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SOUND TRANSMISSION MEASUREMENTS IN THE LONG ISLAND-BERMUDA REGION, SUMMER, 1949

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WASHINGTON, D.C.

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ABSTRACT

Sound transmission measurements at 7.5 and 15.5 kc have been made at eighteen locations along a triangle between Long Island, Bermuda, and the Virginia Capes. Using a lowerable projector suspended from one surface ship and a string of six hydrophones suspended from another, level measurements of a steady signal have been obtained for various depth combinations out to ranges between ten and fifteen miles. The measurements have been plotted as transmission cross-sections showing an excess or deficiency of level at each range relative to a reference value assuming only spherical spreading and attenuation.

Over a large portion of the area, bathythermograms showed an isothermal layer about 100 feet thick overlying the seasonal thermocline. Sound transmission data showed signal deficiencies at short ranges with a gradually increasing relative level beyond, until at extreme ranges levels were found in excess of what would be expected in a homogeneous absorptive ocean. The surface-mixed layer was found effective as a sound channel at all ranges. Near the northern apex of the triangle, an isothermal layer between three and six hundred feet was found to have a pronounced effect on sound transmission, particularly at the higher frequency.

PROBLEM STATUS

This is an interim report on one phase of the continuing problem of sound propagation in the ocean.

AUTHORIZATION

NRL Problem S02-03R
NR 522-030

SOUND TRANSMISSION MEASUREMENTS IN THE LONG ISLAND-BERMUDA REGION, SUMMER, 1949

INTRODUCTION

Previous measurements on the transmission of sound at 8 and 16 kc in the ocean[1] utilized a submarine-mounted transducer as a sound source of adjustable depth and range, together with a string of hydrophones, suspended from a surface ship, at which relative sound levels were measured.

Field operations employing submarine and surface ship in Caribbean waters during ebruary and March 1949 resulted in a number of transmission-anomaly contour cross-sections showing the broad features of the sound field in a reasonably lucid fashion. The present work is in essence an improved extension of this general technique to more northern Atlantic waters during the summer season.

The Caribbean measurements were limited to ranges of 8,000 yards or less, primarily because of communication difficulties with the submerged submarine, even under the comparatively good sonar conditions accompanying the thick wind-mixed layer of the springtime Caribbean. In planning work in the much poorer waters of the summer Middle Atlantic, it was felt desirable to employ a pair of surface ships if at all possible, and so obviate the necessity for constant two-way communication by means of sonar. In addition, a much greater amount of signal output power from the sending transducer was deemed desirable. By such means it was hoped to obtain, in waters of great strategic importance, transmission data at ranges beyond 10 kiloyards that are needed for design and performance prediction of the long-range search sonar of the future.

Transmission measurements were made along the New London (Connecticut)-Bermuda-Virginia Capes-New London triangle on a cruise of 16 days' duration during August 1949 with the USS MALOY (DD-791) and the E-PCE-R 849. Eighteen locations, at water depths most of which were greater than 1,500 fathoms, were occupied along this triangle (Figure 1), and data from fourteen have been reduced. The USN Underwater Sound Laboratory cooperated in making its experimental ship E-PCE-R 849 available for this work and in providing during the cruise the valuable assistance of two of its staff.

METHOD

A receiving system identical to that used previously was employed. It consisted of a string of six B-19H hydrophones at depths of approximately 15, 30, 50, 125, 250, and

[1] Urick, R. J., "Sound Transmission Measurements at 8 and 16 kc in Caribbean Waters, Spring, 1949," (Confidential), NRL Report 3556

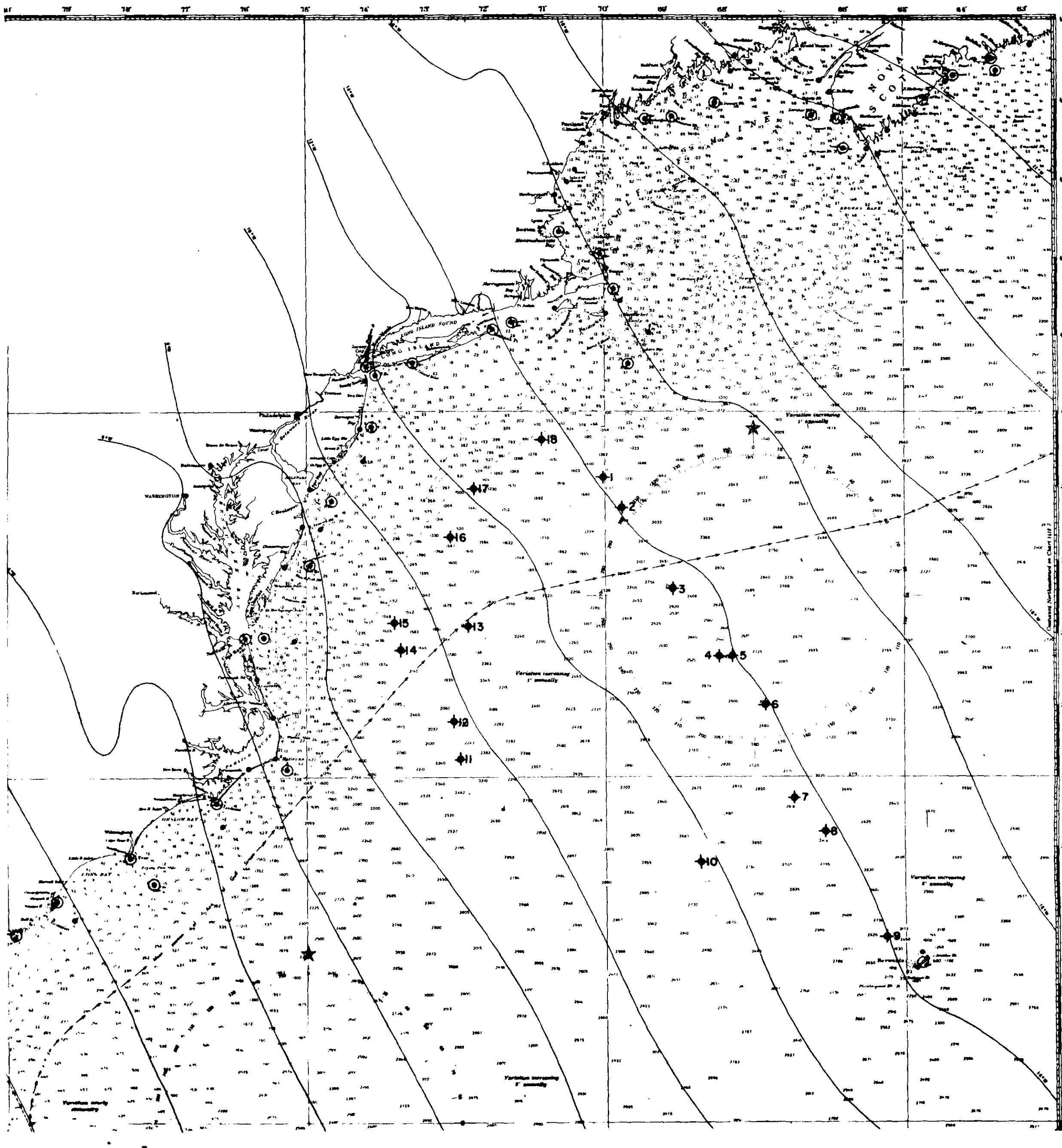

Figure 1 - Stations occupied during cruise

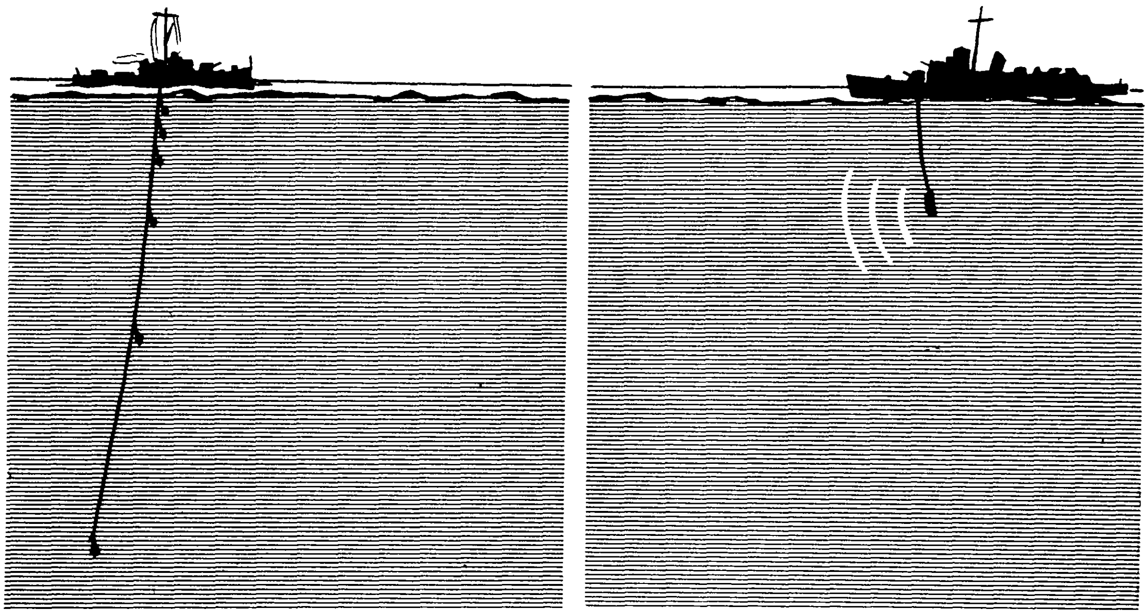

Figure 2

450 feet, the actual depths being determined at any time by a pair of depth gages attached to the string. Sound level measurements at each depth were made in the manner also previously outlined.[2] The sending ship (Figure 2) had suspended from it an underwater telephony transducer with an attached depth gage lowerable to a maximum depth of 400 feet. Instructions as to depth, range, and frequency (either 7.5 or 15.5 kc) were received by radio from the ship bearing the string of hydrophones. A diagramatic illustration of this scheme is shown in Figure 2. The raw data consisted of readings of the average peak value of a fluctuating meter during a period of about 15 seconds. In addition to these readings, records of level during the reading interval were obtained on a Sound Apparatus Co. db-level recorder for verification at a later time. These average peak values as read from the recorder traces were later found to differ from the on-the-spot readings on the average by but 1.3 db.

A calibration of each of the six hydrophones on the receiving ship was made before and after each run through the use of a hull-mounted OCP monitor installed on the E-PCE-R849, and frequent checks of receiver amplifier sensitivity were made during the runs. Calibration of the telephony projector as well as the hydrophones was made later on the NRL sound barge. These calibrations permit conversion to absolute sound pressure level of the sound field for each run, although for all practical purposes relative levels referred to a sufficiently close distance are sufficient. Directivity patterns in a plane containing the axis, for both the projector and hydrophones, are shown for reference in Figure 3.

In the field, the sending and receiving ships took an initial position about 700 yards apart along a line perpendicular to the wind, so as to minimize relative drift. The sending ship then lowered an AN/UQC-1 underwater telephony projector in succession to each of four preassigned depths and there transmitted CW alternately at 7.5 kc and at 15.5 kc.

