Shear wave velocity estimation in the Sylhet Basin, Bangladesh by H/V analysis: implication for geophysical bedrock depth

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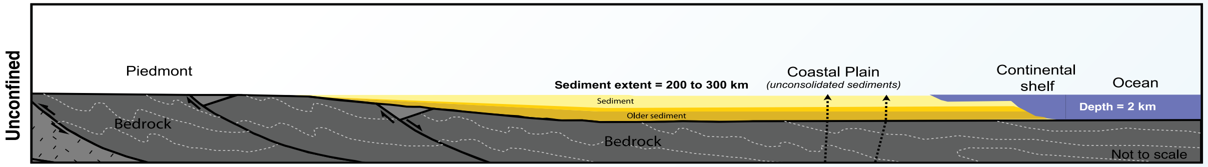
INTRODUCTION

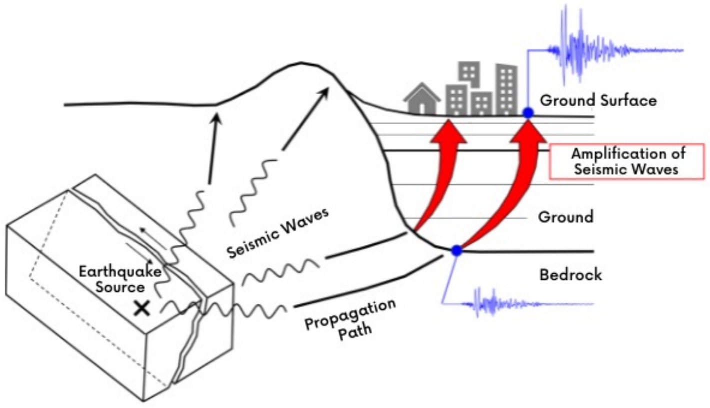
Geophysical bedrock, H/V

Geophysical bedrock: Layer with S-wave velocity (*V_S*) ~ 760 m/s; lithified rock layer (Maena et al., 2020; Morgen et al., 2020)

- Deep bedrock can excite long period waves
- Damage to high-rise buildings

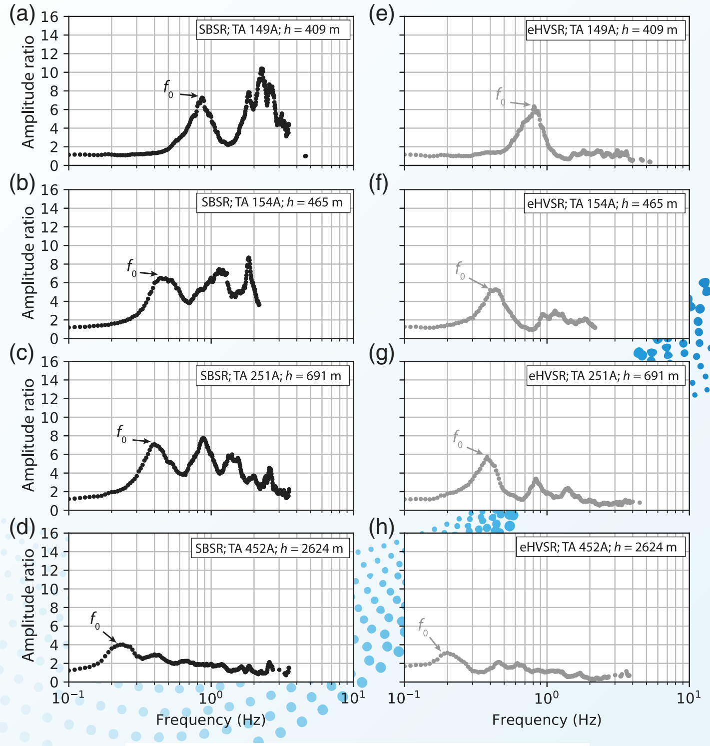
H/V: Ratio between Fourier amplitude spectra of horizontal and vertical components





(Pan et al., 2022)

