夏季 大韓海峽 西水道에 流入되는 Tsushima暖流水의 紀元－2 中層水에 對한 考察

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In Summer, the Origin of Tsushima Warm Current Water in the Western Channel of the Korea Strait－2 on the Water in the Middle Layer

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Contents

Abstract

It was found that three different water masses were vertically situated in the western channel of the Korea Strait in summer. Of these water masses, the origin and inflow path of the middle water were discussed and estimated by comparing with water characteristic of neighbouring sea. As a result, (1) the middle water is formed on the continental shelf in the East China Sea by the mixing of the Kuroshio Water and Chinese Continental Coastal Water, (2) the middle water seems intruded through the sea around 127° E west off Kyushu Island and east off Cheju the Island.

夏季 대한 해협 서수도에는 鉛直的으로 특성이 서로 다른 세개의 水塊가 존재한다. 그 중 中層水에 대하여 인접 해역의 해수 特性과 상호 비교함으로써 그 기원과 유로를 推定하였다. 그 結果, (1) 중층수는 동지나

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해의 대륙붕 상에서 形成된 Kuroshio수와 중국 대륙 연안수와의 混合水인 것으로 나타났다. (2) 중층수는 Kyushu Island의 서쪽 해역, 경도 약 127°E 부근 해역과 제주도와 Goto Islands의 사이 해역을 거쳐 流入된 것으로 나타났다.

1. Introduction

It is known that the Tsushima Warm Current is mixing with the Chinese Continental Water (hereinafter"CCCW") extended into the East China Sea while going up north after branches off the Kuroshio and enters the Japan Sea through the sea between Cheju and Goto Islands, and the eastern and western channel of the Korea Strait (Kondo, 1985). This expression is very rough but contains the essential features concerning the origin and moving path of the Tsushima Warm Current.

Of the Tsushima Warm Current regions, the western channel of the Korea Strait(hereinafter "western channel"), which is about 26 miles wide and has maximum depth of about 227m, shows very complicated hydrographic conditions with various water masses existing such as the Tsushima Warm Current Water, the Korean Coastal Water and the North Korean Cold Current Water etc.

As to the Tsushima Warm Current Water in the western channel in summer, Miyazaki and Abe(1960) reported that waters could be classified into 2 layers by sigma-t 25.20kg/m^3, among which the lower water was the Western North Pacific Central Water defined by Sverdrup et al (1942) with T−S analysis. Lim(1971), however, presented a different description that Tsushima Warm Current was composed of the surface water only which formed on the margional region of the continental shelf in the East China Sea by the mixing of the Kuroshio Water and the East China Sea Water. This discrepancy seems to be raised by the difference of study area selected and analyzing methods employed for their own study.

The above two authors compared T−S relations of both eastern and western channel to find out which water masses in the western channel in summer correspond to the Tsushima Warm Current Water, but Lim and Chang(1969) suggested that three water masses with different characteristics were vertically situated in the western channel in summer.

As it would be thought better to analyze the water masses in the western channel separately for this study, the characteristics of water masses will be identified and the origin and inflow path of middle water will be discussed and estimated by comparing the water properties distribution of the western channel and neighbouring sea in summer in this paper.

2. Materials and Methods

Summertime data of the annual report of oceanographic observations(1976−1988) and mean oceanographic charts of the adjacent seas of Korea(1986) by Fisheries Research and Development Agency of Korea and the annual report of oceanographic meteorological observations(1976−1985) by Japanese Meteorological Agency were used for this study.

Vertical profiles of temperature, salinity, density and dissolved oxygen in the western channel in summer were constructed to identify characteristics of water masses. Of various methods and procedures employable in the course of present study, the station graphs proposed by Montgomery(1954) were used to easily compare the vertical distribution of temperature, salinity and oxyty at 8 different stations marked in Fig. 1. At the same time, water properties distribution along sigma-t 25.30kg／m^3 (see the text) surface was introduced to estimate the inflow path and origin of middle water in western channel in summer.

In this analysis, all data used are average value of temperature, salinity and dissolved oxygen against the depth.

3. Results

3. 1. Vertical profiles in western channel

Fig. 2 is showing the vertical distribution of temperature, salinity, density and oxyty. It was constructed to identify the configuration and characteristics of water masses in the western channel in summer.

From the distribution of temperature in Fig. 2 (a), we can find two discontinuity layers, while only one discontinuity layer at about 10－50m from the salinity distribution in Fig. 2(b). In Fig. 2 (d), one can note that the vertical structure of oxyty distribution is different from that of other sections, that is to say, the oxyty section shows a vertical extreme which can not be seen in termperature, salinity and density sections as oxyty minimum layer(less 4.4ml／l) is found at the depth of 100－170m. From this fact, a question may be arisen that the existence of oxyty minimum layer is caused whether by low oxyty water intruded at the depth of about 125m, or by relatively high oxyty water(more 4.6ml／l) intruded in the bottom from elsewhere.

Fig. 3 is bi-monthly T－S curves for station T and shows that T－S relation under sigma-t 25.30 kg／m^3 seems to have almost constant properties from June through December.

From T－S diagram (Fig. 4) in which all oceanographic data of 205 and 206－line in summer by the Fisheries Research and Development of Korea during 13 years(1975－1987) were plotted, we can see that no heavier waters than sigma－t 26.00kg／m^3 have ever appeared in the Korea Southern Sea.

The above facts reveals that three different water masses are vertically distributed in western channel such as furface, middle and lower water as suggested by Lim and Chang(1969). Since the middle water is characterized by low oxyty water, it is thought no matter to choose sigma－t 25.30 kg／m^3, density of the lowest oxyty core(see Fig. 2(d)), in analyzing middle water.

3. 2. Station graphs at selected stations

Fig. 5 shows the vertical distribution of temperature, salinity and oxyty at 8 selected stations.

