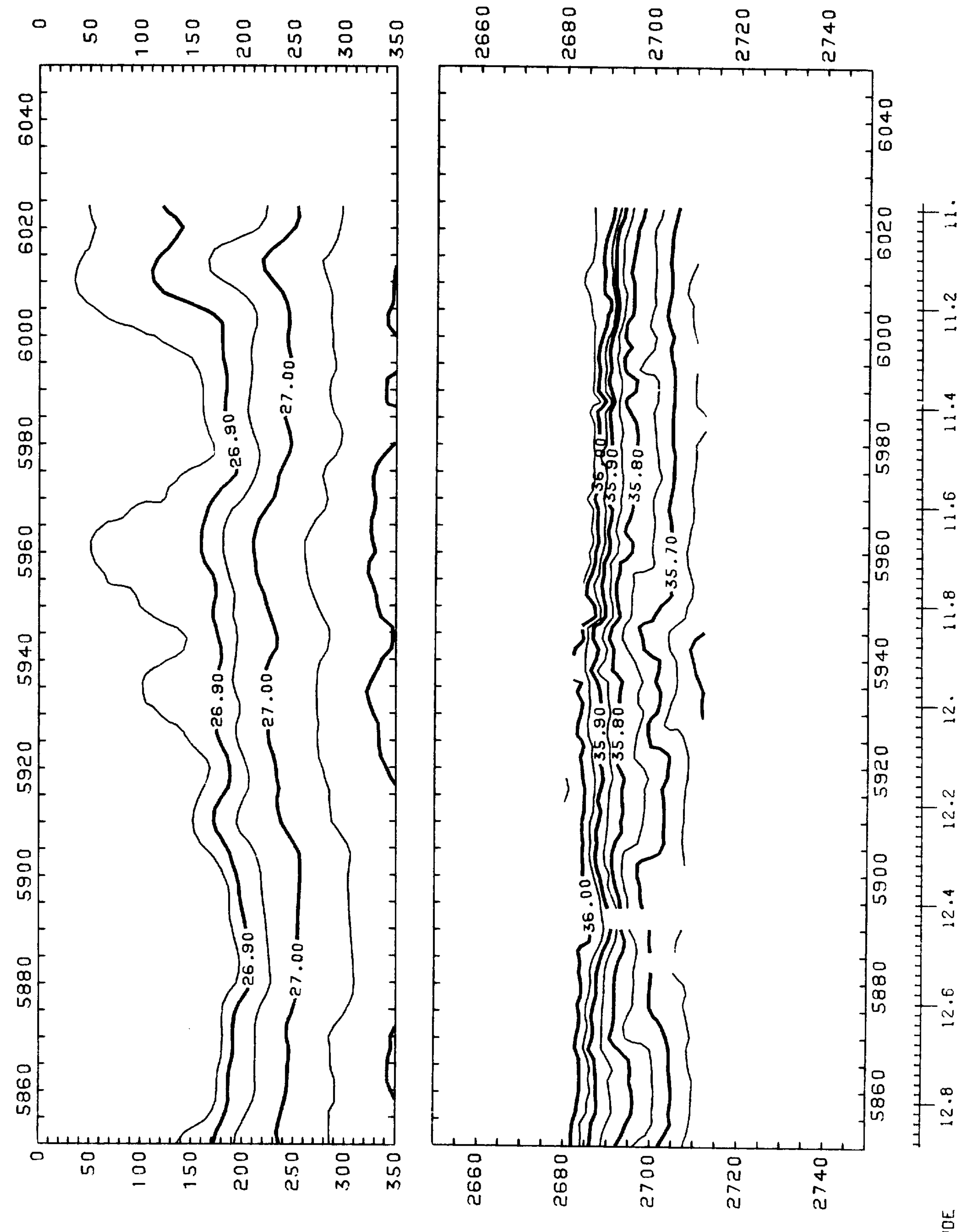
CONTOURS OF POTENTIAL TEMPERATURE(TOP) AND SALINITY(BOTTOM)
X=DISTANCE RUN(KM)   Y=PRESSURE(DB)



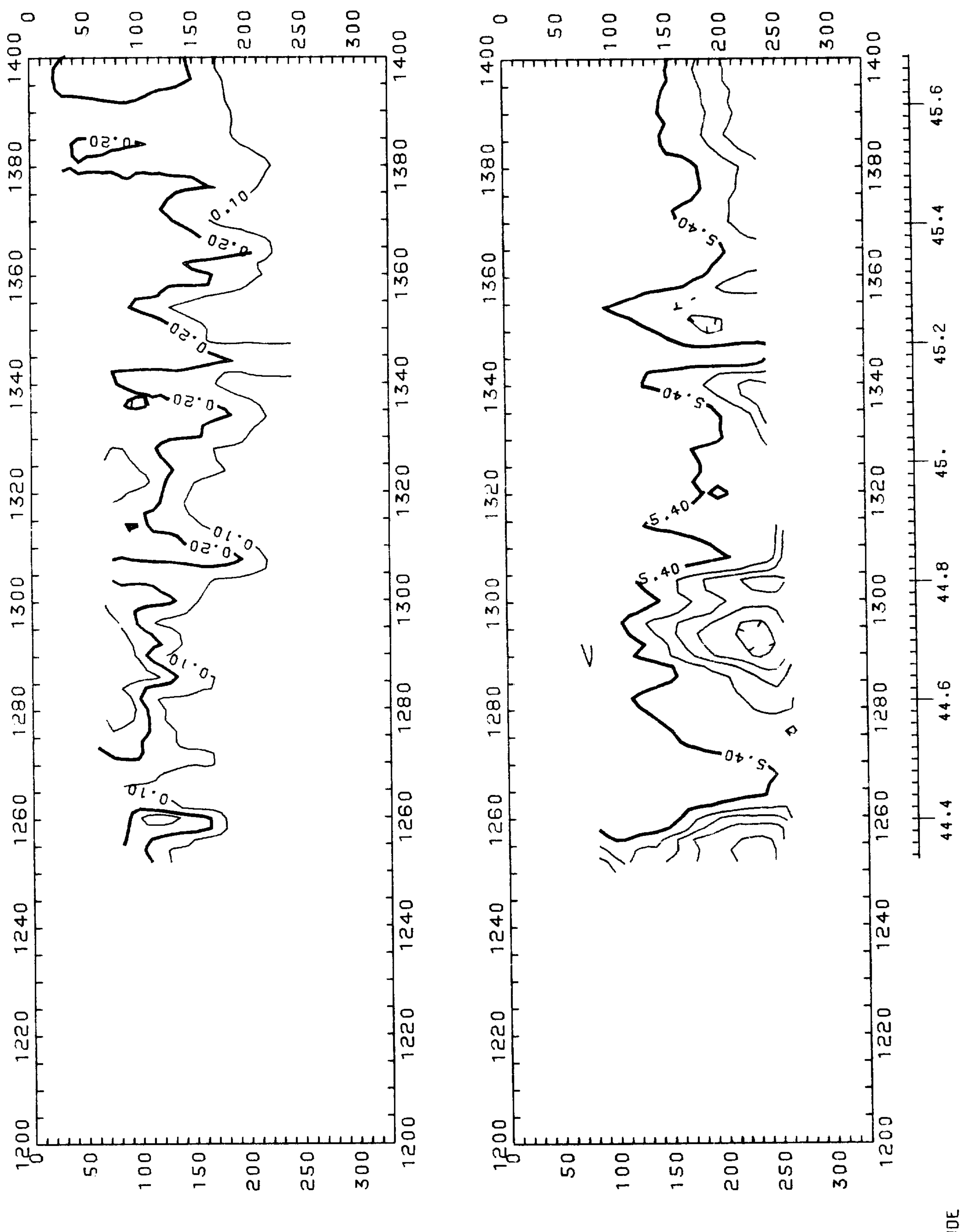
CONTOURS OF SIGMA THETA(TOP) AND SALINITY(BOTTOM)
