精密音響測距による日本海溝を挟んだ相対運動の検出
Detecting a relative motion across the Japan Trench using precise acoustic ranging

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2011年東北地方太平洋沖地震（東北沖地震）では，50 mを超える地震時すべりが発生したと報告されている(例えば，Iinuma et al., 2012 , JGR)．東北沖では，東北沖地震後，精力的にGPS/音響結合方式（以下，GPS/A）による地殻変動観測が実施されており，Tomita et al.（2015, GRL）では計測された太平洋プレートの加速はSun et al.（2014, Nature）がモデル計算で示した粘弾性緩和の寄与で説明可能としている．一方，GPS/A観測のみではプレート境界の局所的な変形様式の詳細は不明である．そこで，我々は，2014年9月～2015年5月の8ヶ月間，海底間音響測距観測を実施した．海底間音響測距は，プレート間を挟んで機器を設置することにより，連続的かつ精密に地殻変動が検出できる．本観測に先立って行われた予備観測では，1 cm/yrの精度で相対速度を検出できることが示されている（長田・他，2014，JpGU)．
本観測では，宮城県沖の日本海溝軸を挟むように3台の機器を設置し，2基線の変位検出を試みた．基線長はそれぞれ約7 kmと10 kmで，4時間毎に音波の送受信を行った．音波の往復走時と精密な音速との積をとることにより，相対距離を検出できる．精密音速は温度，圧力，塩分に依存するため，音波収録と併行して，温度計測も実施した．圧力は理論潮汐NAO.99Jb（Matsumoto et al., 2000, J. Oceanogr.）を使用，塩分濃度は深海底の安定した環境であることから定数とした．なお，精度に関しては，両基線とも2 cm/yr以内であり，予備観測とほぼ同様であった．
約8ヶ月間の測距データを解析したところ，観測精度内の有意な変位は認められず，グローバルモデルによる日本海溝のプレート収束速度（約8 cm/yr）に相当する変形は海溝軸に局在化して存在しないことがわかった．従って，宮城県沖の海溝付近では，少なくとも現在は余効すべりが無く，再固着していると推測される．
2015年9月には，同海域に新たに5台の機器を設置し，約2年間の予定で観測中である．更に，余効すべりが著しいとされる福島県沖（Sun and Wang, 2015, JGR）にも新たに観測点を追加する計画も進行中である．これら新たなデータとも統合し，より精密な日本海溝のプレート相対速度の検出が期待される．

キーワード：海底間音響測距、東北地方太平洋沖地震、日本海溝、余効すべり、海底測地
Keywords: direct path acoustic ranging, the 2011 Tohoku-oki earthquake, the Japan Trench, postseismic slip, seafloor geodesy

Along strike structural variation in the central to northern part of the Japan Trench axis region

Along strike structural variation in the central to northern part of the Japan Trench axis region

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Great earthquakes have occurred along the Japan Trench subduction zone, and some of them, e.g. Meiji Sanriku earthquake in 1896, could have ruptured the shallow portion of the plate boundary fault similar to the 2011 Tohoku earthquake. Geological/geophysical structure in the vicinity of the trench axis is one of the keys to understand the nature of shallow mega thrust events and tsunamigenesis. We have conducted high resolution seismic surveys in the northern part of the Japan Trench axis region in 38 –40.5 N to investigate the detailed structure in the trench axis area. Thrust faults and possible slope failures are observed landward of the trench axis, beneath the lowermost landward trench slope. The deformation and evolution styles of the lowermost landward slope show variation along the trench strike. To the south of the survey area in 38 –39 N, imbricate thrust-and-fold packages is observed but limited within the vicinity of the trench axis. Thickness of the hanging wall sediment is relatively thinner in the lowermost landward slope. These observation could suggest that the lowermost slope has not been well developed in this area. To the north around 40 –40.5 N, frontal thrusts and imbricate structure are clearly observed on the seismic profiles through ~ 10 –15 km landward of the trench axis. Thickness of the hanging wall sediment is thicker in this area. The bending-related faults on the subducted plate are generally not located beneath the lowermost slope up to ~ 10 km landward of the trench. These observations suggest that the imbricate structure has been well developed in the last ~ 10 kyr in this area. Around 39.5 N, it is suggested that slope failures have occurred. The trench axis is filled by slump deposits and debris with chaotic acoustic characteristics. Above mentioned variations in the deformation and evolution style in the lowermost landward slope could affect the mechanism of tsunami generation in the northern Japan Trench. The variation on the thickness of the incoming sediments is also identified along the trench strike. The variation of the sediment thickness on the incoming plate and its relation with the throw of the bending-related normal fault could also be an important factor for the tsunami generation caused by the shallow mega slip events in the northern Japan Trench. In 2015, another high resolution seismic survey was conducted in the Japan Trench off Miyagi-Fukushima region. We acquired 20 seismic profiles and will introduce initial results in this presentation.

キーワード：日本海溝、反射法探査
Keywords: Japan Trench, reflection seismic survey

日本海溝における単独観測点法を用いた低周波微動の検出

Detecting tectonic tremor through frequency scanning at a single station in the Japan Trench subduction zone

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Slow earthquakes, such as tectonic tremors and slow slip events (SSE), are the most distinctive geophysical phenomena on the subducting plate interface and occur at both ends of updip and downdip of coseismic slip areas. Tremors and SSEs have been observed in the subduction zone at the updip portion near the Japan Trench [Kato et al., 2012; Ito et al., 2013, 2015].
Ito et al. (2015) showed three possible tectonic tremor sequences from the excitation of amplitude of ambient noise accompanying SSE. The tremor signals in these sequences with very weak amplitudes were observed at only one station. Here, we apply the frequency scanning analysis to detect and validate tectonic tremors near the Japan Trench; we re-examine the tremor activities from ocean bottom seismometer (OBS) data.
Sit et al. (2012) proposed “the frequency scanning analysis” to detect tectonic tremors by calculating ratios of the envelope waveforms through different bandpass filters of broadband data at a single station in the Cascadia margin. We apply this analysis to the seismic data recorded at 17 short-period OBS network stations deployed in the Japan Trench axis area off Miyagi, northeast Japan. Three types of bandpass filters with frequencies of 2–4 Hz, 10–20 Hz, and 0.5–1.0 Hz, corresponding to the predominant frequency band of tectonic tremors, local earthquakes, and ocean noises, respectively, are adopted.
The results show three major tremor sequences, which correspond to the tremor sequences reported in Ito et al. (2015), suggesting the occurrence of tremors in the subduction zone. Furthermore, we have successfully detected tremor signals at another two sites, especially from the second tremor sequences. We conclude that the second tremor sequence probably occurred in a slightly far area from the Japan Trench, or with larger magnitude than the other two tremor sequences. We have also estimated the release energy of tremors occurring Japan Trench before the largest foreshock of Tohoku-Oki earthquake.