Station K and A are situated at the east of continental slope in the East China Sea, and their properties at 200m are 20.1℃, 34.8‰ and 14.6℃, 34.6‰, respectively which correspond to the Kuroshio Water(Nitani, 1972). Salinity maximum is found between sigma－t 24.00 and 25.00kg／m^3 approximately and waters under salinity maximum belong to Western North Pacific Central Water define by Sverdrup et al(1942). Water properties at these stations at sigma－t 25.30kg／m^3 are 2℃ warmer in temperature, 0.4－0.6 ‰ more in salinity and 0.3ml／l less in oxyty than those of the western channel. Staion B and C are situated on the continental shelf and waters at these stations correspond to CCCW. A very sharp thermocline at the depth of 10－30m is formed and bottom layer is composed of relatively cold(13－16℃) and less saline(33.5－33.6‰) water which was called the Central Bottom Water by Fukase(1975). No heavier water than sigma－t 24.70kg／m^3 exists at Station B and water properties at Station C at sigma－t 25.30kg／m^3 are 4℃

lower in temperature, 0.7‰ less in salinity and 0.4ml/l more in oxyty than those of western channel. Staion D and E are situated in the Cheju Strait and Korea Southern Sea, respectively. Water properties of Station. D are 4℃ lower in temperature, 0.5‰ less in salinity and 0.4ml/l more in oxyty than those of the western channel, but those of Station E show almost same as the western channel at sigma−t 25.30kg/m^3. Station F is situated at the Korea south−eastern sea and its water properties at sigma−t 25.30kg/m^3 are 2℃ lower in temperature, 0.2‰ less in salinity and 0.7ml/l more in oxyty than those of the western channel.

3. 3 Horizontal distribution along sigma−t 25.30kg/m^3 surface

Fig. 6(a) and (b) show temperature and salinity along sigma−t 25.30kg/m^3 surface and Fig. 6(c) shows the depth of the surface where sigma−t equals 25.30kg/m^3.

15−16℃ waters are distributed in the sea around 127° E west off Kyushu island, east off the Cheju island and most of the western channel, while 14−15℃ waters are distributed south and west off Cheju island, Cheju Strait and near−Korean coast of the western channel as shown in Fig. 6(a).

In Fig. 6(b), 34.0−34.2‰ waters are distributed in the sea south off Cheju Island, east off near−Cheju Island and most of the western channel, while 34.2−34.4‰ waters are distributed in the sea between the Cheju and Goto Islands and near−Tsushima coast.

The depth of sigma−t 25.30kg/m^3 shows to become shallower as going up north. Depth of south off Cheju island and Korea Southern Sea ranges from 50 to 100m and that of western channel does from 45 to 120m. Isopleths of depth in Korea Southern Sea, western channel and Korea south−eastern sea seem nearly parallel to Korean coast (Fig. 6(c)).

4. Discussions and Conclusion

4. 1. Characteristics of water masses in the western channel

Three water masses in the western channel in summer can be distiguished such as surface, middle and lower water. Of those water masses, we take in Fig. 2 and 4 that surface and middle water belong to the Tsushima Warm Current Water, lower water is intruded from the Japan Sea as described by Lim and Chang(1969), and middle water is characterized by relatively saline and low oxyty water and shows almost constant throughout the year with little changes in properties(Fig. 2 and 3).

4. 2. The origin and inflow path of the middle water

It can be seen that the Kuroshio Water in the middle of the East China Sea become to change slightly in properties as going up north and shows warmer in teperature, more in salinity and less in oxyty than waters in western channel, and CCCW on the continental shelf shows lower in temperature, less in salinity and more in oxyty. On the other hand, waters in Korea Southern Sea have almost the same properties as in the western channel (Fig. 5). From these facts, it is taken that middle water in western channel is formed in the East China Sea by the mixing of the Kuroshio Water and CCCW. In Fig. 7, all average value of the East China Sea and western channel used for this study were plotted in a T−S diagram. Two thick curves represent the approximate Kuroshio Water and CCCW, and also water distribution range of the western channel was drawn in the same diagram by dotted line. By the mixing ratio along sigma-t 25.30kg/m^3, middle water in the western channel is supposed to be composed of 50−70% of the Kuroshio Water and the rest of CCCW.

Fig. 8 is T−S diagram of 5 selected stations and the shaded area represents Western North Pacific Central Water defined by Sverdrup et al (1942) between 10 and 16℃ in temperature. Though waters between the depth of 150 and 200 m in the western channel shows within the shaded area, its oxyty is 0.5ml/l more than that of the Western North Pacific Central Water present at the Kuroshio region(Fig. 5). Thus, it is thought that Western North Pacific Central Water would not flow into the western channel directly against Miyazaki and Abe's suggestion.

4. 3. Conclusion

In summer, the Tsushima Warm Current Water appears in the western channel can be classified as warm and less saline surface water, and relatively saline and low oxyty middle water which shows nearly consistent in properties throughout the year. Middle water is not the Western North Pacific Central Water as Miyazaki and Abe(1960) suggested but the mixed water between the Kuroshio water and CCCW on the continental shelf in the East China Sea and seems intruded through the sea around 127° E west off the Kyushu Island and east off the Cheju Island.

Acknowledgement

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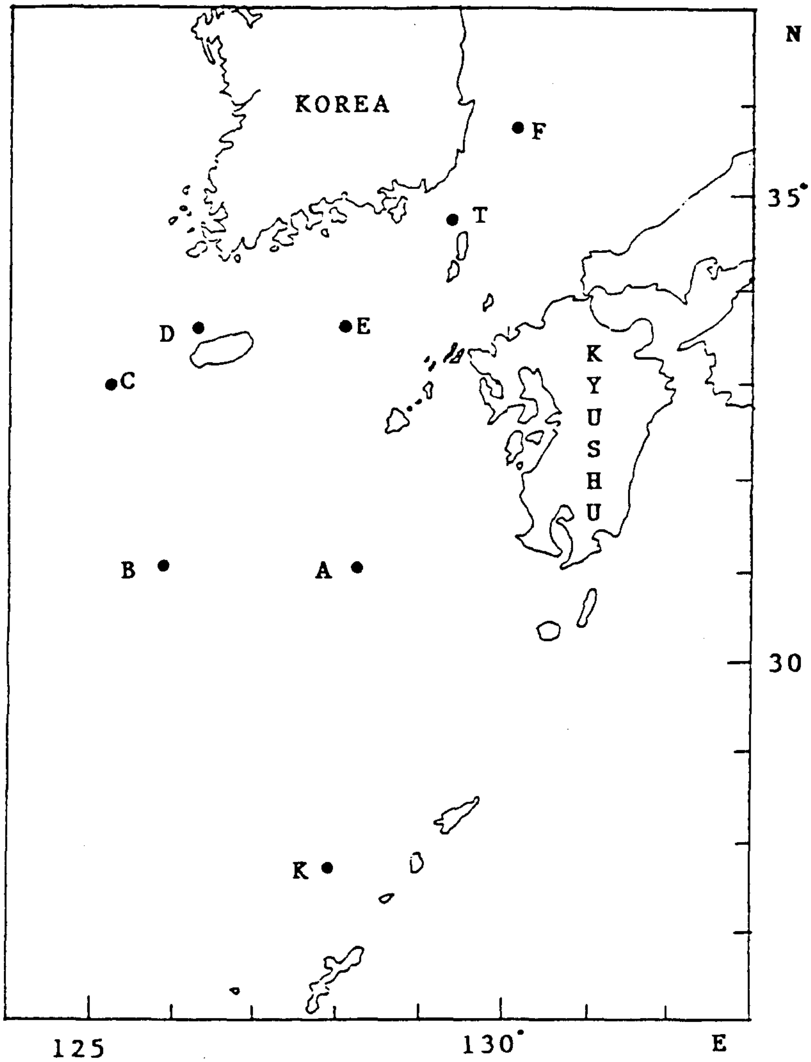


