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Hydrographic observations, with particular reference to upwelling, off the coast of south west Africa in February 1966

by

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INTRODUCTION

During February 1966, HMS HYDRA made a combined fish echo sounding and hydrographic survey off the west coast of South Africa between the Cape coast and Walvis Bay. The hydrographic investigations consisted of a study of the process of upwelling as deduced from a detailed series of bathythermograph observations and the measurement of temperature, salinity, dissolved oxygen and nutrient salts on four sections normal to the coast. The results of the bathythermograph survey will be published elsewhere by N. Bang of the University of Cape Town. This paper presents data recorded on the hydrographic sections and also includes a survey of surface water temperature measured continuously over the echo sounding grid.

The region off south-west Africa is one of the major areas of upwelling. The phenomenon occurs in the prevailing north-going Benguela current and its locality and magnitude varies according to the season. During the summer months the south-east trade winds coincide with the greatest degree of upwelling along the southern portion of the coast off the Cape region. During winter, changes in the distribution of atmospheric pressure over the South Atlantic shift the area of trade winds and cause the region of active upwelling to move northwards (e.g. Walvis Bay). The establishment of a westerly wind regime over the Cape coast leads to a state of quiescence in this area. These seasonal variations have been demonstrated by various workers using temperature and salinity data (Hart and Currie 1960; Stander 1962, 1964 and Shannon 1966). Inorganic phosphate and dissolved oxygen data are mainly confined to the area north of the Orange River. Hart and Currie (1960) measured these parameters between the Orange River and Walvis Bay. Stander (1962) measured phosphate off Walvis Bay and Stander (1964) measured dissolved oxygen between the Orange River and 17°S. Published

data concerning the concentration of phosphate, nitrate, silicate and dissolved oxygen to the south of the Orange River are very sparse. For this reason most of the hydrographic observations made on the present survey were confined to this southern area.

RESULTS

The survey was made between 7 and 27 February 1966. The maximum degree of upwelling at that time of year would be expected to occur in the south of the survey area. Figure 1 shows that the strongest winds measured on hydrographic stations were off the Cape coast with speeds of up to 48-52 knots from a south-easterly direction. Winds were generally much lighter in strength and more variable in direction on the sections to the north, although a south-easterly gale was experienced when the ship was working off Luderitz Bay.

Distribution of sea surface temperature

A detailed evaluation of the degree of upwelling is only possible from a study of the vertical distribution of a variety of parameters. The temperature of the sea surface can, however, be of value in detecting the major cells of upwelling where the cold water reaches the surface. Figure 2 shows the distribution of surface temperature over the survey area between the Cape coast and Walvis Bay. Some anomalies occurred between the values depicted.

The lowest temperatures were recorded along the coast. Values below 12°C were observed south of St. Helena Bay, off the Orange River and off Luderitz Bay. The surface temperature rose to over 19°C offshore along the western edge of the survey grid. The low temperature off the Cape coast, coupled with the strong south-east wind, indicated active upwelling and a tongue of cold water extended offshore from the Cape coast in a north-westerly direction. The strong winds experienced off Luderitz Bay may have caused the active upwelling indicated by the low temperature of the surface water. However, the low values recorded off the Orange River cannot be explained by the wind regime at the time of observation and will be discussed later.

Various workers have presented charts showing the distribution of surface temperature off the west coast of South Africa at different seasons. Shannon (1966) has demonstrated the presence of cold upwelled water along the Cape coast during January 1961, 1963 and 1964. He did not find the tongue of cold water projecting offshore so clearly marked as during the present survey. The survey by Hart and Currie (1960) during March 1950 showed a distribution of surface temperature off the Cape coast similar to that reported by Shannon

(1966). However, Hart and Currie have demonstrated tongues of upwelled water moving offshore at a variety of localities along the west coast of South Africa by means of surface temperature and other parameters. The distribution of surface isotherms off Luderitz Bay showed a considerable similarity between the present survey and that of Hart and Currie. Stander (1964) shows the distribution of surface temperature between the Orange River and Walvis Bay in January 1959, 1960 and 1961. On each occasion the lowest temperatures recorded were off Luderitz Bay. It would therefore appear that this area is subject to upwelling during January and is the exception to the generally quiescent state expected at these latitudes during the summer.

