SEA DEPOSITS.

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Among the numerous problems that come within the province of hydrography are those questions relating to the nature, the origin and the transport of matter in suspension in sea water. Where do the ooze and sand which constitute the bed of our coastal waters, come from ? For instance, why does such and such a depression invariably have a bottom of pure sand while another in close proximity to it has an essentially oozy bed ? How is the transport of such matter effected and in what conditions is the deposit of it carried out ? All of the above are questions of long-standing but which have not so far quite received satisfying and definite answers. All the affirmations or the laws concerning them seem to generalise a few meagre experiments or a few laboratory researches, or even to be only the result of simple assumptions since investigations conducted on a large scale rarely lead to any desired confirmation. It may be admitted, however, that under the vigorous impulse of modern science and technique, methods have greatly developed and, consequently, measurement instruments been much improved and better fitted to pursue the results aimed at. A concrete case illustrating these considerations is notably that connected to the study of transport and deposit of matter in suspension in sea water. Formerly it was accepted that the thickness of a marine deposit was deduced with sufficient accuracy from two measurements, one made in the upper layers of the sea, the other in the vicinity of sea-bottom. Now, such a method is inapplicable when currents come into play, because in this case the sediments are carried to bottom level in the form of a more or less consistent mass and the quantity of matter transported increases in proportion with the rapidity of the current, the lesser age of the deposit and the finer grain of the constituent elements. In a process of silting, it is unquestionably the transport of solid matter by crawling on the sea-floor that exceeds by far all other considerations.

The importance of this transport by crawling is perfectly demonstrated by the diagrams summarising the analysis of a series of samples taken in varied current and depth conditions over a bottom of soft ooze—therefore of recent deposit.

The diagrams show clearly that, with a feeble current, the specific solid content of waters in the vicinity of the sea-floor is greater than the content of upper-layer waters by a few grammes to the metre cube only; but it is to be noted that the difference increases rapidly as soon as the velocity reaches about 30 metres per minute at the surface, i. e. approximately 15 metres per minute at a distance of 5 decimetres from the bottom. From the aspect of the diagrams the importance of the transport of solid matter in the lower layers may be imagined, but unfortunately, this escapes all investigation, from which it is naturally inferred that it is absolutely useless to try to calculate a supply rate of solid matter; so much the more is this the case when it is borne in mind that experiments can yield only relative results for calm weather. Now, the specific content varies considerably with the state of the sea, which implies the use of an augmentation factor the importance of which is in terms of the height of the wave and the thickness of the liquid lower-water layers. Here again, suitable appreciation data are totally lacking. Moreover, it may be easily conceived that it cannot be otherwise and that no credit must be attributed to figures denoting values for the influence of the state of the sea on the specific solid content. It has been seen that the supply-rates of solid matter are by far greatest in the liquid layer quite close to the sea-floor and that the measurement of the density content necessitates the accurate determination of the level at which the samples were taken. But it is difficult to imagine the possibility of making any such accurate measurement while the ship carrying the observers rolls from side to side with the result that the measuring apparatus undergoes alterations in level of perhaps several metres. On the other hand, reliable results may be hoped for only if the instrument used is not leaning on sea-bottom, if during the operation it cannot contact the bottom and so cause an untimely upheaval of sediment, if its presence provokes only a minimum disturbance in nearby liquid streams, if the instrument be not too cumbersome and, in every case, fitted so that during the operation of sampling it shows no appreciable change of altitude due to the impulsive action of the current, and lastly, if the duration of the sampling operation be more or less prolonged—an uninterrupted period of operation would be perfect. Instruments for instantaneous sampling are altogether unsuitable because from the point of view of specific content, sea water is rarely of a homogeneous composition. With regard to this it should not be overlooked that upper-layer waters are of much greater velocity than deep-sea waters and that consequently the liquid streams must interpenetrate during their propagation and so carry into the upper layers the heavily loaded bottom waters; it is this convection phenomenon which, in calm weather and at the period of strong currents, gives the sea a characteristically clouded aspect. From all those considerations it follows that a good instrument must respond to numerous desiderata. A sea-water sampler which we have found quite satisfactory in use is described in "Hydrographic Review", May, 1937. With this sampler we have carried out successful operations in a very strong current (4 to 5 miles) and in close proximity to sea-bottom; it is simple in construction and easy to handle.

The area of Belgian coast where oozy bottom is found is limited to a more or less undulating line starting from Dunkirk and passing some eight miles off Walcheren Island. Beyond this line ooze is rare, while within its limits a whole series of intermediary qualities of sea-bottom is encountered, with a surrounding stretch of pure ooze and pure sand. The different qualities of ooze range from black to light-gray, even yellowish-gray, in colour. The colour of the ooze determines the age of the sediment. An old deposit is invariably composed of black ooze while light-coloured ooze indicates recent sedimentation. When a bulky sample of ooze is detached from the bottom by means of a drag, it is only in its surface layers that light-coloured ooze is found. Black ooze is produced by sulphuration of light-coloured ooze.