X=DISTANCE RUN(KM)   Y=PRESSURE(DB) OR SIGMA THETA*100(CGS)



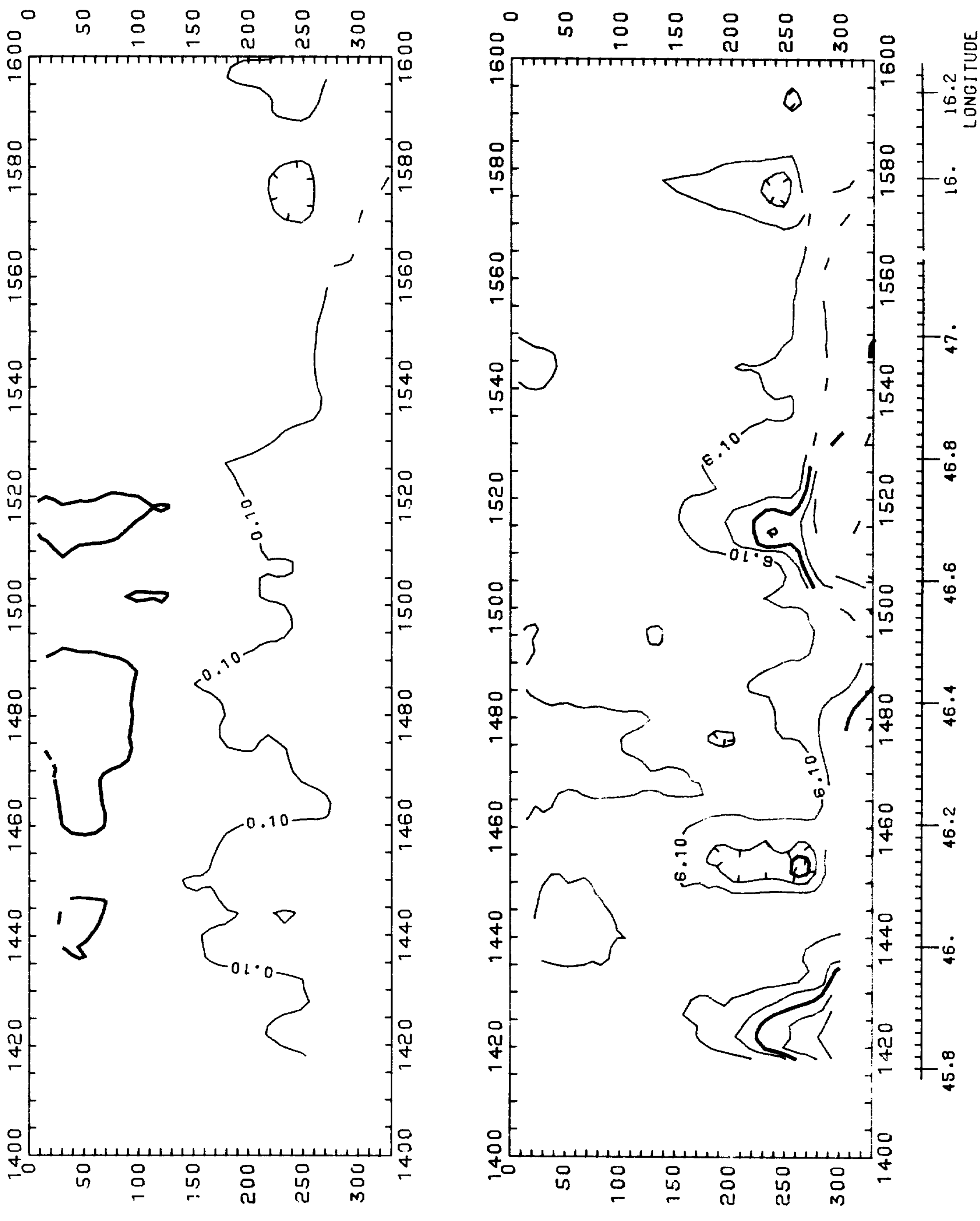
CONTOURS OF POTENTIAL TEMPERATURE(TOP) AND SALINITY(BOTTOM)
X=DISTANCE RUN(KM)   Y=PRESSURE(DB)