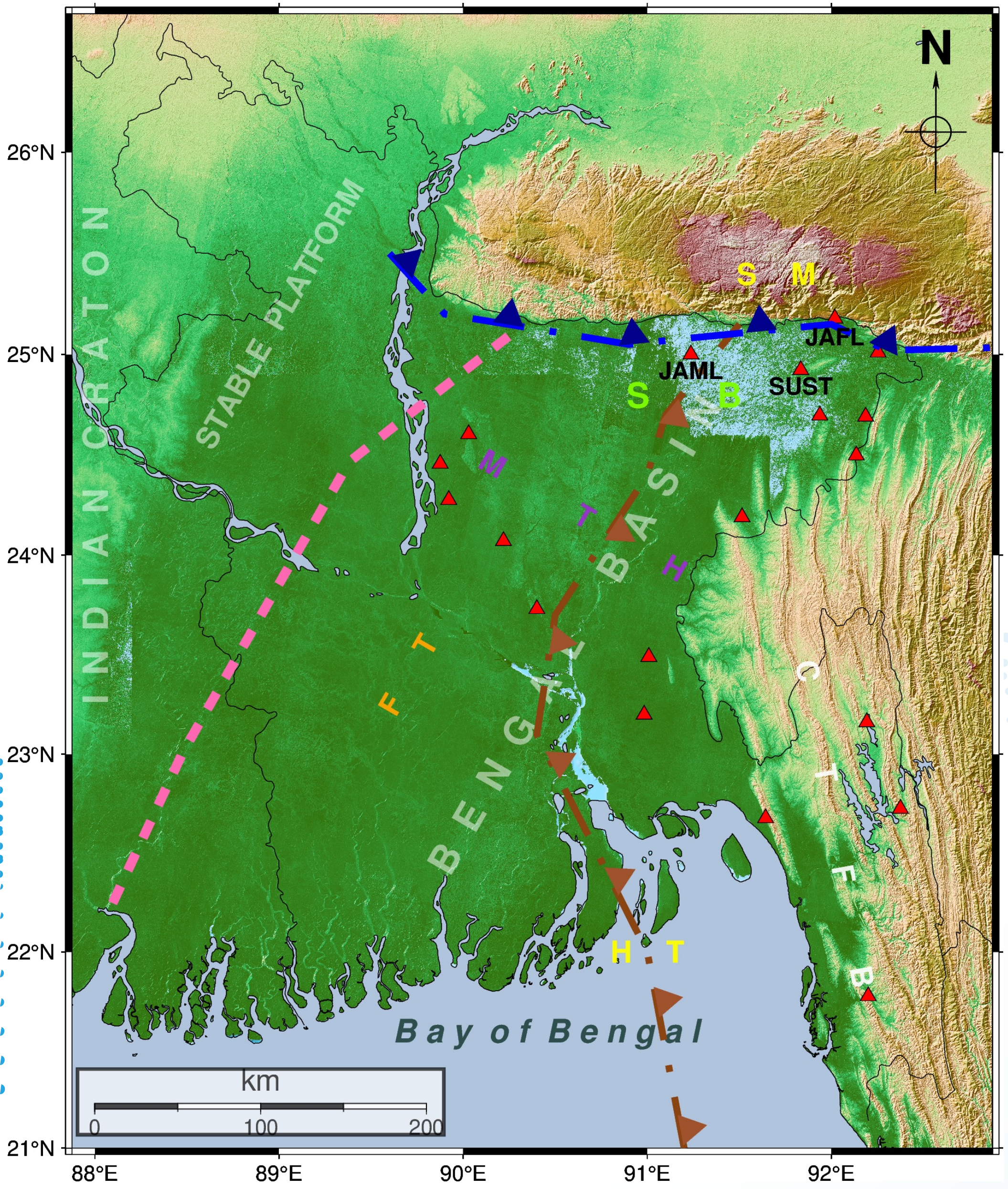
(Seed and Idriss, 1982)



(Schleicher and Pratt, 2021)