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[2] *NRL Report 3556, op. cit.*

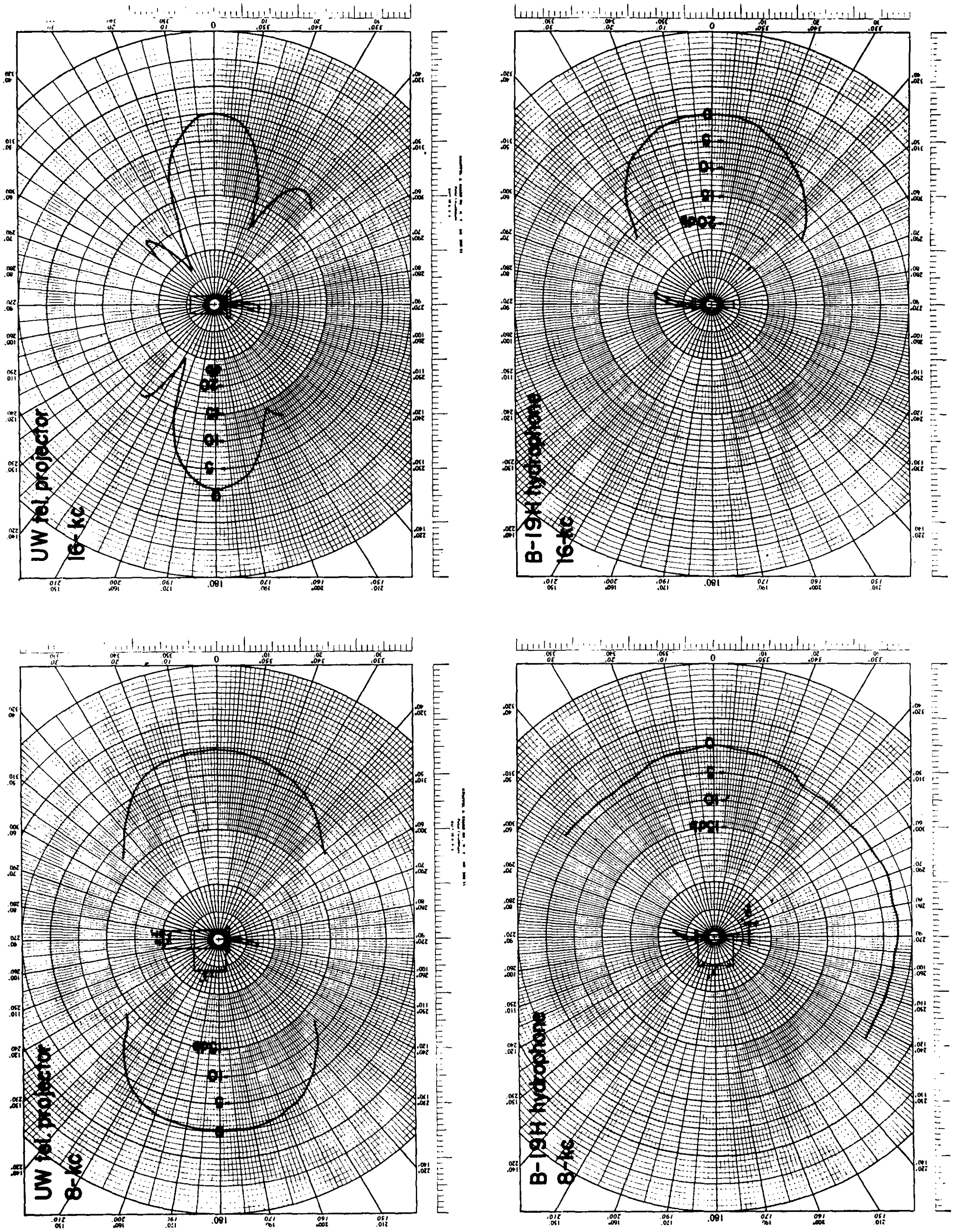

Figure 3 - Beam patterns of projector and hydrophones

On the other ship, the average peak value of this signal was read on a meter and also recorded on a waxed-paper db recorder in succession on each of the six hydrophones. Occasional readings of two depth gages attached to the hydrophone string, and of its entrance angle into the water, were made to enable subsequent determination of the six hydrophone depths. Recorder tapes were also obtained of the signal as received on some one of the hydrophones as the projector was raised continuously from its maximum depth to the surface. Frequent lowerings of 150-foot and 900-foot bathythermographs were made at each range station. Radar ranges were obtained at intervals during the time each range was occupied. This procedure was repeated at each of several such ranges out to a normal maximum range between 20,000 and 30,000 yards.

DATA REDUCTION

Corrections to the raw level readings were made for transducer directivity (important only at the shortest ranges), hydrophone and amplifier sensitivity, changes in projector current, changes in range because of drift at each range station, and for ambient noise when signal and noise were of comparable levels. The average of the corrected measured levels at the closest range of 700 yards for all 14 locations, for depth combinations such that both projector and hydrophone were located in the mixed layer, served as the reference value for further reduction. At 7.5 kc, this reference value was equivalent to a sound pressure of 41 db above 1 dyne/cm^2; at 15.5 kc, 19 db above 1 dyne/cm^2. These values apply to a range of 700 yards. At other ranges the reference value was found by applying to these figures a loss due to spherical divergence plus attenuation, using for the latter an attenuation coefficient in db per kiloyard given by the expression $0.075\ f_{kc}^{1.3}$ for the two frequencies 7.5 and 15.5 kc. Thus at range R yards the reference pressure for all runs was at 7.5 kc

$$41 - 20 \log (R/700) - 1.02\ (R-700)\ 10^{-3}$$

above 1 dyne/cm^2, while at 15.5 kc it was

$$19 - 20 \log (R/700) - 2.67\ (R-700)\ 10^{-3}.$$

In applying losses due to spherical spreading and a nominal value of attenuation, the two best-known sources of sound transmission loss in the sea are allowed for. The differences from these ideal values that were actually observed at locations 5 through 18 of Figure 1 have been plotted. Figures 4 through 17 are a series of cross-sections of the ocean, with depths in feet and range in kiloyards. At each range occupied by the two ships, a vertical line is drawn. At each hydrophone depth there is shown a horizontal line proportional in length to the excess or deficiency of observed signal relative to the reference value at that range, computed as indicated above. Lines and areas to the left indicate regions of low signal strength, while those to the right show regions of signal strength greater than would exist if only spherical spreading and the nominal value of attenuation affected sound transmission in the ocean. Each figure shows plots for each of the projector depths (usually four) at the two frequencies 7.5 kc (called 8 on the plots) and 15.5 kc (called 16). A db scale is shown on each plot, and a 900-foot BT is reproduced at the base of the whole figure. The letter N is shown when the signal level fell so far below noise as not to be readable, and a mark < indicates the equivalent level of the noise background. This condition occurred at a moderate range at the higher frequency because of greater attenuation and an initially lower sound output from the projector.

DISCUSSION

In general the BT's throughout the region show a wind-mixed layer about a hundred feet thick overlying water of moderately steep negative gradient. The four source depths were chosen from the BT in the following manner: 1) The shallowest depth (normally 20 feet) was chosen to be the shallowest that the projector could safely occupy and still avoid hull-shielding and emergence from the water by the roll of the ship; 2) the next depth (about 80 feet) was chosen near the base of the mixed layer; 3) at the third depth the projector was in water of steep negative gradient near the top of the thermocline (except Station 18, Figure 18); 4) the last depth (about 350 feet) was the maximum depth, below the depth of steepest temperature gradient, which the available cable would allow.

Over all but the northern tip of the triangle (Stations 1 and 18, Figure 1) essentially similar BT and sound transmission conditions prevailed, as indicated by Figures 4 through 16. In view of this similarity, an average of all reduced data, except for station 18 to be considered later, is shown as Figure 17. In this figure the average difference between observed and reference levels is plotted for each hydrophone at an average depth and range. Some interesting features will be noted from this figure, or from the figures from which it was derived. When both source and receiver are shallow (source depth 20 feet, hydrophone depths less than 50 feet) there is an excess of signal level, representing the well-known effect of the surface sound channel. This is the same type of behavior that is known in radio propagation as trapping by a ground-based duct. For all other depth combinations when the range is less than 10,000 yards or so, there is regularly observed a deficiency of level that may be ascribed to downward ray-bending by the thermocline below the mixed layer. This deficiency has a tendency to increase with hydrophone depth. Present echo-ranging and most listening sonar is incapable of operating beyond this region of partial shadowing by the ocean's surface and is generally rendered ineffective even at such ranges by this partial shadowing.

Beyond 10,000 yards at 7.5 kc there will be noted a gradual return of signal, until beyond about 25,000 yards its level is higher than it would be in homogeneous, absorptive ocean. Two possible contributors of level at such long ranges are: 1) reflection from the bottom and 2) forward scattering by the same scatterers that are responsible for volume and surface reverberation. An attempt to treat by least squares the data at ranges greater than 10,000 yards, and so derive an appropriate divergence parameter and attenuation coefficient yielded an absurd result, presumably because as the range increases more and more bottom-reflected sound is received as a result of transducer directionality and an increasing incidence angle at the bottom. The reading of average peak levels instead of average sound levels tends to diminish this anomalous increase at long ranges if the extent of fluctuation of signal diminishes with range.

At the northern apex of the triangle (Figure 1, Station 18) the thermocline was found to have an isothermal portion between about 250 and 600 feet, having a profound effect on sound transmission. When both ends of the transmission path lay in this layer, a marked increase of sound transmission was observed. Figure 18 (Station 18) shows that for source depths of 285 and 370 feet, and for the two deepest hydrophones, transmission excesses of 20 to 30 db were found at 15.5 kc. This isothermal portion of the BT denotes an internal sound channel, or layer containing a velocity minimum, which partially traps within itself sound originating within it. This trapping is known from theory to be more effective the higher the frequency, and the data of Station 18 shows greater excesses at 15.5 kc than at 7.5 kc.

It should be emphasized that any sound channel, surface-bounded or internal, is effective only when both source and receiver are located within it. Such channels, since they diminish the loss due to divergence from the source, have considerable effectiveness at long ranges. In addition to Station 18, a similar behavior was observed at Station 1, although the data from this location has not been considered sufficiently complete to be worth reducing. The development of this isothermal layer northward along the northwestern and northeastern legs of the triangle is shown from bottom to top by the BT's of Figure 19. No opportunity to examine the areal or seasonal extent of this channel was available.

Records of the fluctuation of a CW signal at Station 9 are shown in Figure 20 for several combinations of source and receiver depths at five ranges. One record of each pair is for a hydrophone depth of 25 feet, the other for a depth of 320 feet. These are reproductions of waxed-paper records of a Sound Apparatus Co. logarithmic recorder with horizontal lines at 2-1/2 db intervals. At short ranges great fluctuations of comparatively long period will be noted, while at longer ranges the received signal tends to fluctuate more rapidly with a smaller amplitude. At short ranges it may be assumed that the fluctuation is predominantly the result of surface-reflection interference resulting from the motion of the two ships; at longer ranges the importance of volume and bottom-scattered sound increases. The character of the signal for the case of both source and receiver in the surface channel (upper row) should be compared with that for other depth combinations at the same range.

