Active and Passive Surface Wave Testing: Addressing Uncertainty using Open-Source Tools

Inversion of SLC Assembly Hall With Clear Low Velocity Layer

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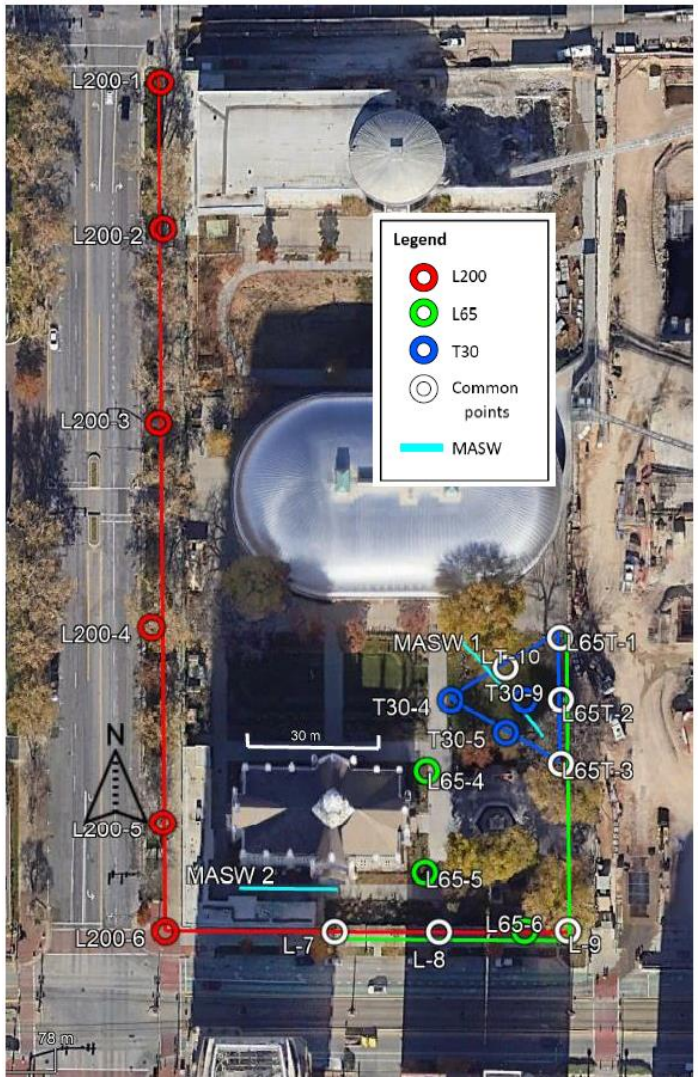
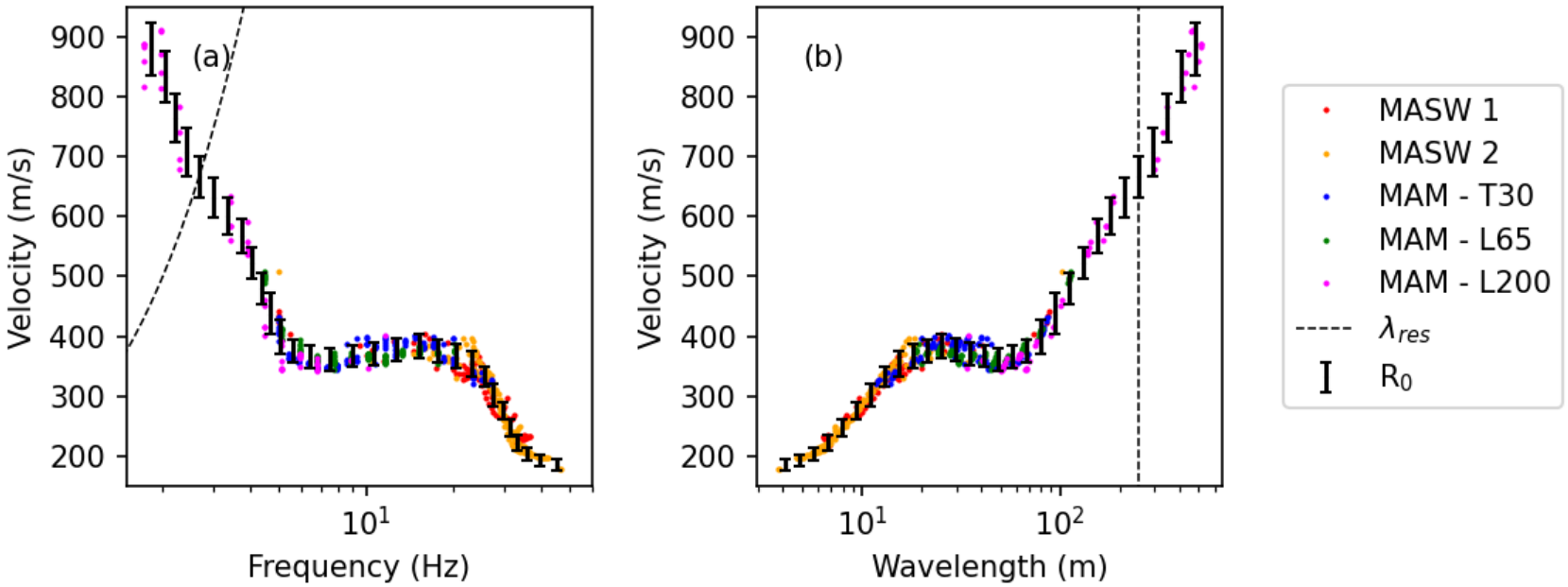


Will be skipping processing and solely focus on inverting the experimental dispersion data.



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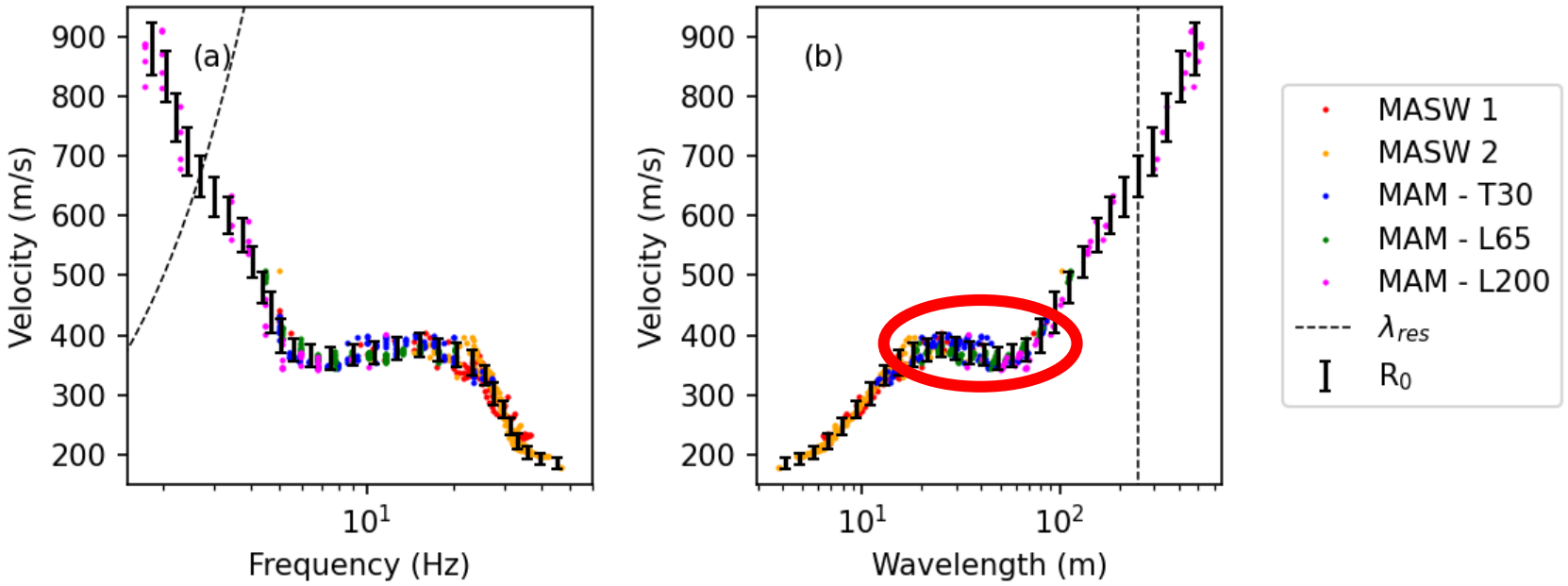

The site has a clear low velocity layer (LVL).
We need to take this into account when we perform the inversion.

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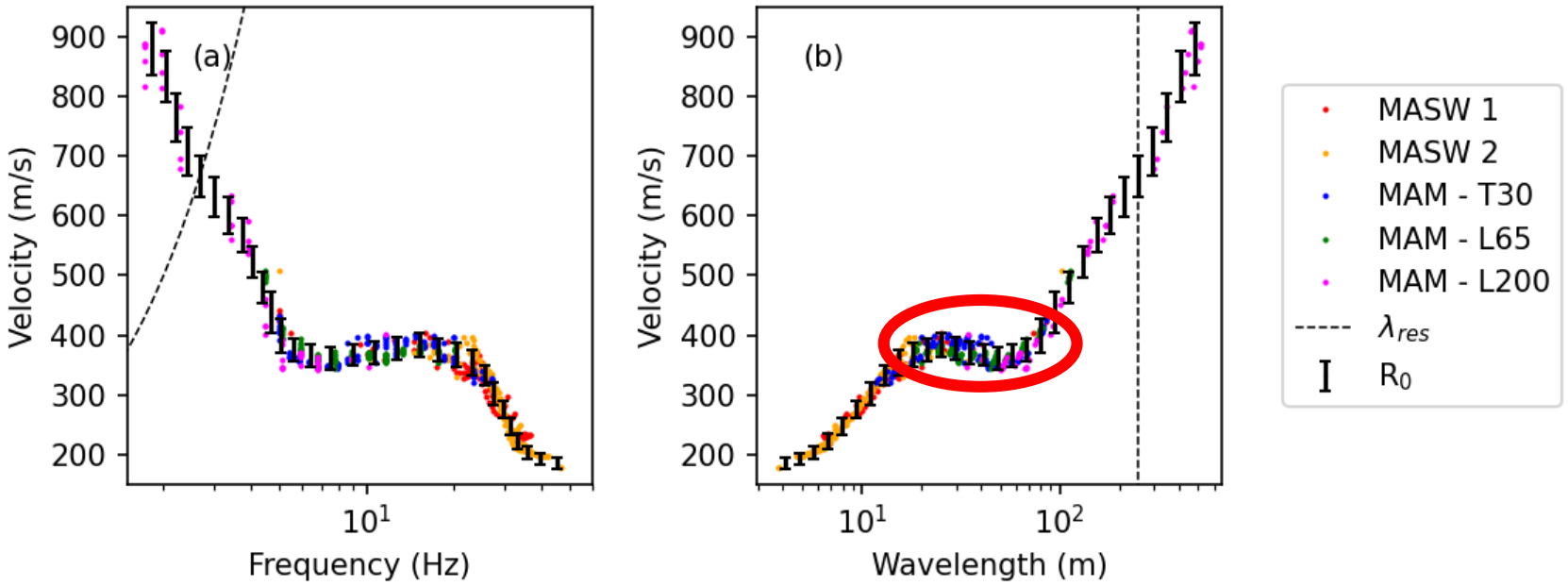

We do not want to allow reversals everywhere, this will result in an over parameterized inversion that would likely not yield reasonable results.

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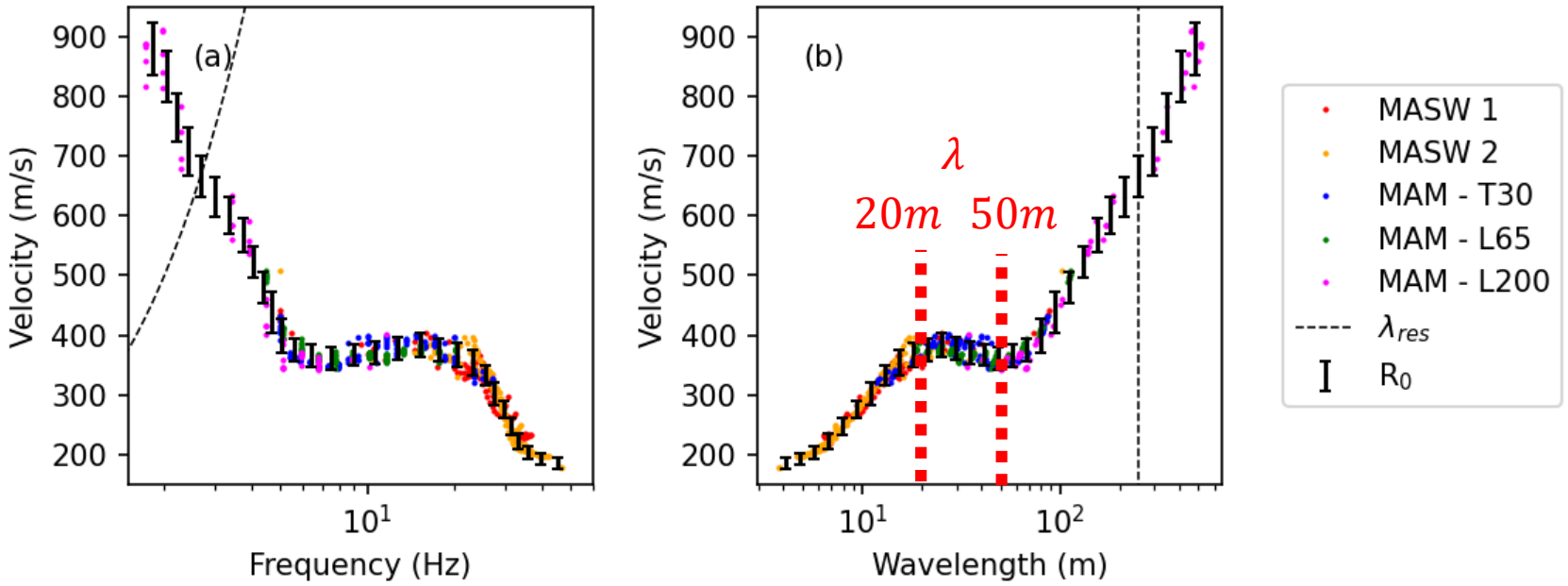
Implies depths between ~7 and 25m.



We want to be strategic in selecting at which depth we allow the reversal. We can get a rough idea of the depth by looking at the wavelengths.

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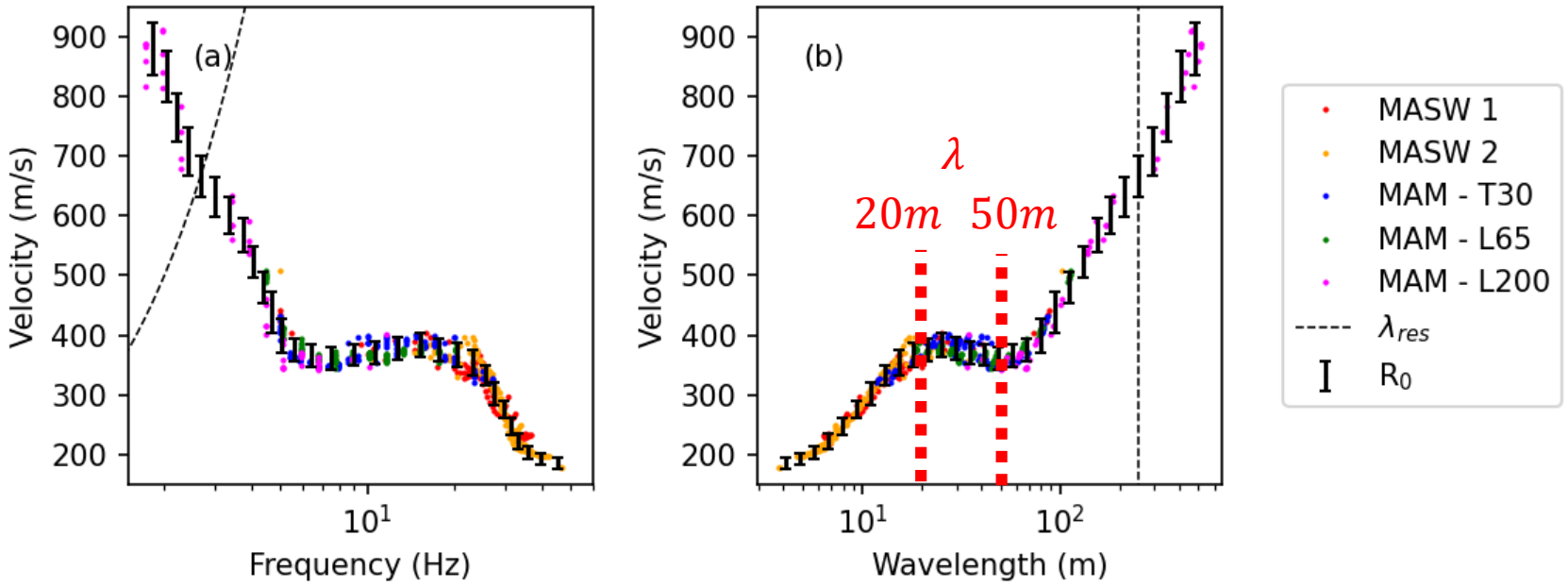
Implies depths between ~7 and 25m.



