Annual Report 1998: Velocity structure of the Los Angeles basin from Sonic Logs and Stacking Velocities

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Introduction

We analyzed direct velocity measurements in the Los Angeles basin from our database of sonic logs and industry reflection profiles to provide calibrations and input data for subsequent editions of the SCEC 3D Velocity Model. In addition, we contributed velocity information to SCEC for processing of LARSE1, and developed velocity functions for four SCSN seismograph stations that were used to precisely relocate the 1987 Whittier Narrows (M6) earthquake sequence.

Contributions to the SCEC 3D Velocity Modeling Effort

Our velocity database in the Los Angeles basin consists of more than 180 sonic logs, check-shot surveys, and 7000 stacking velocity measurements from industry reflection profiles. Log and check-shot data provide extremely precise and accurate measures of P-wave velocities; whereas, stacking measurements provide a coherent grid of velocity measurements throughout the basin. These two data types are well correlated in the stratigraphic section (Fig. 1), where stacking measurements can be calibrated to account for their characteristic overestimation of log velocities by 5-10%. There is a greater variance in velocity measurements of basement, where both stacking measurements and limited borehole data are suspect.

Velocity measurements were assigned to three major stratigraphic units (Qt & Pico Fm; Repetto Fm.; and Mohnian & older strata) and crystalline basement (Fig. 2). The interfaces between these units correspond to the layers used to construct Version 1 of the rule-based SCEC 3D Velocity Model. While the sediment-basement contact generally represents a discrete velocity interface, base Pico, Repetto, and Mohnian horizons generally do not correspond to significant shifts in P-wave velocity. The velocity ranges for each of these units overlap significantly, reflecting a primary dependence of velocity on burial depth (Fig. 2). Moreover, velocity measurements at a given depth within each of these stratigraphic units vary by 20 to 40 %.

We developed a series of depth-velocity functions for six tectonic subdivisions of the basin (Fig. 3). The functions are mean values of interval velocities derived from the stacking measurements, which were calibrated with the sonic logs. The undeformed central basin exhibits the most straightforward (essentially linear) depth-velocity relation. Highly deformed subdivisions of the basin with variable stratigraphy exhibit more complex relations.

In areas of dense well control (e.g., LA downtown and Western Shelf subdivisions), the log data mimic the velocity ranges defined by the stacking velocity measurements (Fig. 3). This implies that the range of velocities at a given depth described by the stacking data is a true measure of lateral velocity variation, and not simply a product of errors in the stacking method. Thus we suggest that these ranges provide realistic uncertainties for the mean velocity functions.

The magnitudes of the lateral velocity variations within stratigraphic units (Fig. 3) are significant (10-50%). These variations are difficult to describe using rule-based modeling approaches with simple age and depth dependence. Nevertheless, we suggest that our results can be used to calibrate and/or provide quantitative uncertainties for subsequent iterations of the rule-based SCEC 3D Velocity Model.

Contributions to LARSE 1 & earthquake relocation efforts

In related efforts, we provided a series of stacking velocity measurements (converted to interval velocities) and sonic log data that were used to process the LARSE 1 seismic reflection/refraction images (Fuis et al., 1998). In addition, we developed four 1D velocity functions corresponding to SCSN seismograph stations (FLA, TCC, SC1, GVR) in the basin from nearby sonic logs and stacking velocity measurements (Fig. 4). These functions were used to precisely relocate the 1987 Whittier Narrows (M6) earthquake sequence (Shaw and Shearer, 1999) and are suitable for various seismologic investigations.

Distribution of data and results

We provide the regional and SCSN velocity functions along with raw sonic logs (.las format) from eleven wells to the SCEC community through our "Online data and resources" webpage (http://sger5.harvard.edu/~SGER/). This contribution more than doubles the SCEC sonic log database.

Related Publications

Shaw, J.H., 1998, Earthquakes: Cracking Los Angeles, Nature, V.394, p.320-321.

