

Supplementary material for Picking Regional Seismic Phase Arrival Times with Deep Learning

Aguilar Suarez & Beroza

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1 Noise generator

It is difficult to secure 5 minute long waveforms free of earthquake signals. Datasets that contain noise samples do so for 120 s waveforms. We chose to generate noise waveforms to train our models. The simplest noise waveforms is a drawn sample from a Gaussian distribution. Second mode is waveforms with spikes that are randomly located in time, with random amplitudes. A third is adding sine functions with random phases and random amplitudes, ranging from a single sine to 100. A last way is to add offsets, again randomly located with random offsets.

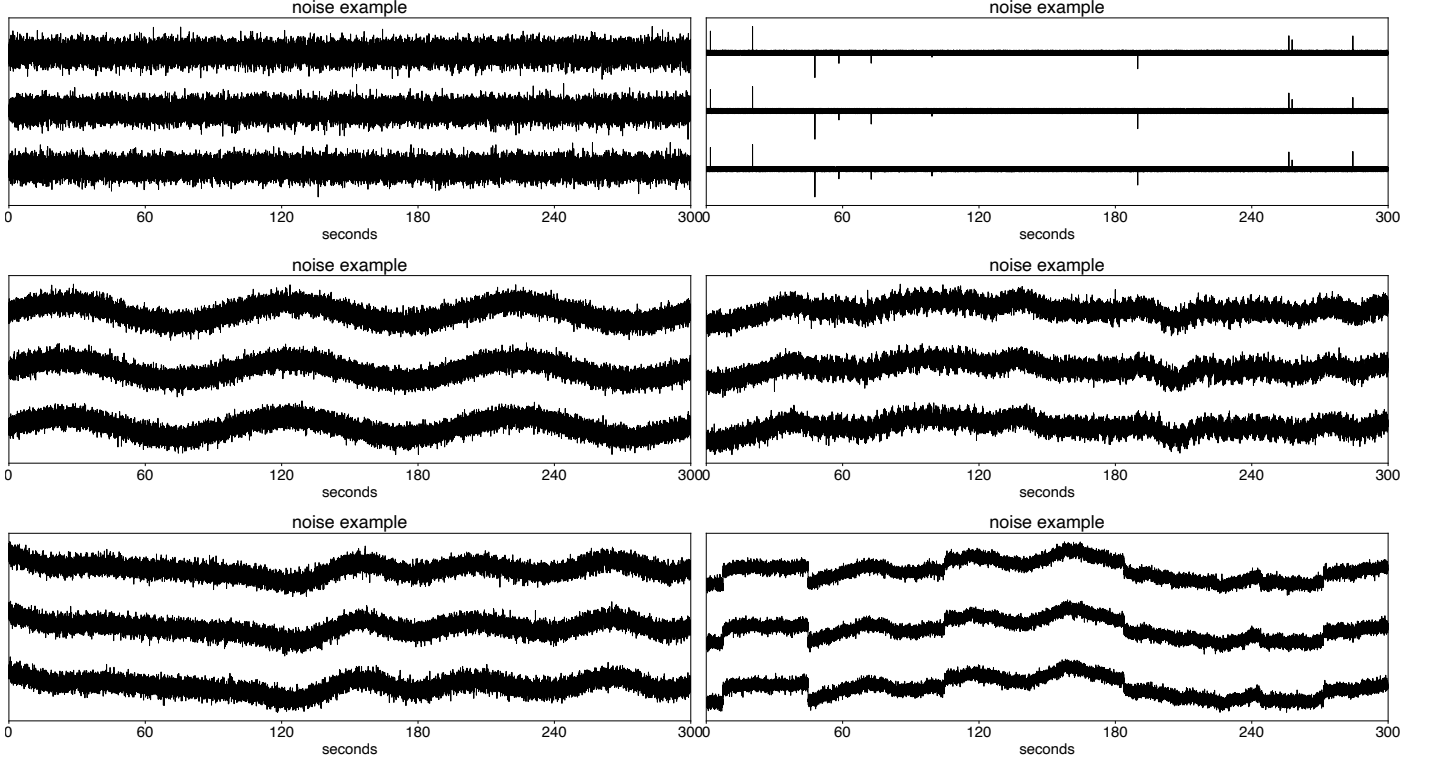


Figure S1: Noise examples used in training. These come from a Gaussian noise generator, and are superimposed with a random number of spikes, a random number of sinusoids and a random number of offsets. The height of spikes, the level of the offsets and the amplitude of the sinusoids are all randomly chosen as every noise example is assembled.

