

**Technical Report
on
“Hydrographic features for the gas hydrate studies of the survey area of
cruise AASGH2 in the Arabian Sea”**

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AASGH2 (Arabian Sea)

1. Introduction

Hydrographic data were collected from the research ship "A.A. Siderenko" in the Arabian Sea in [(70.55°E, 70.95°E) x (15.00°N, 15.50°N)] grid at 15 selected stations, in between stn. Nos 1-24, to explore the possibility of occurrence of gas hydrates. The main source of data were using CTD observations in the Arabian Sea off Goa upto near bottom during the period 9-16, November 2002. The physical and chemical parameters of temperature, salinity, dissolved oxygen and depth and also fluorescence were collected. Contour maps of these parameters were prepared at depths 50 m, 100 m, 200 m, 500 m and 1000 m (or upto maximum depth of observation) to study their variability using surfer ver. 6.01 software. In the present technical report the hydrographic CTD profile diagrams and the derived contour maps are presented and described for the study area which are useful for gas hydrates exploration.

2. Methodology for CTD data collection

i) The CTD System:

The CTD (conductivity, Temperature, Depth) system used in the gas hydrates study onboard AA “Siderenko” for water column hydrographic data collection consists of C,T,D primary sensors and auxiliary sensors for dissolved oxygen and turbidity in the underwater unit.

The CTD system used is SBE911plus, manufactured by M/S Seabird electronics Ltd , USA, which consists of an underwater unit and a deck unit and a single conductor wire rope connecting them. The winch used for lowering and hauling up the underwater unit by driving the wire wound drum is of M/S Dynacon, USA make. The configuration of the CTD unit system was tested individually and installed on board the ship. The single conductor wire is tested for electrical continuity by connecting underwater unit and deck unit through the slip ring and for mechanical strength by attaching a dead weight at the wire rope end without underwater unit and lowering upto approximately 4000m depth in the sea prior to actual CTD casts for data collection with underwater unit. A personal computer (PC) is connected to the deck unit via RS- 232 interface for data acquisition and storage. The underwater unit is fitted within a carousel to which Nansen / Niskin water samplers with lanyards are attachable for water sampling at different depths through a bottle closing mechanism controlled electronically from the deck unit.

ii) Data Format:

The sensors are multiplexed and are digitized in the underwater unit at 24 Hz and the resultant data in Manchester code is transmitted to the deck unit via the single conductor armoured cable. Under water unit power is supplied by the deck unit via the same cable. A microprocessor in the deck unit decodes the incoming stream of under water unit data, converts to binary equivalents of frequencies, and presents the converted data to the IEEE –488 or RS-232C bus. The PC takes the data from the output bus, stores it on hard disk and converts to engineering units for real time display and /or plotting. In the data stream of 12 words, which are sampled at 24 Hz, the relevant word numbers for channels for primary sensors and auxiliary sensors and the

number of channels to suppress are appropriately chosen in the SEASOFT CTD software corresponding to sensor connections in the underwater unit. Each sensor has its own counting electronics circuit, so that all sensors are sampled simultaneously. Two 12 –bit counters are used for each sensor data.

iii) The Sensors:

In the 911plus CTD system the underwater unit primary sensors for temperature, electrical conductivity (for salinity measurements) and pressure and secondary sensors for dissolved oxygen, fluorescence and turbidity are well integrated with the electronic circuitry for sensor multiplexing and signal conditioning .

(a) Primary Sensors:

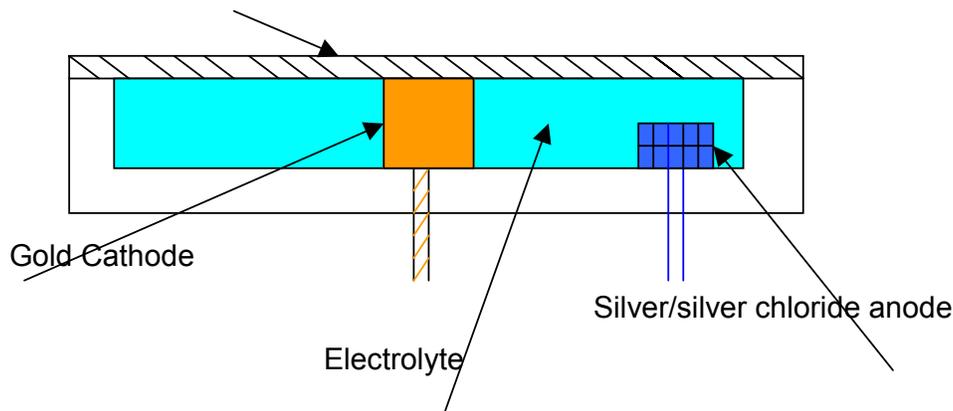
The temperature sensor (model SBE 3 plus) is a compact module containing a pressure-protected high-speed thermistor and “wien bridge oscillator” interface electronics. The conductivity sensor is a 3-electrode platinum two-terminal flow through device. The conductivity sensor (model SBE 4C) is similar in operation and configuration to the temperature sensor, except that the wien bridge variable element is the cell resistance. In the present SBE 9plus CTD underwater unit the temperature and conductivity sensors are equipped with the TC- duct, which provides uniform and constant flow of sea water past the two sensors which are enclosed in the TC – duct in which sea water is pumped in the duct by a motor pump in this present pumped CTD version. This pumped CTD version ensures that the same parcel of sea water at any particular location in the sea is sensed by T and C sensors. The pressure sensor is of digi-quartz type and is of model 410K-105, and paroscientific Inc , USA make. Embedded in pressure sensor is a semi-conductor temperature sensor used to compensate the small ambient temperature sensitivity of the digi-quartz. All the T,C,P sensors output in the form of frequencies and the calibration information for each sensor is contained in a series of numeric coefficients used in equations relating frequency to the measured parameter.

(b) Auxilliary Sensors:

Signals from the auxiliary sensors for dissolved oxygen, fluorescence and turbidity are acquired using conventional voltage-input multiplexed A/D converter. The A/D output is a binary number between 4095 and 0 corresponding to voltages in the range of 0 to +5 volts. The A/D binary values are incorporated into the CTD serial data stream and are available in unconverted form for display or transfer to the system computer. The chlorophyll fluorometer used of M/s SEAPOINT SENSORS Inc , USA make gives chlorophyll- α in seawater. The blue LED lamps direct light through the blue excitation filter/windows illuminating the sensing volume. Chlorophyll- α present in the sensing volume is excited with the blue light and fluoresces red light, a portion of which passes through the detector window. A lens system focuses the fluorescent light on to the photo detector. The fluorometer is of high performance, small size, very low power consumption, high sensitivity, wide dynamic range type and has good ambient light rejection and a low temperature coefficient. Exciting wave wavelength is 470nm peak, 30nm FBHM and emission wavelength is 685nm peak, 30nm FBHM for the fluorometer. The range of the fluorometer used is 0 to 150 μ g/litre with a gain setting of 1X. The turbidity meter used of M/S Seapoint Sensors Inc. USA make measures turbidity by detecting scattered light from suspended particles in water. The light sources are side-by-side 880nm light emitting diodes (LED). The light detectors are side-by-side silicon photo diodes with visible light blocking filters. Light scattered at angles between 15 and 150° from the sensing volume within 5cm of the sensor windows in sea water passes through the detector window and reach the detector. The amount of scattered light that reaches the detector is proportional to the turbidity or particle concentration in the water over a very large range. Sensitivities of 2,10,40 and 200mV/FTU are possible with arrange of 0-25-500 FTU (Formazin turbidity units) and a gain setting of 1X was used in the present observations.

DISSOLVED OXYGEN SENSOR (SBE 43)

Teflon membrane



The dissolved oxygen sensor depends on the diffusion of oxygen through a Teflon membrane. Any surface coating that slows the diffusion will affect the sensor sensitivity and its time response (DO sensors are expected to drift in a similar manner to conductivity. For chemical reasons, they lose sensitivity overtime. The equation for calculating oxygen concentration from sensor output has a slope term, S_{oc} , and an offset term, B_{oc} . It is expected that S_{oc} will slowly increase with time, indicating a decrease in sensitivity. Fouling of the membrane by either oils or bacteria will result in a drift of a more episodic nature).

The dissolved oxygen sensor SBE 43 of M/S SeaBird Electronics, USA make measures flux of oxygen across a teflon membrane through electrolyte and in to a gold cathode. A silver/silver chloride anode is inbuilt in the sensor. The measurement is sensitive to the Teflon membrane permeability which is decreased by oil or bacteria coating and hence the sensor has to be rinsed in triton- X prior to beginning cast to protect membrane as it goes through sea surface. The range of the dissolved oxygen sensor SBE 43 used is 0 to 5 ml/litre. The maximum value of oxygen expected is 10.82 ml/liter. To compute oxygen in mg/liter units, the values of oxygen in ml/l has to be multiplied by 1.42903. A Benthos/Data Sonics altimeter is attached to the CTD frame looking downwards which helps in knowing the height of CTD underwater unit from seabed by using acoustic pulses reflected from sea bottom.

All the sensors were factory-calibrated by manufacturers and only calibration checks were done and the appropriate calibration constants for all the sensors were entered into SEACON program of the seabird SEASOFT software modules.

The temperatures are given in IPTS-90 units and the salinities are given in PSU units.

iv) THE CTD SYSTEM CONFIGURATION (FOR AASGH CRUISES)

SBE 9 plus CTD under water unit: S/N 09P25394 – 0646

Depth Capability (CTD and sensor housings) : 6,800meters.

Pressure Sensor Range: 0 – 10,000 psia

0 – 6885 decibar.

Digi-quartz Pressure Sensor (with temperature compensation) : S/N 83436

Modulo 12P: S/N MOD 12P –0601

AD 590 M (entered in SEACON) : 0.01279181324.

AD 590 B (entered in SEACON) : -9.384090182

Temperature Sensor (3 plus 6800m) : S/N 032939.

Conductivity Sensor (4C 6800m) : S/N 042644.

Pump (SBE 5T) : S/N 053144

A/D input voltage range : 0 to 5 volts DC.

Logic Board EPROM Version 1.0

Modem Interface Installed

Modem Board Microcontroller Version 1.3 : P/N 11194.

Dissolved Oxygen Sensor (SBE 43) : S/N 430073

Fluorometer (Seapoint) : S/N 2376

Turbidity Sensor (Seapoint) : S/N 1767

Altimeter [Benthos/Data Sonics (PSA – 916D)] : S/N 904

Sampling Rate : 24Hz

CTD deck unit : Model SBE 11 PLUS.

v) The CTD Sensor Specifications :

1. Conductivity Sensor :

Model : SBE 4

Serial No. : 2644

Range : 0 to 7 Siemens/meter (S/m)

Accuracy :0.0003 Siemens/meter

Repeatability : 0. 0003 S/m /month

Resolution : 0.00004 S/m @24Hz

Time Response : 0.060 seconds (pumped)

Settling Time : 0.7 seconds to within 0.0001 S/m

Supply Voltage : 6 to 24 Volts DC.

Supply Current : 18mA at 6 Volts; 12 mA at 10 to 24V

Signal output : 1V square wave capacitively coupled

Material : 6800m 7075 – T6 Aluminium

2. Temperature Sensor :

Model : SBE 3 plus

Serial No. : 2939

Range : -5° to +35°C

Accuracy (initial) : +/- 0.001°C

Resolution : 0.0003°C @ 24Hz (samples/second)

Response Time : 0.065 +/- 0.010 seconds.

Self Heating Error : < 0.0001°C in still water

Settling Time : < 0.5seconds to within 0.001°C

Stability : < 0.001°C drift during the initial 6 months

Temperature Scale : ITS – 90

Power required : 11 – 16 Vdc, 25mA

Signal Output : +/- 0.5V square wave

Housing (6800m) : 7075 Aluminium

3. Pressure Sensor :

Model : 410K- 105 (Digiquartz) make : Paroscientific Inc; Washington,
USA

Serial No. : 83436

Pressure Range : 0 to 10,000psia (0 to 6800m depth)

Temperature Range : 0 to 125°C
Resolution : 0.01ppm
Repeatability : 0.005 % FS.
Hysteresis : 0.005 % FS.
Pressure Conformance : 0.005 % FS
Acceleration Sensitivity(3 axis average) : 0.008 % FS/g
Port : oil field
Supply Voltage Sensitivity : negligible
Nominal Pressure Frequency : 34KHz to 38KHz (0 – FS)
Nominal Temperature Frequency; 172KHz + 50ppm/ °C
Power Requirements : 6 to 35Vdc; 2mA
Signal Outputs : square wave, 4Vp-p
Over Pressure : 12 * Full scale

4. Dissolved Oxygen Sensor :

Model : SBE 43
Serial No. : 0073
Type : Teflon membrane
Anode : silver/ silver chloride
Cathode : gold
Range : 0-10.82ml/l

5. Fluorescence Sensor:

Make: Sea point sensors, Inc, USA
Type : chlorophyll measuring type
Serial No. : 2376
Sensitivity/ Range(1X gain) : 0.033V/(µg/l) ; 0-150µg/l
Minimum detectable level : 0.02 µg/ l
Power Requirements : 0 – 20Vdc, 15 mA avg, 27mA peak.
Output : 0 to 5 Vdc
Output Time Constant : 0.1sec
Power – Up transient : 0.6sec
RMS noise (typical) : 1X gain : < 1mV

Excitation Voltage : 470nm peak, 30nm FBHM
Emission wavelength : 685nm peak, 30nm FBHM
Sensing Volume : 340mm³.
Temperature Coefficient ; < 0.2 %/ °C
Operating Temperature : 0 – 65°C
Depth Capability : 6000m

6. Turbidity Sensor :

Make : Seapoint sensors Inc, USA
Serial No. : 1767
Light Source wavelength : 880nm
Scatterance Angles : 15-150°
Linearity : < 2% deviation 0- 750FTU
Sensitivity/Range (1X gain) : 2mV/ FTU ; < 750 FTU
(5X gain) : 10mV/FTU ; 500 FTU
Temperature Coefficient : < 0.05 %/°C
Operating Temperature : 0-65°C
Depth Capability : 6000m
Power Requirements : 7 –20 Vdc; 3.5 mA avg, 6mA peak
Output : 0-5Vdc
Output Time Constant : 0.1 sec
RMS noise : < 1mV
Power- Up Transient Period : <1 sec

7. Altimeter :

Make : Benthos/Data Sonics , USA
Model : PSA-916D
Serial No. : 904

vi) Data Acquisition Procedure using CTD:

The CTD system is checked for correct operation and the “seasoft” CTD software is loaded in the PC. The calibration constants pertaining to the sensors used are entered in SEACON file of SEASOFT programme. The underwater unit is lowered to approximately 10m in the sea by operating the

winch. The deck unit is powered "ON" and "SEASAVE" module is run whereby the underwater unit pump priming to remove air bubbles trapped in the conductivity sensor TC-duct is done and allowed about 2 minutes to stabilize. Then the underwater unit is heaved upto near sea surface (about 1m depth) taking care not to expose the sensors and sampling bottles in the air. Prior to the start of lowering underwater unit into the sea, it is ensured that all the water sampling bottles are opened, otherwise they will be crushed due to water pressure difference in the sea and within the sampling bottle.

Then the data acquisition command in the SEASAVE programme is given and the underwater unit is lowered at a constant rate (at about 1m/s) up to the required depth. In these AASGH cruises the underwater unit was lowered up to near bottom depths and the height of underwater CTD unit above seabed is closely monitored using altimeter output and precautions are taken for CTD sensors not to touch the seabed. Usually the CTD underwater unit is sent up to 20-5 m from the sea bottom. Then water sample is taken by closing a water sampling bottle by giving electronic triggering command from the CTD deck unit after stopping the lowering of the underwater unit at the maximum lowered CTD depth.

The water sampling is then done during up cast using electronic triggering at the required depths by closing the sampling bottles at appropriate depths and bottle marker files are obtained. The water sampling is done only during up cast. Water sampling is done for calibration as well as for physical and chemical analysis. When the CTD underwater unit is brought to sea surface the data acquisition is stopped and the deck unit is powered off. The data stored on the hard disk of PC is in turn stored on floppy disks or compact discs (CDs) as required and subjected to data processing

vii) Data Processing:

The CTD raw data in the form of .DAT binary files are processed using seasoft software modules and converted into .CNV , .ASC files (which are binary and ascii files) and used for plotting profiles of salinity, temperature, DO, fluorescence and turbidity v/s depth and respective contours as a function of space coordinates of latitude and longitude. These .CNV and .ASC files are obtained by subjecting raw .DAT data files to binaveraging (depth

averaging), filtering to eliminate noise and spikes, derivation of computed variables like potential temperature, $\sigma-t$, σ - theta, sound velocity, stability, Brunt-vaisala frequency etc, splitting into up and down cast files, time advancement of sensors and cell thermal constants and so on by use of appropriate seasoft software modules.

In the present report CTD data profile plots at various stations are generated by using SEASOFT modules and the contours are obtained by using surfer ver. 6.01 software. The contours of parameters are obtained at 50 m , 100m , 200m, at average of maximum depths of stations, and at the seabed (which are at the maximum CTD depths and assumed to have the same parameter value at the sea bottom).

Appropriate contour intervals are chosen for contour plots. All the profile and contour plots are analyzed for the study of physical and chemical processes in the area where the data are collected. The results are also discussed and presented in this report.

3. Contours of physical & chemical parameters:

Iso-contour maps of temperature, salinity, dissolved oxygen, fluorescence (chlorophyll concentration) are prepared at the water depths of 50m, 100m, 200m, 500m, 1000m. These contour maps depict the distribution of physical and chemical parameters as a function of depths of water column. Since bottom simulating reflectors (BSRs) noted on the seismic reflection records form parallel to the sea bed, the sea bed characteristics form an important parameter, the temperature at the sea bed was studied. The depth-limited properties are differentiated from the true special features that demarcate gas hydrates. The probable seabed features are highlighted. All the contours give in totality the water column hydrographic characteristics. The source of data is from CTD observations carried out both in Arabian Sea (off Goa) and Bay of Bengal (in Krishna-Godavari basin) which are probable potential sites for occurrence of gas hydrates. The geo-physical studies supplement these data.

4. Hydrographic features:

Observations from Iso-Contours:

(a) Isopleths of horizontal sections (Refer Figs. 32 to 48)

- (1) (i) From the 50m depth temperature contour it can be seen a cold core (21.4°C) at 70.72°E, 15.48°N i.e. towards northern region of the surveyed area. Another cold core almost at the same longitude occurs at 15.12°N and has a temperature of 21.4°C i.e. towards the near north end area of the survey region. A warm core (26.2°) occurs at 15.28°N, 70.68°E (i.e. near middle of the survey area).
- (ii) 50m depth isohaline contours show a high salinity pocket of 40.00 p.s.u. at mid-western region at 15.22°N, 70.92°E. Another high salinity pocket is seen of 41.00 p.s.u. at northern far left region at 15.06°N, 70.55°E. (High salinity values may be spurious due to spikes).

- (iii) 50m depth dissolved oxygen contours show suboxic regions at southern and northern regions of 0.8 ml/litre almost at same longitude of 70.73°E at 15.00°N & 15.50°N respectively. High Dissolved Oxygen (DO) pockets of 2.60 ml/l and 3.00 ml/l occur almost at same latitude of 15.30°N at 70.69°E and 70.90°E respectively.
- (2) 100m Depth contours:
- (i) cold cores are seen of 17.40°C, 17.80°C, 17.60°C almost at 70.70°E longitude at 15.45°E, 15.29°E and 15.12°E respectively. Warm waters prevail towards right at high longitudes of 70.95°E.
 - (ii) High salinity pockets of 38.00 p.s.u., 38.50 psu and 43.00 psu are seen at (15.05°N, 70.55°E), (15.44°N, 70.70°E) and (15.23°N, 70.92°E) respectively. (High salinity values may be spurious due to spikes)
 - (iii) Suboxic pocket of ≈ 0.20 ml/l occurred at 15.07°N, 70.69°E) at the southwest of the region. Almost at the same longitude a comparatively highly oxic pocket of 0.54 ml/l at 15.45°N, 70.69°E.
- (3) 200m Isopleths:
- (i) Warm core of 15.85°C at 15.50°N, 15.76°E and of 15.70°C at 15.10°N, 70.70°E prevailed. Comparatively cold pockets of 14.80°C at 15.30°N, 70.87°E (i.e. in easternside) and of 15.10°C at 15.00°N, 70.73°E at southern end prevailed.
 - (ii) A high salinity pocket of 37.40 P.S.U. occurred at northern end at 15.45°N, 70.67°E. Salinities are less in other areas of the region.
 - (iii) Suboxic waters prevailed in northern region with a pocket of 0.40 ml/l at $\approx 15.50^\circ\text{N}$, 70.75°E. High DO pockets occurred at southwest and mideastern edges with values of 2.40 ml/l at 15.06°N, 70.55°E and 2.20 ml/l at 15.22°N, 70.91°E respectively.
- (4) 2600m Isopleths:

- (i) Warm pockets of 2.11°C at 15.48°N, 70.73°E at northern end occurred. Cold pockets of 2.01°C almost at same longitude at southern end at 15.00°N, 70.72°E prevailed. Another cold pocket of 2.01°C at mid-eastern end at 15.29°N, 70.89°E is seen.
 - (ii) Salinity in the whole region ranged between 34.745psu to 34.752 p.s.u. A low salinity pocket at southeastern end of 34.745 p.s.u. at 15.05°N, 70.95°E and a high salinity pocket at northern end of 34.752 p.s.u. at ≈15.50°N, 70.75°E are specially featured.
 - (iii) Low DO pockets of 2.78 ml/l at (15.50°N, 70.65°E) and (15.12°N, 70.71°E) occurred. Many pockets of DO level of 2.96 – 2.98 ml/l prevailed in the southwestern, southern and mid-eastern regions at (15.06°N, 70.55°E), (15.00°N, 70.73°E) and (15.30°N, 70.89°E) respectively (and one more also at 15.05°N, 70.95°E).
- (5) 2900m Isopleths:
- (i) Isothermal plots not available
 - (ii) Salinity values range from 34.732 psu to 34.736 psu. A low salinity pocket of 34.732 psu occur at southern and northern ends almost at same longitude of 70.720°E and 15.00°N and 15.50°N respectively. A high salinity pocket of >34.736 psu occur approximately at 15.14°N, 70.710°E.
 - (iii) DO levels range from 2.86 – 2.98 ml/l in the whole region. A marked feature is a low DO pocket of 2.86 ml/l approx. at 15.14°N, 70.75°E.
- (6) Isopleths at sea-bed:
- (i) Temperatures at sea-bed ranged from 1.68°C to 1.96°C. It is interesting to observe that easternside temperatures are higher (gradually) than those of the westernside temperatures. A marked feature is that a high temperature regional pocket (of 1.96°C) exists along an axis of 15.24°N between 70.76°E to 70.95°E.

- (ii) Salinities at sea-bed ranged from 34.725 psu to 34.744 psu. In a similar way to temperatures the values of salinities at eastern side are gradually higher than those of the western side. Also a high salinity regional pocket (of 34.744 psu) exists along an axis of 15.24°N between 70.76°E and 70.95°E.
- (iii) Dissolved oxygen values in the region at seabed ranges from 2.96 ml/l to 3.20 ml/l. A low oxitic level pockets of 2.96 ml/l occurred at northern side at 15.52°N, 70.65°E as well also (towards southwardside) at 15.14°N, 70.73°E. A high oxitic level of 3.16 ml/l approx. at 15.44°N, 70.73°E and of 3.20 ml/l approx. at 15.00°N, 70.66°E occurred in the surveyed region of the Arabian Sea.

Note: Probable region of gas hydrate occurrence at seabed is characterized by a simultaneous combination of low temperature, high-salinity and low-oxic levels. Hence these very combination occurrence facilitates us to choose the gas hydrate sites. Probably seepage of gases decreases the temperature and increases salinity and consumes more oxygen i.e. sub-oxic levels is a common feature for gas hydrates to occur.

(b) Vertical Profiles & their general trends: (Refer Figs. 2-31)

The vertical profiles of temperature, salinity, σ_t , fluorescence and dissolved oxygen are plotted for stns (AASGH2)01 to 24 (total: 15 nos) and show similar features for the entire surveyed area. The temperature profile shows no mixed layer (or shallow ML if any) and the temperature range from 29°C to 1.67°C and the variation from surface to sea bottom is gradual. Salinity profiles show a shallow inversion at the surface, and 2nd inversion layer approx. at 320m depth and then a gradual fall off upto the bottom. Salinities ranged from a maximum of 37.40 psu (surface) to 34.726 psu (at the sea bottom).

Density (σ_t) showed a gradual increase from surface to the sea bottom and ranged from a minimum of 22.2 kg/m³ (at surface) to a maximum of 27.7 kg/m³ at the seabottom. The fluorescence data, obtained with seapoint sensor, shows a minimum threshold value at surface to a subsurface peak at \approx 30m and upto a maximum depth of 70m and then the data vanishes right upto sea bottom. The subsurface peak values range from 2.4 μ g/l to 1.3 μ g/l occasional spikes from 3.4 upto 5.7 μ g/l also are seen.

The general trend in the dissolved oxygen data shows a sharp decline from a maximum value at surface and then remains almost constant upto a certain depth and then gradually increases with depth upto the sea bottom. The maximum value at sea surface is 4.2 ml/l (peak). Generally the DO value remained constant at 0.25 ml/l from a depth of about 70 metres to 700 metres and then the value increased gradually with depth upto the sea bottom. The maximum observed value of dissolved oxygen at sea bottom is 3.2 ml/l (at stn. 9) at 15.46°N, 70.66°E) and the minimum value at sea bottom is 2.937 ml/l (at stn. 06 at 15.11°N, 70.71°E).

Note: The bottom-most CTD data were assumed to be same as those of seabed, although strictly they are not so. The heights of CTD above seabed are measured with an altimeter sensor of CTD and minimum Height of CTD above seabed are also given, which gives an estimate of error in seabed data derived from CTD data.

The vertical profiles of CTD data along with the horizontal sections at various depths shows clues to the probable sites for the occurrence of gas hydrates in the Arabian Sea within the surveyed area. This article is NIO Contribution No. 4216.