Fig. 1 Position of selected stations in the study area.

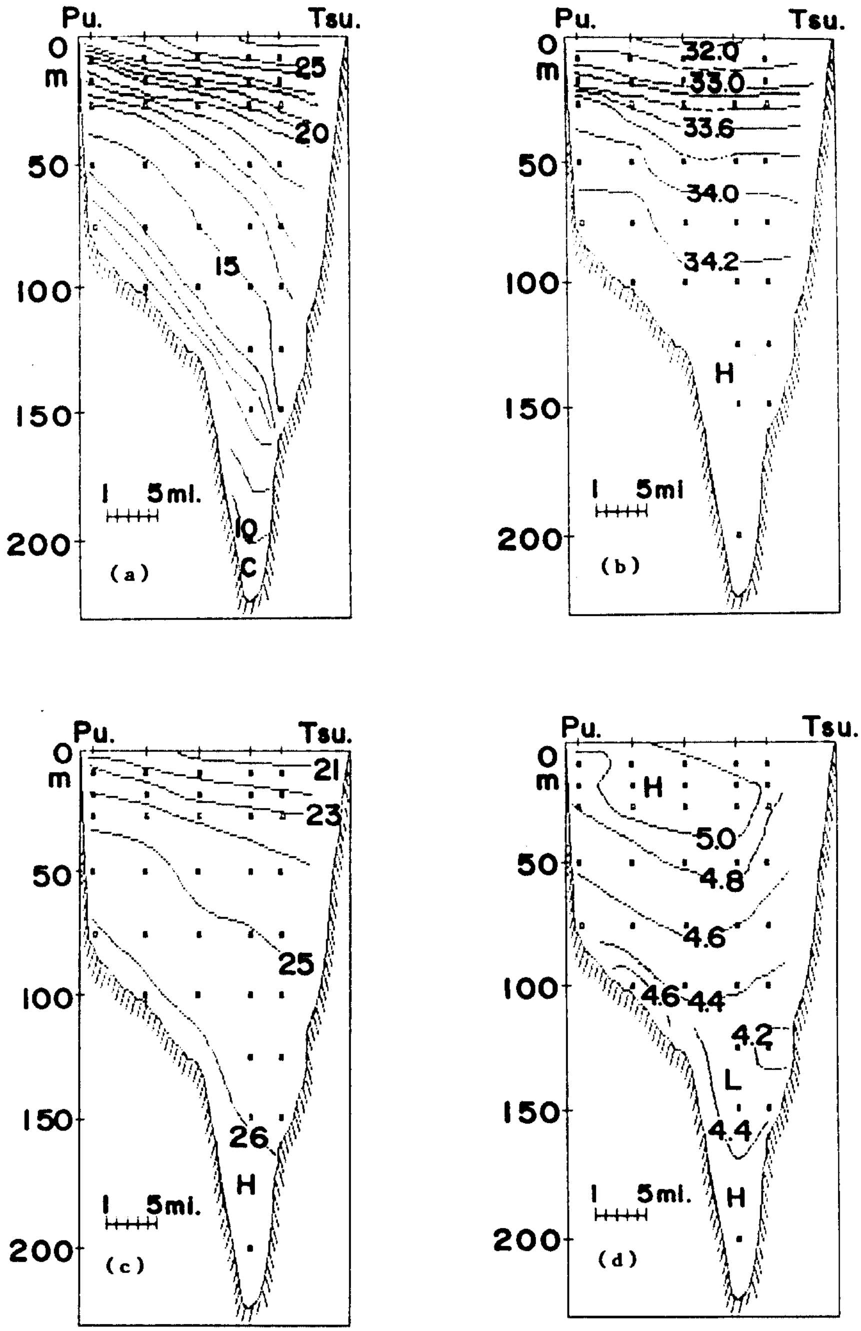


Fig. 2 Vertical sections of temperature(a), salinity (b), density(c) and oxyty(d) in the western channel. Temperature in ℃, salinity in ‰, density in kg/m^3, oxyty in ml/l and depth in meter.

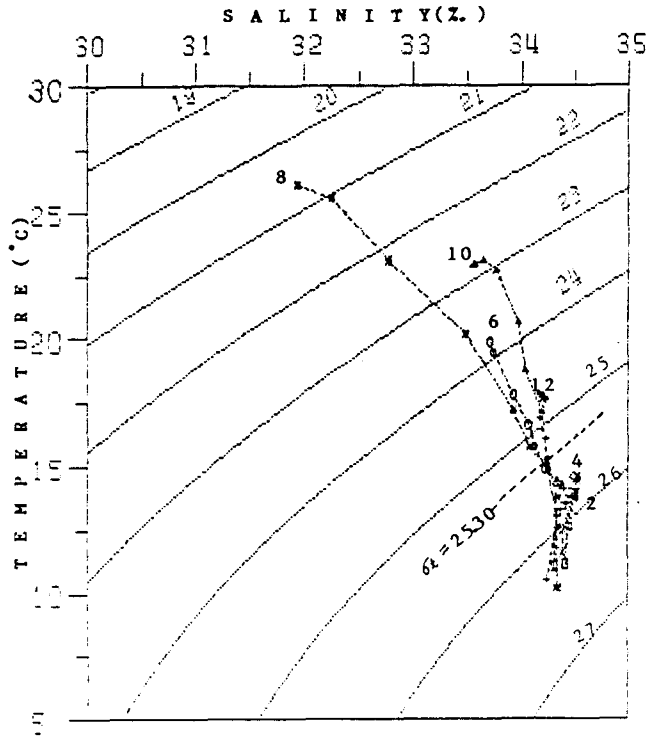


Fig. 3 Bi-monthly T-S curves for station T.