宮城県沖日本海溝浅部における海底地震計アレイ観測

Seismic observations using ocean bottom seismometer arrays off-shore Miyagi, northeast Japan

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Japan Trench is one of the most important subduction zones when discussing the occurrence condition of slow earthquakes. Although recent studies have identified some slow slip events (SSEs) and tectonic tremors in the shallow part of the Japan Trench subduction zone (Kato et al., 2012; Ito et al., 2013; Ito et al., 2015), the existing observation is still very limited because of the sparse seismic network. For the aim of examining detailed activities of shallow seismicity including tectonic tremors, we deployed ocean bottom seismometer (OBS) arrays near the trench. In this study, we analyze 6 months observed array data to show the fundamental performances of installed arrays.
We installed three OBS arrays (AoA1-3) at interval of about 20km near the trench where the anticipated slip area of SSEs and the high coseismic slip area are overlapped. Each array consists of 5 stations spacing about 500m. The station at the center of array has a broad-band OBS and other 4 stations have a short-period OBS, respectively. While the observation is now going on with replacing of the OBSs, the first observation of AoA has been performed for 6 months from the 28 October 2014. Data from all stations have been successfully recovered on May 2015.
For each array data, we conduct a coherence analysis using the moving-window correlation technique to detect coherent signals and estimate their incoming directions (e.g. Fletcher et al., 2006). For every 4s time window, the optimum azimuth and apparent velocity are measured by maximizing the average cross correlation of all pairs of seismograms within an array with an assumption of plane waves.
We successfully detect many coherent signals. The number of signals detected simultaneously by all arrays is about 2,500 in the entire observation period, which includes regional and distant earthquakes or artificial signals like airgun shooting. About 1,000 signals correspond to the regional events in the earthquake catalog of the Japan Meteorological Agency (JMA). For corresponding events the azimuths estimated by two arrays (AoA2, AoA3) are almost consistent with azimuths from JMA epicenters, whereas the azimuths estimated by AoA1 are inconsistent and strongly biased to the specific direction of about 90 degrees, which is probably due to site effects. We also show detected tremor-like signals, though their origins are still uncertain at this time.
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キーワード：日本海溝、スロー地震、微動、海底地震計アレイ

Keywords: Japan Trench, slow earthquake, tremor, OBS array

2012年12月東北沖スラブ内ダブレット地震（Mw7.2）の断層モデルから考察した2011年東北沖地震後のスラブ内応力場

Improved fault model of the Tohoku intraslab earthquake on Dec. 2012 (Mw 7.2) and its implication for the post-2011 stress state

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2012年12月7日に宮城県沖の海溝軸付近において発生したダブレット地震について，震源直近に設置された海底圧力計が捉えた津波記録から，ダブレットを構成するサブイベントの断層モデルの推定を行った．この地震の震源周辺では，東北沖地震前のスラブ内応力は浅部と深部それぞれで伸長・圧縮応力場であることが知られていたが，まず深部の圧縮応力場で逆断層型イベント（57.8km，サブイベント1）が起こり，その12秒後に浅部の伸長場で正断層型イベント（19.5km，サブイベント2）が起こった（いずれもMw7.2，Global CMT）．2011年東北地方太平洋沖地震が発生した影響でスラブ内応力が変化した可能性が指摘されている（例えばObana et al., 2012, GRL）．伸長応力場と圧縮応力場の間には，応力の中立域があると期待され，その深さはスラブ内応力の変化に伴って変化すると考えられる．そのため，我々はこれまで，2つのサブイベントの破壊の深さ方向の広がりから，東北沖地震後の応力中立域の深さを拘束できると考え，各サブイベントの断層モデルの推定を試みてきた．その結果，2つのサブイベントの破壊域は海面から約40kmの深さを境に棲み分けており，2012年の地震時に応力中立域がこの深さにあると推定した（久保田ほか，2015，JpGU; 2015, SSJ; Kubota et al., 2015, AGU）．しかし，これまで用いたデータが津波のみだったため断層の広がりの深さ方向の制約が十分でない可能性があることから，他の観測記録の情報に基づく拘束を与え，断層モデルに関して再検討を進めている．
海底地震計から決定された2012年の地震の余震分布（Obana et al., 2014, EPS; 2015, AGU）によると，サブイベント2の周辺で多くの余震が発生し，その震源が西に傾斜する分布を示す一方，サブイベント1の周辺ではほとんど余震は起こっていなかった．そこで，余震の情報からサブイベント2の断層に拘束を与え，それによる海底上下変動と津波解析から推定された津波波源分布との整合性を検討した．1枚矩形断層を仮定し，その水平位置，走向，傾斜を余震分布に拘束した．断層の上端，下端はそれぞれスラブの表面（海面からの深さ約7km)と，余震分布の下限（~40km）の範囲にあるとし，すべり量はGlobal CMTとスケーリング則に基づいて与えた．この断層モデルから海底上下変動分布を求め，これに水深フィルタ効果（Saito and Furumura, 2009, GJI）を考慮して得られる海面上下変動分布を，津波波形逆解析から推定した波源分布と比べたところ，波源モデルの沈降域の広がりと沈降量をおおむね説明でき，津波波源の沈降部分が基本的にはサブイベント2によって形成されたことがわかった．今後，断層すべりの深さ分布の違いによる海面変動分布パターンに注目して，サブイベント2の断層の深さ方向の広がりについて詳細に検討する．また，地震発生時に設置されていた海底地震計の記録からサブイベント1の破壊開始点の位置を決定することにより，その断層位置を拘束する．さらに，2つのサブイベントの複合破壊による津波の波形計算を行い，各サブイベントの震源断層モデルを改善し，地震活動に基づく先行研究との比較から，応力中立域の深さに着目して，東北沖地震前後でのスラブ内応力場の変化について考察する．

