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SUSPENDED SEDIMENT IN A WAVE FIELD

by

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ABSTRACT

A series of photographs are presented which illustrates the ripple form and the kinematics of suspended sediment in a wave field. The strong shear on the local upstream side of the ripples and the subsequent vortex development on the downstream side is illustrated. Sediment is visible in the body of the fluid above the bed to a height equal to about one half the wavelength of the ripples.

SOMMAIRE

On présente une série de photographies qui illustrent la forme des ondulations et la cinématique des sédiments en suspension dans l'aire d'action d'une vague. Le fort cisaillement du côté amont des ondulations et le développement du tourbillon qui se produit par la suite du côté aval sont illustrés. Les sédiments sont visibles dans le corps du fluide au-dessus du lit à une hauteur d'environ la moitié de la longueur d'onde des ondulations.

MANAGEMENT PERSPECTIVE

This report represents the initial stages of an investigation to provide reliable theories to predict or calculate sediment transport and suspension from the combined action of currents and waves. The theory will be useful for turbidity computations in lakes and to develop models of nearshore transport of sediments.

T. M. Dick
Chief, Hydraulics Division

PERSPECTIVE - GESTION

Le présent rapport est le fruit des premiers stades d'une étude visant à offrir des théories fiables de prédiction ou de calcul du transport et de la mise en suspension des sédiments par l'action combinée des courants et des vagues. La théorie sera utile pour les calculs de la turbidité des lacs et pour l'élaboration de modèles du transport des sédiments près des rives.

Le chef de la Division de l'hydraulique

T. M. Dick

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Wave agitation is the principal cause of sediment motion and sediment suspension in lakes and oceans. It plays a major role in evolution of shorelines where, combined with currents, it causes large volumes of sediment to be transported along shores. Offshore, waves effectively mobilize sediment, resulting in its redistribution within a lake basin. Furthermore, the resuspension of sediment can have adverse implications on water quality.

An understanding of the details of sediment suspension helps in the development of techniques to model the larger scale processes such as the resultant sediment transport due to waves and currents. It is the purpose of this note to present a series of photographs which help to illustrate the details of the sediment motion in the vicinity of the bed forms under the influence of waves. In this case the waves are over a horizontal bed and there are no imposed currents to cause any appreciable sediment transport. The photographs were taken during the course of experiments designed to measure the vertical distribution of sediment concentration under waves.

Several researchers have described the details of sediment motion under waves, as observed in the laboratory (Inman and Bowen, 1962; Bijker et al, 1976). Once ripples have been formed on the bottom, in equilibrium with the prevailing wave conditions, the separation of a strongly sheared flow, entraining sediment at the ripple crest, followed by the formation of a sediment-laden vortex on the lee side of the ripple is responsible for the sediment suspension. The identity of the individual vortices and their loads of sediment are soon lost to the eye. Eventually, as the vortices are dissipated, the sediment settles out of the water column. The turbulence, so obvious near the bed, does not penetrate far into the water column, so that far from the bed, there is no suspended seidment. (This is not true when waves are breaking on a beach, where there is turbulence throughout the water column with accompanying high concentrations of sediment). Nakato et al (1977) observed four distinct peaks of concentration near the bed, within one wave period. They reported that two of the peaks were due to vortices from adjacent ripples, and two from the next to adjacent ripples. The latter are a result of the fact that the water particle orbital length is greater than the ripple wavelength, so that a vortex can be advected from the next to adjacent ripple. It is difficult to discern the vortices in this later stage of dissipation in the photographs presented here.

The photographs shown in this note are of experiments conducted in a wave flume 10 m long, 0.3 m wide and 0.6 m deep. The flume bottom was covered with a 0.10 m layer of sieved glass beads. Their density was 2500 kg/m^3 (specific gravity 2.5) and size range was 0.125 to 0.177 mm. Regular waves were generated with a hinged paddle. The experimental conditions were: water depth of 0.15 m; wave period of 1.0 s; wave height of 0.055 m; water temperature of 24.1°C, mean ripple length of 37 mm; mean ripple height of 4.6 mm.