STUDY AREA

Tectonic setting



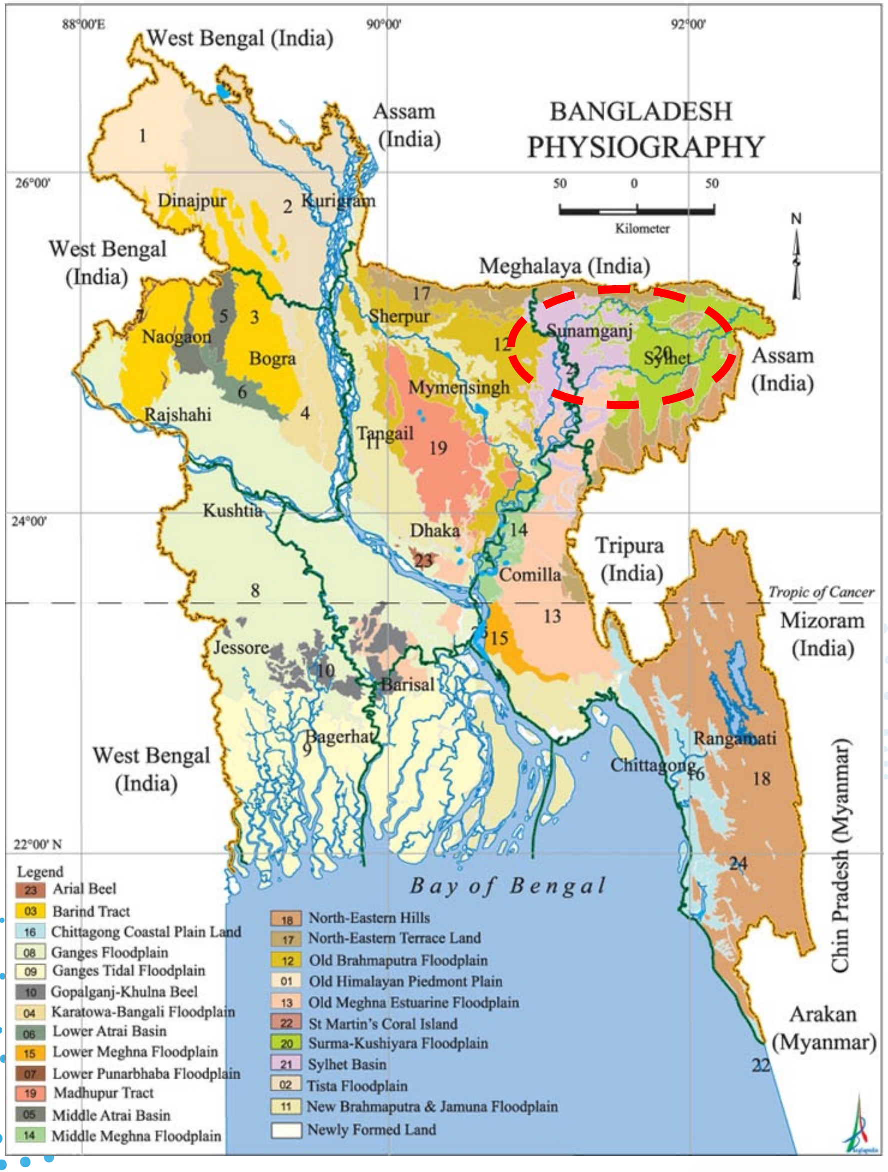
- The Bengal Basin is a foreland basin of the Indian Craton due to obduction of the Burmese Plate from the East
- The Himalayan Arc is also riding it from the north
    - Causes subsidence of the Sylhet basin, a sub basin of the Bengal Basin
- Shillong Massif marks the Northern limit of the Sylhet basin

SM: Shillong Massif; **SB**: Surma Basin; **MTH**: Madhupur-Tripura-High; **FT**: Faridpur Trough; **IBR**: Indo-Burmese Ranges; **CTFB**: Chittagong-Tripura fold belt; **HT**: Hatia Trough

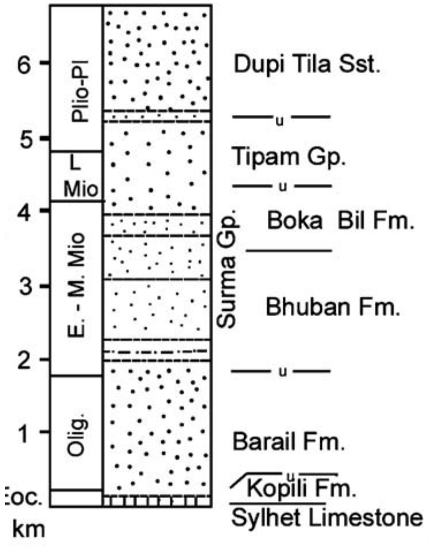
(Alam et al., 2003; Steckler et al., 2016)

STUDY AREA

Stratigraphy and physiography



Physiographic map of Bangladesh (Source: Banglapedia)



(Uddin and Lunderberg, 2003)

General stratigraphy

- Near surface of the deep basin
  - dominated by loose sand dominating units of the Dupi Tila Sandstone Formation
  - Alteration with silt and clay is very common