The use of CW in transmission measurements serves to determine an average level of an initially steady signal as it appears at a certain range. Such CW measurements are probably adequate for prediction of listening ranges. In echo-ranging, however, the character of a single sound pulse becomes important. The use of pulses instead of CW also may serve to throw light on the matter of travel paths at long ranges and the relative importance of forward scattering and bottom reflection as contributors to sound levels at long ranges. Additional transmission studies along these lines are planned for the future.

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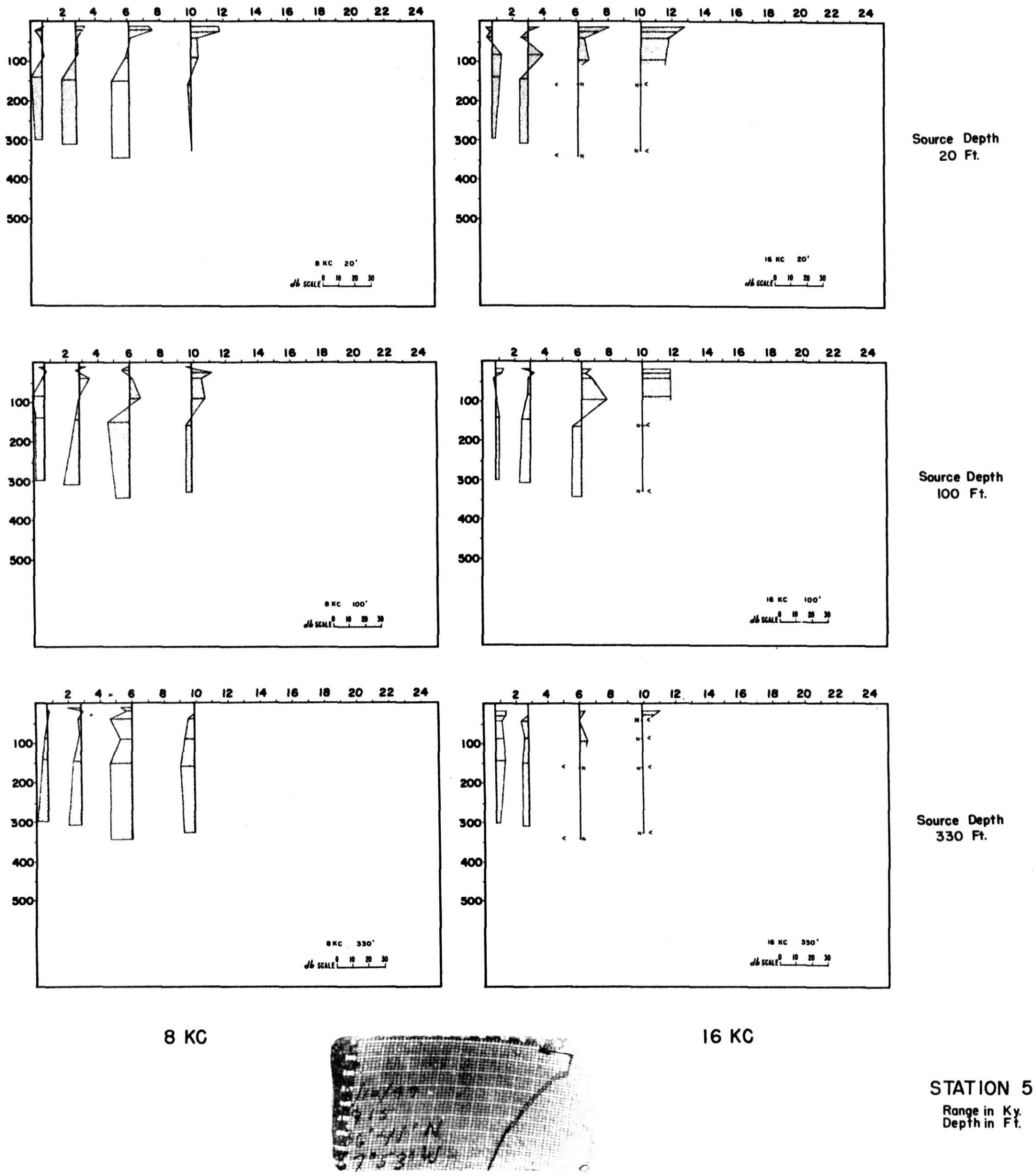