5. Conclusions

The hydrographic features at 15 stations in the study area surveyed in the Arabian Sea were described. Details of the parameters such as near bottom temperature, salinity and dissolved oxygen are given and presented as respective seabed parameter maps. Other horizontal sectional contour

maps of these parameters at depths 50m, 100m, 200m, 500m and 1000m also were presented to delineate their spatial variability.

Although the data acquisition was continuous with depth upto seabed (upto a maximum of ≈ 3200 metres at station 01), the near bottom maps are important for the methane gas hydrate studies. The salient points are:

- a. Seabed temperatures varied between $\approx 1.675^{\circ}\text{C}$ and 2.058°C in the area; DO (Dissolved Oxygen) ranged between ≈ 2.937 ml/l and 3.200 ml/l and the salinity ranged between 34.7237 and 34.7493 psu at the seabed. The variations may partly be attributed to the bathymetric changes and partly to the seawater property changes.
- b. The near bottom temperatures can be used as one of the important parameters in estimating the gas hydrate stability zone thickness map.
- c. Dissolved oxygen and salinity can be used in estimation of some of the microbial communities which serve as proxies for the occurrence of methane gas hydrates.

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AASGH2

Parameters from CTD data at the maximum depth of observation

<i>Station No</i>	<i>Latitude Deg. N</i>	<i>Longitude Deg E</i>	<i>Maximum Depth in mtrs</i>	<i>Temperature at max. depth in deg. C</i>	<i>Salinity at max. Depth in psu</i>	<i>Oxygen at max. Depth in ml/l</i>
Station 01	15.48	70.65	3193	1.6774	34.7237	2.9600
Station 02	15.1	70.7	2593	1.8016	34.7328	3.1043
Station 03	15	70.73	2898	1.7796	34.7319	3.1793
Station 04	15.06	70.56	3162	1.6745	34.7260	3.1709
Station 05	15.06	70.69	2600	2.0575	34.7493	2.9712
Station 06	15.11	70.71	2984	1.7392	34.7297	1.9371
Station 07	15.29	70.69	2821	1.8672	34.7383	3.0930
Station 08	15.23	70.75	2725	1.9708	34.7444	3.0078
Station 09	15.46	70.66	3169	1.6813	34.7270	3.2000
Station 10	15.45	70.68	3139	1.6840	34.7272	3.1800
Station 14	15.49	70.82	2956	1.7577	34.7319	3.1800
Station 15	15.48	70.72	3061	1.6881	34.7278	3.1540
Station 22	15.29	70.89	2661	1.9141	34.7419	3.0200
Station 23	15.05	70.95	2638	1.9209	34.7426	3.0200
Station 24	15.23	70.92	2643	1.9816	34.7452	3.0000

