silicate values might originate from western Caroline Basin through the sill of the Kyushu-Palau Ridge near 4°N and 5°N.

Acknowledgements

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WOCE P19 in the Eastern South Pacific

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Cruise summary

WHP section P19C along 88°E was carried out on RV Knorr between Punta Arenas, Chile, and Panama City, Panama, from 22 February to 13 April 1993. P19C was the seventh Pacific WOCE hydrographic leg on the Knorr and the fourth with basic technical support from Scripps Institution of Oceanography’s Oceanographic Data Facility (SIO/ODF). The cruise track (Fig. 1) was east of the East Pacific Rise for its entire length, and crossed four deep basins (Bellingshausen, Chile, Panama and Guatemala) separated by ridges (Sala y Gomez, Carnegie and Cocos). The track went westward along 54°S out to 88°W and then northward along 88°W and 85°50’W, up to 4°N where the track turned northwestward and then into Central America off Guatemala. This first section is an abbreviated version of the cruise report which was filed with the WOCE Hydrographic Programme Office. The complete cruise report can be obtained from the WHPO at WHOI or through anonymous ftp to sam.ucsd.edu in subdirectory pub/p19 which also includes postscript files for some of the basic vertical sections. Section 2 is a very brief description of some hydrographic features found along the section.

All stations were to within 10 metres of the bottom and included a rosette/CTD cast. Basic station spacing was 30 nm, closing to 20 nm for 3°S – 1°S and 1°N – 3°N, and to 10 nm for 1°S to 1°N. Station spacing at the Chilean and Guatemalan coasts and over the Sala y Gomez Ridge (about 25°S) was less than 30 nm and dictated by topography. Sampling included 108 CTD/rosette stations, 13 large volume sampling (Gerard barrel) stations, and 20 200-metre bio-optics stations (J. Marra of LDEO for JGOFS). Sampling was done with a 36-place General Oceanics pylon on a rosette frame with 10-litre bottles and a CTD, transmissometer, altimeter and pinger. An RDI lowered acoustic doppler profiler (Eric Firing) was mounted inside the rosette frame for 94 stations.

The CTD data stream consisted of elapsed time, pressure, two temperature channels, conductivity, oxygen, altimeter and transmissometer signals. There were no major problems with the CTD measurements. Most of the few problems in conductivity resulted from biological fouling of the rosette/CTD during the cast.

Water samples were collected for analyses of salt, oxygen, silica, phosphate, nitrate and nitrite on all stations and of CFC-11, CFC-12, helium-3, helium-4, tritium, AMS ^{14}C, pCO_2, and total dissolved inorganic carbon on selected stations.

Discrete salinity, oxygen and nutrient values were compared with preliminary data acquired on P17E (Swift, chief scientist, RV Knorr) and P6 (Bryden, chief scientist, RV Knorr), and with data from the 1989 Moana Wave cruise at 9°30'N and the two old 1968 Scorpio sections at 43°S and 28°S. A complete version of the comparisons, with figures and tables, can be found in the WHP P19C cruise report available from anonymous ftp. Salinity accuracy is within WOCE requirements on P19C and the other recent cruises. There are offsets in oxygen amongst the recent cruises which are larger than the precision required but within the accuracy limits, so indicating no fundamental problems. In nutrients however, there may be inter-group differences which exceed the WHP requirements for accuracy.

CTD/rosette station times are shown in Fig. 2. These times are comparable to those from two previous Knorr WOCE legs. These numbers do not include start and stop times, so actual stations times were about 5 minutes longer. Wire speeds were generally 60 metres/minute for downcasts and 70 metres/minute for upcasts; because of stops for bottle trips and slower speeds in the upper 200 metres, the average wire speed for all stations was 55–58 metres/ minute.

Towards the end of the cruise, we started to wait for a few ship rolls before closing bottles in the strong near-surface pycnocline in order to flush the bottle, as suggested long ago by Ray Weiss of SIO. This reduced the differences in CTD and bottle conductivity by two to three orders of magnitude. This suggests that the concept of closing bottles "on the fly" may result in degradation of CTD calibration, particularly in the pycnocline.