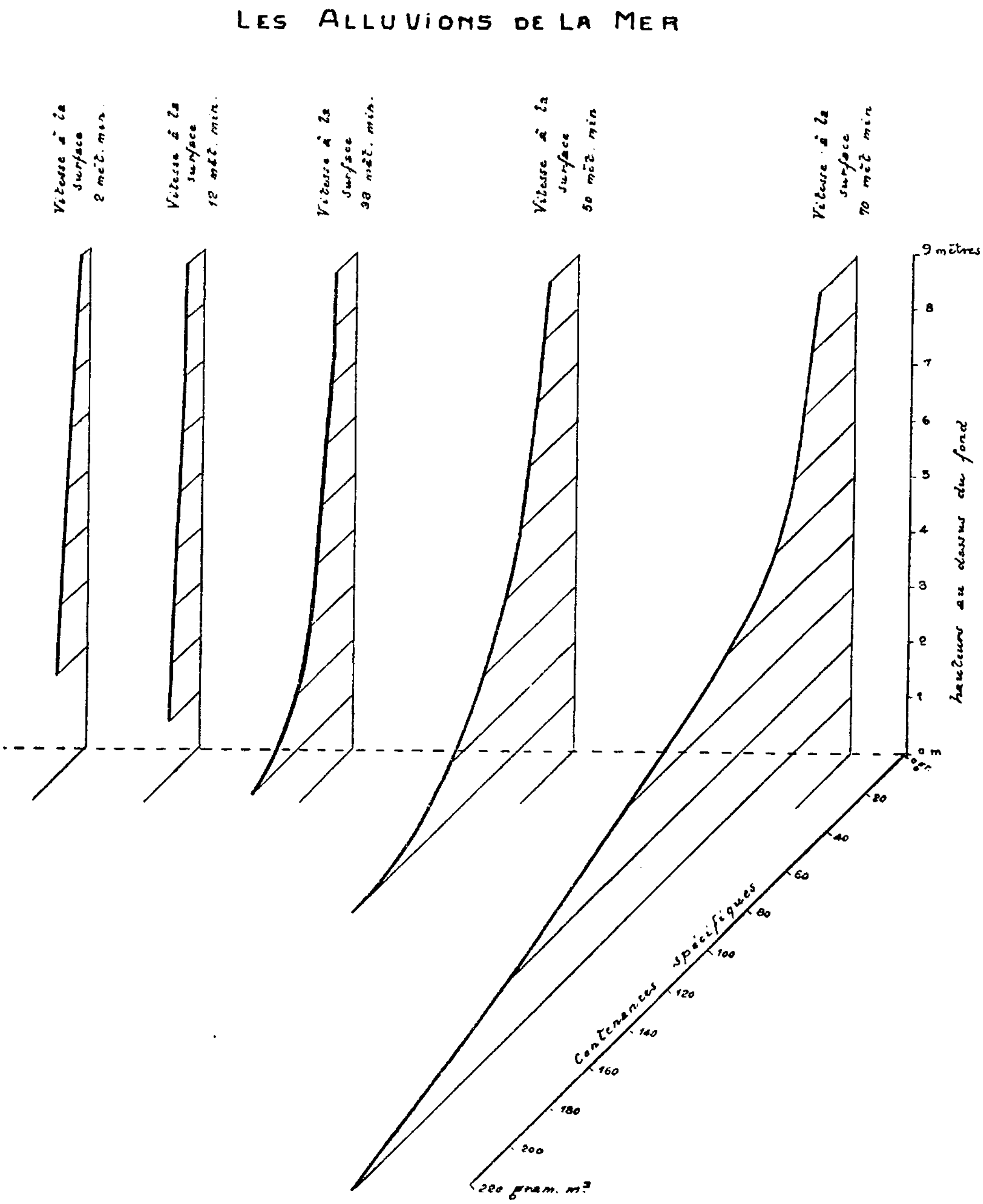
The origin of ooze is still greatly discussed. One is easily led to believe that ooze is composed of extremely fine sandy ingredients or, it may be, of the produce of the wash off clay banks; but since ooze belongs chiefly to littoral areas, it may be questioned whether a great proportion of this ooze is not formed by the refuse of aquatic life. In fact, biology teaches us that young fish like to frequent coastal waters and it should be remembered that young fish are phenomenally voracious. However that may be, it does not appear that ooze comes to the Belgian coast from western sea areas. Recent research on matter in suspension in our coastal waters is conclusive on this point.

The qualities of sand along our sea fronts include ingredients of various dimensions going from very fine sand (grains of less than 0.2 mm. diameter) to small gravel, but fine sand is greatly preponderant, and is moreover the constituent element of our dunes and of the higher part of the foreshore. Sand of average grain and coarse sand (the latter frequently mixed with débris of shell) is as a rule met with only on the crests of shallow banks one of the sides of which is steep, for instance, Middelkerke Bank, Bol van Heyst, while small gravel (also mixed with broken shells) belongs to formations of a special character such as the Ravelingen shoals, the group of knolls known as the Wandelaar Bank, the few shoals lying at the eastern point of the Paardemaarkt, etc.

