## II. Deep Water Sea Floor Multiple Reflections

Recent surveys off Eastern Canada exhibited an unexpectedly severe masking problem with multiple reflections. Masking becomes increasingly severe with increasing water depth for two reasons. First, the group delay of a reverberation operator increases not only with reflection coefficient but also with the two way travel time, thus spreading the contaminating energy deeper into the time section. Second, the topography effect is more serious in deep water than in shallow water. A measure of focusing is found by dividing sea floor depth by a typical topographic radius of curvature. In other words, for a given topography, the focusing effect becomes more severe with increasing water depth. The focusing effect results in amplitude and waveform anomalies on the primary reflected wave which are of increasing severity on higher order multiples. This effect is not modelled by the deconvolution method and is, we believe, what Hofer, Schneider and McBeath (East Coast Canada Marine Seismic Data: Geophysical Problems and Current Approaches, presentation, 42nd annual meeting of SEG) referred to as "geometrical deconvolution detuning". We have learned how to model this effect and as a part of the proposed research we would like to investigate whether such modelling can form the basis for a means to alleviate the masking problems.

A procedure which comes to mind is to take the observed primary, along with all its amplitude anomalies and diffractions, and compute the expected multiple waves, then adaptively subtract the anticipated multiples from the actual ones. This could proceed in a fashion somewhat like that which we illustrated in "Time and Space Adaptive Deconvolution Filters", a presentation by Don C. Riley and John Parker Burg at the 1972 SEG meeting. Since adaptive methods are fairly well known the rest of this section will show only the unpublished results we have already attained on synthesis of sea floor multiple reflections.

We have solved the acoustic wave equation in normal moveout coordinates. In obtaining the differential equation governing multiples, we made the Fresnel approximation and the thin lens approximation. (When conditions warrant both approximations can be rather easily improved.) The partial differential equation is also set up to simulate recording with programmed gain control so that all orders of multiples would come out with the same amplitude if the sea floor were flat. Figure 1 shows the synthetic time section. Early in the time section it is easy to recognize that the dip on the N-th order multiple is nearly equal to N times the dip of the primary. Also focusing can be perceived where the multiples sag downward. Late in the section the situation becomes highly focused and confused. That these kinds of phenomena do exist on field data is clearly exhibited in Figure 2. Even in the shallow water of the Chukchi Sea the focusing effects of sea floor topography on multiples are very pronounced. It will be observed that an irregular sea floor (probably resulting from differential glacial erosion of the Mio-Pliocene fold structure) results in weaker high order multiples where the sea floor is locally convex. Through this "window" the AGC brings the steeply dipping structure into view. These phenomena are most clearly understood on near trace sections. They have been unrecognizable to us on the stacked sections we have seen. We have not yet seen any near trace sections from Eastern Canada and hence are unable to assess quantitatively the comparative importance of sea floor topography in the prediction of those multiples. However, the promise of practical results arising from fundamental studies seems quite clear.