Large-volume sampling (R. Key of Princeton) was made with use of 270-litre Gerard barrels for analyses of ^{14}C, salinity, oxygen and nutrients on 13 stations. All covered the water column below 1000 metres. ^{14}C samples were collected from the rosette for the upper 1000 metres for analysis by AMS.

Underway measurements included Acoustic Doppler Current Profiling (Eric Firing of U. Hawaii), pCO_2, pN_2O (R. Weiss, SIO), and the various variables of Knorr's IMET system (surface water temperature and conductivity, oxygen, meteorological parameters, GPS navigation, ship's speed and heading). Underway bathymetry was recorded every 5 minutes from the Knorr's PDR for our own use in constructing vertical sections and as additional input to the overall data-base (S. Smith - Geological Data Center at SIO).

Twenty-one subsurface ALACE floats were deployed for R. Davis of SIO. The ballast pressure for the floats was 800 to 850 dbar. Six surface drifters were deployed for P. Niiler of SIO.

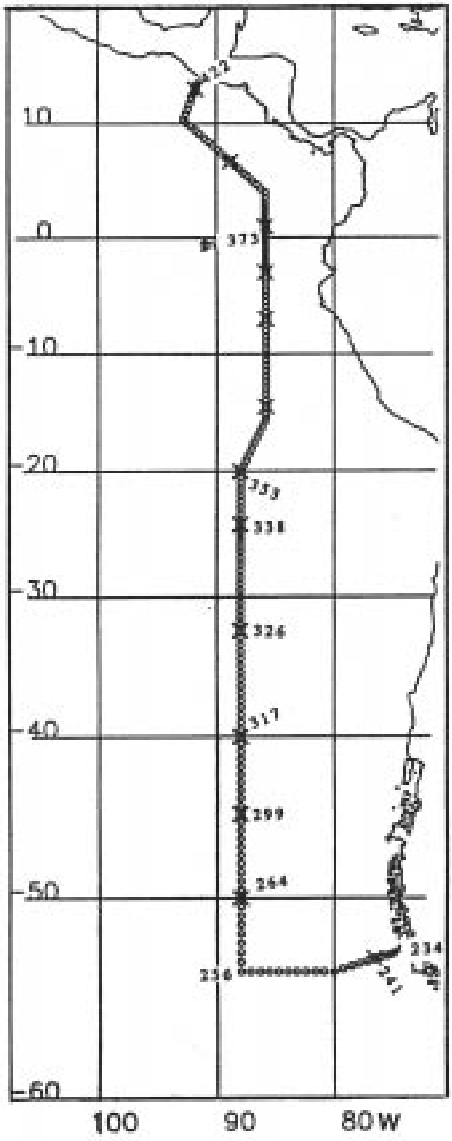

Figure 1. Cruise track for WOCE P19C (RV Knorr 138-12), 22 February 1993 – 13 April 1993. Rosette/CTD stations (circles). Large volume plus rosette/CTD station (crossed circles).

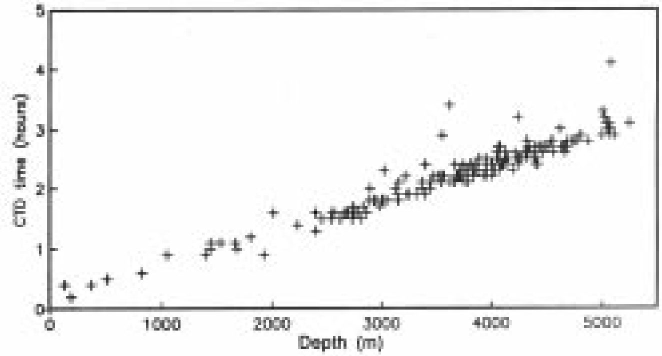

Figure 2. CTD station times (from launch to recovery, not including additional deck time).