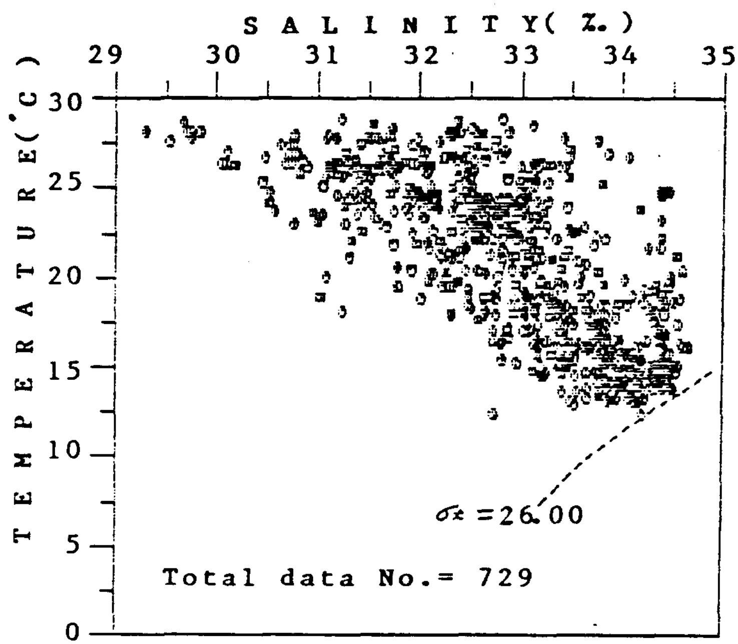
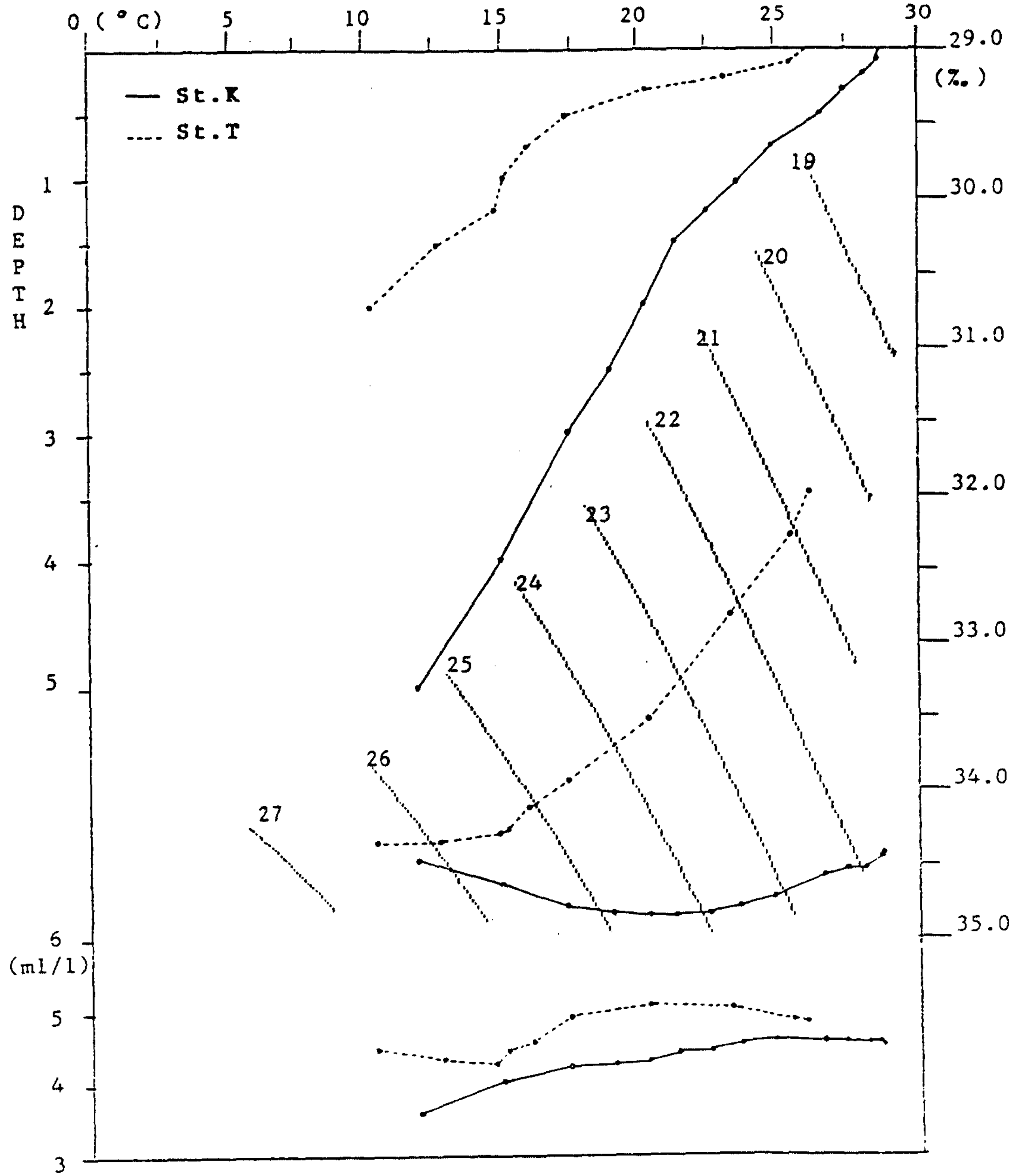