We want to be strategic in selecting at which depth we allow the reversal. We can get a rough idea of the depth by looking at the wavelengths.

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Note that the data is in the format associated with Geopsy v2.10.1

Defining the Inversion Target

Importing the Experimental Dispersion Data

1. Select the desired approach by commenting/uncommenting the appropriate line in the cell below.
2. Review the figure to ensure your data has loaded correctly, then proceed to the next cell.

Back to top

[10]:
```
# Approach 1: Import from comma seperated text file (see swprepost documentation for details).
# target = swprepost.Target.from_csv("example.csv")

# Approach 2: Import from version 2.X.X dinver-style text file (see swprepost documentation for details).
target = swprepost.Target.from_txt_dinver("AssemblyHall_R0.txt", version="2.10.1")

# Approach 3: Import from version 3.X.X dinver-style text file (see swprepost documentation for details).
# target = swprepost.Target.from_txt_dinver("example_dv3.txt", version="3.4.2")


fig, axs = plot_target(target)
print("Import successful, you may proceed.")
```


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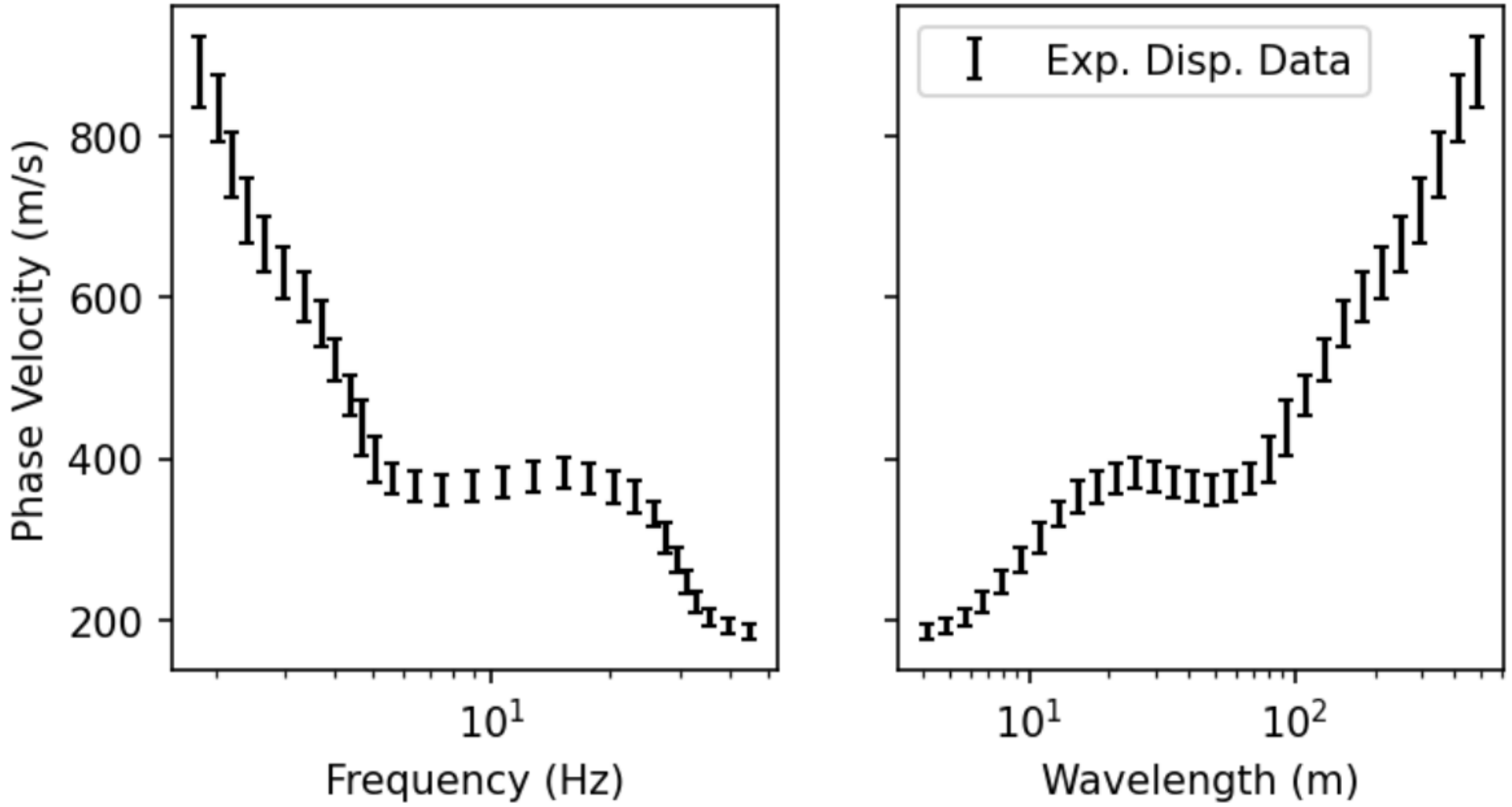

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We will save the data back out in the format associated with Geopsy v3.4.2

Save Target to Disk

After importing your experimental dispersion data and completing any desired resampling, use the cell below to create the `0_targets` directory (if it does not exist) and write your `.target` file. You can confirm that the write was sucessful by examining the created `.target` file using the Dinver graphical user interface.

[11]:
```
target_name = "tar1"          # Name of target file (no .target suffix)
version = "3.4.2"             # Version of Geopsy "2.10.1" or "3.4.2"

# Save to Disk
if os.path.isdir("0_targets/")==False:
    os.mkdir("0_targets/")
target.to_target(f"0_targets/{target_name}", version=version)

# Confirm file exists.
if os.path.exists(f"0_targets/{target_name}.target"):
    print(f"{target_name}.target exists, you may proceed.")
```

```
tar1.target exists, you may proceed.
```


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Minimum and Maximum Vs

$100 < Vs < 1500$ m/s

Minimum and Maximum Vp

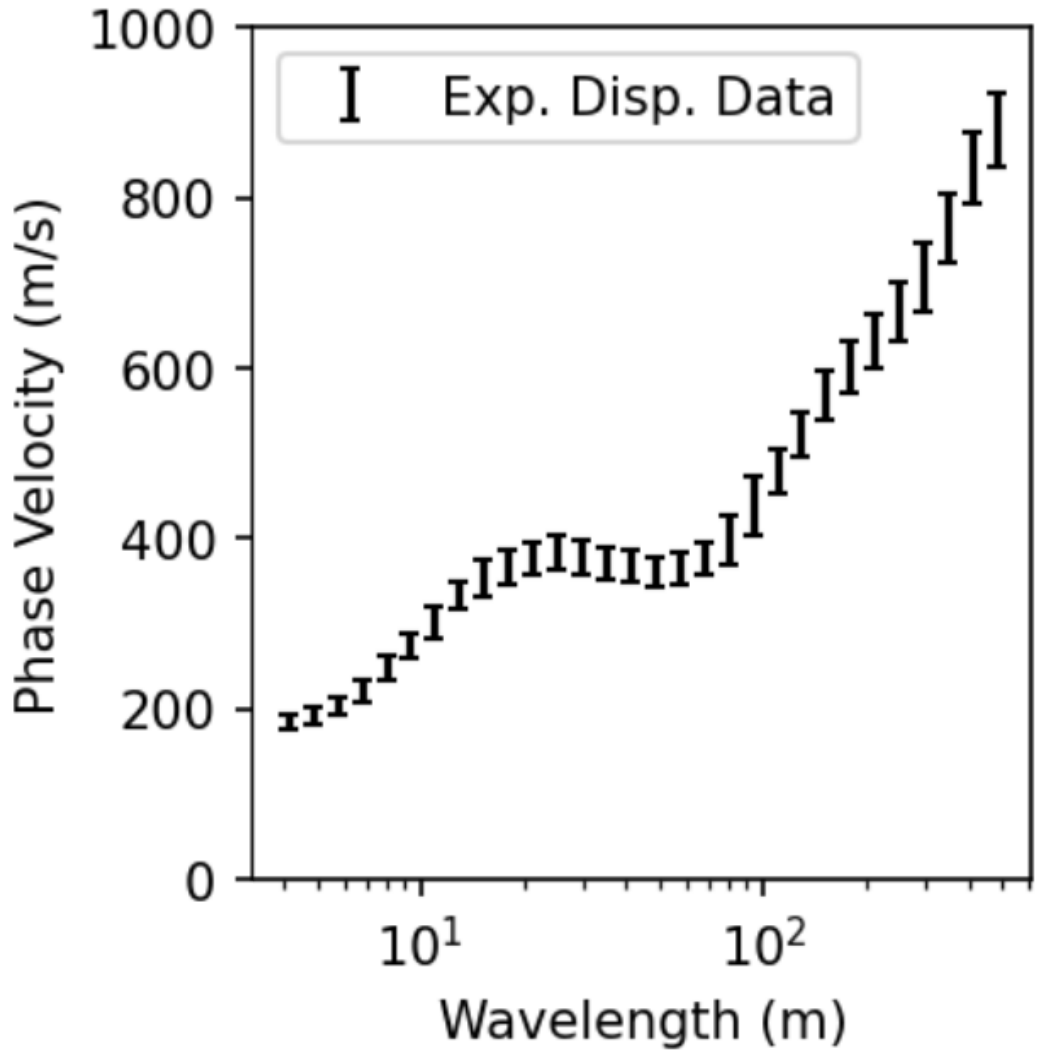
$200 < Vp < 3000$ m/s

Fix Mass Density

$\rho = 2000$ kg/m^3

$\lambda_{min} = 4\ m$ (no layer thinner than 1.3 m)

$\lambda_{max} = 500\ m$ (no deeper than 250 m)



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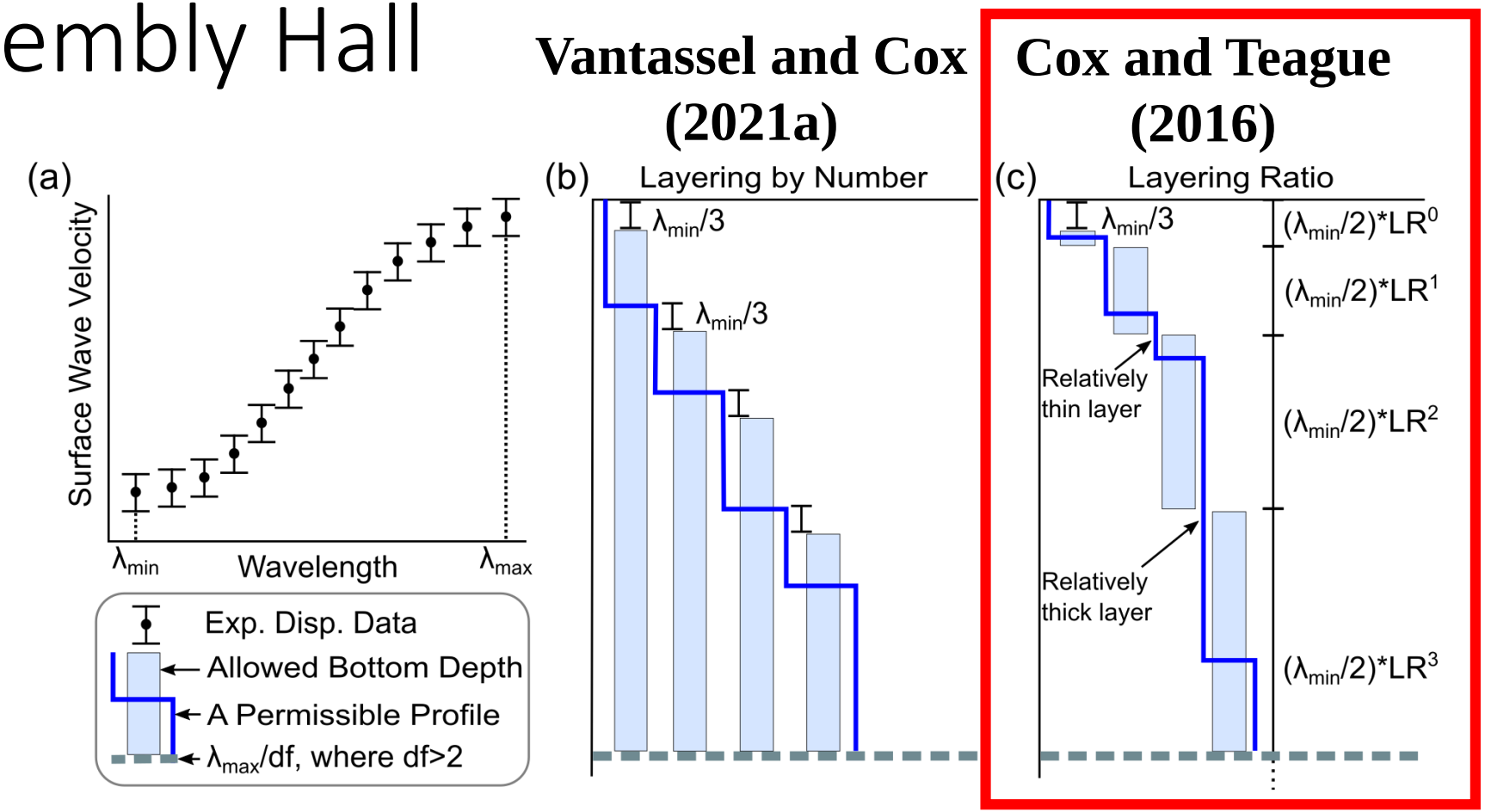

Will use Layering Ratio (LR) approach for this example. Recall both Layering by Number (LN) and Layering Ratio (LR) are valid approaches for parameterization. I know a priori that LRs are a bit easier to modify for this example.

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Will choose
LR=1.5, 2.0, 3.0, and 5.0
Will start with LR=3.0

[13]:
```
# Minimum and maximum for all parameters. Refer to detai
vp_min, vp_max, vp_dec = 200., 3000., False
vs_min, vs_max, vs_dec = 100., 1500., False
pr_min, pr_max = 0.2, 0.5
rh_min, rh_max = 2000., 2000.

# Layering by Number (LN) parameterizations to consider. Add or remove as desired.
# See Vantassel and Cox (2021) for details.
lns = []

# Layering Ratios (LRs) parameterizations to consider. Add or remove as desired.
# See Vantassel and Cox (2021) and Cox and Teague (2016) for details.
lrs = [1.5, 2.0, 3.0, 5.0]

# Depth factor, typically 2 or 3.
depth_factor = 2

# Minimum and maximum wavelength, selected from experimental disperison data by default.
wmin, wmax = min(target.wavelength), max(target.wavelength)
```


