The last paper, "Ion-exchange Properties of Alginates", by I. L. Mongar and A. Wasserman, was read by Dr. Wasserman. Using a flowing system with highly swollen alginate in fibre form, the ratio k_1/k_2 and the velocity coefficient k_2 have been estimated for the following reaction :

$$\text{Ca}\,Alg + \text{NaCl} \underset{k_2}{\overset{k_1}{\rightleftharpoons}} \text{CaNa}\,Alg + \text{CaCl}_2.$$

The calculation of k_2 is based on a knowledge of the diffusion coefficient of calcium chloride in calcium alginate. The value of k_2 obtained is independent of the surface/volume ratio of the gel, and is only moderately influenced by the sodium chloride concentration, pH and temperature.

WIND AND OCEAN CURRENTS

A GEOPHYSICAL Discussion on "Wind and Ocean Currents" was held in the rooms of the Royal Astronomical Society on November 26. The chairman, Dr. A. T. Doodson, emphasized the great complexity of the subject, and gave a brief summary of its various aspects.

The list of problems is headed by the tangential stress between air and water, and this is related to the problems of turbulence in general, and of hydraulic flow. In pipes and channels, the roughness factor remains constant at any one place ; but the surface of the sea is hydrodynamically smooth in the early stages of wind action and hydrodynamically rough in the later stages as the waves are developed. It may be expected that there will be considerable variation in the mechanism by which one fluid acts on the other in the varying conditions. The critical velocity of wind for the setting up of waves, as given by Jeffreys (110 cm./sec.), appears to be well established ; a second critical value of about 700 cm. per sec., about which there is a rapid change in the stress coefficient, appears to correspond to the change from laminar to turbulent flow. In the earlier stages of development of waves, the surface tension of the water plays a part, but there is still some obscurity with regard to the mode of formation of waves in the initial stages.

After a wave is well established, its growth brings other considerations into prominence. Some investigations by Jeffreys, which showed how the pressure variations on the various parts of the wave influenced its growth, have been supplemented by Sverdrup and Munk, who have added a term depending upon the tractive forces which exist when the waves are well developed.

It is in connexion with well-developed waves that practical interest has lain in recent years. Naval operations off beaches, for example, have stimulated investigations into waves of large amplitudes, in the first place, and thence to associated waves. The laws of decay of wave systems are still somewhat obscure as there are two causes of decay : the air resistance as the wave progresses in calm air, and eddy viscosity. It has been recently stated that the former is the sole factor; but this may be doubted for large waves.

The next stage of the problem is that of the transport of volume. In this the part played by the waves tends to go out of sight, but should not be forgotten. Also the influence of the earth's rotation becomes prominent, though it receives little consideration with regard to the genesis and growth of waves. Ekman's theory of wind-driven currents is well established, but is being developed to allow for the influence of boundaries, at the bottom or near the coasts.

Finally, there is the problem of the gradients of surface set up in restricted seas. In this, further considerations arise, bringing in the variation of depth, the free period of the sea, and the characteristics of the atmospheric disturbances, as well as the decay. The part played by wave action in the absorption of energy in these storm surges may be of some importance. This problem differs from that of waves in deep water in that the bottom friction also is of importance. In this end-problem very striking progress has been made in recent years.

To sum up, the problems range from molecular effects to large-scale effects, and it is their inter-relation which needs to be borne in mind when considering the details.

Dr. G. E. R. Deacon pointed out that the energy required to maintain the circulation of water in the oceans can be supplied by the effects of heating, cooling, evaporation and precipitation, and by the stress of the prevailing winds on the surface. Some of the deep-water movements which have velocities of the order of 1 cm. a second may prove to be convection currents, but various lines of investigation show that the surface currents in the oceans, which flow much faster, must derive most of their energy from the wind.

Ekman's theory of wind currents requires that the drift at the surface, in deep water far from land, should be directed 45° to the right of the wind in the northern hemisphere. The average inclination of the surface drift to the wind in different parts of the ocean has been studied by Krummel, Jeffreys, Durst and others, and it proves to be approximately 45°. Jeffreys, interested in the degree of turbulence in wind currents, mentions that this close agreement confirms one of Ekman's basic assumptions, that the eddy viscosity does not change with depth in the water layer affected by the current ; but its magnitude, determined by comparing the observed velocities of wind and current, is of the order of 1,000 times as large as the value of eddy viscosity required by Jeffreys's theory of wave generation. This discrepancy is confirmed by recent work, and waves which are known to travel thousands of miles would be damped out in a few hours by viscosities as large as that required to generate wind currents. No explanation has been found for the discrepancy.

Another effect of the wind is the formation of convection cells in the water. Langmuir noticed that weed in the Sargasso Sea became arranged in parallel lines down wind, and showed, by careful measurements in a lake, that such lines mark zones in which the surface water is converging and sinking ; midway between them he found that the sub-surface water was rising and diverging. A further study was made in the Gulf of Mexico in winds of force 2–4 by Woodcock. He prepared a hundred special numbered drift bottles, each with the minimum buoyancy to keep it awash at the surface, and rowing a small boat across the wind he threw out one bottle every 2 metres. Within 3–5 minutes, the bottles were always re-formed into new lines parallel to the wind. From Langmuir's work and his own it was known that the water in the convergences moves down wind more rapidly than the water between them, and it was assumed that the leading bottle in each line was dropped nearest a convergence. If the convection cells were symmetrical, the leading bottle in each line should be followed by equal numbers from the left and the right; in all but three of his eighteen experiments, however, there were more from the left, and the average was 60 per cent. He concludes that the right-hand convection cell is most strongly developed.