General geomorphology

- Flood plains
- Elevated Terraces
- Lakes

OBJECTIVES & MOTIVATIONS

Objectives

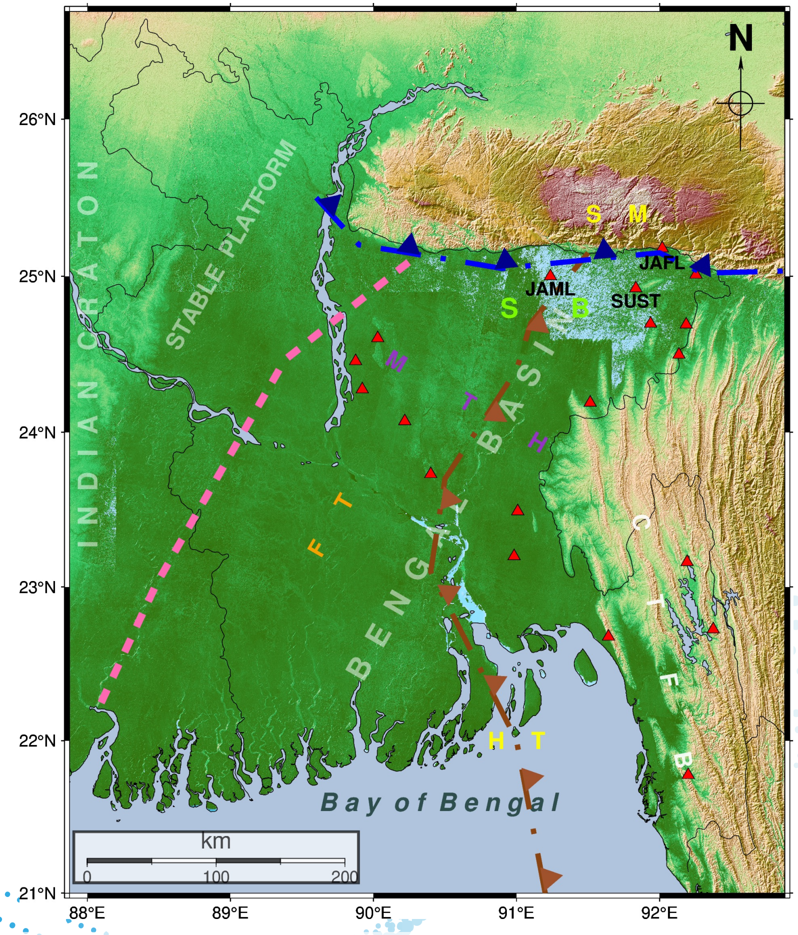
- Estimate H/V curve from noise records (0.2 to 10 HZ)
- Full H/V curve inversion for deeper S-wave velocity profile
- Estimate geophysical bedrock depth in the Sylhet basin, Bangladesh