The mixture of two elements, ooze and sand, forms the infinite series of qualities : oozy sand and sandy ooze. Such qualities of sea-bottom are encountered in depressions where one of the tidal streams is preponderant. A "schaar", whether flood or ebb, arises only where one of these two tidal streams is much stronger than the other. An example illustrative of the above is given by the system Westdiep—Petite Rade, Ostend. The Petite Rade is a flood "schaar" tributary of "*la mouille*" Westdiep where the two tidal streams are approximately of the same order of strength. From the point of view of the nature of the sea-bed, pure ooze is found in the eastern part of the "Petite Rade" which, towards the West, gradually becomes first, sandy ooze, then oozy sand and finally, in the "mouille" of the "Westdiep", pure sand.

An oozy bottom generated by quite a different process, is that of the deep contiguous to the seaward side of the Zeebrugge pier. Before the construction of this gigantic spit, depths of from 51 decimetres (Zand crest) to 76 decimetres below the L W Spring Tide were found. In 1906, i. e. when the construction was completed, depths of from 80 to 185 decimetres, among which was one depression of more than 12 metres, were found up to 500 and 900 metres' distance from the pier. There the sea-floor is of sand and oozy sand.

In 1938, 80 decimetres bottom extended up to 1500 metres from the pier; the " mouille " therefore, has considerably developed in surface but on the other hand, it is to be noted that the very great depths observed in 1906 have disappeared. The maximum is scarcely more than 111 decimetres. Thus from 1906 to 1938 warping has taken place in the immediate approaches to the pier and a deepening in the area somewhat farther offshore. On the other hand, the sandy bottom has



given place to ooze and continuous observation extending over nearly six months at a selected spot situated in these regions, proves that neither the strong Spring tidal streams nor waters agitated by tempest, bring about changes in the quality of sea-bottom.

These few remarks make it clear that the genesis of a marine formation frequently implies certain peculiarities proper to such formation.

The shifting of sand along the beaches springs from a mechanism quite different from that which operates offshore where the movement of matter is limited to a swing to and from a mean position, the swing being governed by the action of tidal streams. It may in fact be conceived that important migrations of sand in one unique direction would necessarily mean notable changes in banks and channels; however, if we refer as far back as trustworthy documentation can carry us, we find that for about a century the configuration of our coast has not as a whole suffered any great modification. It is quite otherwise with the beaches and adjoining areas. Here the wind has a predominant influence and its action is multiple. When the swollen waves engendered by sea-winds beat along the coast and break with violence on the slope of the foreshore, they cause an agitation particularly favourable to the maintenance in suspension of heavy matter detached from the sea-floor, to its transfer towards the coast and finally its projection on the beach whence, by reason of the lowering of levels resulting from the play of the tides, it is caught up again by the winds and directed towards the higher part of the foreshore or, farther on, will reach the coastal chain of the dunes. This explains why we find on our beaches among the sand, shells of various species of sea-life having belonged to the mollusca, carapaces of the crustaceans, pieces of turf—all driven from never-drying areas. Thus it is indeed the wave that nourishes our beaches. Confirmation of our thesis is made evident by a careful study of our large-scale hydrographic charts from which it may be seen that there where the foreshore is " slow "—particularly between the French frontier and Zeebrugge —there always exists in depths of from 1 to 2 metres under Low Water, a depression frequently exceeding 1 metre. This depression invariably appears in the form of a long, narrow ditch, in direction parallel to the shore. An absolutely similar depression generally exists on the drying part of the beach towards mid-tide level. The first depression is that hollowed by the waves at Low, or almost Low Water, while the other is rather to be found in the vicinity of High Water, i. e. at the approach of tidal phases where the level is stationary or varies but very slowly.

Land rains or winds throw back towards the beaches the sands which have accumulated in the form of dunes.

From the above considerations a few basic principles may be laid down which should be borne in mind for future work along the coast and particularly when it is a question of constructions destined to improve or stabilise the maintenance of our beaches—which is a matter of importance for our littoral.

Weather statistics show that in the first months of the year the prevailing winds are those from the open sea; further on in the season, winds from the western regions are of the greater frequency, followed by land-winds. Consequently, the mechanism of sandy deposits may be established as follows : at the beginning of the year, transfer of sand towards the beaches and the dunes; later on, diminution of the beaches and dunes by transport towards the East under the influence of prevailing winds from the West; finally reloading of the beaches by sands from the dunes under the combined action of land rains and winds. It is therefore recommended to set up for the period of the bad season and even into the beginning of the fair season, provisional transversal constructions, such as hedges, on the beaches and slopes of the dunes and to afforest carefully the dunes so that the sand may be stabilised as far as possible and silting towards the East as a result of wind-transport, prevented by every possible means. Is it necessary to emphasise that doing away with the downs and the construction of those lengthy longitudinal sea-dykes are not precisely expedients favourable to the maintenance of our beaches ? It is high time that this should be recognised if the future of our bathing stations is not to be irremediably compromised.