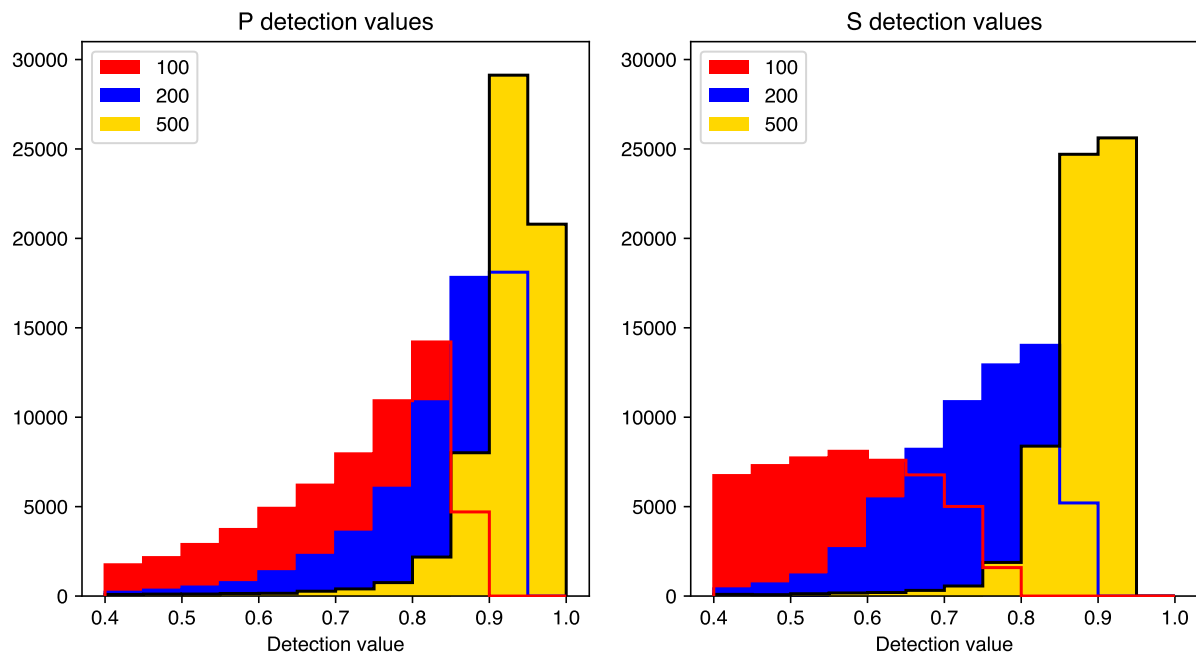


Figure S2: Detection value distributions for three models trained on labels with different widths. The legend indicates the half-length of the base of the triangular labels used.

