A NEW APPLICATION OF ECHO-SOUNDING

by

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By 1937 the biological researches at Wray Castle had reached the stage when a detailed bathymetric survey of Windermere was desirable as a basis for studying features of the lake bed. The Hydrographer to the Admiralty kindly agreed to co-operate on the technical side, and a survey was carried out by Lieut-Commander Farquharson, of the Admiralty's hydrographic staff, using a magneto-striction recording echo-sounding machine of Admiralty pattern manufactured by Messrs. Henry Hughes and Son, Ltd. The main feature of the recorder (Fig. 1) is a drum which is rotated at a constant speed by an electric motor. An arm attached to the drum carries a metal "pen" which traces the record on paper moistened with solution of potassium iodide and propelled slowly through the machine. Contacts on the drum are arranged in such a manner that a supersonic sound impulse is transmitted from an oscillator, below the surface of the water, for an instant when the revolving pen has just begun its transit across the paper. The sound impulse, directed downward, is reflected from the bottom, is picked up by a receiving oscillator also mounted in the water, is amplified and passed to the pen. The rises in voltage at the pen point, consequent on the transmission and return of the signal, cause electrolysis of the potassium iodide and produce brown stains of iodine on the paper — one, the zero mark, at the instant of transmission, and the second on the reception of the echo. The distance along the arc of the pen's track between these two marks represents the depth of water, and the process, repeated at each revolution of the drum, gives a continuous record of depth. The whole equipment, consisting of the recorder, amplifier, oscillators and 12-volt accumulator, can be mounted comfortably in a small launch or rowing boat.

In the survey of Windermere 260 cross-sections, representing some 150 miles of continuous sounding, were recorded during five weeks, and the measurements of depth were afterwards made available by the Admiralty on the 6 in. to a mile scale, with certain areas in greater detail on 25 in. to a mile maps. The results of this survey, sufficiently valuable in the information they provided regarding the depth of water, proved to be of much interest in quite another way. Many of the records not only showed an echo from the floor of the lake, but also a second, though fainter echo, and sometimes more, at vertical distances (measured on the records) of up to 13 metres below the lake floor. It is known that much of the lake bottom is covered by soft mud of considerable depth, presumably overlying rock or glacial clays which formed the floor of the lake at the conclusion of the Ice Age. Therefore, it seemed that the double echo shown on the records could be explained on the assumption that only some of the sound waves transmitted by the machine were reflected from the interface between mud and water, and that others penetrated the waterlogged deposits and were reflected by the harder glacial clay or solid rock underneath. In other parts of the lake (A in Fig. 2) the bottom appeared as an intense black mark with one or more fainter marks below, at apparent distances below the bottom equal to the depth of water. In such cases it seemed justifiable to assume that all the sound waves were reflected from a hard bottom and that, since an air-water interface reflects supersonic sound, they were afterwards re-echoed to and fro between the surface and bottom. If these interpretations were correct, the echo-sounding machine could be used to give information regarding the kind of bottom and the depth of soft deposits. Accordingly, the research was followed up by (1) making observations on the deposits themselves, and (2) carrying out survey with the echo-sounder on fourteen other of the larger lakes in the district.

