Attenuation in the Oceanic Lithosphere and Asthenosphere: Results from Arrays of Ocean Bottom Seismometers

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Using Rayleigh waves, we have measured shear attenuation beneath 4 arrays of ocean-bottom seismometers: MELT and GLIMPSE near the East Pacific Rise; PLATE on 150-160 Ma seafloor in the western Pacific, and the Cascadia Initiative deployments on the Juan de Fuca plate in seafloor 0-10 Ma old. In addition, we measured attenuation of P waves in the 1-15 Hz band beneath PLATE using body waves from intermediate and deep focus earthquakes. For Rayleigh waves, we employed the two-plane-wave technique to account for multi-path interference arising from velocity heterogeneities outside the arrays, the Born approximation to account for focusing and defocusing within the study areas, and station corrections to account for site response and errors in instrument response. Rayleigh wave attenuation coefficients extend from periods of 20 s up to 143 s for Juan de Fuca. The Juan de Fuca area is slightly more attenuating than seafloor of similar age near the East Pacific Rise. Beneath Juan de Fuca, the minimum shear quality factor Q is found centered at about 80 km, just below the expected dry solidus. Q averaged over the well-resolved depth range of 70 to 110 km is 45-50. The existence of the maximum attenuation below the dry solidus beneath young seafloor points to the role of melt removal and consequent dehydration in altering the composition and melting temperature of the mantle. A component of convective downwelling is needed to explain both the rapid increase in shear wave velocity away from the ridge and the attenuation pattern. Comparison of the attenuation of low frequency surface waves with high frequency body waves indicates that intrinsic attenuation is frequency dependent, but that the usually assumed power law form is unlikely to persist throughout the seismic frequency band.

Keywords: Attenuation, Oceanic Lithosphere and Asthenosphere

Rayleigh wave attenuation in the central Pacific upper mantle from the NoMelt experiment

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Ocean basins record fundamental plate-tectonic processes, most notably the creation and evolution of oceanic lithosphere and its interaction with the underlying asthenosphere. The NoMelt array of ocean-bottom seismometers was deployed on ~70 Ma Pacific seafloor with the aim of characterizing the seismic and electrical structure of normal mature oceanic lithosphere-asthenosphere system. Analyses of surface-wave travel times have revealed that the seismic velocities within the array are strongly anisotropic (Lin et al., 2016; Russell et al., 2016), which complicates attempts to infer the thermal structure of the lithosphere and the volatile and partial-melt content of the asthenosphere from isotropic seismic velocity. We present the first measurements of seismic attenuation determined from the NoMelt data set. Rayleigh wave amplitudes and travel times were measured using the Automated Surface Wave Measuring System (Jin and Gaherty, 2015) in the period range 20-150 s. The amplitude data are corrected for the effects of propagation outside the array and used to solve for a single frequency-dependent attenuation coefficient within the array as well as a frequency-dependent term for each receiver. Preliminary results show that the Rayleigh wave attenuation nearly doubles between periods of 40 s and 50 s. A possible interpretation is that this abrupt change corresponds to the transition from low-absorption lithosphere to strongly attenuating asthenosphere. Inverting these values for depth-dependent shear attenuation allows the transition to be more accurately located in depth and inferences about lithospheric thermal structure and the presence of volatiles and melt in the asthenosphere to be drawn.

