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SOME OBSERVATIONS ON SEA WATER CIRCULATION IN THE AREA OF THE DANUBE MOUTHS

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ABSTRACT:

The paper analyses the results of direct marine current measurements carried out off the mouths of the Danube in April and September 1977, corresponding respectively to periods of high and low Danube water discharge. The main factors acting on the regime of the currents within different water layers are considered: wind, river discharge and shoreline direction. The existence of a general southward flow up to 12-15 Nm width has been finally pointed out.

The marine zone from the mouths of the Danube it is extremely interesting from a hydrological point of view because of the penetration into the sea of a great quantity of river water. The complex mixture processes of the two waters, sea and river, having different phisico-chimical characteristics, are strongly influenced by marine currents.

The investigation carried out so far gives us a general image about the sea water movements in the area but as they were based on an insufficient number of observations any further attempt to approaching the subject will be well-come. We hope our observations will contribute to the improvement of the knowledge in the field.

In this area, the river discharge plays an important role in the sea water circulation. For this reason we chose the months of April and September for our cruises as they correspond to high and low Danube water discharge.

Direct measurements were made using floats and current-meters in standard layers. A network of 28 stations was set during each cruise between parallels $45^{o}05'N$ and $40^{o}40'N$ from the shore up to the $30^{o}02'E$ meridian (Fig.1). The stations were located on 6 E-W profiles spaced five miles distance from each other. The distance between stations on each profile is also five miles. In onder to get the same meteorological conditions, we worked intensively, on board of two ships, covering the entire area in 32 hours in April and 36 hours in September.

Before talking into account the results on the two cruises one must emphasize that along the Romanian coast and especially at Sulina and Sf.Gheorghe the prevailing winds blow from north, thus contributing-together with river discharge-to generating and maintaing a southward sea water circulation (2, 5). This must be regarded as a general flow direction, within which the currents do not occur in a stationary state but they change their parameters as a function of the prevalence of a certain temporary wind direction, especially in the superficial layer (3, 6, 7).

Previous to our cruise on 22-23 April, 1977, the atmospheric circulation was dominated by relatively strong northerly winds with daily resultants NNE 9,7 m/s at Sulina and N 7,8 m/s at Constanţa. While carrying out the measurements, the northerly winds blew only at stations located in the northern zone, on profiles A and B, and at three stations on profile C. Under these conditions, the superficial waters moved SW with velocites up to 59 cm/s (Fig.2). Because of the Earth rotation, the Coriolis force causes deviation of the currents to the right, stressing their tendency to gyre toward the shore.

At stations C_3 and C_4, as the wind direction changed, a part of the waters carried by the main SW current get a new direction to NW, driving along in the same direction a certain amount of the stream that flows out from the Sf.Gheorghe branch.

Right near the shore, there is a slight northward circulation that generates a local anticlockwise circulation between

