A V_{S30}-derived Near-surface Seismic Velocity Model

Geoffrey P. Ely (gely@usc.edu),
Patrick Small, Thomas H. Jordan, Philip J. Maechling, Feng Wang.
Southern California Earthquake Center,
University of Southern California, Los Angeles, CA 90089.

Introduction

Shallow material properties, S-wave velocity in particular, strongly influence ground motions, so must be accurately characterized for ground-motion simulations. Available near-surface velocity information generally exceeds that which is accommodated by crustal velocity models, such as current versions of the SCEC Community Velocity Model (CVM-S v4.0) or the Harvard model (CVM-H v6.3). The elevation-referenced CVM-H voxel model introduces rasterization artifacts in the near-surface due to course sample spacing, and sample depth dependence on local topographic elevation. To address these issues, we propose a method to supplement crustal velocity models, in the upper few hundred meters, with a model derived from available maps of V_{S30} (the average S-wave velocity down to 30 meters). The method is universally applicable to regions without direct measures of V_{S30} by using V_{S30} estimates from topographic slope (Wald, et al. 2007). In our current implementation for Southern California, the geology-based V_{S30} map of Wills and Clahan (2006) is used within California, and topography-estimated V_{S30} is used outside of California.

Depth dependence

Various formulations for S-wave velocity depth dependence, such as linear spline and polynomial interpolation, were evaluated against the following priorities: (a) capability to represent a wide range of soil and rock velocity profile types; (b) smooth transition to the crustal velocity model; (c) ability to reasonably handle poor spatial correlation of V_{S30} and crustal velocity data; (d) simplicity and minimal parameterization; and (e) computational efficiency. The favored model includes cubic and square-root depth dependence, with the model extending to a transition depth z_T. A transition depth of $z_T = 350$ m is used to ensure adequate sampling of CVM-H (shallower depths may be unsampled by the CVM-H near topographic features). S-wave velocity at the surface is derived from V_{S30} by a uniform scaling. V_P, and in turn density, are inferred from surface V_S via the scaling laws of Brocher (2005). V_S and V_P are independently interpolated between the surface values and those extracted from the crustal velocity model at the transition depth. Density is derived from interpolated V_P via the Nafe-Drake law of Brocher. Depth dependence for the interpolation is parameterized with

$$
\begin{aligned}
&z = z'/z_T \\
&f(z) = z + b(z - z^2) \\
&g(z) = a - az + c(z^2 + 2\sqrt{z} - 3z) \\
&V_S(z) = f(z)V_{ST} + g(z)V_{S30} \\
&V_P(z) = f(z)V_{PT} + g(z)P(V_{S30}) \\
&\rho(z) = R(V_P)
\end{aligned}
$$

where z' is depth, V_{ST} and V_{PT} are S- and P-wave velocities extracted from the crustal velocity model at depth z_T, $P()$ is the Brocher P-wave velocity scaling law, and $R()$ is the Nafe-Drake law. The coefficient a controls the ratio of surface velocity to original 30 meter average, b controls overall curvature, and c controls near-surface curvature.

The coefficients $a = 1/2$, $b = 2/3$, and $c = 3/2$ were chosen by trial-and-error fitting Boore and Joyner's (1997) generic rock profile and CVM-S generic soil profiles, as well as to produce smooth and well-behaved profiles when applied to the CVM-H at the selected CyberShake sites.