The sequence of photographs, in Figures 1 to 4 illustrate the sediment motion under the wave crest; under the back face of the wave; the trough; and the forward face of the wave. The field of view of the camera was large enough to include the water surface, and the figures are enlargements. Thus the exact location of the enlargements relative to the wave profile is known. The waves were moving from right to left.

In Figure 1 the ripples are under the wave crest, so that the water velocity is at a maximum, towards the left. There apparently is a strong shear flow on exposed face of the ripples, with separation at the crests. A sheet of sediment is flowing off each crest, and a vortex rotating counterclockwise has developed in the lee of each crest. The sheet of sediment coming off the crest is moving nearly horizontally, and only rises slightly above the crest elevation.

In Figure 2 the ripples are under the back face of the wave when the water profile is slightly above the mean water level so that there is still a slight velocity to the left. The strong shearing action is passed, but the highest sediment concentration is still to the left (lee) side of the crests. This is particularly evident on the right hand ripple. The vortex has started to move upwards as indicated by the fact that the cloud of sediment has risen above the crest elevation.

The ripples are shown directly under the wave trough in Figure 3. The water particle velocity is at its maximum towards the right. Now there is a strong shear flow on the left face of the ripples and the flow is tearing sediment off the crest into the separation region on the right. The flow in this separation region is clockwise. At this stage the sediment is not above the crest elevation. The remainder of the vortices generated under the crest of the wave are seen, just to the left of the crests, to be enlarging upwards and also moving to the right. The sediment marking the vortex is visible to about one ripple height above the crest elevation.

Finally, in Figure 4, the sediment is shown under the forward face of the wave, where the wave profile is at the mean water level. The vortex formed to the right of the ripple crest, under the wave trough, is growing and starting to expand upwards. The evidence of the vortices formed under the previous wave crest is obscurred by the more recently suspended sediment, but the highest sediment plume near the right of the photograph may be from such a beginning.

Utilizing a method developed by the authors (in preparation), the distribution in the vertical of the sediment concentration has been estimated for the conditions in the photographs, and is shown in Figure 5 by the straight line (the dots are measured values). By integrating the distribution, the total amount of sediment in suspension can be determined to be 5×10^{-5} kg/m^2. It is easy to visualize how even weak currents superimposed on modest waves of the type shown here can move substantial volumes of sediment.

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FIGURE CAPTIONS

Figure 1 Suspended sediment under a wave crest: water velocity is maximum towards the left.

Figure 2 Suspended sediment under the back face of a wave crest when the water surface is just above the mean water level: water velocity is small, towards the left.

Figure 3 Suspended sediment under a wave trough: water velocity is maximum towards the right.

Figure 4 Suspended sediment under the front face of a wave crest when the water surface is at the mean water level: the water velocity is near zero.

Figure 5 Distribution of sediment concentration as a function of elevation above the bed. The experimental conditions are the same as those for the photographs.