Figure 4 - Transmission cross-sections, station 5

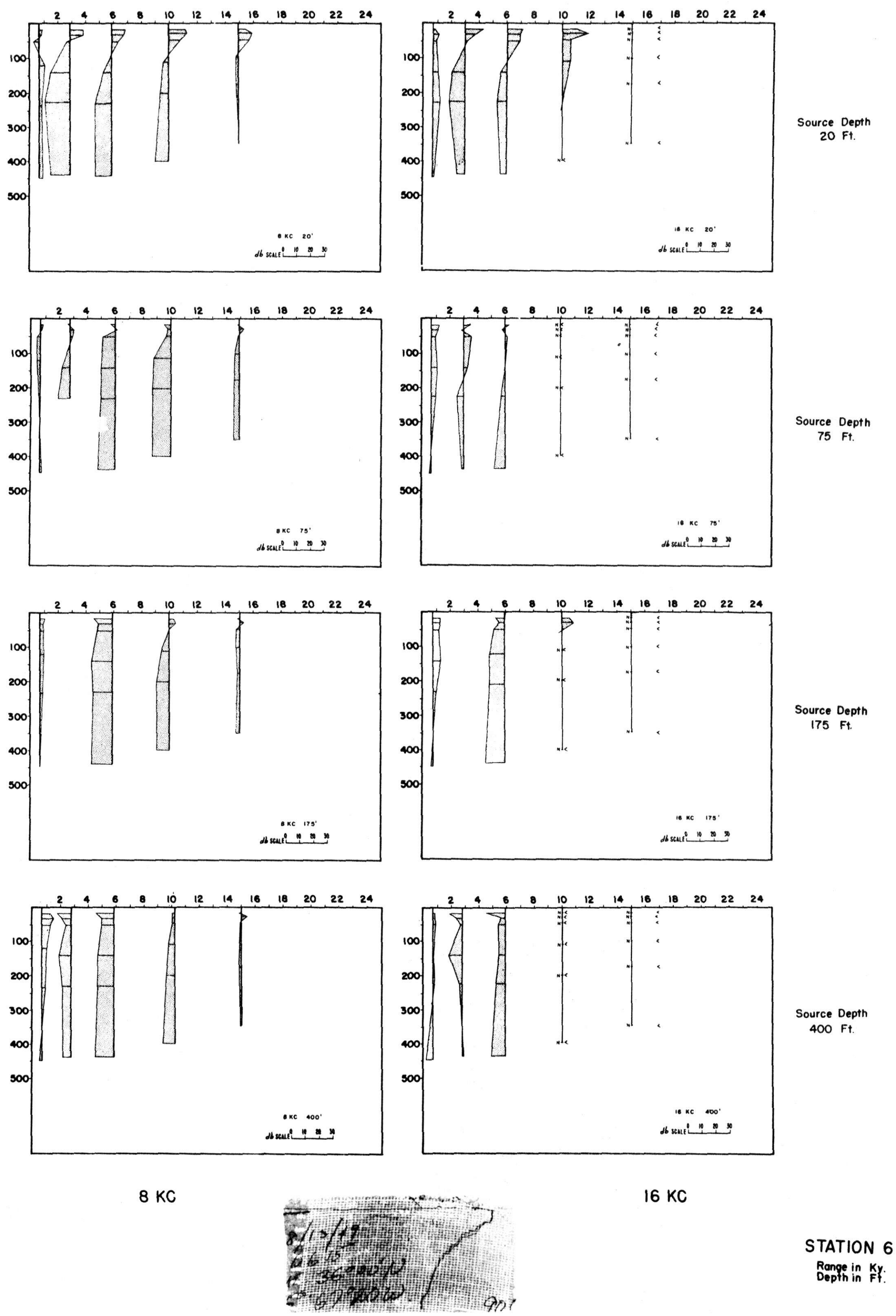

Figure 5 - Transmission cross-sections, station 6

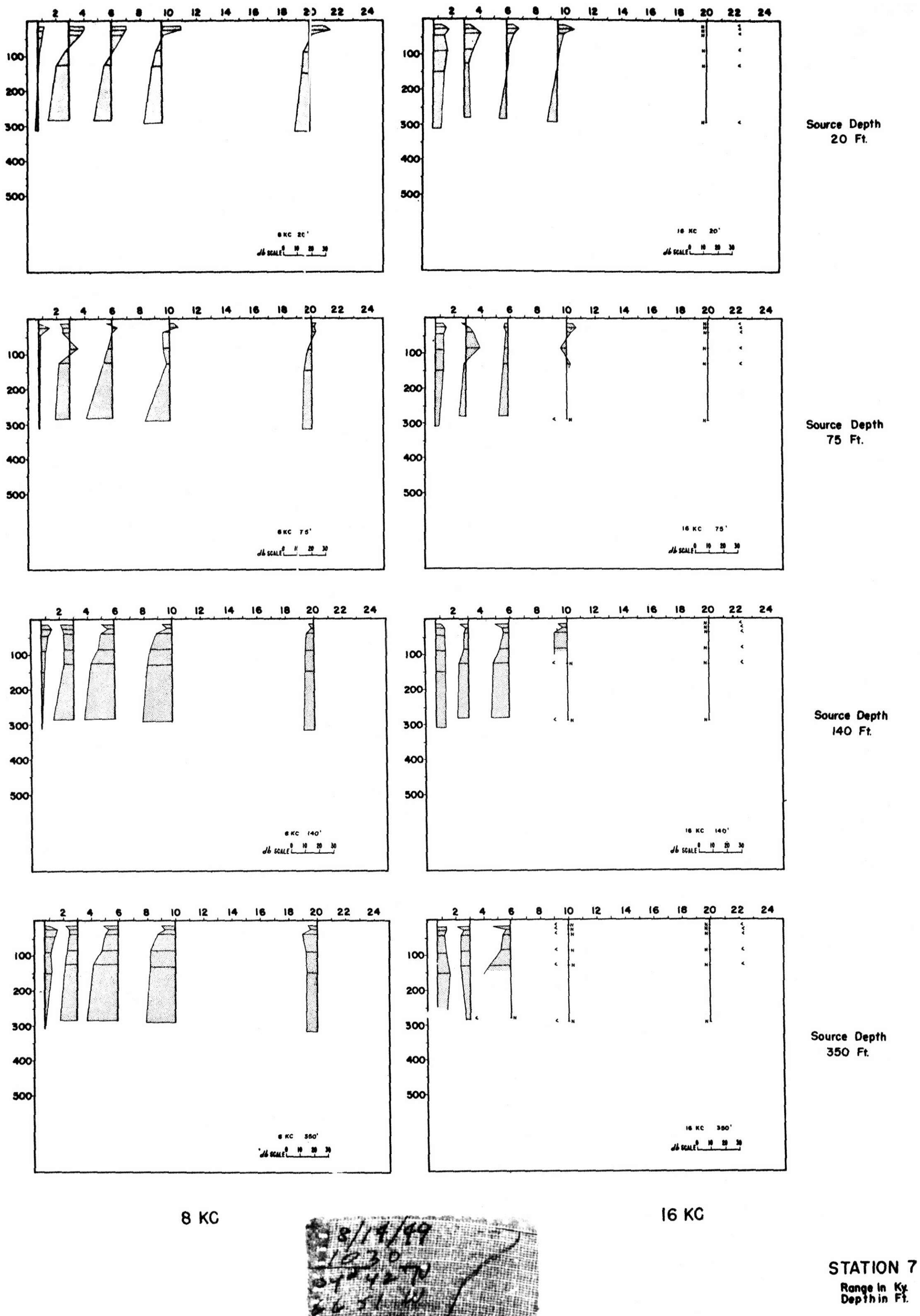

Figure 6 - Transmission cross-sections, station 7

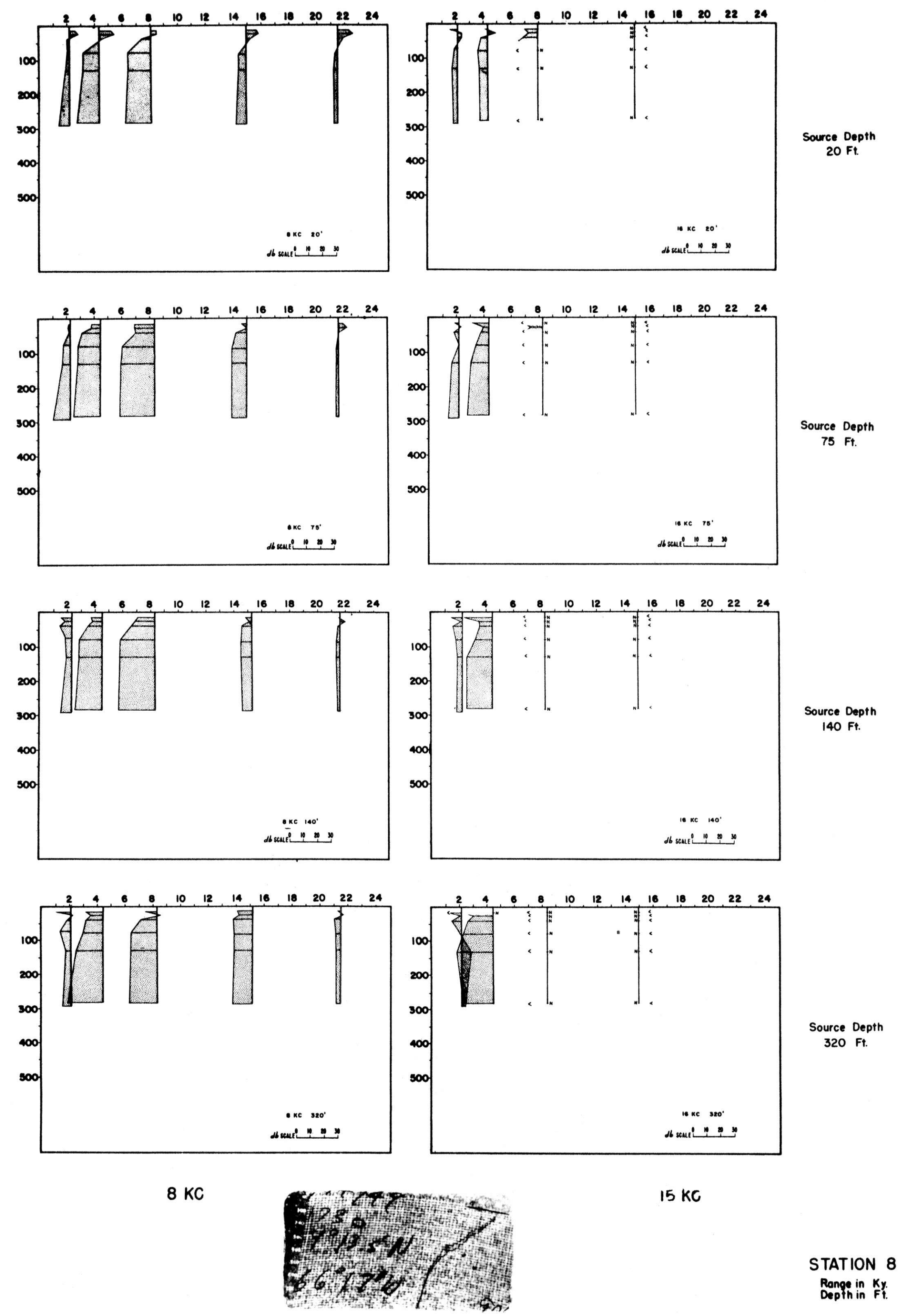

Figure 7 - Transmission cross-sections, station 8