キーワード：津波、ダブレット地震、スラブ内応力、2011年東北地方太平洋沖地震
Keywords: Tsunami, Doublet earthquake, Intraslab stress state, 2011 Tohoku-Oki earthquake

2011年東北地方太平洋沖地震津波の遠地DARTデータに基づく海面変位の津波インバージョン
Tsunami inversion for sea surface displacement from far-field DART data of the 2011 Tohoku tsunami

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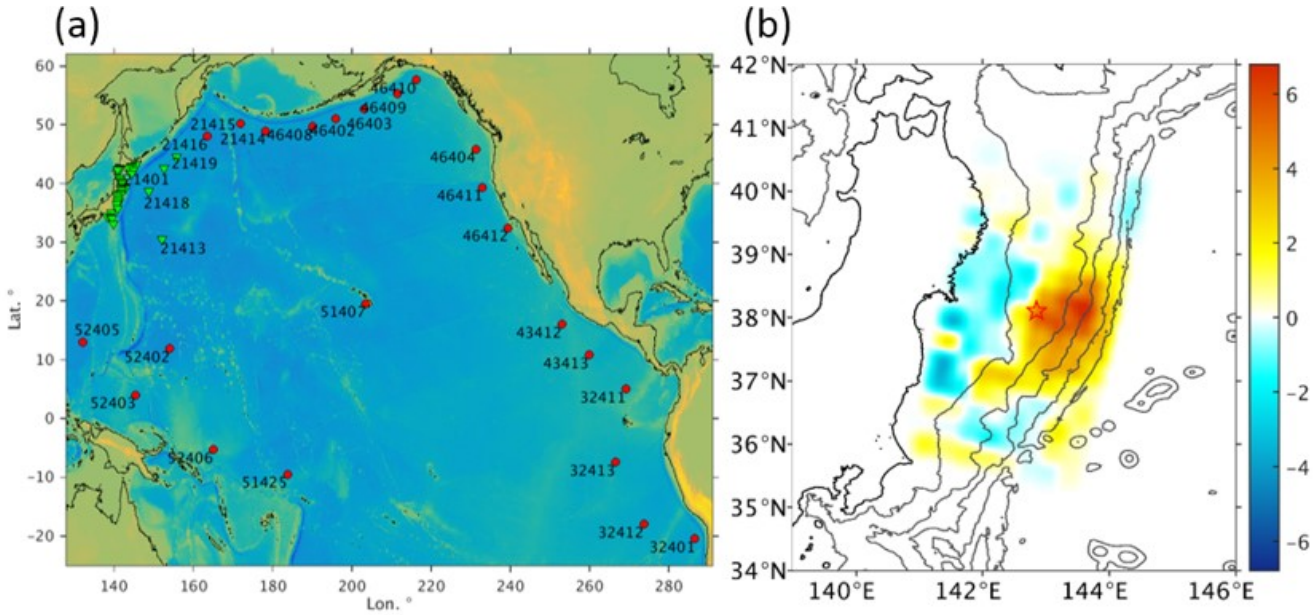
We re-examined the 2011 Tohoku tsunami source using far-field DART data, which was not used in previous waveform inversions. Only near-field stations around Japan were used in most inversion studies of the 2011 tsunami. Although the number of available tsunami gauges such as tidal gauge, ocean-bottom pressure gauge and DART increased after the 2004 Indian Ocean tsunami, most tsunami gauges are coastal gauges and DART gauges in the deep ocean are still fewer. For an accurate and reliable tsunami waveform inversion, the azimuthal coverage of stations is important. For a better station coverage, tsunami waveforms recorded at far-field stations must be utilized.
Problems that prevented to use far-field tsunami data in inversion were travel time-delay and polarity reversal of tsunami waveforms recorded at far-field stations. However, Watada et al. (2014, JGR) proposed a phase correction method, which corrects the tsunami waveforms simulated by solving the linear shallow water equations into a dispersive waveform which accounts for the effects of elastic tsunami loadings on the Earth, compression of seawater, and gravitational potential change associated with tsunami propagation. With the phase correction method, we are able to use the waveforms recorded at far-field stations and attain more azimuthally complete result in waveform inversion.
We apply the phase correction method to synthetic linear long waves and use those phase-corrected far-field waveforms together with near-field waveforms in the inversion. We re-examined the result of 2011 Tohoku earthquake tsunami. Both single time window and multiple time window inversion are performed. The poor azimuthal coverage of near-field stations are replenished by far-field stations. Because the previous studies used abundant near-field (< 2 hour traveltime) data of 2011 Tohoku tsunami, effects of additional far-field stations is limited.
Fig. (a) Far-field stations (red dot) used in this research, reverse triangles are for near-field stations. (b) Inversion result of simultaneous movement after adding far-field stations.

キーワード：津波、インバージョン、遠地、DART、東北地方太平洋沖地震津波
Keywords: tsunami, inversion, far-field, DART, Tohoku tsunami



