UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

TECHNICAL LETTER NUMBER 15

A PROGRESS REPORT ON SEISMIC MODEL STUDIES*

by

J. H. Healy** and G. B. Mangan**

DENVER, COLORADO

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Technical Letter
Crustal Studies-15
December 23, 1963

Dr. Charles C. Bates
Chief, VELA UNIFORM Branch
Advanced Research Projects Agency
Department of Defense
Pentagon
Washington 25, D. C.

Dear Dr. Bates:

Transmitted herewith are 10 copies of:

TECHNICAL LETTER NUMBER 15

A PROGRESS REPORT ON SEISMIC MODEL STUDIES*

by

J. H. Healy** and G. B. Mangan**

Sincerely,

L. C. Pakiser

L. C. Pakiser, Chief
Branch of Crustal Studies

* Work performed under ARPA Order No. 193-63.
** U. S. Geological Survey, Denver, Colorado.

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A PROGRESS REPORT ON SEISMIC MODEL STUDIES*

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J. H. Healy** and G. B. Mangan**

The value of seismic-model studies as an aid to understanding wave propagation in the earth's crust was recognized by early investigators (Tatel and Tuve, 1955). Preliminary model results were very promising, but progress in model seismology has been restricted by two problems: (1) difficulties in the development of models with continuously-variable velocity-depth functions, and (2) difficulties in the construction of models of adequate size to provide a meaningful wave-length to layer-thickness ratio. The problem of a continuously-variable velocity-depth function has been partly solved by a technique using two-dimensional plate models constructed by laminating plastic to aluminum, so that the ratio of plastic to aluminum controls the velocity-depth function (Healy and Press, 1960). These techniques provide a continuously-variable velocity-depth function, but it is not possible to construct such models large enough to study short-period wave propagation in the crust.

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** U. S. Geological Survey, Denver, Colorado.

This report describes improvements in our ability to machine large models. Two types of models are being used: one is a cylindrical aluminum tube machined on a lathe, and the other is a large plate machined on a precision planer. Both of these modeling techniques give promising results and are a significant improvement over earlier efforts.

To model seismic-wave propagation in the crust, it is necessary to have approximately the same ratio of wave length to layer thickness in the model that is found in the crust and is recorded on typical seismograms. Arrivals on refraction seismograms range in frequency between 2 and 5 cps, depending on the nature of the source and the particular phases. A 3-cps phase traveling at 6 km/sec, for example, will have a wave length of 2 km. If one is trying to model the reflection of this phase from the top of an intermediate layer, say, 16 km deep, the depth of the layer on the model should be 8 wave lengths. When using a plate model, it is necessary to have the wave length more than 10 times the model thickness to avoid dispersion of the plate wave. The minimum thickness of a model that can be machined practically is about 1/16th of an inch, and a minimum practical wave length is about 3 cm in this model. Therefore, it is necessary that the layer thickness of the model be approximately 40 cm. To study refraction and reflection from this layer to a distance of about 10 times the layer depth would require that the model be about 400 cm long. If we wish to study reflections and other arrivals from deeper layers in the crust, the model becomes proportionately longer. But models this large become increasingly difficult to machine and to move from place to place.

As a preliminary step toward larger models, we chose a 1-foot diameter aluminum tube with 1/16th-inch wall thickness which was mounted on a lathe. A step 1/32-inch deep was cut in the top 8 cm of this tube. This step was then filled with an epoxy resin plastic which was allowed to harden, and then the model was machined so that the total thickness of the laminated part of the model was 1/16th of an inch. The velocity of this laminated sheet can be calculated (Healy and Press, 1960), and the calculated velocities (Figure 1) agree approximately with the measured velocities of 4.7 km/sec in the layer and 5.4 km/sec in the aluminum sheet. This method of model construction was successful and probably could be expanded to a model of at least 3 ft in diameter.

We contacted various machine shops in the Denver area in an attempt to find facilities for machining large cylinders. To our surprise, we found one shop that claimed they could machine a model from a flat sheet on a large precision planer. They constructed a trial model which seems to be satisfactory. This model is 6 feet long