Fig. 4 T-S diagram for 205 and 206-line in summer during 13 years(1975-1987).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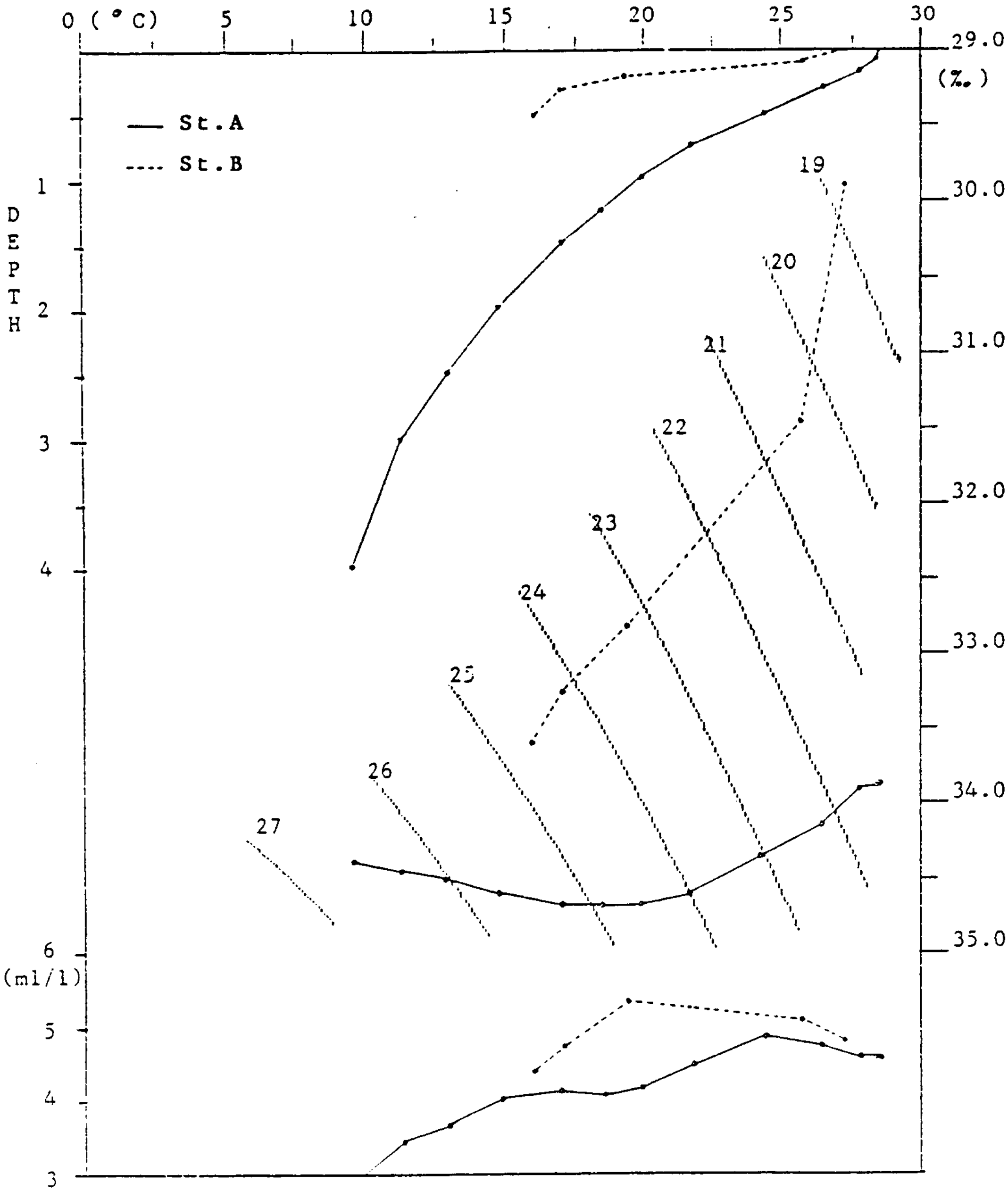