Shaw, J.H., and P. M. Shearer, 1999, An elusive blind-thrust fault beneath metropolitan Los Angeles, Science, in press.

Related Abstracts

Fuis, G. S., J. M. Murphy, T. Ryberg, W. J. Lutter, C. H. Thurber, and J. H. Shaw, 1998, Imaging faults in the Los Angeles Region, Southern California, Using data from the Los Angeles Regional seismic Experiment (LARSE), Fall Meeting Program, AGU.

Shaw, J. H., and P. M. Shearer, 1998, A blind-thrust fault beneath metropolitan Los Angeles identified from seismic reflection profiles and precise earthquake locations, Fall Meeting Program, AGU.

Süss, M. P., and J. H. Shaw, 1998, High-resolution modeling of seismic velocities in the Los Angeles basin, California, Fall Meeting Program, AGU.

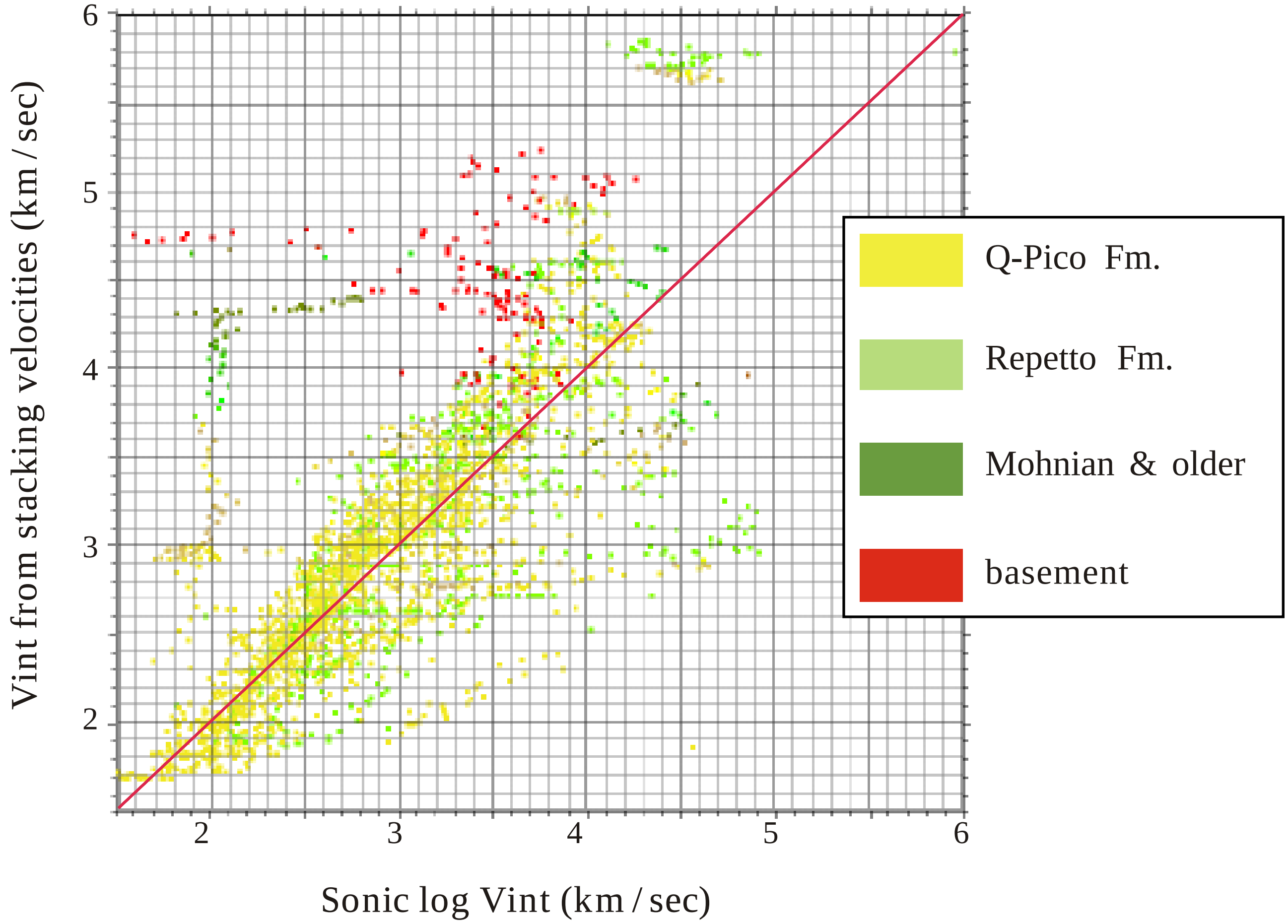


Figure 1: Cross-plot of interval velocities derived from stacking velocities and sonic logs. The two independent data types show strong correlation in the stratigraphic section. Interval velocities derived from stacking velocities characteristically over estimate sonic log measurements by 5-10%. This systematic variation is readily accounted for by calibrating the stacking velocity measurements with the sonic log data. Ouliers generally represent inaccurate stacking velocity measurements or sonic log measurements in damaged boreholes and / or gas-saturated reservoirs.