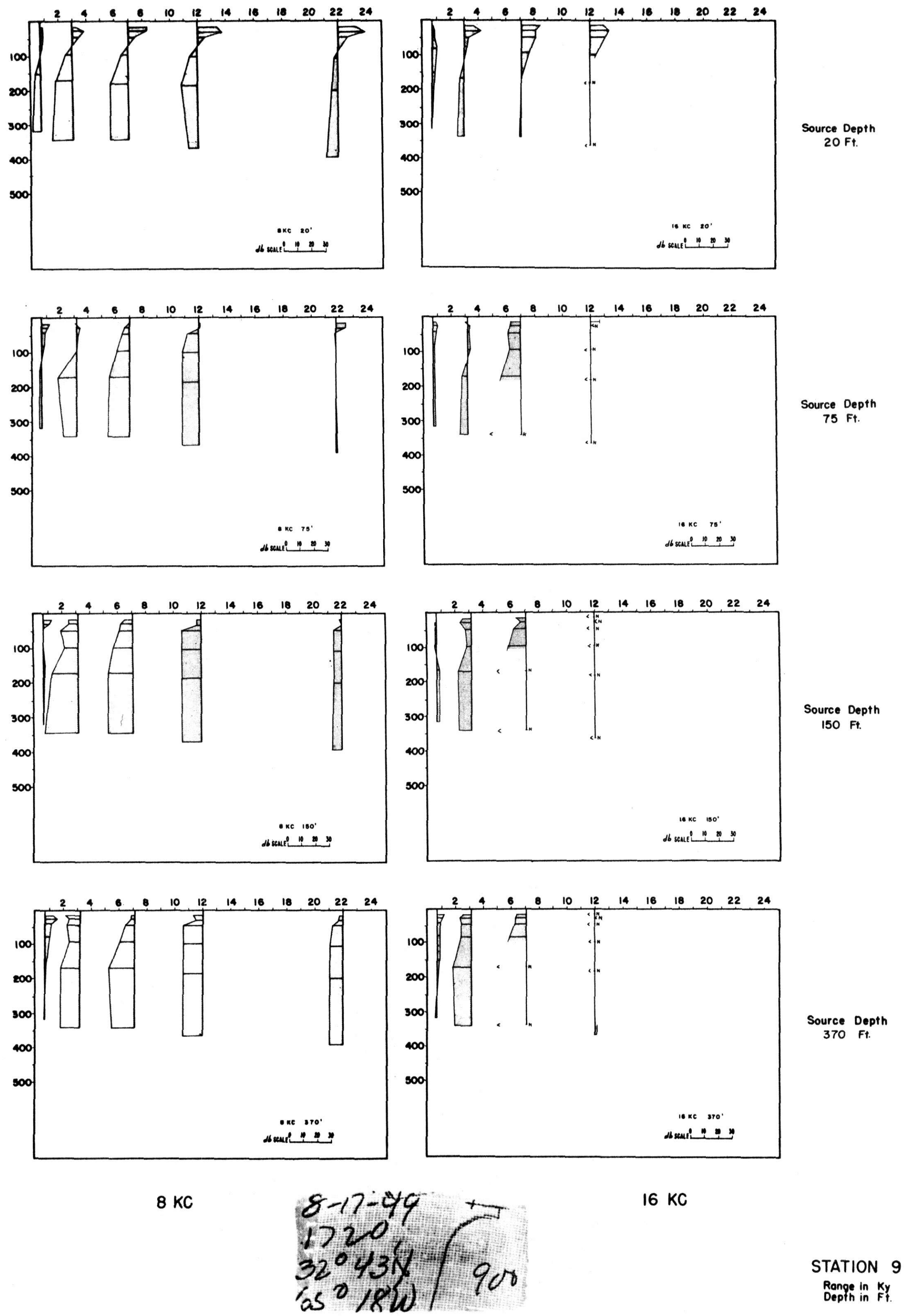

Figure 8 - Transmission cross-sections, station 9

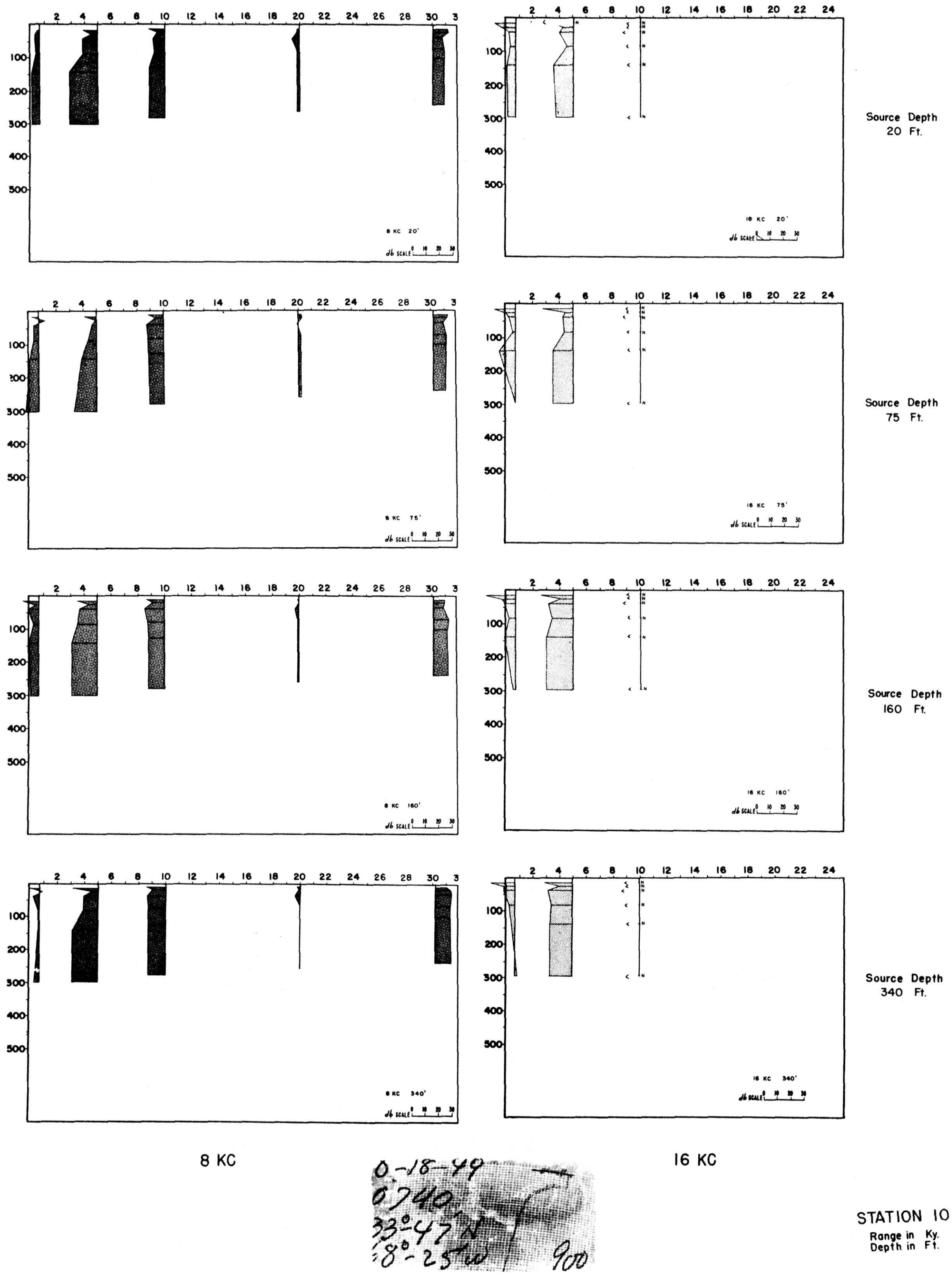

Figure 9 - Transmission cross-sections, station 10

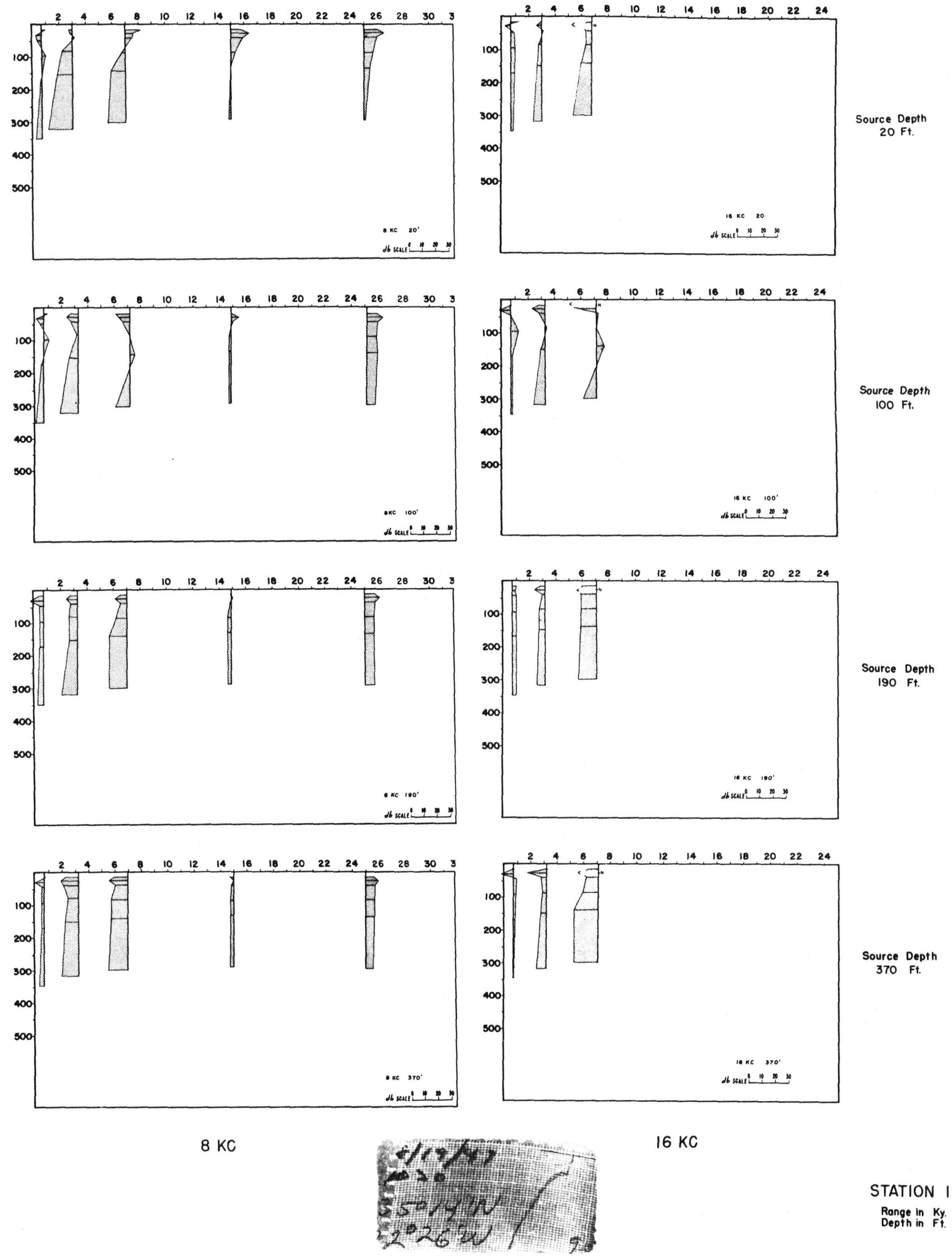

Figure 10 - Transmission cross-sections, station 11

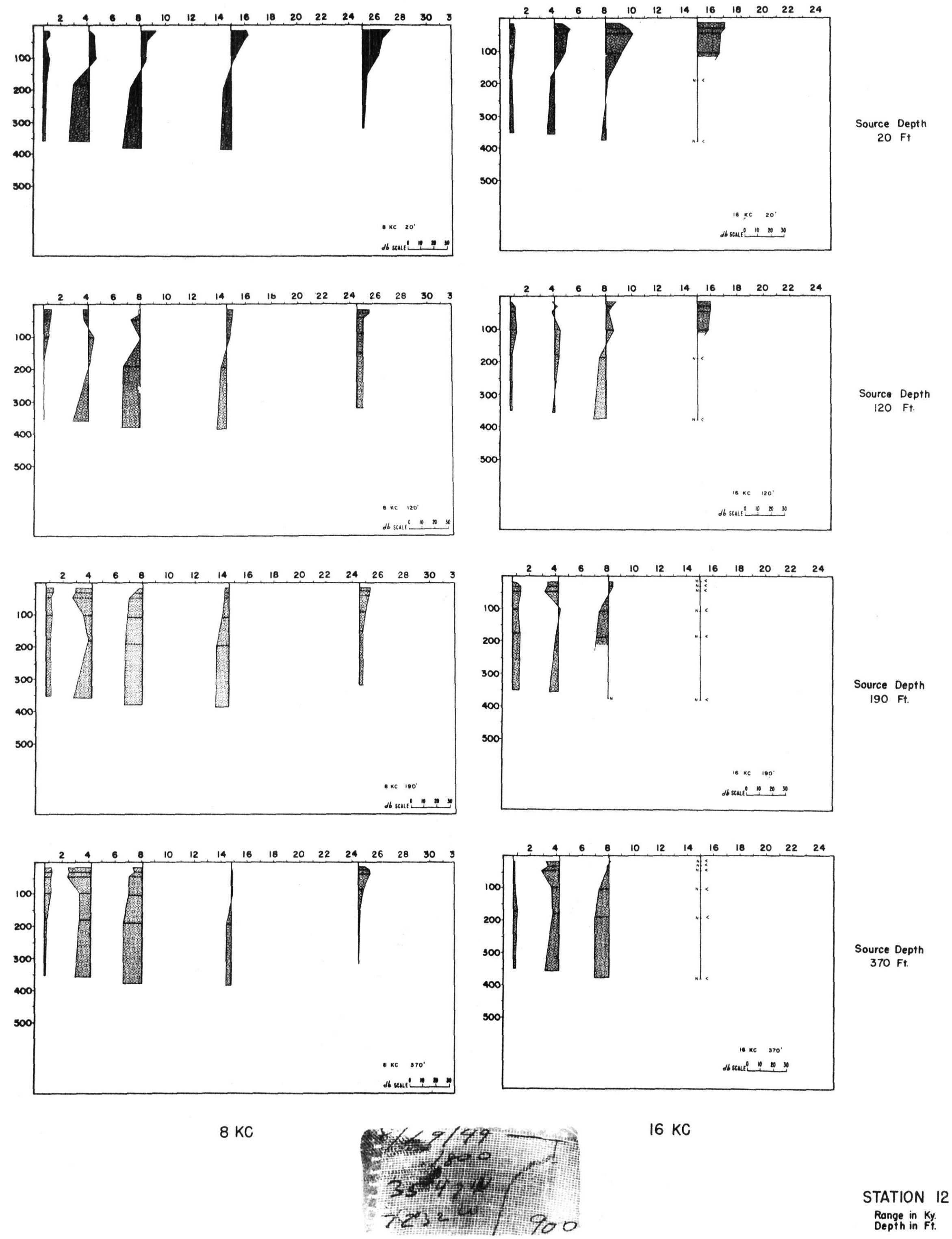

Figure 11 - Transmission cross-sections, station 12