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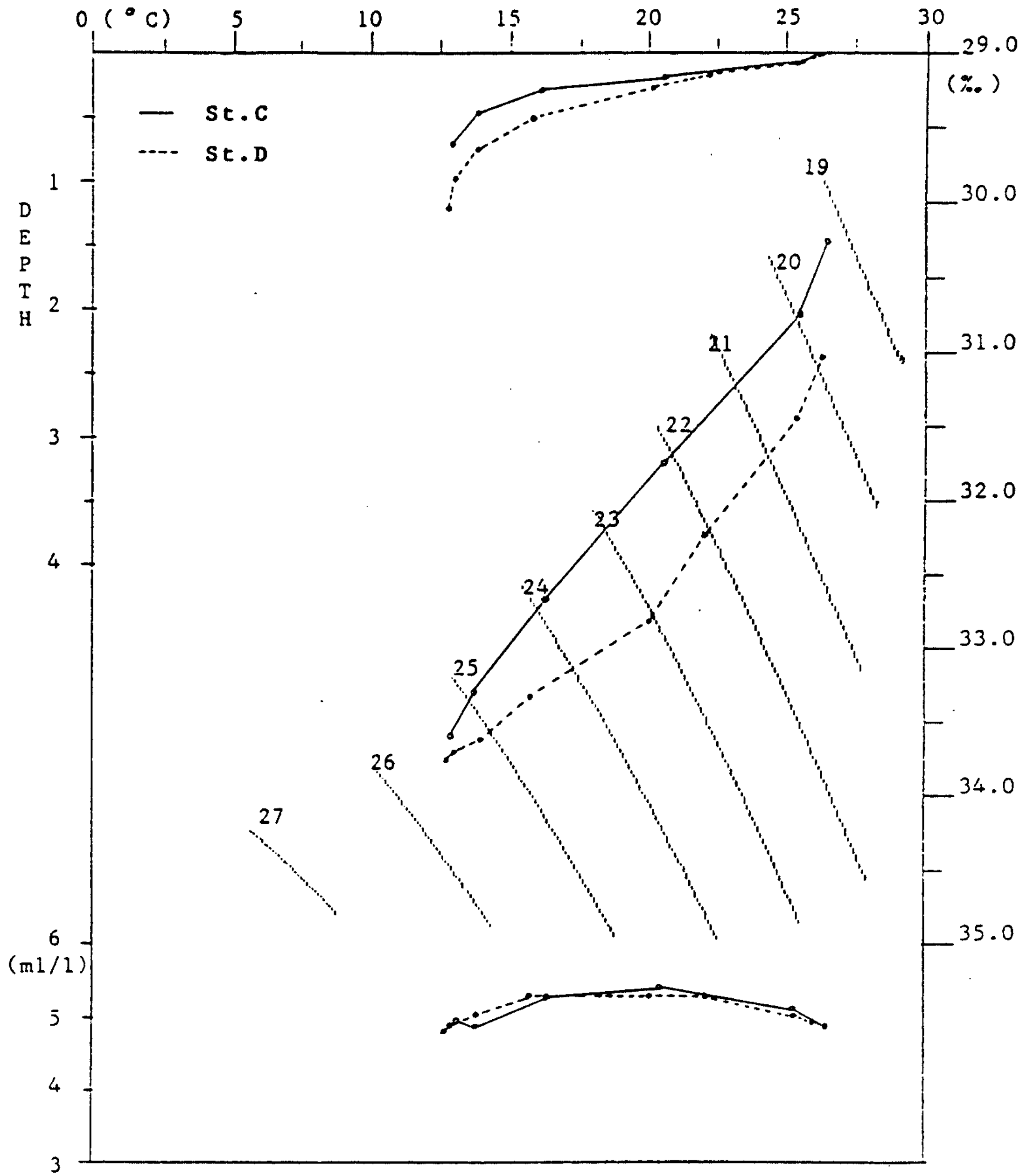
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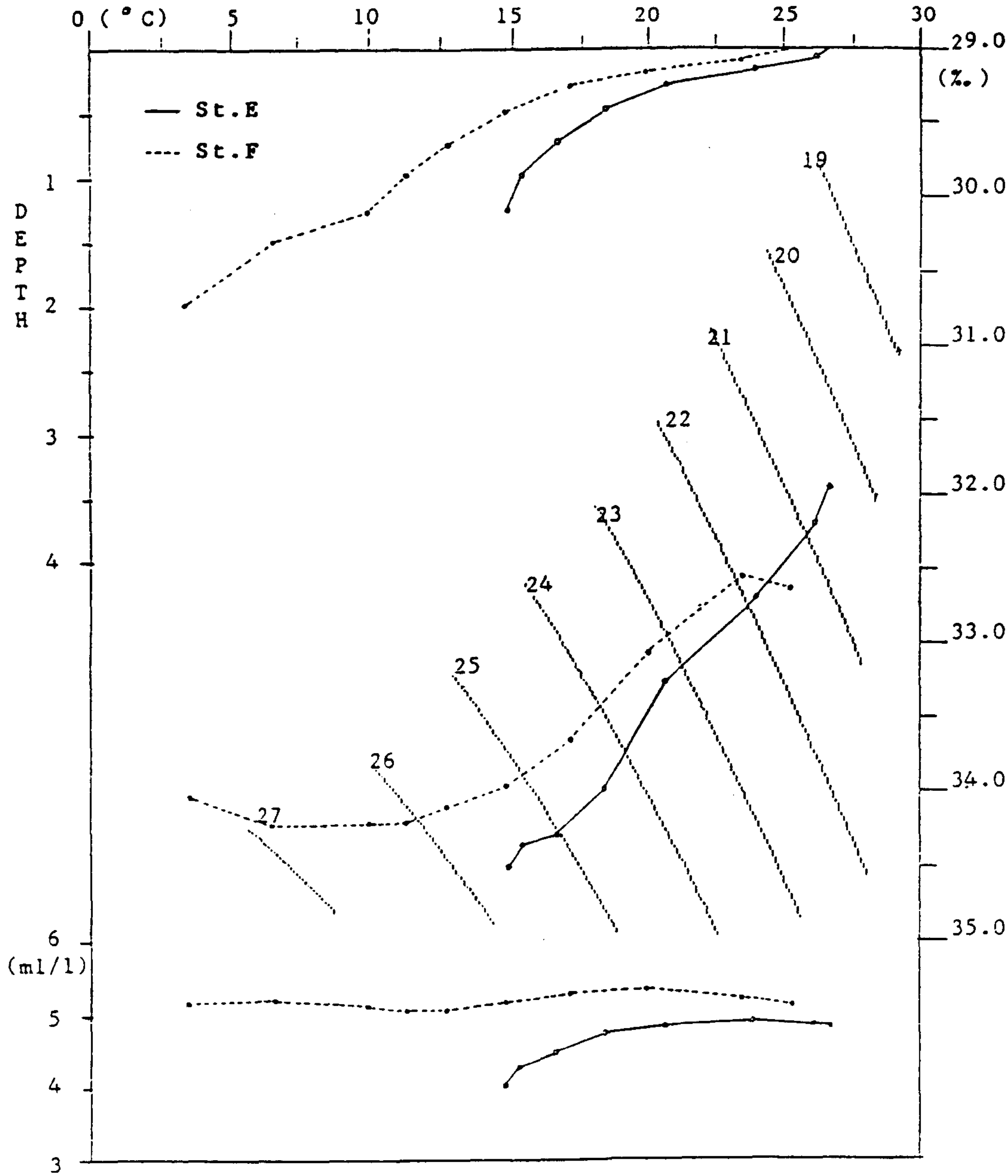