Keywords: attenuation, lithosphere, volatiles

Seismic properties of hydrous and partially molten synthetic dunites

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The influence of hydrous, but water-undersaturated conditions and aspects of the role of partial melting of upper-mantle materials, remain to be clarified through ongoing experimental work.
Water-undersaturated conditions have been realised in the laboratory in the relatively oxidizing environment within Pt capsules/sleeves. Specimens of synthetic Ti-doped olivine have been hot-pressed within Pt capsules with a range of Ti concentrations from 176 to 802 atom ppm Ti/Si. At sufficiently oxidizing conditions, a stable extended defect is formed involving Ti/Mg substitution charge balanced by double protonation of a neighbouring Si vacancy (Berry et al., *Geology*, 2005)., The concentrations of chemically bound H range between 330 to 1150 atom ppm H/Si (Berry et al., *Geology*, 2005). Torsional forced-oscillation tests were conducted at seismic periods of 1 –1000 s and 200 MPa confining pressure during slow staged cooling from 1200 to 25°C. Each Ti-doped specimen showed mechanical behaviour of the high-temperature background type involving monotonically increasing dissipation and decreasing shear modulus with increasing oscillation period and increasing temperature. The modulus dispersion and dissipation measured under these water-undersaturated conditions are markedly stronger than for a similarly prepared specimen tested dry within an Ni-Fe sleeve under more reducing conditions. However, the data for the hydrous specimens display only limited sensitivity of the seismic properties to variation of the concentration of the Ti-hydroxyl defect. The lower shear moduli and higher dissipation measured under water-undersaturated conditions are clearly attributable to the different chemical environment. Presumably, the contrasting chemical compositions (and hence effective viscosities) of grain-boundary regions and/or differing populations of lattice defects are responsible. Clarification of the relative roles of grain-boundary sliding and any additional intragranular relaxation under increased f_{H2O} and f_{O2} thus offers the prospect of an improved understanding of the seismological signature of more oxidized/hydrous portions of the Earth's upper mantle, such as subduction zone environments (Cline et al., *Nature Geoscience*, submitted). Concerning the seismic properties of partially molten lherzolite, bulk modulus relaxation caused by stress-induced change in the proportions of coexisting crystalline and melt phases has recently been proposed (Li and Weidner, *PEPI*, 2013). In order to further assess this possibility, a forced oscillation experiment has been conducted at seismic frequencies on a newly prepared synthetic dunite specimen (sol-gel olivine + 2.6% added basaltic melt glass) utilizing an enhanced capacity of the ANU apparatus to operate in both torsional and flexural oscillation modes. Shear modulus and dissipation data are consistent with those for melt-bearing olivine specimens previously tested in torsion, with a pronounced dissipation peak superimposed on high-temperature background. Flexural data exhibit a monotonic decrease in the complex Young's modulus with increasing temperature under trans-solidus temperatures. The observed variation of Young's modulus, closely comparable with that measured by Li and Weidner, is well described by the approximation $1/E \sim 1/3G$, which holds when $G/3K << 1$. At high homologous temperatures, when the shear modulus is low, extensional and flexural oscillation measurements thus offer little resolution of bulk modulus –leaving the possibility of its partial relaxation unresolved. Planned experiments involving the measurement of volume changes caused by oscillating confining pressure may provide the answer (Cline and Jackson, *GRL*, 2016).

Keywords: seismic wave attenuation, water-undersaturated conditions, partial melting

Experimental study of polycrystal anelasticity at near-solidus temperatures and its seismological applications

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For a quantitative interpretation of the seismic velocity and attenuation structures in the upper mantle, we need to clarify the rock anelasticity [e.g., Jackson et al. 2002]. In particular, scaling law to extrapolate experimental results to the mantle is necessary. Polycrystal anelasticity follows the Maxwell frequency scaling $Q^{-1}(f/f_M)$ with f_M = unrelaxed elastic modulus / diffusion creep viscosity [Morris and Jackson 2009; McCarthy et al. 2011]. However, the applicability of this scaling law is limited to $f/f_M < 10^4$ [Takei et al. 2014], and the scaling law applicable to the seismic frequency range ($10^6 =< f/f_M =< 10^9$) has been unknown.
We made an experimental approach to the polycrystal anelasticity at near-solidus temperatures by using a rock analogue (organic polycrystals) and found that the deviation from the Maxwell frequency scaling at high normalized frequencies can be described by using homologous temperature T/T_m, where T_m represents solidus [Yamauchi and Takei 2016]. The most remarkable finding is that polycrystal anelasticity is significantly enhanced just below the solidus temperature ($0.94 < T/T_m < 1$) in the absence of melt. Viscosity is also reduced in the same temperature range. These changes, which are caused by a solid-state mechanism, were large even for the samples which generate very small melt fraction (< 1%) at $T = T_m$. In contrast, when melt fraction is small (< 1%), the effects of melt generation at $T = T_m$ on elasticity, anelasticity, and viscosity were negligibly small. We established a new anelasticity model by parameterizing these experimental data.
The applicability of this new model to the mantle was shown by the fitting to the horizontal profiles of seismic shear wave velocity in the Pacific mantle at 50 and 75 km depths, which shows a steep reduction of V_S just below the solidus temperature [Priestley and McKenzie 2013]. Then, we applied the new anelasticity model to the vertical profiles of V_S showing a discontinuous (steep) reduction at LAB; we used the temperature profiles calculated by the plate-cooling model and the solidus temperature calculated by assuming various distributions of volatile (H_2O). The new anelasticity model enables us to interpret these seismological structures, including the seismic discontinuity, by the solid-state mechanism at near-solidus temperatures without invoking melt.