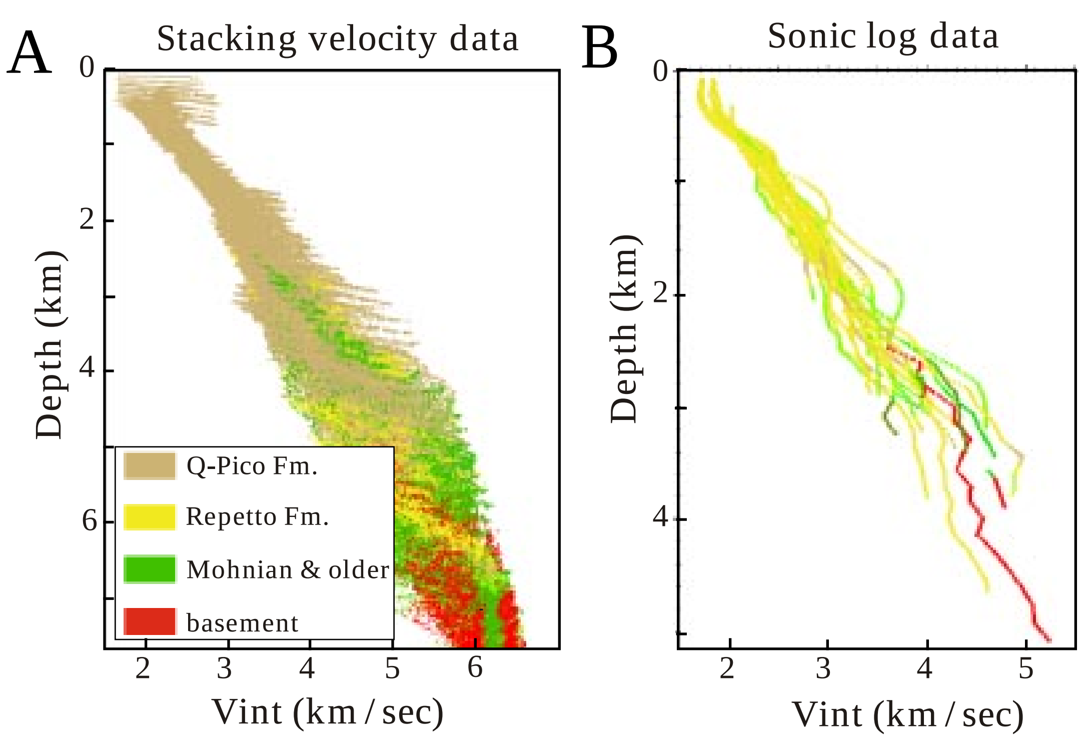
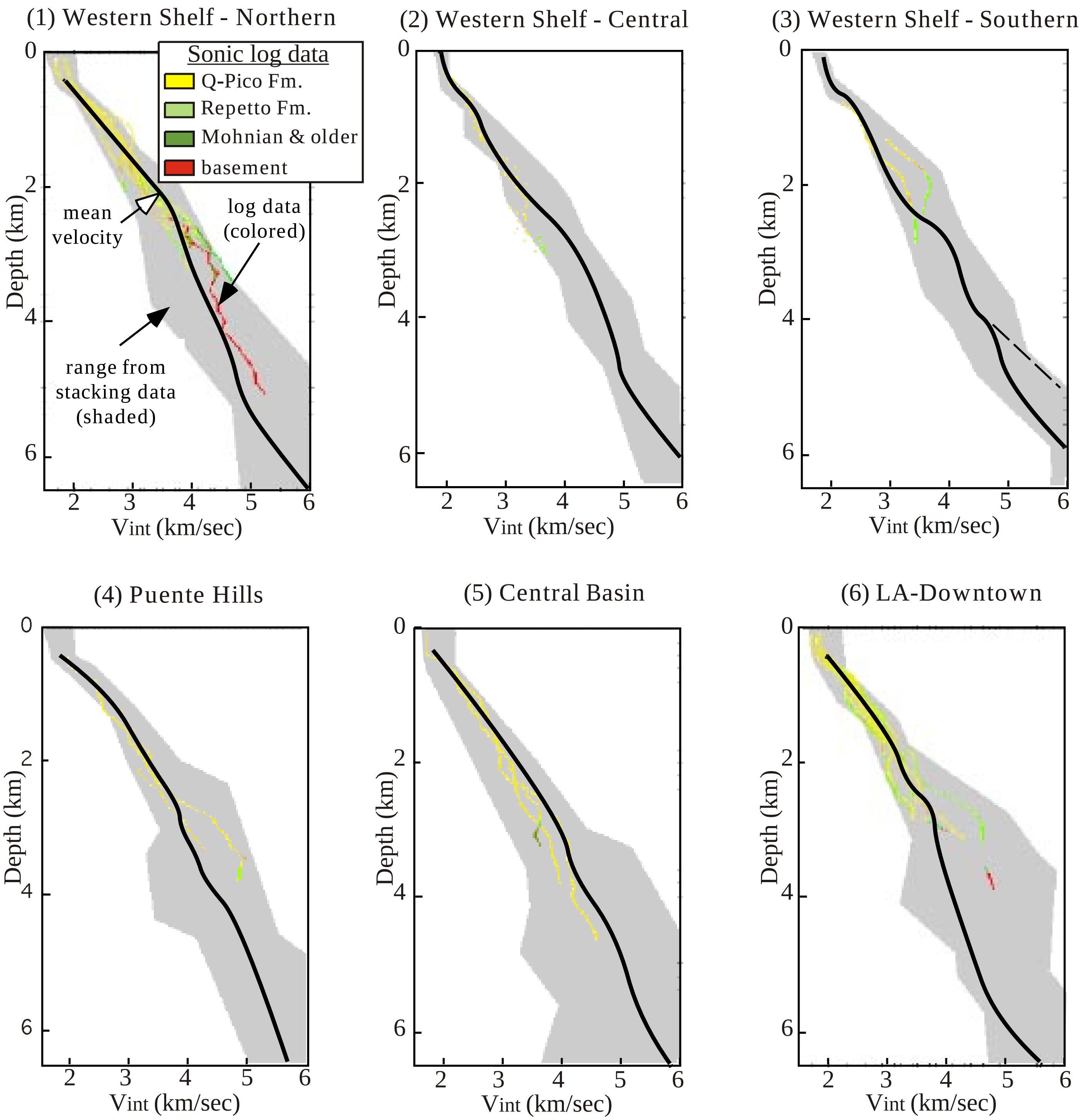


Figure 2: (A) Plot of interval velocities derived from stacking velocities for an area in the northern Los Angeles basin. (B) Plot of interval velocities derived from a subset of sonic logs distributed throughout the basin. Note: 1) the overlapping ranges of velocities for each of the stratigraphic units, and; 2) the range of velocities at a given depth for each of the stratigraphic units.