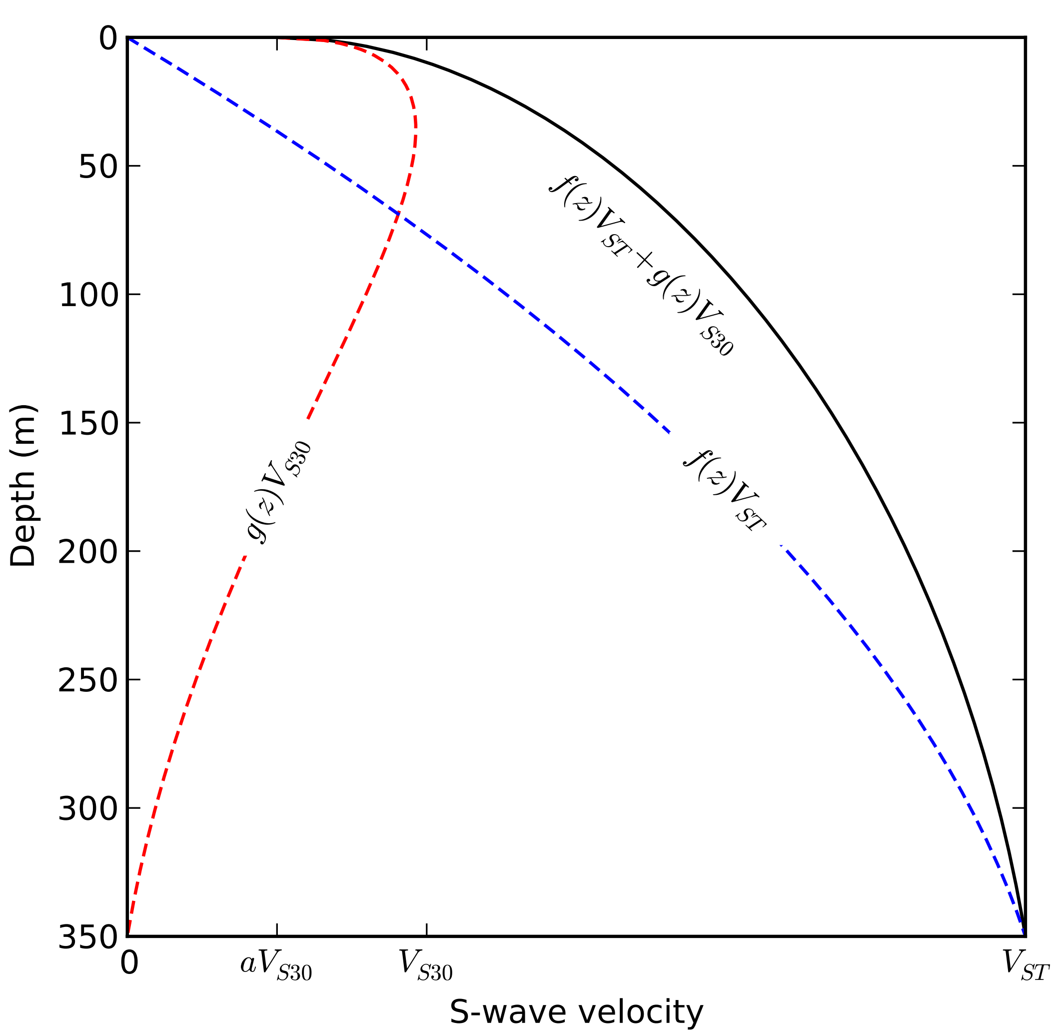

Figure 1: Generic S-wave velocity profile for all soil types is a summation of shallow component $g(z)$ scaled by V_{S30} (red), and deep component $f(z)$ scaled by V_{ST} (blue).

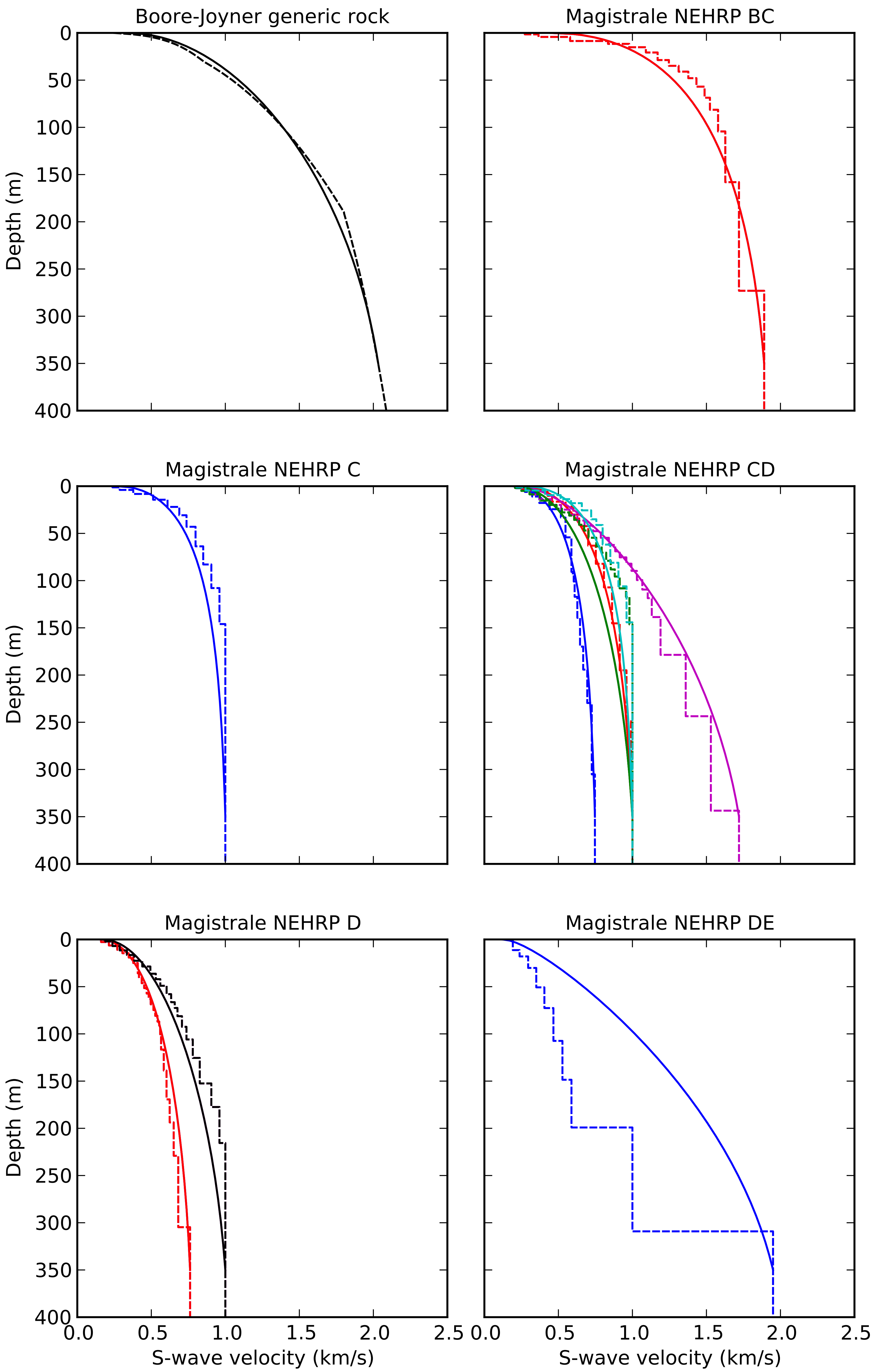

Figure 2: Generic V_S profiles (dashed lines) of Boore and Joyner (1997) and Magistrale (2000) with proposed model (solid lines).

Implementation

The new near-surface model (know at the geotechnical layer, or GTL) has been implemented as a Python library using CVM-H v6.3 voxet data, and is available as part of the Computational Seismology Tools. In testing, extraction of a 18.5 billion node, 208 Gb mesh, using three processors (one each for ρ, V_P and V_S) on the NICS Kraken machine, takes 4 hours. The new GTL is also integrated into the SCEC CVM Toolkit by Patrick Small, to be released in early 2011.

