Improving Iso-surface Depth ($z_{1.0}$) Estimates for California Sites from Measured Profiles and Geology-Based Proxy Models for Ground Motion Studies

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1. Abstract

Accurate estimates of subsurface shear wave velocity (V_S) structure are essential for predicting ground motions and ensuring the resilience of lifeline infrastructure during earthquakes. The depth to V_S = 1000 m/s ($z_{1.0}$) is a key parameter in ground motion models, yet it is often unavailable or inaccurately represented, especially outside sedimentary basins. $z_{1.0}$ is seldom measured but rather estimated from community velocity models (CVMs), which are three-dimensional representations of the subsurface geology developed using tomographic inversions or rule-based methods and constrained with deep site investigation data. The resolution of these CVMs can be too coarse to capture shallow subsurface features needed to estimate $z_{1.0}$, especially at sites located outside of basins or close to basin margins. In this study, we compiled 253 measured $z_{1.0}$ values from the Shear Wave Velocity Profile database (VSPDB; Kwak et al. 2021) and developed an extrapolation model to estimate $z_{1.0}$ at an additional 875 sites using shallow V_S profiles that do not reach the 1000 m/s horizon. These values were aggregated within surface geologic units to create a regional $z_{1.0}$ database with associated uncertainty. This geology-based approach provides more reliable estimates where CVMs are sparse or unreliable. The resulting database enhances seismic hazard models and supports more accurate site response analyses, directly benefiting the seismic design and risk assessment of critical infrastructure systems and advancing community resilience goals across California

2. Introduction

- We evaluate CVM based $z_{1.0}$ against a geology-based $z_{1.0}$ proxy (Stewart et al., 2025) within the CVM detailed domains of Southern and Northern California (Fig. 3-5).
- Using measured $z_{1.0}$ from VSPDB velocity profiles as ground truth (Fig. 1), we compute residuals (measured - predicted) for both methods and compare their bias and dispersion to identify the lower-bias predictor (Fig. 4).

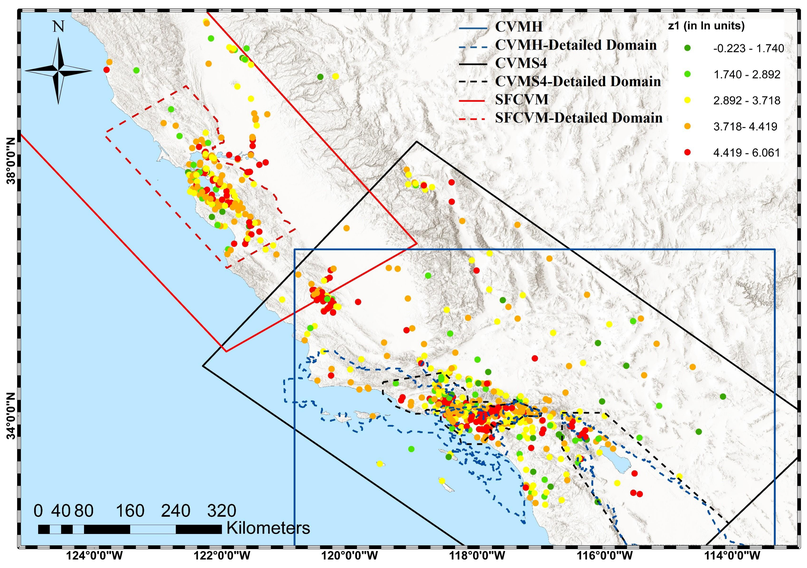

Figure 1: *Map shows $z_{1.0}$ values at locations with V_S profiles in CA that cross V_S=1000m/s. The red, blue and black boxes show model boundaries for SFCVM 21.1 (Aagaard, 2021), CVMS4 (Lee et al.; 2014) and CVMH 15.1.1 (Shaw et al; 2015). The black boundaries represent basin outlines Nweke et al. (2022).*

3. Geology based $z_{1.0}$ Model

The proposed extrapolation model (Stewart et al., 2025) is leveraged to extend an additional 622 V_S profiles to obtain $z_{1.0}$. Further both measured and extrapolated profiles are used to develop a geology based $z_{1.0}$ model presented below in figure 2.

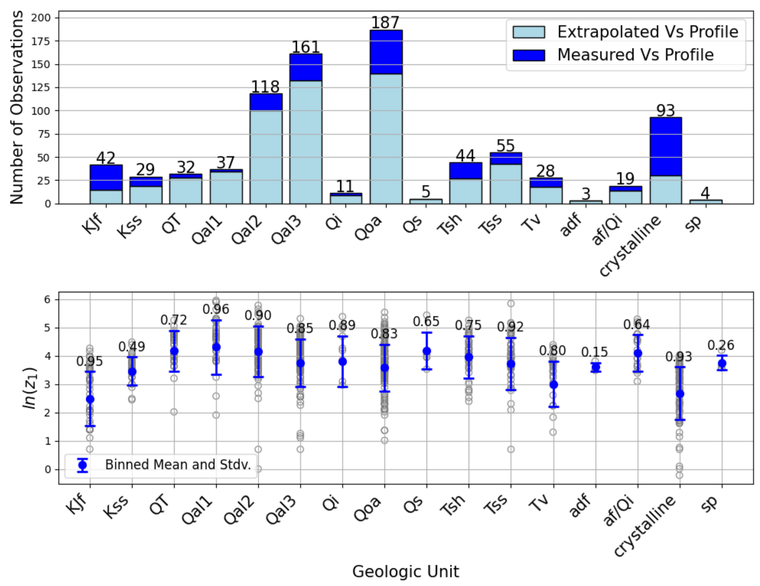

Figure 2: *Top panel shows bar chart with the number of measured or inferred (by extrapolation) $z_{1.0}$ values in CA geological units, while bottom panel shows means (μ_{lnz1}) and standard deviations (σ_{lnz1}) of natural log $z_{1.0}$ values in different Wills et al. (2015) geologic units.*