Table - 1

AASGH2
STATION PLOTS

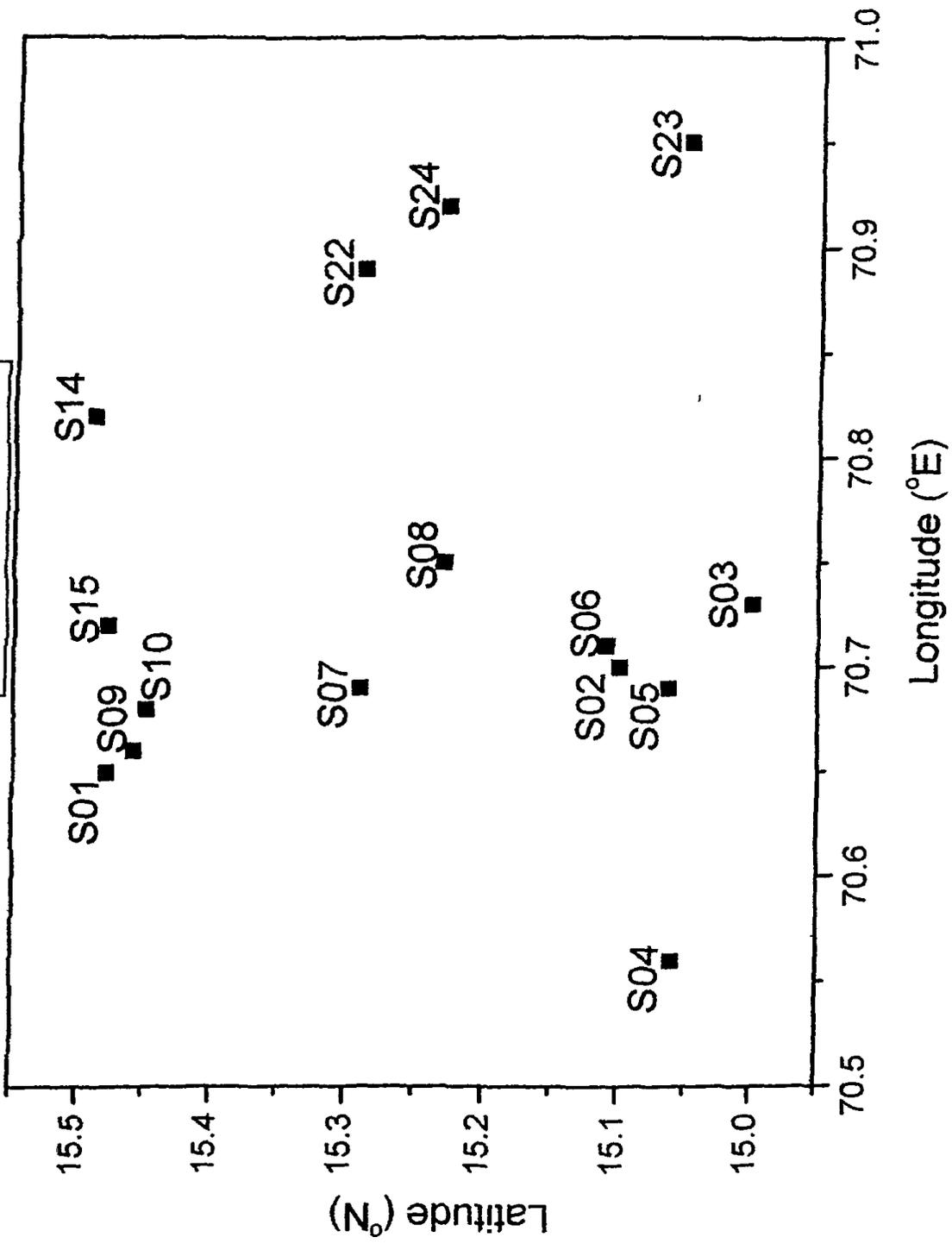


FIG. 1

AASGH2, stat01

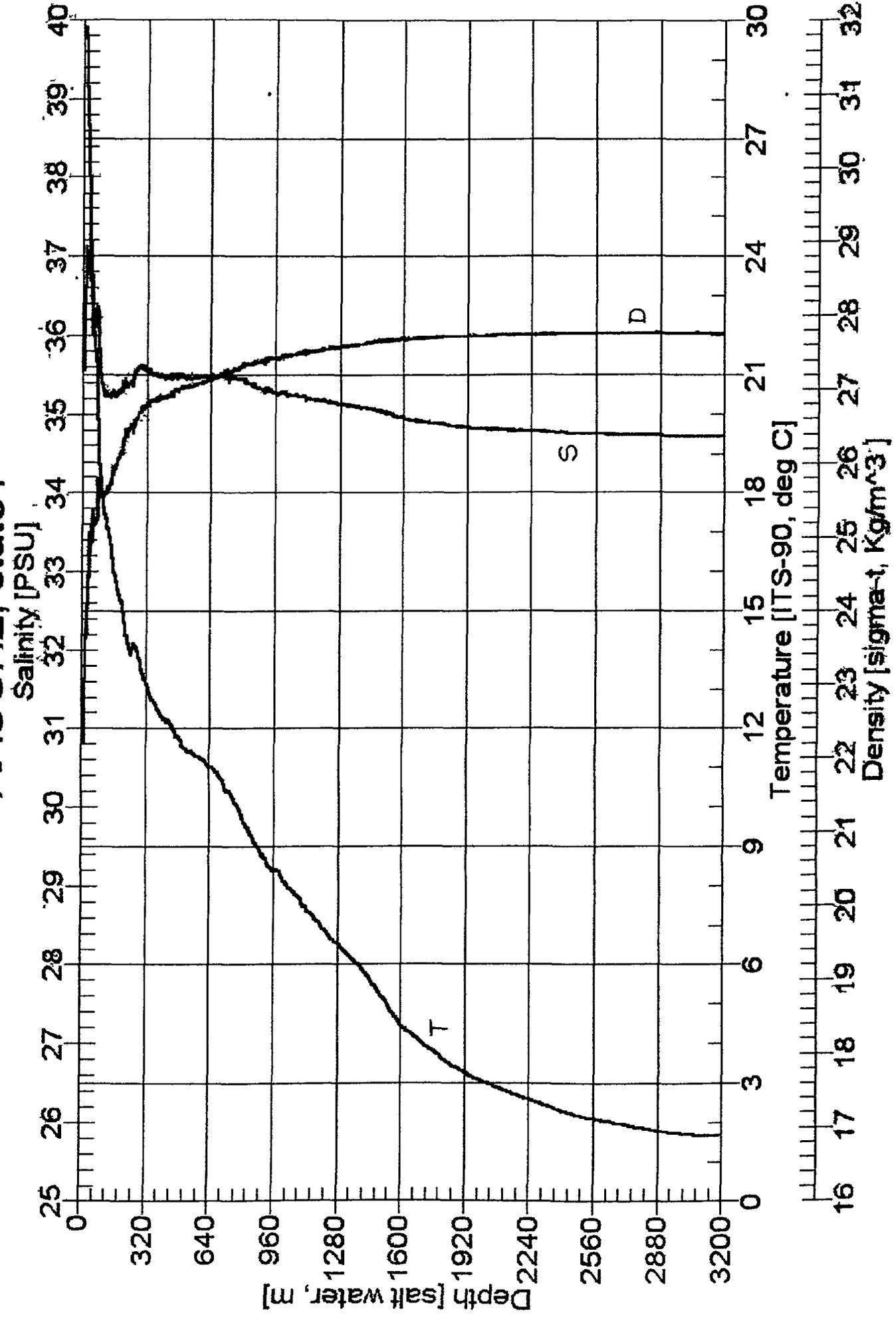


FIG. 2

AASGH2, stat02

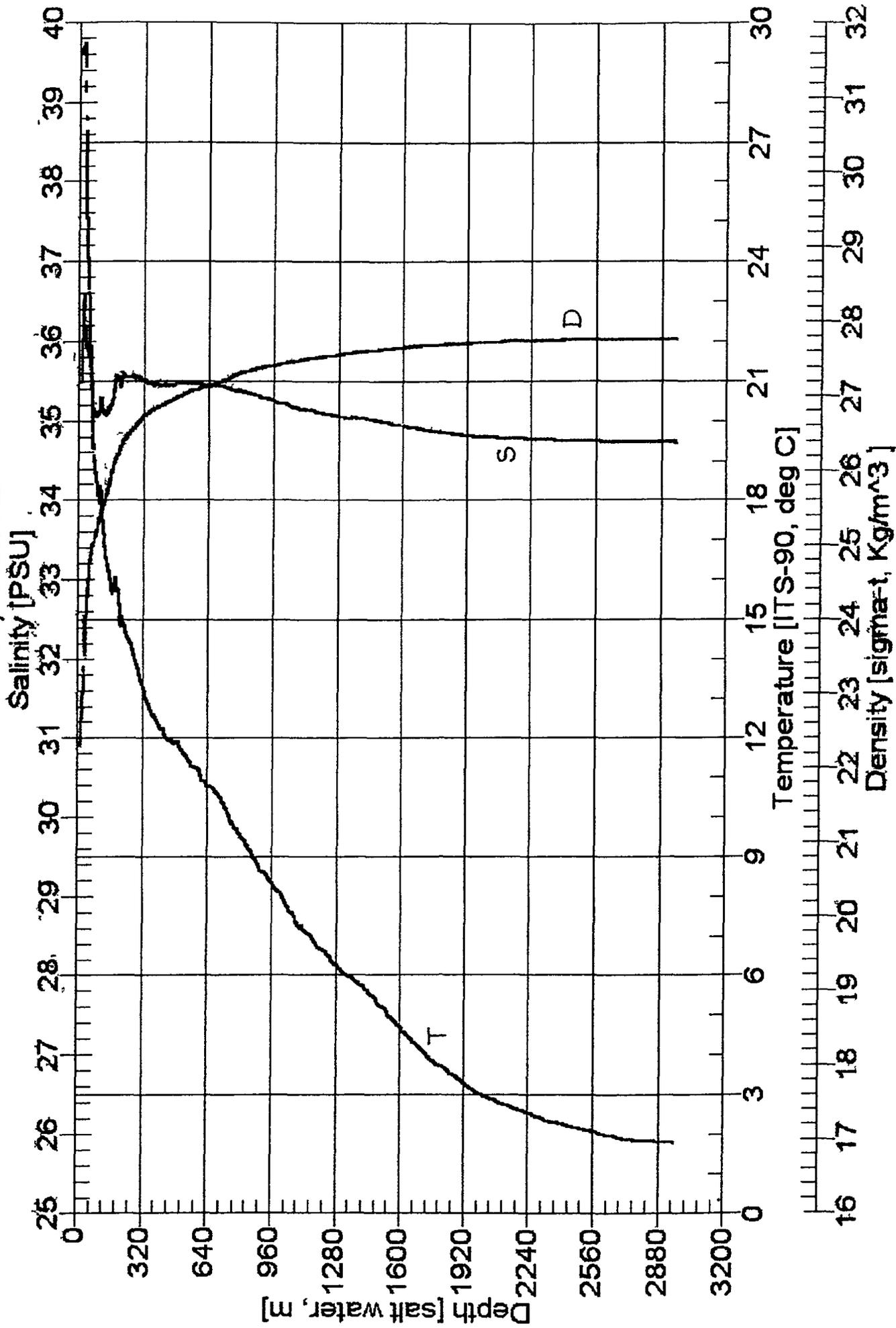


FIG. 3

AASGH2, stat03

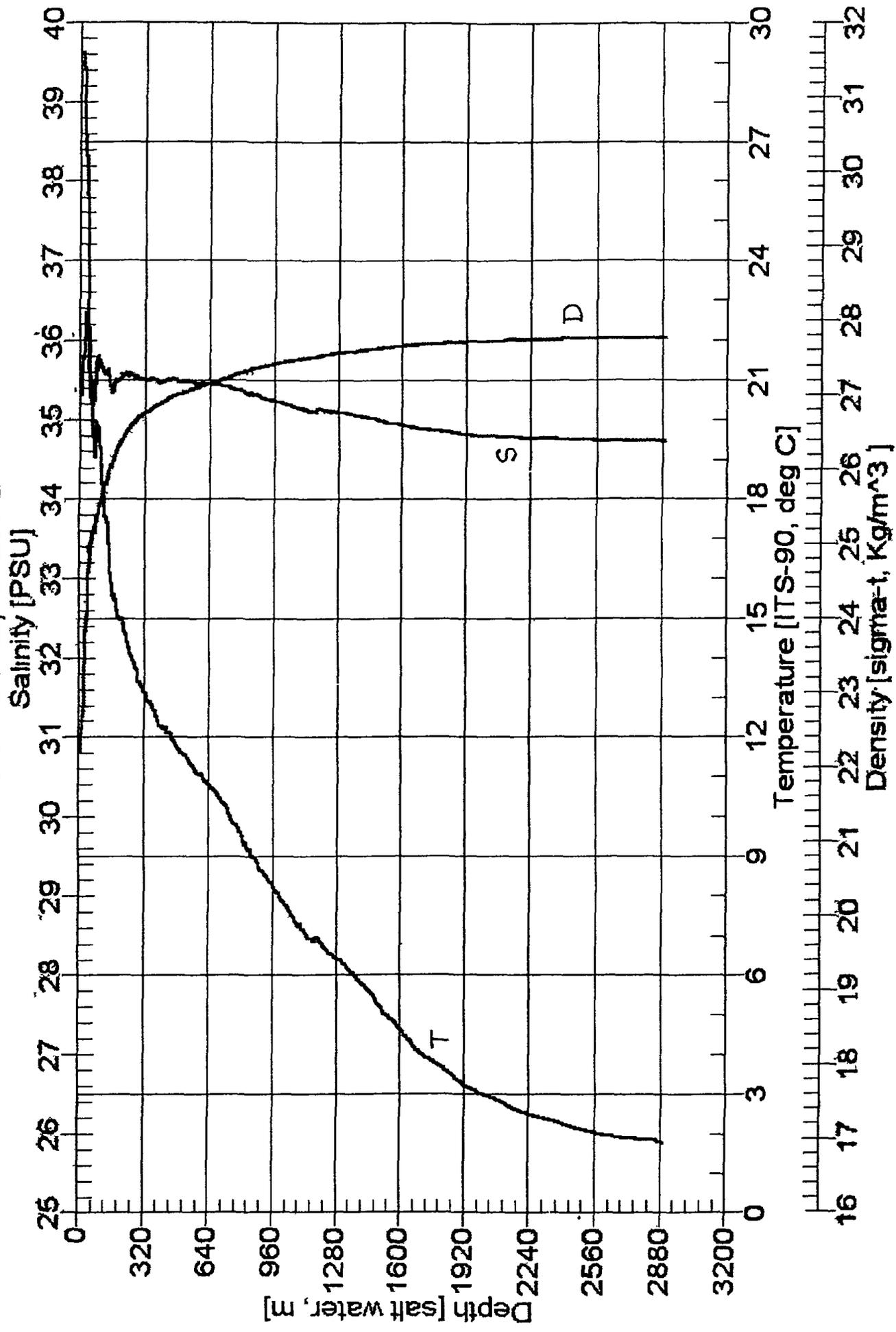


FIG. 4

AASGH2, stat04

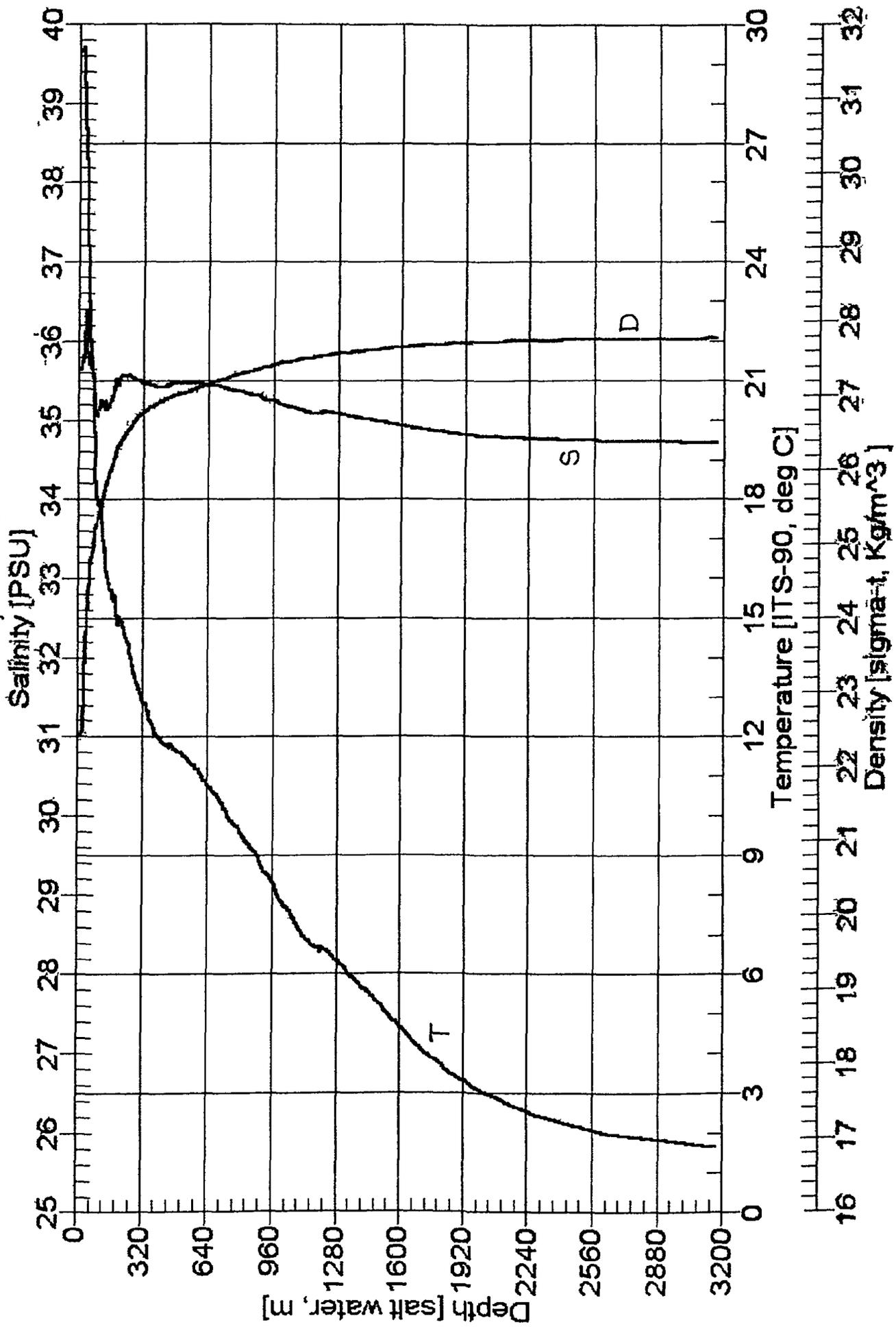


FIG. 5

AASGH2, stat05

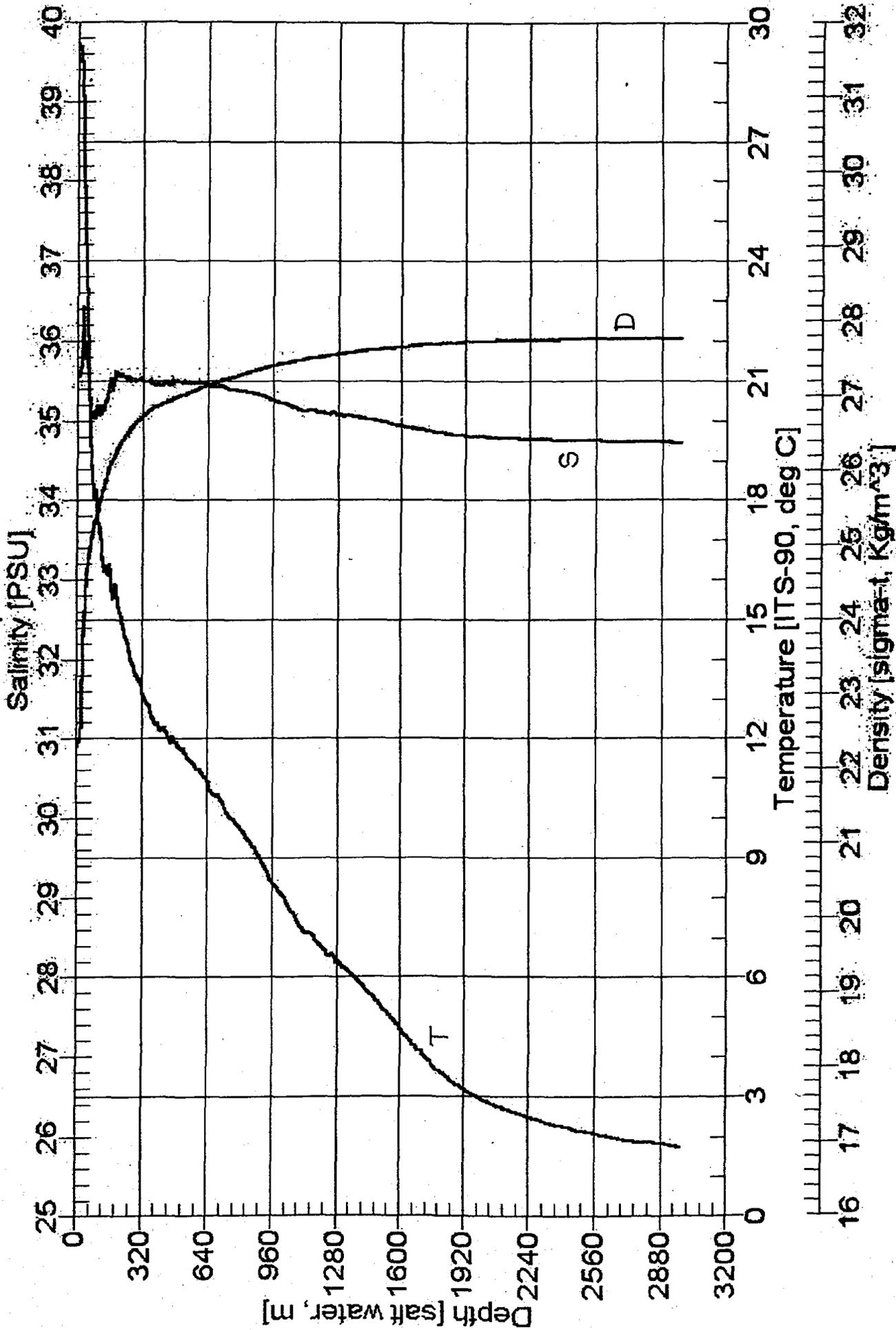


FIG. 6

AASGH2, stat06

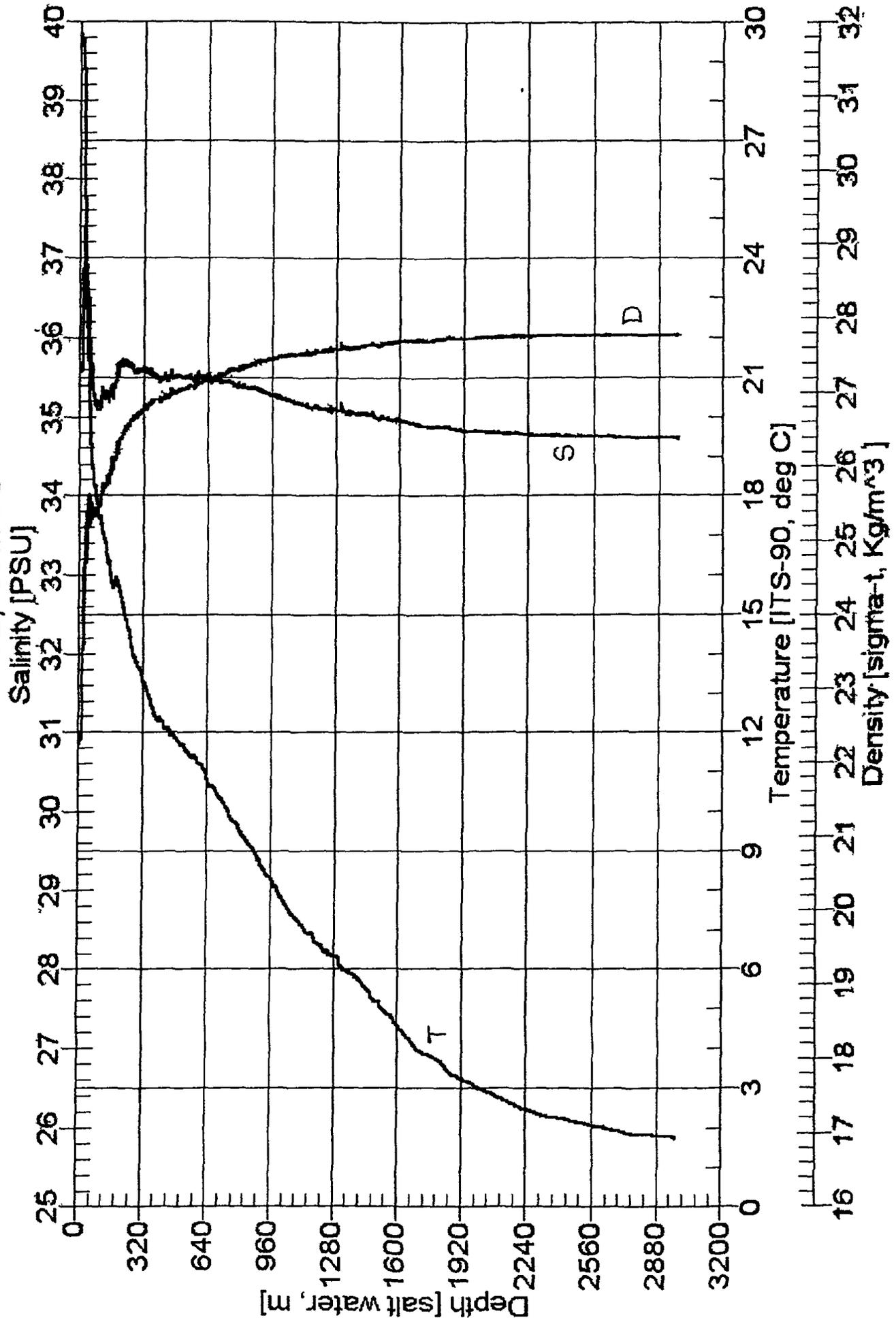


FIG.7

AASGH2, stat07

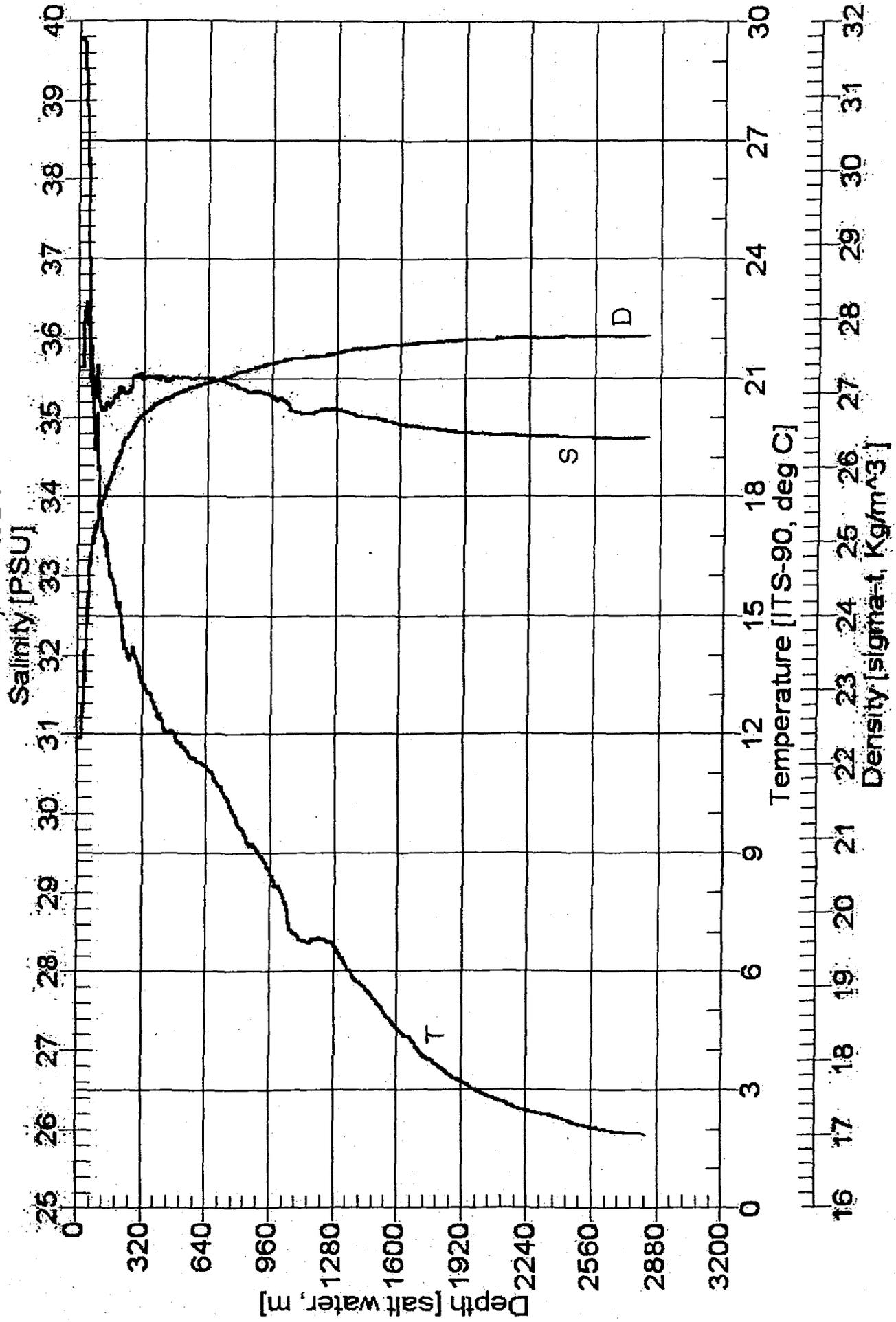


FIG. 8

AASGH2, stat08

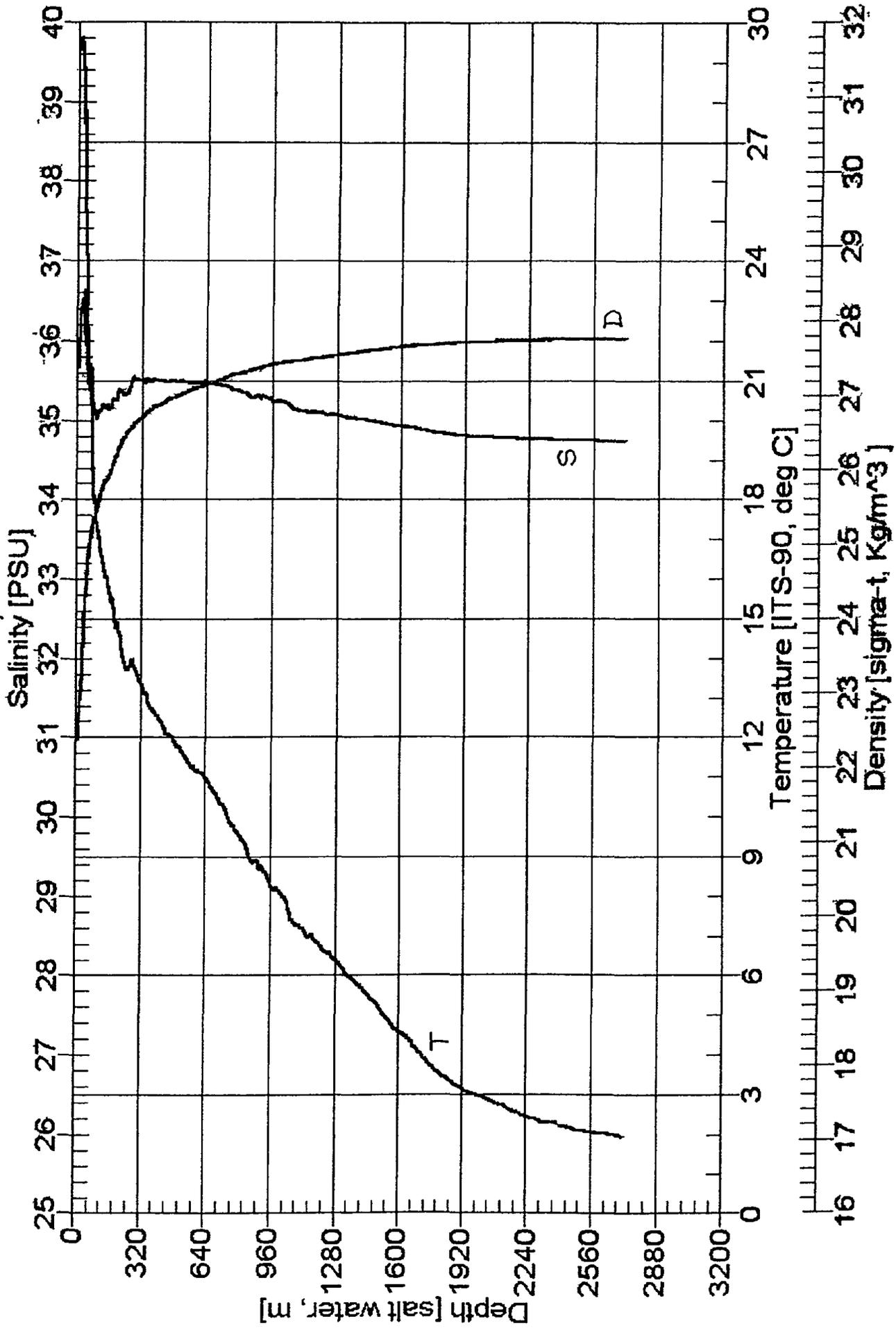


FIG. 9

AASGHZ, stat09

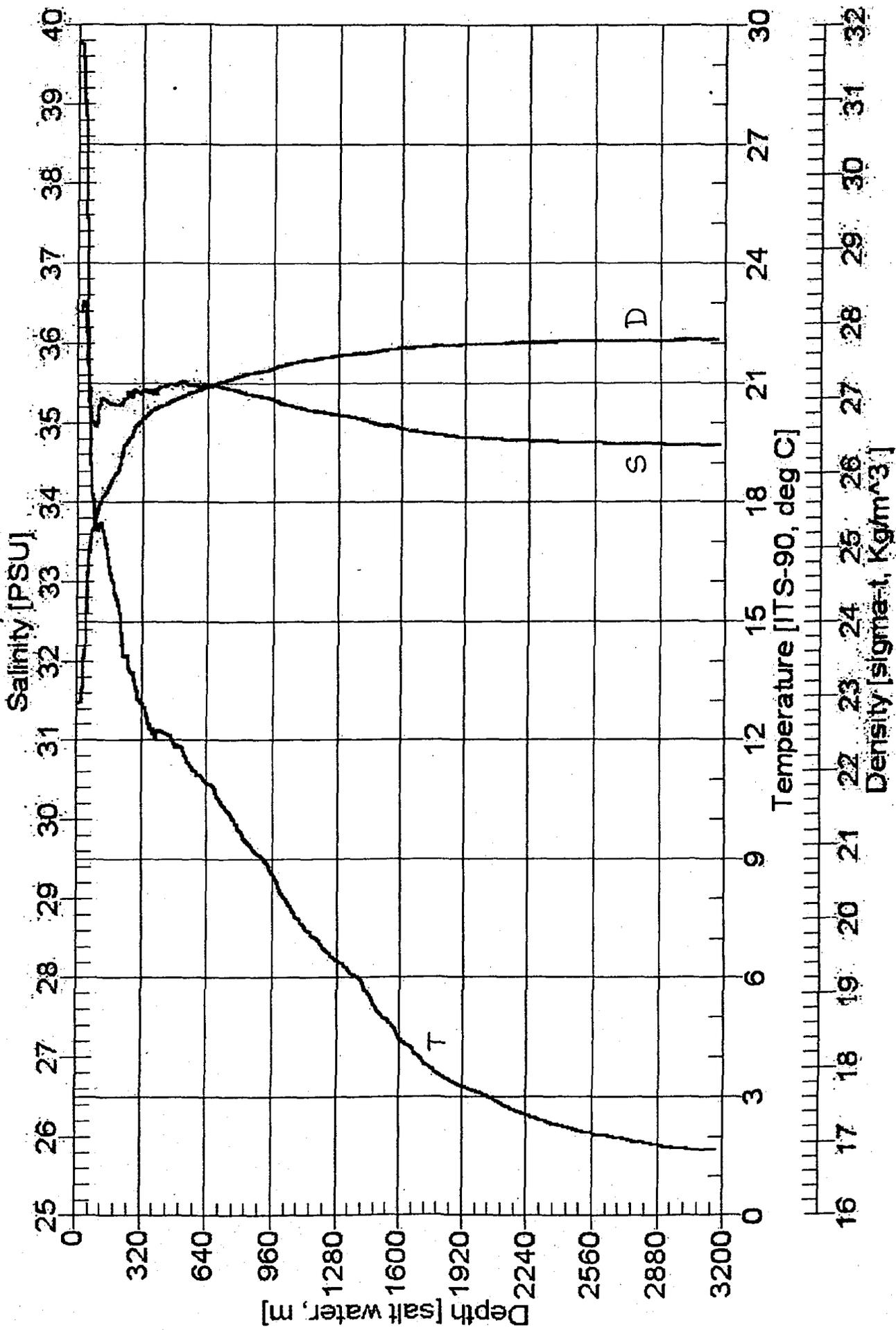


FIG. 10

AASGH2, stat10

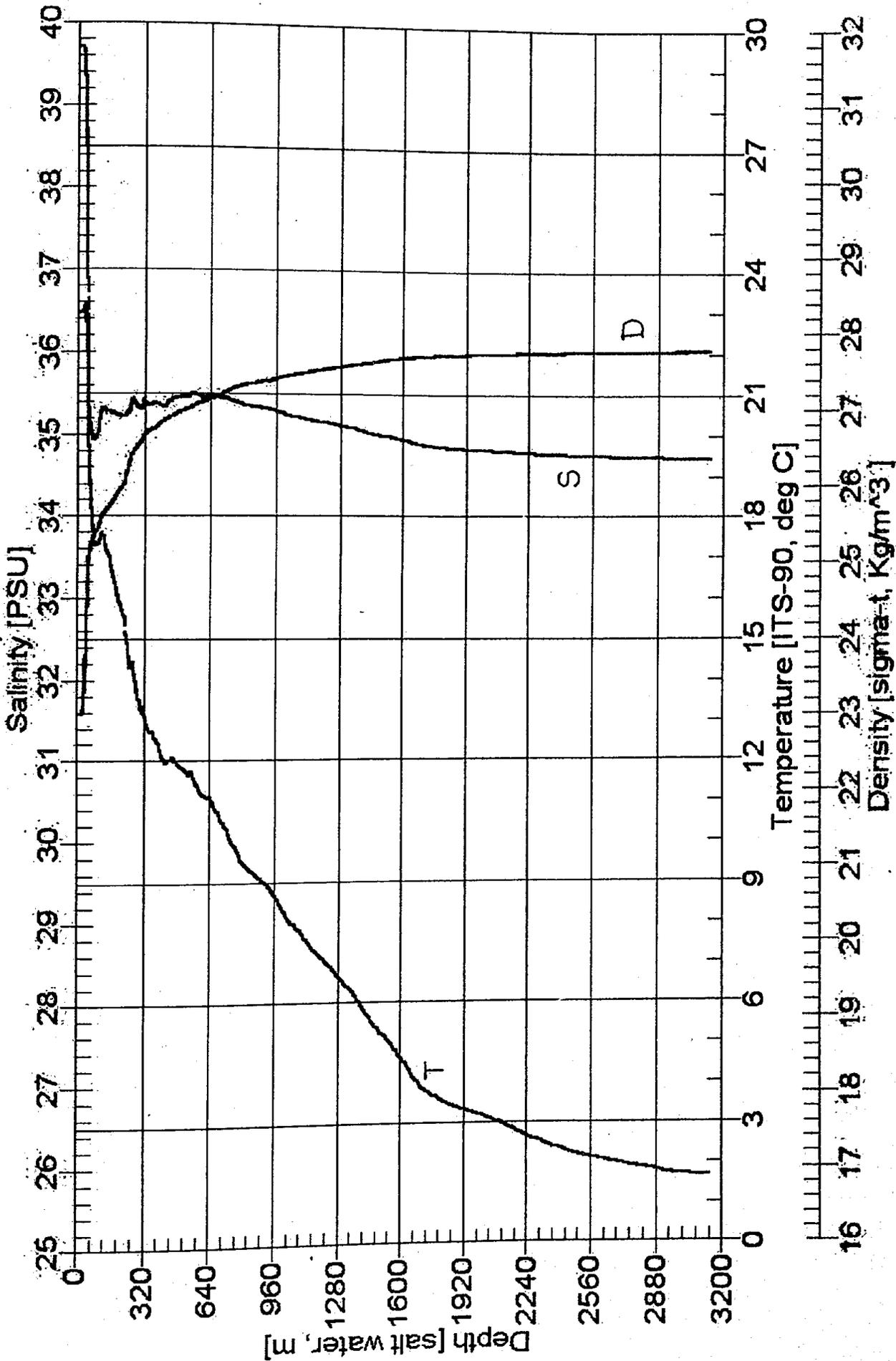


FIG. 11

AASGH2, stat14

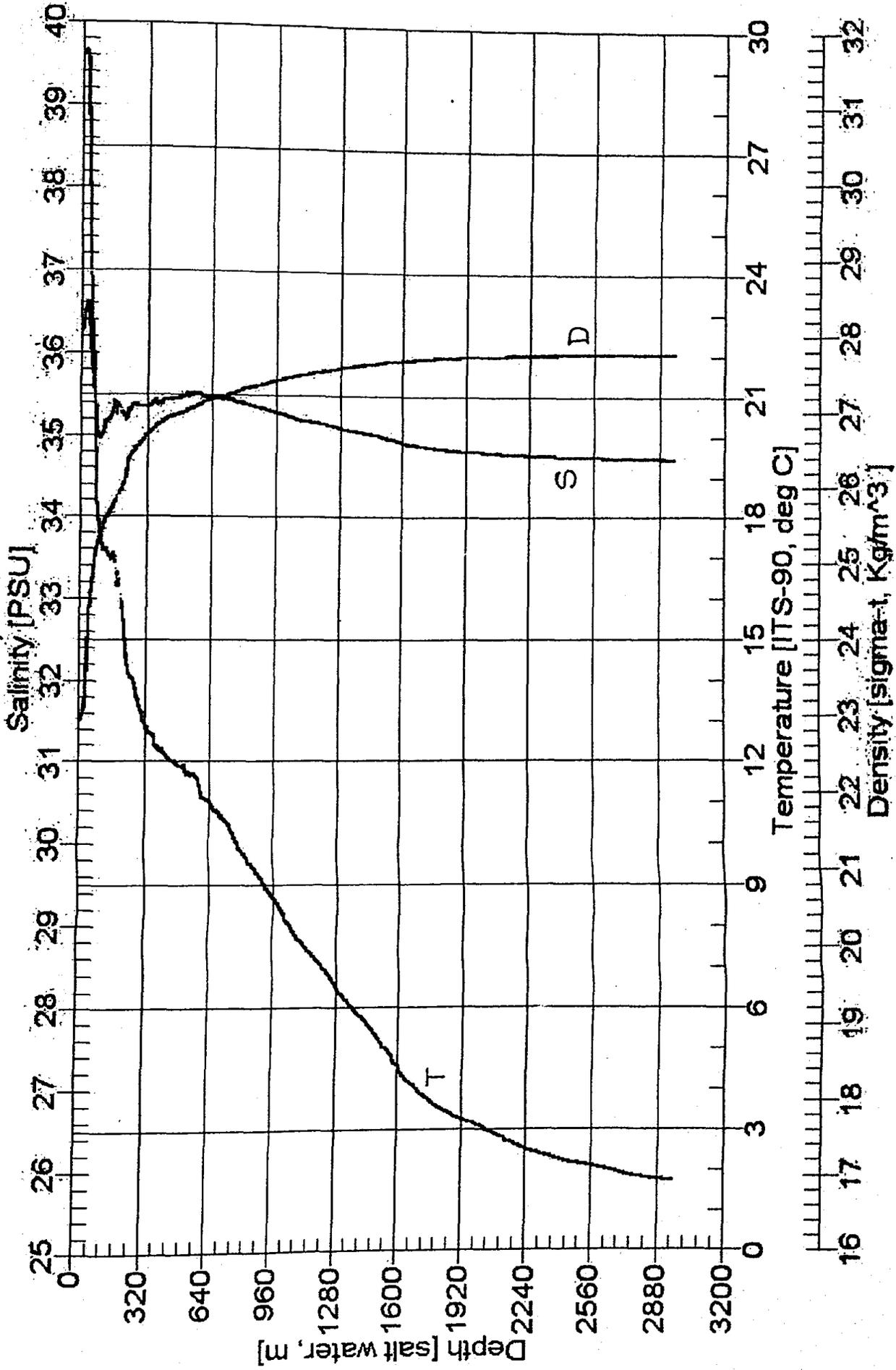


FIG. 12

AASGH2, stat15

Salinity [PSU]

