Book: Dynamical Oceanography
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For large-scale flows in the deep ocean at locations far away from the equator, the relative vorticity can be neglected with respect to the planetary vorticity.

a. a. Argue why this holds and show that for a constant density flow, the shallow-water potential vorticity Π *reduces to*

$$\Pi = \frac{f}{H}$$

where H *is the thickness of the layer and* $f = f_0 + \beta_0 y$ *is the Coriolis parameter on the* β *plane.*

In regions excluding the equator, $\sin\theta$ is $O(1)$, so that low-Rossby-number flows have the property that their relative vorticity is small compared to the planetary vorticity. One immediate consequence of this fact is that large-scale flows are hardly ever free of vorticity and their vorticity is primarily the planetary vorticity.
The potential vorticity (taking constant density) is $\Pi = (\zeta + f)/H$. Since for large-scale flows in the deep ocean far away from the equator, the relative vorticity is much smaller in magnitude than the planetary vorticity $f = f_0 + \beta_0 y$, it follows that $\Pi = f/H$, where H is the depth of the layer.

Consider now the east to west flow over a seamount as sketched in the figure on page 87.

b. Describe the path of a watercolumn in this flow.

When the flow enters the western part of the ridge, the layer thickness H decreases. Conservation of potential vorticity then indicates that f should decrease and hence on the Northern Hemisphere, the flow moves equatorward. After passing the ridge, the layer thickness increases again and the flow moves poleward.