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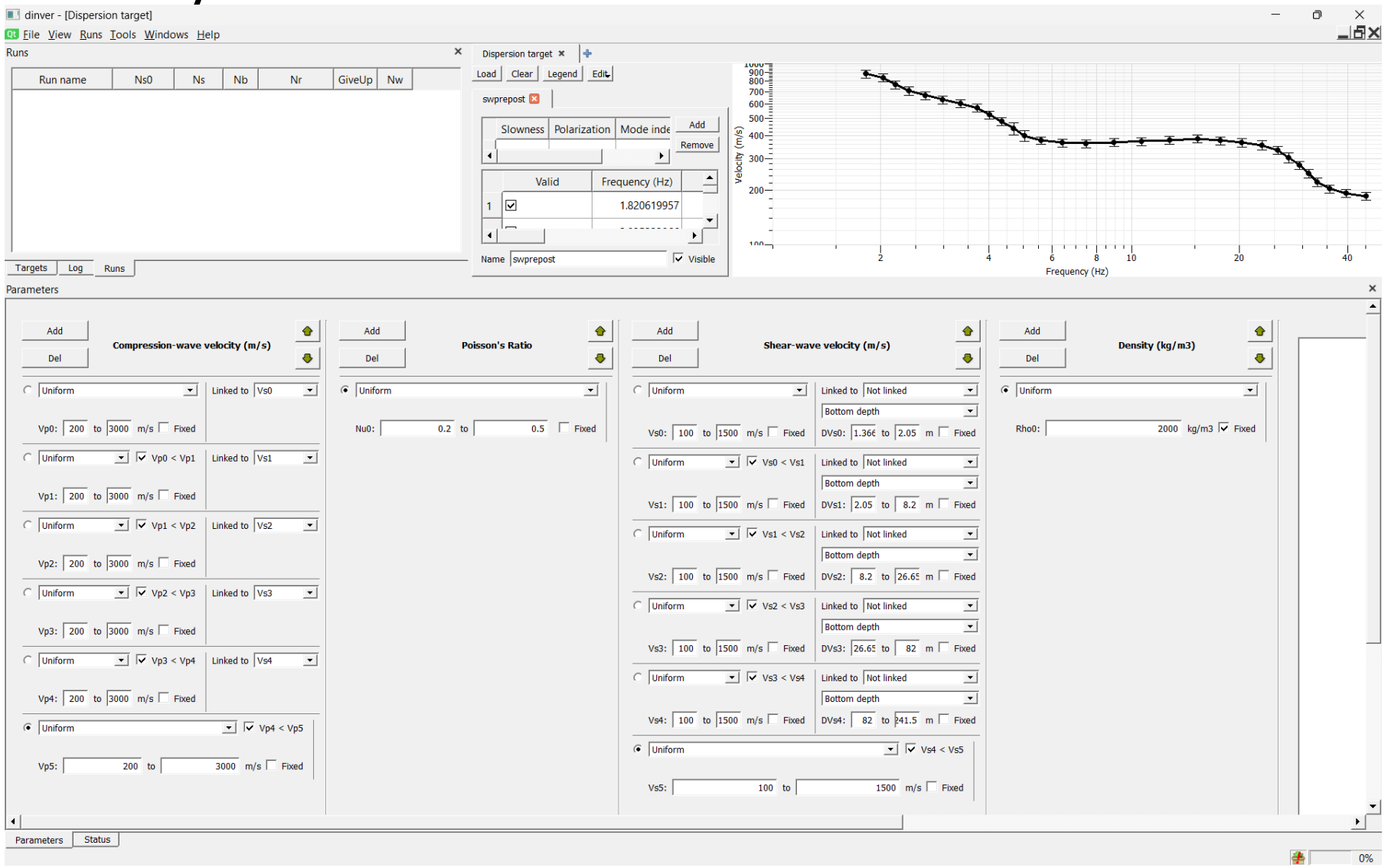

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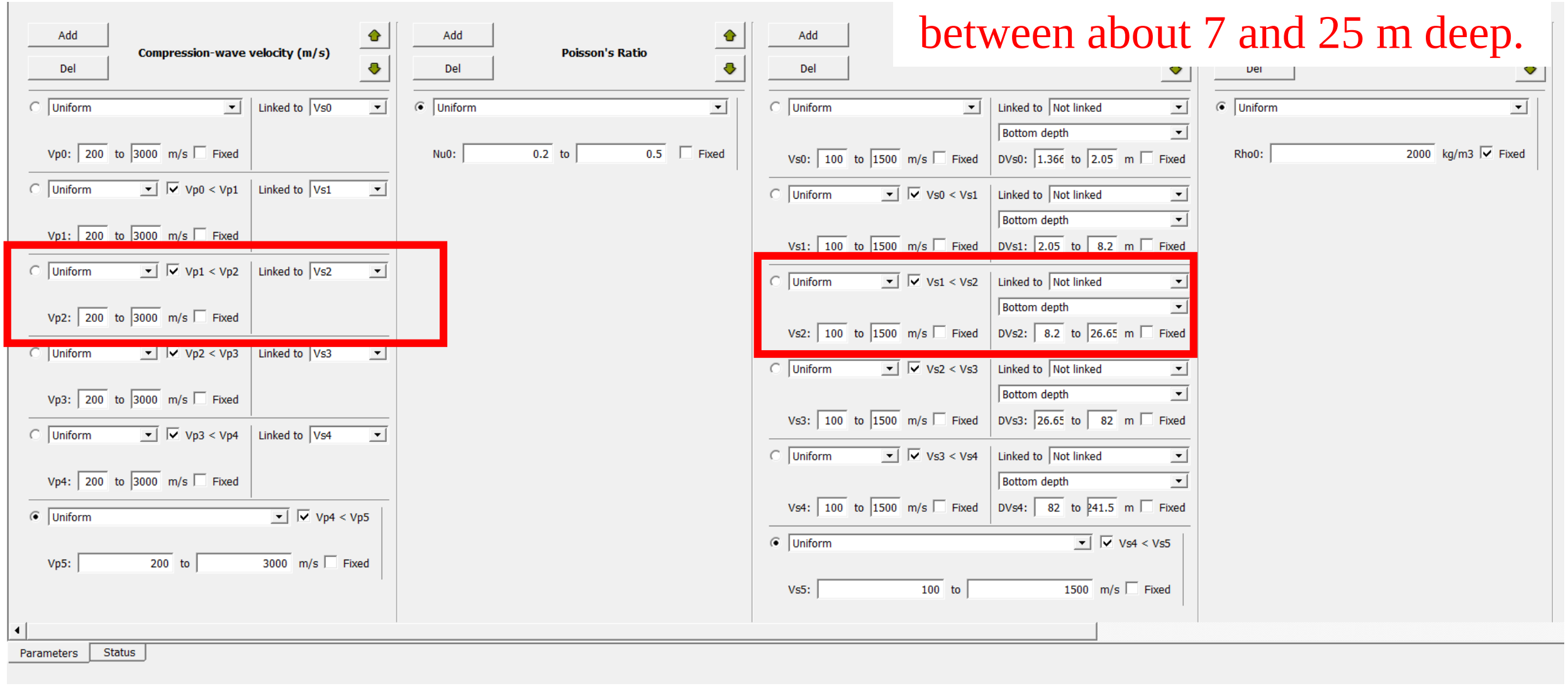
Recall we estimated the reversal between about 7 and 25 m deep.



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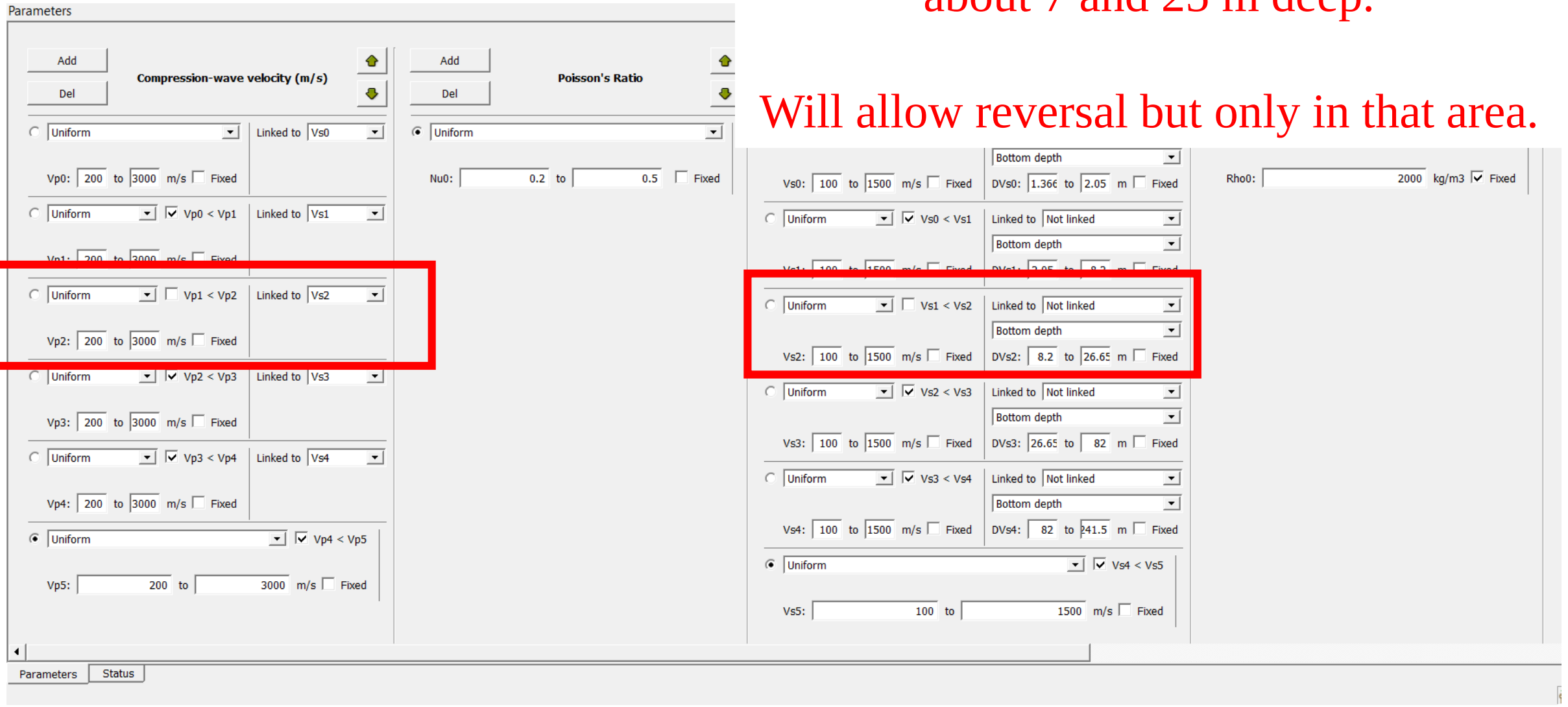
Recall we estimated the reversal between about 7 and 25 m deep.

Will allow reversal but only in that area.



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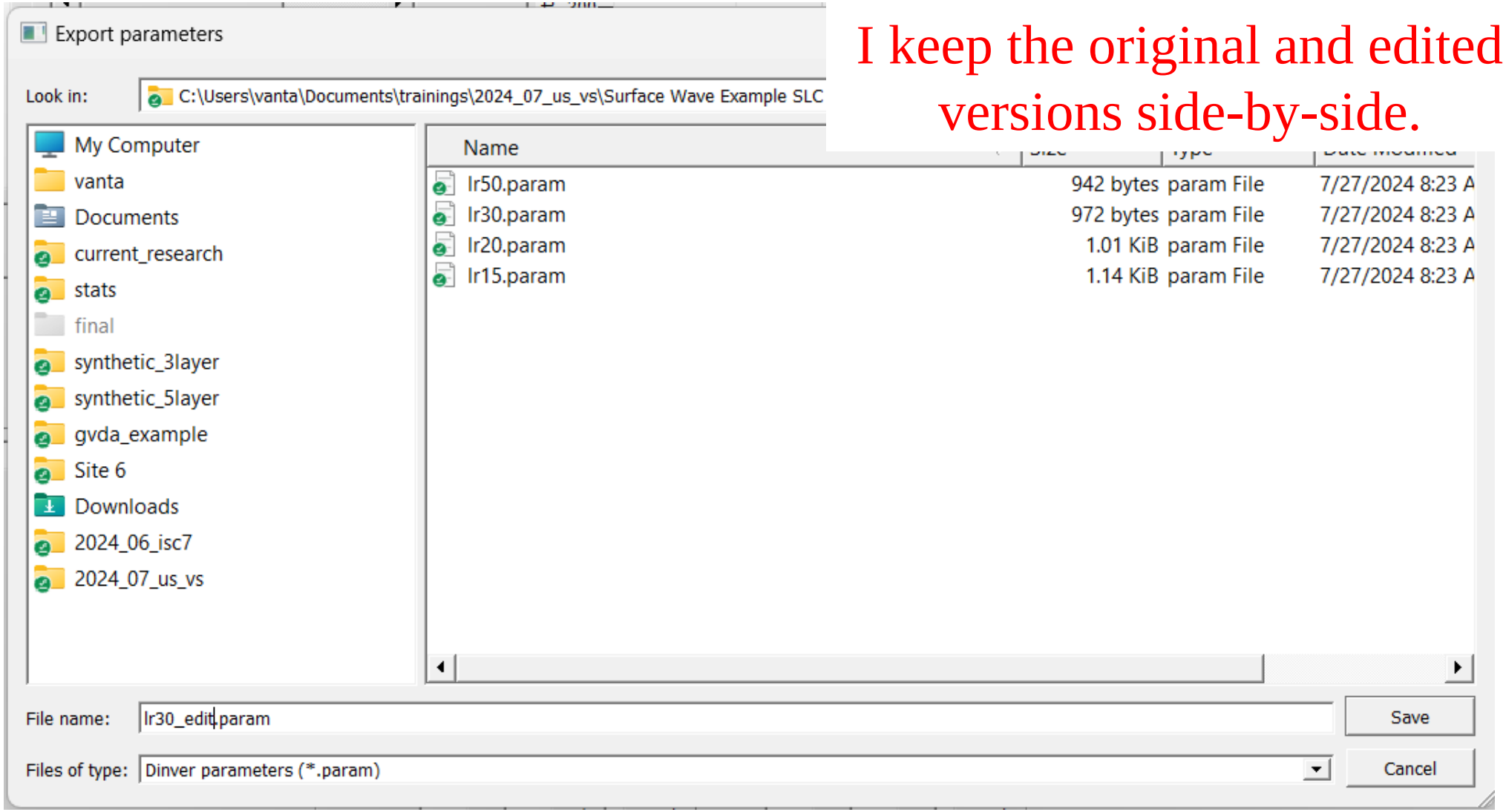

I keep the original and edited versions side-by-side.

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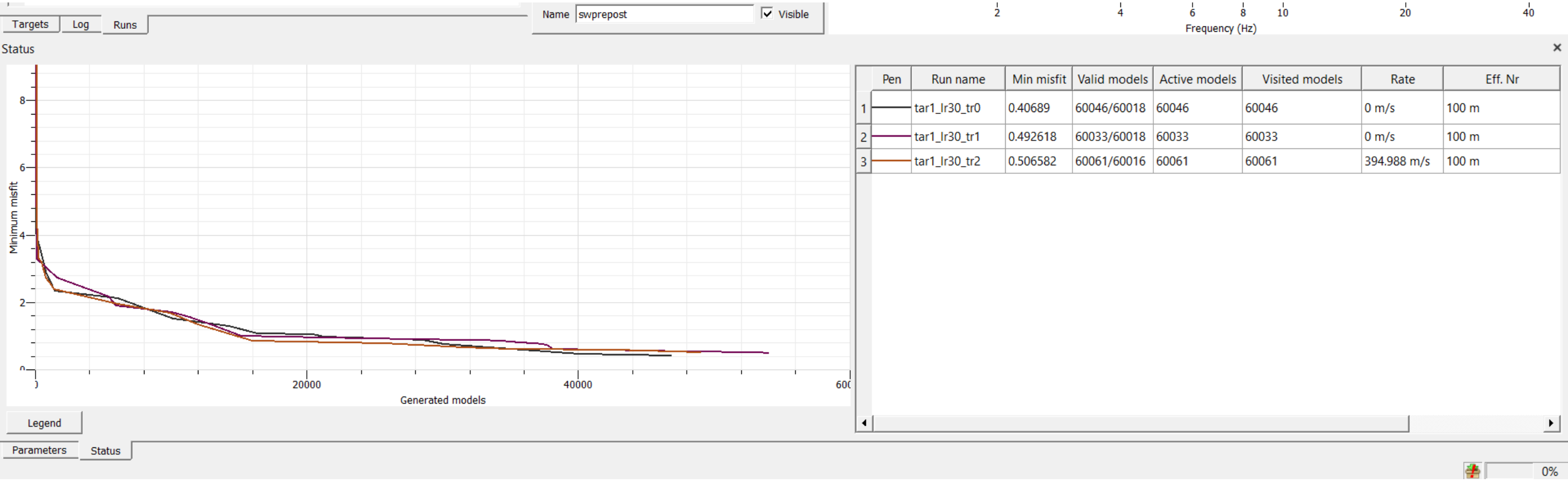

	Pen	Run name	Min misfit	Valid models	Active models	Visited models	Rate	Eff. Nr
1		tar1_lr30_tr0	0.40689	60046/60018	60046	60046	0 m/s	100 m
2		tar1_lr30_tr1	0.492618	60033/60018	60033	60033	0 m/s	100 m
3		tar1_lr30_tr2	0.506582	60061/60016	60061	60061	394.988 m/s	100 m

We do not get very low dispersion misfits like we saw at CUSSO. Data is more complicated and harder to fit.

