Next Generation Seismic Studies of the New Madrid Seismic Zone

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Investigations

Since mid-October 1989, the 40 three-component PANDA (Portable Array for Numerical Data Acquisition) stations have been deployed in the central New Madrid seismic zone (NMSZ) in 2- to 6-km interstation spacings. More than 500 earthquakes with magnitude ranging from -2.0 to 4.6 were on-scale recorded by PANDA during the first 19 months of field operation. The onset of P and S arrivals can be unambiguously determined from the vertical and two horizontal components, respectively, to obtain accurate and reliable earthquake locations that are otherwise impossible using data from regional seismic networks alone.

Results

Three-component digital seismograms collected in the region by PANDA are characterized by (1) very weak direct S arrivals on the vertical component, which can, however, be identified unambiguously from the two horizontal components, and (2) at least two prominent secondary arrivals between the direct P and S arrivals, one (Sp) dominant on the vertical component and the other (Ps) with smaller amplitude on the two horizontal components (Figure 1). Travel time differences between the Sp and S and between the P and Ps are the same from different earthquakes to the same station and are different between stations. Polarization analyses of three-component seismograms and travel time measurements confirm the interpretations that these two secondary arrivals are the P to S (Ps) and S to P (Sp) converted waves that occurred at the bottom of the sedimentary cover beneath each station. Therefore, travel time differences between the direct and the converted waves are used to calculate the depth to the bottom of the unconsolidated sediments beneath each station by assuming almost vertical raypaths for the direct and the converted waves. A three-dimensional representation of the geometry of the sedimentary basin in the upper Mississippi embayment is thus constructed by contouring the converting point beneath each PANDA station. The Tertiary boundary of the embayment was digitized and used to define the outer boundary of the sedimentary basin (Figure 2). In general, the geometry of the bottom of the sedimentary basin is very smooth except for the central portion where the contact between the sedimentary basin and the underlying Paleozoic sedimentary rock is disturbed. This disturbed area coincides with the upward extension of the southwesterly dipping fault zone ($\sim 52°$ dip angle) and may represent results of recent tectonic activities from the underlying rift system.

Unlike the broad and almost vertical fault zone extending to lower crust determined by many previous studies in the region, cross-sectional views of the new data clearly define a narrow inclined fault zone with $\sim 52°$ dipping in the southern and $\sim 37°$ in the north toward southwest direction extending from beneath the sedimentary basin (~ 0.6 km) to about 13 km depth. In contrast to the central NMSZ, the northern end of the southwestern segment and the southern end of the Northeast segment of the NMSZ are characterized by

almost vertical fault zone that intersects with the central zone around Ridgely, Tennessee, and around New Madrid, Missouri respectively, where seismicity are the highest in the region. Over the 19 months of PANDA operation, seismicity shows a seasonal pattern that can be correlated with the fluctuation of regional water level. Such correlations may suggest that seasonal variations of regional hydroinduced pressure in the upper crust due to water level changes on the surface may play an important role in the generation of earthquakes in the central NMSZ. Three-dimensional velocity inversions for P and S waves are calculated independently to investigate velocity structures in the upper crust. Preliminary inversion results suggest a P-wave low velocity zone at depth between 2.5 and 5 km which may be associated with clastic sediment filling the graben. Earthquakes were relocated using the new velocity model after inversion. Figure 3 shows several representative cross sectional views of the central NMSZ using data base located by regional network model (regional), Walter Mooney's velocity model (old), and the new velocity model obtained from velocity inversions. The linear fault zone features have been significantly improved when new velocity model is used. The fault zone geometry in the central NMSZ show a very clear correlation and response to the dirction of the pinching northeastern segment NMSZ in the north and the southwestern segment NMSZ in the south.

