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Investigations on the dynamic of coastal upwelling off Cap Blanc

by

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The area of investigation comprises the region between Cap Barbas and Cap Blanc off the NW African coast. Due to the high values of the global radiation sums prevailing in this area, the formation of an isothermic layer with a thickness of several decameters and with a high salinity and a low nutrient content is certain if the effects of the wind are only slight. This surface layer is separated from the deeper, colder water with a low salinity and a high nutrient content by a layer with steep vertical parameter gradients. According to fig. 1 (HAGEN, 1974 a) there are principally four distinct phases of development of the upwelling.

Fig. 1 A simple scheme of the development of cold water upwelling circulation cells off the NW African coast

In the first case (fig. 1a), the pycnocline is horizontal. The actual sea level does hardly deviate from the horizontal level (NN: mean surface level). As continuous winds start blowing

parallel to the coast or with a slight offshore component, this results in the mass transport of water near the surface and near the bottom in an offshore direction. The structure of the water body becomes increasingly barocline. The transport of water towards the coast, which is necessary for reasons of continuity, takes place in the intermediate zone above and below the pycnocline.
The accumulation of water masses caused by the wind in the region before the coast (characterised by the positive anomaly in the dynamic depth ΔD) forces the pycnocline downwards in some distance from the coast (convergence); it rises again as the coast is approached (divergence). The physical sea level responds inversely. This stage of transition is shown in fig. 1b.

In the course of the further development, the rise in the pycnocline reaches such proportions near the coast that the isopycnics reach the surface in the inshore region (region with a negative dynamic anomaly). The result is an increasingly pronounced horizontal gradient which, if sufficiently high values are reached, causes a density gradient current parallel to the coast which, once again, acts for the zonalcomponent of current as a "barrier" surface front.

A third circulation cell as shown in fig. 1c is formed in the immediate coastal area. If this development continues, the location of the density gradient current moves towards the sea (fig. 1d). It begins to affect the deeper layers and is inclined towards the coast at a small angle in the same way as the boundary layer. The offshore drifting water in the onshore region is forced to sink down along this barrier and in subsurface layers causes weak instabilities.
At the offshore flank of the barrier the onshore flowing water above the pycnocline ascends and forms a "secundary" cold water upwelling marked by lower intensity and no enrichment of nutrients.

The water moved towards the shore below the pycnocline reaches the surface of the actual inshore cold water upwelling region between the "barrier" and the coast. The cours of the surface front is narrow connected with the cours of the shelf-edge.
Between Cap Barbas and Cap Blanc prevails a main current with SW-direction. It is composed by the Canary current, the winddrift and the geostrophical current.
EKMAN (1923) showed, that if a current is running over increasing depths a curl contra solem is originating. This curl shifts to the surface front. In the front area the eddy is drifting with the main current to S-SW-direction. Near the front its intensity is decreasing by influence of lateral eddy flux. Thus the curl is moving to southern areas with lower horizontal pressure gradients.

In summertime the surface front south-westerly from the Banc d' Arguin is changing from meridional to zonal direction.

Fig. 2 Cours of the surface front during summertime in the NW African upwelling region

That results is a "steady state" of the contra solem eddy southerly of Cap Blanc, (fig. 2), HAGEN (1974 b). This curl receives energy from southward running eddies. Between this eddy contra solem and the coastline an eddy cum sole arises, which is favoured by the coast configuration and the bottom topography.
In the region off Cap Blanc the mass deficit between the surface front and the coast is balanced not only by a current normal to the coast (fig. 1) but also by a northward running compensation current near the bottom from the Banc d'Arguin region.