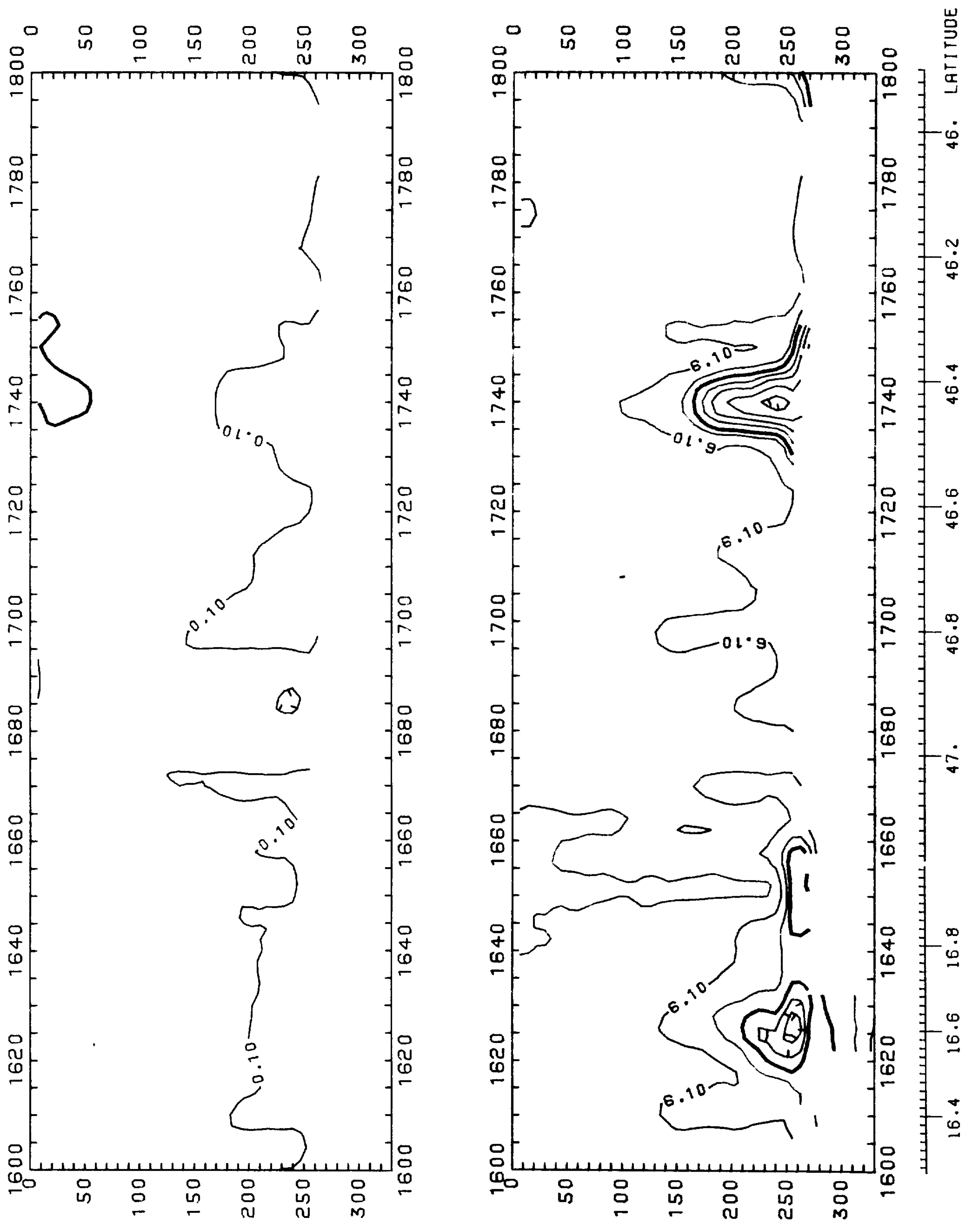
CONTOURS OF SIGMA THETA(TOP) AND SALINITY(BOTTOM)
X=DISTANCE RUN(KM) Y=PRESSURE(DB) OR SIGMA THETA*100(CGS)



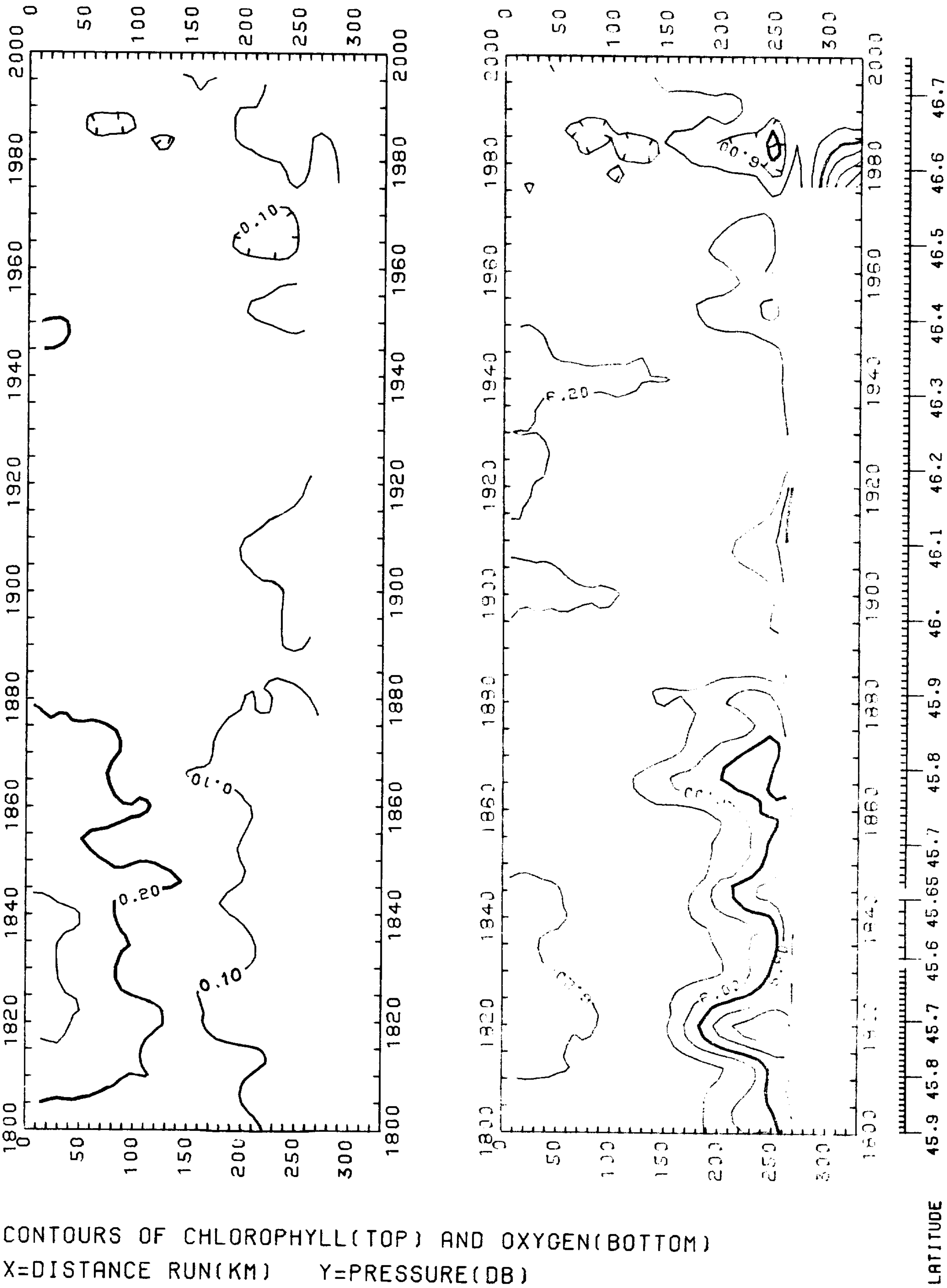