References

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CVM-S v4.0

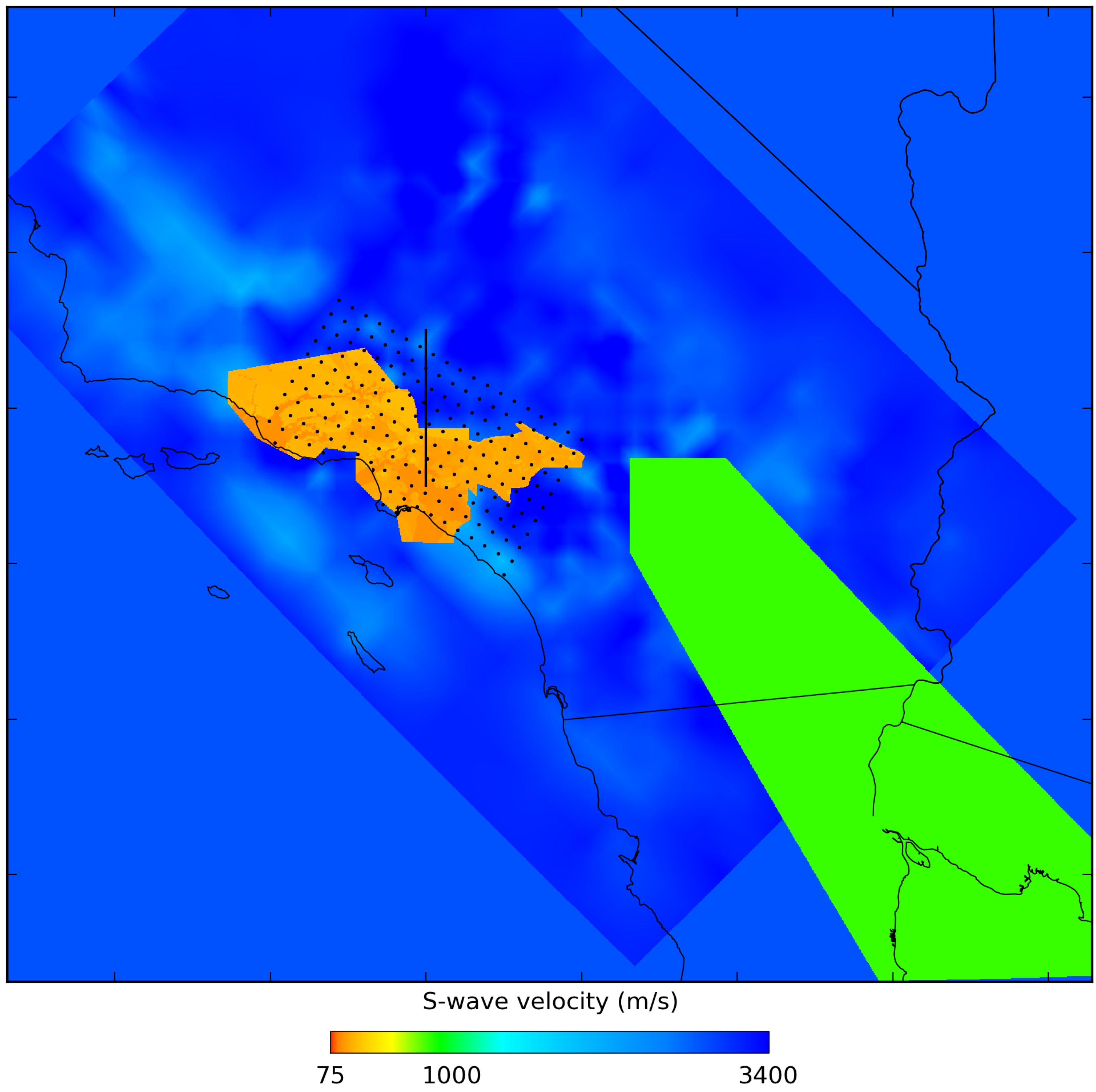

Figure 3: CVM-S v4.0 surface S-wave velocity with marked cross-section and vertical profile locations. Color scale is clipped at 400 m/s.