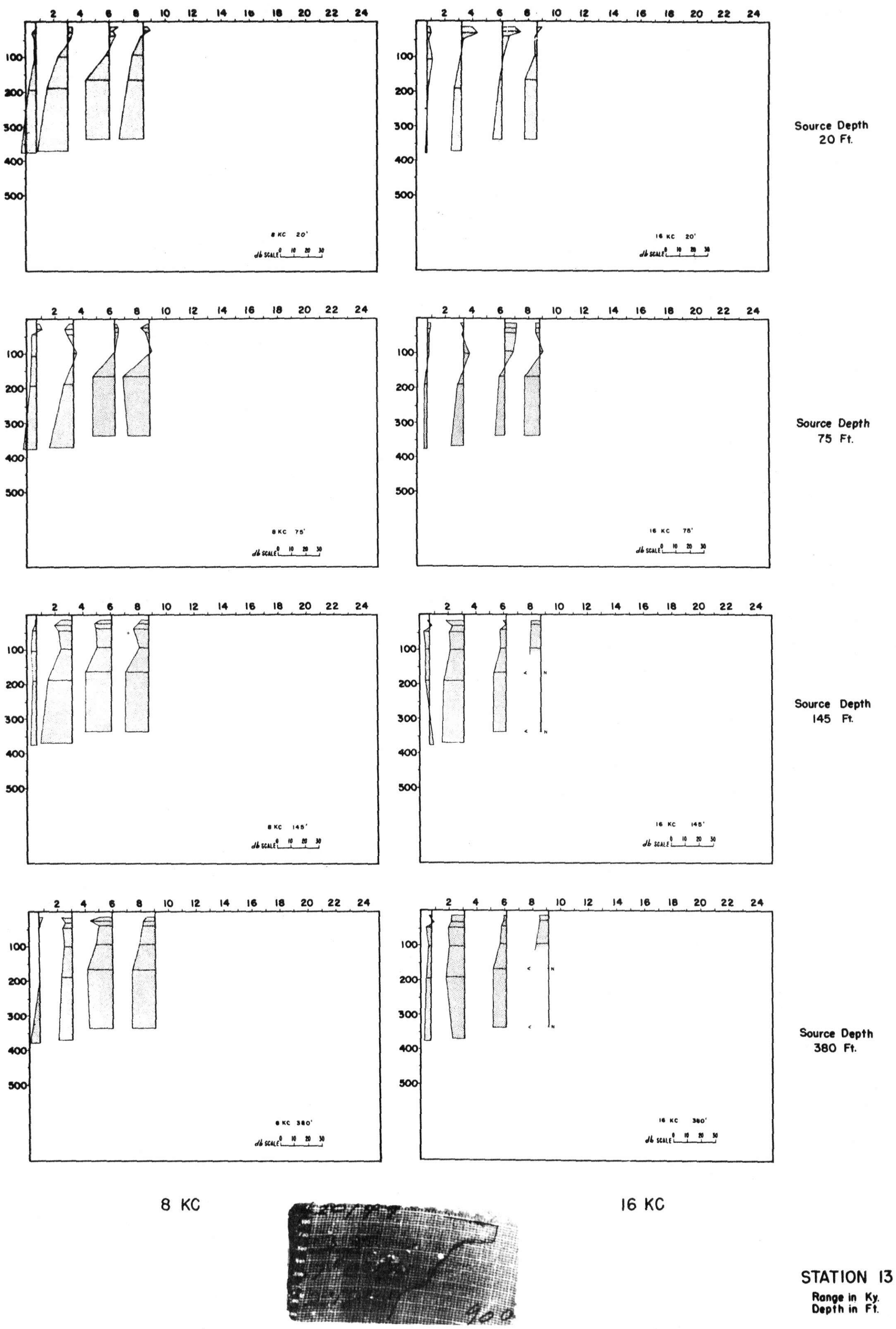

Figure 12 - Transmission cross-sections, station 13

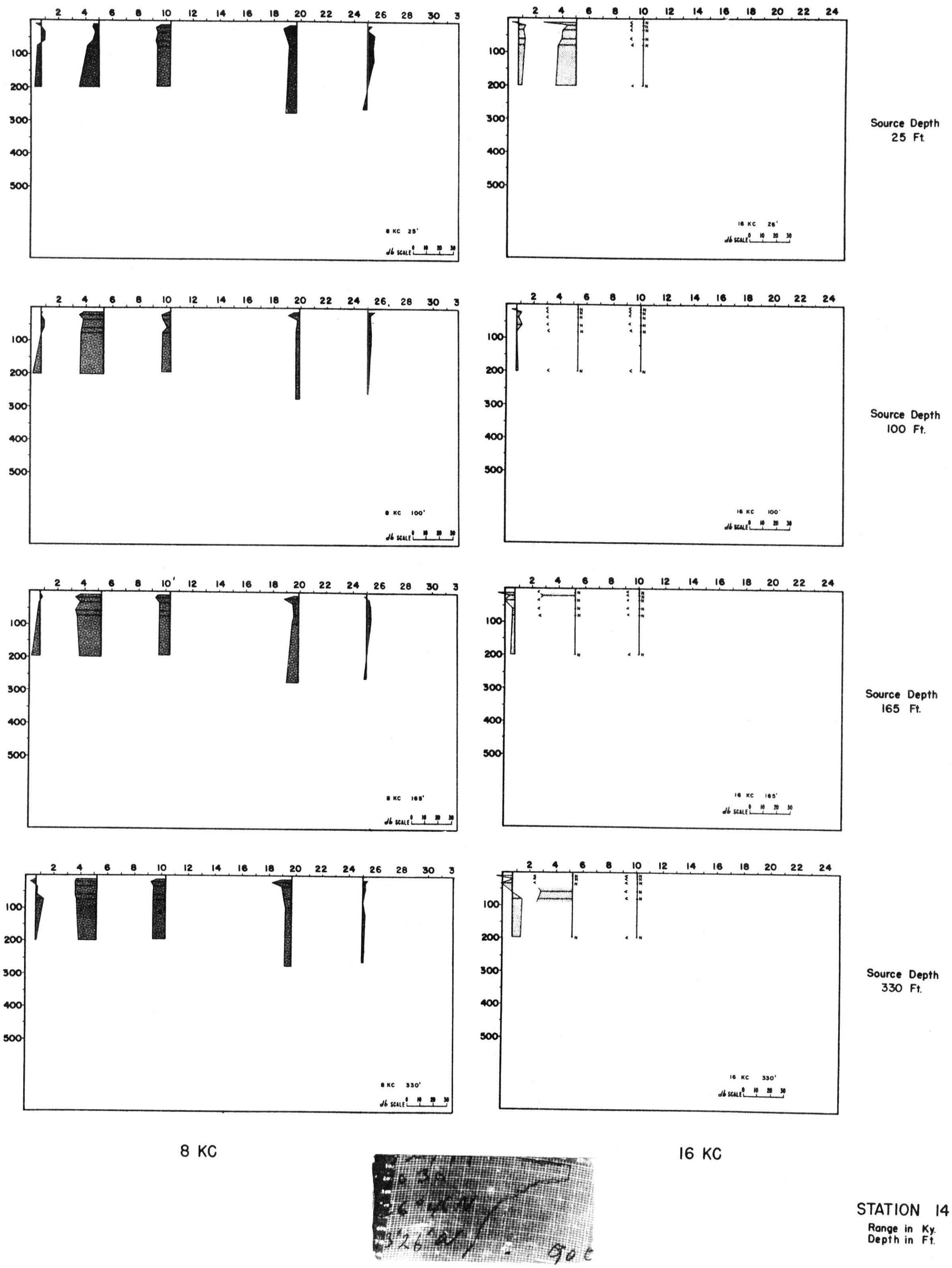

Figure 13 - Transmission cross-sections, station 14

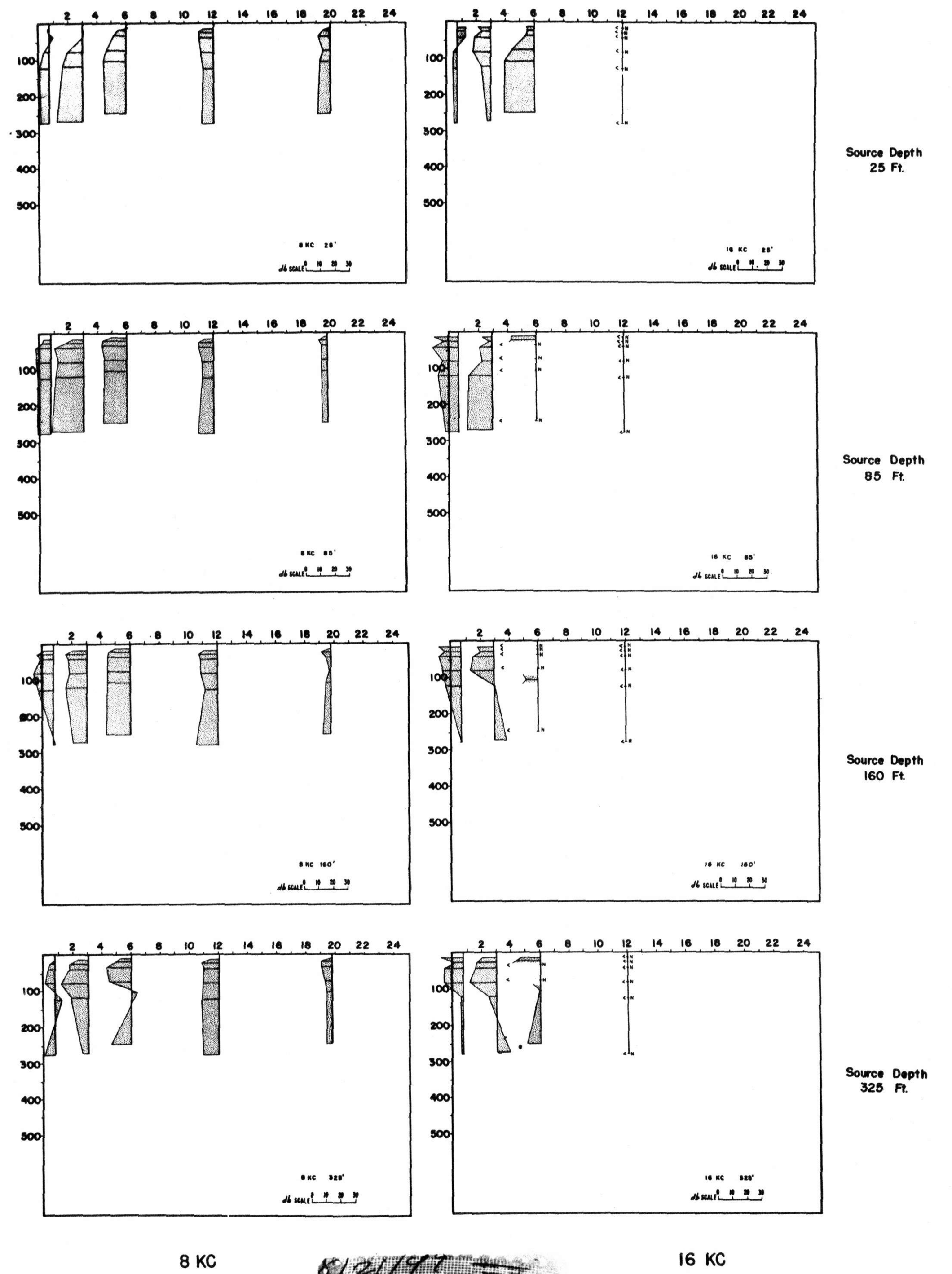

Figure 14-Transmission cross-sections, station 15

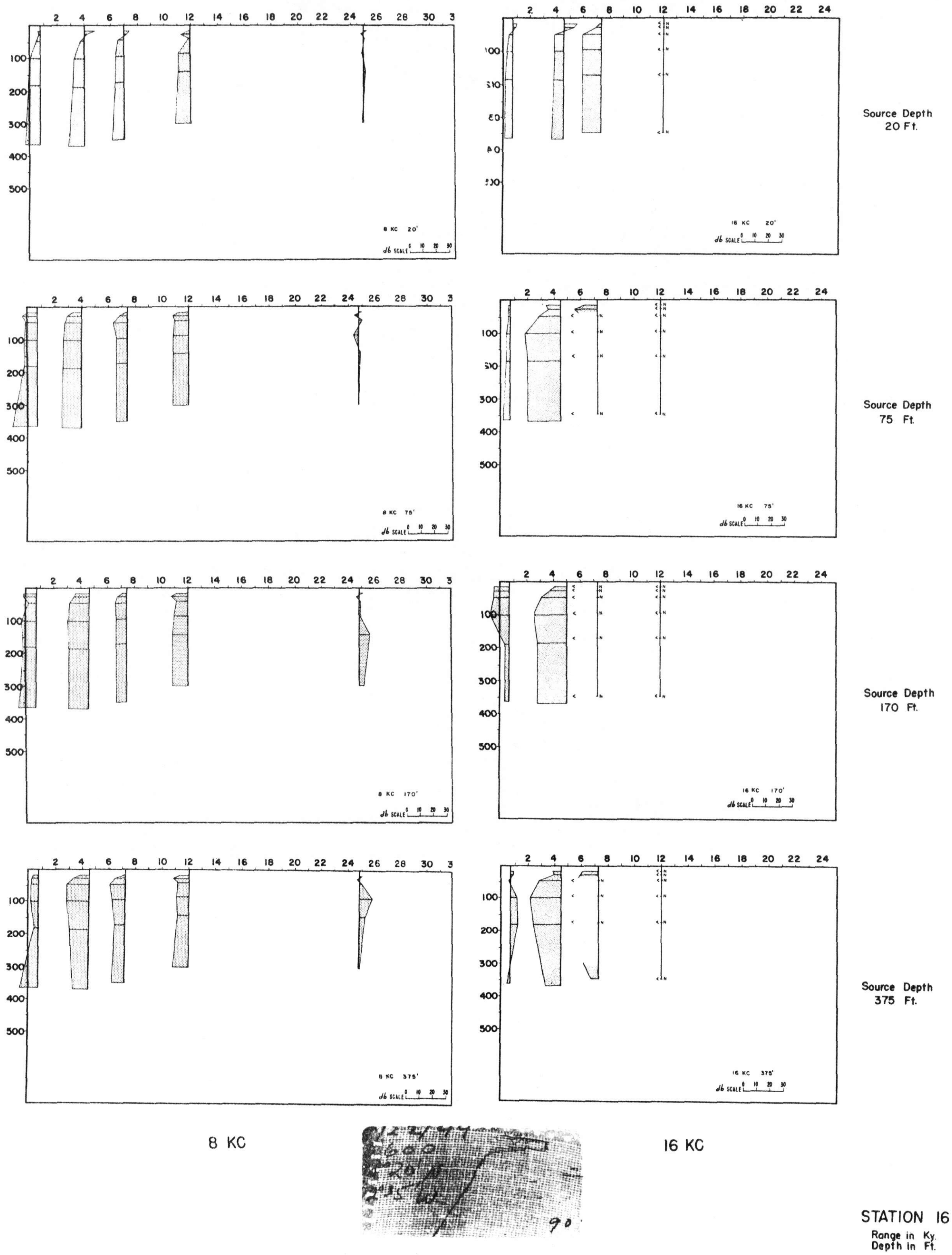