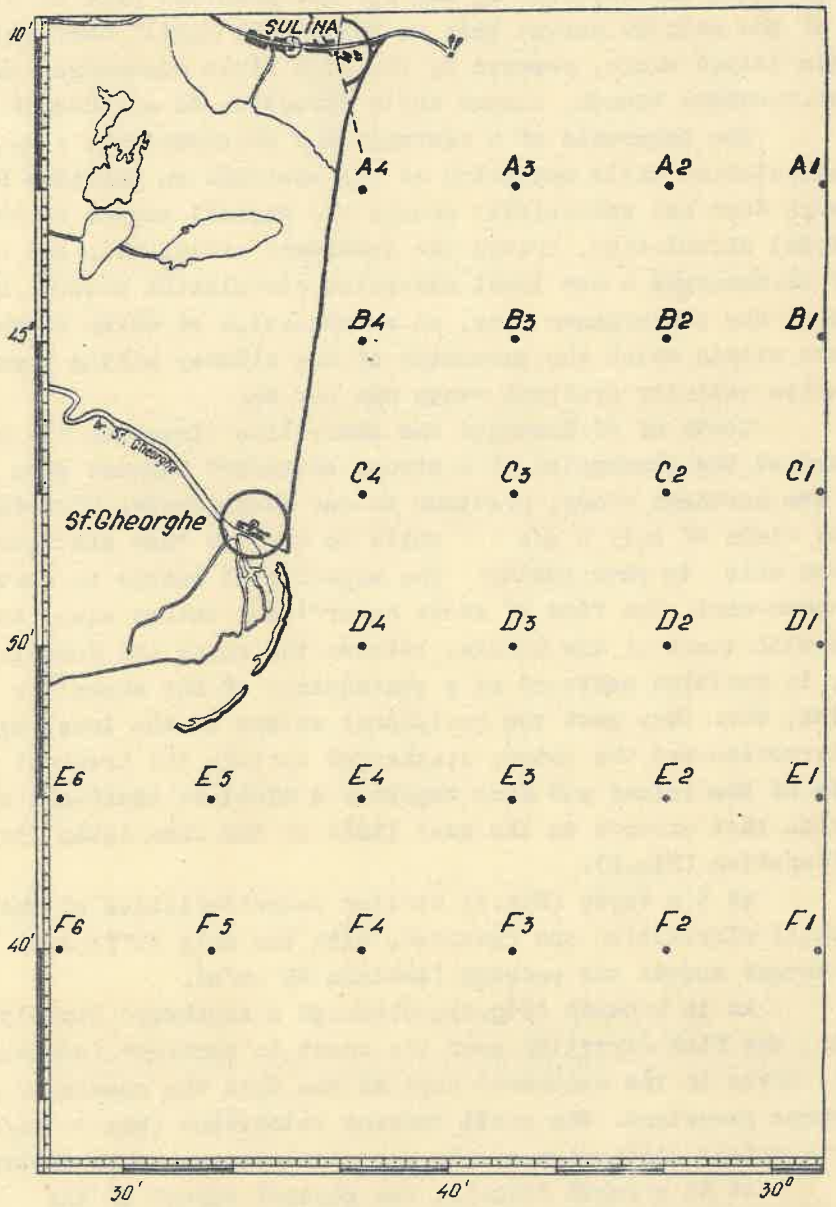

Fig.1 - The network of stations for measurements in the zone of the Danube mouths in 1977.

the shore and the stations A_4 and B_4. The greatest part of the waters of the main SW curent keep on their flow untill they approach Sahalin Island where, pressed by the high river discharge from the Sf.Gheorghe branch, change their direction to south-east.

The occurance of a westerly and southwesterly atmospheric circulation while measuring at the stations on profiles E and F, though does not essentially change the general aspect of the superficial circulation, abates the southward circulation and so, SE of Sf.Gheorghe a new local clockwise circulation occurs. Because of the convergence area, an accumulation of water masses appears within which the intensity of the sideway mixing processes makes salinity gradient reach 4‰ per Mm.

South of Sf.Gheorghe the shore line direction did not encouraged the generation of a strong southward current even during the northern winds, previous to our measurments. Therefore, the SW winds of only 5 m/s while we were on that stations have been able to move easily the superficial waters to north and north-east. The flow of these superficial waters along the coast with those of the Danube, between the shore and Sahalin Island, is deviated eastward as a consequence of the shoreline direction, too. They meet the peripheral waters of the local cyclonic formation and the waters discharged through the break at the middle of the island and form together a distinct southward circulation that extends to the east limit of the area taken into consideration (Fig.2).

At 5 m depth (Fig.3) similar characteristics of the superficial circulation are recorded, with the only difference that the current speeds are reduced (maximum 45 cm/s).

At 1o m depth (Fig.4), although a southward circulation exists, the flow direction near the coast is contrary (compensation), while in the southeast part of the area the nonsteady regime become prevalent. The small current velocities (max 37 cm/s) show important diminution of the wind influence on this layer.

At 2o m depth (Fig.5), the general aspect of the circulation is changed. The greatest part of the area is marked by a northward flow (as a countercurrent) having velocities of up to 24 cm/s. There is only a small narrow strip in the NE of the area where a southward circulation exists in this layer, off the

