# Nationwide site amplification mapping using GIS-based Japan engineering geomorphologic classification database

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# Background

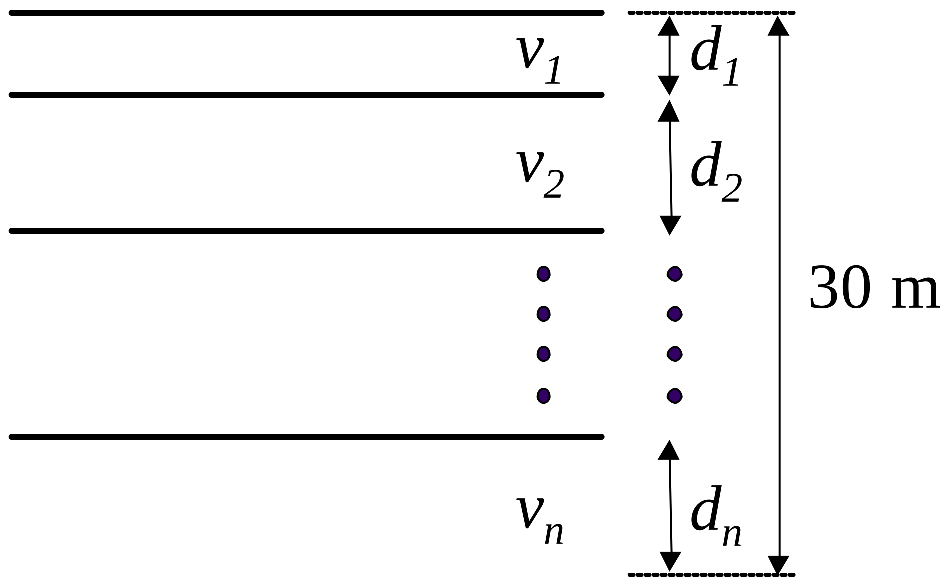
- In preparation for massive earthquakes, it is necessary to obtain appropriate site characteristics of a wide area across administrative districts.

- Approximate estimation of ground amplification is possible only with the shear-wave velocity of the surface layer (Borcherdt and Gibss 1976).

- and the amplification of strong ground motion is correlated with the average shear-wave velocity from the surface to a certain depth (Joyner and Fumal 1984, Midorikawa 1987), such as AVS30 (average shear-wave velocity of ground in the upper 30m depth).

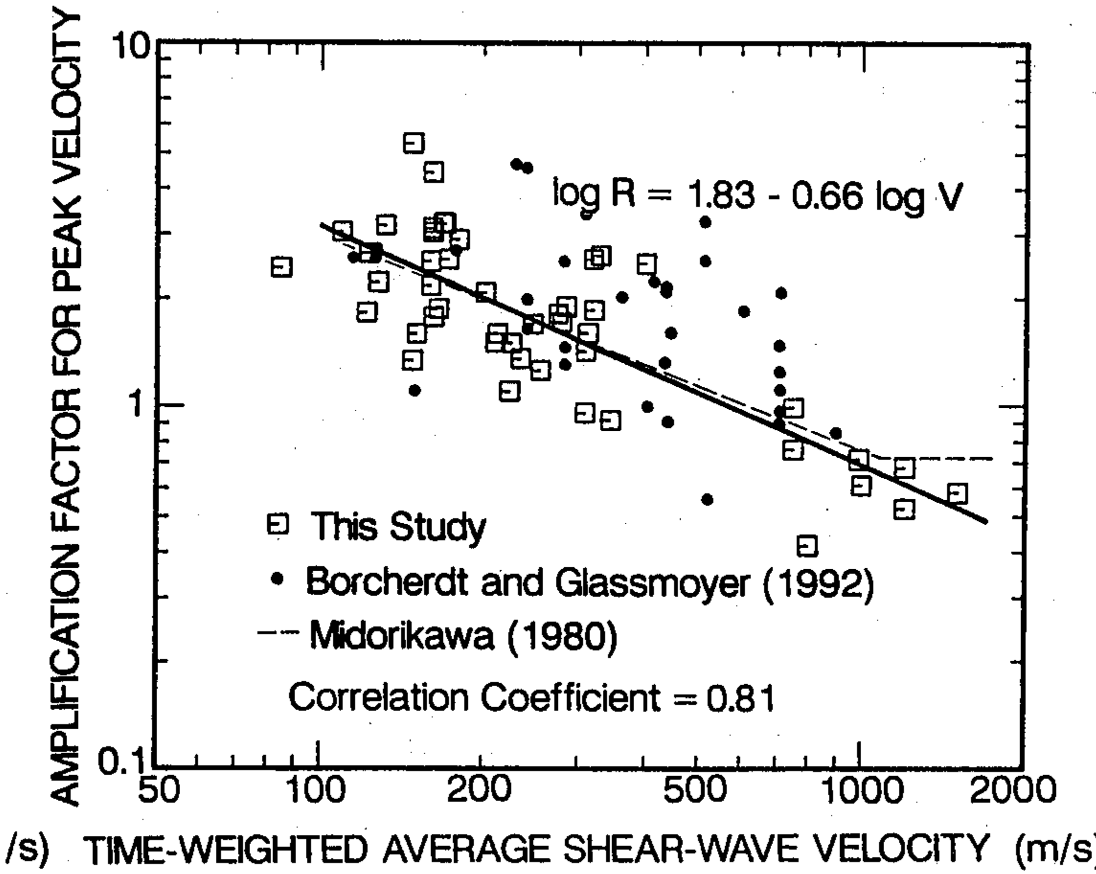
- In the U.S., AVS30 is used for soil classification for seismic code (BSSC 2003).

# Time-weighted Average Shear-wave Velocity of Ground( AVS30)




$$\mathrm{AVS30} = \frac{30}{\sum_{i=1}^{n} d_i / v_i} \quad \text{[m/s]}$$

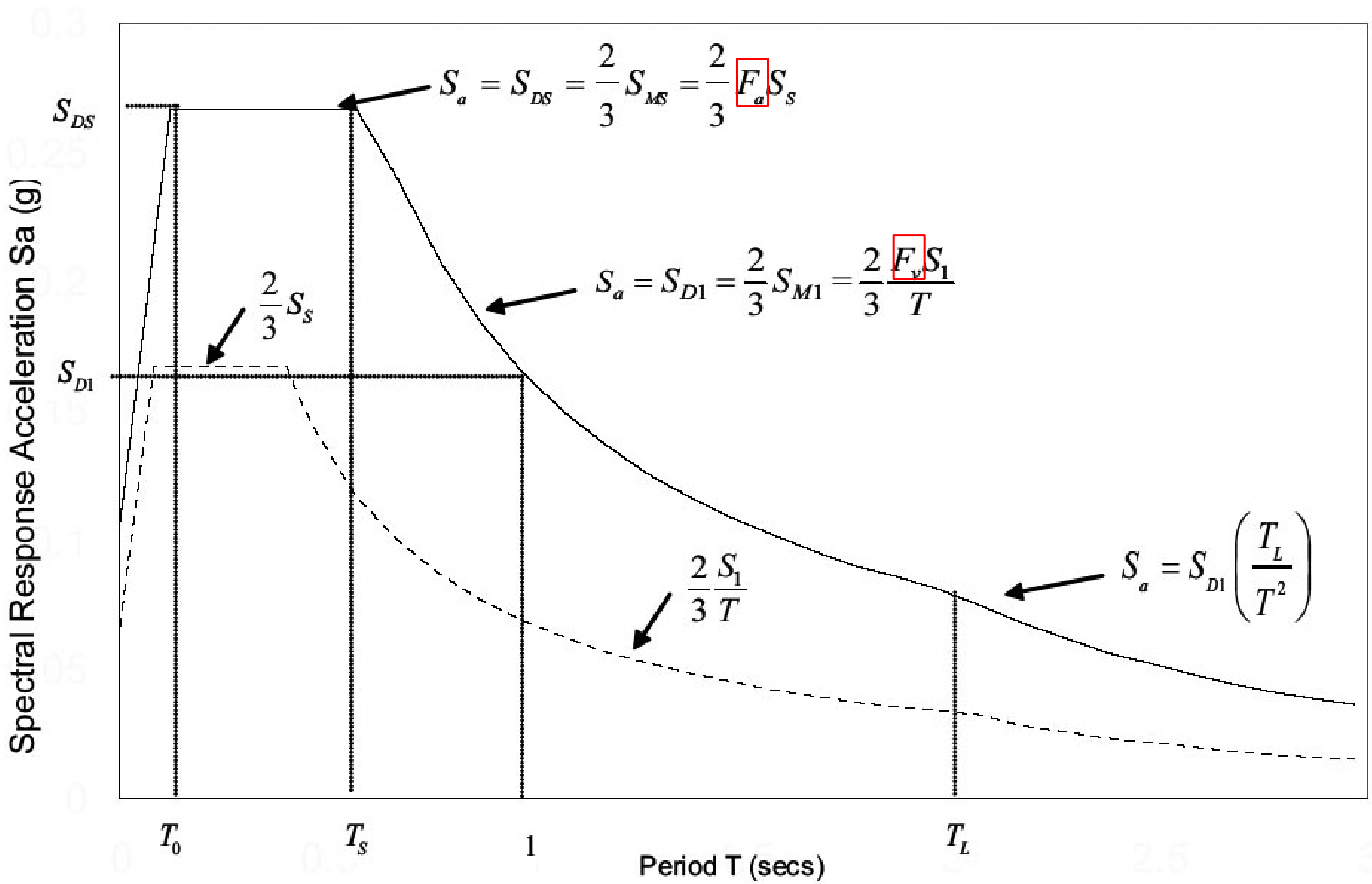
# Relationship Between AVS30 and Amplification Factor of PGV



(b) Peak Ground Velocity

Midorikawa, S., Matsuoka, M., and Sakugawa, K.: Site effect on string-motion records observed during the 1987 Chiba-ken-toho-oki, Japan earthquake, 9th JEES, Vol. 3, pp.85-90, 1994.