キーワード：非弾性、部分溶融、地震波減衰、地震波低速度、LAB
Keywords: anelasticity, partial melting, seismic attenuation, seismic low velocity, LAB

Significant shear and bulk attenuation in the Tonga-Lau subduction system

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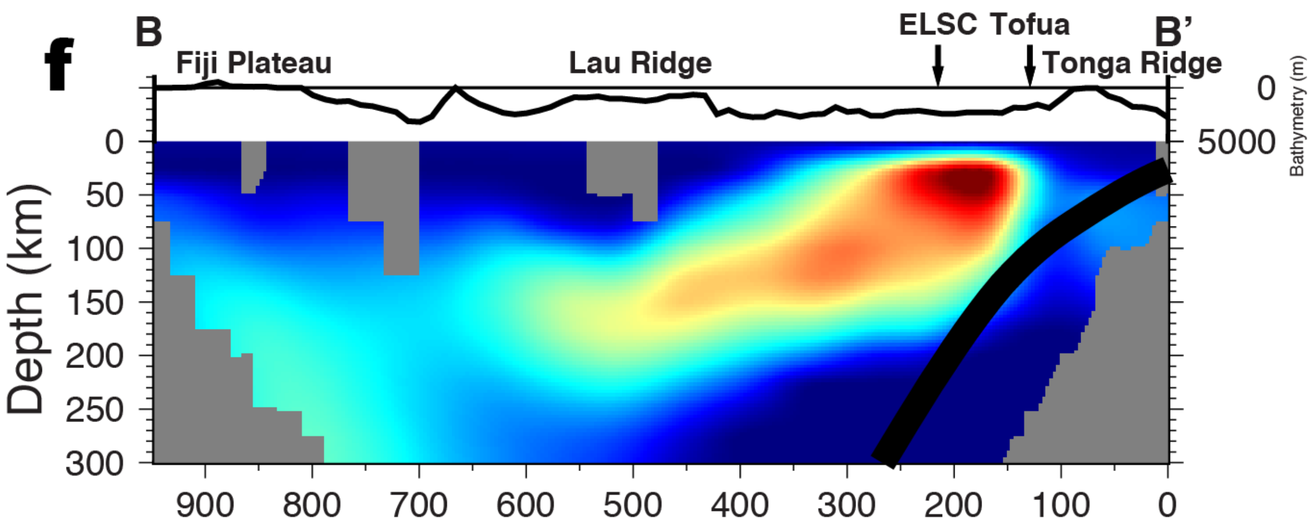
We image the 3-D attenuation structures of the Tonga subduction zone and the Lau back-arc basin using local earthquake waveforms recorded by the 2009-2010 Ridge2000 Lau Spreading Center Imaging project. Amplitude spectra of P and S waves from local earthquakes are inverted for the path-average attenuation operator (t^*) along with the seismic moment and corner frequency with varying frequency-dependent exponent (α). Analysis shows that the data are best fit by the assumption of $\alpha \approx 0.3$, supporting the laboratory-based models of grain boundary sliding. The t^* measurements are inverted with various techniques to obtain 3-D tomographic models of Q_P, Q_S, and Q_P/Q_S. Results show strong anomalies of high *P*- and *S*-wave attenuation within the upper 100 km of the mantle beneath the back-arc basin. Perhaps the highest seismic attenuation ($Q_P < 30$ and $Q_S < 20$) known in the mantle is found immediately beneath the spreading center. High attenuation anomalies form an inclined zone dipping from the back-arc spreading centers to the west away from the slab. This high-attenuation zone in the back-arc requires not only abnormally high temperature but also the existence of partial melt, suggesting that hot materials supplied from the Australian mantle upwell along with the mantle wedge flow pattern, triggering extensive decompression melting near the back-arc spreading centers. The back-arc basin attenuation anomalies show low Q_P/Q_S ratios (< 1.5), in contrast to more conventional Q_P/Q_S ratios (> 1.8) beneath the Fiji Plateau. This suggests that the bulk attenuation is as large as the shear attenuation beneath the back-arc spreading centers and near the Tonga slab, where abundance of partial melt and free water are expected, invoking mechanisms of bulk attenuation involving free fluids.