CONTOURS OF CHLOROPHYLL(TOP) AND OXYGEN(BOTTOM)
X=DISTANCE RUN(KM)   Y=PRESSURE(DB)



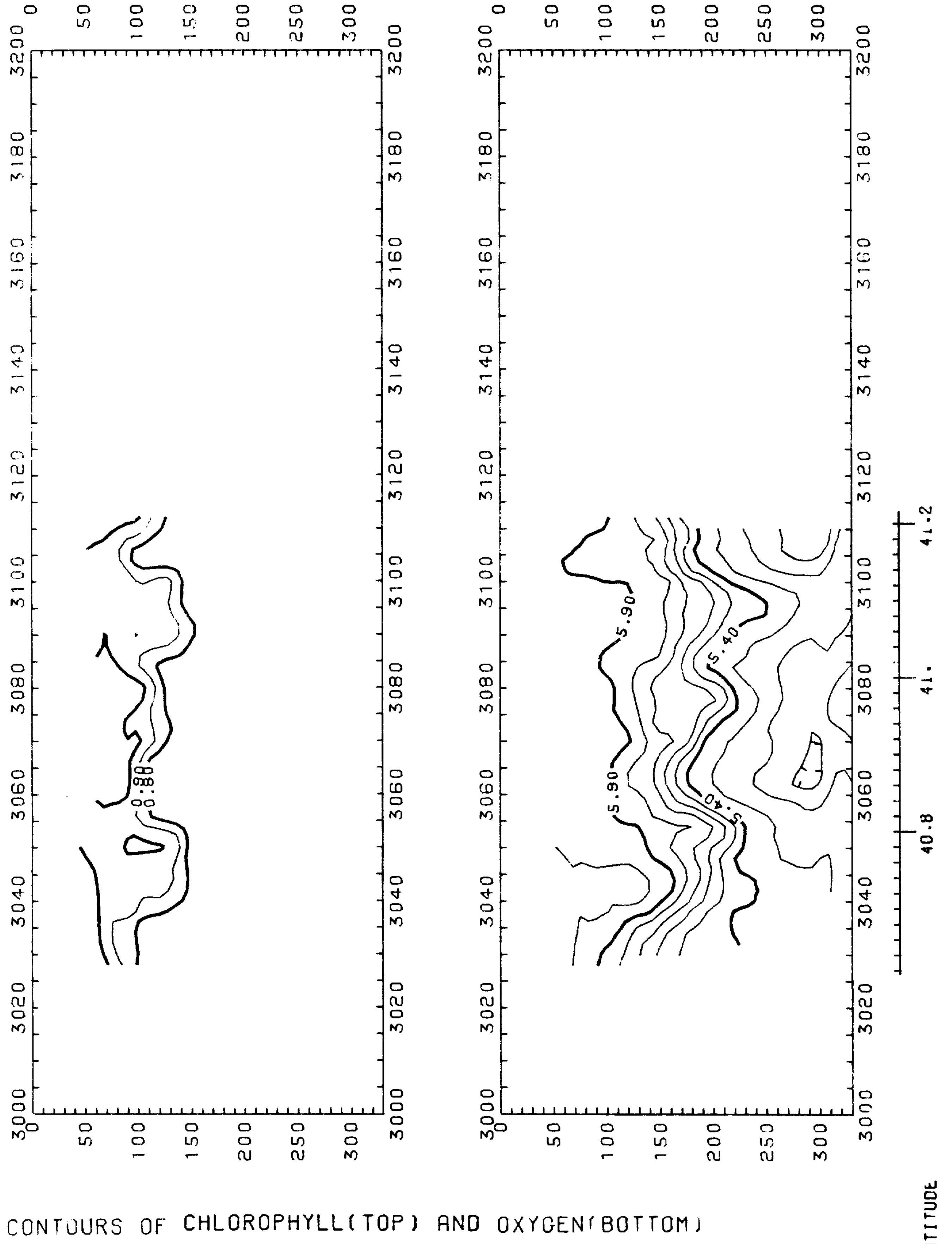
CONTOURS OF CHLOROPHYLL(TOP) AND OXYGEN(BOTTOM)
X=DISTANCE RUN(KM) Y=PRESSURE(DB)



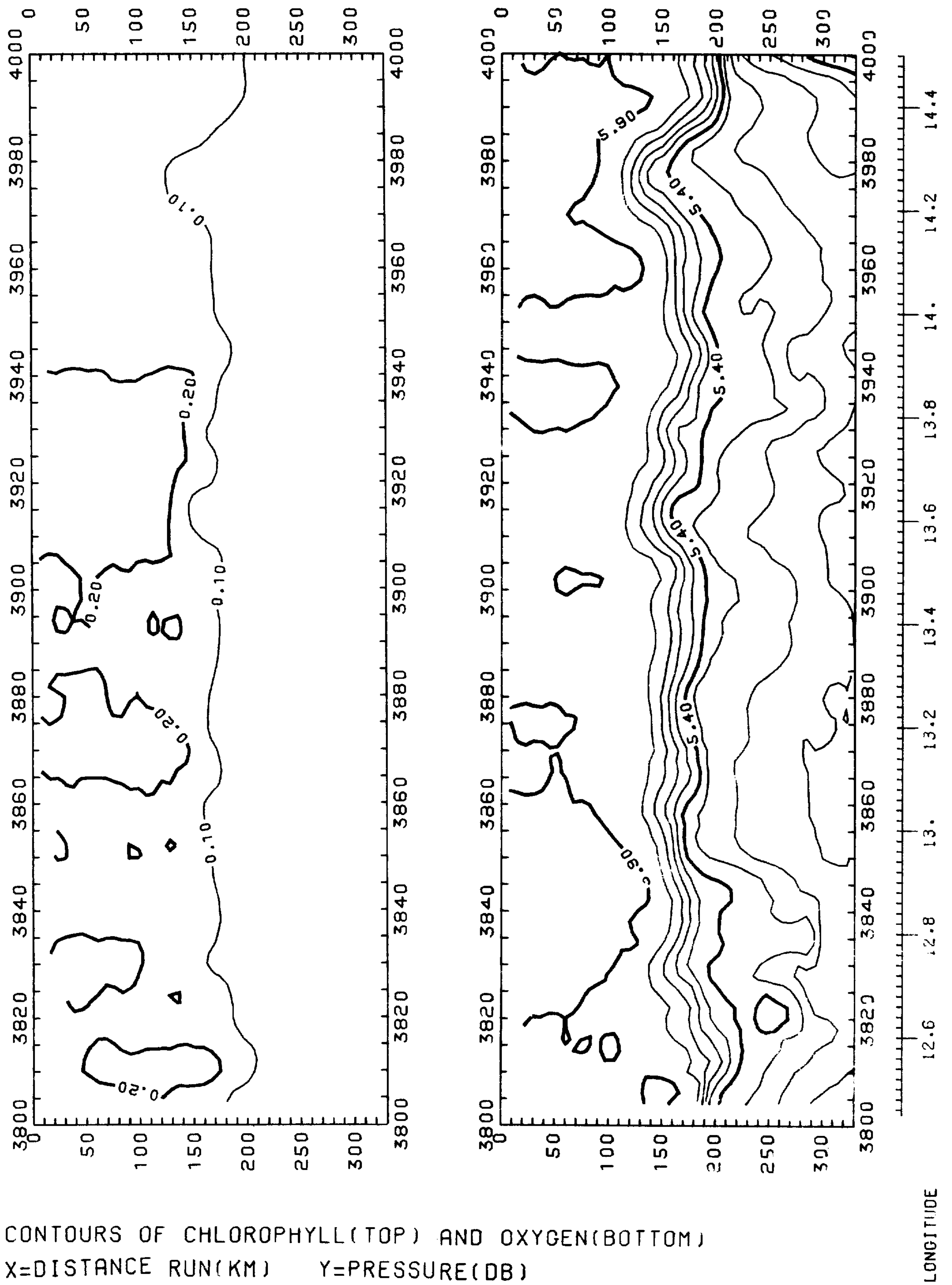