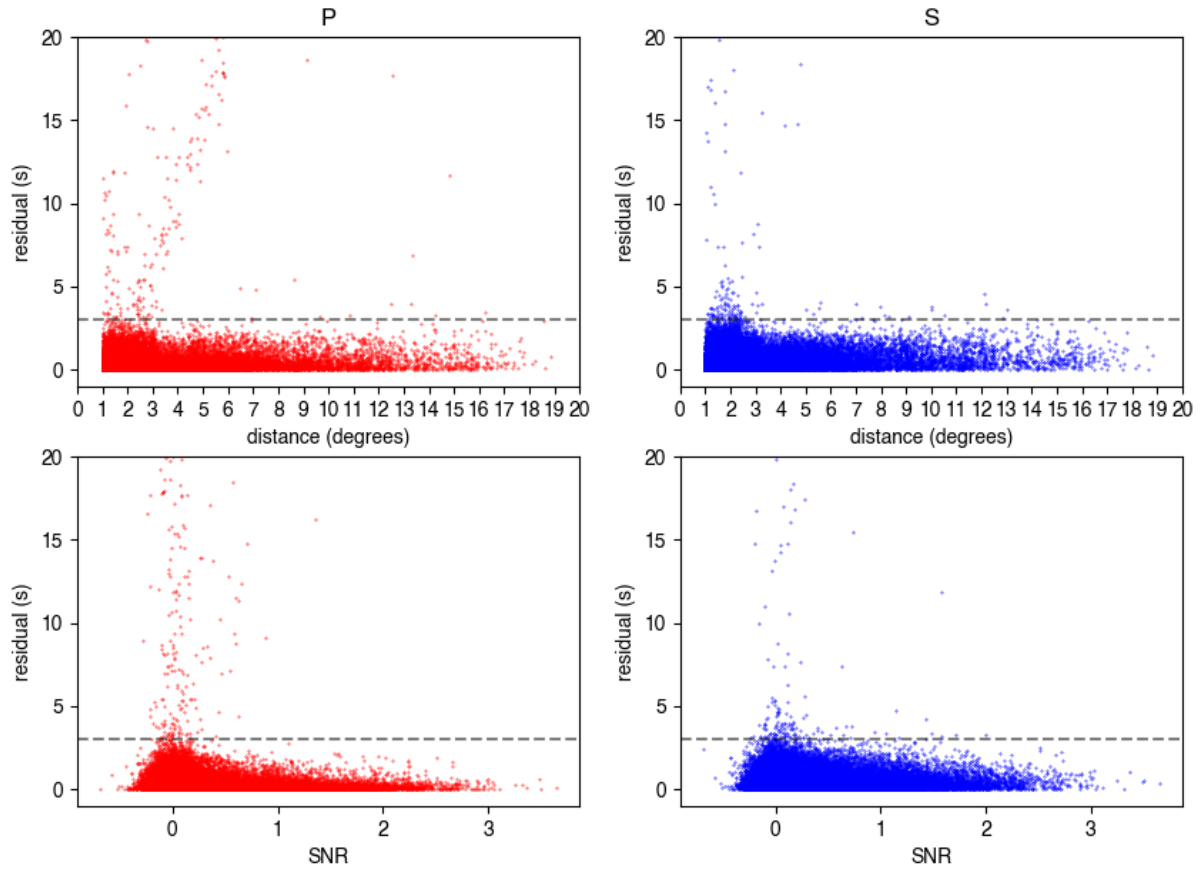


Figure S3: Residuals as functions of both the source to receiver distance and the signal to noise ratio for the test set. Left column shows P waves and right column S waves. The gray dotted line indicates the 3 second threshold used to declare true positives, which is plotted in Figure 3 of the main text. There is no clear correlation between distance and residuals.