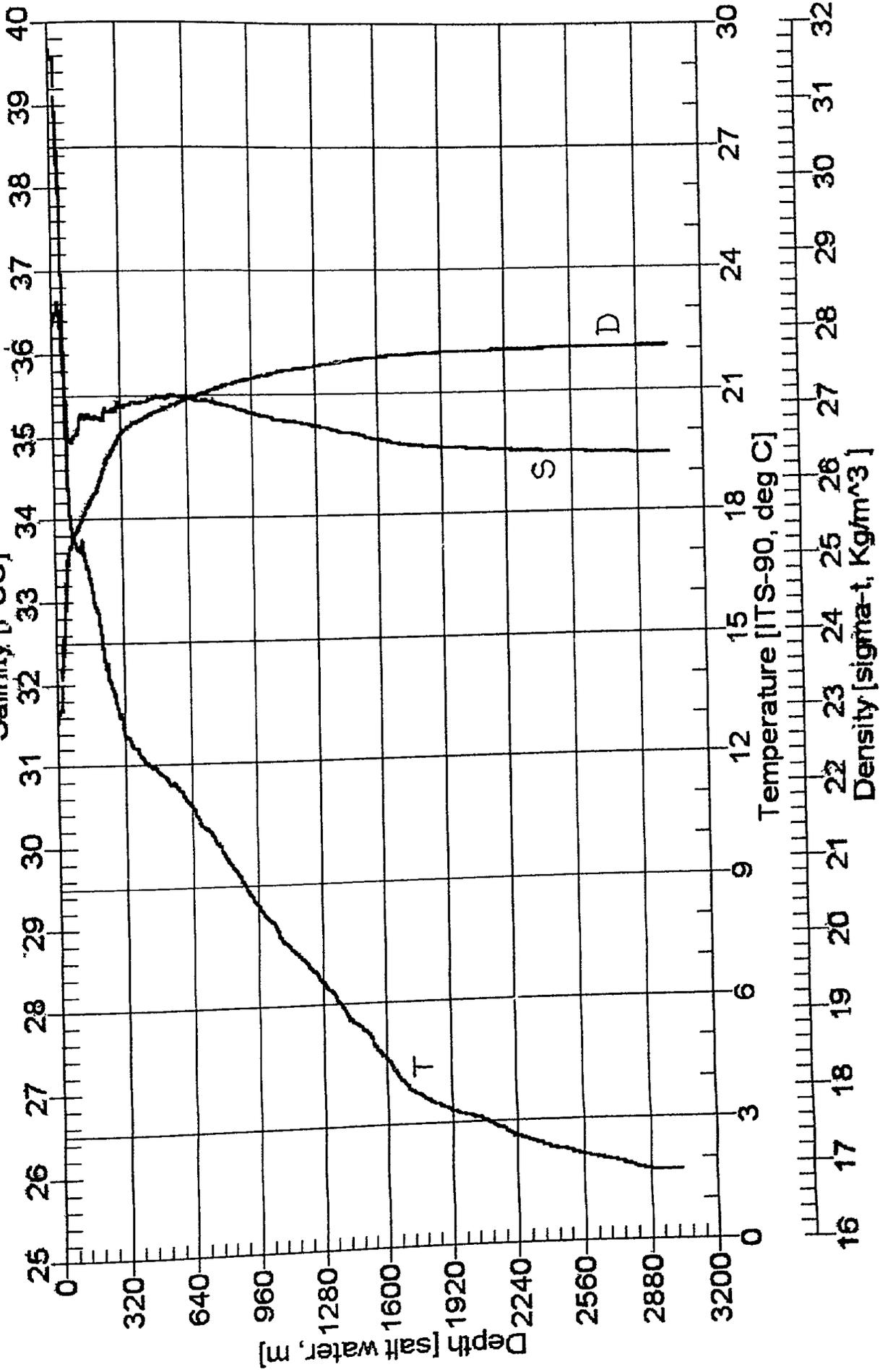


FIG. 13

AASGH2, stat22

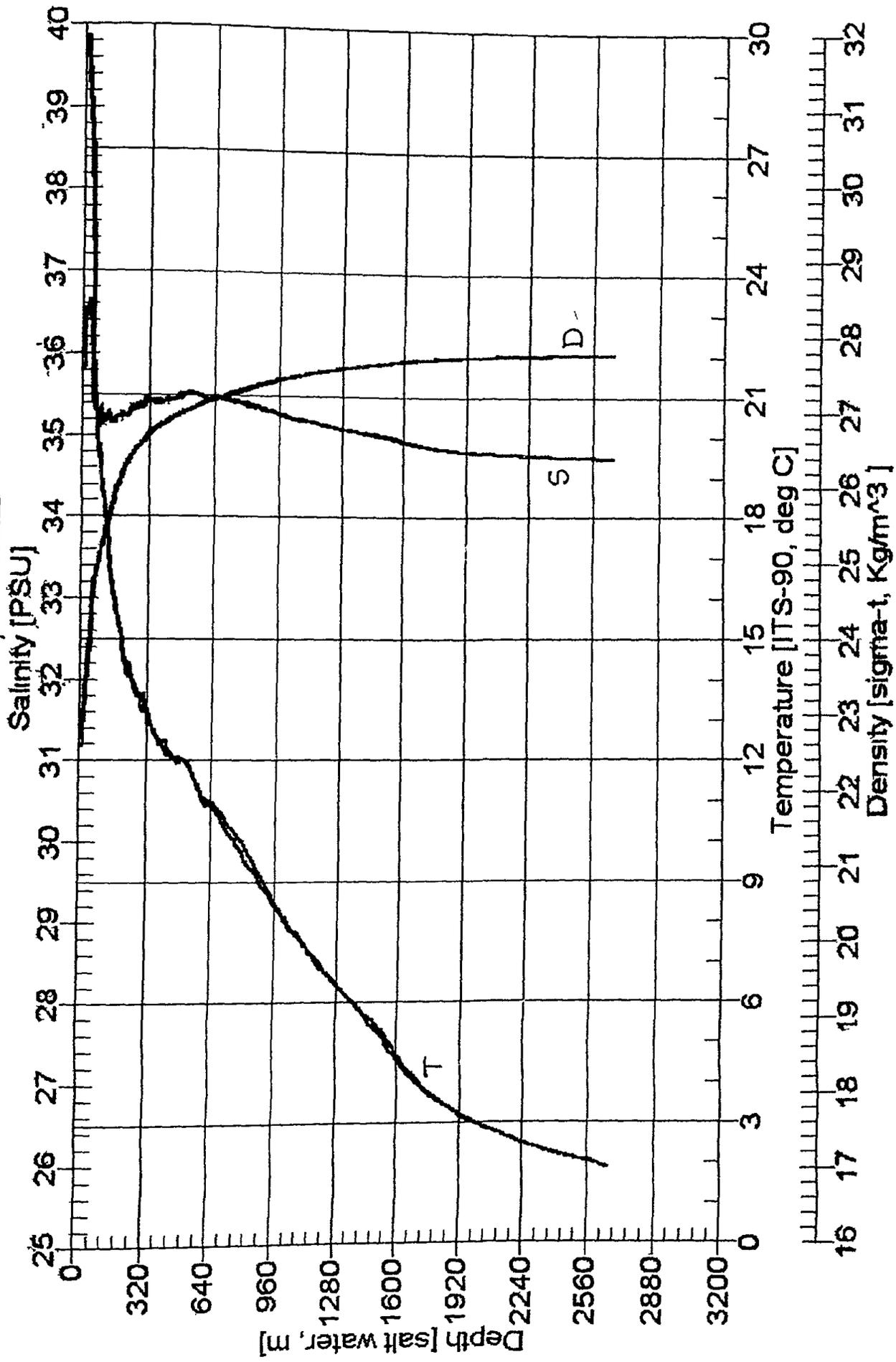


FIG. 14

AASGH2, stat23

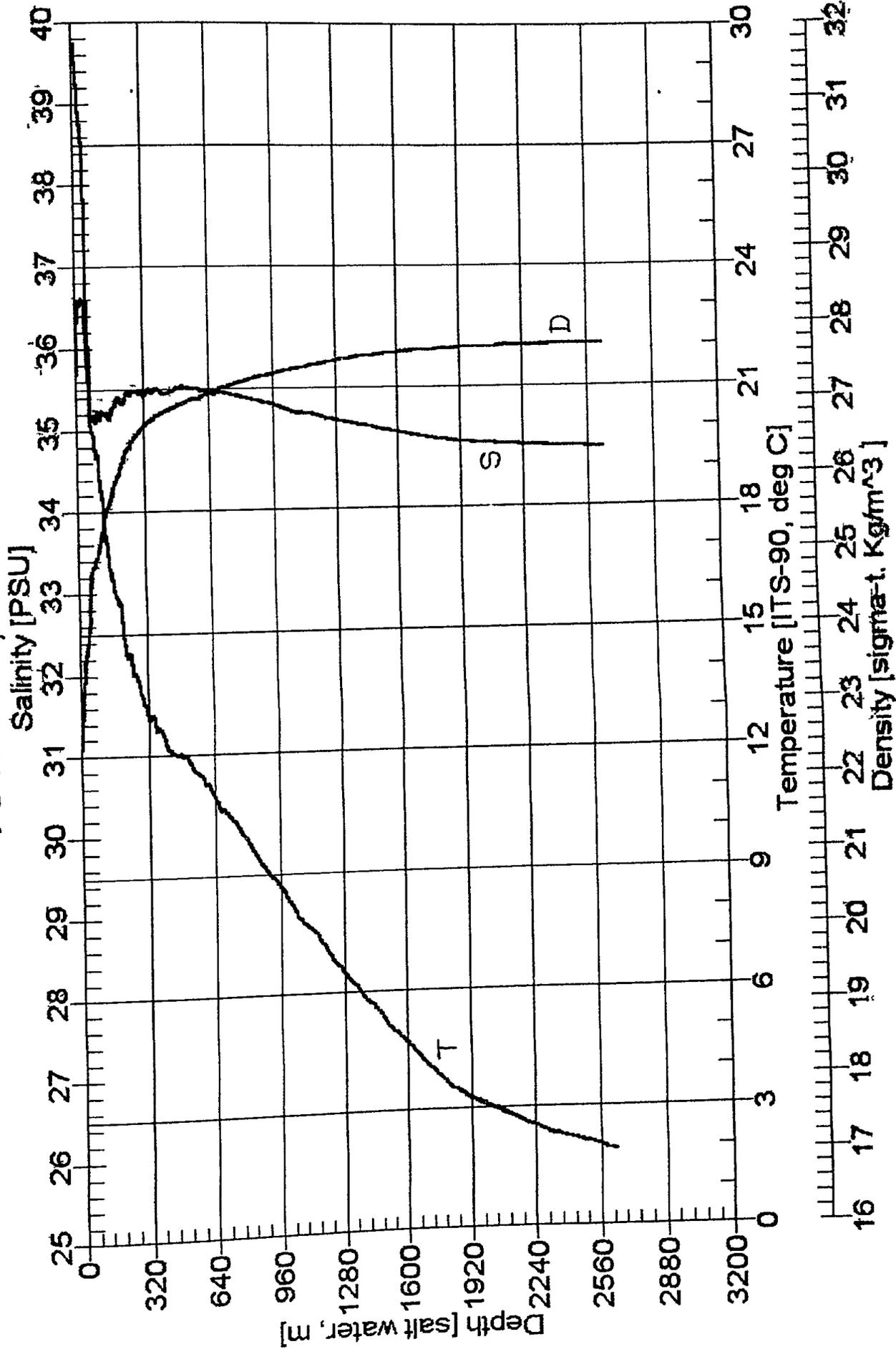


FIG. 15

AASGH2, stat24

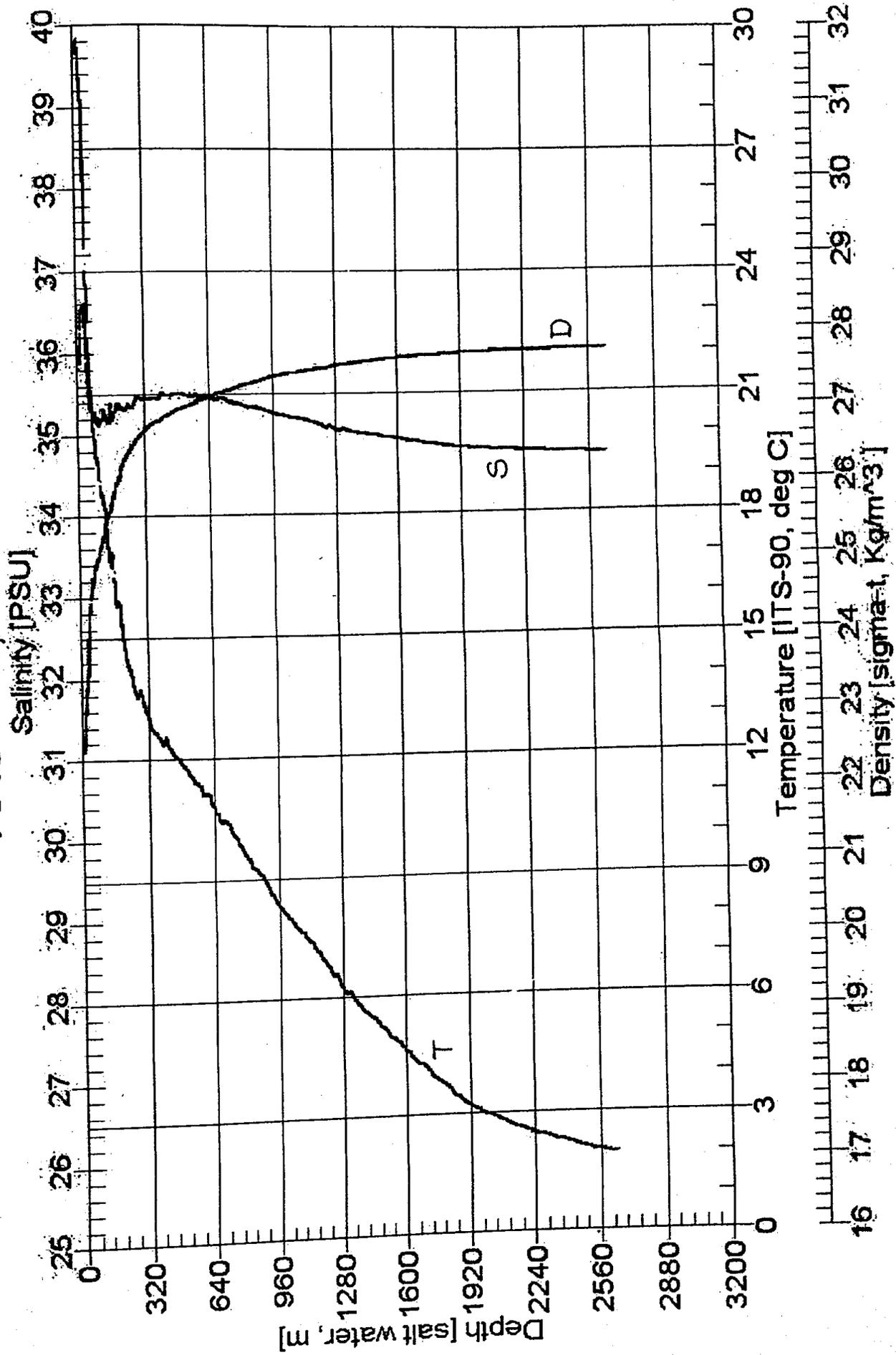


FIG. 16

AASGH2, stat01

Fluorescence, Seapoint

($\mu\text{g}/\ell$)

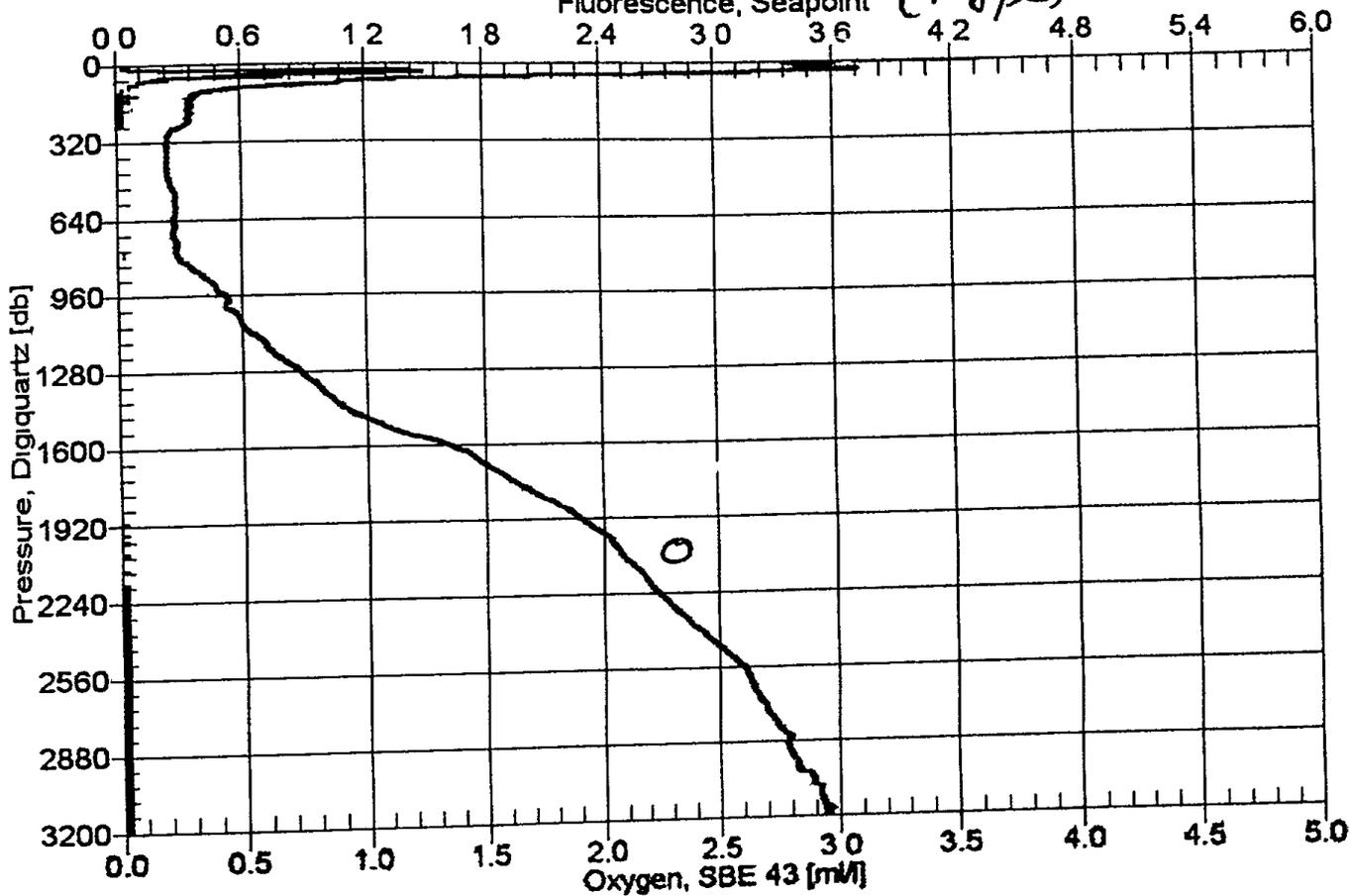


FIG. 17

AASGH2, stat02

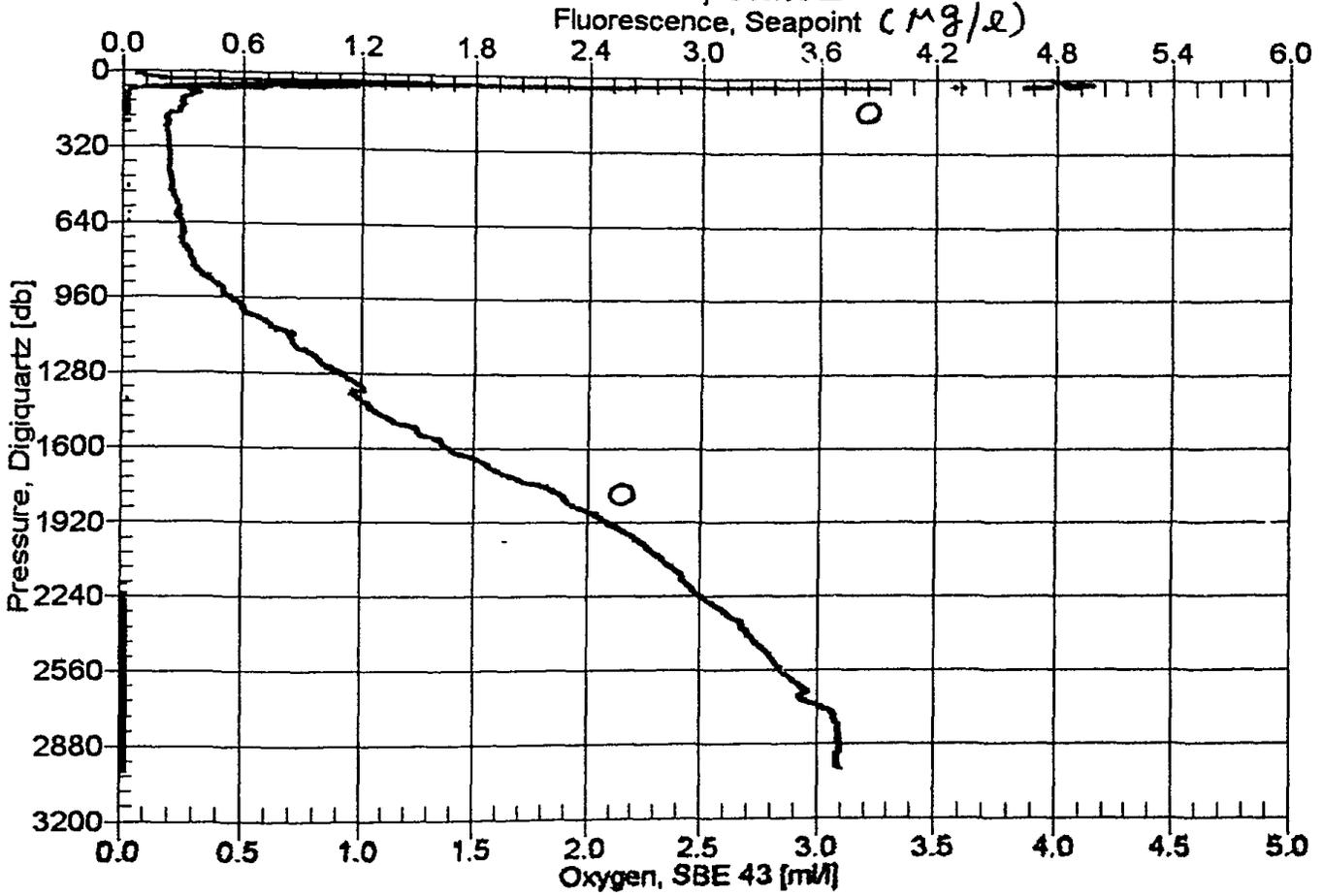


FIG. 18

AASGH2, stat03

Fluorescence, Seapoint [$\mu\text{g/l}$]

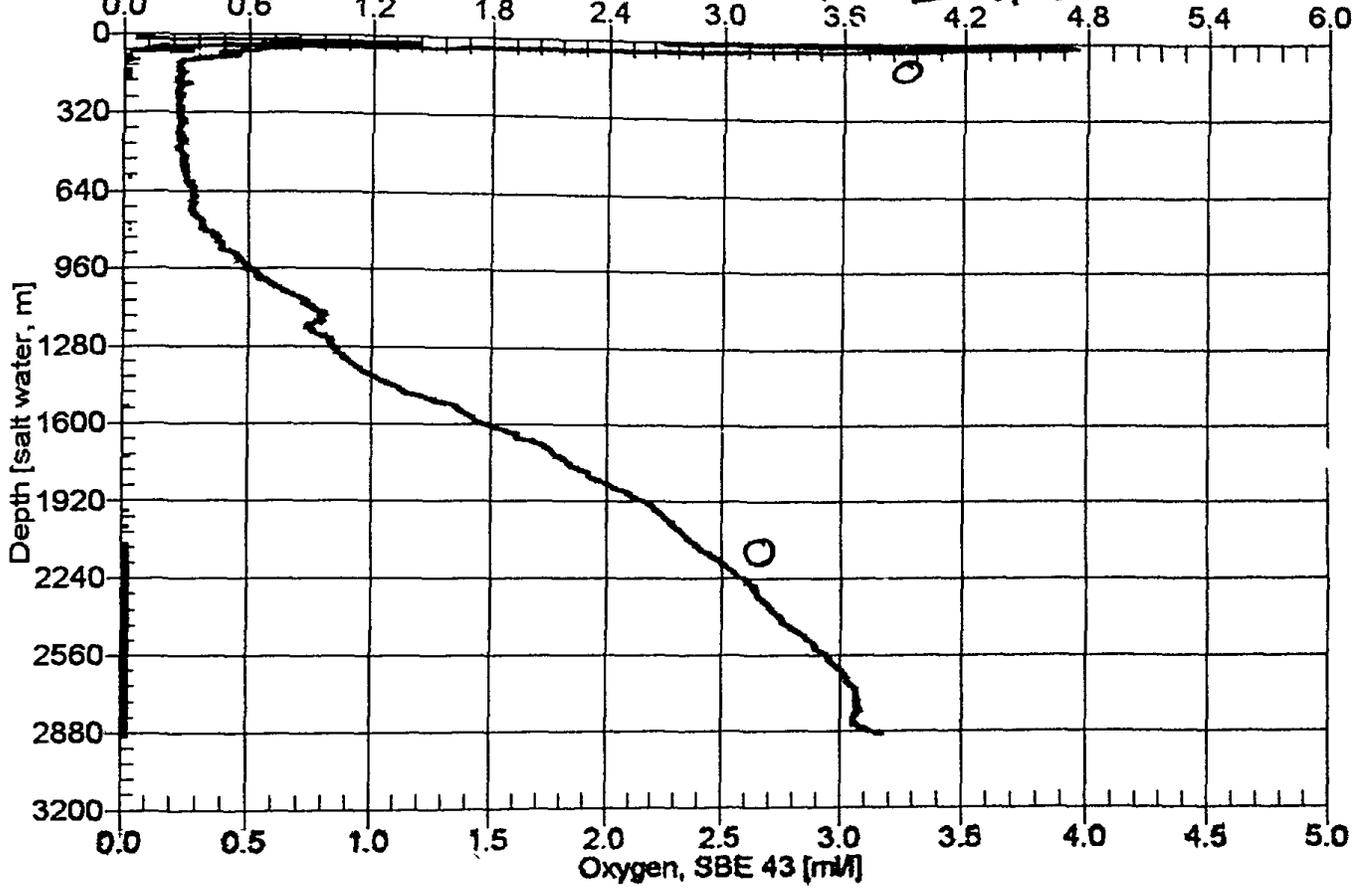


FIG. 19

AASGH2, stat04

Fluorescence, Seapoint [$\mu\text{g/l}$]