Results of the hydrographic sections

Cape section

Strong south-east winds were experienced on this section and all parameters clearly showed active upwelling (Figure 3), which was particularly reflected in the high concentration of nutrient salts found throughout the water column at the inshore end of the section.

St. Helena Bay section

Winds were light and southerly during this section and all parameters indicated upwelling (Figure 4), particularly at the edge of the shelf (Figure 4). Nutrient salts were low in the 0-25 metre layer along the whole section however and it is possible that upwelling had been active earlier but was now quiescent. Phytoplankton production had removed the nutrients brought to the surface by the earlier activity. The sinking and decay of plankton may have led to regeneration of nutrient salts in the bottom layer. Evidence for this is provided by the relatively high concentration of nutrient salts and low dissolved oxygen content found near the bottom at station 44.

Roodewall Bay section

Winds were light and variable during this section, yet all parameters showed some evidence of upwelling (Figure 5). The low concentration of nutrient salts in the 0-25 metre layer, coupled with the high values near the bottom, suggest a quiescent state of upwelling similar to that observed off St. Helena Bay. The relatively low salinity on the surface at the inshore end of the Roodewall Bay section probably represented water that had upwelled along the coast and then moved seawards.

Orange River section

Light winds, mainly from a southerly direction, were recorded on this section. The parameters showed only slight evidence of upwelling (Figure 6). The low concentration of nutrient salts at the surface, coupled with high values near the bottom, indicated a quiescent state. The low salinity and high concentration of silicate in the surface water at the inshore station was probably caused by freshwater run-off from the Orange River. The discrepancy between the inshore temperature of 12°C recorded on the surface temperature survey (Figure 2), and the surface value of 17°C in Figure 6, resulted from the thermograph sensing head being at a depth of approximately 2 metres, and hence in the cold upwelled water, whereas the reversing bottle was in the warmer surface water.

DISCUSSION

The present investigation has demonstrated a south to north diminution in the degree of upwelling between the four sections. It is probable that the process was only active off the Cape coast at the time of observation and that a state of quiescence existed on the other sections.

It is generally accepted that upwelling is a complex process which can only be partly evaluated by a knowledge of local winds at the time of observation. Yoshida (1955) pointed out that a time lag of a few days to a week may occur between the cause and the effect; moreover, he later suggested that coastal upwelling may occur in the absence of a local wind (Yoshida 1967). Factors such as the offshore wind regime, the influence of internal waves and the topography of the coastline all generate upwelling. Copenhagen (1953) has shown that certain parts of the coast of south-west Africa are more prone to upwelling than others. A more detailed consideration of the dynamics of this process as applied to the present investigation will be published elsewhere by N. Bang.

Frequent observations at each locality over a period of time are necessary to accurately determine the age of upwelled water on the shelf. However, the nutrient salt content of the water can often provide information on the degree of activity not apparent by the more conservative constituents such as salinity. The northern sections of the present investigation showed relatively low concentrations of nutrient salts at the surface on the inshore stations, although the distribution of salinity indicated the presence of upwelled water at these locations. The depletion of nutrient salts at the surface, coupled with their apparent regeneration near the

bottom, indicated a quiescent state of upwelling at the time of observation. Conversely, the high concentration of nutrient salts at the surface off the Cape coast indicated an active process.

The main value of the hydrographic investigation has therefore been to provide nutrient salt data for the area south of the Orange River and to use these parameters to estimate the degree of upwelling activity.

SUMMARY

Temperature, salinity, dissolved oxygen, phosphate, nitrate and silicate were measured off the Cape coast, St. Helena Bay, Roodewall Bay and the Orange River during February 1966. Active upwelling was found off the Cape coast but the process appeared to be quiescent on the other sections. The distribution of nutrient salts was found to be a useful parameter in determining the activity of upwelling.

A survey of surface water temperature between the Cape coast and Walvis Bay showed the major localities of upwelling at the time of the survey.