Fig. 5 Station graphs at 8 selected stations. Depth (hectometer), oxyty and salinity are plotted as abscissa for the common ordinate of temperature. The family of straight lines along T−S curve represent density in kg／m³.

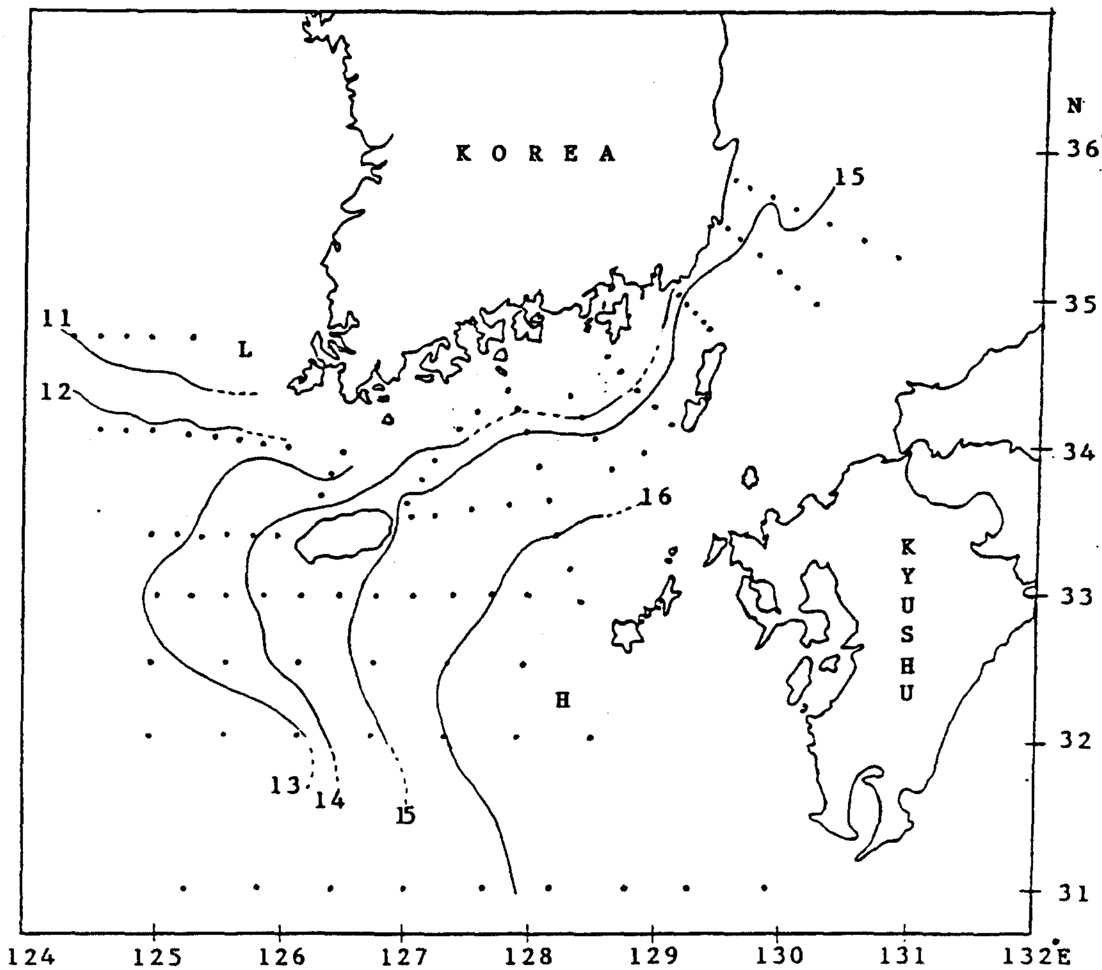

Fig. 6(a) Temperature(℃) where sigma－t equals 25.30kg／m³.

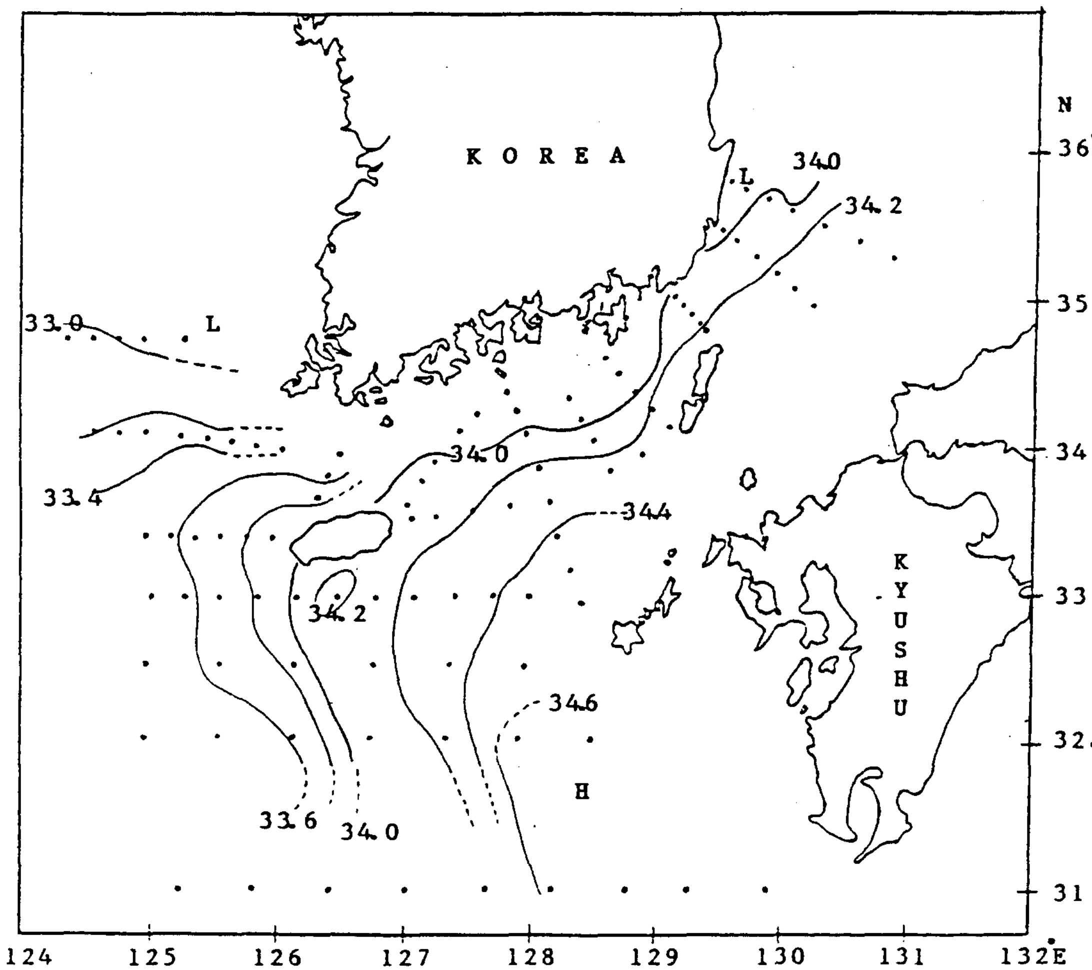

Fig. 6(b) Salinity(‰) where sigma−t equals 25.30 kg/m³.