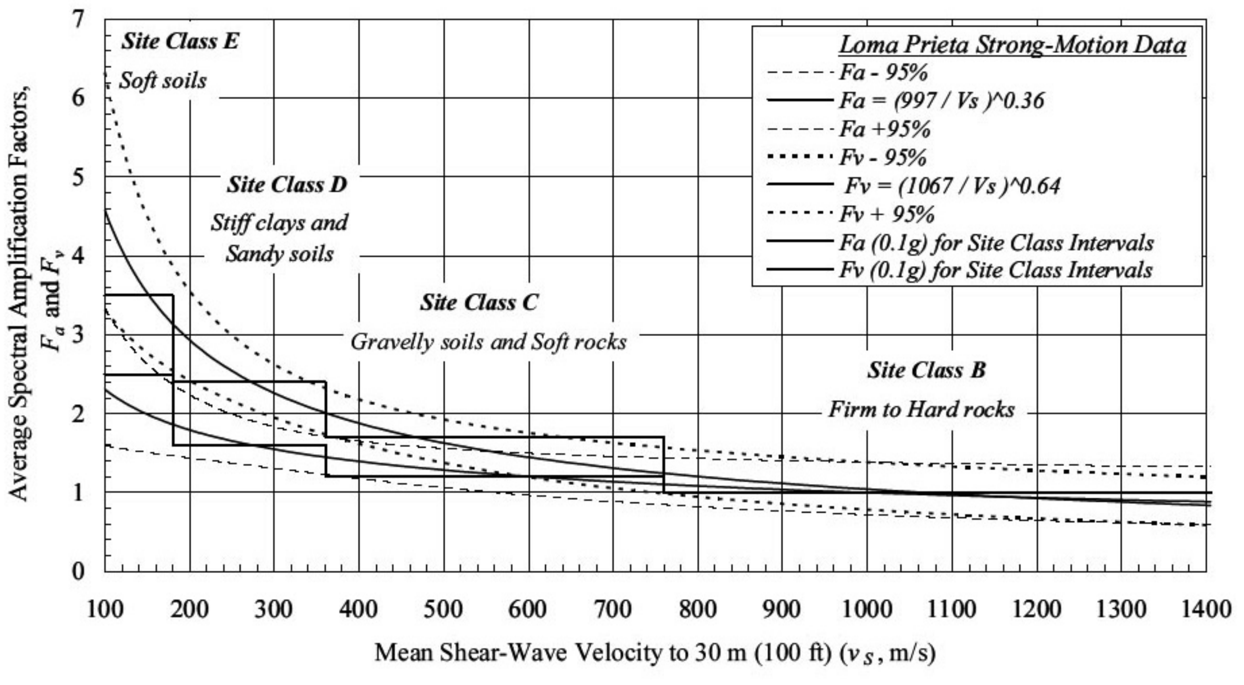
# Design Response Spectral Acceleration in U.S. Seismic Code




NEHRP (National Earthquake Hazards Reduction Program) (Borcherdt, 2004)

# Site Classification and Spectral Amplification Factor

A Hard rock with measured shear wave velocity, $\bar{v}_s > 5{,}000$ ft/sec (1500 m/s).
B Rock with 2,500 ft/sec < $\bar{v}_s$ < 5,000 ft/sec (760 m/s < $\bar{v}_s$ < 1500 m/s),
C Very dense soil and soft rock with 1,200 ft/sec < $\bar{v}_s$ < 2,500 ft/sec (360 m/s < $\bar{v}_s$ < 760 m/s) or with either N > 50 or $\bar{s}_u$ > 2,000 psf (100 kPa),
D Stiff soil with 600 ft/sec < $\bar{v}_s$ < 1,200 ft/sec (180 m/s < $\bar{v}_s$ < 360 m/s) or with either 15 < N < 50 or 1,000 psf < $\bar{s}_u$ < 2,000 psf (50 kPa < $\bar{s}_u$ < 100 kPa)
E A soil profile with $\bar{v}_s$ < 600 ft/sec (180 m/s) or with either $N < 15$, $\bar{s}_u$ < 1,000 psf, or any profile with more than 10 ft (3 m) of soft clay defined as soil with $PI > 20$, $w \geq 40$ percent, and $\bar{s}_u$ < 500 psf (25 kPa),




NEHRP (National Earthquake Hazards Reduction Program) (Borcherdt, 2004)

# Background *cont.*

- For site amplification mapping in wide area, Digital National Land Information (DNLI) is sometimes employed, based on the clarifying the relationship between site characteristics of borehole data and geologic/geomorphologic condition in DNLI.

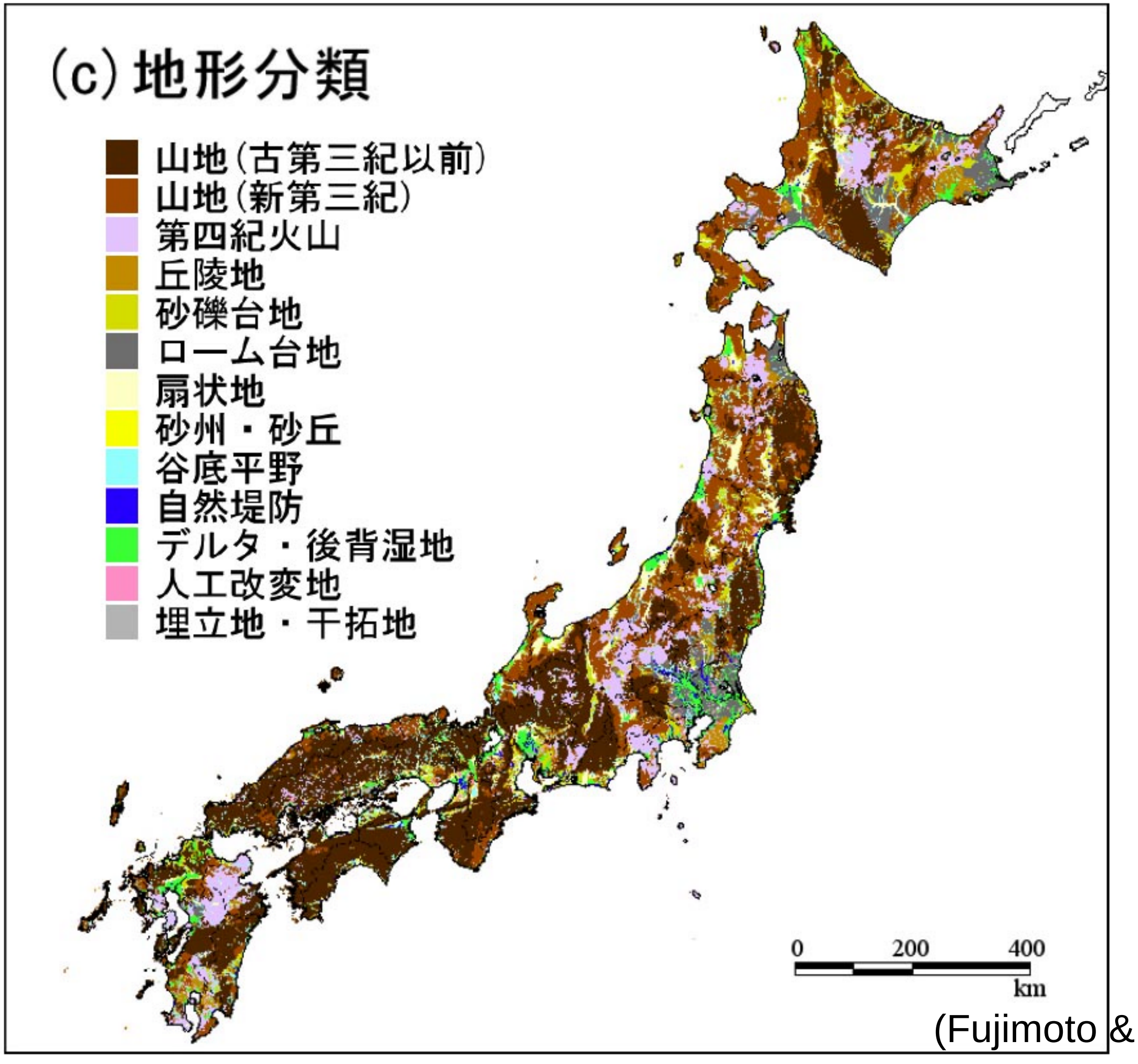
- For example,

  Kanto district: Midorikawa and Matsuoka (1995)

  Chukyo district: Fukuwa et al. (1998)

  Allover Japan: Fujimoto and Midorikawa (2003)

# Geomorphologic Classification Map based on DNLI




(Fujimoto & Midorikawa, 2003)

# Objective

- In this study, we upgrade the site amplification mapping nationwide using more reliable dataset.

# Problem-1 and Solution

## - database -

- The land classification in DNLI and its base map present several problems in the evaluation of subsurface ground conditions.
  - Different classification systems and different unit names
  - Do not include the latest information on artificial changes to the land such as filled land
  - Do not enough reflect ground conditions in the shallow subsurface

- “Japan Engineering Geomorphologic Classification Map (JEGM)” (Wakamatsu et al. 2004) is used.