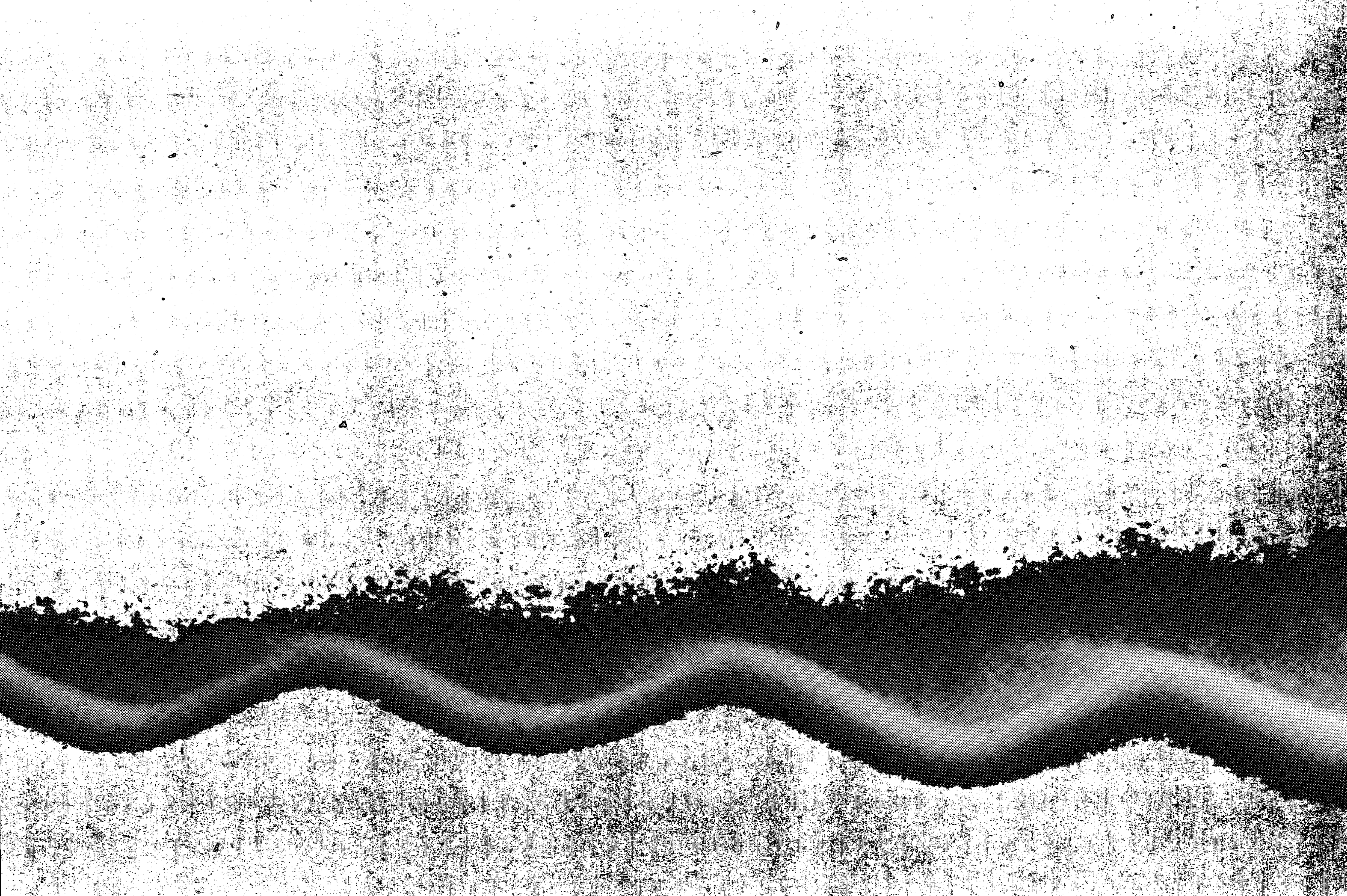

Fig. 1