Keywords: Back-arc spreading, Seismic attenuation, Partial melting, Tonga subduction zone, Lau basin



Seismic attenuation beneath Japan: Close links to arc magmatism, seismogenesis and crustal deformation

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Nakajima et al. (2013, JGR) proposed a new technique to precisely estimate seismic attenuation along a ray path, which can minimalize a strong tradeoff between corner frequency and attenuation term. They estimated 3D P-wave attenuation structure beneath Tohoku, Japan, and discussed magmatism is controlled by a mantle-wedge process that depends strongly on spatial variations in the degree of partial melt in the upwelling flow. In recent years, we have estimated 3D P-wave seismic attenuation structures beneath Kanto (Nakajima, EPS, 2014), Kyushu (Saita et al., GRL, 2015), and central Japan (Nakajima and Matsuzawa, EPS, 2017) using the method of Nakajima et al. (2013). These studies have provided important constraints on the genesis of earthquakes in the subducting Philippine Sea slab, an along-arc variation in arc magmatism in Kyushu, and the cause of a high-strain-rate zone called the Niigata-Kobe Tectonic Zone. We will review the results of these studies and show the relationship between seismic attenuation and velocity structures in the crust and the uppermost mantle in different tectonic settings, providing important roles of seismic attenuation on the understanding of ongoing processes in the Earth.

Effect of Light Elements to Heterogeneity of Attenuation in the Earth's Inner Core

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Seismic observations have provided strong evidence of hemisphere variations, showing less attenuation, and lower seismic P-wave velocity in the western hemisphere than in the eastern hemisphere in the uppermost 100 km of the inner core (Deuss, 2014; Poupinet, Pillet, & Souriau, 1983; Souriau, 2015; Tanaka & Hamaguchi, 1997). Two major hypotheses have been proposed to explain these features: (a) inner core translation, wherein eastern hemisphere is melting at the surface of the inner core and the other side is solidifying (Monnereau, Calvet, Margerin, & Souriau, 2010), partial melting may play a key role to produce such attenuation heterogeneity at the inner core boundary; (b) thermochemical convection occurs (Alboussière et al.,2010; Deuss, 2014), which may cause the distribution of light elements. Therefore, knowledge of alloy with partial molten texture and anelastic behavior of light elements-bearing alloy is necessary to constrain the heterogeneity in the Earth's inner core. As sulfur and silicon have been considered to be more probable candidates of light elements in the inner core (Miller, 2009; Poirier, 1994; Sakamaki et al., 2016; Tsuchiya & Fujibuchi, 2009), we investigated the attenuation behavior of iron alloy containing these elements.