# Problem-2 and Solution

## - interpretation of geomorphologic condition -

- In previous studies, there is no guarantee whether it accurately reflects the geomorphologic condition of the borehole site.
  - They mainly refer to the standard grid cell (approx. 1km square) landform classification that includes the site in order to decide the geomorphologic unit of the shear-wave velocity survey site.

↓

- We plot the location of each borehole site on land classification maps on a scale of 1: 50,000 that are the base paper maps for the JEGM and interpret the geomorphologic unit of the site accurately.

# Flow of This study

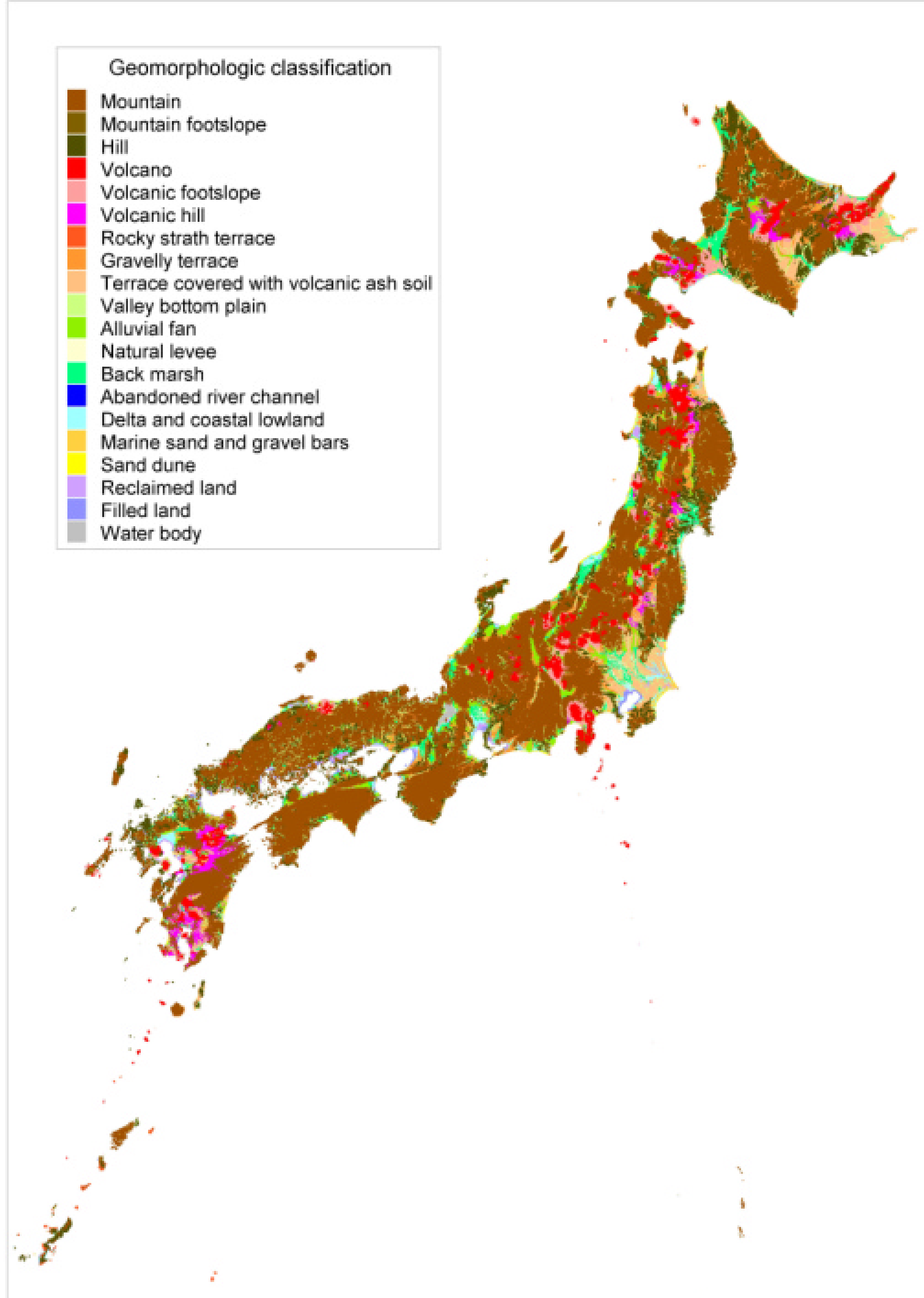
1. Calculating AVS30 from nationwide borehole data set with PS logging.
2. Interpreting geomorphologic classification at shear-wave velocity sites.
3. Examining the mean value of AVS30 for each geomorphologic unit.
4. Developing the empirical formula to estimate AVS30 from geomorphologic and geographic information.
5. AVS30 mapping using JEGM.

# Japan Engineering Geomorphologic Classification Map (JEGM)

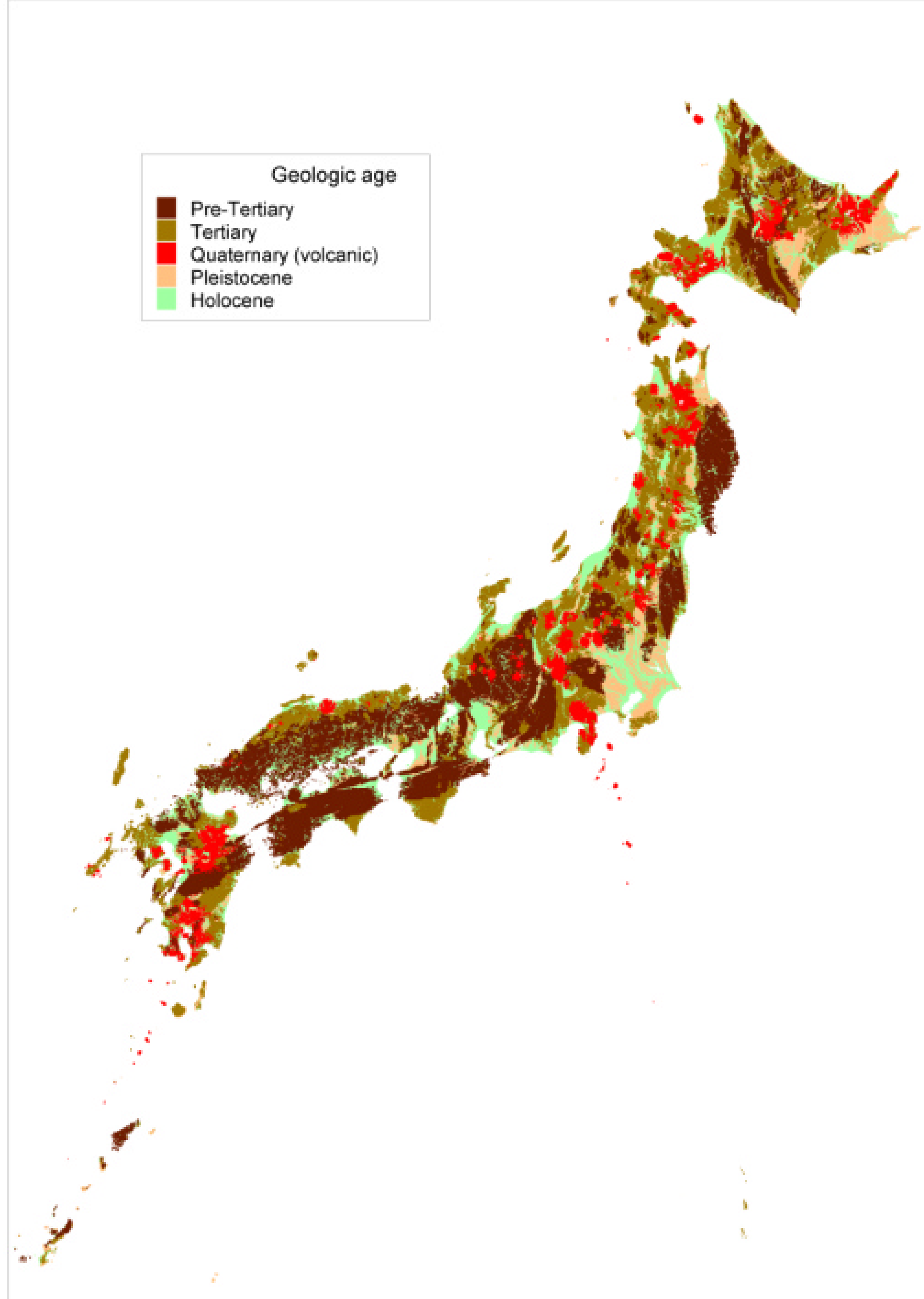
developed by Wakamatsu et al. (2004)

- Attribute: Geomorphologic classification, Surface geology, Slope gradient, and Relative relief
- Grid size: longitude 45 x latitude 30 second square (approx. 1 x 1 km^2)
- Covered area: Allover Japan (approx. 380,000 cells)