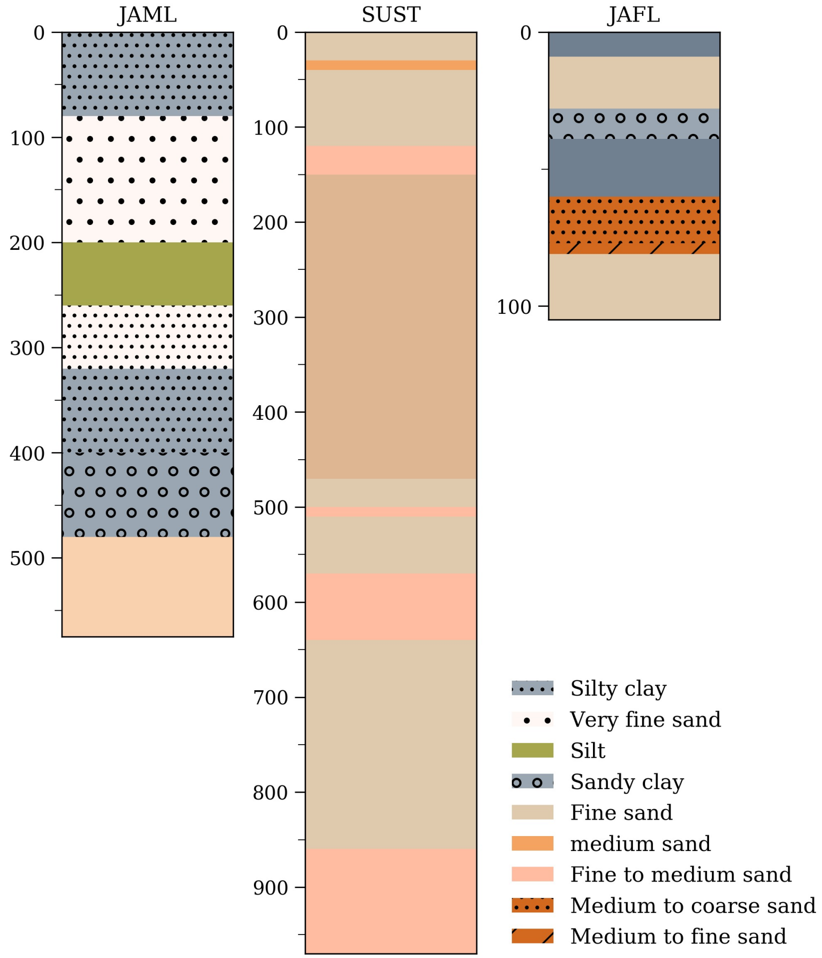
Motivations

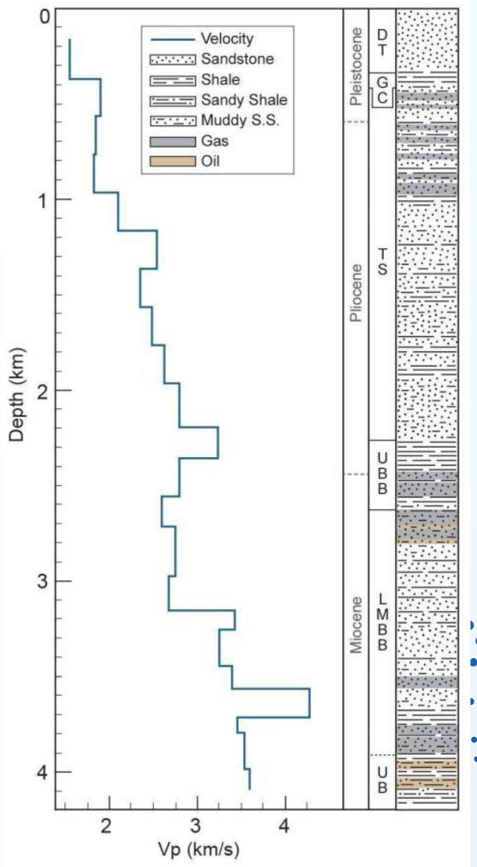
- ✓ H/V analysis is being applied for the 1st time in the study area
- ✓ Rahman et al. (2021) estimated geophysical bedrock depth only at the capital city Dhaka (10 sites)
  - deep bedrock (>175 m)
- ✓ This study is the 1st attempt to estimate bedrock depth in the Sylhet basin

DATA

Seismic stations, lithologs, TWTT







(Burgi et al., 2021)

Continuous seismic record 15 days

Seismic stations (IRIS) ▲

- JAML
- SUST
- JAFL

Lithologs from water borehole

- BWDB

TWTT

- BAPEX

METHODOLOGY

H/V estimation, inversion

H/V from seismic trace

- Mean and trend removal from seismic trace
- Tapering
- Window length is 100 s
- Overlap by 90%
- Total horizontal energy $H = \sqrt{{H_1}^2 + {H_2}^2}$
- H/V computed from 0.2 to 10 Hz

Theory of microtremor for H/V

- H/V at a given frequency (ω) when the wavefield is diffused

$$[H/V](x,\omega) = \sqrt{\frac{E_1(\boldsymbol{x},\omega)+E_2(\boldsymbol{x},\omega)}{E_3(\boldsymbol{x},\omega)}} = \sqrt{\frac{Im(G_{11}+G_{22})}{Im(G_{33})}}$$

E = directional energy density

Im(G) = imaginary part of the Green's function

Subscripts 1,2 are for horizontal and 3 for vertical components

- Directional energy density in direction *i*,

$$E_i(x,\omega) = \rho\omega^2\langle u_i(\boldsymbol{x}_A,\omega)u_i^*(\boldsymbol{x}_A,\omega)\rangle$$
$$\propto Im[G_{ii}(\boldsymbol{x}_A,\boldsymbol{x}_A,\omega)]$$

E_i = directional energy density at frequency f, $\omega = 2\pi f$ (circular frequency), ρ = mass density, u_i = displacement in direction *I*

(Sánchez-Sesma et al., 2011)

Misfit function

$$E(m) = \frac{1}{n}\sum_j^n \frac{\left(d_j^{obs} - d_j^{theo}(m)\right)^2}{\sigma_j^2}$$

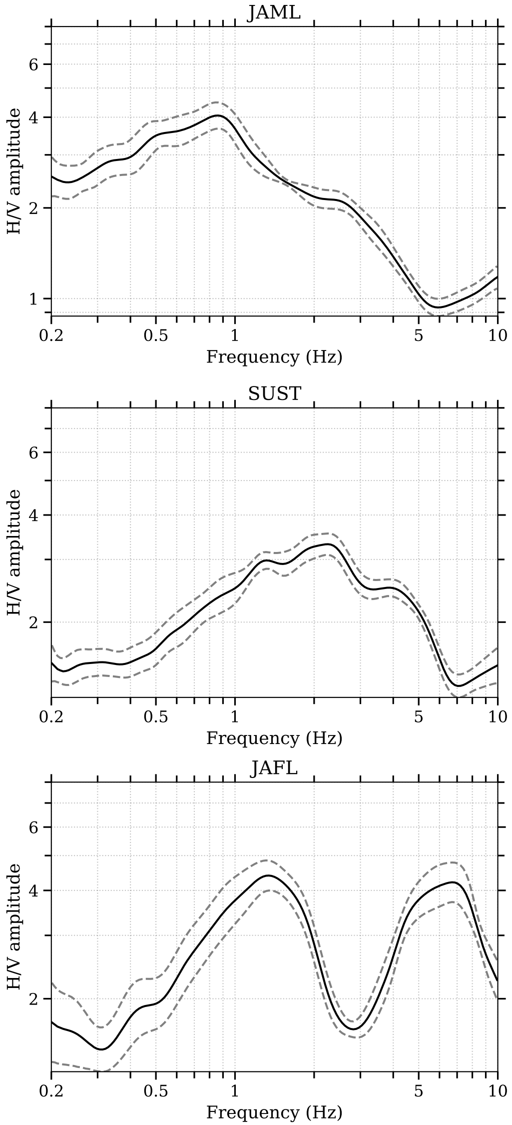
n is the number of frequency samples, d_j^{obs} notifies the observed value, d_j^{theo} denotes the theoretical value, σ signifies standard deviation