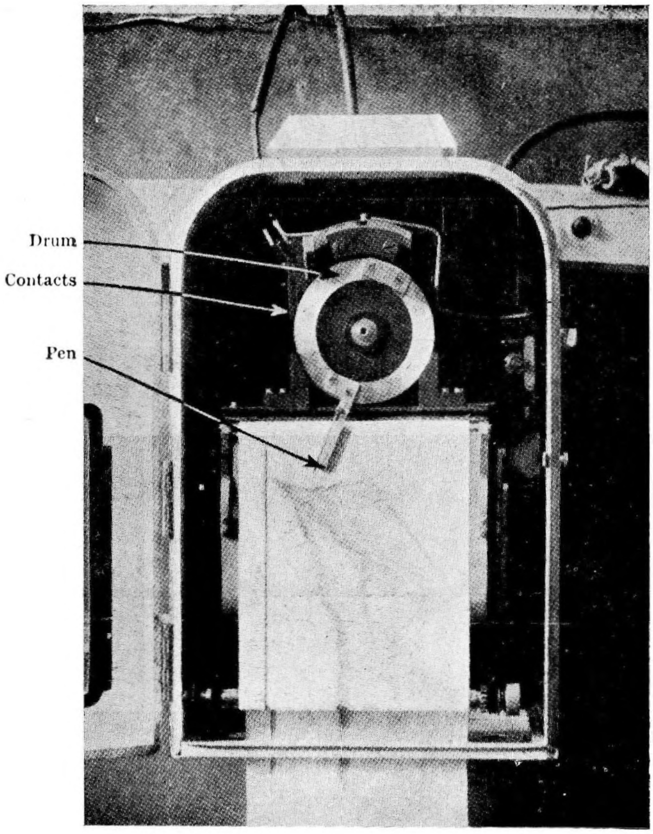

FIG. 1.

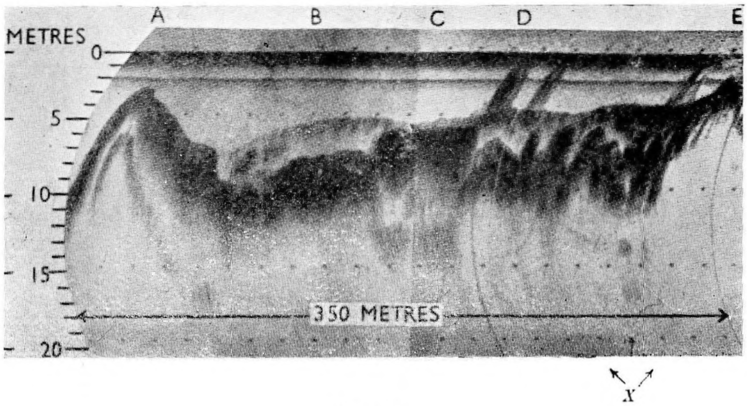

FIG. 2.

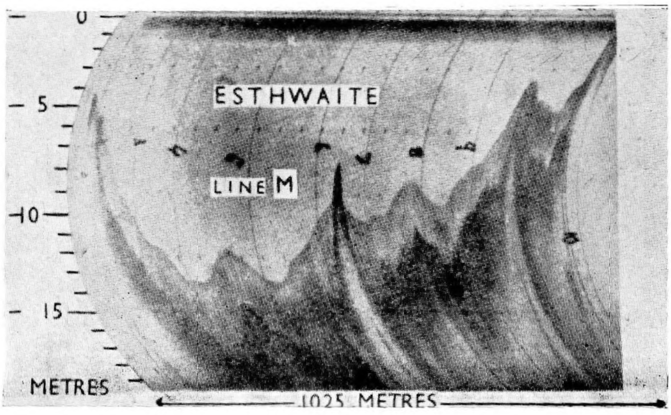

FIG. 3.

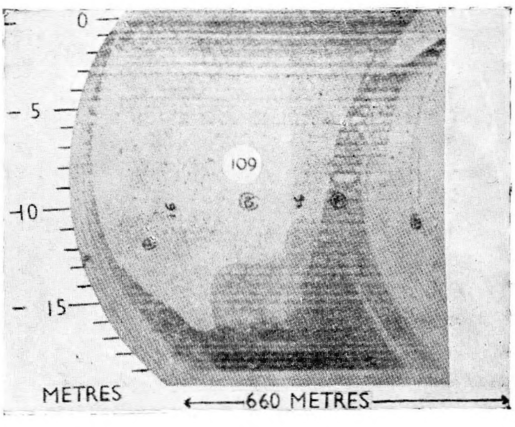

FIG. 4.

In the first of these projects, sections such as that shown in Fig. 2 were examined and it was confirmed by the use of lead and grab that at *A* the bottom is bare rock, at *B* it is soft mud, at *C* stiff clay overlain by a thin deposit of soft mud. At *D* beds of water weed (Potamogeton) growing in the mud were under the oscillators as the superficial marks made their appearance on the record, and at *E* a stony bottom could be seen through the shallow water. Direct measurements of the actual depth of soft deposit were made with a probe of special design constructed by Dr. J.A. Ramsey of Cambridge, Of twenty-one such measurements made under favourable conditions, all showed depths which agreed to within a foot with the depth of deposit as indicated on the echo records. In addition, cores of the deposits have been obtained from some parts of the lake, first with a simple tube driven into the bottom and later with a special coresampler described previously(1). The examination of cores is important because many of the echo-records (for example, at some points in Fig. 2) indicate stratification of the deposits. Moreover, the cores throw light on the post-glacial history of the lake basin; they show fine varving in the deposits, and there is an alternation between periods in which inorganic, probably ice-eroded, particles are predominant with periods when the bulk of the deposit is made of the shells of diatoms. The succession of diatom and other organic remains in these cores is being studied by Miss W. Pennington of the University of Reading.