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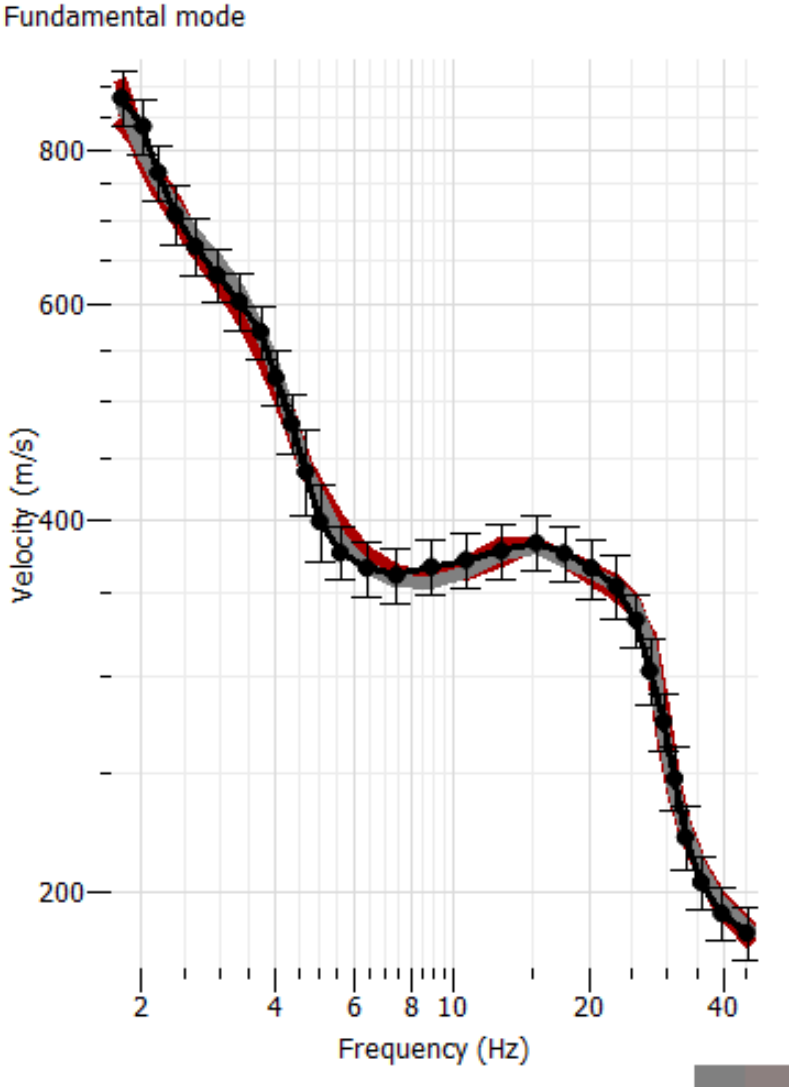

Nonetheless, the fits we are getting are reasonable.

So very important to look at the experimental and theoretical data side-by-side.

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	Pen	Run name	Min misfit	Valid models	Active models	Visited models	Rate	Eff. Nr
1		tar1_lr30_tr0	0.331191	120094/120...	120094	120095	0 m/s	100 m
2		tar1_lr30_tr1	0.381114	120062/120...	120062	120062	0 m/s	100 m
3		tar1_lr30_tr2	0.332511	120119/120...	120119	120119	31.9693 m/s	100 m

But we can also increase the number of models we search if we think the interpretation is good, but more searching is required.

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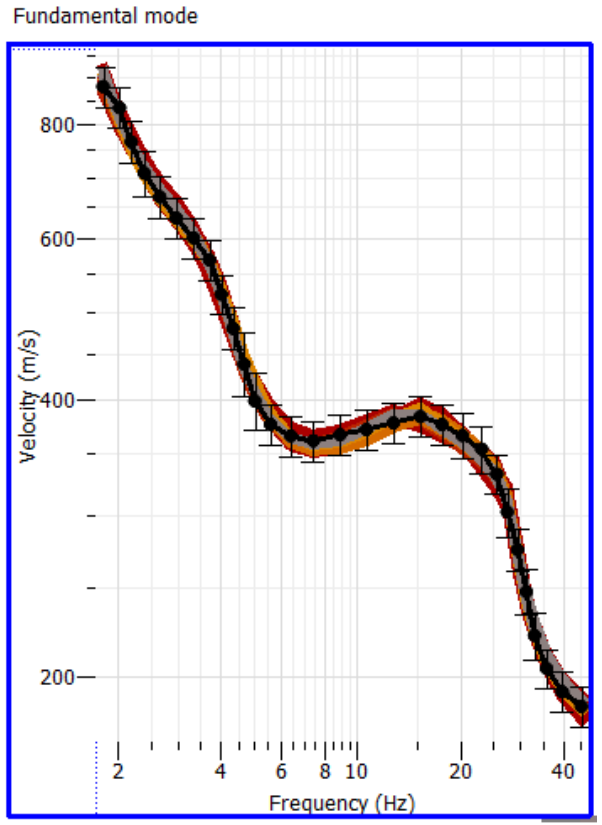

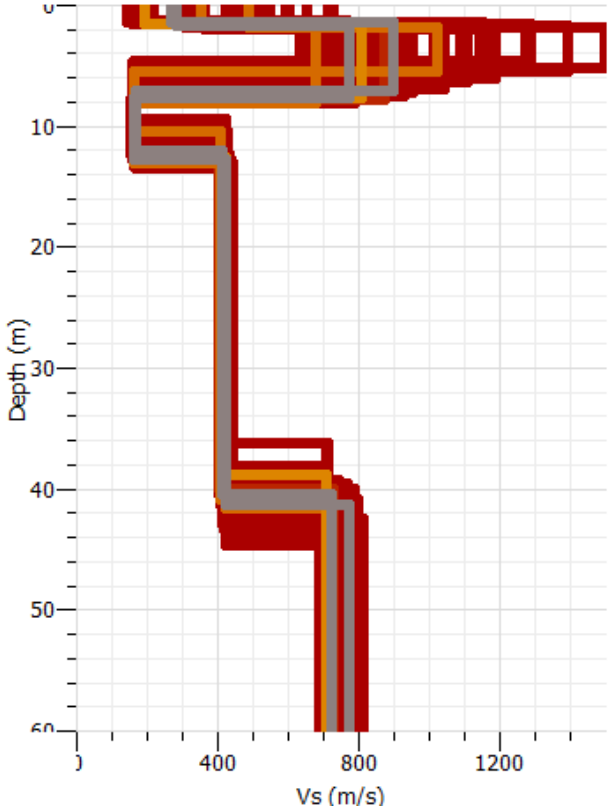

Here is our first attempt results.
What do we think?

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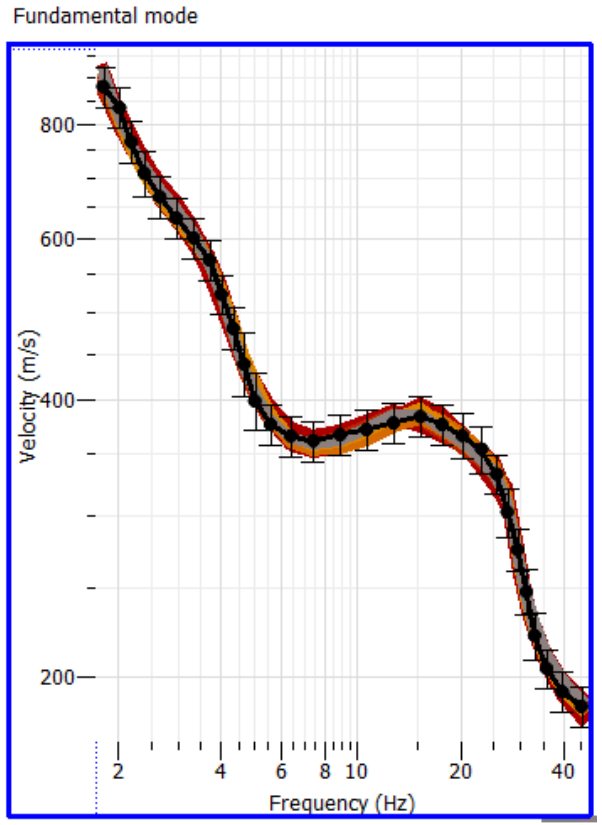
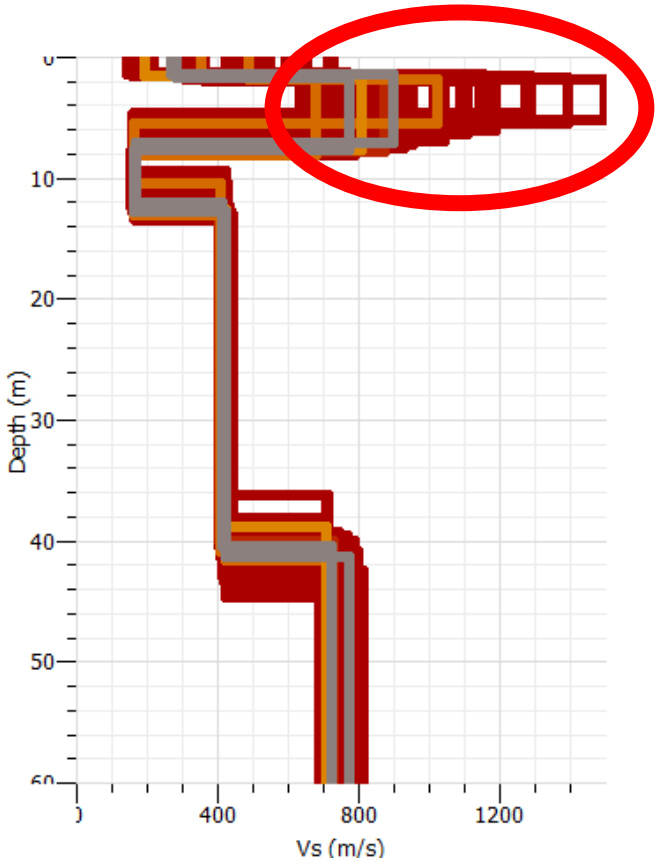
Good fit to data.





But this is a bit suspicious.

Have maximum Vs followed by minimum Vs.

What can we do?
Further constrain inversion using Geology and local site information.

Here is our first attempt results.
What do we think?

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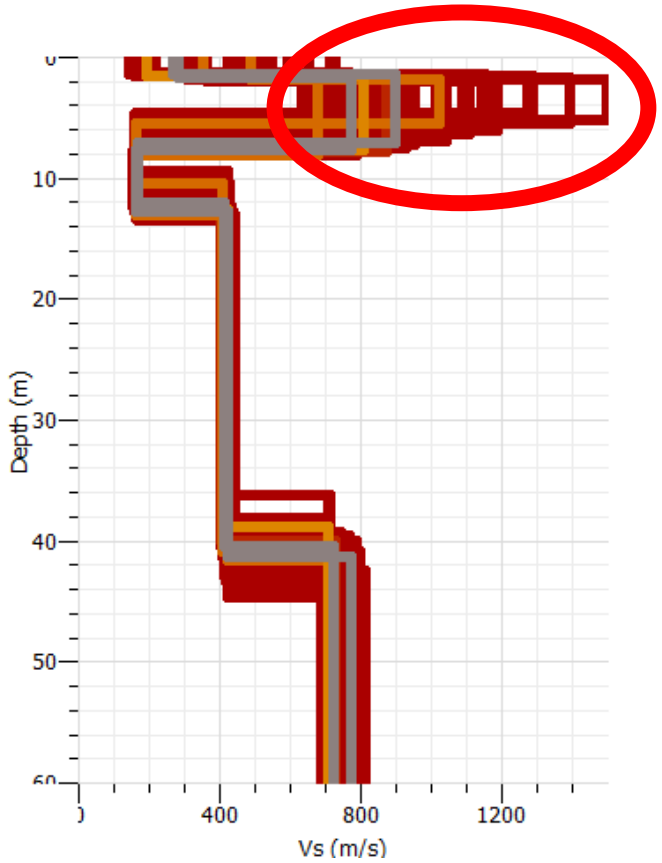
Good fit to data.



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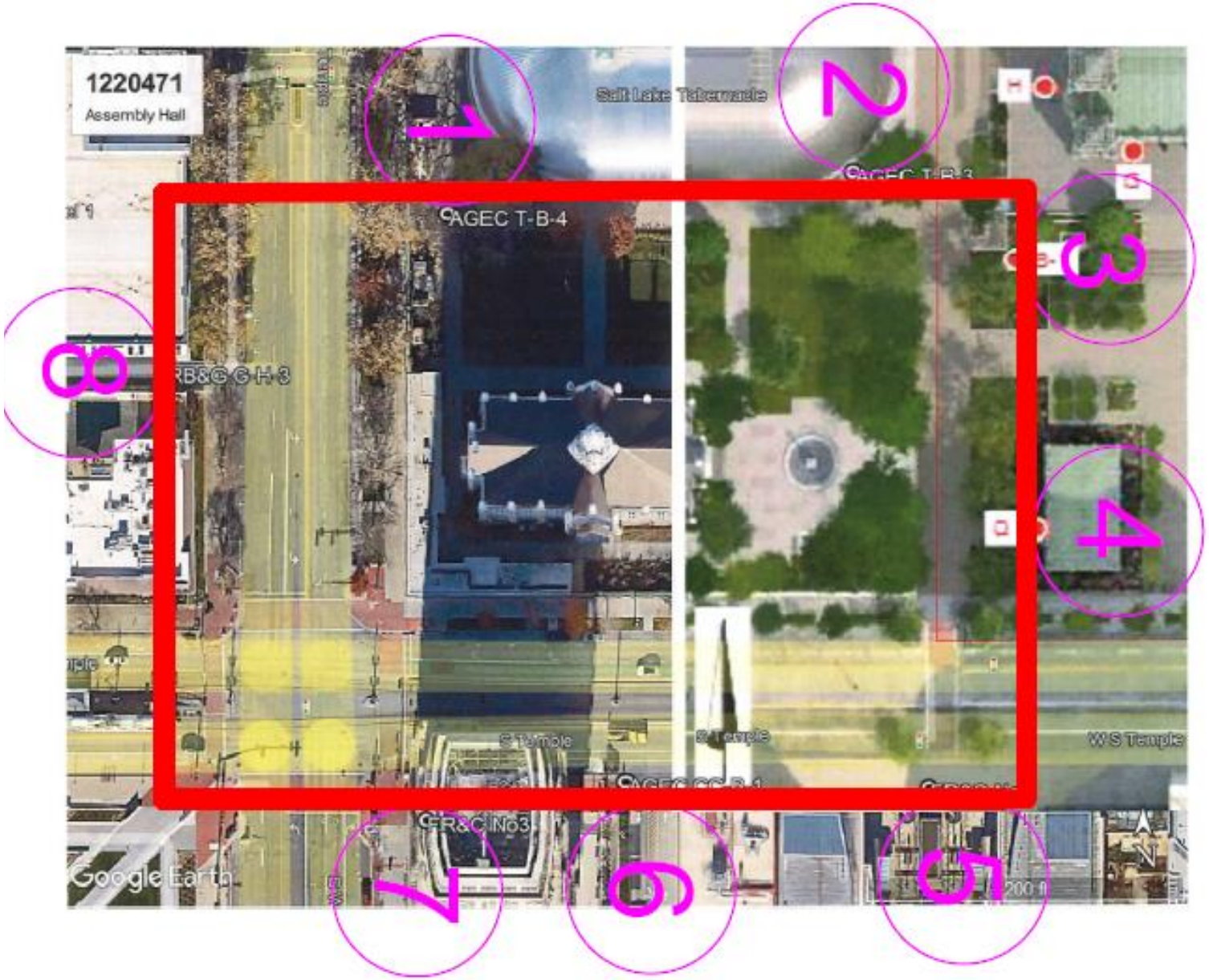
We have invasive data at the SLC.

Lets look at how we could have used that in our inversion to better constrain our depths.