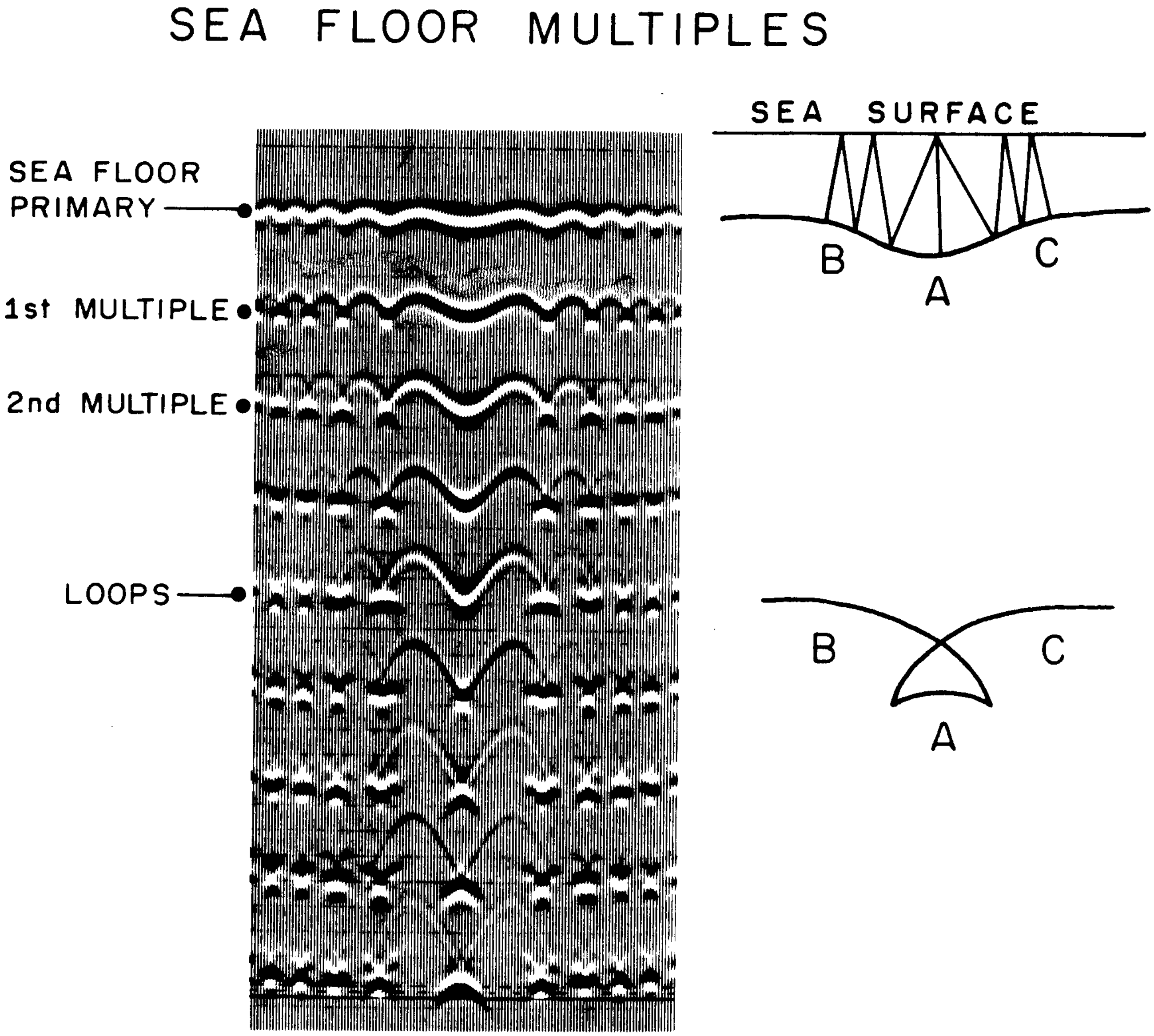

Figure 1. Synthetic Sea Floor Multiple Reflections (right) and ray diagram (left) to explain travel time loops. Note increasing dip on higher order multiples and dominance of focusing effects at late times. Note 90° phase shift of focused waves.