ACKNOWLEDGEMENTS

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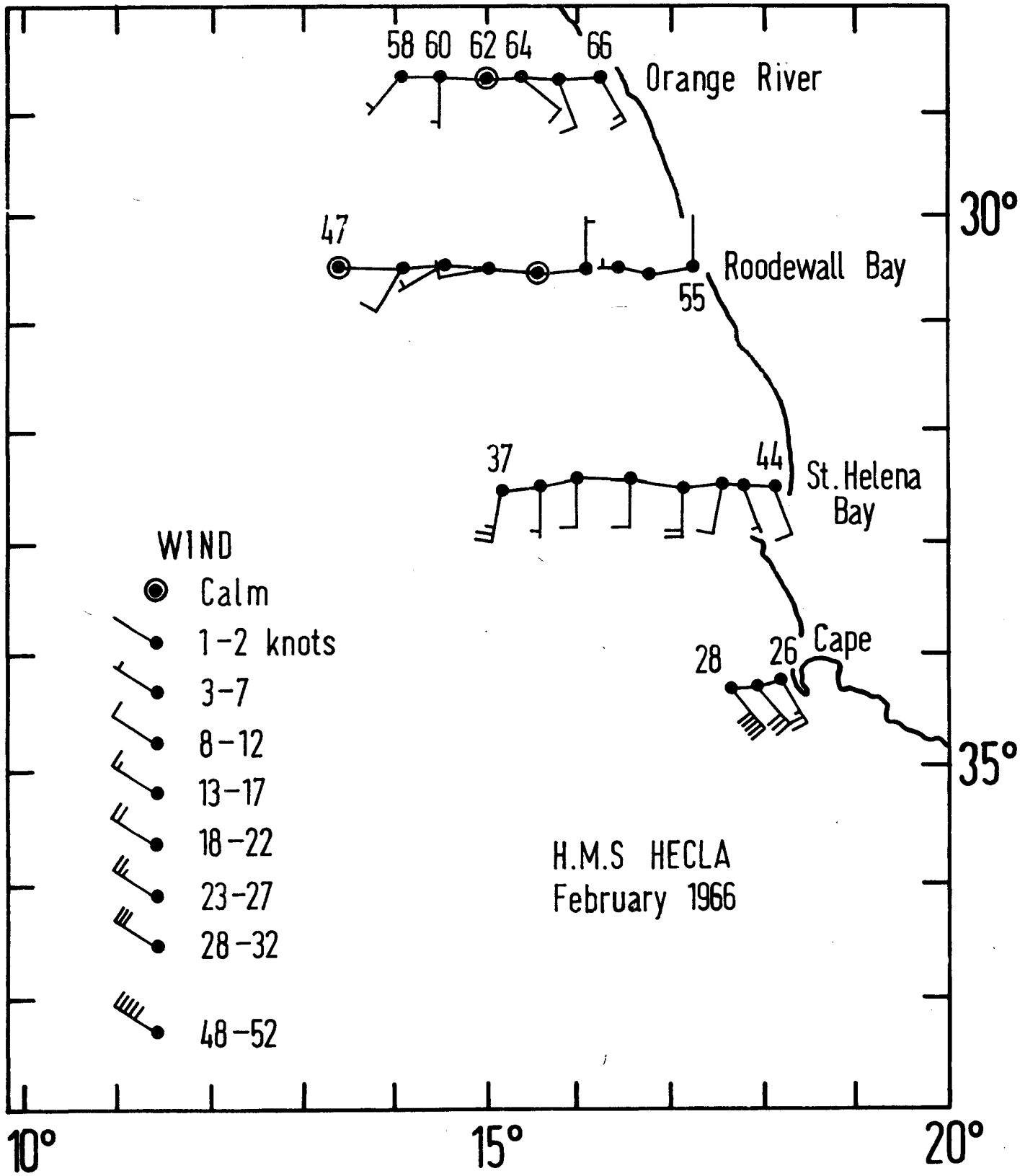

Figure 1 Station positions with wind speed and direction at time of observation.