Variation of the subduction structure along the Nansei-Shoto trench

Variation of the subduction structure along the Nansei-Shoto trench

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The Nansei-Shoto subduction zone, extending 1,200 km from Kyushu to Taiwan, has been intensively examined in terms of seismic coupling along the plate boundary and tsunami potentials. On the contrary to other subduction zones nearby, the Nansei-Shoto subduction zone has lacked clear evidence of great megathrust earthquakes (M>8) for the last few hundred years and thus the overall interplate coupling is thought to be weak (Peterson and Seno, 1984). Correspondingly, slow slip events and very low frequency earthquakes are ubiquitously distributed in the forearc region (Nishimura, 2014; Nakamura and Sunagawa, 2015), supporting the idea that the plate interface is “weakly” coupled. One of the exceptional great earthquakes known in the history is the 1911 Kikai-jima earthquake (M8.0) in the northern part of the subduction zone at ~29ºN (Usami, 1996). Recent studies suggest that this earthquake may have been a shallow interplate event that accompanied a large tsunami (Goto, 2013). However, background subduction structure generating such an event in a weakly-coupled condition remains enigmatic.
In order to improve our understanding of the seismic potentials and the controlling factors of the seismogenic process in the Nansei-Shoto subduction zone, JAMSTEC has been working on the integrated seismic project that consists of two-dimensional active-source experiments and extensive passive observations. In 2015, multichannel seismic reflection data were collected along two lines that cross the potential source region of the 1911 Kikai-jima earthquake. Together with refraction/wide-angle reflection data obtained by Japan Coast Guard in the same area, we succeeded in imaging the structure of the subducting slab and the frontal wedge.
The most prominent structural feature we found is a ~100-km-wide low-velocity zone at the seaward edge of the overriding plate within which multiple landward-dipping reflectors are imaged. This structure is very similar to the accretionary prisms in the Nankai subduction zone and is in a great contrast with the non-accretionary frontal wedge (with less than 40 km width) in the southernmost part of the Nansei-Shoto subduction zone. This difference probably comes from the structural variation of the incoming plate and the amount of sediment supply into the trench: To the north lie a series of volcanic ridges of late Cretaceous to early Eocene ages (Amami Plateau, Daito Ridge and Oki-Daito Ridge), while the West Philippine basin to the south exhibits a deep seafloor with little amount of sediments on its top. Large bathymetric highs and volcanic products on the incoming plate may have contributed to produce the accretionary frontal wedge and anomalous earthquakes in the northern part of the Nansei-Shoto subduction zone.

キーワード：Megathrust earthquakes、Plate subduction、Active-source experiments
Keywords: Megathrust earthquakes, Plate subduction, Active-source experiments

Evidence for a fluid-rich layer beneath the Nankai Trough megathrust fault off the Kii Peninsula inferred from receiver function inversion

Evidence for a fluid-rich layer beneath the Nankai Trough megathrust fault off the Kii Peninsula inferred from receiver function inversion

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Exploring fluid distribution on megathrust faults is an important issue, since the fluid affects frictional property and thus slip behaviors on the faults. Scattered teleseismic phases, or receiver functions (RFs), have made significant contributions to understand the fluid content of the subducting plates. Most recently, we developed a technique to compute RFs using data from ocean-bottom seismometers (OBSs) with the removal of the water reverberations and produced RF image beneath the offshore region around the Kii Peninsula [Akuhara and Mochizuki, 2015, JGR]. The image roughly suggests that a low-velocity zone (LVZ) exists along the plate interface beneath the offshore region, at seismogenic zone depth.
In this study, we conducted RF inversion analysis to assess the property of the LVZ quantitatively. We employed relatively high-frequency range (<4 Hz) for the analysis to separate P-to-S conversion phases (our targets) from sediment-related reverberations. The inversion analysis aimed to determine 1-D velocity structures beneath each OBS deployed around the Kii Peninsula which can well explain observed RFs. This optimization was realized by neighborhood algorithm [Sambridge, 1999]. The results elucidate the presence of thin low-velocity zone (LVZ) beneath, or along, the plate interface. Its average thickness among the sites is 2 km, and the P- and S-wave velocities are 3 and 2 km/s, respectively. We consider that this LVZ reflects incoming sediment layer, the upper part of the oceanic crust, or the combination of the both. In any case, fluid-rich property is strongly expected from the extremely low velocities. So far, we conducted the inversion analysis at only 5 sites out of whole 32 sites within our OBS network. We still see, however, the systematic spatial change in the LVZ properties: both thickness and velocities of the LVZ tend to decrease toward the rupture area boundary between the 1944 Tonankai and 1946 Nankai earthquake. Further investigation into the other sites may offer more insight into how fluid controls slip behavior of megathrust earthquakes.

キーワード：沈み込み帯、レシーバ関数
Keywords: subduction zone, receiver function

地震波動シミュレーションをデジタル岩石に適用して得られた南海トラフ周辺の地震断層の特徴
Characterization of Nankai Seismogenic Fault by Applying Dynamic Wave Propagation Simulation to Digital Rock Models

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In the Nankai Trough , the Philippine Sea plate is subducting beneath the Japanese Island at 4-6.5cm/s. The plate interface in the Nankai Trough is active seismogenic fault and causes massive earthquakes and tsunamis. However, the active seismogenic fault is too deep to drill through it. Thus, it is difficult to investigate its characteristic. To understand the characteristics of the deep active fault (i.e., plate interface), we use P- and S-wave velocities (Vp, Vs) of the digital rocks extracted from outcrop of ancient plate boundary fault at Nobeoka in Kyushu, southwest Japan. By comparing the elastic properties derived from digital rock with seismic velocity (e.g., Vp/Vs) acquired around the in situ seismogenic fault, we characterize the deep seismogenic fault. We extract 3D digital rock models with the size of 5mm x 5mm x 5mm from 3D micro-CT images. By using Finite Difference Method (FDM), we perform the dynamic wave propagation simulation and measure the effective Vp, Vs, and ratio of P-and S-wave velocities (Vp/Vs) of 3D digital rock models. Moreover, using this approach, we can identify the heterogeneity, which strongly influences to the seismic velocity. Here, we investigate the sensitivity of Vp and Vs to crack-filling materials. The heterogeneous texture, such as fracture or pore space was identified based on comparison of the density and porosity from digital rock model with the average of porosity from laboratory measurement. We can measure Vp and Vs for heterogeneity texture with any fracture-filling materials by replacing the pore space with dry, water saturated and mineral filling (quartz and calcite) conditions. The results demonstrated that the pore space in the dry and water saturated conditions significantly decreases velocity. The Vp/Vs ratio of water saturated case (Vp/Vs=~1.84) is higher than dry condition (Vp/Vs=~1.75). In the mineral-filling model (quartz and calcite), the P and S-waves travel faster than dry and water saturated conditions. This is because the bulk and shear modulus are increased in these mineral filling condition. The Vp/Vs of mineral-filling cases is lower than water saturated case, because S-wave cannot travel through the fluid which highly decreased in water fill pore case. Therefore, low Vp/Vs at coseismic region observed in the Nankai Trough region could be explained by the mineral filling of cracks.