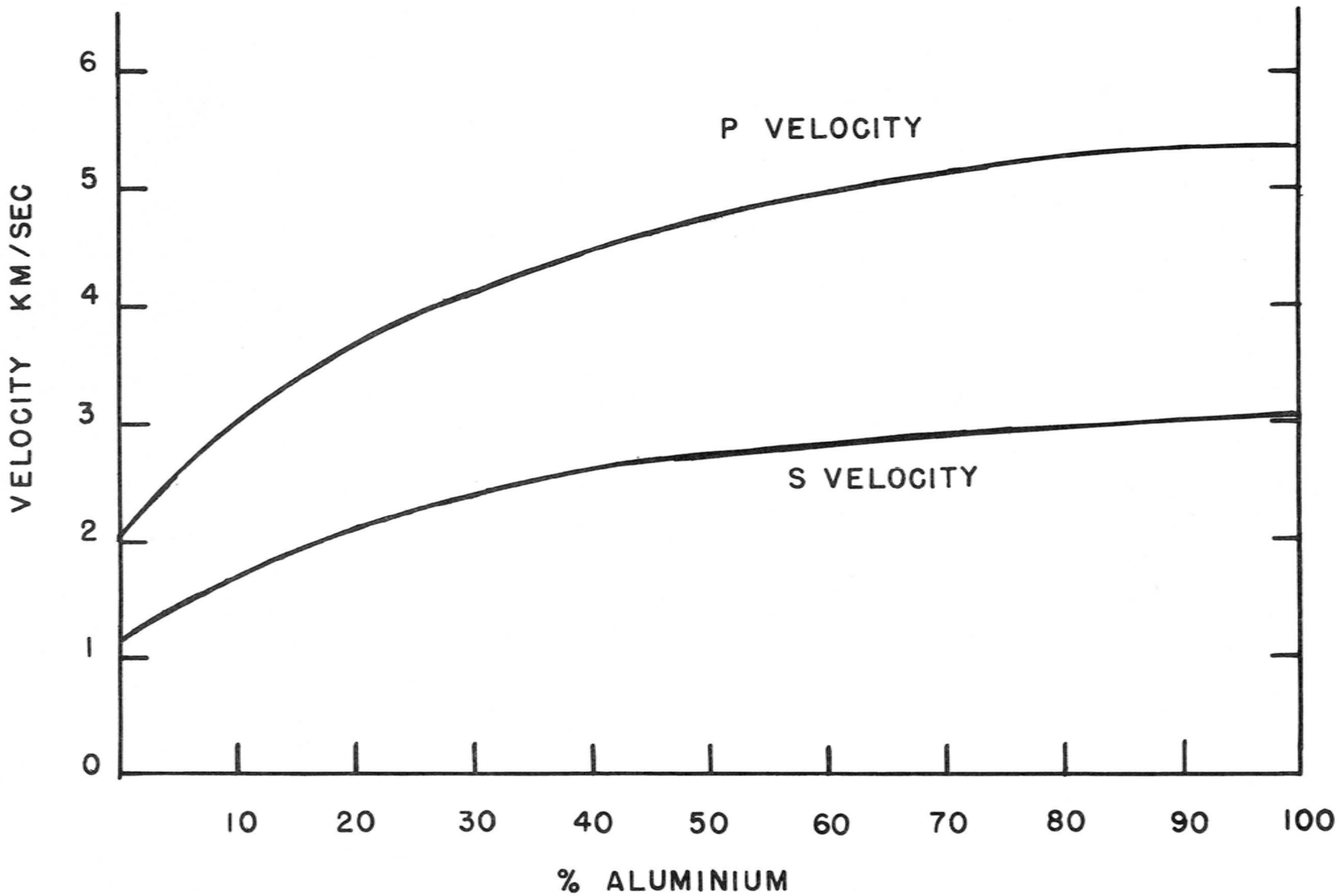

Figure 1.--Plate compressional-wave velocity and shear velocity as a function of the proportions of aluminum and plastic.

and has a crust 18.3 cm thick. Figure 2 shows the different models. The second model has not yet been studied, but sample seismograms from a cylindrical model have been completed (Figure 3).

In addition to illustrating the model technique, these seismograms have some practical significance. The velocity contrast in the model of 4.7 to 5.4 km/sec is proportional to a contrast in the crust of 6 km/sec to 6.9 km/sec, and this is appropriate for the contrast between a silicic crust and a gabbroic intermediate layer. If the intermediate layer is 10 km deep, the seismogram would model a real crust if the real frequency is 2 cps. The seismogram shows the merging of the refracted and reflected energy with the direct energy between 45 and 60 km from the source. This phenomenon might be completely missed in a field program with widely-spaced units.

Two-dimensional laminated plate models considerably larger than any previously reported models known to the authors have been constructed. These larger models make it possible to approximate more closely seismic-wave propagation in the earth's crust.

