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Application of the Coda Calibration Tool (CCT) Methodology to Intermediate Depth Events in the Vrancea Region, Romania

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INTRODUCTION AND MAIN RESULTS

The Vrancea seismic zone is affected by crustal and intermediate-depth earthquakes and represents a natural laboratory for testing the Coda Calibration Tool (CCT). Recent enhancements of the CCT, including the use of hypocentral distance in 1D narrowband coda models, allow more reliable estimates of source parameters such as Mw, radiated energy, apparent stress, and corner frequency. The intermediate-depth seismic activity of Vrancea is characterised by moderate to large events and minimal aftershock contamination. It provides important constraints for refining path-term calibration and improving the accuracy of seismic source characterization.

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CCT is freely available to the community and we welcome testing and collaboration in the spirit of improving upon the tool over the next year.
https://github.com/LLNL/coda-calibration-tool

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Introduction

The Vrancea seismic zone exhibits high seismic activity comprising both crustal and intermediate-depth earthquakes (Fig. 1; 60-180km) with distinct source mechanisms. The subcrustal events can reach magnitudes up to 7.4 (Mw), constituting a natural laboratory for calibration and validation of the Coda Calibration Tool (CCT), based on the empirical method outlined by *Mayeda et al*. (2003). The objective of applying the CCT for intermediate-depth events is to obtain stable and reliable estimates of source parameters: moment-magnitude, radiated energy, corner frequency, and apparent stress, and then to extend to evens too small for waveform modelling. The stability of coda wave is key advantage for CCT to provide better source parameters than direct-wave methods and to improve the characterization of subcrustal

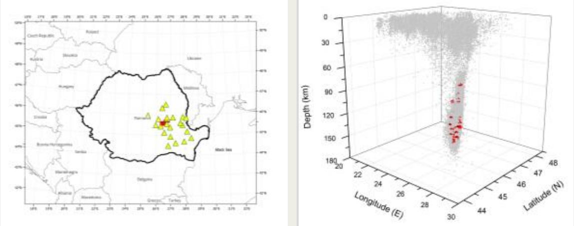

Fig.1. Map showing the location of seismic stations and seismic events used for CCT calibration.

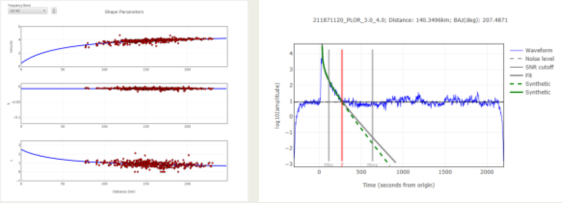

Fig.2. hape parameter example for 3-4 Hz shows peak velocity and envelope shape parameter measurements.

Methods/Data

We applied CCT to a dataset of 41 subcrustal earthquakes (Fig.1; 77-151km) with Mw > 4.0 recorded in Vrancea and 23 seismic stations distributed around the study region. The input dataset consisted of waveform envelopes processed in narrow frequency bands (Fig.2). CCT was configured to incorporate hypocentral distance in the calibration procedure, allowing for improved path corrections (Fig.3) across various source depths. For each event, the calibrated envelopes were used to compute the seismic moment magnitude (Mw), radiated energy, corner frequency and apparent stress (Fig.4; 5; 6).

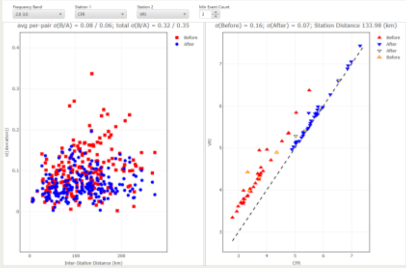

Fig.3. Path correction at 2–3 Hz: all data (left) vs. CFR and VRI stations (right).

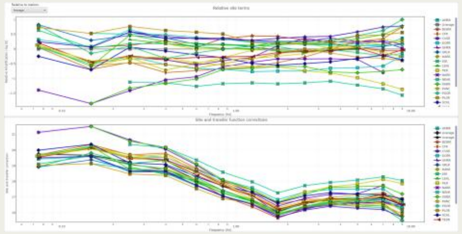

Fig.4. Site terms

Site terms were derived from reference apparent stress and Mw's values, allowing the transformation of distance-corrected coda amplitudes (dimensionless) into physical units of N·m (Fig.4).