4. Residual Investigation

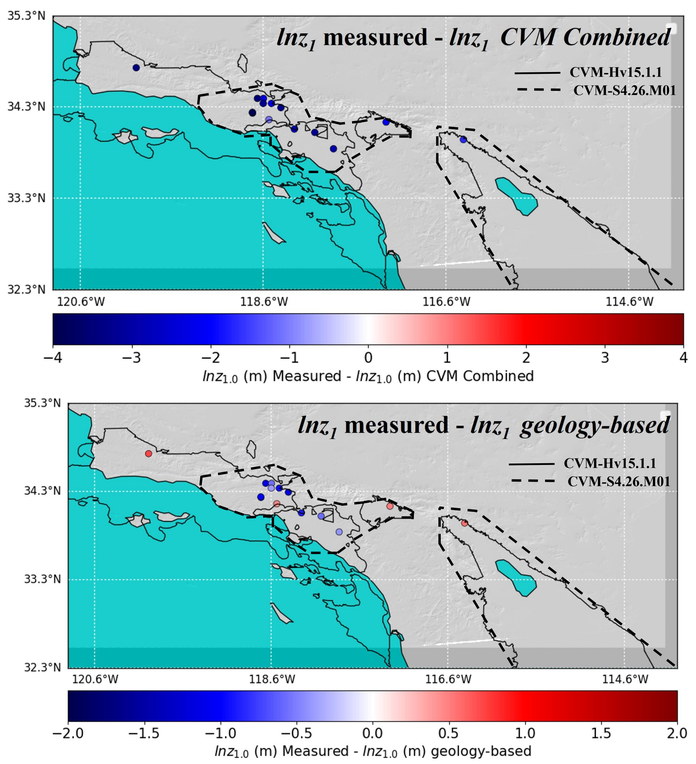

Figure 3: *Map shows $z_{1.0}$ residuals at pre-quaternary sites with measured $z_{1.0}$ in CVM-Hv15.1.1. and CVM-S4.26.M01 detailed domain in SoCal.*

4. Residual Investigation

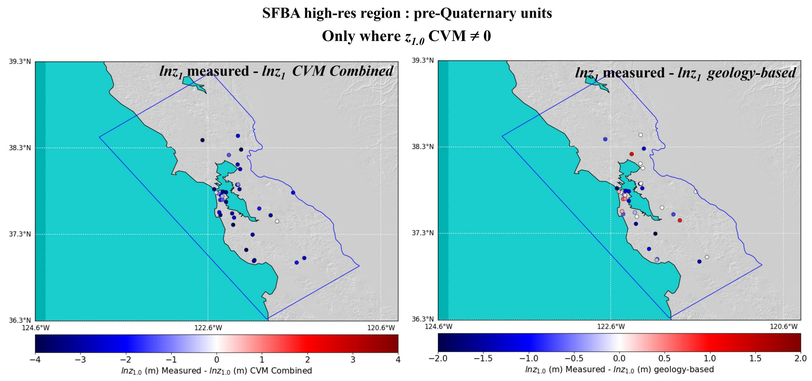

Figure 4: *Map shows $z_{1.0}$ residuals at pre-quaternary sites with measured $z_{1.0}$ in CVM detailed domain in NorCal.*

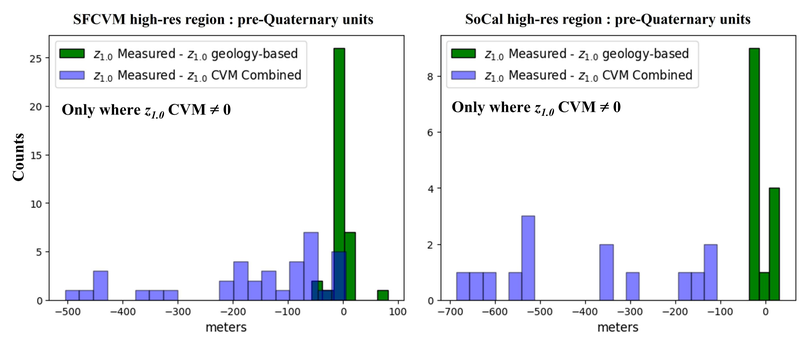

Figure 5: *Histograms for $z_{1.0}$ residuals at pre-quaternary measured Vs profile sites in CVM detailed domains .*

5. Conclusion

- CVM based $z_{1.0}$ overestimates $z_{1.0}$ in CVM detailed domains. Residuals are mostly negative (measured - CVM based), often by hundreds of meters, even after excluding sites with $z_{1.0}$ = 0.
- Geology-based $z_{1.0}$ is better centered and cluster near zero with lower bias and smaller spread in both SoCal and SFBA.
- Recommendation: Using the geology-based $z_{1.0}$ as the preferred method to assign $z_{1.0}$ in CVM detailed domain for pre-quaternary (Non-Basin) sites. This recommendation has been implemented for producing maps of $z_{1.0}$ and $z_{2.5}$ (Buckreis et al., 2025)

6. References

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