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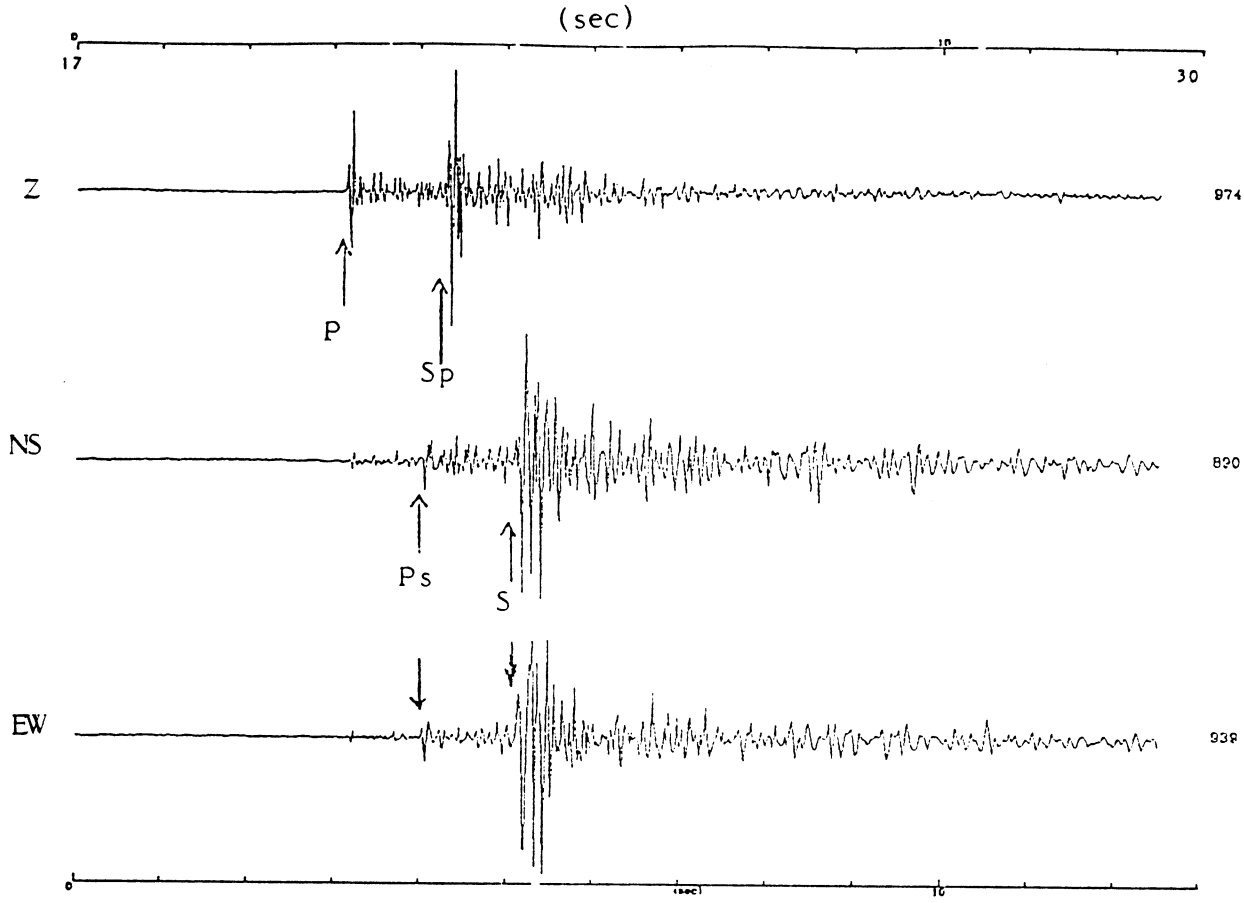

Figure 1. A typical three-component digital seismogram recorded by the PANDA station in the New Madrid seismic zone. Cearly direct P, S, and converted Ps and Sp can be identified.