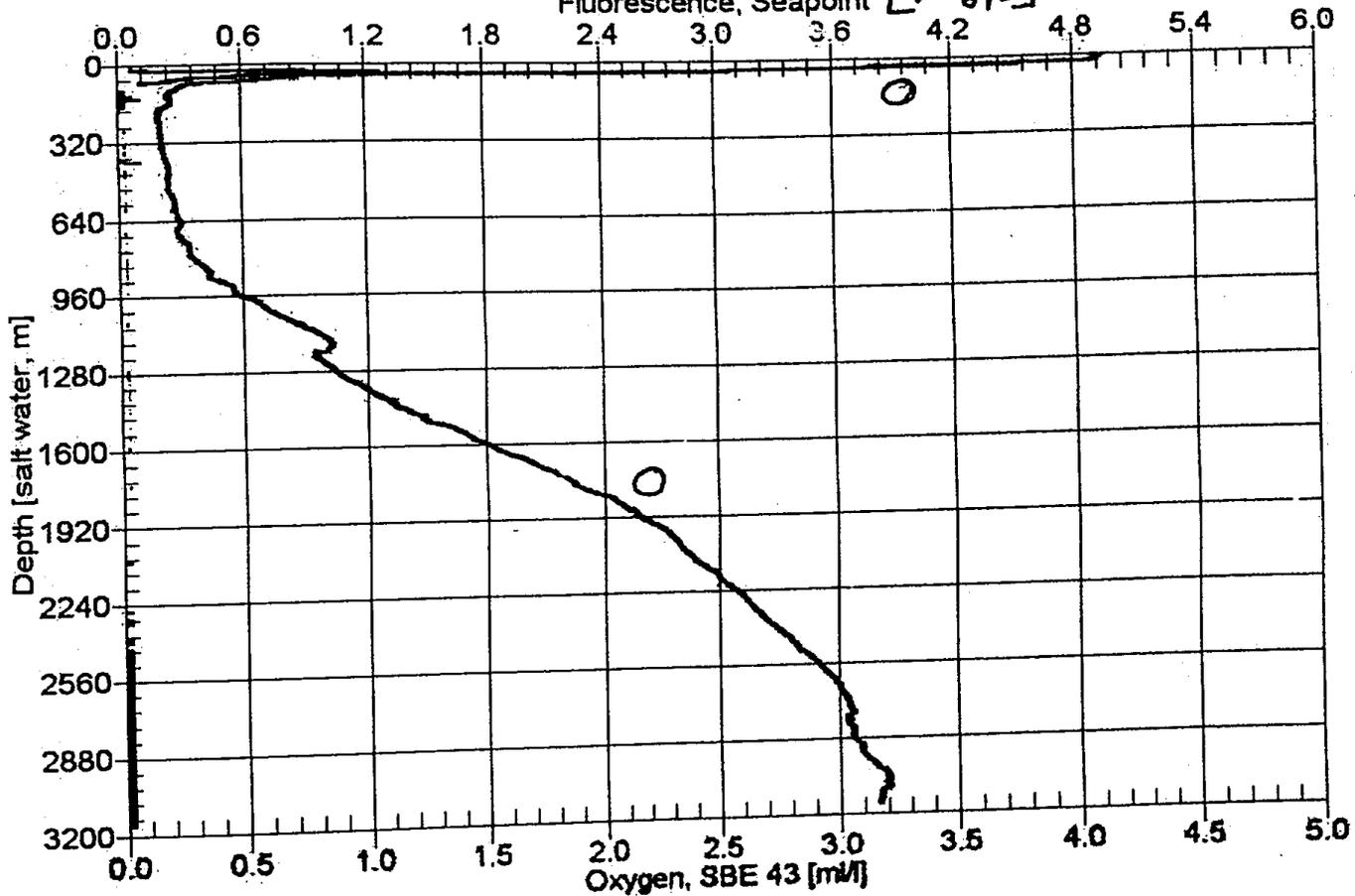


FIG. 20

AASGH2, stat05

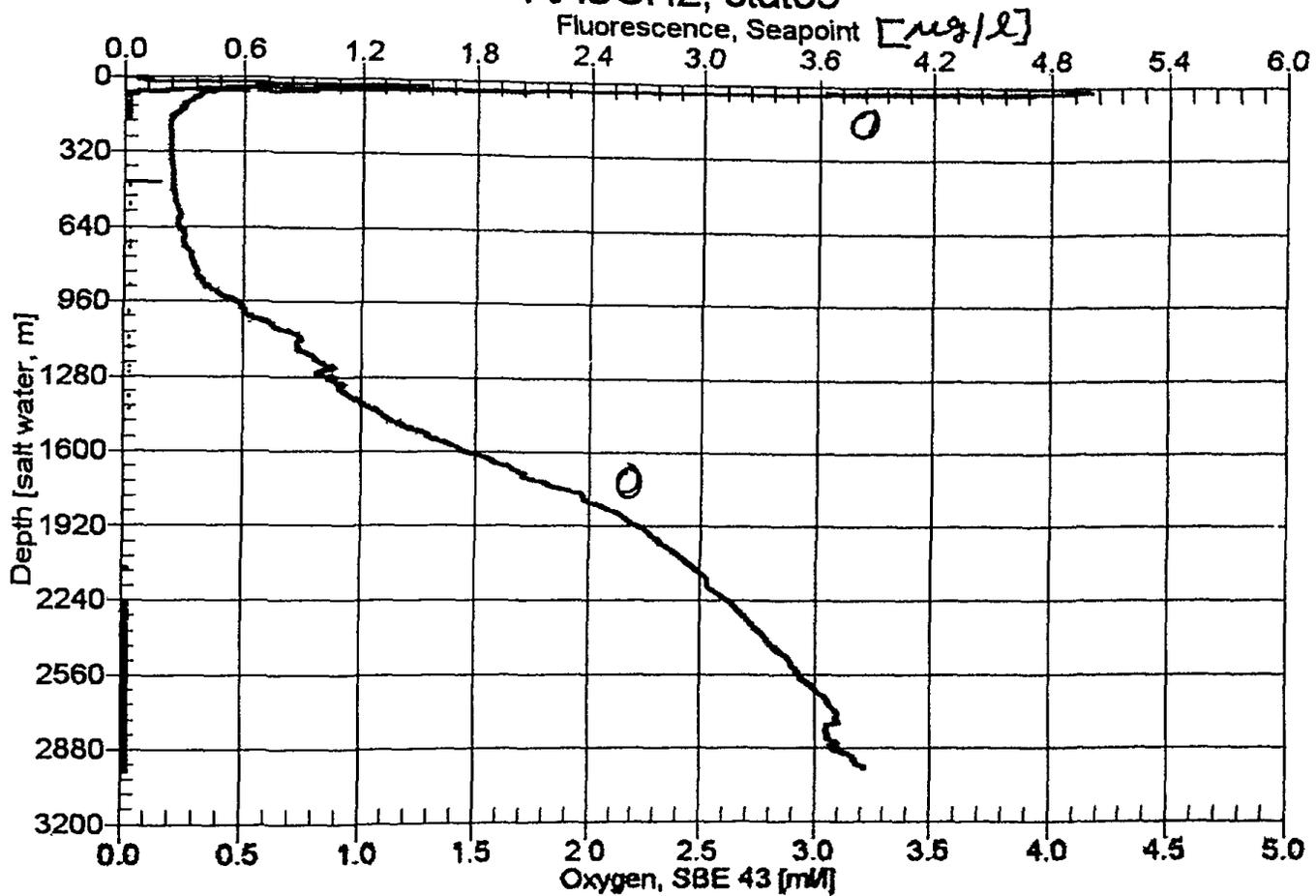


FIG. 21

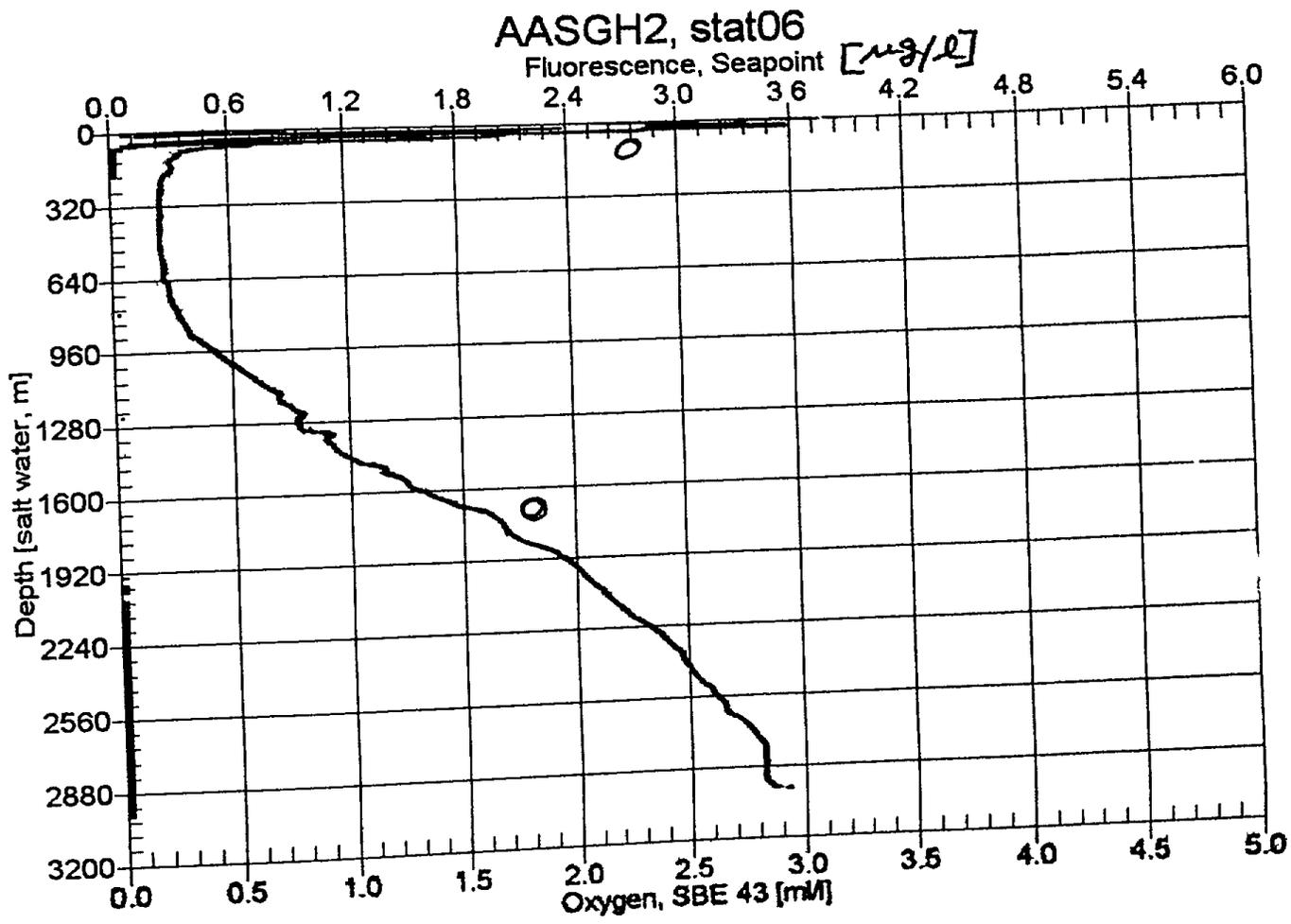


FIG. 22

AASGH2, stat07

Fluorescence, Seapoint [$\mu\text{g/l}$]

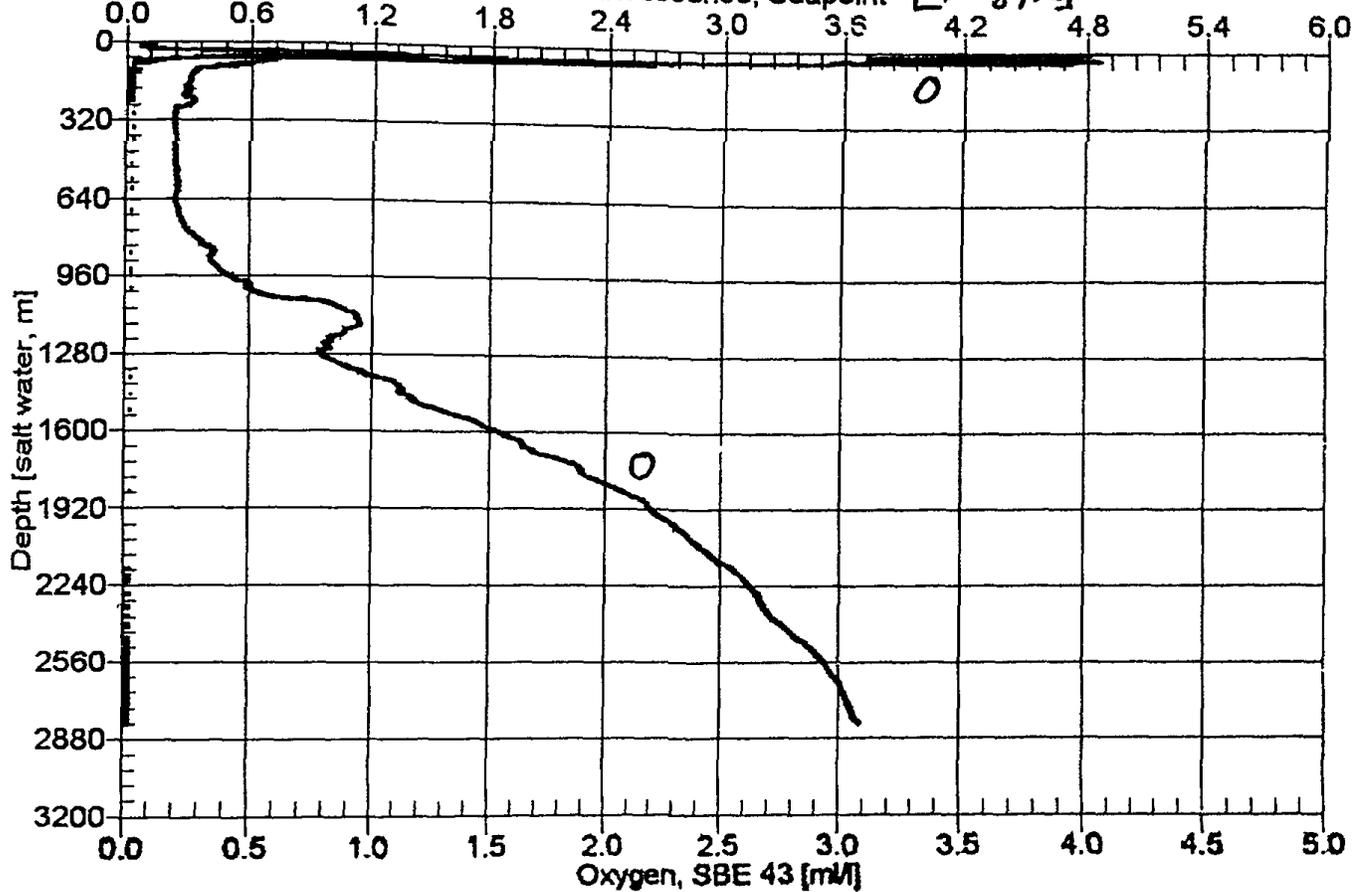


FIG. 23

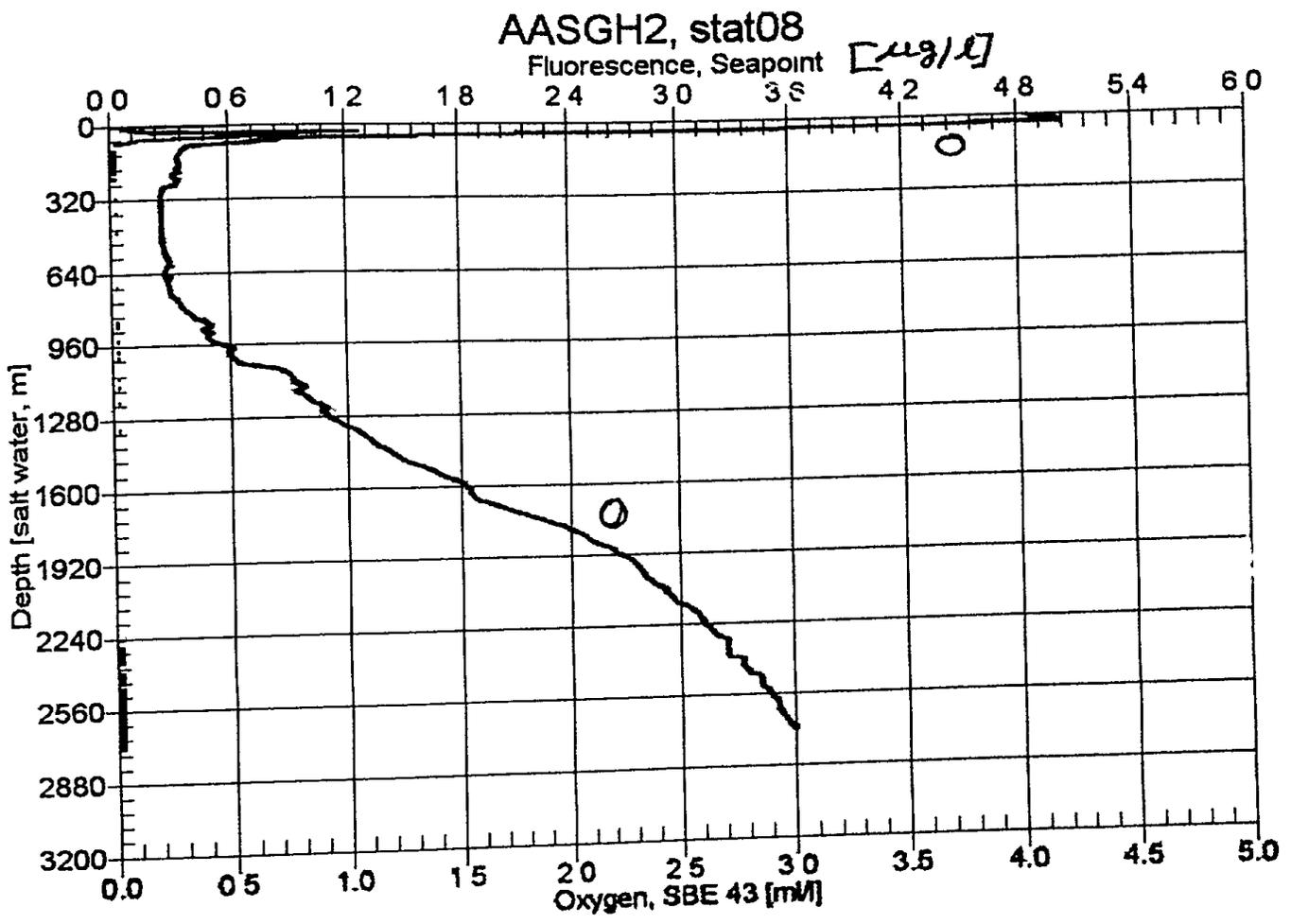


FIG. 24

AASGH2, stat09

Fluorescence, Seapoint [$\mu\text{g/l}$]

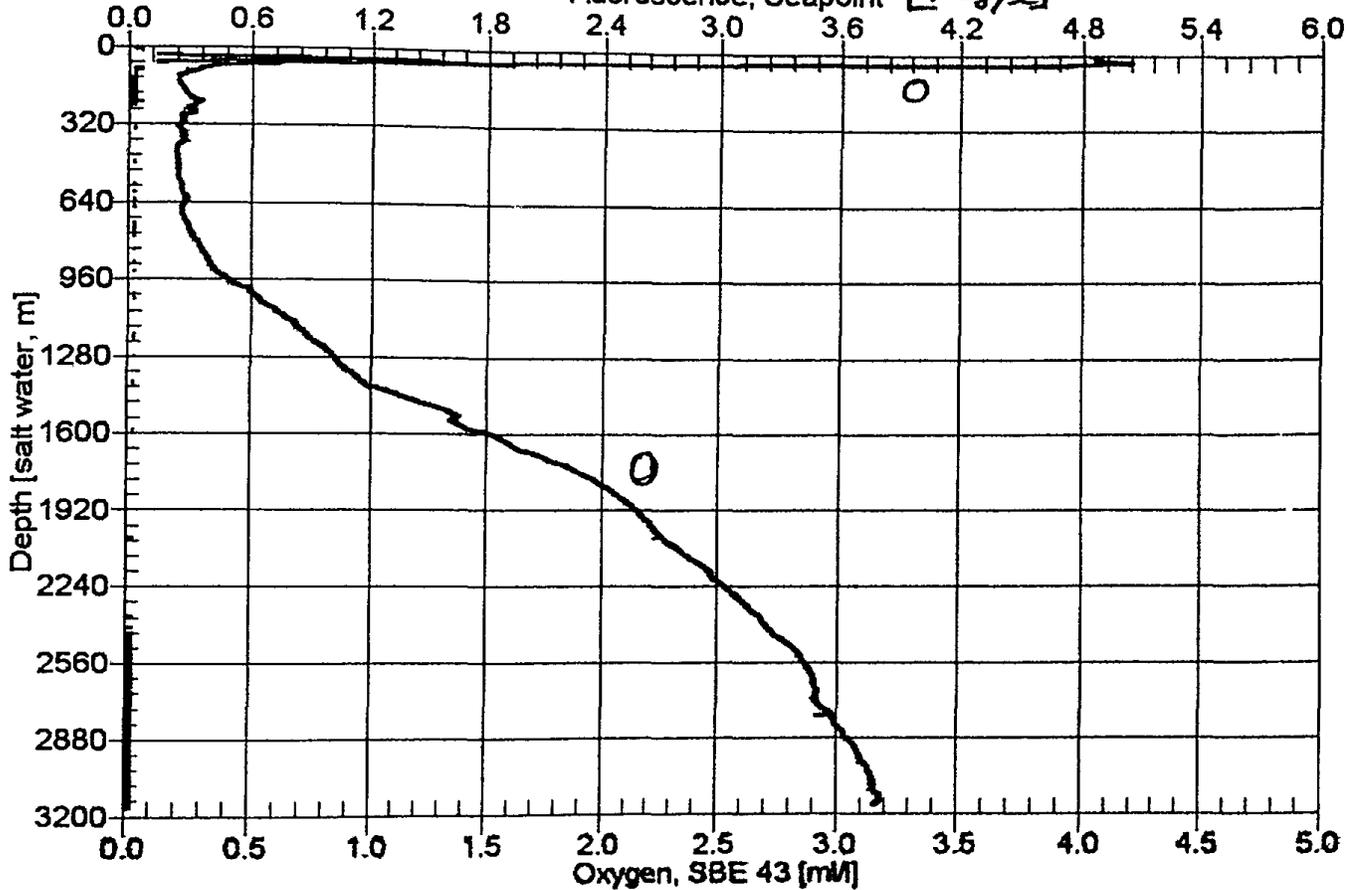


FIG. 25

AASGH2, stat10

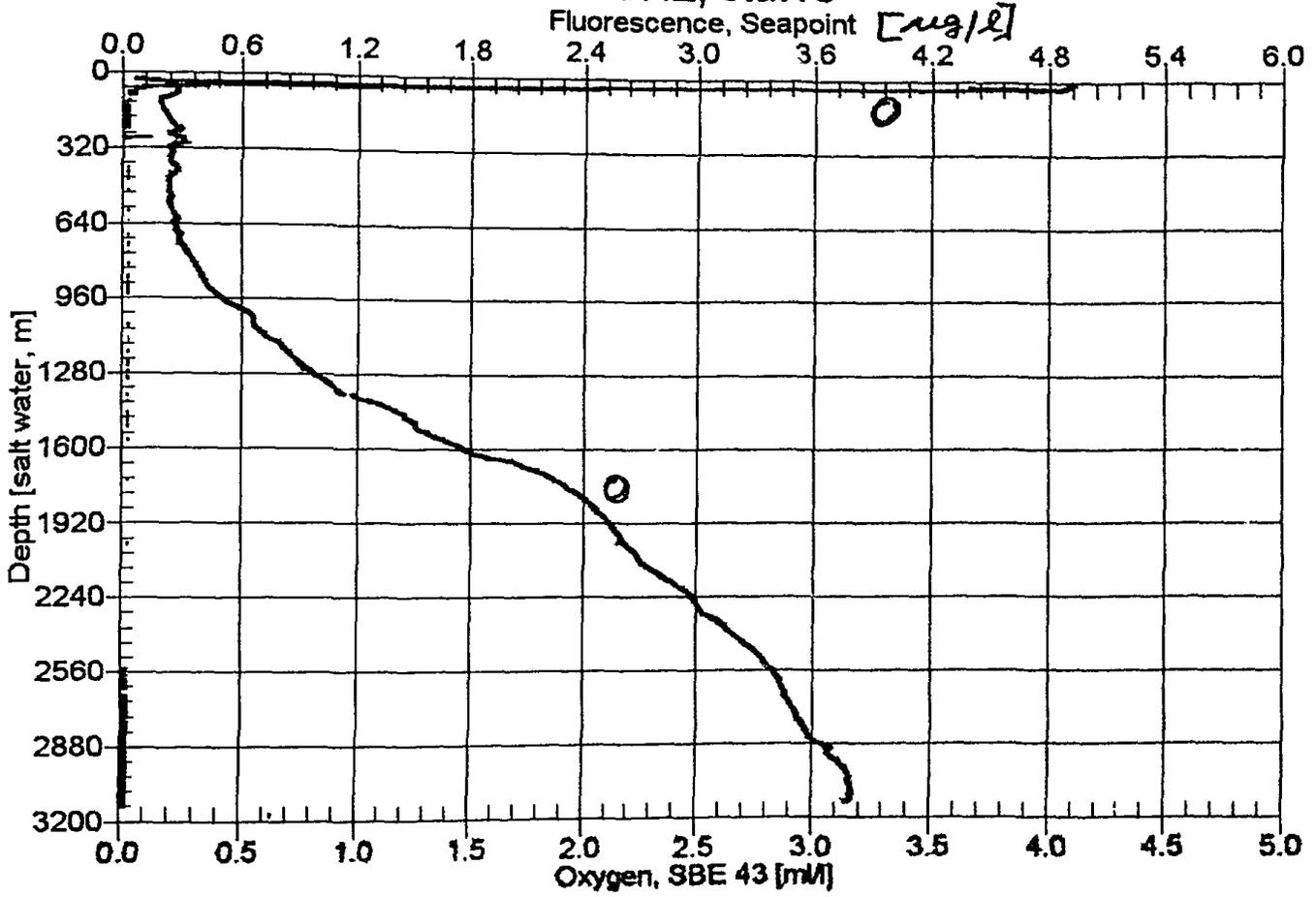


FIG. 26

AASGH2, stat14

Fluorescence, Seapoint [$\mu\text{g/l}$]

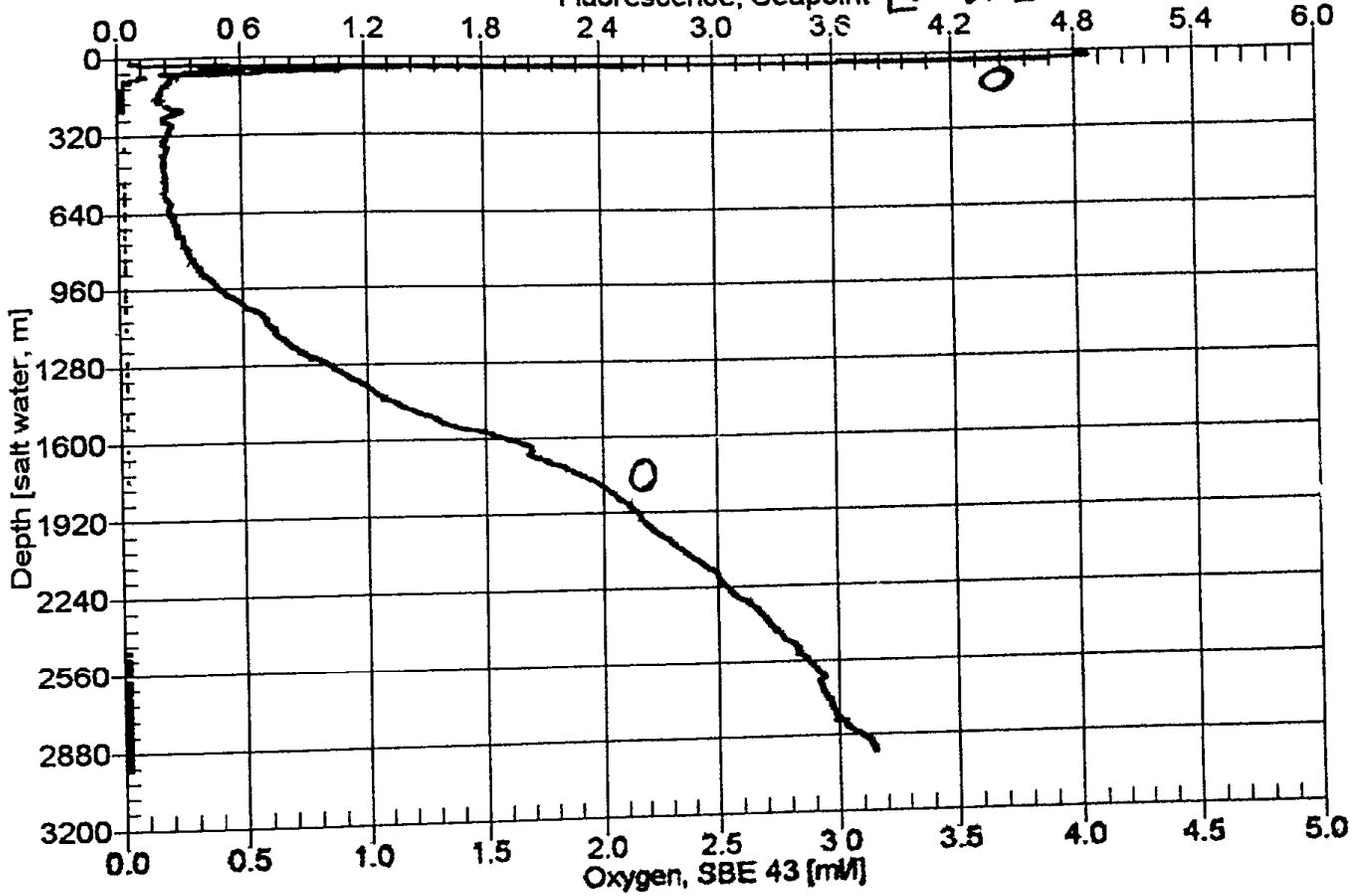


FIG.27

AASGH2, stat15

Fluorescence, Seapoint [$\mu\text{g/l}$]

