Seismotectonics in the Northeastern United States

14-08-001-G1796

John E. Ebel, James W. Skehan, S.J., and David C. Roy
Weston Observatory
Dept. of Geology and Geophysics
Boston College
Weston, MA 02193
(617) 899-0950

Objective: The primary objective of this research is to improve the calculated locations of earthquake hypocenters in New England (particularly to better constrain the event focal depths) by relocating earthquakes using new network station travel-time residuals. These residuals are to be found from a time-term tomographic analysis of the P wave arrivals on the New England Seismic Network (NESN) stations from the 1984 Maine Seismic Refraction Profile (MSRP) and from the 1988 New York-New England Seismic Refraction Experiment (NY-NEX). The relocated earthquake hypocenters are used to reexamine the present seismotectonics of the northeastern United States in an effort to identify seismically active structures in the region.

Crustal Structure Analysis: A new computer code to perform a tomographic time-term analysis for New England has been put together by Zhu (1991). The code is more general and flexible than that used by Kafka and Ebel (1988) in their tomographic analysis of Maine. The new code has been tested successfully on several synthetic data sets. We have analyzed a data set consisting of P-wave first arrivals from the MSRP and NY-NEX experiments to search for lateral crustal velocity variations throughout New England. This work was performed in several steps. First, travel times from the P arrivals from the data set were used to construct a plane layered starting model for the tomographic analysis. While based on a completely different set of stations, the starting model was very close to the crustal model for Maine found by Luetgert et al. (1987). This starting model was then used to invert for lateral and vertical seismic velocity variations across the region. Time terms for both the shot points and the stations were calculated relative to this tomographic model. As a final step, shot and station time terms were also calculated relative to the starting model, which was held fixed. These time terms were calculated to be used in the HYPO78 program for event location. HYPO78 does not allow lateral velocity variations in the crustal model, so the full time-term analysis results which include the lateral velocity variations cannot be used directly in that program.

Crustal Structure Results: The tomographic time-term analysis found crustal seismic velocity variations throughout northern New England. These velocity variations are generally consistent with other crustal models for the region (Figure 1). In particular, the upper crust was found to have strong lateral velocity variations (Figure 2) which show some correlation with the surface geology. In particular, the metasediments of the Kearsarge-Central Maine Synclinorium have somewhat lower seismic velocities than the average, and the mafic plutonic belts through the regions are somewhat faster than average. The lower crust is much more laterally uniform in seismic velocity than the upper crust, although a reduced velocity region under the White Mountains of New Hampshire is imaged at about 20 km depth (Figure 3). The Moho deepens from SSE at a depth of 33 km to NNW at the U.S.-Canada border in

Maine at a depth of 38 km. Time terms relative to the tomographic model, shown in Figure 4, are generally quite small. In contrast, the time terms relative to the plane-layered starting model with no lateral velocity variations are much larger (Figure 5).

Event Location Analysis: A major goal of this research was to try to improve event locations and focal depths by the calculation of a more accurate crustal model and set of station time terms for the region. We tested this by relocating the 1984 MSRP blasts using the Chiburis and Ahner (1980) crustal model (C&AM) and the starting model (SM) found from this analysis. C&AM, derived from data from southern New England, has rather different layer velocities than the models which have been derived using data from Maine (Figure 1). Surprisingly, it proved to be somewhat more accurate at locating the shots than SM, even when we included the time terms of Figure 5 in SM. The average epicentral error with C&AM is 3.59 km, while with SM it is 3.93 km without the station time terms and 4.30 km with the station time terms. The average depth error for these surface-focus shots is 3.44 km with C&AM, 7.14 km with SM and no time terms, and 7.27 km with SM and the time terms.

Conclusions: Errors in the calculation of epicenters and depths of seismic events (earthquakes and blasts) in New England are only a very weak function of the crustal seismic velocity structure used in the location program. Even a somewhat inappropriate crustal model gives epicenters and depths comparable to those from better models of the region, and knowledge of the lateral variations of the crustal seismic velocities cannot be easily used to improve hypocenter accuracy. We view our results as indicating that seismic station density, station distribution, and seismogram signal-to-noise are the controlling factors affecting the calculation of accurate event epicenters and depths for events in New England. One implication of this analysis is that in New England a sparse network of seismic stations, such as that planned for the National Seismic Network, will constrain earthquake epicenters to no better than +-5 to +-10 km and earthquake depths to no better than +-10 km.