# Geomorphologic Classification Map



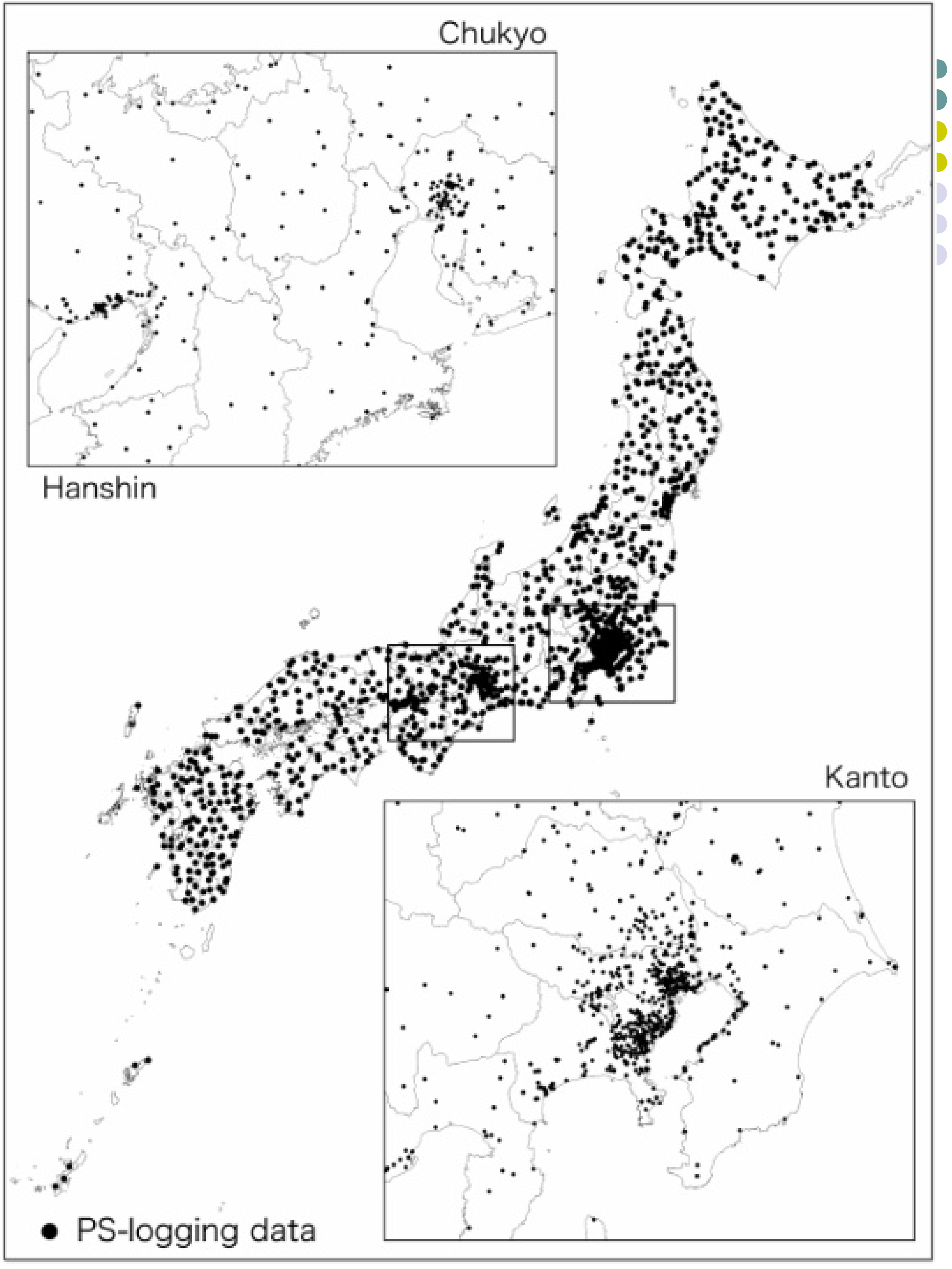
# Surface Geology Map



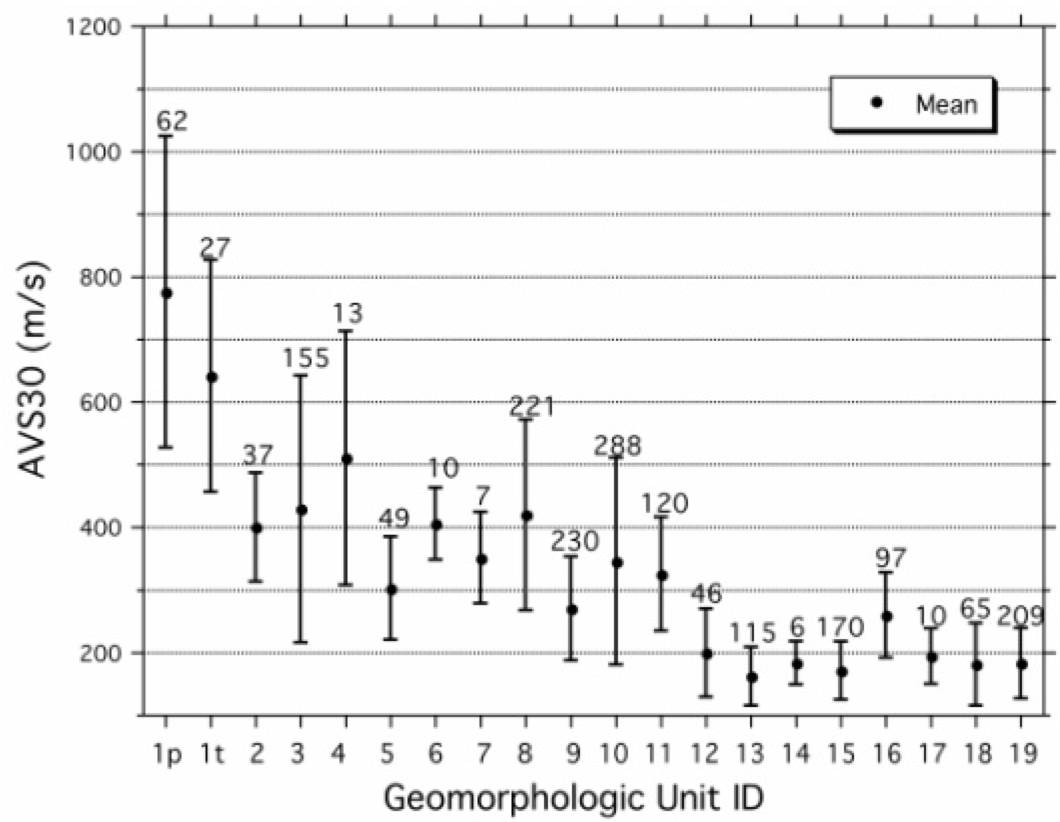
# Distribution of AVS30 Sites

K-data 1001 ? 509 sites
H-data 495 ? 435 sites
Y-data 150 ? 87 sites
M-data 539 ? 425 sites
F-data 71 ? 66 sites
T-data 650 ? 415 sites

Total 1937 sites



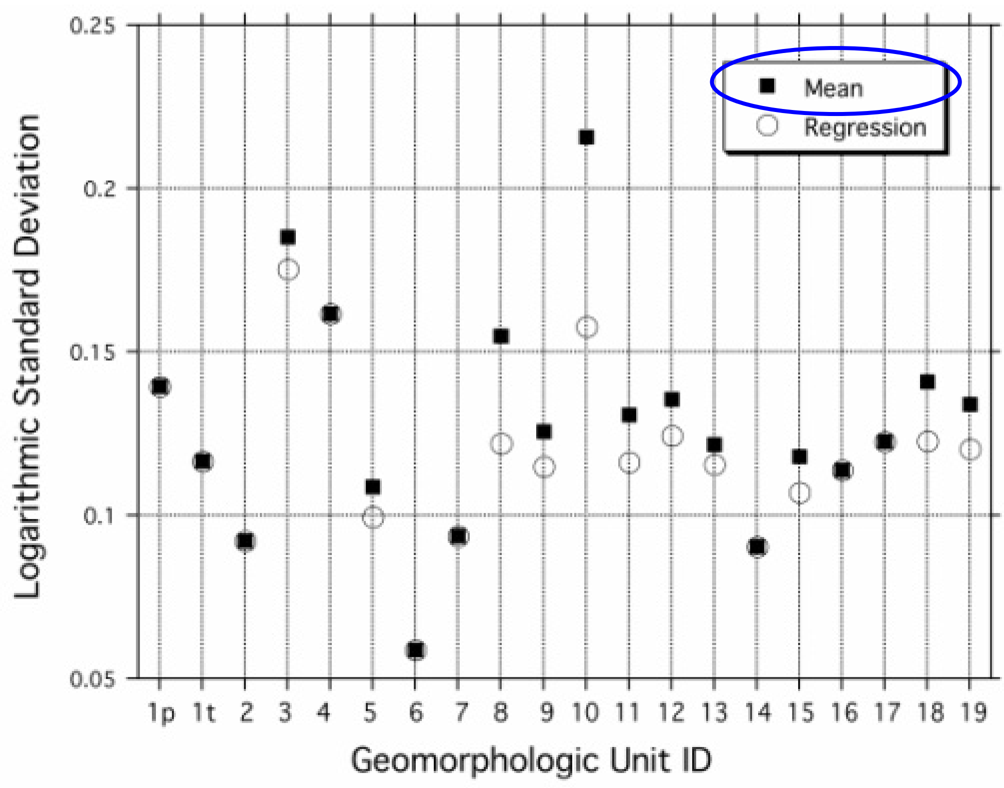
# Mean AVS30 and S.D. by Geomorphologic Unit




1p: Mountain(Pre-Tertiary) 1t: Mountain(Tertiary) 2: Mountain footslope
3: Hill 4: Volcano 5: Volcanic terrace 6: Volcanic hill 7: Rocky terrace
8: Gravelly terrace 9: Terrace covered with volcanic ash soil
10: Valley bottom lowland 11: Alluvial fan 12: Natural levee
13: Back marsh 14: Abandoned river channel 15: Delta and coastal lowland
16: Sand and gravel bars 17: Sand dune 18: Reclaimed land 19: Filled land

- In general, the higher the altitude, the larger the AVS30 value becomes.
- The order of AVS30 almost corresponds to the grain size of deposits that forms each geomorphologic unit, (gravel > sand > clay).

# AVS30 Estimation Accuracy by Geomorphologic Unit

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- Estimating using mean values by geomorphologic units, dispersion of valley bottom plain is especially large, with ± 0.22 of logarithmic standard deviation.