Figure 15 - Transmission cross-sections, station 16

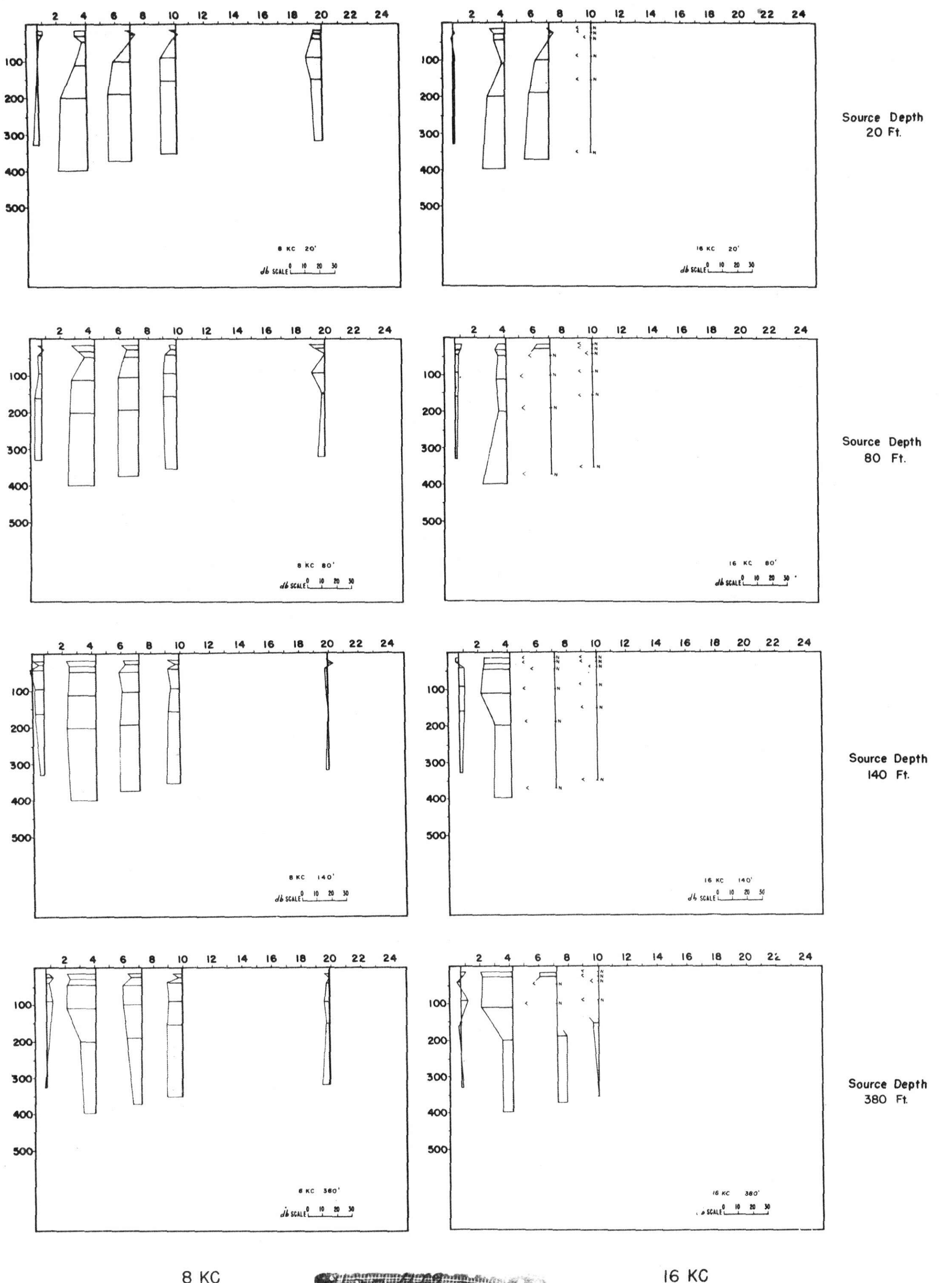

Figure 16 - Transmission cross-sections, station 17

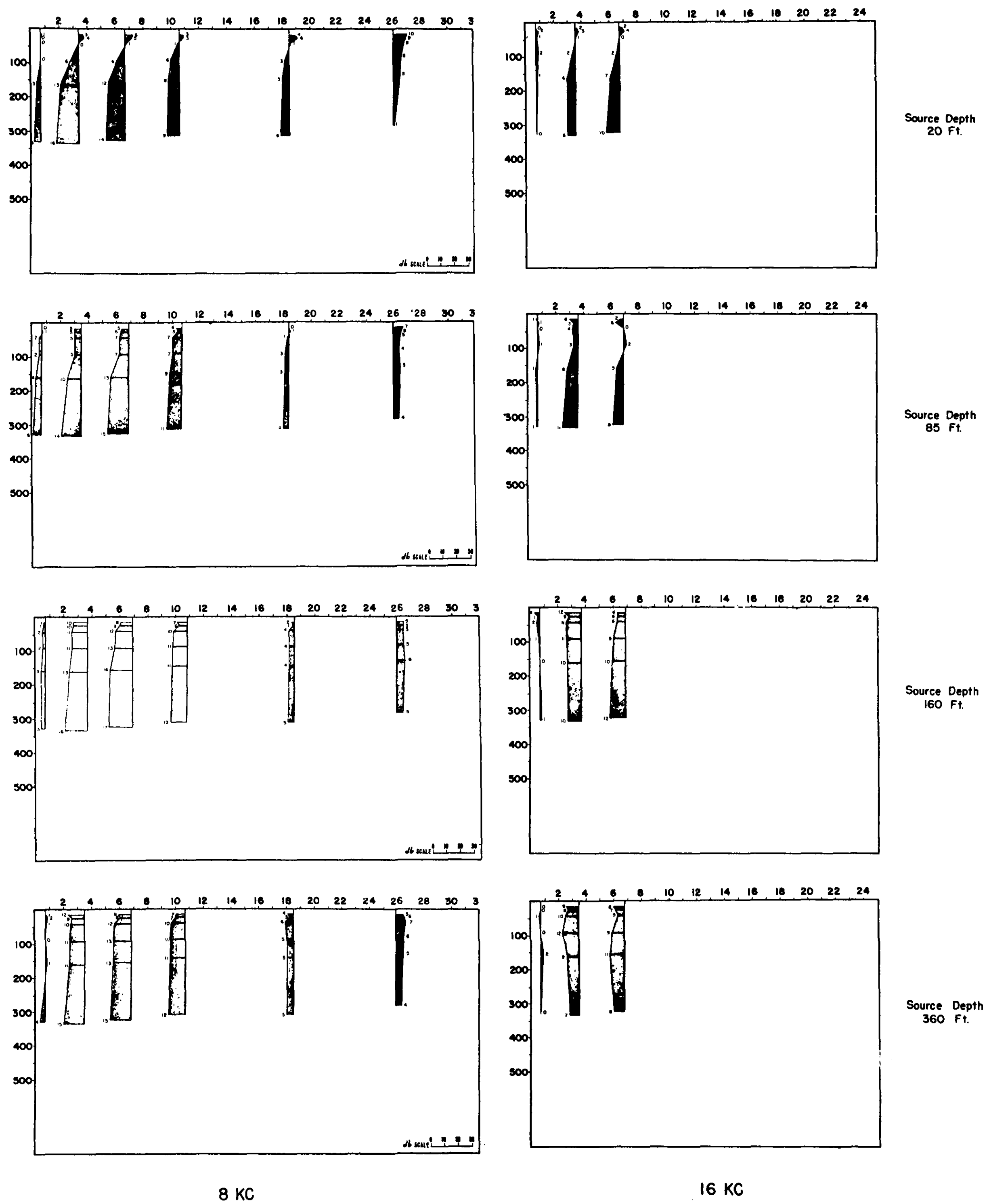

Figure 17 - Average transmission cross-sections, stations 5 to 17

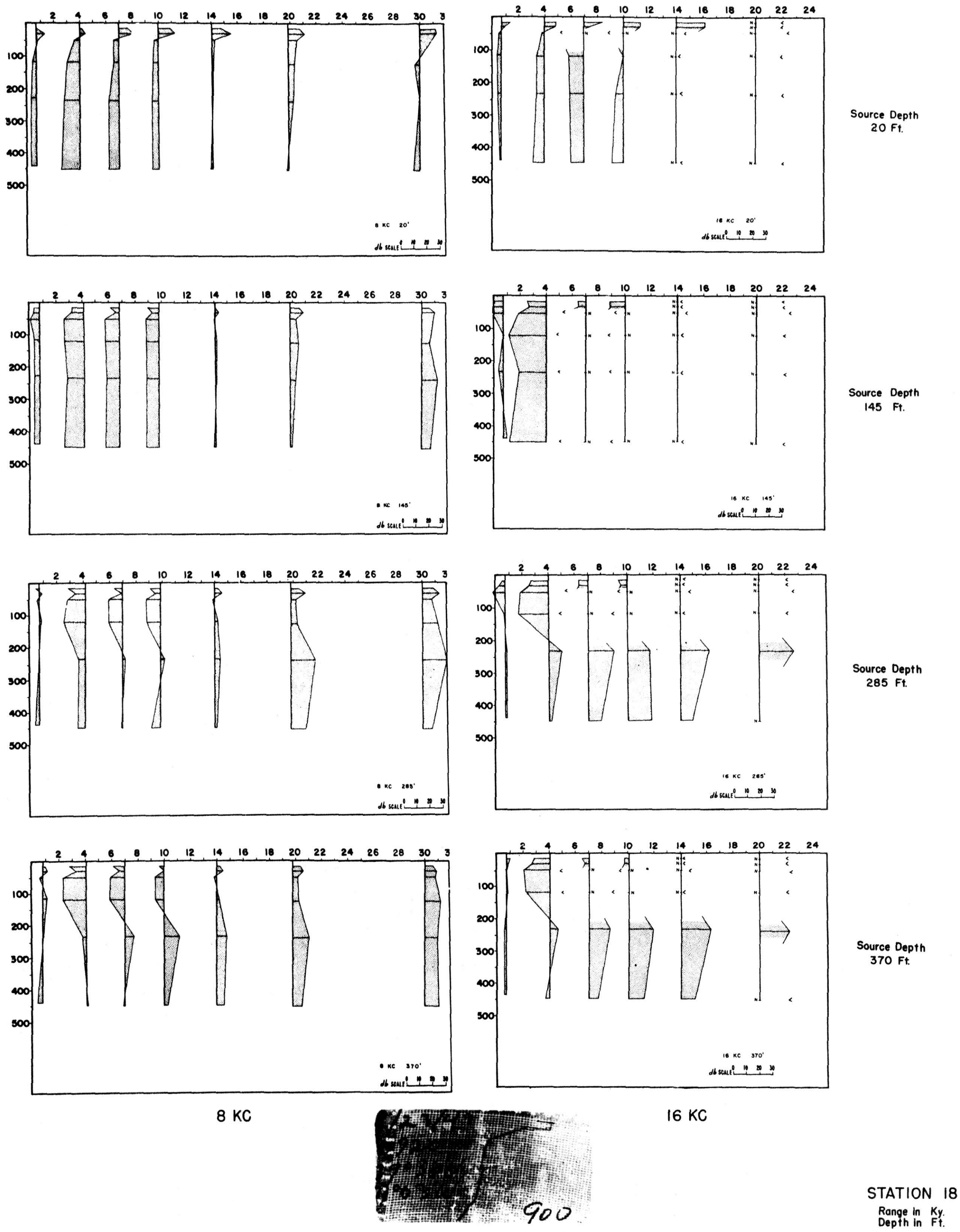

Figure 18 - Transmission cross-sections, station 18