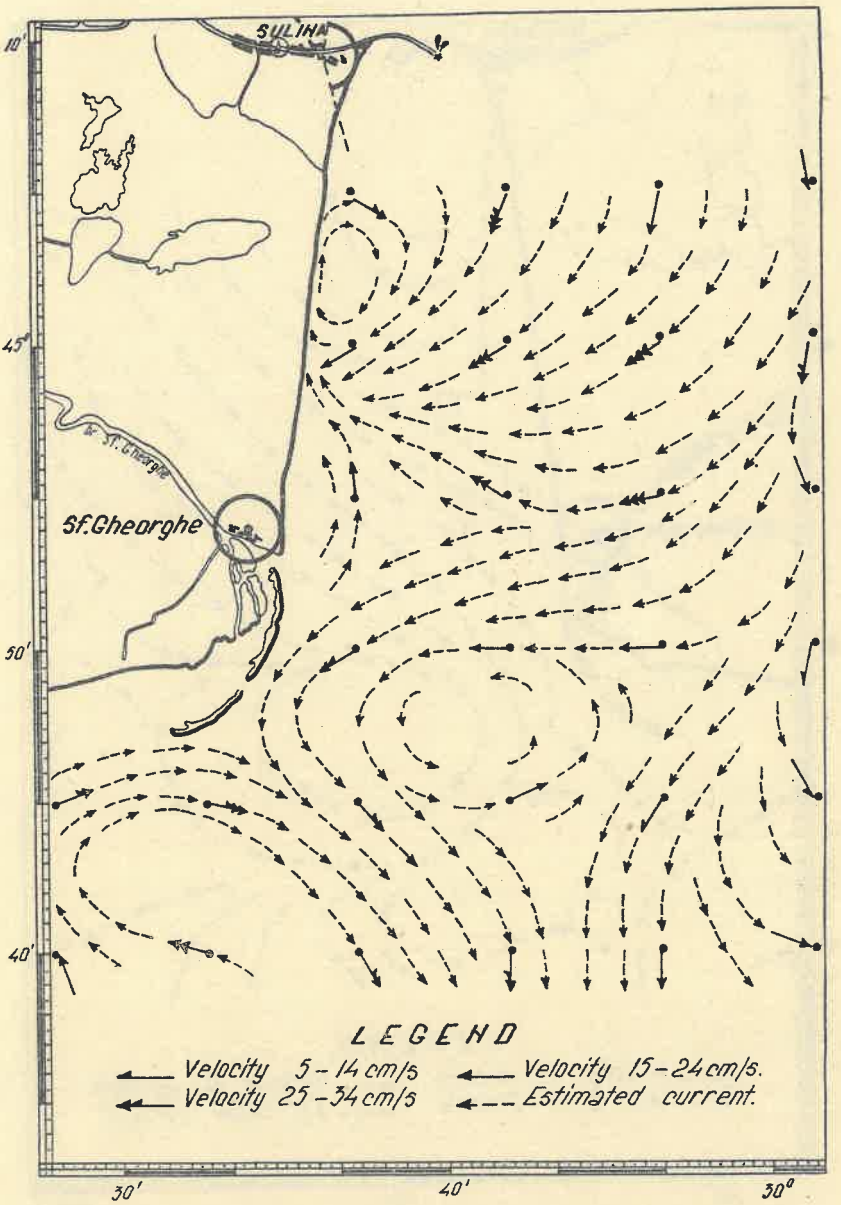

Fig.2 - Surface sea currents in the zone of the Danube mouths (April 22-23, 1977).

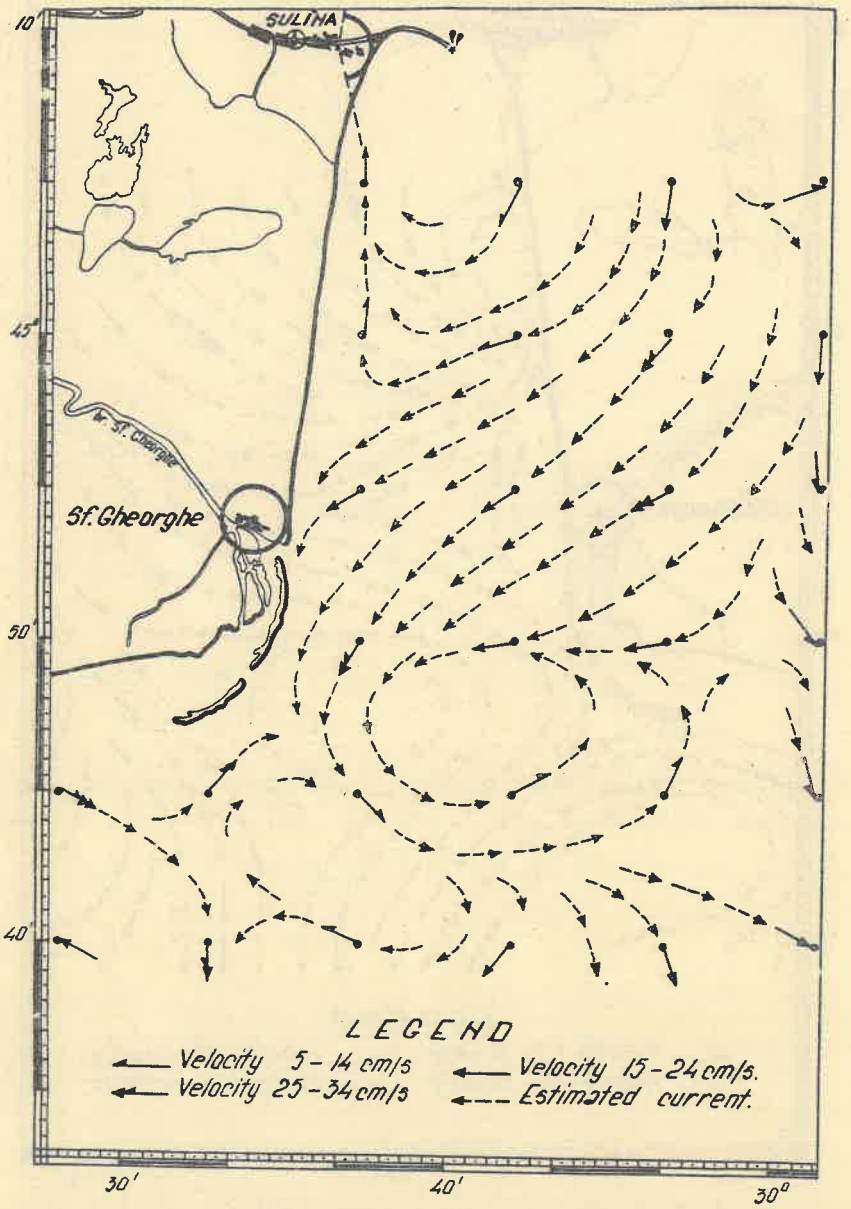

Fig.3 - Sea currents at 5 m depth in the zone of the Danube mouths (April 22-23, 1977)