- Therefore, we need to take geographic conditions other than the geomorphologic unit into consideration.

# Estimating AVS30 from Geographic Information

According to the sedimentation process, following indices are considered to estimate AVS30 for each geomorphologic unit.

- Elevation (Ev)
- Distance from major river (Dr)
- Distance from coastline (Dc)
- Slope gradient (Sp)
- Distance from mountain or hill of pre-Tertiary or Tertiary (Dm)

explanatory valuables

Multiple regression analysis

# Regression Equation and Coefficient for Estimating AVS30

| ID | Geomorphologic unit | Regression coefficient (Standard regression coefficient) | | | | s.d. |
|---|---|---|---|---|---|---|
| | | a | b | c | d | σ |
| 1p | Mountain (pre-Tertiary) | 2.900 | 0 | 0 | 0 | 0.139 |
| 1t | Mountain (Tertiary) | 2.807 | 0 | 0 | 0 | 0.117 |
| 2 | Mountain footslope | 2.602 | 0 | 0 | 0 | 0.092 |
| 3 | Hill | 2.349 | 0 | 0.152 (0.219) | 0 | 0.175 |
| 4 | Volcano | 2.708 | 0 | 0 | 0 | 0.162 |
| 5 | Volcanic footslope | 2.315 | 0 | 0.094 (0.382) | 0 | 0.100 |
| 6 | Volcanic hill | 2.608 | 0 | 0 | 0 | 0.059 |
| 7 | Rocky terrace | 2.546 | 0 | 0 | 0 | 0.094 |
| 8 | Gravelly terrace | 2.493 | 0.072 (0.270) | 0.027 (0.101) | -0.164 (-0.336) | 0.122 |
| 9 | Terrace covered with volcanic ash soil | 2.206 | 0.093 (0.269) | 0.065 (0.223) | 0 | 0.115 |
| 10 | Valley bottom lowland | 2.266 | 0.144 (0.447) | 0.016 (0.040) | -0.113 (-0.265) | 0.158 |
| 11 | Alluvial fan | 2.350 | 0.085 (0.419) | 0.015 (0.059) | 0 | 0.116 |
| 12 | Natural levee | 2.204 | 0.100 (0.368) | 0 | 0 | 0.124 |
| 13 | Back marsh | 2.190 | 0.038 (0.178) | 0 | -0.041 (-0.152) | 0.116 |
| 14 | Abandoned river channel | 2.264 | 0 | 0 | 0 | 0.091 |
| 15 | Delta and coastal lowland | 2.317 | 0 | 0 | -0.103 (-0.403) | 0.107 |
| 16 | Sand and gravel bars | 2.415 | 0.000 | 0 | 0 | 0.114 |
| 17 | Sand dune | 2.289 | 0 | 0 | 0 | 0.123 |
| 18 | Reclaimed land | 2.373 | 0 | 0 | -0.124 (-0.468) | 0.123 |
| 19 | Filled land | 2.404 | 0 | 0 | -0.139 (-0.418) | 0.120 |

$\log AVS30 = a + b \log Ev + c \log Sp + d \log Dm \pm \sigma$

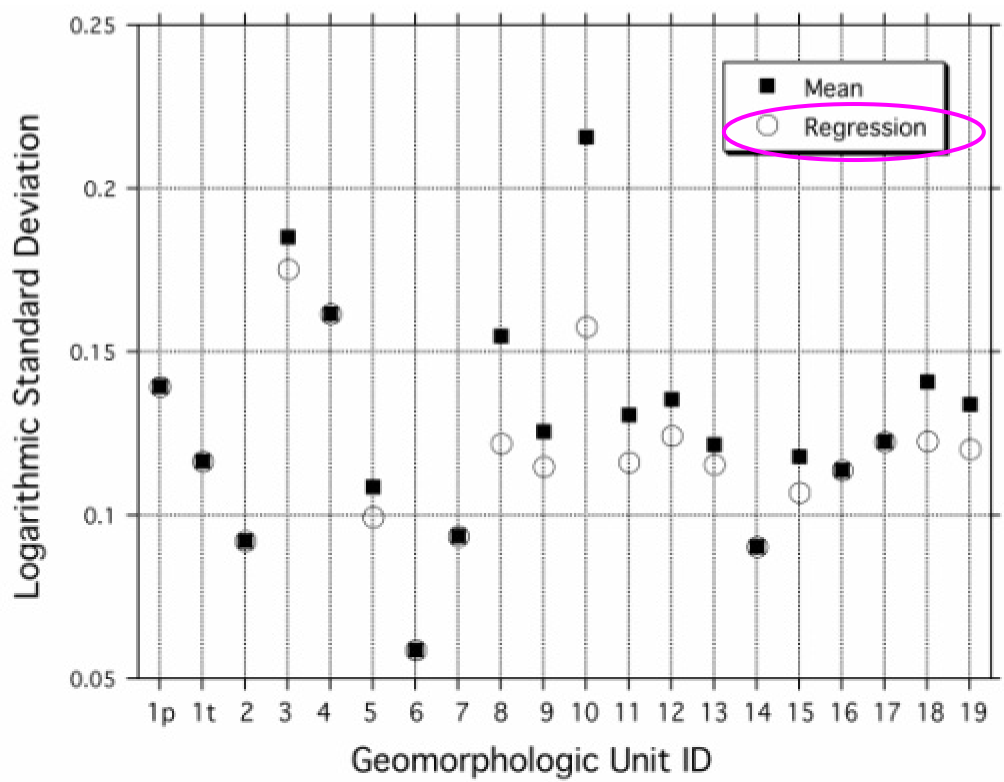
$AVS30$: Average S-wave velocity (m/s), $Ev$: Elevation (m), $Sp$: (Tangent of slope) * 1000,

$Dm$: Distance (km) from mountain or hill of pre-Tertiary or Tertiary

# Discussion for Regression Coefficient

- What we can generalize from the regression coefficients is that the higher the elevation, the steeper the slope gradient and the shorter the distance from the mountain or hill, AVS30 values become larger. In the upstream region of a river (an area at a high altitude with steep slope gradient), the AVS30 becomes larger as the grain size of deposits is larger, and the closer the distance to the mountain or hill, the shallower the depth to a bedrock.
- The trend of the obtained regression coefficient is considered to be consistent with the sedimentary environment of the geomorphologic unit.

# AVS30 Estimation Accuracy by Geomorphologic Unit

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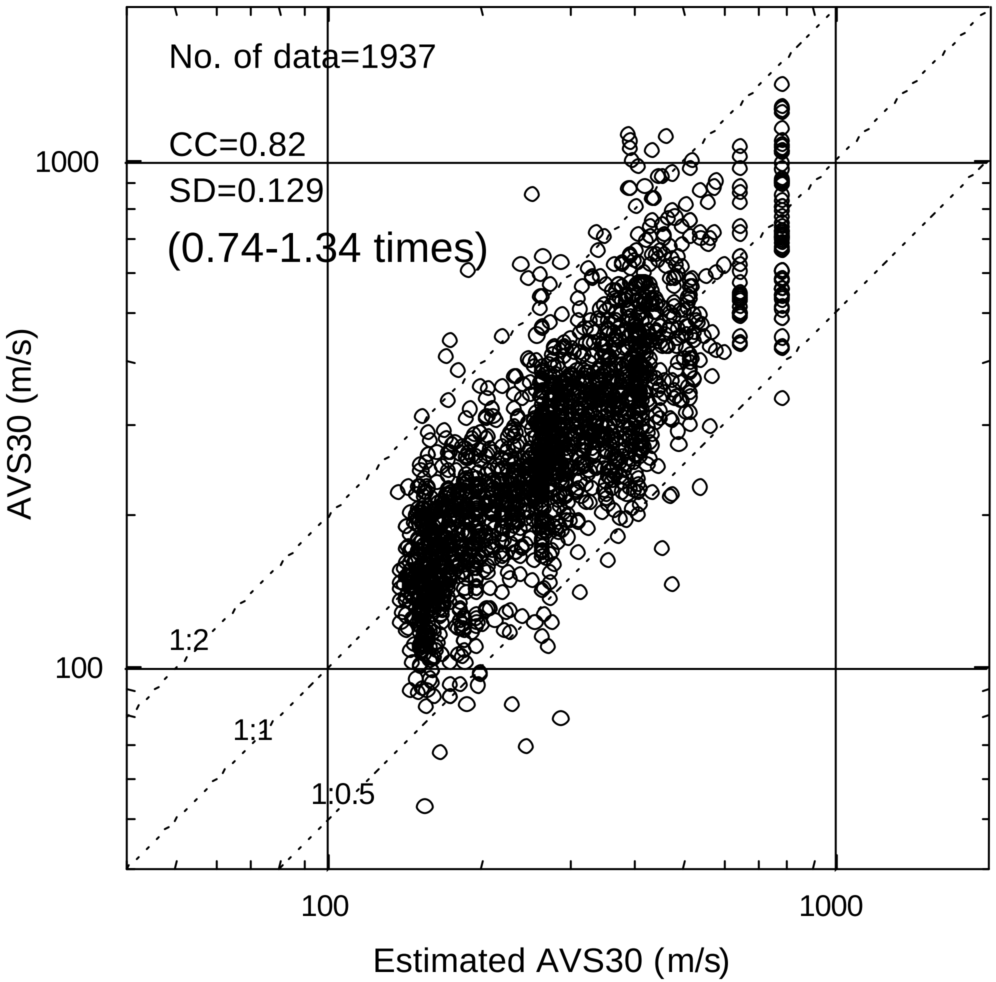
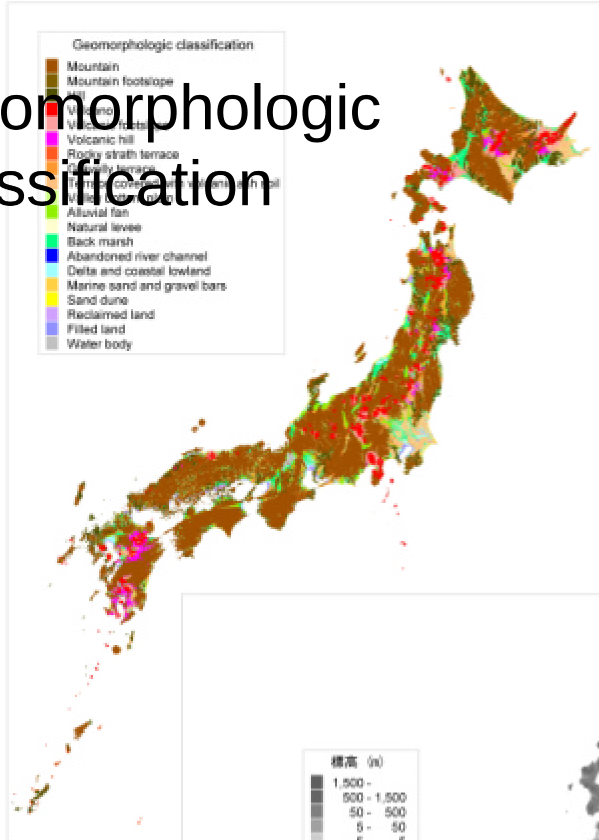
- Use of a regression equation significantly improve AVS30 estimation accuracy for valley bottom plain, and other geomorphologic units also show smaller dispersion.