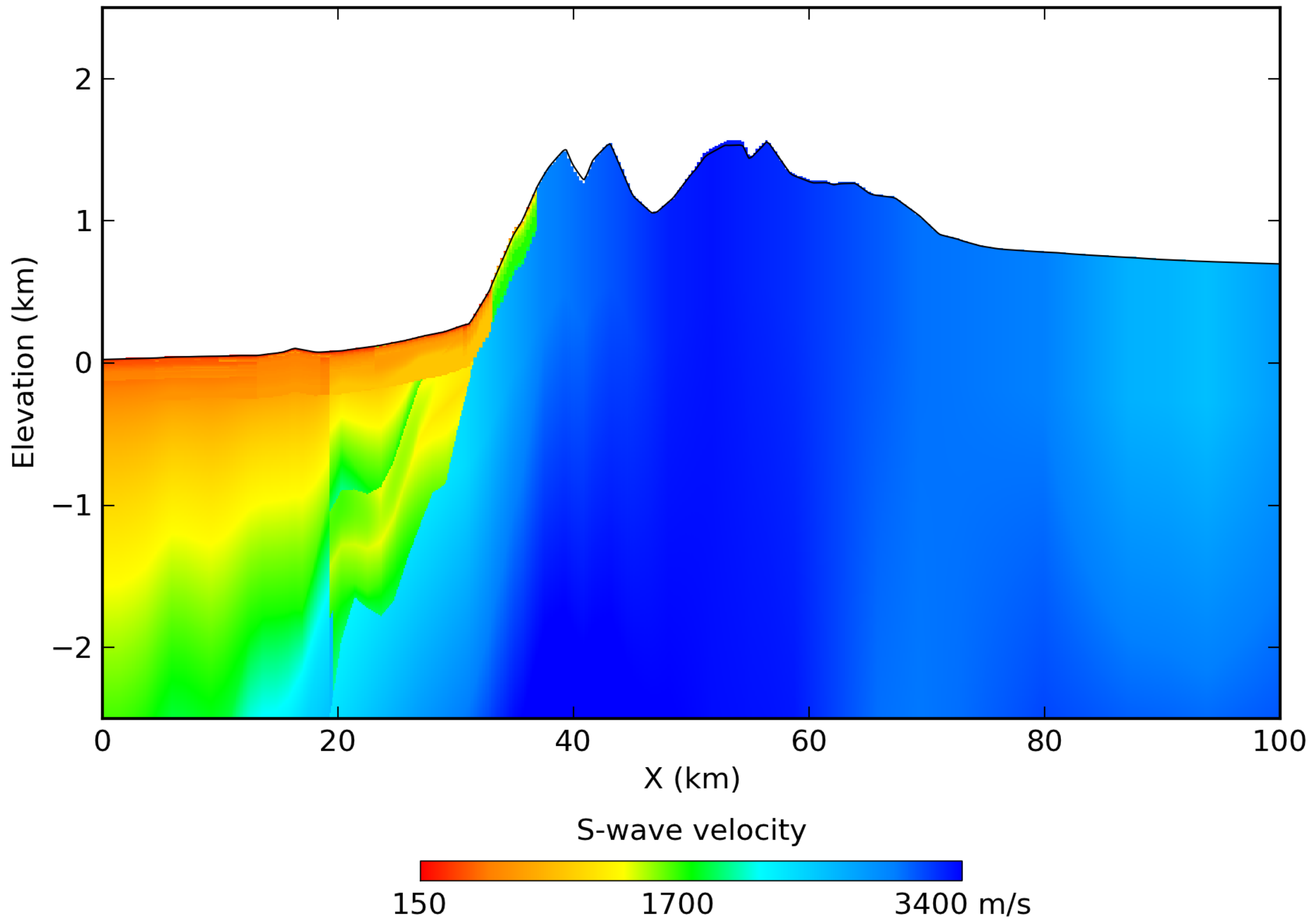

Figure 4: CVM-S v4.0 S-wave velocity cross-section through the Los Angeles basin and San Gabriel Mountains.

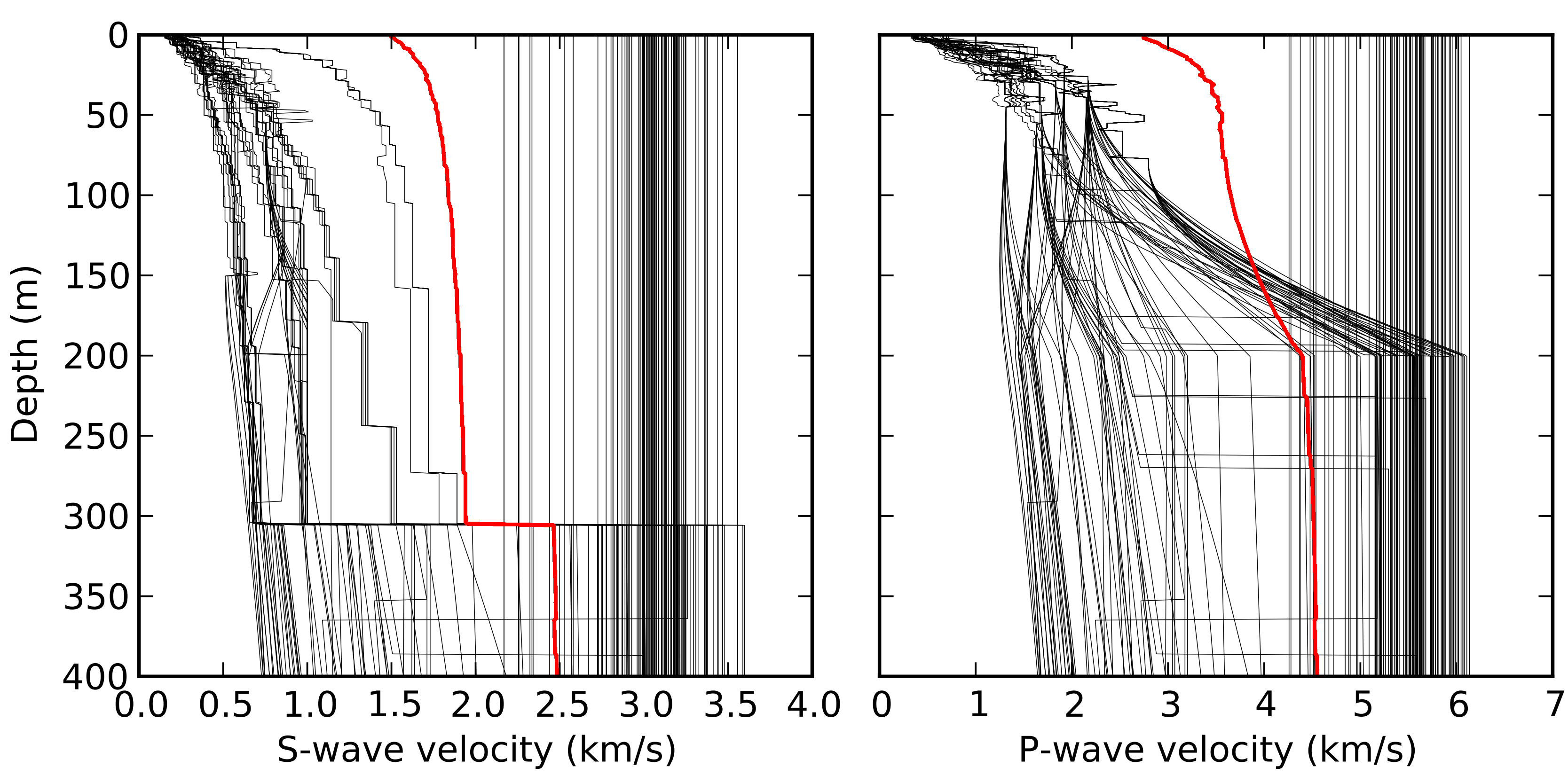

Figure 5: CVM-S v4.0 S- and P-wave velocity profiles.

