

The Crustal and Upper Mantle Shear
Velocity Structure of Eastern North
America from the Joint Inversion
of Receiver Function and
Surface-Wave Dispersion

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Chapter 1

Introduction

1.1 The Problem

Among the oldest and most fundamental problems in seismology are determining the velocity-depth relation accurately, ascertaining the nature of discontinuities within the Earth, and translating this information into knowledge of the materials that constitute the interior of the earth. The crust, which occupies the outermost shell of the Earth, has always been of great interest to seismologists. In addition, knowledge of crustal structure is a prerequisite for obtaining precise information on the nature of the Earth's interior below the Moho discontinuity. The crust can be defined as the outer shell of the earth laying above the level at which the P-wave velocity increases rapidly or discontinuously to values in excess of 7.8 km/sec.

The seismic structure of the crust and upper mantle provides critical information regarding lithospheric composition and evolution. There are large variations in fundamental properties such as crustal and upper mantle velocity structure, and the depth to the lithospheric/asthenospheric boundary. The seismic velocity structure of major tectonic regions provides important constraints on theories for the formation and evolution of the Earth crust. For the first part of the 20th century, most studies on velocity structure were restricted to the determination of one-dimensional models of the solid Earth and of differ-

ent regions within it. Recently, with the introduction of better data and computational methods, seismologists were able to determine three-dimensional velocity models with better resolution of finer feature in the Earth. Geophysicists study the seismic velocity structure of the crust and upper mantle to determine the composition and thickness of the outer layer of the earth and to be able to accurately locate earthquakes and understand them.

In the past years much progress has been made toward understanding the nature and evolution of the different tectonic provinces of North America. Previous studies gave different Earth models for North America, but neither the teleseismic P-wave delay times nor active source surveys have had the earthquake source and station density required to determine the detailed velocity structure of the sub-crustal lithosphere (Mooney and Meissner, 1991 and 1992; Holbrook et al., 1992; Christensen and Mooney 1995). The overall structure of these regions cannot be measured directly and a reliable estimate of their structure requires a combination of data from a number of discrete studies. Most of our information about the seismic velocity structure of North America has been obtained by refraction and reflection methods which are more localized. With the development of long period seismometers it is possible to obtain more information about the sub-surface properties through surface and body waves.

North America is an ideal region to obtain detailed and reliable seismological information and increase our understanding of continental tectonics: it has a large number of modern, broadband, digital seismographs (Figure 1.1) and

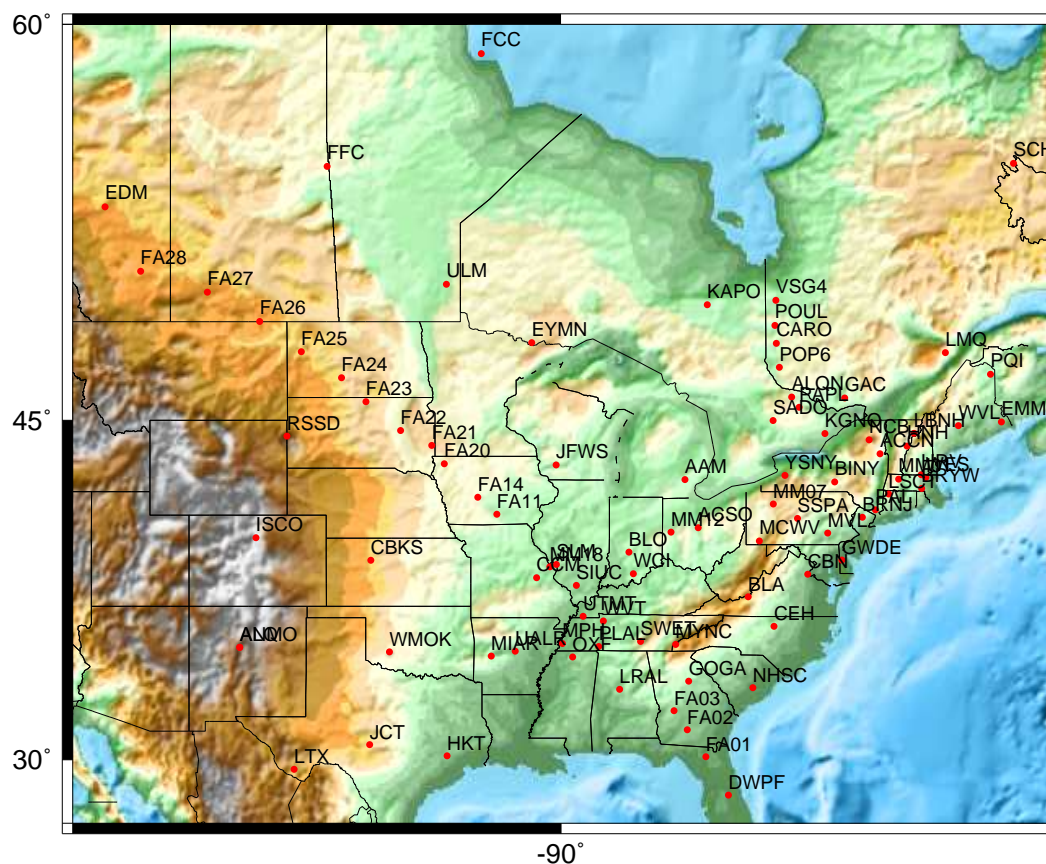


Figure 1.1: Locations of permanent and temporary (MOMA (MM) and FLED (FA) arrays) broadband seismic stations in Eastern North America used in this study

high seismicity on its southern and western borders.