CONTOURS OF CHLOROPHYLL(TOP) AND OXYGEN(BOTTOM)
X=DISTANCE RUN(KM) Y=PRESSURE(DB)



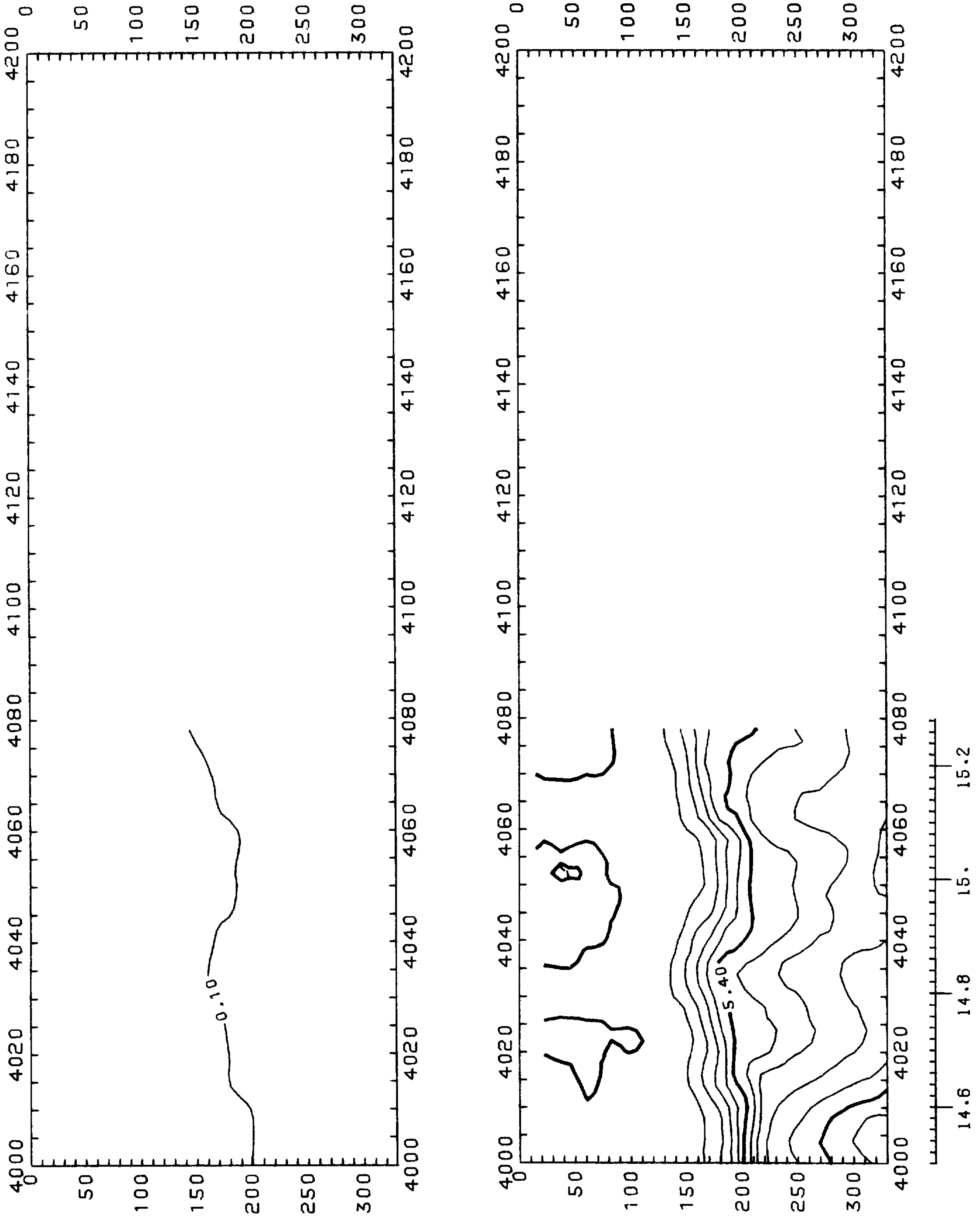
CONTOURS OF CHLOROPHYLL(TOP) AND OXYGEN(BOTTOM)
X=DISTANCE RUN(KM)   Y=PRESSURE(DB)



