3rd SYMPOSIUM ON THE COOPERATIVE STUDY OF THE KUROSHIO AND ADJACENT REGIONS (CSK).

INTERMEDIATE WATERS NORTH OF NEW-GUINEA.

by

H. ROTSCHI, C. COLIN, C. HENIN, C. OUDOT

Centre ORSTOM of Noumea (New-Caledonia).

1972

-§-

Since the region of New-Guinea is the meeting place of the westward currents and the zone of formation of the eastward flows of the equatorial Pacific, it has a special importance on the Pacific dynamics and hydrology. Cruises of the Ryofu-Maru (Masuzawa 1967, 1968, 1970) (Akamatsu and Sawara 1969) have studied it every year since 1967 along the meridian 137° E and several russian and japanese cruises have been devoted to its description. Nevertheless, it has appeared that the distribution and density of observations between 140° E and 155° E was inadequate, to permit a good and detailed understanding of the water masses and of their movements and of the time variations which can occur due to the well known seasonal changes in the surface circulation and in the meteorological conditions in the western equatorial Pacific.

Two cruises of the N.O. CORIOLIS, research vessel of the "Centre ORSTOM de Nouméa", New-Caledonia, FOC 1 (january-february 1971)and FOC 2 (june-july 1971) have been devoted to the study of this region.

They include four equatorial cross-sections, 180-300 miles spaced, with hydrological observations and current measurements at stations distant of 30 miles. Results of observations show that at intermediate depths, below 200 m, the hydrological structure is fairly complicated. This is particularly true of the oxygen distribution because the oxygen content of the various sources of water is more contrasted than their salinity and nutrient salts content.

Former studies at 170° E (Colin and Rotschi 1970) having shown that the water circulation below the surface layer, in the equatorial region, is close to geostrophic, it appeared justified to make an isentropic analysis of the distribution of the hydrological properties along some isanosteric surfaces of special interest. Isanosteric surfaces 160 cl/t (26.4 g/l), 125 cl/t (26,8 g/l) and 100 cl/t (17,1 g/l) have been chosen to study the distribution of oxygen. The former, used by Tsuchiya (1968) is, in the equatorial central Pacific, in the lower part of the Cromwell current. The second is specific, in the northern Pacific, of the north Pacific intermediate water (Reid 1965) and according to Masuzawa (1970) is characterized, in the western Pacific, by a vertical salinity maximum between the north Pacific intermediate water and the Antarctic intermediate water and by a vertical oxygen minimum originating along the coast of central America. The last one is very near the density at which is found the Antarctic intermediate water (Johnson 1972).

In june-july 1971, the meridional sections of oxygen against thermosteric anomaly show that at 160 cl/t three different water masses are encountered. South of the equator, at 154° E, there is water with an oxygen content lower than 3.0 ml/l and a salinity close to 35.0 ‰. Its core lies at smaller density and the water at it gets lighter westwards. It is fairly abundant at 154° E, almost absent at 145°30 E and totally absent at 142°30 E. On surfaces with a higher thermosteric anomaly of the order of 210 cl/t this water still shows at 145°30 E but apparently not at 142°30 E. Thus it dilutes with adjacent water westwards and this indicates a general westward displacement. South of the equator the only possible source for such a water is the oxygen minimum off Peru the core of which, according to Tsuchiya (1968) flows westwards south of the equator, on the 160 cl/t isanosteric surface. North of the Peru water and right at the equator there is a water characterized by a lateral and vertical oxygen maximum with a concentration greater then 3.4 ml/l. Its salinity is near 35.0 ‰ and it is more abundant at 145°30 E then at 154° E. Thus, it is likely to move eastwards. Tsuchiya (op. cit) and Rotschi and Wauthy (1969) have shown that this is Coral sea water entering the region mostly through the Vitiaz straight, flowing along the northern coast of New-Guinea and taken eastwards at the equator by the Cromwell current. Further north, the water has a low oxygen content and salinity. It is water of the northern hemisphere oxygen minimum (Masuzawa, 1967) , the core of which is found near the 125 cl/t isanosteric surface (Reid, 1965) and which shows during the cruise FOC 2 (june-july 1971) at 130-140 cl/t. It is formed off the central America coast. Geopotential topography of the 160 cl/t isanosteric surface indicates that this water is likely to move westwards as well as eastwards. Moving westwards, it is part of a west flow which has been evidenced at 170° E during almost all the cruises of the N.O. Coriolis, which is located at about 3° N, north of the northern deep extension of the Cromwell current, and which has a low oxygen content, indeed lower than ever found earlier at this latitude in the Central Pacific. When it moves eastwards it belongs to the lower part of the north equatorial countercurrent (Tsuchiya op.cit.) and was formerly within the lower layers of the southern portion of the north equatorial current (Masuzawa 1967).

On the 125 cl/t isanosteric surface, the Peru water has virtually disappeared south of the equator. Nevertheless, it is clearly identified at the equator below the Coral sea water, by an oxygen minimum. There the oxygen concentration is lower than 2.6 ml/l and the salinity of the order of 34.7 $^{o}/_{oo}$. The eastern origin of this water is confirmed by Reid (1965), Rual (1969), H isard and Rual (1970) and by its westward erosion and its disappearance at 142°30 E. It pertains to the equatorial intermediate current which has been found at 170° E to flow westwards, below the Cromwell current, from a depth of about 300 m down. North and south of the equator, both sides of the oxygen minimum, there is water with a higher oxygen content. South of the equator it cannot have any other origin than the Coral sea through the Vitiaz straight, the St. Georges Chanel and the passage between New Ireland and Bougainville. North of the equator it is the trace of the Coral sea water which flows westwards along the north coast of New Guinea and turns afterwards east. It is entrained eastwards by the lower part of the north equatorial countercurrent and mixes with adjacent waters so that its oxygen content decreases to the east. At about 3° N appears the oxygen minimum of the central America water in which the geostrophic current is mostly westwards. This confirms the existence of a westward current north of the equator, at depths greater than 400 m and flowing all through the Pacific near 4° N, with water low in oxygen.