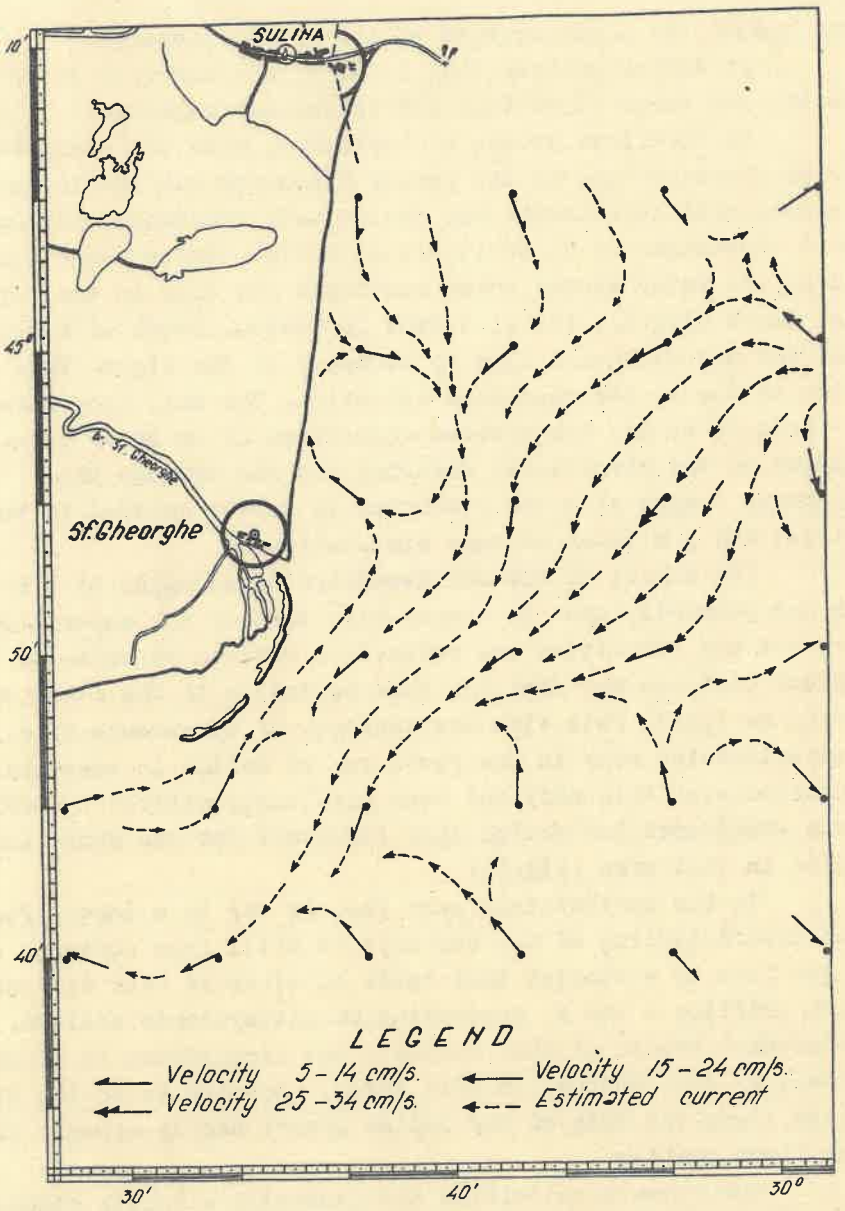

Fig.4 - Sea currents at lo m depth in the zone of Danube mouths (April 22-23, 1977).

Sulina branch, as a consequence of its great discharge.

At depths greater than 3o-4o m, the currents loose their intensity and their directions and become heterogenous.

In the first decade of September, when the measurement campaign corresponding to low Danube discharge was carried out, the atmospheric circulation was exclusively southward, having diurnal resultants of up to 11 m/s at Sulina. Under these circumstances, the water masses moved southward not only in the superficial layer (Fig.6), but also down to bottom. South of Sahalin Island the net southward flow is diverged to the right. This deviation is due to the shoreline direction. The main flow direction (from NE to SW) has maximum velocities of up to 77 cm/s. The influence of the river water reaching the sea through the Sf.Gheorghe branch at a low discharge is hardly noticed in the superficial and 5 m layer current circulation.

The aspect of the southwestward circulation at 5 m depth has generally much in common with that of the superficial layer, but the velocities are reduced to maximum 35 cm/s. In the northwest part one may find the same deviation to the right that appeared on April. This time the tendency of appearance of a local anticlockwise eddy in the south bay of Sulina is more evident. The existence of this eddy had been previously noticed by BONDAR (1) who considered its action very important for the shore morphodynamics in that area (Fig.7).