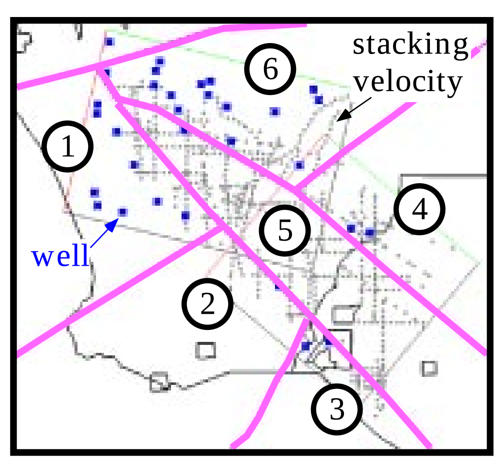
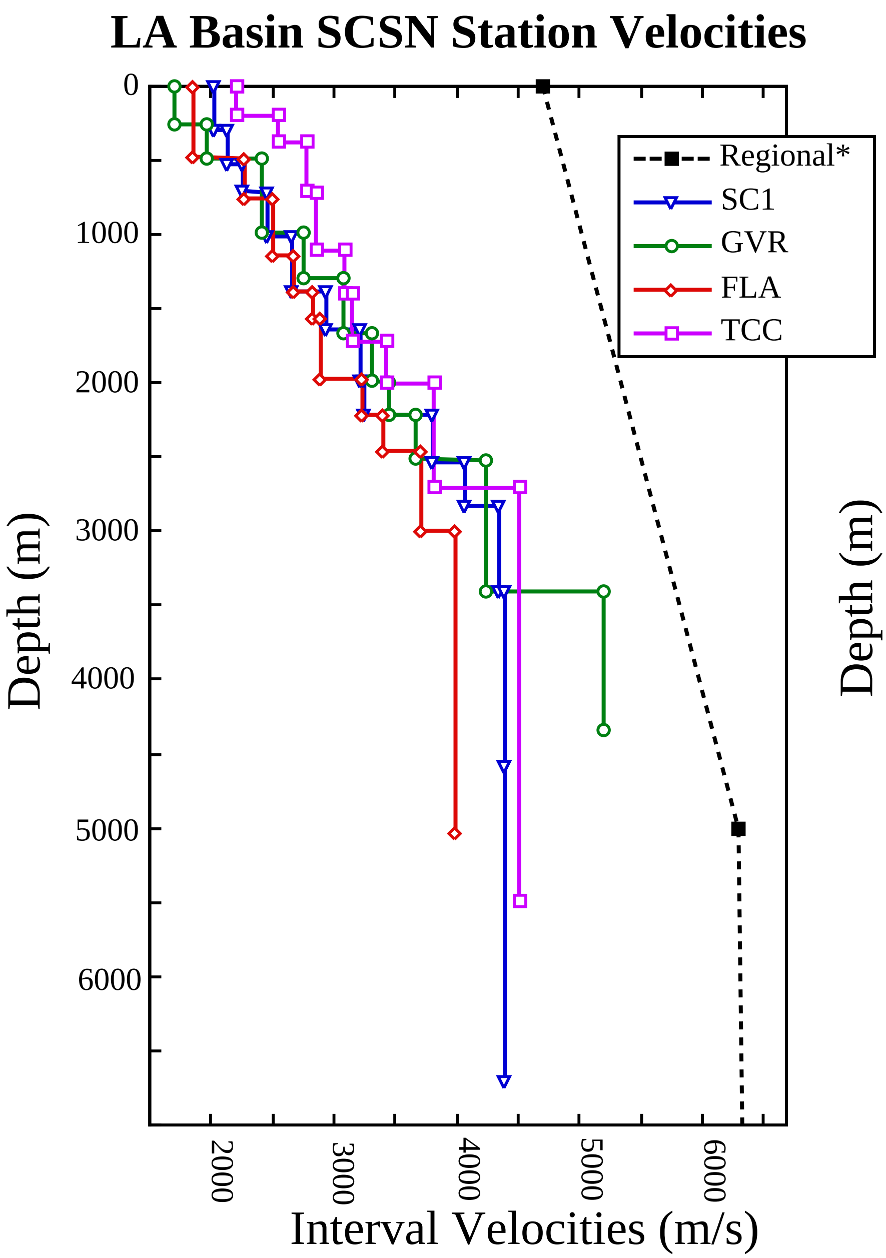