Results: M_w and Apparent Stress

The analysis of the Vrancea dataset produced stable source parameters. The values for Mw from coda envelopes agree with the magnitudes obtained from independent sources (Fig.6; 7) such as waveform inversion package (ISOLA), while apparent stress show depth and magnitude variability (Fig.8). The average across the seismic stations used in this study reduced path and site effects, confirming CCT as a reliable tool for characterizing subcrustal seismicity.

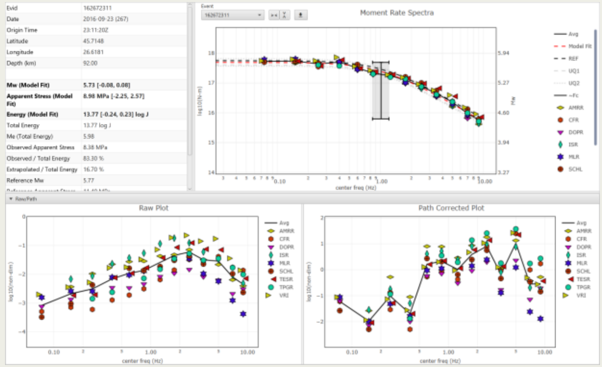

Fig.5. Raw (bottom left) and Path-corrected (bottom right) coda amplitudes, scaled through site-transfer calibration, resulting in moment source spectra in N-m units (top right).

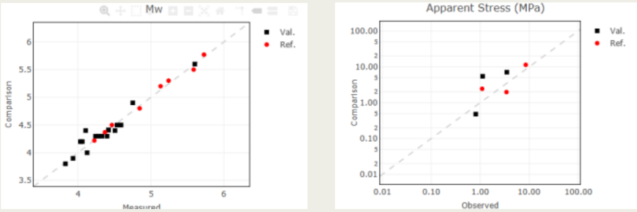

Fig.6. (left) Mw of validation events (black squares) vs Mw from coda spectral fitting (x-axis), as displayed in the Source Spectra tab; reference event magnitudes (red circles) are also indicated; (right) the apparent stresses of the reference events and validation events are reliably reproduced after calibration. We note that coda spectral ratios using the method of Mayeda et al., (2007) to determine apparent stress did not appear to depend on depth for these events (not shown).

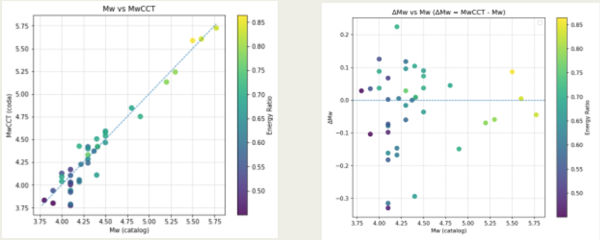

Fig.7. Comparison between MwCCT and Mw (left) and ΔMw = MwCCT – Mw versus Mw (right) color-scaled by Energy Ratio

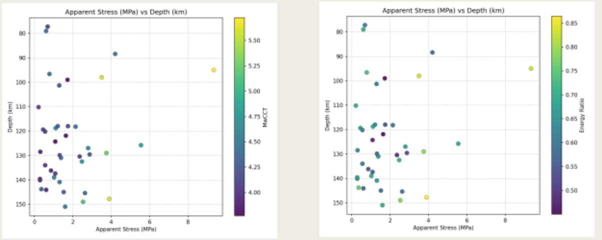

Fig.8. Scatter plot of Apparent Stress (MPa) vs. Depth (km)-color-scaled MwCCT (left) and Energy Ratio (right)

Conclusions

The comparison between catalog magnitudes (Mw, from ISOLA waveform inversion) and CCT-derived magnitudes (MwCCT from coda calibration) shows differences within ±0.3, with MwCCT providing more stable estimates across depths. This can allow for stable Mw and apparent stress estimates for events too small for conventional methods.