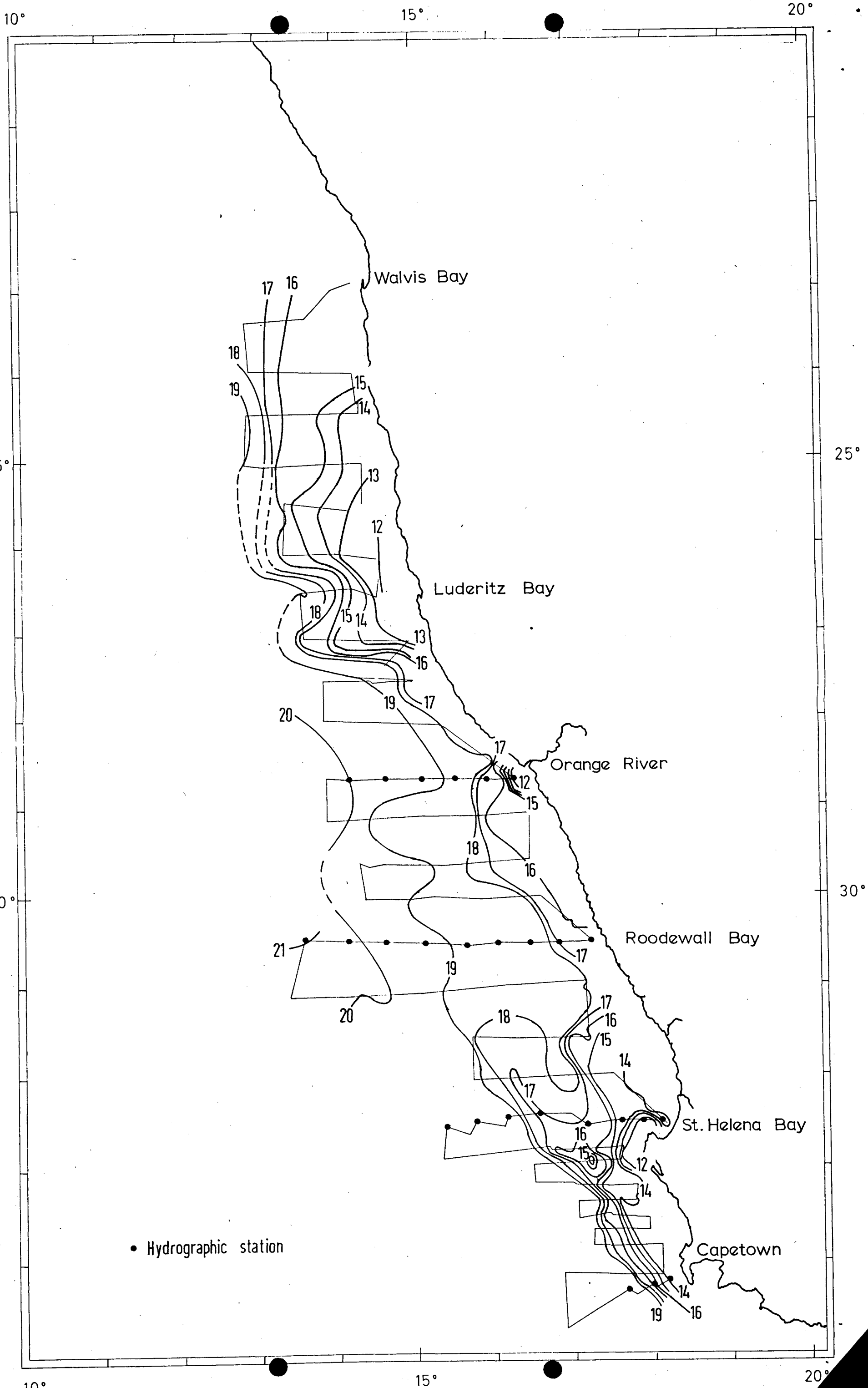

Figure 2 Surface temperature °C measured between 7-27 February 1966. Isotherms superimposed on ship's track.