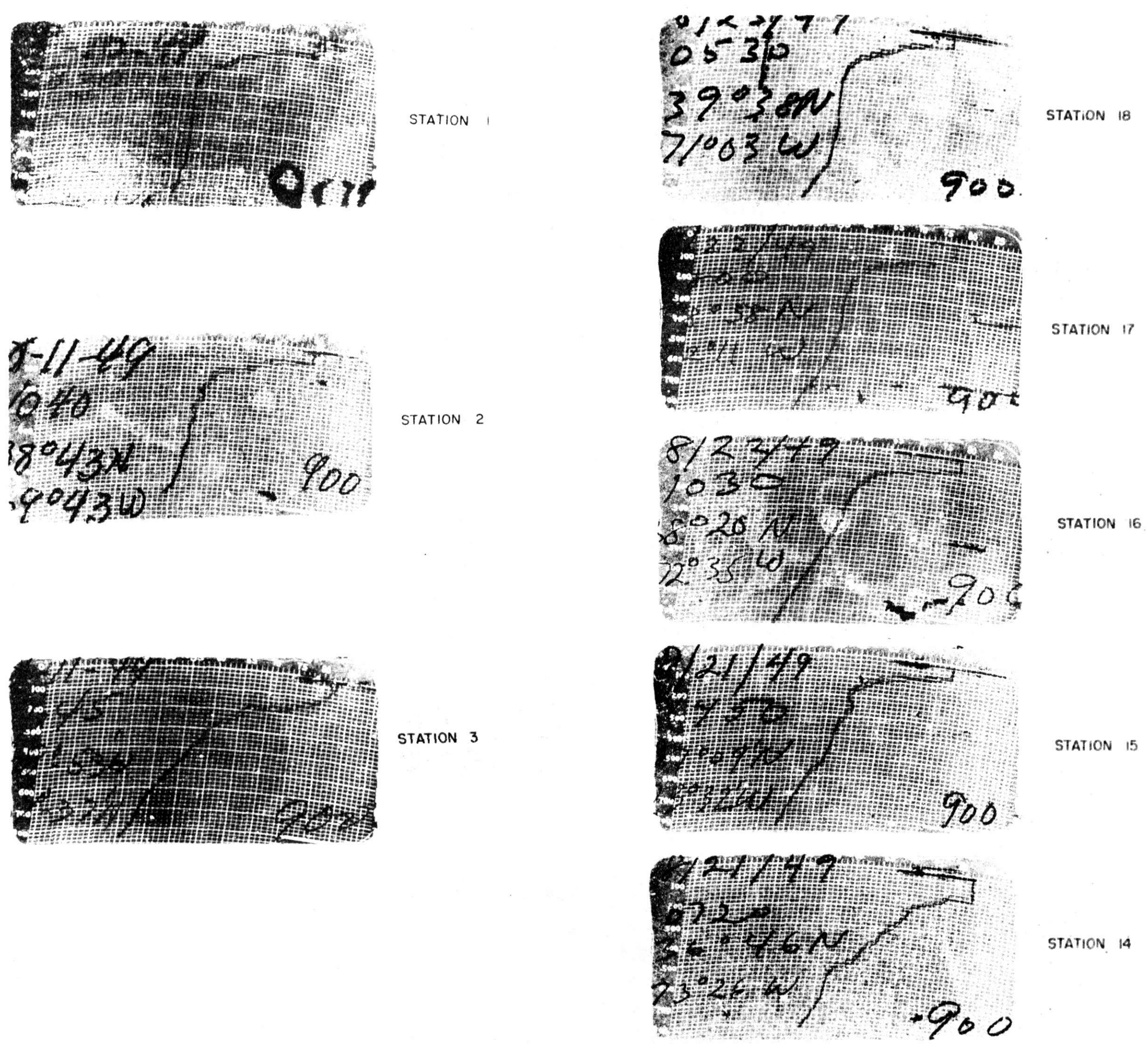

Figure 19 - Bathythermograms showing areal development of internal isothermal layer

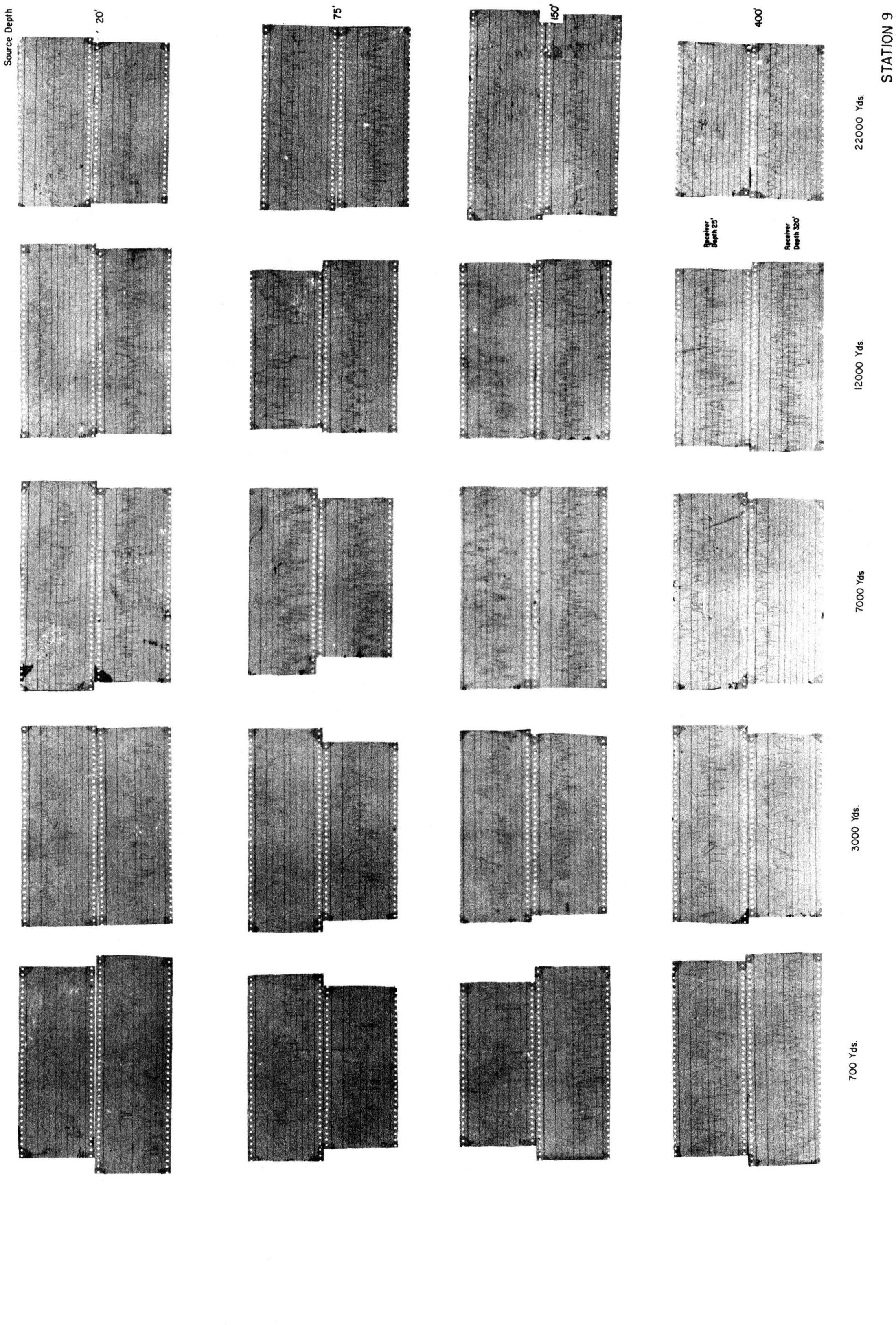

Figure 20 - Recorder traces of CW signal for various depth and range combinations. Freq. 7.5 kc

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