Temporal changes in S-wave velocity structure at a borehole site after strong ground motion shock

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1. Introduction

Applying coda spectral ratio and coda wave interferometry methods to a pair of ground surface and borehole seismograms which experienced strong ground motion, we measured rapid drop of S-wave velocity (V_S) near the ground surface and its recovery for over a few years.

2. Data and Method

The KiK-net station SMNH01 was shaken by the 2000 Western Tottori Earthquake (06/10/2000, Mw 6.7) and recorded maximum acceleration of 720 gal for the NS component.

This station is equipped with two accelerometers; one is on the ground surface and another is at the bottom of 100 m depth borehole.

3. Temporal Change in Spectral Ratio and Time Derivative of CCF of Coda Waves

- The lowest peak frequency of the coda spectral ratio decreases from 4.5 to 3.9 Hz after the strong ground motion. Then, it continued to recover to the original value for over a few years.
- The peak lag time of the time derivative of CCF for the NS component shows the S-wave travel time from the borehole bottom to the ground surface. It increased 20ms after the strong ground motion, and continued to recover to the original value for over a few years.
- The peak lag time of the time derivative of CCF for the UD component shows the P-wave travel time. Change of the P-wave travel time is seen, however, it is less reliable compared to that of the S-wave travel time because of low coherence.

4. Modeling of Coda Spectral Ratio

We assume scattered SH and SV waves 3-D isotropically incident to the borehole sensor with random phases.

5. Temporal Change in Velocity Structure

- We searched shear modulus (μ) of upper layers (0~22m) fitting theoretical coda spectral ratio to the observed spectral ratio for the NS component and estimated temporal change in P- and S-wave velocity structures. Increase of the S-wave travel time is fixed to the change of the lag time observed on time derivative of CCF for the NS component.

Table. 1 Conditions for the parameter estimation (for the NS comp.)

<table>
<thead>
<tr>
<th>Search condition</th>
<th>Before the mainshock</th>
<th>After the mainshock</th>
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<tbody>
<tr>
<td>Lame constant λ (Pa)</td>
<td>50-170% of well-log data</td>
<td>25-100% of before the mainshock</td>
</tr>
<tr>
<td>Density ρ (kg/m³)</td>
<td>ρ = 310 Vp²/2 (Vp of well-log data is used for all the periods)</td>
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<tr>
<td>Frequency f (Hz)</td>
<td>1-5 Hz</td>
<td></td>
</tr>
<tr>
<td>Q</td>
<td>Q0 = Q0 = 0.01 Vp²/f</td>
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- 35% drop and following recovery are estimated for V_S at the ground depth less than 11m.
- Estimated V_p structure doesn’t show significant change, which doesn’t explain the observed change of P-wave travel time on the UD component.

6. Conclusion

- The peak frequency of the coda spectral ratio dropped from 4.5 to 3.9Hz, and the S-wave travel time increased 20ms after the strong ground motion. They continued to recover to the original values for over a few years.
- Temporal change in shear modulus at the depth less than 11m is responsible to the observed change of the S-wave travel time. However, it cannot explain the change of the P-wave travel time.