Three different alloys (iron, S-bearing, Si-bearing alloy) were studied. Starting materials, for S- and Si-bearing alloys were synthesized at 1 GPa in a piston cylinder apparatus. The S-bearing alloy was used to investigate anelastic behavior of the partial molten state. The measurement of seismic attenuation was conducted by in situ X-ray radiographic observation at 1.6 GPa and up to 1473 K using the deformation-DIA press at the bending magnet beam line BL04B1 at SPring-8 (Yoshino et al., 2016). The alumina aggregate, sapphire single crystal and forsterite single crystal were used as a reference material in a series of experiments. The periods of oscillation were from 0.5 to 100 s.

Pure iron with average gran size, 10 μm, showed no frequency dependence of seismic attenuation factor Q^{-1} in bcc phase, and week temperature dependence. For S-bearing samples with initially partial molten texture, melt separation occurred during experiment. The attenuation information of partial molten state could not be obtained. Attenuation of Si-bearing samples (average grain size larger than 1 mm) became larger with increasing Si-concentration, and showed no frequency and temperature dependences.

The experimental results showed that the seismic attenuation of Fe alloy is not frequency (0.01-2 Hz) dependent, which is consistent with the observed seismic data that there is no frequency dependence in some range of frequency due to different relaxation time in the uppermost inner core (Li & Cormier, 2002; Souriau & Roudil, 1995). The silicon can influence the heterogeneity of attenuation in the Earth's inner core. If silicon is one of the dominant light elements in the core, which means the concentration of silicon in west hemisphere is higher than it in east hemisphere in the uppermost 100 km of the inner core combined with the sound velocity data of Si-bearing alloy (Lin, 2003). So it can support the opinion that the core freezes in western hemisphere in uppermost of the inner core, growing the solid inner core and releasing silicon (Gubbins et al., 2011; Monnereau et al., 2010). It is needed to constrain the relationship between seismic attenuation and molten state.

Keywords: heterogeneity, inner core, attenuation, light element, partial melting

転位が岩石の非弾性に与える影響：有機多結晶体を用いたアナログ実験
Effect of dislocation on rock anelasticity: Analogue experiment using organic polycrystals

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地震波速度と減衰という2つの観測量は岩石の弾性と非弾性を反映した情報であるため，これらの観測から地球内部の状態を推定するには弾性と非弾性のふるまいを理解する必要がある．岩石の非弾性メカニズムは詳しくは明らかにされていないが，粒界すべりと転位運動の主に2つが提案されている．粒界は面欠陥として，転位は線欠陥として岩石中に普遍的に存在し，地震波伝播の際にすべり運動することでエネルギーを散逸させて，地震波の速度分散と減衰を引き起こす．実験の難しさから，転位による岩石非弾性の実験的研究は粒界すべりに比べて限られており [1, 2]，詳細なメカニズムを明らかにするにはデータが不足している．そこで本研究では，岩石アナログ物質を使用した常温常圧実験によって，転位が引き起こす非弾性の高精度，広周波数帯域での測定を実現する．

岩石アナログ物質には，ボルネオール多結晶体 [3] を用いた．この物質では，粒界による非弾性がすでに詳細に調べられているため [4, 5, 6]，そこからのずれとして転位の影響を調べることができる．まず，この試料に転位を導入するための温度・差応力条件を 調べるため，変形機構図（差応力 σ と歪速度 $d\varepsilon/dt$ の関係）の作成を行った．封圧0.8 MPa，温度40℃，50℃において，様々な1軸圧縮応力下で変形し，流動則を求めた．その結果，50℃で差応力が1 MPaを上回ると，拡散クリープから転位クリープ（$d\varepsilon/dt \propto \sigma^5$）に遷移することが分かった．転位クリープが生じたことは微細構造中の粒界移動の痕跡からも裏付けられた．