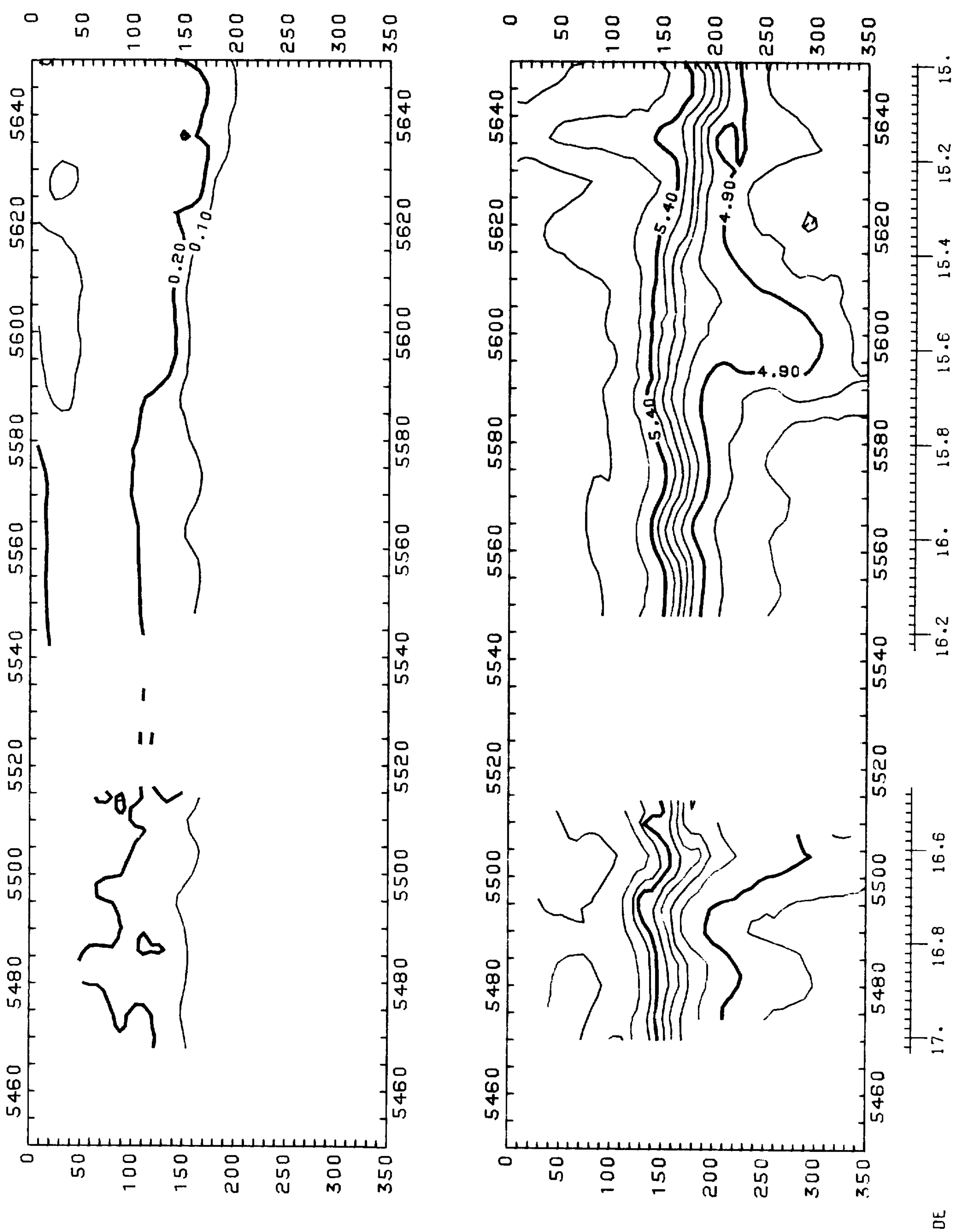
CONTOURS OF CHLOROPHYLL(TOP) AND OXYGEN(BOTTOM)
X=DISTANCE RUN(KM) Y=PRESSURE(DB)



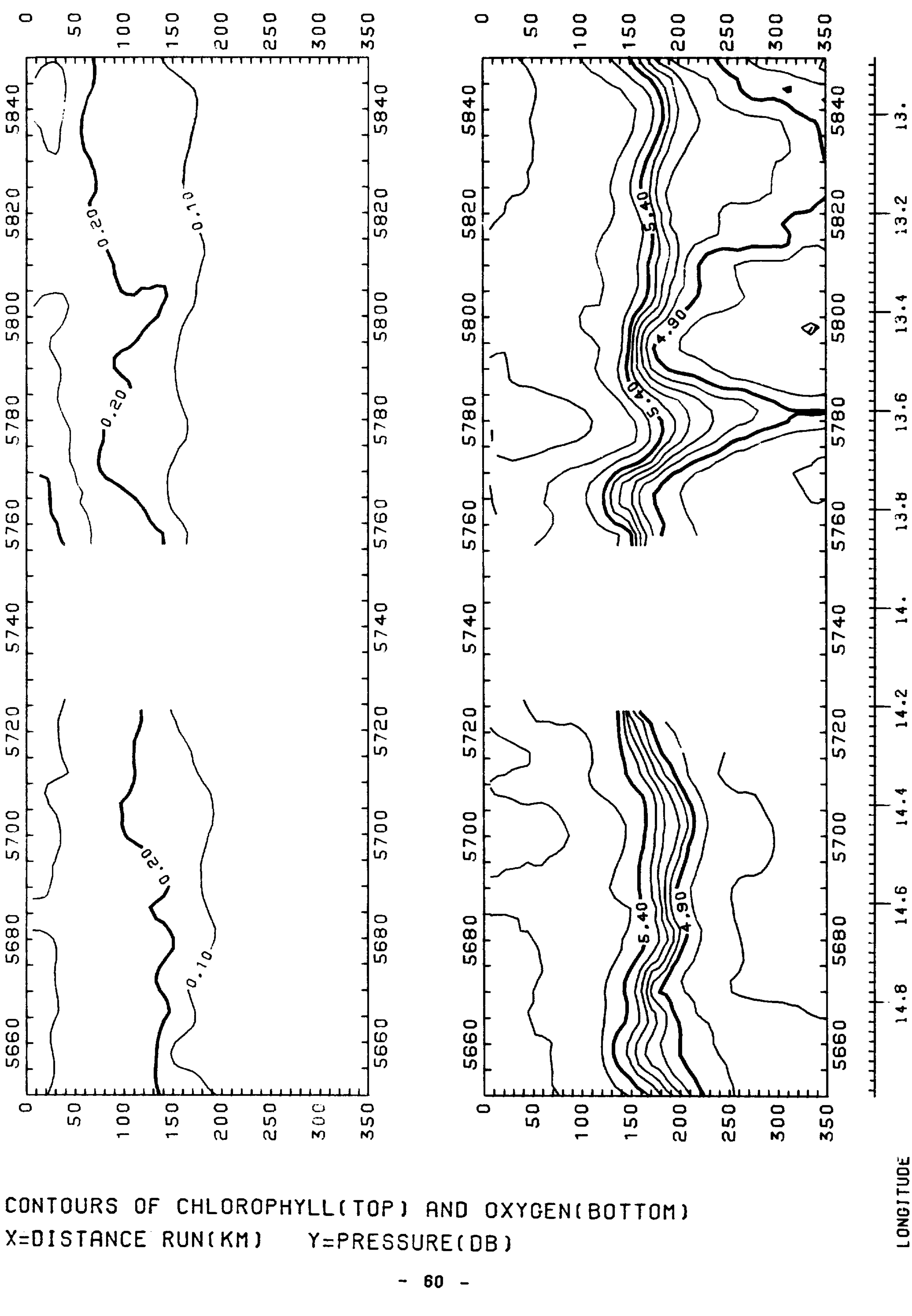
CONTOURS OF CHLOROPHYLL(TOP) AND OXYGEN(BOTTOM)