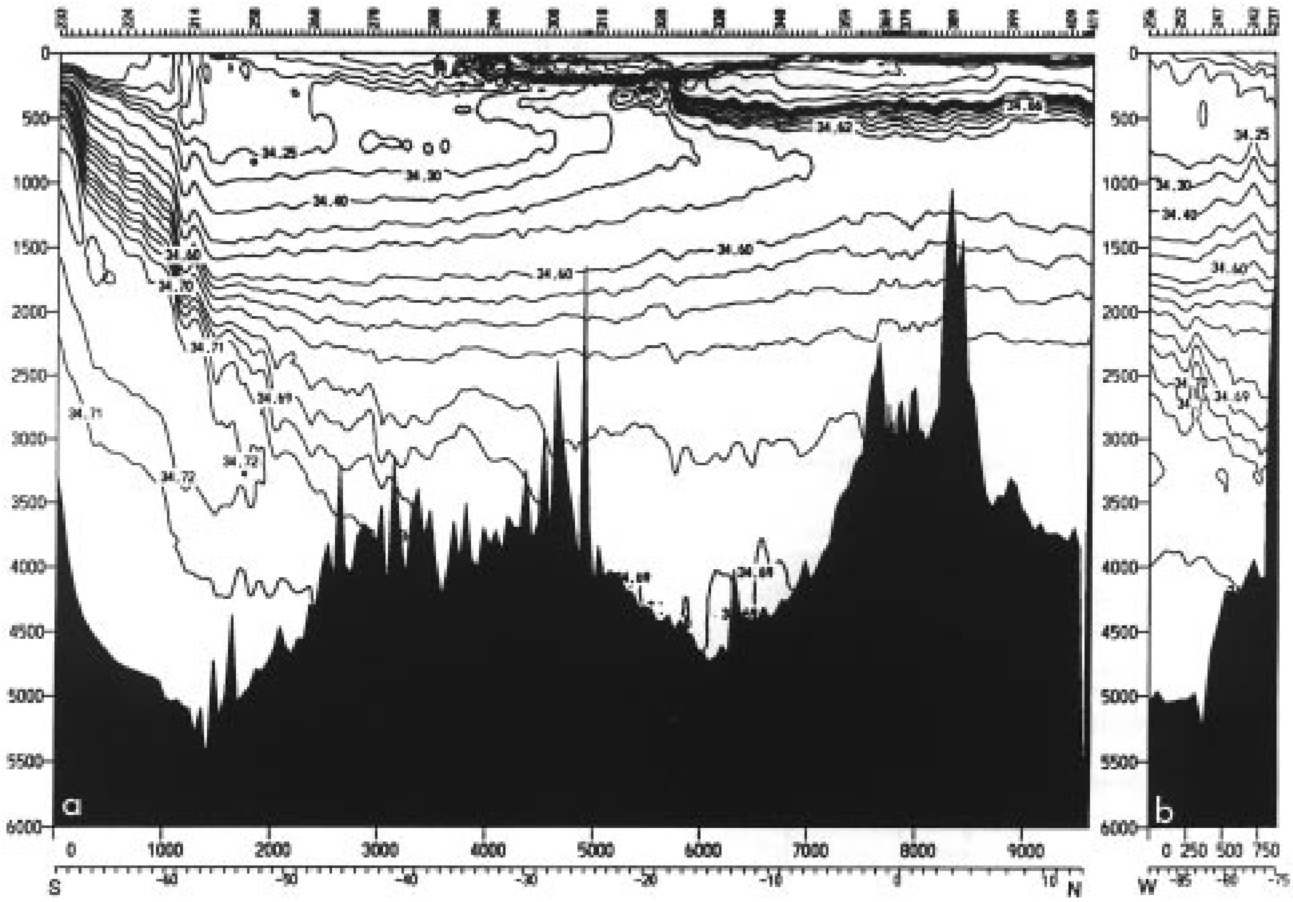

Figure 3. Vertical section of salinity along (a) 88°W and (b) 54°S from 88°W to South America. The portion of 88°W south of 54°S was collected by J. Swift of SIO on the previous WOCE leg on the RV Knorr.

Preliminary results

Vertical sections of potential temperature, salinity, oxygen and silica illustrate some of the major water mass features encountered along 88°W and eastward along 54°S. The 88°W section was extended southwards in Figs. 3 and 4 with the stations collected on the preceding leg by Swift (see article in International WOCE Newsletter No. 18), which are used here with his permission.