次に，決定した条件下で転位クリープさせた試料の非弾性を，10^{-4}–10^{2} Hzの帯域における強制振動実験 [5] によって測定した．拡散クリープ領域（σ = 0.27 MPa），遷移領域（σ = 1.3 MPa），転位クリープ領域（σ = 1.9 MPa）の3つの差応力条件を選び，小さい差応力条件から大きい条件へと順に変えて1つの試料を変形させ，各変形後の非弾性特性を測定した．非弾性測定では，1軸応力の正弦的な変化に対する1軸歪応答を測定する強制振動実験を行い，ヤング率と減衰（非弾性特性）を求めた．その結果，高差応力下でのクリープ後ほどヤング率が減少し，減衰が増加した．更に，こうした非弾性特性の変化は，10 日～2 週間程度かけて行った非弾性測定の間に，拡散クリープ後の状態までほぼ完全に回復することも分かった．これらの結果から，転位クリープによって試料中に導入された転位によって非弾性が増大し，その転位が回復（消滅）することで非弾性特性も回復したと解釈される．

更に，転位による非弾性緩和の時間スケールを制約するための実験を行った．転位クリープ領域（σ = 1.9 MPa）の差応力条件下で変形させた別試料のヤング率を，変形前後において，中心周波数が10^6 Hzの超音波を用いて測定した．具体的には，試料中に超音波を伝播させて縦波と横波の速度を測定することでヤング率を求めた．その結果，10^6 Hzでは変形前後でヤング率が変化せず，どちらも非緩和ヤング率に一致することが分かった．

以上の結果から，本研究の多結晶体試料では，転位が引き起こす非弾性緩和の大部分は10^2–10^6 Hzの帯域に存在していることが明らかとなった．転位による非弾性緩和は10%程度のヤング率の低下をもたらす強度を持ち，その時間スケールは粒界によるものに比べて短かった．

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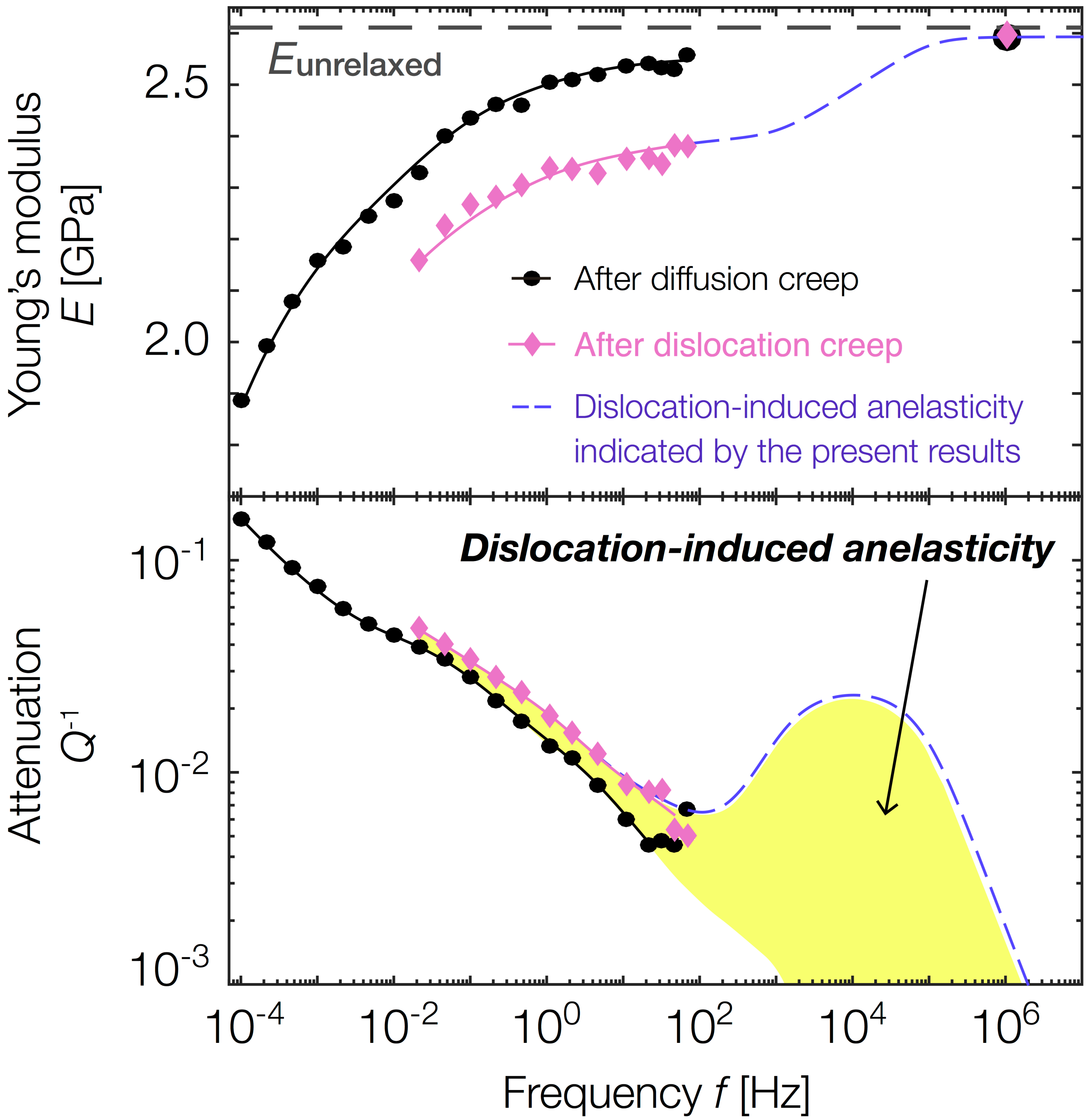
キーワード：非弾性、転位、地震波減衰、アナログ実験、欠陥、多結晶体
Keywords: anelasticity, dislocation, seismic attenuation, analog experiment, defect, polycrystal