X=DISTANCE RUN(KM)   Y=PRESSURE(DB)



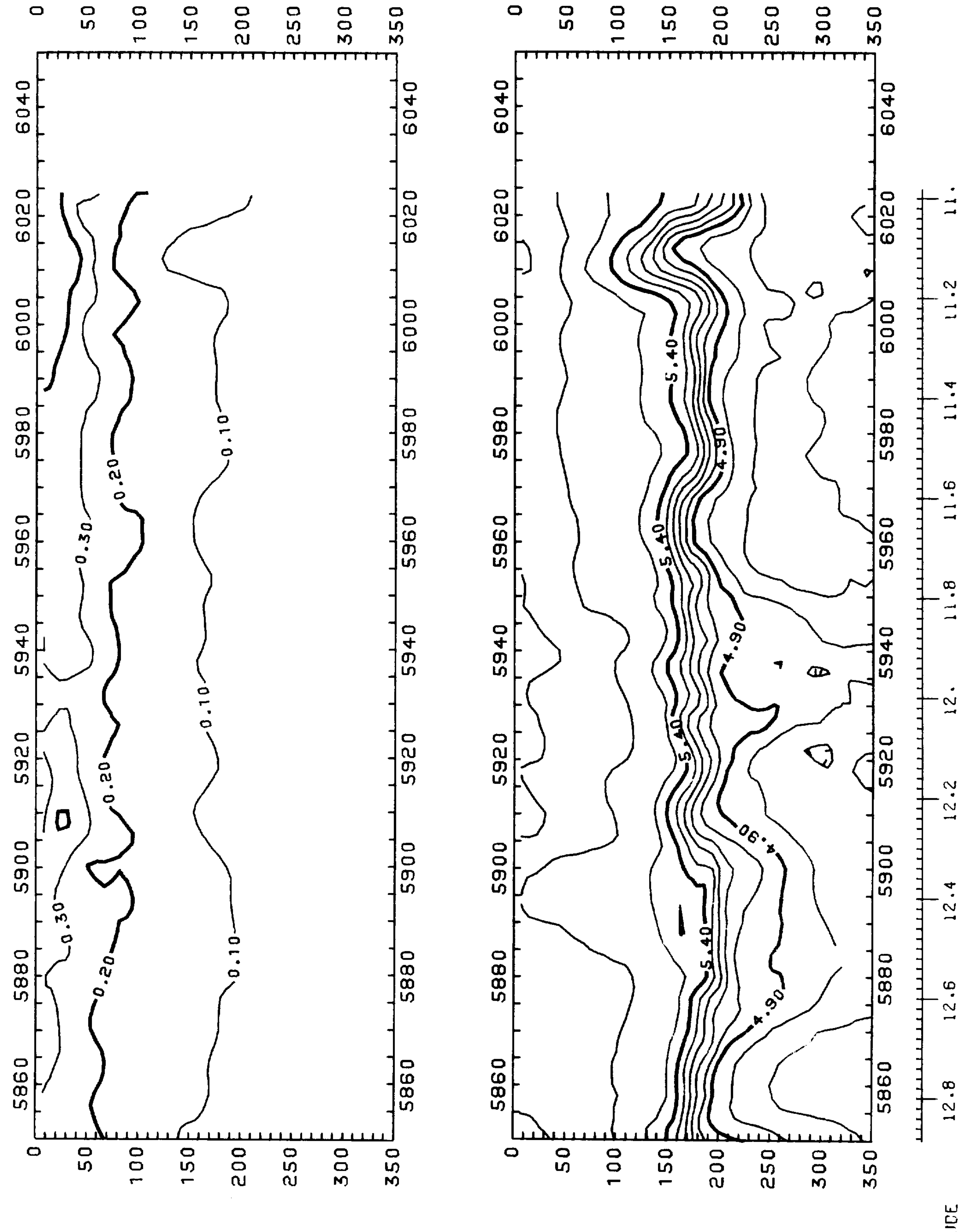
CONTOURS OF CHLOROPHYLL(TOP) AND OXYGEN(BOTTOM)
X=DISTANCE RUN(KM)   Y=PRESSURE(DB)



CONTOURS OF CHLOROPHYLL(TOP) AND OXYGEN(BOTTOM)
X=DISTANCE RUN(KM)   Y=PRESSURE(DB)



CONTOURS OF CHLOROPHYLL(TOP) AND OXYGEN(BOTTOM)
X=DISTANCE RUN(KM)   Y=PRESSURE(DB)



CONTOURS OF CHLOROPHYLL(TOP) AND OXYGEN(BOTTOM)
X=DISTANCE RUN(KM)   Y=PRESSURE(DB)