TRANSFORMATION OF SIDE-SCAN SONAR RECORDS TO A LINEAR DISPLAY

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ABSTRACT

A procedure for removing the linear and nonlinear distortion in side scanning sonar records is described. The sonographs are placed on one rotating drum and optically scanned. The optical signal is converted to an electrical voltage and marks an electrosensitive paper on the second drum. The two drums have a common shaft and rotate together. The position and rate of scan of the marking stylus is controlled to remove the distortion. An example of a distorted and corrected sonograph is shown.

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The range of a side-scan sonar record is nonlinearly related to the distance along the ocean bottom because the sound travels from the transducer to the scattering feature and back by the proper ray path. For a simple isovelocity case, the geometry is shown in fig. 1. If $D \ll S_{max}$, the distortion is negligible except for the near range. At greater depths, the near-range distortion extends farther into the record. For morphological studies it is desirable to have a linear display of the bottom features.

The slant-range problem may be handled by different techniques. A true-range presentation may be accomplished in the mechanical recorder, as in a nonlinear helix on the recording drum. The sonographs reported by Clay *et al.*, 1964, were made by a mechanical recorder having a nonlinear sweep and correction for the ship's speed was made by enlarging in one dimension by a continuous flow camera. This technique has limited use since the transducer must be towed at the one correct constant height above the bottom. The slant-range problem can be solved with an electronically controlled nonlinear sweep on an oscillographic display or digital processing of data (either real time or replay). The processing can also be handled by nonlinear mechanical transformation of graphic records. Since most of the side-scan sonar data are taken in this fashion, we will describe this procedure.

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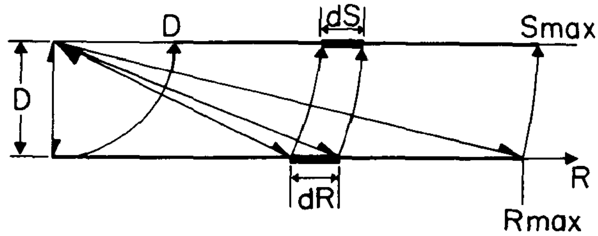

FIG. 1. — Slant-range geometry. D represents the height of the transducer above bottom. Distances are projected along circular arcs to the horizontal to show the slant-range display of the sonograph.

Figure 2 shows that the nonlinearity of the sonograph due to slant-range presentation is significant, especially in the first part of the record after the bottom trace. The bottom appears on the record at the slant range equal to D, the height of the transducer above bottom. After slant range of about 2D, it is evident that the distortion is quite small. To display the slant-range increment dS, the increment dS must be expanded by the factor (dR/dS) from $S=D$ to $S=S_{max}$. Since :

$$S = (D^2 + R^2)^{\frac{1}{2}}$$

$$\frac{dR}{dS} = \frac{S}{R}$$

The expansion factor (dR/dS) is shown in fig. 3.

The expansions were made by an optical-scanning scale changer, shown in fig. 4. It was made at the Geophysical and Polar Research Center

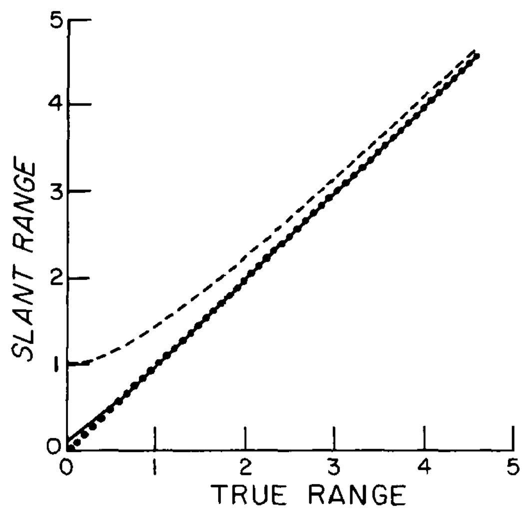

FIG. 2. — Slant range *vs.* true range and the slant-range correction. The ranges are given in units of D. The dashed line shows the uncorrected slant-range function for sonographs. The solid line gives the transformed slant-range function after processing the sonograph by the optical-scanning scale changer. The dotted line shows the perfect true-range function.

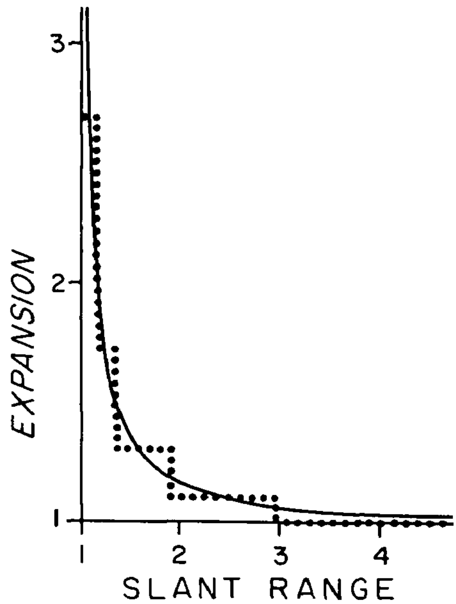

FIG. 3. — True-range expansion factor. The expansion factor, (dR/dS), for conversion of slant-range to true-range display is given by the solid line. Slant-range is given in units of D. The step function (dotted line) was used on the optical-scanning scale changer. Figure 2 shows how the slant-range — true-range relationship is changed by the step transformation. Original and transformed sonographs are shown in Figure 5.