In the northwestern part too, at the 1o m layer (Fig.8), the northward turning of the currents is still more obvious, taking the form of a ringlet that tends to close at half distance between profiles A and B, generating an anticyclonic nucleus. In the shoreward branch of this ringlet, the circulation is directed northward by compesation. In this layer, opposite to spring time, the flow along the axis of the Sulina branch hardly appears even on the first profile.

The curents velocities are generally slightly higher than those measured in spring, as a consequence of the strong northerly winds. However, the maximum velocities are lower 28, as against 37 cm/s, because of a low river discharge in the period.

At 2o m depth (Fig.9) the current direction is preva-

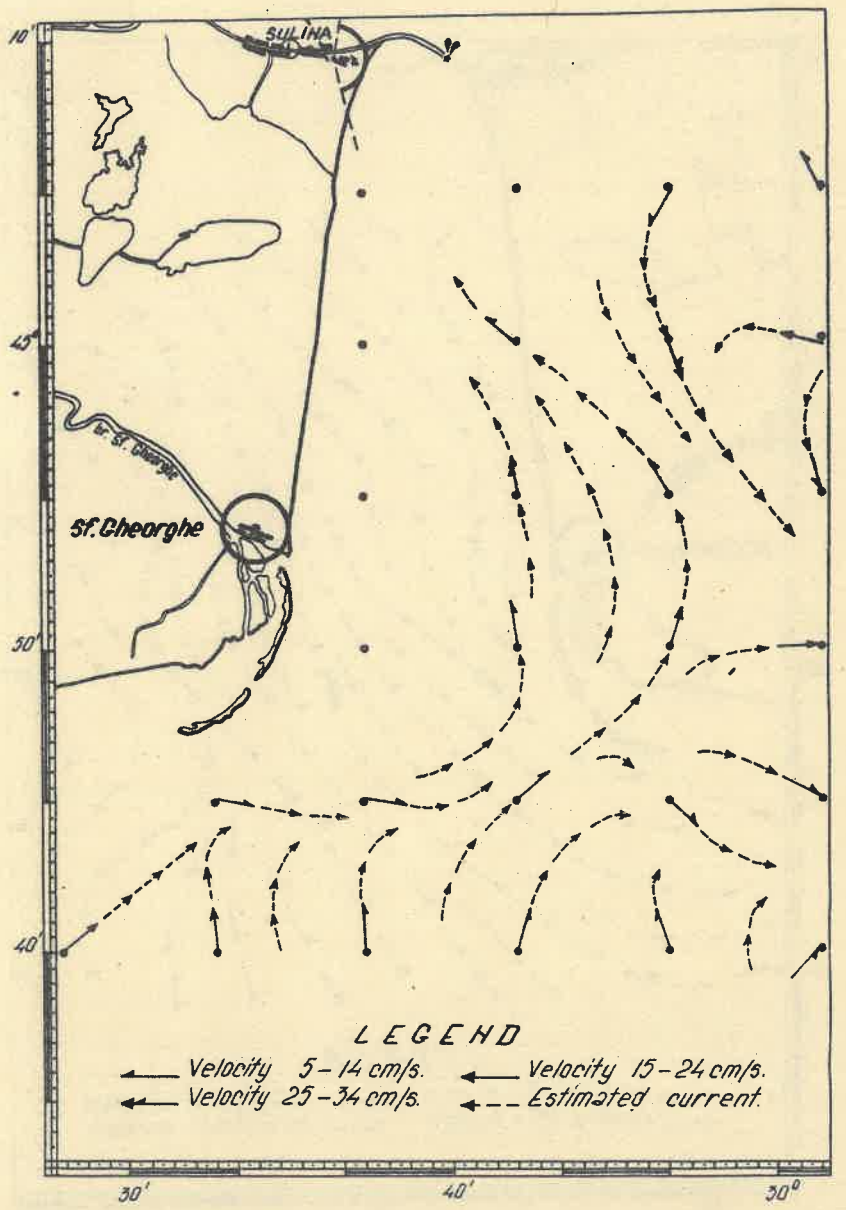

Fig.5 - Sea currents at 2o m depth in the zone of the Danube mouths (April 22-23, 1977).