キーワード：震源断層、南海トラフ、動的波動シミュレーション、デジタル岩石
Keywords: seismogenic fault, Nankai Trough, dynamic wave simulation, digital rock

Improvement of 3D MCS data processing by advanced technology in Nankai trough

Improvement of 3D MCS data processing by advanced technology in Nankai trough

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For the next stage of the deep scientific drilling in Nankai trough seismogenic zone, it is essential to know exactly shapes and depths of the mega-splay and the subducting oceanic plate, and fine structures in accreted sediments around the drilling site. Three dimensional multi-channel seismic (3D MCS) survey data were acquired in Kumano nada, and original data processing were also carried out in 2006. The 3D geometry of megasplay fault system in the Nankai trough subduction zone and detail structures in the frontal accretionary prism were revealed. However, any detail structures are not clear in the old accretionary prism between Kumano forearc basin and the megasplay fault, which are essential information for the successful deep drilling. The most difficult problem of the 3D seismic data is strong water-period surface related multiples which highly decrease the image quality. Especially in the deeper part than about 5 km, the resolution of the reflection image is very low with bandlimited signals by applying the specific processing to eliminate the multiples and noise with the technology of the day.
In order to obtain the clearer depth image for the next deep drilling target, reprocessing of the 3D data is highly required with advanced technology in a decade after the original data processing. There are three major scientific goals on the reprocessing of the 3D MCS data. First, 3D geometry and relationship between megasplay and plate interface beneath outer ridge, where multiples obscure clear imaging, to reveal whether decollement steps down to the plate interface or connects to the megasplay. Second, the fine scale imaging is required in the old accretionary prism beneath Kumano Basin. Distribution of faults, folds, or fractures, should be revealed to compare the seismic scale dipping structures to the nearly vertical fractures obtained at C0002 hole drilled by D/V Chikyu. Third, the reliability and the resolution of the velocity model should be improved to prove whether the low velocity zone (LVZ) in the outer wedge continue to that beneath the megasplay beneath Kumano Basin, and how much this velocity contrast contributes to the negative polarity in the megasplay fault.
The combination of the recent surface-related multiple elimination (SRME) and other noise attenuation techniques for better multiple attenuation, and broadband processing will contribute to enhancement of the deep reflection signals. Then, the sophisticated velocity model building to improve resolution and reliability, and the recent pre-stack migration method in depth domain with the updated data improve the depth image for mega-splay fault and the subducting plate. The advanced beam migration technique beyond the conventional Kirchhoff migration helps to image the steep dip fold and fault structures inside the old accretionary prism beneath the Kumano basin.

キーワード：Nankai trough、3D MCS
Keywords: Nankai trough, 3D MCS

南海掘削Exp. 348で採取されたコア試料に対する三軸剪断試験結果：Geomechanics解析への応用
Result of triaxial shear test on core sample taken in NanTroSEIZE Exp. 348: Implications for geomechanics analysis.

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In order to determine shear failure parameters of the Nankai accretionary prism sediments, triaxial shear test was conducted for core sample taken in the IODP Expedition 348. Core sample for the test was taken at 2183 mbsf in Hole C0002P and ~30 cm whole-round core sample was dedicated to the test. 5 plugs (~25 mm diameter and ~50 mm length) were sampled from the whole-round core. One plug (3R1-0) was used for test experiment to set up triaxial apparatus and 4 plugs (3R1-1, 3R1-2, 3R1-3 and 3R1-4) were applied to triaxial tests under different confining pressures. The triaxial test was conducted by using a triaxial test apparatus installed in Core Lab of OYO Corp. Effective confining pressures were 1 MPa (3R1-1), 2 MPa (3R1-2), 4 MPa (3R1-3), and 7 MPa (3R1-4). As the result, rock strength parameters (Cohesion, Internal friction angle and Unconfined compressional strength (UCS)) were determined as follows:
Cohesion: 1.8 MPa, Internal friction angle: 32.08 deg., UCS: 6.5 MPa.
The obtained UCS is obviously lower than those of the Kumano Basin sediments and typical basin formations. This observation indicates that rock strength of the Nankai accretionary prism would be weakened by deformation during accretion process. In this presentation, UCS-log Vp curve of the Nankai accretionary prism are presented and discussed its implication to geomechanical analysis for future NanTroSEIZE expedition.

キーワード：南海掘削、三軸剪断試験、一軸圧縮強度、ジオメカニクス
Keywords: NanTroSEIZE, Triaxial shear test, Unconfined Compressional Strength, Geomechanics

Submarine landslide on the hanging wall of mega-splay fault, Kumano-nada, Nankai Trough

Submarine landslide on the hanging wall of mega-splay fault, Kumano-nada, Nankai Trough

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Submarine landslide in the Kumanonada splay fault, Nankai Trough, southwest Japan were explored by Navigable Sampling System (NSS), Atmosphere and Ocean Research Institute, the University of Tokyo. A sedimentary sequence in the area was cored by IODP Expedition 333 in advance as the ‘‘Nankai Trough Submarine Landslides History”. The Pleistocene to Holocene sequence of stacked mass-transport deposits was recovered at Site C0018, located within a slope basin on the footwall of the mega-splay fault. Six mass-transport deposit (MTD) units intercalated with coherent intervals were recovered within 1Ma. Although the MTD occurrences were regarded to have been induced by the past Nankai earthquake events, the found frequency of MTDs is absolutely lower than that of To-nankai and Nankai earthquake as every 100-200 year intervals during the historical times. This discrepancy indicates that our understanding on the collapsing induced by the mega-splay faulting is not enough. In order to have well documentations on the relationship between the mega-splay fault and MTDs, we implemented a sub-bottom imaging around the mega-splay fault using NSS. We recovered the image which shows that a 20-m thick sediment layer slid down about 50-m high on the hanging wall of mega-splay fault. Also the image shows that the small depression formed by this sliding was aggraded by fill deposits after the event. If those events were corresponding to a mega-splay faulting in a time, the record will be a proxy to shows the timing of mega-splay faulting in past. And the dimension interpreted from obtained image is useful to assess the risk of hazard induced by mega-splay faulting. We will discuss the scenario of this collapse using data acquired during the cruise.