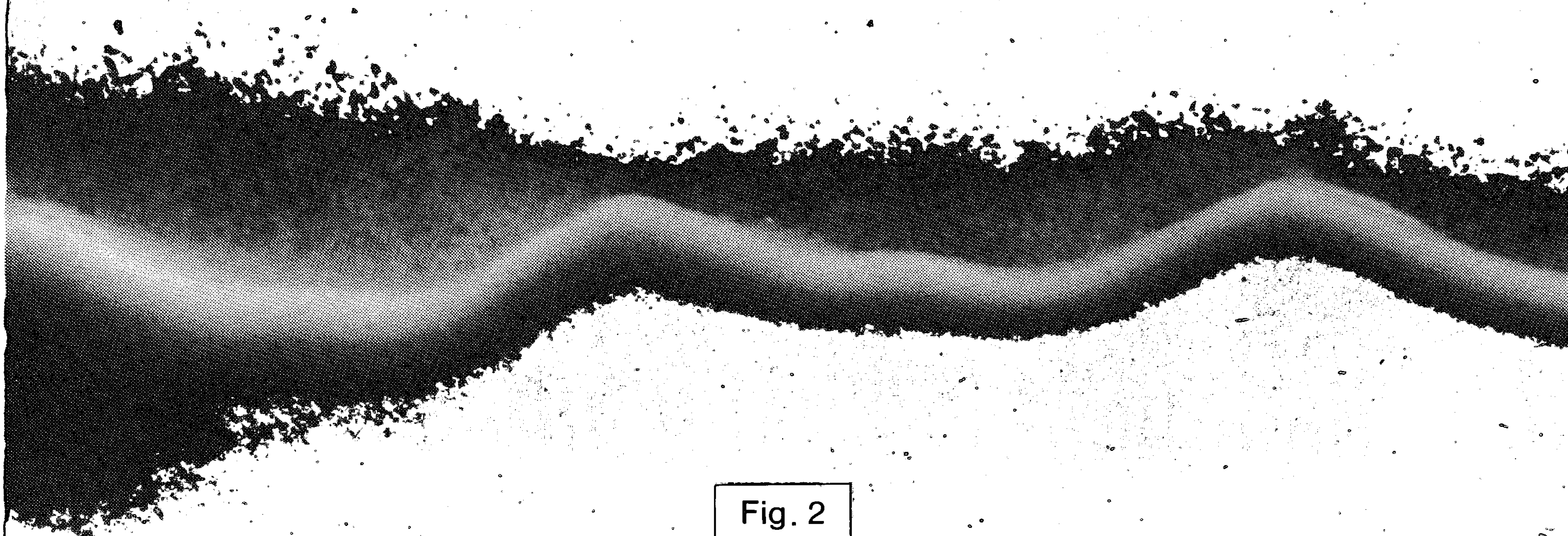

Fig. 2

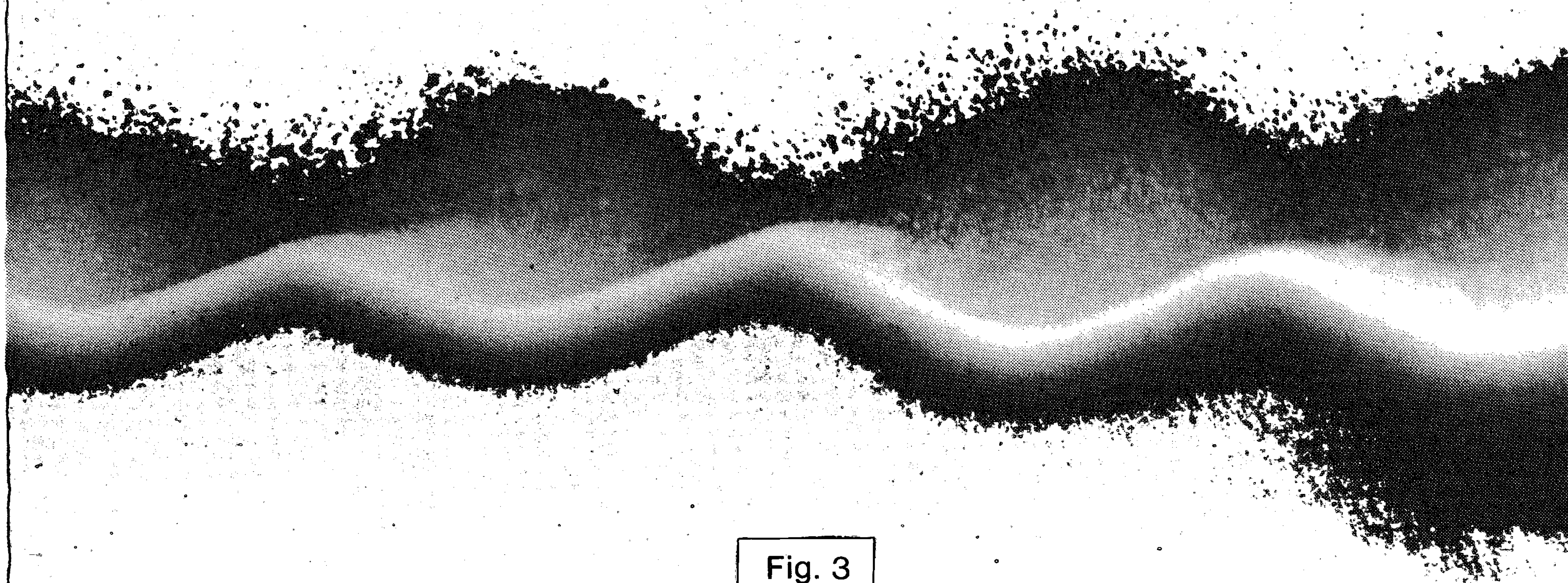

