subliquidus temperatures and at varying cooling rates, did not always yield microstructures as predicted by the stable phase diagram of Fig. 1. With rapid cooling rates, caused by difficulty in the nucleation of Al_2O_3, the homogenized melts were supercooled through the Al_2O_3 + liquid field without any Al_2O_3 precipitation. However, when an identical or the same mixture was again homogenized and cooled slowly, the precipitation of Al_2O_3 as predicted by the stable Al_2O_3 liquidus was realized (Fig. 2). In fact, with slow cooling rates, it was possible to follow the extension of the Al_2O_3 liquidus below the transition temperature and to maintain an Al_2O_3 + liquid (48 percent Al_2O_3) mixture at 1753°C for up to 1 month (Fig. 1).

Similarly, the extension of the mullite liquidus above the transition temperature was realized when an attempt was made to measure the melting temperature of a theoretically dense, polycrystalline mullite specimen (*12*) with a composition of 71.8 percent Al_2O_3. The specimen started decomposing into a mixture of liquid and Al_2O_3-rich mullite above ≈ 1816°C, and melting was completed congruently at ≈ 1880° ± 10°C without the formation of Al_2O_3. The composition of mullite shifted along the extension of the solidus up to 76 percent Al_2O_3 at 1880°C. In Fig. 1, we extended the mullite solidus up to 83.2 percent Al_2O_3 since this composition was the highest Al_2O_3 content detected in any mullite precipitated from a melt during this study. This value agrees well with the compositions of mullite single crystals grown from a melt by Bauer *et al.* (82.57 percent Al_2O_3) (*2*). The maximum temperature for this composition is tentatively set at ≈ 1890°C. The solid solution limit and the maximum temperature, however, are subject to change as more data become available on the metastable extensions of the mullite liquidus and solidus lines.

The stable phase diagram, outlined with solid lines in Fig. 1, is the composite of two binary eutectic diagrams: SiO_2-mullite in the absence of Al_2O_3 and SiO_2-Al_2O_3 in the absence of mullite. The metastable SiO_2-mullite equilibrium diagram, as presented here, thus effectively explains the controversial melting behavior of mullite and the formation of high-Al_2O_3 mullites only when they are precipitated from a melt. In the presence of Al_2O_3, the solid solution field is limited to a narrow range; thus the highest Al_2O_3 content that can be incorporated into mullite by solid-state reaction is 74.0 percent Al_2O_3. A detailed account of this work will be presented elsewhere (*13*).

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Mesoscale Ocean Eddies in the North Pacific: Westward Propagation

Abstract. *A set of subsurface temperature measurements in the trade wind region northeast of Hawaii reveals large perturbations about the mean state, with zonal wavelengths of 480 kilometers. The perturbations are identified as mesoscale baroclinic eddies, and they appear to drift westward at a rate of 4.7 ± 2.0 centimeters per second. The large-scale (> 1000 kilometers) baroclinic flow at a depth of 200 meters is 1.5 ± 0.7 centimeters per second, also toward the west, and comparable in magnitude with the eddy drift velocity; this finding suggests that the eddy drift is strongly influenced by the large-scale flow. Mesoscale eddies have been discovered in the tropical and subtropical Atlantic Ocean. Their existence in the Pacific Ocean is now confirmed.*

Large perturbations have been observed in the general circulation of the Atlantic Ocean (*1*) with time and horizontal space scales of 100 days and 500 km, respectively. These features are frequently referred to as mesoscale eddies. Eddies with similar characteristics have now been discovered in the North Pacific, from the data of the "Trade Wind Zone Oceanographic Pilot Study" (*2*). To collect these data, the R.V. *Townsend Cromwell* repeatedly oc-

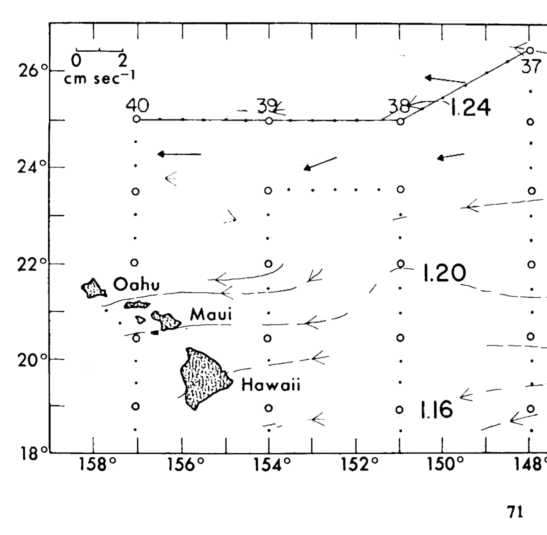

Fig. 1. R.V. *Townsend Cromwell* hydrographic (open circles) and bathythermographic (closed circles) stations. Contours of the dynamic height anomalies (boldface numerals) of the 200-dbar surface relative to the 1200-dbar surface (dashed lines) are based on a 16-month average at each hydrographic station; contour interval, 0.02 dynamic meter. Heavy arrows indicate the mean flow velocity according to the scale in the upper-left corner.

cupied a sequential pattern of hydrographic and bathythermographic (BT) stations near Hawaii, at 1-month intervals from February 1964 to June 1965. The station pattern consisted of 42 hydrographic stations measuring temperature and salinity to a depth of 1200 m and 148 BT stations measuring temperature to a depth of 240 m. The pattern ran between 10°N and 26.5°N, 148°W and 157°W. Only the northern half of the pattern is shown in Fig. 1.