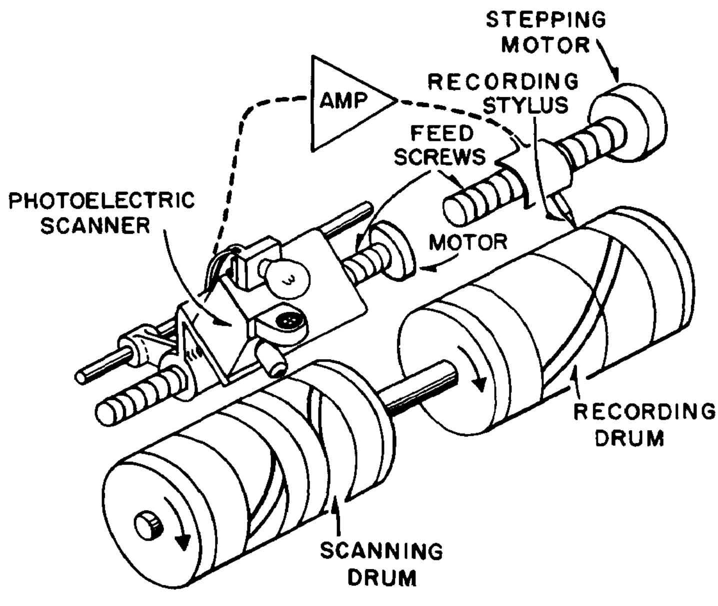

FIG. 4. — Optical-scanning scale changer.

by modifying a facsimile copying machine (Stenofax Model S-6). The instrument consists of two drums which revolve at the same speed. The original sonograph is placed on the scanning drum, with the ship's track parallel to the drum circumference. As the two drums revolve, a photoelectric scanner on a carriage moves at a fixed speed on a feed screw along the length of the scanning drum. A stylus on a different carriage moves along the length of the recording drum on a feed screw which is turned by a variable-speed stepping motor. Electrical signals amplified from the photoelectric scanner cause the stylus to burn darker spots on the electrosensitive recording paper. When the scanning is finished, a facsimile of the sonograph is produced with the dimensions around the drum unchanged and those across the drum changed according to the ratio of the "read" and "write" traverse speeds.

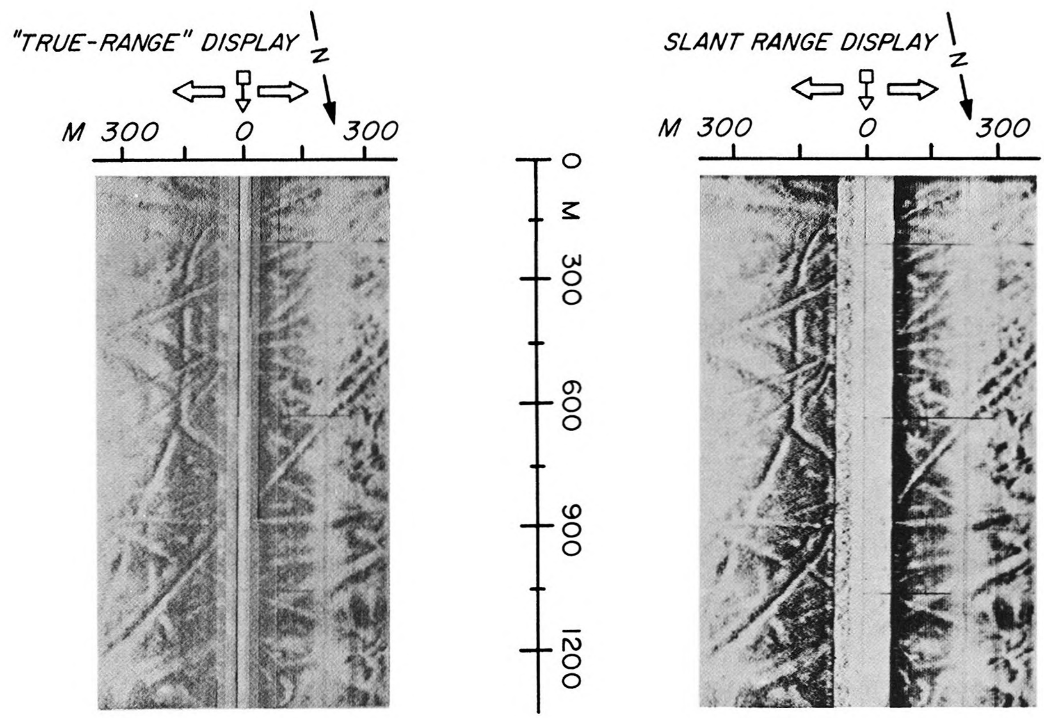

Fig. 5. — Sonograph Transformation. The original sonograph in slant-range display is shown at the right. The "true-range" sonograph (left) has been corrected for lateral scale distortion and for slant-range distortion on the optical-scanning scale changer. The sonograph from Berkson and Clay, 1973, displays iceberg-scour grooves on the floor of Lake Superior at 75 m depth. The continuity of grooves crossing the ship's track is now more apparent. The lighter zone in the right channel of the sonograph is caused by an interference lobe that involves rays reflecting off the hull of the ship and rays taking the direct path.

The transformed sonograph shown in fig. 5 was made on the optical-scanning scale changer. The expansion function was approximated by the function with the five-step function shown in fig. 3 by expanding five slant-range zones of the sonograph by the appropriate factors. The lateral-scale distortion due to ship's speed was also corrected during this process by using an expansion factor,

$$E' = E\frac{t}{r}$$

where E is the expansion shown in fig. 3, and t and r are the distances along the track and range directions corresponding to a unit distance on the sonogaph.

The expansion may be accomplished by any device that changes the scale of a record along one axis without changing the scale along the orthogonal axis, such as a flow-camera or an anamorphic optical system. An advantage of the optical-scanning scale changer is that a perfect transformation is possible by sending the proper signals to the stepping motor.

ACKNOWLEDGEMENTS

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