Fig. 3

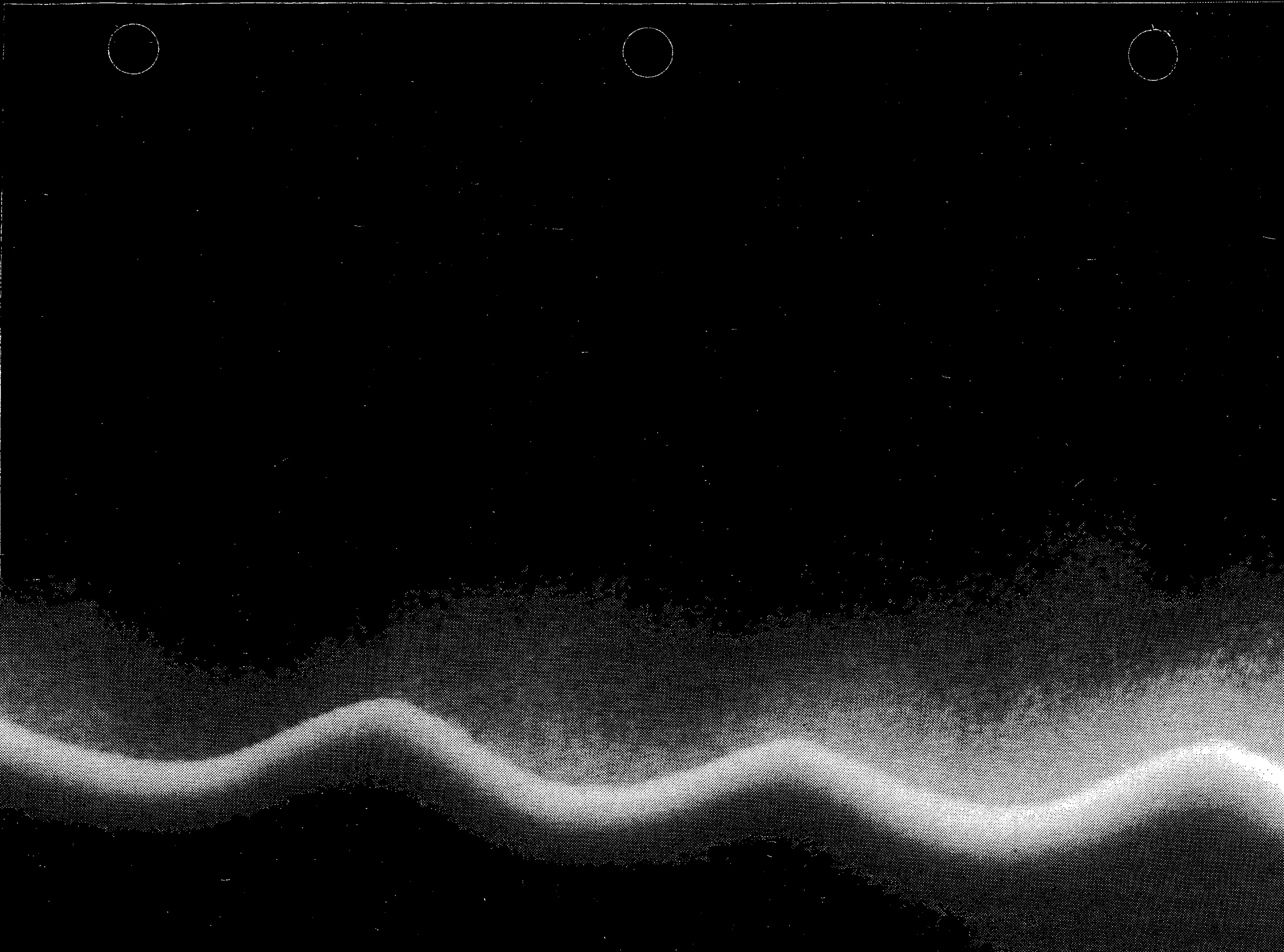