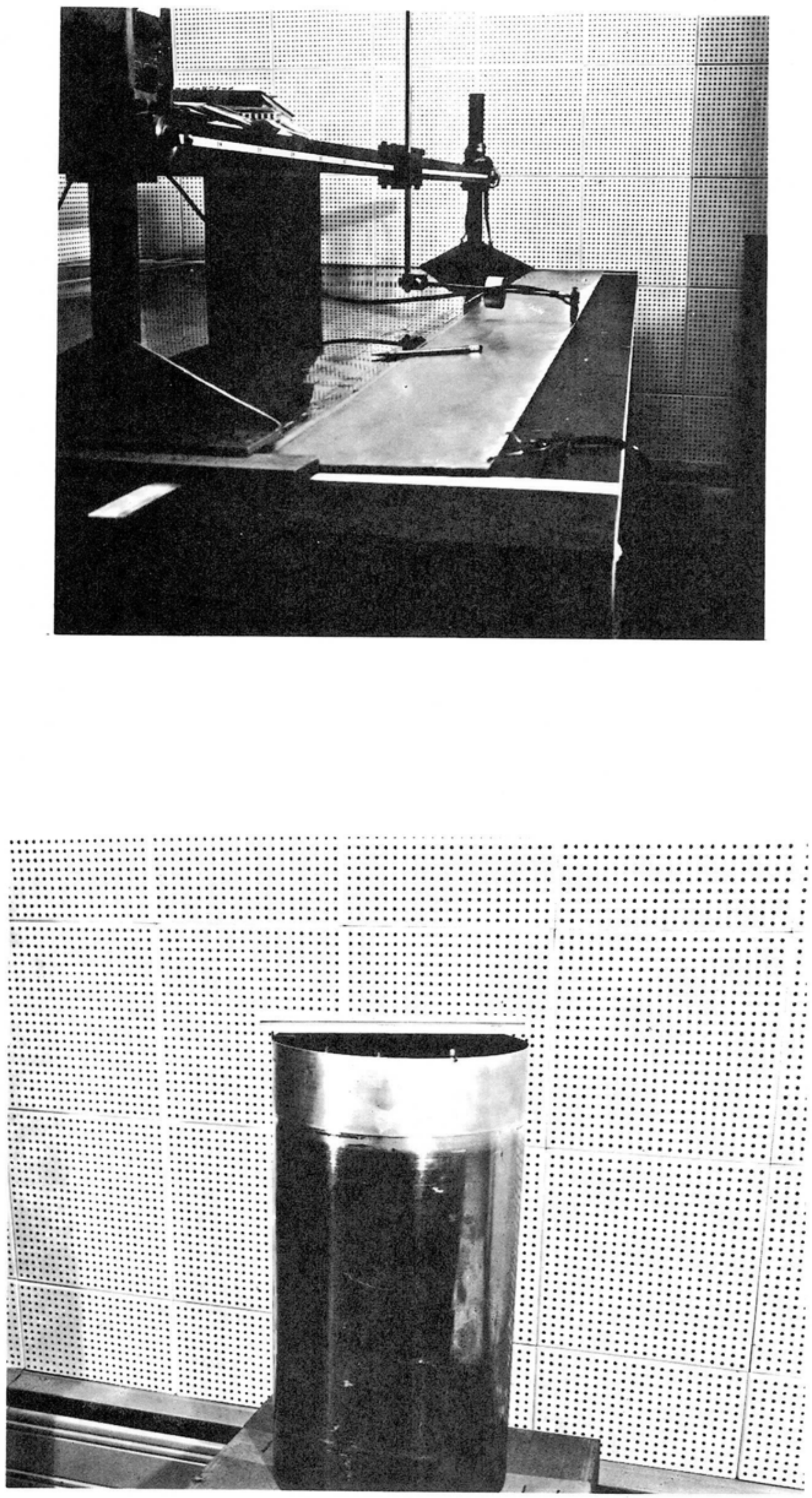

Figure 2.--Two models constructed of laminated sheets of plastic and alumium.

Figure 3.--Seismogram taken on cylindrical model, one layer over a halfspace. The layer has a compressional wave velocity of 4.7 km/sec and a halfspace has a compressional wave velocity of 5.4 km/sec. The traces are shifted in time so that an arrival of 4.7 km/sec falls approximately on a vertical line. The theoretical traveltimes, computed by ray theory, for the direct arrival, the refracted arrival, and the first reflection are plotted on the seismogram. Ten microsec time marks are superimposed on each trace.

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Healy, John H., and Frank Press, 1960, Two-dimensional seismic models with continuously variable velocity depth and density functions: Geophysics, v. 25, no. 5, p. 987-997.

Tatel, Howard E., and Merle A. Tuve, 1955, Seismic exploration of a continental crust, in Crust of the Earth--a symposium, edited by A. Poldervaart: Geol. Soc. America, Spec. Paper 62, p. 35-50.