References:

Chiburis, E.F., and R.O. Ahner, 1980. Northeastern U.S. Seismic Network Bulletin No. 15 - Seismicity of the Northeastern United States April 1, 1979 - June 30, 1979, published by Weston Observatory, Department of Geology and Geophysics, Boston College, Weston, MA.

Hughes, S., and J.H. Luetgert, 1991. Crustal Structure of the New England Appalachians and Adirondack Mountains: The 1988 New England - New York Seismic Refraction Profile, submitted to J. Geophys. Res.

Kafka, A.L., and J.E. Ebel, 1988. Seismic Structure of the Earth's Crust Underlying the State of Maine, Studies in Maine Geology: Volume 1, pp. 137-156, published by the Maine Geological Survey, Augusta, ME.

Luetgert, J.H., C.E. Mann, and S.L. Klemperer, 1987. Wide-Angle Deep Crustal Reflections in the Northern Appalachians, Geophys. J. R. astr. Soc., 89, 183-188.

Taylor, S.R., and M.N. Toksöz, 1979. Three-Dimensional Crust and Upper Mantle Structure of the Northeastern United States, J. Geophys. Res., 84, 7627-7644.

Zhu, H., 1991 (in progress). A Tomographic Analysis of the Crust of New England, M.S. thesis, Department of Geology and Geophysics, Boston College, Chestnut Hill, MA.