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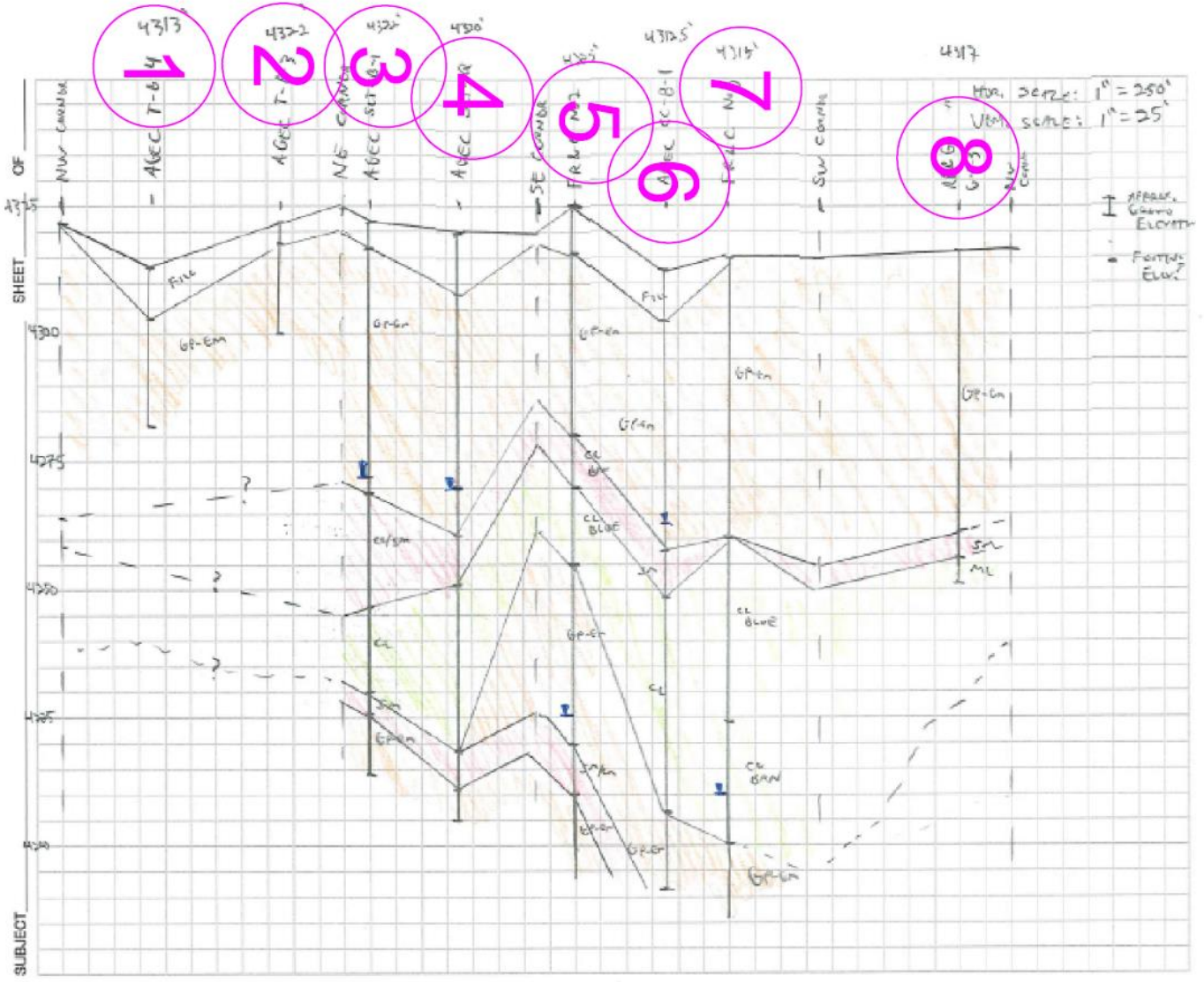
Fence diagram that wraps the site.

For surface wave inversion we need some broad average values that we can use in our 1D inversion.



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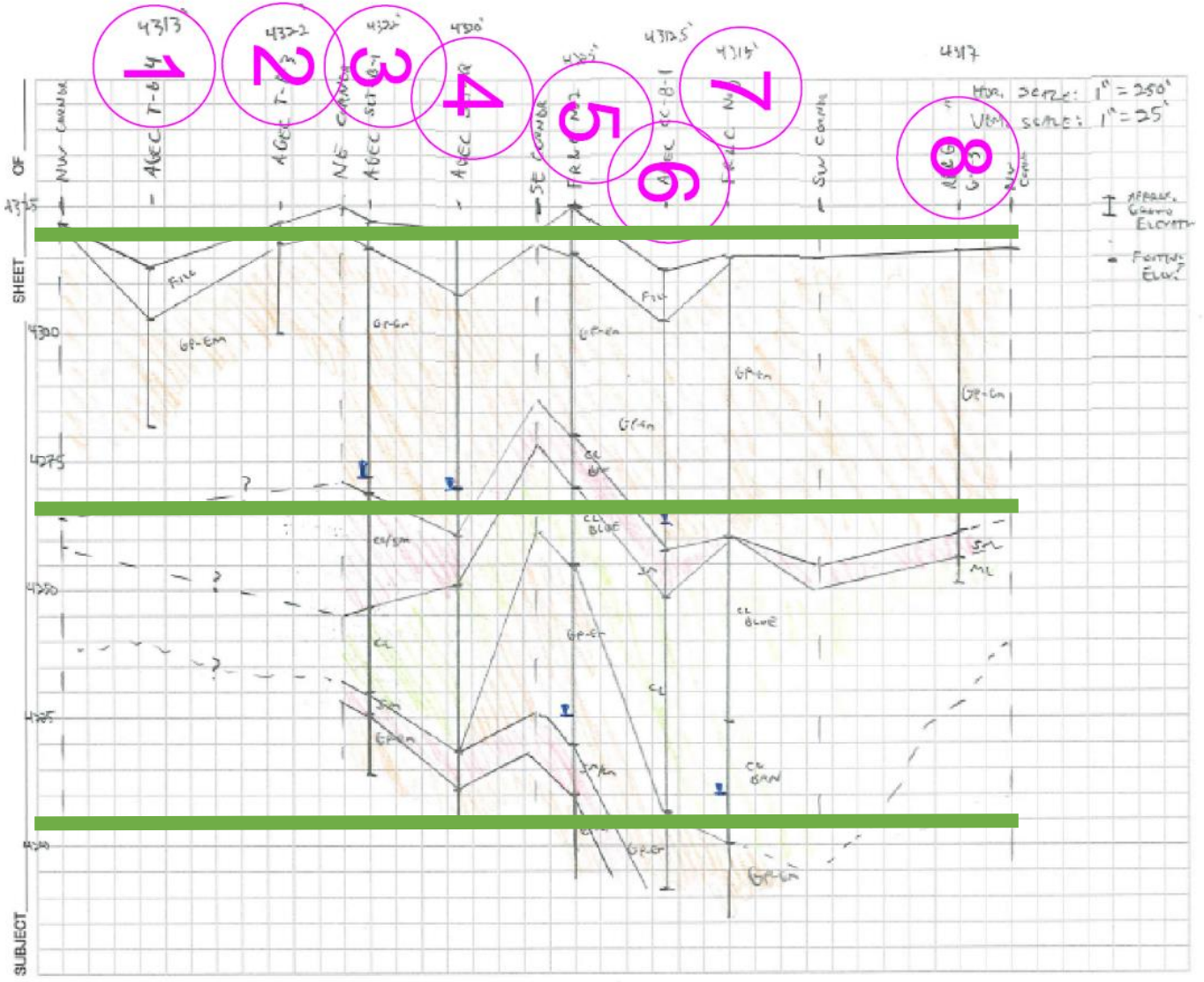
Ground Surface ELEV = 4320 ft

Bottom of Gravel ELEV = 4265 ft

Bottom of Clay ELEV = 4205 ft



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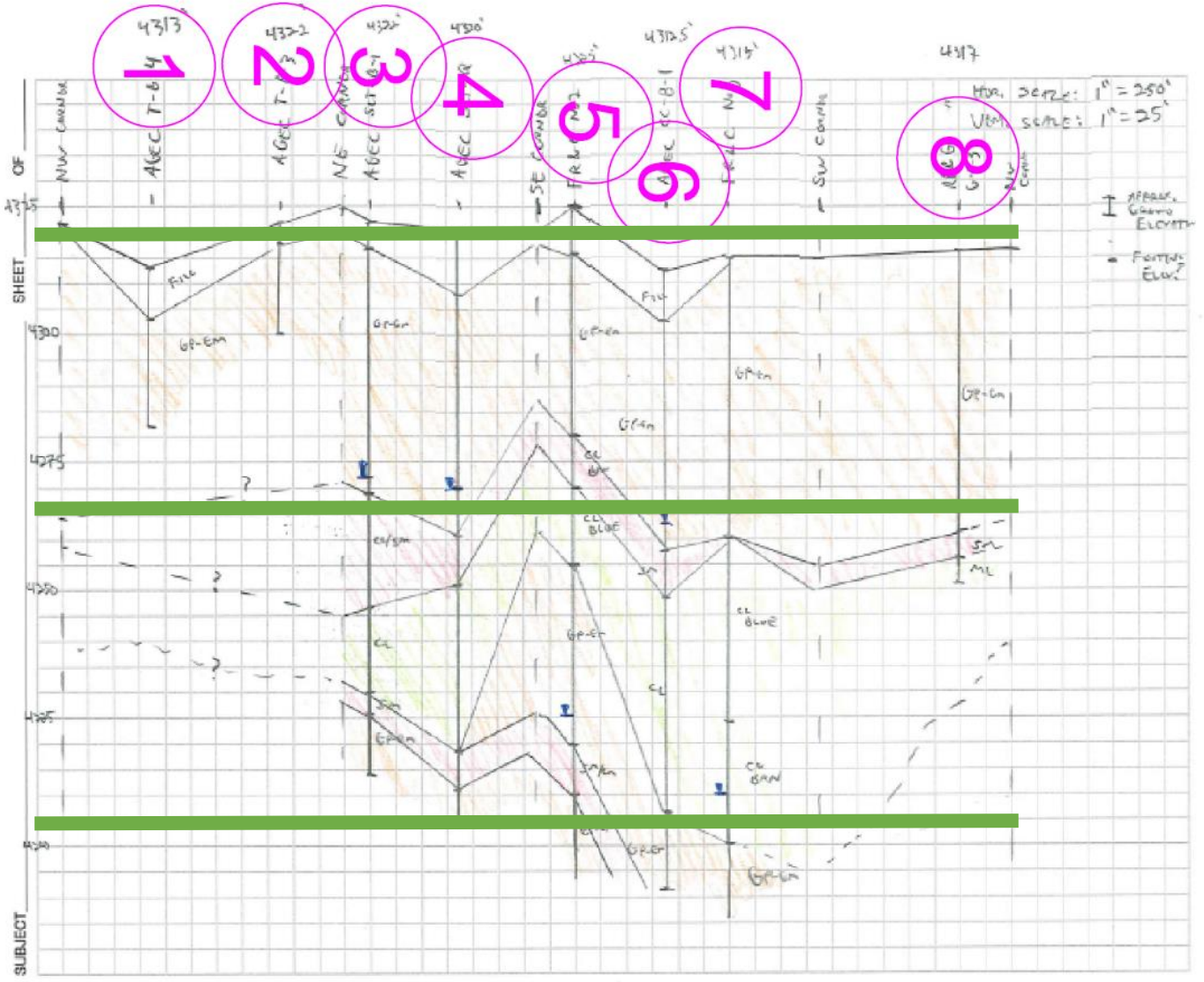
~ 16 m Gravel

~ 18 m Clay



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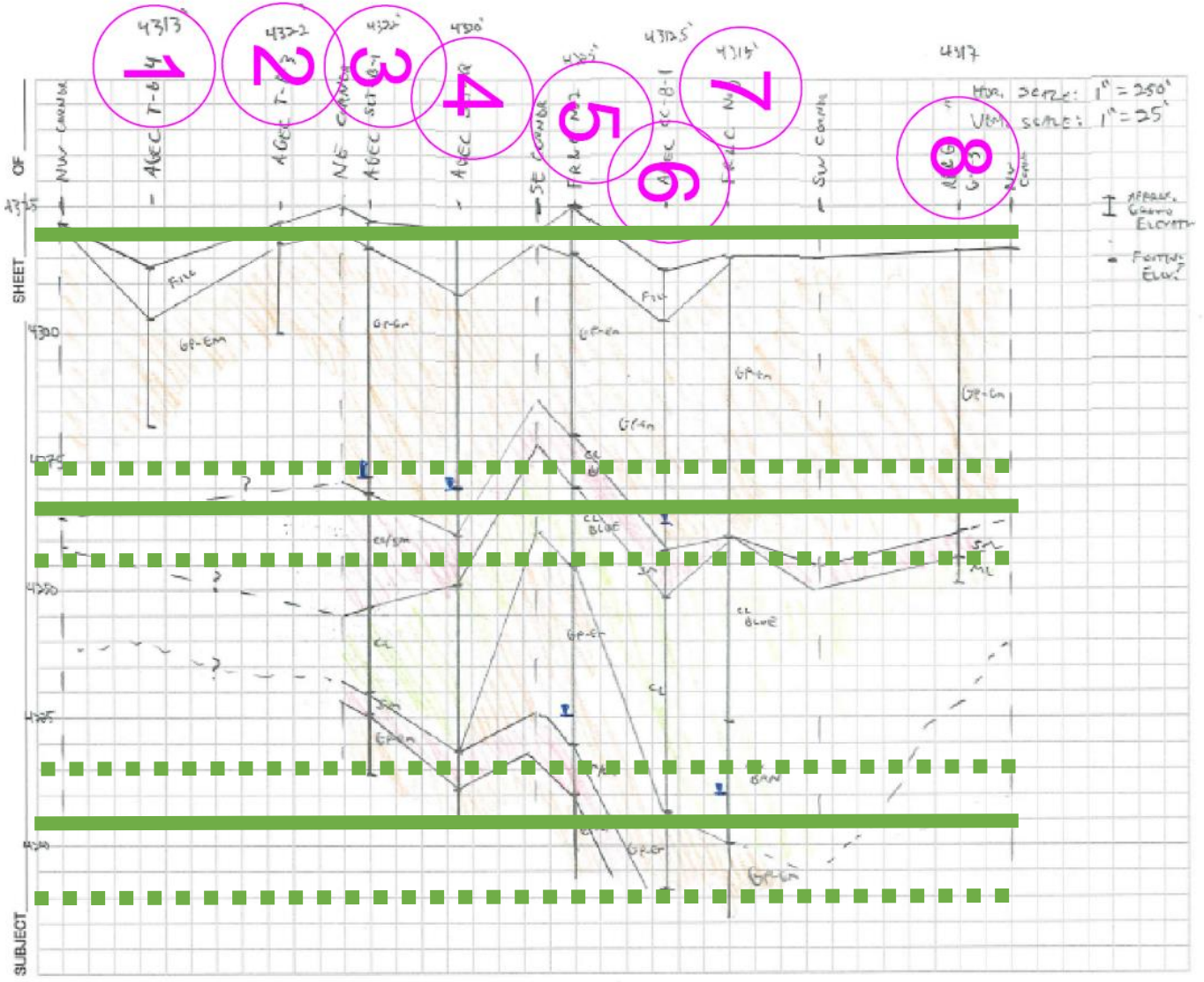

~ 14 m

~ 23 m

Approximate Depths

~ 32 m

~ 40 m

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Reference Vs Profiles

$V_s = A_s(\sigma'o/Pa)^{n_s}$

where:
Vs = shear wave velocity at any depth/confining pressure
As = reference shear wave velocity at one atmosphere of mean effective stress confining pressure
σ'o = mean effective stress at any depth/confining pressure
Pa = atmospheric pressure in same units as σ'o
n_s = stress exponent of normalized mean effective stress (often assumed = 0.25)

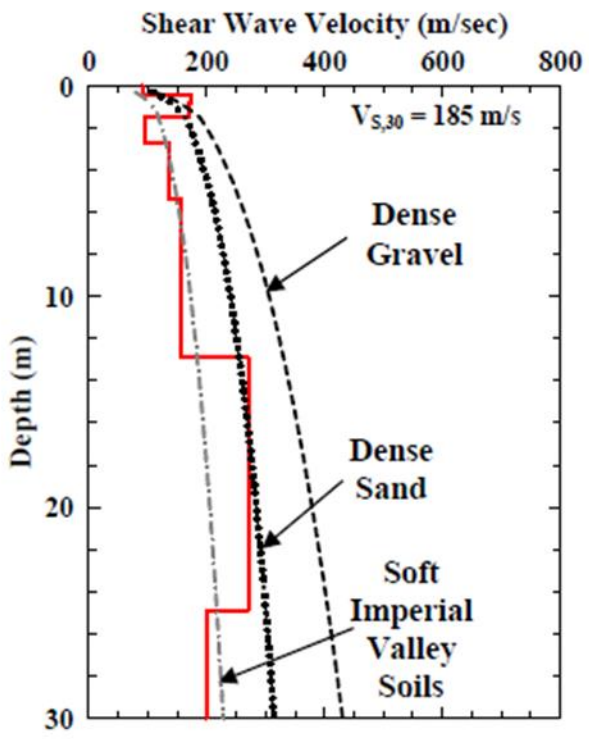
Soil Type	$V_{s,ref}$ or A_s (m/s)	n_s
Soft Clay	103	0.273
Medium Clay	192	0.273
Loose Sand	148	0.266
Medium Sand	230	0.266
Dense Sand	255	0.261
Dense Gravel	312	0.331

Menq (2003), Lin et al. (2014), Rahimi et al. (2019)