1. The major Pacific water masses on the section were Antarctic Intermediate Water (stability and salinity minimum/oxygen maximum at 400–600 metres), Pacific Deep Water (oxygen minimum at 1500–2000 metres and silica maximum at about 2800 metres), North Atlantic Deep Water or Upper Circumpolar Water (salinity maximum at about 3500 metres), and Antarctic Bottom Water or Lower Circumpolar Water (oxygen maximum and salinity minimum at the bottom). At the top of the Chile Rise, between 43° and 41°S, the Antarctic Bottom Water and Circumpolar Water disappeared and did not reappear as we crossed into the western portion of the Chile Basin. The Chile Basin was filled to the bottom with a much more homogeneous water mass than in the Bellingshausen Basin, with high silica, low oxygen and relatively warm water (greater than 1.4°C). The sill depth for the Chile Basin appears to be at about 3500 m. The bottommost waters in the Chile Basin have higher oxygen and lower silica than those above, indicating southern origin.
2. At 54°S off the coast of Chile there was a clear eastern boundary regime of about 500 km width at 54°S, extending to the ocean bottom. Characteristics of this regime are relatively low oxygen in the Pacific Deep Water oxygen minimum, relatively low salinity in the Circumpolar Water salinity maximum, relatively high silica in the Pacific Deep Water silica maximum, and potential vorticity signatures for these water masses which also indicate an eastern boundary regime. Properties in this eastern boundary region match fairly well with those found at the northern side of the Bellingshausen Basin, between about 45 and 50°S. Large-scale currents are therefore probably southward to the bottom along the eastern boundary, out to 81°W. They are also eastward along 88°W at the northern side of the Bellingshausen Basin, indicating cyclonic flow in accord with Reid (1986).
3. The near-surface waters in a large patch west of southern Chile (54°S, 79°W up to 52°S, 88°W) were very similar to Antarctic Intermediate Water (AAIW).

The salinity minimum was nearly non-existent in this outcrop region and the oxygen in the pycnostad was at the surface value. The density of the thick pycnostad was 27.01 σ_θ. This was only slightly less dense than the well-defined salinity minimum AAIW found east and north of the patch (27.02 σ_θ). A well-defined oxygen maximum was also found in the AAIW east and north of the patch. Dynamic height at the surface relative to deeper levels was essentially flat throughout the patch, rising both to the east and to the north, suggesting a broad cyclonic flow around it of waters which then enter Drake Passage. This suggests that the local Subantarctic Mode Water in the southeastern Pacific is essentially identical to the AAIW which spreads northward, probably by subduction, in the eastern South Pacific.

The low potential vorticity signature of the AAIW was found as far north as about 30°S. The well-defined oxygen maximum associated with the AAIW is found as far north as about 24°S. The salinity minimum of course extends to the northern end of the section in the North Pacific off Guatemala. The density of the salinity minimum shifts rapidly from about 27.1 σ_θ to 27.3 σ_θ between 20° and 17°S. There is significant fine structure (interleaving) at the minimum between about 23°S and 17°S. The highest salinity AAIW is found in the equatorial region and north of the equator. Oxygen in the equatorial AAIW is 0.5 ml/l higher than under the low oxygen regimes 10° south and 5° north of the equator.

4. Low salinity surface water extending westward from South America centred at about 40°S was evident in prior work, and has been called the Deacon jet. This fresh water was very clearly defined along 88°W between 54°S and 34°S, with an abrupt front at the northern edge. Changes in dynamic height at the surface relative to deeper levels suggest eastward flow throughout the low salinity tongue, despite the apparent source of the lowest salinity water to the east, based on historical data. It extends down to about 200 metres and is the apparent source of the shallow salinity minimum found in the northern subtropical gyre of the South Pacific. The shallow salinity minimum is evident on this section between 38°S and 20°S.

5. There was an isopycnal uplift at station 242, at 54°S, 77°W, in the upper 1500 metres, accompanied by even stronger uplift of properties. This suggests a cyclonic flow around the rise offshore of the Chile Trench.