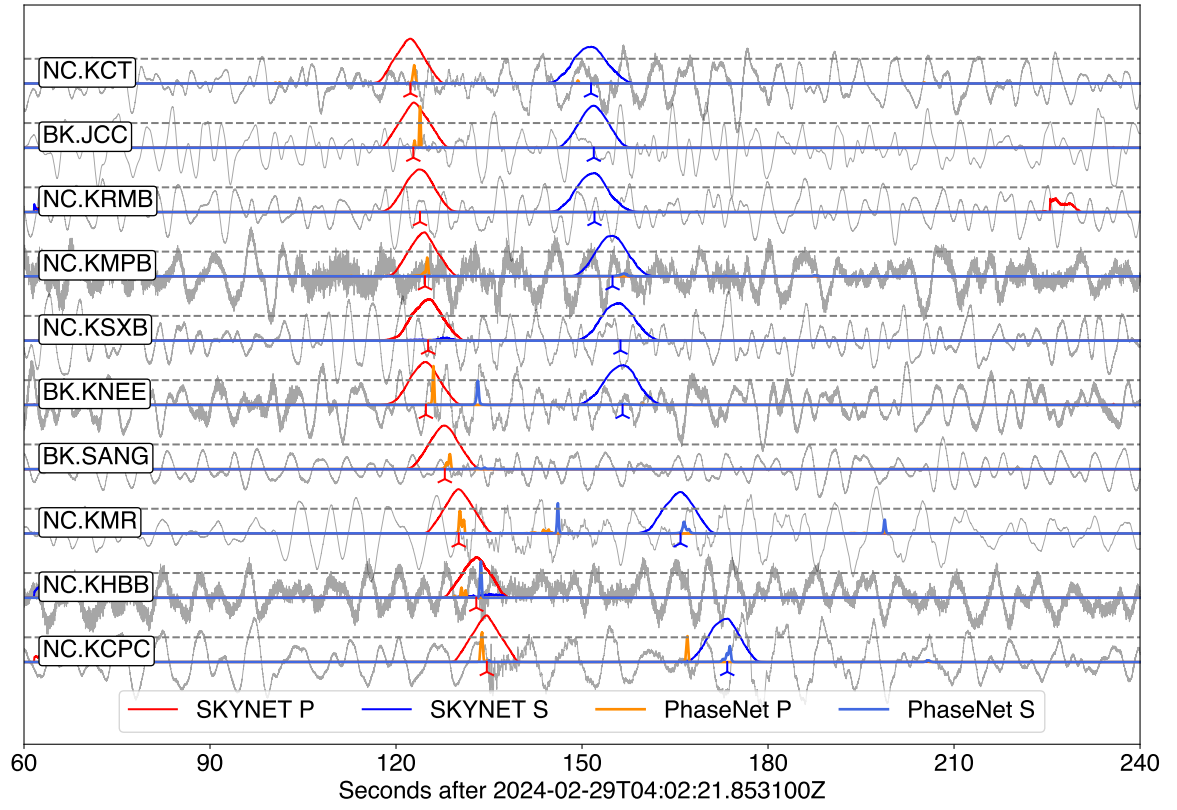


Figure S4: Gorda ridge event picked by both models. Same as Figure 5 in the main text but displaying raw unfiltered waveforms.