キーワード：Submarine landslide、meag-splay fault、Nanki Trough、Navigable Sampling System
Keywords: Submarine landslide, meag-splay fault, Nanki Trough, Navigable Sampling System

南海付加体内部の力学特性： 掘削カッティングス試料を用いたインデンテーション試験による解析
Strength and mechanical behavior of the Nankai accretionary prism sediments from NanTroSEIZE Expedition 348

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岩石の力学特性は，一般に直径・長さ数十mm以上の試料を用いた圧縮・引張実験によって調べられる（e.g., Paterson and Wong, 2005）．しかし，海洋底掘削、特にライザーシステムを用いた超深度掘削では，直径数cmの掘削コア試料は限られた深度からしか採取されない可能性が高く，コア試料を用いるだけでは岩石物理特性の連続データを得ることはできない．そこで本研究では，ライザー掘削によって連続採取されるカッティングス試料を用いたインデンテーション試験から，地下深部の圧力条件下での物理特性を調べるための手法開発を試みた．手法開発では，異なるPorosityを呈する4種類の堆積岩（Carrara marble, Rajasthan砂岩，白浜砂岩，Berea砂岩）を用いて，インデンテーション試験と一軸圧縮実験を室温・大気圧条件下にておこなった．その結果，インデンテーション試験と一軸圧縮実験から得られるヤング率には指数関数的な相関があり，最大強度は線形相関であることがわかった．これらの相関式を用いると，インデンテーション試験から一軸圧縮条件下における岩石の物理特性を推定することが可能となった．

この手法を応用し，南海付加体を構成する堆積物の力学特性が深度方法約2kmにわたって連続的にどのように変化するのかをインデンテーション試験によって調べた．試験には，IODP NanTroSIEZE第348次研究航海で超深度ライザー掘削孔Site C0002の海底面下870m～3058m（以下，mbsf）の間で採取されたカッティングス試料の中から固結したものを取り出したhand-picked intact cuttings試料を用いた．インデンテーション試験は，直径4mmのサファイアの球状圧子を用いて，載荷速度は秒速0.5N，最大荷重は100Nとした．試験は，室温・大気圧下において，人工海水で飽和させた試料について排水条件下でおこなった．上記で求めた相関関係，および内部摩擦角と間隙率の相関から地下深部での内部摩擦角を推定することによって，現位置におけるヤング率と強度を推定した．その結果，SiteC0002における付加体物質のヤング率は，870mbsf～2000mbsfにかけて0.5GPaから2.2GPa程度まで増加し，その後3000mbsfまで2.2GPa程度とほぼ値が変わらないことが明らかになった．また最大強度は870mbsf～3000mbsfにかけて数MPaから70MPa程度まで増加傾向を示した．これらの結果は，2200mbsfにて採取されたコア試料を用いた三軸圧縮変形実験の結果と調和的であることがわかった．付加体堆積物のような比較的多孔質な物質を用いたインデンテーション試験から，地下深部での物質の力学特性を調べることが可能であることが確認できた．

キーワード：付加体、インデンテーション試験、IODP、第348次研究航海
Keywords: Accretionary prism, Indentation test, IODP, Expedition 348

Tectonic stress of the upper-plate crust above the Tonankai seismogenic zone

Tectonic stress of the upper-plate crust above the Tonankai seismogenic zone

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The crustal physical property is necessary information to understand the seismogenic mechanism. Soft sediment changes to hard rock to be the seismogenic material during plate subduction. In this process, strength is the most developing property than the other of the porosity, bulk density, elastic wave velocity and etc. The sediment lithification depends on the stress due to strain hardening, and the strength of the sediment products us the stress condition in the plate subduction zone.
IODP Exp.338 took samples from 1000 mbsf to 2000 mbsf above the seismogenic zone of the Tonankai earthquake of 1944 (Mw=8.0) during Nankai Trough Seismogenic Zone Drilling Project (Moore et al., 2013). Because the riser-drilling, the cutting-sample were taken in all section differ from the core samples. These cutting-samples have the potential to make the strength profile of upper plate in the subduction zone. We develop new method to estimate the rock strength using the needle penetrator that applicable for small cuttings-sample. Since the needle penetration makes the Mode I crack, the obtained strength concerns with cohesion of the rock. This needle-penetration strength was compared with uniaxial compression strength using various strength samples of mortar and natural sandstones.
In the result, higher cohesive samples were obtained at deeper section at site C0002. The cohesion gradient increases suddenly at the boundary between the Kumano basin and the accretionary prism. The accretionary sediment may suffer tectonic stress, and high cohesion gradient can be explained by increasing tectonic stress with depth. In case of frictional sliding, shear stress within upper plate increases with depth above the asperity. The cohesion curve may show upper plate stress field in the seismogenic zone.

キーワード：沈み込み帯地震、国際深海掘削科学、物性
Keywords: subduction earthquakes, IODP, physical property

Frictional properties of the Northern Shimanto Belt rocks at a seismogenic pressure and temperature condition

Frictional properties of the Northern Shimanto Belt rocks at a seismogenic pressure and temperature condition

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We conducted triaxial friction experiments on the Northern Shimanto Belt rocks exhumed from the seismogenic zone, at an effective confining pressure of 75 MPa and a temperature of 150°C, and at axial displacement rates (V_{axial}) changed stepwise among 0.1, 1 and 10 μm/s, in order to investigate their frictional properties at a seismogenic condition. Tested samples are sandstone, mudstone and chert from the Yokonami mélange, basalt from the Kure mélange, and sandstone and mudstone from the Nonokawa Formation, all collected in central Shikoku Island. XRD analyses of tested samples revealed that the content of total clay minerals is 15.1 wt%, 11.8 wt% and 0 wt%, respectively in the Yokonami mélange sandstone, mudstone and chert, 1.9 wt% in the Kure mélange basalt, 16.3 wt% and 32.9 wt%, respectively in the Nonokawa sandstone and mudstone.
Friction experiments of tested samples revealed that the steady-state friction coefficient (μ_{ss}) decreases with increasing content of total clay minerals, except for the Nonokawa sandstone with a relatively high μ_{ss} of 0.62 in spite of its moderate content of total clay minerals. μ_{ss} at V_{axial} = 1 μm/s is 0.65 for the Yokonami mélange chert, 0.63 for the Kure mélange basalt, 0.52 for the Yokonami mélange mudstone, 0.50 for the Nonokawa sandstone, and 0.37 for the Nonokawa mudstone. The Yokonami mélange chert without clay minerals and the Nonokawa mudstone with 32.9 wt% clay minerals exhibited an increase in μ_{ss} when V_{axial} was increased and vice versa, i.e., velocity strengthening. Microstructures of these samples after experiments show that deformation is distributed within the gouge layer. In contrast, other samples with 1.9–16.3 wt% clay minerals exhibited a decrease in μ_{ss} when V_{axial} was increased and vice versa, i.e., velocity weakening. Microstructures of these samples after experiments show that deformation is localized along a continuous slip surface. Experimental conditions suggest that dissolution-precipitation processes are possibly responsible for such change in velocity dependence of friction according to the content of clay minerals.
Our results suggest that seismogenic faulting would occur in rocks with 2–20 wt% clay minerals, but not in rocks without or rich in clay minerals, provided that other conditions are the same.