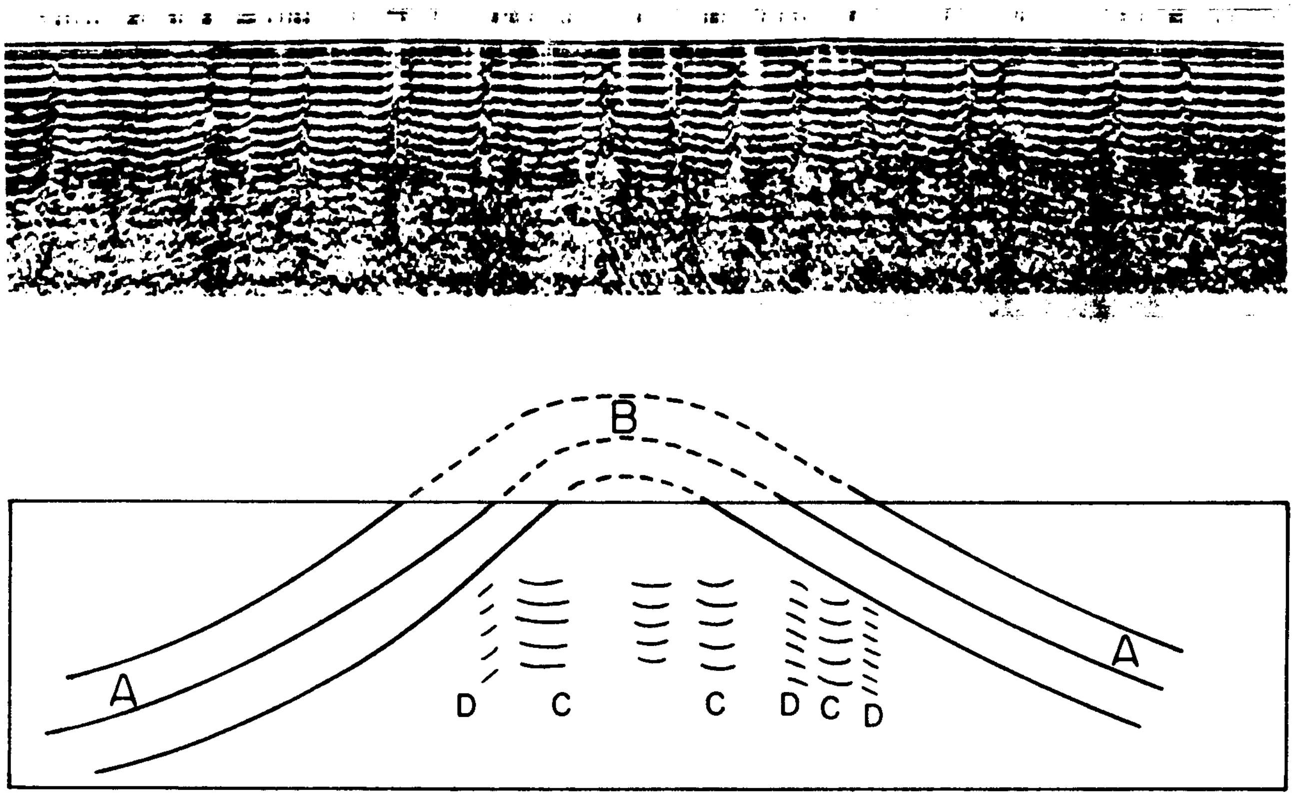

Figure 2. Example of focusing effects on multiple reflections in near trace section at Chukchi Sea. These effects are obscured by stacking.

A. Existing structure

B. Former structure unevenly eroded away leaving localities of sea floor convex or concave

C. High order multiple reflections focusing where the sea floor is concave.

D. Existing structural dip exposed in windows where the multiples are weak (i.e., where convex sea floor causes multiple to spread rapidly).

A part of the computer program which created Figure 1 can be run backwards. This "running backwards" of the program which creates synthetic multiples from a known sea floor topography we will choose to call "multiple migration" because of the analogy with primaries. The center frame of Figure 3 is the same synthetic data as Figure 1. The multiple migration of this data is shown on the right frame of Figure 3. The highly confused pattern of multiples has become flat lying and quite regular. This process of organizing and regularizing multiples can be expected to be extremely useful in their adaptive elimination. If the multiples are migrated under the incorrect assumption that they are primaries the left part of Figure 3 results. Basically the strong lateral amplitude variations on the time section give rise to circular arcs (there is a 5:1 vertical exaggeration) in the migration. We have seen such arcs on migrated data. Perhaps they can be used as another means of distinguishing multiples from primaries.