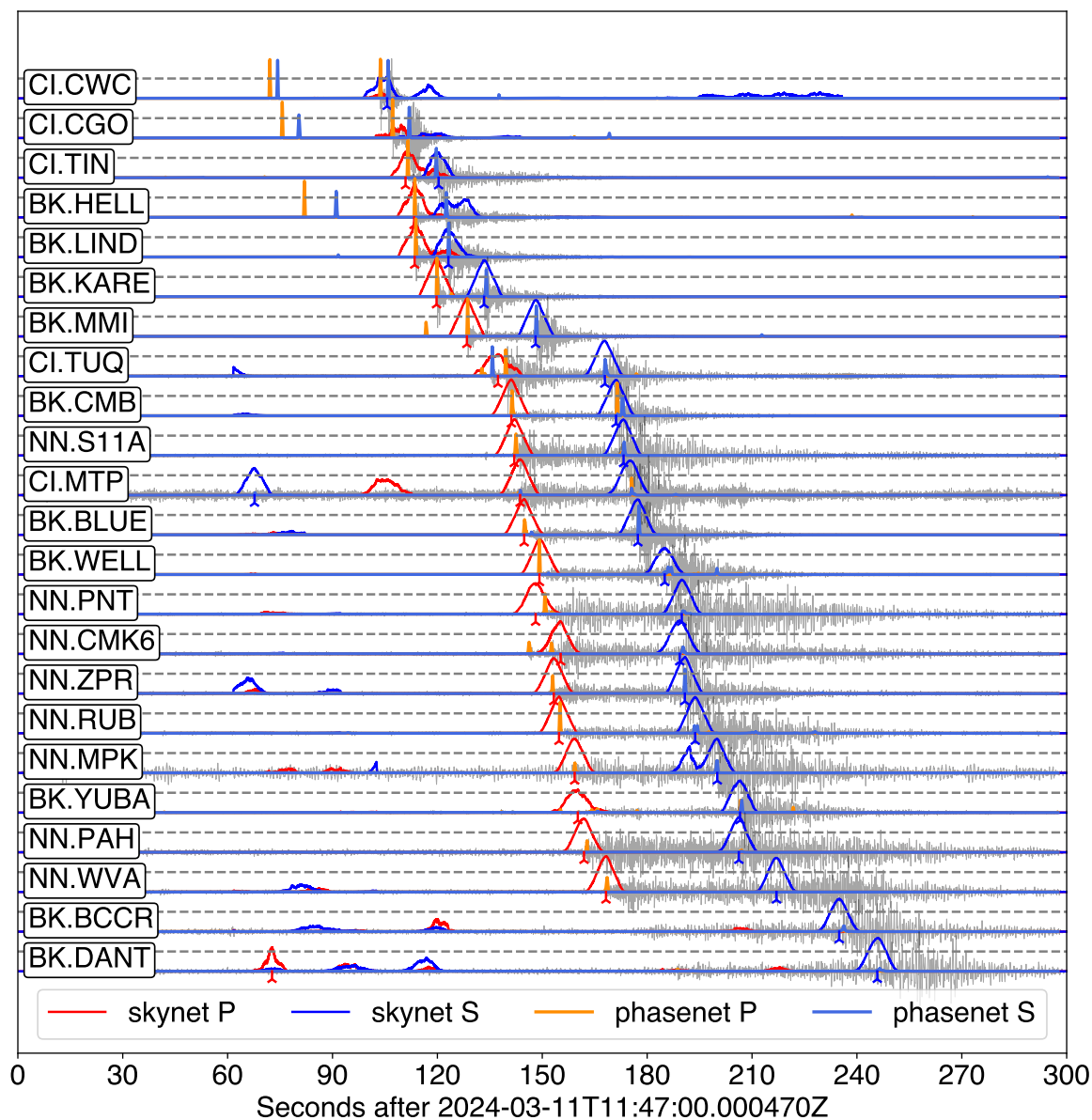


Figure S5: Comparison between SKYNET and PhaseNet results for an earthquake in the Lone Pine region. PhaseNet performs the best in the nearby stations, whereas SKYNET performs the best in the farther away ones.

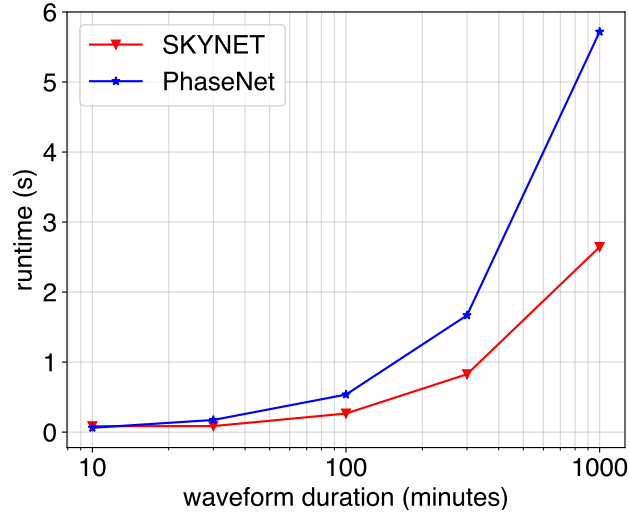


Figure S6: Runtime comparison between the original PhaseNet implementation in Seisbench and SKYNET.