Figure 3: (above) Plots of mean inteval velocities for six tectonic subdivisions of the basin derived from seismic stacking velocities calibrated to sonic logs. (right) Map of tectonic subdivisions with positions of selected stacking velocity measurements and wells with sonic logs.



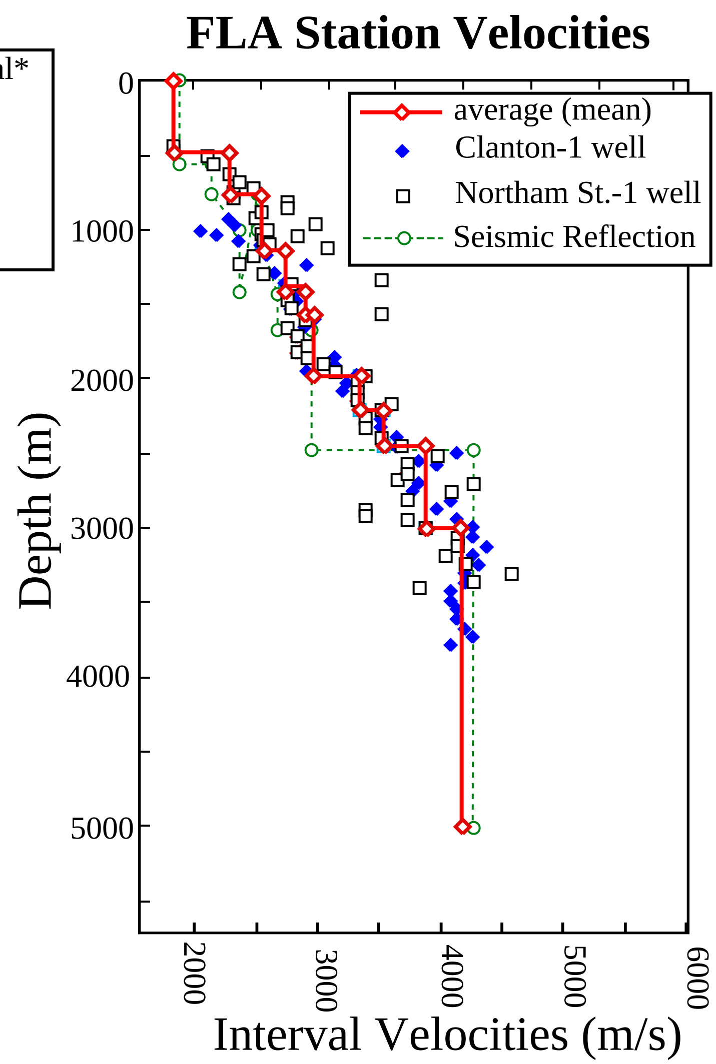


Figure 4: (left) Velocity functions derived from sonic logs and stacking measurements for four SCSN seismograph stations. The regional model is modified from Hadley and Kanamori (1977). (right) Plot of data used to derive the mean velocity function for station FLA. These functions were used to precisely relocate the 1987 Whittier Narrows (M6) earthquake sequence (Shaw and Shearer, 1999) and are suitable for various seismologic investigations.