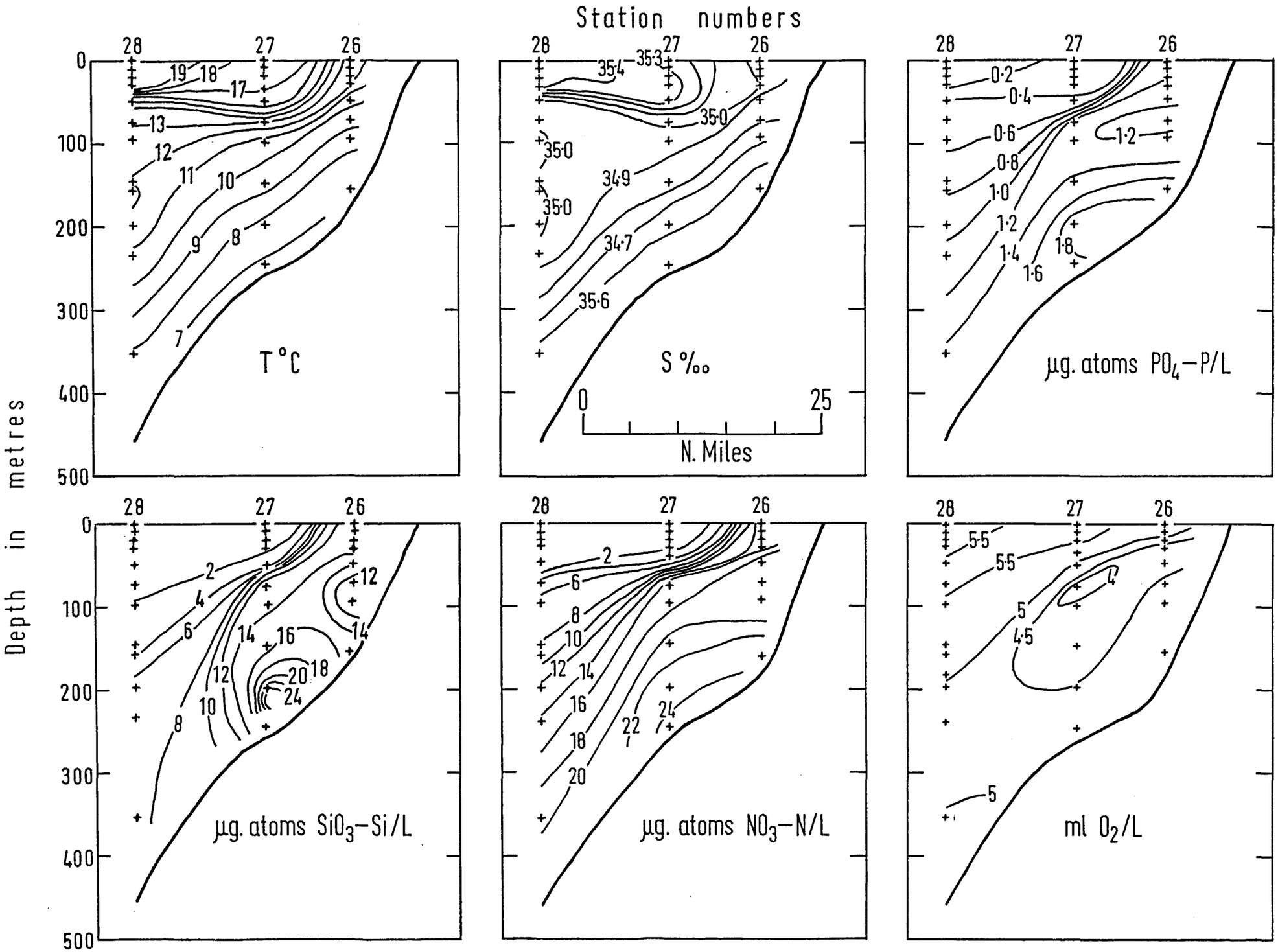

Figure 3 Cape section. 7 February 1966. Observations of temperature, salinity, phosphate, silicate, nitrate and oxygen.