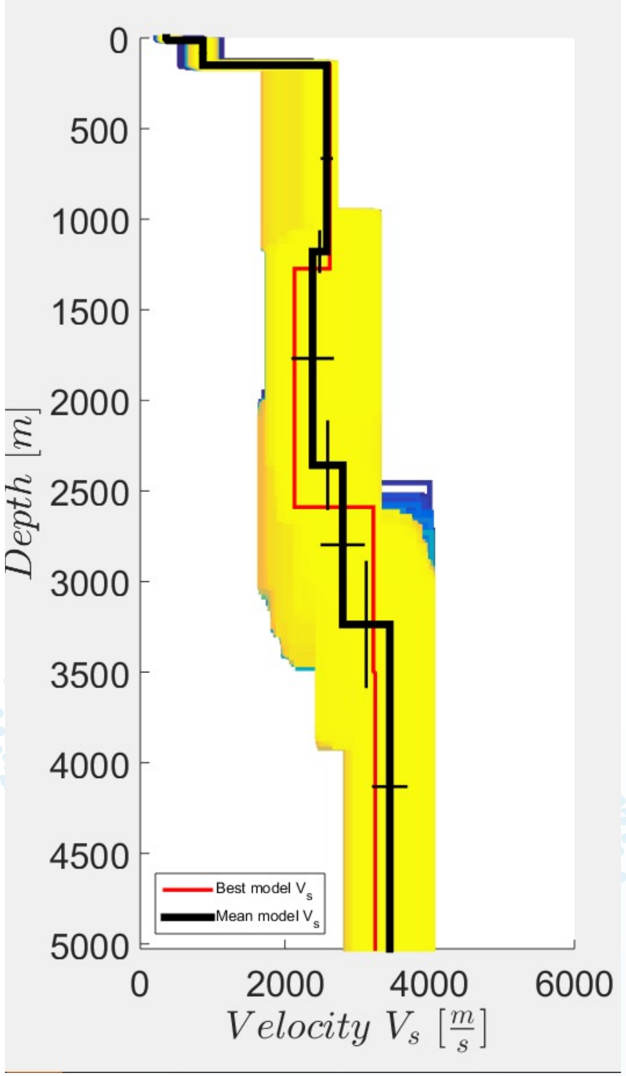
Parameters: V_P, V_S, *density, Poisson's ratio, thickness*