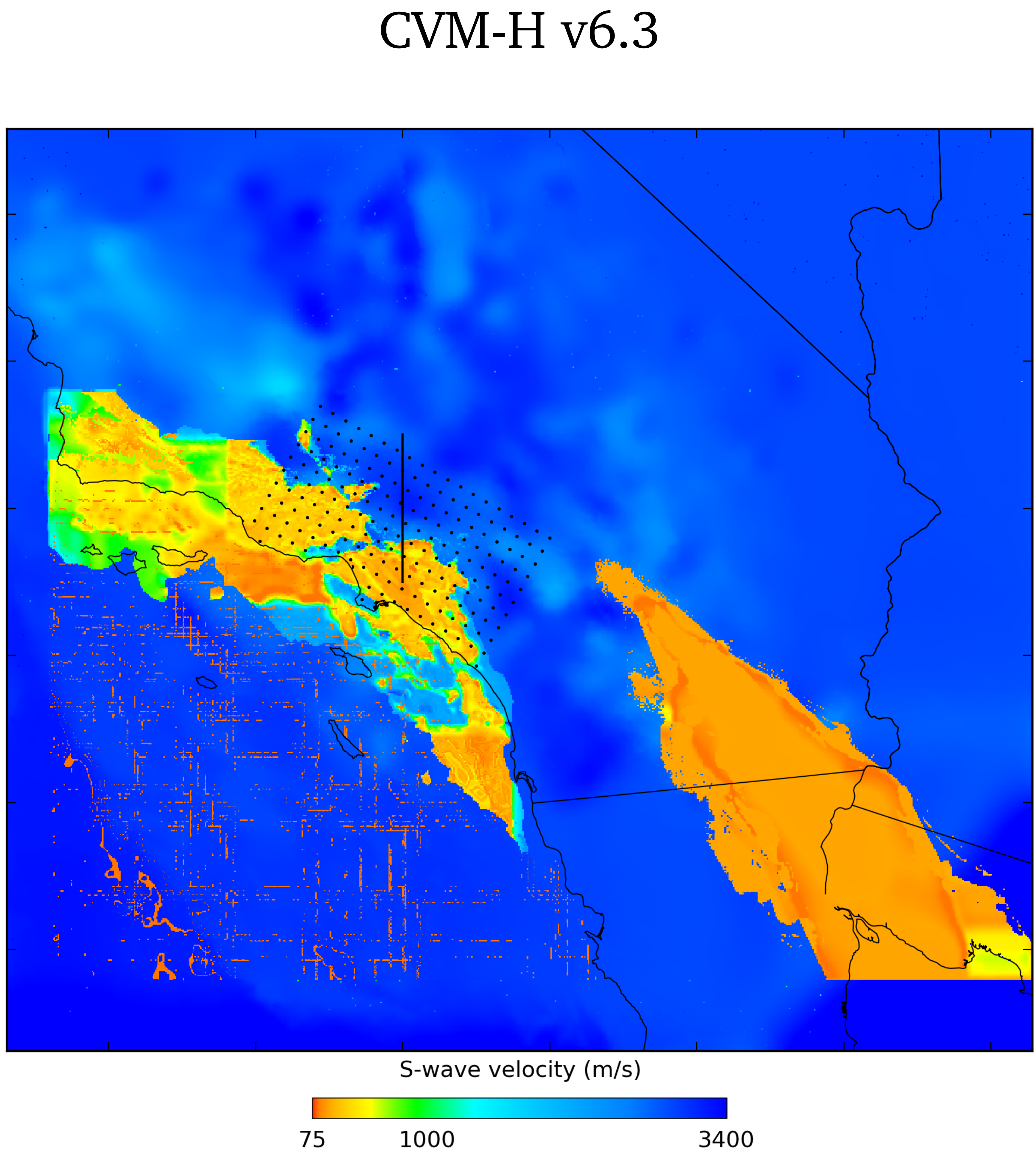

Figure 6: CVM-H v6.3 surface S-wave velocity with marked cross-section and vertical profile locations. White areas indicate locations where the voxet model does not reach the ground surface.