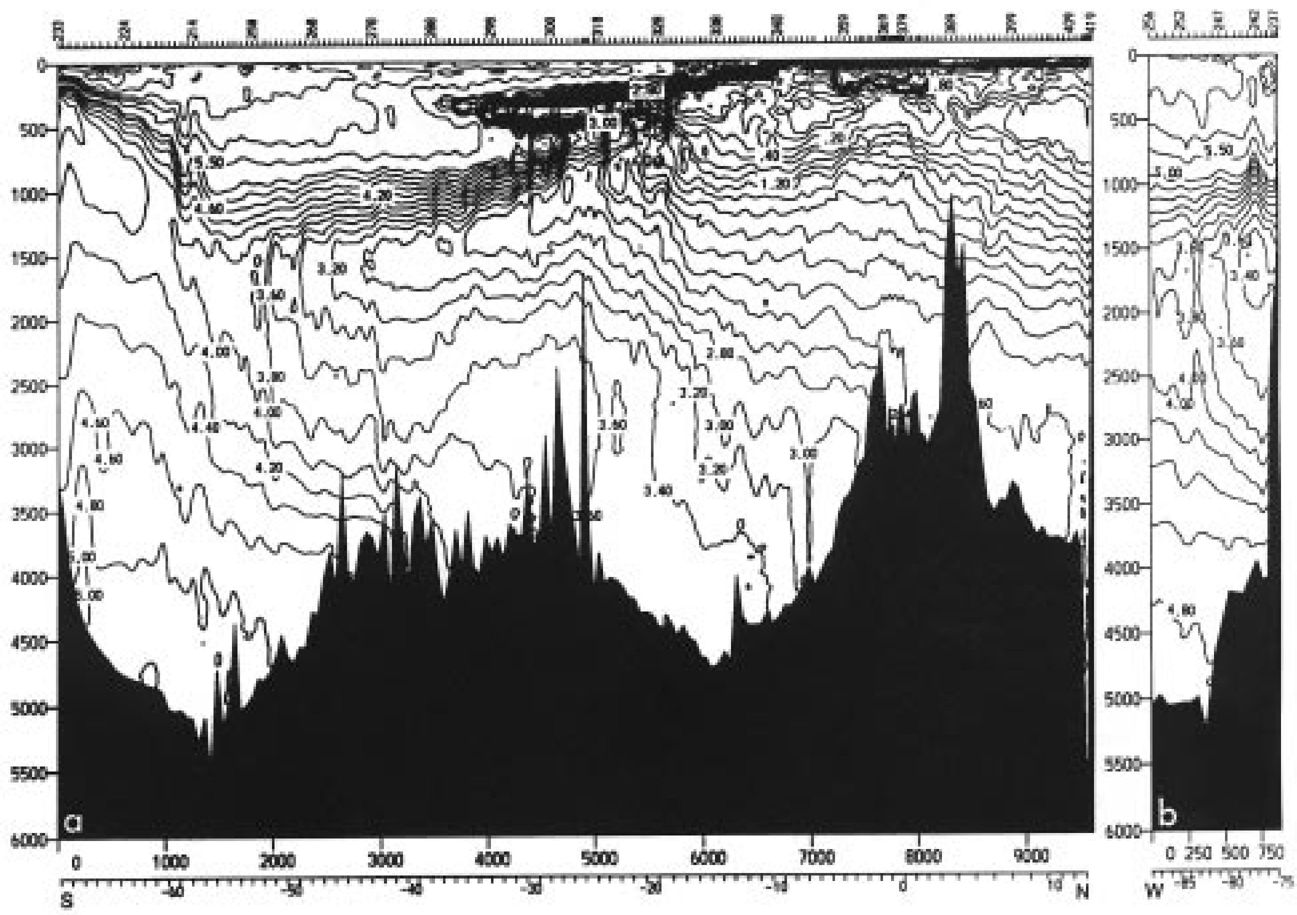

Figure 4. Vertical section of oxygen (ml/l) along (a) 88°W and (b) 54°S from 88°W to South America.