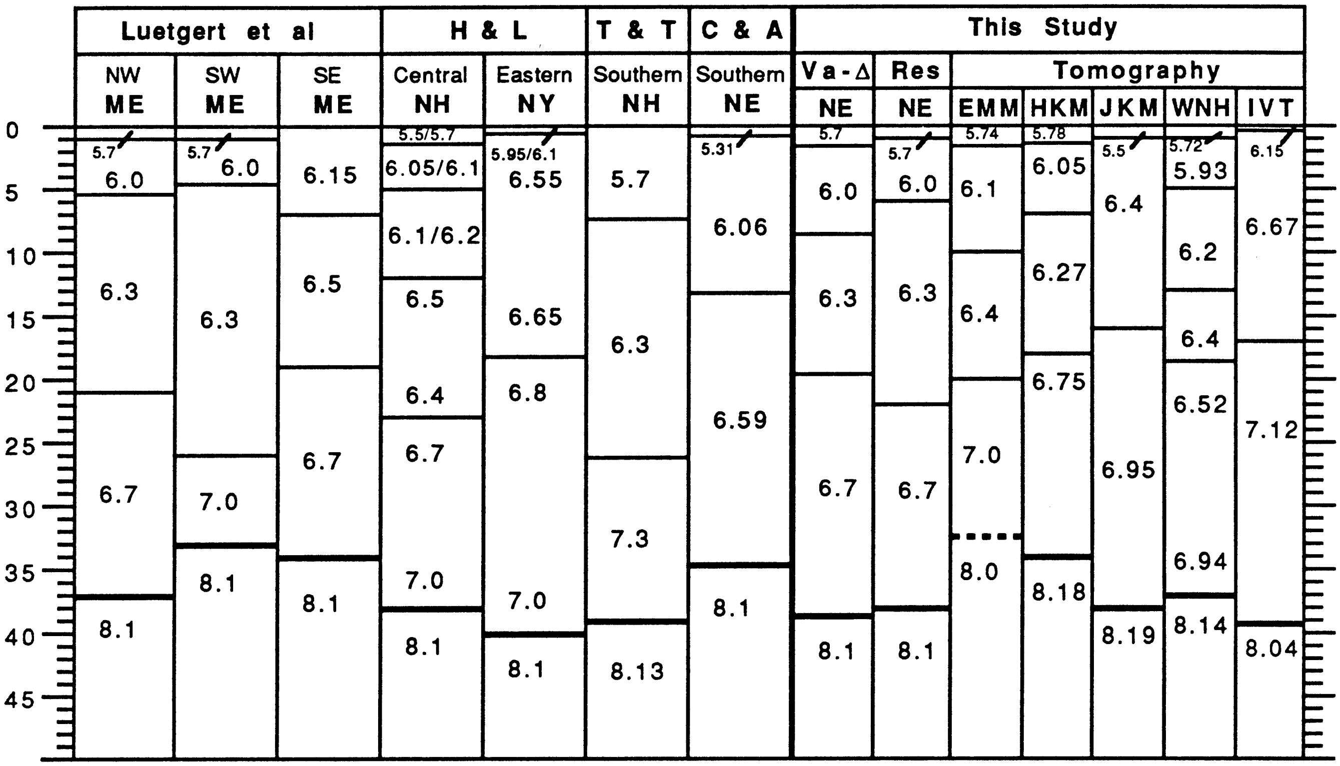

Figure 1. A comparison of the different velocity structures of the crust of New England determined by different researchers. The crustal models are those of Luetgert et al. (1987), H & L - Hughes and Luetgert (1991), T & T - Taylor and Toksoz (1979), C & A - Chiburis and Ahner (1980). The abbreviations are: ME - Maine; NH - New Hampshire; NY - New York; NE - New England. EMM, HKM, JKM, WNH and IVT are seismic stations operating in New England (see Figure 4). The model Va-Δ was determined from the MSRP and NY-NEX travel times at the seismic network stations in New England. The model Res is the starting model used for the time-term computation where the crustal model was fixed. The dashed line for the Moho boundary at EMM indicates that the depth of this boundary was not constrained by the analysis.