Attempts have been made to use the effect of the earth's rotation to explain the symmetrical development of the convection cells, but without success. Munk has suggested that the convection cells are combined with a drift of the Ekman type.

Mr. F. Ursell then outlined an investigation of waves as they are affected by the rotation of the earth. It was shown by Stokes that regular trains of water waves are accompanied by a mass transport in the direction of propagation, provided that the effects of non-conservative forces such as the viscous forces and the Coriolis force are negligible so that the waves are free from vorticity. It has been suggested that this transport might set up large-scale ocean currents. However, in geophysical applications, the Coriolis force may not be negligible and vorticity may be generated. This question requires mathematical study. An idealized problem has been considered by Mr. Ursell in which the geopotential gradient (including the centrifugal force) is constant in magnitude and direction; so the wave motion may be thought of as taking place on a plane earth, on which there is a Coriolis field. In the first place, considering regular wave trains which can travel unchanged in such a field, it is necessary to take the non-linear equations of motion, as the mass transport is considerable only for waves of substantial height. But for non-linear equations the principle of superposition does not apply, so that we cannot hope for a complete solution of the equations. (An illustration was given of the difference between linear and non-linear behaviour.) Nevertheless, a good deal can be said about the mass transport. Mr. Ursell began by showing that the plane touching all the crests is normal to the direction of gravity. Then, by an extension of Bernoulli's theorem, it was shown that the mass transport, if any, must be in the direction of propagation. Finally, Bjerknes's theorem on the circulation along a circuit moving with the fluid was used to show that the mass transport at any depth is zero, so that the fluid particles move in closed orbits. The stationary state of waves on a rotating earth must therefore approximate closely to the type studied by Gerstner (1802) rather than to Stokes waves. The foregoing arguments do not apply on the equator.

Bjerknes's theorem may also be applied to the non-stationary state. Consider an area of still water which is being invaded by waves. The motion is initially irrotational, so that the waves formed in this area are initially of Stokes type. As they build up, a mass transport is set up. Bjerknes's theorem then shows that this current changes its direction continuously, the direction turning through four right angles in 12 cosecφ hours, where φ is the latitude. Ocean waves should therefore be accompanied by rotating inertia currents. Such currents have hitherto been explained as set up by a wind drag on the surface which ceases when a current has been established. This requires a large value of the eddy viscosity, which would lead to very rapid damping of the resulting motion. It may be that the wave mechanism described here will serve to explain some known inertia currents satisfactorily, but further measurements of waves are needed before a detailed comparison can be made.

Lastly, Mr. R. H. Corkan gave an account of the derivation of certain constants of the sea, of interest to oceanographers, a by-product of his work on storm surges. These surges are waves of much longer periods than surface waves, and the associated transport of water is of great importance. It might be thought that a single well-developed surge would give information as to the period of the oscillation, and that its rate of decay would give an approximate value of the coefficient of eddy viscosity. It was stated that such a simple method cannot be used for surges experienced in the Thames, since the surge has three main contributions: one from local winds, one from winds over the North Sea, and one from a surge propagated inwards from the north of Scotland and travelling around the North Sea in an anti-clockwise direction. The latter contribution is a passing wave, and its rate of decay cannot be ascertained from observations at a single place, such as are applicable in studying the decay of an oscillation of the sea itself. The removal of such an external effect and the allowance for periodic variations in the winds are necessary before the data can be utilized for the desired constants.

Mathematical formulæ for the oscillation of the sea under the influence of a variable wind were described. These involve the free period of the sea and the eddy viscosity. After the wind dies down, there is a decaying oscillation with the free period, which was quite accurately determined from a large number of surges as 30 hr., and the ratio of the first positive amplitude to the next negative amplitude was shown to be approximately 4, so that the decay is very rapid. Very precise figures could not be given because of the complexity of the phenomenon, but it was shown that the mathematical formulæ were justified only on the assumption of no bottom current; the alternative of finite bottom current would require unduly large current velocities. The decay factor corresponds to a coefficient of eddy viscosity of about 1,300 C.G.S. units.

The relation between wind velocity and elevation, with the damping factor of 4, with certain assumptions as to the effective length of channel over which it operated, gave a stress coefficient of 0·0023 C.G.S. units. This is in good agreement with values obtained by other investigators, and showed that the various results derived from the investigation were in conformity with one another. The need for caution in deducing constants from observations uncorrected for all possible oscillatory causes was fully evident.

There was unfortunately very little opportunity for discussion.

THE KAURI TREE IN NEW ZEALAND

An article dealing with the controversy over the question of the preservation of the famous kauri tree of New Zealand, with particular reference to the treatment and control of Waipoua Forest, was published in *Nature* of January 10, 1948. The article ended on an optimistic note, as it was felt that it should not be difficult to reach agreement. Unfortunately, that agreement has not been reached,