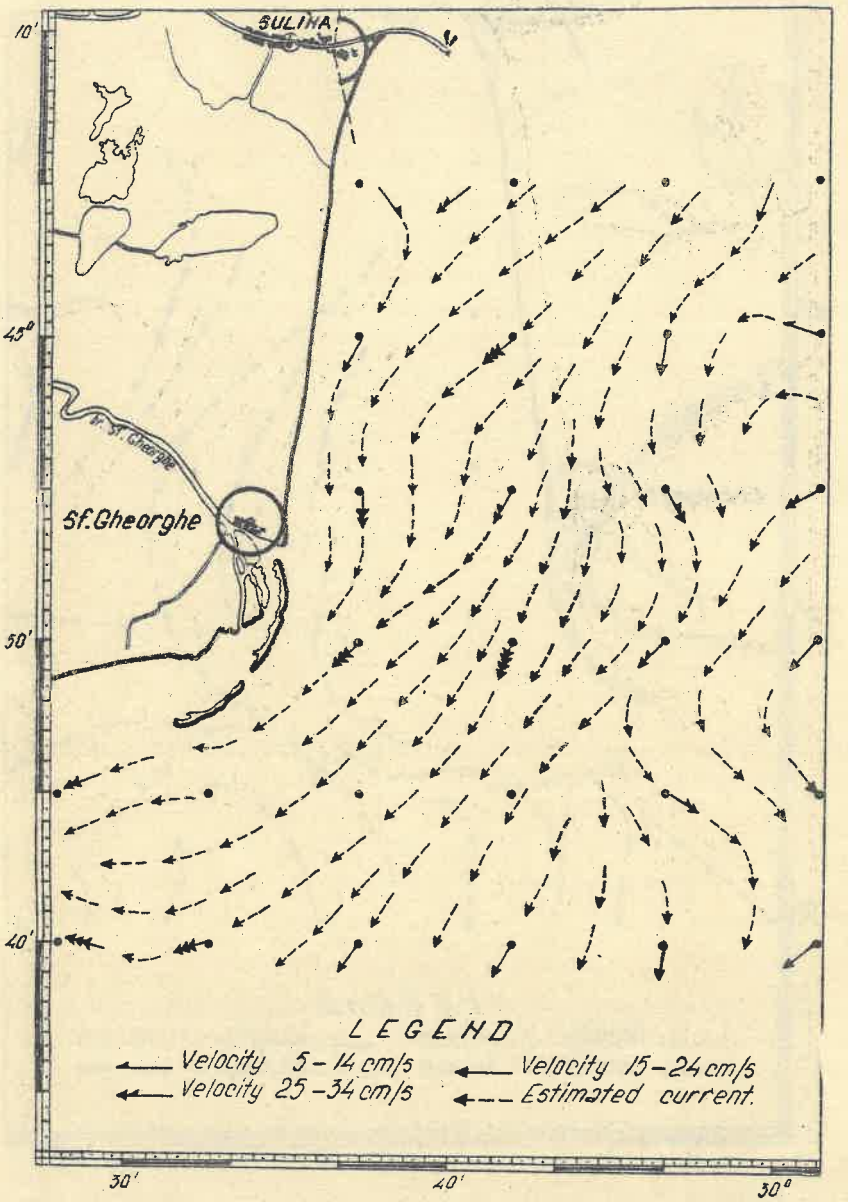

Fig.6 - Surface sea currents in the zone of the Danube mouths (September 7-8, 1977).