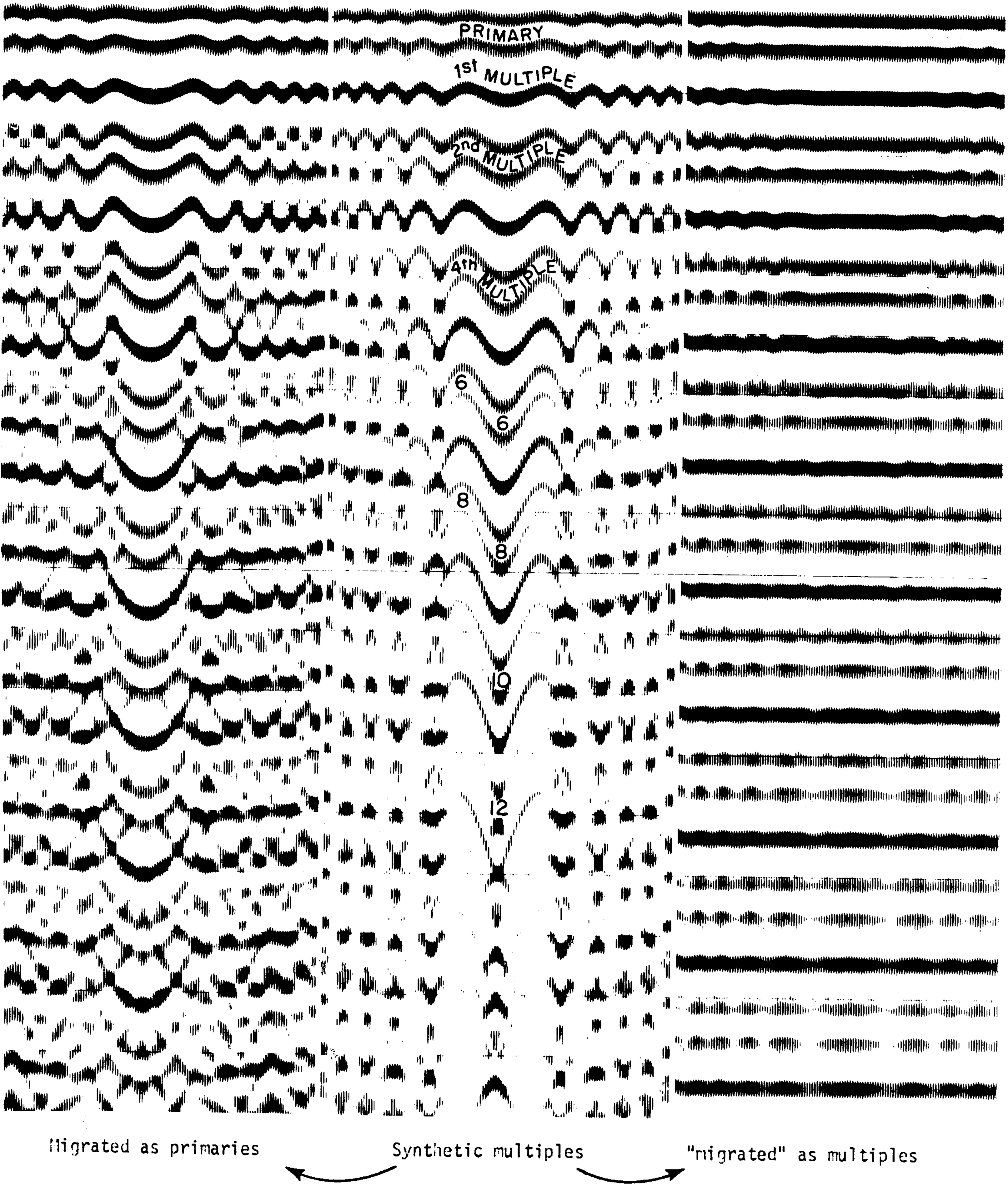

Figure 3. "Migration" of Synthetic Multiples