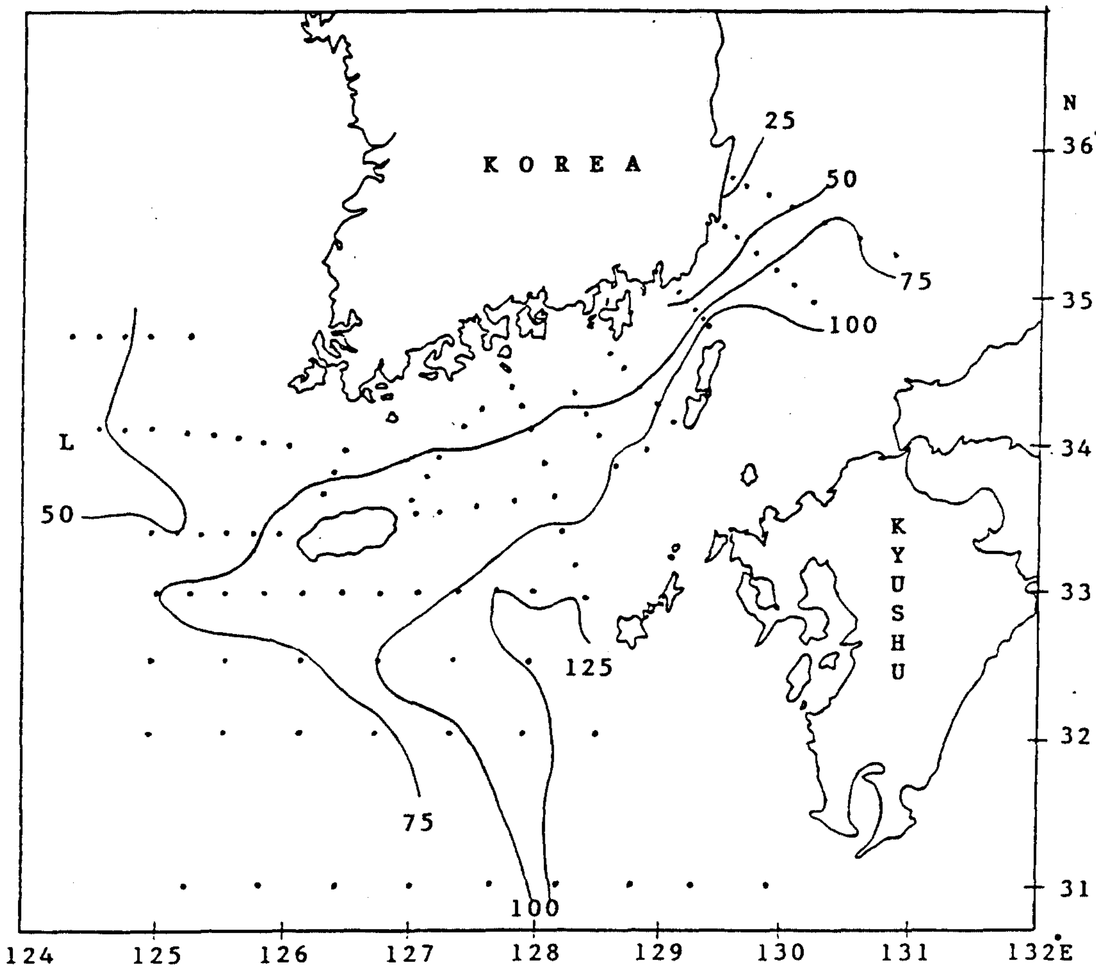

Fig. 6(c) Depth(meter) of the surface where sigma－t equals 25.30kg／m³.

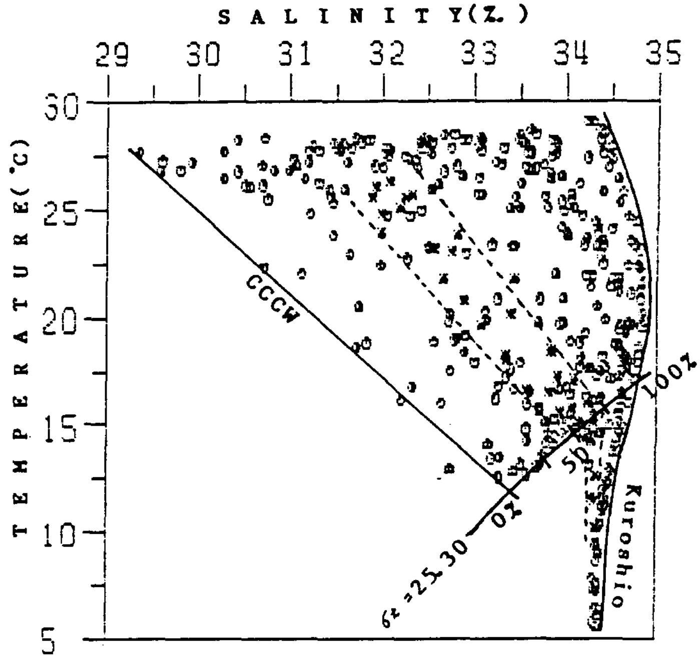

Fig. 7 T−S diagram for East China Sea(0) and western channel(*) in summer. Dotted line indicates approximate range of water property distribution in the western channel.

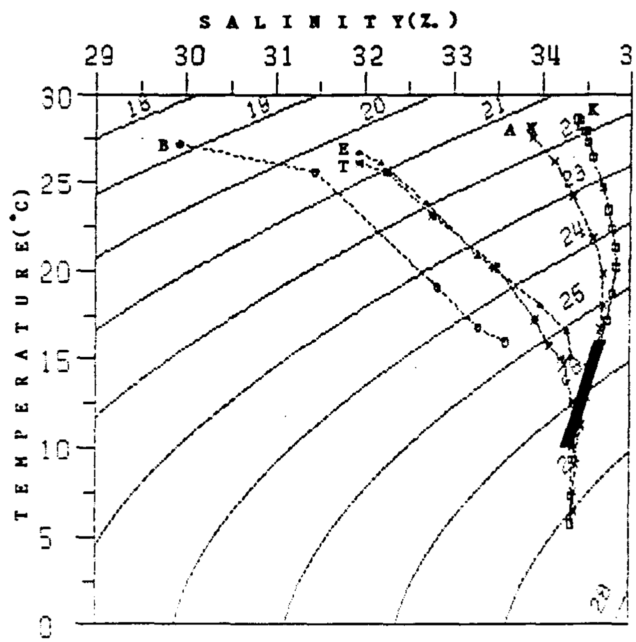

Fig. 8 T−S curves for 5 stations. The shaded area (between 10 and 160℃ in temperature.) indicates the Western North Pacific Central Water defined by Sverdrup et al (1942)