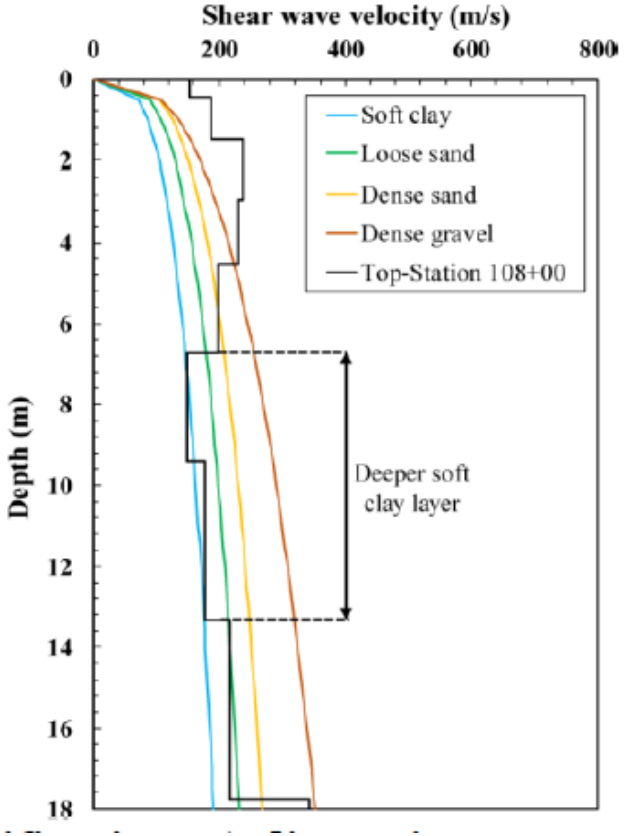
$\sigma'_0 = \frac{\sigma'_v + 2K_0\sigma'_v}{3}$; if $K_0 \sim 0.5$ then $\sigma'_0 = \frac{2\,\sigma'_v}{3}$

where σ'_v = vertical effective stress

Lin et al. (2014)



Rahimi et al. (2019)



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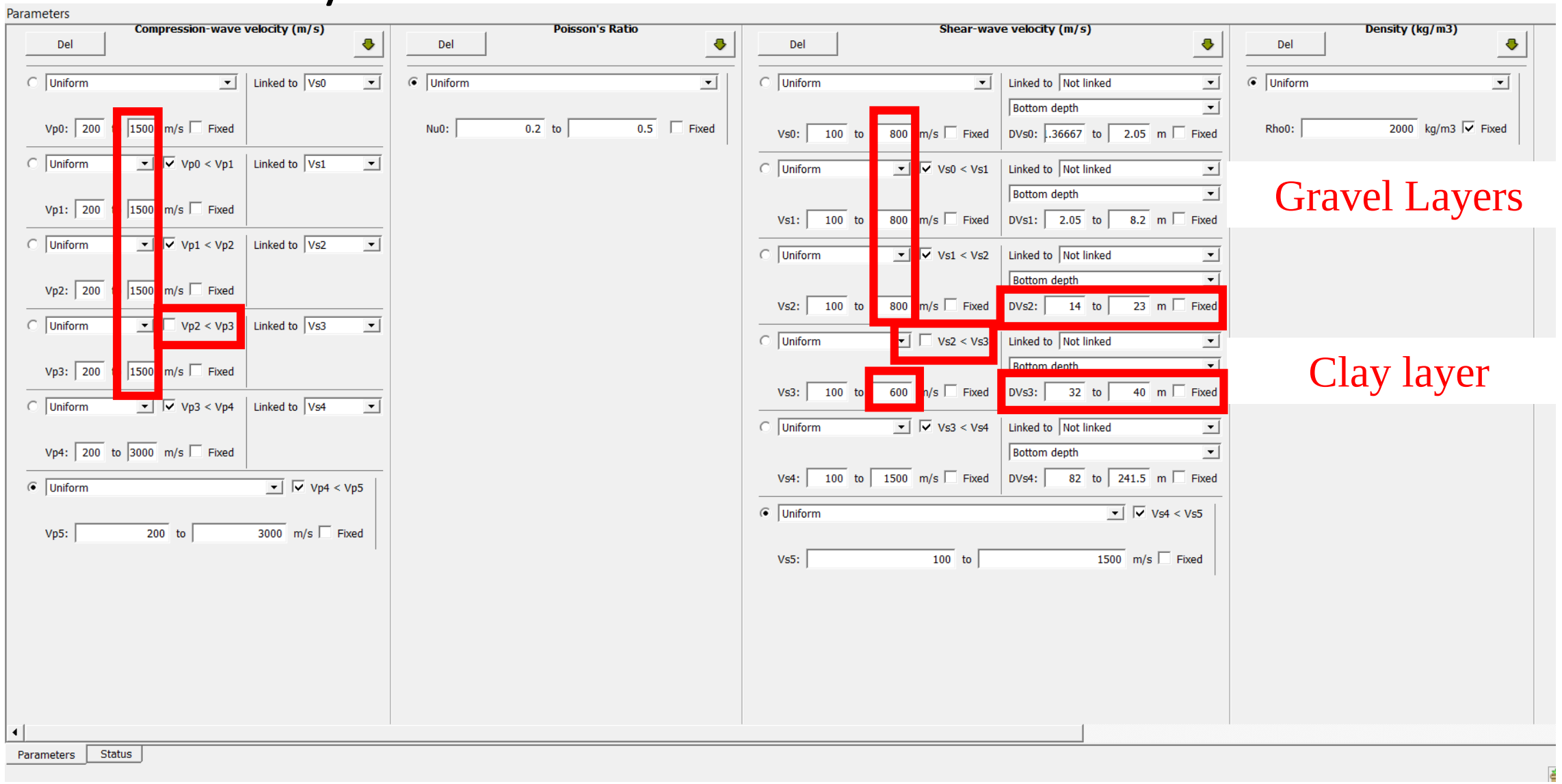

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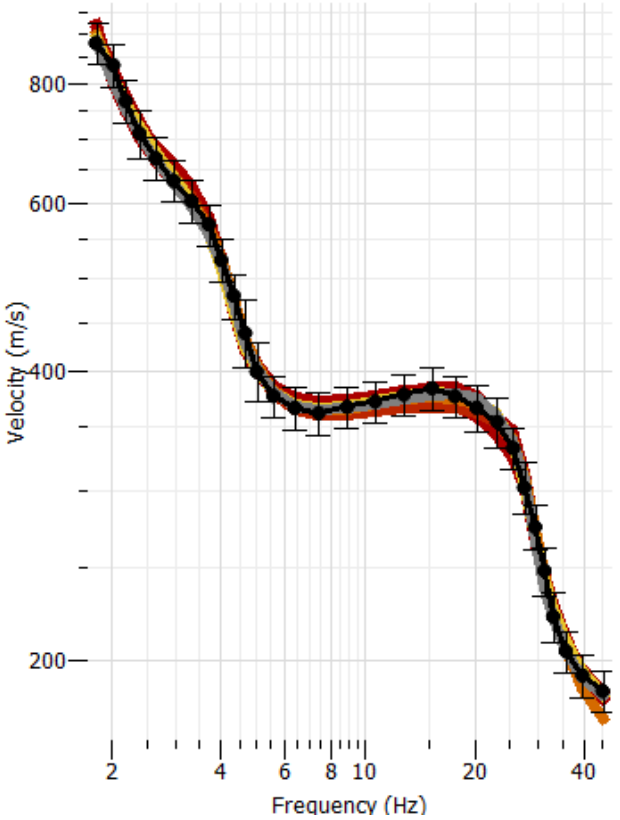

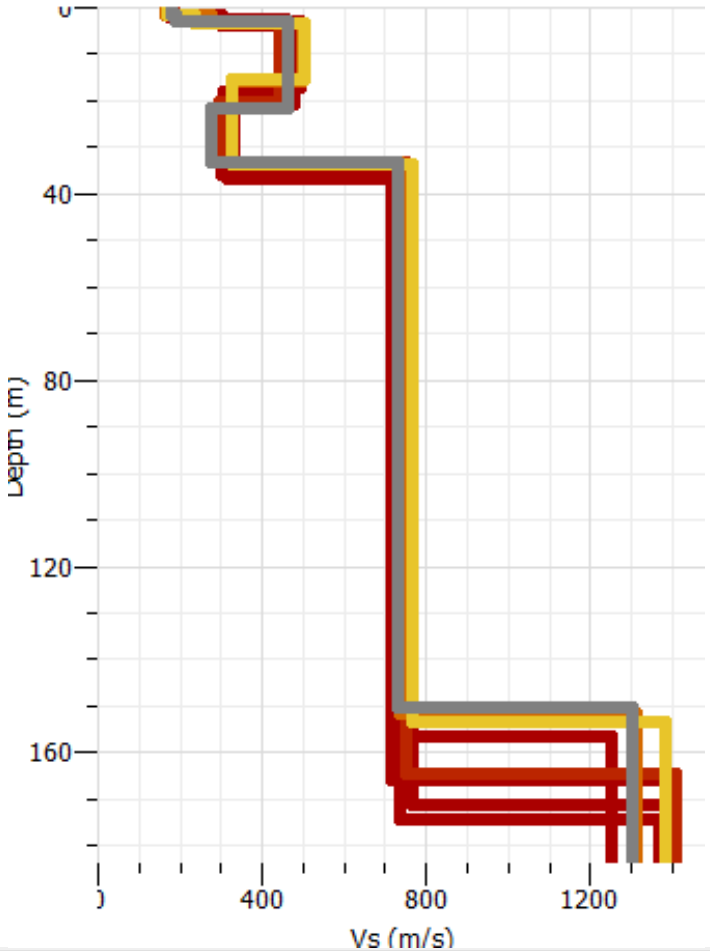

	Pen	Run name	Min misfit	Valid models	Active models	Visited models	Rate	Eff. Nr	Rejected	Give up
1		tar1_lr30_tr0	0.320875	60027/60016	60027	60030	0 m/s	100 m	3 m	0 m
2		tar1_lr30_tr1	0.386364	60026/60015	60026	60027	0 m/s	100 m	1 m	0 m
3		tar1_lr30_tr2	0.38681	60034/60016	60034	60036	0 m/s	100 m	2 m	0 m

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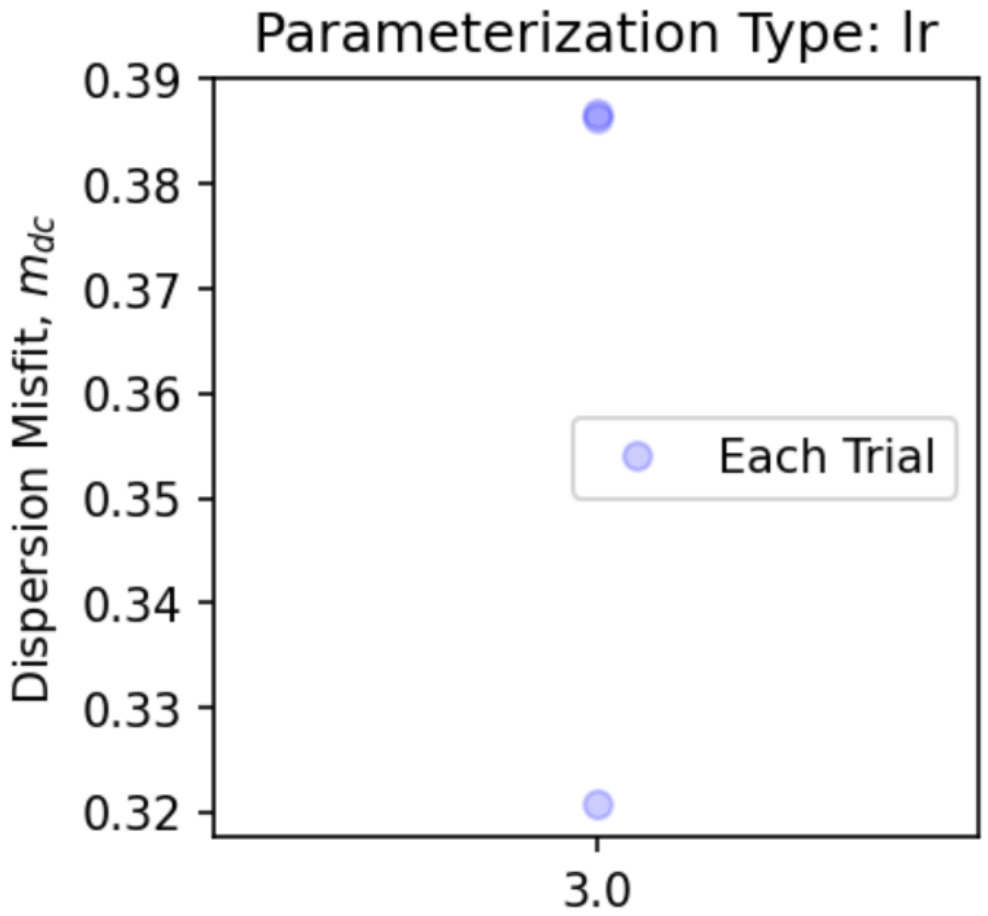

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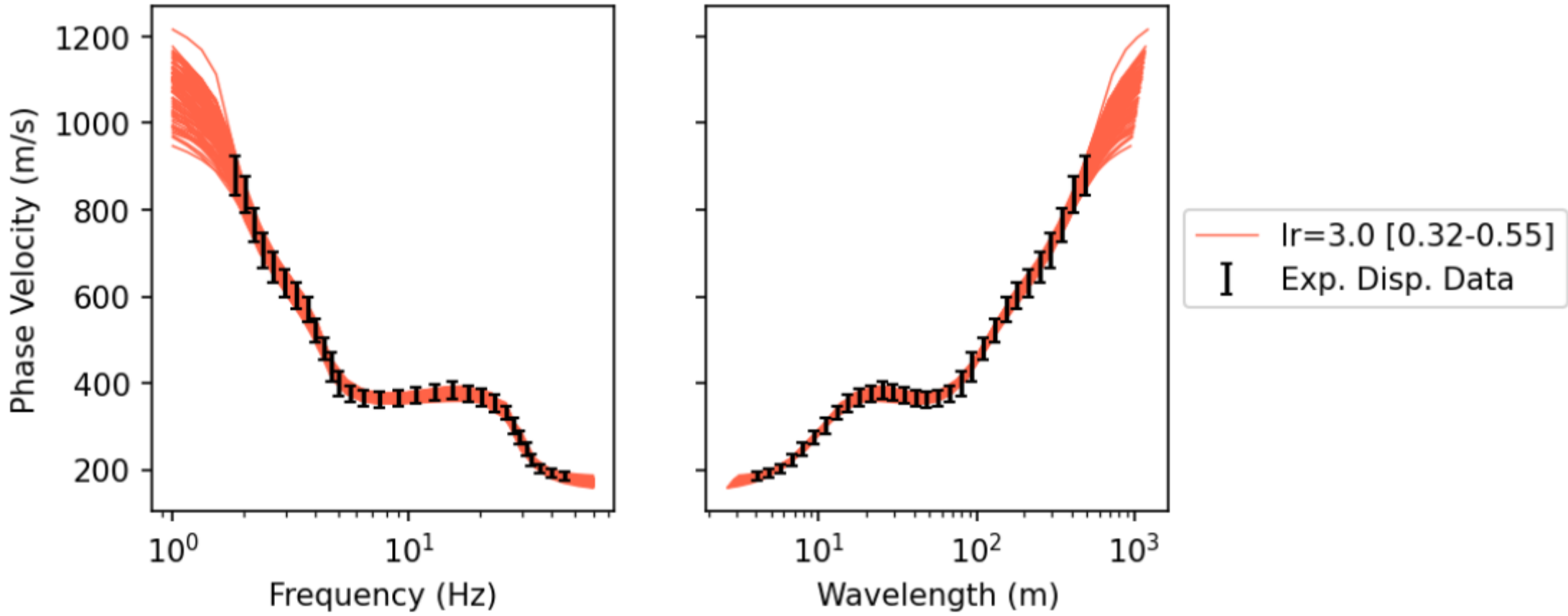