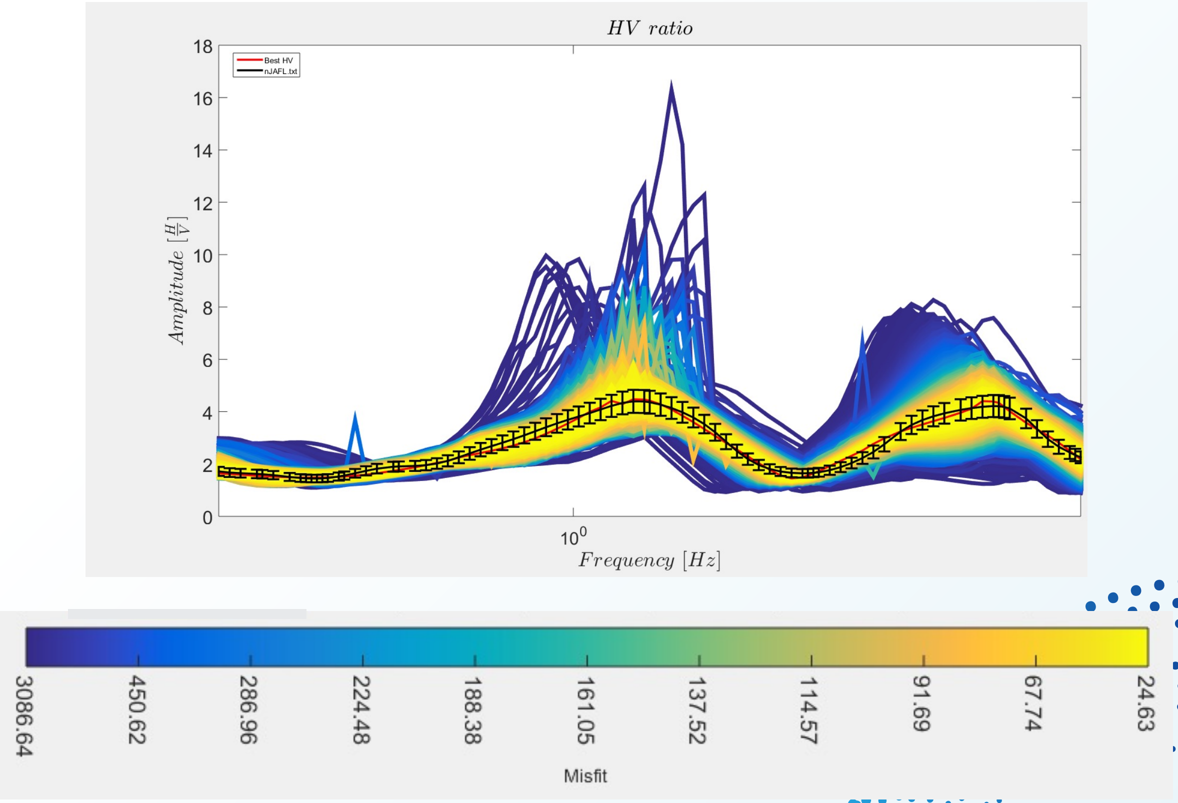
(García-Jerez et al., 2016)

RESULTS

Observed H/V, inversion







Examplaray station: JAFL

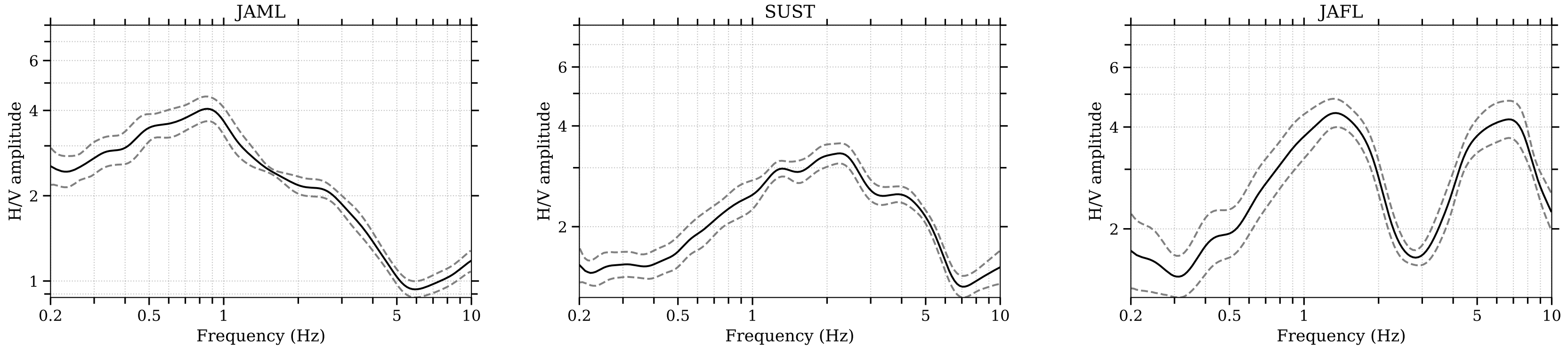
- Observed and best-fit HVSR with generated models
- Best-fit and average Vs profile with generated models