キーワード：friction、Northern Shimanto Belt、seismogenic condition
Keywords: friction, Northern Shimanto Belt, seismogenic condition

南海トラフ巨大分岐断層における断層運動によって促進されたイライト化反応
Faulting-promoted illitization along the megasplay fault in the Nankai Trough

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The transformation of smectite to illite is thought to have important role on faulting because illitization can change friction strength and produce fluid overpressure by dehydration reaction. We performed X-ray diffraction analyses of sediment samples around the megasplay fault in the Nankai accretionary prism, recovered from Integrated Ocean Drilling Program (IODP) Expedition 316 Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE). Quantitative analysis of the illite fraction in illite-smectite mixed layers (I-S) crystallites shows that the dark gouge has ~10% more illite content than that in the host rock. If applying a kinetic expression obtained under a static condition from the previous works, the observed mineralogical anomaly requires an event of frictional heating that have caused temperature rise to an extraordinarily high level around the dark gouge. We combined data from XRD analyses with modified kinetic simulations of illitization to quantify effect of mechanochemical processes. As a result, if we applied an activation energy ~30% lower than the value from the previous works, illitization can be reasonably explained by frictional heating. These results suggest that seismic slip helped to overcome kinetic barrier due to mechanochemical processes in the fault zone.

キーワード：沈み込み帯、断層ガウジ、摩擦発熱
Keywords: Subduction zone, Fault gouge, Frictional heating

炭質物の多角的分析による巨大分岐断層滑りパラメータの推定

Determination of slip parameters of subduction earthquake by using multiple analyses of carbonaceous materials

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プレート沈み込み境界で周期的に発生する地震は，巨大津波を伴い人間社会に大きな被害を及ぼす．地震時のすべりはプレート境界のみならず，プレート境界深部で分岐した逆断層に伝搬し，より大きな津波を引き起こす可能性があるため，巨大分岐断層での地震時の滑り挙動の理解が重要である．
滑り面における摩擦発熱履歴から，地震時の剪断応力などの滑りパラメータを推定することが可能である．その検出方法として，炭質物の熱熟成に伴うビトリナイト反射率の増加やラマンスペクトルのD・Gピーク強度比の変化が提案されている．しかし炭質物の熱熟成過程は，その初期状態や元素組成に強く依存し，また剪断による構造変化等の影響があるという問題があった．そのため，ある炭質物では単一の分析結果からの推定でなく，多角的な分析による確認が不可欠である．
そこで本研究では，南海トラフ巨大分岐断層の滑り挙動を明らかにするため，四国四万十帯久礼メランジ中に発達する過去の巨大分岐断層（アウトオブシーケンス衝上断層）を対象とし，採取試料から抽出した炭質物において，加熱実験・分光測定（IR及びRaman）・CHNSO元素組成分析を行った．その結果，滑り面の最高温度は400-600℃であると推定された．さらに，一次元熱拡散シミュレーションを用いた滑りパラメータの推定を行った結果，滑り量はいずれの場合でも10 m以下であることがわかった．累積滑り量が2.5-5.5 kmと推定されていることを考慮すると，本断層では少なくとも数百回の地震が繰り返し起こったことが示唆される．

キーワード：炭質物、摩擦発熱、分光分析、元素分析、すべりパラメータ
Keywords: carbonaceous materials, frictional heat, spectrometry, elemental analysis, slip parameters

四国西部，明浜地域に分布する四万十帯の被熱構造と断層の形成過程

The thermal structure and formation process of faults in Akehama area of the Northern Shimanto Belt, western Shikoku, Japan

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四万十帯は，海洋プレートの沈み込みに伴い形成された付加コンプレックスを主体としている（平ほか，1980）．九州東部や四国中・東部では，メランジュ帯や，シュードタキライトを伴う脆性断層などの強変形帯の存在が知られており（例えばTaira et al., 1988, Mukoyoshi et al., 2006），沈み込み帯周辺での長期的・短期的な変形現象を記録していると考えられている．このような断層解析や被熱構造解析は，四国においては主に中・東部を中心に行われ，西部での調査例は多くない．大橋・金川（2014）では，四国西部の四万十帯の一部で東西走向，高角北傾斜の脆性断層が密集する脆性剪断帯があり，地震性断層運動を示唆する炭酸塩鉱物基質の断層角礫を伴うことを確認している．そこで本研究は，大橋・金川（2014）によって見出された四国西部（西予市明浜地域）に発達する断層帯について，岩相・変形マッピング，断層記載，多重逆解法を用いた古応力場解析，およびビトリナイトの反射率測定より被熱構造解析を行った．また，被熱温度より，断層上・下盤の温度差がどの程度あるかを算出し，その温度差をつくるための累積変位量を見積もり，破砕帯の幅と変位量の関係を比較した．そして，これらの調査をもとに，四国西部の四万十帯北帯に発達する断層帯の形成場と形成メカニズムを明らかにしていく．