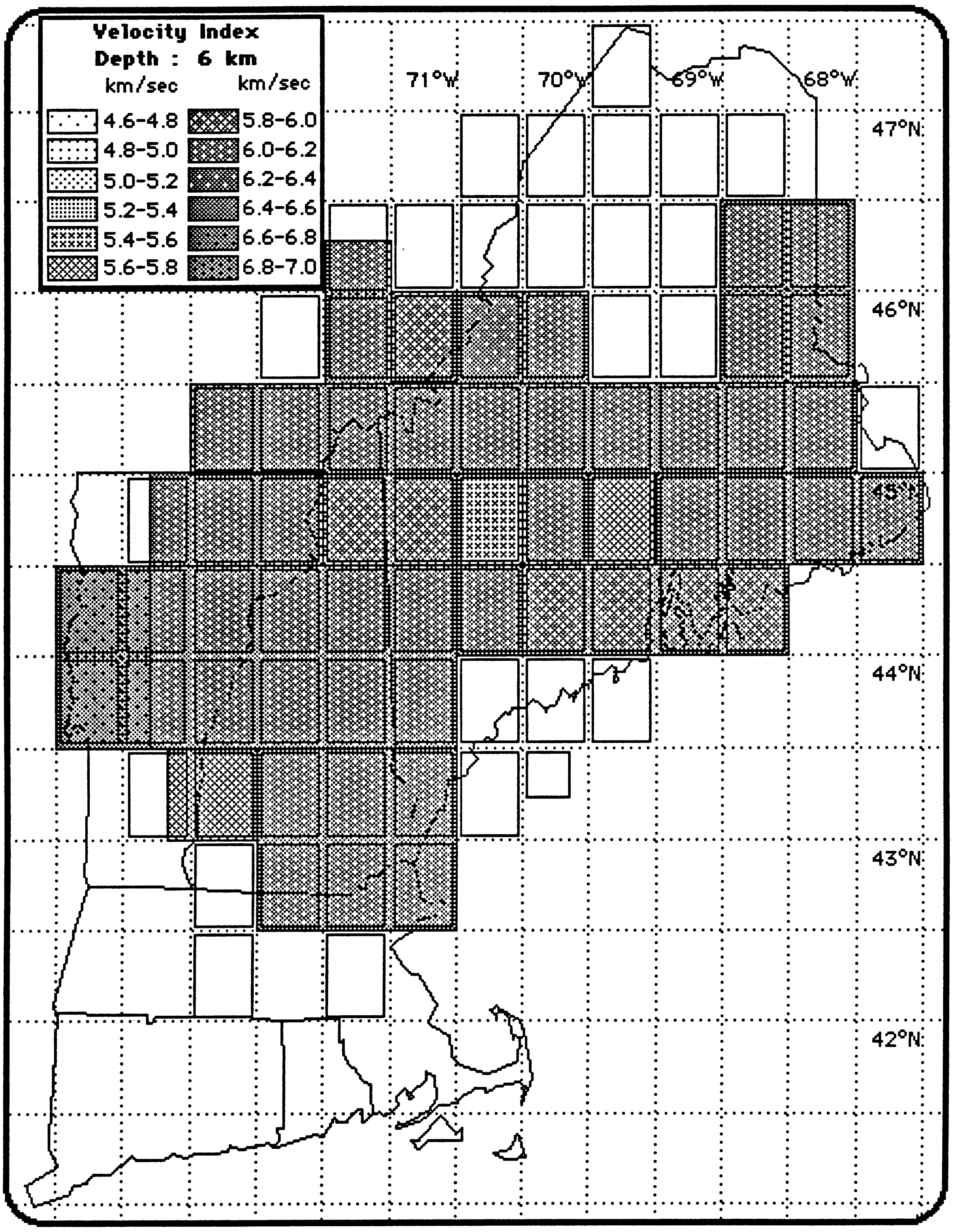

Figure 2. Results of the time-term tomographic analysis for the seismic velocity distribution in New England at a depth of 6 km.

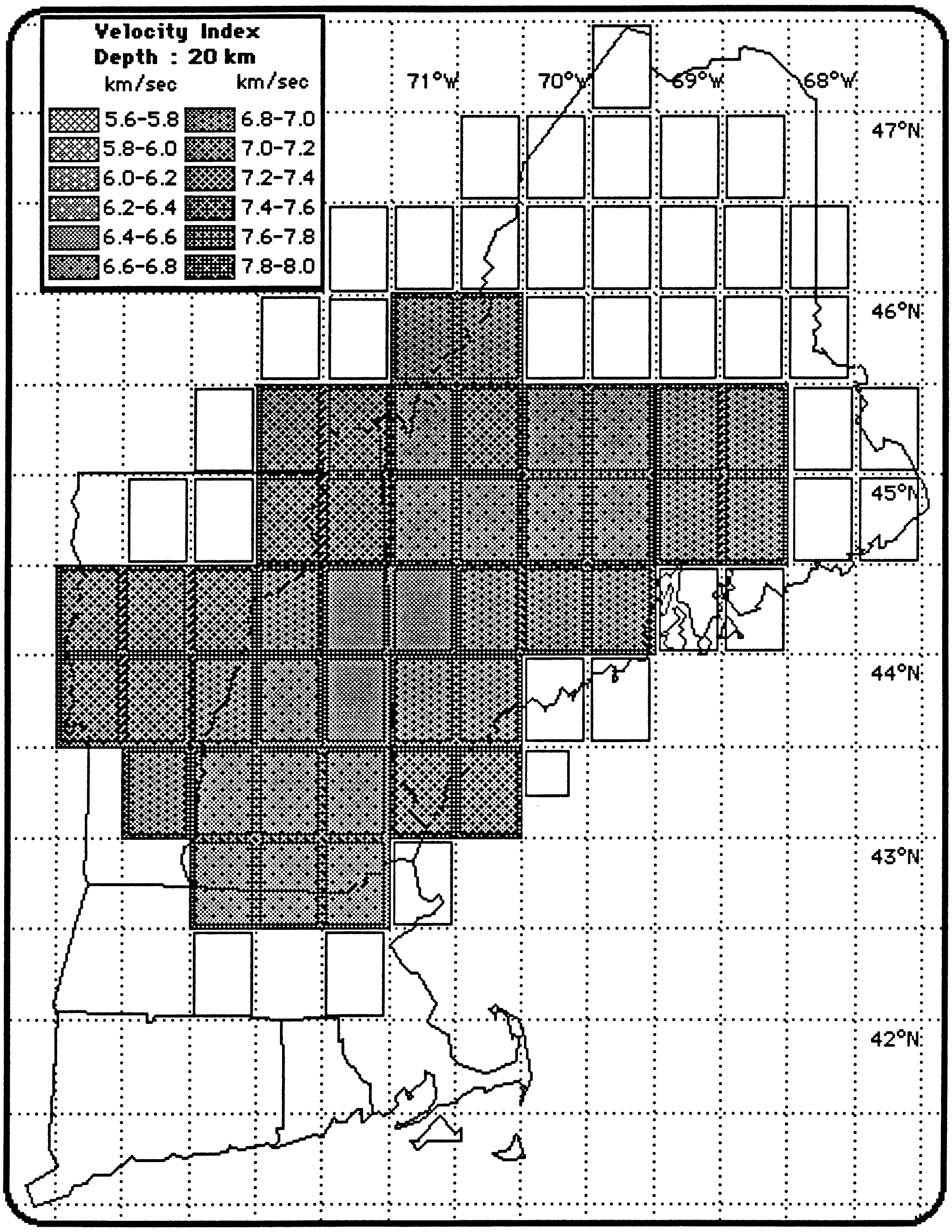

Figure 3. Results of the time-term tomographic analysis for the seismic velocity distribution in New England at a depth of 20 km.