E unrelaxed
Young's modulus
E [GPa]
2.5
2.0
After diffusion creep
After dislocation creep
Dislocation-induced anelasticity
indicated by the present results
Dislocation-induced anelasticity
Attenuation
Q-1
10-1
10-2
10-3
10-4
10-2
10^0
10^2
10^4
10^6
Frequency f [Hz]

地震波エンベロープで制約された海洋リソスフェア・アセノスフェアの内部減衰
Intrinsic Attenuations in the Oceanic Lithosphere and Asthenosphere Constrained by Seismogram Envelopes

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It is widely accepted that the oceanic lithosphere and asthenosphere have high-Q and low-Q, respectively, however, it is not very clear to which extent such attenuations are affected by seismic wave scattering (e.g., Shito et al. 2015, JGR; Kennett and Furumura 2013, GJI). To distinguish the intrinsic and scattering attenuations, analyzing seismogram envelopes is known to be effective. We deployed broadband ocean bottom seismometers on the old Pacific seafloor between 2010-2014 (NOMan Project, http://www.eri.u-tokyo.ac.jp/yesman/). We had quite large number of aftershocks of 2011 Great Tohoku Earthquake and succeeded in obtaining envelopes of Po/So and T-phase at various distances. The data purely sample the old ocean, which should provide unique opportunities to quantitatively constrain the attenuations in the ocean. We applied our envelope simulation method (Takeuchi 2016, JGR) and obtained the attenuation model by grid-searching the best structural parameters to explain the observations.

One of the most unique features of Po/So is that spatial attenuation (i.e., energy loss rate per unit propagating distance) is independent from wave type (P- or S-wave) and frequency (Butler 1987, JGR). Several previous studies (e.g, Sereno & Orcutt 1987, JGR; Mallick & Frazer 1990, GJI) explained such features by slightly ad-hoc attenuation models (strong frequency dependency; larger P attenuations than S). In contrast, we tried to explain the observations without such assumptions and succeeded in explaining most of the observed features. The results suggest that the saturation of backscattering coefficients at higher wavenumbers is primarily responsible for the constant spatial attenuation.