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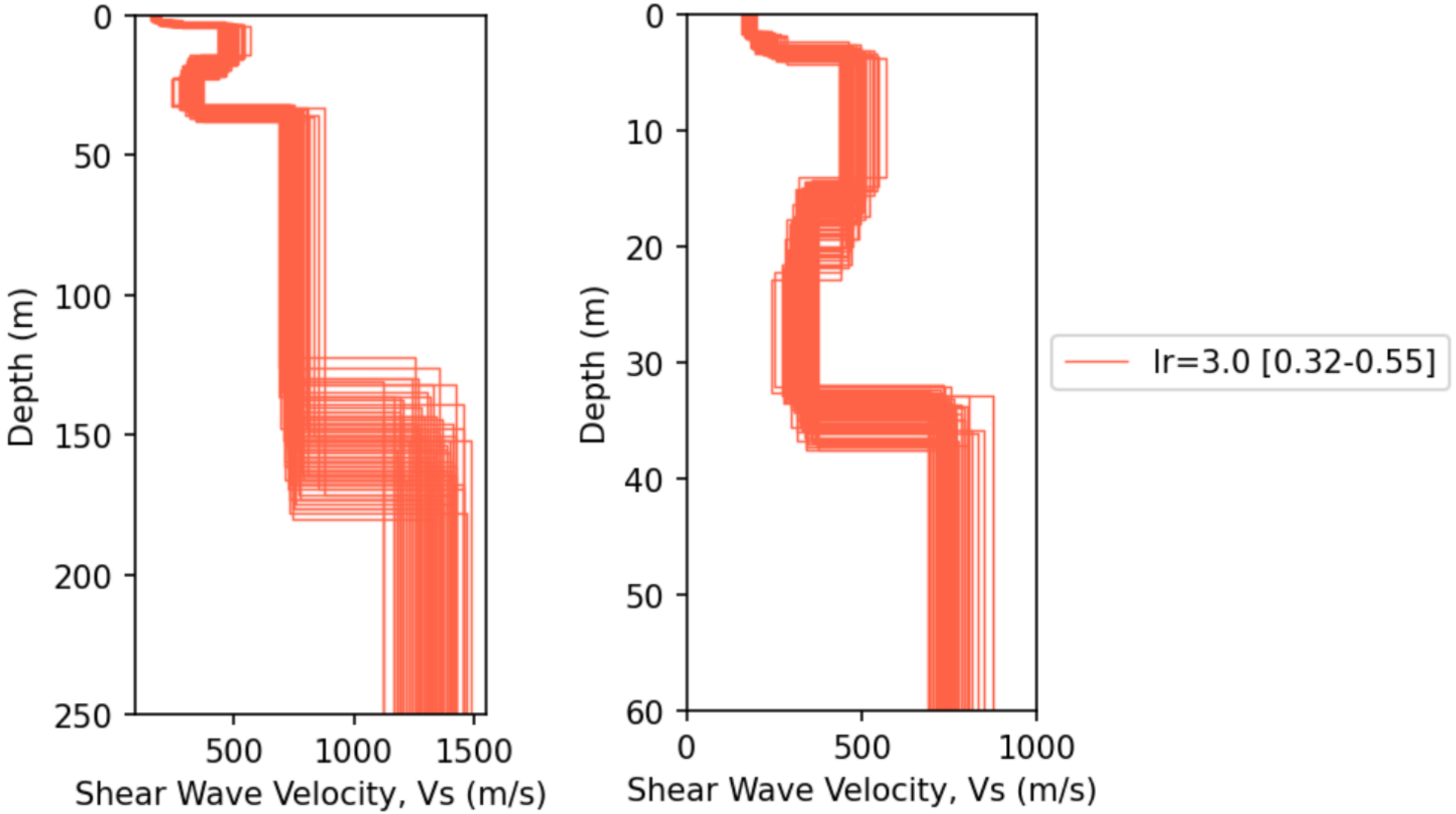

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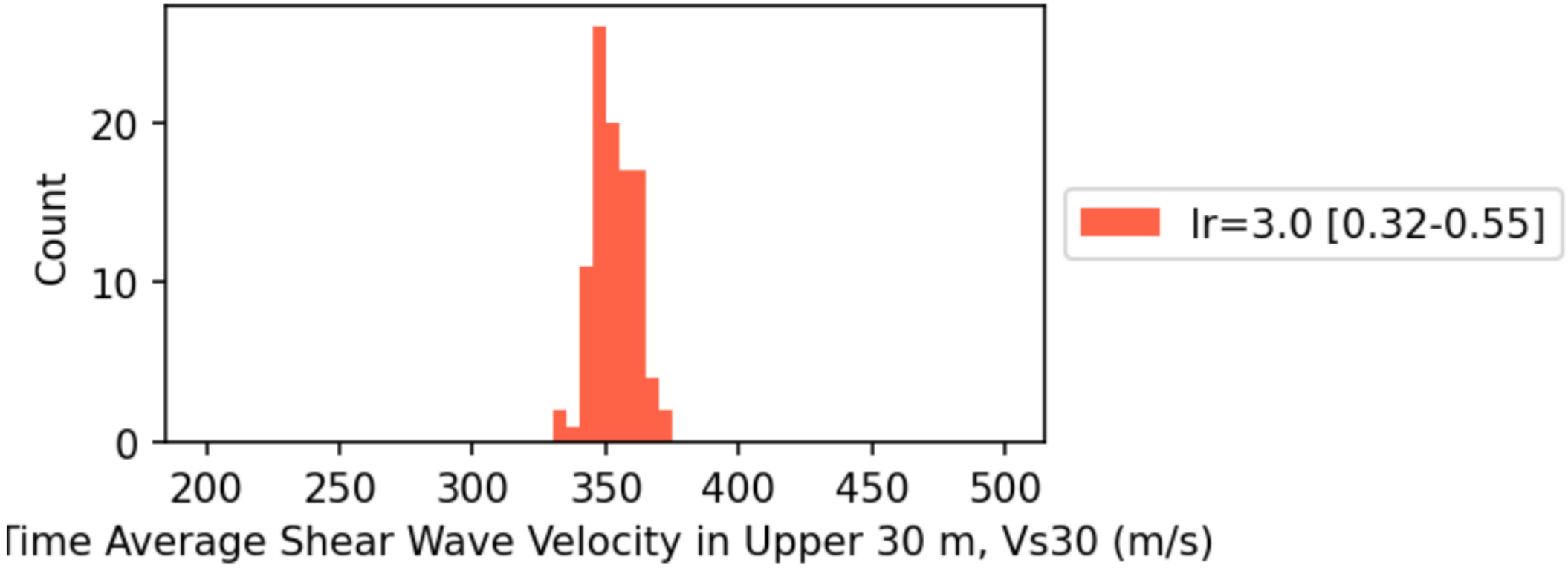

Mean Vs30: 353 m/s
Standard Deviation of Vs30: 8 m/s

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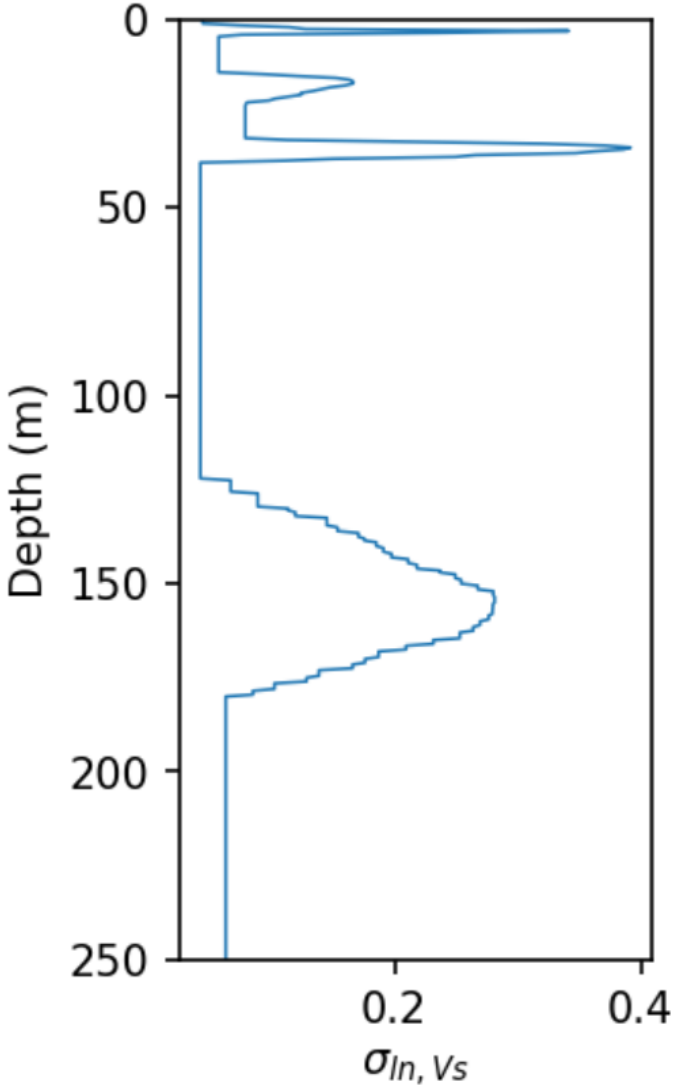

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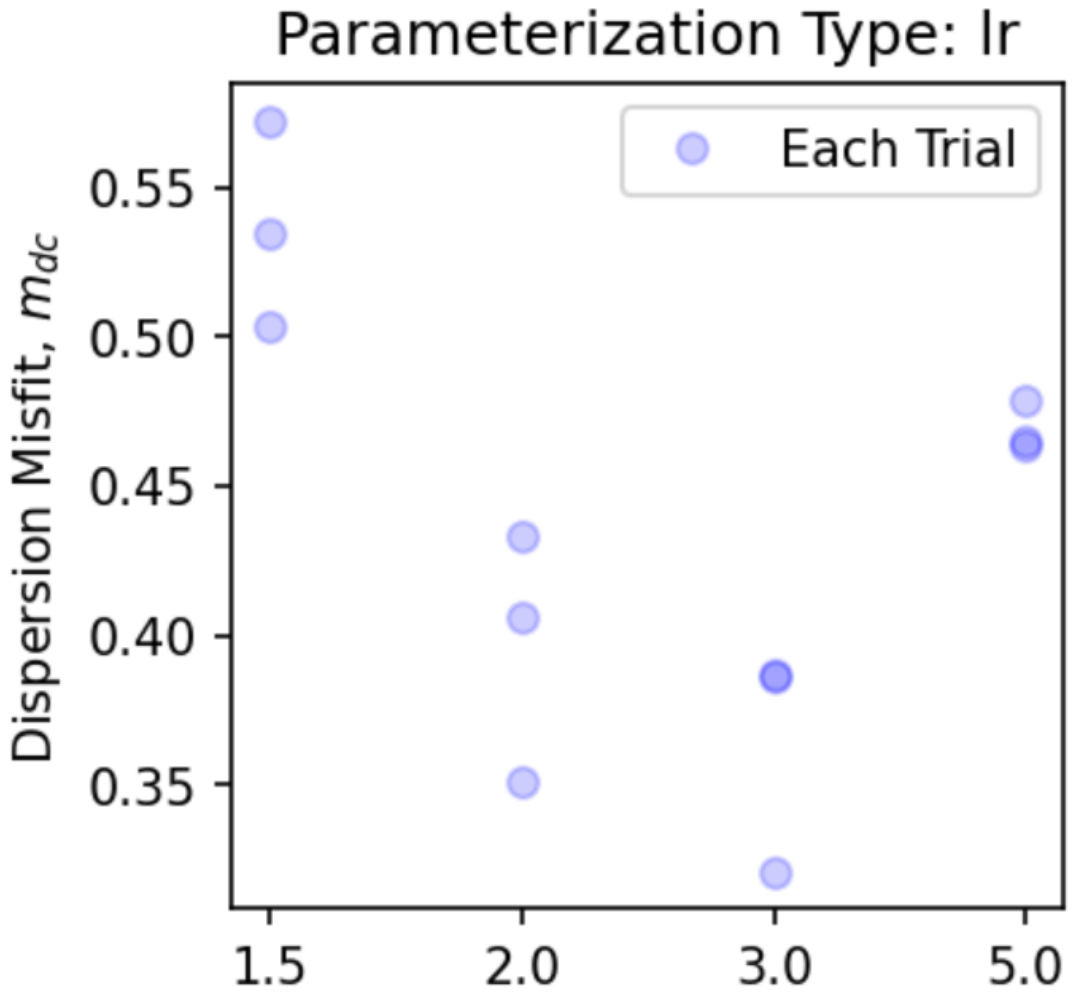

Repeat for multiple parameterizations.

Have to edit each individually in Dinver.

Lots of repetitive changes make it easy to make mistakes so be cautious and check your work carefully.

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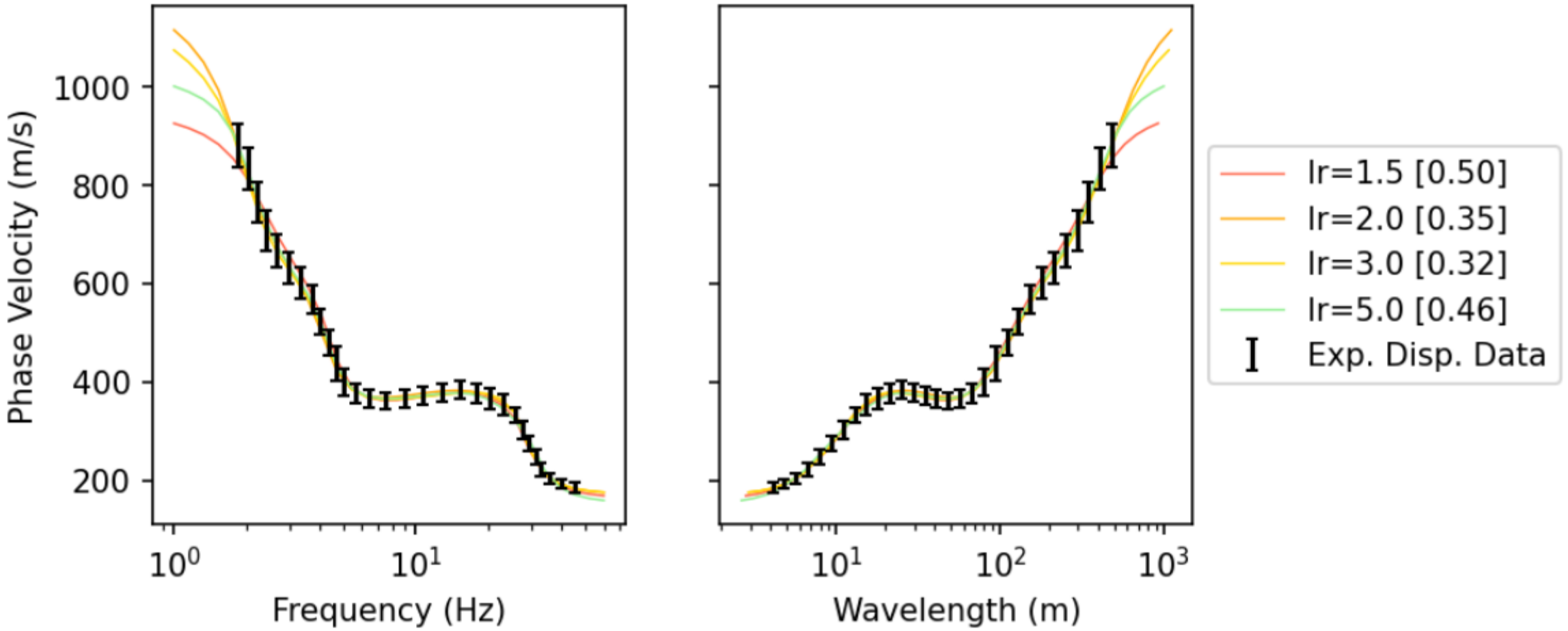
Best fit models



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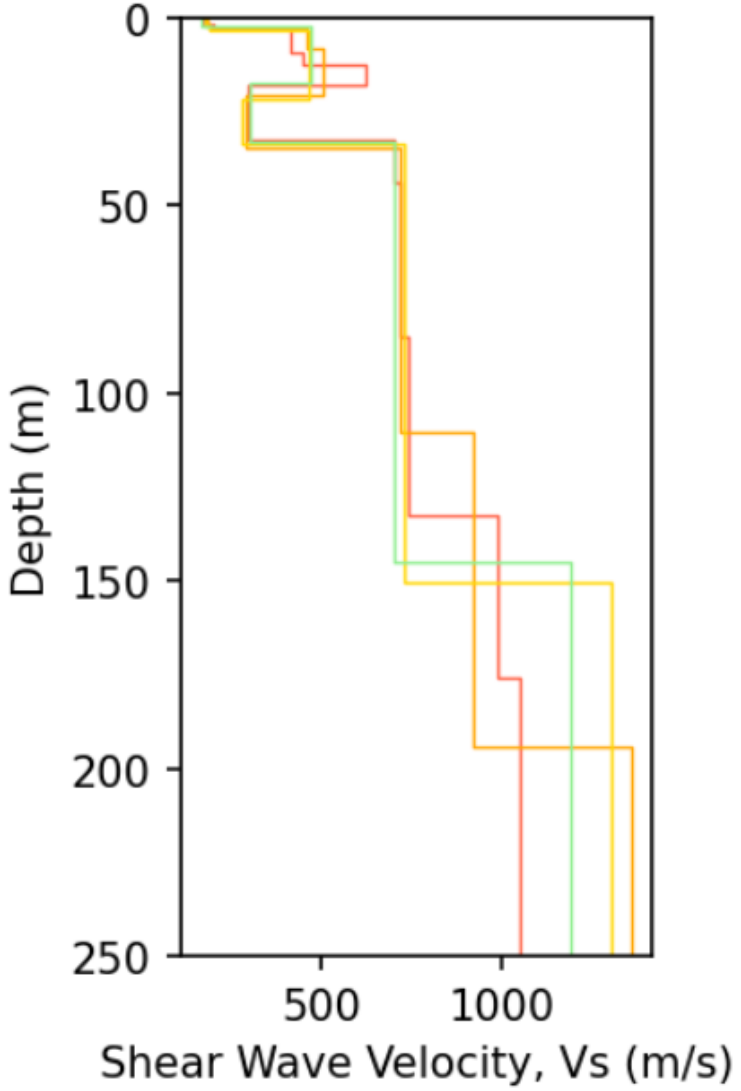