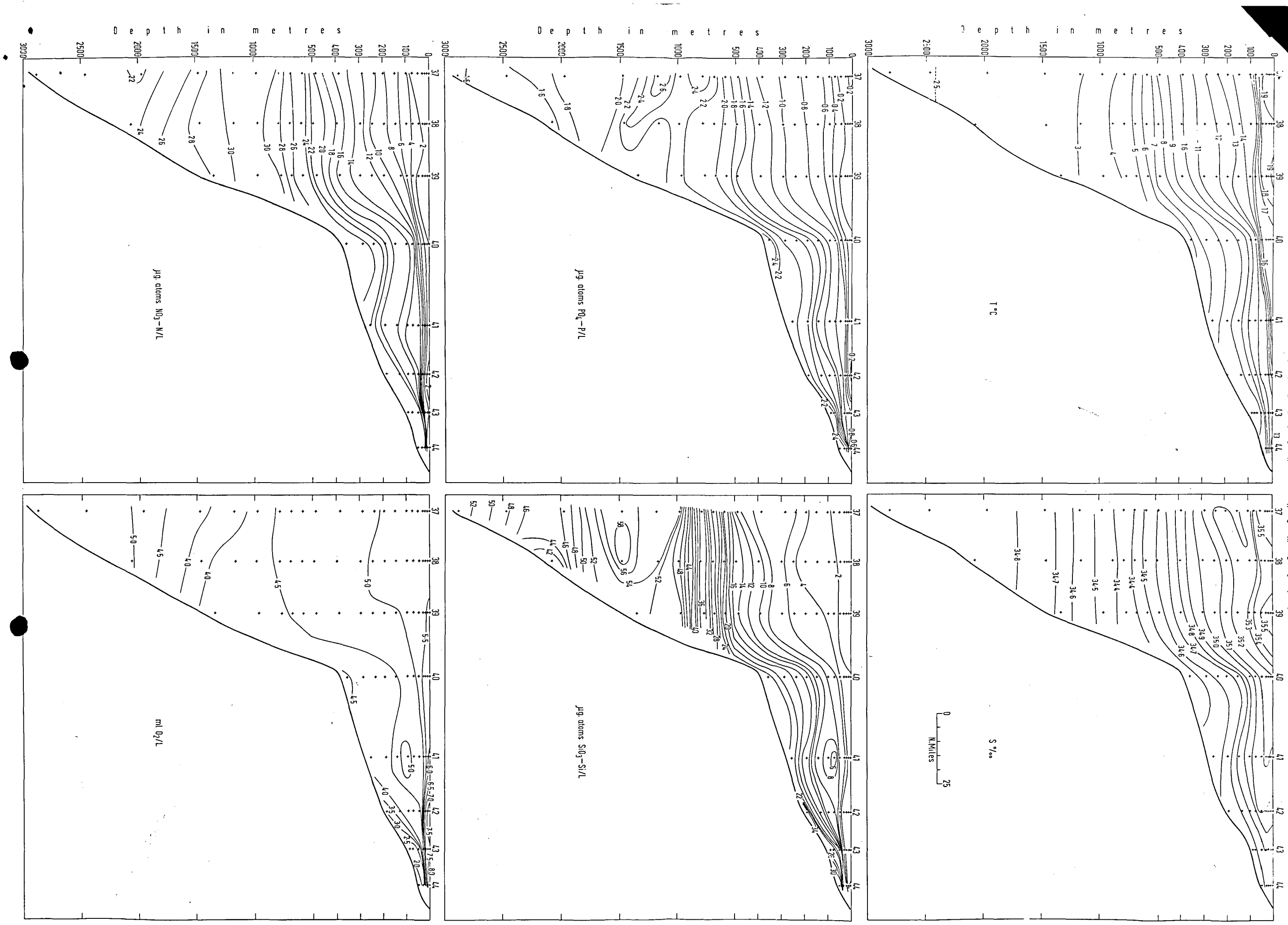

Figure 4 St. Helena Bay section. 10-12 February 1966. Observations of temperature, salinity, phosphate, silicate, nitrate and oxygen.