Studies during the recent years have clearly shown that the physical properties of the upper mantle beneath North America vary significantly from east to west and that the details of this variation correlate with the major tectonic provinces of the continents. The western part of North America includes the subduction zones in the Pacific Northwest, a major strike-slip boundary along the coast of California, the wide continental extension in the Basin and Range, and the Rocky Mountains. The eastern side of the continent hosts the older Ap-

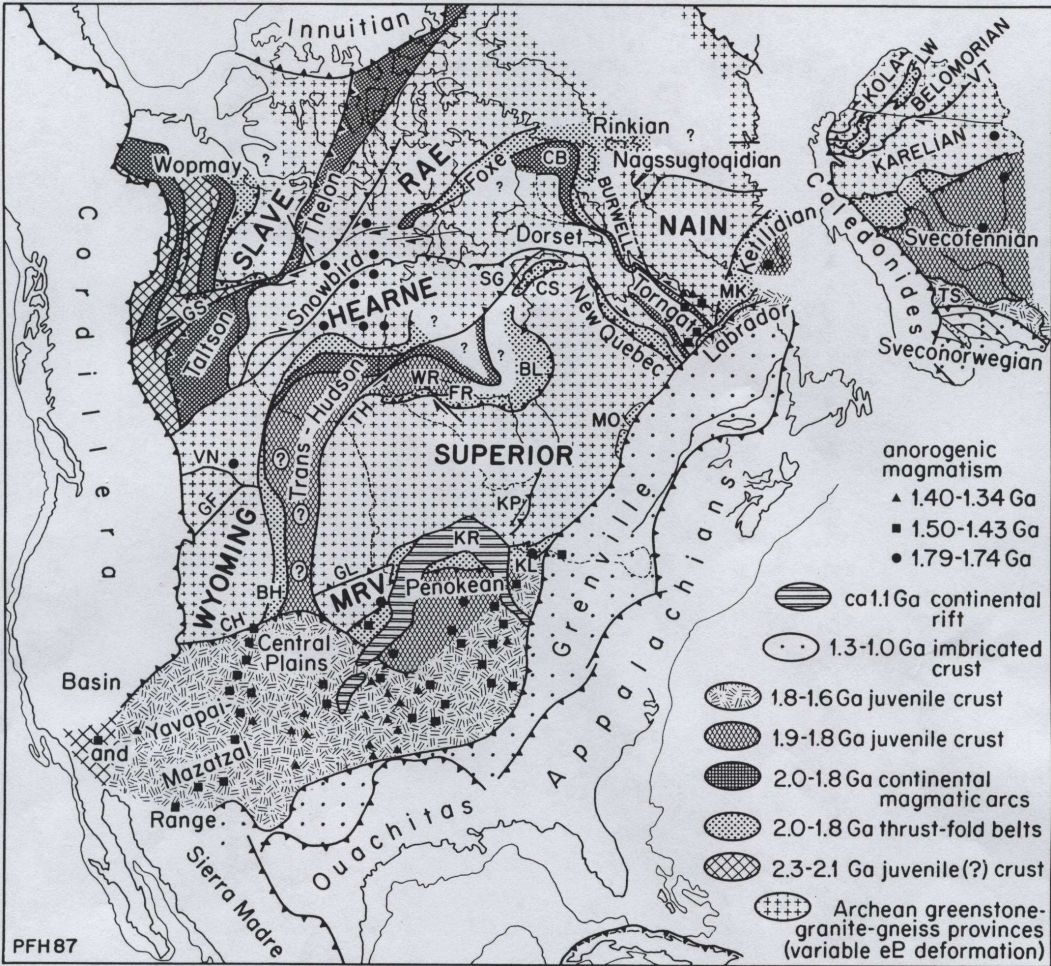


Figure 1.2: North America crustal Provinces (Hoffman, 1989)

palachian Mountains as well as the shields and platforms that comprise the eastern conterminous U.S. and Canada (Figure 1.2).

Although, numerous seismic reflection and refraction studies have been conducted in North America, few shear-wave velocity models are available that cover a large enough area to develop crustal velocity models that are representative of the North America. Although the wealth of information provided by numerous geophysical and geological surveys of the North America has greatly increased our knowledge and understanding of this region, the deep struc-

ture (>40 km) is still largely unknown and poses many interesting questions. Again, these studies were not evenly distributed. The fundamental goal of this study is to use modern broadband seismic data to estimate certain crust and upper mantle properties: depth to Moho, average crustal V_P/V_S ratio, and the use of receiver functions to define the sharpness of the Moho transition. The relationship of these parameters to crustal age and tectonic history will be considered.

The teleseismic P-wave receiver function is sensitive to the shear-velocity structure and has been used to resolve boundaries to depths of 60 km (e.g. Owens, 1987). It provides site specific information and is sensitive to both dip angle and direction of interface geometry (e.g. Cassidy, 1992). Rayleigh waves are known to be sensitive mainly to the shear-wave velocity, and with long enough wavelength they can penetrate the upper mantle. Potentially, joint inversion can provide accurate shear-wave velocity structure to better understand the elastic moduli and densities of the study regions. Since both receiver functions and surface wave dispersion curves are sensitive to the same medium parameters, a joint inversion of the two techniques should reduce the uncertainties associated with the individual inversion of each data set and minimize the dependence of the final results the initial model. It is hoped that a systematic study of crustal features will show regional variations that can then be related to our current knowledge about the crust. The detailed shear-wave velocity structure determined for each site will may be the starting point for defining the three-dimensional nature of the crust.