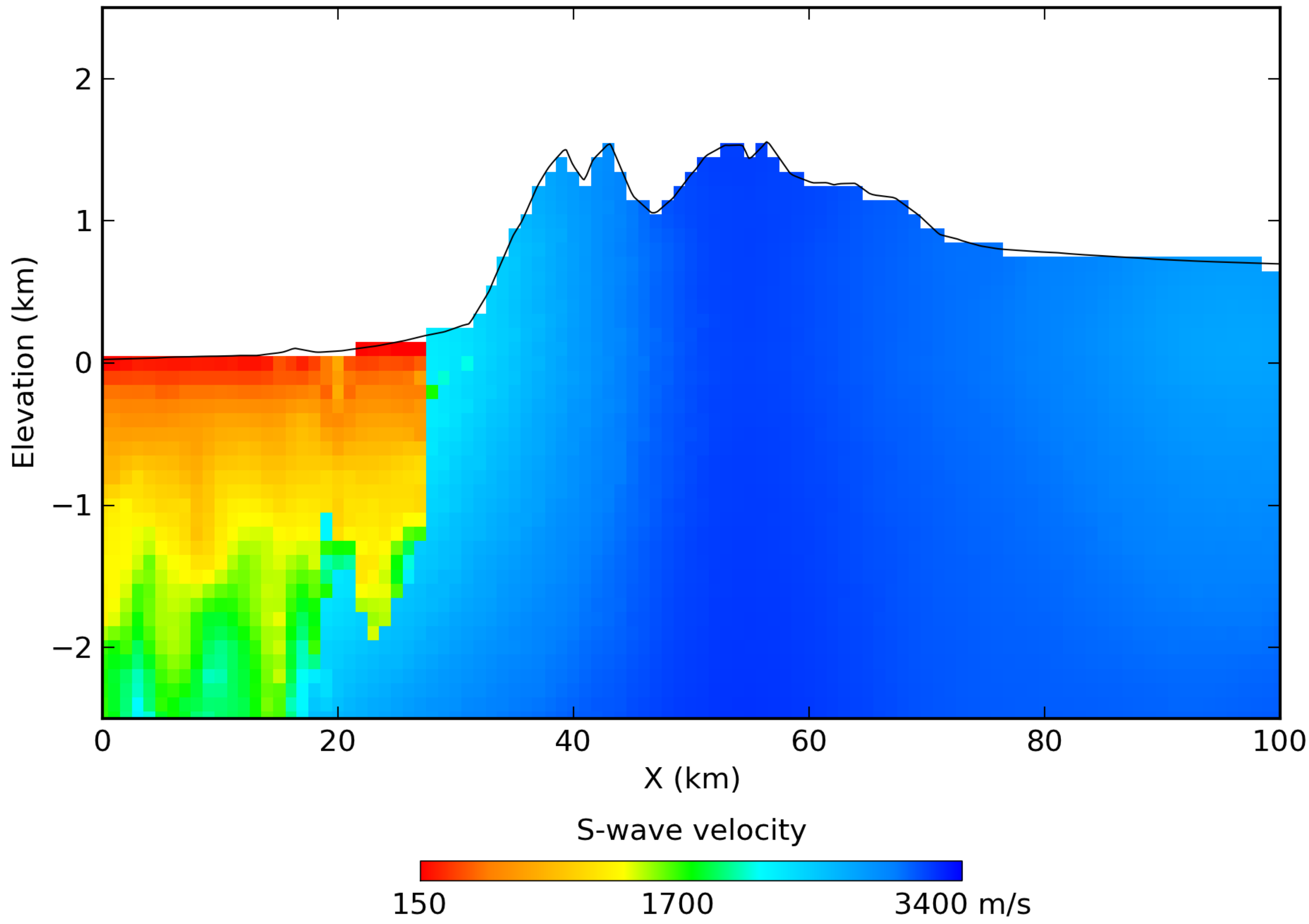

Figure 7: CVM-H v6.3 S-wave velocity cross-section through the Los Angeles basin and San Gabriel Mountains.

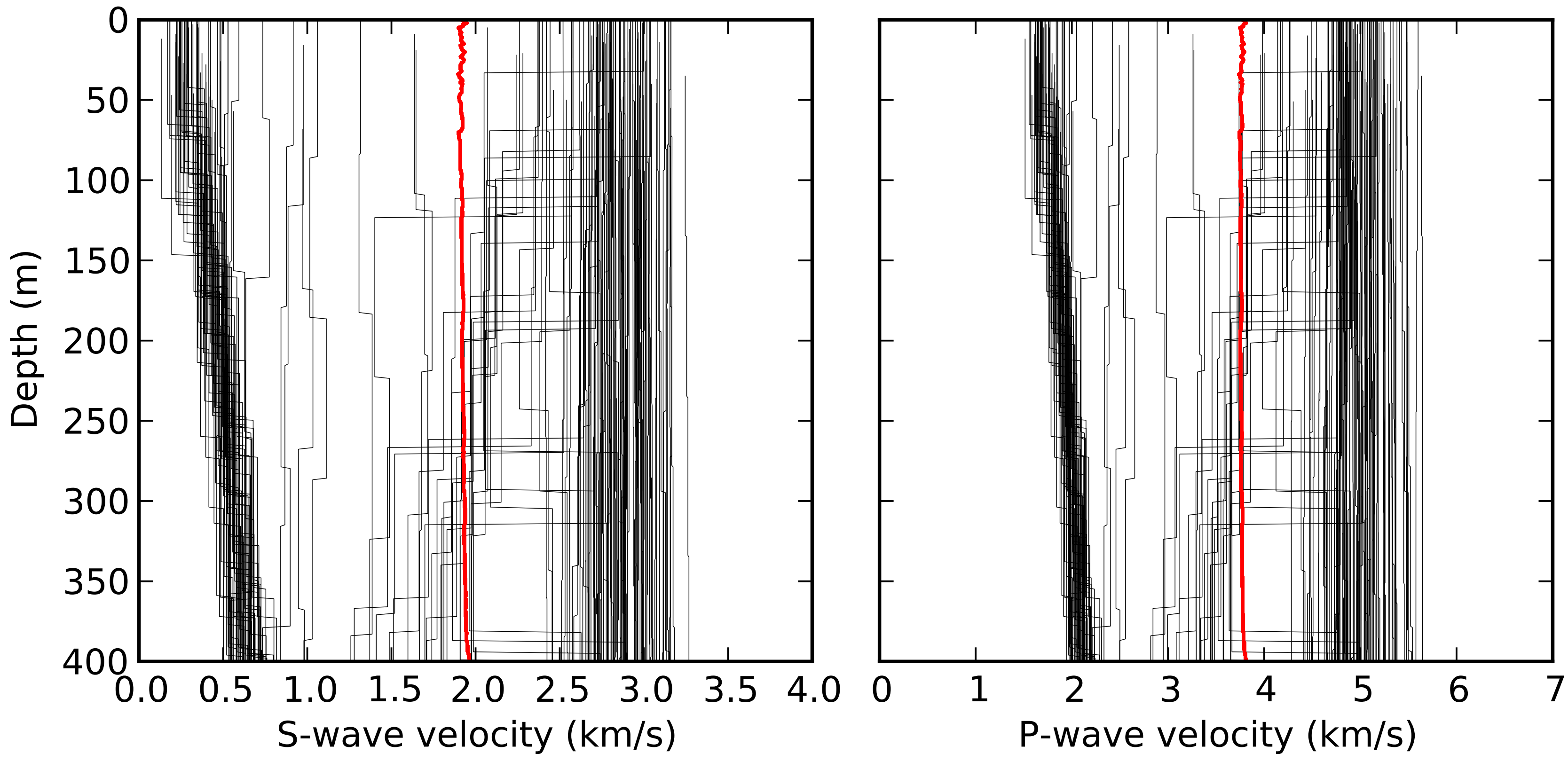

Figure 8: CVM-H v6.3 S- and P-wave velocity profiles.