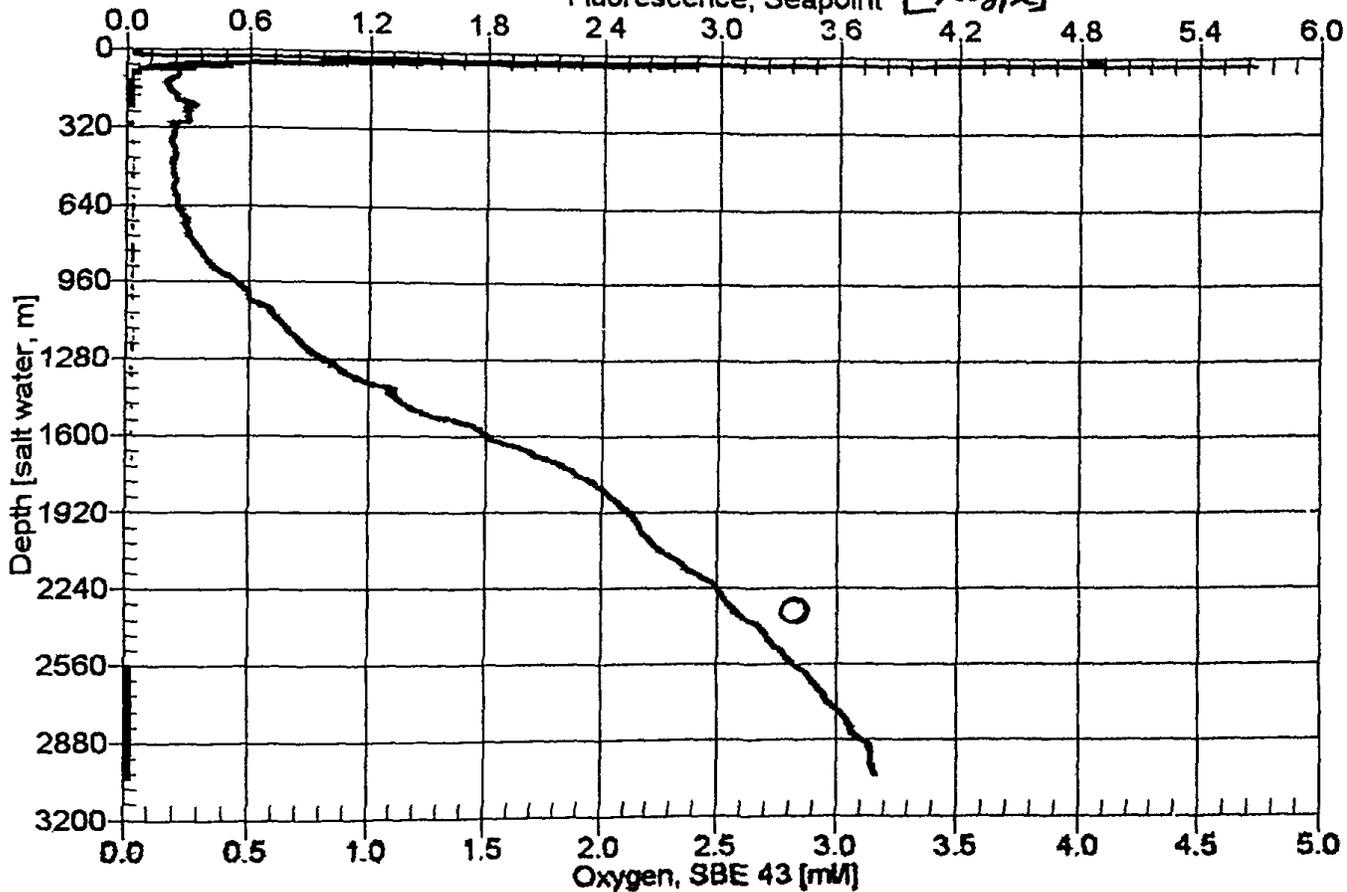


FIG. 28

AASGH2, stat22

Fluorescence, Seapoint [$\mu\text{g/l}$]

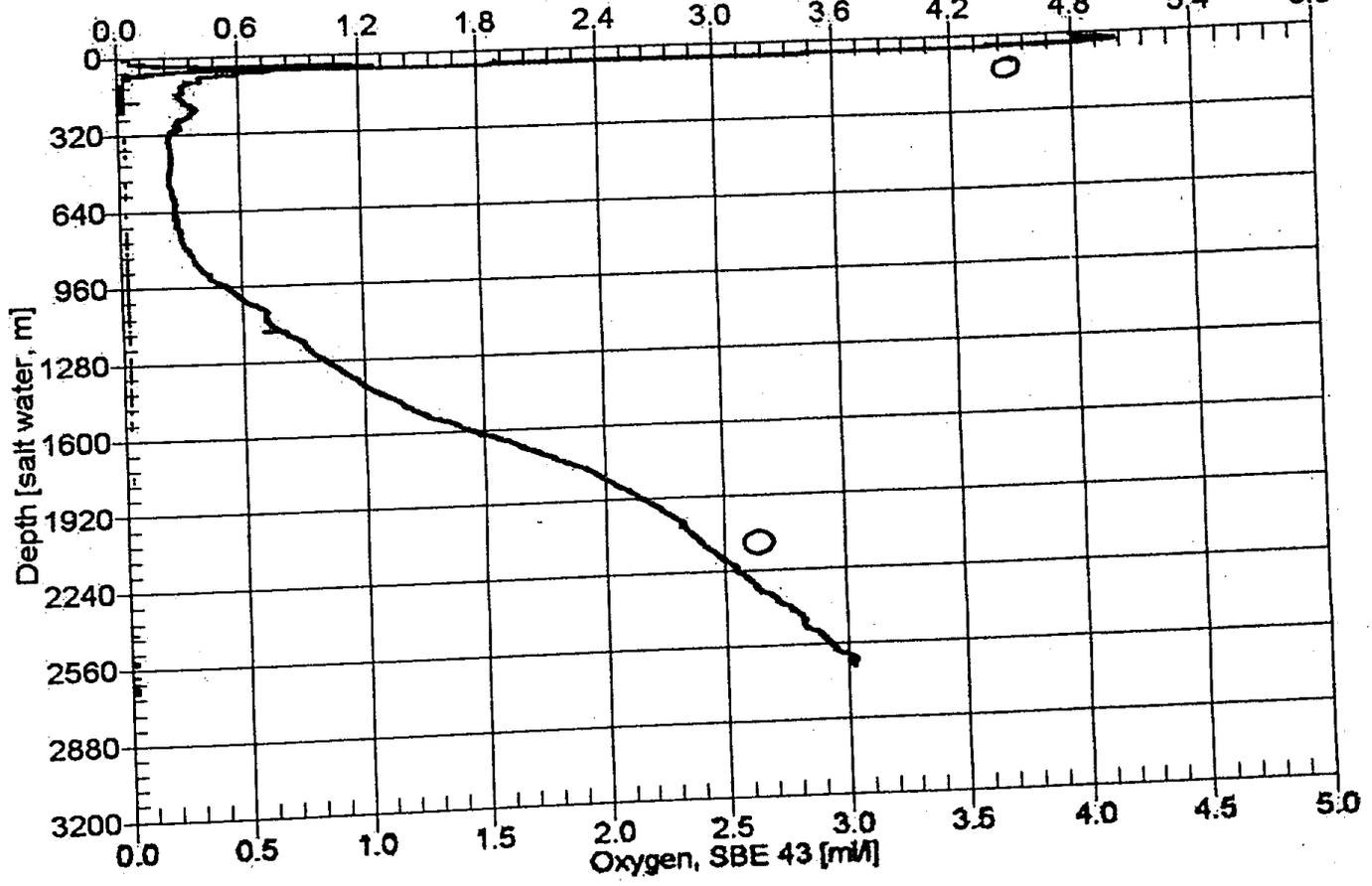


FIG. 29

AASGH2, stat23

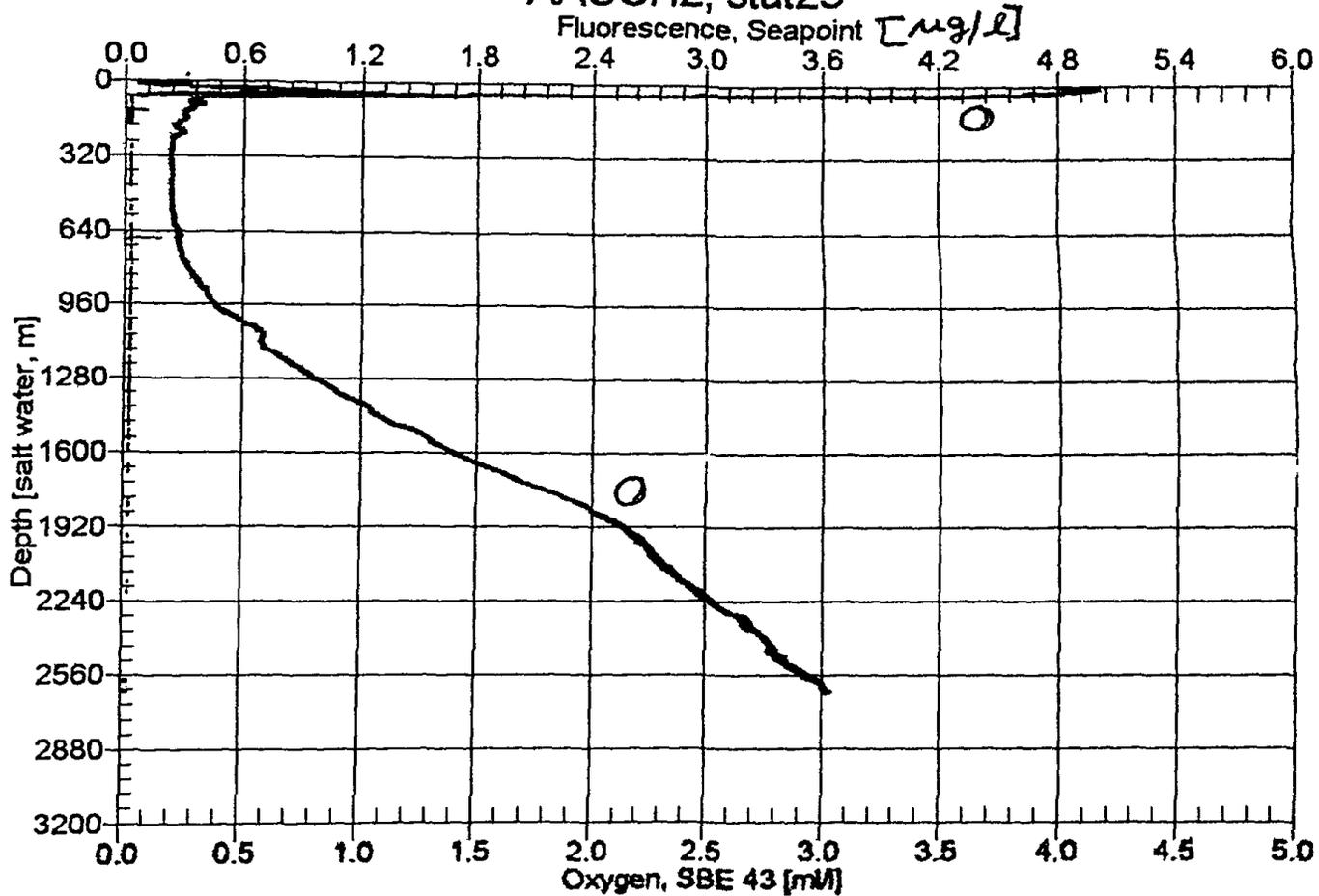


FIG. 30

AASGH2, stat24

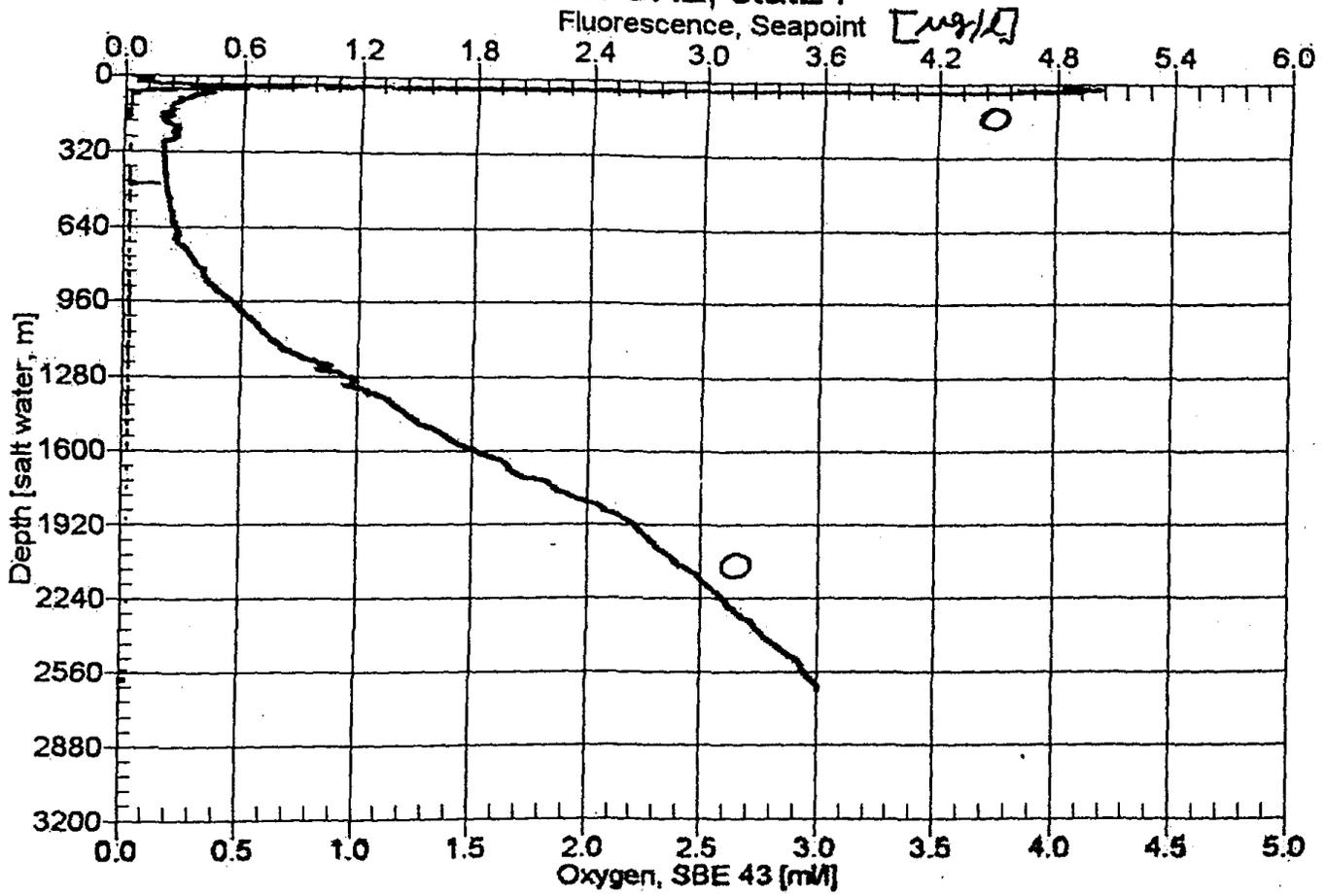


FIG. 31

AASGH2
(Temperature contour at 100m depth)

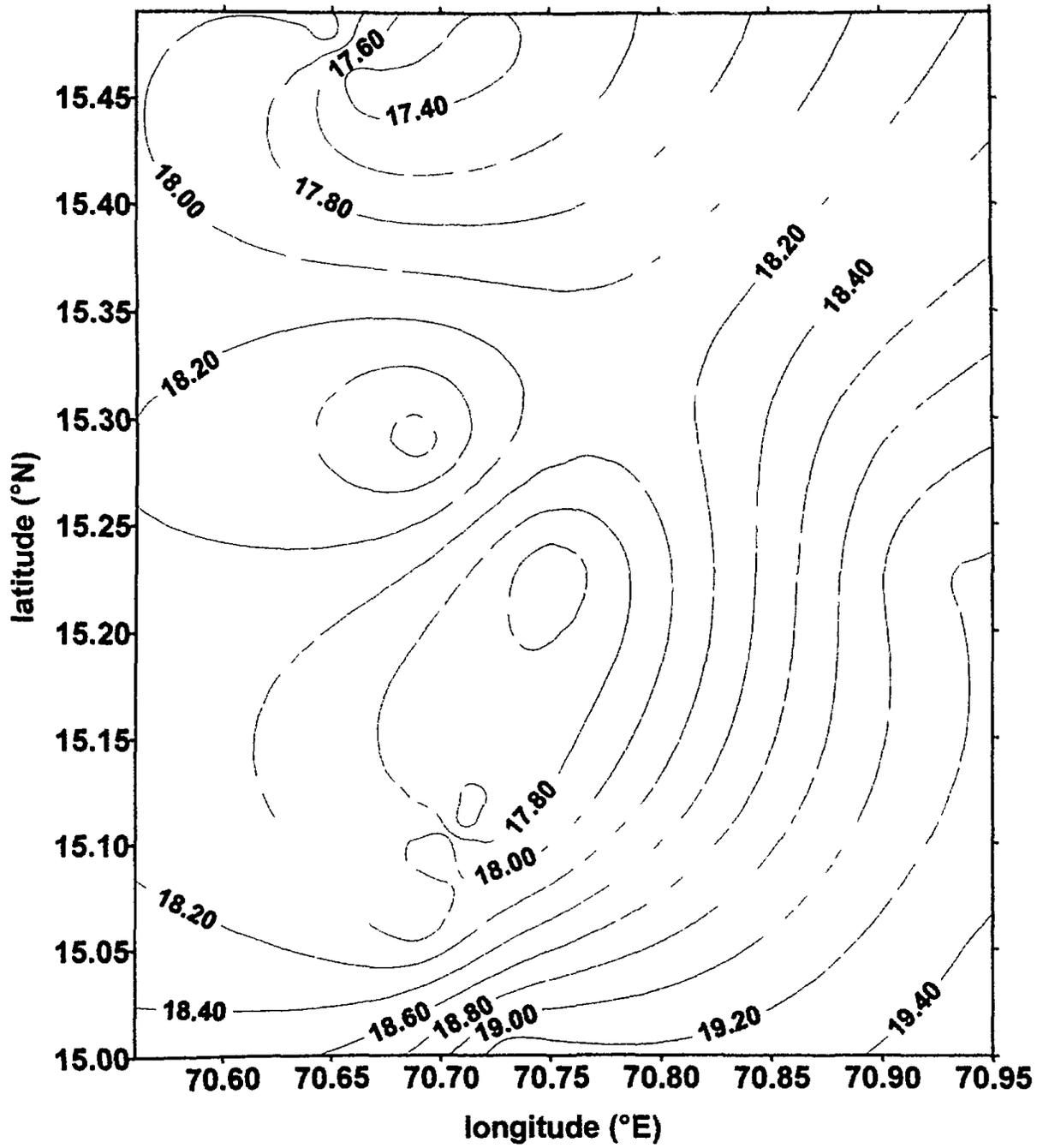


FIG.33

AASGH2
(Temperature contour at 200m depth)

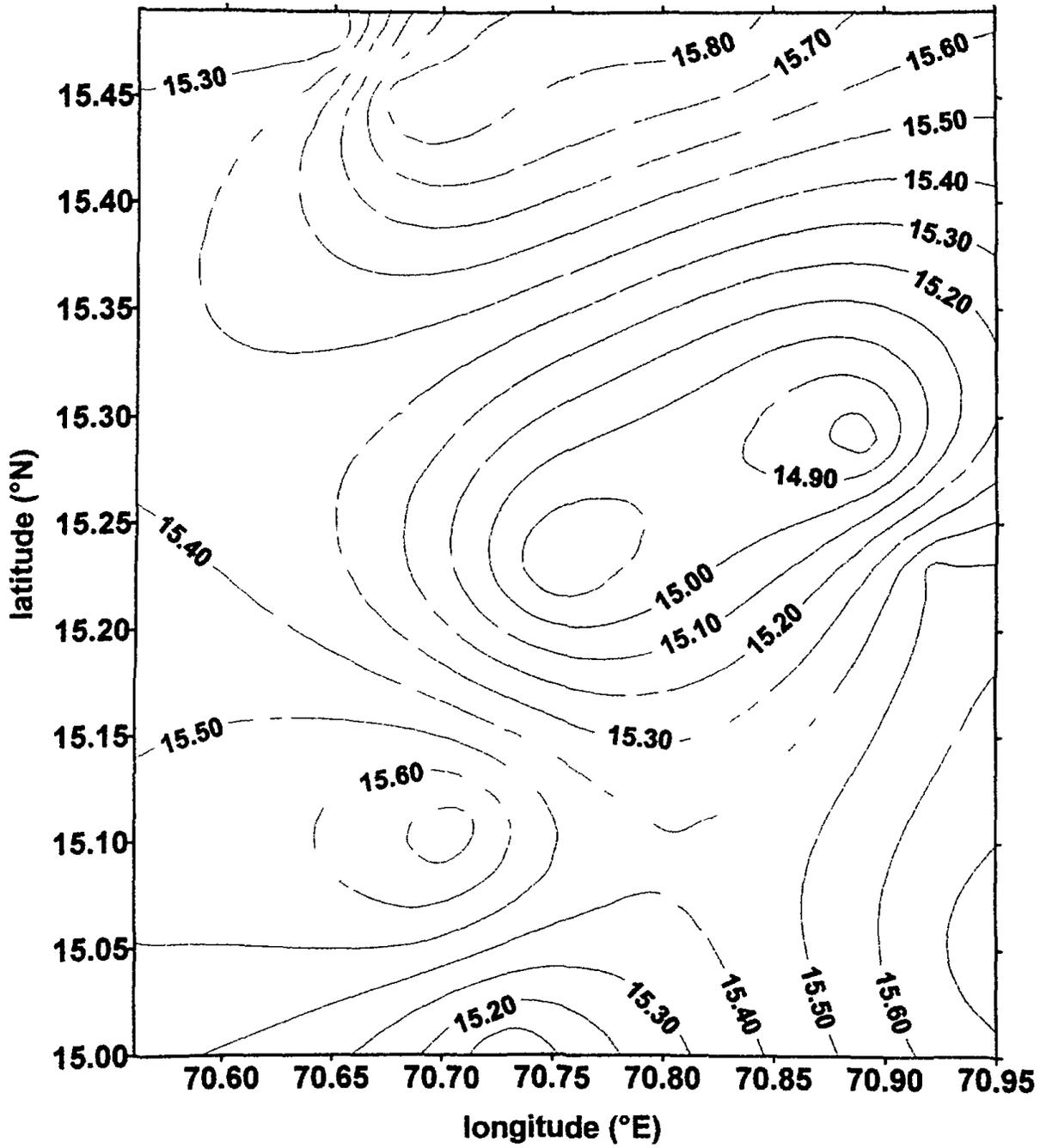


FIG. 34

AASGH2
(Temperature contour at 2600m depth)

