Observations of Anomalous Seismic Attenuation and Evidence of a highly attenuative aseismic zone in the active collision orogen of Taiwan.

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References


Outline

• 1. Introduction
• 2. Data and Method
• 3. Results
• 4. Discussion
• 5. Conclusion
Introduction
- Seismic attenuation
- Temperature
- GPS measurements
- Cracks
- Seismic velocity structures
  - (Rau and Wu, 1995; Ma et al., 1996; Kim et al., 2005; Wu et al., 2007)
- Seismic anisotropy
- Q structures
- Very Active Collision Orogeny
Data and Method
Data analysis and Mothed

- Linear seismic array.
- 25 broadband stations.
- Spacing of 4~5 Km.
- Trillium, GPS receiver for timing.
- April 2005 to July 2006
  - Eastern Taiwan : 153
  - Western Taiwan : 15
- $3.5M_L \sim 5.0 \ M_L : 149 + 15$
- $5.0M_L \sim 5.5 \ M_L : 4$
- A total of 3213 P- and 3421 S-wave arrivals.
Data analysis and Mochtend
Data analysis and Mothed

\[ H(f) = S(f) \times P(f) \times R(f) \times I(f) \]

- \( S(f) \) : The source spectrum
- \( P(f) \) : The path spectrum
- \( R(f) \) : The site spectrum
- \( I(f) \) : The instrument response
**Data analysis and Mothed**

$$S(f) = \frac{\Omega_0}{\left[1+(f/f_c)^2\gamma\right]^{1/2}}$$

- $f$: Frequency.
- $\Omega_0$: The low-frequency spectral asymptote.
- $f_c$: The corner frequency.
- $\gamma$: The source spectral falloff.
- $\omega^2$ source model, $\gamma = 2$.
- Don’t constrain $f_c$.
  (Sarker and Abers, 1998)
Data analysis and Mothed

\[
P(f)R(f) = \exp(-\pi t^*f)
\]

\[
t^*(P, S) = \int_{\text{ray path}} \frac{1}{Q(P, S)V(P, S)} \, dr = t_0^*(P, S) + \frac{T(P, S)}{Q(P, S)}
\]

• \(t^*(P, S)\) : The observed attenuation parameter.
• \(t_0^*(P, S)\) : Near-station site effect of \(t^*\).
• \(Q(P, S)\) : The quality factor.
• \(T\) : Travel times.
• \(V\) : Velocity of P-wave (Chen and Shin, 1998) and S-wave.
Data analysis and Mothed

Separating path and site effects

\[ t^*(P,S) = t_0^*(P,S) + \frac{T_{(P,S)}}{Q_{(P,S)}} \], \, t_0^* = 0

Averaged residuals of \( t^* \) for all observed events to get an estimate of \( t_0^* \).

Iterated three times

Estimated \( Q \) from ( \( t^* - t_0^* \) )

The simul2000

Q structure
Result
Figure of $t^*$ - Epicentral distance

$$t^*(P,S) = t_0^* (P,S) + \frac{T_{(P,S)}}{Q_{(P,S)}}$$
Figure of $t^*$- Travel times
Figure of $t^*$ - S wave travel times
Figure of t*- P wave travel times
The colored dots denote increasing travel times from blue to red.
Figure of $t^*$ - S wave travel times

Group A, C and B events with a depth deeper than 12 km.

Only group B events with a depth shallower than 12 km.
Figure of $t^*$ - Focal depth

(b)

![Graph showing $t^*$ for different stations SL01 to SL25 with corresponding focal depth and group classification. The map on the right shows locations A, B, and C with symbols indicating different groups.](image)
Western stations
SL01-SL14 stations

\[ \bar{Q}_s \approx 2000 \]
\[ \sim \text{Constant} \]

Eastern stations
SL15-SL25 stations

\[ \bar{Q}_s \approx 630 \]
\[ \text{Low } Q \]

\[ \bar{Q}_s \approx 970 \]
\[ \text{High } Q \]
Two-dimensional raytracing method

(Chen and Shin, 1998)

Probable depths of the anomalous zone

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>B</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epicentral distances</td>
<td>50</td>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td>Theoretical values</td>
<td>9.9</td>
<td>11.4</td>
<td>12.8</td>
</tr>
<tr>
<td>Observed values</td>
<td>10~12</td>
<td>17~20</td>
<td>26~28</td>
</tr>
</tbody>
</table>
Figure of $t^*$ - Focal depth

(a) P wave: 1326 $t^*$
(b) P wave: 492 $t^*$ (Western)
(c) P wave: 834 $t^*$ (Eastern)

(d) S wave: 2860 $t^*$
(e) S wave: 1410 $t^*$ (Western)
(f) S wave: 1470 $t^*$ (Eastern)
Discussion
Temperature beneath Central Range

\[ T = \left[ 1100 - 150f^{0.06} \log_{10}(Q_s) \pm 50 \right] ^\circ C. \]

(Kampfmann and Berckhemer, 1985)

680–750 °C

Magma!!
Presence of fluids or partial melting

- Fluid-saturation (Toksöz et al., 1979; Hauksson and Shearer, 2006)
- Qs/Qp < 1 and high Vp/Vs: Fullysaturated rocks.

Kim et al. (2005)
Presence of fluids or partial melting

• Kim et al. (2005) explain that the high $V_p/V_s$ ratio corresponds to a highly fractured or water-saturated transition region.

• Wu et al. (2007) suggest that the high $V_p/V_s$ ratio is related to the suture of the two plates.
Lee and Cheng, 1986

- High surface heat flows
Lin 2000
Liang et al., 2007

• Moho depth of Philippine Sea plate was estimated to be about 23 km
Tectonic implications

- High pressure and temperature (Teng, 1990).
- Low-velocity structures at depth (Kim et al., 2005).
- Fluid-saturation (Toksöz et al., 1979; Hauksson and Shearer, 2006)
Tectonic implications

- Implied that the aseismic zone is probably related to high geothermal temperature and partial melting effects due to collision of the plates.
Conclusions
Conclusions

• From Figure of t*- Travel, t*-Back azimuth, and t*- Focal depth, lateral variations of attenuation is higher over the eastern part located an anomalous zone of high-seismic attenuation.

• The anomalous zone depth is at about 15–20 km as judged from two-dimensional raytracing.
Conclusions

• The Qs/Qp < 1 indicates that fully fluid-saturated rocks may exist in the lowest-Q zone.

• Significant variations with depth in crustal Q structures are revealed a low-Qp and Qs zone is further identified at depth 15 to 25 km.
Conclusions

• By combinations with several geophysical evidences, high geothermal and partial melting effects may exist in the lowest-Q area which in turn causes an aseismic zone beneath the southeastern Central Range.
• END
Figure of t*- S wave travel times