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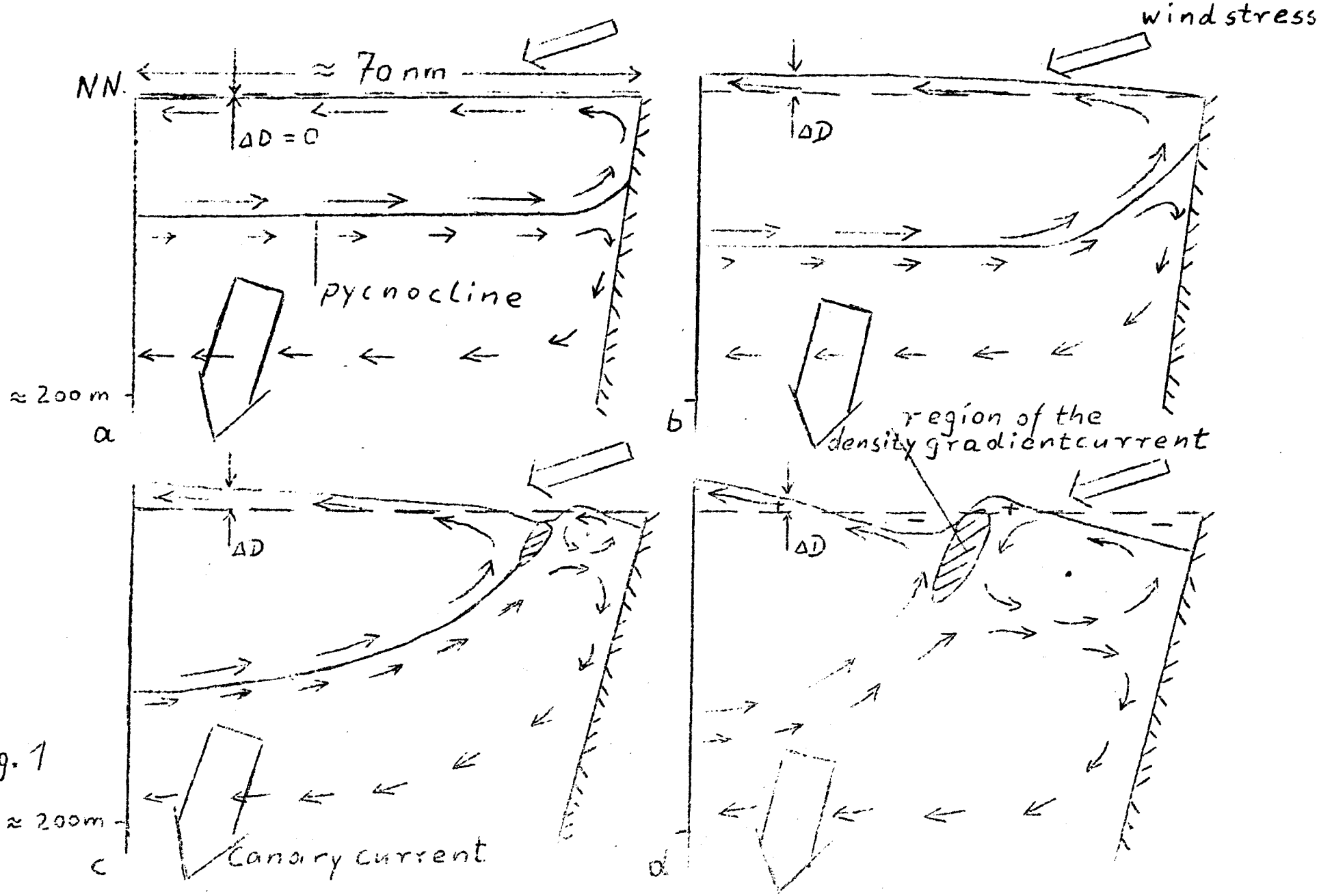
NN.
≈ 70 nm
ΔD = 0
pycnocline
≈ 200 m
a
windstress
ΔD
b
region of the
density gradientcurrent
ΔD
≈ 200m
c
Canary current
ΔD
d