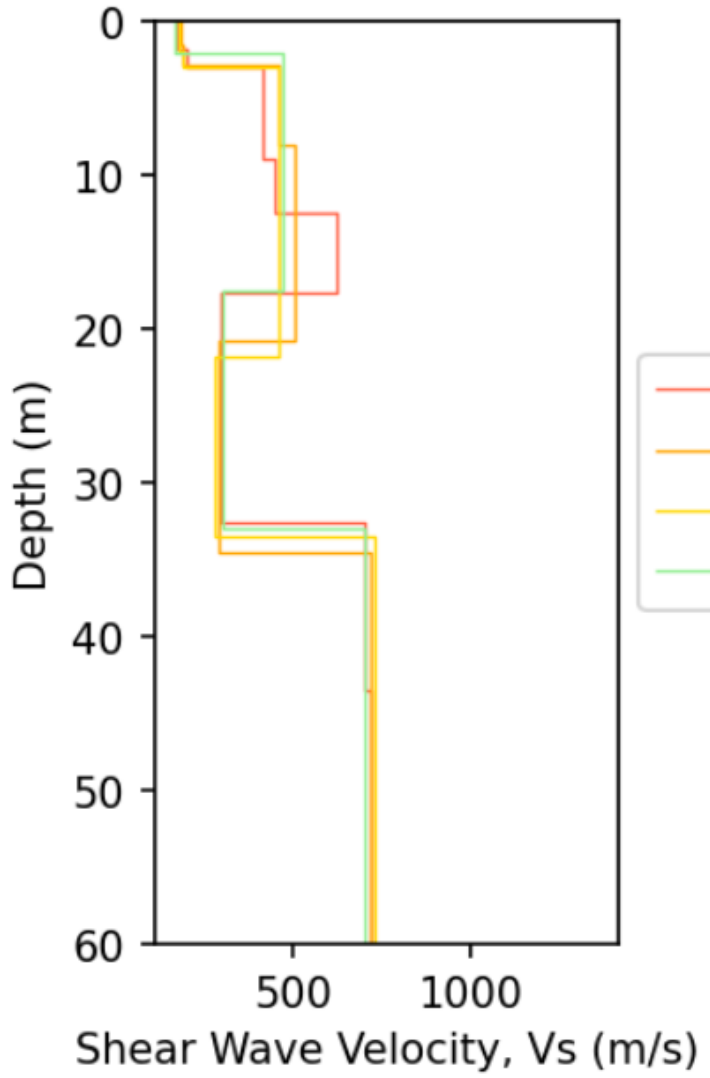

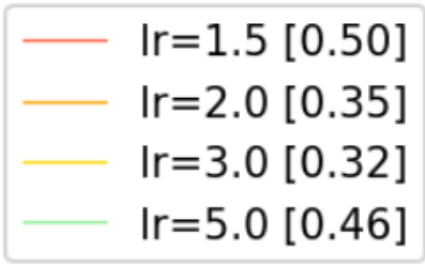

Best fit models.

Which one would you pick?

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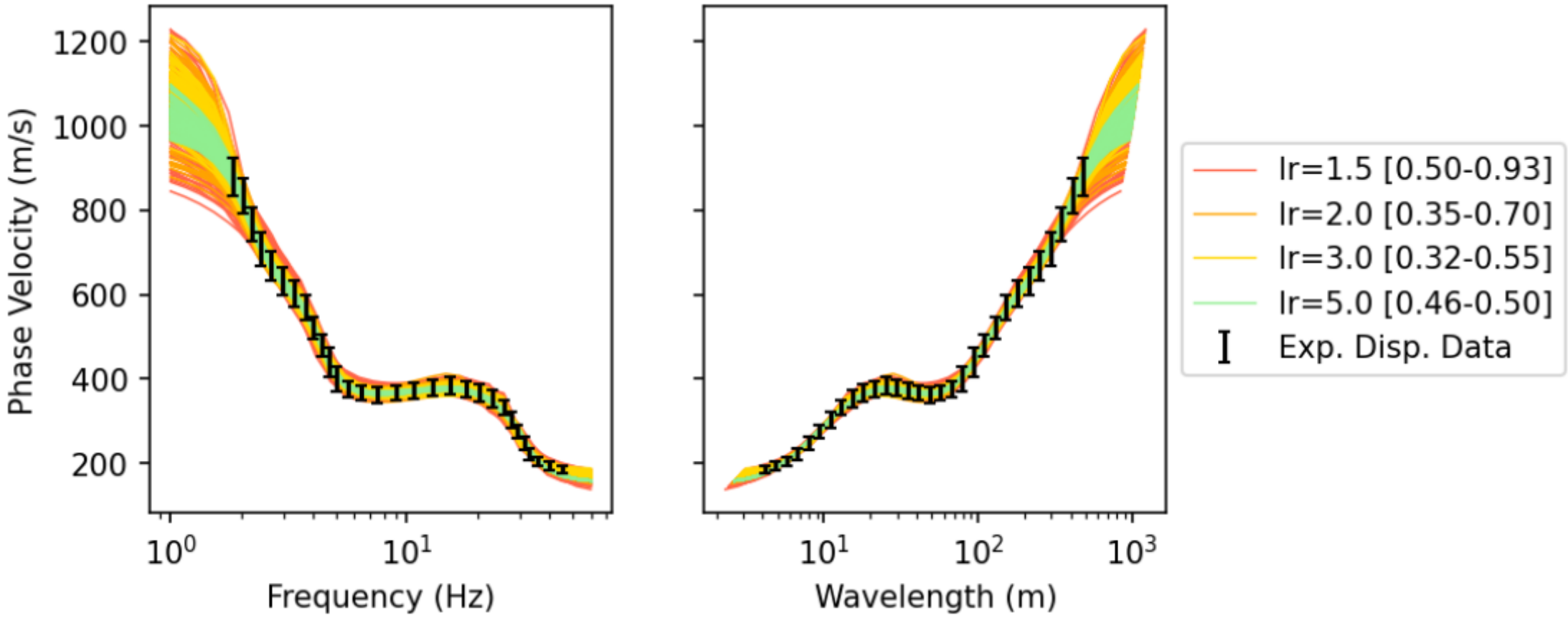

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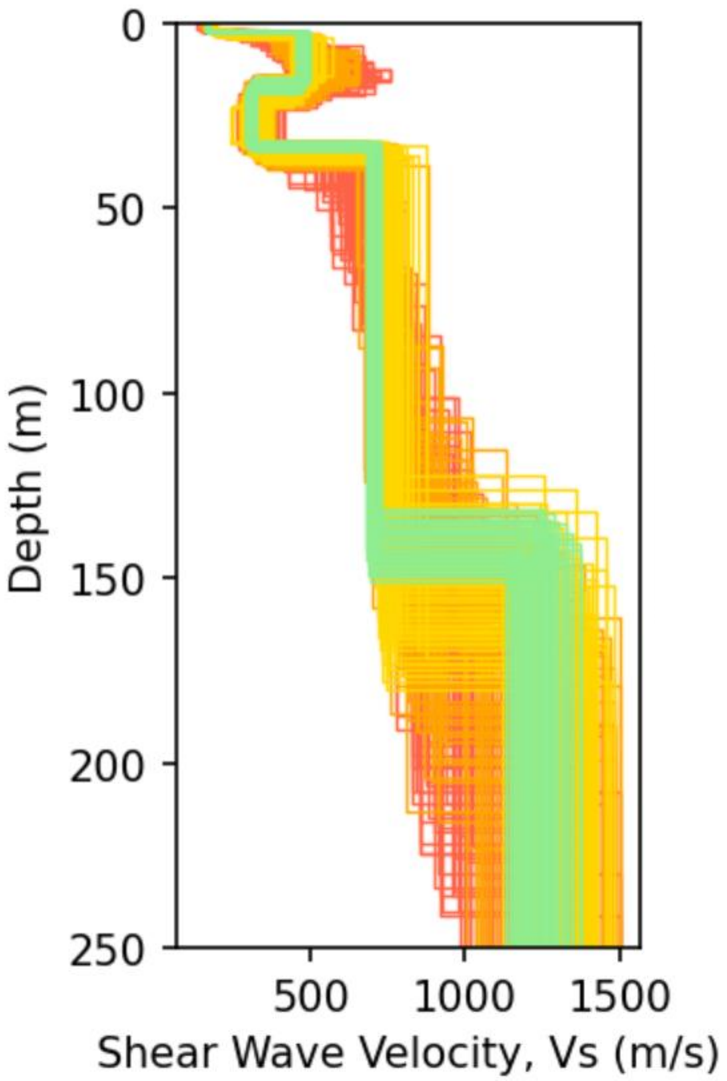

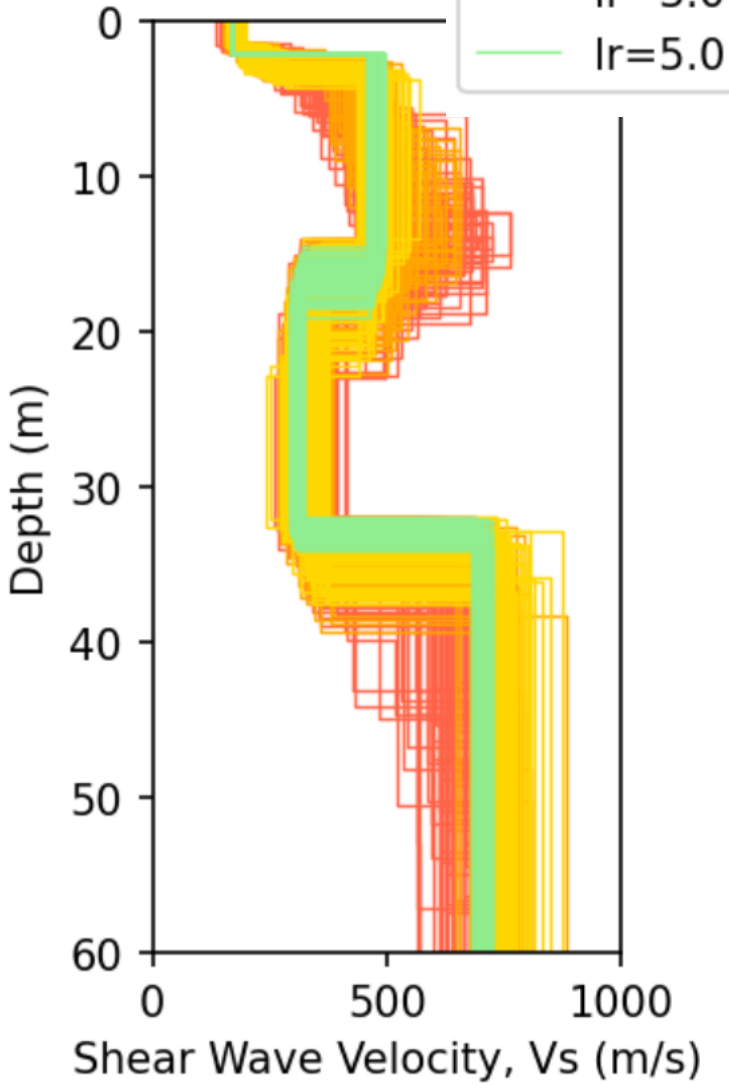

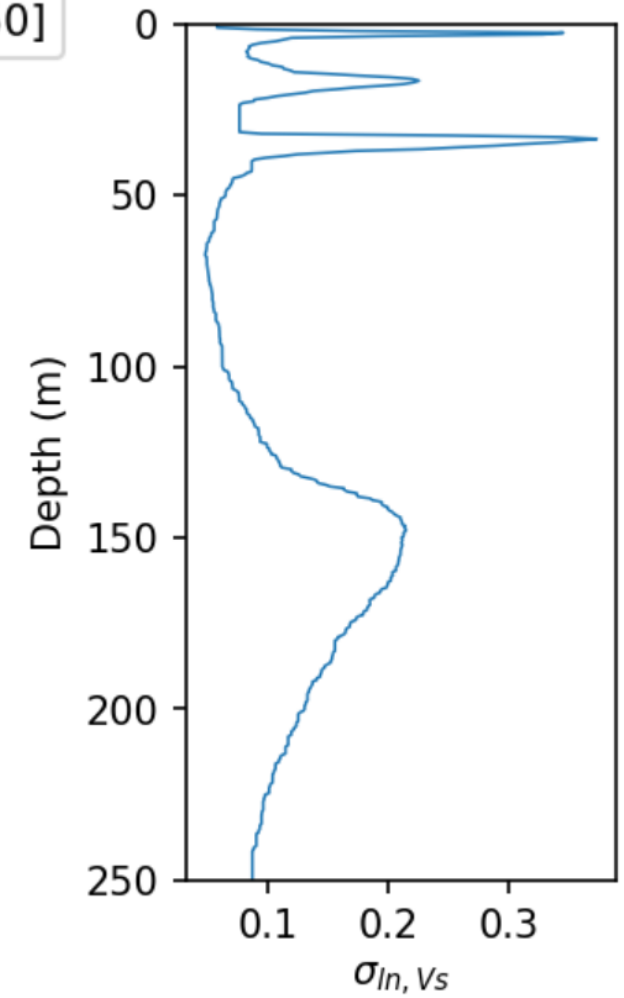

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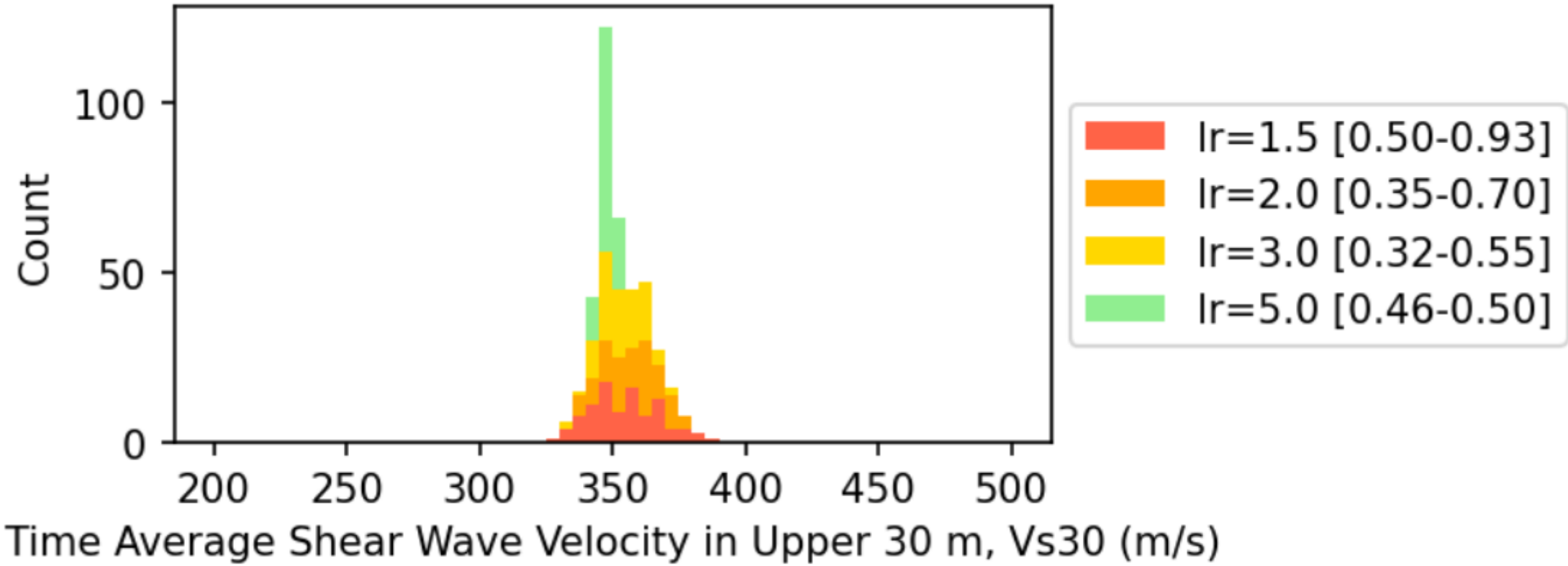

Mean Vs30: 353 m/s
Standard Deviation of Vs30: 10 m/s

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