調査の結果，当地域の断層帯は砂岩，泥岩及び砂泥互層を原岩とし，破砕帯はカタクレーサイトで幅が数cmから数10 cm，東西走向の北傾斜，条線はレイク角が平均32° W，そして右横ずれ成分を含む逆断層センスが多く確認された．調査で得られた断層スリップデータをもとに多重逆解法による古応力場解析を行ったところ，北西-南東方向の最大主応力軸σ1，北東-南西方向の最小主応力軸σ3が求まった．また，断層帯を挟んだビトリナイト反射率(Rm)のギャップは0.18%（温度に換算すると約11°C）以下であり，Mukoyoshi et al.（2006）や北村ほか（2014）で認められているような0.3%を超える明瞭なギャップは存在しない．反射率ギャップ0.18%を生じさせるのに必要な斜め横ずれ変位量を推定したところ，0.04〜0.23 kmであり，求められた変位量に比べてトータルの破砕帯の幅（約6 m）は有意に大きい．

以上の被熱構造との関係性から，今回の調査地域の断層帯は最大被熱イベント以前に形成されたものであると考えられる．また，未〜半固結時変形の特徴に乏しいため，本研究の断層帯はある程度の固結性を獲得した付加プリズムの前部で形成されたと推測できる．また，今回の調査において斜め横ずれを示す断層が多く確認された．これは，これらの断層がノンアンダーソン型断層であることを示唆する．今後は断層帯の内部構造や微細組織について，より詳細に解析を行う予定である．

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[引用文献]
平 朝彦・田代 正之・岡村 真・甲藤 次郎，1980，高知県四万十帯の地質とその起源，平 朝彦・田代正之編，四万十帯の地質学と古生物学-甲藤次郎教授還暦記念論文集，林野弘済会出版，319－389.
Taira,A.,Katto,J.,Tashiro,M.,Okamura,M. and Kodama,K.,1988, The Shimanto Belt in Shikoku, Japan. Cretaceous to Miocene accretionary prism. Mod Geol., 12, 5－46.
Mukoyoshi,H.,Sakaguchi,A.,Otsuki,K.,Hirono,T. andSoh,W.,.2006, Co-seismic frictional melting along an out-of-sequence thrust in the Shimanto accretionary complex. Implications on the tsunamigenic potential of splay faults in modern subduction zones, Earth Planet.Sci.Lett.,245, 330-343.
大橋 聖和・金川 久一，2014，四国西部四万十帯トラバース，日本地質学会学術大会講演要旨

北村 真奈美・向吉 秀樹・廣瀬 丈洋, 2014, 付加体内部に発達する断層の変位量と幅との相関関係, 地質雑, 120, 11－21.

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Keywords: Subduction zone, Northern Shimanto Belt, Vitrinite reflectance, Paleostress analysis, Oblique-slip faults

九州四万十帯延岡衝上断層における断層帯中軸部の変化に富んだ化学組成
Variable chemical composition of the Nobeoka thrust fault core in Shimanto Belt, Kyusyu

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The Nobeoka thrust in Kyushu is a tectonic boundary thrust in the Shimanto Belt, Cretaceous-Miocene accretionary complex in Southwest Japan. The Nobeoka thrust is presumed to be a fossilized megasplay fault which was branched from plate boundary fault (Kondo et al., 2005), and represents multiple deformations at seismogenic depths (~ 10 km below sea floor) (Kondo et al., 2005). Kondo et al. (2005) described lithology and macroscopic/microscopic structure of hanging wall, footwall, and the fault core. Fukuchi et al. (2014) showed mineralogical features across the fault zone based on X-ray Diffraction (XRD) analysis. However, Fukuchi et al. (2014) mainly focused on the illite crystallinity of the hanging wall side, and detail description on mineralogical/geochemical features of the fault core is still to be investigated. Therefore, this study was designed to determine chemical/mineralogical features of the fault core of the Nobeoka thrust. For this purpose, we performed elemental mapping on polished slab-shape samples retrieved the outcrop of the fault core of the Nobeoka thrust by using X-ray fluorescence (XRF) core scanner installed at Kochi Core Center (KCC).
Analyzed sample contains hanging wall, footwall, and ~15 cm-thick fault core. The fault core is bounded from both hanging- and footwall by ~3 mm-thick dark zones. Compared with the wall rocks, the dark boundaries and matrix of the fault core are enriched in Al, K, Ti, Mn, Fe and Mg, and depleted in Si, P, and S. My observation implies the following: (1) matrix of the fault core and the dark boundaries between the fault core and hanging-/footwall correspond with the enrichment of white mica and/or chlorite; (2) Depletion of S would reflect dissolution of pyrite and/or gypsum, suggesting the existence of oxidative fluid within the fault core.

キーワード：延岡衝上断層、XRF core scanner
Keywords: Nobeoka thrust, XRF core scanner

遠洋性珪質堆積物中に発達する大規模剪断帯の構造

Mesoscale structures of a large shear zone developed within pelagic siliceous sediments

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Subduction zones where old oceanic plate underthrust are characterized by thick pelagic incoming sediments originating from diatomaceous/radiolarian oozes. For a better understanding of deformations along plate boundary megathrust in such a setting, we investigate the Ohwaki outcrop in the Mino Belt, which represents a shear zone of a master floor thrust of imbricated thrust sheets composed of cherts and clastic rocks.
The occurrence of the shear zone was presented by geologic mapping based on aerial photographs taken by an unmanned aerial vehicle (UAV). A ~50-m-thick cataclastic shear zone composed of early Triassic carbonaceous black shale matrix including angular blocks of bedded/massive chert, siliceous mudstone, and shale with sandstone blocks bounds early-middle Triassic pelagic rocks and middle Jurassic terrigenous rocks. In contrast to the disrupted and cataclastic deformation of carbonaceous black shale within the shear zone, hanging wall strata of thick bedded/massive chert only exhibits early-stage ductile asymmetric folds.
Stratigraphically controlled occurrence of the shear zone is analogous to the plate boundary fault in the Japan Trench drilled by IODP Expedition 343 and in-sequence thrusts of imbricated chert-clastics sequence in the Inuyama area, in terms of shear localization to weak horizon within pelagic sediments. However, total thickness of the shear zone observed in the Ohwaki outcrop is one order larger than other strata-bound fault zones. Occurrence of a thick shear zone with angular blocks of host rocks would be likely to reflect shear zone thickening caused by strain hardening due to post-failure fluid discharge and hydrofracuring maintained by fluid overpressure. It is speculated that low permeability of lithified chert (10^{-19} to 10^{-21} m^2) would contribute to fluid pressure fluctuation in large shear zones within pelagic sediments.