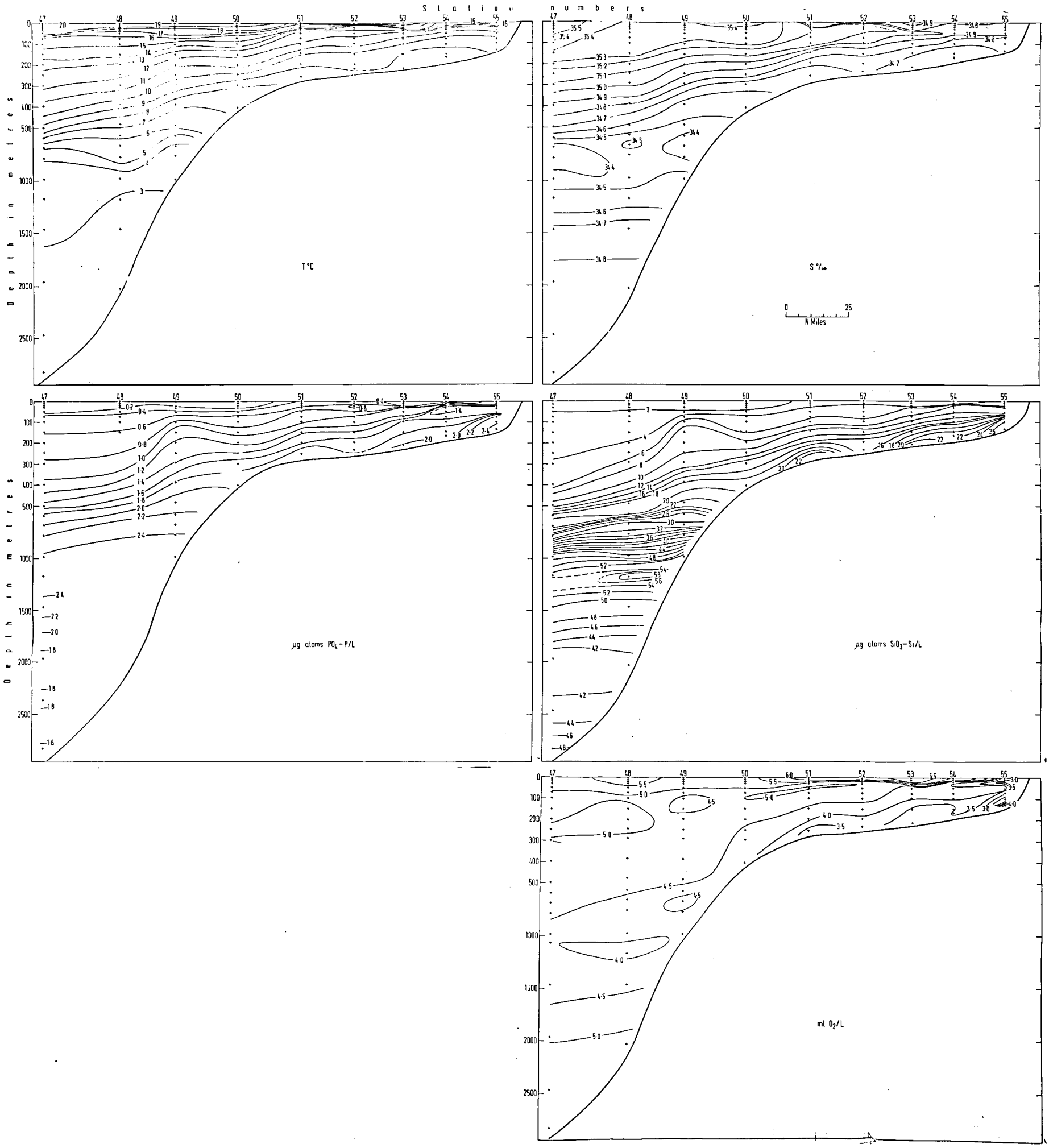

Figure 5 Roodewall Bay section. 14-15 February 1966. Observations of temperature, salinity, phosphate, silicate and oxygen.