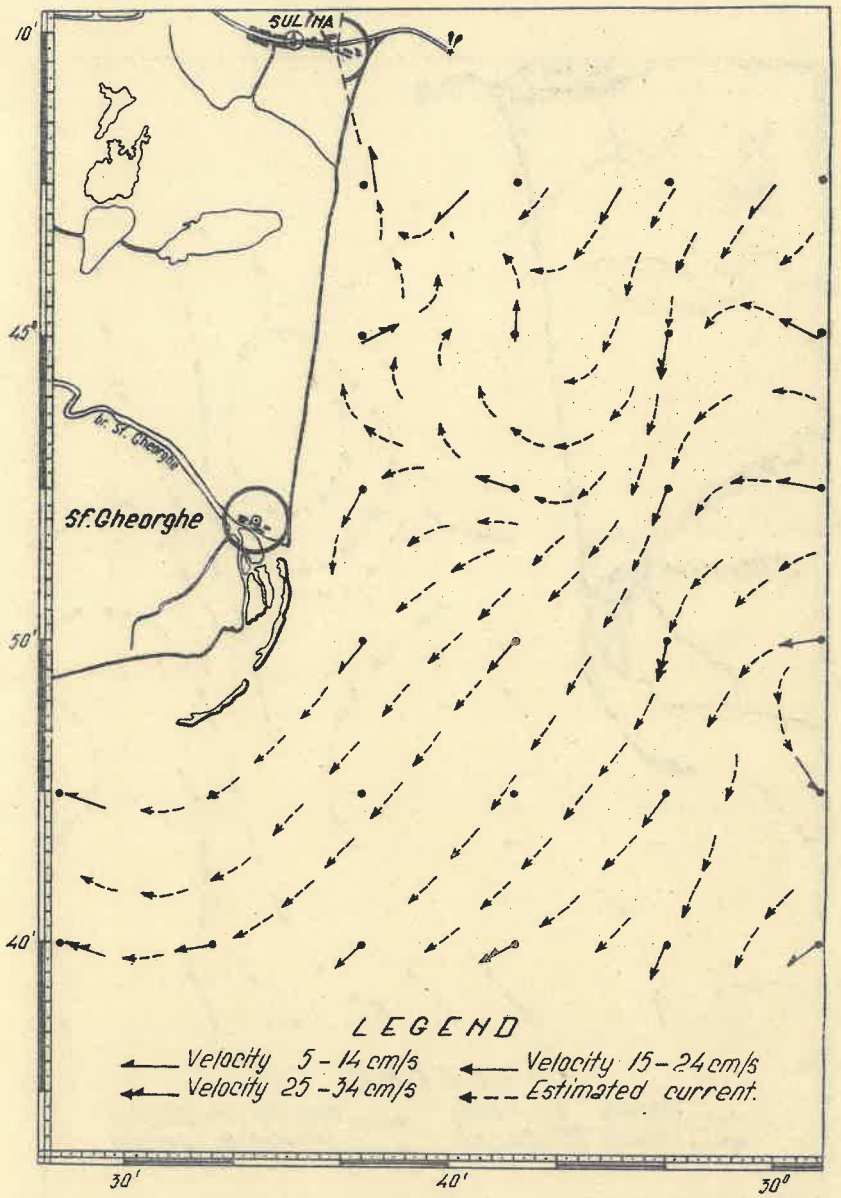

Fig.7 - Sea currents at 5 m depth in the zone of the Danube mouths (September 7-8, 1977).

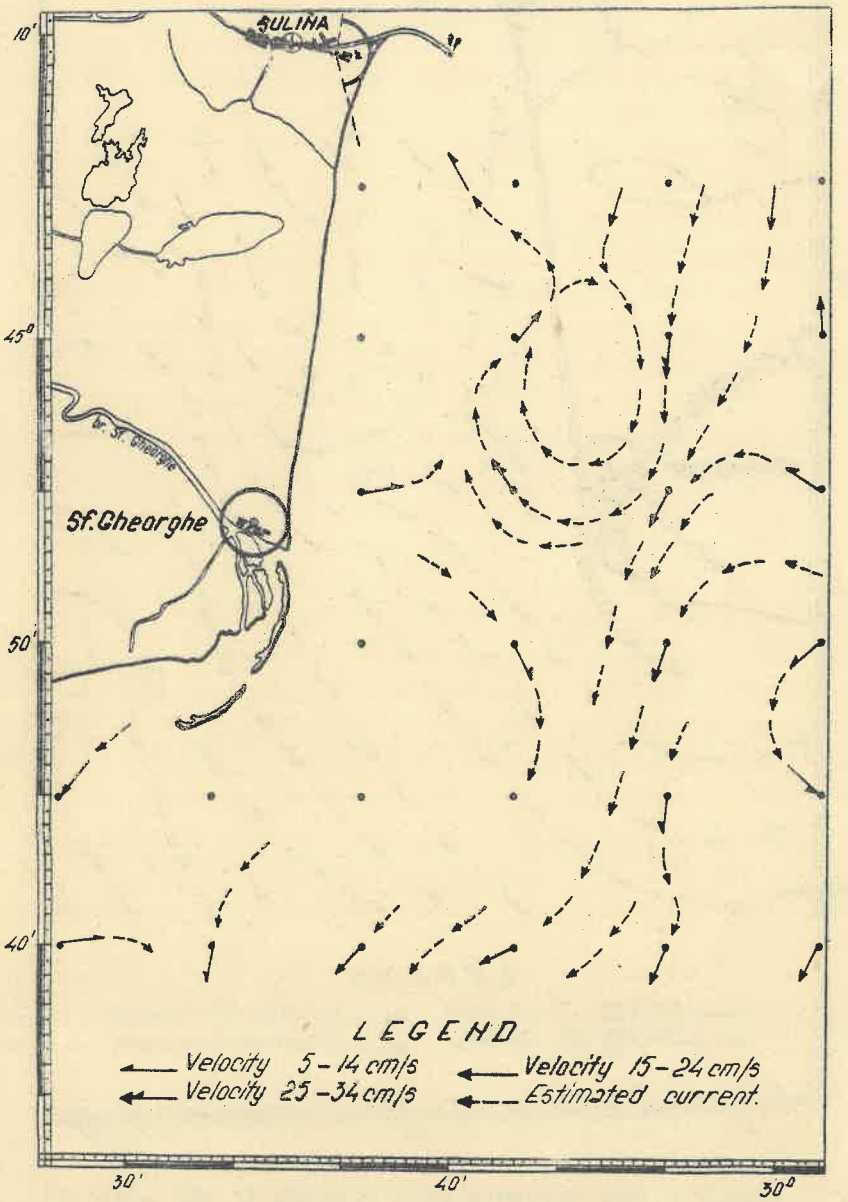

Fig.8 - Sea currents at 10 m depth in the zone of the Danube mouths (September 7-8, 1977).

lently southward, with velocities of up to 22 cm/s. Near the shore only, in a very narrow strip, a northward countercurrent flows parallel with the coast.

At 3o m depth the aspect is similar but the velocities do not exceed 18 cm/s.

Comparing the resulting circulation maps for both seasons-spring and autumn-one may notice that in the east part of the area, on the meridian of the offing stations, at all horizons, most of the currents have directions prevalently southward in spring and westward in autumn.