キーワード：減衰、散乱波
Keywords: attenuation, scattered wave

Seismic attenuation structure beneath Nazca Plate subduction zone in S. Peru

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We estimate seismic attenuation in terms of quality factors, QP and QS using P and S phases, respectively, recorded from Peru Subduction Experiment (PeruSE) array deployed above Nazca Plate subduction zone between 13˚S and 18˚S latitude in S. Peru. We first relocate 285 earthquakes with magnitude ranges of 4.0–6.0 and depth ranges of 20–250 km. We then assume a double-corner frequency source model to measure t*, which is an integrated attenuation through the seismic raypath between the regional earthquakes and stations. The measured t* are inverted to construct three-dimensional attenuation structures of S. Peru. Checkerboard test results for both QP and QS structures show that we have good resolution in the slab-dip transition zone between flat and normal slab subduction down to a depth of 120 km. Both QP and QS results show high attenuation in the mantle wedge along the normal slab-dip region. Also, both show relatively higher attenuation continued down to a depth of 100 km beneath volcanic arc and also beneath the Quimsachata volcano, located farther away from the arc. We plan to compare our results with velocity models previously derived from various tomography studies for understanding structural heterogeneity, thermal conditions, and fluid content in the study area. Also, we relate measured attenuation in the mantle wedge to material properties such as viscosity to understand the subduction zone dynamics.

Keywords: attenuation, Peru

紀伊半島下の詳細な地震波減衰構造
Detailed seismic attenuation structure beneath Kii peninsula, southwestern Japan

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Three-dimentional seismic attenuation structure (frequency-independent Qp) beneath Kinki region is estimated using t* determined by applying the S-coda wave spectral ratio method to waveform data from the nationwide dense seismic network and temporary seismic observations beneath Kinki region [Shibutani and Hirahara, 2016]. Method and analysis procedure used in Kita and Matsubara [2016] were adopted in this study. The temporary seismic observation was performed from May 2004 to March 2013. The seismic attenuation structure was imaged beneath Kii peninsula at depths down to 50 km. The resolution of the image was improved comparing to that in the previous study [Kita and Matsubara, 2016 JGR] , in which only data from the nationwide dense seismic network was used. Very low-Qp portion is clearly imaged in the continental plate at depths ~30 km beneath from Osaka to southern Kyoto. The location of the very low-Qp portion corresponds to the location of Low Vp and Vs portion by Shibutani and Hirahara [2016]. Beneath Kii peninsula, hypocenters of low frequency earthquakes determined by Ohta and Ide [2011] are located above relatively low-Qp portion within the subducting oceanic crust. The location of the relatively low-Qp beneath the low frequency earthquakes also corresponds to low Vp and low Vs portion obtained by Shibutani and Hirahara [2016]. At the depths of 30 and 50 km, high-Qp portions are imaged beneath Kumano, Shingu, Kouyasan and Izumi-Ohtsu region. The strike of the high-Qp region corresponds almost to that of segmentation boundary of Vp/Vs structure [Akuhara et al., 2013] and tremors.

キーワード：地震波減衰構造、スロー地震、地震波速度構造、t*、西南日本
Keywords: Seismic attenuation structure, Slow earthquakes, Seismic velocities structures, t*, Southwestern Japan

Seismic Attenuation Tomography of Gofar Transform Fault, East Pacific Rise Using OBS Observations

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Gofar transform fault of East Pacific Rise generates M_w 5.5-6 large earthquakes quasi-periodically on some segments of the fault, which are separated by stationary rupture barriers. Earthquakes in the seismic cycle of the large earthquake have clear spatial and temporal evolutions. To better understand the relationship between the earthquake behavior and the physical properties of the fault zone along the strike, Woods Hole Oceanographic Institution deployed a broadband ocean bottom seismograph (OBS) array on Gofar transform fault for 1-year continuous measurements, which successfully captured a M_w 6.0 earthquake on18 September 2008 and provided an unprecedented dataset. By using t* values determined from fitting seismic waveform frequency spectrum, we have conducted three-dimensional seismic attenuation tomography to determine along-strike attenuation structure. Combined with the high-resolution earthquake locations and Vp, Vs and Vp/Vs models determined from seismic velocity tomography, we found that the seismicity behavior is mainly controlled by structure heterogeneities along the fault.

Keywords: Gofar transform fault, Seismic attenuation tomography, Structure segmentation