The surveys of other lakes, made by members of the staff at Wray Castle, serve to confirm the main bathymetric features as determined by H.R. Mill(2). These surveys were not of the same detail as that of Windermere, but sufficient sections were recorded to obtain a good idea of the bottom characters. The photograph of a representative record from Esthwaite Water, reproduced in Fig. 3, shows a mound of hard bottom projecting through an even layer of soft deposit. Over the rest of the section the thickness of soft deposit is roughly uniform and the mud profile follows in smoother outline the irregularities of the hard floor below.

In other cases, for example at *D* in Fig. 2, such irregularities are masked by a level blanket of mud. Fig. 4 shows another type of sedimentation in a region — the narrows joining the north and south basins of Windermere — in which an appreciable water flow is to be expected. The figure shows a scoured channel on one side with a mud bank on the other, a condition which might be expected from the configuration of the locality. A more complex kind of sedimentation, in which the deposit appears to be divided into a series of strata, is suggested by other records. All these types of record have been exactly reproduced over the same positions at different times by two recorders having differences in the details of construction, and recording on different scales.

It must be emphasized that further direct observations on the deposits are required before the interpretation of the echo-records can be accepted without reserve. The speed of travel and the penetration of supersonic sound in waterlogged deposits have yet to be determined, and the nature of the interfaces from which it is reflected awaits investigation. But it seems probable from the results mentioned above that the echo-sounding machine provides a means of measuring the result of subaqueous deposition over long periods of time. Such measurements would be of practical use in connexion with reservoirs and harbours where the deposition of soft deposit on a hard floor often takes place rapidly. They would also be of much interest to hydrographers, geologists and limnologists. For example, in each lake so far examined, the total volume of soft deposit, as computed from the echo-records, is found to be related to the size and character of the drainage basin. This is illustrated in the accompanying table of values for selected lakes.

The figures in the last column but one represent the depth of deposit in centimetres if it were spread evenly over the whole drainage basin, and may be regarded as an index of silitng rate. Pearsall(3) showed the controlling influences of the silting rate on the distribution of aquatic plants; his classification of the lakes of the district on this basis is corroborated by the new data from echo-sounding.

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(1) *Jenkin, B.M., and Mortimer, C.H.,* Nature, 142, 834 (1938). *See also* Hydr. Rev. Vol. XVI, N° 1, 111 (1939).

(2) *Mill, H. R.,* Geog. J., 6, 46-73, 135-166 (1895).

(3) *Pearsall, W. H.* Proc. Roy. Soc. B. 92, 259-84 (1921).

Since the work described above was carried out, the work of Stocks[4] and Rust[5] has been brought to our notice. Using a different type of non-recording echo-sounder in Kiel Bay, they obtained double and multiple echoes over soft bottoms in contrast to single echoes over hard bottoms, and they put forward an interpretation similar to the one advanced here.

	Mean depth of water (metres)	Mean depth of deposit (metres)	Volume of deposit (106 cubic metres)	Drainage area (sq. km.)	Volume of deposit / Drainage area	% drainage area on uncultivated hills
Haweswater	12.0	0.52	0.7	29.1	2.4	92
Ennerdale Water..	18.9	0.88	2.5	44.1	5.7	94
Coniston Water ..	24.1	1.09	5.4	60.7	8.9	78
Windermere	23.8	1.62	24.1	230.5	10.5	70

(4) *Stocks, T.,* Naturwiss., 23, 383-87 (1935). *See also* Hydr. Rev., Vol XII, N° 2, 101-05 (1935).

(5) *Rust, H.,* Naturwiss., 23, 387-89 (1935). *See also* Hydr. Rev., Vol. XII, N° 2, 106-09 (1935).