Taking into account this fact and the general current circulation map of the Black Sea (4), we consider that there is, along the 3o°E meridian, a branch of the clockwise current of the Black Sea coming from the Crimeean coast that meets the southward nearshore current and then flow southward together, forming the well-known current of Rumelia. This will transport the mixed Danubian and marine waters far to the south, having a very important influence on the hydrological and hydrochemical regime of the coastal marine waters.

It is also to be noticed that the width of the general southward flow is by about 5 Mm greater in April when there is a high river discharge.

In conclusion, one may say that:

- At both high and low Danube river discharges, when the northerly winds prevail a general southward current appears in the marine area of the Danube mouths, with a width of 12-15 Mm. The temporary changes of wind direction do not essentialy modify the current regime. They can determine the appearance of some locale addies in the superficial layer, favouring the mixing processes.

- The differences in current regime at high or low Danube water discharge, though they occured, were blurred by the strong influence of the northerly winds that blow before and during the observations (especially in autumn).

- The intensity of the currents diminishes with depth and the flow directions become more instable.

- At the 1o-2o m layer, near the shore, compensation currents appear. The area of their action is much ristricted in

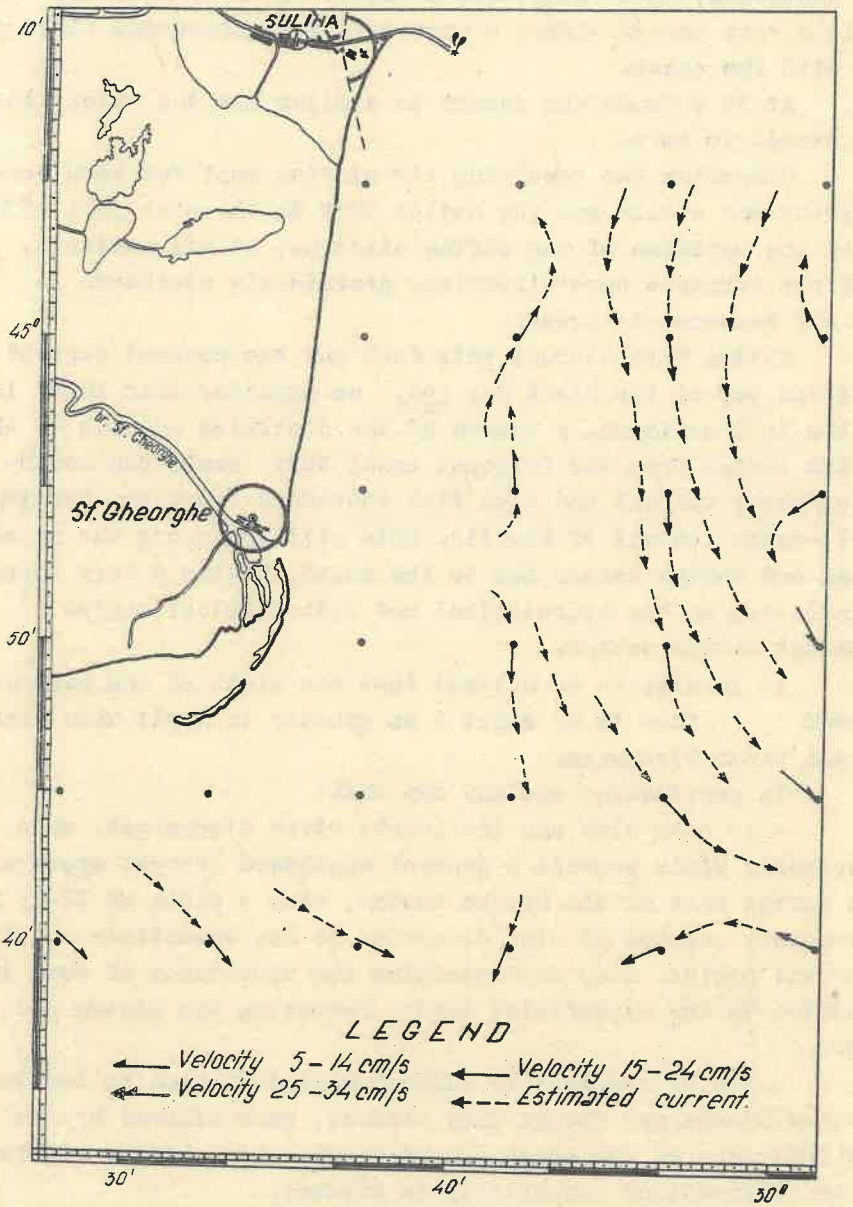

Fig.9 - Sea currents at 20 m depth in the zone of the Danube mouths (September 7-8, 1977)

the autumn because of the deep extension of the southward circulation generated by strong northerly winds.

- Off the coast, on the 30°E meridian a junction occurs between the southward coastal current and the northern branch of the general Black Sea clockwise current.

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