From the hydrographic data Charnell *et al.* (*2*) calculated the dynamic depth of isobaric surfaces. The dynamic height of an isobaric surface near 200 m, relative to that of an isobaric surface near 1200 m, was then calculated for each hydrographic station. Since each station was occupied 16 times, the mean and standard error of the 16 measurements were computed. The resulting field, plotted on Fig. 1, exhibits the large-scale, long-term mean baroclinic flow at 200 m relative to

Table 1. Dates of coverage for vertical sections of temperature between R.V. *Townsend Cromwell* stations 37 and 40.

Section	Dates
1	3–5 March 1964
2	2–4 April 1964
3	1–3 May 1964
4	2–4 June 1964
5	2–4 July 1964
6	29–31 July 1964
7	Missing
8	17–19 September 1964
9	17–19 October 1964
10	21–23 November 1964
11	17–19 December 1964
12	21–24 January 1965
13	24–26 February 1965
14	25–27 March 1965
15	27–29 April 1965
16	28–31 May 1965
17	29 June–1 July 1965

1200 m in this region, directed toward the west-southwest, with speeds of 1.5 ± 0.7 cm sec^{-1} around 25°N.

The line of stations between stations 37 and 40, running between 148°W and 157°W, lies roughly parallel to the contours of the isobaric surface at 200 m. The ship moved along this line from east to west in a 2-day period during the dates shown in Table 1. In the resulting 16 vertical sections of temperature (Fig. 2), the isotherms show large wavelike perturbations about their mean state, suggestive of mesoscale ocean eddies. Autocorrelation-lag analysis of the 18°C isotherm gave an average zonal wavelength of 480 km. The BT data from the stations forming corners near stations 37 and 40 suggest a similar meridional wavelength (*3*).

Prominent perturbations were selected by eye and labeled with lowercase and uppercase letters. The westward drift of these features from section to section is readily apparent in many cases but questionable in others. The lines of constant phase were drawn by inspection in Fig. 2. I tested this choice by forming the time and space (east-west) lagged autocorrelation of the 18°C isotherm depths from the sections in Fig. 2. Significant positive correlations were achieved with an average lag of 115 ± 55 km per month to the west, an indication of an average westward phase speed of 4.5 ± 2.0 cm sec^{-1}.

In spite of the large errors in the phase speeds of both the mesoscale eddies and the large-scale mean baroclinic flow at 200 m, the agreement in sign between the eddy phase speed and the baroclinic flow speed and their comparable magnitudes suggest that the mean flow strongly influences the path taken by the eddies, in a manner analogous to the case of atmospheric cyclones.

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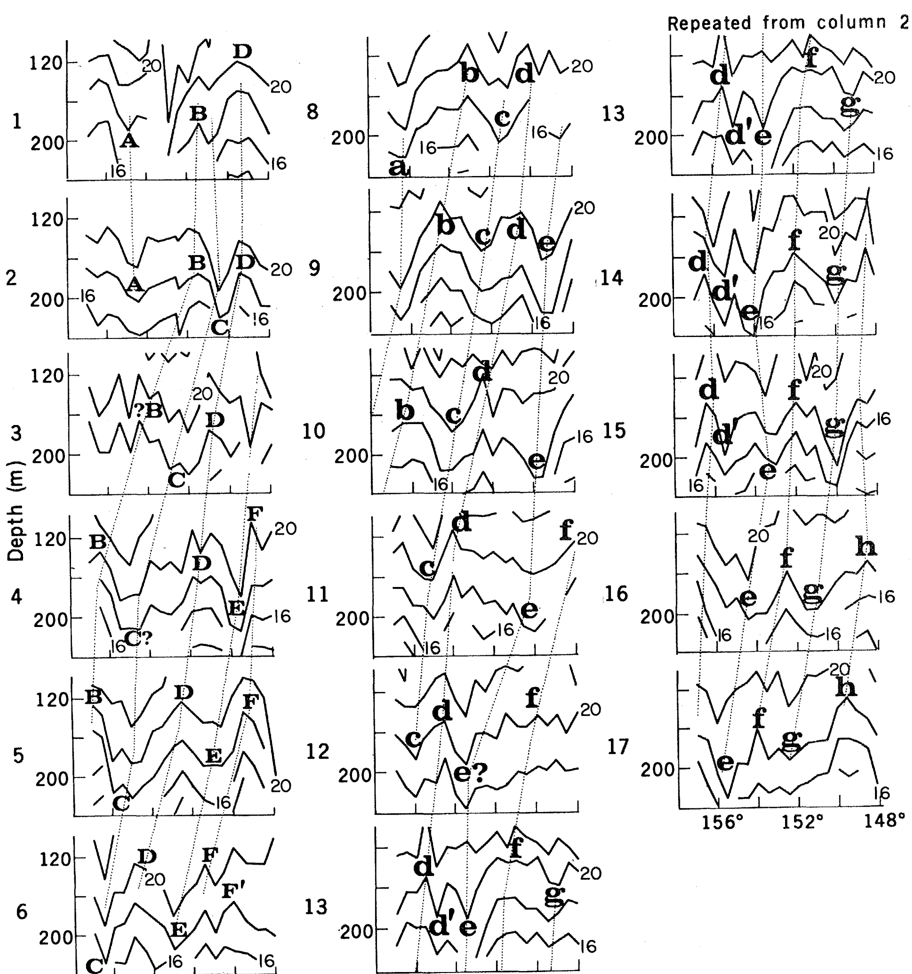

Fig. 2. Vertical sections of temperature (in degrees Celsius) along stations 37 to 40 from Fig. 1. Each section was covered 16 times at 1-month intervals (Table 1). Dotted lines show the westward propagation of lettered features over several months.

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