6. The high salinity northern subtropical surface water penetrates to about 200 metres depth between its onset near 38°S up to about 20°S (northern limit of the underlying salinity minimum). North of this, the higher salinity influence plunges down to about 500 metres, and north of about 12°S there is a well-defined sub-surface salinity maximum at about 100 metres depth.
7. The section crossed the equator in the deepest part of the narrow region between the Galapagos Islands and South America. The maximum depth here was around 3000 metres. This is an active geothermal region. Centred about the equator the bottom water was noticeably warmer (by 0.3°C) than on either side of the bathymetric rise, and quite uniform over about 700 metres from the bottom. This uniform bottom layer was also more uniform in oxygen and salinity than on either side of the equator, indicating mixing. The equatorial band (within 2° of the equator) also has striking vertical structure from 500 metres to the ocean bottom, evidenced in an increase in layering as quantified by minima and maxima of Vaisala frequency, compared with the more monotonic structure farther from the equator.
8. The oxygen minima north and south of the equator in this region are notable for the very low values of oxygen very close to the surface (less than 0.02 ml/l). The oxycline separating the surface saturated layer from the underlying minimum layer lies at about 50 metres depth. A double nitrite maximum is found associated with the oxygen minima north and south of the equator: south of the equator the deeper nitrite maximum is at about 150 metres and north of the equator it is centred at 400 metres.

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WOCE Observations in the Pacific Ocean

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During the years 1991–1994 the Pacific Ocean was subjected to an intensive one-time survey resulting in the grid of sections illustrated in Fig. 1 Repeated hydrographic sections, time series stations, current meter moorings and high density XBT sections began in 1990 and will continue to monitor the Pacific through 1997. Fig. 2 shows schematically where the continuing observations are. Absent from Fig. 2 are the low density XBT sections, subsurface floats, surface drifting buoys and sea level stations which will also continue throughout the WOCE Field Phase.

Providing WOCE data and products to a large science community in a timely way is a central aim of WOCE, in order that the data from individual sections and projects can be included in the wider synthesis of WOCE data. Many of the data sets collected since 1990 should now be in the public domain but still

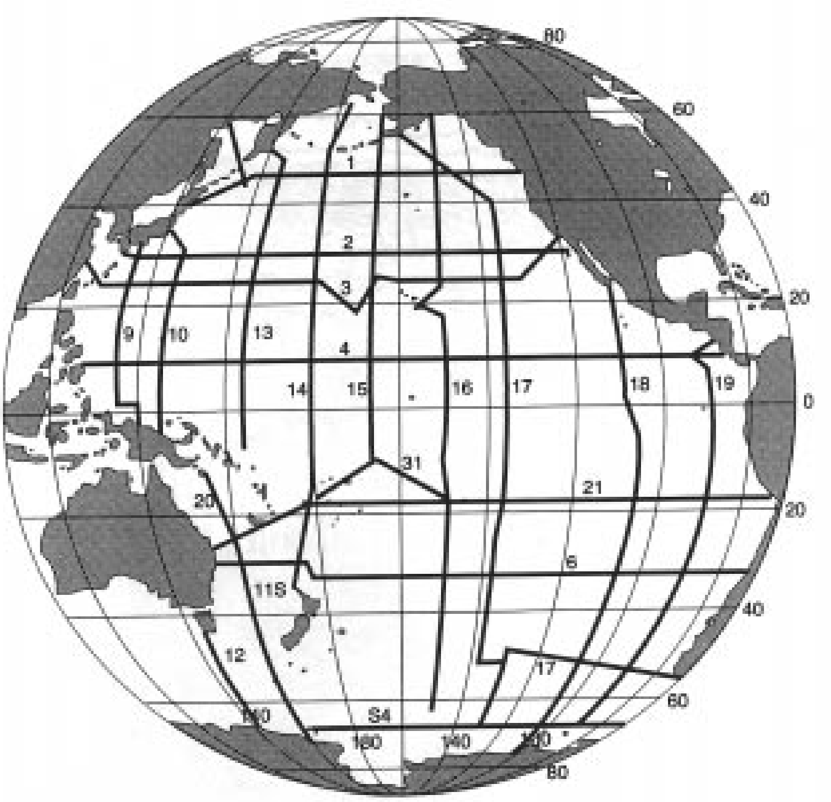

Figure 1. Completed Pacific Ocean One Time Survey Sections.