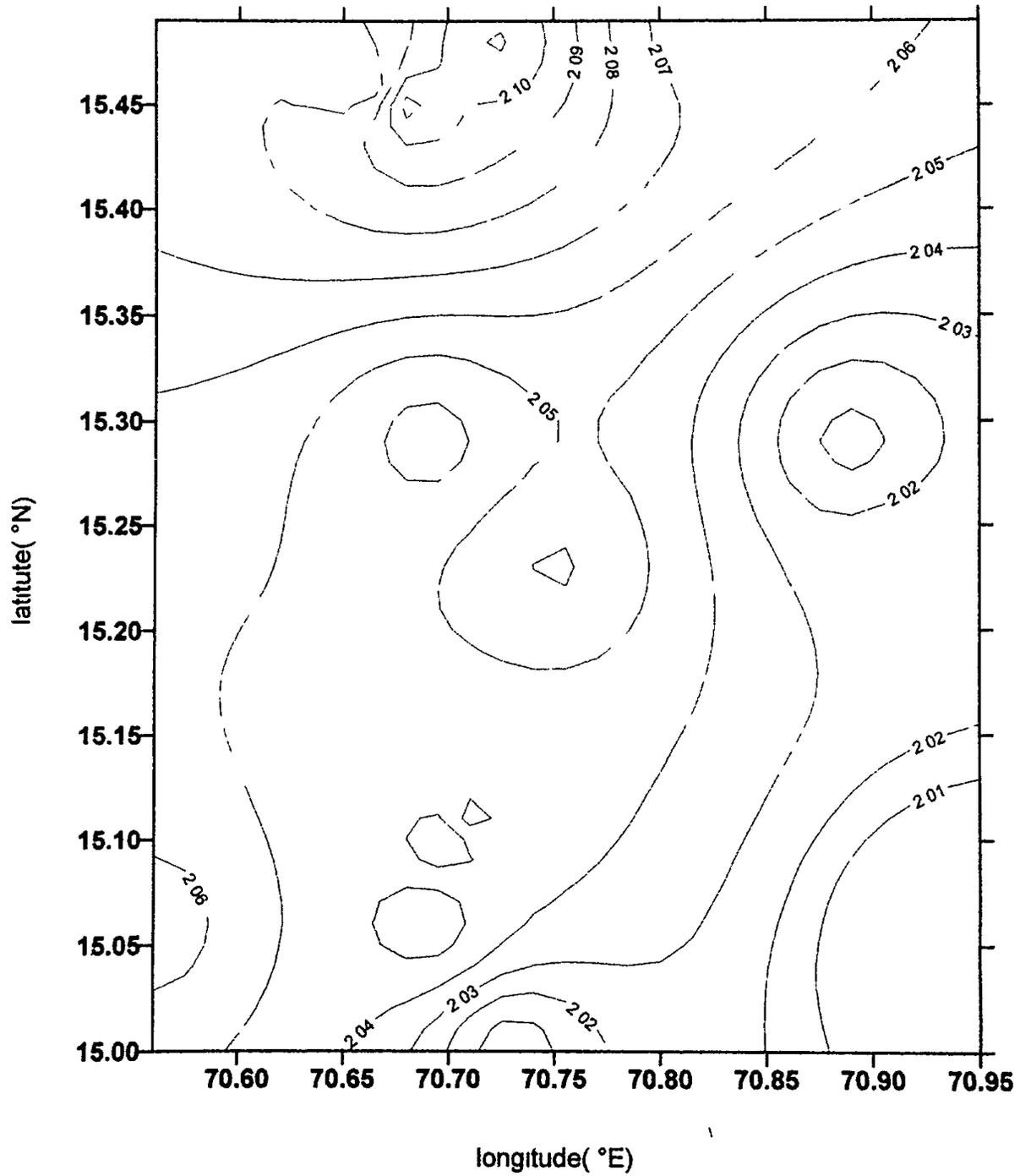


FIG. 35

aasgh2
(Temperature contour at seabed)

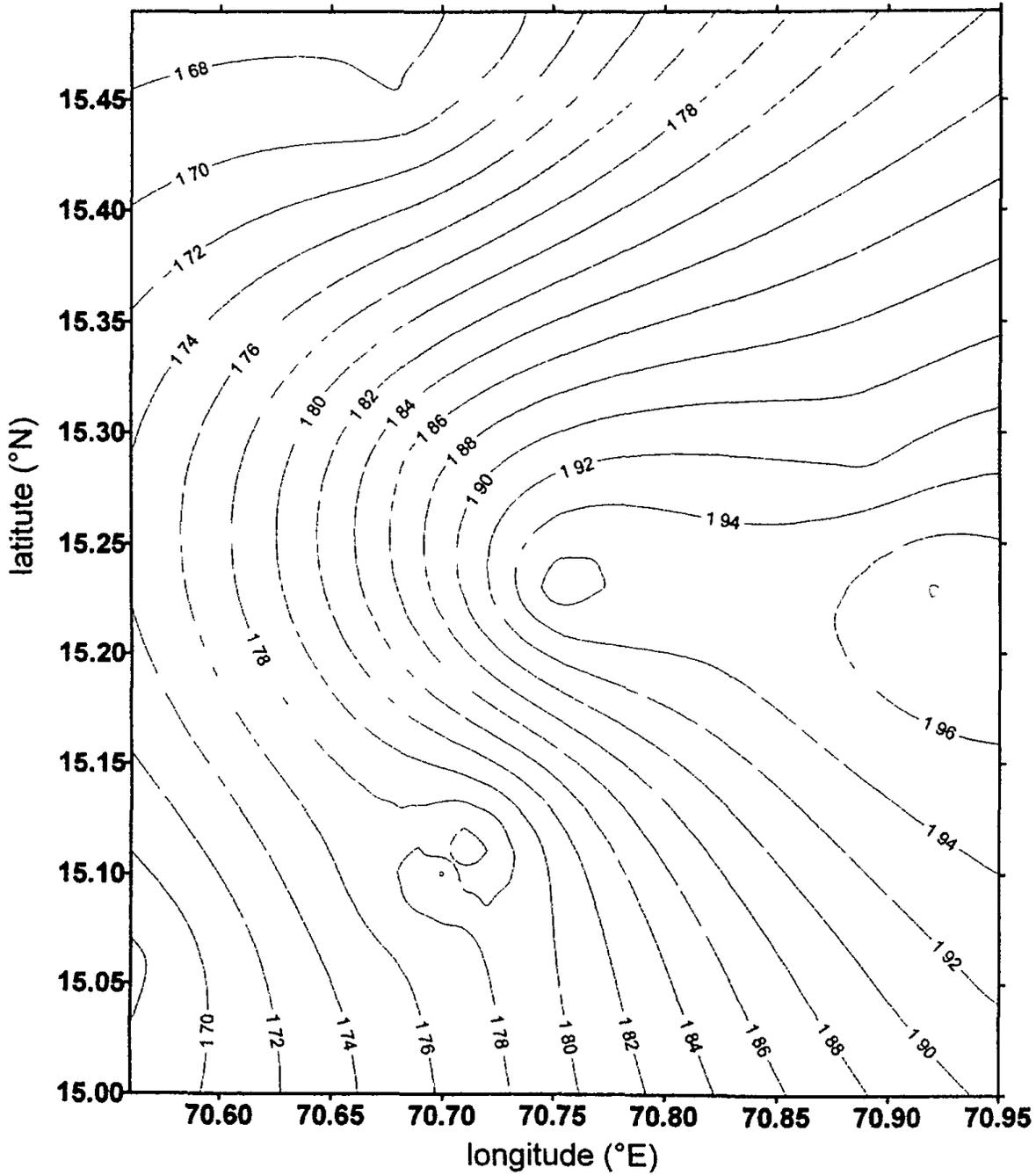


FIG. 36

AASGH2
(Salinity Contour at 50m depth)

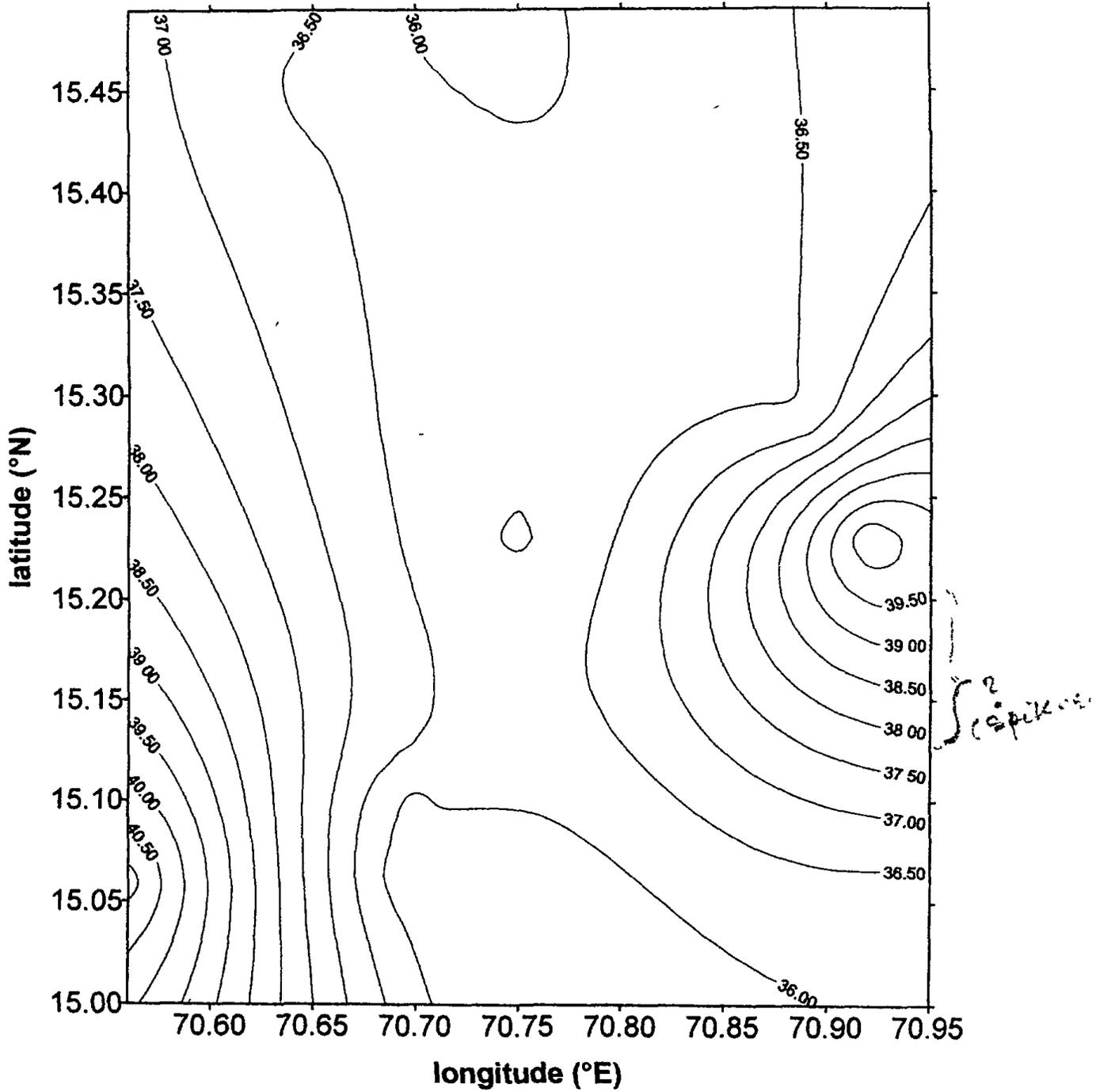


FIG. 37

AASGH2
(Salinity contour at 100m depth)

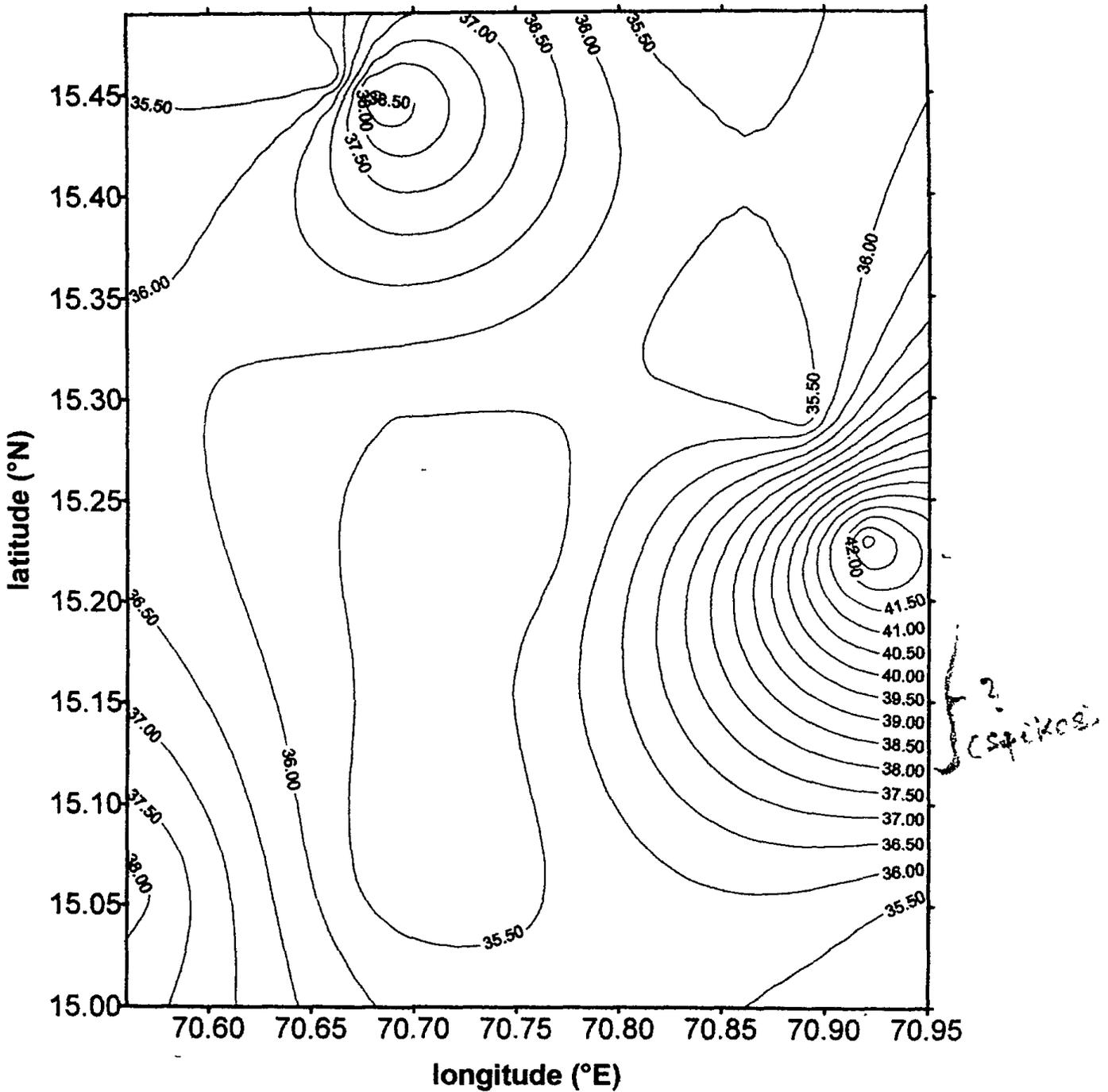


FIG. 38

AASGH2
(Salinity contour at 200m depth)

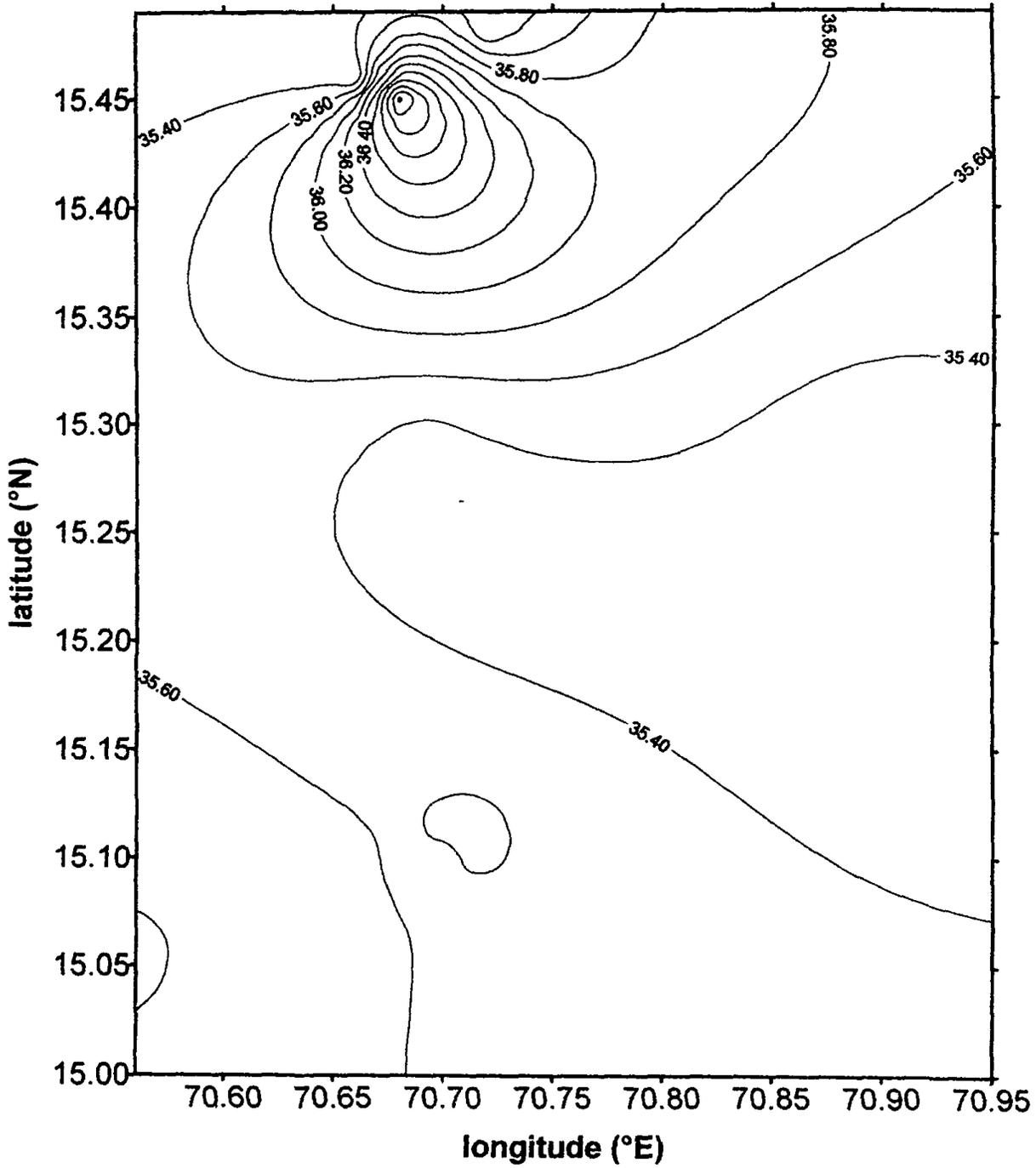


FIG. 39

AASGH2
(Salinity contour at 2600m depth)

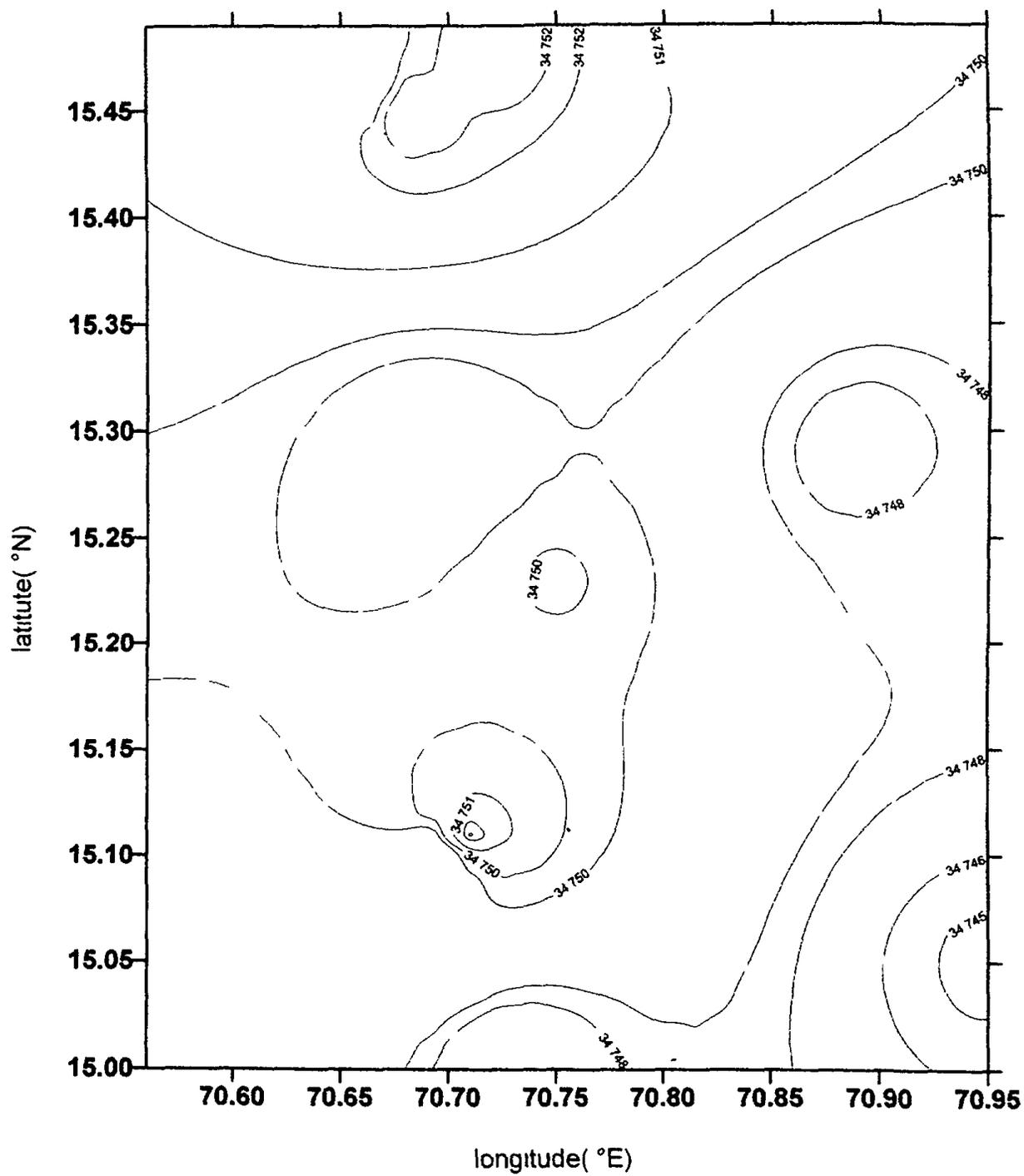


FIG.40

AASGH2
(Salinity contour at 2900m depth)

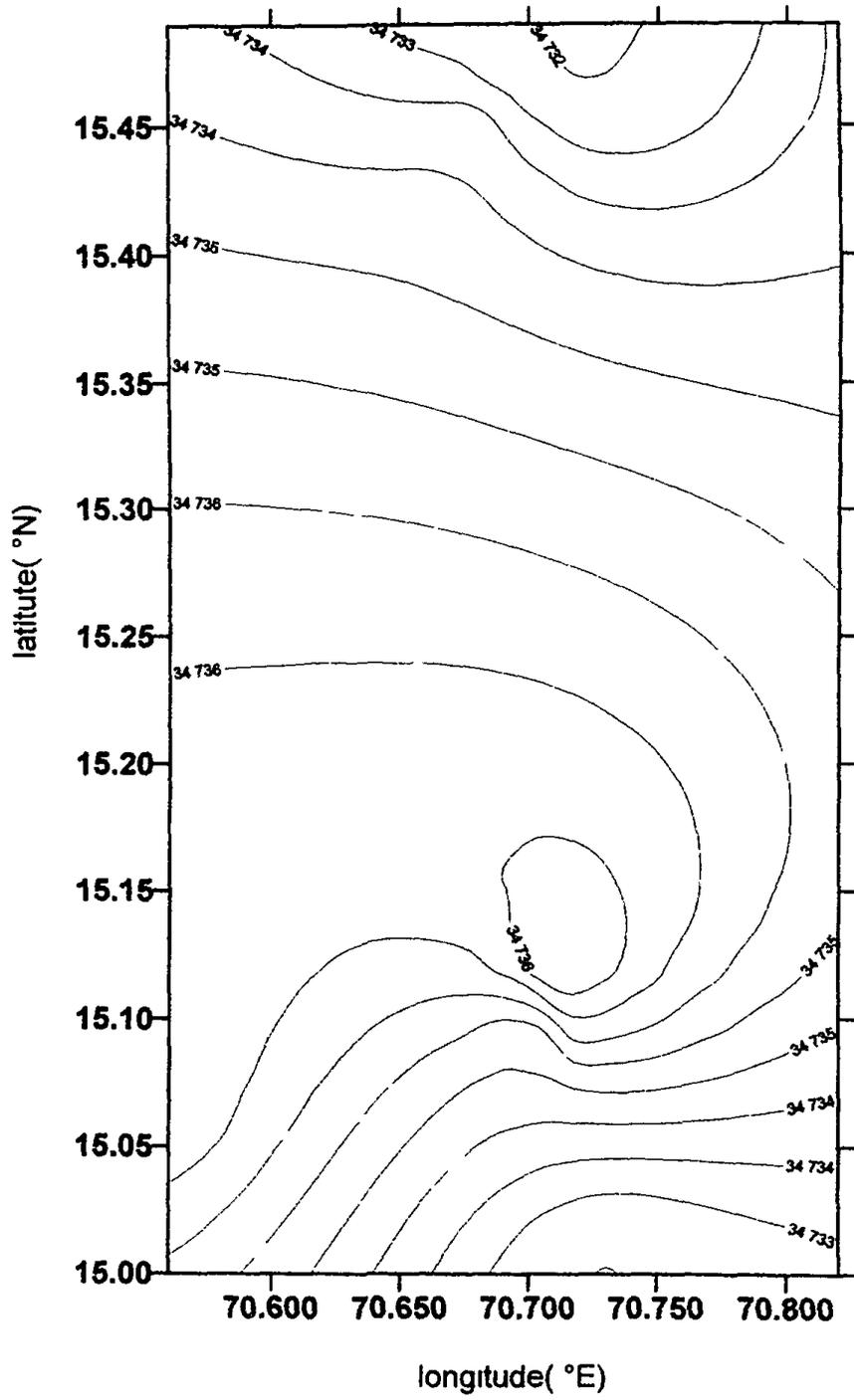


FIG. 41

aasgh2
(Salinity contour at seabed)