On the isanosteric surface 100 cl/t, a water with an oxygen content below 3.0 ml/l appears at 154° E, south of the equator. It can only derive from the Peru water and it fades away westwards along the parallel 2°S. South of it and west of 150° E, an oxygenated water flow westwards along the north coast of New Guinea after having entered the Bismarck sea through the Vitiaz straight. During its displacement, it turns to the east and forms a tongue of oxygenated water in which, south of the equator, the oxygen content decreases eastwards. North of the equator this water mixes with a water appearing on the section at 137° E of the Ryofu Maru and coming from the Celebes sea. The mixture forms the transition between the Coral sea water and the central America water. The presence of numerous maxima, minima and frontal zones with strong meridional gradients suggests that this is a region where the circulation is complicated and with little lateral mixing. There are probably circulatory cells with relatively small dimensions.

Direct current measurements are in good agreement with the main water displacements suggested by the isentropic hydrological analysis. In the south part of the four cross sections, the flow is westwards along the north coast of N ew Guinea. It does effectively transport Coral sea water to the west. North of the equator the measured current in the upper intermediate waters is mostly eastwards. Nevertheless at about 3° N a westward current is clearly seen west of 154° E. At the equator, the direction of the flow changes with depth. On the 160 cl/t isanosteric surface, the southern part of the Peru current has a westward component, whereas its northern part flows to the east. This eastward flow comprises also the Coral sea water at the equator and the central America water north of it. At 125 cl/t the measured currents show three regions of westward flow, along the north coast of N ew Guinea, north of 3° N and at the equator where it transports low oxygen content water of the equatorial intermediate current. The later is well marked at 154° E and 149° E but not so obvious at 145°30 E and 142°30 E which confirms the conclusions drawn from the hydrological analysis. Elsewhere, the flow is eastwards. Measurements do not allow a study of the currents at 100 cl/t where they are very weak. Neverthless the acceleration potential suggests an eastward current at the equator embeded in a general westward transport. More generally, the geostrophic currents on the three surfaces do confirm the main features of the circulation as defined by the current measurement and the hydrological analysis. Finally, the hydrology clearly indicates, what is confirmed by the current measurements, that the limit between the Cromwell current and the equatorial intermediate current is near the isanosteric surface 130 cl/t, at a higher density, and thus at a greater depth than at 170° E where it coincides more or less with the isanosteric surface 160 cl/t.

The cruise FOC 1 made in januray-february of the same year shows the same water masses participating to the hydrology at intermediate depths north of New-Guinea. Nevertheless, the Peru water south of the equator and the central America water seem to be less abundant whereas the equatorial Peru water of the equatorial intermediate current is more abundant. The absence of central America water reflects the weakening, during this period of the year, of the north equatorial counter-current (Kendall 1970, Wyrtki and Kendall 1967). The greater abundance of the equatorial Peru water reflects a stronger equatorial intermediate current. This is confirmed by the current measurements. Important fluctuations can thus affect the intermediate waters.

AKAMATSU H. and T. SAWARA. 1969 - The preliminary report of the third cruise for CSK, January to March 1969. Oceanogr. Mag. 21, 1, 83-96.

COLIN C. and H. ROTSCHI. 1970 - Aspects geostrophiques de la circulation Est-Ouest dans l'Océan Pacifique equatorial occidental. C.R. Acad. Sc. Paris, 271, 929-932.

HISARD Ph. and P. RUAL. 1970 - Courant equatorial intermédiaire de l'Océan Pacifique et contre-courants adjacents. Cah. ORSTOM, sér. Oceanogr., 8, 1, 21-47.

JOHNSON R.E. 1972 - Antarctic intermediate water in the south Pacific ocean. Ph. D. Thesis, Oregon State University, 170 pp.

KENDALL T.R. 1970 - The Pacific equatorial countercurrent. Int. Center for Environmental Res., Laguna Beach, 19 pp.

MASUZAWA J. 1967 - An oceanographic section from Japan to New-Guinea at 137° E, in January 1967. Oceanogr. Mag. 19, 2, 95-118.

MASUZAWA J. 1968 - Second cruise for CSK, Ryofu Maru, January to March 1968. Oceanogr. Mag. 20, 2, 173-185.

MASUZAWA J., AKIYAMA T., KAWARADA Y. and T. SAWARA. 1970 - Preliminary report of the Ryofu Maru Cruise Ry 7001 in January-March 1970. Oceanogr. Mag., 22, 1, 1-25.

REID J.L. 1965 - Intermediate waters of the Pacific Ocean. The Johns Hopkins Oceanographic studies n° 2, The Johns Hopkins Press, Baltimore, 85 pp.

ROTSCHI H., and B. WAUTHY. 1969 - Remarques sur le courant de Cromwell. Cah. ORSTOM, Sér. Oceanogr., 7, 2, 27-43.

RUAL P. 1969 - Courants équatoriaux profonds. Deep-Sea Res., 16, 387-391.

TSUCHIYA M. 1968 - Upper waters of the intertropical Pacific Ocean The Johns H opkins Oceanographic studies, n° 3, The Johns Hopkins Press, Baltimore, 50 pp.

WYRTKI K. and R. KENDALL. 1967 - Transports of the Pacific Equatorial Countercurrent. J. Geophys. Res. 72, 8, 2073-2076.