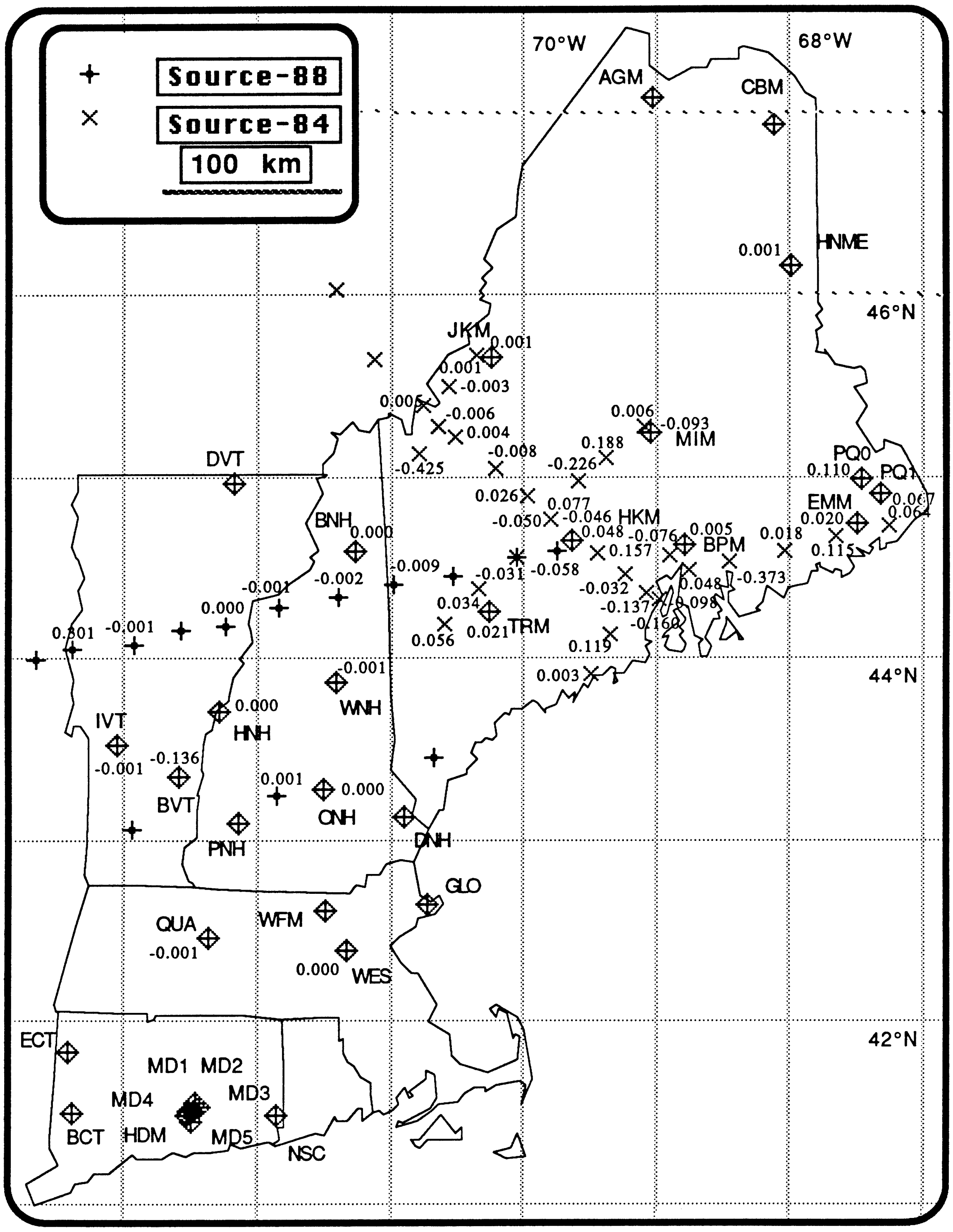

Figure 4. Source and receiver time terms in seconds relative to the laterally-varying tomographic seismic velocity model for the study region.