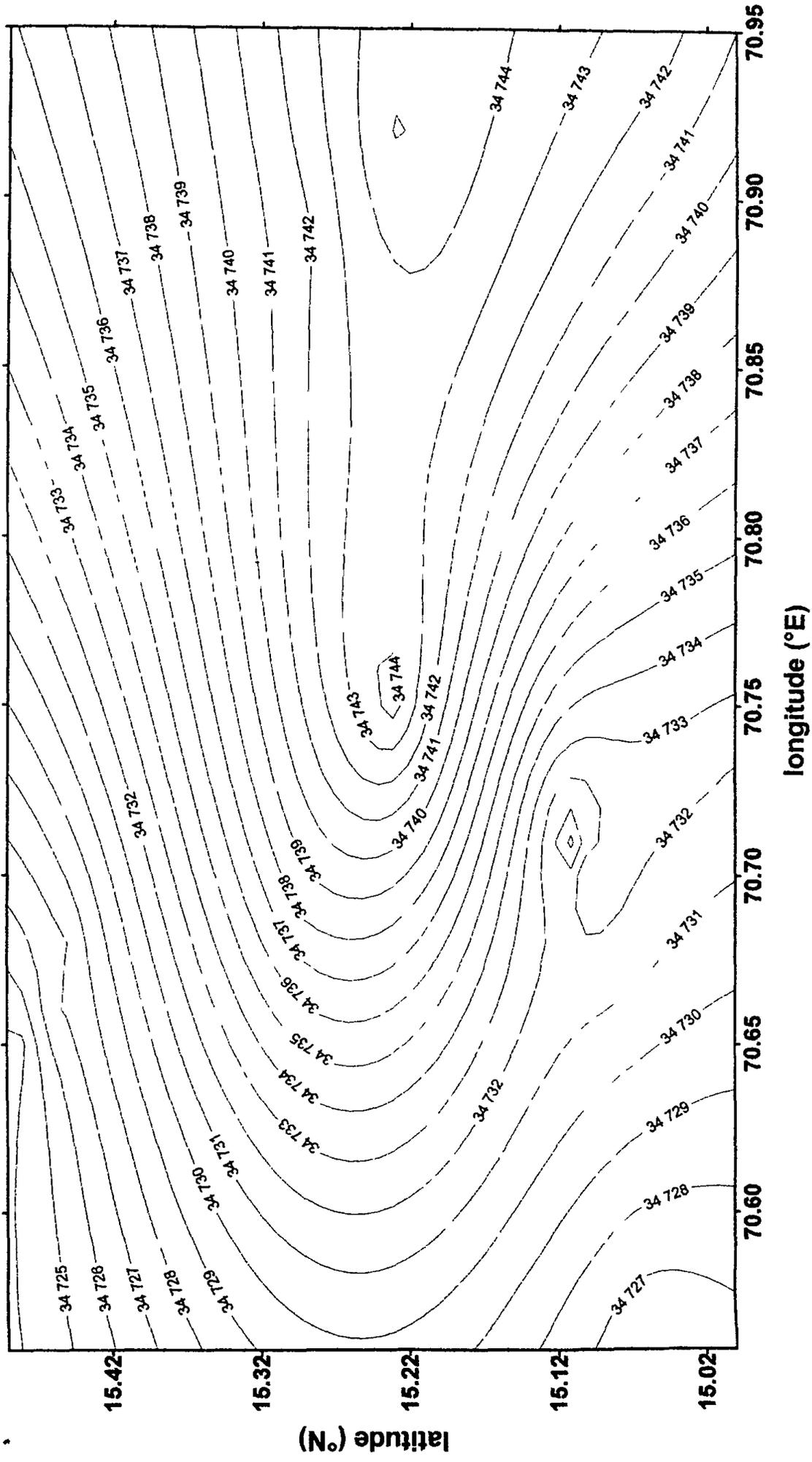


FIG.42

AASGH2
(Dissolved oxygen contour at 50m depth)

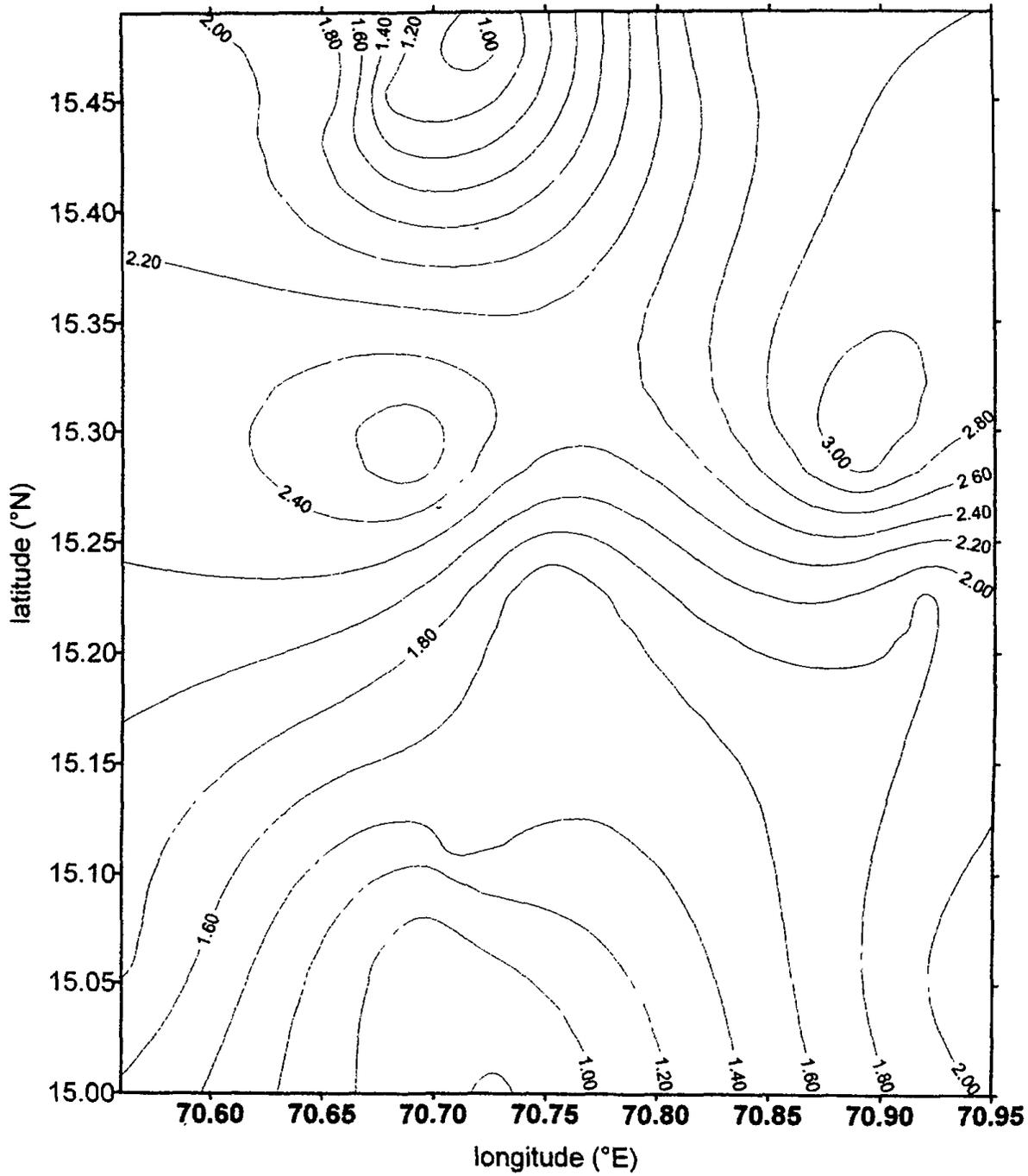


FIG.43

AASGH2
(Dissolved Oxygen at 100m depth)

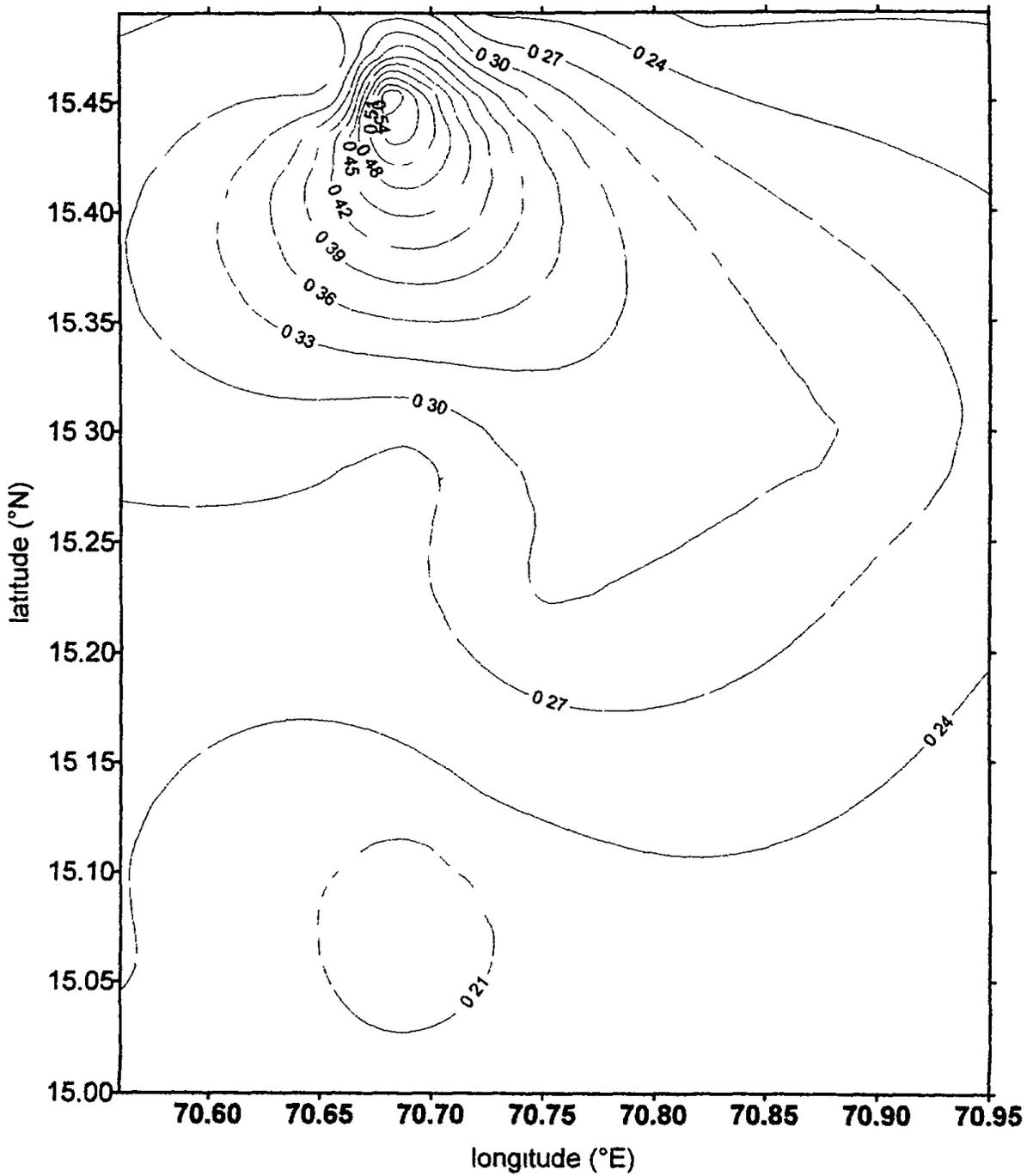


FIG.44

AASGH2
(Dissolved oxygen contour at 200m depth)

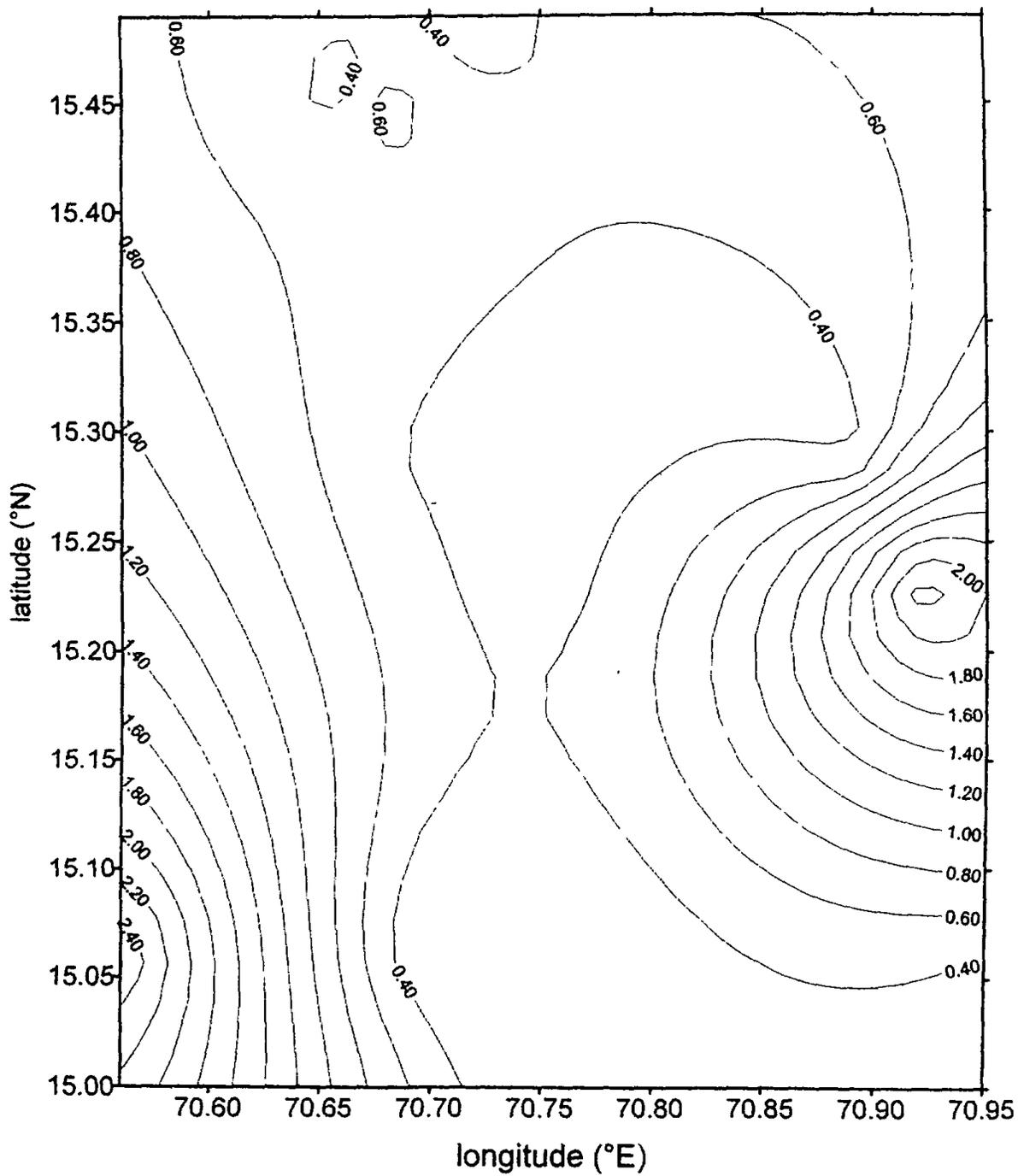


FIG.45

AASGH2
(Dissolved Oxygen contour at 2600m depth)

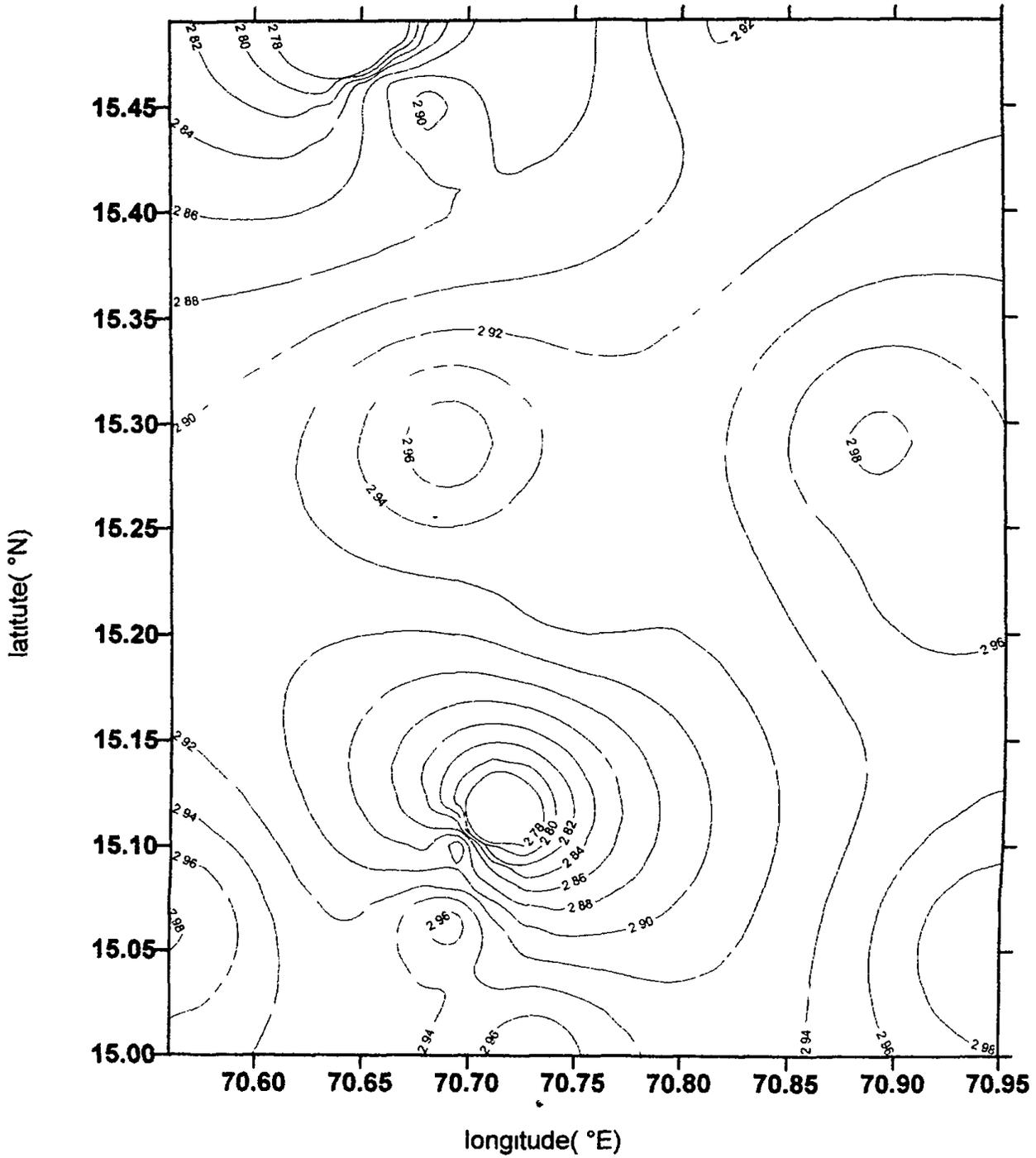


FIG. 46

AASGH2
(Oxygen contour at 2900m depth)

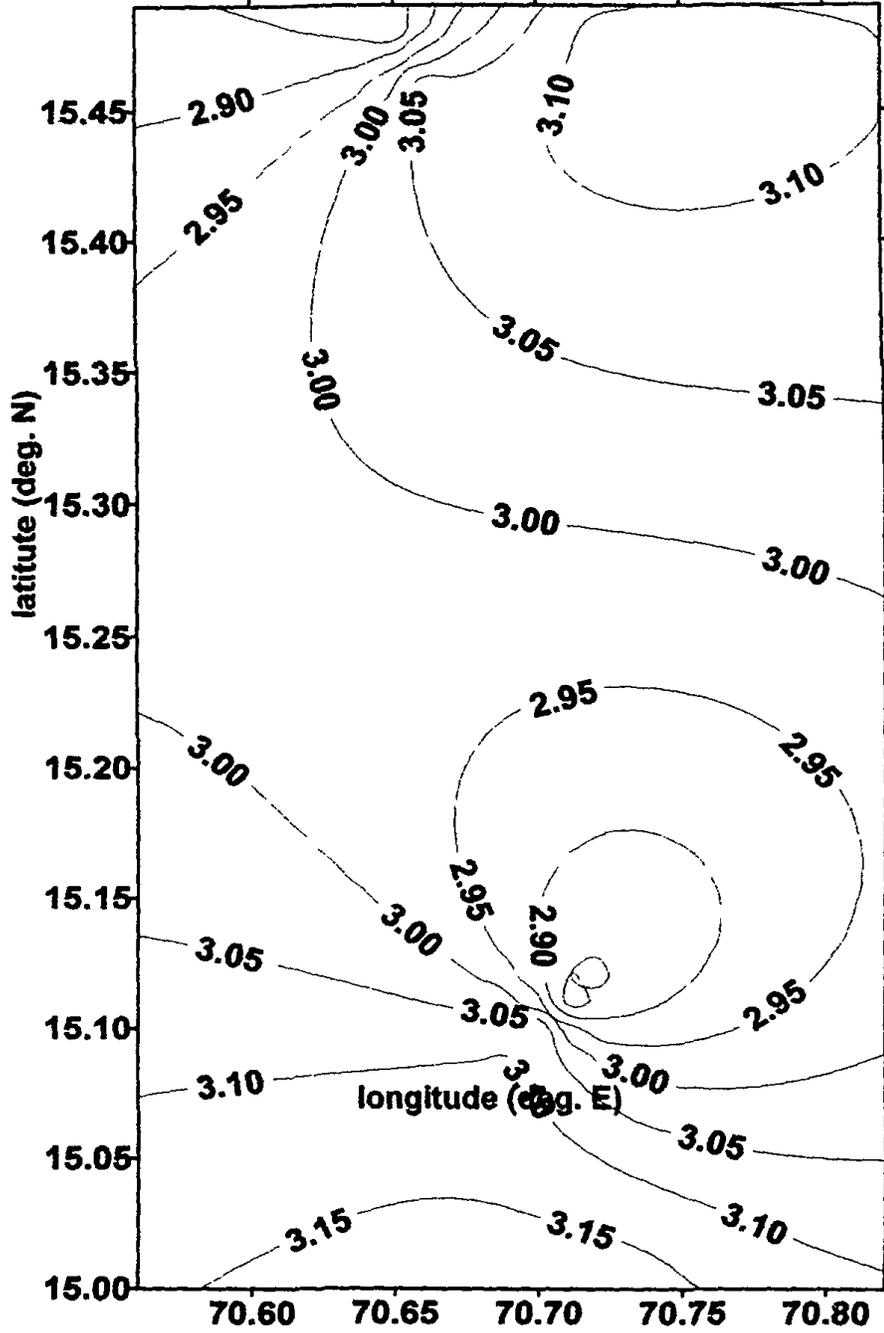


FIG. 47

AASGH2
(Dissolved oxygen countour at seabed)

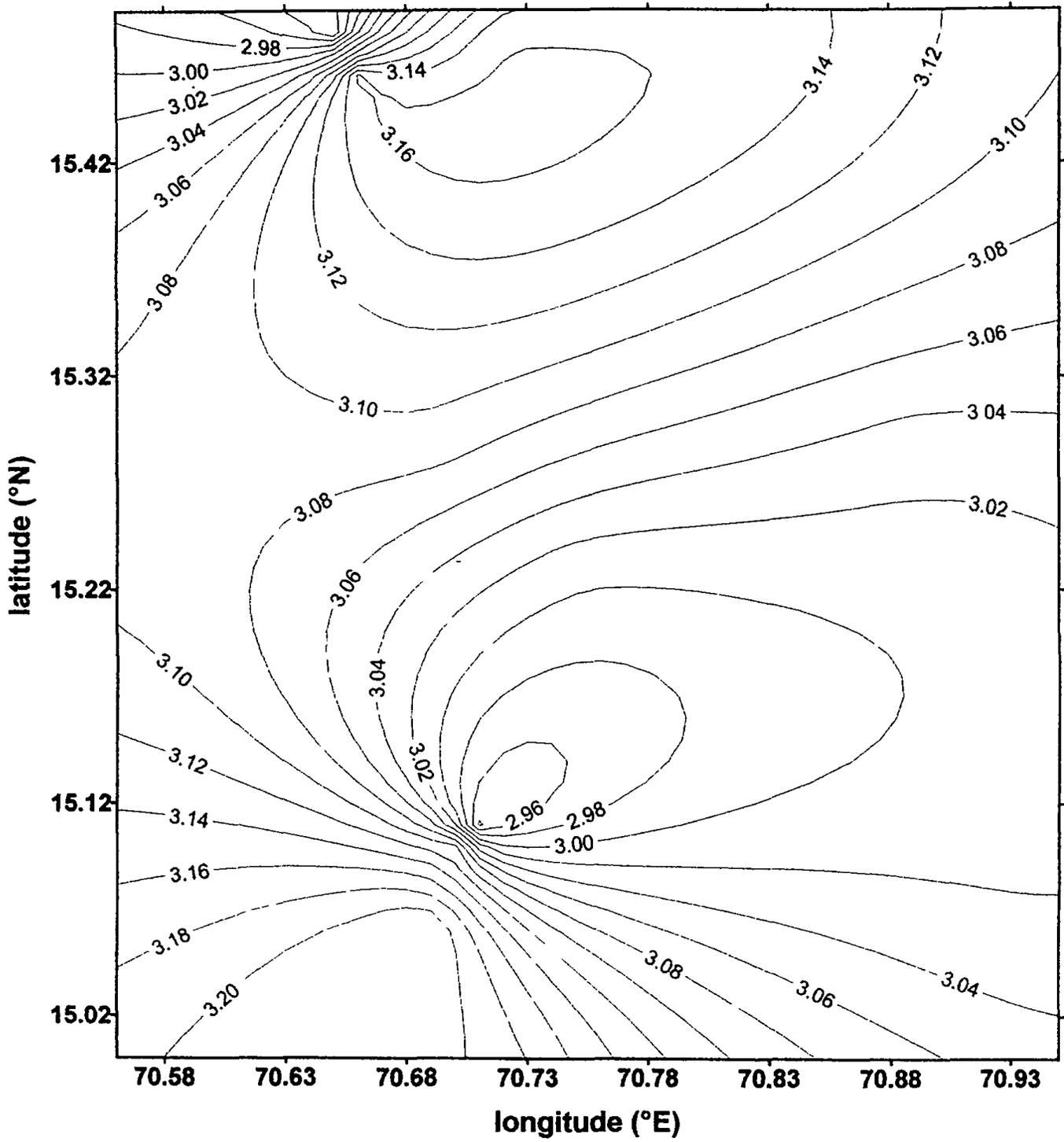


FIG. 48