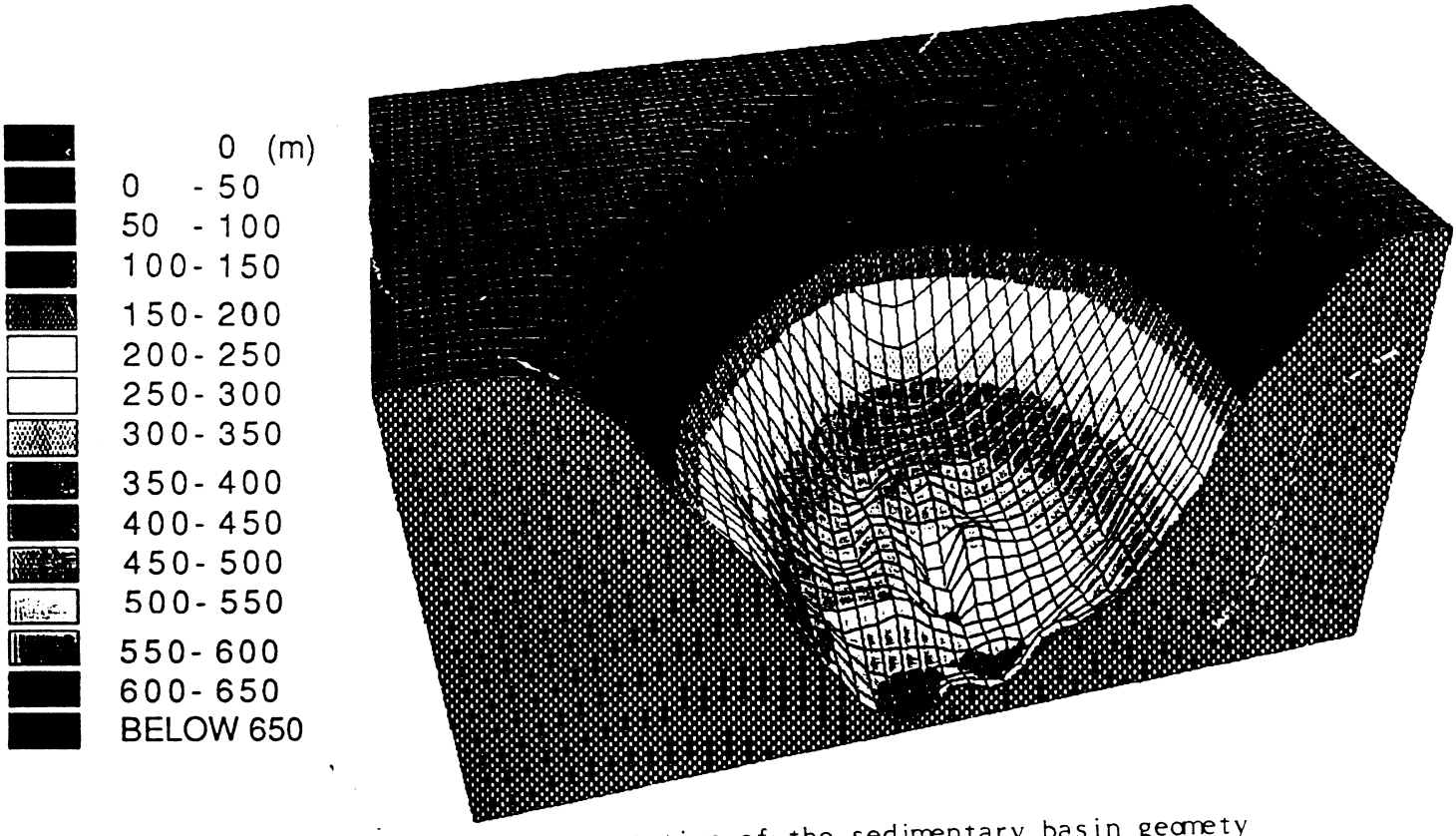

Figure 2. A three-dimensional presentation of the sedimentary basin geomety in the upper Mississippi embayment determined from the conversion points of the strong secondary waves beneath each PANDA station.