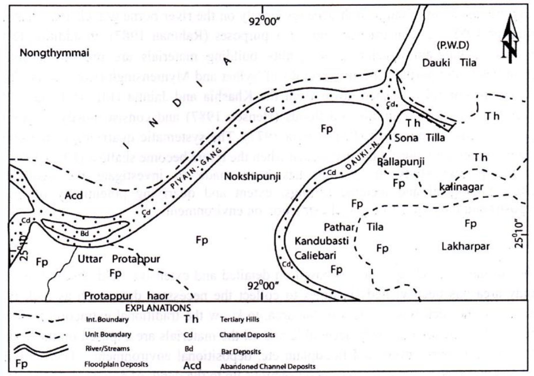
Dashed lines: standard deviation

Solid black line: average HVSR curve from all of the windows

DISCUSSION

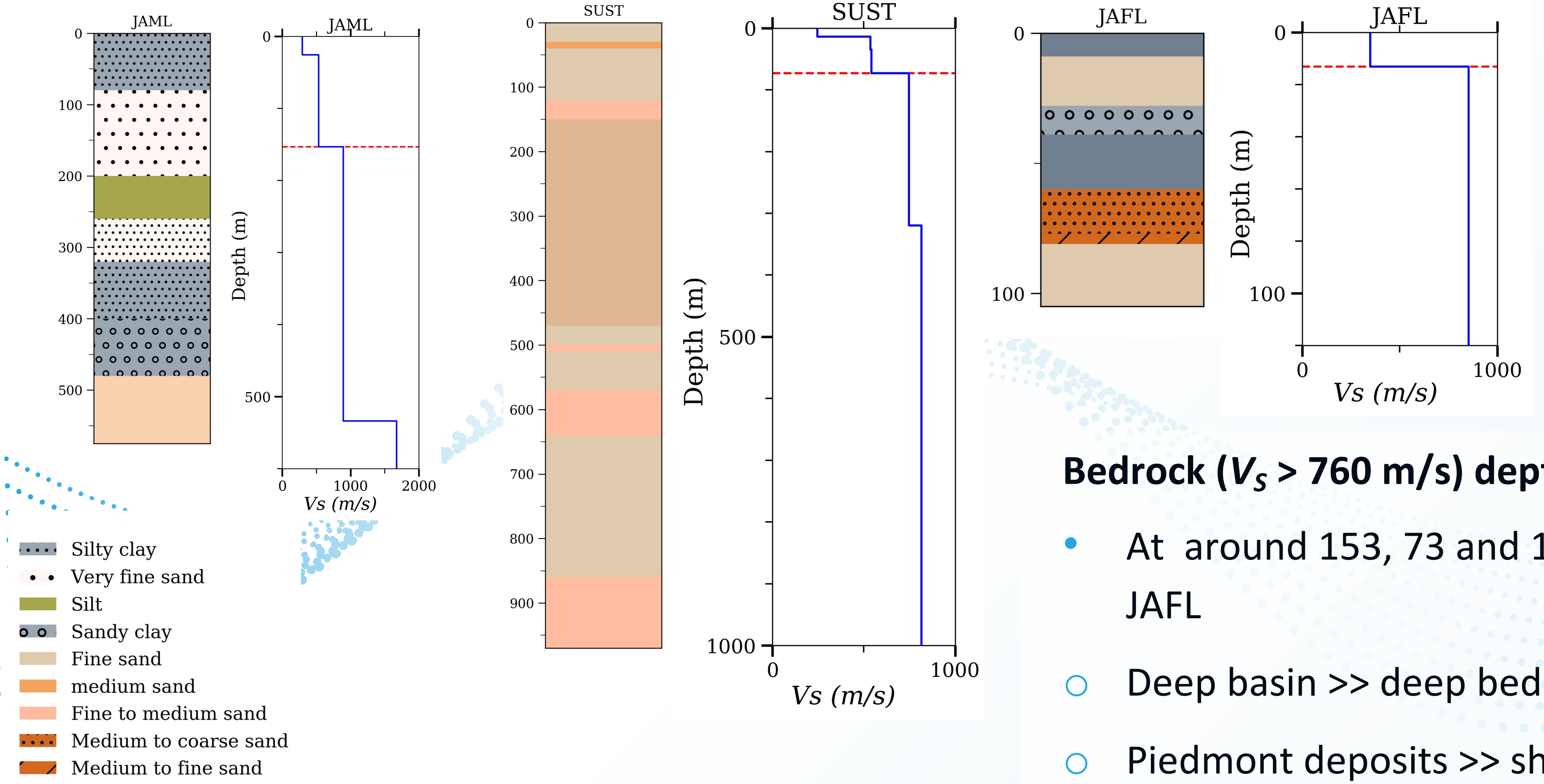
Geophysical bedrock depth





Geomorphology around station JAFL

(Sarker et al., 2015)



Bedrock position

Bedrock (V_S > 760 m/s) depth from V_S profile

- At around 153, 73 and 13 m, respectively at JAML, SUST and JAFL
  - Deep basin >> deep bedrock >> high-rise buildings
  - Piedmont deposits >> shallow bedrock >> low-rise buildings

CONCLUSIONS

- 1D S-wave velocity profile is estimated below 3 seismic stations in the Sylhet basin, Bangladesh by full H/V curve inversion
- Deep geophysical bedrock (> 30 m) has been identified from V_S profile
  - Shallow one (at < 30 m depth) is related to near surface piedmont deposits
- V_{S30} based earthquake ground motion estimation is not appropriate for deep bedrock
- Dense seismic measurement and adequate borehole information is recommended for future studies in the study area

THANK YOU

Additional information

Full profiles