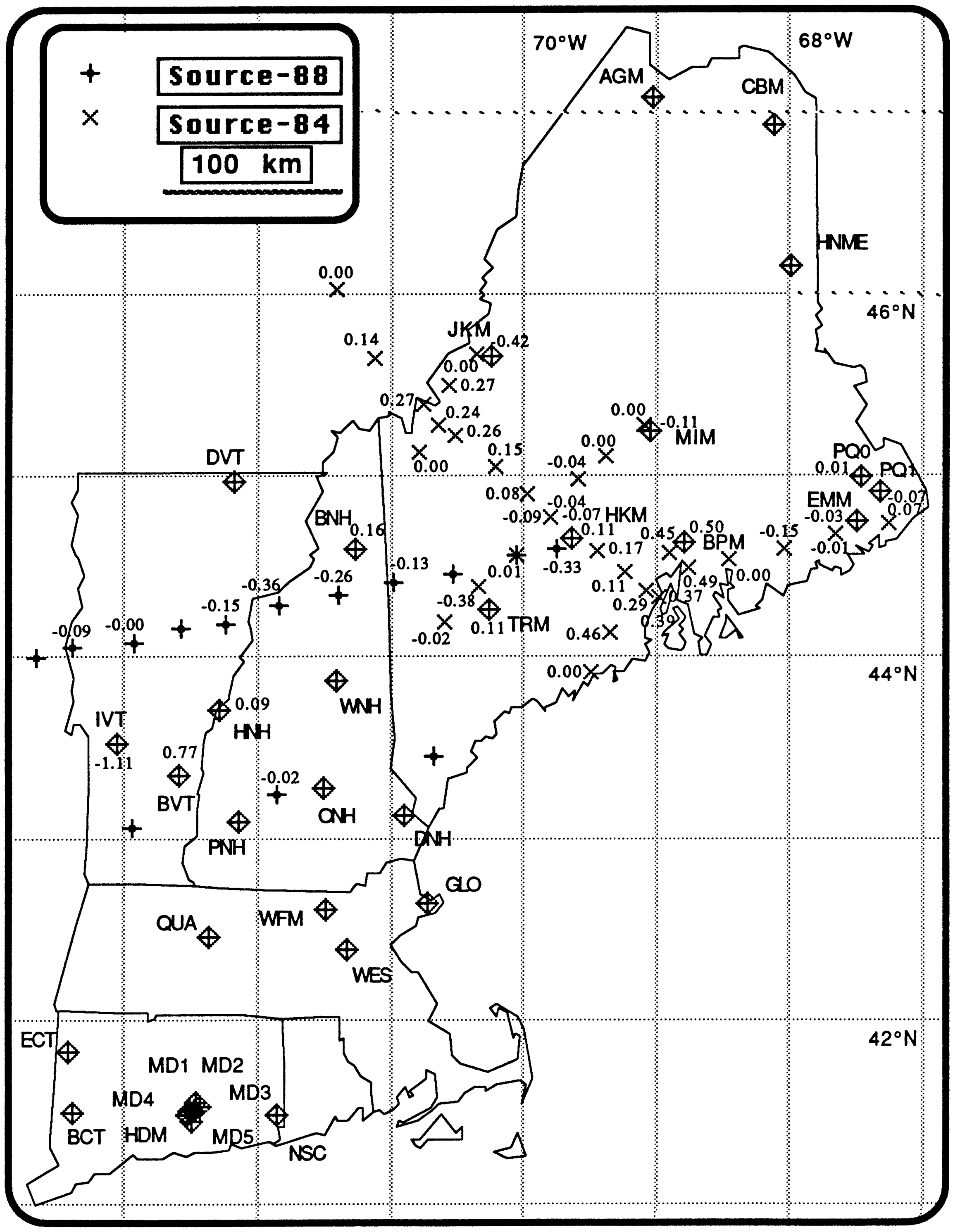

Figure 5. Source and receiver time terms in seconds relative to the fixed starting seismic velocity model (model Res of Figure 1) for the study region.