CVM-H v6.3 + GTL

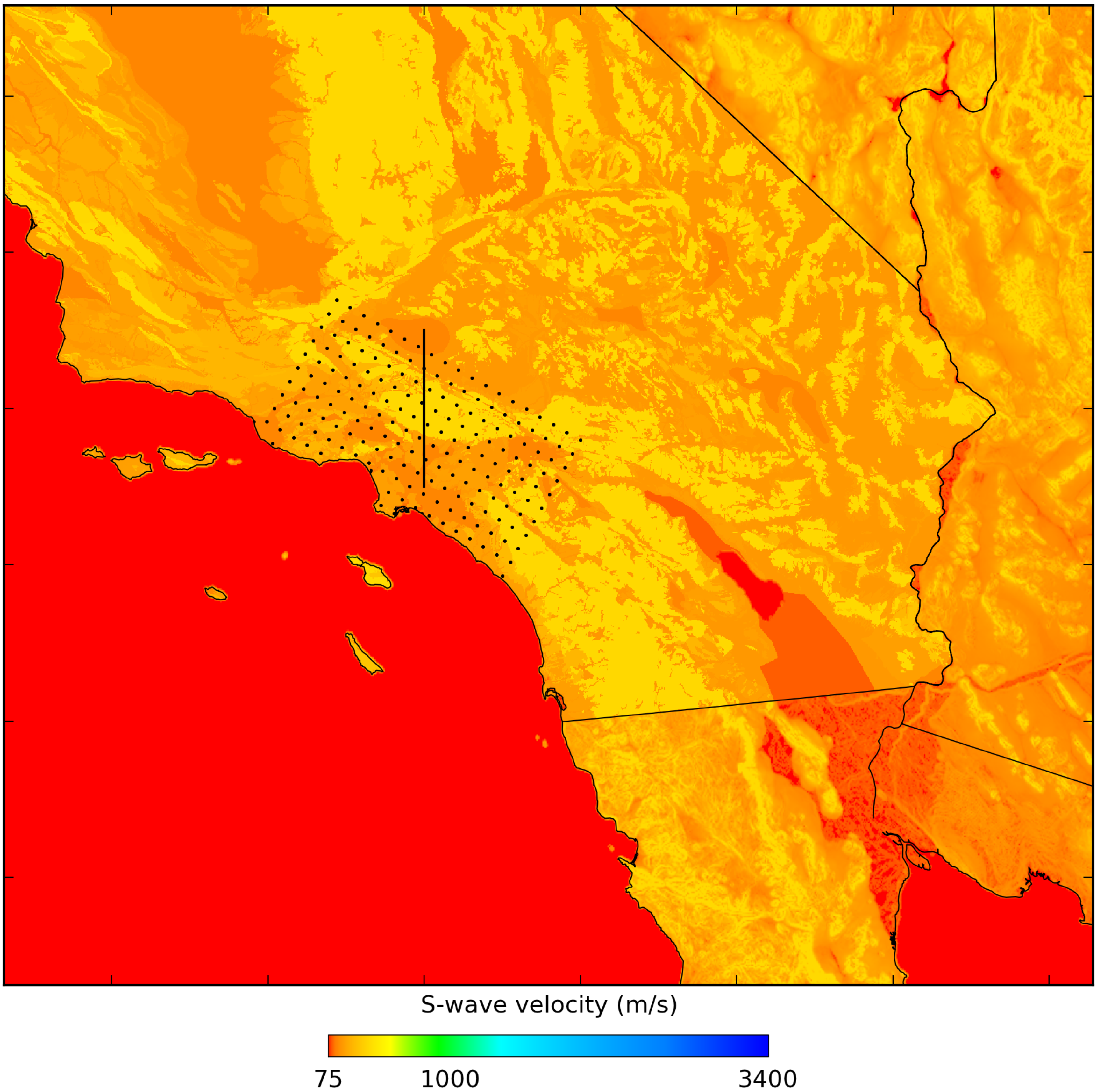

Figure 9: GTL surface S-wave velocity derived from Wills and Clahan (2006) geology based V_{S30} map, supplemented outside of California with Wald et al. (2007) map.