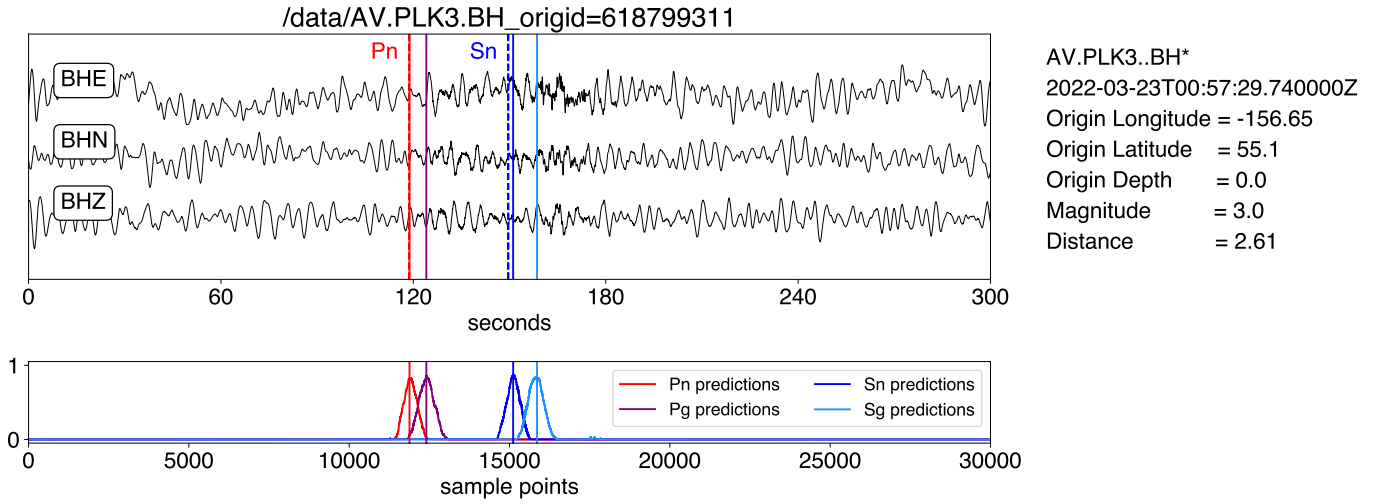


Figure S7: Same as Figure 9(d) but displaying raw waveforms.

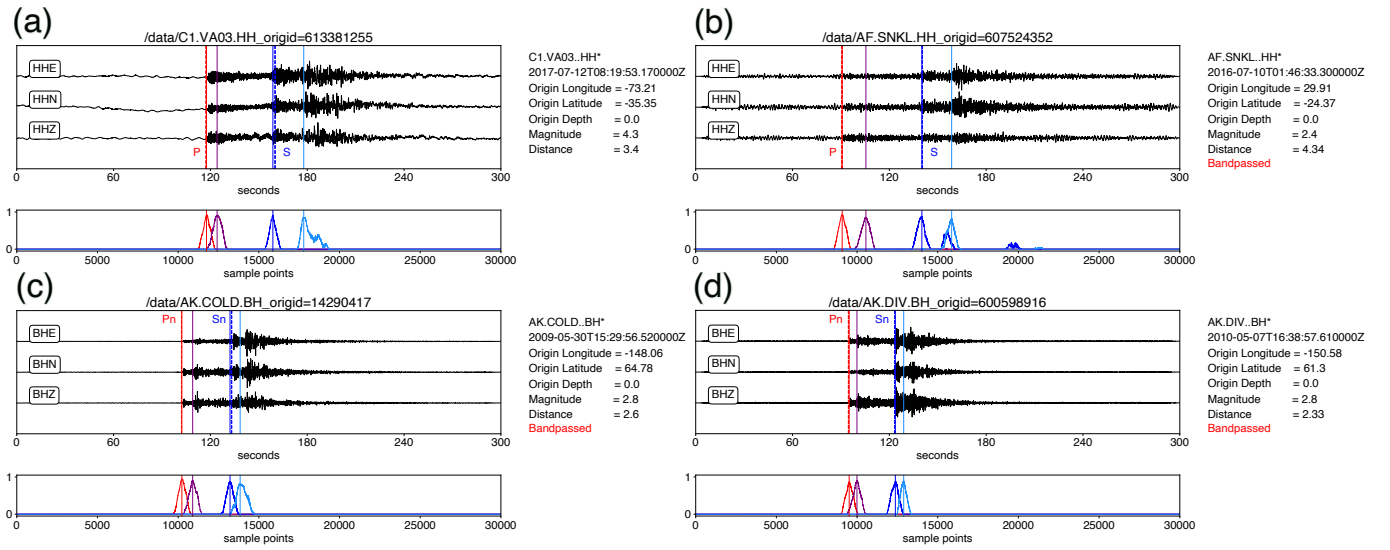


Figure S8: Examples flagged by the multiphase picker that were filtered out by the manual screening. For these four examples, they had only one P and one S arrival labeled, which are the ones with accompanying letters (P,S,Pn,Sn). (a) and (b) have high value prediction for Pg, but no arrival is visible either in the raw or bandpassed waveforms. However, the predicted Sg arrival seems accurate. (c) and (d) contain visible Pg arrivals that are accurately picked by our model. (c) shows a Sg arrival that is not accurately picked by our model. (d) Even though there is a second package of S wave energy there is no clear arrival.