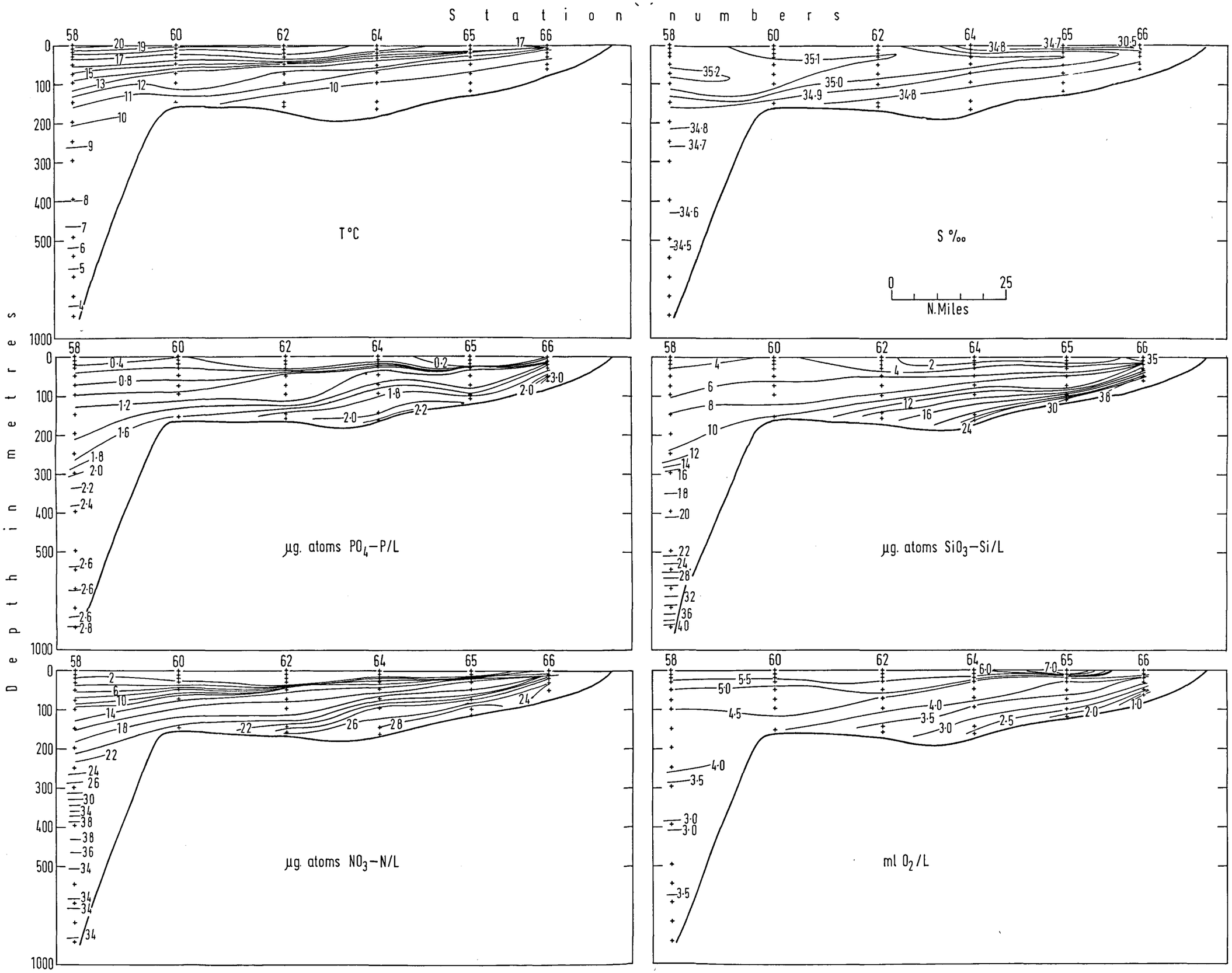

Figure 6 **Orange River section. 18-19 February 1966. Observations of temperature, salinity, phosphate, nitrate and oxygen.**

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