Fig. 4

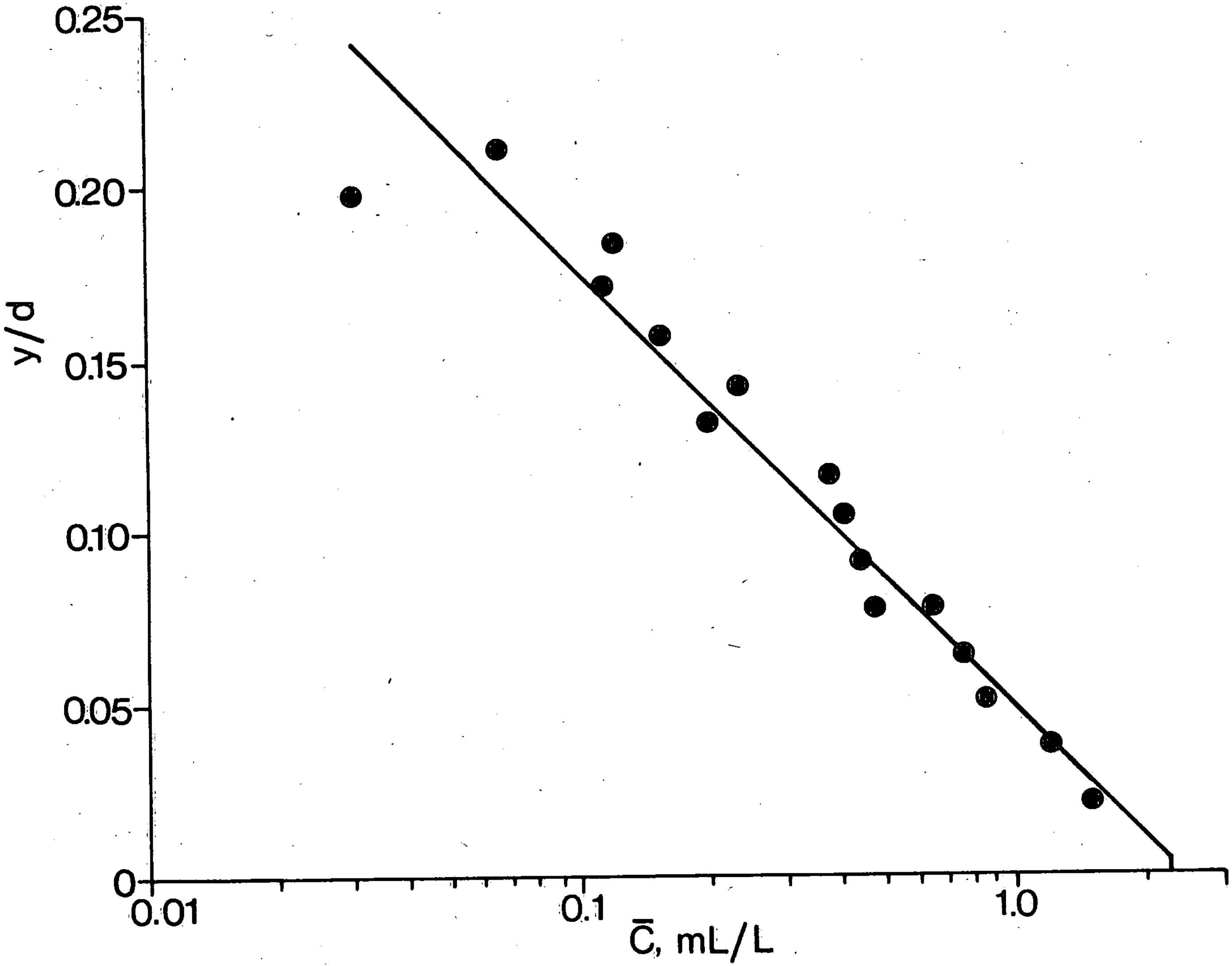

Fig. 5