# Relationship between AVS300 Estimated by Regression Analysis and Actual AVS30




- Estimation by regression equation improved the estimation accuracy by ±0.129 of logarithmic standard deviation, which shows that AVS30 can be estimated more accurately than by existing empirical formula (Fujimoto and Midorikawa 2003).

Geomorphologic classification



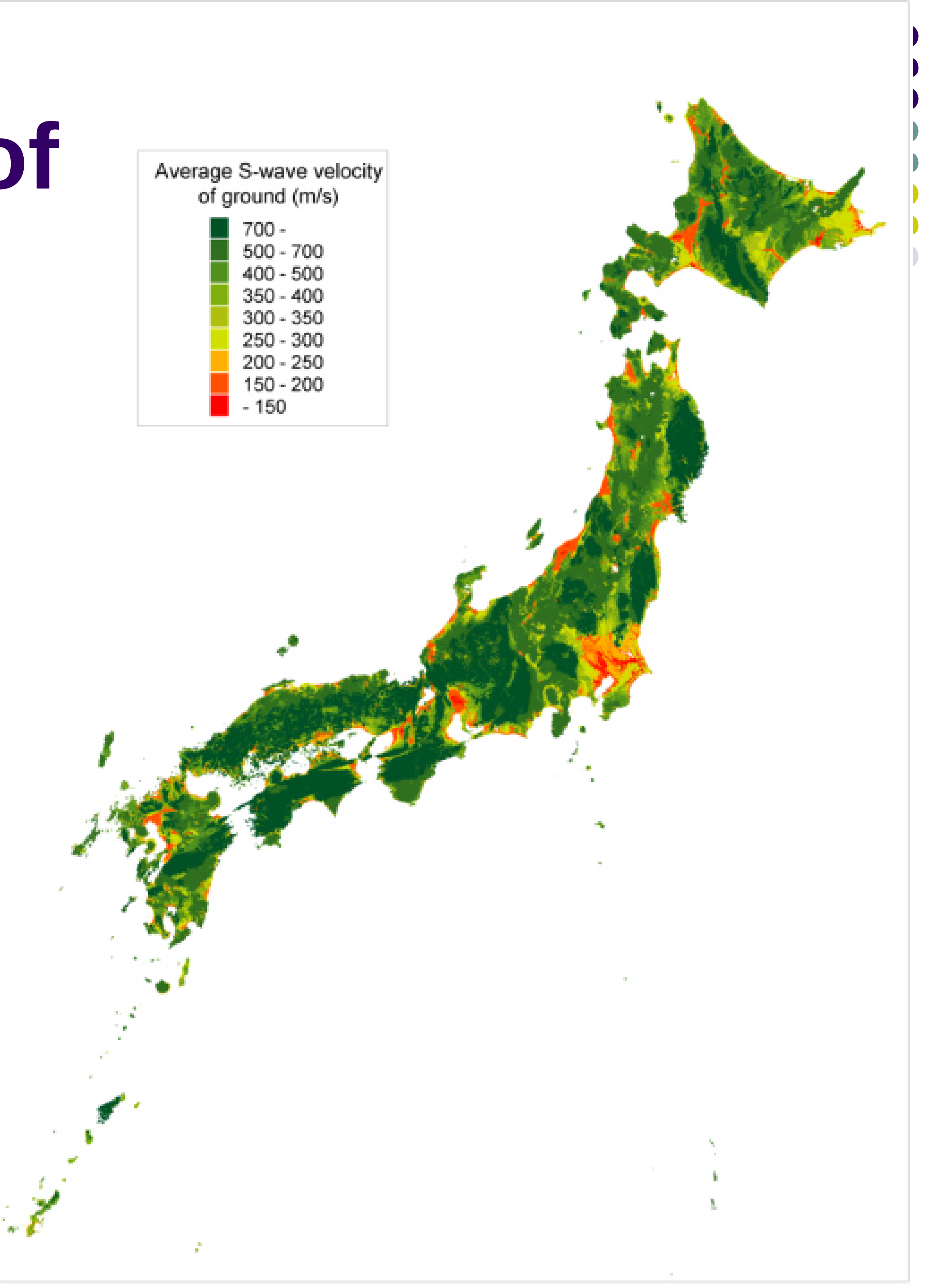

Slope gradient



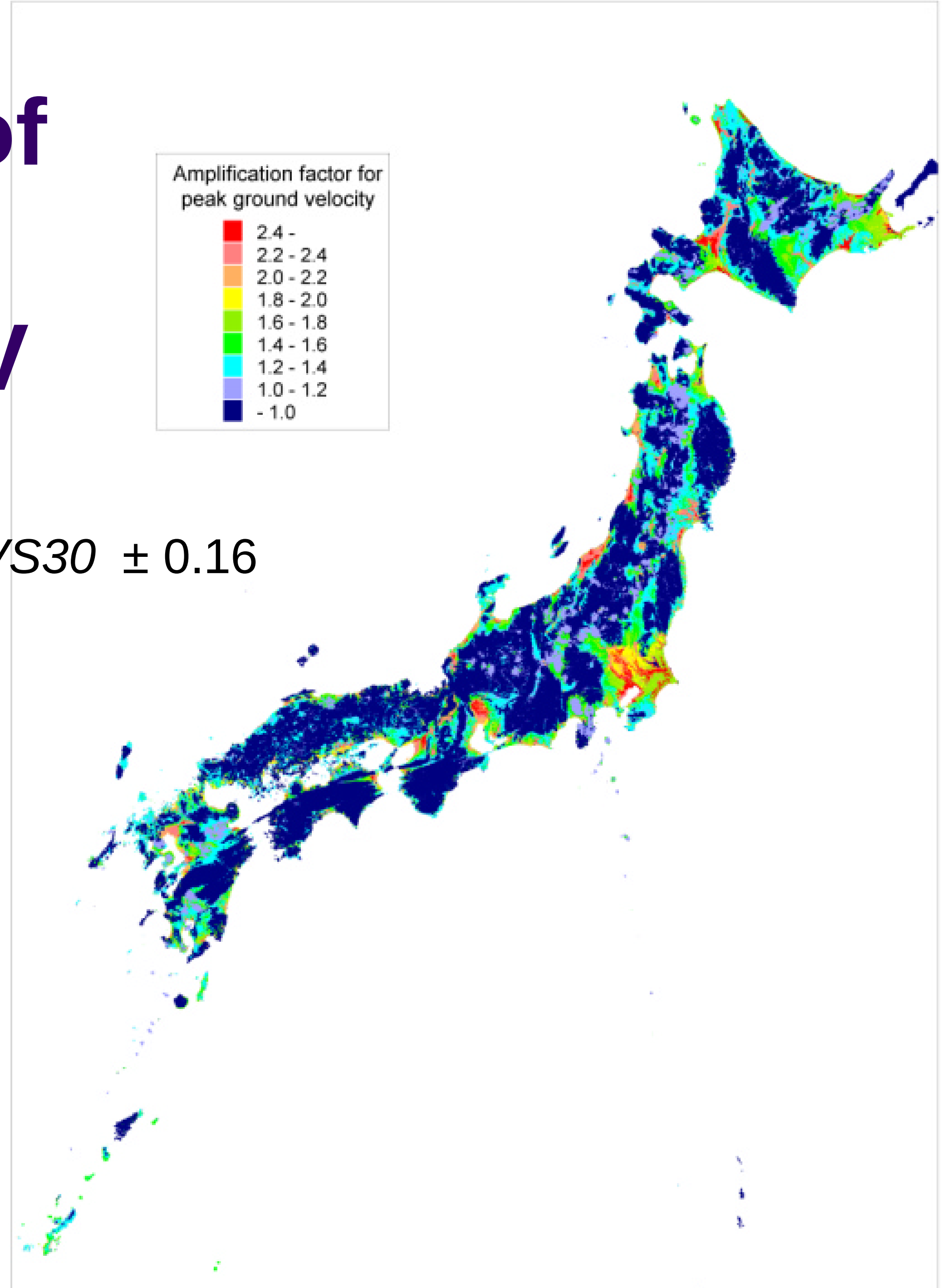
Elevation


Distance from mountain or hill

# Distribution of Estimated AVS30

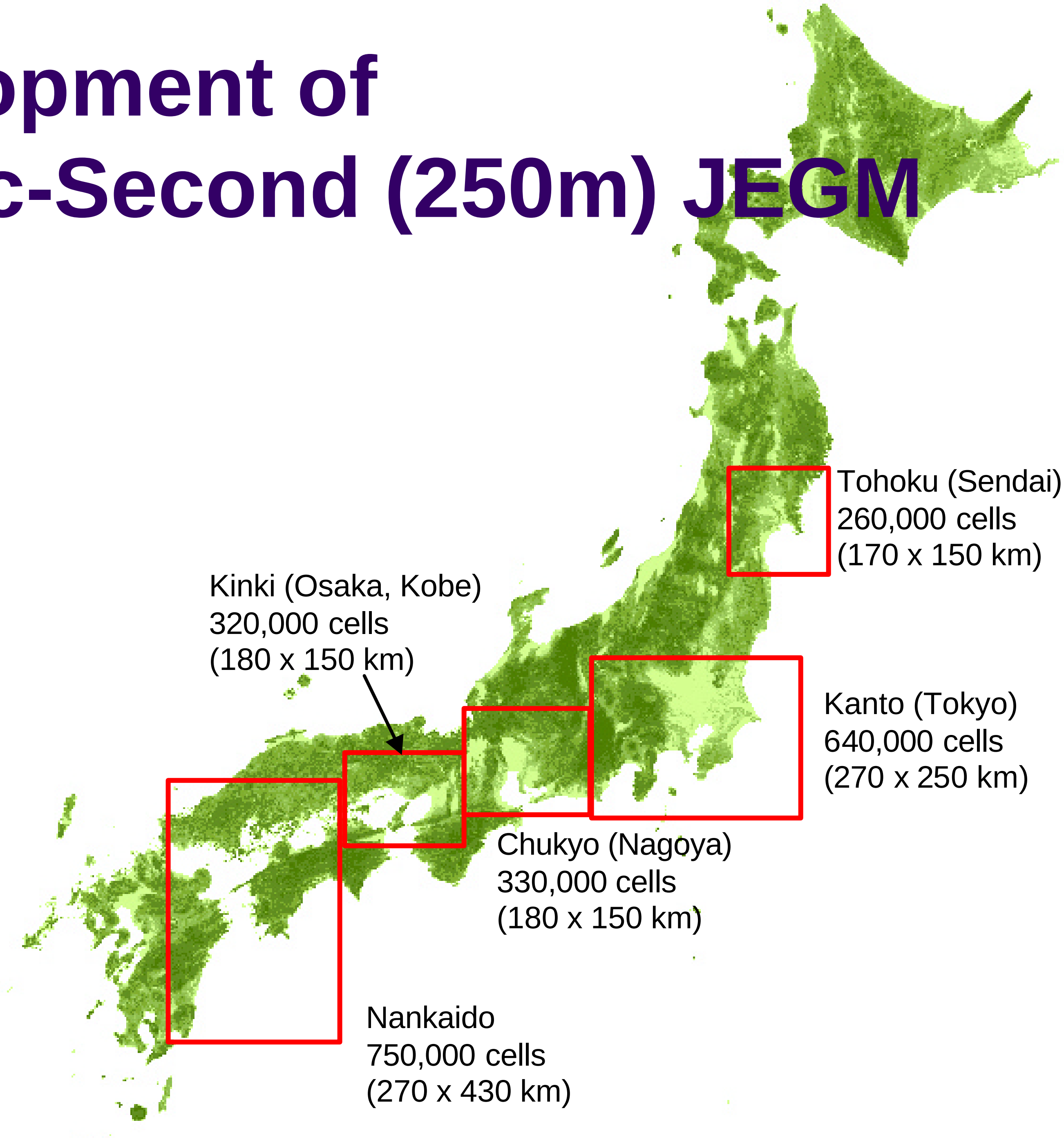


# Distribution of Amplification Factor of PGV

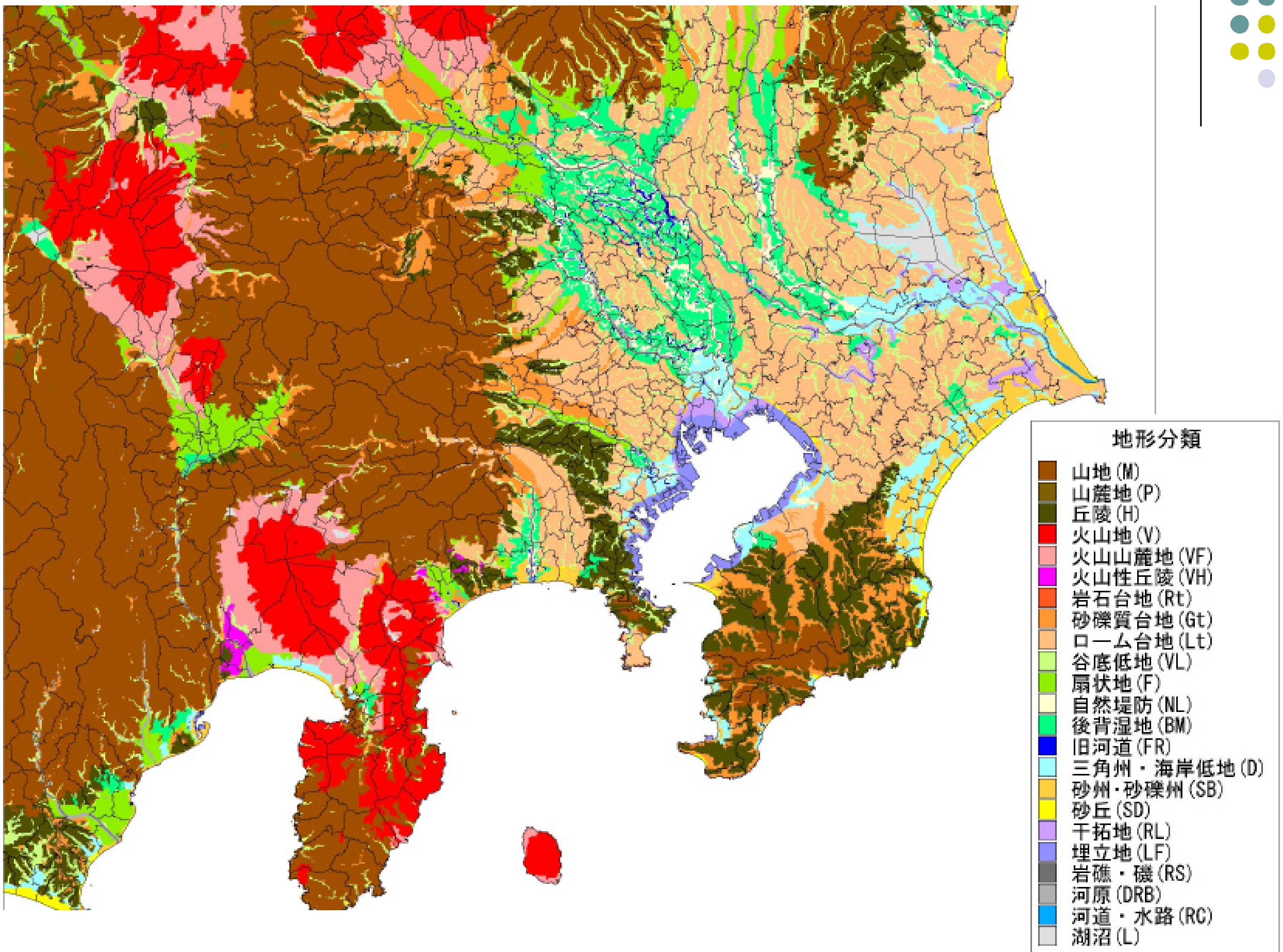



$\log ARV = 1.83 - 0.66 \log AVS30 \pm 0.16$
(Midorikawa et al. 1994)