Fig. 1

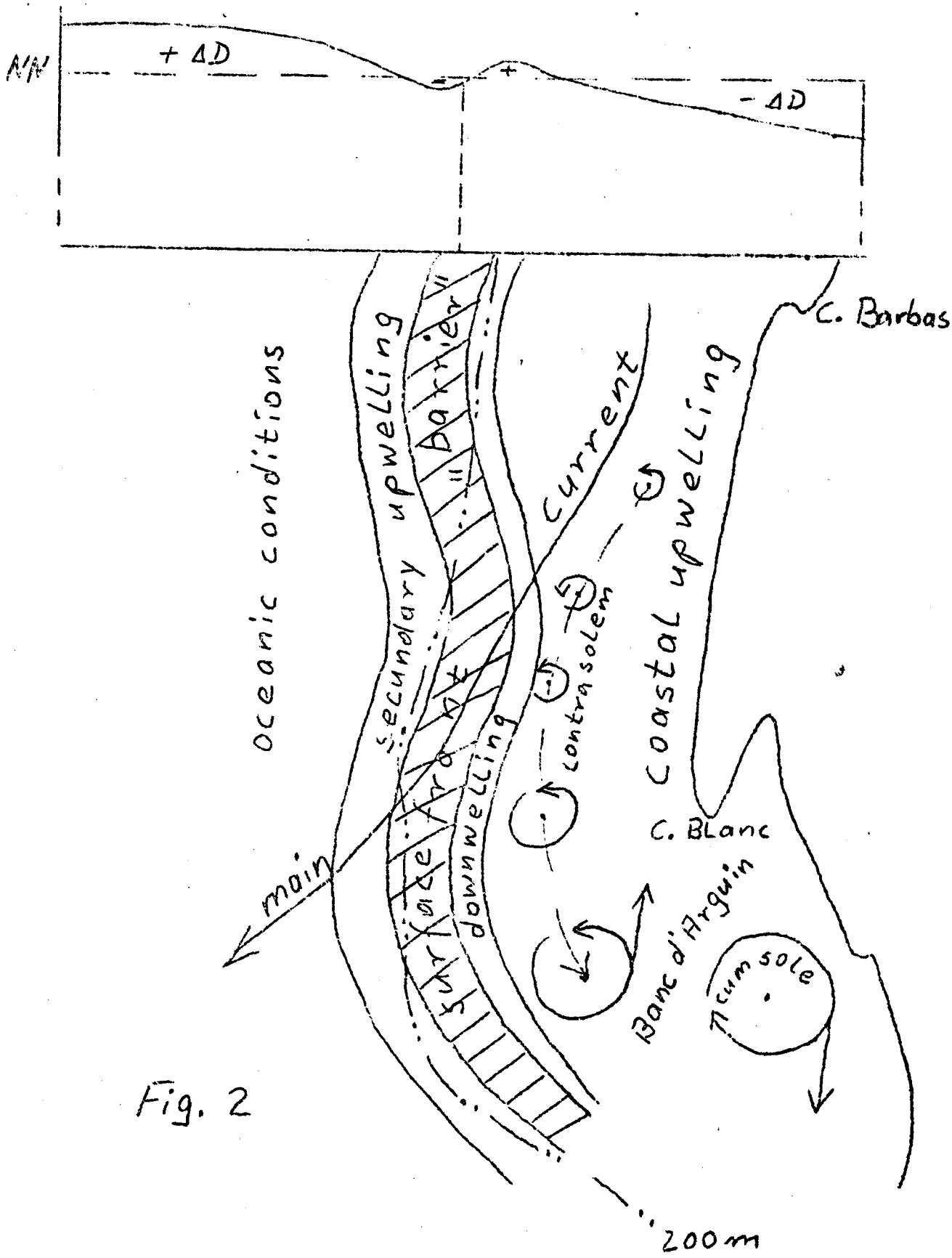
NN
+ ΔD
- ΔD
oceanic conditions
secondary upwelling
Barrier
current
C. Barbas
coastal upwelling
contra sole
C. Blanc
main
surface front
downwelling
Banc d'Arguin
cum sole
200 m

Fig. 2