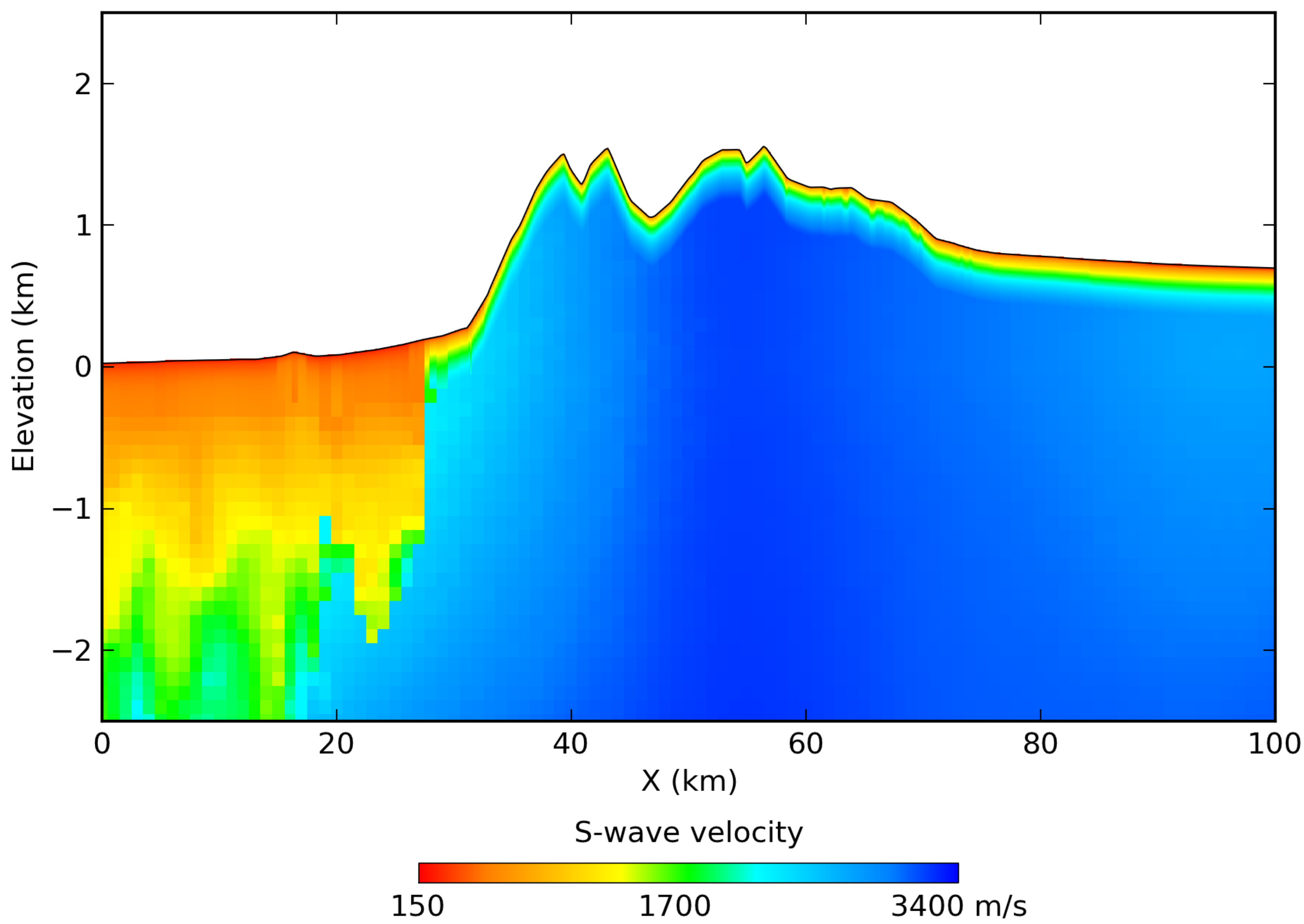

Figure 10: CVM-H v6.3 + GTL S-wave velocity cross-section through the Los Angeles basin and San Gabriel Mountains.

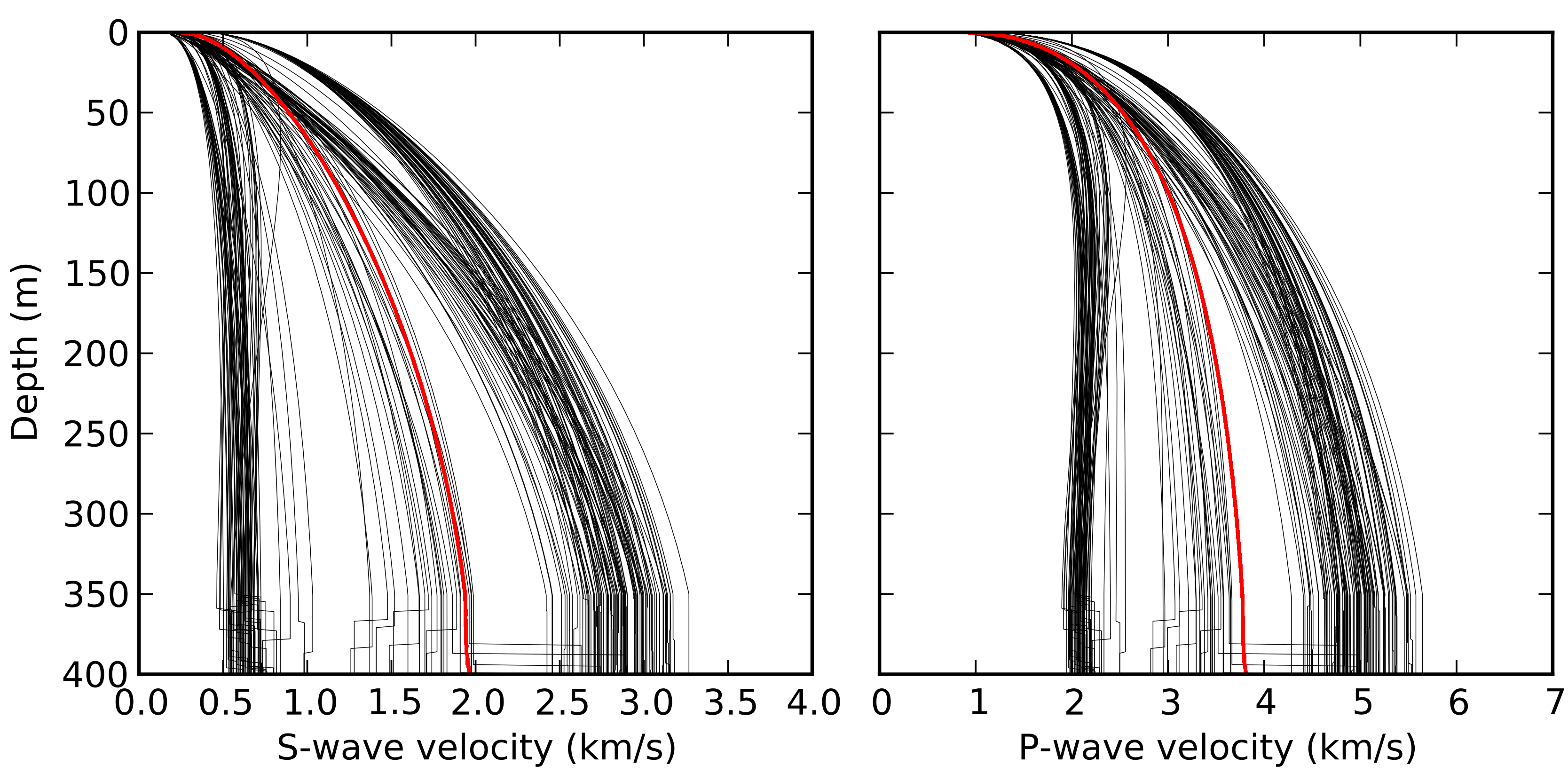

Figure 11: CVM-H v6.3 + GTL S- and P-wave velocity profiles.