# Development of 7.5-Arc-Second (250m) JEGM

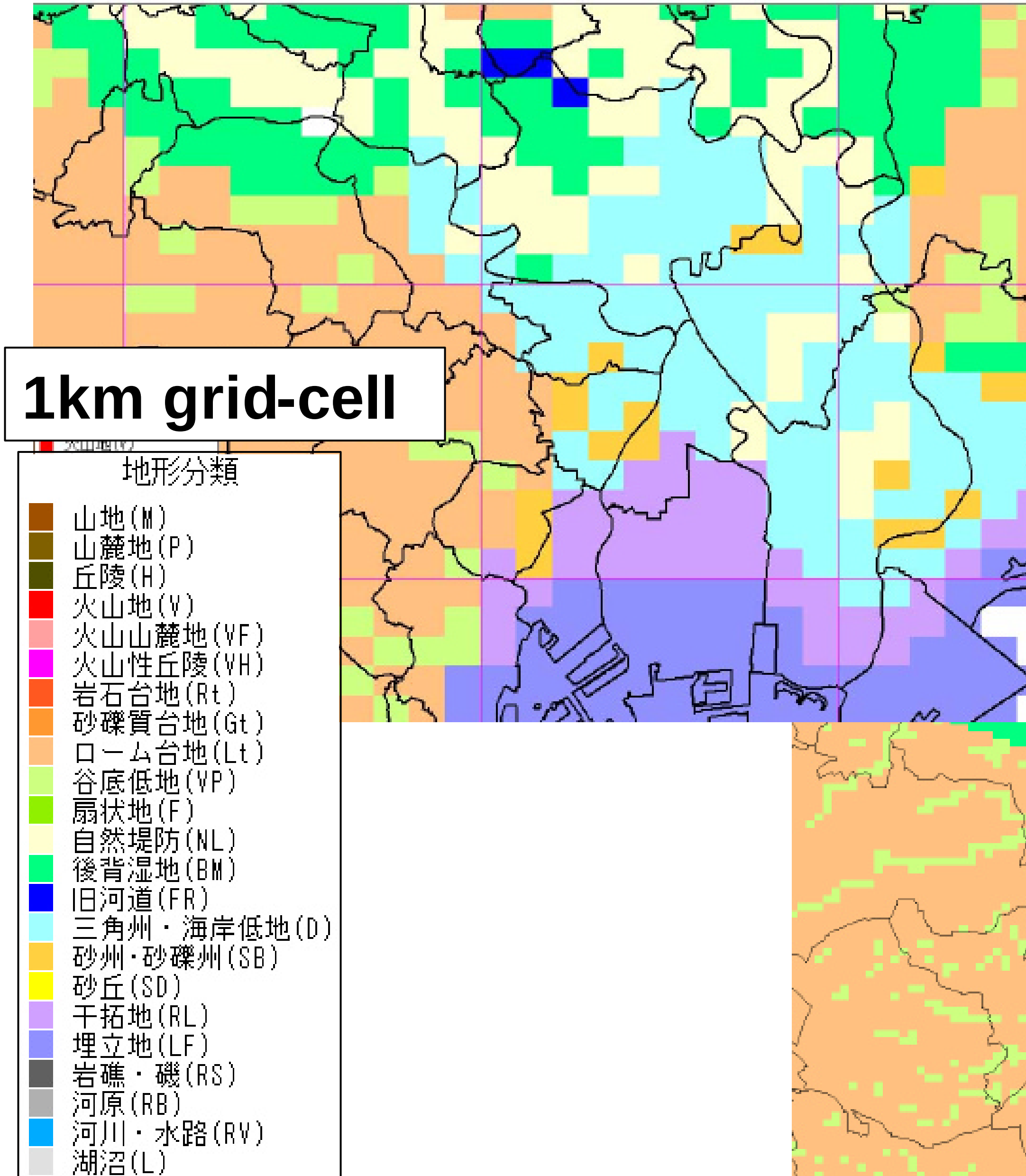


# 7.5-Arc-Second JEGM (Kanto)

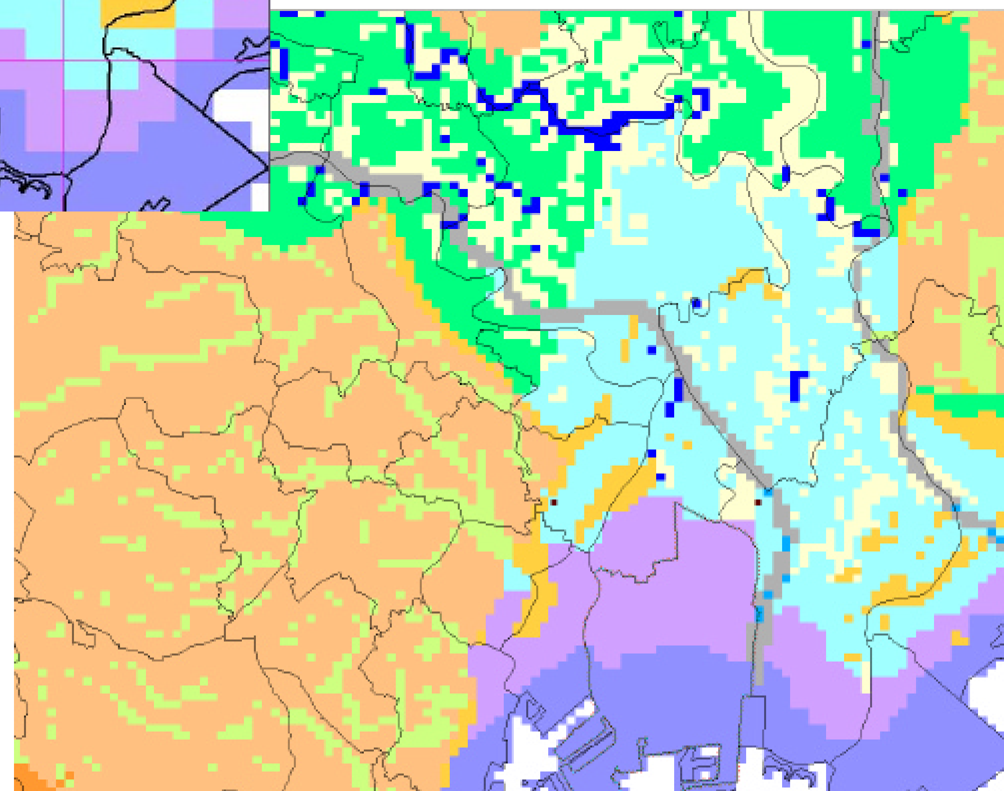


# Central Tokyo

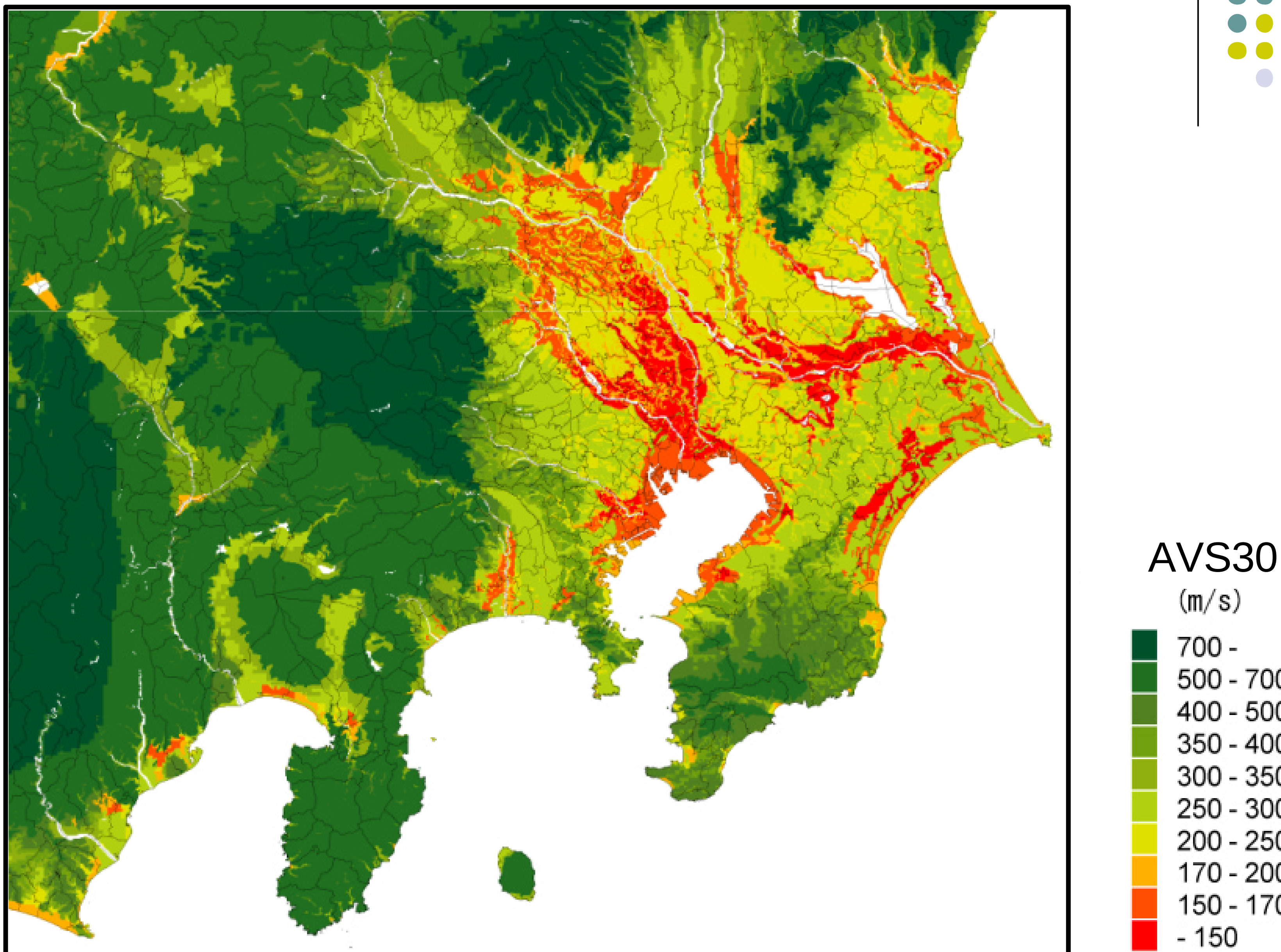
1km grid-cell




250m grid-cell



# AVS30 Map by 7.5-Second JEGM



# Concluding Remarks

- In this study, we intended to estimate average shear-wave velocity in upper 30m (AVS30) that is closely related to site amplification using "Japan Engineering Geomorphologic Classification Map (JEGM)" that was developed according to engineering-based geomorphologic classification standards.

- Accurate geomorphologic unit classification of the survey sites was performed by visual interpretation. As consequence, a significant difference in AVS30s by the geomorphologic unit was confirmed.
- Multiple linear regression analyses using geographic characteristics, such as elevation, slope gradient, distance from mountain and hill, as explanatory variables were carried out in order to estimate AVS30.
- A nationwide AVS30 mapping by using the JEGM was demonstrated

# Thank you very much for your attention