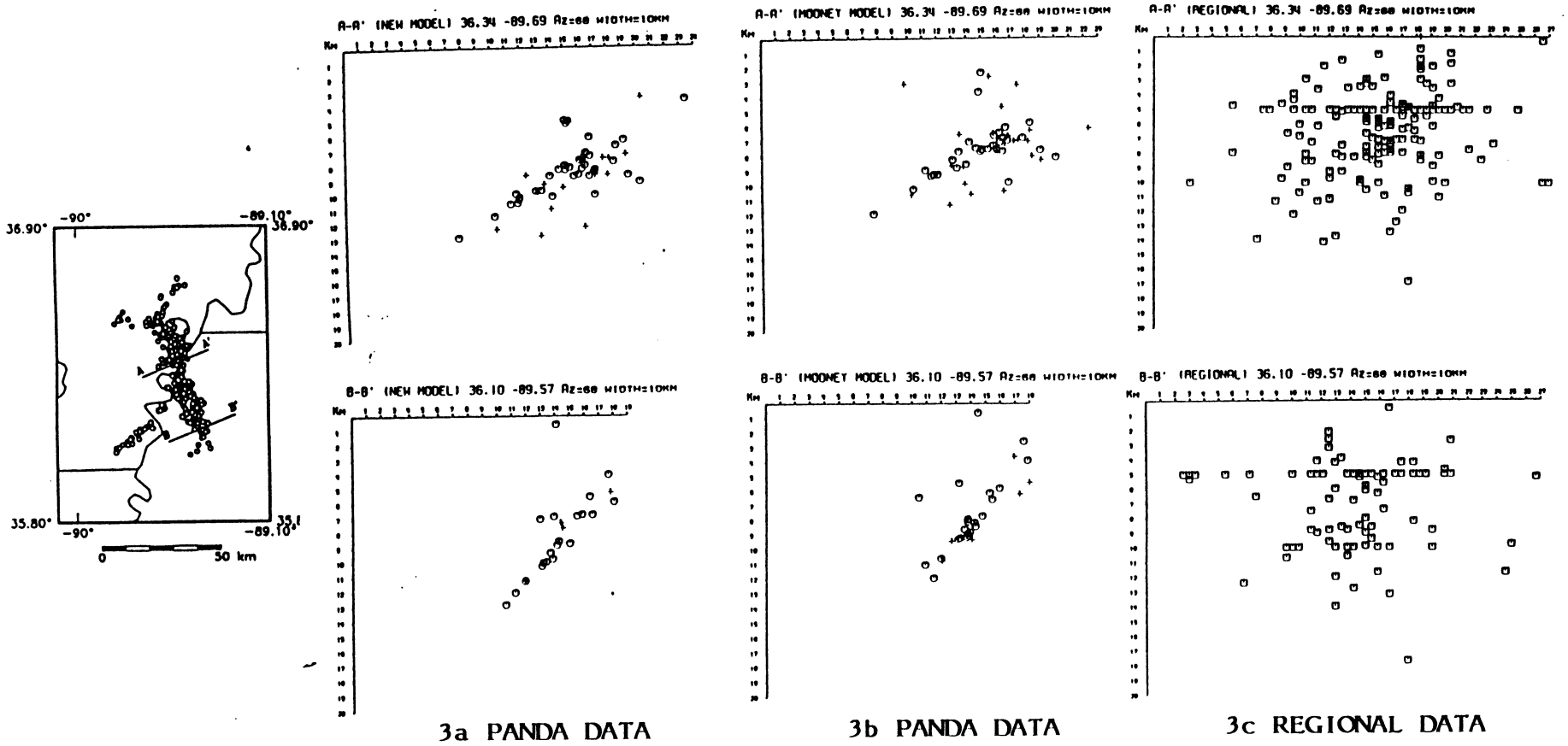

Figure 3. Two representative cross-sectional views of the central New Madrid seismic zone, A-A' (top three) in the north and B-B' (bottom three) in the south. Map views of the seismicity determined from the PANDA array and locations of A-A' and B-B' are shown in the left. Data used to construct (3a) and (3b) are PANDA locations (Oct. 1989 - May 1991) determined by a new velocity model obtained from 3-dimensional P and S velocity inversions and by a velocity model determined from seismic reflection/refraction data by Mooney and Andrews (1984) respectively. Data used in (3c) are the regional seismic network data (June 1974 - Dec. 1990). It is clear that data quality has been improved dramatically from (3c) to (3b), and from (3b) to (3a). The fault zone dips about 52° in the B-B' section and about 37° in the A-A' section.